TENNESSEE VALLEY AUTHORITY

SEQUOYAH NUCLEAR PLANT

DIESEL GENERATOR EVALUATION REPORT

(DGER)

ENCLOSURE 1

TABLE OF CONTENTS

I. BACKGROUND

TVA performed Sequoyah Nuclear Plant (SQN) diesel generator (DG) preoperational (preop) tests TVA-13B(1) and -13B(2) during the period of August through October 1980 to satisfy the test requirements of NRC Regulatory Guide (RG) 1.9, revision 0. During a subsequent review of the test results, TVA identified deficiencies in the test requirements; specifically, the preop tests did not adequately verify compliance to RG 1.9, revision 0, and TVA's commitments as documented in the FSAR section 8.3.1.2.1. These deficiencies were documented in Significant Condition Report (SCR) SQNEEB8515 (B43 851125 904) on November 20, 1985.

Additionally, the Employee Concern Program received a concern regarding the technical adequacy of the testing and analysis of the SQN DGs. During the subsequent investigation, the Nuclear Safety Review Staff (NSRS) validated several of the concerns and documented their findings in NSRS Report No. I-85132-SQN.

In a subsequent review of the disposition of SCR SQNEEB8515 (performed through the SQN Design Baseline Verification Program), TVA determined that the specified corrective action was inadequate and that the required demonstration of the DG's capability to provide adequate onsite power as defined by RG 1.9 had not been accomplished. This deficiency was redocumented in SCR SQNEEB8715 (B25 870207 035) and was confirmed by a review of the preop tests during the Restart Test Program.

In order to resolve the DG test issue, TVA initiated DG load sequence testing in July 1987. This testing effort utilized the DG loading analysis completed as part of SQN electrical calculations program. This testing was performed utilizing available plant systems and loads; however, due to the plant's capabilities, the applied loads were less than the maximum design loading. DG 1A-A was found to deviate from RG 1.9 voltage limit recommendations during recovery from transients caused by step load increases. CAQR SQP871238 was issued on July 22, 1987, to document this deficiency. Following additional testing, this CAQR was revised to document similar deficiencies on DGs 1B-B, 2A-A, and 2B-B. This CAQR was evaluated and closed with no modifications required.

During evaluation of the load sequence test data, anomalies were identified in the electrical performance characteristics of DG 1B-B. Following comparison of the test data and determination of a proposed corrective action, DG 1B-B was repaired (voltage regulator stability setting was adjusted and a ring-tongue terminal lug on the output of the voltage regulator was replaced) and retested. DG 1B-B performed satisfactorily and similarly to DG 1A-A.

Using the test results, a voltage evaluation was performed to adjust the loads to the maximum value and to evaluate the low voltage systems. This evaluation was performed with regards to the voltage requirements of RG 1.9. TVA initially discussed this calculation with NRC at SQN on January 21, 1988. Based on the results of this and subsequent meetings, it was concluded that TVA would utilize another analytical method using the test data to provide assurance that the diesel generators will perform their intended safety function with margin.

II. PURPOSE

The purpose of this report is to document that:

1. The DG test results are bounded by analysis.

2. Safety-related systems/components will perform their intended safety function when powered by the DG, with acceptable margin.

III. DIESEL GENERATOR (D/G) VOLTAGE ANALYSIS AND DETERMINATION OF VOLTAGE MARGIN

During the diesel generator load sequence testing, it was not possible to fully load all the motors to their design basis load; therefore, the maximum voltage transients were not obtained for all the load sequence steps.

As a result, diesel generator voltage analysis (Attachment 1) was performed to establish the worst-case voltage profile for the 6.9KV and 480V Class 1E power system based on diesel generator test results, and establishes margins that exist in the connected equipment during the predicted worst-case voltage profiles. In order to determine the maximum transient voltage dip, the actual test voltage transients were increased to the maximum loading condition. The increased voltage drop was determined to be the test voltage drop adjusted by the ratio of maximum design load current to test load current.

Tables 1 and 2, attached, summarizes these results. The minimum 6.9KV shutdown board voltage was determined to be 76.5 percent* and the minimum 480V shutdown board and motor control center (MCC) voltage was determined to be 77 percent and 75.6 percent respectively. This condition occurs during approximately 7 to 16 percent of any motor's acceleration time.

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*All voltages in this document are percent of system rated voltages (6.9KV, 480V) unless otherwise indicated.

TABLE 1

WORST CASE 6.9 KV BUS VOLTAGE CORRECTED FOR SCHEDULE LOAD

START MOTOR ①	SEQ. TIME SEC. ②	PRETRAN VOLTAGE PU ③	SOURCE DG ④	PRIOR TO START: DG LOAD FIELD TEST ⑤	PRIOR TO START: DG LOAD SCHEDULE [REF. 3.1] ⑥	PU DIP FIELD TEST ⑦	ADDITIONAL PU DIP DUE TO LOADING DIFFEREN ⑧	TOTAL PU DIP [⑦+⑧] ⑨	PU MINIMUM BUS VOLTAGE [③-⑨] ⑩
CCP	2	1.009	2A	1736 ∠54.5	1206 ∠42	0.174	0.0	0.174	0.835
SI	5	0.991	2B	1102 ∠21.8	1717 ∠34.7	0.162	0.010	0.172	0.819
RHR	10	0.969	2B	1251 ∠25.3	2025 ∠32.5	0.159	0.013	0.172	0.797
ERCW	15	1.001	1B	1417 ∠30.3	2382 ∠30.9	0.187	0.012	0.199	0.802
AFW	20	0.965	2A	1903 ∠29.5	3049 ∠31	0.183	0.017	0.200	0.765
CCWP	30	1.008	2B	2495 ∠31.1	3526 ∠29.9	0.110	0.013	0.123	0.885
CSP+FP*	180	1.0	2A	3083 ∠33.3	3837 ∠29.7	0.200▲	0.012	0.212	0.788

* 200HP FP WAS STARTED WITH CSP.

▲ ADJUSTED THE FIELD TEST DIP TO COMPENSATE THE EFFECT OF 200HP F.P (DIP = 0.039PU)

NOTE : FOR COLUMN ① THRU ⑤ AND ⑦ SEE TABLE-A1

TABLE 2

WORST CASE 480V STND. BD. VOLTAGE

CORRECTED FOR SCHEDULE LOAD

SEQ. TIME SEC. ①	PRE TRAN VOLTAGE PU ②	PU DIP FIELD TEST ③	ADDITIONAL PU DIP DUE TO LOADING DIFFERENCE ④	TOTAL PU DIP ⑤ [③+④]	PU MIN. BUS VOLTAGE ⑥ [②-⑤]
0	1.06	-	-	-	1.06
2	1.0	0.163	0.0	0.163	0.837
5	1.017	0.167	0.010	0.177	0.84
10	0.994	0.148	0.013	0.161	0.833
15	1.017	0.183	0.012	0.195	0.822
20	0.975	0.179	0.017	0.196	0.779
30	1.033	0.188	0.013	0.201	0.832
180 (CSP+FP*)	1.012	0.23▲	0.012	0.242	0.77

* 200HP FP WAS STARTED WITH CSP.

▲ ADJUSTED THE FIELD TEST DIP TO COMPENSATE THE EFFECT OF 200HP F.P (0.051PU DIP)

NOTE : COLUMN ① THRU ③ , SEE TABLE - A2

IV. AVAILABLE MARGINS

The voltage transient can potentially effect the performance of the diesel generator systems and the components they power. The following sections discuss each of these items with regard to transient voltage effects on the components. The available margins between the anticipated transients and the components operation has been identified.

A. Diesel Generator Capacity

Chart 1 shows a comparison of the ratings for the diesel generators to the maximum anticipated design basis load for the heaviest loaded diesel generator (2B-B). In summary, it shows that there is at least 8 percent margin between the manufacturer's rating and the maximum design loads for the first 2 hours and at least 2.3 percent margin for greater than 2 hours. This is acceptable margin since the maximum load must be less than or equal to rated capacity.

B. Motor Voltage Margin

In order to ensure that the motors powered by the DG during the worst-case design basis event have adequate voltage for starting and/or running, a review of the 6.6KV and 460V motors speed-torque characteristics was performed. This review evaluated the unique types of 6.6KV and 460V motors (e.g., safety injection, centrifugal charging, motor operated valves, etc.).

Using the basic relationship that torque for a motor is proportional to the square of the voltage, (See ANSI C50.41, Paragraph 11), we can determine the minimum voltage required to sustain pump motor speed and the minimum voltage required to sustain breakaway.

Below is a pump/motor speed-torque curve (Figure 1) for the SQN containment spray pump that displays these pertinent characteristics. This curve is typical for NEMA Class B motors which are used at SQN.

TYPICAL PUMP/MOTOR SPEED-TORQUE CURVES

FIGURE 1

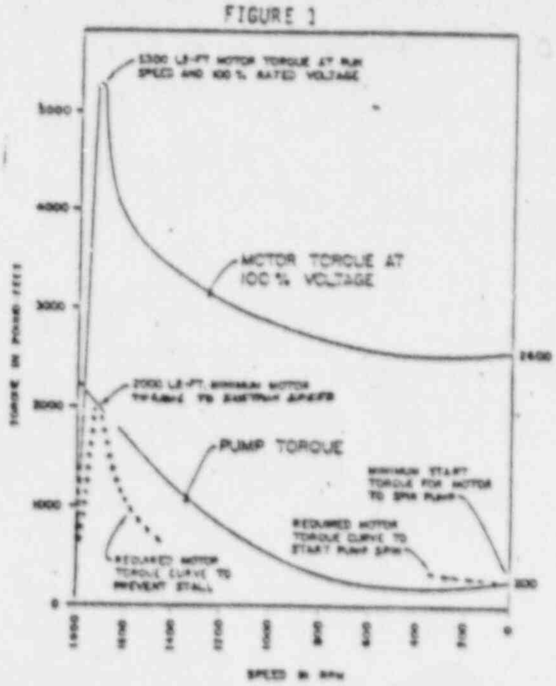
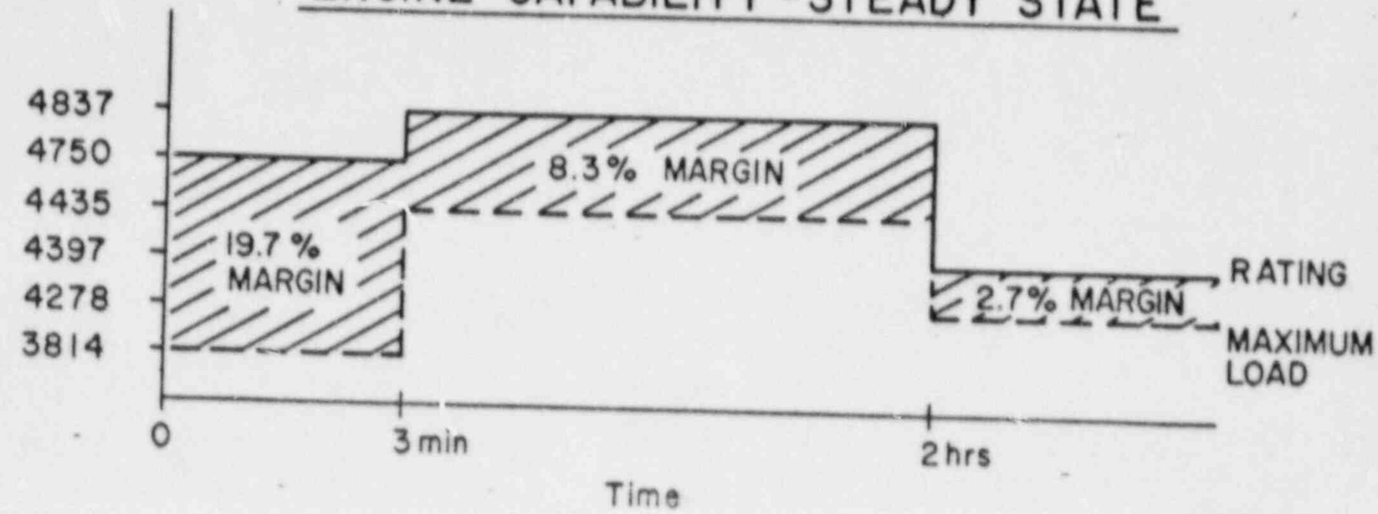


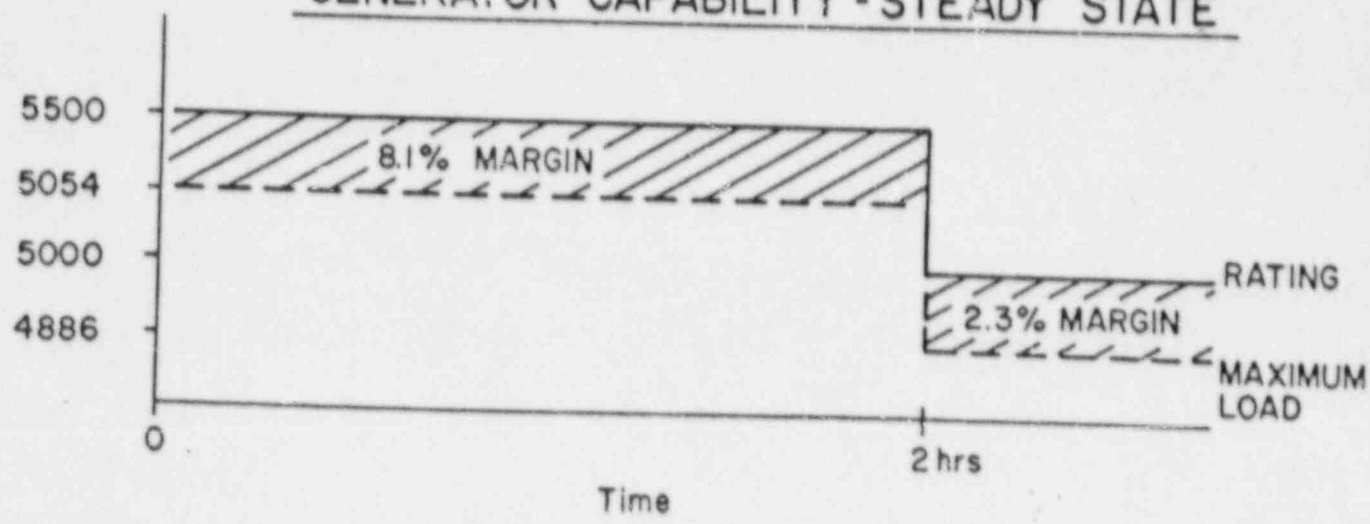
CHART I

MARGINS
DIESEL GENERATOR RATINGS vs. LOAD

ENGINE CAPABILITY - STEADY STATE



GENERATOR CAPABILITY - STEADY STATE



MFG's D/G RATINGS

	0-3 min	3 min-2 hrs	CONTINUOUS
ENGINE	4750 KW	4837 KW	4397 KW
GENERATOR	5500 KVA	5500 KVA	5000 KVA

For 6.6KV motors and a very large 460V motor, the analytical technique resulted in the following:

MOTOR	MINIMUM SUSTAINING MOTOR VOLTAGE TO SUSTAIN ROTATION (Percent V at Bus)	MINIMUM BREAKAWAY MOTOR VOLTAGE TO SUSTAIN ROTATION (Percent V at Bus [Locked Rotor])
CCP	64	33
SI	54	32
RHR	56	37
ERCW	63	36
AFW	55	35
CCS (480 Volt)*	44	29
CSP	59	27

*At motor terminal

The small 460-volt motors are standard NEMA designs; therefore, the minimum start and sustaining voltages are evaluated utilizing the standards from which they are designed. NEMA MG1-12.37 and 12.38 were used to obtain the locked-rotor and breakdown torque values for design types A and B motors for various horsepowers. "Motor Application and Maintenance Handbook" edited by R. M. Smeaton was used to obtain typical data for the pump, fan, and compressor loads. This data corresponds to the points of interest for the motor/load speed torque curve.

Motor loads have been evaluated to determine the maximum voltage dip which still allows adequate torque to sustain the load rotation. For the 6.6KV motor, the limiting voltage for running motors was determined to be 64 percent, and the limiting breakaway voltage was 37 percent. For 460-volt motors the limiting voltage for running motors is 68 percent and limiting breakaway voltage is 59 percent. In addition, for a 460-volt motor/pump load, calculations predict additional margin in the rotating inertia of the load with the occurrence of short-term voltage dips (e.g., for 65 percent of 460V for 1/2 second, speed drop of the low inertia pump would be less than 6.18 percent).

TVA sees no adverse effect on the mechanical system performance since the thermal and mechanical inertia is such that a 1/2-second decrease in flow of air or water would have effects that would be within the normal operating fluctuations of these type systems. This assumes the associated motors and controls do not trip as a result of this voltage decrease. Therefore, the minimum 6.9KV margin for the maximum expected voltage dip is 12.5 percent on a 6.9KV base and 6.3 percent (including cable voltage drop of 2.7 percent) on a 480V base.

C. Motor Starter Contactor VOLTAGE MARGIN

In safety-related circuits at Sequoyah, size 1, 2, and 3 contactors are used. For unit 2 operation, approximate number of each types of each contactor size are:

Size 1	Approximately 500	(27 ampere rating)
Size 2	Approximately 60	(45 ampere rating)
Size 3	Approximately 15	(90 ampere rating)

The limiting MCC contactor circuits are manufactured by Arrow-Hart Incorporated. Size 1 contactors are supplied from smaller control power transformers than larger contactors and experience lower per unit voltage. As such, the size 1 contactors are the limiting application; therefore, the contactor dropout and pickup characteristics of Size 1 contactors were investigated. Tests were performed at TVA's Chickamauga Laboratory using new and used contactors from SQN. These tests yield a minimum drop out voltage of 54 percent and minimum pickup voltage of 73.6 percent on a 110V base. The corresponding required voltages on a 480V base are 49.5 percent and 67.5 percent respectively.

Conclusion:

1. Dropout

   Using the adjusted test voltage from Attachment 1 the adjusted voltage anticipated at 480V MCC's is 75.6 percent; therefore, the minimum margin is 26 percent above the required voltage of 49.5 percent (54 percent on contactor base of 110V).

2. Pickup

   The adjusted voltage anticipated at the 480V MCC's is 85 percent when a MCC contactor closes concurrently with the starting of a 6.6KV motor and 75.6 percent when there is a delay such that the contactor picks up at maximum voltage dip. These values are above the minimum required voltage of 67.5 percent (73.6 percent on a contactor base of 110V). Therefore, the minimum margin is 17.5 percent if contactor closes concurrently and is 8.1 percent if there is a delay.

D. Motor Operated Valve (MOV) Torque and Time Margin

   All MOVs that would be actuated during the loading sequence for a design basis event were evaluated for increased stroke times due to transient voltage dips. All MOVs under consideration are rated for a minimum start voltage of 77 percent* and can develop 100 percent torque at this voltage. Since motor-operated valve voltage varies over its stroke, it is appropriate to examine the average voltage. The average voltage experienced based on the adjusted load conditions for the loading sequence is approximately 95 percent; therefore, the voltage margin is 18 percent.

   In addition, all MOVs required during this time have a minimum of 5.3 percent design margin in their stroke times. This was determined by the design criteria safety limit minus the plant testing results which results in the following: of the 58 valves under consideration, 37 have greater than 100 percent margin, 18 have greater than 10 percent margin, but less than 100 percent, and 3 greater than 5 percent, but less than 10 percent margin. It should be noted that these margins are not sensitive to increases in the transient voltage dip.

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*This value has been adjusted from 80 percent on a motor base of 460V to 77 percent on a system base of 480V.

E. Overcurrent Protection Margin

All motors that are load sequenced have their overcurrent protective devices set at a minimum of 200 percent of locked rotor current to ensure that tripping will not occur. Additionally, the load will not trip inadvertently since the transients under consideration are less than one second in duration and actuation is at least 10 seconds.

F. Diesel Generator Load Sequence Timer Margin

In order to determine the load sequence timer margin calculations "27S1A" and "DG TIMER RELAYS" were reviewed. "DG TIMER RELAYS" (Attachment 2) addresses the affects of sequence timer inaccuracies upon DG loading by calculating the minimum time between load steps. Calculation "27S1A" (Attachment 3) calculates the maximum time it takes to provide power to the sequenced loads. Both calculations are based on the methodology presented ISA 67.04, "SETPOINTS FOR NUCLEAR SAFETY-RELATED INSTRUMENTATION USED IN NUCLEAR POWER PLANTS" and Reg Guide 1.105, "INSTRUMENT SETPOINTS FOR SAFETY-RELATED SYSTEMS."

"DG TIMER RELAYS" calculates the minimum time interval between loadings by calculating the root-sum-square (square root of the sum of the squares) of the random errors asociated with two adjacent relays. The root-sum-square technique is addressed in ISA 67.04. Also note that there is one systematic error associated with these relays, a bias error due to ambient temperature changes. Since all relays are located in the same cabinet, all relays will experience the same ambient temperature changes; therefore, this effect cancels out for adjacent sequence timers. The results of this calculation are summarized in Figure 2.

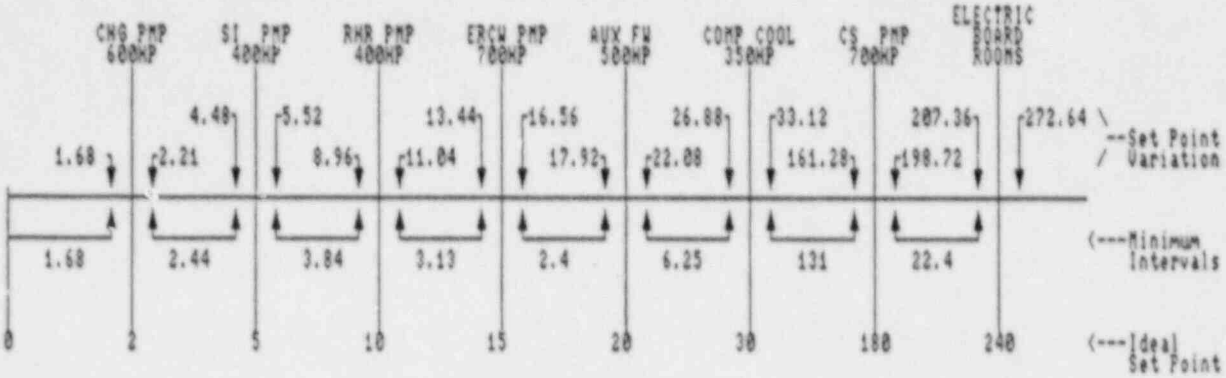
"27S1A" calculates errors associated with each timer in turn (errors calculated for only one relay rather than adjacent relays) since the parameter of concern is maximum time to make electric power available to a particular load. This means the bias error associated with temperature must also be included in the accuracy. The results are for a concurrent loss of offsite power and safety injection initiation, and are summarzied in Figure 3.

These calculations previously resulted in a change for the auxiliary feedwater and component cooling system timers and these figures reflect this change.

DIESEL LOAD SEQUENCING

Figure 2

SUMMARY OF "DG TIMER RELAYS"



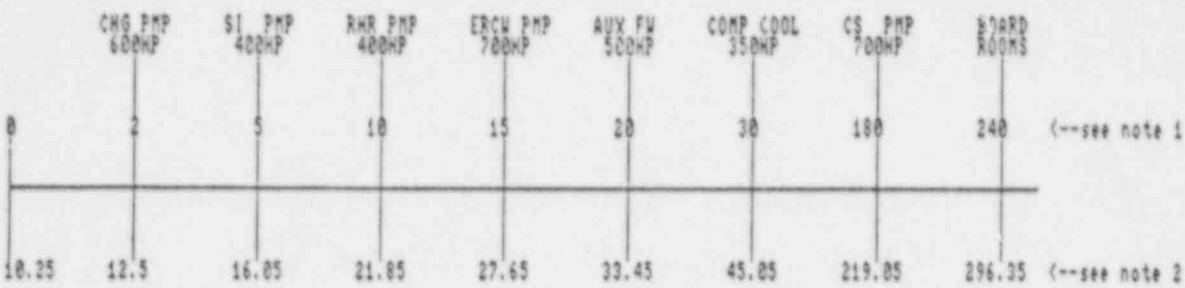
LOAD STEP (SECONDS)

Variations about ideal setpoint are shown for algebraic error combinations.

Minimum interval times shown are for Square Root of the Sum of the Squares (SRSS) combinations of errors(pg 42DG timers)

Figure 3

SUMMARY OF "27S1A"



(seconds)

note 1 - Sequence timer setpoints (provided for comparison purposes).

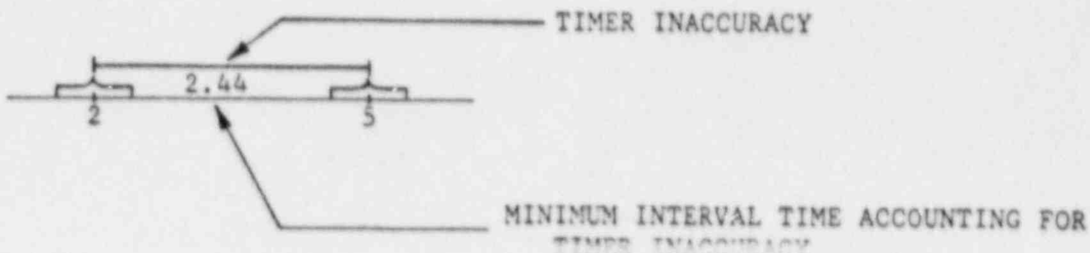
note 2 - Time from initial loss of offsite power until load breaker closure. Includes [illegible] generator runup time (10 sec), and load breaker closure time for two breakers at 0.125 sec per breaker.

Table 3 summarizes the effect of the voltage transient effect on motor starting time and its effect on load sequence time interval including timer accuracy and repeatability. The analysis accounts for the overlap of acceleration between the SI and CCP for the worst case.

Table 3

6.6 KV MOTOR ACCELERATION TIME

MOTOR	WORST CASE MOTOR TERM VOLTAGE PU 6.6KV BASE	MIN. TIME INTERVAL SEC (FIG.2)	ACCELERATION TIME			
			MEASURED FROM TEST IN SECS	MIN. VOLT FOR FIRST ONE SEC & 100% AVERAGE THE REST SEC	100% RATED VOLTAGE FOR THE ENTIRE PERIOD SEC	MARGIN BETWEEN (3)&(5) SEC
(1)	(2)	(3)	(4)	(5)	(6)	
CCP	0.867	2.44	2.15	3.33	2.99	*
SI	0.833	3.84	2.80	3.39	3.01	0.45
RHR	0.811	3.13	1.83	1.85	1.39	1.28
ERCW	0.782	2.4	1.56	1.67	1.20	0.73
AFW	0.778	6.25	3.46	3.77	3.22	2.48
CSP	0.798	22.4	2.56	2.79	2.35	19.61



* Margin is not applicable since CCP and SI pump motor starts could overlap; however, this condition has been considered in the calculation, and it has been established that this overlap will not cause any additional drop over what has been observed during testing.

In conclusion, the analysis (Attachment 2 and 3) shows that there is acceptable margin between the start of any two motors to allow full voltage recovery of the first before the start of the second for the worst-case set of start signal offsets generated by the sequence timers.

V. EXCITATION/REGULATOR PERFORMANCE

Attachment 4 is a report from NEI Peebles--Electric Products Inc., regarding the voltage response characteristics of the voltage regulator/excitation system installed at Sequoyah Nuclear Plant. The purpose of this report is to further explain why the DG was responding in the manner seen during the test.

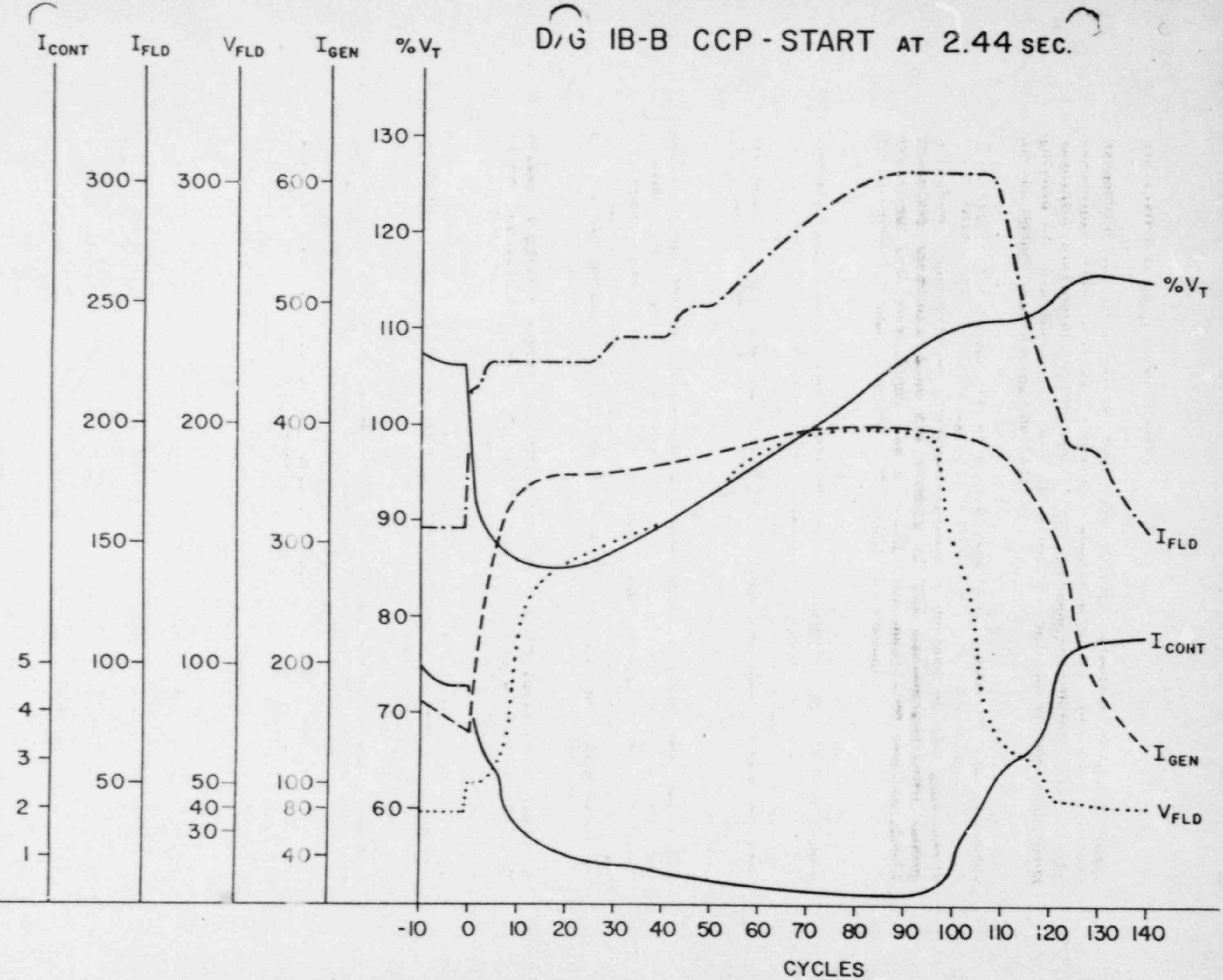
This report shows how the effective reactance values of the generator vary with the exciter/regulator response time and saturation. Effective reactance as discussed herein is defined as the generator's transient reactance plus the effects of the exciter/regulator during transient load conditions. As a result, the analytical results should be conservative when compared with actual measurement.

The following is a comparison between the test data and the characteristics predicted in the NEI Peebles report. D/G 1B-B test data was compiled for this comparison (Figures 4 through 8). Figure 5, "D/G 1B-B SI-Start at 5.56 sec" will be analyzed as an example of exciter response and the time lag created by voltage regulator transition from "full-on" to "full-off."

Immediately prior to motor start, the generator terminal voltage was still above nominal since the transient load current was not fully decayed. As a result, the voltage regulator control current (Icont) was at approximately 4.5A, and the exciter field voltage was at a minimum. Thus, in an attempt to lower the terminal voltage, the regulator was driving the saturable transformers into full saturation. Upon start of the motor, the generator terminal voltage (%Vt) sharply drops due to the sudden change in load as seen by the generator. Sensing this, the voltage regulator begins decreasing control current to cause an increase in exciter voltage. However, there is a time delay of approximately 10 cycles from the initial decrease in control current until there is a resultant change in exciter voltage. It takes an additional time delay of approximately 30 cycles for the control current to decrease to a value that will allow the exciter voltage build-up to transition to its maximum rate.

As seen from the curve, minimum terminal voltage occurs at approximately 20 cycles. At this point, the exciter has not yet reacted to the voltage decrease and the field current is still provided by the generator flux instead of the exciter voltage. Therefore, the voltage dip experienced in the test represents the maximum anticipated voltage dip for this load step. Further, there is acceptable margin in the timer sequence to accommodate the potential delay associated with the regular/exciter (See Table 3).

In conclusion, as a result of using these test results, TVA has bounded the test results by analysis. Further, the characteristics of the generator excitation system from the test data agrees with that predicted by the NEI Peebles report.



D/G IB-B CCP - START AT 2.44 SEC.
I_{CONT}
I_{FLD}
V_{FLD}
I_{GEN}
$\% V_T$
130
120
110
100
90
80
70
60
300
250
200
150
100
50
300
200
100
50
40
30
600
500
400
300
200
100
80
40
5
4
3
2
1
-10 0 10 20 30 40 50 60 70 80 90 100 110 120 130 140
CYCLES

FIGURE 4

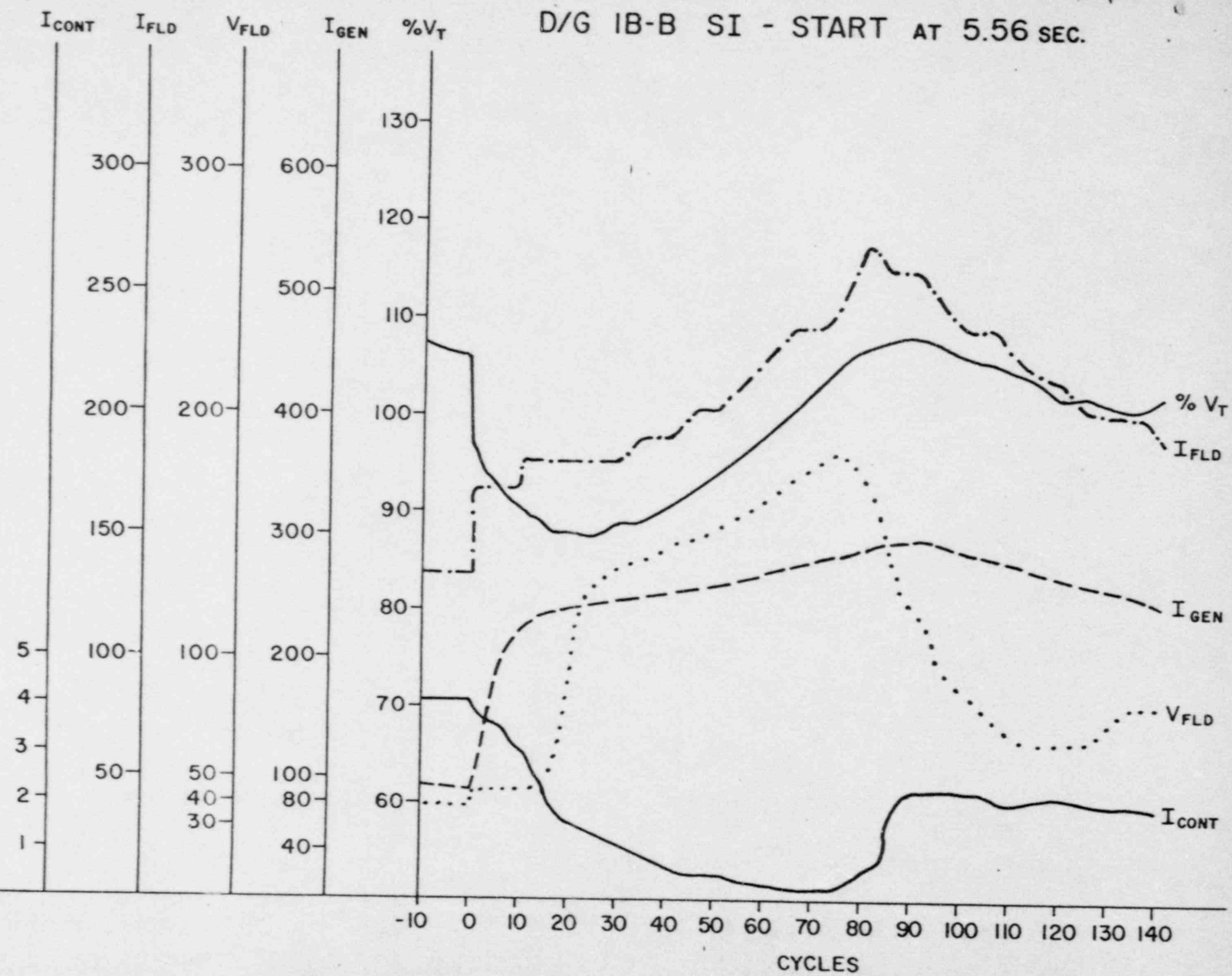

D/G IB-B SI - START AT 5.56 SEC.
I CONT
I FLD
V FLD
I GEN
%V T
% V T
I FLD
I GEN
V FLD
I CONT
CYCLES

FIGURE 5

D/G IB-B RHR - START AT 10.55 SEC.

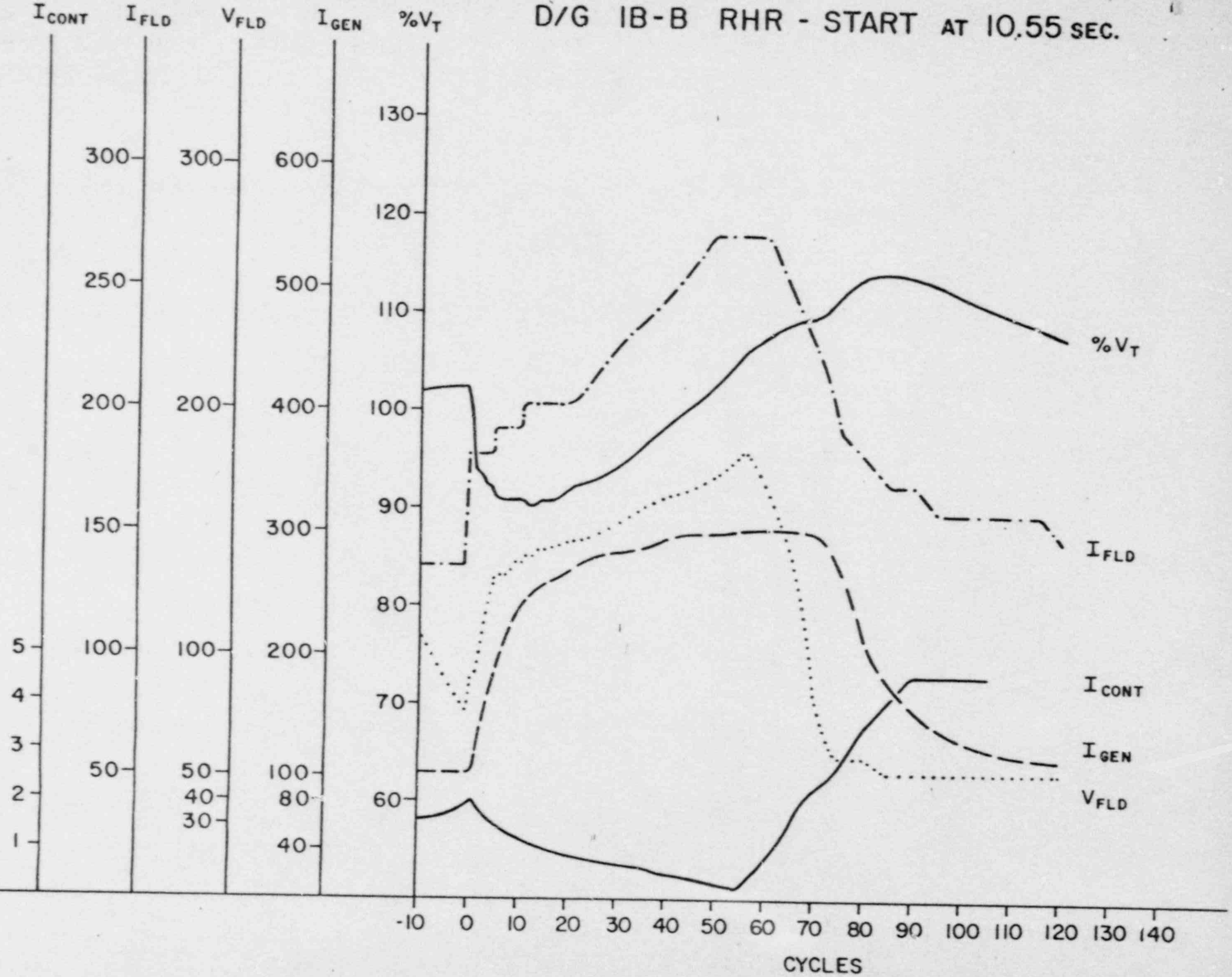


FIGURE 6

D/G 1B-B ERCW - START AT 16.11 SEC.

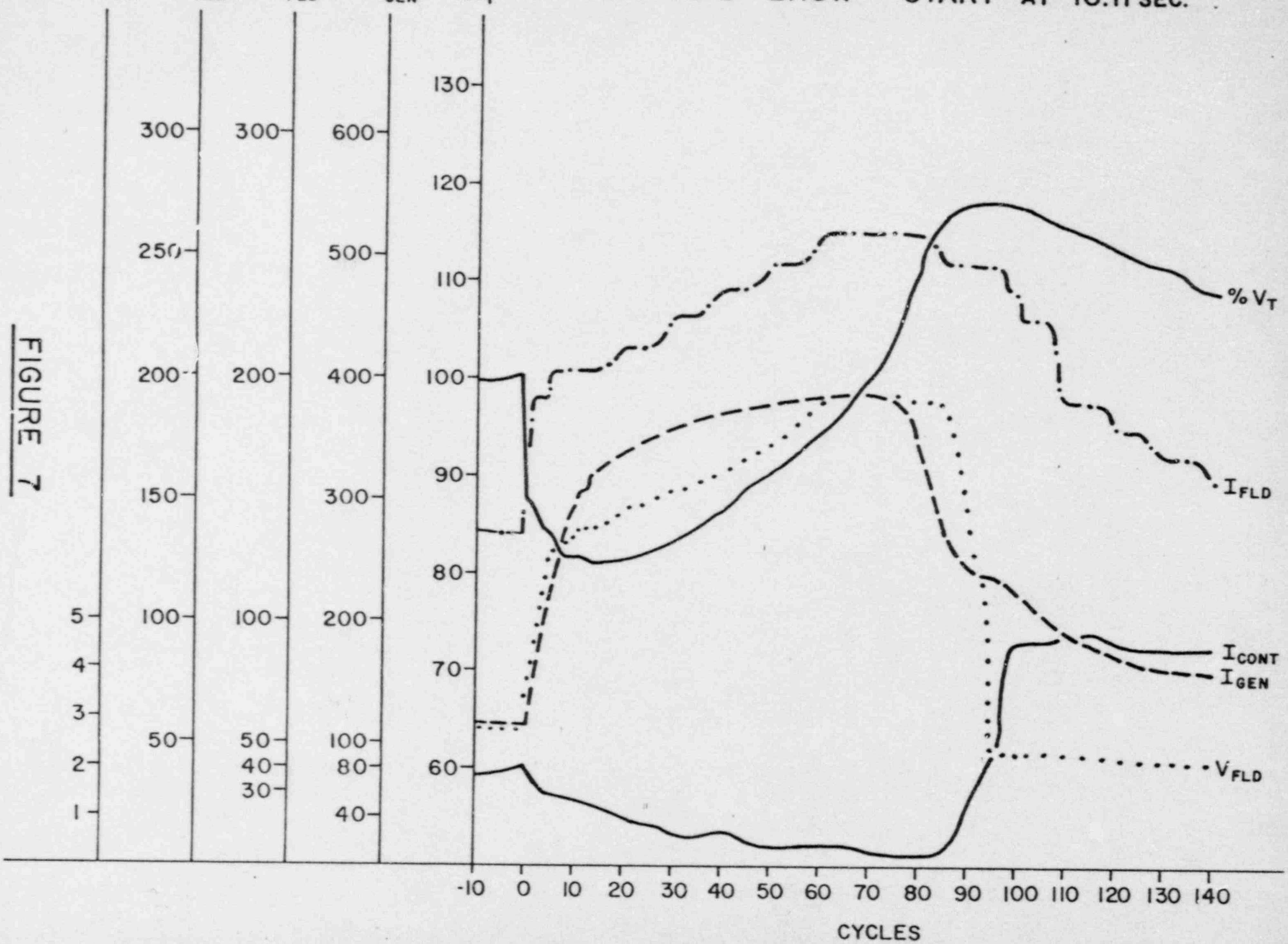


FIGURE 7

D/G IB-B CCW - START AT 21.2 SEC.

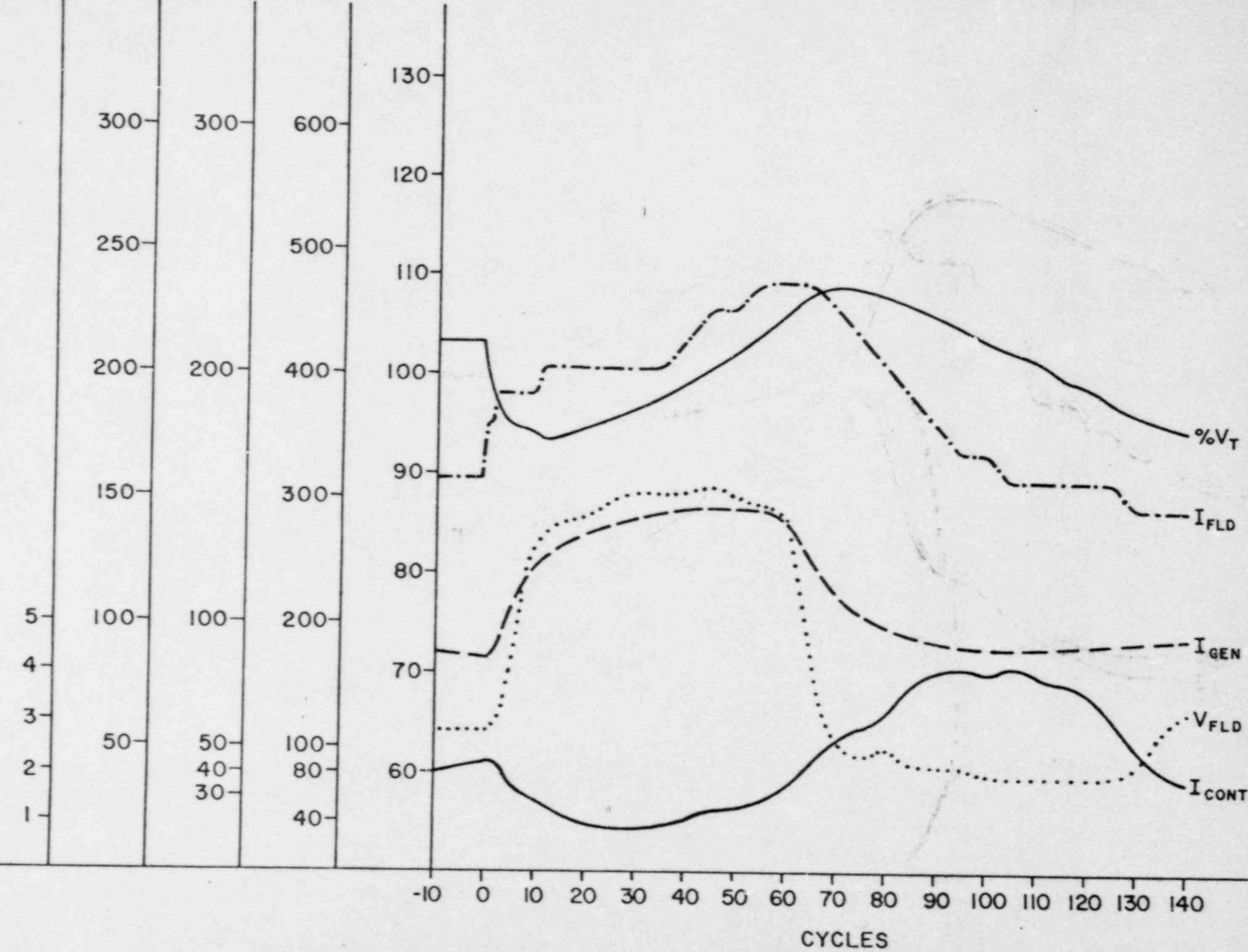


FIGURE 8

VI. REVIEWERS SUMMATIONS

The following summaries were prepared by Mr. Charles Concordia and Mr. Russ Allen at the request of the Tennessee Valley Authority.

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Comments on Sequoyah Nuclear Plant
Diesel Generator - Starting of Motor Loads

At the request of TVA, I have considered the performance of the diesel generator; particularly the successful starting of several motor loads in sequence, and the results of calculation and test of the motor starting. A major question was the larger voltage dip found in test as compared to the calculation in some cases.

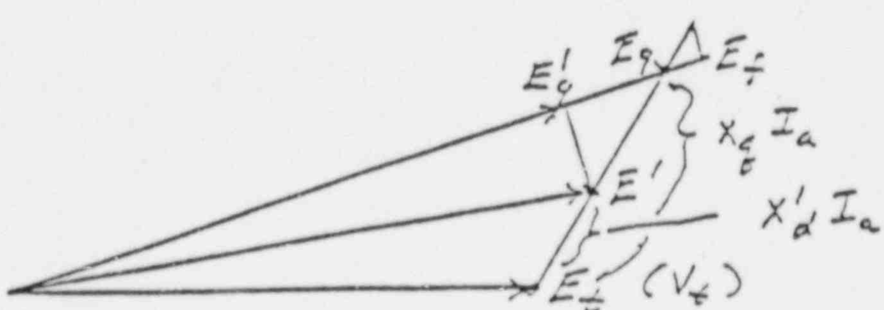
The generator field excitation is supplied by an "SCPT" system. In this system the generator field voltage is taken from both generator terminal voltage and armature current is such a proportion that just the right voltage is supplied to maintain the terminal voltage (whatever it is). That is:

$$E_{field} \; \alpha \; V_{term} + j \, x_d I_{arm}.$$

Thus, theoretically, is a load (for example, the primarily reactive load of a stationary motor) is suddenly applied, the voltage will drop in a very few cycles, to a somewhat lower value and simply remain at this new value. It should not drop further because the field voltage has automatically increased to supply the required greater field current. No voltage-regulator action is required. However, since there usually is a voltage regulator, it will send a signal to increase the field current further, to bring the terminal voltage back to normal. In the SCPT as originally designed, and in the present generators, the voltage regulator acts by shunting part of the supply voltage ($V_t + j\, x_d I_a$) in effect changing the proportionality factor α.

From this brief explanation it would seem reasonable to calculate the voltage dip by simply using the initial drop [after the subtransient (amortisseur) currents have died away in a few cycles], and, as I understand it, this is what was done. In the present case, the calculation of subsequent starts was complicated by the previous motor loads, which were considered as constant--apparent-power loads. This should be realistic.

I have independently calculated several cases to explore the effects of the previous loads and of the approximation to the conventional assumption of constant field flux linkage by assuming constant voltage back of generator direct-axis transient reactance (i.e., assuming E' as an approximation to E'_q in the diagram below) (see Reference 1).



From my calculations I concluded that both effects were rather small. For example, in one case:

Previous Load	Voltage Dip	Constant
22%	11.9%	E'
44%	12.9%	E'
22%	11.6%	E'q

This is a 1% increase for doubling the previous load and a 0.3% decrease for using the more "exact" method of constant E'q.

Then to explain the observed discrepancies there seemed to remain two possibilities: the transient reactance assumed was too small or the transient caused by the last previous disturbance had not yet disappeared. Further inspection of the test results showed that indeed the transient had not disappeared so it was not necessary to assume a wrong x'd (although a few percent error in x'd is not uncommon).

In several cases the generator terminal voltage was still a few percent high when the next motor load was applied. Referring to our previous explanation of the voltage regulation this means that the field supply voltage was (or should be) considerably reduced so that in the first place, the field voltage did not immediately increase to a value sufficient to maintain (or limit) the dip to the initial transient value so the voltage decreased further, and in the second place, the regulator was too slow to counteract this decrease.

Two observations can be made:
First, fortunately since the larger voltage dip started from a higher level, the actual minimum voltage was not smaller than that for an initial drop from 100% voltage, at least in all the cases I considered.
Second, this behavior following a transient conditions is not a new phenomenon. I worked on one of the very first SCPTs (see Reference 2, 1961 AIEE Trans.) and in fact predicted and observed the same effect. Figure 8 of Reference 2 shows the application of load and the removal of about 75% of it after 0.833 second. It was very interesting to see that on the removal (at V = 0.97) the initial transient rise of 10% was increased by 3% more because of the previous transient and the resulting maximum voltage was V = 1.10, exactly as would result from removal at steady state and V = 1.0. (This was the calculated result. The test result was slightly smaller.) This effect, of arriving at about the same maximum or minimum voltage, is very similar to that observed in the present tests and discussed above.

In the present tests we could have hoped that there was sufficient time to arrive at a steady state for each new load application. However, no harm seems to have resulted, as the minimum voltage was not lowered. Further, I understand that a faster (and different) regulator may eventually be installed.

In the calculations and test of Reference 2, the object of load removal after only 0.833 second was precisely to evaluate this possible transient effect, simulating approximately the starting of an induction motor. This was why we had to go further and calculate the voltage-regulator <u>response</u> as well as the initial dip. We may add that one aspect of the SCPT exciter is that, because the field voltage should go immediately to the value required to prevent further decline, the voltage regulator does not need to be very fast. However, new types have been developed since, substituting solid-state regulators for the original "saturating" regulators.

Since we feel that the test results have been adequately explained, it remains only to consider the extrapolation to full motor-load conditions. As the new motor at each step will take somewhat longer to accelerate, there will be somewhat less time for the transient to decay. However, in the test and calculation results so far this transient effect has been negligible <u>on the minimum voltage</u>. (The interval in the old AIEE paper was only 0.833 second). Moreover, the initial shock of new load is not increased by this extrapolation, only the previous load and the acceleration times are increased, so the effect is small in any case, as our discussion above has indicated.

The effect of generator speed dip was briefly discussed. In fact some frequency drop may be beneficial rather than harmful. Induction motors respond to volts/Hertz rather than volts, at least over a moderate range. Thus, a motor will start as well <u>or better</u> at 95% voltage <u>and</u> 95% frequency than at 100% voltage and frequency. If the minimum voltage observed at 95% frequency is, e.g., 80%, the motor starting behavior (and the previous motor load also) will be about as for 84% voltage at normal frequency. The running motor load will be decreased slightly but for only a very brief time.

Finally, from all of these considerations, and from my understanding of the motor minimum-voltage requirements, it would seem that the starting performance should be entirely adequate.

In spite of this opinion, we cannot resist mentioning a few factors that could be considered <u>if</u> it is desired to make further improvements.

1. A faster-responding voltage <u>regulator</u>, and one that would not suppress the built-in <u>exciter</u> response of the SCPT.

2. Keeping the voltage setpoint at, e.g., 105% as long as the diesel generator is not being used and up to, e.g., 35 seconds after start, then automatically reducing to 100% after all loads have been started.

3. Increasing the load current compounding (the $j \times {}_dI_a$ term). This may mean increasing the contribution from the current transformer of the SCPT.

References:

1. "Synchronous Machines" (Book) J. Wiley & Sons, 1951 by C. Concordia (See Chapter 9, pp 200-201, and p 36)

2. "Performance of a New Static-Magnetic Exciter and Voltage Regulator for Round Rotor Marine Steam Turbine Generators" by D. F. Talcott, P. M. Tabor, and C. Concordia, AIEE Trans., Vol. 80, June 1961, pp 141-148 (See Figures 8, 2, and 3, and App. II)

REVIEW

by R. E. Allen

Per TVAs request, I have made an overall review of the background, approval, general results and conclusions of the TVA DG Voltage and Margin Analysis (DGVMA) effort relative to determination of start sequence load step voltage dips. Others have made a detailed review of the test results or the calculations and their specific technical assumptions.

I have concluded that, based on the DG reduced load test results and the DGVMA, there is reasonable confidence that the Sequoyah diesel generator units have the capability of starting accelerating and running the required safety-related loads with acceptable voltage margins.

This conclusion is based on the high degree of conservatism in the TVA approach to determining the voltage drop and margin in each start-sequence load step. First, the voltage drops are observed from a worst-case scenario comprised of the composite of the worst-case load steps from all four diesel generators, a condition that cannot physically occur. Second, it is assumed that the largest random load is switched on simultaneously with each start-sequence load step, a condition that is highly improbable. Third, the major portion of the voltage dip for each load step has been determined by test with the remainder, which is due to the difference between the pretransient scheduled and test loads, determined by a conservative analysis.

SC/3999F

In the latter case, there are three components to the load step voltage drops; that contributed by the locked rotor (starting condition), that contributed by the pretransient test load and that contributed by the delta between the pretransient scheduled and test loads. Of these, the first two are determined by test and third by approximate but conservative calculations. Of the three, the locked rotor component causes the majority of the voltage dip. Part of the remaining five to ten percent is determined by test. Consequently, the third component, determined by analysis, was expected to be and was found to be very small.

Table 4
SUMMARY OF MARGINS

COMPONENT	PERCENT MINIMUM MARGIN
6.6KV Motors - Sustain	12.5
460V Motors - Sustaining	6.3
Contactors - Dropout	26.0
Contactors - Pickup	8.1
MOV Performance and Stroke Times	18% (Voltage)/5.3% (Time)/56% Torque
Diesel Generator Loading	2.3

VII. Conclusions

Based on the summary of margins listed above in Table 4 we have determined that the diesel generator will perform its intended safety function by starting and accelerating all required loads within the required limits, with acceptable margins even when considering worse-case voltage and sequence timer inaccuracy and maximum motor starting time. Furthermore, it is concluded that the test results have been bounded by analysis.

Attachment 1

Diesel Generator Voltage Analysis

(B25 880223 305)

TVA 10697 (DNE 6-86) ORIGINAL DNE CALCULATIONS

QA Record

TITLE	PLANT/UNIT
DIESEL GENERATOR VOLTAGE & MARGIN ANALYSIS	SQN UNITS 1&2

PREPARING ORGANIZATION	KEY NOUNS (Consult RIMS DESCRIPTORS LIST)
DNE EEB	DIESEL GENERATOR, VOLTAGE, CALCULATIONS

BRANCH/PROJECT IDENTIFIERS: SQN-E3-015

Each time these calculations are issued, preparers must ensure that the original (RO) RIMS accession number is filled in.

Rev	(for RIMS' use)	RIMS accession number
R0		B25 '88 0223 305
R_		
R_		
R_		

APPLICABLE DESIGN DOCUMENT(S): RG-1.9

SAR SECTION(S): 8.3

UNID SYSTEM(S):

Revision 0	R1	R2	R3
ECN No. (or indicate Not Applicable) N/A			
Prepared A.N. PAL apal.			
Checked S. MAZUMDAR Smazumdar			
Reviewed GLNicc			
Approved [signature]			
Date 2/23/88			
List all pages added by this revision.			
List all pages deleted by this revision.			
List all pages changed by this revision.			

Use form 10534 if more space required

Safety-related? Yes ☒ No ☐

Statement of Problem

TO ESTABLISH THE LOAD MARGIN FOR THE DIESEL GENERATORS (DG) RESULTING FROM A BOUNDING CASE EVALUATION OF THE AUXILIARY POWER SYSTEM PERFORMANCE FOR DESIGN BASIS EVENT LOADING. ALSO CALCULATE MINIMUM VOLTAGE AT CONNECTED EQUIPMENT USING THIS BOUNDING CASE ANALYSIS TO SHOW THAT SAFETY-RELATED SYSTEMS/COMPONENTS WILL PERFORM THEIR INTENDED SAFETY FUNCTION WHEN POWERED BY THE DG, WITH ACCEPTABLE MARGIN.

Abstract

These calculations contain an unverified assumption(s) that must be verified later. Yes ☐ No ☒

FSAR COMPLIANCE REVIEW [signature] for LE

THIS CALCULATION ESTABLISHES 1) THE WORST CASE VOLTAGE PROFILE FOR THE 6.9 KV AND 480V CLASS IE POWER SYSTEM BASED ON DIESEL GENERATOR TEST RESULTS, AND 2) THE MARGINS THAT EXIST IN THE CONNECTED EQUIPMENT DURING THE PREDICTED WORST-CASE VOLTAGE PROFILES.

IT HAS BEEN DETERMINED THAT THE DG WILL PERFORM ITS INTENDED SAFETY FUNCTION BY STARTING AND ACCELERATING ALL REQUIRED LOADS WITHIN THE REQUIRED LIMITS, WITH ACCEPTABLE MARGINS EVEN CONSIDERING WORST CASE VOLTAGE AND SEQUENCE TIMER INACCURACY AND MAXIMUM MOTOR STARTING TIME. FURTHERMORE, IT IS CONCLUDED THAT THE TEST RESULTS HAVE BEEN BOUNDED BY ANALYSIS.

CALC. CONSISTS OF TOTAL OF 277 PAGES.

☐ Microfilm and store calculations in RIMS Service Center

Microfilm and destroy. ☐

☐ Microfilm and return calculations to: Return to G. Hunley Address: P-179 SB-K X-3257

cc: RIMS, SL 26 C-K

TVA

Title: DG VOLTAGE AND MARGIN ANALYSIS

REVISION LOG

SQN-E3-015

Revision No.	DESCRIPTION OF REVISION	Date Approved

CALCULATION INDEPENDENT REVIEW VERIFICATION FORM

SQN-E3-015 — Calculation No.

0 — Revision

Method of independent review used (check one or more):

1. Alternate calculation method ______
2. Testing method ______
3. Other method ✓

Justification (explain below):

Method 1: Identify the pages where the alternate calculation has been included in the calculation package and explain why this method is adequate.

Method 2: Identify the QA documented source(s) where testing adequately demonstrates the adequacy of this calculation and explain.

Method 3: Justify the technical adequacy of the calculation and explain how the adequacy was verified (calculation is similar to another, based on accepted handbook methods, appropriate sensitivity studies included for confidence, etc.).

REVIEWED PURPOSE, RESULTS AND CONCLUSIONS FOR TECHNICAL ADEQUACY AND REASONABLENESS. REVIEWED USE OF DESIGN INPUT FOR ADEQUACY. SPOT CHECKED CALCULATION METHODS FOR CORRECTNESS AND TECHNICAL ADEQUACY. REVIEWED CALCULATION PER NEP 3.1 REV 1 ATTACHMENT 10. THE CALCULATION METHOD IS BASED UPON ACCEPTED TEXTBOOK METHODS.

[signature] — Design Verifier (Independent Reviewer)

2-23-88 — Date

TVA 489H (EN DES-2-78) TENNESSEE VALLEY AUTHORITY SHEET OF

SUBJECT DG VOLTAGE & MARGIN ANALYSIS PROJECT

SQN-E3-015

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FSAR SECTION 8.3 HAVE BEEN REVIEWED FOR COMPLIANCE BASED ON CALCULATION RESULTS THE CALCULATION RESULTS SHOW THAT THE INTENT OF RG. 1.9 IS SATISFIED WITH THE EXCEPTION OF OVERVOLTAGE. THIS HAS BEEN DOCUMENTED IN A CAQR # SQP 871238. THIS CAQR HAS BEEN CLOSED WITH NO PHYSICAL MODIFICATIONS.

J. D. Hutson[signature]
ABC

SUBJECT DIESEL GENERATOR VOLTAGE & MARGIN ANALYSIS PROJECT SQN

SQN-E3-015

COMPUTED BY G.Pal DATE 2/22/88 CHECKED BY Sm DATE 2/23/88

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT'D)

1.0 PURPOSE

The purpose of this calculation is to establish the load margin for the diesel generators (DG) resulting from a bounding case evaluation of the auxiliary power system performance for design basis event loading. Calculate the minimum voltages at connected equipment using this bounding case analysis to show that safety-related systems/components will perform their intended safety function when powered by the DG, with acceptable margin..

1.1 PROCEDURE

The basis of this calculation are actual field test results of load sequence testing of all four diesel generators for SQN units 1 and 2.

The DG data obtained by testing was analyzed for each load sequence step. The minimum voltages at each step were compared and the lowest voltage for the step was selected to establish a worst case composite DG voltage profile for the 6.9KV and 480V shutdown boards.

During the diesel generator load sequence testing performance, it was not possible to fully load all the motors to their design basis load; therefore, the maximum voltage transients were not obtained for all the load sequence steps. In order to determine the maximum transient voltage, the composite worst case test voltage transients were adjusted ~~to~~ for the maximum loading that would occur for a loss of offsite power concurrent with a loss of coolant accident (LOOP/LOCA). This maximum loading is called schedule loading henceforth.

The calculation modified the composite test voltage profile to produce a conservative voltage profile which accounts for the most severe bounding case evaluation of factors not enveloped by actual testing. All of these bounding case factors do not occur simultaneously on any one diesel generator. By determining a bounding case value for each factor, and then combining their bounding case factors, this calculation provides a conservative estimate of some concerns. However, it ensures that the analysis has provided a bounding case evaluation of all concerns.

From these adjusted worst case voltages, the worst case voltages were calculated at the 480V Motor Control Center (MCC), 460V motors, and 460 MOVs. The cable drops used to calculate the above voltages were the worst cable impedance identified for each of the MCCs and loads to bound the analysis. The cable drop evaluation and field test results are document in Appendixes F and A respectively. The voltage analysis methodology and detailed calculations are documented in Appendix B.

Conservate factors used to bound the voltage analysis include the following:

A. The composite diesel generator voltage profile based on the worst case load sequence transient voltage dips for all four DGs.

B. The scheduled load profile based on the worst case loaded DG (DG 2B-B).

C. The contactor dropout,pickup analysis based on:

1) Maximum control circuit length of 5350 feet which is the maximum of all MCC control circuits. This results in a very conservative analysis since typical circuit length is 1500-2500 feet.

2) Smallest control transformer of 100VA.

3) Combined load of one size 1 contactor, one solenoid, and one timer.

D. Considers all running motors as constant MVA loads which results in a more severe voltage transient.

E. Does not consider the boosting effect of the running induction motors providing a generator effect during a sudden drop of bus voltage. This effect should reduce the voltage transient.

SQN-E3-015

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Verified fm Date 2/23/88

SUBJECT DG VOLTAGE & MARGIN ANALYSIS PROJECT SQN

SQN-E3-015

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2.0 ASSUMPTIONS

2.1 PRE TRANSIENT RUNNING LOADS ARE TREATED AS CONSTANT MVA LOAD (CONSERVATIVE)

2.2 FOR THIS ASSUMPTION, SEE APPENDIX-E SH. E3

2.3 FOR THESE ASSUMPTIONS, SEE APPENDIX-G SH. G3

2.4 THE EFFECT OF STARTING THE LARGEST LOADS OF THE RANDOM LOAD BLOCK (60HP A/C COMPRESSOR AND 25HP AIR HANDLING UNIT) FOR EACH LOAD SEQUENCE STEP IS CONSIDERED. ALL OTHER RANDOM LOADS ARE ASSUMED TO BE RUNNING FOR ALL LOAD SEQUENCED STEPS (CONSERVATIVE)

SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT SQN

SQN-E3-015

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3.0 SOURCES OF DESIGN INPUT INFORMATION (REFERENCES)

3.1 CALC. SQN-E3-002 REV. 7

3.2 ICF 37-999 - DG 1A FIELD TEST

3.3 STI 111 - DG 1B FIELD TEST

3.4 STI 77 - DG 2A FIELD TEST

3.5 STI 78 - DG 2B FIELD TEST

3.6 CALC. OE2-EEB CAL 001, REV. 9

3.7 CALC. SQN-APS-006, REV. 3

3.8 CALC. SQN-APS-010 REV. 2

3.9 CALC. DG TIMER RELAYS, REV 1 DATED 8/31/87
RIM NO B25880122F

3.10 MOTOR DATA SHEETS

A. SI PUMP, DATED 2/21/69
B. RHR PUMP, DATED 1/25/71
C. ERCW PUMP, DATED 6/1/76
D. AFW PUMP, DATED 4/19/72
E. CCWP, DATED 6/4/81
F. CSP, DATED 3/22/72
G. CENT. CHARG. PUMP, DATED 3/9/71

SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT SQN-E3-015

COMPUTED BY aPat DATE 2/22/88 CHECKED BY Sm DATE 2/22/88

3.11 DROP OUT VOLTAGE REPORT FOR SEQUOYAH NUCLEAR PLANT ON ARROW-HART CONTACTORS (ATTACHED IN APPENDIX-G)

3.12 PICK UP VOLTAGE REPORT FOR SEQUOYAH NUCLEAR PLANT ON ARROW-HART CONTACTORS (ATTACHED IN APPENDIX-H)

3.13 MOVATS TEST FOR MOV. ANALYSIS REPORT PREPARED FOR SQN NUCLEAR GENERATING STATION : THRUST SIGNATURE ANALYSIS. RIM # 870602T0001

3.14 QIR MEB SQN 87194 R0 RIM. 844 871210 009

3.15 DG DATA SHEET (ATTACHED IN APPENDIX-H)

3.16 CAL. SQN-E3-011 REV. 2

3.17 DEMONSTRATED ACCURACY CALC. 27S1A RIM # 825 83 0126456

3.18 REG GUIDE 1.9 R0

3.19 FSAR SECTION 8.3

SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT SQN-E3-015

COMPUTED BY apat DATE 2/22/88 CHECKED BY Sm DATE 2/22/88

4.0 DESIGN INPUT DATA

4.1 FIELD TEST TRACE

ICF 37-999 - DG 1A FIELD TEST

STI - 111 - DG 1B FIELD TEST

STI - 77 - DG 2A FIELD TEST

STI - 78 - DG 2B FIELD TEST

SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT SQN-EE-015

COMPUTED BY aPal DATE 2/22/88 CHECKED BY Sm DATE 2/22/88

5.0 DOCUMENTATION OF ASSUMPTIONS

5.1 ASSUMPTION 2.1

TREATING MOTORS AS CONSTANT MVA LOADS PROVIDES THE MAXIMUM VOLTAGE DROP

5.2 ASSUMPTION 2.2

FOR DOCUMENTATION OF THIS ASSUMPTION SEE APPENDIX E, SH. E3

5.3 ASSUMPTIONS 2.3

FOR DOCUMENTATION OF THESE ASSUMPTIONS, SEE APPENDIX-G SH. G6

5.4 ASSUMPTION 2.4

THIS ASSUMPTION PROVIDES THE HEAVEST LOADING WHICH IS A WORST CASE ANALYSIS.

SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT SQN-EE-015

COMPUTED BY aPal DATE 2/22/88 CHECKED BY Sm DATE 2/22/88

6.0 COMPUTATIONS / ANALYSIS

SEE APPENDICES.

SUBJECT DG VOLTAGE & MARGIN ANALYSIS PROJECT SQN-E3-015

COMPUTED BY aPal DATE 2/22/88 CHECKED BY Grr DATE 2/22/88

7.0 SUPPORTING GRAPHICS

FIG.-1 REPRESENTS THE ONE-LINE DIAGRAM FOR A TYPICAL POWER TRAIN OF THE ONSITE POWER DISTRIBUTION SYSTEM.

FIG. 2 COMPARES THE TEST LOADING TO THE SCHEDULED (LOOP + LOCA) LOADING.

SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT SQN

SQN-E3-015

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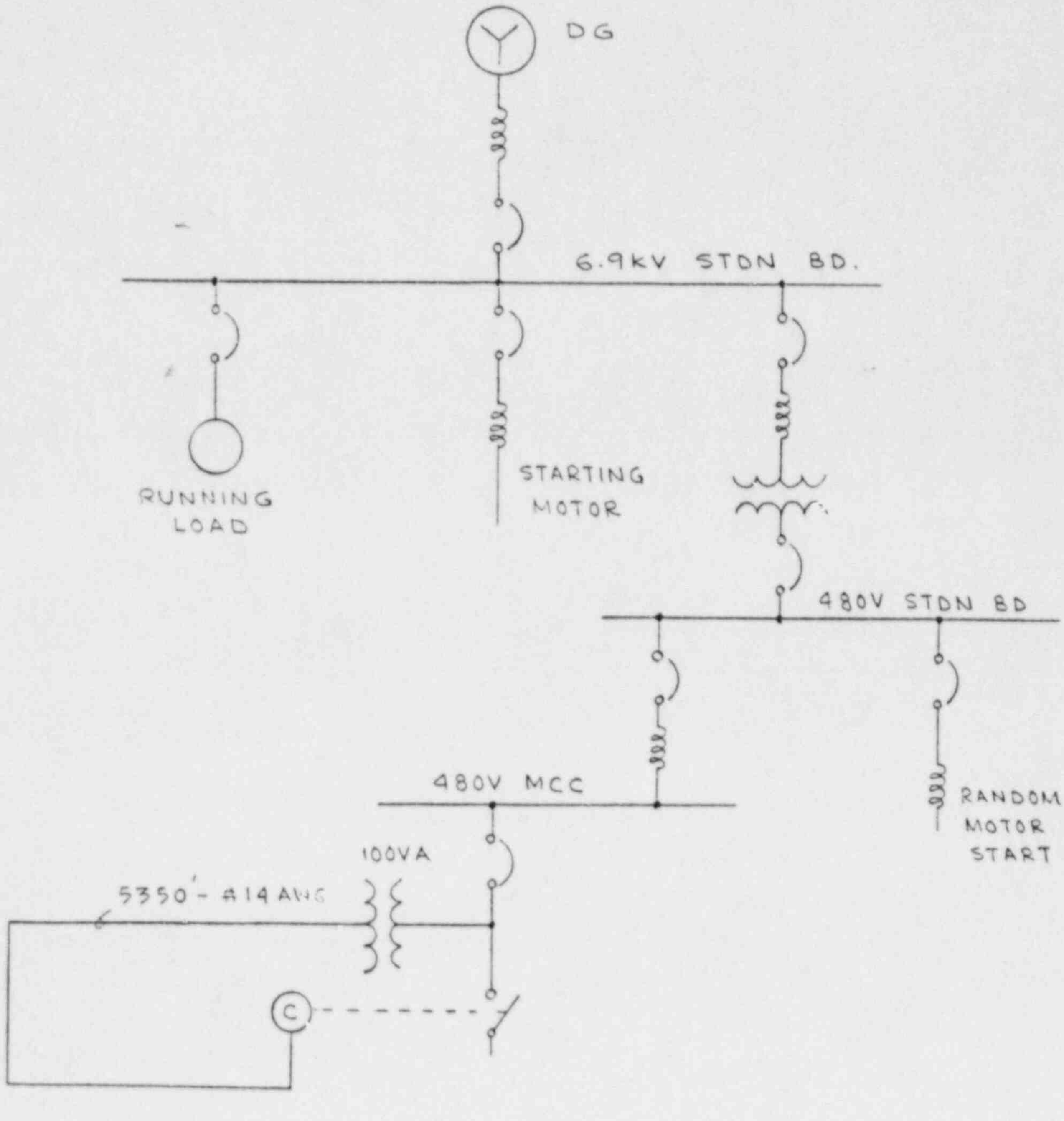
FIG. 1



ON LINE DIAGRAM

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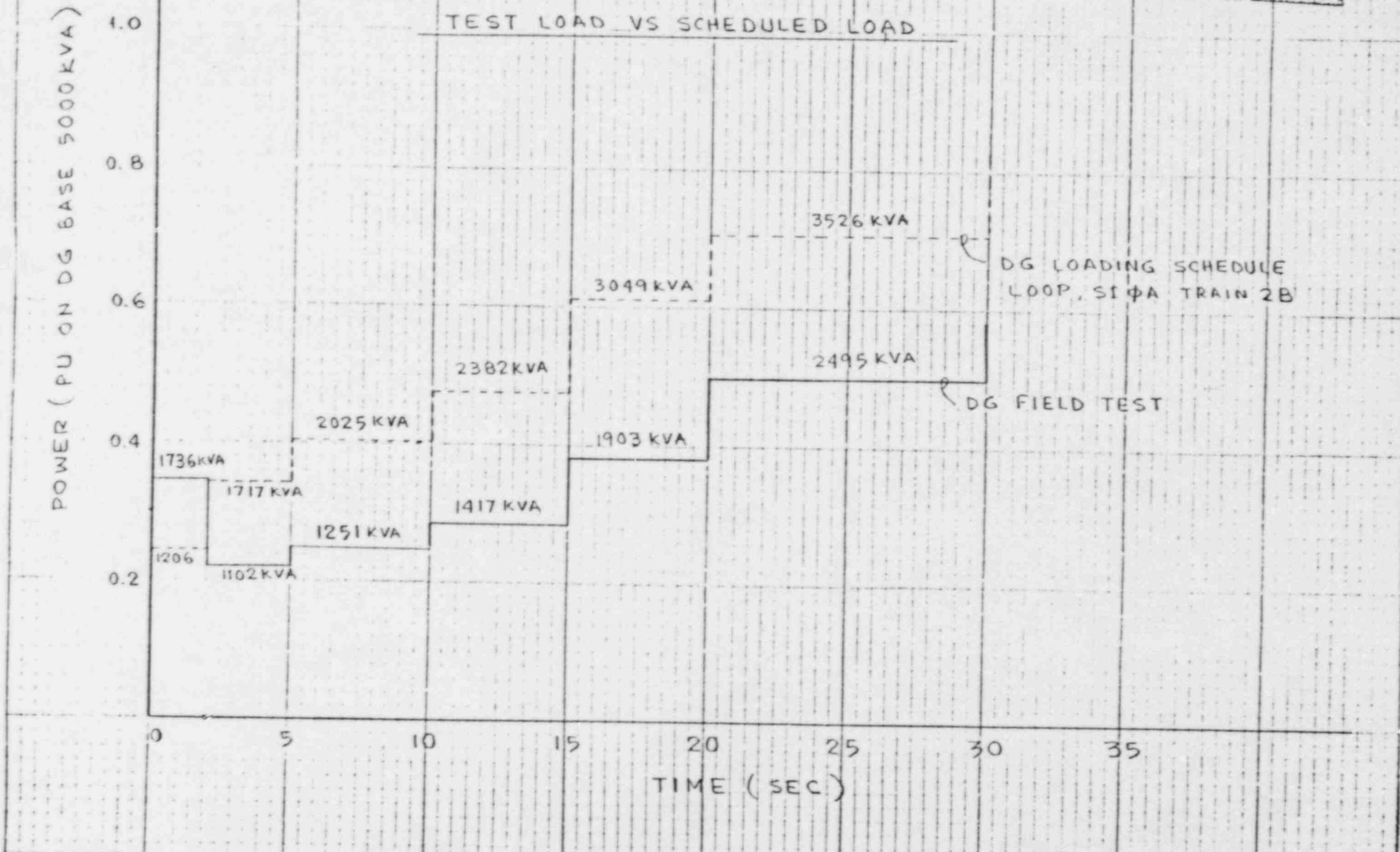
Sheet 12 of

FIG. 2

TEST LOAD VS SCHEDULED LOAD



8.0 Results of Voltage Analysis and Determination of Available Margins

The voltage transient can potentially effect the performance of the diesel generator systems and the components they power. The following sections discuss each of these items with regard to transient voltage effects on the components. The available margins between the anticipated transients and the components operation has been identified.

8.1. Diesel Generator Voltage Analysis

Tables 1 and 2, attached, summarizes the results of the DG voltage analysis. The minimum 6.9 KV shutdown board voltage was determined to be 76.5 percent and the minimum 480V shutdown board and motor control center (MCC) voltage was determined to be 77 percent and 75.6 percent respectively both for approximately 16 cycles.

The lowest motor terminal voltages are as follows:

6.6 KV motor	76.2 percent
460V Switchgear motor	74.3 percent
460V MCC Motor	74.5 percent
460V MCC MOV	74.6 percent

The calculations supporting these results are in Appendix B.

WORST CASE 6.9 KV BUS VOLTAGE
CORRECTED FOR SCHEDULE LOAD

START MOTOR ①	SEQ. TIME SEC. ②	PRETRAN VOLTAGE PU ③	SOURCE DG ④	PRIOR TO START: DG LOAD FIELD TEST ⑤	PRIOR TO START: DG LOAD SCHEDULE [REF. 3.1] ⑥	PU DIP FIELD TEST ⑦	ADDITIONAL PU DIP DUE TO LOADING DIFFEREN ⑧	TOTAL PU DIP [⑦+⑧] ⑨	PU MINIMUM BUS VOLTAGE [③ - ⑨] ⑩
CCP	2	1.009	2A	1736 ∠54.5	1206 ∠42	0.174	0.0	0.174	0.835
SI	5	0.991	2B	1102 ∠21.8	1717 ∠34.7	0.162	0.010	0.172	0.819
RHR	10	0.969	2B	1251 ∠25.3	2025 ∠32.5	0.159	0.013	0.172	0.797
ERCW	15	1.001	1B	1417 ∠30.3	2382 ∠30.9	0.187	0.012	0.199	0.802
AFW	20	0.965	2A	1903 ∠29.5	3049 ∠31	0.183	0.017	0.200	0.765
CCWP	30	1.008	2B	2495 ∠31.1	3526 ∠29.9	0.110	0.013	0.123	0.885
CSP+FP *	180	1.0	2A	3083 ∠33.7	3837 ∠29.7	0.200 ▲	0.012	0.212	0.788

* 200 HP FP WAS STARTED WITH CSP.

▲ ADJUSTED THE FIELD TEST DIP TO COMPENSATE THE EFFECT OF 200HP F.P (DIP = 0.039PU)

NOTE : FOR COLUMN ① THRU ⑤ AND ⑦ SEE TABLE-A1

TABLE 1

S&N-E3-015

PREPARED ___ DATE 2/22/88

CHECKED ___ DATE 2/22/88

TABLE 2

WORST CASE 480V STND. BD. VOLTAGE

CORRECTED FOR SCHEDULE LOAD

SEQ. TIME SEC. – ①	PRE TRAN VOLTAGE PU ②	PU DIP FIELD TEST ③	④ ADDITIONAL PU DIP DUE TO LOADING DIFFERENCE	⑤ TOTAL PU DIP [③+④]	⑥ PU MIN. BUS VOLTAGE [②-⑤]
0	1.06	–	–	–	1.06
2	1.0	0.163	0.0	0.163	0.837
5	1.017	0.167	0.010	0.177	0.84
10	0.994	0.148	0.013	0.161	0.833
15	1.017	0.183	0.012	0.195	0.822
20	0.975	0.179	0.017	0.196	0.779
30	1.033	0.188	0.013	0.201	0.832
180 (CSP+FP*)	1.012	0.23▲	0.012	0.242	0.77

* 200HP FP WAS STARTED WITH CSP

▲ ADJUSTED THE FIELD TEST DIP TO COMPENSATE THE EFFECT OF 200HP F.P (0.051PU DIP)

NOTE : COLUMN ① THRU ③ SEE TABLE - A2

8.2 Effect of Random Loads

TVA has determined that the D ald be capable of accommodating the application of a random process load block (i.e., sixteen loads that are controlled by process parameters such as flow, pressure, etc.). We have assumed that 14 of these loads are running and that two of the largest loads are starting to calculate the additional voltage drop. The increase in the 6.9KV and 480V system transient voltage dip resulting from this random process load block is 1.9 percent, and 2.4 percent respectively. (See Appendix C)

~~This evaluation is documented in Appendix C.~~ apal

8.3. Motor Starter Contactor Voltage Margin

In safety-related circuits at Sequoyah, size 1, 2, and 3 contactors are used. For Unit 2 operation, approximat number of each types of each contactor size are:

Size 1 Approximately 500 (27 ampere rating)
Size 2 Approximately 60 (45 ampere rating)
Size 3 Approximately 15 (90 ampere rating)

All of these are of the same manufacturer, Arrow-Hart Incorporated. Size 1 contactors are supplied from smaller control power transformers than larger contactors and experience lower per unit voltage. As such, the size 1 contactors are the limiting application; contactor dropout and pickup characteristics of Size 1 contactors were investigated. Tests were performed at TVA's Chicamauga Laboratory using new and used contactors from SQN. These tests yield a minimum drop out voltage of 54 percent and minimum pickup voltage of 73.6 percent on a 110V base. The corresponding required voltages on a 480-volt base are 49.5 percent and 67.5 percent respectively.

Conclusion:

1. Dropout

Using the minimum adjusted test voltage from Appendix B the minimum adjusted voltage anticipated at 480V MCCs is 75.6 percent; therefore, the minimum margin is 26 percent above the required voltage of 49.5 percent (54 percent on contactor base of 110V).

2. Pickup

The minimum adjusted voltage anticipated at the 480V MCCs is 85 percent when a MCC contactor closes concurrently with the starting of a 6.6KV motor and 75.6 percent when there is a delay such that the contactor picks up at minimum voltage. Therefore, the margin is 17.5 percent if contactor closes concurrently and is 8.1 percent if there is a delay. These minimum voltage values are above the minimum required voltage of 67.5 percent (73.6% on a contactor base of 110V).

8.4. Motor Operated Valve Torque and Time Margin

All MOVs that would be actuated during the loading sequence for a design basis event were evaluated for increased stroke times due to transient voltage dips. All MOVs under consideration are rated for a minimum start voltage of 77 percent* and can develop 100 percent torque at this voltage. Since there is more time above 77 percent than there is below 77 percent (more over-travel than under-travel) in the travel time, it is more appropriate to examine the average voltage. The average voltage experienced based on the adjusted load conditions for the loading sequence is approximately 95 percent; therefore, the voltage margin is 18 percent.

In addition, all MOVs required during this time have a minimum of 5.3 percent margin in their stroke times. This was determined by the design criteria safety limit minus the plant testing results which results in the following: of the 58 valves under consideration, 37 have greater than 100 percent margin, 18 have greater than 10 percent margin but less than 100 percent, and 3 greater than 5 percent but less than 10 percent margin.

*This value has been adjusted from 80 percent on a motor base of 460V to 77 percent on a system base of 480V.

8.5 Overcurrent Protection Margin

Due to transients during the loading sequence, all switchgear motors have their overcurrent protective devices set at a minimum of 200 percent of locked rotor current to ensure that tripping will not occur. Additionally, the load will not trip inadvertently since the transients under consideration are less than one second in duration and actuation is at least 10 seconds.

8.6 Diesel Generator Load Sequence Timer Margin

In order to determine the load sequence timer margin calculations "27S1A" and "DG TIMER RELAYS" were reviewed. "DG TIMER RELAYS" (Reference 3.9) addresses the effects of sequence timer inaccuracies upon DG loading by calculating the minimum time between load steps. Calculation "27S1A" (Reference 3.17) calculates the maximum time it takes to make electric power available to the sequenced loads. Both calculations are based on the methodology presented ISA 67.04, "SETPOINTS FOR NUCLEAR SAFETY-RELATED INSTRUMENTATION USED IN NUCLEAR POWER PLANTS" and Reg Guide 1.105, "INSTRUMENT SETPOINTS FOR SAFETY-RELATED SYSTEMS."

"DG TIMER RELAYS" calculates the minimum time interval between loadings by calculating the root-sum-square of (square root of the sum of the squares) the random errors associated with two adjacent relays. The root-sum-square technique is addressed in ISA 67.04. Also note that there is one systematic error associated with these relays, a bias error due to ambient temperature changes. Since all relays are located in the same cabinet, all relays will experience the same ambient temperature changes; therefore, this effect cancels out for adjacent sequence timers. The results of this calculation are summarized in Figure 2.

"27S1A" calculates errors associated with each timer in turn (errors calculated for only one relay rather than adjacent relays) since the parameter of concern is maximum time required to make electric power available to a particular load. This means the bias error associated with temperature must also be included in the accuracy. The results are for a concurrent loss of offsite power and safety injection initiation, and are summarizied in Figure 3.

These calculations previously resulted in a change for the auxiliary feedwater and component cooling system timers and these figures reflect this change.

DIESEL LOAD SEQUENCING

SQN-E3-015

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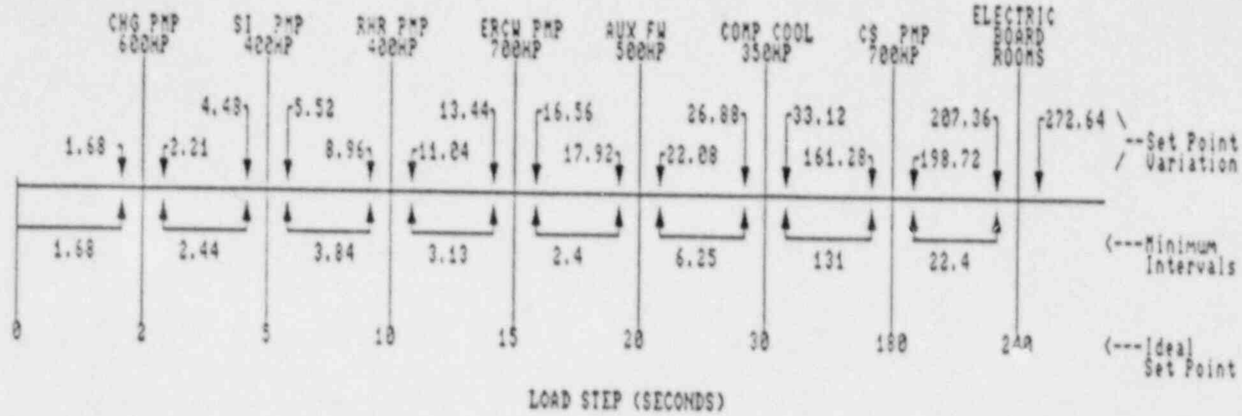
Sheet 22 of ____

Figure 2

SUMMARY OF "DG TIMER RELAYS"

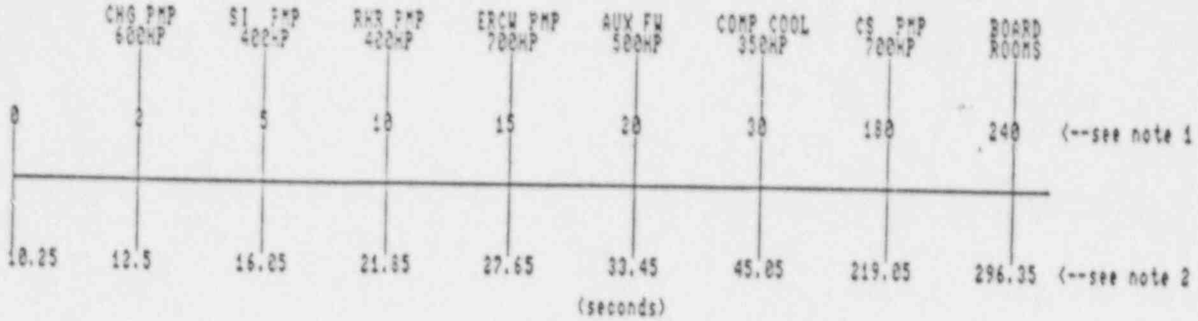


Variations about ideal setpoint are shown for algebraic error combinations.

Minimum interval times shown are for Square Root of the Sum of the Squares (SRSS) combinations of errors(pg 42DG timers)

Figure 3

SUMMARY OF "27S1A"



note 1 - Sequence timer setpoints (provided for comparison purposes).

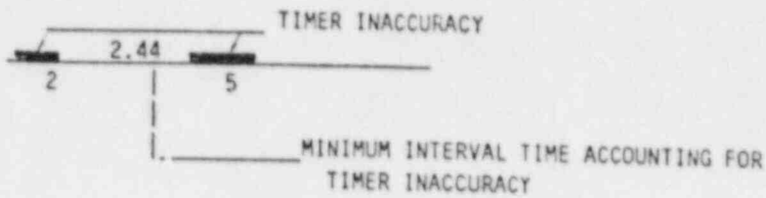
note 2 - Time from initial loss of offsite power until load breaker closure. Includes sequence timer timeout, diesel generator runup time (10 sec), and load breaker closure time for two breakers at 0.125 sec per breaker.

Table 3 summarizes the voltage transient effect on motor starting time and its effect on load sequence time interval including timer accuracy and repeatability. The analysis in Appendix D accounts for the overlap of acceleration between the SI and CCP for the worst case.

TABLE 3

6.6 KV MOTOR ACCELERATION TIME

MOTOR	WORST CASE MOTOR TERM VOLTAGE PU 6.6KV BASE	MIN. TIME INTERVAL SEC (C)	ACCELERATION TIME			
			MEASURED FROM TEST IN SECS	MIN. VOLT FOR FIRST ONE SEC & 100% AVERAGE THE REST, SEC	100% RATED VOLTAGE FOR THE ENTIRE PERIOD SEC	MARGIN BETWEEN 3 & 5 SEC
(1)	(2)	(3)	(4)	(5)	(6)	
CCP	0.867	2.44	2.15	3.33	2.99	*
SI	0.833	3.84	2.80	3.39	3.01	
RHR	0.811	3.13	1.83	1.85	1.39	0.45
ERCW	0.782	2.4	1.56	1.67	1.20	1.28
AFW	0.778	6.25	3.46	3.77	3.22	0.73
CSP	0.798	---	2.56	2.79	2.35	2.48



* Margin is not applicable since CCP and SI pump motor starts could overlap; however, this condition has been considered in the Appendix D and it has been established that this overlap will not cause any additional drop over what has been observed during testing.

8.7 Diesel Generator Capacity

Chart 1 shows a comparison of the ratings for the diesel generators to the maximum anticipated scheduled load for the heaviest loaded diesel generator (2B-B). In summary, it shows that there is at least 8 percent margin between the manufacturer's rating and the maximum scheduled loads for the first 2 hours and at least 2.3 percent margin for greater than 2 hours. This is acceptable margin since the maximum load must be less than or equal to rated capacity.

8.8 Motor Voltage Margin

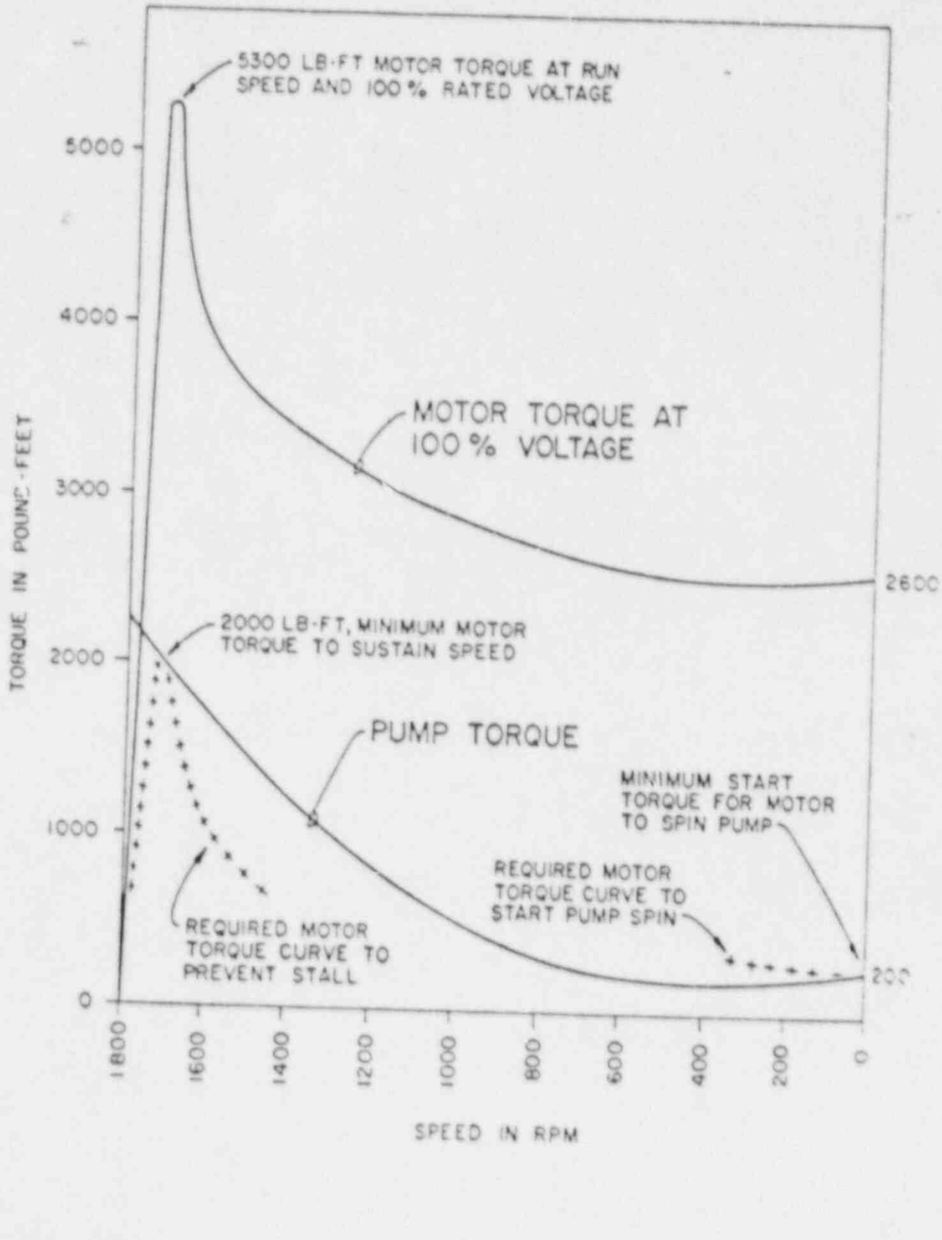
In order to ensure that the motors powered by the DG during the worst case design basis event have adequate voltage for starting and/or running, a review of the 6.9KV and 480V motors speed-torque characteristics was performed. This review evaluated the unique types of 6.6KV and 460V motors (e.g., safety injection pump, centrifugal charging pump, motor operated valves, etc.).

Using the basic relationship that torque for a motor is proportional to the square of the voltage (See ANSI C50.41, Paragraph 11), we can determine the minimum voltage required to sustain pump motor speed and the minimum voltage required to sustain breakaway

Below is a pump/motor speed-torque curve for the SQN containment spray pump that displays these pertinent characteristics. This curve is typical for NEMA Class B motors which are used at SQN.

TYPICAL PUMP/MOTOR SPEED-TORQUE CURVES

FIGURE 1



For 6.9KV motors and a very large 460-volt motor, the analytical technique resulted in the following:

MOTOR	MINIMUM SUSTAINING MOTOR VOLTAGE TO SUSTAIN ROTATION (Percent V at Bus)	MINIMUM BREAKAWAY MOTOR VOLTAGE TO SUSTAIN ROTATION (Percent V at Bus (Locked Rotor)
CCP	64	33
SI	54	32
RHR	56	37
ERCW	63	36
AFW	55	35
CCS (480 Volt)*	44	29
CSP	59	27

*At motor terminal

The small 460-volt motors are standard NEMA designs; therefore, the minimum start and sustaining voltages are evaluated utilizing the standards from which they are designed. NEMA MG1-12.37 and 12.38 were used to obtain the locked-rotor and breakdown torque values for design types A and B motors for various horsepowers. "Motor Application and Maintenance Handbook" edited by R. M. Smeaton was used to obtain typical data for the pump, fan, and compressor loads. This data corresponds to the points of interest for the motor/load speed torque curve.

SQN - E3 - 015

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In conclusion, motor loads have been evaluated to determine the maximum voltage dip which still allows adequate torque to sustain the load rotation. For the 6.6KV motor, the limiting voltage for running motors was determined to be 64 percent, and the limiting breakaway voltage was 37 percent. For 460-volt motors the limiting voltage for running motors is 68 percent and limiting breakaway voltage is 59 percent. In addition, for a 460-volt motor/pump load, calculations predict additional margin in the rotating inertia of the load with the occurrence of short-term voltage dips (e.g., for 65 percent percent for 1/2 second, speed drop of the low inertia pump would be less than 6.18 percent). TVA sees no adverse effect on the mechanical system performance since the thermal and mechanical inertia is such that a 1/2-second decrease in flow of air or water would have effects that would be within the normal operating fluctuations of these types systems. This assumes the associated motors and controls do not trip as a result of this voltage decrease. Therefore, the minimum 6.9KV margin for the maximum expected voltage dip is 12.5 percent of 6.9KV and minimum 480V margin is 6.3 percent of 480V.

9.0 Conclusions

TABLE 4

SUMMARY OF MARGINS

COMPONENT	PERCENT MINIMUM MARGIN
6.6 KV MOTORS - SUSTAIN/BREAKAWAY	12.5/39.5
460V MOTORS - SUSTAINING	6.3
CONTACTORS - DROPOUT	26.0
CONTACTORS - PICKUP	8.1
MOV PERFORMANCE AND STROKE TIMES	18 (Voltage)/5.3 (Time)/56 (Torque)
DIESEL GENERATOR LOADING	2.3

Based on the summary of margins listed above in Table 4 we have determined that the diesel generator will perform its intended safety function by starting and accelerating all required loads within the required limits, with acceptable margins. The margins are not only sufficient to allow for test inaccuracies, but provide the capability for the DG to start and accelerate all required loads concurrent with the random process load block. Furthermore, it is concluded that the test results have been bounded by analysis and the DG meet the intent of Regulatory Guide 1.9.

SQN-E3-015

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APPENDIX - A

TABULATION OF TEST DATA

PURPOSE

THE PURPOSE IS TO DEVELOP COMPOSITE WORST CASE VOLTAGE PROFILES FOR 6.9KV AND 480V STDN. BOARDS BASED ON THE FIELD TESTS OF FOUR DIESEL GENERATORS.

DESIGN INPUT DATA

FIELD TEST TRACE

ICF 37-999 - DG 1A FIELD TEST

STI - 111 - DG 1B FIELD TEST

STI - 77 - DG 2A FIELD TEST

STI - 78 - DG 2B FIELD TEST

PROCEDURE

THE PRETRANSIENT AND MINIMUM VOLTAGE AT DIFFERENT LOADING STEPS WERE OBTAINED FROM THE FIELD TESTS OF FOUR DIESEL GENERATORS (TABLE A1 & A2). THE MINIMUM VOLTAGES AT EACH STEP WERE COMPARED AND

SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT SQN

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THE LOWEST VOLTAGE FOR THE STEP WAS SELECTED TO ESTABLISH A WORST CASE COMPOSITE VOLTAGE PROFILE FOR THE 6.9 KV AND 480 V STDN BOARDS.

BECAUSE THE MODIFICATION OF THE LOAD SEQUENCE STEP FOR THE CCS PUMP AND AFW PUMP HAS NOT BEEN DONE ON UNIT-1 (FOR UNIT-2 RESTART), SOME ADJUSTMENT ON TEST RESULT DATA FOR THESE TWO STEPS ON UNIT-1 WERE MADE (SEE SH. A7) IN ORDER TO BE ABLE TO COMPARE THE LOWEST VOLTAGE FOR ALL FOUR DIESELS. AN EXAMPLE OF THE ADJUSTMENT CALCULATION IS INCLUDED AS PART OF TABLE-A1 SH. A8.

RESULTS

THE WORST CASE COMPOSITE VOLTAGE PROFILES FOR THE 6.9 KV AND 480 V STDN BOARDS ARE SHOWN IN FIGS.-A1 AND A2

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SQN-E3-015

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NOTES FOR TABLES A1 AND A2

VPRETRAN = VOLTAGE PRIOR TO BREAKER CLOSER.

VMIN = MINIMUM VOLTAGE DUE TO START OF A MOTOR

$$\% \text{ DIP} = \frac{\text{VPRETRAN} - \text{VMIN}}{6.9} \times 100 \quad @ \text{ 6.9KV BASE.}$$

KW SS = STEADY STATE KW FOR THE LOAD STEP

KW PRETRAN = KW SS OF PREVIOUS STEP.

TIME INTERVAL = DURATION OF TIME IN SEC BETWEEN TWO LOADING STEPS.

KW ACC = ACCELERATING KW

EXPLANATION OF LOADING SEQUENCE DIFFERENCE BETWEEN UNITS 1 AND 2

SEQ STEP	UNIT 1	UNIT 2
20S	CCS	AFW
25S	AFW	---
30S	---	CCS

6.9KV VOLTAGE PROFILE FROM TEST — SQN-E3-015

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% DIP IS CALCULATED AT 6.9 KV BASE

TABLE - A1

NOMINAL TIME STEP		6.9KV S/D BD 1A-A (REF: 3.2)	6.9KV S/D BD 1B-B (REF: 3.3)	6.9KV S/D BD 2A-A (REF: 3.4)	6.9KV S/D BD 2B-B (REF: 3.5)	WORSTCASE VOLTAGE PROFILE
0	V@ ACB CLOSED	6.68	7.59	7.62	7.814	6.68
	V_{MIN}	5.68	5.85	5.88	5.84	5.68
	% DIP	14.5	25.2	25.2	28.6	14.5
	V@ 40% INT	7.28	6.74	6.78	6.72	7.28
	V@ 60% INT	7.43	7.47	7.20	7.36	7.43
	V_{MAX}	7.49	7.62	-	7.45	7.43
	TIME INTERVAL	2.32	2.41	2.34	2.3	2.32
	KW ACC	980	1104	1008	1220	980
2 (CCP)	$I_{PRETRAN}$	166.5	144.5	144	174	144
	$V_{PRETRAN}$	7.49	7.35	6.96	7.39	6.96
	V_{MIN}	6.27	5.91	5.76	5.96	5.76
	% DIP	17.7	20.87	17.4	20.7	17.4
	V@ 40% INT	6.66	7.06	7.2	7.39	7.2
	V@ 60% INT	7.87	7.65	7.92	7.97	7.92
	V_{MAX}	7.96	8.06	7.98	8.03	7.98
	TIME INTERVAL	3.16	3.125	3.32	4.06	3.32
	KW SS	835	960	936	1023	936
5 (SI)	$I_{PRETRAN}$	92.1	92.3	90	93	93
	$V_{PRETRAN}$	7.19	7.35	7.08	6.84	6.84
	V_{MIN}	6.01	6.09	5.88	5.72	5.72
	I@ V_{MIN}	249	248.83	246	240	240
	KW@ V_{MIN}	1176	1296	1224	1365	1365
	% DIP	17.1	18.3	17.4	16.2	16.2
	V@ 40% INT	7.22	7.06	7.20	7.45	7.45
	V@ 60% INT	7.37	7.18	7.32	7.51	7.51
	V_{MAX}	7.67	7.53	7.56	7.63	7.63
	TIME INTERVAL	5.10	4.96	4.92	4.02	4.02
	KW SS	891	1056	972	1131	1131

6.9KV VOLTAGE PROFILE FROM TEST

SQN-E3-015

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NOMINAL TIME STEP		6.9KV S/D BD 1A-A	6.9KV S/D BD 1B-B	6.9 KV S/D BD 2A-A	6.9KV S/D BD 2B-B	WORSTCASE VOLTAGE PROFILE
10 (RHR)	I PRETRAN	101	102.3	102	108	108
	V PRETRAN	6.75	7.09	6.54	6.69	6.69
	V MIN	6.04	6.32	5.91	5.59	5.59
	I @ VMIN	240	264.88	222	246	246
	KW @ VMIN	1319	1584	1368	1580	1580
	% DIP	10.3	11.16	9.1	15.9	15.9
	V @ 40% INT	7.4	7.29	7.44	7.93	7.93
	V @ 60% INT	6.87	6.53	6.84	7.27	7.27
	VMAX	7.88	7.94	7.80	8.12	8.12
	TIME INTERVAL	5.66	5.54	4.96	4.83	4.83
	KW SS	1141	1224	1188	1293	1293
15 (ERCW)	I PRETRAN	118.8	118.4	120	129	118.4
	V PRETRAN	7.05	6.91	7.02	6.84	6.91
	V MIN	5.74	5.62	5.76	5.68	5.62
	I @ VMIN	357	349.2	360	354	349.2
	KW @ VMIN	1800	1920	1800	1939	1920
	% DIP	19.0	18.7	18.3	16.8	18.7
	V @ 40% INT	7.93	7.88	7.95	8.03	7.88
	V @ 60% INT	6.87	6.88	7.68	7.30	6.88
	VMAX	8.08	8.24	8.07	8.12	8.24
	TIME INTERVAL	4.56	5.09	3.41	4.3	5.09
	KWSS	1693	1848	1656	1795	1848

6.9 KV VOLTAGE PROFILE FROM TEST

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NOMINAL TIME STEP		6.9KV S/D BD. 1A-A	6.9KV S/D BD. 1B-B	6.9 KV S/D BD. 2A-A	6.9 KV S/D BD. 2B-B	WORSE CASE VOLTAGE PROFILE
	I PRETRAN	–	–	165	192	165
	V PRETRAN	6.93	7.18	6.66	6.63	6.66
	V MIN	5.90 *	6.2 *	5.40	5.84	5.40
	I @ V MIN	–	–	348	360	348
20	KW @ V MIN	–	–	1980	2298	1980
	% DIP	14.9	14.2	18.3	11.4	18.3
(AFWP)	V @ 40% INT	–	–	7.08	7.2	7.08
	V @ 60% INT	–	–	7.08	6.9	7.08
	V MAX	–	–	7.50	7.57	7.50
	TIME INTERVAL	–	–	10.19	8.95	10.19
	KWSS	1747 *	1992 *	1980	2137	1980
	I PRETRAN	–	–	192	207	207
	V PRETRAN	7.16	6.91	6.87	6.96	6.96
	V MIN	6.30 **	6.26 **	6.36	6.2	6.2
	I @ V MIN	–	–	282	288	288
	KW @ V MIN	–	–	2232	2478	2478
30	% DIP	12.5	9.4	7.4	11.0	11.0
	V @ 40% INT	–	–	–	7.78	7.78
(CCS)	V @ 60% INT	–	–	–	7.05	7.05
	V MAX	–	–	7.5	8.0	8.0
	TIME INTERVAL	–	–	–	–	–
	KWSS	2121 **		2196	2585	2585
	V PRETRAN	6.9	–	6.9	6.9	6.9
120	V MIN	6.63	–	6.63	6.63	6.63
(F.P)	% DIP	3.91	-	3.91	3.91	3.91
MANUAL						

** MODIFIED TO ACCOUNT FOR CCS START AT 30s NOMINAL. TEST WAS DONE BASED ON AFW PUMP START AT 25s NOMINAL.

* MODIFIED TO ACCOUNT FOR AFWP START. TEST WAS DONE BASED ON CCS PUMPS START AT 20s NOMINAL.

6.9 KV VOLTAGE PROFILE FROM TEST — SQN-E3-015

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TABLE BELOW IS BASED ON ACTUAL TEST RESULT WITH CCS PUMP STARTING AT 20SEC AND AFWP STARTING AT 25S NOMINAL.

NOMINAL TIME STEP		6.9KV S/D BD 1A-A	6.9KV S/D BD 1B-B
20 (CCS)	I PRETRAN	181.1	172.6
	V PRETRAN	6.93	7.18
	VMIN	6.10	6.5
	I @ VMIN	360	264.88
	KW @ VMIN	2228	2112
	% DIP	12.0	9.86
	V @ 40% INT	7.61	6.79
	V @ 60% INT	6.57	6.97
	VMAX	8.05	7.56
	TIME INTERVAL	4.94	5.06
	KW SS	2067	1992
25 (AFW)	I PRETRAN	210.9	192.6
	V PRETRAN	7.16	6.91
	VMIN	6.10	5.97
	I @ VMIN	399	377.26
	KW @ VMIN	2495	2448
	% DIP	15.4	13.6
	V @ 40% INT	-	-
	V @ 60% INT	-	-
	VMAX	7.64	7.59
	TIME INTERVAL	-	-
	KW SS	2121	-

TEST RESULT ADJUSTMENT

EXAMPLE :

AT NOMINAL 25S AFWP STARTED PER TEST

$V_B = 7.16$ KV

$V_D = 7.16 - 6.10$
$= 1.06$ KV

IF THE SAME MOTOR STARTS AT NOMINAL 20S WHEN BUS VOLTAGE $V_B' = 6.93$ KV

V_D' = VOLTAGE DROP DUE TO START OF AFWP

$= \frac{6.93}{7.16} \times 1.06$

$= 1.026$ KV

V_M' = MINM VOLTAGE

$= 6.93 - 1.026$

$= 5.90$ KV

NOTE: $V_D \propto I_{LR} \propto V_B$

V_D = VOLTAGE DROP V_B = BUS VOLTAGE.

6.9 KV VOLTAGE PROFILE FROM TEST

SQN-E3-015

COMPUTED JRC DATE 2-15-88
CHECKED BPai DATE 2-17-88

NOMINAL TIME		6.9 KV S/D BD. 1A-A	6.9 KV S/D BD. 1B-B	6.9KV S/D BD. 2A-A	6.9KV S/D BD 2B-B	WORSE CASE VOLTAGE PROFILE
	V PRETRAN	6.90	—	6.90	6.96	6.90
	V MIN	5.68	—	5.61	5.68	5.61
2 ND	% DIP	17.7	—	18.7	18.6	18.7
ERCW PP	V MAX	8.05	—	7.92	7.99	7.92
	KW SS	2851	—	2574	3142	2574
(MANUAL)						
(NOTE)						
	I PRETRAN			258	--	258
	V PRETRAN	6.93	SEE	6.90	6.69	6.90
	V MIN	5.39	NOTE	5.25	5.29	5.25
180	I @ V MIN	648	BELOW	528	588	528
CSP + F.P.	KW @ V MIN	3493		3114	3770	3114
	% DIP	22.3		23.9	20.3	23.9
	V MAX	8.08		8.07	7.9,	8.07
(MANUAL)	KW SS	3456		3258	3770	3258

NOTE: THE TEST FOR DG 1B-B WAS STOPPED AT 30 SEC.. THE DG 1B-B PRE-TRANSIENT VOLTAGE AT t=30 SECONDS WAS NOMINAL (6.91 KV). SINCE THE OTHER DG's PRE-TRANSIENT VOLT. AT t=180 SECONDS ARE APPROXIMATELY AT NOMINAL, IT IS REASONABLE TO EXPECT THAT THE VOLTAGE FOR DG 1B-B WILL ALSO BE CLOSE TO NOMINAL. THEREFORE, THE ANTICIPATED VOLTAGE DIP SHOULD ALSO BE CLOSE TO THE SAME AS THOSE EXPERIENCED FOR THE OTHER 3 DIESELS FOR THIS STEP.

NOTE.: 2 ND. ERCW PUMP STARTED MANUALLY TO PROVIDE REPRESENTATIVE PRETRANSIENT KW FOR 180 S STEP.

480V VOLTAGE PROFILE FROM TEST

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TABLE - A2

% DIP IS CALCULATED AT 480V BASE

NOMINAL TIME		DG - 1A		DG - 1B		DG 2A		DG 2B	
		480V S/D BD		480V S/D BD.		480V S/D BD		480V S/D BD	
		1A1-A	1A2-A	1B1-B	1B2-B	2A1-A	2A2-A	2B1-B	2B2-B
0	V MAX	517V	510V	506V	504V	480V	484V	494V	508V
	KW	720		539	539	579	432	639	509
2	V PRETRAN	517V	510V	506V	502V	480V	480V	494V	508V
	V MIN.	442V	438V	412V	406V	404V	402V	406V	424V
	V MAX	553V	546V	557V	558V	542V	544V	555V	561V
	KW SS			306	267	338	216	338	242
	% DIP	15.6	15.0	19.6	20.0	15.8	16.3	18.3	17.5
5	V PRETRAN	513V	506V	518V	520V	456V	496V	488V	492V
	V MIN.	422V	422V	431V	430V	416V	456V	408V	410V
	V MAX		528V	522V	524V	524V	526V	539V	539V
	KW SS			257V	230	277	180	289	242
	% DIP	19.0	17.5	18.1	18.7	8.3	8.3	16.7	17.1
10	V PRETRAN	477V	468V	496V	496V	456V	460V	477V	479V
	V MIN	434V	428V	445V	446V	420V	420V	406V	408V
	V MAX		542V	551V	552V	534V	538V	561V	563V
	KW SS			257V		289	180	289	242
	% DIP	9.0	8.3	10.6	10.4	7.5	8.3	14.8	14.8
15	V PRETRAN	501V	494V	488V	488V	486V	490V	477V	479V
	V MIN.	414V	412V	400V	402V	408V	410V	410V	408V
	V MAX	560V	550V	567V	568V	546V	546V	563V	563V
	KW SS			257		277	180	289	242
	% DIP	18.1	17.1	18.3	17.9	16.3	16.7	14.0	14.8

480V VOLTAGE PROFILE FROM TEST.

SQN-E3-015

COMPUTED alal DATE 2/18/88

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NOMINAL TIME		DG 1A		DG 1B		DG 2A		DG 2B	
		480V S/D BD		480V S/D BD		480V S/D BD		480V S/D BD	
		1A1-A	1A2-A	1B1-B	1B2-B	2A1-A	2A2-A	2B1-B	2B2-B
20	V PRETRAN	474V	476V	502	504V	468V	476V	465V	469V
	V MIN.	*407V	*410V	*435V	*436V	382V	384V	418V	418V
	V MAX	557V	544V		–	516V	520V	531V	534V
	KW SS –					277		289	242
	% DIP	14.0	13.8	13.9	14.2V	17.9	19.2	9.8	10.6
30	V PRETRAN	501V	496V	482V	488V	480V	480V	461V	494V
	V MIN.	*422V	*406V	*406V	*447V	414V	452V	408V	410V
	V MAX.	525V	520V			512V	516V	547V	549V
	KW SS		339			470	180	289	485
	% DIP	16.4	18.5	16.4	8.5	13.8	5.8	11.0	17.5
20	V PRETRAN	474V	476V	502V	504V				
	V MIN	399V	390V	420V	462V				
	V MAX.	557V	544V	522V	526V				
	KW SS			453					
	% DIP	15.6	17.9	17.1	8.75				
25	V PRETRAN	501V	496V	482V	488V				
	V MIN.	430V	428V	418V	422V				
	V MAX	525V	520V	524V	528V				
	KW SS		339	453					
	% DIP	14.8	14.2	13.3	13.75				
120 (F.P) (MAN)	V PRETRAN						480		486
	V MIN						456		461.5
	% DIP						5.0		5.1

* ADJUSTED TO ACCOUNT FOR MODIFIED LOADING SEQUENCE.

SHEET A12 OF

480V VOLTAGE PROFILE FROM TEST

CAL. SQN-E3-015

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NOM. TIME		DG 1A		DG 1B		DG 2A		DG 2B	
		480V S/D BD		480V S/D BD		480V S/D BD		480V S/D BD.	
		1A1-A	1A2-A	1B1-B	1B2-B	2A1-A	2A2-A	2B1-B	2B2-B
2nd ERCW START	V PRETRAN			–	–	474	480	486	486
	V MIN			–	–	386	454	396	396
	V MAX			–	–	536	486	551	551
	KW SS			–	–				
(180s) CSP + FIRE PUMP START	V PRETRAN	485	481	–	–	474	480	490	486
	V MIN	377	363	–	–	362	452	367	351
	V MAX	550	545	–	–	536	483	551	543
	KW SS			–	–				

Prepared BPai Date 2/19/88
Verified Sam Date 2/19/88
Sheet A13 of

SQN-E3-015

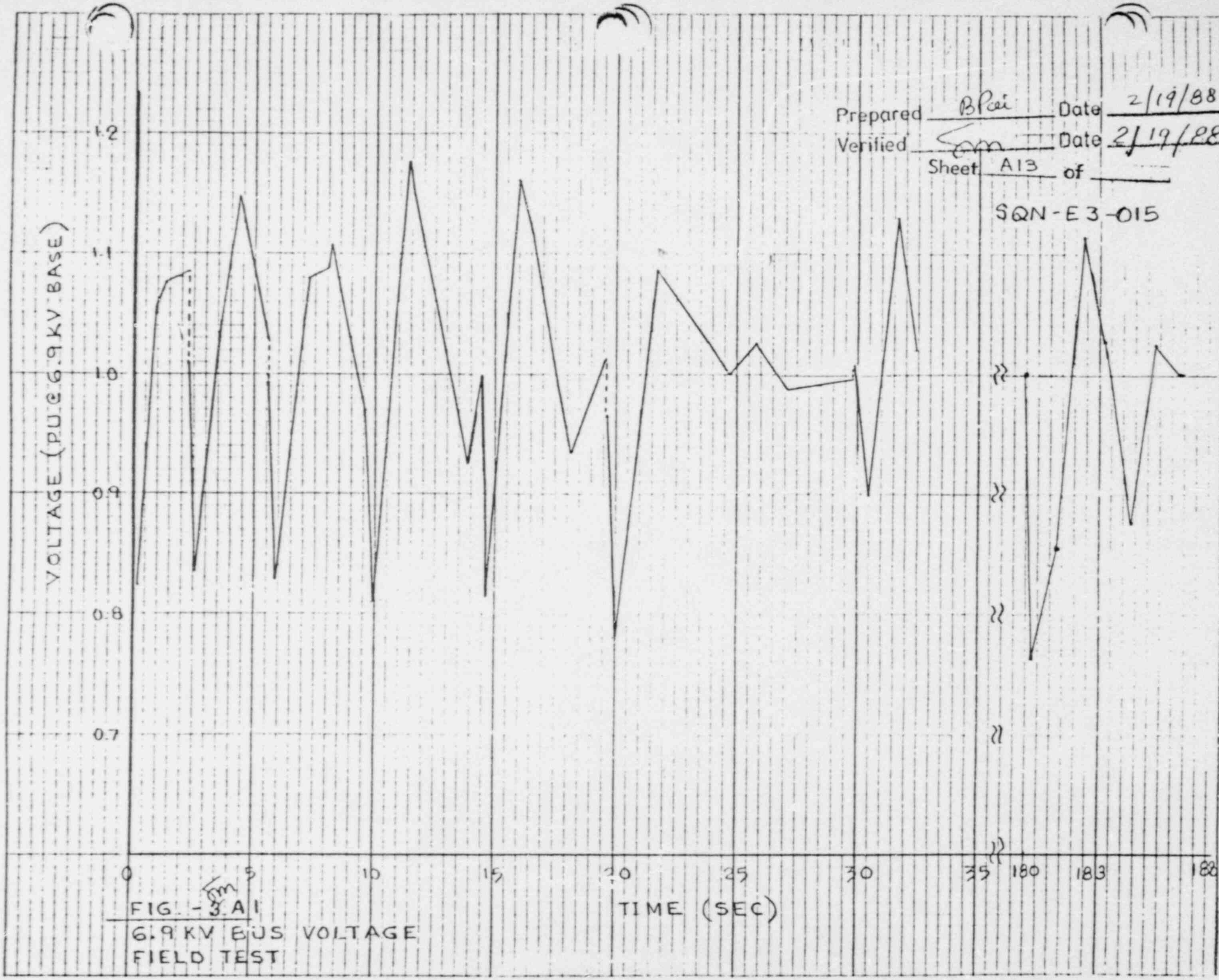

FIG. - 3.A1
6.9 KV BUS VOLTAGE
FIELD TEST

Prepared aPal Date 12/15/88
Verified [illegible] Date 2/19/82
Sheet A14 of
SQN-E3-015

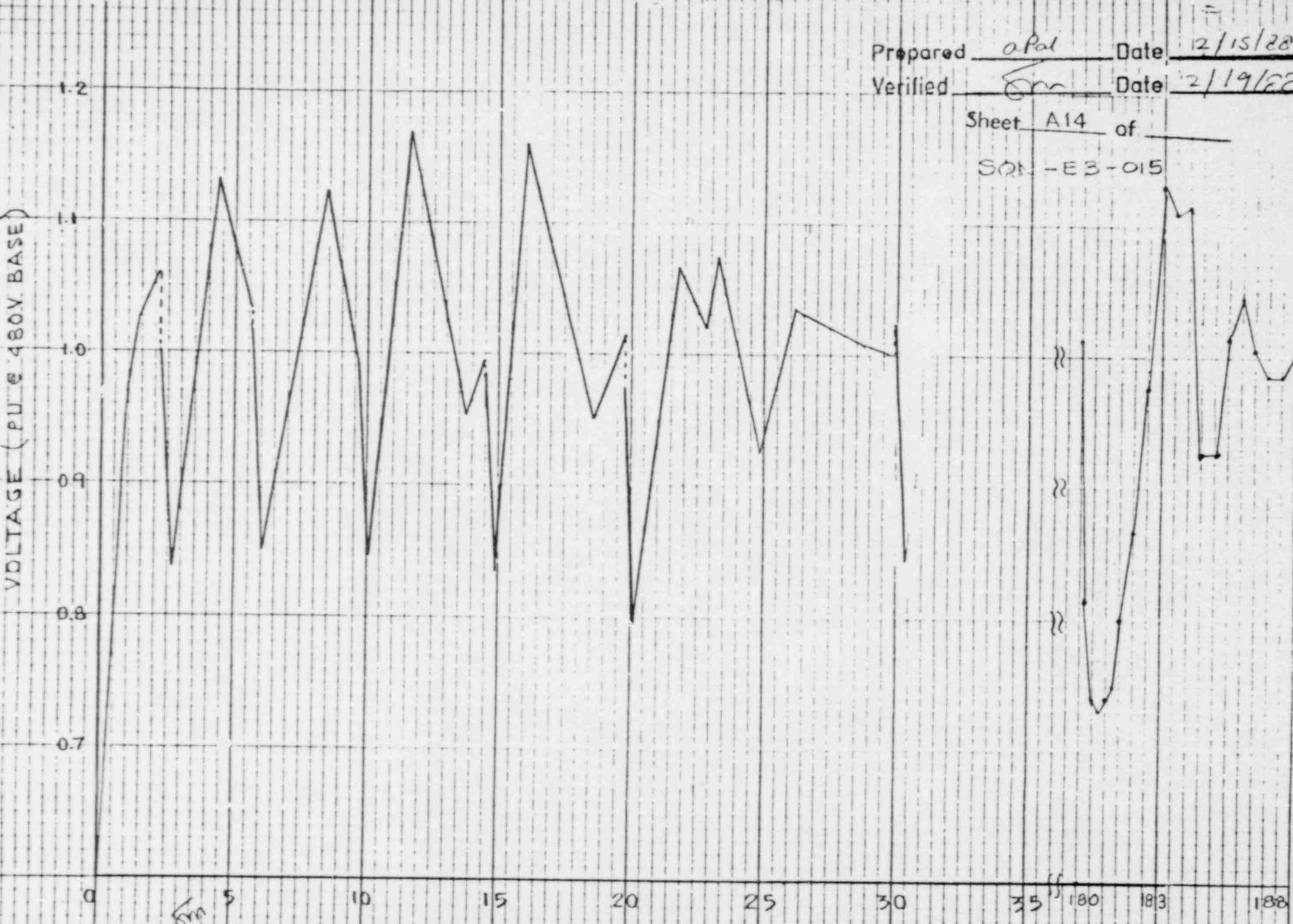

FIG - 4 A2
480V BD. VOLTAGE
FIELD TEST

SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT SQN

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APPENDIX- B

CORRECTION FOR SCHEDULED LOOP + LOCA LOAD

SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT SQN

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PURPOSE

TO CONSERVATIVELY COMPENSATE THE TEST RESULTS TO IDENTIFY THE LOWEST EXPECTED VOLTAGES AT THE 6.9KV, 480V SWITCHGEAR, AND 480V MCC'S FOR A DESIGN BASIS EVENT CONCURRENT WITH A LOOP. THIS IS ACCOMPLISHED BY COMPENSATING FOR THE DIFFERENCE BETWEEN THE SCHEDULED (LOCA / LOOP) PRETRANSIENT LOAD AND THE ACTUAL PRETRANSIENT LOAD AVAILABLE DURING TESTING.

BACKGROUND

DURING THE DIESEL GENERATOR LOAD SEQUENCE TESTING PERFORMED, IT WAS NOT POSSIBLE TO FULLY LOAD ALL THE MOTORS TO THEIR DESIGN BASIS LOAD; THEREFORE, THE MAXIMUM VOLTAGE TRANSIENTS WERE NOT OBTAINED FOR ALL THE LOAD SEQUENCE STEPS. IN ORDER TO DETERMINE THE MAXIMUM TRANSIENT VOLTAGE, THE ACTUAL TEST VOLTAGE TRANSIENTS ARE INCREASED TO THOSE THAT WILL OCCUR FOR THE MAXIMUM LOADING OF A DESIGN BASIS ACCIDENT.

SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT SQN

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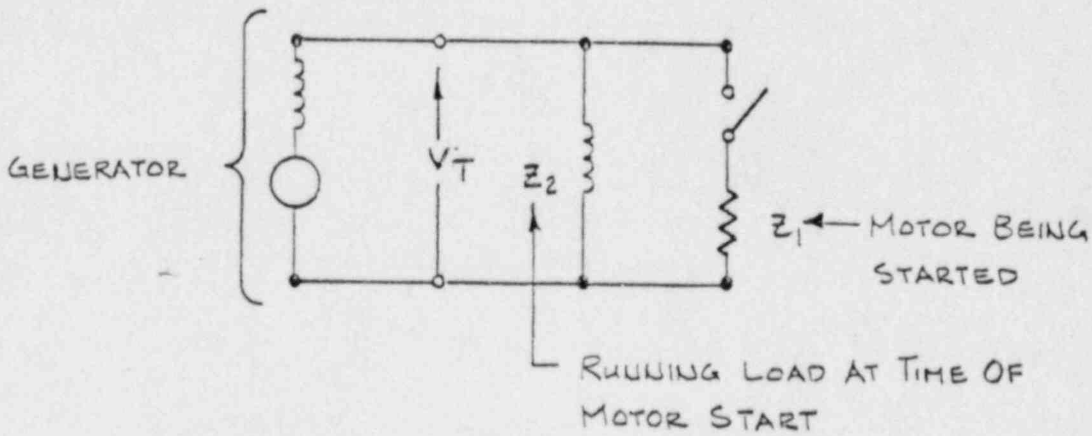
PROCEDURE

THE CIRCUIT BELOW DEPICTS THE BASIC SITUATION



THE TESTED RUNNING LOAD IS LESS THAN THE MAXIMUM DESIGN RUNNING LOAD. THE TEST RUNNING LOAD MUST BE INCREASED AND THE ADDITIONAL VOLTAGE DROP (ΔV) MUST BE SUBTRACTED FROM THE LOWEST TESTED VOLTAGE (V_T) TO OBTAIN THE LOWEST EXPECTED VOLTAGE.

THE AUXILIARY SYSTEM LOAD FOR THE MOST HEAVILY LOADED DIESEL GENERATOR (2B-B) WAS USED IN THIS ANALYSIS FOR ALL LOAD STEPS. THIS PROVIDES A BONDING CASE LOADING FOR ALL DG'S.

SUBJECT: DG VOLTAGE AND MARGIN ANALYSIS PROJECT: SQN

SQN-E3-015

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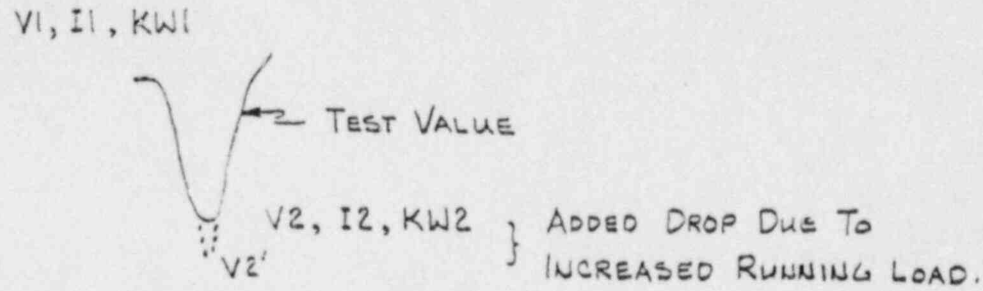
METHODOLOGY



THE ADDITIONAL VOLTAGE DIPS DUE TO THE DIFFERENCE BETWEEN THE PRETRANSIENT SCHEDULED AND TEST LOADS MAY BE APPROXIMATED BY APPLYING THE RATIO OF THE CURRENT CHANGE CAUSED BY THE ADJUSTMENT FROM THE TEST TO SCHEDULED PRETRANSIENT LOADS, TO THE TEST VOLTAGE DROP. IF

- $V1$ = PRETRANSIENT VOLTAGE FROM TEST
- $I1$ = PRETRANSIENT CURRENT FROM TEST
- $KW1$ = PRETRANSIENT KW FROM TEST
- $V2$ = MINIMUM VOLTAGE DUE TO MOTOR START FROM TEST
- $I2$ = RESULTANT CURRENT (RUN + START) AT VOLTAGE V2 FROM TEST
- $KW2$ = KW AT MINIMUM VOLTAGE V2 FROM TEST
- ΔI_T = CHANGE IN CURRENT DUE TO STARTING
- ΔKVA = CHANGE IN RUNNING LOAD
- ΔI_C = CHANGE IN CURRENT FOR CHANGE IN KVA
- ΔV = TEST VOLTAGE DROP
- $\Delta V'$ = VOLTAGE DROP DUE TO SCHEDULE LOAD
- V_2' = MINIMUM BUS VOLTAGE DUE TO SCHEDULED LOAD

SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT

SQN-E3-015

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$$\Delta I_T = I_2 \angle\theta - I_1 \angle\theta$$

$$\Delta KVA = KVA\ (\text{Scheduled}) - KVA\ (\text{Test})$$

$$\Delta I_C = \frac{\Delta KVA}{\sqrt{3}\, V_2} - \frac{\Delta KVA}{\sqrt{3}\, V_1}$$

$$\Delta V = V_1 - V_2$$

THEN THE MINIMUM BUS VOLTAGE DUE TO THE SCHEDULED LOAD (V_2') IS GIVEN BY THE PRETRANSIENT VOLTAGE FROM THE TEST (V_1) REDUCED BY THE VOLTAGE DROP DUE TO SCHEDULED LOAD ($\Delta V'$) AS

$$V_2' = V_1 - \Delta V'$$

WHERE THE VOLTAGE DROP DUE TO SCHEDULED LOAD ($\Delta V'$) IS THE TEST VOLTAGE DROP (ΔV) ADJUSTED BY THE RATIO OF THE CURRENT CHANGES CAUSED BY THE CHANGE IN PRETRANSIENT KVA AS IN

$$V_2' = V_1 - (\Delta V)\left(\frac{\Delta I_T + \Delta I_C}{\Delta I_T}\right)$$

AND THE ADDITIONAL VOLTAGE DIP CAUSED BY THE DIFFERENCE IN SCHEDULED AND TEST PRETRANSIENT VOLTAGES IS

$$\text{Additional Voltage Dip} = \frac{\Delta V' - \Delta V}{\text{Base Voltage}} \quad (\text{in } \% \text{ @ } V_{BASE})$$

SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT

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THIS METHODOLOGY GIVES A CONSERVATIVE VALUE OF MINIMUM VOLTAGE SINCE THIS EVALUATION IS DONE WITH CONSTANT KVA LOADS AND NEGLECTS THE EFFECTS OF THE VOLTAGE REGULATOR / EXCITER BY ASSUMING REGULATOR HAS ADJUSTED TO THE INITIAL PRETRANSIENT LOAD.

SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT SQN-E3-015

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TO DETERMINE THE MINIMUM VOLTAGE AT THE 480V SHUTDOWN BOARD DUE TO LOADING DIFFERENCE AT THE 6.9KV STDN BOARD, THE 480V BUS VOLTAGE DIP WILL ALSO BE INCREASED BY THE SAME PERCENTAGE AS THE 6.9KV BUS VOLTAGE DIP. THE CALCULATED ADDITIONAL VOLTAGE DROP ($\Delta V' - \Delta V$) IS ADDED TO THE 480V TEST VOLTAGE DIP.

THIS METHOD IS CONSERVATIVE SINCE THE DIFFERENCE BETWEEN SCHEDULED AND TESTED LOAD OCCURS PRIMARILY AT THE 6.9KV BOARD. ADDITIONAL ADJUSTMENTS ARE MADE FOR DIFFERENCES BETWEEN SCHEDULED AND TESTED LOAD AT THE 480V BOARD AS DEFINED BELOW.

AT 2 SEC. STEP (CCP START) THE TEST LOAD IS 530 KVA GREATER THAN SCHEDULE LOAD. HENCE NO ADJUSTMENT TO VOLTAGE DIP IS REQUIRED.

AT 180 SEC. A 200 HP FIRE PUMP WAS STARTED CONCURRENTLY WITH CSP. THE FIELD TEST DIP WAS ADJUSTED TO COMPENSATE FOR THE EFFECT OF 200 HP FIRE PUMP. THE ADJUSTMENT OF THE FIELD TEST VOLTAGE DIP (SHEET A7) AT THE 6.9KV SHUTDOWN BOARD DUE TO START OF FIRE PUMP ALONE IS 3.9 %. THE ADJUSTMENT OF THE FIELD TEST VOLTAGE DIP (SHEET A11) AT THE 480V SHUTDOWN BOARD DUE TO START OF FIRE PUMP ALONE IS 5.1 %.

SUBJECT ______ PROJECT ______

SQN-E3-015

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RESULTS

TABLES B1 AND B2, ATTACHED, SUMMARIZES THESE RESULTS. THE MINIMUM 6.9KV SHUTDOWN BOARD VOLTAGE WAS DETERMINED TO BE 76.5 PERCENT OF NOMINAL AND THE MINIMUM 480V SHUTDOWN BOARD AND MCC VOLTAGE WAS DETERMINED TO BE 77 PERCENT AND 75.6 PERCENT OF NOMINAL RESPECTIVELY, BOTH FOR APPROXIMATELY 16 CYCLES.

TABLE B3 SUMMARIZES THE 6.6KV MOTOR TERMINAL VOLTAGES. THE LOWEST 6.6KV MOTOR TERMINAL VOLTAGE IS 76.2 PERCENT OF NOMINAL.

THE LOWEST 460V MOTOR TERMINAL VOLTAGE FED FROM 480V STDN BD IS 74.3 PERCENT OF 480V.

THE LOWEST 460V MOTOR AND MOV TERMINAL VOLTAGES ARE 74.5 AND 74.6 PERCENT OF 480V RESPECTIVELY.

TABLE - B1

WORST CASE 6.9 KV BUS VOLTAGE CORRECTED FOR SCHEDULE LOAD

START MOTOR ①	SEQ. TIME SEC. ②	PRETRAN VOLTAGE PU ③	SOURCE DG ④	PRIOR TO START: DG LOAD FIELD TEST ⑤	PRIOR TO START: DG LOAD SCHEDULE [REF. 3.1] ⑥	PU DIP FIELD TEST ⑦	ADDITIONAL PU DIP DUE TO LOADING DIFFEREN. ⑧	TOTAL PU DIP [⑦+⑧] ⑨	PU MINIMUM BUS VOLTAGE [③ - ⑨] ⑩
CCP	2	1.009	2A	1736 ∠54.5	1206 ∠42	0.174	0.0	0.174	0.835
SI	5	0.991	2B	1102 ∠21.8	1717 ∠34.7	0.162	0.010	0.172	0.819
RHR	10	0.969	2B	1251 ∠25.3	2025 ∠32.5	0.159	0.013	0.172	0.797
ERCW	15	1.001	1B	1417 ∠30.3	2382 ∠30.9	0.187	0.012	0.199	0.802
AFW	20	0.965	2A	1903 ∠29.5	3049 ∠31	0.183	0.017	0.200	0.765
CCWP	30	1.008	2B	2495 ∠31.1	3526 ∠29.9	0.110	0.013	0.123	0.885
CSP+FP *	180	1.0	2A	3083 ∠33.3	3837 ∠29.7	0.200 ▲	0.012	0.212	0.788

* 200HP FP WAS STARTED WITH CSP.

▲ ADJUSTED THE FIELD TEST DIP TO COMPENSATE THE EFFECT OF 200HP F.P (DIP = 0.039PU)

NOTE : FOR COLUMN ① THRU ⑤ AND ⑦ SEE TABLE - A1

SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT SQN

SQN-E3-015

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TABLE - B2

WORST CASE 480V STND. BD. VOLTAGE

CORRECTED FOR SCHEDULE LOAD

SEQ. TIME SEC. - ①	PRE TRAN VOLTAGE PU ②	PU DIP FIELD TEST ③	④ ADDITIONAL PU DIP DUE TO LOADING DIFFERENCE	⑤ TOTAL PU DIP [③+④]	⑥ PU MIN. BUS VOLTAGE [②-⑤]
0	1.06	-	-	-	1.06
2	1.0	0.163	0.0	0.163	0.837
5	1.017	0.167	0.010	0.177	0.84
10	0.994	0.148	0.013	0.161	0.833
15	1.017	0.183	0.012	0.195	0.822
20	0.975	0.179	0.017	0.196	0.779
30	1.033	0.188	0.013	0.201	0.832
180 (CSP+FP*)	1.012	0.23 ▲	0.012	0.242	0.77

* 200HP FP WAS STARTED WITH CSP

▲ ADJUSTED THE FIELD TEST DIP TO COMPENSATE THE EFFECT OF 200HP F.P (0.051PU DIP)

NOTE : COLUMN ① THRU ③ SEE TABLE - A2

SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT SQN

SQN-E3-015

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TABLE - B3

MINIMUM MOTOR TERMINAL VOLTAGE

DURING MOTOR STARTING

MOTOR	WORST CASE 6.9 KV BUS VOLTAGE [TABLE-B1]	CALCULATED MOTOR TERMINAL VOLTAGE		VOLTAGE DROP IN %
		6.9KV BASE	6.6KV BASE	
CCP	0.835	0.829	0.867	0.6
SI	0.819	0.816	0.853	0.3
RHR	0.797	0.794	0.83	0.3
ERCW	0.802	0.766	0.801	3.6
AFW	0.765	0.762	0.797	0.3
CSP	0.788	0.783	0.818	0.52

WORST CASE VOLTAGE DROP DURING RUNNING FOR ERCW MOTOR IS 0.89% OF 6.9KV.

TVA 489H (EN DES-2-78) TENNESSEE VALLEY AUTHORITY SHEET B12 OF

SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT SQN

SQN-E3-015

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WORST CASE MINIMUM 480V STDN BD. VOLTAGE IS 0.77 PU AT 480V

WORST CASE VOLTAGE DROP BETWEEN 480V STDN. BD. AND MOTOR FED FROM 480V STDN. BD IS 0.027 PU (REFER APPENDIX-F SH. F12)

WORST CASE MOTOR TERMINAL VOLTAGE FED FROM 480V STDN. BD IS 0.77 - 0.027 = 0.743 PU OR 74.3 %.

SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT SQN

SQN-E3-015

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WORST CASE MINIMUM 480V STDN. BD. VOLTAGE IS 0.77 PU AT 480V.

WORST CASE VOLTAGE DROP BETWEEN 480V STDN. BD. AND 480V MCC IS 0.014 PU (REFER TO APPENDIX-F SH. F12)

WORST CASE MINIMUM 480V MCC VOLTAGE IS 0.77 - 0.014 = 0.756 PU OR 75.6%

WORST CASE VOLTAGE DROP BETWEEN 480V STDN. BD AND MOTOR FED FROM MCC IS 0.025 PU (REFER TO APPENDIX-F SH F12)

WORST CASE 460V MOTOR TERMINAL VOLTAGE IS 0.77 - 0.025 = 0.745 PU OR 74.5%

WORST CASE VOLTAGE DROP BETWEEN 480V STDN BD. AND MOV IS 0.024PU (REFER TO APPENDIX-F SH F12)

WORST CASE 460V MOV TERMINAL VOLTAGE IS 0.77 - 0.024 = 0.746 PU OR 74.6%

Sheet B14 of ____

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SQN-E3-015

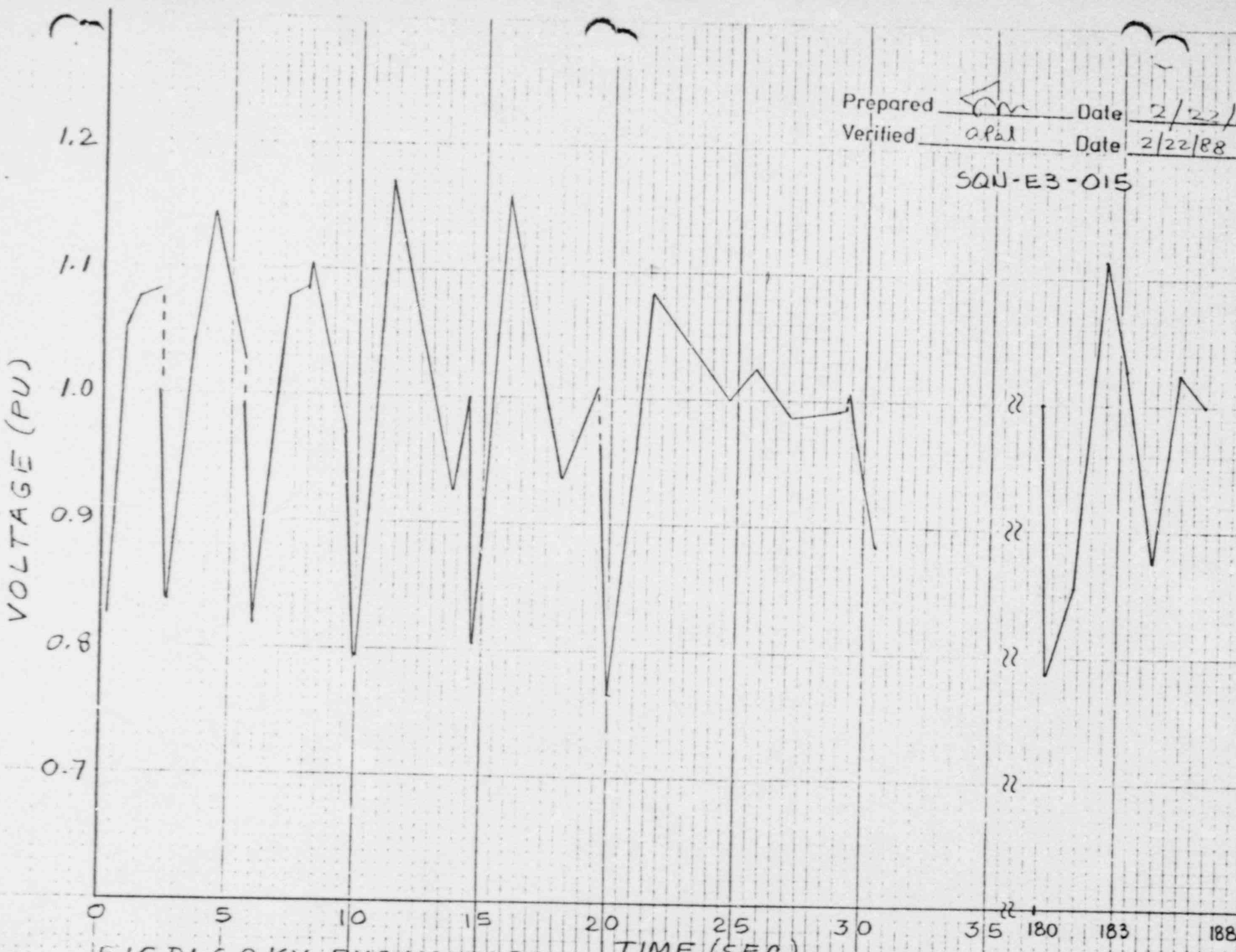

FIG B1 6.9KV BUS VOLTAGE CORRECTING FOR SCHEDULE LOAD

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SQN-E3-015

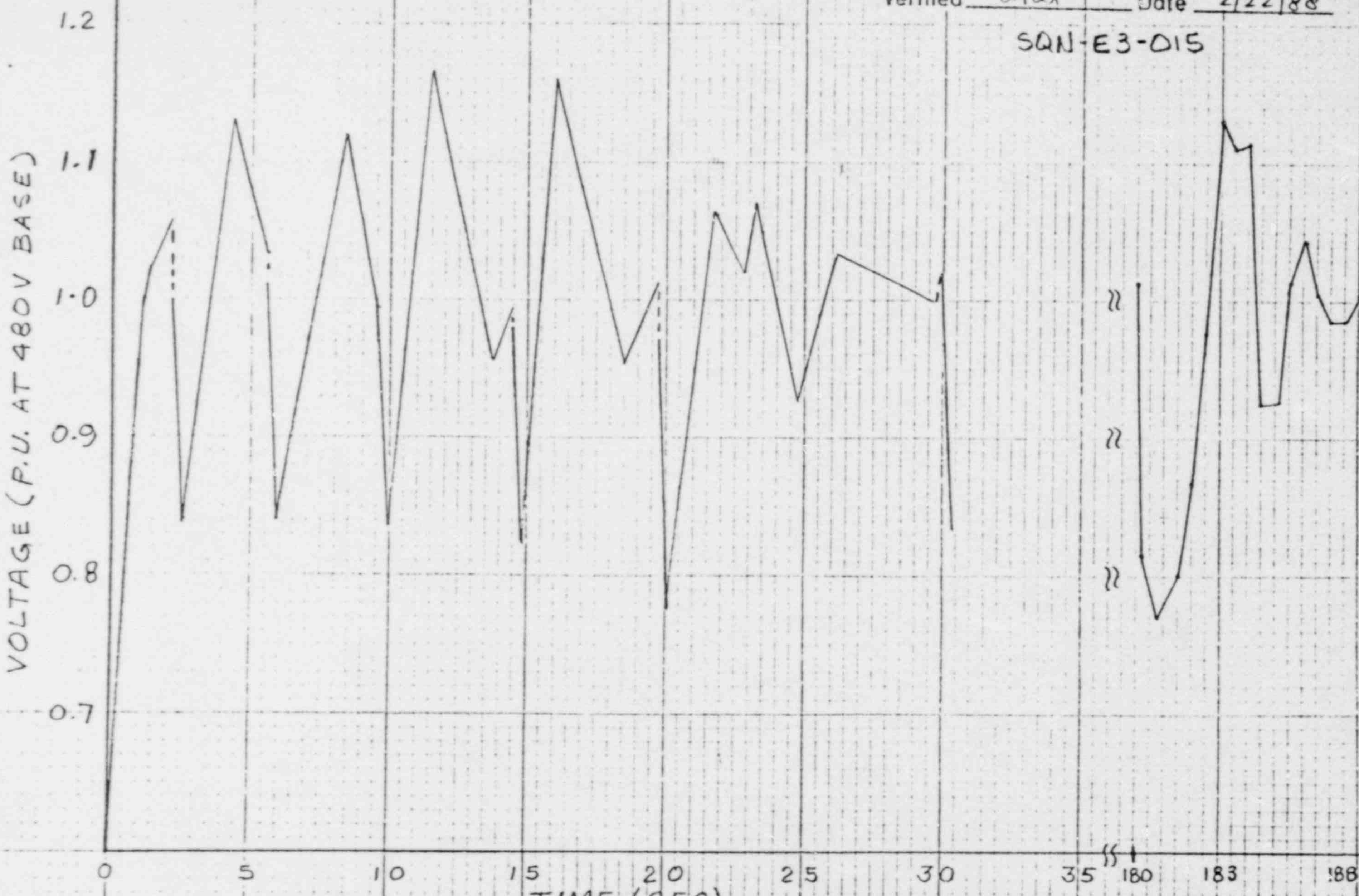

FIG. 82 480V BD. VOLTAGE.
CORRECTING FOR SCHEDULE LOAD

Sheet B15 of

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CALCULATIONS

FOR RUNNING SCHEDULED LOAD, SEE REF. 3.1

FOR TEST DATA, SEE APPENDIX - A

DG - 2B

SIP @ 5 Secs

SHEET B17 OF

SQN - E3-015

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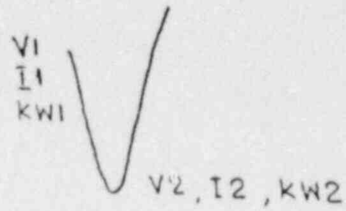
TEST LOADING



V1 = PRETRANSIENT VOLTAGE

= 6.84 KV

I1 = PRE TRANSIENT CURRENT

= 93A

KW1 = PRE TRANSIENT KW = 1023

$\cos\theta_1 = KW1/\sqrt{3}\,V1\,I1 = 0.9285$ $\theta_1 = 21.8°$

KVA1 = 1101.8

V2 = MINIMUM VOLTAGE DUE TO MOTOR START = 5.72 KV

I2 = RESULTANT CURRENT (RUNNING + STARTING) AT V2 = 240A

KW2 = KW AT MINIMUM VOLTAGE V2 = 1365

$\cos\theta_2 = KW2/\sqrt{3}\,V2\,I2 = 0.5741$ $\theta_2 = 55°$

CHANGE IN CURRENT = ΔI_T

$= I_2 \angle\theta_2 - I_1 \angle\theta_1$

$= 240\angle 55° - 93\angle 21.8$

$= 137.66 + j196.6 - 86.35 - j34.54$

$= 51.31 + j\,162.06$

$= 170\angle 72.43$

TVA 11030 (WM-7-75)

SCHEDULE LOADING

RUNNING LOAD = 1410.4KW + j 978.7 KVAR

= 1716.7 ∠34.76

DIFFERENCE LOADING

ΔKVA = DIFFERENCE IN RUNNING LOAD

= KVA (SCHEDULE) - KVA1(TEST)

= 1410.4 + j 978.7 - 1023 - j 409.2

= 387.4 + j569.5 = 688.8 ∠55.8

ΔI_c = CHANGE IN CURRENT FOR ΔKVA

$$= \frac{\Delta KVA}{\sqrt{3}\ V_2} - \frac{\Delta KVA}{\sqrt{3}\ V_1}$$

$$= \frac{688.8}{\sqrt{3} \times 5.72} - \frac{688.8}{\sqrt{3} \times 6.84}$$

= 69.52 - 58.14 = 11.38 ∠55.8

$\Delta I_T + \Delta I_c$ = 51.31 + j 162.06 + 6.4 + j 9.41

= 57.71 + j 171.47

= 180.92 ∠71.4

ΔV = TEST VOLTAGE DROP

$= V1 - V2 = 6.84 - 5.72 = 1.12$

VOLTAGE DROP DUE TO SCHEDULE LOAD = $\Delta V'$

$$= \Delta V \times \frac{\Delta I_T + \Delta I_C}{\Delta I_T}$$

$$= 1.12 \times \frac{180.92}{170} = 1.19 \text{ KV}$$

MINIMUM BUS VOLTAGE DUE TO SCHEDULE LOAD

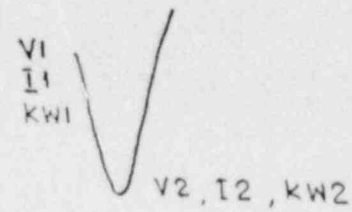
$= V1 - \Delta V'$

$= 6.84 - 1.19 = 5.65 \text{KV}$

$= 0.819$ PU @ 6.9 KV

$$\text{ADDITIONAL DIP} = \frac{1.19 - 1.12}{6.9} = 0.010 \text{ PU @ } 6.9 \text{kV}$$

TEST LOADING



VI = PRETRANSIENT VOLTAGE
= 6.69 KV

I1 = PRE TRANSIENT CURRENT
= 108 A

KW1 = PRETRANSIENT KW = 1131

$\cos\theta_1$ = KW1/ $\sqrt{3}$ V1 I1 = 0.9038 θ_1 = 25.34

KVA1 = 1251.4

V2 = MINIMUM VOLTAGE DUE TO MOTOR START = 5.59 KV

I2 = RESULTANT CURRENT (RUNNING + STARTING) AT V2 = 246A

KW2 = KW AT MINIMUM VOLTAGE V2 = 1580

$\cos\theta_2$ = KW2 / $\sqrt{3}$ V2 I2 = 0.6634 θ_2 = 48.4

CHANGE IN CURRENT = ΔI_T

$= I_2 \angle\theta_2 - I_1 \angle\theta_1$

$= 246 \angle 48.4 - 108 \angle 25.34$

$= 163.33 + j183.96 - 97.6 - j46.22$

$= 65.73 + j137.74$

$= 152.62 \angle 64.5$

TVA 11030 (WM-7-75)

DG - 2B

SHEET B21 OF

SQN-E3-015

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SCHEDULE LOADING

RUNNING LOAD = 1708 kW + j 1088 KVAR

$= 2025.09 \angle 32.5$

DIFFERENCE LOADING

ΔKVA = DIFFERENCE IN RUNNING LOAD

= KVA (SCHEDULE) - KVA1(TEST)

$= 1708 + 1088 - 1131 - j\,535.6$

$= 577 + j\,552.4 = 798.8 \angle 43.75$

ΔI_c = CHANGE IN CURRENT FOR ΔKVA

$$= \frac{\Delta KVA}{\sqrt{3}\ V_2} - \frac{\Delta KVA}{\sqrt{3}\ V_1}$$

$$= \frac{798.8}{\sqrt{3} \times 5.59} - \frac{798.8}{\sqrt{3} \times 6.69}$$

$= 82.5 - 68.94 = 13.56 \angle 43.75$

$\Delta I_T + \Delta I_c = 65.73 + j\,137.74 + 9.8 + j\,9.38$

$= 75.53 + j\,147.12$

$= 165.4 \angle 62.8$

TVA 11030 (WM-7-75)

ΔV = TEST VOLTAGE DROP

= V1 - V2 = 6.69 - 5.59 = 1.1

VOLTAGE DROP DUE TO SCHEDULE LOAD = $\Delta V'$

$$= \Delta V \times \frac{\Delta I_T + \Delta I_C}{\Delta I_T}$$

$$= 1.1 \times \frac{165.4}{152.62} = 1.19$$

MINIMUM BUS VOLTAGE DUE TO SCHEDULE LOAD

= V1 - $\Delta V'$

= 6.69 - 1.19 = 5.5 KV

= 0.797 PU @ 6.9 KV

$$\text{ADDITIONAL DIP} = \frac{1.19 - 1.1}{6.9} = 0.013$$

DG - 1B ERCW 15 Sec.

SHEET 823 OF

SQN - E3 - 015

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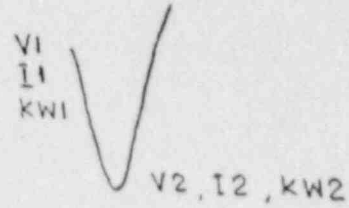
TEST LOADING



V1 = PRETRANSIENT VOLTAGE
= 6.91

I1 = PRE TRANSIENT CURRENT
= 118.4A

KW1 = PRE TRANSIENT KW = 1224 KW

$\cos\theta_1$ = KW1 / $\sqrt{3}$ V1 I1 = θ_1 = 30.25

KVA1 = 1417 = 1224.0 − j 713.86

V2 = MINIMUM VOLTAGE DUE TO MOTOR START = 5.62

I2 = RESULTANT CURRENT (RUNNING + STARTING) AT V2 = 349.2

KW2 = KW AT MINIMUM VOLTAGE V2 = 1920

$\cos\theta_2$ = KW2 / $\sqrt{3}$ V2 I2 = .565 θ_2 = 55.61

CHANGE IN CURRENT = ΔI_T

$= I_2 \angle\theta_2 - I_1 \angle\theta_1$

= 197.236 − j 288.164

102.278 − j 59.647

94.958 − j 228.517

$247.46 \angle 67.44$

TVA 11030 (WM-7-75)

SCHEDULE LOADING

RUNNING LOAD = 2042.5 KW + j 1225.4 KVAR

= 2381.9 ∠30.96

$\overline{\Delta KVA}$ = DIFFERENCE IN RUNNING LOAD

= KVA (SCHEDULE) − KVA1(TEST)

= 818.5 − 511.54

= 965.20 ∠32

2042.5 − j1225.4
1224.0 − j713.9
818.5 − 511.5

ΔIc = CHANGE IN CURRENT FOR ΔKVA

$$= \frac{\Delta KVA}{\sqrt{3}\ V_2} - \frac{\Delta KVA}{\sqrt{3}\ V_1} = \frac{\Delta KVA}{\sqrt{3}}\left(\frac{V_1 - V_2}{V_1 V_2}\right)$$

= 84.09 − j52.55 − 68.39 + j42.74

= 15.7 − j9.81

94.96 − j228.52

$\Delta I_T + \Delta I_c$ = 110.66 − j 238.3 = 262.74

ΔV = TEST VOLTAGE DROP

= V1 - V2 = 1.29

VOLTAGE DROP DUE TO SCHEDULE LOAD = $\Delta V'$

$$= \Delta V \times \frac{\Delta I_T + \Delta I_C}{\Delta I_T}$$

= 1.37

MINIMUM BUS VOLTAGE DUE TO SCHEDULE LOAD

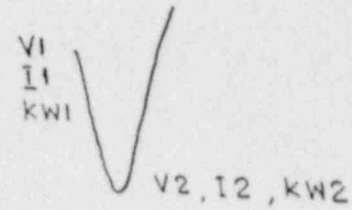
= V1 - $\Delta V'$

= 5.54

= .803 PU @ 6.9 KV

$$\text{ADDITIONAL DIP} = \frac{1.37 - 1.29}{6.9} = 0.012 \text{ PU @ } 6.9\text{KV}$$

TEST LOADING



V1 = PRETRANSIENT VOLTAGE
= 6.66

I1 = PRE TRANSIENT CURRENT
= 165

KW1 = PRE TRANSIENT KW = 1656

$\cos\theta_1$ = KW1/ $\sqrt{3}$ V1 I1 = 0.870 θ_1 = 29.5

KVA1 = 1903.35

V2 = MINIMUM VOLTAGE DUE TO MOTOR START = 5.40

I2 = RESULTANT CURRENT (RUNNING + STARTING) AT V2 = 348

KW2 = KW AT MINIMUM VOLTAGE V2 = 1980

$\cos\theta_2$ = KW2 / $\sqrt{3}$ V2 I2 = 0.608 θ_2 = 52.53

CHANGE IN CURRENT = ΔI_T

$$= I_2 \angle \theta_2 - I_1 \angle \theta_1$$

$$= 348 \angle 52.53 - 165 \angle 29.5$$

$$= (211.7 + 276.2j) - (143.61 + 81.25j)$$

$$= 68.09 + 194.95j$$

$$= 206.5 \angle 70.75$$

SCHEDULE LOADING

RUNNING LOAD = 2614 kW + j 1568.6 KVAR

= 3048.5 $\angle 30.97$

ΔKVA = DIFFERENCE IN RUNNING LOAD

= KVA (SCHEDULE) - KVAI(TEST)

= (2614 + 1568.6j) - (1656.59 + 937.25j)

= 957.41 + 631.35j = 1146.8 $\angle 33.4$

ΔI_c = CHANGE IN CURRENT FOR ΔKVA

$$= \frac{\Delta KVA}{\sqrt{3}\ V2} - \frac{\Delta KVA}{\sqrt{3}\ V1}$$

$$= \frac{1146.8}{\sqrt{3}\ 5.40} - \frac{1146.8}{\sqrt{3}\ 6.66}$$

= 122.61 - 99.42 = 23.19 $\angle 33.4$

$\Delta I_T + \Delta I_c$ = (68.09 + 194.95j) + (19.36 + 12.77j)

= 87.45 + 207.72j

= 225.38 $\angle 67.17$

ΔV = TEST VOLTAGE DROP

= V1 - V2 = 6.66 - 5.40 = 1.26

VOLTAGE DROP DUE TO SCHEDULE LOAD = $\Delta V'$

$$= \Delta V \times \frac{\Delta I_T + \Delta I_C}{\Delta I_T}$$

$$= 1.26 \; \frac{225.38}{206.5} = 1.375$$

MINIMUM BUS VOLTAGE DUE TO SCHEDULE LOAD

= V1 - $\Delta V'$

= 6.66 - 1.375 = 5.28

= 0.766 PU @ 6.9 kV

ADDITIONAL DIP = $\frac{1.375 - 1.26}{6.9}$ = 0.017 PU @ 6.9 kV

DG - 2B

CCWP START @ 30 SEC

SHEET 329 OF

SQN-E3-015

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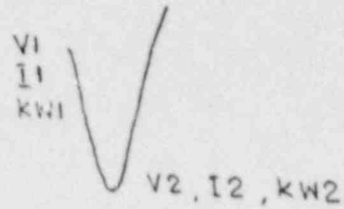
TEST LOADING



V1 = PRETRANSIENT VOLTAGE

= 6.96 kV

I1 = PRE TRANSIENT CURRENT

= 207 A

KW1 = PRE TRANSIENT KW = 2137

$\cos\theta_1$ = $KW1/\sqrt{3}\,V1\,I1$ = 0.8564 $\theta_1 = 31.1$

KVA1 = 2495.4

V2 = MINIMUM VOLTAGE DUE TO MOTOR START = 6.2 KV

I2 = RESULTANT CURRENT (RUNNING + STARTING) AT V2 = 288 A

KW2 = KW AT MINIMUM VOLTAGE V2 = 2478

$\cos\theta_2$ = $KW2/\sqrt{3}\,V2\,I2$ = 0.8012 $\theta_2 = 36.75$

CHANGE IN CURRENT = ΔI_T

$= I_2\angle\theta_2 - I_1\angle\theta_1$

$= 288\angle 36.75 - 207\angle 31.1$

$= 230.3 + j\,172.3 - 177.3 - j\,106.9$

$= 53.5 + j\,65.4$

$= 84.5\angle 50.7$

TVA 11030 (WM-7-75)

SCHEDULE LOADING

RUNNING LOAD = 3055.3 KW + j 1759.7 KVAR

ΔKVA = DIFFERENCE IN RUNNING LOAD

= KVA (SCHEDULE) - KVA1(TEST)

= 3055.3 + j 1759.7 - 2137 - j 1288.5

= 918.3 + j 471.2 = 1032.6 ∠27.15

ΔI_c = CHANGE IN CURRENT FOR ΔKVA

$$= \frac{\Delta KVA}{\sqrt{3}\ V_2} - \frac{\Delta KVA}{\sqrt{3}\ V_1}$$

$$= \frac{1032.6}{\sqrt{3} \times 6.20} - \frac{1032.6}{\sqrt{3} \times 6.96}$$

= 96.2 - 85.7

= 10.5 ∠27.15 = 9.3 + j 4.8

$\Delta I_T + \Delta I_c$ ~~[illegible]~~ = 53.0 + j 65.4 + 9.3 + j 4.8

= 62.3 + j 70.2

= 94.2 ∠48.2

TVA 11030 (WM-7-75)

ΔV = TEST VOLTAGE DROP

$= V1 - V2 = 6.96 - 6.2 = 0.76$

VOLTAGE DROP DUE TO SCHEDULE LOAD = $\Delta V'$

$$= \Delta V \times \frac{\Delta I_T + \Delta I_C + I_{RAND.\ START}}{\Delta I_T}$$

$$= 0.76 \times \frac{94.2}{84.5} = 0.85$$

MINIMUM BUS VOLTAGE DUE TO SCHEDULE LOAD

$= V1 - \Delta V'$

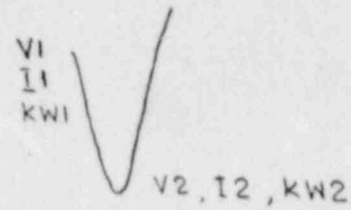
$= 6.96 - 0.85 = 6.11$ kV

$= 0.885$ PU @ 6.9 kV

$$\text{ADDITIONAL DIP} = \frac{.85 - .76}{6.9} = 0.013 \text{ PU @ } 6.9 \text{ kV}$$

TVA 11030 (WM-7-75)

TEST LOADING



V1 = PRETRANSIENT VOLTAGE
= 6.90

I1 = PRE TRANSIENT CURRENT
= 258

KW1 = PRE TRANSIENT KW = 2574

$\cos\theta_1$ = KW1/ $\sqrt{3}$ V1 I1 = 0.835 θ1 = 33.4

KVA1 = 3083.4

V2 = MINIMUM VOLTAGE DUE TO MOTOR START = 5.25

I2 = RESULTANT CURRENT (RUNNING + STARTING) AT V2 = 528

KW2 = KW AT MINIMUM VOLTAGE V2 = 3114

$\cos\theta_2$ = KW2 / $\sqrt{3}$ V2 I2 = 0.649 θ2 = 49.57

CHANGE IN CURRENT = ΔI_T

$= I_2 \angle\theta_2 - I_1 \angle\theta_1$

$= 528\angle 49.57 - 258\angle 33.4$

$= (342.42 + 401.9j) - (215.39 + 142.02j)$

$= 127.03 + 259.88$

$= 289.26\angle 63.95$

TVA 11030 (WM-7-75)

SCHEDULE LOADING

RUNNING LOAD = 3334.3 KW + j 1899.2 KVAR

= 3837.3 $\angle$ 29.67

ΔKVA = DIFFERENCE IN RUNNING LOAD

= KVA (SCHEDULE) − KVA1(TEST)

= (3334.3 + 1899.2j) − (2574.2 + 1697.35j)

= 760.1 + 201.85j = 786.44 $\angle$ 14.87

ΔIc = CHANGE IN CURRENT FOR ΔKVA

$$= \frac{\Delta KVA}{\sqrt{3}\ V_2} - \frac{\Delta KVA}{\sqrt{3}\ V_1}$$

$$= \frac{786.44}{\sqrt{3}\ 5.25} - \frac{786.44}{\sqrt{3}\ 6.90}$$

= 86.49 − 65.80 = 20.69 $\angle$ 14.87

$\Delta I_T + \Delta I_c$ = (127.03 + 259.88j) + (20 + 5.31j)

147.03 + 265.19j

303.22 $\angle$ 61

TVA 11030 (WM-7-75)

DG - 2A @ 180 SEC

ΔV = TEST VOLTAGE DROP

= V1 - V2 = 6.9 - 5.25 = 1.65

VOLTAGE DROP DUE TO SCHEDULE LOAD = $\Delta V'$

$$= \Delta V \times \frac{\Delta I_T + \Delta I_C}{\Delta I_T}$$

$$= 1.65 \ \frac{303.22}{289.26} = 1.73$$

MINIMUM BUS VOLTAGE DUE TO SCHEDULE LOAD

= V1 - $\Delta V'$

= 6.9 - 1.73 = 5.17

= 0.749 PU @ 6.9 KV

$$\text{ADDITIONAL DIP} = \frac{1.73 - 1.65}{6.9} = 0.012 \text{ PU @ 6.9 kV}$$

SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT SQN

SQN-E3-015

COMPUTED BY [illegible] DATE 2/18/88 CHECKED BY [illegible] DATE 2/18/88

APPENDIX - C

DROP DUE TO RANDOM LOAD

SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT SQN

SQN-E3-015

COMPUTED BY [signature] DATE 2/22/88 CHECKED BY [signature] DATE 2/22/88

PURPOSE:

TO DETERMINE THE EFFECT ON THE 6.9 KV AND 480V SHUTDOWN BOARD TRANSIENT VOLTAGE DIPS DUE TO THE STARTING OF THE LARGEST RANDOM LOAD BLOCK CONCURRENT WITH THE SEQUENCE LOAD STEP WITH THE REMAINING RANDOM PROCESS LOADS RUNNING.

PROCEDURE

REFERENCE 3.1 DEFINES SIXTEEN RANDOM LOADS THAT START BY INDEPENDENT PROCESS SIGNALS THAT COULD BE STARTED ANYWHERE IN THE LOADING SEQUENCE. WE HAVE ASSUMED THAT THE SIMULTANEOUS START OF ALL SIXTEEN RANDOM PROCESS LOAD IS NOT CREDIBLE, HOWEVER, THE LARGEST LOAD BLOCK COULD CREDIBLY START CONCURRENTLY WITH A SEQUENCED LOAD STEP. FOR THIS ANALYSIS THE TOTAL RUNNING RANDOM PROCESS LOADS IS 134 KVA WITH THE LARGEST LOAD BLOCK CONSISTING OF A 60 HP A/C COMPRESSOR WITH ITS ASSOCIATED 25 HP AIR HANDLING UNIT.

THE RUNNING RANDOM PROCESS LOADS IS ADDED TO THE SCHEDULE RUNNING TO OBTAIN THE MODIFIED SCHEDULE RUNNING LOAD. THE ADDITIONAL VOLTAGE DIP DUE TO THIS MODIFIED SCHEDULE RUNNING LOAD IS CALCULATED BASED ON THE PROCEDURE DESCRIBED IN APPENDIX B. THE 480V SHUTDOWN BOARD VOLTAGE DIP WILL ALSO BE INCREASED BY THE SAME PERCENTAGE AS THE 6.9 KV BUS VOLTAGE DUE TO THE RUNNING RANDOM PROCESS LOAD.

THE VOLTAGE DROP ON 6.9 KV BUS DUE TO 480V RANDOM STARTING LOAD (85 HP) IS TAKEN AS LINEARLY PROPORTIONAL TO THE VOLTAGE DROP ON 6.9 KV BOARD DUE TO START OF FIRE PUMP (200 HP) ALONE.

($3.91 \times \frac{85}{200} = 1.66\%$ APPENDIX A SH. A7)

SUBJECT: DG VOLTAGE AND MARGIN ANALYSIS PROJECT: SQN

SQN-E3-015

COMPUTED BY: afal DATE: 2/22/88 CHECKED BY: SM DATE: 2/22/88

THE VOLTAGE DROP ON 480V SHUTDOWN BOARD DUE TO 480V RANDOM STARTING LOAD (85 HP) IS TAKEN AS LINEARLY PROPORTIONAL TO THE VOLTAGE DROP ON 480V SHUTDOWN BOARD DUE TO START OF FIRE PUMP (200 HP) ALONE.

($5.1 \times \frac{85}{200} = 2.17\%$ APPENDIX A SH. A11)

RESULTS

TABLES C1 AND C2 SUMMARIZE THE 6.9 KV AND 480V SHUTDOWN BOARD VOLTAGES CORRECTED FOR 134 KVA OF RUNNING RANDOM PROCESS LOAD AND 85 HP OF STARTING LOAD CONCURRENT WITH EACH LOAD STEP. IT SHOULD BE NOTED THAT THIS COULD ONLY OCCUR ON ONE LOAD STEP FOR EACH DIESEL.

THE WORST CASE 6.9 KV AND 480V SYSTEM VOLTAGE TRANSIENT CORRESPONDING TO THIS CONDITION IS 1.9 PERCENT AND 2.4 PERCENT RESPECTIVELY. SEE TABLES C3 AND C4.

TABLE - C1

WORST CASE 6.9 KV BUS VOLTAGE

CORRECTED FOR SCHEDULE LOAD + RANDOM RUNNING LOAD + RANDOM START LOAD

START MOTOR ①	SEQ. TIME SEC. ②	PRETRAN VOLTAGE PU ③	SOURCE DG ④	PRIOR TO START: DG LOAD FIELD TEST ⑤	PRIOR TO START: DG LOAD SCHEDULE [REF. 3.1] ⑥	PU DIP FIELD TEST ⑦	ADDITIONAL PU DIP DUE TO LOADING DIFFEREN ⑧	[⑦+⑧+0.017] TOTAL PU DIP INCLUDING DIP DUE TO RAND START LOAD ⑨	PU MINIMUM BUS VOLTAGE [③-⑨] ⑩
CCP	2	1.009	2A	1736 ∠54.5	1206 ∠42	0.174	0.0	0.174 ⊛	0.835
SI	5	0.991	2B	1102 ∠21.8	1717 ∠34.7	0.162	0.012	0.191	0.800
RHR	10	0.969	2B	1251 ∠25.3	2025 ∠32.5	0.159	0.014	0.190	0.779
ERCW	15	1.001	1B	1417 ∠30.3	2382 ∠30.9	0.187	0.013	0.217	0.784
AFW	20	0.965	2A	1903 ∠29.5	3049 ∠31	0.183	0.018	0.218	0.747
CCWP	30	1.008	2B	2495 ∠31.1	3520 ∠30.01	0.110	0.014	0.141	0.867
CSP+FP *	180	1.0	2A	3083 ∠33.3	3837 ∠29.7	0.200 ▲	0.014	0.231	0.769

* 200HP FP WAS STARTED WITH CSP.

▲ ADJUSTED THE FIELD TEST DIP TO DELETE THE EFFECT OF 200HP F.P (DIP = 0.039PU)

NOTE 1: ADDITIONAL DROP DUE TO START OF 85HP RANDOM LOAD IS 0.017PU.

⊛ NO CORRECTION DUE TO RANDOM LOAD START IS DONE SINCE TEST LOAD IS 530KVA MORE.

SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT SQN

SQN-E3-015

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TABLE - C2

WORST CASE 480V STDN. BD. VOLTAGE

CORRECTED FOR SCHEDULE LOAD + RANDOM RUNNING LOAD + RANDOM START LOAD.

SEQ TIME SEC ①	PRETRAN VOLTAGE (MEASURED) ② PU	PU DIP FIELD TEST ③	ADDITIONAL PU DIP DUE TO LOADING DIFFERENCE ④	PU DIP DUE TO START OF RANDOM LOAD ⑤	TOTAL PU DIP ⑥ [③+④+⑤]	PU MIN. BUS VOLTAGE [② - ⑥] ⑦
0	1.06	–	–	–	–	1.06
2	1.0	0.163	–	–	0.163 ⊛	0.837
5	1.017	0.167	0.012	0.022	0.201	0.816
10	0.994	0.148	0.014	0.022	0.184	0.810
15	1.017	0.183	0.013	0.022	0.218	0.799
20	0.975	0.179	0.018	0.022	0.219	0.756
30	1.033	0.188	0.014	0.022	0.224	0.809
180 (CSP+FP*)	1.012	0.23 ▲	0.014	0.022	0.266	0.745

* 200 HP FP WAS STARTED WITH CSP

▲ ADJUSTED THE FIELD TEST DIP TO COMPENSATE THE EFFECT OF 200HP F.P (0.051 PU)

⊛ NO CORRECTION DUE TO RANDOM LOAD START IS DONE SINCE TEST LOAD IS 530 KVA MORE.

NOTE : COLUMNS ① THRU ③ SEE TABLE - A2

. COLUMN ④ DIP IS DUE TO SCHEDULED LOAD + RANDOM RUNNING LOAD.

SUBJECT ______ PROJECT SQN

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TABLE - C3

6.9KV BUS VOLTAGE DROP DUE TO RANDOM RUNNING + RANDOM START LOAD

SEQ. TIME SEC ①	TOTAL DIP DUE TO SCHEDULE LOAD + RANDOM RUNNING + RANDOM START LOAD [TABLE C1] ②	TOTAL DIP DUE TO SCHEDULE LOAD [TABLE B1] ③	DIP DUE TO RANDOM RUNNING + RANDOM START LOAD [②-③] ④
2	0.174	0.174	0
5	0.191	0.172	0.019
10	0.190	0.172	0.018
15	0.217	0.199	0.018
20	0.218	0.200	0.018
30	0.141	0.123	0.018
180	0.231	0.212	0.019

TABLE - C4

480V STDN BD. VOLTAGE DROP DUE TO RANDOM RUNNING + RANDOM START LOAD

SEQ. TIME SEC ①	TOTAL DIP DUE TO SCHEDULE LOAD + RANDOM RUNNING + RANDOM START LOAD [TABLE-C2] ②	TOTAL DIP DUE TO SCHEDULE LOAD [TABLE B1] ③	DIP DUE TO RANDOM RUNNING + RANDOM START LOAD [②-③] ④
2	0.163	0.163	0
5	0.201	0.177	0.024
10	0.184	0.161	0.023
15	0.218	0.195	0.023
20	0.219	0.196	0.023
30	0.224	0.201	0.023
180	0.266	0.242	0.024

CALCULATION

RANDOM LOAD RUNNING. [REF 3.1]

TOTAL RANDOM LOAD RUNNING = 194.3 + j 99.2

480V BD RM A/C CPRSR RUNNING = 49.27 + j 33.11

480V BD RM 2A AHU2B-B RUNNING = 21.16 + j 14.22

RANDOM LOAD RUNNING - 2 LOADS STARTING

= 123.87 + j 51.87

= 134.3 ∠22.72 KVA

SHEET C8 OF C25

DG - 2E

SI PUMP START @ 5 SEC

INCLUDING RANDOM RUNNING LOAD

SQN-E3-015

COMPUTED aPal DATE 2/14/88

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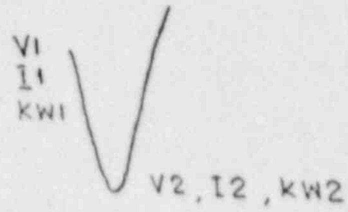
TEST LOADING



V1 = PRETRANSIENT VOLTAGE

= 6.84 KV

I1 = PRE TRANSIENT CURRENT

= 93 A

KW1 = PRE TRANSIENT KW = 1023

$\cos\theta_1$ = KW1/ $\sqrt{3}$ V1 I1 = 0.9283 $\theta_1 = 21.8^\circ$

KVA1 = 1101.8

V2 = MINIMUM VOLTAGE DUE TO MOTOR START = 5.72 KV

I2 = RESULTANT CURRENT (RUNNING + STARTING) AT V2 = 240A

KW2 = KW AT MINIMUM VOLTAGE V2 = 1365

$\cos\theta_2$ = KW2 / $\sqrt{3}$ V2 I2 = 0.5741 $\theta_2 = 55^\circ$

CHANGE IN CURRENT = ΔI_T

$= I_2 \angle\theta_2 - I_1 \angle\theta_1$

$= 240 \angle 55^\circ - 93 \angle 21.8^\circ$

$= 137.66 + j196.6 - 86.3 - j34.5$

$= 51.36 + j162.1$

$= 170 \angle 72.4$

TVA 11030 (WM-7-75)

SCHEDULE LOADING

RUNNING LOAD = 1410.4 KW + j 978.7 KVAR

RANDOM RUNNING LOAD = 123.9 KW + j 51.9 KVAR

TOTAL RUNNING LOAD = 1534.3 + j 1030.6

ΔKVA = DIFFERENCE IN RUNNING LOAD

= KVA (SCHEDULE) − KVAI(TEST)

= 1534.3 + j 1030.6 − 1023 − j 409.2

= 511.3 + j 621.4 = $804.7 \angle 50.55$

ΔI_c = CHANGE IN CURRENT FOR ΔKVA

$$= \frac{\Delta KVA}{\sqrt{3}\ V_2} - \frac{\Delta KVA}{\sqrt{3}\ V_1}$$

$$= \frac{804.7}{\sqrt{3} \times 5.72} - \frac{804.7}{\sqrt{3} \times 6.84}$$

= 81.2 − 67.9 = $13.3 \angle 50.55$

$\Delta I_T + \Delta I_c$ = 51.36 + j 162.1 + 8.45 + j 10.27

= 59.81 + j 172.37

= $182.45 \angle 70.86$

ΔV = TEST VOLTAGE DROP

$= V1 - V2 = 6.84 - 5.72 = 1.12\,KV$

VOLTAGE DROP DUE TO SCHEDULE LOAD = $\Delta V'$

$$= \Delta V \times \frac{\Delta I_T + \Delta I_C}{\Delta I_T}$$

$$= 1.12 \times \frac{182.45}{170} = 1.202$$

MINIMUM BUS VOLTAGE DUE TO SCHEDULE LOAD

$= V1 - \Delta V'$

$= 6.84 - 1.202 = 5.638\,KV$

$= 0.8171$ PU @ 6.9 KV

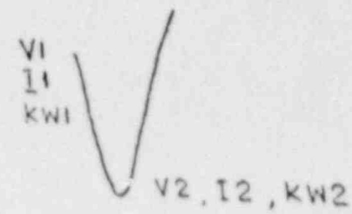
$$\text{ADDITIONAL DIP} = \frac{1.202 - 1.12}{6.9}$$

$= 0.012$ PU @ 6.9 KV

DG - 2B
RHR START @ 10 SEC
INCLUDING RANDOM LOAD RUNNING

COMPUTED alal DATE 2/14/83
CHECKED Sm DATE 2/14/86

TEST LOADING



$V1$ = PRETRANSIENT VOLTAGE
= 6.69 KV

$I1$ = PRE TRANSIENT CURRENT
= 108 A

$KW1$ = PRE TRANSIENT KW = 1131

$\cos\theta_1 = KW1/\sqrt{3}\, V1\, I1 = 0.9038$ $\theta 1 = 25.34°$

$KVA1 = 1251.4$

$V2$ = MINIMUM VOLTAGE DUE TO MOTOR START = 5.59 KV

$I2$ = RESULTANT CURRENT (RUNNING + STARTING) AT V2 = 246 A

$KW2$ = KW AT MINIMUM VOLTAGE V2 = 1580

$\cos\theta_2 = KW2/\sqrt{3}\, V2\, I2 = 0.6634$ $\theta 2 = 48.4$

CHANGE IN CURRENT $= \Delta I_T$

$= I_2 \angle\theta_2 - I_1 \angle\theta_1$

$= 246 \angle 48.4 - 108 \angle 25.34$

$= 163.33 + j183.95 - 97.6 - j46.22$

$= 65.73 + j137.74$

$= 152.52 \angle 64.5$

TVA 11030 (WM-7-75)

SCHEDULE LOADING

RUNNING LOAD = 1708 kW + j 1088 KVAR

RANDOM RUNNING LOAD = 123.9 kW + j 51.9 KVAR

TOTAL RUNNING LOAD = 1831.9 + 1139.9

ΔKVA = DIFFERENCE IN RUNNING LOAD

= KVA (SCHEDULE) - KVAI(TEST)

= 1831.9 + j 1139.9 − 1131 − j 535.6

= 700.9 + j 604.3 = 925.4 $\angle 40.77$

ΔI_c = CHANGE IN CURRENT FOR ΔKVA

$$= \frac{\Delta kVA}{\sqrt{3}\ V_2} - \frac{\Delta kVA}{\sqrt{3}\ V_1}$$

$$= \frac{925.4}{\sqrt{3} \times 5.59} - \frac{925.4}{\sqrt{3} \times 6.69}$$

= 95.6 − 79.9

= 15.7 $\angle 40.77$ = 11.9 + j 10.3

$\Delta I_T + \Delta I_c$ = 65.73 + j 137.74 + 11.9 + j 10.3

= 77.63 + j 148.04

= 167.2 $\angle 62.3$

ΔV = TEST VOLTAGE DROP

$= V1 - V2 = 6.69 - 5.59 = 1.1 \text{ KV}$

VOLTAGE DROP DUE TO SCHEDULE LOAD = ΔV′

$$= \Delta V \times \frac{\Delta I_T + \Delta I_C}{\Delta I_T}$$

$$= 1.1 \times \frac{167.2}{152.62} = 1.20 \text{ KV}$$

MINIMUM BUS VOLTAGE DUE TO SCHEDULE LOAD

$= V1 - \Delta V'$

$= 6.69 - 1.2 = 5.49 \text{ KV}$

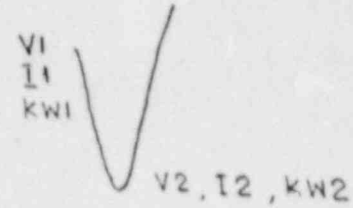
$= 0.796$ PU @ 6.9 KV

ADDITIONAL DIP $= \frac{1.20 - 1.1}{6.9} = 0.014$ PU @ 6.9KV

DG - 1E
ERCW START @ 15 SEC.
INCLUDING RANDOM LOAD RUNNING

COMPUTED [initials] DATE 2/14/82
CHECKED [initials] DATE 2/14/82

TEST LOADING



$V1$ = PRETRANSIENT VOLTAGE
= 6.91 KV

$I1$ = PRE TRANSIENT CURRENT
= 118.4 A

$KW1$ = PRE TRANSIENT KW = 1224

$\cos\theta_1 = KW1/\sqrt{3}\,V1\,I1 = 0.8637$ $\theta_1 = 30.25$

$KVA1 = 1417$

$V2$ = MINIMUM VOLTAGE DUE TO MOTOR START = 5.62

$I2$ = RESULTANT CURRENT (RUNNING + STARTING) AT V2 = 349.2

$KW2$ = KW AT MINIMUM VOLTAGE V2 = 1920

$\cos\theta_2 = KW2/\sqrt{3}\,V2\,I2 = 0.5648$ $\theta_2 = 55.61$

CHANGE IN CURRENT $= \Delta I_T$

$= I_2 \angle\theta_2 - I_1 \angle\theta_1$

$= 349.2\angle 55.61 - 118.4\angle 30.25$

$= 197.2 + j288.2 - 102.3 - j59.6$

$= 94.9 + j228.6$

$= 247.5\angle 67.45$

SCHEDULE LOADING

RUNNING LOAD = 2042.5 KW + j 1225.4 KVAR

RANDOM RUNNING LOAD = 123.9 KW + j 51.9 KVAR

TOTAL RUNNING LOAD = 2166.4 + j 1277.3

ΔKVA = DIFFERENCE IN RUNNING LOAD

= KVA (SCHEDULE) − KVAI (TEST)

= 2166.4 + j 1277.3 − 1224 − j 713.8

= 942.4 + j 563.5 = 1098 $\angle 30.9$

ΔIc = CHANGE IN CURRENT FOR ΔKVA

$$= \frac{\Delta KVA}{\sqrt{3}\ V_2} - \frac{\Delta KVA}{\sqrt{3}\ V_1}$$

$$= \frac{1098}{\sqrt{3} \times 5.62} - \frac{1098}{\sqrt{3} \times 6.91}$$

= 112.8 − 91.7

= 21.1 $\angle 30.9$ = 18.1 + j 10.8

$\Delta I_T + \Delta I_c$ = 94.9 + j 228.6 + 18.1 + j 10.8

= 113.0 + j 239.4

= 264.7 $\angle 64.7$

ΔV = TEST VOLTAGE DROP

$= V1 - V2 = 6.91 - 5.62 = 1.29$ KV

VOLTAGE DROP DUE TO SCHEDULE LOAD = $\Delta V'$

$$= \Delta V \times \frac{\Delta I_T + \Delta I_C}{\Delta I_T}$$

$$= 1.29 \times \frac{264.7}{247.5} = 1.38 \text{ KV}$$

MINIMUM BUS VOLTAGE DUE TO SCHEDULE LOAD

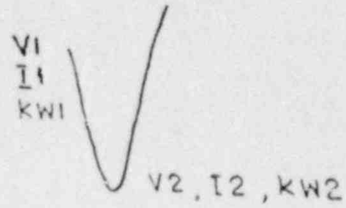
$= V1 - \Delta V'$

$= 6.91 - 1.38 = 5.53$ KV

$= 0.801$ PU @ 6.9 KV

ADDITIONAL DIP $= \frac{1.38 - 1.29}{6.9} = 0.013$ PU @ 6.9 KV

TEST LOADING



V1 = PRETRANSIENT VOLTAGE
= 6.66 KV

I1 = PRE TRANSIENT CURRENT
= 165 A

KW1 = PRE TRANSIENT KW = 1656

$\cos\theta_1 = KW1/\sqrt{3}\, V1\, I1 = 0.87$ $\theta_1 = 29.54$

KVA1 = 1903.4

V2 = MINIMUM VOLTAGE DUE TO MOTOR START = 5.4 KV

I2 = RESULTANT CURRENT (RUNNING + STARTING) AT V2 = 348 A

KW2 = KW AT MINIMUM VOLTAGE V2 = 1980

$\cos\theta_2 = KW2 / \sqrt{3}\, V2\, I2 = 0.6083$ $\theta_2 = 52.53$

CHANGE IN CURRENT $= \Delta I_T$

$= I_2 \angle\theta_2 - I_1 \angle\theta_1$

$= 348 \angle 52.53 - 165 \angle 29.54$

$= 211.7 + j\,276.2 - 143.5 - j\,81.4$

$= 68.1 + j\,194.8$

$= 206.4 \angle 70.7$

SCHEDULE LOADING

RUNNING LOAD = 2614 KW + j 1568.6 KVAR

RANDOM RUNNING LOAD = 123.9 KW + j 51.9 KVAR

TOTAL RUNNING LOAD = 2737.9 + j 1620.5

ΔKVA = DIFFERENCE IN RUNNING LOAD

= KVA (SCHEDULE) − KVAI(TEST)

= 2737.9 + j 1620.5 − 1656 − j 938.3

= 1081.9 + j 682.2 = 1279.0 ∠32.23

ΔIc = CHANGE IN CURRENT FOR ΔKVA

$$= \frac{\Delta KVA}{\sqrt{3}\ V_2} - \frac{\Delta KVA}{\sqrt{3}\ V_1}$$

$$= \frac{1279}{\sqrt{3} \times 5.4} - \frac{1279}{\sqrt{3} \times 6.66}$$

= 136.7 − 110.9 = 25.8 ∠32.23

= 21.8 + j 13.8

$\Delta I_T + \Delta I_c$ = 68.1 + j 194.8 + 21.8 + j 13.8

= 89.9 + j 208.6

= 227.1 ∠66.7

DG - 2A

AFW @ 20 Secs

SHEET C19 OF C25

SQN-E3-015

COMPUTED BPai DATE 2/18/88

CHECKED [illegible] DATE 2/18/88

ΔV = TEST VOLTAGE DROP

$= V1 - V2 = 6.66 - 5.4 = 1.26\ KV$

VOLTAGE DROP DUE TO SCHEDULE LOAD = $\Delta V'$

$$= \Delta V \times \frac{\Delta I_T + \Delta I_C}{\Delta I_T}$$

$$= 1.26 \times \frac{227.1}{206.4} = 1.386\ kV$$

MINIMUM BUS VOLTAGE DUE TO SCHEDULE LOAD

$= V1 - \Delta V'$

$= 6.66 - 1.386 = 5.274\ KV$

$= 0.764$ PU @ 6.9 kV

ADDITIONAL DIP $= \frac{1.386 - 1.26}{6.9}$

$= 0.018$ PU @ 6.9 KV

TVA 11030 (WM-7-75)

DG - 2B

CCWP START @ 30 SEC.

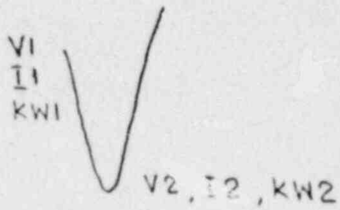
INCLUDING RANDOM LOAD RUNING

SQN-E3-015

COMPUTED [initials] DATE 2/15/82

CHECKED [initials] DATE 2/15/82

TEST LOADING



V1 = PRETRANSIENT VOLTAGE

= 6.96 KV

I1 = PRE TRANSIENT CURRENT

= 207 A

KW1 = PRE TRANSIENT KW = 2137

$\cos\theta_1 = KW1/\sqrt{3}\,V1\,I1 = 0.8564$ $\theta_1 = 31.09$

KVA1 = 2495.4

V2 = MINIMUM VOLTAGE DUE TO MOTOR START = 6.2 KV

I2 = RESULTANT CURRENT (RUNNING + STARTING) AT V2 = 288 A

KW2 = KW AT MINIMUM VOLTAGE V2 = 2478

$\cos\theta_2 = KW2/\sqrt{3}\,V2\,I2 = 0.8012$ $\theta_2 = 36.75$

CHANGE IN CURRENT $= \Delta I_T$

$= I_2 \angle\theta_2 - I_1 \angle\theta_1$

$= 288 \angle 36.75 - 207 \angle 31.09$

$= 230.8 + j172.3 - 177.3 - j106.9$

$= 53.5 + j65.4$

$= 84.5 \angle 50.7$

TVA 11030 (WM-7-75)

SCHEDULE LOADING

RUNNING LOAD = 3055.8 kW + j 1759.7 KVAR

RANDOM RUNNING LOAD = 123.9 KW + j 51.9 KVAR

TOTAL RUNNING LOAD = 3179.7 + j 1811.6

ΔKVA = DIFFERENCE IN RUNNING LOAD

= KVA (SCHEDULE) - KVAI(TEST)

= 3179.7 + j1811.6 - 2136.95 - j1288.58

= 1042.75 + j 523.02 = $1166.5 \angle 26.64$

ΔI_c = CHANGE IN CURRENT FOR ΔKVA

$$= \frac{\Delta KVA}{\sqrt{3}\ V_2} - \frac{\Delta KVA}{\sqrt{3}\ V_1}$$

$$= \frac{1166.5}{\sqrt{3} \times 6.2} - \frac{1166.5}{\sqrt{3} \times 6.96}$$

= 108.6 - 96.3 = $11.8 \angle 26.64$

= 10.5 + j 5.3

$\Delta I_T + \Delta I_c$ = 53.5 + j 65.4 + 10.5 + j 5.3

= 64 + j 70.7

= $95.4 \angle 47.85$

ΔV = TEST VOLTAGE DROP

$= V1 - V2 = 6.96 - 6.2 = 0.76$ KV

VOLTAGE DROP DUE TO SCHEDULE LOAD = $\Delta V'$

$$= \Delta V \times \frac{\Delta I_T + \Delta I_C}{\Delta I_T}$$

$$= 0.76 \times \frac{95.4}{84.5} = 0.858$$

MINIMUM BUS VOLTAGE DUE TO SCHEDULE LOAD

$= V1 - \Delta V'$

$= 6.96 - 0.858 = 6.102$ KV

$= 0.8843$ PU @ 6.9 KV

ADDITIONAL DIP $= \frac{0.858 - 0.76}{6.9}$

$= 0.014$ PU @ 6.9 KV

SHEET C23 OF C25

DG - 2A

SQN - E3 - 015

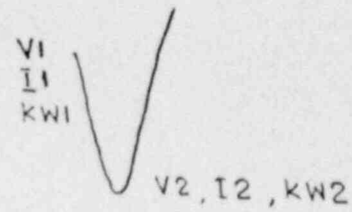
CSP + F P START @ 180 SEC

INCLUDING RANDOM LOAD RUNNING

COMPUTED aPal DATE 2/18/88

CHECKED Sm DATE 2/18/88

TEST LOADING



$V1$ = PRETRANSIENT VOLTAGE
= 6.90 KV

$I1$ = PRE TRANSIENT CURRENT
= 258 A

$KW1$ = PRE TRANSIENT KW = 2574

$\cos\theta_1 = KW1/\sqrt{3}\,V1\,I1 = 0.835$ $\qquad \theta 1 = 33.4$

$KVA1 = 3083.4$

$V2$ = MINIMUM VOLTAGE DUE TO MOTOR START = 5.25 KV

$I2$ = RESULTANT CURRENT (RUNNING + STARTING) AT $V2$ = 528 A

$KW2$ = KW AT MINIMUM VOLTAGE $V2$ = 3114

$\cos\theta_2 = KW2/\sqrt{3}\,V2\,I2 = 0.649$ $\qquad \theta 2 = 49.57$

CHANGE IN CURRENT $= \Delta I_T$

$= I_2 \angle\theta_2 - I_1 \angle\theta_1$

$= 528 \angle 49.57 - 258 \angle 33.4$

$= 342.42 + 401.9 - 215.39 - j142.02$

$= 127.03 + j\,259.88$

$= 239.26 \angle 63.95$

SCHEDULE LOADING

RUNNING LOAD = 3334.3 KW + j 1899.2 KVAR

RANDOM RUNNING LOAD = 123.9 KW + j 51.9 KVAR

TOTAL RUNNING LOAD = 3458.2 + j 1951.1

ΔKVA = DIFFERENCE IN RUNNING LOAD

= KVA (SCHEDULE) − KVAI(TEST)

= 3458.2 + j 1951.1 − 2574 − j 1697.4

= 884.2 + j 253.7 = 919.9 $\angle 16$

ΔI_c = CHANGE IN CURRENT FOR ΔKVA

$$= \frac{\Delta KVA}{\sqrt{3}\ V_2} - \frac{\Delta KVA}{\sqrt{3}\ V_1}$$

$$= \frac{919.9}{\sqrt{3} \times 5.25} - \frac{919.9}{\sqrt{3} \times 6.9}$$

= 101.2 − 76.97

= 24.23 $\angle 16$ = 23.3 + j 6.7

$\Delta I_T + \Delta I_c$ = 127.03 + j 259.88 + 23.3 + j 6.7

= 150.33 + j 266.58

= 306.0 $\angle 60.6$

ΔV = TEST VOLTAGE DROP

$= V1 - V2 = 6.9 - 5.25 = 1.65\ kV$

VOLTAGE DROP DUE TO SCHEDULE LOAD = $\Delta V'$

$$= \Delta V \times \frac{\Delta I_T + \Delta I_c}{\Delta I_T}$$

$$= 1.65\ kV \times \frac{306}{289.26} = 1.75\ kV$$

MINIMUM BUS VOLTAGE DUE TO SCHEDULE LOAD

$= V1 - \Delta V'$

$= 6.9 - 1.75 = 5.15\ kV$

$= 0.746$ PU @ 6.9 kV

ADDITIONAL DIP $= \frac{1.75 - 1.65}{6.9} = 0.014$ PU @ 6.9 kV

TVA 489H (EN DES-2-78) TENNESSEE VALLEY AUTHORITY SHEET D1 OF

SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT SQN

SQN-E3-015

COMPUTED BY aPal DATE 2/17/88 CHECKED BY Sm DATE 2/22/88

APPENDIX - D

LOAD SEQUENCE TIME INTERVAL

E[illegible]JATION.

SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT SQN

SQN-E3-015

COMPUTED BY afal DATE 2/22/88 CHECKED BY Sm DATE 2/22/88

PURPOSE

TO CALCULATE THE ACCELERATION TIMES OF THE 6.6 KV MOTORS AT 100% OF RATED VOLTAGE FOR THE ENTIRE ACCELERATING TIME AND FOR THE MINIMUM CALCULATED MOTOR TERMINAL VOLTAGE FOR ONE SECOND WITH RECOVERY TO 100% AVERAGE RATED VOLTAGE FOR THE REMAINING ACCELERATION TIME.

PROCEDURE

THE CABLE DROPS TO THE 6.6 KV MOTORS ARE CALCULATED IN APPENDIX F.

USING VENDOR SUPPLIED MOTOR AND LOAD SPEED TORQUE CURVES, THE SPEED-TORQUE CURVE AT MINIMUM MOTOR TERMINAL VOLTAGE WAS DEVELOPED USING $T @ V_{MIN} = V_{MIN}^2 \times T @ 100\% V$. THE ACCELERATION TIME IS CALCULATED BASED ON THE FOLLOWING EQUATION

$$T = \sum t = \sum \frac{J}{308 \times Ma} \times \Delta RPM$$

WHERE: J = MOMENT OF INERTIA OF ROTATING PARTS (MOTOR + LOAD)

ΔRPM = RPM CHANGE

Ma = AVERAGE ACCELERATING TORQUE
= MOTOR TORQUE - LOAD TORQUE

SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT SQN

SQN-E3-015

COMPUTED BY aPal DATE 2/22/88 CHECKED BY Sm DATE 2/22/88

RESULTS

TABLE D1 SUMMARIZES THE EFFECT OF THE VOLTAGE TRANSIENT EFFECT ON MOTOR ACCELERATING TIME AND ITS EFFECT ON LOAD SEQUENCE MINIMUM TIME INTERVAL AS DEFINED IN REFERENCE 3.9 AND SUMMARIZED IN ATTACHMENT D1.

THE OVERLAPPING OF CCP AND SIP ACCELERATION IS EVALUATED AND FOUND ACCEPTABLE. FOR DETAIL EVALUATION SEE ATTACHMENT D2

SUBJECT ______ PROJECT ______

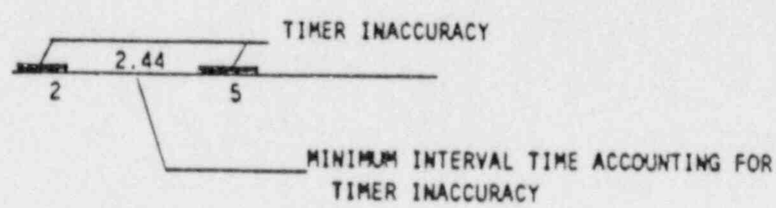
SQN-E3-015

COMPUTED BY afai DATE 2/22/88 CHECKED BY [signature] DATE 2/22/88

TABLE D1

6.6 KV MOTOR ACCELERATION TIME

MOTOR (1)	WORST CASE MOTOR TERM VOLTAGE PU 6.6KV BASE (2)	MIN. TIME INTERVAL SEC (C) (3)	ACCELERATION TIME: MEASURED FROM TEST IN SECS (4)	ACCELERATION TIME: MIN. VOLT FOR FIRST ONE SEC & 100% AVERAGE THE REST SEC (5)	ACCELERATION TIME: 100% RATED VOLTAGE FOR THE ENTIRE PERIOD SEC (6)	ACCELERATION TIME: MARGIN BETWEEN 3 & 5 SEC
CCP	0.867	2.44	2.15	3.33	2.99	*
SI	0.833	3.84	2.80	3.39	3.01	0.45
RHR	0.811	3.13	1.83	1.85	1.39	1.28
ERCW	0.782	2.4	1.56	1.67	1.20	0.73
AFW	0.778	6.25	3.46	3.77	3.22	2.48
CSP	0.798	—	2.56	2.79	2.35	—



* Margin is not applicable since CCP and SI pump motor starts could overlap; however, this condition has been considered in the calculation, and it has been established that this overlap will not cause any additional drop over what has been observed during testing.

TVA 489H (EN DES-2-78) TENNESSEE VALLEY AUTHORITY SHEET D5 OF

SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT SQN

SQN-E3-015

COMPUTED BY aPal DATE 2/22/88 CHECKED BY SM DATE 2/22/88

ACCELERATION TIME CALCULATION

FOR MINIMUM MOTOR TERMINAL VOLTAGE

REFER TO TABLE-B3

CHARGING PUMP

Computed: JKC Date: 2-15-88
Checked: BPai Date: 2/15/88

$$t = \frac{J}{308\ M_a} \Delta RPM$$

J = MOMENT OF INERTIA OF ROTATING PARTS

= 528.8 Lb ft^2 (MOTOR) + 260 Lb ft^2 (PUMP)

= 788.8 Lb ft^2

M_a = ACCELERATING TORQUE

= MOTOR TORQUE - LOAD TORQUE

$$t = \frac{788.8}{308 \times M_a} \Delta RPM = \frac{2.56104}{M_a} \Delta RPM$$

FOR ΔRPM = 100

$$t = \frac{256.104}{M_a}$$

CHARGING PUMP

COMPUTED JK DATE 2-15-88
CHECKED BPai DATE 2-15-88

V = 100% FULL VOLTAGE

$$t = \frac{256.104}{M_a}$$

Δ RPM	Ma IN Lb ft.	ACCELERATING TIME, t IN SEC.	TOTAL ACCELERATING TIME, SEC.
0 - 100	1855	0.138	0.138
100 - 200	1870	0.137	0.275
200 - 300	1700	0.151	0.426
300 - 400	1545	0.166	0.592
400 - 500	1640	0.156	0.748
500 - 600	1640	0.156	0.904
600 - 700	1645	0.156	1.060
700 - 800	1585	0.162	1.222
800 - 900	1560	0.164	1.386
900 - 1000	1460	0.175	1.561
1000 - 1100	1400	0.183	1.744
1100 - 1200	1330	0.193	1.937
1200 - 1300	1270	0.202	2.139
1300 - 1400	1200	0.213	2.352
1400 - 1500	1160	0.221	2.573
1500 - 1600	1580	0.162	2.735
1600 - 1700	1770	0.145	2.880
1700 - 1800	2440	0.105	2.985

SHEET D8 OF

SQN-E3-015

CHARGING PUMP

COMPUTED JRC DATE 2-15-88

CHECKED B Pai DATE 2-16-88

V = 86.7% OF FULL VOLTAGE (6600V) FOR 1 SEC.

100% VOLTAGE AFTER 1 SEC.

$$t = \frac{256.104}{M_a}$$ M_a BASED ON 86.7% VOLTAGE

Δ RPM	M_a IN Lb ft	ACCELERATING TIME, t IN SEC.	TOTAL ACCELERATING TIME, SEC.
0-100	1365	0.188	0.188
100-200	1390	0.184	0.372
200-300	950	0.270	0.642
300-400	1115	0.230	0.872
400-500	1170	0.219	1.091
500-600	1640	0.156	1.247
600-700	1645	0.156	1.403
700-800	1585	0.162	1.565
800-900	1560	0.164	1.729
900-1000	1460	0.175	1.904
1000-1100	1400	0.183	2.087
1100-1200	1330	0.193	2.280
1200-1300	1270	0.202	2.482
1300-1400	1200	0.213	2.695
1400-1500	1160	0.221	2.916
1500-1600	1580	0.162	3.078
1600-1700	1770	0.145	3.223
1700-1800	2440	0.105	3.328

PREPARED BY: [illegible] 2-16-88
Checked by: B Pai 2/16/88

(A)

LEB 3/15/75

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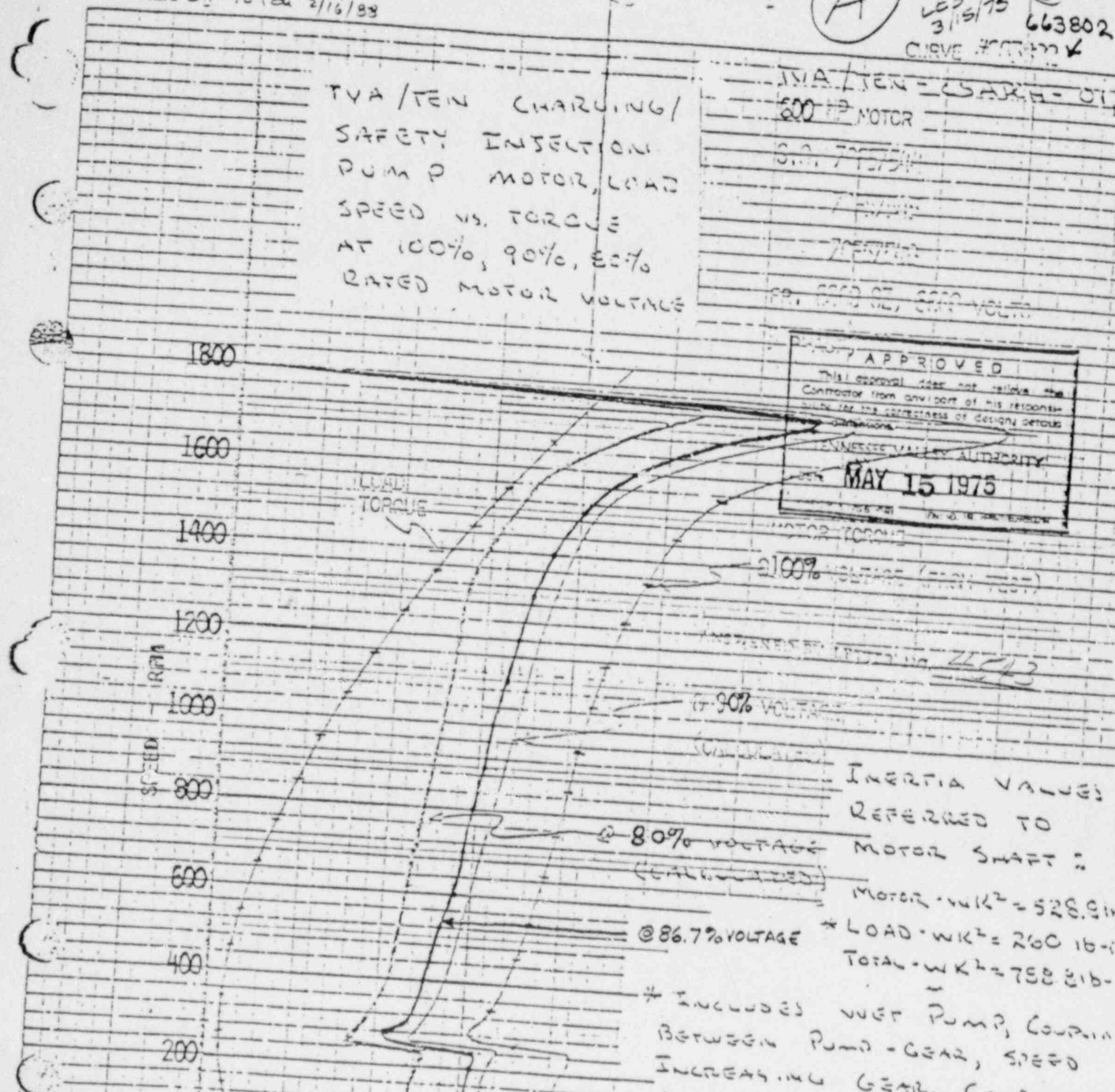

MECH. ENGR. BR.

TVA
FEB 10 75
PROJECT SEQUOYAH 1 & 2
CONTRACT [illegible]

SHEET E-107

MS 137

CURVE [illegible] * RLT

$$t = \frac{J}{308\ Ma} \ \Delta RPM$$

where t = time in seconds

J = Moment of Inertia of Rotating Parts

= 114.70 lb.ft² (Motor) + 13.00 lb.ft² (Load)

= 127.70 lb.ft²

Ma = Accelerating torque

= Motor torque - Load torque

For $\Delta RPM = 200$,

$$t = \frac{127.70}{308 \times Ma} \times 200$$

$$= \frac{82.92}{Ma}$$

SUBJECT SI PROJECT SQN

SQN-E3-015

COMPUTED BY aPal DATE 2/8/88 CHECKED BY Sm DATE 2/9/88

100 % OF 6.6 KV DURING ENTIRE PERIOD

$t = 82.92 / Ma$

Δ RPM	Ma , lbft.	ACCELERATING TIME , t IN SEC	TOTAL ACCEL. TIME , SEC.
0 - 200	580	0.143	0.143
200 - 400	605	0.137	0.280
400 - 600	595	0.139	0.419
600 - 800	580	0.143	0.562
800 - 1000	561	0.148	0.710
1000 - 1200	541	0.153	0.863
1200 - 1400	522	0.159	1.022
1400 - 1600	497	0.167	1.189
1600 - 1800	466	0.178	1.367
1800 - 2000	432	0.192	1.559
2000 - 2200	410	0.202	1.761
2200 - 2400	388	0.214	1.975
2400 - 2600	371	0.224	2.199
2600 - 2800	356	0.233	2.432
2800 - 3000	361	0.230	2.662
3000 - 3200	473	0.175	2.837
3200 - 3400	975	0.085	2.922
3400 - 3576	902	0.092	3.014

83.3 % of 6.6KV for 1sec and 100% for the remaining period

$$t = \frac{82.92}{Ma}$$

Δ RPM	Ma lb.ft	Accelerating time t in secs	Total accelerating time in secs
0-200	350	0.237	0.237
200-400	395	0.210	0.447
400-600	400	0.207	0.654
600-800	390	0.213	0.867
800-1000	375	0.221	1.088
1000-1200	541	0.153	1.241
1200-1400	522	0.159	1.400
1400-1600	497	0.167	1.567
1600-1800	466	0.178	1.745
1800-2000	432	0.192	1.937
2000-2200	410	0.202	2.139
2200-2400	388	0.214	2.353
2400-2600	371	0.224	2.577
2600-2800	356	0.233	2.810
2800-3000	361	0.230	3.040
3000-3200	473	0.175	3.215
3200-3400	975	0.085	3.300
3400-3576	902	0.092	3.392 secs

$$t = \frac{J}{308\,Ma} \Delta RPM$$

where t = time in seconds

J = Moment of Inertia of Rotating Parts

= 235 lb. ft² (Motor) + 46 lb. ft² (Load)

= 281 lb. ft²

Ma = Accelerating torque

= Motor torque − Load torque

For $\Delta RPM = 100$

$$t = \frac{281}{308\,Ma} \times 100$$

$$= \frac{91.234}{Ma}$$

$$t = \frac{J}{308\,Ma} \Delta RPM$$

where t = time in seconds

J = Moment of Inertia of Rotating Parts

= 235 lb. ft² (Motor) + 46 lb. ft² (Load)

= 281 lb. ft²

Ma = Accelerating torque

= Motor torque − Load torque

For $\Delta RPM = 100$

$$t = \frac{281}{308\,Ma} \times 100$$

$$= \frac{91.234}{Ma}$$

Sheet ____ of ____

SQN-E3-015 7612171F0306 SI

C0063

$$T\ @\ 78.2\%\ V = \left(\frac{0.782}{0.8}\right)^2 \times T\ @\ 80\%\ V$$

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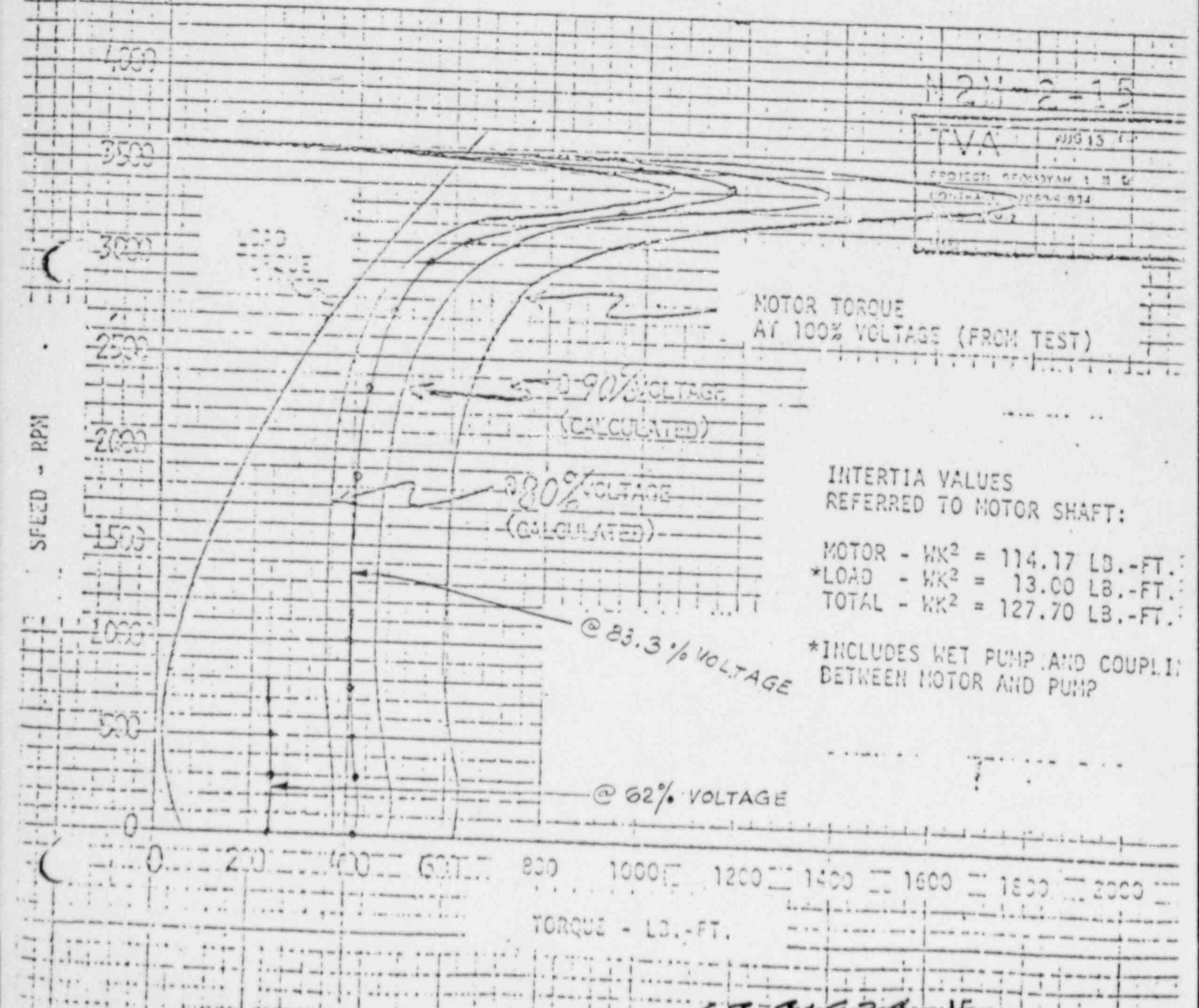
TVA/TEN SAFETY
INJECTION PUMP
MOTOR, LOAD SPEED
VS. TORQUE AT
100%, 90%, 80%
RATED MOTOR VOLTAGE
LETTER NO. TVA-S177

CURVE #663805
TVA/TEN-SIAPSI-01, 02
400 H.P. MOTOR
S.O. 69F43503
69F43504
69F43505
69F43506
FRAME 5809H, 6000 VOLTS
3 PHASE, 60 HZ.



INTERTIA VALUES
REFERRED TO MOTOR SHAFT:

MOTOR - WK^2 = 114.17 LB.-FT.
*LOAD - WK^2 = 13.00 LB.-FT.
TOTAL - WK^2 = 127.70 LB.-FT.

*INCLUDES WET PUMP AND COUPLI
BETWEEN MOTOR AND PUMP

68-91934-15

D15

SQN-E3-015

RHR

Blai DATE 2/15/88
CHECKED JFC DATE 2-15-88

$$t = \frac{91.234}{Ma}$$

100% voltage for the entire period

ΔRPM	Ma	Accelerating time t in secs	Total accelerating time in secs.
0-100	980	0.093	0.093
100-200	1060	0.086	0.179
200-300	1060	0.086	0.265
300-400	1100	0.083	0.348
400-500	1140	0.080	0.428
500-600	1160	0.079	0.507
600-700	1180	0.077	0.584
700-800	1180	0.077	0.661
800-900	1160	0.079	0.740
900-1000	1120	0.081	0.821
1000-1100	1120	0.081	0.902
1100-1200	1100	0.083	0.985
1200-1300	1100	0.083	1.068
1300-1400	1120	0.081	1.149
1400-1500	1200	0.076	1.225
1500-1600	1440	0.063	1.288
1600-1700	2040	0.045	1.333
1700-1783	1740	0.052	1.385 secs.

RHR

COMPUTED BPai DATE 2/15/88
CHECKED JTC DATE 2-15-88

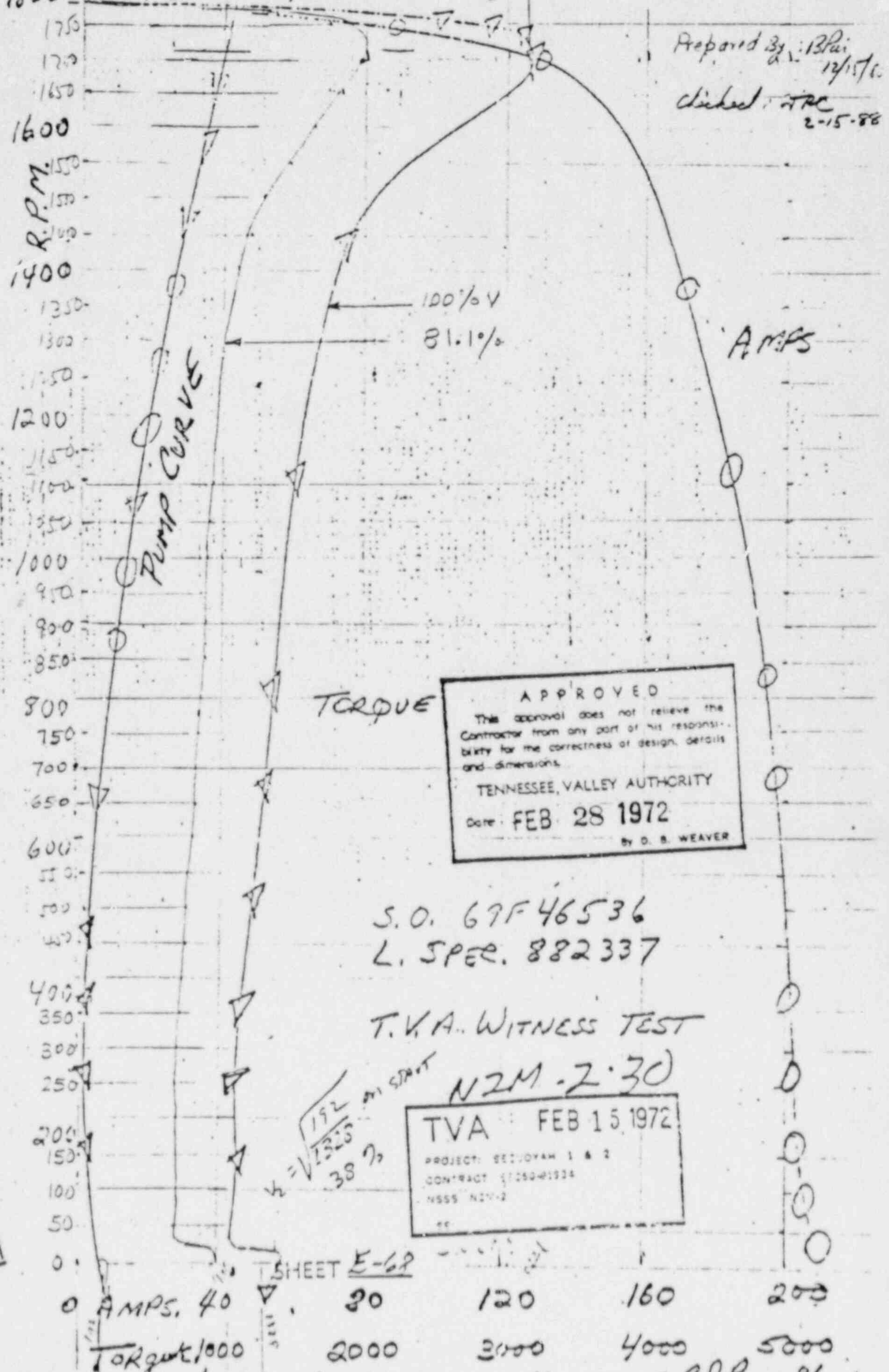
$$t = \frac{91.234}{Ma}$$

81.1 % of 6600V for 1sec and 100% for the remaining period.

ΔRPM	Ma	Accelerating time t in secs	Total accelerating in secs.
0-100	560	0.163	0.163
100-200	620	0.147	0.310
200-300	640	0.143	0.453
300-400	660	0.138	0.591
400-500	680	0.134	0.725
500-600	680	0.134	0.859
600-700	700	0.130	0.989
700-800	660	0.138	1.127
800-900	1160	0.079	1.206
900-1000	1120	0.081	1.287
1000-1100	1120	0.081	1.368
1100-1200	1100	0.083	1.451
1200-1300	1100	0.083	1.534
1300-1400	1120	0.081	1.615
1400-1500	1200	0.076	1.691
1500-1600	1440	0.063	1.754
1600-1700	2040	0.045	1.799
1700-1783	1740	0.052	1.851 secs.

1800 5809 LLD W1 400 H.P. 6600 VOLTS 3Ø 60 Hz 4.

Prepared By: [illegible] 12/15/[illegible]
Checked: [illegible] 2-15-88



MECHANICAL FILE

$V_2 = \sqrt{\frac{1102}{3221}} = 58.6\%$

starting

ERCW

DIB

SQN - E3 - 015

COMPUTED JRC DATE 2-15-88

CHECKED BPai DATE 2-16-88

$$t = \frac{J}{308\ Ma} \Delta RPM$$

J = MOMENT OF INERTIA OF ROTATING PARTS

= 1320 Lb ft² (MOTOR) + 159 Lb ft² (PUMP)

= 1479 Lb ft²

Ma = ACCELERATING TORQUE

= MOTOR TORQUE - LOAD TORQUE

$$t = \frac{1479\ Lb\ ft^2}{308\ Ma} \Delta RPM = \frac{4.802}{Ma} \Delta RPM$$

FOR ΔRPM = 45

$$t = \frac{4.802}{Ma}(45) = \frac{216.1}{Ma}$$

TVA 489H (EN DES-2-78) TENNESSEE VALLEY AUTHORITY SHEET D19 OF

SUBJECT ERCW PROJECT SQN

SQN-E3-015

COMPUTED BY aPal DATE 2/8/88 CHECKED BY [illegible] DATE 2/8/88

100 % OF 6600V FOR ENTIRE PERIOD

$t = 216.1 / Ma$

Δ RPM	Ma lb-ft	ACCEL. TIME t IN SEC.	TOTAL ACCEL. TIME, SEC.
0 - 45	3793	0.057	0.057
45 - 90	3975	0.054	0.111
90 - 135	4048	0.053	0.164
135 - 180	3975	0.054	0.218
180 - 225	3902	0.055	0.273
225 - 270	3793	0.057	0.330
270 - 315	3684	0.059	0.389
315 - 360	3574	0.060	0.449
360 - 405	3538	0.061	0.510
405 - 450	3465	0.062	0.572
450 - 495	3355	0.064	0.636
495 - 540	3355	0.064	0.700
540 - 585	3319	0.065	0.765
585 - 630	3319	0.065	0.830
630 - 675	3392	0.064	0.894
675 - 720	3465	0.062	0.956
720 - 765	3757	0.057	1.013
765 - 810	4194	0.052	1.065
810 - 855	4668	0.046	1.111
855 - 880	2553	0.085	1.196

D20

ERCW

SQN-E3-015

COMPUTED JRC DATE 2-16-88
CHECKED BPai DATE 2-16-88

V = 78.2% OF 6600V FOR 1 SEC.
100% VOLTAGE AFTER 1 SEC.
t = 216.1 / Ma

ΔRPM	Ma lb ft	ACCELERATING TIME, t IN SEC.	TOTAL ACCELERATING TIME, SEC.
0-45	2112	0.102	0.102
45-90	2304	0.094	0.196
90-135	2352	0.092	0.288
135-180	2256	0.096	0.384
180-225	2208	0.098	0.482
225-270	2112	0.102	0.584
270-315	2064	0.105	0.689
315-360	1920	0.113	0.802
360-405	1872	0.115	0.917
405-450	1728	0.125	1.042
450-495	3355	0.064	1.106
495-540	3355	0.064	1.170
540-585	3319	0.065	1.235
585-630	3319	0.065	1.300
630-675	3392	0.064	1.364
675-720	3465	0.062	1.426
720-765	3757	0.057	1.483
765-810	4194	0.052	1.535
810-855	4668	0.046	1.581
855-880	2553	0.085	1.666

ERCW

SQN-E3-015

JLC 2-15-88
BPW 2-15-88

455HA778

Sequoyah N.P. - ERCW Pumps

SUBJECT AFW PROJECT SQN

SQN-E3-015

COMPUTED BY [illegible] DATE 2/5/88 CHECKED BY [illegible] DATE 2/5/88

V = 75% OF 66:0V FOR 1 SEC.

AVERAGE ACCELERATING TORQUE = 33% OF F.L.TORQUE

= 0.33 × 738 lb ft.

$$t = \frac{\Delta RPM \times J}{308 \times Ma}$$

$$\Delta RPM = \frac{t \times 308 \times Ma}{J}$$

$$= \frac{1.0 \times 308 \times 0.33 \times 738}{197.3}$$

= 380 RPM.

FOR 75% OF 6600V FOR 1 SEC, THE MOTOR WILL ATTAIN SPEED OF APPROX. 400 RPM.

SUBJECT AFW PROJECT SQN

SQN-E3-015

COMPUTED BY afa! DATE 2/5/88 CHECKED BY EM DATE 2/5/88

75% OF 6600V FOR FIRST ONE SEC. AND 100% FOR REMAINING PERIOD.

$$t = \frac{J}{308\ Ma}\ \Delta RPM$$

J = MOMENT OF INERTIA OF ROTATING PARTS

= 14.3 lb ft² (Pump) + 183.0 lb ft² (motor)

= 197.3 lb ft²

Ma = ACCELERATING TORQUE

= MOTOR TORQUE − LOAD TORQUE.

$$\text{MOTOR F.L. TORQUE} = \frac{500 \times 33000}{2\pi \times 3560} = 738\ \text{lb ft}.$$

FOR $\Delta RPM = 200$

$$t = \frac{197.3}{308 \times Ma} \times 200$$

$$= \frac{128.117}{Ma}$$

SUBJECT AFW PROJECT SQN

SQN-E3-015

COMPUTED BY [illegible] DATE 2/5/88 CHECKED BY [illegible] DATE 2/5/88

$$t = \frac{128.117}{Ma} = \frac{128.117}{\% \times 738}$$

Δ RPM	Ma (% F.L.T)	ACCELERATING TIME, t IN SEC	TOTAL ACCELERATING TIME, SEC
0 - 200	33	0.526	0.526
200 - 400	33	0.526	1.052
400 - 600	74	0.236	1.288
600 - 800	78.5	0.221	1.509
800 - 1000	83.5	0.208	1.717
1000 - 1200	88.5	0.196	1.913
1200 - 1400	93	0.187	2.100
1400 - 1600	102	0.170	2.27
1600 - 1800	109	0.159	2.429
1800 - 2000	115	0.151	2.58
2000 - 2200	123	0.141	2.721
2200 - 2400	128.5	0.135	2.856
2400 - 2600	137	0.127	2.983
2600 - 2800	145	0.120	3.103
2800 - 3000	143	0.121	3.224
3000 - 3200	132	0.132	3.356
3200 - 3400	107	0.162	3.518
3400 - 3560	68	0.255	3.773 SEC.

SUBJECT AFW PROJECT SQN

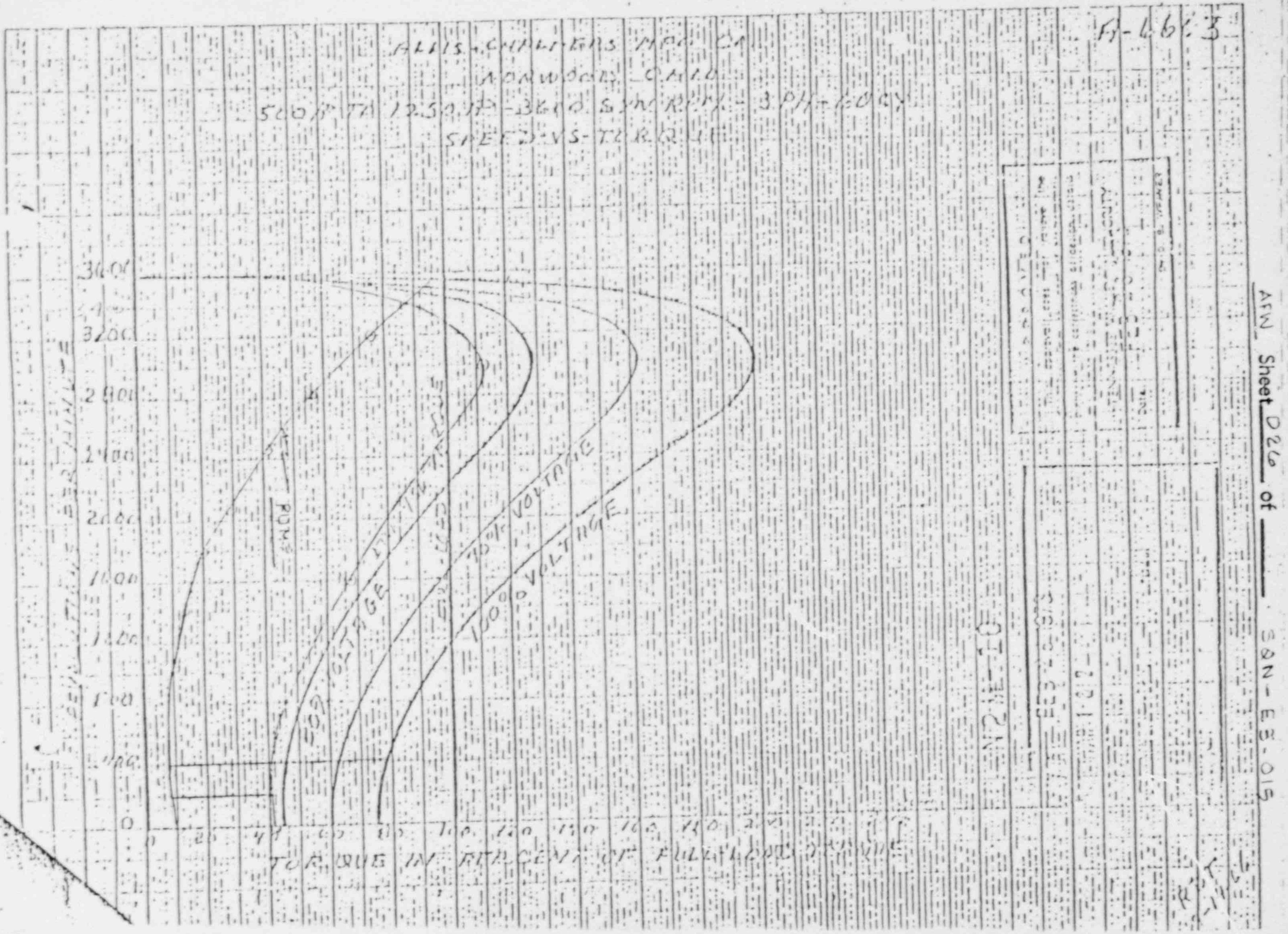
SQN-E3-015

COMPUTED BY [illegible] DATE 2/5/88 CHECKED BY [illegible] DATE 2/5/88

100% OF 6600 V FOR ENTIRE PERIOD.

Δ RPM	Ma (% FLT)	ACCELERATING TIME IN SEC.	TOTAL ACCEL. TIME, SEC
0 - 200	68	0.255	0.255
200 - 400	70.5	0.246	0.501
400 - 3560		2.721	3.222 SEC.

PUMP CURVE (T vs SPEED) IS TAKEN FROM 3HMTA-9
TVA - SEQUOYAH 1&2 AFW PUMP DWG NO. N-1382



3HMTA-9, T.V.A. - SEQUOYAH 1&2 AUX.F.W. PUMP S/N 11-71-68 TO 11-71-71

PUMP SPEED VS TORQUE CURVE
(ESTIMATED)

STARTING TORQUE WITH VALVE OPEN AND SET AT DESIGN FLOW FOR RATED SPEED AND VOLTAGE

100% FULL LOAD TORQUE = 8610 LB-INS

100% FULL LOAD SPEED = 3560 RPM

FJN
1 FEB 88

$$t = \frac{J}{308\ M_a} \Delta RPM$$

J = MOMENT OF INERTIA OF ROTATING PARTS

= MOTOR + LOAD = 851 Lb ft²

M_a = ACCELERATING TORQUE

= MOTOR TORQUE − LOAD TORQUE

$$t = \frac{851}{308\ M_a} \Delta RPM = \frac{2.763}{M_a} \Delta RPM$$

FOR RPM = 100

$$t = \frac{2.763}{M_a}(100) = \frac{276.3}{M_a}$$

TVA 489H (EN DES-2-78) TENNESSEE VALLEY AUTHORITY SHEET D29 OF

SUBJECT CSP PROJECT SQN

SQN-E3-015

COMPUTED BY Sm DATE 2/9/88 CHECKED BY [illegible] DATE 2/9/88

Entire period at 100% voltage

Δ RPM	Ma in Lb.Ft	Accelerating Time in Sec.	Total Accelerating Time in Sec
0 - 100	2225	.124	.124
100 - 200	2250	.123	.247
200 - 300	2275	.121	.368
300 - 400	2325	.119	.487
400 - 500	2300	.120	.607
500 - 600	2300	.120	.727
600 - 700	2250	.123	.85
700 - 800	2200	.126	.976
800 - 900	2125	.130	1.106
900 - 1000	2050	.135	1.241
1000 - 1100	1950	.142	1.383
1100 - 1200	1950	.142	1.525
1200 - 1300	1850	.149	1.674
1300 - 1400	1800	.154	1.828
1400 - 1500	1725	.160	1.988
1500 - 1600	1850	.149	2.137
1600 - 1700	2400	.115	2.252
1700 - 1800	2900	.095	2.347

79.8 % VOLTAGE FOR 1 SEC.
100% VOLTAGE AFTER 1 SEC.
t = 276.3/Ma

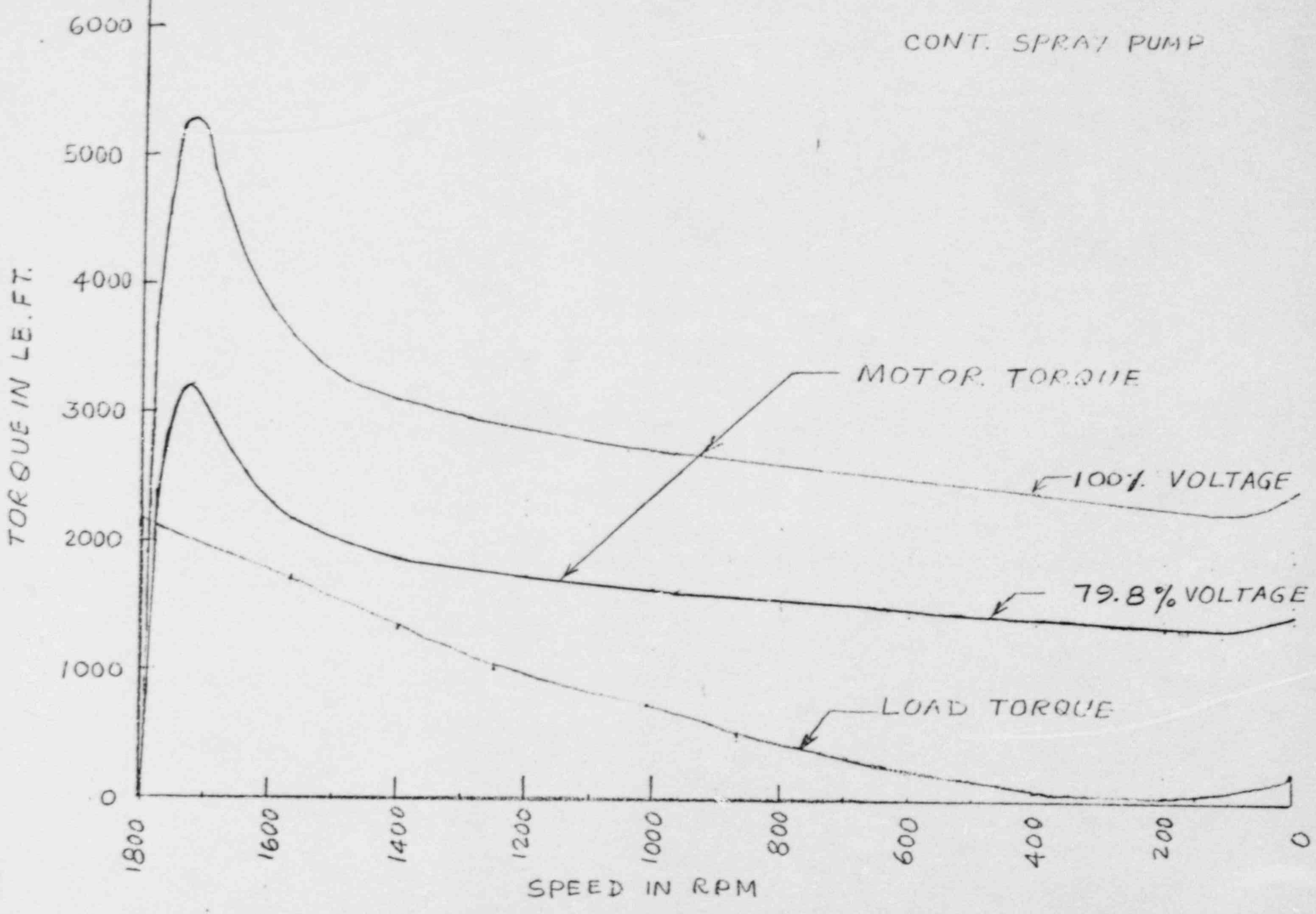
Δ RPM	Ma lbft	ACCELERATING TIME IN SEC.	TOTAL ACCELERATING TIME IN SEC.
0-100	1260	0.219	0.219
100-200	1300	0.213	0.432
200-300	1330	0.208	0.640
300-400	1350	0.205	0.845
400-500	1320	0.209	1.054
500-600	2300	0.120	1.174
600-700	2250	0.123	1.297
700-800	2200	0.126	1.423
800-900	2125	0.130	1.553
900-1000	2050	0.135	1.688
1000-1100	1950	0.142	1.830
1100-1200	1950	0.142	1.972
1200-1300	1850	0.149	2.121
1300-1400	1800	0.154	2.275
1400-1500	1725	0.160	2.435
1500-1600	1850	0.149	2.584
1600-1700	2400	0.115	2.699
1700-1800	2900	0.095	2.794 Secs

SQN-E3-015

JRC 2-17-88 Grr 2/8/88

Blai 2-17-88 OP.C 2/9/88

CONT. SPRAY PUMP



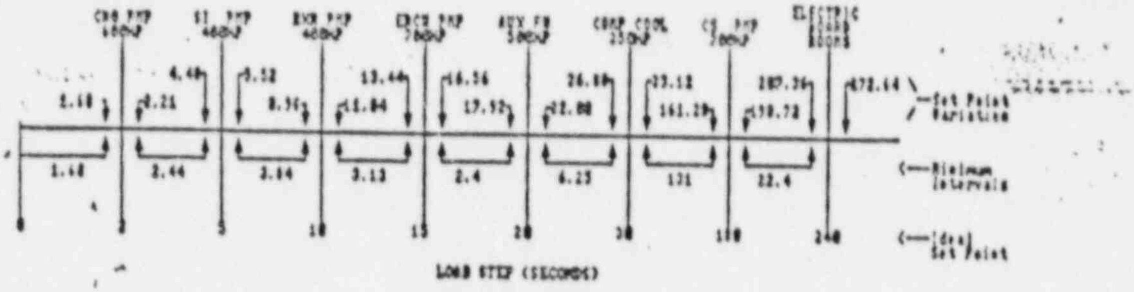
G. DG Timer Relays

Calculations "27S1A" and "DG TIMER RELAYS" address DG sequence timers. Calculation "DG TIMER RELAYS" addresses the affects of sequence timer inaccuracies upon DG loading by calculating the minimum time between load steps. Calculation "27S1A" calculates the maximum time it takes to make electic power available to the sequenced loads. Both calculations are based on the methodologyy presented ISA 67.04, "SETPOINTS FOR NUCLEAR SAFETY-RELATED INSTRUMENTATION USED IN NUCLEAR POWER PLANTS" and Reg Guide 1.105, "INSTRUMENT SETPOINTS FOR SAFETY-RELATED SYSTEMS."

"DG TIMER RELAYS" calculates the minimum time interval between loadings by calculating the root-sum-square of the random errors asociated with two adjacent relays. NOTE: The root-sum-square technique is addressed in ISA 67.04. This methodology yields a 95 percent confidence level for the time intervals. NOTE: Per Reg Guide 1.105 R2, " Typically, the NRC staff has accepted 95 percent as a probability limit for errors." There is one systematic error associated with these relays, a bias error due to ambient temperature changes. Since all relays are located in the same cabinet, all relays will experience the same ambient temperature changes; therefore, this effect cancels out for adjacent sequence timers.

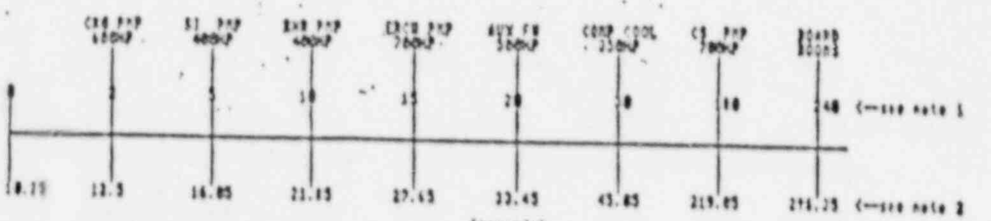
"27S1A" calculates errors associated with each timer in turn (errors calculated for only one relay rather than adjacent relays) since the parameter of concern is maximum time to make electric power available to a particular load. This means the bias error associated with temperature must also be included in the accuracy. The results are for a concurrent loss of offsite power and safety injection initiation.

SUMMARY OF "DG TIMER RELAYS"



Variations about ideal setpoint are shown for algebraic error combinations.
Minimum interval times shown are for Square Root of the Sum of the Squares (SRSS) combinations of errors(pg 42 timers)

SUMMARY OF "27S1A"



note 1 = Sequence timer setpoints (provided for comparison purposes).
note 2 = Time from initial loss of offsite power until load breaker closure. Includes sequence timer timeout, diesel generator runup time (10 sec), and load breaker closure time for two breakers at 0.125 sec per breaker.

OVER LAPPING OF CCP & SIP ACCELERATION SQN-E3-015

COMPUTED [initials] DATE 2/16/88
CHECKED [initials] 2/18/88

OVERLAP IN ACCELERATION PERIOD OF CCP & SIP

Field Test STI 77 indicates that in the worst case the CCP accelerated in 2.15 secs. (DG-2A).

The motor acceleration calculation (SH. D8) indicates that the CCP can take maximum of 3.328 sec to come to full speed.

The Ref 3.9 indicates a minimum timer gap of 2.44 sec between CCP and SIP starting.

Thus, under worst case, the maximum acceleration overlap between CCP and SIP may be 3.328 − 2.44 = .888 sec ≃ .9 sec.

So under this worst case the preloading on SIP starting corresponds to the test (CCP) readings at 0.9 sec prior to SIP start.

From STI-77, the corresponding test readings are

I = 108 A and kW = 1008 kW.

Thus under worst case timer variation which may cause overlap of acceleration period of CCP and SIP by .9 sec will cause the SI Pump to start with preloading condition of I = 108 A and kW = 1008 kW.

SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT SQN
SQN-E3-015

COMPUTED BY [illegible] DATE 2/2/88 CHECKED BY [illegible] DATE 2/22/88

During the field testing the SI pump started with preloading current of 90A and KW = 936 kW.

Thus there is a preload increase of 108 - 90 = 18 A and 1008 - 936 = 62 kW if there be 0.9 sec overlapping between CCP and SIP acceleration compared the actual test preloading.

Because of the inductive nature of the system fed by the DG, the drops due to the running loads are mostly in quadrature with the DG terminal voltage while the voltage drop due to the starting loads are in phase with the DG terminal voltage. Thus the drop caused by the marginal increase in the preloading condition will be marginal and for this calculation it can be concluded that the worst case overlapping of CCP and SIP acceleration will cause insignificant drop over the drop caused by the start of the SIP alone.

SUBJECT DG VOLTAGE AND MARGIN ANALYIS PROJECT SQN
SQN-E3-015

COMPUTED BY Sm DATE 2/21/88 CHECKED BY O.Pal DATE 2/21/88

As an additional verification the total current during the acceleration of CCP + SIP and CSP + FP including running loads are compared below.

Schedule load at start of SIP

$$= 1716.7 \angle 34.76 \text{ KVA}$$

Running current due to schedule load at SIP start

$$I_A = \frac{1716.7 \angle 34.76}{\sqrt{3} \times 6.9}$$

$$= 143.6 \angle 34.76$$

$$= 118.0 - j\,81.9$$

$$CCP\ I_{LR} = 315 \angle 73.3 = 90.52 - j\,301.71 = I_B$$

$$SI\ I_{LR} = 215 \angle 75.5 = 53.82 - j\,208.15 = I_C$$

$$CSP\ I_{LR} = 355 \angle 74.1 = 97.26 - j\,341.42 = I_D$$

$$FP\ I_{LR} = \frac{460}{6600} \times 1100 \angle 78.48 = 15.31 - j\,75.12 = I_E$$

Schedule load at start of CSP = 3837.3 ∠29.67 kVA

Running current due to schedule load at CSP start

$$I_F = \frac{3837.3 \angle 29.67}{\sqrt{3} \times 6.9} = 279 - j\,158.9$$

$I_A + I_B + I_C = 262.4 - 591.76 = 647.33 \angle 66 = I_{CCP+SI}$

$I_D + I_E + I_F = 391.6 - 575.44 = 696.03 \angle 55 = I_{CSP+FP}$

$I_{CSP+FP} - I_{CCP+SI} \approx 50A.$

As the total current during the acceleration of the CSP and FP is more than the total current during the start of the CCP and SIP, we can conclude that the voltage drop during the CSP and FP acceleration bounds the voltage drop during the overlapping operation of the CCP and SIP.

The test results on the worst case DG 2A at 180 sec indicate a 23.9% voltage drop on the start of CSP+FP. The corresponding maximum test current is 522 A. From this as a rough approximation it can be concluded that a 50A difference provides additional margin of 50×.239/522 = 2.3% on the bounding case of CSP+FP start.

TVA 489H (EN DES-2-78) TENNESSEE VALLEY AUTHORITY Page E-1 SHEET OF

SUBJECT DG VOLTAGE & MARGIN ANALYSIS PROJECT SQN

SQN-E3-015

COMPUTED BY atal DATE 2/18/88 CHECKED BY Bfai DATE 2/18/88

APPENDIX - E

MOTOR SUSTAINING AND MIN. BREAKAWAY VOLTAGE

Purpose: For motors supplied power from the diesel generator, determine the minimum voltage (during a ½ second reduced voltage condition) required at the distribution boards to: (1) avoid any motor stalling and (2) rotate any motor from standstill. Also, show that an approximate 5% drop in voltage below the minimum value found in (1) above will result in a speed decrease but not a stall condition during the ½ second degraded voltage period.

Sources of Design Information:

1. Motor/Pump Curves:
   - ERCW - See Appendix D
   - AFW - See Appendix D
   - CSP - See Appendix D
   - RHR - See Appendix D
   - SI - See Appendix D
   - CCP - Contract 81-828634-1 (Attachment E-1)
   - CCS - See Appendix D
2. ANSI Std. C50.41-1982, page A-13 (Attachment E-2)
3. Motor Application and Maintenance Handbook edited by R.M. Smeaton (Attachment E-3)
4. NEMA Std. MG1-12.37, November 1978 part 12, page 7 (Attachment E-4)
5. NEMA Std. MG1-12.38, November 1978 part 12, page 8 (Attachment E-5)

Methods and Procedures: See pages E4 through E5 and E10 through E12.

Prepared J.R. Arnett Date 2/22/88
Verified R.S. Green Date 2/22/88

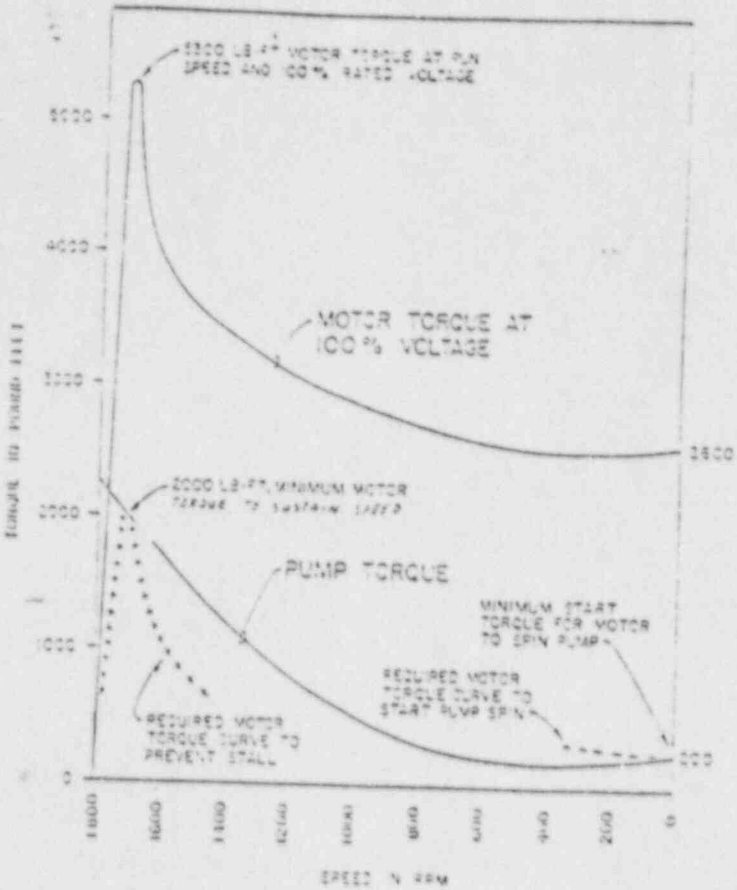
SQN-E3-015

Assumptions: 460-volt motor load characteristics are bounded by those tabulated in Table 2.

Documentation of Assumptions: The load characteristics listed in Table 2 were taken from Smeaton's "Motor Application and Maintenance Handbook", which, per Smeaton, tend to be the maximum encountered in the tabulated types of loads and may give conservative results.

Prepared J.R. Arnett Date 2/22/88
Verified R.S. Brun Date 2/22/88

SQN Containment Spray (CSP)
PUMP/MOTOR SPEED-TORQUE CURVES



Prepared *L.R. Arnett* Date 2-17-88
Verified *R.S. Brown* Date 2-17-88

SQN-E3-015

QUESTION: For a running pump, what minimum voltage will produce the torque required to keep the pump ~~run~~ running?

The torque requirement at reduced voltage is read directly from the pump curve and corresponds to the speed at which the motor develops maximum torque at 100% voltage. In this example this torque is 2000 lb-ft.

Using the basic relationship that motor torque is proportional to the square of the voltage and that there is a linear relationship between the speed-torque curves at different voltages (See ANSI C50.41, Paragraph 11), we can determine the minimum voltage required to sustain motor speed.

$T \propto V^2$ and $\frac{T_S}{T_R} = \frac{V_S^2}{V_R^2}$ where

T_S = Sustaining torque from curve
T_R = Peak torque at rated volts
V_S = Sustaining minimum voltage
V_R = Rated voltage

For this example $V_S = \sqrt{\frac{T_S}{T_R}} V_R = \sqrt{\frac{2000}{5300}} V_R = 61.4\% V_R$

In order to determine the minimum voltage to start spinning a pump from standstill (Breakaway Voltage V_B), we use the same method as ~~above~~ stated before, except we start with the minimum torque required to spin the pump from zero speed. For this example the required start torque is 200 lb.-ft. as read from the pump curve.

$$T \propto V^2$$

$$\frac{T_B}{T_R} = \frac{V_B^2}{V_R^2}$$

where
T_B = Breakaway Torque from pump curve
T_R = Motor starting torque at rated voltage
V_B = Breakaway Voltage
V_R = Rated Voltage

$$V_B = \sqrt{\frac{T_B}{T_R}}\, V_R$$

$$100 \times \sqrt{\frac{T_B}{T_R}} = \%\ \text{Rated Voltage}$$

$$V_B = \sqrt{\frac{200}{2600}}\, V_R = .28\, V_R$$

Minimum Breakaway Voltage, V_B = 28% Rated Voltage

page C-0

Motor	Pump/Motor Curve	(1) Motor Torque @ Rated Volts	(1) Pump Torque @ RUN Speed	(2) ~~Stall~~ sustaining Volts % Rated	(1) Pump Breakaway Torque	(1) Motor Starting Torque	(2) Min. Breakaway Volts, % Rated
ERCW	455HA778	200%	85%	65	11.5%	100%	34
AFW	N-1382	200%	65%	57	10 %	75 %	36.5
CSP	2-8-88	5300 lb-ft	2000 lb-ft	61.4	200 lb-ft	2600 lb-ft	28
RHR	E-68	3221 lb-ft	1106 lb-ft	58.6	192 lb-ft	1328 lb-ft	38
SI	663805	1760 lb-ft	560 lb-ft	56.4	70 lb-ft	620 lb-ft	33.6
CCP ~~Chrg. Pump~~	663802	4460 lb-ft	2000 lb-ft	67	250 lb-ft	2150 lb-ft	34
CCS	A14689	210%	45%	46	9%	100%	30

(1) These values were taken directly from the manufacturer's speed-torque curves. Torques listed in percent are referenced to full load torque.

(2) The ~~stall~~ sustaining voltage and minimum breakaway voltage were calculated using the relationship $\frac{T_1}{T_2} = \frac{V_1^2}{V_2^2}$ $V_1 = \sqrt{\frac{T_1}{T_2}}\, V_2$

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R.S. Green 2/17/88

SQN-E3-015

TABLE I - LARGE INDUCTION MOTORS

For the small ~~480~~ 460 volt motors, a minimum start voltage and sustaining voltage are calculated for a generalized case rather than using specific speed-torque curves.

NEMA MG1-12.37 and 12.38 give the locked rotor and breakdown torque values for Design A and B motors. These values very with the motor synchronous speed. To be conservative this calculation is based on motor speed values that give the highest sustaining voltage and the highest start voltage requirements.

Typical load characteristic data is taken from Table I of "Motor Application and Maintenance Handbook" edited by R.M. Smeaton. The following loads were considered:-

Load	Motor Horsepower
1. Air Handling Units /Fans	75, 50, 25, 20, 15, 5, 3, 2, 1½, ½
2. Water Pumps	20, 15
3. Strainers (Centrifugal Pumps)	3
4. Compressors	60, 20, 10

Using the basic relationship that torque is proportional to the square of the voltage, we can calculate the sustaining voltage (Vs) and breakaway voltage (VB) for small motors as before by using the typical data for torque at zero speed, full load, and motor breakdown.

SQN-E3-015

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FANS (Propeller - Axial)

Horsepower	(1) Breakaway Torque % Full Load	(1) Peak Running Torque % Full Load	(2) Motor Start Torque % Full Load	(2) Motor Breakdown Torque % Full Load	(3) Minimum Breakaway Voltage, % Rated	(3) ~~Start~~ sustaining Volts % Rated
75	40	100	105	200	61.7	70.7
50	40	100	120	200	57.7	70.7
25	40	100	125	200	56.6	70.7
20	40	100	125	200	56.6	70.7
15	40	100	125	200	56.6	70.7
5	40	100	130	205	55.5	69.8
3	40	100	130	205	55.5	69.8
2	40	100	130	210	55.5	69
1.5	40	100	130	210	55.5	69
1/2	40	100	140	225	53.5	66.7
PUMPS (Centrifugal)						
20	40	100	125	200	56.6	70.7
15	40	100	125	200	56.6	70.7
STRAINERS (Centrifugal Pump)						
3	40	100	~~125~~ 130	~~200~~ 205	~~56.6~~ 55.5	~~70.7~~ 69.8
COMPRESSORS (Reciprocating)						
60	40	100	120	200	57.7	70.7
20	40	100	125	200	56.6	70.7
10	40	100	125	200	56.6	70.7

(1) Values from Motor Application and Maintenance Handbook

(2) Values from NEMA MG1- 12.37 and 12.38

(3) Calculated based on relationship $V_1 = \sqrt{\frac{T_1}{T_2}}\, V_2$

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SQN-E3-015

TABLE 2 - SMALL INDUCTION MOTORS

SQN-E3-015

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CONCLUSION

The limiting voltage condition for both large and small induction motors is the sustaining voltage rather than the breakaway voltage. Comparison of Table 1 for large induction motors and Table 2 for small induction motors shows that the limiting low voltage is the sustaining voltage for the small motors. This limiting voltage is a minimum of 70.7 % of rated voltage ~~to~~ required to sustain motor speed.

Motor Speed Changes

With an induction motor initially running at full voltage and full load, a voltage reduction to the minimum voltage required to sustain ~~speed~~ will cause a slight speed decrease to the speed at which the motor produces maximum (breakdown) torque. Any further reduction in voltage will cause the motor to begin to stall and the speed will decrease further.

For 460-volt motors a voltage drop to 70.7% rated voltage will allow the motor to continue to run. We wish to determine what the speed reduction will be if the voltage drops low enough to begin to stall. Based on actual motor data for a pump and motor (Attached curves A-14689 and A-14690), we can calculate the decrease in speed. For this calculation we will assume that the voltage drops to 65% rated voltage, remains there for ½ second, then recovers.

The equation for deceleration is:

(1) $t = \frac{Wk^2 \Delta N}{308 T}$

where
- t = time of deceleration
- Wk^2 = total motor and load inertia
- ΔN = change of speed, rpm
- T = net deceleration torque, lb-ft (Load torque − Motor generated torque)

(2) $\Delta N = \frac{t (308 T)}{Wk^2}$

From: Motor Application and Maintenance Handbook, page 3-14.

The actual data used is based on a 350 HP motor in conjunction with a pump having a Wk^2 of 130 lb-ft. (See attached manufacturer's curve A-14690). The actual data shows the motor inertia is about 2 times that of the pump. This particular motor is double the horsepower required for the application. We will assume that the motor and pump inertia are the same. Therefore Wk^2 for equation (2) is $130 + 130 = 260$ lb-ft.

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When the motor runs at 70.7% voltage, the motor output -que is equal to the load torque. The required motor -ting is 175 HP. The load torque can then be calculated calculating the torque of a 175 HP motor as follows:

) $\text{Torque} = \dfrac{\text{Horsepower}\,(5252)}{\text{Motor Speed}}$ From: Motor Application and Maintenance Handbook, page 3-9.

$$\text{Torque} = \frac{175\,(5252)}{1200} = 766 \text{ lb-ft}$$

When the motor runs at 70.7% voltage, this is a -teady-state condition and can be considered 100% voltage -or this calculation. By using a simple ratio we can -alculate the equivalent of 65% rated voltage.

$$\frac{70.7}{100} = \frac{65}{X} \qquad X = 91.9\% \text{ Sustaining Voltage}$$

Using the relationship $T \propto V^2$ we can determine the -aximum torque produced at 65% rated voltage referenced the calculated torque at 70.7% rated voltage.

$$T_{65} = \left(\frac{91.9}{100}\right)^2 T_{70.7} = 0.844\,(766) = 647 \text{ lb-ft}$$

Then the torque, T, for equation (2) becomes

$$T_{LOAD} - T_{motor\ at\ 65\%\ Volts} = 766 - 647 = 119 \text{ lb-ft}$$

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-N-E3-015 Prepared J. R. Arnett Date 2/18/88
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Summary of Results: The preceeding calculations determine the minimum required motor terminal voltages for sustaining rotation and starting rotation (breakaway). These voltages are converted from motor base to system base using the appropriate multiplier, e.g. 6.6/6.9 or 460/480; for 6.6 KV motors, appropriate cable drops from Appendix B, Table B-3 are added to breakaway calculations and for the ERCW motor, cable drop for sustaining voltage is also included (other 6.6 KV motor cable drops for running operation are not significant).

Motor	Minimum Sustaining Motor Voltage (Percent V at Motor Bus)	Minimum Breakaway Motor Voltage (Percent V at Bus - Locked Rotor)
CCP	64	33
SI	54	32
RHR	56	37
ERCW	63	36
AFW	55	35
CCS (460 volt)*	44	29
CSP	59	27
460 Volt Motors *	68	59

* At motor terminal

Summary Conclusion: The conclusion of this calculation is that for 6.6 KV motors the minimum voltage to sustain rotation is 64% and to start rotation is 37%. For ~~480~~ 460 volt (JRA) motors the minimum voltage to sustain rotation is 68% and to start is 59%.

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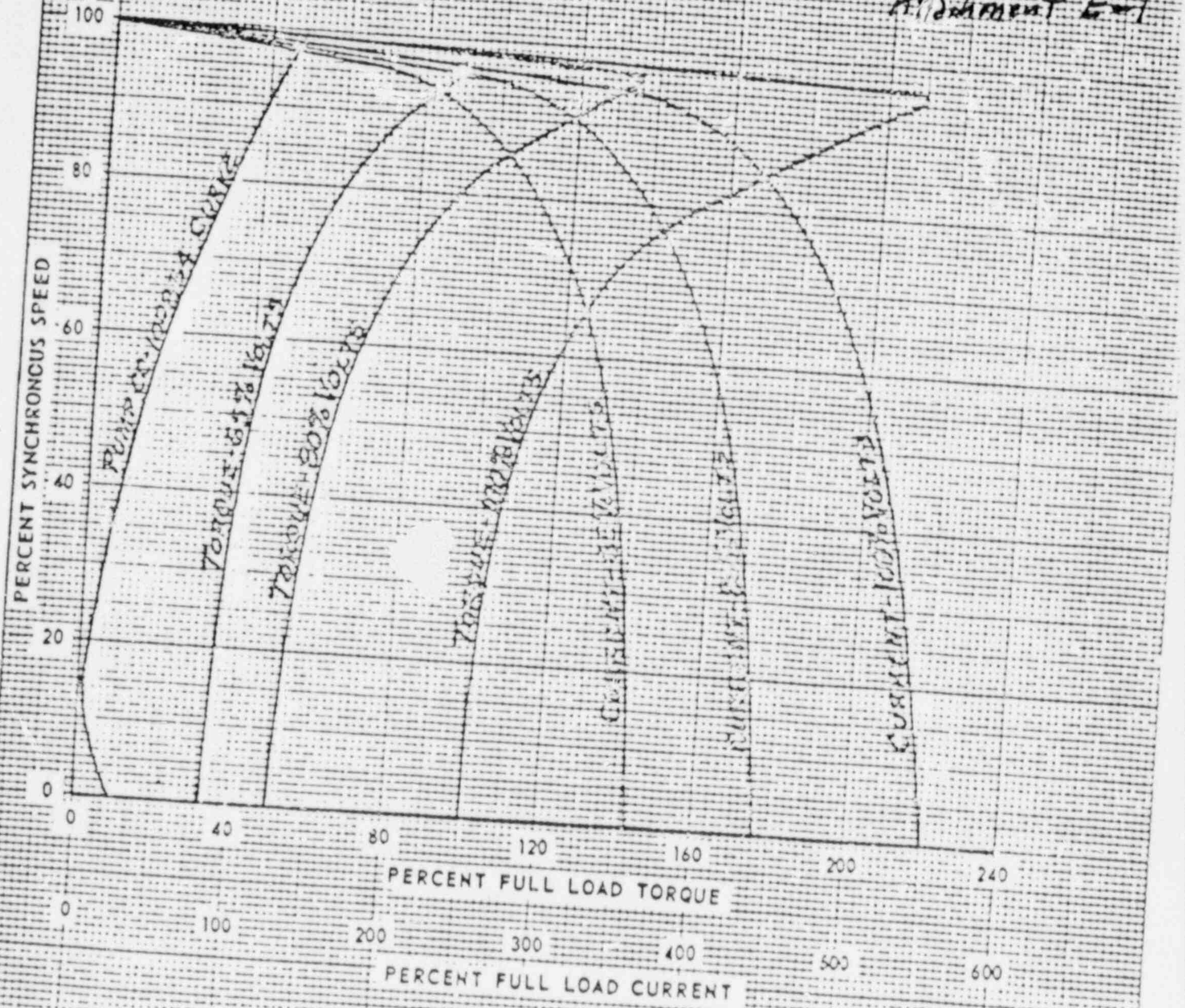
Page E-14

Attachment E-1



2-19-82

W.D.S.

REVD 6-20-82

W.D.S.

SIEMENS-ALLIS, INC.

INDUCTION MOTOR
CALCULATED
SPEED VS TORQUE & CURRENT
CURVE

H.P. 350	R.P.M. 1788
VOLTS 460	PH. 3
AMPS 404	HZ 60

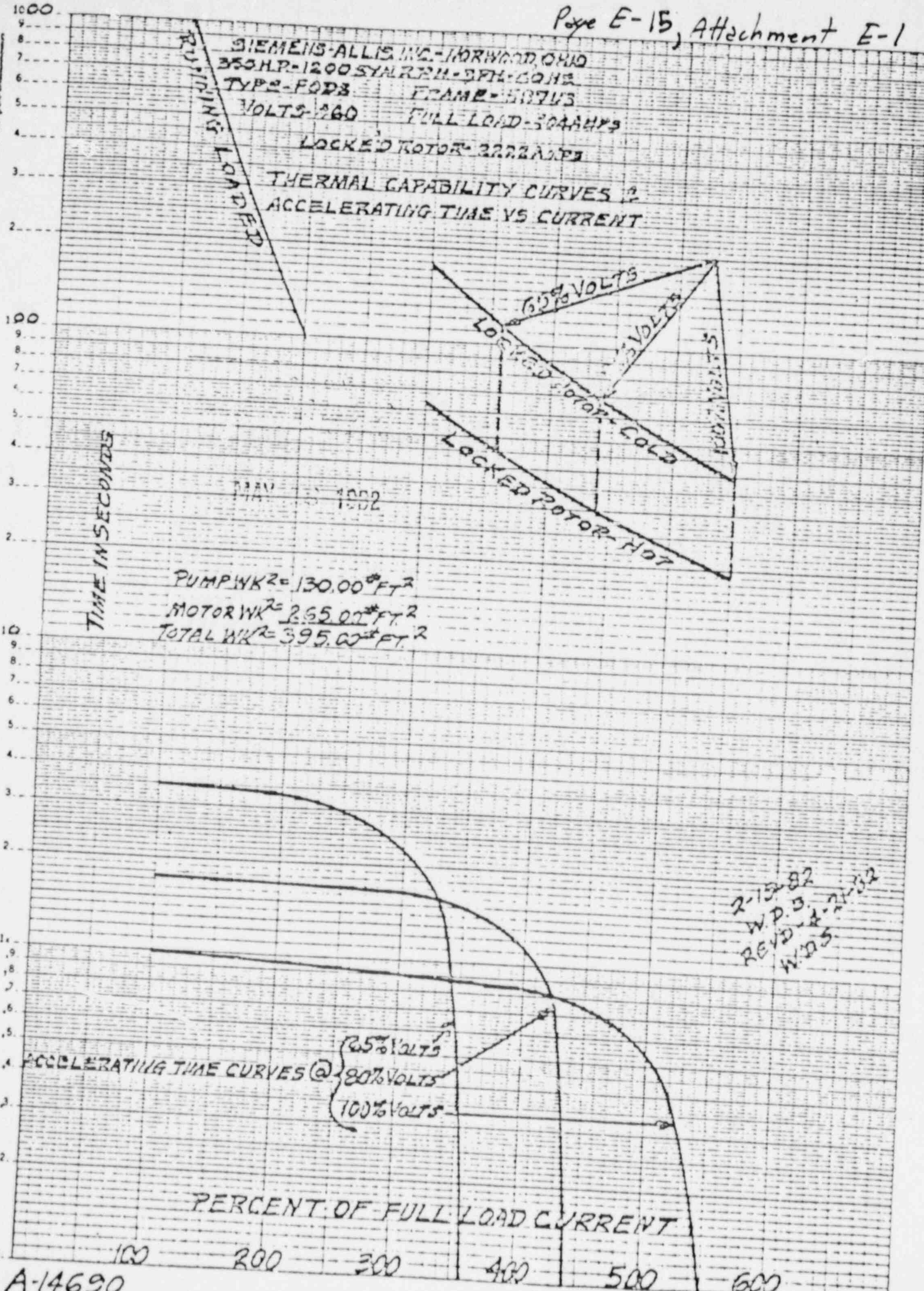
This approval does not relieve the ... of design details

A-14689

MAY 18 1982

Prepared L.R. Arnett Date
Verified R.S. Green Date 2 82

SQ11-E3-015



MAY 1982

K+E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS KEUFFEL & ESSER CO. MADE IN U.S.A.

A-14690

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SQN-E3-015
PAGE E-16, Attachment E-2

Table 3
Minimum Torques at
Rated Voltage and Frequency

Design	Percent of Full-Load Torque		
	Locked-Rotor	Pull-Up	Breakdown*
NT	70	70	190
HT	200	150	190

*See also 14.3 of this standard.

and a resistance of 10 ohms at 25°C.[7] The detector length shall be approximately as follows:

Core Length (inches)	*Approximate Detector Length (inches)*
12 or less	6
Greater than 12 and less than 40	10
40 or greater	20

10.4.2 **Thermocouples.** When specified, thermocouples shall be used for embedded detectors. Unless otherwise noted, thermocouples shall have a copper-constantan junction.

10.4.3 **Locations of Embedded Detectors.** At least six detectors shall be built into the machine, suitably distributed around the circumference, located between the coil sides, and in positions having normally the highest temperature along the length of the slot.

The detector shall be located in the center of the slot (with respect to the slot width) and in intimate contact with the insulation of both the upper and lower coil sides whenever possible; otherwise, it shall be in contact with the insulation of the upper coil side (that is, the coil side nearest the air gap). Each detector shall be installed, and its leads brought out, so that the detector is effectively protected from contact with cooling medium. If the detector does not occupy the full length of the core, suitable packing shall be inserted between the coils to the full length of the core to prevent the cooling medium from directly contacting the detector.

11. Torques

The locked-rotor, pull-up, and breakdown torques, with rated voltage and frequency applied, shall be not less than those shown in Table 3. Unless otherwise specified, a Design NT motor shall be supplied.

In addition, for NT motors the developed torque [illegible] any speed up to that at which breakdown torque [illegible]curs, with rated voltage and frequency applied, sha[illegible] at least 1.5 times the torque obtained from a curve [illegible] varies as the square of the speed and is equal [illegible] of rated full-load torque at rated speed.

NOTE: The percent torque values with [illegible]age applied are approximately the same [illegible] multiplied by the square of the ratio [illegible] rated voltage.

12. Starting Requirements

12.1 **Starting Capabilities.** Motors shall be designed for across-the-line starting, and shall be capable of making either of the starts described in 12.1.1 and 12.1.2, provided that the load inertia (Wk^2), the load torque during acceleration, the applied voltage and frequency, and the method of starting are those for which the motor was designed.

12.1.1 Two starts in succession, coasting to rest between starts with the motor initially at ambient temperature.

12.1.2 One start with the motor initially at a temperature not exceeding its rated-load operating temperature.

12.2 **Number of Starts.** It should be recognized that the number of starts should be kept to a minimum since the life of the motor is affected by the number of starts.

If the normal starting duty exceeds three starts per day, the starting duty shall be specified.

12.3 Starting Information Nameplate

12.3.1 A starting information nameplate, setting forth the starting capabilities specified in 12.1.1 and 12.1.2, shall be supplied mounted on the motor.

12.3.2 If specified, the starting information nameplate shall also include the minimum time at standstill and the minimum time running prior to an additional start. When specifying this additional information on the starting nameplate, the motor manufacturer shall be furnished the following information:

(1) The expected voltage and frequency at the motor terminals under starting conditions

(2) The total load inertia (Wk^2) referred to the motor shaft

(3) The speed-torque characteristics of the load during starting conditions

[7] Although 10-ohm resistance detectors are usually employed, the use of detector elements with other resistance values (made from other metals) is recognized, and these may be furnished when specified.

TABLE 1. Load Characteristics of Various Machines

¹ description	Load torques, % full-load drive torques: Break-away	Accel-erating	Peak running	Inertia ratio (see notes)	Am-bient	Environ-ment	Mount-ing	How driven?	Adjust-able speed range, max	Remarks
tuators:										
Screw-down (rolling mills)	200	150	125	1	A	D	R	L	2:1	Could be intermittently operated
Positioning	150	110	100	1	3C	5	RV	L	6:1 S	See text
gitators:										
Liquid	100	100	100	2	AW	FJ	RV	B	3:1	Can be direct-connected
Slurry	150	100	100	2	AW	CDJ	RV	B	......	Settling of solids when idle may cause difficult restarting
arrels, tumbling (foundry)	50	150	100	3	A	DJ	R	B		
ars, boring, rotary kiln	75	125	100	4	A	DJ	R	B	4:1	Reversing required
eaters:										
Standard	110	120	100	4	AW	DJ	R	B		
Breakers	110	120	120	4	AW	5	R	B		
lowers, centrifugal:										
Valve closed	30	50	40	60	3	5	R	BLT	3:1	Some applications would require constant speed
Valve open	40	110	100	60	3	5	R	BLT	3:1	Same as above
lowers, positive-displacement, rotary, bypassed	40	40	100	2	AW	DJ	R	L		
reakers, flake, starting loaded	150	110	100	2	A	DEJ	R	B		
alenders, textile or paper	75	110	100	3	AW	J	R	L		
ard machines, textile	100	110	100	2	A	E	R	L		
entrifuges (extractors)	40	40	125	50	AW	DJ	R	L	......	Starting unloaded*
hippers, wood, starting empty	50	40	200	100 max	AW	D	R	T		
ompactors, solids	100	110	125	1	A	DEJ	R	L	2:1	Constant speed may be used
Compressors, axial-vane, loaded	40	100	100	8	AW	DJ	R	L		
Compressors, reciprocating, start unloaded	40	50	100	10	A	DJ	R	BL		
onverters, copper, loaded	150	150	125	8	AH	D	R	L	4:1 S	See text
Conveyors, belt (loaded)	110	130	100	4	A	CDJ	R	B	......	Inertia depends on load (see text)
Conveyors, drag (or apron)	100	150	100	2	AH	D	R	B	......	Starting loaded. Inertia depends on load (see text)
Conveyors, screw (loaded)	150	100	100	1	AH	CDEJ	R	B		
Conveyors, shaker-type (vibrating)	50	150	75	6	AH	DJ	I	B	......	See text
Coolers, hot solids, rotary (loaded)	175	140	100	2	AH	DJ	R	L		
Coolers, grate, reciprocating (loaded)	50	125	75	1	A	DJ	R	B	3:1	
Coolers, grate, oscillating (loaded)	50	100	10	1	A	DJ	R	B	1.5:1	
Coolers, grate, traveling (stoker-type)	100	110	100	1	AH	D	R	L	6:1	Starting loaded—torque-limiting drive is desirable
Cranes, traveling:										
Bridge motion	100	300	100	4	AH	CDJ	R	L	10:1	Drives must be suited to duty cycle and service. Hoisting inertia depends on load
Trolley motion	100	200	100	4	AH	CDJ	R	L	10:1	
Hoist motion	50	200	100	......	AH	CDJ	R	L	10:1	
Crushers, gyratory:										
Starting unloaded	50	60	300	2	AC	DJ	R	B	......	Large crushers are usually direct-connected
Choke-fed	100	200	300	2	AC	DJ	R	B	......	Reverse jogging may be necessary to start
With feeder	100	150	150	2	AC	DJ	R	B		
Crushers, jaw:										
Starting unloaded	50	100	200	10	AC	DJ	R	B	......	Usually started unloaded*
Choke-fed			200	10	AC	DJ	R	B		
Crushers, pulverizing (hammer-mill)	50	100	150	25	A	CDJ	R	L		Usually started unloaded*
Crushers, roll:										
...ng unloaded	50	50		10	A	DJ	R	B	......	*
...fed, loaded	200	200	150	10	A	DJ	R	B		
...ars, balling drum	50	150	150	25	A	DJ	R	L	2:1	See text
C... heads, dredge	50	125	150	2	W		R	L	S	
Dampers, fan, centrifugal, cold	200	200	100	1	AC	CDEJ	RV	L	S	See text*
Dampers, fan, centrifugal, hot	400	300	100	1	AH	CDJ	RV	L	S	See text*
Drawbridges	100	125	100	10	AW		R	L	......	Drive coordination required*
Draw presses (flywheel)	50	50	200	10	A	D	R	B	......	High inertia*
Drill presses	25	50	150	2	A	D	R	B		

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TABLE 1. Load Characteristics of Various Machines (Continued)

Load description	Load torques, % full-load drive torques: Breakaway	Accelerating	Peak running	Inertia ratio (see notes)	Ambient	Environment	Mounting	How driven?	Adjustable speed range, max	Remarks
Drums, balling (ore)	50	125	100	4	A	D	R	B	2:1	See text
Dryers, rotary (rock or ore)	50	150	100	4	AH	D	R	B		
Dryers, grain	50	100	90	2	AH	DJ	R	L		
Edgers (starting unloaded)	40	30	200	10	A	DE	R	B	....	High inertia*
Elevators, bucket (starting loaded)	150	175	150	2	AHC	CDJ	R	L	....	Antirollback required
Elevators, freight (loaded)	100	125	100	4	ACW	DFJ	R	L	S	
Elevators, man lift	50	125	100	1	AH	5	R	L		
Elevators, personnel (loaded)	110	150	100	4	AHC	5	R	L	10:1	Speed range required during acceleration and deceleration
Escalators, stairways (starting unloaded)	50	75	100	2	A	.....	R	L		
Extractors (press type)	50	150	150	1	3	5	RV	L		
Extruders (rubber or plastic)	100	150	100	1	3	5	R	L		
Fans, centrifugal, ambient:										
Valve closed	25	60	50	25	ACW	5	R	BT	2:1	•
Valve open	25	110	100	25	ACW	5	R	BT	2:1	•
Fans, centrifugal, hot gases:										
Valve closed	25	60	100	60	AH	DJ	R	B	3:1	•
Valve open	25	200	175	60	AH	DJ	R	B	3:1	Peak running overload torque occurs when handling colder gases
Fans, propeller, axial-flow	40	110	100	25	AH	DJ	R	BT	....	High inertia*
Feeders, belt (loaded)	100	120	100	2	3	5	R	B	10:1 S	
Feeders, distributing, oscillating drive	100	150	100	4	AW	CDJ	R	B	6:1 S	Starting loaded
Feeders, screw, compacting rolls	100	100	100	1	AW	CDEJ	RV	L	S	Starting loaded, torque limited
Feeders, screw, filter-cake	100	100	100	1	3	DJ	R	B	3:1 S	Starting loaded

J. R. Arnett 2/17/88 SQN-E3-015

R.S. Green 2/17/88

Load description	Breakaway	Accelerating	Peak running	Inertia ratio (see notes)	Ambient	Environment	Mounting	How driven?	Adjustable speed range, max	Remarks
Feeders, screw, dry	150	100	100	1	AH	CDEJ	R	B	3:1 S	Starting loaded
Feeders, slurry, ferris-wheel	110	100	75	2	AW	DJ	R	B	3:1 S	Starting loaded
Feeders, table	125	110	100	2	A	DJ	R	L	6:1 S	Starting loaded
Feeders, vane-type	150	80	75	1	AW	CDEJ	R	L	6:1 S	Starting loaded
Feeders, vibrating, magnetic	100	100	100	....	AH	CDEJ	R	L	3:1 S	Starting loaded. No rotating member
Feeders, vibrating, motor-driven	50	150	100	4	AH	CDEJ	RV	L	3:1 S	Starting loaded
Forge presses	25	50	150	10	AH	D	R	B	....	High inertia*
Frames, spinning, textile	50	5	100	2	A	E	R	B		
Furnaces, holding, copper	150	125	100	4	AH	D	R	L	4:1 S	Overhauling load
Gates, diverting, solids	200	125	100	1	3	CDJ	R	L	S	
Gates, locks, hydraulic	25	200	200	2	W	.....	R	L	S	•
Generators, electric, flywheel-type	50	100	400	100	A	.....	R	L	....	High inertia*
Generators, electric, general use	25	30	150	3	AH	D	R	L		
Generators, electroplating	25	30	100	3	AW	F	R	L		
Generators, welding	30	50	200	3	AHC	D	RV	L	....	Peak torque required when arc is struck
Grates, indurating (preheater)	100	110	200	3	AHC	DJ	R	L	4:1 S	
Grates, stoker (furnace)	75	110	100	1	AH	D	R	L	2:1 S	
Grinders, metal	25	50	100	2	A	D	RV	LB	....	Starting unloaded
Grinders, pulp or meat	40	50	150	2	AW	F	R	L	....	Starting unloaded
Grinders, pulp-magazine type	50	50	150	5	AW	CJ	R	L	....	Starting unloaded
Grinders, pulp, pocket-type	40	30	150	5	AW	CJ	R	L	....	Starting unloaded
Hammers, power, flywheel	50	50	150	10	A	D	R	B	....	High inertia*
Hoists, skip	100	150	100	10	A	D	R	L	6:1	•
Hydropulpers	125	125	150	1	W	.....	R	L		
Indexers	150	200	150	2	A	D	R	L		•
Ironers, laundry (mangles)	50	50	125	1	3	.....	R	L	S	•
...rs, woodworking	50	125	125	1	A	E	R	L		
..., plug out	50	50	150	9	AW	.....	R	L	....	•
... rotary (loaded)	200	125	125	4	AH	DJ	R	B or L	6:1 S	See text
...washers, rock or ore (loaded)	75	125	150	1	AW	J	R	B		
Looms, textile, without clutch	125	125	150	2	A	E	R	L		•
Machines, boring (loaded)	150	150	100	2	A	D	R	L	6:1	Constant-hp drives may be required
Machines, bottling	50	50	100	2	AW	.....	R	B		

Page E-19

Attachment E.

Load description	Load torques, % full-load drive torques: Break-away	Accel-erating	Peak running	Inertia ratio (see notes)	Am-bient	Environ-ment	Mount-ing	How driven?	Adjust-able speed range, max	Remarks
..esses, punch (no flywheel)	10	40	150	1	A	D	R	B	....	See text, high inertia*
Pug mill (solids mixing)	150	125	100	1	A	CDJ	RV	T	....	Solids may "set up" on emergency shutdown
Puller, car	150	110	100	25	A	D	R	L	....	Inertia depends on number of cars
Pumps, adjustable-blade, vertical	50	40	125	1	AW	.....	RV	T	....	Unloaded start
Pumps, centrifugal discharge open	40	100	100	1	AW	FJ	RV	T	....	Loaded start
Pumps, oil-field, flywheel	50	200	200	10	AC	D	R	B	....	*
Pumps, oil, lubricating	40	150	150	1	AC	D	R	L	....	Cold oil can cause drive overloads
Pumps, oil, fuel	40	150	150	1	AC	D	R	L	....	Peak torque caused by more viscous oils
Pumps, propeller	40	100	100	1	AW	F	RV	LT	....	Handling nonviscous fluids
Pumps, reciprocating, positive-displacement	40	30	150	1	AW	.....	R	B	....	Starting dry, handling nonviscous fluids
Pumps, reciprocating, positive-displacement	40	30	20	1	AW	.....	R	B	....	Bypassed, handling nonviscous fluids
Pumps, reciprocating, positive-displacement	100	100	150	4	AW	.....	R	B	....	3 cylinder, not bypassed, handling a nonviscous fluid
Pumps, screw-type, started dry	40	30	100	1	AW	F	R	L	....	Handling nonviscous fluids
Pumps, screw-type, primed, discharge open	40	100	100	1	AW	F	R	L	....	Handling nonviscous fluids
Pumps, slurry-handling, discharge open	100	100	100	1	AW	D	R	B		
Pumps, turbine, centrifugal, deep-well	50	100	100	2	AW	.....	RV	L		
Pumps, vacuum (paper-mill service)	60	100	150	4	AW	.....	R	L		

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Verified R.S. [illegible] 2/17/88

SQN-E3-015

Load description	Load torques, % full-load drive torques: Break-away	Accel-erating	Peak running	Inertia ratio (see notes)	Am-bient	Environ-ment	Mount-ing	How driven?	Adjust-able speed range, max	Remarks
..ps, vacuum (other applications)	40	60	100	4	A	.....	R	L		
Pumps, vacuum, reciprocating	40	60	150	10	A	.....	R	B	....	Starting unloaded*
Pumps, vane-type, positive-displacement	100	150	150	1	A	DJ	R	L	....	Viscous fluids may overload drive
Rolls, bending	150	150	100	2	A	D	R	L		
Rolls, compacting (loaded)	100	110	125	1	A	DJ	R	L		
Rolls, crushing (sugarcane)	50	110	125	2	AW	J	R	L		
Rolls, flaking	30	50	100	2	A	E	R	B		
Sanders, woodworking, disk or belt	30	50	100	1	A	D	R	L or B		
Saws, band, metalworking	30	50	100	4	A	D	R	B		
Saws, circular, metal, cutoff	25	50	150	6	A	D	R	L		
Saws, circular, wood, production	50	30	150	10	A	E	R	B	....	High inertia*
Saws, edger (see Edgers)										
Saws, gang	60	30	150	10	A	D	R	B	....	High inertia*
Saws, trimmer	40	30	150	10	A	D	R	B	....	High inertia*
Screens, centrifugal, paper-mill	50	100	100	50	AW	FJ	R	L	....	High inertia*
Screens, centrifugal (centrifuges)	40	60	125	50	AW	DJ	R	L	....	High inertia*
Scree.., rotary, stone (trommel)	70	100	100	1	A	DJ	R	B		
Screens, vibrating	50	150	70	6	3	5	I	B	....	See text
Separators, air (fan-type)	40	100	100	15	A	CJ	R	L	....	High inertia
Shakers, foundry or car	50	150	70	6	AHC	5	K	B	....	See text
Shears, flywheel-type	50	50	120	10	A	D	R	B	....	See text*
Shovels, dragline, hoisting motion	50	150	100	4	A	CDJ	R	L	6:1	See text on Cranes*
Shovels, dragline, platform motion	50	100	100	4	A	CDJ	R	L	4:1	See text on Cranes*
Shovels, large, digging motion	50	200	200	3	ACW	CDJ	R	L	10:1	See text on Cranes*
Shovels, large, platform motion	50	100	100	4	ACW	CDJ	R	L	4:1	See text on Cranes*
Shredders (see Crushers, pul..izing)										
shaker-type	50	100	70	3	A	EJ	IV	B		
, traveling-grate-type	50	110	100	1	A	CD	R	L	2:1	Torque-limiting drive is desirable
S..agers	100	110	150	1	A	C	R	L		

Page E-20, Attachment E-4

TABLE 12-1 (SEE MG 1-12.35)

Hp	Locked-rotor Current, Amperes*	Design Letters	Hp	Locked-rotor Current, Amperes*	Design Letters
1 or less	20	B, D	30	289	B, C, D
1½	27	B, D	40	387	B, C, D
2	34	B, D	50	482	B, C, D
3	43	B, C, D	60	578	B, C, D
5	61	B, C, D	75	722	B, C, D
7½	84	B, C, D	100	965	B, C, D
10	107	B, C, D	125	1207	B, C, D
15	154	B, C, D	150	1441	B, C, D
20	194	B, C, D	200	1927	B, C
25	243	B, C, D			

* The locked rotor current of motors designed for voltages other than 230 volts shall be inversely proportional to the voltages.

MG 1-12.37 Locked-rotor Torque of Single-speed Polyphase Squirrel-cage Integral-horsepower Motors with Continuous Ratings ▲

A. The locked-rotor torque of Design A and B, 60- and 50-hertz, single-speed, polyphase squirrel-cage motors, with rated voltage and frequency applied, shall be not less than the following values which are expressed in percent of full load torque. For applications involving higher torque requirements, see the locked-rotor torque values for Design C and D motors.

Hp	Synchronous Speed, Rpm						
60 hertz	3600	1800	1200	900	720	600	514
50 hertz	3000	1500	1000	750	...	...	...
½	...	...	...	140	140	115	110
¾	...	...	175	135	135	115	110
1	...	275	170	135	135	115	110
1½	175	250	165	130	130	115	110
2	170	235	160	130	125	115	110
3	160	215	155	130	125	115	110
5	150	185	150	130	125	115	110
7½	140	175	150	125	120	115	110
10	135	165	150	125	120	115	110
15	130	160	140	125	120	115	110
20	130	150	135	125	120	115	110
25	130	150	135	125	120	115	110
30	130	150	135	125	120	115	110
40	125	140	135	125	120	115	110
50	120	140	135	125	120	115	110
60	120	140	135	125	120	115	110
75	105	140	135	125	120	115	110
100	105	125	125	125	120	115	110
125	100	110	125	120	120	115	110
150	100	110	120	120	115	115	110
200	100	100	120	120	115	115	...
250	70	80	100	100	115	...	...
300	70	80	100	...	...	...	...
350	70	80	100	...	...	...	...
400	70	80	...	...	...	...	...
450	70	80	...	...	...	...	...
500	70	80	...	...	...	...	...

▲ Revised.

(Continued)

Prepared J.R. Arnett Date 2/12/88
Verified R.S. Green Date 2/17/88

Page E-21, Attachment E-5

B. The locked-rotor torque of Design C, 60- and 50-hertz, single-speed, polyphase squirrel-cage motors, with rated voltage and frequency applied, shall be not less than the following values which are expressed in percent of full-load torque.

Hp		Synchronous Speed, Rpm		
	60 hertz	1800	1200	900
	50 hertz	1500	1000	750
3		...	250	225
5		250	250	225
7.5		250	225	200
10		250	225	200
15		225	200	200
20–200, inclusive		200	200	200

C. The locked-rotor torque of Design D, 60- and 50-hertz, 4-, 6- and 8-pole, single-speed, polyphase squirrel-cage motors rated 150 horsepower and smaller, with rated voltage and frequency applied, shall be not less than 275 percent, expressed in percent of full-load torque.

NEMA Standard 8-7-1947, revised 6-24-1949; 11-17-1955; 11-17-1966; 7-16-1969; 9-20-1978.

MG 1-12.38 Breakdown Torque of Single-speed Polyphase Squirrel-cage Integral-horsepower Motors with Continuous Ratings ▲

A. The breakdown torque of Design A and B, 60- and 50-hertz, single-speed, polyphase squirrel-cage motors, with rated voltage and frequency applied, shall be not less than the following values which are expressed in percent of full-load torque.

Hp		Synchronous Speed, Rpm						
	60 hertz	3600	1800	1200	900	720	600	514
	50 hertz	3000	1500	1000	750	...	...	...
1/2		...	...	...	225	200	200	200
3/4		...	...	275	220	200	200	200
1		...	300	265	215	200	200	200
1½		250	280	250	210	200	200	200
2		240	270	240	210	200	200	200
3		230	250	230	205	200	200	200
5		215	225	215	205	200	200	200
7½		200	215	205	200	200	200	200
10–125, inclusive		200	200	200	200	200	200	200
150		200	200	200	200	200	200	...
200		200	200	200	200	200	...	...
250		175	175	175	175	...	...	...
300–350		175	175	175	...	...	...	...
400–500, inclusive		175	175	...	...	...	...	...

B. The breakdown torque of Design C, 60- and 50-hertz, single-speed, polyphase squirrel-cage motors, with rated voltage and frequency applied, shall be not less than the following values which are expressed in percent of full-load torque.

Hp		Synchronous Speed, Rpm		
	60 hertz	1800	1200	900
	50 hertz	1500	1000	750
3		...	225	200
5		200	200	200
7½–200, inclusive		190	190	190

NEMA Standard 1-26-1948, revised 6-24-1949; 11-17-1955; 11-17-1966; 7-16-1969; 9-20-1978.

▲ Revised.

Prepared J.R. Arnett Date 2/17/88
Verified R.S. Green Date 2/17/88

SQN-E3-015

SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT

SQN-E3-015

COMPUTED BY [signature] DATE 2/18/88 CHECKED BY [signature] DATE 2/18/88

APPENDIX - F

CABLE VOLTAGE DROP

NOTE: THE PORTION OF THIS APPENDIX IS TAKEN FROM THE FOLLOWING CALCS:

SQN-E3-011 REV.2

OE'2-EEB-CAL 001 REV.9

SUBJECT APPENDIX - F PROJECT SQN

SQN - E3-015

COMPUTED BY PBfai DATE 2/22/88 CHECKED BY E. Iglesias DATE 2/22/88

PURPOSE

To calculate the voltage drops due to cable impedances during starting of the following:

1) 6.6 KV motors

2) 480V MCCs

3) 460V motors and MOVs

and the 6.6 KV ERCW motor during running.

Procedure

6.6 KV motor terminal voltage during starting is calculated by subtracting the $I_{LR} \times Z_{CAB}$ drop from the minimum bus voltage due to start of the motor. Similarly, 6.6 KV motor terminal voltage during running is calculated by subtracting the $I_{FL} \times Z_{CAB}$ drop from the minimum bus voltage.

The 480V loads prior to start of AFW

pump was calculated by SHTDN BDS and MCC from Ref 3.1.

The voltage drop between the SHTDN BDS and MCC is calculated as follows:

$$\sqrt{3}\, I\,(R\cos\theta + X\sin\theta)$$

where I = current at minimum voltage

$\cos\theta$ = p.f. of load

R = Cable resistance

X = Cable reactance

The worstcase 460V motor fed from SHTDN BD and MCC and MOV motor terminal voltages are taken from Ref 3.6.

Results:

The voltage drops are summarized in Figure F1 for 480V and Table B3 of Apendix B for 6.9KV.

6.6 KV MOTOR TERMINAL VOLTAGE

BASE MVA = 100

BASE KV = 6.9

BASE AMPS = $\frac{100 \times 10^3}{\sqrt{3} \times 6.9}$ = 8367.4 A

MOTOR DATA OBTAINED FROM REF. 3.1

CABLE DATA OBTAINED FROM REF. 3.6

CCP

I_{LR} = 315 A

$P.F_{LR}$ = 0.2868

WORST CASE CABLE = 2/0 - 656'

Z_{CAB} = 0.0712 + j0.0512 Ω/φ

= (0.0712 + j0.0512) × 100/(6.9)^2

= 0.1495 + j 0.1075 PU = 0.1841 ∠35.7

$V_{MOTOR\ TERM}$ = 0.835 ∠0 − [315/8367.4 ∠−cos^{-1} 0.2868 × 0.1841 ∠35.7]

= 0.835 ∠0 − (0.0376 ∠−73.3 × 0.1841 ∠35.7)

= 0.835 ∠0 − 0.006922 ∠−37.6

= 0.835 + j0 − 0.005484 + j 0.00422

= 0.8295 + j 0.00422

= 0.8295 PU @ 6.9 kV

= 0.867 PU @ 6.6 kV

VOLTAGE DROP = 0.835 − 0.8295

= 0.0055 PU @ 6.9 kV

= 0.6 % AT 6.9 kV

SI MOTOR

I_{LR} = 215 A

$P.F_{LR}$ = 0.25

WORST CASE CABLE = 2/0 - 576'

$\vec{Z}_{CAB}$ = 0.0625 + j 0.0449 Ω/φ

= (0.0625 + j 0.0449) × 100 / 6.9²

= 0.1313 + j 0.0943 PU = 0.16165 ∠35.7

$V_{MOTOR\ TERM}$ = $0.819 \angle 0 - \left[\frac{215}{8367.4} \angle -\cos^{-1} 0.25 \times 0.16165 \angle 35.7 \right]$

= $0.819 \angle 0 - \left[0.0257 \angle -75.5 \times 0.16165 \angle 35.7 \right]$

= 0.819 ∠0 − 0.004154 ∠−39.8

= 0.819 + j0 − 0.00319 + j0.002659

= 0.81581 + j 0.002659

= 0.81581 PU @ 6.9 KV

= 0.8529 PU @ 6.6 KV

VOLTAGE DROP = 0.819 − 0.81581 = 0.00319 PU @ 6.9 KV
= 0.3 % AT 6.9 KV

RHR

I_{LR} = 210 A

$P.F_{LR}$ = 0.302

WORST CASE CABLE = 2/0 - 615'

$Z_{CAB} = 0.0667 + j\,0.048\ \Omega/\phi$

$= (0.0667 + j0.048) \times 100 / 6.9^2$

$= 0.1401 + j\,0.1008$ PU $= 0.1726 \angle 35.73$

$V_{MOTOR\ TERM} = 0.797 \angle 0 - \left[\frac{210}{8367.4} \angle -72.4 \times 0.1726 \angle 35.73 \right]$

$= 0.797 \angle 0 - 0.00433 \angle -36.67$

$= 0.797 + j0 - 0.00347 + j\,0.002586$

$= 0.79353 + j\,0.002586$

$= 0.79353$ PU @ 6.9 kV

$= 0.8296$ PU @ 6.6 kV

VOLTAGE DROP = 0.797 - 0.79353

= 0.3 % AT 6.9 kV

ERCW

I_{LR} = 337 A

$P.F_{LR}$ = 0.17

WORST CASE CABLE = 2/0 - 4550'

$Z_{CAB} = 0.4937 + j0.3549 \ \Omega/\phi$

$= (0.4937 + j0.3549) \times 100 / 6.9^2$

$= 1.037 + j0.7454$ PU $= 1.2771 \angle 35.7$ PU

$V_{MOTOR\ TERM} = 0.802 \angle 0 - \left[\frac{337}{8367.4} \angle -\cos^{-1} 0.17 \times 1.2771 \angle 35.7 \right]$

$= 0.802 \angle 0 - (0.0403 \angle -80.2 \times 1.2771 \angle 35.7)$

$= 0.802 \angle 0 - 0.0515 \angle -44.5$

$= 0.802 + j0 - 0.0367 + j0.0361$

$= 0.7653 + j0.0361$

$= 0.7661$ PU @ 6.9 kV

$= 0.801$ PU @ 6.6 kV

VOTAGE DROP = 0.802 - 0.7661

= 0.0359 PU @ 6.9 kV

= 3.6 % AT 6.9 kV

AFW

I_{LR} = 280A

$P.F_{LR}$ = 0.18

WORST CASE CABLE = 2/0 -

$Z_{CAB} = 0.0495 + j0.0356\ \Omega/\phi$

$= (0.0495 + j0.0356) \times 100/6.9^2$

$= 0.104 + j0.075$ PU $= 0.128 \angle 35.8$

$V_{MOTOR\ TERM} = 0.765 \angle 0 - \left[\frac{280}{3367.4} \angle -\cos^{-1} 0.18 \times 0.128 \angle 35.8 \right]$

$= 0.765 \angle 0 - 0.00428 \angle -43.83$

$= 0.765 + j0 - 0.0031 + j0.00296$

$= 0.7619 + j0.00296$

= 0.7619 PU @ 6.9 kV

= 0.7965 PU @ 6.6 kV

VOLTAGE DROP = 0.765 - 0.7619

= 0.0031 PU @ 6.9kV

= 0.3 % AT 6.9kV

CSP

I_{LR} = 355 A

P.F $_{LR}$ = 0.2711

WORST CASE CABLE = 2/0 - 621'

Z_{CAB} = 0.061 + j 0.0438 Ω/Φ

= (0.061 + j 0.0438) × 100/ 6.9²

= 0.1281 + j 0.092 = 0.1577 ∠35.7

$V_{MOTOR\ TERM}$ = $0.788\angle 0 - \left[\frac{355}{8367.4}\angle -\cos^{-1}0.2711 \times 0.1577\angle 35.7\right]$

= 0.788∠0 − (0.0424 ∠−74.3 × 0.1577 ∠35.7)

= 0.788∠0 − 0.006686 ∠−38.6

= 0.788 + j0 − 0.00523 + j 0.004172

= 0.78277 + j 0.004172

= 0.78278 PU @ 6.9 kV

= 0.8184 PU @ 6.6 kV

VOLTAGE DROP = 0.788 − 0.78278

= 0.00522 PU @ 6.9 kV

= 0.522 PERCENT AT 6.9 KV.

ERCW RUNNING VOLTAGE DROP

I_{FL} = 58.4 A

$\cos\theta$ = 0.856

Z_{CAB} = 1.2771 $\angle 35.7$ PU

WORST CASE 6.9 KV STDN BD. VOLTAGE IS 0.765 PU

$$V_{MOTOR\ TERMINAL} = 0.765\angle 0 - \left[\frac{58.4}{8367.4} \angle -31.1 \times 1.2771 \angle 35.7 \right]$$

$$= 0.765 \angle 0 - 0.00891 \angle 4.6$$

$$= 0.765 + j0 - 0.00888 - j0.000715$$

$$= 0.7561 - j0.00715$$

= 0.7561 PU @ 6.9 KV

= 0.7905 PU @ 6.6 KV

VOLTAGE DROP = 0.765 − 0.7561

= 0.0089 PU AT 6.9 KV

= 0.89 % AT 6.9 KV

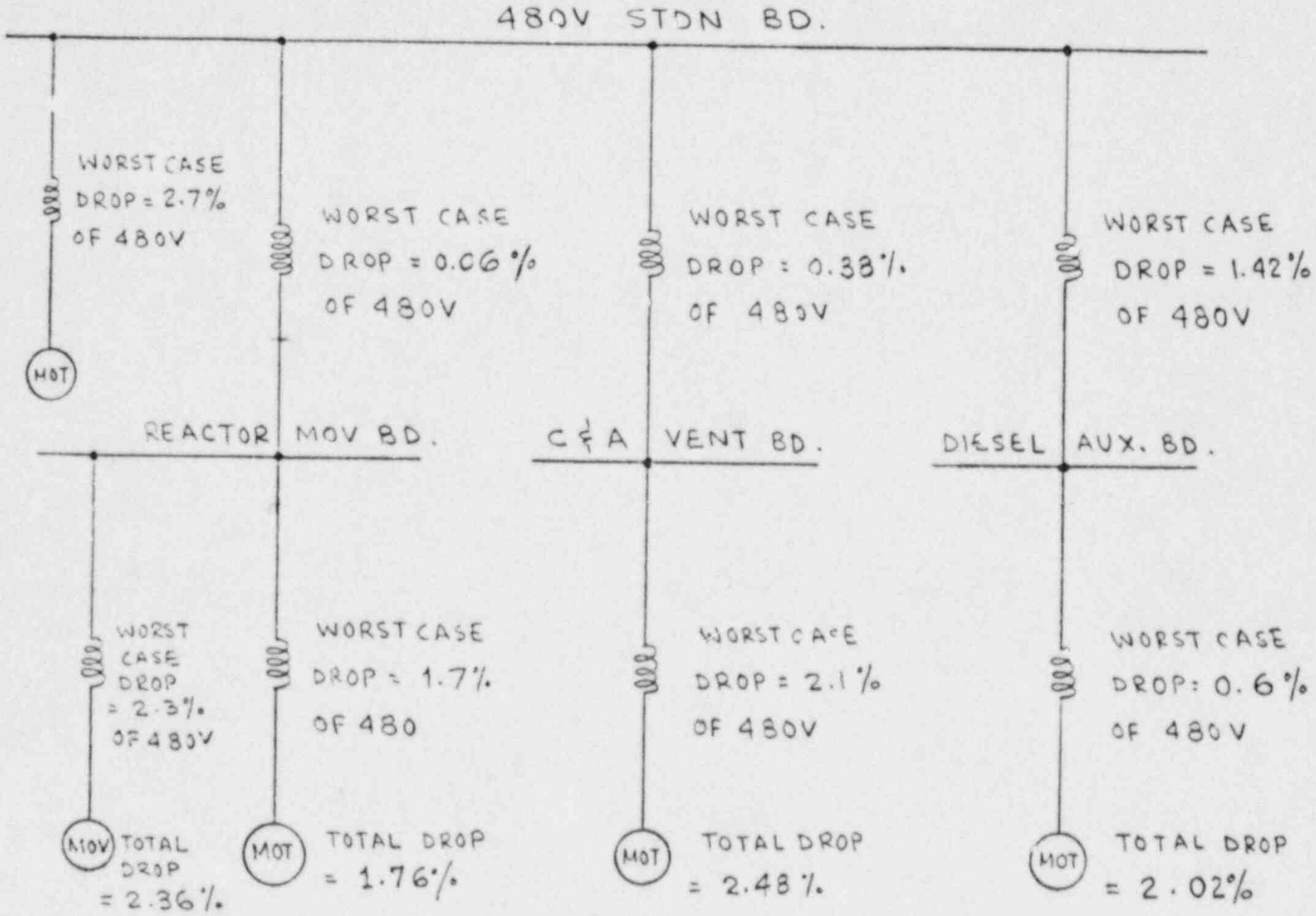
SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT SQN

SQN-E3-015

COMPUTED BY APal DATE 2/17/88 CHECKED BY Sm DATE 2/17/88

480V SYSTEM

FIG. F1



1. WORST CASE DROP BETWEEN 480V STDN BD AND MCC IS 1.4% OF 480V
2. WORST CASE DROP BETWEEN 480V STDN BD AND MOV MOTOR TERMINAL IS 2.4% OF 480V
3. WORST CASE DROP BETWEEN 480V STDN BD. AND A MOTOR FED FROM MCC IS 2.5% OF 480V
4. WORST CASE DROP FOR LOADS FED FROM 480V STDN BD IS 2.7% OF 480V

TVA 489H (EN DES-2-78) **TENNESSEE VALLEY AUTHORITY** SHEET F13 OF

SUBJECT ______ PROJECT ______

R. Singh 1-18-88 SQN-E3-015

COMPUTED BY DATE CHECKED BY APal DATE 1/19/88

480V LOADS PRIOR TO AFWPUMP START (20SEC)

480V C & A BLDG VENT BD 2B1-B RUNNING LOADS [REF 3.2] BPal 2/22/8

COMPT	LOAD
11B	2.45 + j 3.73
12C	4.74 + j 3.31
12D	16.83 + j 9.08
1D2	1.50 + j 0.00
4A	4.18 + j 2.48
4B	4.18 + j 2.48
4C	4.18 + j 2.48
5C	2.54 + j 1.64
6C	2.99 + j 0.00
6D	0.22 + j 0.87
7C	2.86 + j 2.29
7D2	2.87 + j 2.76
8A	17.18 + j 9.27
8D1	0.77 + j 0.21
8D2	0.72 + j 0.96
8E	16.83 + j 9.08
9A	0.59 + j 0.65
9C	4.18 + j 2.48
9D	2.86 + j 2.29
3C	4.18 + j 2.48
3B	2.54 + j 1.64
5A	2.54 + j 1.64
TOTAL	102.53 + j 62.42 KVA

TVA 489H (EN DES-2-78) TENNESSEE VALLEY AUTHORITY SHEET F14 OF

SUBJECT ______ PROJECT ______

COMPUTED BY R. Singh DATE 1-18-88 SQN-E3-015

CHECKED BY aPal DATE 1/19/88

480V REAC. MOV BD. 2B1-B RUNNING LOADS

[REF 3.1] BPavi 2/22/88

10 B	12.43 + j 16.57
11 A	12.43 + j 16.57
14 E	11.95 + j 15.93
7C	1.10 + j 1.47
7E	1.63 + j 2.17
8C	7.65 + j 10.20
TOTAL	47.19 + j 62.91
10 B	−10.76 − j 14.34
11 A	−10.76 − j 14.34
14 E	−10.33 − j 13.77
5C2	1.90 + j 1.58
8C	−7.65 − j 2.23
7C	4.64 + j 6.18
7C	−5.74 − j 7.65
14E	−1.63 − j 2.17
7E	3.25 + j 4.33
10 B	−1.67 − j 2.23
11 A	−1.67 − j 2.23
7E	−4.88 − j 6.50
8B	1.00 + j 1.34
8C	0.00 − j 1.91
TOTAL	2.89 + j 2.91 KVA

TVA 489H (EN DES-2-78) TENNESSEE VALLEY AUTHORITY SHEET F15 OF

SUBJECT ______ PROJECT SQN-E3-015

COMPUTED BY R Singh DATE 1-18-88 CHECKED BY apal DATE 1/19/88

480V SHTDN BD 2B1-B RUNNING LOADS [REF 3.2] BPai 2/22/88

COMPT.	LOAD.
3A	61.19 + j 45.89
3B	60.18 + j 27.42
4B	40.90 + j 23.18
2C	44.89 + j 0.00
2D	17.96 + j 2.70
TOTAL	225.12 + j 105.19 KVA

480V DIESEL AUX BOARD 2B1-B RUNNING LOAD

1D	3.0 + j 0.00
4A	13.39 + j 8.65
5A1	40.48 + j 19.61
6A	12.27 + j 9.53
6C	8.39 + j 6.07
6D	1.61 + j 1.55
7B	0.37 + j 0.57
7D	0.72 + j 0.96
7E1	16.07 + j 1.61
TOTAL	96.30 + j 48.55 KVA

TVA 489H (EN DES-2-78) TENNESSEE VALLEY AUTHORITY SHEET F16 OF

SUBJECT ______ PROJECT ______

R. Singh 1-18-88 SQN-E3-015

COMPUTED BY DATE CHECKED BY [signature] DATE 1/19/88

480V REAC MOV BD 2B2-B RUNNING LOADS

[REF 3.~~2~~ 1] BPai 2/22/88

COMPT.	LOAD
16C	20.56 + j 27.41
17A	20.56 + j 27.41
2E	1.00 + j 1.34
4E	1.00 + j 1.34
8D	2.63 + j 3.51
16C	110.29 + j 255.31
17A	110.29 + j 255.31
2E	1.39 + j 1.85
4E	4.02 + j 5.35
16C	−130.84 − j 282.72
17A	−130.84 − j 282.72
2E	− 2.39 − j 3.19
4E	− 5.02 − j 6.69
8D	− 2.63 − j 2.91
11B	5.74 + j 7.65
11E	5.74 + j 7.65
TOTAL	11.50 + j 15.90 KVA

SUBJECT ______ PROJECT ______

R. Swigh 1-18-88 SQN-E3--015

COMPUTED BY DATE CHECKED BY [signature] DATE 1/19/88

480V DIESEL AUX BOARD 2B2-B RUNNING LOADS

[REF 3.~~2~~ 1] [initials] 2/22/89

COMPT	LOAD
1D	3.00 + j 0.00
5A2	3.78 + j 4.42
6A	1.24 + j 1.66
6C	8.39 + j 6.07
6D	12.27 + j 9.53
7A	2.79 + j 2.38
7C	0.72 + j 0.96
7D	16.07 + j 1.61
6A	-0.96 - j 1.27
TOTAL	47.3 + j 25.36 KVA

480V ERCW MCC 2B-B RUNNING LOADS

2A	2.32 + j 3.62
5D	0.83 + j 0.00
TOTAL =	3.15 + j 3.62 KVA

480V SHTDN BD 2B2-B RUNNING LOADS

10A	119.40 + j 70.85
3B	60.18 + j 27.42
5D	40.90 + j 23.18
8C	44.89 + j 0.00
TOTAL	265.37 + j 121.45 KVA

SUBJECT ______ PROJECT ______

COMPUTED BY R. Singh DATE 1-18-88 SQN-E3-015

CHECKED BY [illegible] DATE 1/19/88

2B1-B TOTAL RUNNING LOADS

480 V SHTDN BD 2B1-B = 225.12 + j 105.19
480 V C & A BLDG VENT BD 2B1-B = 102.53 + j 62.42
480 V DIESEL AUX BOAD 2B1-B = 96.30 + j 48.55
480 V REAC MOV BOARD 2B1-B = 2.89 + j 2.91

TOTAL LOAD = 426.84 + j 219.07 KVA

2B2-B TOTAL RUNNING LOADS

480 V SHTDN BD 2B2-B = 265.37 + j 121.45
480 V DIESEL AUX BOARD 2B2-B = 47.30 + j 25.36
480 V REAC MOV BOARD 2B2-B = 11.50 + j 15.90

324.17 + j 162.71 KVA

SUBJECT: APPENDIX F PROJECT: SQN

SQN-E3-015

COMPUTED BY: BPai DATE: 2/22/88 CHECKED BY: E. Sfaros DATE: 2/22/88

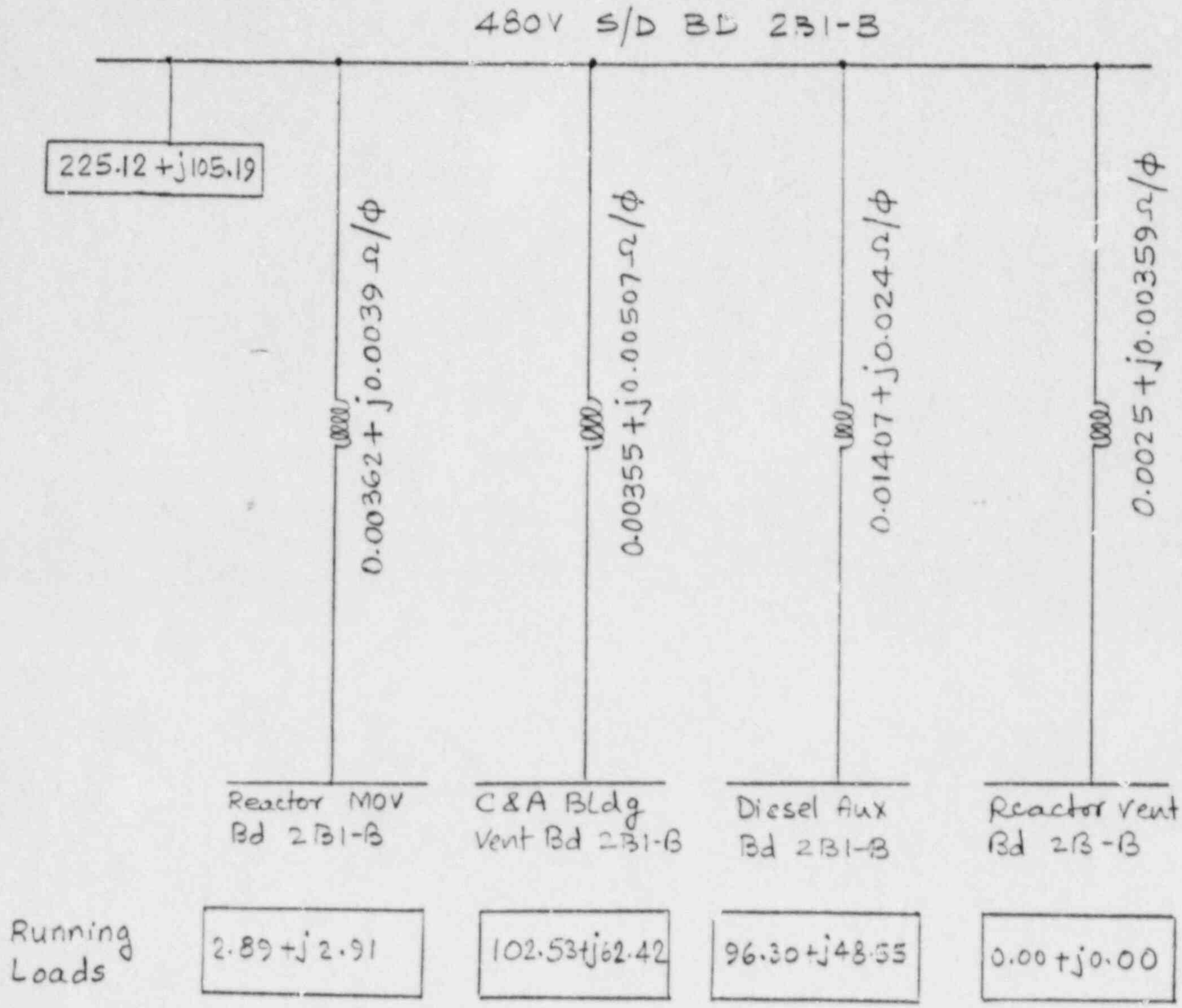


FIG. F2

Reactor MOV Bd 2B1-B

Running Load $= 2.89 + j\,2.91$

$= 4.1 \angle 45.2$ KVA

Voltage at S/D Bd 2B1-B $= 0.77 \times 480V$

$= 369.6V$

Load Current $= \frac{4.1 \times 10^3}{\sqrt{3} \times 369.6} = 6.4A$

Voltage drop $= \sqrt{3} \times 6.4 (0.00362 \cos 45.2 + 0.0039 \sin 45.2)$

$= 0.059$

$= \frac{0.059 \times 100}{480} = 0.012\%$ of 480V

C & A Bldg Vent Bd 2B1-B

Running Load $= 102.53 + j62.42$

$= 120.04 \angle 31.3$ KVA

Voltage at S/D Bd 2B1-B $= 0.77 \times 480V = 369.6V$

Load Current $= \frac{120.04 \times 10^3}{\sqrt{3} \times 369.6}$

$= 187.5A$

SUBJECT APPENDIX F PROJECT SQN

SQN-E3-015

COMPUTED BY Blai DATE 2/22/88 CHECKED BY E. Iglesias DATE 2/22/88

Voltage drop $= \sqrt{3} \times 187.5 (0.00355 \cos 31.3 + 0.00507 \sin 31.3)$

$= 1.84V$

$= \frac{1.84 \times 100}{480} = \underline{0.38\% \text{ of } 480V}$

Diesel Aux Bd 2B1-B

Running Load $= 96.30 + j\,48.55$

$= 107.85 \angle 26.76$

Load current $= \frac{107.85 \times 10^3}{\sqrt{3} \times 369.6} = 168.47$

Voltage drop $= \sqrt{3} \times 168.47 (0.01407 \cos 26.76 + 0.024 \sin 26.76)$

$= 6.82V$

$= \frac{6.82 \times 100}{480} = \underline{1.42\% \text{ of } 480V}$

worst Case.

TVA 489H (EN DES-2-78)

TENNESSEE VALLEY AUTHORITY

SHEET F22 OF

SUBJECT: APPENDIX - F

PROJECT: SQN

SQN-E3-015

COMPUTED BY: [signature] DATE: 2/22/88 CHECKED BY: [signature] DATE: 2/22/88

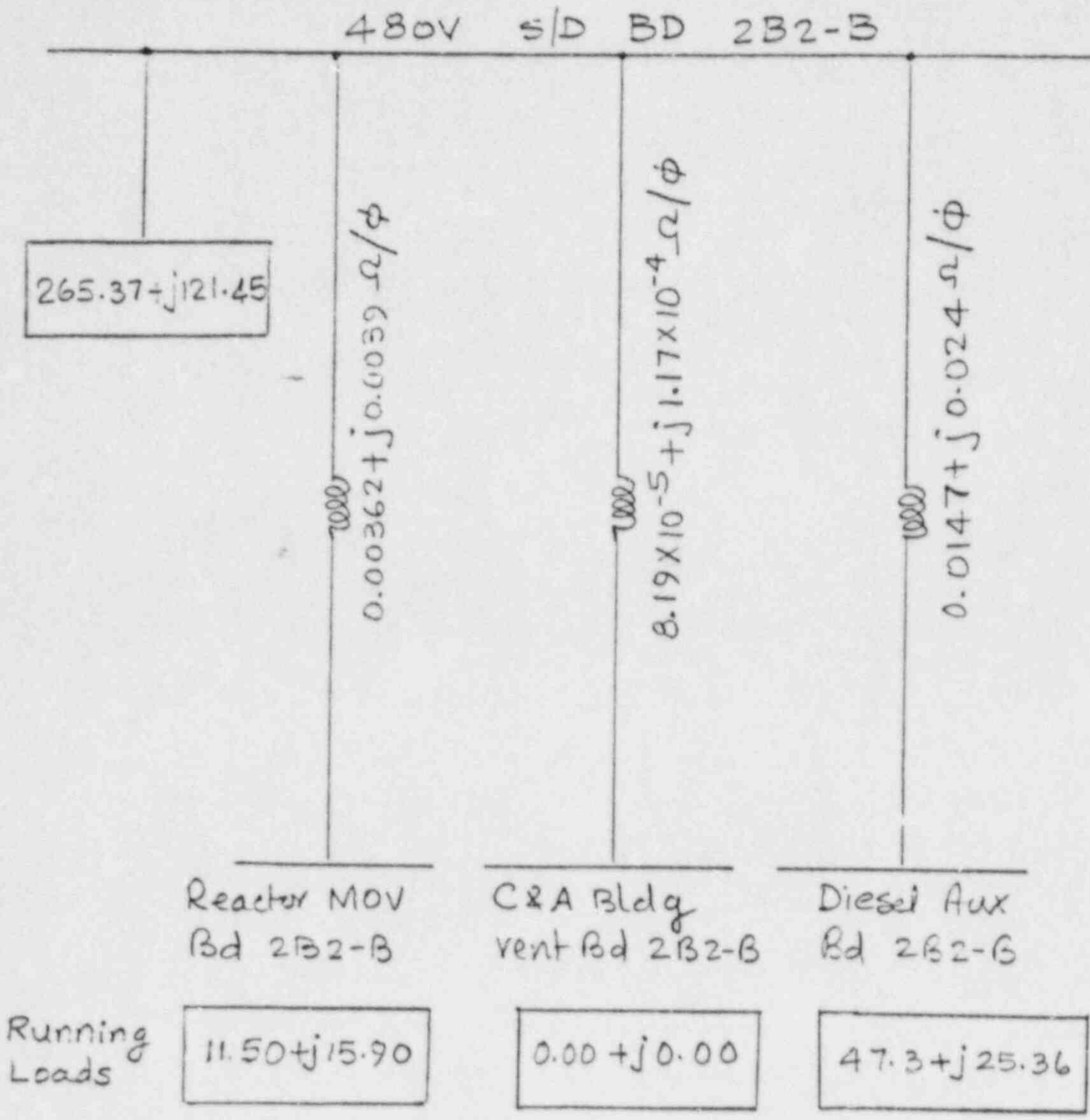


FIG - F3

SUBJECT APPENDIX - F PROJECT SQN

SQN-E3-015

COMPUTED BY Blai DATE 2/22/88 CHECKED BY E. Iglesias DATE 2/22/88

Reactor MOV Bd 2B2-B

Running Load = 11.50 + j 15.90

= 19.62∠54.1 KVA

Voltage at 480V S/D Bd = 0.77 × 480

= 369.6 V

Load Amps = $\frac{19.62 \times 10^3}{\sqrt{3} \times 369.6}$ = 30.65 A

Voltage drop = $\sqrt{3}$ × 30.65 (0.00362 cos 54.1 + 0.0039 sin 54

= 0.280

= $\frac{0.280 \times 100}{480}$ = 0.058% of 480V

Diesel Aux Bd 2B2-B

Running Load = 47.3 + j 25.36

= 53.67∠28.2 KVA

Voltage at 480V S/D Bd = 0.77 × 480

= 369.6 V

Load Amps = $\frac{53.67 \times 10^3}{\sqrt{3} \times 369.6}$ = 83.84 A

Voltage drop = $\sqrt{3}$ × 83.84 (0.0147 cos 28.2 + 0.024 sin 28.2)

= 3.53 = $\frac{3.53 \times 100}{480}$ = 0.735% of 480V

SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT SQN

SQN-EB-015

COMPUTED BY aPal DATE 2/17/88 CHECKED BY Sm DATE 2/17/88

WORST CASE VOLTAGE DROP FOR LOADS FED FROM 480V STDN. BDS.

STUDY OF AC APS LOADING ANALYSIS (REF. 3.6; RELEVANT PAGES ATTACHED) INDICATES THAT THE MAXIMUM VOLTAGE DROP TAKES PLACE AT THE TERMINAL OF CCS PUMP 2B-B WHICH IS

446 - 433 = 13V = 2.7% OF 480V

DATA FILE = C:N2S2A1-A.DAT PREPARED BY : JMR DATE 6-18-87

LOADING FILE = C:N2S2A1-A.ASI CHECKED BY : MDB DATE 6-18-87

This run was made on 06-15-1987 at 12:28:09

SQN-E3-015

F25

SOURCE and TRANSFORMER DATA

SOURCE VOLTAGE = 6560 Volts

SOURCE IMPEDANCE = 0+j 0Ω/0

TRANSFORMER TAP = .975

TOTAL BASE LOAD = 1530 KVA | 30.33°
TOTAL BASE CURRENT = 1887 Amps

480V SHUTDOWN BD 2A1-A

BOARD BASE LOAD(except MCCs) = 634 KVA |@ 26.57°
BOARD BASE VOLTAGE = 444 VOLTS

A1	DUMMY LOAD	0 HP	444 V	444 V
✓B1	ELEC BD RM AIR HAND UNIT A-A	75 HP(base load)	4?? V	436 V
~~B2~~	~~AUX BLDG GEN SUPPLY FAN 2A~~	~~150 HP~~	~~[illegible]~~	~~437 V~~
✓B3	CRDM COOLER FAN 2A-A	75 HP(base load)	39? V	436 V
✓B4	REACT LWR CMPT FAN 2A-A	50 HP(base load)	429 V	441 V
B5	CCS PUMP 2A-A	350 HP(base load)	357 V	432 V
~~C1~~	~~SPENT FUEL PIT PMP C-S~~	~~100 HP(base load)~~	~~[illegible]~~	~~[illegible]~~
C2	CVC SIS HT TR XFMR A1	0 HP(base load)		443 V
~~C3~~	~~CNTMT AIR RETURN FAN 2A1-A~~	~~50 HP~~	~~[illegible]~~	~~437 V~~

NOTE :

LOADS WHICH ARE TRIPPED OR NOT BASE LOAD ARE CROSSED OUT.

DATA FILE = N2S2A2-A.DAT PREPARED BY : M.D. Bowman DATE 8/14/87

LOADING FILE = N2S2A2-A.ASI CHECKED BY : J.A. Reddy DATE 9/7/87

This run was made on 08-14-1987 at 09:12:15

SOURCE and TRANSFORMER DATA

SQN-E3-015

F26

SOURCE VOLTAGE = 6560 Volts

SOURCE IMPEDANCE = 0+j 0Ω/Ø

TRANSFORMER TAP = 1

TOTAL BASE LOAD = 694 kVA | 28.06°
TOTAL BASE CURRENT = 878 Amps

480V SHUTDOWN BD 2A2-A

BOARD BASE LOAD(except MCCs) = 573 kVA |@ 23.94°
BOARD BASE VOLTAGE = 445 VOLTS

A1	DUMMY LOAD	0 HP	445 V	445 V
~~B1~~	~~SHTDN BD RM AIR HAND UNIT 2A-A~~	~~75 HP(base load)~~	~~420 V~~	~~441 V~~
~~B2~~	~~AUX BLDG GEN EXH FAN 2A~~	~~125 HP~~	~~405 V~~	~~438 V~~
B3	CONT RD DR MECH COOL FAN 2C	75 HP(base load)	394 V	437 V
~~B4~~	~~FIRE PUMP 2A-A~~	~~200 HP~~	~~368 V~~	~~418 V~~
B6	REACT LWR CMPT COOL FAN 2C-A	50 HP(base load)	416 V	440 V
~~C2~~	~~ELEC BD ROOM A/C CPRSR A-A~~	~~125 HP(base load)~~	~~371 V~~	~~432 V~~
~~C3~~	~~SHTDN BD RM CHILLER PKG A-A~~	~~250 HP(base load)~~	~~377 V~~	~~437 V~~
C4	CVC SYS HT TR XFMR A3	0 HP(base load)		443 V
C5	STANDBY LTG CAB LS1	0 HP(base load)		434 V
~~D2~~	~~FUEL HDL EXH FAN A~~	~~100 HP~~	~~411 V~~	~~438 V~~

DATA FILE = N2S2B1-B.DAT

LOADING FILE = N2S2B1-B.ASI

PREPARED BY : M.D. Bowman DATE 8-25

CHECKED BY : J.W. Ruddy DATE 8-25

This run was made on 08-25-1987 at 13:47:(

SOURCE and TRANSFORMER DATA

SOURCE VOLTAGE = 6560 Volts

SQN-E3-015

SOURCE IMPEDANCE = 0+j 0Ω/Ø

F 27

TRANSFORMER TAP = .975

TOTAL BASE LOAD = 1321 kVA | 31.18°
TOTAL BASE CURRENT = 1629 Amps

480V SHUTDOWN BD 2B1-B

BOARD BASE LOAD(except MCCs) = 650 kVA |@ 26.85°
BOARD BASE VOLTAGE = 446 VOLTS

A1	DUMMY LOAD	0 HP	446 V	446 V
~~B2~~	~~AUX BLDG GEN SUP FAN 2B~~	~~150 HP~~	~~421 V~~	~~442 V~~
~~B3~~	~~SFP PMP B-B~~	~~100 HP(base load)~~	~~405 V~~	~~440 V~~
B4	ELEC BD RM AHU B-B	75 HP(base load)	405 V	438 V
B5	CRDM COOL FAN 2B	75 HP(base load)	409 V	442 V
C1	CCS PUMP 2B-B	350 HP(base load)	360 V	433 V
C2	RLCC FAN 2B-B	50 HP(base load)	417 V	441 V
~~C4~~	~~RECIR CHG PUMP~~	~~200 HP~~	~~386 V~~	~~436 V~~
C5	HT TR-CVC B1 XFMR	0 HP(base load)		437 V
C6	STANDBY LTG CAB LS3 XFMR	0 HP(base load)		432 V

DATA FILE = C:N2S2B2-B.DAT PREPARED BY : JamR DATE 6-18-

LOADING FILE = C:N2S2B2-B.ASI CHECKED BY : MDB DATE 6-18-

This run was made on 06-15-1987 at 14:16:4

SOURCE and TRANSFORMER DATA

SQN-E3-015

F28

SOURCE VOLTAGE = 6560 Volts

SOURCE IMPEDANCE = 0+j 0Ω/0

TRANSFORMER TAP = .975

TOTAL BASE LOAD = 1044 kVA | 29.28°
TOTAL BASE CURRENT = 1288 Amps

480V SHUTDOWN BD 2B2-B

BOARD BASE LOAD(except MCCs) = 728 kVA |@ 26.51°
BOARD BASE VOLTAGE = 451 VOLTS

A1	DUMMY LOAD	0 HP	451 V	451 V
~~B1~~	~~ELEC BD RM A/C COMPR B-B~~	~~125 HP(base load)~~	~~414 V~~	~~447 V~~
~~B2~~	~~AUX BLDG GEN EXH FAN 2B~~	~~125 HP~~	~~408 V~~	~~444 V~~
B3	COMP COOL SYS PMP C-S	350 HP(base load)	363 V	440 V
~~B4~~	~~SHTDN BD RM AIR HAND UN 2B-B~~	~~75 HP(base load)~~	~~426 V~~	~~447 V~~
B5	CRD MECH COOL FAN 2D	75 HP(base load)	407 V	445 V
~~B6~~	~~FIRE PUMP 2B-B~~	~~200 HP~~	~~374 V~~	~~426 V~~
~~C2~~	~~UN 2 REACT BLDG CRANE~~	~~123 HP~~	~~441 V~~	~~450 V~~
C3	REACT LWR COMPT COOL FAN 2D-B	50 HP(base load)	428 V	447 V
C4	CVC SYS HT TR XFMR B3	0 HP(base load)		450 V
~~C5~~	~~CONTMT AIR RETURN FAN 2B-B~~	~~50 HP~~	~~427 V~~	~~445 V~~
~~D1~~	~~MN TURB TURN GEAR OIL PMP~~	~~75 HP(base load)~~	~~396 V~~	~~438 V~~

SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT SQN

SQN-E3-015

COMPUTED BY aPal DATE 2/17/88 CHECKED BY Sm DATE 2/17/88

VOLTAGE DROP BETWEEN 480V MCC AND LOADS

A. WORST CASE VOLTAGE DROP BETWEEN 480V REACTOR MOV BDS AND LOADS.

STUDY OF AC APS LOADING ANALYSIS (REF. 3.6; RELEVANT PAGES ATTACHED) INDICATES THAT THE MAXIMUM VOLTAGE DROP TAKES PLACE AT THE TERMINAL OF REFUEL WTR PURIFICATION PUMP A WHICH IS

442 - 434 = 8V = 1.7% OF 480V

B. WORST CASE VOLTAGE DROP BETWEEN 480V C & A BLDG. VENT BDS AND LOADS.

STUDY OF AC APS LOADING ANALYSIS (REF. 3.6; RELEVANT PAGES ATTACHED) INDICATES THAT THE MAXIMUM VOLTAGE DROP TAKES PLACE AT THE TERMINAL OF PRIM. WTR MAKEUP PMP 2B WHICH IS 440 - 430 = 10V = 2.1% OF 480V

SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT SQN

SQN-E3-015

COMPUTED BY apal DATE 2/17/88 CHECKED BY [initials] DATE 2/17/88

C. WORST CASE VOLTAGE DROP BETWEEN DIESEL AUX. BOARDS AND LOADS.

STUDY OF AC APS LOADING ANALYSIS (REF. 3.6, RELEVANT PAGES ATTACHED) INDICATES THAT THE MAXIMUM VOLTAGE DROP TAKES PLACE AT THE TERMINAL OF DG 2B-B AIR COMPRESSOR 2 WHICH IS 434 - 431 = 3V = 0.6% OF 480V

SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT SQN
SQN-E3-015
COMPUTED BY [initials] DATE 2/19/88 CHECKED BY [initials] DATE 2/19/88

D. WORST CASE VOLTAGE DROP BETWEEN 480V REACTOR MOV BD'S AND VALVES.

Study of AC APS Loading Analysis (Ref. 3.6, Relevant Pages Attached) indicates that the maximum voltage drop takes place at the terminal of RCP THER BARR CNTMT ISOL which is 445V − 434V = 11V = 2.29% of 480V.

DATA FILE · C:N2S2B2-B.DAT PREPARED BY : JMR DATE 6-18

LOADING FILE = C:N2S2B2-B.ASI CHECKED BY : MDB DATE 6-18

This run was made on 06-15-1987 at 14:17:

480V REACTOR MOV BD 2B2-B

F32

SQN-E3-015

BOARD BASE LOAD = 0 KVA |@ 0.00°
BOARD BASE CURRENT = 0 Amps
BOARD BASE VOLTAGE = 451 Volts

NOTE: LOADS IDENTIFIED AS BASE LOAD ARE ON THE DIESEL.

A1	DUMMY LOAD	0 HP (base load)		451 V
~~B3~~	~~STEAM FW PMP ISOL VLV~~	~~1.6 HP~~	~~419 V~~	~~446 V~~
B4	ERCW HDR 2B ISOL VLV	.33 HP	447 V	451 V
B5	ERCW HDR 2B ISOL VLV	.33 HP	447 V	451 V
B6	ANNULUS ISOL VLV	.67 HP	443 V	448 V
~~C1~~	~~SUPP HDR 2B ISOL VLV~~	~~.5 HP~~	~~393 V~~	~~440 V~~
~~C2~~	~~AB ERCW 2B ISOL VLV~~	~~.33 HP~~	~~392 V~~	~~440 V~~
C3	LWR CNTMT 2A ISOL VLV	.33 HP	447 V	451 V
C4	LWR CNTMT 2B ISOL VLV	.33 HP	445 V	450 V
C5	LWR CNTMT 2B ISOL VLV	.13 HP	448 V	451 V
C6	ANNULUS ISOL VLV	.67 HP	433 V	448 V
D1	LWR CNTMT 2B ISOL VLV	.13 HP	448 V	451 V
D2	LWR CNTMT 2D ISOL VLV	.33 HP	447 V	451 V
D3	LWR CNTMT 2D ISOL VLV	.13 HP	449 V	451 V
~~D4~~	~~CNTMT SP HT EXC 2B VLV~~	~~.33 HP~~	~~435 V~~	~~449 V~~
~~D5~~	~~CNTMT SP HR EXC 2B VLV~~	~~.33 HP~~	~~433 V~~	~~449 V~~
~~D6~~	~~AB SUPP HDR 2B ISOL VLV~~	~~.5 HP~~	~~412 V~~	~~445 V~~
E1	UPPR CNTMT 2A ISOL VLV	.13 HP	449 V	451 V
E2	UPPR CNTMT 2C ISOL VLV	.13 HP	449 V	451 V
E3	UPPR CNTMT 2B ISOL VLV	.13 HP	450 V	451 V
~~E4~~	~~CNDS DEMIN SUP VLV~~	~~.13 HP~~	~~416 V~~	~~446 V~~
E5	UPPR CNTMT 2D ISOL VLV	.13 HP	449 V	451 V
E6	COMPT HEAT EXCH C VLV	.33 HP	447 V	451 V
F1	UPPR CNTMT 2B ISOL VLV	.13 HP	446 V	451 V
F2	UPPR CNTMT 2D ISOL VLV	.13 HP	448 V	451 V
~~F3~~	~~LOOP 3 LINE VLV~~	~~1 HP~~	~~405 V~~	~~443 V~~
~~F4~~	~~CCS PMP 1A-A & 1B-B VLV~~	~~1.25 HP~~	~~433 V~~	~~447 V~~
~~F5~~	~~RHR HT EXCH B VLV~~	~~.33 HP~~	~~412 V~~	~~444 V~~
F6	ERCW HDR 2B ISOL VLV	.7 HP	445 V	450 V
~~G1~~	~~CCS PMP A & B ISOL VLV~~	~~.33 HP~~	~~394 V~~	~~443 V~~
~~G2~~	~~ERCW 2B ISOL VLV~~	~~.7 HP~~	~~440 V~~	~~449 V~~
~~G3~~	~~CCS HT EXCH B & C VLV~~	~~.33 HP~~	~~395 V~~	~~443 V~~
~~G4~~	~~CCS HT EXCH B-C VLV~~	~~.33 HP~~	~~412 V~~	~~443 V~~
~~G5~~	~~SFPCS HT EXCH A VLV~~	~~.13 HP~~	~~417 V~~	~~446 V~~
~~G6~~	~~HPFP HDR 2 CONT VLV~~	~~.13 HP~~	~~417 V~~	~~446 V~~
~~H1~~	~~CCS PMP 2A-A & 2B-B VLV~~	~~.33 HP~~	~~420 V~~	~~444 V~~
~~H2~~	~~CCS PMP 2A-A & 2B-B VLV~~	~~.33 HP~~	~~394 V~~	~~443 V~~
~~H3~~	~~SFPCS HT EXCH B VLV~~	~~.13 HP~~	~~417 V~~	~~446 V~~
~~H4~~	~~CCS PMP 2A-A & 2B-B VLV~~	~~1.25 HP~~	~~433 V~~	~~447 V~~
~~H5~~	~~RHR HT EXC B ISOL VLV~~	~~.33 HP~~	~~412 V~~	~~444 V~~
~~H6~~	~~LOOP 4 LINE VLV~~	~~1 HP~~	~~402 V~~	~~442 V~~
J1	RC PMP CNTMT ISOL VLV	.13 HP	448 V	451 V
J2	RCP CNTMT ISOL VLV	.13 HP	446 V	451 V
~~J3~~	~~HT EXC ISOL VLV~~	~~.33 HP~~	~~396 V~~	~~443 V~~
J4	RCP CNTMT ISOL VLV	.7 HP	443 V	450 V
J5	RCP ISOL VLV	.13 HP	449 V	451 V
~~J6~~	~~RHR HT EXC OUT VLV~~	~~.33 HP~~	~~424 V~~	~~447 V~~
K1	STEAM GEN FW ISOL VLV	.33 HP	375 V	440 V
K2	STM GEN FW ISOL VLV	.33 HP	395 V	444 V

DATA FILE = C:N2S2A1-A.DAT PREPARED BY : JMR DATE 6-18-87

LOADING FILE = C:N2S2A1-A.ASI CHECKED BY : MDB DATE 6-18-87

This run was made on 06-15-1987 at 12:28:51

480V REACTOR MOV BD 2A1-A

BOARD BASE LOAD = 68 KVA |@ 22.13°
BOARD BASE CURRENT = 89 Amps
BOARD BASE VOLTAGE = 442 Volts

SQN-E3-015

F33

~~B1~~	~~INCORE INST RM A/C COOL FN 2A~~	~~5 HP~~	~~406 V~~	~~434 V~~
~~B2~~	~~CHARGING PMP MIN FLOW VALVE~~	~~1.6 HP~~	~~416 V~~	~~430 V~~
B3	VOL CONT TANK OUTLET ISOL VLV	.67 HP	437 V	440 V
B4	REFUEL WTR STG TANK VLV	1 HP	431 V	440 V
B4R	CENT CHGR PMP 2A AUX OIL PMP	2 HP(base load)	406 V	436 V
~~B5~~	~~SIS PMP OUT RCS LOOP 1 & 3 H L~~	~~2.6 HP~~	~~414 V~~	~~436 V~~
~~B6~~	~~RWST-BREAK HDR 1A FLOW CONT V~~	~~3.3 HP~~	~~396 V~~	~~434 V~~
C1	CNTMT SMP SPY HDR 2A FL CONT V	5.2 HP	404 V	435 V
C2	CSP 2A-A RECIRC FL CONT VLV	.13 HP	439 V	441 V
~~C3~~	~~CNTMT SPY HDR 2A ISOL VLV~~	~~3.7 HP~~	~~407 V~~	~~436 V~~
~~C4~~	~~RHR SPRAY HDR 2A ISOL VLV~~	~~5.2 HP~~	~~414 V~~	~~437 V~~
~~C5~~	~~SIS BORON INJ TANK HTR 2A-A~~	~~0 HP~~		~~433 V~~
~~C6~~	~~INCORE INST RM CIRC PMP 2A~~	~~1.5 HP~~	~~385 V~~	~~432 V~~
~~D1L~~	~~RADI LONG DRD 1SEV SUPPLY XFMR~~	~~0 HP~~		~~431 V~~
~~D1R~~	~~RHR S/S ISOL VLV~~	~~4 HP~~	~~382 V~~	~~434 V~~
~~D2~~	~~RHR PMP 2A-A INLET FL CONT VLV~~	~~1.6 HP~~	~~410 V~~	~~436 V~~
~~D3~~	~~INCORE INST RM CHILL WTR SPS 2~~	~~10 HP~~	~~401 V~~	~~427 V~~
~~D4L~~	~~RAD. PL 1&2 DIST MTR 2A-A~~	~~20 HP~~	~~301 V~~	~~422 V~~
D4R	RHR PMP 2A-A MIN FLOW VLV	1.6 HP	415 V	433 V
~~D5~~	~~RHR HT EXCH 2A BYPASS VLV~~	~~2.6 HP~~	~~422 V~~	~~432 V~~
~~D6~~	~~RCS PRESS RELIEF CONT VLV~~	~~1.6 HP~~	~~420 V~~	~~438 V~~
~~E1~~	~~UHI ACCUM ISOL VLV GAS~~	~~.7 HP~~	~~415 V~~	~~436 V~~
~~E2~~	~~RWST-RHR PMP FL CONT VLV~~	~~5.3 HP~~	~~408 V~~	~~437 V~~
~~E3~~	~~SIS PMP DISCH-RWST SHUTOFF VLV~~	~~1.6 HP~~	~~410 V~~	~~437 V~~
~~E4~~	~~SIS PMP INLET-CVCS CHRG PMP V~~	~~.67 HP~~	~~437 V~~	~~439 V~~
~~E5~~	~~RHR HT EXCH 1-CVCS CHGR PMP V~~	~~3.7 HP~~	~~419 V~~	~~430 V~~
F1	SIS BORON INJ TK SHUTOFF VLV	2 HP	424 V	439 V
~~F2~~	~~SIS 2A-A OUTLET FLOW CONT VLV~~	~~1.6 HP~~	~~412 V~~	~~437 V~~
~~F3~~	~~SIS PMP 1A-A INLET VLV~~	~~1 HP~~	~~414 V~~	~~436 V~~
F4	SIS BORON INJ TK INLET SHT VLV	2 HP	425 V	439 V
~~F5~~	~~CNTMT SUMP FLOW ISOL VLV~~	~~10.5 HP~~	~~367 V~~	~~430 V~~
~~F6~~	~~SI-RCS LOOP 2 & 3 FLOW CONT VL~~	~~13.23 HP~~	~~401 V~~	~~435 V~~
~~G1~~	~~UHI RCS DISCH PMP RECIRC VLV~~	~~.7 HP~~	~~400 V~~	~~433 V~~
G2	BORIC TANK XFER PMP 2A-A	15 HP(base load)	420 V	437 V
*G3	BORIC ACID BATCHING TK HTR 4	0 HP(base load)		424 V
G4	BORIC ACID TANK B HTR A-A	0 HP(base load)		433 V
~~G5~~	~~SIS ACC TK 3 FLOW ISOL VLV~~	~~21 HP~~	~~425 V~~	~~435 V~~
~~G6~~	~~SIS ACC TK 1 FLOW ISOL VLV~~	~~20.56 HP~~	~~424 V~~	~~434 V~~
~~H1~~	~~UHI ACCUM ISOL VLV GAS~~	~~.7 HP~~	~~415 V~~	~~436 V~~
H2	REFUEL WTR PURIFICATION PMP A	15 HP(base load)	409 V	434 V
~~H3~~	~~RE-D CNTMT PIT SUMP EJECT PMP~~	~~1.5 HP~~	~~423 V~~	~~439 V~~
H5	CMP CL SY THR BAR BST PMP 2A-A	15 HP(base load)	412 V	435 V
H6	SEAL FLOW ISOL VALVE	.5 HP	435 V	440 V
J1	CHARGING FLOW ISOL VALVE	1 HP	426 V	438 V

* HEATER LOADS CAN TOLERATE LOW VOLTAGE

DATA FILE = N2S2B1-B.DAT

LOADING FILE = N2S2B1-B.ASI

PREPARED BY : M.D. Bowman DATE 8-25-8

CHECKED BY : J.M. Rudd DATE 8-25-8

This run was made on 08-25-1987 at 13:49:1

480V REACTOR MOV BD 2B1-B

SQN-E3-015

F34

BOARD BASE LOAD = 54 kVA |@ 20.44°
BOARD BASE CURRENT = 70 Amps
BOARD BASE VOLTAGE = 444 Volts

~~B1~~	~~INCORE INSTR RM COOL FAN 2B~~	~~5 HP~~	~~409 V~~	~~436 V~~
~~B2~~	~~INCORE INSTR RM WTR COMP 1B~~	~~10 HP~~	~~394 V~~	~~426 V~~
~~B3~~	~~INCORE INSTR RM CIRC PMP 2B~~	~~1.5 HP~~	~~388 V~~	~~436 V~~
~~B4~~	~~SIS BOARD INJ TK HTR 2B-B~~	~~0 HP~~		~~437 V~~
~~B5~~	~~REFUEL PURITY PUMP B~~	~~15 HP~~	~~406 V~~	~~434 V~~
C1	BORIC ACID XFER PMP 2B-B	15 HP (base load)	419 V	439 V
* C2	BORIC ACID BATCH TK HTR 3	0 HP (base load)		426 V
C3	BORIC ACID TK B HTR B-B	0 HP (base load)		436 V
C6	CENT CHG PMP-2B AUX OIL PMP	2 HP (base load)	400 V	436 V
D1	CCS THERM BARR BSTR PMP 2B-B	15 HP (base load)	415 V	437 V
~~D2~~	~~BACK FLOW GATE HOIST 2B-B~~	~~20 HP~~	~~378 V~~	~~421 V~~
~~D4~~	~~RHR SYS ISOL VLV~~	~~4 HP~~	~~388 V~~	~~435 V~~
D5	SEAL FLOW IRON VLV	.7 HP	432 V	441 V
D6	CHR FLOW ISOL VLV	1.6 HP	425 V	437 V
~~E1~~	~~CHG PMP MIN FLOW VLV~~	~~1.5 HP~~	~~406 V~~	~~435 V~~
E2	VOL CONT TK ISOL VLV	.67 HP	437 V	441 V
E3	CHG PMP FLOW VLV	1.3 HP	441 V	443 V
~~E4~~	~~EMER BORON CONT VLV~~	~~1 HP~~	~~414 V~~	~~437 V~~
~~E5~~	~~SIS PMP B-B DISCH VLV~~	~~1 HP~~	~~413 V~~	~~438 V~~
~~E6~~	~~REF WTR STORAGE TK VLV~~	~~1.3 HP~~	~~414 V~~	~~439 V~~
~~F1~~	~~SIS PMP INLET PMP VLV~~	~~.67 HP~~	~~434 V~~	~~440 V~~
~~F2~~	~~SIS PMP HT EXC B VLV~~	~~3.3 HP~~	~~405 V~~	~~438 V~~
~~F3~~	~~SIS PMP OUTLET RCS VLV~~	~~2.6 HP~~	~~405 V~~	~~436 V~~
F4	SIS BORON INJ TK VLV	2 HP	418 V	440 V
~~F5~~	~~SIS PMP B-B FLOW CONT VLV~~	~~1.6 HP~~	~~416 V~~	~~440 V~~
~~F6~~	~~SIS PMP B-B INLET VLV~~	~~1 HP~~	~~419 V~~	~~439 V~~
G1	SIS BORON INJ TK VLV	2 HP	419 V	440 V
~~G2~~	~~SIS TK 4 ISOL VLV~~	~~21 HP~~	~~406 V~~	~~438 V~~
~~G3~~	~~CNTMT SUMP FLOW VLV~~	~~10.5 HP~~	~~343 V~~	~~428 V~~
~~G4~~	~~SIS TK 2 ISOL VLV~~	~~20.56 HP~~	~~374 V~~	~~427 V~~
~~G5~~	~~SI TO 1 & 4 CONT VLV~~	~~13.23 HP~~	~~385 V~~	~~433 V~~
~~G6~~	~~RHR RECIRC VLV~~	~~5.2 HP~~	~~384 V~~	~~432 V~~
~~H1~~	~~UHI ACCUM ISOL VLV~~	~~.7 HP~~	~~420 V~~	~~439 V~~
~~H2~~	~~RCS RELIEF CONT VLV~~	~~1.6 HP~~	~~402 V~~	~~437 V~~
H3	SPRAY HDR 2B ISOL VLV	3.3 HP	415 V	439 V
H4	SPRAY PMP 2B RECIRC VLV	.13 HP	439 V	443 V
~~H5~~	~~SPRAY HDR 2B CONT VLV~~	~~5.2 HP~~	~~405 V~~	~~437 V~~
~~H6~~	~~SPRAY HDR 2B CONT VLV~~	~~3.3 HP~~	~~411 V~~	~~439 V~~
~~J1~~	~~RHR SP HDR 2B ISOL VLV~~	~~5.2 HP~~	~~397 V~~	~~435 V~~
~~J3~~	~~RHR PMP 2B-B CONT VLV~~	~~1.6 HP~~	~~412 V~~	~~438 V~~
J4	RHR PMP 1B FLOW VLV	1.6 HP	418 V	440 V
~~J5~~	~~RHR HEAT EXCH B VLV~~	~~2.6 HP~~	~~410 V~~	~~438 V~~
~~J6~~	~~SIS PMP SHUTOFF VLV~~	~~2 HP~~	~~412 V~~	~~439 V~~
~~K1~~	~~UHI ACCUM ISOL VLV~~	~~.7 HP~~	~~419 V~~	~~439 V~~
~~K2~~	~~SIS PMP 2B B SHUTOFF VLV~~	~~1.6 HP~~	~~425 V~~	~~437 V~~

DATA FILE = N2S2A2-A.DAT PREPARED BY : M.D. Bowman DATE 8/14/87

LOADING FILE = N2S2A2-A.ASI CHECKED BY : J.M. Ruddy DATE 8/17/87

This run was made on 08-14-1987 at 09:13:44

480V REACTOR MOV BD 2A2-A

SQN-E3-015

F35

BOARD BASE LOAD = 0 kVA |@ 0.00°
BOARD BASE CURRENT = 0 Amps
BOARD BASE VOLTAGE = 445 Volts

A1	DUMMY LOAD	0 HP(base load)		445 V
~~B2~~	~~STM FL AUX FDWTR TURB ISOL VLV~~	~~1 HP~~	~~428 V~~	~~442 V~~
B3	ERCW HDR 2A ISOL VLV	.33 HP	441 V	444 V
B4	ERCW HDR 2A ISOL VLV	.33 HP	441 V	444 V
B5	ERCW HDR 2A ISOL VLV	.7 HP	433 V	442 V
B6	ERCW HDR 2A ISOL VLV	.7 HP	439 V	444 V
~~C1~~	~~AUX BLDG ERCW HDR 2A ISOL VLV~~	~~.33 HP~~	~~367 V~~	~~437 V~~
C2	LWR CNTMT 2A COOL SUP ISOL VLV	.13 HP	442 V	444 V
C3	LWR CNTMT 2C COOL SUP ISOL VLV	.13 HP	442 V	444 V
C4	LWR CNTMT 2C COOL DIS ISOL VLV	.13 HP	441 V	444 V
C5	L CNTMT 2B COOL DIS ISOL VLV O	.33 HP	439 V	444 V
C6	L CNTMT 2D COOL DIS ISOL VLV O	.13 HP	443 V	445 V
~~D1~~	~~SFPCS HTX SUP HDR~~	~~.33 HP~~	~~390 V~~	~~437 V~~
~~D2~~	~~CNTMT SPR HT EXCH 2A S CT VLV~~	~~.33 HP~~	~~429 V~~	~~443 V~~
~~D3~~	~~CNTMT SPR HT EXCH 2A DIS VLV~~	~~.33 HP~~	~~430 V~~	~~443 V~~
~~D4~~	~~A BLDG AIR CLR S HDR 2A ISOL V~~	~~.5 HP~~	~~408 V~~	~~430 V~~
D5	U CNTMT VT CLR 2A SUP ISOL VLV	.13 HP	443 V	445 V
D6	U CNTMT VT CLR 2C SUP ISOL VLV	.13 HP	443 V	445 V
E1	U CNTMT VT CLR 2B DIS ISOL VLV	.13 HP	444 V	445 V
E2	U CNTMT VT CLR 2D DIS ISOL VLV	.13 HP	443 V	445 V
~~E3~~	~~S HDR 2A HDR 1B ISOL VLV~~	~~.5 HP~~	~~420 V~~	~~442 V~~
~~E4~~	~~CMP COOL HT EXCH 2B DIS CT VLV~~	~~.33 HP~~	~~429 V~~	~~443 V~~
E5	U CNTMT VT COOL 2A DIS ISOL V	.13 HP	441 V	444 V
E6	U CNTMT VT COOL 2C DIS ISOL V	.13 HP	441 V	444 V
~~F1~~	~~RHR HTX 2A HDR INLET VLV~~	~~.33 HP~~	~~406 V~~	~~437 V~~
~~F2~~	~~MISC EQUIP HDR INLET VLV~~	~~.33 HP~~	~~405 V~~	~~437 V~~
~~F3~~	~~CCS HT EXCH B OUTLET VLV~~	~~.33 HP~~	~~406 V~~	~~437 V~~
~~F4~~	~~CCS HTX B & C OUTLET ISOL VLV~~	~~.33 HP~~	~~389 V~~	~~436 V~~
F5	RCP SPRAY ISOL VLV	.67 HP	425 V	441 V
~~F6~~	~~CCS HTX B & C INLET ISOL VLV~~	~~.33 HP~~	~~405 V~~	~~437 V~~
~~G1~~	~~CCS HTX B INLET VLV~~	~~.33 HP~~	~~405 V~~	~~437 V~~
G2	EXCESS LTDWN HTX CONT INLET V	.13 HP	442 V	444 V
G3L	RCP TB RETURN CONT ISOL VLV	1 HP	434 V	443 V
G3R	RCP THER BARR CNTMT ISOL VLV	.67 HP	393 V	434 V
G4	RCP OC RETURN CONT ISOL VLV	.13 HP	442 V	444 V
G5	CNTMT STANDPIPE ISOL VLV	.67 HP	434 V	443 V
~~G6~~	~~RCP OIL CLR HDR CNTMT ISOL VLV~~	~~.13 HP~~	~~422 V~~	~~441 V~~
~~H1~~	~~STM GEN FEEDWTR ISOL VLV~~	~~33 HP~~	~~387 V~~	~~436 V~~
~~H2~~	~~RHR HT EXCH 2A OUTLET~~	~~.33 HP~~	~~411 V~~	~~440 V~~
~~H3~~	~~B ACID & GAS STRIP EVAP PKG 2A~~	~~.33 HP~~	~~407 V~~	~~437 V~~
~~H4~~	~~AFP TURB STM S-STM GEN 1 ISOL~~	~~1 HP~~	~~421 V~~	~~440 V~~
~~H5~~	~~STEAM GEN FW ISOL VLV~~	~~33 HP~~	~~383 V~~	~~436 V~~
~~H6~~	~~SAMP HT EXCH HDR OUTLET VLV~~	~~.67 HP~~	~~442 V~~	~~445 V~~
~~J1~~	~~LOOP 1 DEAERATION LINE VLV~~	~~1 HP~~	~~408 V~~	~~438 V~~
~~J2~~	~~ANNULUS STANDPIPE ISOL VLV~~	~~.67 HP~~	~~434 V~~	~~443 V~~
~~J3~~	~~LOOP 2 DEAERATION LINE VLV~~	~~1 HP~~	~~409 V~~	~~438 V~~
~~J4~~	~~AFP TURB STM-STM GEN 4 ISOL V~~	~~1.6 HP~~	~~412 V~~	~~440 V~~
~~J5~~	~~ANNULUS SPRINK ISOL VLV SUP~~	~~.67 HP~~	~~434 V~~	~~443 V~~
[illegible]	~~LWR CNTMT 2A COOL DIS ISOL VLV~~	~~.13 HP~~	~~442 V~~	~~444 V~~

DATA FILE = C:N2S2A1-A.DAT PREPARED BY : JMR DATE 6-18-8

LOADING FILE = C:N2S2A1-A.ASI CHECKED BY : MDB DATE 6-18-8

This run was made on 06-15-1987 at 12:32:05

480V CONT & AUX BLDG VENT BD 2A1-A

SQN-E3-015

F36

BOARD BASE LOAD = 349 kVA |@ 26.27°
BOARD BASE CURRENT = 460 Amps
BOARD BASE VOLTAGE = 438 Volts

B1L	RAD MON & SAMP XFMR	0 HP(base load)		436 V
B2	PIPE CHASE CLR FAN 2A-A	20 HP(base load)	412 V	433 V
B3	AB GAS TRTMT SYS FAN A-A	20 HP(base load)	396 V	429 V
B4	SHTDN XFMR RM 2A EXH FAN 2A3-A	2.5 HP(base load)	426 V	436 V
B5	SHTDN XFMR RM 2A EXH FAN 2A1-A	2.5 HP(base load)	425 V	436 V
B6	SHTDN XFMR RM 2A EXH FAN 2A2-A	2.5 HP(base load)	427 V	437 V
~~C1~~	~~CNTMT ANN VACUUM FAN 2A~~	~~1.5 HP~~	~~411 V~~	~~434 V~~
C2	PEN RM EL 669 CLR FAN 2A-A	5 HP(base load)	411 V	433 V
C3	PEN RM EL 690 CLR FAN 2A-A	5 HP(base load)	409 V	432 V
C4	PEN RM EL 714 CLR FAN 2A-A	5 HP(base load)	399 V	430 V
C5	RES HT REM PMP 2A-A RM CLR FAN	3 HP(base load)	406 V	433 V
C6	CNTMT SP PMP 2A-A RM CLR FAN	5 HP(base load)	403 V	431 V
D1	PERM HYD MITG SYS 26B	0 HP(base load)		435 V
D2	EMER GAS TRTMT RM CLR A-A	3 HP(base load)	413 V	434 V
D3	AUX CONT AIR CMPRSR A-A	20 HP(base load)	414 V	433 V
D4	CNTMT PURGE AIR EXH MON	.75 HP(base load)	433 V	438 V
D5	CONT RM INTAKE MON	.75 HP(base load)	433 V	437 V
D6	480V BD RM 2A PRES FAN 2A1-A	3 HP(base load)	426 V	436 V
E1L	SHTDN BD RM CPRSR A-A XFMR	0 HP(base load)		434 V
E1R	COND VACUUM PUMP AIR EXH MON	.75 HP(base load)	420 V	436 V
E2	125V BAT RM III EXH FAN 2B1-A	.5 HP(base load)	434 V	437 V
~~E3~~	~~AUX CHRG PMP 2A~~	~~1 HP~~	~~[illegible] V~~	~~433 V~~
E4	PRIM WTR MAKEUP PMP 2A	20 HP(base load)	405 V	429 V
E5	480V BD RM 2A A/C COND 2A-A	15 HP(base load)	424 V	435 V
E6	480V BD RM 2B PRES FAN 2B1-A	3 HP(base load)	429 V	436 V
F1	GAS EFF RAD MON	5 HP(base load)	411 V	432 V
F2	480V BD RM 2A A/C AHU 2A-A	10 HP(base load)	432 V	434 V
F3	125V BAT RM IV EXH FAN 2A1-A	.5 HP(base load)	434 V	436 V
F4	SIS PMP 2A-A RM COOL FAN	3 HP(base load)	408 V	433 V
F5	CENT CHG PMP 2A-A CLR FAN	5 HP(base load)	410 V	433 V
F6L	AB GAS TRTMT HUM HTR A-A	0 HP(base load)		433 V
F6R	CONT RM EMER INTAKE RAD MON	.75 HP(base load)	429 V	437 V
G1	AUX FDWTR XFR SP CLR FAN A-A	5 HP(base load)	417 V	434 V
G2	SHTDN BD RM EL 734 CIR PMP A-A	20 HP(base load)	409 V	432 V
~~G3~~	~~SHTDN BD RM B PRES FAN 2A-A~~	~~1 HP~~	~~424 V~~	~~436 V~~
G4	480V BD RM 2A A/C CPRSR 2A-A	50 HP(base load)	395 V	430 V
G5L	CNTMT BLDG LWR COMPT AIR MON	3 HP(base load)	404 V	431 V
G5R	SHIELD BLDG VENT MON	3 HP(base load)	416 V	434 V

DATA FILE = N2S2B1-B.DAT 7-31.3 pg

PREPARED BY : M.D. Bowman DATE 8-25

LOADING FILE = N2S2B1-B.ASI

CHECKED BY : J. an. Ruddy DATE 8-25-

This run was made on 08-25-1987 at 14:00:

480V CONT & AUX BLDG VENT BD 2B1-B

BOARD BASE LOAD = 305 KVA |@ 29.49°
BOARD BASE CURRENT = 400 Amps
BOARD BASE VOLTAGE = 440 Volts

SQN-E3-015
F37

B1	SHTDN XFMR RM 2B EXH FAN 2B3-B	2.5 HP(base load)	424 V	438 V
B2	SHTDN XFMR RM 2B EXH FAN 2B1-B	2.5 HP(base load)	427 V	438 V
B3	SHTDN XFMR RM 2B EXH FAN 2B2-B	2.5 HP(base load)	425 V	438 V
B4	AUX CONT AIR CMPRSR B-B	20 HP(base load)	419 V	436 V
B5	RECIP CHG PMP RM CLR FAN	3 HP(base load)	420 V	437 V
B6	SI PMP 2B-B RM CLR FAN	3 HP(base load)	409 V	435 V
C1	CENT CHRG PMP 2B-B CLR FAN	5 HP(base load)	408 V	434 V
C2	PEN RM EL 669 CLR FAN 2B-B	5 HP(base load)	404 V	433 V
C3	PEN RM EL 690 CLR FAN 2B-B	5 HP(base load)	414 V	435 V
C4	PEN RM EL 714 CLR FAN 2B-B	5 HP(base load)	420 V	436 V
C5	RES HT REM PMP 2B-B FAN	3 HP(base load)	408 V	435 V
C6	CONT SPRAY PMP 2B-B CLR FAN	5 HP(base load)	402 V	433 V
D1	EMER GAS TMT RM CLR B-B	3 HP(base load)	426 V	438 V
~~D2~~	~~CNTMT ANN VACUUM FAN 2B~~	~~1.5 HP~~	~~420 V~~	~~437 V~~
D3	480V BD RM 2B A/C 2B-B	60 HP(base load)	407 V	435 V
D4	UNIT CONT ANN SYS	0 HP(base load)		439 V
D5	CONT RM INTAKE RAD MON	.75 HP(base load)	435 V	439 V
D6R	AUX BLDG GAS TMT HTR B-B	0 HP(base load)		438 V
E1	480V BD RM 2A FAN 2A2-B	3 HP(base load)	426 V	438 V
E2R	CNTMT BLDG UP COMPT AIR MON	3 HP(base load)	429 V	438 V
E3	PRIM WTR MAKEUP PMP 2B	20 HP(base load)	405 V	430 V
E4	480V BD RM 2B A/C 2B-B	20 HP(base load)	423 V	437 V
E5L	COND VAC PMP AIR EXH MON	.75 HP(base load)	428 V	439 V
E5R	CNTMT PURGE AIR EXH MON	.75 HP(base load)	434 V	439 V
E6	PIPE CHASE CLR FAN 2B-B	20 HP(base load)	409 V	434 V
F1	125V BATT RM IV EXH FAN 2A2-B	.5 HP(base load)	432 V	439 V
F2	PERM HYD MIT SYS 268	0 HP(base load)		438 V
F3	AUX FDWTR & BA CLR FAN B-B	5 HP(base load)	416 V	435 V
F4	480V BD RM 2B FAN 2B2-B	3 HP(base load)	420 V	436 V
F5	480V BD RM 2B A/C 2B-B	25 HP(base load)	421 V	435 V
~~F6~~	~~SHTDN BD RM B FAN 2B-B~~	~~1 HP~~	~~427 V~~	~~438 V~~
~~G1~~	~~AUX CHGR PMP 2B~~	~~1 HP~~	~~395 V~~	~~434 V~~
G2	125V VIT BATT RM III FAN 2B2-B	2 HP(base load)	424 V	437 V
G3	BATT RM EL 669 EXH FAN C-B	2 HP(base load)	415 V	435 V
G4	GAS EFF RAD MON	5 HP(base load)	411 V	434 V
G5	AB GAS TMT SYS FAN B-B	20 HP(base load)	416 V	436 V

DATA FILE = C:N2S2A1-A.DAT   PREPARED BY : JMR   DATE 6-18-8

LOADING FILE = C:N2S2A1-A.ASI   CHECKED BY : MDB   DATE 6-18-8

[illegible]s run was made on 06-15-1987 at 12:35:2

480V DIE[illegible] AUX [illegible] 2A1-A

SQN-E3-015

F38

BOARD BASE LOAD = B[illegible] 32.05°
BOARD BASE CURRENT = [illegible] Amps
BOARD BASE VOLTAGE = 43? Volts

~~B3~~	~~DSL ENG HT EXCH SUP VLV~~	~~.11 HP~~	~~412 V~~	~~431 V~~
~~B4~~	~~DG DAY TNK FUEL OIL XFER PMP~~	~~1 HP~~	~~420 V~~	~~435 V~~
~~B5~~	~~C3 TR AERCW PP ST TR HR DST PL~~	~~0 HP~~		~~430 V~~
~~B6~~	~~DISCH HEADER ISOL VLV~~	~~.67 HP~~	~~405 V~~	~~434 V~~
~~C1~~	~~AUX ERCW TRAVEL SCREEN A-A~~	~~1 HP~~	~~410 V~~	~~433 V~~
C2	DG ELEC PNL VENT FAN	15 HP(base load)	421 V	435 V
C3L	DGB LIGHTING CAB LC46	0 HP(base load)		435 V
~~C4~~	~~EL 722 CORRIDOR HEATER~~	~~0 HP~~		~~435 V~~
C5	DG ROOM EXH FAN 2-A	15 HP(base load)	422 V	435 V
C6	DG 2A-A AIR COMPRESSOR	10 HP(base load)	422 V	435 V
D1	DG MUFFLER RM EXH FAN	1.5 HP(base load)	434 V	437 V
D2	DG BATT HOOD EXH FAN	.33 HP(base load)	425 V	435 V
D3	DG ENG AUX LUBE OIL PMP	.75 HP(base load)	417 V	435 V
D4L	DG ENG WTR HTR/LUBE OIL PMP	1 HP(base load)		437 V

DATA FILE = N2S2A2-A.DAT PREPARED BY : M.D. Bowman DATE 8/14/87

LOADING FILE = N2S2A2-A.ASI CHECKED BY : J.M. Ruddy DATE 8/17/87

This run was made on 08-14-1987 at 09:22:58

480V DIESEL AUX BD 2A2-A

SQN-E3-015

F39

BOARD BASE LOAD = 38 kVA |@ 40.22°
BOARD BASE CURRENT = 50 Amps
BOARD BASE VOLTAGE = 441 Volts

~~B1R~~	~~DG SPACE HTR~~	~~0 HP~~		~~441 V~~
~~B3~~	~~DG ELECT BD RM HTR~~	~~0 HP~~		~~440 V~~
~~B4~~	~~ERCW HDR DISCH SHTOFF VLV~~	~~.67 HP~~	~~416 V~~	~~436 V~~
~~B5~~	~~AUX ERCW SCREEN WASH PMP~~	~~10 HP~~	~~412 V~~	~~435 V~~
~~B6~~	~~DG DAY TNK FUEL OIL XFER PMP~~	~~1 HP~~	~~425 V~~	~~439 V~~
~~C1~~	~~ERCW HDR RET DISCH SHTOFF VLV~~	~~.67 HP~~	~~416 V~~	~~436 V~~
C2R	DG BATTERY CHGR	0 HP(base load)	441 V	441 V
~~C3~~	~~DG RM HTR B~~	~~0 HP~~		~~439 V~~
~~C4~~	~~DG ROOM HTR A~~	~~0 HP~~		~~439 V~~
~~C5~~	~~EMG DSL ENG HT EXCH SUP VLV~~	~~.11 HP~~	~~441 V~~	~~441 V~~
C6	DG AIR COMPRESSOR	10 HP(base load)	428 V	440 V
D1	DG ROOM EXH FAN	15 HP(base load)	425 V	439 V
D2	DG BD ROOM EXH FAN	3 HP(base load)	429 V	439 V
D3	DG ENG AUX LUBE OIL PMP	.75 HP(base load)	427 V	439 V
D4	DG ENG WTR HTR/LUB OIL PMP	1 HP(base load)		441 V

DATA FILE = N2S2B1-B.DAT PREPARED BY : M.D. Bowman DATE 8-25

LOADING FILE = N2S2B1-B.ASI CHECKED BY : J.M. Ruddy DATE 8-25-

This run was made on 08-25-1987 at 14:13:(

480V DIESEL AUX 2B1-B

SQN-E3-015

F40

BOARD BASE LOAD = 83 KVA |@ 32.08°
BOARD BASE CURRENT = 110 Amps
BOARD BASE VOLTAGE = 434 Volts

~~D2~~	~~DSL ENG HT EXCH SUP VLV~~	~~.11 HP~~	~~408 V~~	~~429 V~~
~~D3~~	~~DG DAY TNK FUEL OIL XFER PMP~~	~~1 HP~~	~~424 V~~	~~432 V~~
~~D4~~	~~DISCH HEADER ISOL VLV~~	~~.67 HP~~	~~410 V~~	~~429 V~~
~~D5~~	~~AUX ERCW TRAVEL SCREEN B-B~~	~~1 HP~~	~~404 V~~	~~429 V~~
D6	DG ELECT PNL VENTILATION FAN	15 HP(base load)	413 V	431 V
E2L	DG B LIGHTING CAB LC 48	0 HP(base load)		431 V
~~E3~~	~~EL 722 CORRIDOR HEATER~~	~~0 HP~~		~~430 V~~
E4	DG ROOM EXH FAN 2-B	15 HP(base load)	413 V	432 V
~~E5~~	~~AUX BOILER FUEL OIL PMP B~~	~~5 HP~~	~~395 V~~	~~425 V~~
E6	DG 2B-B AIR COMPRESSOR 2	10 HP(base load)	415 V	431 V
F1	DG MUFFLER RM EXH FAN	1.5 HP(base load)	430 V	434 V
F2	DG BATT HOOD EXH FAN	.33 HP(base load)	429 V	433 V
F3	DG ENG AUX LUBE OIL PMP	.75 HP(base load)	420 V	431 V
F4L	DG ENG WTR HTR/LUBE OIL PMP	1 HP(base load)		434 V

DATA FILE = C:N2S2B2-B.DAT PREPARED BY : JMR DATE 6.K

LOADING FILE = C:N2S2B2-B.ASI CHECKED BY : MDB DATE 6.8

This run was made on 06-15-1987 at 14:20

480V DIESEL AUX BD 2B2-B

SQN-E3-015

F41

BOARD BASE LOAD = 38 kVA |@ 40.23°
BOARD BASE CURRENT = 49 Amps
BOARD BASE VOLTAGE = 446 Volts

~~B1R~~	~~DG SPACE HTR~~	~~0 HP~~		
~~B4~~	~~DG ELECT BD RM HTR~~	~~0 HP~~		~~445~~
~~B5~~	~~ERCW HDR DISCH SHTOFF VLV~~	~~.67 HP~~		~~445~~
~~B6~~	~~AUX ERCW SCREEN WASH PMP~~	~~10 HP~~	~~429 V~~	~~442~~
~~C1~~	~~DG DAY TNK FUEL OIL XFER PMP~~	~~1 HP~~	~~412 V~~	~~439~~
~~C2~~	~~ERCW HDR RET DISCH CAN SHTOFF~~	~~.67 HP~~	~~434 V~~	~~443~~
C3R	DG BATTERY CHGR	0 HP (base load)	~~430 V~~ 445 V	~~442~~ 445
~~C4~~	~~DGB FUEL OIL XFER PMP~~	~~7.5 HP~~	~~427 V~~	~~442~~
~~C5~~	~~DG ROOM HTR~~	~~0 HP~~		~~440~~
~~C6~~	~~DG ROOM HTR~~	~~0 HP~~		~~442~~
~~D1~~	~~ENG DSL ENG HT EXCH SUP VLV~~	~~.11 HP~~	~~445 V~~	~~446~~
D2	DG AIR COMPRESSOR	10 HP (base load)	429 V	444
D3	DG ROOM EXH FAN	15 HP (base load)	424 V	443
D4	DG BD ROOM EXH FAN	3 HP (base load)	432 V	444
D5	DG ENG AUX LUBE OIL PMP	.75 HP (base load)	431 V	443
D6	DG ENG WTR HTR/LUB OIL PMP	1 HP (base load)		446

SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT SQN-
SQN-E3-015

COMPUTED BY aPal DATE 2/17/88 CHECKED BY BPai DATE 2/18/88

APPENDIX - G

STARTER COIL DROPOUT VOLTAGE

SUBJECT STARTER COIL DROPOUT VOLTAGE PROJECT SQN

SQN-E3-015

COMPUTED BY BPai DATE 2/22/88 CHECKED BY Sm DATE 2/22/88

1.0 PURPOSE

To determine the minimum voltage at the MCC so that the voltage across the energized starter coil is 54% of 110V during Emergency Diesel Generator load sequencing; and prove this minimum voltage is higher than the starter coil dropout voltage. The following boards were evaluated:

1. Reactor MOV Boards
2. Cont and Aux. Boards
3. Diesel Aux Boards

2.0 ASSUMPTIONS

2.1 For starter coil dropout evaluation, Seal-in VA for the starter coil, relay, solenoid etc was used.

2.2 Only 100VA control power transformer (CPT) is considered in this evaluation.

3.0 SOURCE OF DESIGN INPUT INFORMATION

3.1 SQN-APS-010 REV. 2

3.2 DROP OUT VOLTAGE REPORT FOR SEQUOYAH NUCLEAR PLANT ON ARROW-HART CONTACTOR

SUBJECT STARTER COIL DROPOUT VOLTAGE PROJECT SQN-E3-015

COMPUTED BY B Pai DATE 2/17/88 CHECKED BY Om DATE 2/17/88

4.0 DESIGN INPUT DATA (CONT'D)

4.4 Size 1 starter seal-in

VA	21
Watts	6
Rated Voltage	110V
Dropout Voltage	0.54×110V = 59.4V

4.5 ASCO Solenoid seal-in

VA	41.5
Watts	20.0
Rated voltage	120V

4.6 Agastat 7000 Series timer

VA	18
Watts	7
Rated voltage	120V

4.0 DESIGN INPUT DATA

4.1 14 AWG Copper conductor

Resistance 0.3413 Ω/100'

Reactance 0.00825 Ω/100'

4.2 100VA Control transformer

Resistance 8.44 Ω

Reactance 1.15 Ω

Turns Ratio $\left(\frac{N_P}{N_S}\right) = 3.7$

4.3 Maximum Control circuit Length for

Reactor MOV Boards 5182'

Cont. & Aux. Boards 5350'

Diesel Aux. Boards 864'

SUBJECT STARTER COIL DROPOUT VOLTAGE PROJECT SQN-E3-015

COMPUTED BY Bpai DATE 2/17/88 CHECKED BY Sm DATE 2/17/88

5.0 DOCUMENTATION OF ASSUMPTIONS

5.1 Assumption 2.1 is conservative since it includes all possible components in a control circuit.

5.2 100VA CPT has worst internal impedance of all the CPTs. This is a conservative assumption.

5.0 COMPUTATION / ANALYSIS

5.1 METHODOLOGY

The review of control circuits which are required during DG loading revealed the following combination of the devices which are energized.

1. Starter only
2. Starter and solenoid
3. Starter, solenoid and a relay.

The review of the control circuit lengths revealed the longest control circuit is 5350 feet long.

In order this calculation envelop every conceivable control circuit combination, the calculation was performed by taking into account the longest control circuit

SUBJECT STARTER COIL DROPOUT VOLTAGE PROJECT SQN-E3-015

COMPUTED BY Blai DATE 2/17/88 CHECKED BY [illegible] DATE 2/17/88

5.0 COMPUTATION/ANALYSIS (CONT'D)

length (5350'), starter coil, Agastat timer, and solenoid valve all connected in parallel at the end of the control circuit.

5.2 IMPEDANCE CALCULATION

Starter

$$Z_3 = \frac{V^2}{VA} = \frac{(110)^2}{21} = 576\,\Omega$$

$$PF = \cos\theta = \frac{W}{VA} = \frac{6}{21} = 0.286$$

$$R = Z\cos\theta = 576 \times 0.286 = 165\,\Omega$$

$$X = \sqrt{Z^2 - R^2} = \sqrt{(576)^2 - (165)^2} = 552\,\Omega$$

$$\theta = \cos^{-1}(0.286) = 73.35^\circ$$

Asco Solenoid

$$Z_1 = \frac{V^2}{VA} = \frac{(120)^2}{41.5} = 347\,\Omega$$

$$\cos\theta = PF = \frac{W}{VA} = \frac{20}{41.5} = 0.482$$

$$\theta = \cos^{-1}(0.482) = 61.22^\circ$$

$$R = Z\cos\theta = 347 \times 0.482 = 167\,\Omega$$

$$X = \sqrt{Z^2 - R^2} = \sqrt{347^2 - 167^2} = 304\,\Omega$$

5.0 COMPUTATION / ANALYSIS (CONT'D)

Agastat Relay

$Z_2 = \frac{V^2}{VA} = \frac{(120)^2}{18} = 800\ \Omega$

$PF = \cos\theta = \frac{W}{VA} = \frac{7}{18} = 0.389$

$\theta = \cos^{-1}(0.389) = 67.12°$

$R = Z\cos\theta = 800 \times 0.389 = 311\ \Omega$

$X = \sqrt{Z^2 - R^2} = \sqrt{800^2 - 311^2} = 737\ \Omega$

Control circuit

Resistance $= 53.50 \times 0.3413\ (\Omega/100')$

$= 18.3\ \Omega$

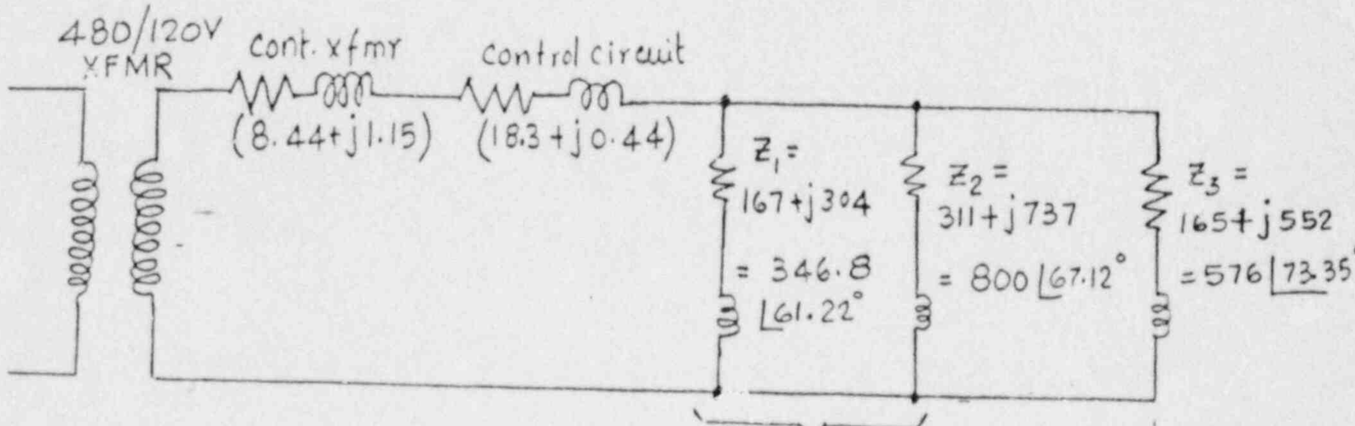
Reactance $= 53.50 \times 0.00825\ (\Omega/100')$

$= 0.44\ \Omega$

SUBJECT: STARTER COIL DROPOUT VOLTAGE PROJECT: SQN-EB-015

COMPUTED BY: B Pai DATE: 2/17/88 CHECKED BY: [initials] DATE: 2/17/88

5.0 COMPUTATION / ANALYSIS (CONT'D)



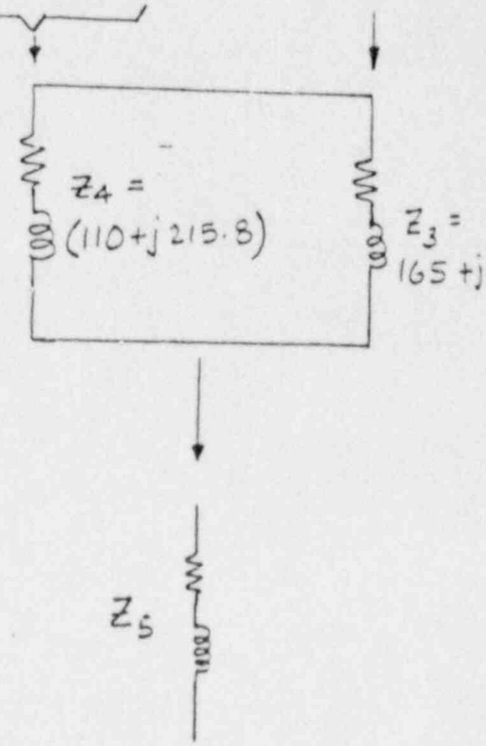
$$Z_1 + Z_2 = 478 + j1041$$

$$= 1145.5 \angle 65.34^\circ$$

$$Z_4 = \frac{346.8 \angle 61.22 \times 800 \angle 67.12^\circ}{1145.5 \angle 65.34}$$

$$= 242.2 \angle 63^\circ$$

$$Z_4 = (110 + j215.8)\,\Omega$$



$$Z_3 + Z_4 = 275 + j767.8$$

$$= 815.6 \angle 70.3^\circ$$

$$Z_5 = \frac{Z_3 \cdot Z_4}{Z_3 + Z_4} = \frac{576 \angle 73.35 \times 242.2 \angle 63^\circ}{815.6 \angle 70.3}$$

$$= 171.0 \angle 66.05$$

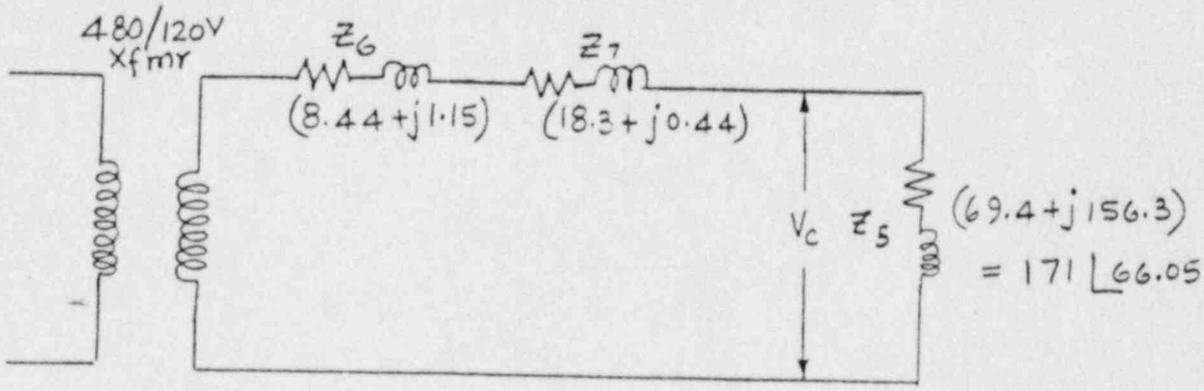
$$= (69.4 + j156.3)\,\Omega$$

SUBJECT STARTER COIL DROPOUT VOLTAGE PROJECT SQN

SQN-E3-015

COMPUTED BY BPai DATE 2/17/88 CHECKED BY SM DATE 2/17/88

5.0 COMPUTATION/ANALYSIS (CONT'D)



$$Z_5 + Z_6 + Z_7 = 96.14 + j\,157.89$$

$$= 184.86 \angle 58.66°$$

Voltage at the MCC when the coil voltage is 0.54 PU

$$V_{MCC} = \frac{0.54 \times 3.7 \times 184.86 \times 110}{171}$$

$$= 237.6\text{V}$$

With 1.4% voltage drop between 480V Switchgear and MCC [REF: APPENDIX ~~D~~ F] BPai 2/18/88

Minimum voltage required at the 480V switchgear } = 237.6 + (0.014 × 480)

= 244.32V

= 50.9% AT 480V

TVA 489H (EN DES-2-78) TENNESSEE VALLEY AUTHORITY SHEET G12 OF

SUBJECT ______ PROJECT ______ SQN-E3-015

COMPUTED BY alal DATE 2/21/88 CHECKED BY Sm DATE 2/22/88

DROP OUT MARGIN

WORST CASE MINIMUM VOLTAGE AT 480V

STDN BD. IS 0.77 PU @ 480V

WORST CASE MINIMUM VOLTAGE AT 480V

MCC IS 0.77 - 0.014 (APPENDIX F)

= 0.756 PU AT 480V

CALCULATED MINIMUM VOLTAGE REQUIRED AT 480V MCC TO ENSURE THAT THE CONTACTOR COIL VOLTAGE IS AT LEAST AT 54 PERCENT (110V BASE) TO PREVENT CONTACTOR DROPOUT IS 237.6 VOLTS = 237.6/480 = 0.495 PU AT 480V

MINIMUM MARGIN IS 0.756 - 0.495

= 0.261 PU AT 480V

= 26 PERCENT AT 480V

[TE]NNESSEE VALLEY AUTHORITY TELECOPY MESSAGE

MACHINE USED TO TRANSMIT: Brand / Model	TRANSMISSION SPEED: 1 2 3 4 6
TVA Verification No.	FTS Verification No.

[TE]LECOPIER / [TE]LEPHONE NO. ▶ 6873

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[NO.] OF PAGES [IN]CLUDING COVER [PA]GE)	DATE TRANSMITTED	TIME TRANSMITTED	SUBJECT
10	2-9-88	10:00 ☑ a.m. ☐ p.m.	Voltage Dropout Tests

NAME: Ken Breene	COMPANY NAME
ADDRESS	TELEPHONE NO. ( )–
NAME: Jerry Wormsley	ACCOUNT NO.
ADDRESS: LP 6SC 1-C	TELEPHONE NO. (615)-697-4337

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[R]ECEIVING OPERATOR — TIME RECEIVED ☐ a.m. ☐ p.m.

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[SP]ECIAL INSTRUCTIONS:

SQN-E3-015
G13

REF. 3.11

TVA 64 (OS-9-65) (OP-WP-5-05)

UNITED STATES GOVERNMENT

Memorandum

TENNESSEE VALLEY AUTHORITY

TO : W. S. Raughley, Chief, Electrical Engineering Branch, DNE, W8 C126 C-K

FROM : Richard L. Morley, Chief, Central Laboratories Services Branch, LA PSC 1-C

DATE : February 8, 1988

SUBJECT: VOLTAGE DROPOUT TESTS FOR ARROW-HART CONTACTORS

The attached report is a summary of data gathered for Ken Greene, Division of Nuclear Engineering (DNE), for evaluation of contactors for Sequoyah Nuclear Plant.

If you need any additional information, please contact me at extension 4317 or Jerry Wormsley at extension 4337.

RLM

SQN-E3-015

G14

JAW:RLM:SWH
0311S/088W

SQN-E3-015
615

DROPOUT VOLTAGE REPORT
FOR
SEQOUYAH NUCLEAR PLANT
ON
ARROW-HART CONTACTORS

J. A. Wormsley, Engineer

J. B. Ragsdale, Jr., QA/QC

R. L. Morley, Chief, CLSB

SQN-E3-015
G16

INVESTIGATION OF CONTACTOR DROPOUT VOLTAGE FOR ARROW HART CONTACTOR

The Central Laboratories Services Branch provided tests for the determination of dropout voltages for certain Arrow Hart contactors for Sequoyah Nuclear Plant. These tests were requested by Ken Greene of the Division of Nuclear Engineering on January 14, 1988 and were performed on January 14 and 15, 1988.

All work performed in conjunction with this test was accomplished with the CLSB Quality Assurance Program which complies with all applicable requirements of 10 CFR 50/Appendix B and ANSI N45.2. Defects are reported in accordance with the requirements of 10 CFR 21.

Tests were performed on four samples. Two were contactors that had been removed from the plant and two were from the plant storeroom. The storeroom's contactors were returned to the plant; one contactor was held at CLSB for other investigations, and the other one was returned to Ken Greene.

The contactor under test was mounted in an approximate vertical position and the voltage and contact conditions monitored. The contacts were monitored in two different manners. Resistance was measured on the first two and current through the coil on the final two contactors that were tested. Tests were made with voltages stepped down in steps and held for generally 10 seconds. Tests were made with rapid drops to the 60 volt level for one contactor. Elevated temperature tests were made on one contactor. The results of the tests are tabulated in Table I through Table VI.

The standards used for this test were:

DESCRIPTION	MANUFACTURER	MODEL	USTVA#	CAL. DATE	DUE DATE
Digital Voltmeter	John Fluke	8400	305628	1-4-88	4-4-88
Digital Multimeter	Keithley	197	537811	11-9-87	2-9-88
Digital Multimeter	Keithley	197	548490	11-25-87	2-25-88
Digital Stopwatch	Micronta	63-5009A	902653	10-1-87	10-1-88
Glass Thermometer	Fisher	---	903322	10-9-87	10-9-88

SQN-E3-015
G17

TABLE I

SAMPLE 1 (removed from plant service)

VOLTS APPLIED	DWELL TIME	CONTACT OHMS	COMMENTS
120	10 Sec.	1.4 ohms	Pickup
110	10 "	1.4 "	
100	10 "	1.4 "	
90	10 "	1.4 "	
80	10 "	1.4 "	Hum begins
70	10 "	5-8 variable	
65	10 "	1-4 variable	
60	10 "	3-6 variable	
55			Dropout 56-59V.
5 Minute interval			
80	10 Sec.	0.6 ohms	Pickup and hum begins
70	10 "	6-20 variable	Hum increase
65	10 "	0.4--0.8 "	" "
60	10 "	6--11 "	" "
55			Dropout 56-57V.
5 Minute interval			
80	10 Sec.	10 ohms	Pickup and hum begins
70	10 "	10-open cir.	Hum increase
65	10 "	2.5 ohms	" "
60	10 "	2.5 "	" "
55	10 "		Dropout at 57 V.
5 Minute interval			
80	10 Sec.	12 ohms	Pickup and hum begins
70	10 "	open circuit	Hum increase
65	10 "	4--15 ohms	" "
60	10 "	3--5 "	" "
55			Dropout at 57 V.

SQN-E3-015
G18

TABLE II

SAMPLE 1 (Contacts cleaned and reassembled. Contact resistance 0.18 ohms)

VOLTS APPLIED	DWELL TIME	COIL CURRENT	COMMENTS
120	10 Sec.	129.1 ma.	Pickup
110	10 "	153.4	
100	10 "	109.1	
90	10 "	91.9	
80	10 "	76.6	
70	10 "	62.9	
65	10 "	55.4	
60	10 "	124	Dropout
1 Minute interval			
90	Rapid drop	----	Pickup
60	60 Sec. Slow drop	62.6 ma.	Dropout 57 V.
1 Minute interval			
90	Rapid drop	----	Pickup
58	No stop	----	Dropout
1 Minute interval			
90	Rapid drop	----	Pickup
60	60 Sec.	----	Dropout 57 V.
1 Minute interval			
90	Rapid drop	----	Pickup
60	60 Sec.	62 ma.	Dropout 57 V.

SQN-E3-015
G19

TABLE III

SAMPLE 2 (removed from plant service)

VOLTS APPLIED	DWELL TIME	CONTACT OHMS	COMMENTS
120	10 Sec.	0.19 ohms	Pickup
110	10 "	0.19 "	
100	10 "	0.19 "	
90	10 "	0.19 "	
80	10 "	0.19 "	
70	10 "	0.19 "	Hum begins
65	10 "	0.19 "	
60	10 "	0.19 "	
55		----	Dropout 54-55V.
5 Minute interval			
80	10 Sec.	0.20 ohms	Pickup
70	10 "	0.19 "	
65	10 "	0.19 "	Hum begins before 60 V.
60	10 "	0.19 "	Hum increase
55		0.19 "	Dropout 54 V.
5 Minute interval			
80	10 Sec.	0.20 ohms	Pickup
70	10 "	0.20 "	
65	10 "	0.20 "	Hum begins before 60 V.
60	10 "	0.20 "	Hum increase
55			Dropout at 54.5 V.
5 Minute interval			
80	10 Sec.	0.20 ohms	Pickup
70	10 "	0.20 "	
65	10 "	0.20 "	Hum begins
60	10 "	0.20 "	Hum increase
55			Dropout at 53.5 V.

NOTE: Coil resistance is 11.7 ohms.

SQN-E3-015
G20

TABLE IV

SAMPLE 2 (Temperature elevated to 45°C. overnight)

VOLTS APPLIED	DWELL TIME	COIL CURRENT	COMMENTS
120	10 Sec.	179.6 ma.	Pickup
110	10 "	149.8	
100	10 "	126.3	
90	10 "	106.7	
80	10 "	88.8	
70	10 "	73.7	
65	10 "	66.3	
60	10 "	58.0	
55	10 "	52.5	Dropout 54 V.
5 Minute interval			
90	10 Sec.	----	Pickup
80	10 Sec.	89.6 ma.	
70	10 "	74.1	
65	10 "	66.5	
60	10 "	59.5	
55	Hold	53.9	Dropout after 30 Sec.
5 Minute interval			
90	10 "	107.3 ma.	Pickup
80	10 "	89.9	
70	10 "	84.0	
65	10 "	66.7	
60	10 "	58.7	
55	30 Sec.	53.4	Dropout 54.6 V.

SQN-E3-015
G21

TABLE V

SAMPLE 3 (Mexico -overlabeled A-H Conneticutt)

VOLTS APPLIED	DWELL TIME	COIL CURRENT	COMMENTS
120	10 Sec.	167.8 ma.	Pickup
110	10 "	141.8	
100	10 "	120.2	
90	10 "	101.7	
80	10 "	85.2	
70	10 "	70.6	Hum begins
65	10 "	65.2	
60	10 "	74.4	
55			Dropout 56.6 V.
5 Minute interval			
90	10 Sec.	102.2 ma.	Pickup
80	10 Sec.	85.6	
70	10 "	70.4	Hum begins at 74 V.
65	10 "	63.3	Hum
60	2 Min.	95-130(incr.)	Hum
55	10 "		Dropout at 59.1 V.
5 Minute interval			
90	10 Sec.	101.7 ma.	Pickup
80	10 Sec.	84.9	
70	10 "	70.4	Hum begins at 73 V.
65	10 "	62.2	Hum
60	1 Min.	63.4	Hum
55	No stop		Dropout at 54.8 V.

SQN-E3-015
G22

TABLE VI

SAMPLE 4 (Mexico -overlabeled A-H Conneticutt)

VOLTS APPLIED	DWELL TIME	COIL CURRENT	COMMENTS
120	10 Sec.	159.0 ma.	Pickup
110	10 "	135.0	
100	10 "	114.6	
90	10 "	96.9	
80	10 "	81.2	
70	10 "	67.2	
65	10 "	60.6	Hum begins at 67 V.
60	10 "	52.8	Hum increase
55	No stop		Dropout 45 V.

5 Minute interval

90	10 Sec.	97.4 ma.	Pickup
80	10 Sec.	81.3	
70	10 "	67.1	
65	10 "	60.4	Hum begins before 65 V.
60	10 "	52.6	Hum increase
55	10 "	49.0	
50	10 "	49.6	
45	10 "	46.8	Dropout at 42.8 V.

5 Minute interval

90	No stop	97.0 ma.	Pickup
60	10 "	54.1	Hum begins before 60 V.
55	10 "	49.5	Hum
50	10 "	49.9	Hum increase
45	10 "	47.0	Dropout at 41.9 V.

SUBJECT: DG VOLTAGE AND MARGIN ANALYSIS PROJECT: SQN

SQN-E3-015

COMPUTED BY: APat DATE: 2/18/88 CHECKED BY: BPai DATE: 2/18/88

APPENDIX - H

CONTACTOR PICKUP VOLTAGE

SUBJECT ______ PROJECT ______

SQN-EB-015

COMPUTED BY [signature] DATE 2/22/88 CHECKED BY [signature] DATE 2/22/88

PURPOSE

TO DETERMINE THE MINIMUM VOLTAGE AT THE MCC SO THAT THE VOLTAGE ACROSS THE STARTER COIL IS 73.6% OF 110 V (81 V) DURING EMERGENCY DIESEL GENERATOR LOAD SEQUENCING; AND TO DETERMINE THE MARGIN BETWEEN THE MINIMUM MCC VOLTAGE AND STARTER PICK UP VOLTAGE.

PROCEDURE

REFER TO APPENDIX - G

VOLTAGE AT MCC WHEN THE COIL VOLTAGE IS 0.736 PU (81 V) [REF. 3.12 ATTACHED] IS

$$V_{MCC} = \frac{81 \times 3.7 \times 184.86}{171}$$

$$= 324 \text{ VOLTS}$$

$$= 0.675 \text{ PU AT } 480\text{V}$$

MINIMUM VOLTAGE REQUIRED AT THE 480V MCC IS 0.675 PU TO ENSURE THAT CONTACTOR COIL VOLTAGE IS AT LEAST 0.736 PU AT 110V (81V) FOR CONTACTOR PICK UP.

SUBJECT ______ PROJECT SQN-E3-015

COMPUTED BY aPal DATE 2/22/88 CHECKED BY Sm DATE 2/22/88

PICKUP MARGIN

MINIMUM VOLTAGE REQUIRED AT THE 480V MCC'S TO ENSURE THAT THE CONTACTOR COIL VOLTAGE IS AT LEAST 0.736PU AT 110V FOR CONTACTOR PICKUP IS 0.675 PU AT 480V

THE MINIMUM ADJUSTED VOLTAGE AT THE 480V MCC WHEN A 480V CONTACTOR CLOSES CONCURRENTLY WITH THE STARTING OF A 6.6 KV MOTOR IS 0.85 PU (SH. H5)

THE MINIMUM MARGIN IS 0.85 - 0.675 = 0.175PU OR 17.5 PERCENT AT 480V.

THE WORST CASE MINIMUM VOLTAGE AT THE 480V MCC IS 0.77 - 0.014 (APPENDIX-F SH. F12)

= 0.756 PU AT 480V

THE MINIMUM MARGIN IS 0.756 - 0.675 PU

= 0.081 PU OR 8.1PERCENT

SUBJECT DG VOLTAGE ANALYSIS AND MARGIN PROJECT SQN-E3-015

COMPUTED BY SM DATE 2/19/88 CHECKED BY aPat DATE 2/22/88

CORRECTION ON CONTACTOR PICKUP DUE TO VARIATION OF GENERATOR IMPEDANCE

The profiles of various voltage and current characteristics of DG 1B at the start of ERCW is shown on attached Figure 5 reproduced from field test traces.

The voltage profile V_T indicates that at start there is an initial sharp drop followed by a slow drop over about next fifteen seconds. The initial drop is basically limited by the generator direct axis subtransient reactance X''_d and the slowly dropping part by the generator direct axis transient reactance X'_d.

Our voltage dip calculations are based on worst case drop which corresponds to the drop at the end of the slowly decaying period.

At the start of a 6.9kV motor, the associated 480V motor contactor will pick up by the end of the initial sharp drop and much before the bus voltage reaches the bottom. For example

SUBJECT ______ PROJECT ______

SQN-E3-015

COMPUTED BY aPal DATE 2/22/88 CHECKED BY aPal DATE 2/22/88

under scheduled load condition, while the worst case maximum voltage drop on the start of the CSP+FP is .242 P.U at the 480V Bd, the associated 480V contactors will pick up before this drop.

From Ref. 3.15 the generator X''d = .242 and X'd = .148.

The initial drop = $\frac{.148}{.242} \times .242 = .148$ P.U.

Thus the voltage available for contactor pick up is 1.012 - .148 = .864 P.U at 480V.

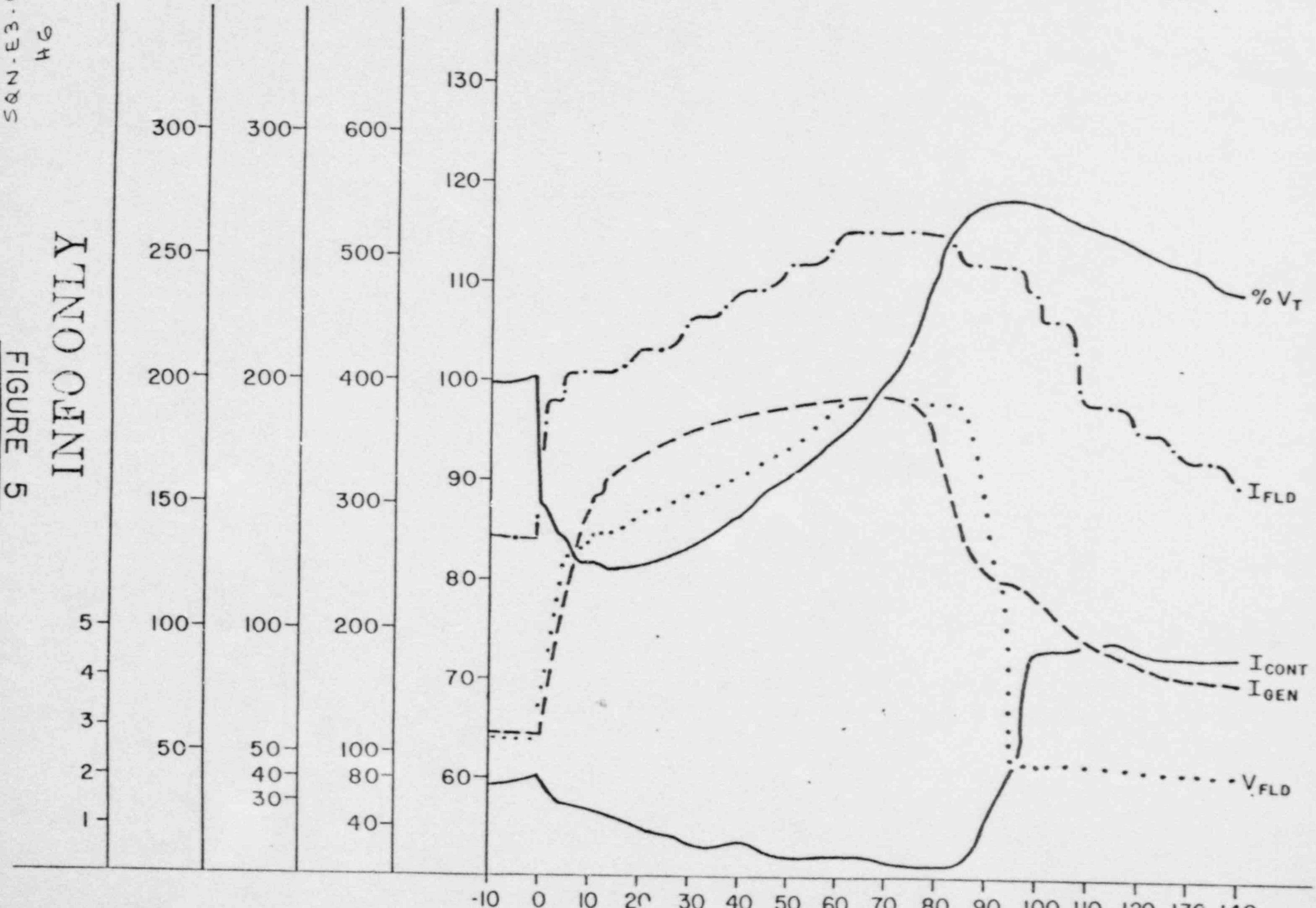
From Appendix F, the worst case drop between the 480V Board and 480V MCC = 0.014 P.U.

So the worst case minimum voltage available at 480V MCC

= .864 - .014 = .85 P.U on 480V base

SQN-E3-015
#6

D/G 1B-B ERCW - START AT 16.11 SEC.



INFO ONLY

FIGURE 5

ENNESSEE VALLEY AUTHORITY TELECOPY MESSAGE

MACHINE USED TO TRANSMIT: Brand	Model	TRANSMISSION SPEED: 1 2 3 4 6

TEL COPIER TELEPHONE NO.	6893	IMPORTANT! IF YOU DO NOT RECEIVE ALL PAGES CALL US BACK AS SOON AS POSSIBLE	TVA Verification No.	FTS Verification No.
NO. OF PAGES (INCLUDING COVER PAGE) 11	DATE TRANSMITTED 2·16·88	TIME TRANSMITTED 3:50 ☐ a.m. ☑ p.m.	SUBJECT Voltage Pickup Tests	

FOR	NAME Keno Greene	COMPANY NAME	
	ADDRESS W 8C174 C-K	TELEPHONE NO. ( )- 0190-K	
FROM	NAME Terry Wormsley	ACCOUNT NO.	
	ADDRESS LA PSC 1-C	TELEPHONE NO. ( )- 4317-C	

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SPECIAL INSTRUCTIONS:

SQN-E3-015
H7

REF. 3.12

TVA 64 (OS-9-65) (OP-WP-5-85)

E13 880216 002

UNITED STATES GOVERNMENT

Memorandum

TENNESSEE VALLEY AUTHORITY

TO : W. S. Raughley, Chief, Electrical Engineering Branch, DNE, W8 C126 C-K

FROM : R. L. Morley, Chief, Central Laboratories Services Branch, LA PSC 1-C

DATE : February 16, 1988

SUBJECT: VOLTAGE PICKUP TESTS FOR ARROW-HART CONTACTORS

The attached report is a summary of data gathered at the Central Laboratories Services Branch (CLSB) for Ken Greene, Division of Nuclear Engineering (DNE). This data is needed for evaluation of contactors at Sequoyah Nuclear Plant.

If you need any additional information, please contact me at extension 4317 or Jerry Wormsley at extension 4337.

RLM

SQN-E3-015

H8

RLM:JAW:SWH
Attachments
cc: RIMS, MR 4N 72A-C
J. K. Greene, W8 C144 C-K

SQN-E3-015
H9

PICKUP VOLTAGE REPORT
FOR
SEQUOYAH NUCLEAR PLANT
ON
ARROW-HART CONTACTORS

J. A. Wormsley, Engineer

J. B. Ragsdale, Jr., QA/QC

R. L. Morley, Chief, CLSB

SQN-E3-015
H10

INVESTIGATION OF CONTACTOR PICKUP VOLTAGE FOR ARROW-HART CONTACTOR

The Central Laboratories Services Branch performed tests for the determination of dropout voltages for certain Arrow-Hart contactors for Sequoyah Nuclear Plant. These tests were requested by Ken Greene of the Division of Nuclear Engineering on February 12, 1988 and were performed on February 13 and 14, 1988.

All work performed in conjunction with this test was accomplished with the CLSB Quality Assurance Program which complies with all applicable requirements of 10 CFR 50/Appendix B and ANSI N45.2. Defects are reported in accordance with the requirements of 10 CFR 21.

Tests were performed on seven samples. Five were contactors that had been removed from the plant and two were from the plant storeroom. The storeroom's contactors were returned to the plant; one contactor was held at CLSB for other investigations, and the others were returned to Ken Greene.

The contactor under test was mounted in an approximate vertical position and the voltage, coil current, and contactor conditions monitored. The data for each contactor tested is provided in table form in TABLE I through TABLE VII.

The instrumentation used for this test were:

DESCRIPTION	MANUFACTURER	MODEL	USTVA#	CAL. DATE	DUE DATE
Digital Multimeter	Keithley	197	548489	1-16-88	3-16-88
Digital Multimeter	Keithley	197	548501	11-25-87	2-25-88
Digital Stopwatch	Micronta	63-5009A	902653	10-1-87	10-1-88
Glass Thermometer	ERTCO	ASTM-17F	S/N83388	2-12-88	2-12-89

SQN-E3-015
H11

TABLE I

SAMPLE 1 (Removed from plant service).

VOLTS APPLIED	DWELL TIME	COIL CURRENT	COMMENTS
45	10 sec.	558.5 ma	No pickup
50	10 "	619.5 "	" "
55	10 "	679.2 "	" "
60	10 "	743.3 "	" "
65	10 "	803.6 "	" " , hum
70	10 "	865.1 "	" " "
75	10 "	930.1 "	" " "
80	---	76.8 "	Pickup, buzz, latched
75	10 "	930.0 "	No pickup, hum
76	10 "	940.8 "	" " "
77	---	72.3 ma	Pickup, buzz, latched
77	10 "	954.9 ma	No pickup, hum
78	10 "	965.1 "	" " "
79	0.5 sec.	75.0 ma	Pickup, buzz, latched
79	10 sec.	973.4 "	No pickup, hum
80	---	76.4 ma	Pickup, buzz, latched
80	---	76.5 "	" " "
80	---	76.6 "	" " "
80	---	76.4 "	" " "
79	10 sec.	973.8 ma	No pickup, hum

Average temperature during test: 71 degrees F.

SQN-E3-015
H12

TABLE II

SAMPLE 2 (Removed from plant service).

VOLTS APPLIED	DWELL TIME	COIL CURRENT	COMMENTS
45	10 sec.	558.7 ma	No pickup
50	10 "	623.3 "	" "
55	10 "	686.1 "	" "
60	10 "	749.0 "	" "
65	10 "	811.3 "	" " , hum
70	10 "	871.8 "	" " "
75	---	82.1 "	Pickup
70	10 "	874.8 "	No pickup, hum
71	10 "	883.9 "	" " "
72	---	77.5 ma	Pickup
72	10 "	896.8 ma	No pickup, hum
72	---	77.2 "	Pickup
73	---	78.9 ma	"
73	---	78.6 "	"
73	---	78.8 ma	Pickup

Average temperature during test: 71 degrees F.

SAN-E3-015
H13

TABLE III

SAMPLE 3 (Overlabeled Arrow-Hart, from plant storeroom).

VOLTS APPLIED	DWELL TIME	COIL CURRENT	COMMENTS
45	10 sec.	564.6 ma	No pickup
50	10 "	626.7 "	" "
55	10 "	690.2 "	" "
60	10 "	753.6 "	" "
65	---	63.0 ma	Pickup, loud buzz
65	---	62.3 ma	" " "
60	10 sec.	753.2 "	No pickup, hum
61	10 "	765.7 "	" " "
62	10 "	776.2 "	" " "
63	---	59.8 "	Pickup, loud buzz
63	---	60.0 ma	" " "
63	---	59.6 "	" " "
63	10 sec.	787.4 "	No pickup, hum
64	---	61.2 "	Pickup, loud buzz
64	10 sec.	798.4 "	No pickup, hum
65	---	62.8 "	Pickup, loud buzz
65	---	62.3 "	" " "
65	---	62.2 "	" " "
65	---	62.3 "	" " "

Average temperature during test: 72 degrees F.

SQN-E3-015
H14

TABLE IV

SAMPLE 4 (Overlabeled Arrow-Hart, from plant storeroom).

VOLTS APPLIED	DWELL TIME	COIL CURRENT	COMMENTS
45	10 sec.	571.2 ma	No pickup
50	10 "	636.5 "	" "
55	10 "	698.5 "	" "
60	10 "	760.9 "	" "
65	---	60.4 ma	Pickup, buzz
60	10 sec.	760.1 "	No pickup, hum
61	10 "	772.7 "	" " , loud hum
62	10 "	783.5 "	" " " "
63	10 "	794.7 "	" " " "
64	---	58.0 "	Pickup, buzz
64	10 sec.	805.4 "	No pickup, hum
64	---	58.6 ma	Pickup, buzz
64	10 sec.	805.1 "	No pickup, hum
65	---	60.2 "	Pickup, buzz
65	10 sec.	816.4 "	No pickup, hum
65	10 "	816.2 "	" " "
66	10 "	828.3 "	" " "
66	10 "	829.3 "	" " "
66	---	60.7 "	Pickup, buzz
66	---	61.7 "	" "
66	---	60.3 "	" "
66	10 sec.	828.1 ma	No pickup, hum
67	---	63.0 "	Pickup, hum
67	---	62.9 "	" "
67	---	63.1 "	" "
67	---	62.9 "	Pickup, no hum
67	---	62.8 "	" " "
67	---	62.9 "	Pickup, buzz
67	---	62.9 "	Pickup, hum
67	---	62.8 "	Pickup, no hum

Average temperature during test: 72 degrees F.

SQN-E3-015
H15

TABLE V

SAMPLE 5 (Labeled Federal Pacific Electric; removed from plant.)

VOLTS APPLIED	DWELL TIME	COIL CURRENT	COMMENTS
45	10 sec.	567.5 ma	No pickup, hum
50	10 "	630.5 "	" " "
55	10 "	694.4 "	" " "
60	10 "	756.5 "	" " "
65	10 "	820.3 "	" " "
70	---	76.2 "	Pickup, buzz
70	---	76.2 "	" "
65	---	68.2 "	" "
65	---	68.3 "	" "
65	10 sec.	821.6 ma	No pickup, hum
66	---	70.1 "	Pickup, buzz
66	---	69.9 "	" "
66	---	69.8 "	" "
66	---	69.9 "	" "
66	---	69.9 "	Pickup, buzz

Average temperature during test: 72 degrees F.

SQN-E3-015
H16

TABLE VI

SAMPLE 6 (Mechanical lockout device tied to Sample 7 and reset to rest against Sample 6).

VOLTS APPLIED	DWELL TIME	COIL CURRENT	COMMENTS
45	10 sec.	561.9 ma	No pickup, hum
50	10 "	625.7 "	" " "
55	10 "	688.6 "	" " "
60	10 "	748.4 "	" " "
65	10 "	812.8 "	" " "
70	10 "	875.9 "	" " "
75	10 "	704.7 "	Pickup, no latch, loud buzz
80*	---	88.2 "	Pickup, latch, buzz
80	10 sec.	741.8 "	Pickup, no latch, loud buzz
80	10 "	743.4 "	" " " " "
81	---	89.8 "	Pickup, latch, buzz
81	10 sec.	749.8 "	Pickup, no latch, loud buzz
81	10 "	749.4 "	" " " " "
82	---	91.4 "	Pickup, latch, buzz
82	---	91.4 "	" " "
82	---	91.2 "	" " "
82	---	91.2 "	" " "
82	---	91.2 "	" " "
83	---	93.4 "	" " "
81	---	89.6 "	" " "
81	---	89.4 "	" " "
81	10 sec.	748.1 "	Pickup, no latch, loud buzz
81	---	89.1 "	Pickup, latch, buzz

*NOTE: Delete-not mechanically reset to rest on Sample 6.

Average temperature during test: 72 degrees F.

TABLE VII

SAMPLE 7 (Mechanical lockout device tied to Sample 6 and reset to rest against Sample 7).

VOLTS APPLIED	DWELL TIME	COIL CURRENT	COMMENTS
45	10 sec.	566.6 ma	No pickup, hum
50	10 "	629.7 "	" " "
55	10 "	692.3 "	" " "
60	10 "	756.3 "	" " "
65	10 "	818.4 "	" " "
70	10 "	881.7 "	" " "
75	10 "	689.2 "	Pickup, no latch, loud buzz
80	10 sec.	726.9 "	" " " "
85	---	100.8 "	Pickup, latch, quiet
81	---	93.7 "	" " "
81	---	93.8 "	" " "
81	---	93.9 "	" " "
81	---	93.7 "	" " "
81	---	94.6 "	" " "
80	---	92.8 "	" " "
80	---	92.8 "	" " "
79	10 sec.	718.9 "	Pickup, no latch, loud buzz

Average temperature during test: 72 degrees F.

REF. 3.15

SQN-E3-015 H18

SERIAL NO. 17105018/21	200	A. C. SYNCHRONOUS GENERATOR DATA	SALES ORDER NO. 17105018/21	DATE 6/7/71

[illegible] .0805	KVA 5000	VOLTS 6900	AMPS 418	PHASE 3 (6 wire)	HERTZ 60
FRAME 140	INSUL. CLASS B	P.F. .8	POLES 8	DUTY Cont.	RPM 900

GENERATOR:

1	Direct Axis Synchronous Reactance (Unsaturated)	Xd	1.57	P.U.
2	Quadrature Axis Synchronous Reactance (")	Xq	.776	P.U.
3	Direct Axis Transient Reactance (Rated Voltage)	X'd	.242	P.U.
4	Direct Axis Subtransient Reactance (" ")	X"d	.148	P.U.
5	Quadrature Axis Subtransient Reactance (" ")	X"q	.165	P.U.
6	Zero Sequence Reactance (" ")	Xo	.114	P.U.
7	Negative Sequence Reactance (" ")	X2	.156	P.U.
8	Direct Axis Transient Open Circuit Time Constant	T'do	4.08	Sec.
9	Short Circuit Transient Time Constant	T'd	.77	Sec.
10	Short Circuit Subtransient Time Constant	T"d	.045	Sec.
11	Synchronous Impedance Unit on Rated KVA Base		9.54	Ohms
12	Short Circuit Ratio	SCR	.71	
13	Field Resistance at 25 Deg. C	[illegible]	.495	Ohms
14	Field Current at Full Load, Rated Voltage and Power Factor		148 *	Amps
15	Field Current at No Load, Rated Voltage		68.2	Amps
16	Field Current at No Load 60% Volts		37.3	Amps
17	Continuous Duty Field Voltage		111.5	Volts
18	Inherent Regulation		40%	%
19	Recommended Field Discharge Resistor 1.0	Ohms	50	Amps
20	Synchronizing Power Coefficient at No Load	PrNL	6480	KW/El.Rad
21	Synchronizing Power Coefficient at Full Load	PrFL	9050	KW/El.Rad
22	Unbalance Magnetic Pull at .031" Displacement	Pd (1/IN)	9000	Lbs.
23	Magnetization Characteristics		Curve No. 2310	

STATIC EXCITATION

SERIAL NO.	600	D.C. EXCITER DATA	TYPE L-

KW	VOLTS	AMP	RPM	INSUL. CLASS

2	[Fiel]d Resistance at 25 Deg. C		Ohms
3	Recommended Rheostat: Plate(s)	Ohms	Amps
4	Saturation Curve	Curve No.	

*Rev. was 146 - 6/14/71

TVA 489H (EN DES-2-78) TENNESSEE VALLEY AUTHORITY SHEET I1 OF

SUBJECT D.G. VOLTAGE ANALYSIS PROJECT SQN-E3-015

COMPUTED BY afal DATE 1/22/88 CHECKED BY Sm DATE 1/22/88

APPENDIX - I

JUSTIFICATION OF INSTANTANEOUS SETTINGS OF MOTOR PROTECTIVE DEVICES

NOTE: THIS APPENDIX IS TAKEN FROM CALC. SQN-E3-011 REV. 2

SUBJECT DG VOLTAGE ANALYSIS PROJECT

COMPUTED BY afal DATE 1/22/88 CHECKED BY [signature] SQN-E3-015 DATE 1/22/88

6.6 KV MOTORS

Maximum voltage prior to start of 6.6 KV motor when fed from D/G is 7.49 kV [See sh A5 - A9]

Max. Voltage = 7.49 / 6.6 = 1.135 PU @ 6.6 KV base.

DC offset = 1.6

ILRA (including D.C offset) = 1.6 × 1.135

= 1.816 PU

Instantaneous setting of overcurrent relay shall be

$$\frac{1.816}{*0.9} = 2.02 \text{ PU} \simeq 2 \text{ PU OF LRA}$$

* relay tolerance

460V MOTORS

Maximum voltage prior to start of 460V motor when fed from D/G is 520V [See sh A10 & A11]

Max. Voltage = 520/460 = 1.13 PU @ 460V base

DC off set = 1.6

ILRA (including DC offset) = 1.6 × 1.13 = 1.81 PU

Instantaneous setting of breaker shall be $\frac{1.81}{*0.9}$ = 2.01 PU

* breaker tolerance.

≃ 2 PU OF LRA

TVA 489H (EN DES-2-78) TENNESSEE VALLEY AUTHORITY SHEET 13 OF

SUBJECT ________ PROJECT SQN-E3-015

COMPUTED BY ata DATE 1/22/88 CHECKED BY R DATE 1/25/88

The instantaneous setting of 6.6KV and 460V CCS motors were reviewed and it was determined that ERCW and CCS motors instantaneous setting were set less than 2PU of LRA. The DCN 139A and 140A were issued to change the instantaneous setting of ERCW and CCS motors to atleast 2PU LRA.

SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT SQN

SQN-E3-015

COMPUTED BY aPal DATE 2/17/88 CHECKED BY BFai DATE 2/18/88

APPENDIX - J

OVERVOLTAGE ANALYSIS

NOTE: THIS APPENIX IS TAKEN FROM CALC. SQN-E3-011 REV. 2

SUBJECT D.G VOLTAGE ANALYSIS PROJECT SQN-E3-015

COMPUTED BY [signature] DATE 1/22/88 CHECKED BY [initials] 1/27/88 DATE 1/22/88

EFFECTS OF D.G. OVERVOLTAGE

Diesel Generator field test results (sheet 44) demonstrate that the D.G. produced a worst case overvoltage of 8.24kv at the 6.9kV shutdown Board during the emergency loading sequence. This is equivalent to 8.24/6.6 = 1.25 p.u voltage on 6.6kV base. The maximum permissible for continuous operation of electrical equipment is 1.1 p.u. voltage.

The diesel generators being for emergency operation will very rarely operate isolated from the power system. In normal testing they will be paralleled with the power system which will damp out the voltage excursions we have observed during the testing. The voltage excursions that take place during the first 30 seconds of the load sequencing period can only occur during the loss of offsite power event or during surveillance testing every 18 months. After the first 30 seconds, the voltage regulator brings the diesel generator voltage to the rated voltage of 6.9 kV. During this sequencing mode, the voltage excursion above 7.26 (1.10 of 6.6 kv) is for a total of approx 11 seconds with each of the spikes lasting approx 1 second

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In general the insulation of electrical equipment can withstand higher voltage for such short duration. The test voltage for overpotential (Hipot) test is two times the rated voltage plus 1000 volts (14.2 KV for 6.6 KV system) for one minute.

The limits of over-excitation of transformers are given in IEEE Transactions, Volume PAS-85, NO. 8, August 1966. This specifies the followings as the permissible transient over-excitation levels for power transformers under loaded operation.

Time in Sec	Volt/Hertz
0	1.35
7.5	1.25
15	1.20
30	1.18
60	1.15
Continuous	1.05

The transformers rated at 6.9 kV can withstand 1.2×6.9 = 8.28 kV for 15 seconds and are above the worst case generator voltage profile of 8.24 KV. The minimum frequency recorded

SUBJECT D. G. VOLTAGE ANALYSIS PROJECT SQN-E3-015

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during the test is 56 Hz but the total duration duration below 59.5 Hz is for less than 2 seconds.

The worst case 6.6 kV motor volt/hertz on starting is

$$= \frac{8.24\,kV}{6.6\,kV} \Big/ \frac{60\,Hz}{60\,Hz} = 1.25 \text{ P.u Volt/Hz}$$

The 8.24 kV used in the above calculation is the worst case board voltage. The worst case board voltage at the start of any 6.6 kV motor is 7.62 kV and the corresponding volt/hertz is

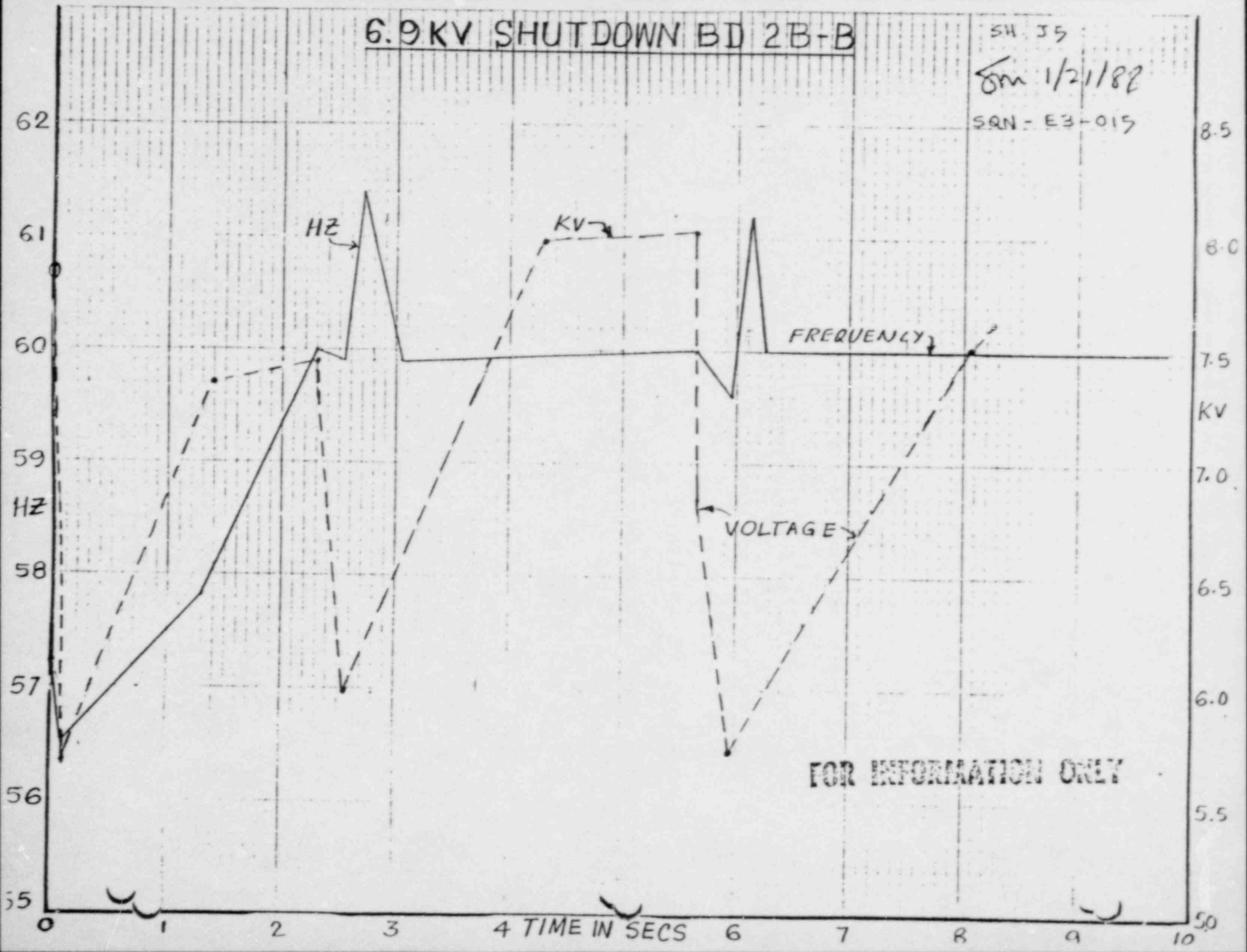
$$= \frac{7.62}{6.6} \Big/ \frac{60}{60} = 1.15 \text{ P.U. Volt/Hz}.$$

The graphs in sheets 290-294 shows that the maximum board voltage and frequency do not occur at the same instant and because of that no correction is required for the frequency dip in this evaluation.

The calculation SQN-APS-005 Rev.1, indicates worst case Volt/Hertz of 1.2835 on Fast Bus Transfer.

The ANSI C50.41-1977 requires motor to be designed for 1.33 p.u Volt/Hertz.

Considering above facts, it is concluded that D.G voltage excursion will not be a concern to any other equipment.



FOR INFORMATION ONLY

SUBJECT DG SPECIAL TEST RESULTS PROJECT SQN

M.D. Bowman 1/20/88
COMPUTED BY DATE CHECKED BY DATE

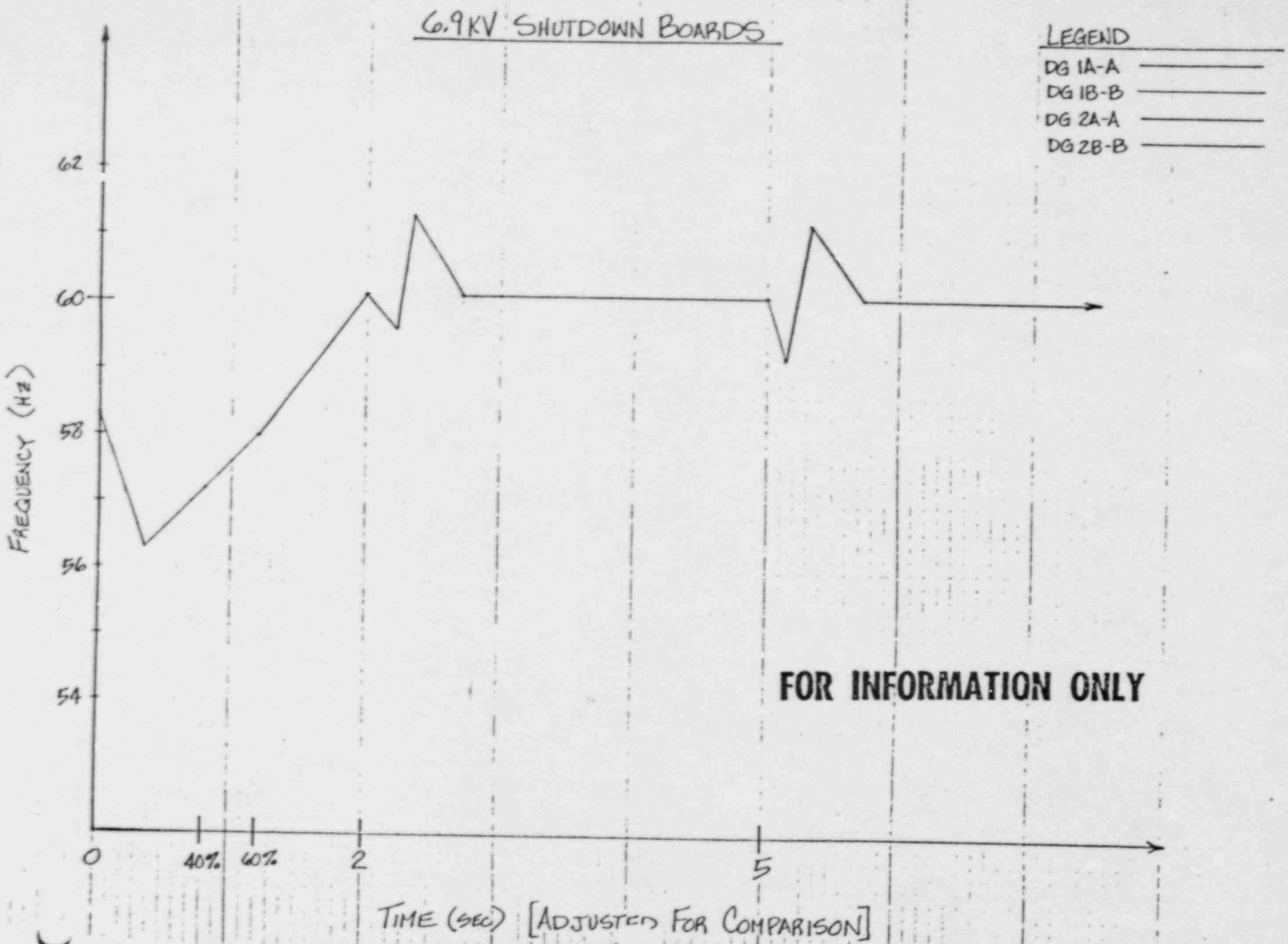
	DG 1A-A		DG 1B-B		DG 2A-A		DG 2B-B	
TIME SEQUENCE	f	time	f	time	f	time	f	time
0	58.3	0	56.9	0	57.9	0	57.1	0
DIP	56.3	0.34	56.5	0.6	57.0	0.15	56.4	0.15
40%	57.2	—	57.4	—	58.9	—	57.1	—
60%	58.0	—	57.4	—	59.4	—	57.8	—
2sec nom.	60.1	—	60.0	—	60.4	—	59.9	—
DIP	59.6	0.21	58.6	0.11	59.7	0.3	59.8	0.24
PEAK	61.3	0.34	61.1	0.21	60.9	0.52	61.4	0.41
SS	60.1	0.71	60.0	0.43	60.4	0.76	59.9	0.75
5sec nom.	60.1	—	60.0	—	60.2	—	59.9	—
DIP	59.2	0.13	59.3	0.21	59.4	0.36	59.5	0.28
PEAK	61.2	0.31	61.1	0.40	61.1	0.45	61.0	0.41
SS	60.1	0.73	60.0	0.60	60.2	0.60	60.0	0.55

DATA EXTRACTED FROM 6.9KV STRIPCHARTS USING THE FOLLOWING FORMULA:

$$f = \left[\frac{l_{(1\,second)}}{l_{(5\,cycles)}}\right] \times \left(\frac{60}{12}\right), \quad \text{where } l = \text{scaled length},\ f = \text{frequency in Hz}$$

FOR INFORMATION ONLY

DSL GEN | 1A-A TEST RESULTS
SQN-E3-015 SH 37



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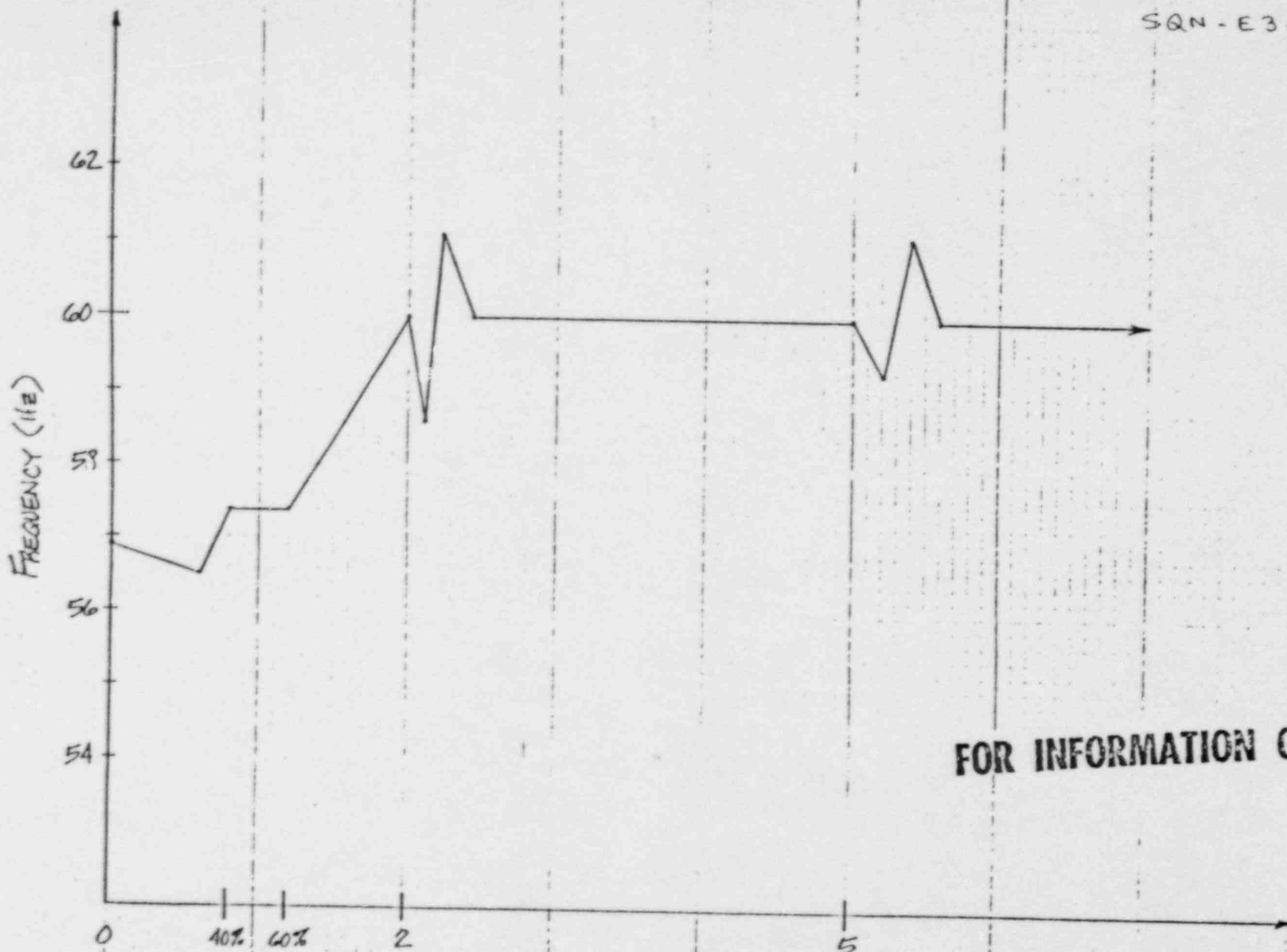
DSL GEN 1B-B TEST RESULTS

Sh. 38
SQN-E3-015



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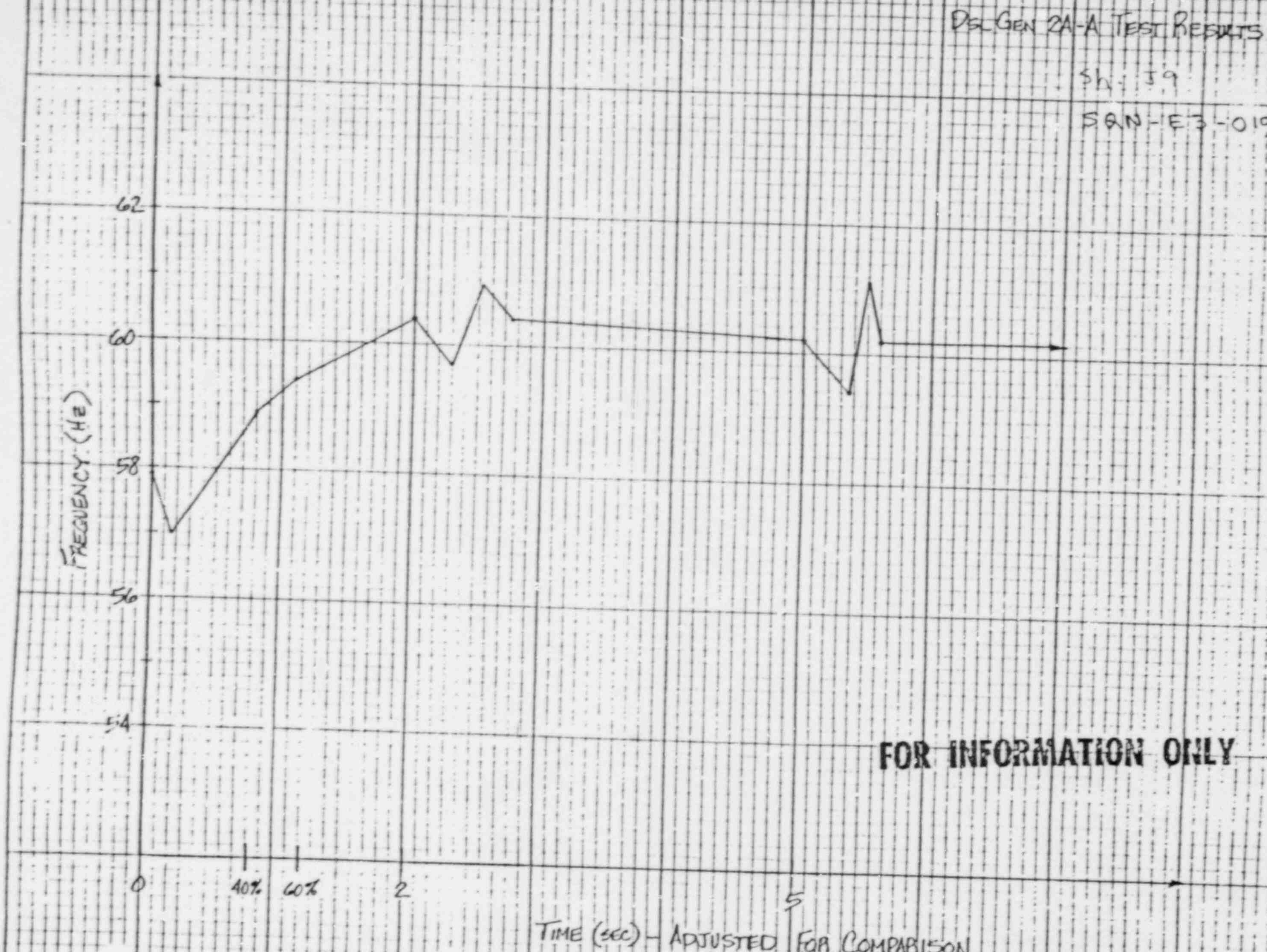
M. D. Bowman 1/28/88



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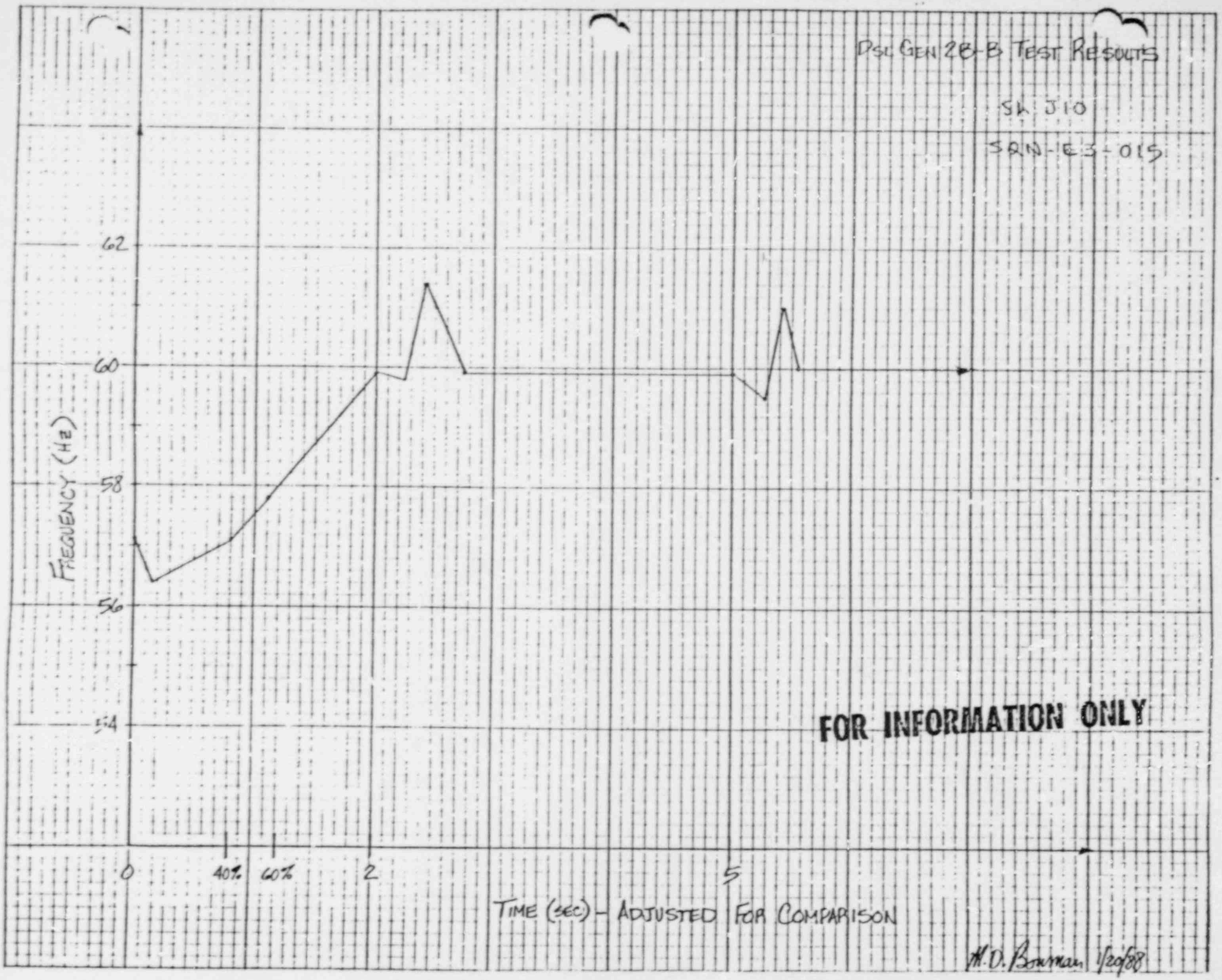

DSL GEN 2B-B TEST RESULTS
Sh. J10
SRN-E3-015
FREQUENCY (Hz)
62
60
58
56
54
0
40%
60%
2
5
TIME (SEC) - ADJUSTED FOR COMPARISON
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SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT SQN
SQN-E3-015

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APPENDIX - K

MOV STROKE TIMES

SUBJECT DG VOLTAGE AND MARGIN ANALYSIS PROJECT SQN
SQN-E3-015

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PURPOSE:

Establish the worst case stroke time margin available on all motor operated valves (MOV's) that would be actuated during the diesel generator loading sequence due to a design basis event.

DESIGN INPUT:

From Ref. 3.6 all the MOV'S fed from 480V Reactor MOV Boards 2A1-A, 2A2-A, 2B1-B, AND 2B2-B for Phase B Safety Injection during diesel generator load sequencing are recorded in Table-K1, Column ①. Actual tested valve stroke times are listed in column ③.
From Ref. 3.13 (copy attached) the corresponding design criteria stroke time is recorded in column ②.

Ref. 3.14 demonstrates that all the valves listed in Table-K1 will operate satisfactorily with 80% rated voltage with many valves operating satisfactorily at 75% rated voltage.

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CALCULATION:

In Table K1, subtracting column ③ from column ②, the time margin is recorded in column ④ in seconds and in column ⑤ as a percentage of column ③.

Column ⑤ indicates that the worst case margin is 5.3 percent based on stroke time.

Ref. 3.14 indicates that all MOV's will operate satisfactorily at 80% of their rated voltage which is 460V. This corresponds to 80 x 460/480 = 77% of 480V shutdown board voltage.

From Appendix F, we observe a worst case voltage drop of 2.4% for MOV Cable. So worst case voltage at 480V board need be 77+2.4 ≃ 80%.

Fig. B-2 indicates that the 480V board voltage has an average value approximately 95 percent. Converting to 460V MOV rated voltage, this average voltage corresponds to 95 x 480/460 ≃ 100% rated voltage.

These MOV's are subjected to maximum load at start. Satisfactory operation of a MOV at 80% rated voltage demonstrates that

SUBJECT ________ PROJECT SQN

SQN-E3-015

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Voltage Margin

Fig B-2 indicates that the 480V board voltage has an average value of approximately 95% of 480V.

All MOVs will operate satisfactorily at 80% of 460V which corresponds to

$80 \times \frac{460}{480} = 77\%$ of 480V.

Therefore, the voltage margin = 95-77

= 18%

the MOV motors must produce at least the required load torque at 80% voltage or will produce $(100/80)^2 = 156\%$ required load torque when the average sequence voltage is 100%. Thus, the test voltage profile of the 480V Board corrected for scheduled load ensures that the motors will actually provide a 56% margin in torque performance

Evaluation of column (5) of Table K-1 indicates that there is a minimum 5.3 percent margin in worst case stroke time. The results of this column are summarized as follows:

Total # of MOV's	= 58	
Margin above 100%	= 37	37/58 = 64%
Margin between 10% & 100%	= 18	18/58 = 31%
Margin between 5% & 10%	= 3	3/58 = 5%

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SQN-E3-015

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Evaluation of Column ④ of Table K-1 indicates that there are 8 valves that have less than 2 second margin. These are shown below:

Valve #	Description	Design Stroke Time	MOVAT's Test stroke time	Margin in secs.
FCV-63-26	SIS BORON INJ TK SHTOFF VLV	10	9.1	0.9
FCV-63-39	SIS BOR INJ TK INLET SHTOFF VLV	10	8.5	1.5
FCV-3-33	STM GEN FDWTR ISOL VLV.	7.5	6.1	1.4
FCV-3-87	STM. GEN FDWTR ISOL VLV.	7.5	6.1	1.4
FCV-63-25	SIS BORON INJ TANK SHTOFF VLV	10	9.3	0.7
FCV-63-40	SIS BORON INJ TANK INLET SHTOFF VLV	10	8.8	1.2
FCV-3-47	STM GEN FDWTR ISOL VLV	7.5	6.3	1.2
FCV-3-100	STM GEN FDWTR ISOL VLV	7.5	6.2	1.3

A review of the Diesel Generator Loading Analysis reveals all the above valves start at time t=0. Since the stroke times for the above valves

SUBJECT ______ PROJECT SQN

SQN-E3-015

COMPUTED BY BPai DATE 2/22/88 CHECKED BY Sm DATE 2/22/88

are equal to or less than 10 secs these valves will not see less than 80% of their rated voltage.

Per Table - B2

SEQ. Time	PU Min Bus Voltage	Cable (worstcase) impedancedrop	PU Minm Voltage at the MOV
0 secs	1.06	0.024	1.036
2	0.837	0.024	0.813
5	0.84	0.024	0.816
10	0.833	0.024	0.809

The minimum voltage that MOV will see = **0.809 PU of 480V**

SUBJECT PROJECT SQN
SQN-E3-015

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CONCLUSION:

This detail analysis demonstrates that the MOV motors will have enough voltage to overcome the worst case load torque requirement by a margin of 56% and worst case stroke time by a margin of 5.3%.

The MOV's have a voltage margin of 18%.

SQN-E3-015

COMPUTED Blai DATE 2/19/88
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SUMMARY OF MOV STROKE TIME MARGIN

TABLE-K1

VALVE # ①	DESIGN CRITERIA STROKE TIME SEC ②	MOVAT'S TEST STROKE TIME SEC ③	MARGIN ④ = ② - ③ SEC	MARGIN ⑤ = 100④/②
FCV-62-63	20	8.4	11.6	138
FCV-62-90	15	10.8	4.2	39
LCV-62-132	20	9.2	10.8	117
LCV-62-135	40	10.6	29.4	277
FCV-72-34	10	5.9	4.1	70
FCV-72-39	60	14.3	45.7	320
FCV-74-12	10	7.4	2.6	35
FCV-63-26	10	9.1	0.9	10
FCV-63-39	10	8.5	1.5	18
FCV-3-116B	42	THESE VALVES WILL NOT BE ENERGIZED FOR FIRST THREE MINUTES.		
FCV-3-116A	42			
FCV-3-136A	55			
FCV-3-136B	55			
FCV-67-83	60	21.0	39.0	186
FCV-67-87	70	58.8	11.2	19
FCV-67-91	60	22.2	37.8	170
FCV-67-95	70	60	10	17
FCV-67-104	60	28.1	31.9	114
FCV-67-112	60	29.5	30.5	103
FCV-67-130	60	20.9	39.1	187
FCV-67-133	60	20.9	39.1	187
FCV-67-139	60	20.3	39.7	196
FCV-67-142	60	20.8	39.2	188
FCV-67-295	60	20.2	39.8	197
FCV-67-296	60	[illegible]0.8	39.2	188
FCV-26-243	20	7.3	12.7	174
FCV-70-143	60	23.4	36.6	156
FCV-70-90	60	17.8	42.2	237
FCV-70-92	60	21.8	38.2	175
FCV-70-133	15	NON ACTIVE		
FCV-70-139	30	NON ACTIVE		
FCV-26-240	20	7.2	12.8	178
FCV-3-33	7.5	6.1	1.4	[illegible]
FCV-3-87	7.5	6.1		

TABLE-K1

VALVE #	DESIGN CRITERIA STROKE TIME SEC	MOVAT'S TEST STROKE TIME SEC	MARGIN	
			SEC	%
FCV-62-61	20	8.1	11.9	147
FCV-62-91	15	9.5	5.5	58
LCV-62-136	40	10	30	300
FCV-63-25	10	9.3	0.7	7.5
FCV-63-40	10	8.8	1.2	13.6
FCV-72-2	60	14.5	45.5	314
FCV-72-13	10	5.8	4.2	72
FCV-74-24	10	7.5	2.5	33
LCV-62-133	20	8.7	11.3	130
FCV-3-126B	42	THESE VALVES FOR FIRST THREE	WILL NOT BE MINUTES.	ENERGIZED
FCV-3-126A	42			
FCV-26-241	20	7.2	12.8	178
FCV-67-88	60	27.4	32.6	119
FCV-67-96	60	28.5	31.5	111
FCV-67-99	60	22.3	37.7	169
FCV-26-244	20	7.2	12.8	178
FCV-67-103	70	62.9	7.1	11
FCV-67-107	60	33.3	26.7	80
FCV-67-111	60	57	3	5.3
FCV-67-131	60	20.6	39.4	191
FCV-67-134	60	20.7	39.3	190
FCV-67-138	60	20.6	39.4	191
FCV-67-141	60	20.6	39.4	191
FCV-67-152	60	38.6	21.4	55
FCV-67-297	60	21.0	39.0	186
FCV-67-298	60	19.2	40.8	213
FCV-3-179B	55	THESE VALVES FOR FIRST THREE	WILL NOT BE MINUTES	ENERGIZED
FCV-3-179A	55			
FCV-70-87	60	18.0	42	233
FCV-70-89	60	55.1	4.9	8.9
FCV-70-134	60	18.0	42	233
FCV-70-140	60	22.4	37.6	168
FCV-3-47	7.5	6.3	1.2	19
FCV-3-100	7.5	6.2	1.3	21

K-11

TVA 10587 (OE-8-85)

RIMS ACCESSION NUMBER

SQN-E3-015

EXCEPTION REQUEST AND APPROVAL FORM

Design Criteria Number: SQN-DC-V-2.15	Exception Number: EX-SQN-DC-V-2.15-3
Section(s): 4.4(9)	Plant and Unit(s): SEQUOYAH Units 1 and 2

☐ Check if Approved with Qualifications

REQUEST	APPROVAL
Prepared: Kelly Ann Craig	Prepared: K. R. Turnbull / ABC
Approved: M R Belew	Checked: A. B. Carrey
Date: 1/20/88	Approved: VA Binns
	Date: 1/20/88

A. Summary Description of Exception

This grants exemptions to the containment isolation valve stroke time requirements for the containment isolation valves listed herein.

B. Detailed Description and Justification of Exception

The valves listed on the attached sheet are exempted from meeting the containment isolation valve stroke time requirements.

The basis for this exemption is that a finite amount of time is required for an accident to progress to the point of fuel overheating and the subsequent release of fission products to the containment atmosphere. The few additional seconds required for the valves to close is not sufficient for degraded core fission products to be released to the containment atmosphere, much less excape through these lines which penetrate containment. For this reason, this exception is acceptable. This exception allows for degraded voltage. The probability of the response time increasing due to degraded voltage is small.

cc: RIMS, SL26 C-K

K-12

SQN-E3-015

C. Safety Considerations

Based on the discussion in Section B, there will be no detrimental effect upon the ability to 1) safely shut the plant down, or 2) mitigate offsite doses post accident as required in 10CFR100.

D. Originating Organization Evaluation and Qualification

This change is acceptable only for those valves and times specifically listed herein (see attachment).

K-13

SQN-EB-015

ATTACHMENT

EXCEPTION SQN-DC-V-2.15-3
VALVE LISTING

VALVE #	STROKE TIME	LINE ID
67-87	70 SEC	ERCW
67-95	70 SEC	ERCW
67-103	70 SEC	ERCW

VALVE I.D.	VLV & LINE SIZE (INCHES)	CLOSURE TIME (SEC)	REFERENCE
FCV-62-63	4*	20	47W809-1
FCV-62-90	3*	15	"
LCV-62-132	4*	20	"
LCV-62-135	8*	40	"
FCV-72-34	2*	10	47W812-1
FCV-72-39	12*	60	"
FCV-74-12	2*	10	47W810-1
FCV-63-26	-	10	QIR SQP-87-529 (B25871002002)
FCV-63-39	-	10	"
FCV-3-116 A&B	-	42	DIM-SQN-DC-V-13.9.8-5
"	-	42	QIR-SQP-SQN-88-185 (B25880222023)
FCV-3-136 A&B	-	55	DIM-SQN-DC-V-13.9.8-5
FCV-67-83	-	60	EX-SQN-DC-V-2.15-1
FCV-67-87	-	70	EX-SQN-DC-V-2.15-3
FCV-67-95	-	70	"
FCV-67-91	-	60	EX-SQN-DC-V-2.15-1
FCV-67-104	-	60	"
FCV-67-112	-	60	"
FCV-67-130	-	60	"
FCV-67-133	-	60	"
FCV-67-139	-	60	"
FCV-67-142	-	60	"
FCV-67-295	-	60	"
FCV-67-296	-	60	"
FCV-26-240	4*	20	" & 47W850-1
FCV-26-243	4*	20	" & 47W850-10
FCV-70-143	-	60	EX-SQN-DC-V-2.15-1
FCV-70-90	-	60	"
FCV-70-92	-	60	"
FCV-70-133	3*	15	47W859-3
FCV-70-139	6*	30	47W859-2
FCV-3-33	-	7.5	QIR SQP-87-529 (B25871002002)
FCV-3-87	-	7.5	"
FCV-62-61	4*	20	47W809-1
FCV-62-91	3*	15	"
LCV-62-136	8*	40	"
FCV-63-25	-	10	QIR SQP-87-529 (B25871002002)
FCV-63-40	-	10	"
FCV-72-2	12*	60	47W812-1
FCV-72-13	2*	10	"
FCV-74-24	2*	10	47W810-1
LCV-62-133	4*	20	47W809-1

FCV-3-126 A&B	-	42	DIM-SQN-DC-V-13.9.8-5
"	-	42	QIR-SQP-SQN-88-185 (B25880222023)
FCV-26-241	4*	20	47W850-10
FCV-26-244	4*	20	"
FCV-67-88	-	60	EX-SQN-DC-V-2.15-1
FCV-67-96	-	60	"
FCV-67-99	-	60	"
FCV-67-103	-	70	EX-SQN-DC-V-2.15-3
FCV-67-107	-	60	EX-SQN-DC-V-2.15-1
FCV-67-111	-	60	"
FCV-67-131	-	60	"
FCV-67-134	-	60	"
FCV-67-138	-	60	"
FCV-67-141	-	60	"
FCV-67-152	-	60	"
FCV-67-297	-	60	"
FCV-67-298	-	60	"
FCV-3-179 A&B	-	55	DIM-SQN-DC-V-13.9.8-5
FCV-70-87	-	60	EX-SQN-DC-V-2.15-1
FCV-70-89	-	60	"
FCV-70-134	-	60	"
FCV-70-140	-	60	"
FCV-3-47	-	7.5	QIR SQP-87-529 (B25871002002)
FCV-3-100	-	7.5	"

* These valve closure times were obtained by using DIM-SQN-DC-V-2.15-2. This DIM states that valves less than 2 inches have closure times of 10 seconds, valves between 2 and 12 inches have closure times of 5 seconds per inch of valve diameter, and valves greater than 12 inches have 60 seconds closure times.

PREPARED Kelly Ann Craig DATE 2/22/88
CHECKED Navin S. Shah DATE 2/22/88

SUBJECT PROJECT SQN-E3-015

COMPUTED BY alal DATE 2/22/88 CHECKED BY Sm DATE 2/22/88

APPENDIX - L

DG LOAD MARGIN

SQN-E3-015

Prepared M.D. Bowman Date 2-21-88
Verified a Pal Date 2-21-88

SH. L2

PURPOSE

To determine the margin between the worse-case maximum applied loading and the steady-state ratings for the Sequoyah Nuclear Plant (SQN) diesel generators.

REFERENCES

1. DNE Calculation SQN-E3-002, "Diesel Generator Load Analysis", Revision 6 (F´3 870826 902)

2. Letter to U. S. Nuclear Regulatory Commission from Tennessee Valley Authority dated Feb. 27, 1987, "Sequoyah Nuclear Plant-Electrical Calculations-Diesel Generator Ratings" (L44 870227 811)

ANALYSIS

Ratings

Diesel Generator sets have 2 basic limitations - maximum engine horsepower, which determines the KW rating, and maximum generator current, which determines the KVA rating. As seen in Reference 2, the SQN diesel engines have a rating of 4750 KW for the first 3 minutes of operation following a cold start, a 2 hour rating of 4837 KW, and a continuous rating of 4397 KW. These values account for generator efficiency and represent KW supplied to the electrical system. Thus, the diesel generator set can supply 4750 KW for the first 3 minutes of operation, 4837 KW for up to 2 hours, and 4397 KW continuously without damage.

As also seen in Reference 2, the generators have a 2 hour rating of 5500 KVA and a continuous rating of 5000 KVA (at power factors of greater than or equal to 0.8). Thus, the diesel generator set can supply 5500 KVA for up to 2 hours and 5000 KVA continuously without damage.

Therefore, the combined diesel generator set ratings are 5500 KVA/4750 KW for the first 3 minutes of operation (following a cold start), 5500 KVA/4837 KW for up to 2 hours, and 5000 KVA/4397 KW continuously. These ratings are shown in Chart 1.

Loading

In order to determine the maximum diesel generator loading for comparison to each of the above ratings, load values were taken from Reference 1. These values can be used to

determine the worse-case loading because they represent the loads applied to Diesel Generator 2B-B which is the heaviest loaded diesel generator. Using the loading total summary tables on sheets 43, 44, 45, 116, and 117 of Reference 1, the maximum steady-state load (running KW and KVA) sequenced on the diesel generator during the first 3 minutes, the first 2 hours, and continuously (greater than 2 hours) was determined for each of the three cases of Loss of Offsite Power (LOOP), LOOP concurrent with a Phase-A Safety Injection (SI), and LOOP concurrent with a Phase-B SI.

The worse-case maximum steady-state KW load during the first 3 minutes of operation was 3814 KW at 30 seconds into the LOOP/Phase-A SI scenario. The worse-case maximum steady-state KW and KVA load during the first 2 hours was 4435 KW and 5054 KVA, both at 120 minutes into the LOOP/Phase-B SI scenario. The worse-case maximum steady-state KW and KVA load for greater than 2 hours was 4278 KW and 4886 KVA (after the non-essential loads are shed by the operator), both for the LOOP/Phase-B SI scenario. All of the loading values had power factors greater than 0.87. These worse-case maximum steady-state loading values are shown in Chart 1.

Margin

Concerning the margin between the engine ratings and the worse-case maximum steady-state KW loading, there is a 19.7% margin for the 3 minute rating, an 8.3% margin for the 2 hour rating, and a 2.7 % margin for the continuous rating.

Concerning the margin between the generator ratings and the worse-case maximum steady-state KVA loading, there is an 8.1% margin for the 2 hour rating and a 2.3% margin for the continuous rating.

These margins are shown in Chart 1.

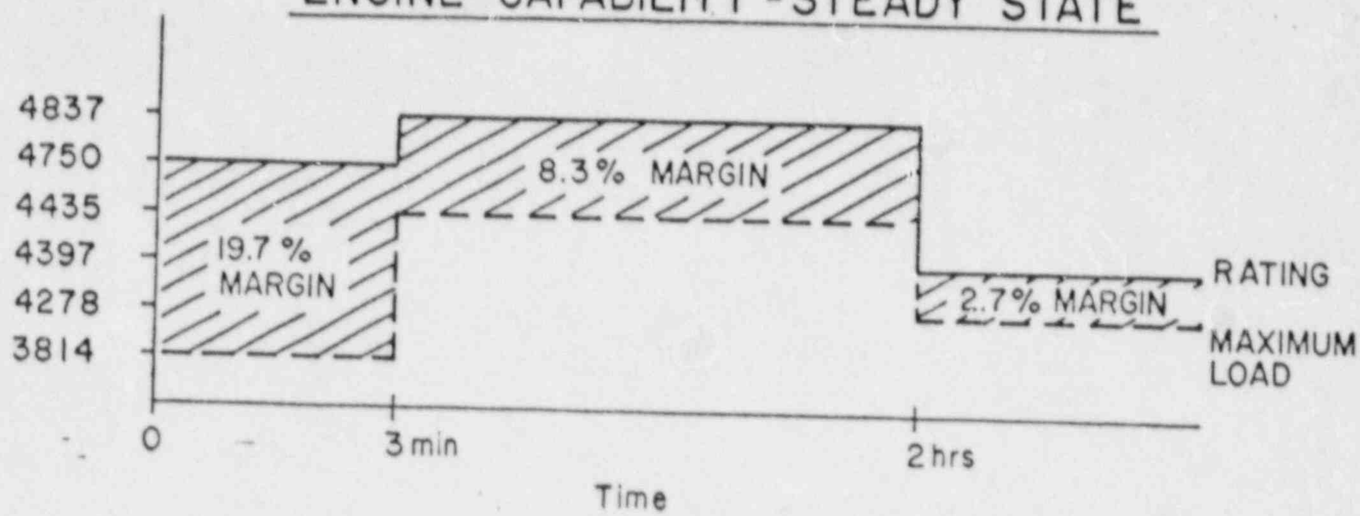
CONCLUSION

The results of this analysis show that the worse-case maximum steady-state loading does not exceed the SQN diesel generator ratings.

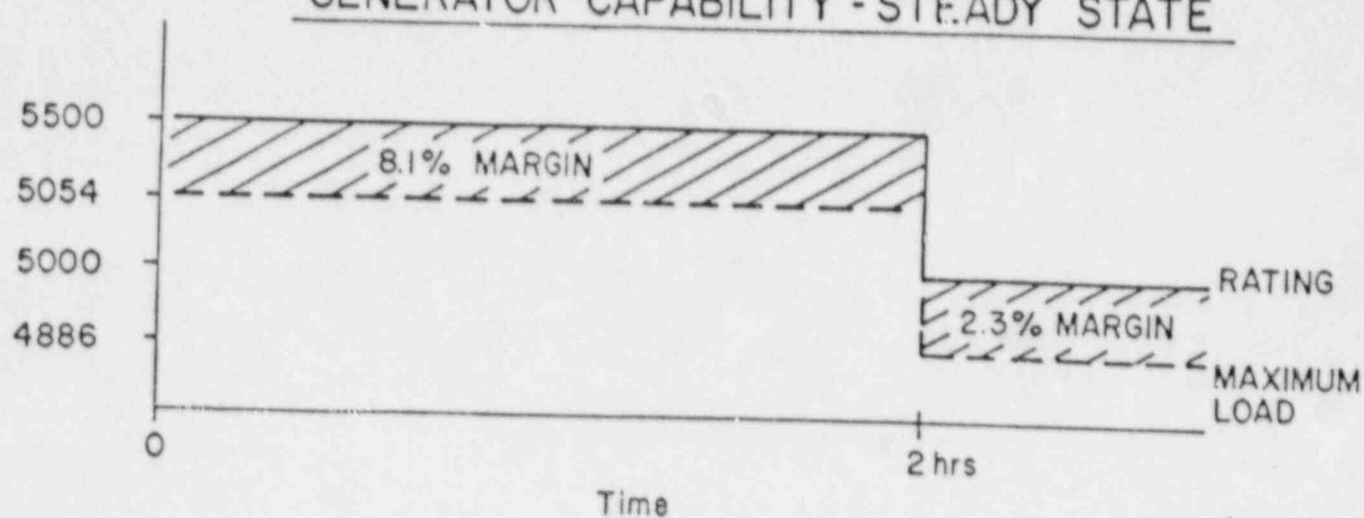
CHART I

MARGINS
DIESEL GENERATOR RATINGS vs. LOAD

ENGINE CAPABILITY - STEADY STATE



GENERATOR CAPABILITY - STEADY STATE



2/22/88
2/21/88

MFG's D/G RATINGS

	0-3 min	3 min-2 hrs	CONTINUOUS
ENGINE	4750 KW	4837 KW	4397 KW
GENERATOR	5500 KVA	5500 KVA	5000 KVA

Attachment 2

Demonstrated Accuracy Calculation: DG Timer Relays

(B25 880122 451)

ORIGINAL

TVA 10697 (DNE-QA-6-86) DNE CALCULATIONS **QA Record** #77

Title: DEMONSTRATED ACCURACY CALCULATION : DG TIMER RELAYS		Plant/Unit: SEQUOYAH / 1 & 2
Preparing Organization: EEB-I&C	KEY NOUNS (Consult RIMS Descriptors List): I&C, INSTR, CALIBRATION, SETPOINT, ACCURACY	
Branch/Project Identifiers: DG TIMER RELAYS	Each time these calculations are issued, preparers must ensure that the original (RO) RIMS accession number is filled in.	

Rev	(for RIMS' use)	rims accession number
R0	870619D0029 (907)	B43 '87 0615 905
R1	870911C0011	B43 '87 0831 902
R2	FOR INFORMATION ONLY	B25 '88 0122 451
R		

Applicable Design Document(s):

SAR Section(s) | UNID System(s)

	Revision 0	R1	R2	R3
ECN No. (or Indicate Not Applicable)		7222 7216	N/A	
Prepared	[signature]	F. Chomicki	F. Chomicki	
Checked	[signature]	[signature]	[signature]	
Reviewed	M R Belew	RDHall	RDHall	
Approved	J. D. Hutson	[signature]	McBellin	
Date	6/13/87	8/31/87	1/20/88	
USE FORM TVA 10534 IF MORE SPACE REQUIRED: List all pages added by this revision		25A	11, 12, 13, 14, 42A	
List all pages deleted by this revision				
List all pages changed by this revision		2, 7, 12, 21, 27, 29, 30, 31, 32, 42, 38, 43	2, 3A, 25A, 5, 110	

Safety-related? Yes (✓) No ( )

Statement of Problem

Determine the accuracy of the subject instrument loop(s) and demonstrate that the accuracy is adequate for the intended purpose. Primary elements are located in a MILD environment.
Subject devices __ /are ✓ /are not part of PAM.

FOR INFORMATION ONLY

ABSTRACT (These calculations contain an unverified assumption(s) that must be verified later. ~~Yes (✓)~~ No (✓))
Calculations were performed to determine the accuracy of the subject instrument loop(s). The determined accuracies were compared to the required accuracies, setpoints, safety limits and/or operating limits and the accuracy for the loop(s) listed below were demonstrated to be acceptable for the intended function of the instrument loop(s). This calculation applies to the instrument loop(s) listed below:

6.9KV SHUTDOWN BOARD LOGIC RELAY PANELS:
1A-A, 2A-A, 1B-B & 2B-B

R2 FSAR COMPLIANCE REVIEW [signature] LE 1/21/88

THIS CALCULATION CONSISTS OF ~~43~~ ~~44~~ 45 PAGES AND ~~9~~ 9 ATTACHMENTS FOR A TOTAL OF ~~105~~ ~~106~~ 115 PAGES.

( ) Microfilm and store calculations in RIMS Service Center
(X) Microfilm and return calculations to: J. D. Hutson

Microfilm and destroy. ( )
Address: WB 8111 C-K

cc: RIMS, SL 26 C-K

DNEI - 2548W

Return to G. Hunley
P-179 SB-K X-8263

FSAR REVIEW

Chapters reviewed:

8.3 "onsite power"

TABLE 8.3.1-2

TECH SPECS. SECTION 16.4.6

RESULTS:

REVISION 0 & 1 of THIS CALC. :

TABLE 8.3.1-2 WILL BE REVISED PER ECN'S 7222, & 7216 TO address LOADING SEQUENCE, AS A RESULT, TECH SPEC VALUES WILL ALSO BE REVISED.

REVISION 2

REV 2 does not affect fSAR.

TVA

Title: DC TIMER RELAYS	REVISION LOG

Revision No.	DESCRIPTION OF REVISION	Date Approved
1	CALCULATION REVISED TO SUPPORT ECN 7216 & 7222	
2	REVISED TO DELETE REQUIREMENT 4 ON PAGE 2 BASED ON NEW ATTACHMENTS 12, 13, & 14. ADDED FSAR REVIEW. ADDED SUMMARY OF RESULTS FOR SCALING INFO.	1/20/88

TVA 10534 (EN DES-4-78)

CALCULATION INDEPENDENT REVIEW VERIFICATION FORM

DG TIMER RELAYS — Calculation No.

2 — Revision

Method of independent review used (check one or more):

1. Alternate calculation method ✓
2. Testing method ______
3. Other method ______

Justification (explain below):

Method 1: Identify the pages where the alternate calculation has been included in the calculation package and explain why this method is adequate.

Method 2: Identify the QA documented source(s) where testing adequately demonstrates the adequacy of this calculation and explain.

Method 3: Justify the technical adequacy of the calculation and explain how the adequacy was verified (calculation is similar to another, based on accepted handbook methods, appropriate sensitivity studies included for confidence, etc.).

Reviewed R2 changes only.

The time delay function of the relays included in this calculation is performed by the discharge of captured air through a variable orifice. A sequence of events following a tornado was identified which could possibly result in the time delay relays performing improper timing functions.

The Systems Engineering Branch (SEB) was ask to determine the probability of occurrence of the identified sequence of events (attachment 12)

R2 changes consist of including SEB's probability of occurrence (attachments 13 & 14) as a bases for not considering a tornado depressurization in the accuracy calculation.

I concur with the conclusions based upon the probability of occurrence

J. B. [signature] — Design Verifier (Independent Reviewer)

01/19/88 — Date

BRANCH/PROJECT IDENTIFIER DG UNDER RELAYS
DEMONSTRATED ACCURACY CALCULATION

TABLE OF CONTENTS

REV 0	PREP [initials]	DATE 5-11-87	CHECK [initials]	DATE 5-12-87	SHEET 1 C/O 2
REV 1	PREP	DATE	CHECK	DATE	SHEET C/O
REV 2	PREP	DATE	CHECK	DATE	SHEET C/O

BRANCH/PROJECT IDENTIFIER DG TIMER RELAYS
DEMONSTRATED ACCURACY CALCULATION

PURPOSE

The purpose of this calculation is a) to determine the accuracy of the instrumentation covered by this calculation, and b) to demonstrate that the instrumentation is sufficiently accurate to perform its intended function without safety or operational limits being exceeded.

ASSUMPTIONS

✓ This calculation contains no assumptions.

_ The following assumptions were used in the performance of this calculation. These assumptions require further analysis. This calculation may require revision if the assumptions below are shown to be invalid.

R1

R1

REQUIREMENTS

1) NOTE 7 PAGE 19 IMPOSES REQUIREMENTS ON CALIBRATION PROCEDURES.

2) DEVICES MUST BE CALIBRATED EVERY 15 MOS.

3) Page 43 requires DG Voltage Analysis be performed based on timing results of this Calculation.

~~4) Page 25A requires ECN for Timer replacements~~ R2

R1

REV	0	PREP	GC	DATE	5-19-87	CHECK	RP	DATE	5-19-87	SHEET 2	C/O 3
REV	1	PREP	GC	DATE	8-31-87	CHECK	EJF	DATE	9-21-87	SHEET	C/O
REV	2	PREP	GC	DATE	1-12-88	CHECK	ZPZ	DATE	1-14-88	SHEET	C/O

BRANCH/PROJECT IDENTIFIER DG [illegible] RELAYS
DEMONSTRATED ACCURACY CALCULATION

SOURCE OF DESIGN INPUT INFORMATION (REFERENCES)

REF #	ATT #	REFERENCE (MIMS#)
1	1	AGASTAT PRODUCT LITERATURE
2	2	SEISMIC TEST PROCEDURE ON 6900-VOLT SHUTDOWN BOARD LOGIC PANELS for SEQUOYAH NUCLEAR PLANT UNITS 1 & 2
3	3	QUALIFICATION TEST REPORT 43706-2 REVISION B
4	4	QUALIFICATION TEST REPORT ES-1000
5	5	TVA DWG. 47W200-3 R15 "EQUIPMENT PLAN"
6	6	TVA DWG 47E235-07 R2 "ENVIRONMENTAL DATA"
7	7	TVA BID ACCEPTANCE AND PERFORMANCE REQUIREMENTS for CONTRACT 72C8-53738 for BATTERY CHARGERS
8		CONTRACT 83003 & 839170
9	8	SEQUOYAH NUCLEAR DIESEL GENERATOR LOADING SEQUENCE CALCULATION, SQN E3 002,21
10		DNE CALCULATION "A REVIEW of ELECTRICAL COMPONENTS IN A RADIATION ENVIRONMENT of ≤5x10⁴ RADS" (B43 860721 903)
11	9	AGASTAT TO TVA LETTER (GEB84 0119028)

REV 0 PREP [illegible] DATE 5-11-87 CHECK RP DATE 5-12-87 SHEET 3 C/O 3A
REV 1 PREP ____ DATE ____ CHECK ____ DATE ____ SHEET ____ C/O ____
REV 2 PREP ____ DATE ____ CHECK ____ DATE ____ SHEET ____ C/O ____

BRANCH/PROJECT IDENTIFIER DC TIMER RELAYS
DEMONSTRATED ACCURACY CALCULATION

SOURCE (REFERENCES) OF DESIGN INPUT INFORMATION

REF #	ATT #	REFERENCE (RIMS#)
12		ECN 6715
13		TVA Dwgs 45N765-16, 45N765-19, 45N765-13, 45N765-15, 45N779-2, 45N785-6, 45N765-7, 45N779-46
14	10	6.9kV Logic Pnl Bill of Material
15	11	"Mean Monthly Number of Tornadoes by States," Climate Analysis Center, Washington, D.C.
16	12	QIR EEB 87961 (B43 87 0924 902)
17	13	Memo from L.W. Lau to J.B. Hosmer, (B81 87 0928 001)
18	14	QIR SEB87003 (B81 87 1014 001)

R2

REV	PREP	DATE	CHECK	DATE	SHEET	C/O
0	JC	5-11-87	RC	5-12-87	3A	4
1	JC	8-31-87	GJH	8/31/87		
2	JC	1-14-88	RCJ	1-14-88		

BRANCH/PROJECT IDENTIFIER DG TIMER RELAYS
DEMONSTRATED ACCURACY CALCULATION

DESIGN INPUT DATA

A) DEFINITIONS & ABBREVIATIONS

Aa	ACCIDENT ACCURACY-ACCURACY OF A DEVICE IN A HARSH ENVIRONMENT CAUSED BY AN ACCIDENT
Aas	COMBINED ACCIDENT AND SEISMIC ACCURACY
Ab	ACCEPTANCE BAND-THE RANGE OF VALUES AROUND THE CORRECT VALUE DETERMINED TO BE ACCEPTABLE WITHOUT RECALIBRATION
AB	AUXILIARY BOILER LINE BREAK
AF	AFW PUMP TURBINE STEAM SUPPLY LINE BREAK
An	NORMAL ACCURACY-ACCURACY OF A DEVICE LOCATED IN A ENVIRONMENT NOT AFFECTED BY AN ACCIDENT OR PRIOR TO AN ACCIDENT
As	POST SEISMIC ACCURACY
AV	ALLOWABLE VALUE-SAFETY LIMIT/REQUIRED ACCURACY MINUS NON-MEASUREABLES; USED FOR THE PURPOSE OF DETERMINING REPORTABILITY ONLY.
CV	CVCS LETDOWN LINE BREAK
De	DRIFT INACCURACY
HELB	HIGH ENERGY LINE BREAK
IAD	INTEGRATED ACCIDENT DOSE
ICRe	INPUT TEST INSTRUMENT READING INACCURACY
ICTe	INPUT TEST INSTRUMENT CALIBRATION INACCURACY
INDRe	INDICATOR READING ERROR
IRe	INACCURACY DUE TO CABLE LEAKAGE
L	LOSS OF COOLANT ACCIDENT
M	MARGIN-THE DIFFERENCE BETWEEN THE SAFETY LIMIT/OPERATING LIMIT AND THE NORMAL/ACCIDENT ACCURACY (Mn=NORMAL MARGIN Ma=ACCIDENT MARGIN)
N/A	NOT APPLICABLE
OCRe	OUTPUT TEST INSTRUMENT READING INACCURACY

REV 0	PREP JC	DATE 5-11-87	CHECK RP	DATE 5-?-87	SHEET 4	C/O 5
REV 1	PREP	DATE	CHECK	DATE	SHEET	C/O
REV 2	PREP	DATE	CHECK	DATE	SHEET	C/O

DESIGN INPUT DATA

A) DEFINITIONS & ABBREVIATIONS CONTINUED

OCTe	OUTPUT TEST INSTRUMENT CALIBRATION INACCURACY
PRCSe	PROCESS UNCERTAINTY
PSEe	INACCURACY DUE TO POWER SUPPLY VARIATIONS
PV	PROCESS VALUE (ACTUAL)
RADe	INACCURACY DUE TO ACCIDENT RADIATION EXPOSURE
Re	REPEATABILITY INACCURACY
RH	RHR LINE BREAK
RNDe	NORMAL RADIATION DOSE BETWEEN CALIBRATION
Se	INACCURACY FOLLOWING A SEISMIC EVENT
SECu	SPAN ERROR CORRECTION UNCERTAINTY
SL	SAFETY LIMIT
SP	SETPOINT
SPEe	ZERO ERROR DUE TO EFFECTS OF OPERATING PRESSURE
TAe	TEMPERATURE EFFECT AT ACCIDENT CONDITIONS
TID	TOTAL 40 YEARS INTEGRATED DOSE
TNe	TEMPERATURE EFFECT IN THE MAXIMUM/MINIMUM ABNORMAL TEMPERATURE RANGES
TPRe	TEST POINT RESISTOR ERROR
WLe	WATERLEG UNCERTAINTY
WLHP	WATERLEG HIGH POINT
WLLP	WATERLEG LOW POINT
RSS	ROOT-SUM-SQUARE
SP	SETPOINT
AWF	THE ERRORS MEASURABLE AT TIME OF CALIBRATION. USED BY FIELD TO VERIFY THAT INSTRUMENT(S) ARE FUNCTIONING W/IN THE BOUNDS OF THE ACCURACY CALCULATION.

R2

REV 0	PREP [illegible]	DATE 5-11-87	CHECK RP	DATE 5-12-87	SHEET 5	C/O 6
REV 1	PREP	DATE	CHECK	DATE	SHEET	C/O
REV 2	PREP [illegible]	DATE 1-14-88	CHECK KPJ	DATE 1-14-88	SHEET	C/O

BRANCH/PROJECT IDENTIFIER DG [illegible]
DEMONSTRATED ACCURACY CALCULATION

DESIGN INPUT DATA

B) LOOP COMPONENT LIST

LOOP ID#	COMPONENT ID#
6.9KV LOGIC RELAY PNL	CP ST-1A
1A-A	SIP ST-1A
2A-A	RHR ST-1A
1B-B	ESCW-A ST-1A
2B-B	CCS ST
	AFW ST-1A
	CSP ST-1A
	EB-ST

(Components bracketed: ONE EACH PER PANEL)

REV 0	PREP [illegible]	DATE 5-11-87	CHECK R.F.	DATE 5-12-87	SHEET 4 C/O 7
REV 1	PREP	DATE	CHECK	DATE	SHEET C/O
REV 2	PREP	DATE	CHECK	DATE	SHEET C/O

BRANCH/PROJECT IDENTIFIER DG TIMER RELAYS

DEMONSTRATED ACCURACY CALCULATION

DESIGN INPUT DATA

C) LOOP FUNCTION

THE FUNCTION OF THE DEVICES ADDRESSED IN THIS CALCULATION IS TO LOAD THE DIESEL GENERATORS BY CONNECTING LOADS IN A TIMED SEQUENCE. THE TIMING IS IMPORTANT IN THAT AFTER A LOAD IS CONNECTED, THE DIESELS MUST BE GIVEN TIME TO RECOVER BEFORE THE NEXT LOAD IS CONNECTED.

THE WORST [illegible] SEQUENCE (PER REF. 9 AND CONSULTATION WITH PREPARERS OF REF. 9) IS ANALY[illegible] [illegible] WILL ENVELOPE OTHER SEQUENCES. R1

TIMER ERROR [illegible]FECT ON PROCESS LOADS ADDRESSED IN DNE CALC "2751A" TO BE ISSUED AT A LATER DATE.

C) LOOP REQUIREMENTS AND LIMITS (BISTABLE)

RESPONSE TIME: RESPONSE TIME AND ACCURA[illegible] ARE SYNONYMOUS [illegible] THIS APPLICATION.

SAFETY LIMITS: PER ATTACHMENT 8 THE REQUIRED ACCURACY FOR THE TIMING RELAYS IS ± 5%

OPERATING LIMITS:

SETPOINT: SEE PAGE 21 NOTE 10

REV 0	PREP GC	DATE 5-21-87	CHECK RP	DATE 5-21-87	SHEET 7	C/O 8
REV 1	PREP [illegible]	DATE 5-24-87	CHECK [illegible]	DATE [illegible]	SHEET	C/O
REV 2	PREP	DATE	CHECK	DATE	SHEET	C/O

BRANCH/PROJECT IDENTIFIER DG TIMER RELAYS
DEMONSTRATED ACCURACY CALCULATION

DESIGN INPUT DATA

D) COMPONENT DATA

VALID FOR DEVICES IDENTIFIED ON SHEET(S): 6

COMPONENT: AGASTAT TIMER RELAYS CONTRACT #: 83403 / 839179 (SEE NOTE 10) REFERENCE #: SEE NOTE 10

MANUFACTURER/MODEL: AGASTAT 7000 SERIES (SEE NOTE 10) REFERENCE #: 8

INPUT RANGE & UNITS: NA NOTE #: REFERENCE #:

OUTPUT RANGE & UNITS: NA NOTE #: REFERENCE #:

OVERRANGE LIMIT: NA NOTE #: REFERENCE #:

CALIBRATED SPAN: NA NOTE #: REFERENCE #: 1

ROOM #/ PANEL #: SEE NOTE 9 NOTE #: 9 REFERENCE #: 6, 13

ELEVATION/ COORDINATE: 734' / SEE NOTE 9 NOTE #: 9 REFERENCE #: 6, 5

MIN/MAX ABNORMAL TEMP: 60/104°F NOTE #: REFERENCE #: -

ACCIDENT TEMPERATURE: NA NOTE #: REFERENCE #: 6

RADIATION TID (RAD): 1.8 x 10³ NOTE #: REFERENCE #: 6

RADIATION IAD (RAD): < 1 x 10⁴ NOTE #: REFERENCE #: 6

INSTRUMENT TAP INFORMATION REFERENCE #: NA

WLHP TAP ELEVATION: NA WLHP CONDENSING POT ELEVATION: NA

WLLP TAP ELEVATION: NA WLLP CONDENSING POT ELEVATION: NA

EVENT/CATEGORY/OPERATING TIME: NA NOTE #: REFERENCE #:

____ / ____ / ____ (MILD ENVIRONMENT)

____ / ____ / ____

____ / ____ / ____

____ / ____ / ____

____ / ____ / ____

REV 0	PREP 4c	DATE 5-11-87	CHECK RJP	DATE 5-12-87	SHEET 4	C/O 9
REV 1	PREP	DATE	CHECK	DATE	SHEET	C/O
REV 2	PREP	DATE	CHECK	DATE	SHEET	C/O

BRANCH/PROJECT IDENTIFIER DG [illegible] RELAYS
DEMONSTRATED ACCURACY CALCULATION

DESIGN INPUT DATA
D) COMPONENT DATA CONTINUED

COMPONENT: [illegible] RELAY

PARAMETER	VALUE/UNITS	NOTE #	REFERENCE #
Re	±5% of SP / ±10% of SP	1	1
De	±2.7% of SP	2	3, 4
TNe	TNe(RANDOM) ±7.2 % of SP / TNe(BIAS) ±5.6% of SP	5	3, 4
SPEe	NA		
SECu	NA		
PSEe	NEGLIGIBLE	4	3, 4
RNDe	NA	8	10
TPRe	NA		
ICTe	NEGLIGIBLE	6	
ICRe	NA	11	
OCTe	NA	12	
OCRe	NA	12	
Ab	±5% of SP	7	
Se	Negligible	3	2
RADe	NA	8	10
TAe	NA		
WLe	NA		
PRCSe	NA		
INDRe	NA		
IRe	NA		

REV 0 PREP [illegible] DATE 5-[illegible] CHECK [illegible] DATE 5-19-87 SHEET 9 C/O 10
REV 1 PREP ____ DATE ____ CHECK ____ DATE ____ SHEET ____ C/O ____
REV 2 PREP ____ DATE ____ CHECK ____ DATE ____ SHEET ____ C/O ____

BRANCH/PROJECT IDENTIFIER DC TIMER RELAYS

DEMONSTRATED ACCURACY CALCULATION

DESIGN INPUT DATA

E) COMPONENT DATA NOTES

COMPONENT: TIMER RELAY

#	NOTE
1	VENDOR DATA STATES THAT FOR THE MODEL DO12 TIMER THE REPEAT ACCURACY IS ± 5% FOR DELAYS OF 200 SECONDS OR LESS, ±10% FOR > 200 SEC.
2.	TIME DEPENDENT DRIFT IS CAUSED BY TWO MECHANISMS 1) MECHANICAL FATIGUE AND 2) TIME/TEMPERATURE INDUCED CHANGES IN PHYSICAL PROPERTIES.
	THE TIMING FUNCTION OF THIS RELAY IS ACCOMPLISHED BY FORCING CAPTURED AIR IN THE TIMING CHAMBER THROUGH A VARIABLE ORIFICE UNTIL THE CAPTURED AIR IS TOTALLY EXHAUSTED AND THE CONTACTS TRANSFER. THE MAJOR MECHANICAL PARTS THAT ARE UTILIZED FOR THIS FUNCTION ARE: A DIAPHRAGM OPERATING SPRING AND A TIMING DISK (WHOSE ROTATION POSITIONS THE VARIABLE ORIFICE). BECAUSE OF THIS TYPE OF CONSTRUCTION AND THE FACT THAT THE RELAYS ARE NOT NORMALLY CYCLED EXCEPT FOR TESTING, THE ENGINEERING JUDGEMENT IS MADE THAT A TIME DEPENDENT DRIFT WOULD BE NEGLIGIBLE. (SEE REFERENCE 11 FOR DETAILS OF RELAY CONSTRUCTION)
	THIS IS BORNE OUT IN QUALIFICATION TESTING DONE BY WYLE LABS ON THE E7000 SERIES RELAY. (ATTACH 3 & 4). THE TESTED RELAYS WERE SUBJECTED TO CYCLE AGING OF 27,500 CYCLES AND TEMPERATURE AGING THAT SIMULATED A SERVICE LIFE OF 20 YEARS AT 75°F. BECAUSE THE DELAY SETTINGS WERE READJUSTED AFTER EACH TEST, A TRUE DRIFT VALUE CANNOT BE DETERMINED, HOWEVER, UPON ANALYSIS OF THE RESULTS AN APPROPRIATE ENGINEERING CONCLUSION CAN BE DRAWN.

REV 0 PREP [illegible] DATE 5-11-87 CHECK [illegible] DATE 5-12-87 SHEET 10 C/O 11
REV 1 PREP ____ DATE ____ CHECK ____ DATE ____ SHEET ____ C/O ____
REV 2 PREP ____ DATE ____ CHECK ____ DATE ____ SHEET ____ C/O ____

BRANCH/PROJECT IDENTIFIER DC TIMER RELAYS
DEMONSTRATED ACCURACY CALCULATION

( ) DESIGN INPUT DATA
E) COMPONENT DATA NOTES

COMPONENT: TIMER RELAY

#	NOTE
2) (con't)	Of the several relays tested, the typical pre vs post test shift for temperature aging was ~20%. The worst case shift was 34%. For cycle aging the worst case shift was 12.5%. (See attachment 4)
	Conservatively estimating that the relays will be cycled once a month for 40 years, and conservatively using the worst case shift of 12.5%, a per calibration shift (18 mo + 25%) would be $(12.5\%) \times \left(\frac{1 \times 22.5}{27{,}500}\right) = .01\%$ per calibration, which is negligible (This assumes a linear relation between cycles and drift)
	The thermal aging results worst case is 34%. However, this number includes 1) repeatability 2) test equipment error and 3) dial setting error. Dial setting error is included because after each test the relays were reset to zero delay to perform various other functional checks and then the relay dial was readjusted for the next test. Considering that the repeatability = ±5%, test equipment error should have been minimal and dial setting error is judged to be ±2% (based on 50 graduations on the dial - see attachment 1.) the errors strictly attributed to aging could be as little as $34 - (5^2 + 2^2)^{1/2} \simeq 28.6\%$ for the worst case condition. Considering a 20yr period and 75°F, the worst case error would be - -

REV 0	PREP FC	DATE 5-11-87	CHECK RP	DATE 5-12-87	SHEET 11	C/O 12
REV 1	PREP	DATE	CHECK	DATE	SHEET	C/O
REV 2	PREP	DATE	CHECK	DATE	SHEET	C/O

DESIGN INPUT DATA

E) COMPONENT DATA NOTES

COMPONENT: TIMER RELAY

#	NOTE
2) (CON'T)	$\left(\frac{225}{20 \times 12}\right) \times 23.6\% = 2.7\%$ HOWEVER, THIS CALCULATION WILL REQUIRE CALIBRATION FOR A MAXIMUM PERIOD OF 15 MOS. ∴ $\frac{15}{20 \times 12} \times 34\%$ (MAXIMUM ERROR) $= 2.1\%$ R1
	FOR CONSERVATISM IN THIS CALCULATION A VALUE OF ±2.7% WILL BE
	INCLUDED FOR DRIFT FOR THE E7000 AND 7000 SERIES RELAYS.
	NOTE: DUE TO SAME CONSTRUCTION, THE E7000 AND 7000
	RELAY DRIFT IS CONSIDERED TO BE EQUIVALENT
	(SEE ATTACHMENT 9)

R1

BRANCH/PROJECT IDENTIFIER DC TIMER RELAYS
DEMONSTRATED ACCURACY CALCULATION

DESIGN INPUT DATA

E) COMPONENT DATA NOTES

COMPONENT: TIMER RELAY

#	NOTE
3)	SEISMIC TESTING WAS DONE ON BOTH THE 7000 AND E7000 SERIES RELAYS. THE TEST FOR THE E7000 RELAYS WAS CONDUCTED IN SUCH A MANNER AS TO MAKE IT DIFFICULT TO DETERMINE ACCURACY SHIFTS DUE ONLY TO SEISMIC TESTING (REFER TO ATTACH 4). HOWEVER, THE DATA FROM THIS TEST STRONGLY SUGGESTS THAT SEISMIC SHIFTS ARE MINIMAL. THE DATA FROM SEISMIC TESTING OF THE 7000 SERIES RELAYS (ATTACH 2) WILL BE USED FOR THE E7000 AS WELL AS 7000 RELAYS SINCE THE FUNCTIONAL CONSTRUCTION OF THE RELAYS ARE IDENTICAL (SEE REF. 11)
	PER ATTACH. 2, THE RELAYS WERE TESTED AT FREQUENCIES BETWEEN 1 AND 33 Hz AT STEPS OF 1 Hz. BEFORE AND AFTER TEST VALUES FOR 3 RELAYS WERE NOTED FOR EACH STEP. PAGE 33 IS A BREAKDOWN OF DEVIATIONS FROM BEFORE AND AFTER TEST VALUES AND DEVIATIONS FROM POST TO NEXT PRE TEST VALUES.
	FOR EACH RELAY (LABELED D1, D2 & F), THE STANDARD DEVIATION OF BEFORE VS AFTER TEST DEVIATIONS WAS CALCULATED. THE STANDARD DEVIATION FOR THE RELAYS SET AT 31 SEC DELAY AND 20 SEC DELAY WERE APPROXIMATELY EQUAL. ADDITIONALLY, THE POST TEST VS NEXT PRE TEST DATA WAS ANALYZED AND THE STANDARD DEVIATION CALCULATED. ALSO, FOR THE "F" RELAY, THE PRE VS DURING TEST VALUES WERE ANALYZED AND THE STANDARD DEVIATION DETERMINED. FINALLY, THE MEAN VALUE OF EACH SAMPLE WAS DETERMINED. THE RESULTS ARE SUMMARIZED ON THE NEXT PAGE.

DESIGN INPUT DATA

E) COMPONENT DATA NOTES

COMPONENT: TIMER RELAY

\# NOTE

3) (CONT)

	RELAY D1	RELAY D2	RELAY F	
BEFORE VS AFTER σ	.129	.200	.123	
AFTER VS NEXT BEFORE σ	.11	.183	.116	
BEFORE VS AFTER MEAN VALUE	0	-.006	+.011	
AFTER VS NEXT BEFORE MEAN VALUE	-.003	+.009	-.009	
BEFORE VS DURING σ	N/A	N/A	.126	
BEFORE VS DURING MEAN VALUE	N/A	N/A	+.03	
DELAY TIME NOMINAL	20	20	31	

(ALL VALUES IN SECONDS)

THREE THINGS ARE APPARENT FROM THIS TABLE: 1) THE STANDARD DEVIATION OF EACH RELAY IS WELL BELOW THE STATED REPEATABILITY VALUE OF ±5% (D1 = .62%, D2 = 1% & F = .4%) 2.) THE MEAN VALUE IS ZERO, AND 3) THE STANDARD DEVIATION OF THE "F" RELAY DURING SEISMIC TESTING IS APPROXIMATELY THE SAME AS AFTER THE TESTING (AFTER = .397%, DURING = .406%).

THIS MAKES A STRONG CASE FOR CONSIDERING POST SEISMIC EFFECTS NEGLIGIBLE BECAUSE: 1) IF THE SEISMIC VIBRATIONS HAD INTRODUCED A PRECISION ERROR, ONE WOULD PRESUME THAT THE STANDARD DEVIATIONS TABULATED ABOVE WOULD BE AT LEAST AS GREAT AS THE REPEATABILITY VALUE OF THE DEVICE (±5%) 2) IF

DESIGN INPUT DATA

E) COMPONENT DATA NOTES

COMPONENT: TIMER RELAY

#	NOTE
3) (CON'T)	THE SEISMIC TESTS INTRODUCED A BIAS ERROR, THE MEAN VALUE OF THE THREE RELAYS WOULD BE NON ZERO AND OF A CONSISTENT SIGN AND 3) PREVIOUS EXPERIENCE HAS SHOWN THAT WHERE THERE ARE POST SEISMIC EFFECTS, EFFECTS DURING VIBRATION TESTING ARE NOTICEABLY GREATER (WHICH IS NOT THE CASE HERE). ADDITIONALLY, LOOKING AT THE DATA ON PAGE 33, IT IS SEEN THAT THERE ARE NO CUMULATIVE EFFECTS FROM THE STEP TESTING, i.e., DEVIATIONS AFTER THE LAST STEPS ARE NO GREATER THAN DEVIATIONS DURING THE INITIAL STEP TESTS. THIS INDICATES THAT THERE IS NO CORRELATION BETWEEN THE VIBRATION TESTING AND THE DEVIATIONS. Finally, a comparison of pre Test values (D1=20.1, D2=20.0, & F=31.6) TO VALUES NOTED AFTER ALL SEISMIC TESTING WAS PERFORMED (D1=20.1, D2=20.1, & F=31.6) SHOWS THAT THE DEVIATIONS WERE D1=0%, D2=0.5% AND F=0% WHICH ALSO INDICATES SEISMIC EFFECTS ARE NEGLIGIBLE.
	THE PRECEDING DATA & ANALYSES ARE THE BASIS FOR MAKING THE ENGINEERING JUDGEMENT THAT SEISMIC EFFECTS ARE NEGLIGIBLE.

DESIGN INPUT DATA
E) COMPONENT DATA NOTES

COMPONENT: TIMER RELAY

#	NOTE
4)	QUALIFICATION TESTING (ATTACH 3-4) included TESTING of 8 RELAYS AT LOW AND high VOLTAGE LEVELS. THE MINIMUM difference IN VOLTAGE WAS 102 TO 145 VOLTS. BOTH AC AND DC RELAYS WERE TESTED, however, for THE purposes of THIS CALCULATION, ALL RELAYS WILL BE ANALYZED ON A PER VOLT BASIS REGARDLESS of AC OR DC OPERATION. EACH RELAY WAS TESTED AT TEMPERATURES BETWEEN 40 AND 172°F. AT EACH TEMPERATURE STEP (9 IN ALL) THE VOLTAGE WAS CHANGED FROM LOW TO HIGH AND RELAY VALUES NOTED. THIS CALCULATION WILL CONSERVATIVELY CONSIDER THE DEVIATIONS AS TOTALLY ATTRIBUTABLE TO POWER SOURCE VARIATIONS RATHER THAN PARTIALLY DUE TO high OR LOW TEMPERATURE EFFECTS.
	PAGE 34 IS A TABULATION of % deviation for THE 9 READINGS ON THE 8 RELAYS. THESE VALUES WERE USED TO CONSTRUCT THE HISTOGRAM ON PAGE 35 which INDICATES THE ERRORS CAN BE CHARACTERIZED BY A GAUSSIAN DISTRIBUTION. THE MEAN VALUE WAS CALCULATED TO BE ≈ ZERO (-.754%) AND THE STANDARD DEVIATION WAS CALCULATED TO BE 4.47% OR ≈4.5%. TO ACHIEVE A 95% CONFIDENCE LEVEL, THE 2-SIGMA VALUE of 9% WILL BE USED AND THE DEVIATIONS WILL BE CONSIDERED TO BE LINEAR WITH MAGNITUDE of VOLTAGE DEVIATION.

POWER TO THE RELAYS IS supplied by THE battery chargers which produce 135V ± 1% (ATTACH 7). THE VOLTAGE AT THE RELAYS WILL BE

REV 0 PREP ?C DATE 5-11-87 CHECK RP DATE 5-12-87 SHEET 16 C/O 17
REV 1 PREP ____ DATE ____ CHECK ____ DATE ____ SHEET ____ C/O ____
REV 2 PREP ____ DATE ____ CHECK ____ DATE ____ SHEET ____ C/O ____

BRANCH/PROJECT IDENTIFIER ~C TIMER RELAYS
DEMONSTRATED ACCURACY CALCULATION

D E S I G N   I N P U T   D A T A

E) COMPONENT DATA NOTES

COMPONENT: TIMER RELAY

#	NOTE
a) (con't)	ABOUT 125 VOLTS PLUS OR MINUS 1.35 VOLTS. THEREFORE, FOR A 95%
	CONFIDENCE LEVEL, POWER SUPPLY ERROR = $\frac{9\%}{43V} \times 1.35V = \pm 0.3\%$.
	CONSIDERING THE MAGNITUDE OF THE OTHER ERRORS CONSIDERED IN
	THIS CALCULATION, ± 0.3% ERROR IS NEGLIGIBLE.

REV 0 PREP ___ DATE 5-11-87 CHECK R.P. DATE 5-12-87 SHEET 17 C/O 18
REV 1 PREP ___ DATE ___ CHECK ___ DATE ___ SHEET ___ C/O ___
REV 2 PREP ___ DATE ___ CHECK ___ DATE ___ SHEET ___ C/O ___

BRANCH/PROJECT IDENTIFIER DG Timer relays

DEMONSTRATED ACCURACY CALCULATION

DESIGN INPUT DATA

E) COMPONENT DATA NOTES

COMPONENT: Timer Relay

#	NOTE
5)	Per ref. 9, 8 relays were cycled and the delay times noted for temperatures between 90°F and 172°F. This was done for both low and high coil voltages (102 to 145 volts min differ. Sheet 36 is a compilation of deviation percentages for the 10°F step between 40 & 50°F and the 20°F steps between 50 and 150°F. Also calculated were mean and standard deviation values for each step.

the results of the computations show an inconsistency in the data. The 40 to 50°F and 50 to 70°F steps indicated a positive shift (mean value) of 1 & 3.6 respectively, while the rest of the data showed a negative shift for an increase in temperature. On sheet 39 is a plot of mean values vs temperature increase using 70°F as a reference for values ≥70°F. This plot graphically shows the contradiction; from 70 to 172°F the graph is well defined and shows a trend decrease in mean value for increase in temperature while the 40 to 70°F step values are abrupt departures from the 70 to 172°F trend. The dashed line on the plot represents the curve that would result if the sign of the mean values were reversed for the 40 to 70°F data. The dashed line plot is much closer to what

REV	PREP	DATE	CHECK	DATE	SHEET	C/O
0	JC	5-14-87	RO	5-19-87	18	18A
1						
2	JC	1-12-88	KJZ	1-19-88		

BRANCH/PROJECT IDENTIFIER DG TIMER RELAYS
DEMONSTRATED ACCURACY CALCULATION

DESIGN INPUT DATA

E) COMPONENT DATA NOTES

COMPONENT: TIMER RELAY

#	NOTE
5) (CONT.)	one would expect, but whether the data was transposed when the test values were recorded is not known.

Given the above, the data from 40 to 70°F is considered unuseable. However, since the service temperature (60°F) only extends past the lowest usable test value (70°F) by 10°F, a new plot was created (page 40) with mean and σ values from 70 to 172°F and the 10°F portion from 60 to 70°F extrapolated.

The new plot (page 40) shows that for the temperature range 60 to 110°F which envelopes the in service temperature range of 60 to 104°F, the worst case σ value is 3.6% (the trend indicates that the σ value for 60 to 70°F would be no greater than 3.6%). Therefore,

$TNe_{(RANDOM)} = 2\cdot\sigma = 2 \times 3.6 = 7.2\%$ of setpoint.

REV 0 PREP R.P. DATE 5-19-87 CHECK 2C DATE 5-19-87 SHEET 18A C/O 18B
REV 1 PREP ____ DATE ____ CHECK ____ DATE ____ SHEET ____ C/O ____
REV 2 PREP ____ DATE ____ CHECK ____ DATE ____ SHEET ____ C/O ____

BRANCH/PROJECT IDENTIFIER DG TIMER RELAYS
DEMONSTRATED ACCURACY CALCULATION

DESIGN INPUT DATA
E) COMPONENT DATA NOTES

COMPONENT: TIMER RELAY

#	NOTE
5) (con't.)	Any bias shift in setpoint due to temperature change should cause all setpoints of consecutive relays to shift in the same direction, thus canceling the effects. The exception is the first relay (0 to 2 seconds). A bias shift due to a maximum in service temperature change (104 - 60 = 44 °F) is calculated as follows:

ΔT (°F)	Mean (%)
40	-5.1
44	$TNe_{(BIAS)}$
60	-7.6

(Data is from Table, Sheet 38)

$$\frac{44-40}{60-40} = \frac{TNe_{(BIAS)} - (-5.1)}{-7.6-(-5.1)}$$

$$TNe_{(BIAS)} = -5.6\%$$

Since it is not known at what temperature the relay will be calibrated nor what temperature the environment will experience at any given time (most probable temp. is 75°F - normal conditions) a bidirectional random term is justified for use in these calculations. However, for conservatism a bidirectional bias term of +5.6% and -5.6% will be used, i.e., $TNe_{(BIAS)} = \pm 5.6\%$.

REV	PREP	DATE	CHECK	DATE	SHEET	C/O
0	R.F.	5-10-87	[illegible]	[illegible]	18B	19
1						
2						

BRANCH/PROJECT IDENTIFIER DC TIMER RELAYS
DEMONSTRATED ACCURACY CALCULATION

DESIGN INPUT DATA
E) COMPONENT DATA NOTES

COMPONENT: TIMER RELAY

#	NOTE
6.)	A REQUIREMENT of THIS CALCULATION PER NOTE 7 IS A CALIBRATION TIMER w/ A DIGITAL READOUT TO 1/100th of A SEC. IT IS EXPECTED THAT A TIME PIECE of THIS NATURE WILL HAVE NEGLIGIBLE INACCURACY COMPARED TO THE OTHER INACCURACIES IN THIS CALCULATION. THEREFORE, PER ENGINEERING JUDGEMENT, ICTe IS NEGLIGIBLE.
7.)	The following is a requirement of this calculation:
	1) THE CALIBRATION of THE RELAYS MUST BE PERFORMED BY INITIATING THE RELAY TIMER DELAY AND THE CALIBRATION TIMER SIMULTANEOUSLY. HAVING ONE SWITCH BOTH START THE TIMER AND THE CALIBRATION DEVICE SIMULTANEOUSLY IS DESIRED. HAVING ONE TECHNICIAN VERBALLY OR VISUALLY SIGNAL ANOTHER TECHNICIAN AS TO THE START of EITHER DEVICE IS NOT ACCEPTABLE.
	2) THE END of THE DELAY PERIOD MUST SIMILARLY BE DETERMINED.
	THE TRANSFER of THE RELAY CONTACTS STOPPING THE CALIBRATION TIMER IS DESIRABLE.
	3) THE ACCEPTANCE BAND (AB) IS ARBITRARILY CHOOSEN TO BE ±5%, ±5% of MAX DELAY
	4) DIGITAL TIMER w/ A READOUT TO AT LEAST 1/100th of A SEC MUST BE USED.

REV 0 PREP DC DATE 5-11-97 CHECK [illegible] DATE [illegible] SHEET 19 C/O 20
REV 1 PREP ___ DATE ___ CHECK ___ DATE ___ SHEET ___ C/O ___
REV 2 PREP ___ DATE ___ CHECK ___ DATE ___ SHEET ___ C/O ___

BRANCH/PROJECT IDENTIFIER DC TIMER RELAYS

DEMONSTRATED ACCURACY CALCULATION

DESIGN INPUT DATA

E) COMPONENT DATA NOTES

COMPONENT: TIMER RELAY

#	NOTE
6.	THIS DEVICE IS LOCATED IN AN ENVIRONMENT WHERE THE TID DOES NOT EXCEED 5×10^4 RADS. BASED ON INFORMATION CONTAINED IN DNE CALCULATION TITLED, "A REVIEW OF ELECTRONIC COMPONENTS IN A RADIATION ENVIRONMENT OF $\leq 5 \times 10^4$ RADS," REV. 0 (RIMS NO. B43 860721 903) RADIATION EFFECTS ARE NEGLIGIBLE.

REV 0	PREP SC	DATE 5-11-87	CHECK RP	DATE 5-12-87	SHEET 20	C/O 21
REV 1	PREP	DATE	CHECK	DATE	SHEET	C/O
REV 2	PREP	DATE	CHECK	DATE	SHEET	C/O

BRANCH/PROJECT IDENTIFIER D C TIMER RELAYS
DEMONSTRATED ACCURACY CALCULATION

DESIGN INPUT DATA

E) COMPONENT DATA NOTES

COMPONENT: TIMER RELAY

#	NOTE			
9.)	SHUTDOWN BD RELAY LOGIC PNL ID	ELEVATION	COL	ROOM
	1A-A	734	A6-S	6.9KV SHUTDOWN BD. RM
	2A-A	734	A4-S	"
	1B-B	734	A11-S	"
	2B-B	734	A8-S	"

10.)

LOAD	TIMER TAG #	TIMER CONTACT #	SCHEMATIC	TIMER MODEL #	DELAY IN SEC
CENTRIFUGAL CHG. PMP	CP ST-1A	83403	45N765-16	7012PBL	2
SAFETY INJ. PMP	SIP ST-1A	83403	45N765-14	7012PD	5
RESID. HT. REM. PMP	RHR ST-1A	83403	45N765-13	7012PD	10
ERCW PUMP	ERCW-A ST-1A	83403	45N765-15	7012PD	15
COMP. COOLING PMP	CCS ST	83403	45N779-2	7012PD	30**
AUX. FEEDWATER PUMP	AFW ST-1A	83403	45N765-6	7012PD	20**
CONT. SP. PMP	CSP ST-1A	839179	45N765-7	E7012PKL	150*
ELEC. Bd. RM AHU	EB-ST	839179	45N779-46	E7012PKL	240*

R1

*PER ECN 6715 **PER ECN 7216 ONLY & 7222 UNIT 1

11) DIGITAL TIMER THEREFORE NO READING ERROR (SEE NOTE 7)

12) DEVICE OUTPUT IS A CONTACT TRANSFER ∴ ECTe & OCRe ARE NA.

REV 0 PREP FC DATE 5-11-87 CHECK RP DATE 5-12-87 SHEET 21 C/O 22
REV 1 PREP FC DATE 8-24-87 CHECK SJD DATE 9/29/87 SHEET ___ C/O ___
REV 2 PREP ___ DATE ___ CHECK ___ DATE ___ SHEET ___ C/O ___

BRANCH/PROJECT IDENTIFIER DG Timer Relays
DEMONSTRATED ACCURACY CALCULATION

COMPUTATIONS/ANALYSES

A) PROCESS UNCERTAINTY DISCUSSION/CALCULATION

✓ NO PROCESS UNCERTAINTY EXISTS FOR THIS CALCULATION BECAUSE:

✓ THE MEASURED PARAMETER IS THE PARAMETER OF CONCERN; THEREFORE, PROCESS VARIATIONS ARE ACCOUNTED FOR IN THE DETERMINATION OF SAFETY AND/OR OPERATIONAL LIMITS.

___ OTHER: SEE DISCUSSION BELOW.

___ PROCESS UNCERTAINTY DOES EXIST AND IS DETAILED IN THE FOLLOWING DISCUSSION/CALCULATION.

REV 0	PREP GC	DATE 5-11-87	CHECK RP	DATE 5-12-87	SHEET 22	C/O 23
REV 1	PREP ___	DATE ___	CHECK ___	DATE ___	SHEET ___	C/O ___
REV 2	PREP ___	DATE ___	CHECK ___	DATE ___	SHEET ___	C/O ___

COMPUTATIONS/ANALYSES

B) WATERLEG UNCERTAINTY DISCUSSION/CALCULATION

✓ APPLICABLE TO ALL LOOPS LISTED ON SHEET 6.

___ APPLICABLE ONLY TO LOOPS: ______

✓ WATERLEG UNCERTAINTY IS NOT CONSIDERED FOR THE CALCULATION BECAUSE:

✓ NO WATERLEG EXISTS FOR THIS CALCULATION.

___ THE EFFECTS OF WATERLEG CHANGES ARE INSIGNIFICANT. SEE DISCUSSION/CALCULATION BELOW.

___ OTHER. SEE DISCUSSION/CALCULATION BELOW.

___ A WATERLEG UNCERTAINTY DOES EXIST FOR THIS LOOP. SEE CALCULATION/DISCUSSION BELOW.

___ SEE SENSING LINE DIAGRAM ON SHEET ___ OF THIS CALCULATION.

COMPUTATIONS/ANALYSES

C) ACCURACY DISCUSSION

___ The accuracy of this instrument for normal, post seismic and accident conditions will be determined by considering the parameters tabulated in the design input section of this calculation.

The accuracy calculation for seismic (As) is bounding for all seismic events.

✓ The square root of the sum of the squares method shall be used in this calculation for calculating accuracy since the factors affecting accuracy are independent variables.

___ Bi-directional errors and uni-directional errors will be combined in a manner such that the sum of the positive uni-directional errors will be added to the positive portion of the bi-directional error (obtained from the square root of the sum of the squares method), and the sum of the negative uni-directional errors will be added to the negative portion of the bi-directional error.

This method is conservative. Therefore, it will be used in this calculation.

Example: (+/-)10 = bi-directional error
+5 = first uni-directional error
-2 = second uni-directional error

Total Error = (+10 +5) to (-10 -2) = +15 to -12

___ other: ______________________________

For the purpose of this calculation, accuracy is defined as the range of actual process values that may exist for a given indicated or bistable trip value, e.g. an accuracy of +10 psig to -5 psig means that for a indicated or bistable trip value of 100 psig, the actual process pressure may be anywhere between 95 and 110 psig.

All system analysis based on or using accuracy values from this calculation should take into account the fact that operator action and/or automatic initiations may occur at a process value differing from the indicated or setpoint values by the amount of the calculated inaccuracies.

BRANCH/PROJECT IDENTIFIER DG TIMER RELAYS
DEMONSTRATED ACCURACY CALCULATION

ENTIRE PAGE REVISED ON R2

COMPUTATIONS/ANALYSES

C) ACCURACY DISCUSSION (CONTINUED)

TORNADO DEPRESSURIZATION:

DUE TO THE INFORMATION CONTAINED IN ATTACHMENT 12, 13, & 14 THE EFFECTS ON ACCURACY OF A TORNADO DEPRESSURIZATION NEED NOT BE CONSIDERED IN THIS CALCULATION.

REV 0	PREP	DATE	CHECK	DATE	SHEET 25A C/O 26
REV 1	PREP	DATE	CHECK	DATE	SHEET C/O
REV 2	PREP JL	DATE 1-14-88	CHECK KPJ	DATE 1-14-88	SHEET 25A C/O 26

BRANCH/PROJECT IDENTIFIER DG TIMER RELAYS
DEMONSTRATED ACCURACY CALCULATION

COMPUTATIONS/ANALYSES

C) ACCURACY DISCUSSION (CONTINUED)

THE PARAMETER OF IMPORTANCE IN THIS CALCULATION IS THE TIME BETWEEN WHICH ONE RELAY TRANSFERS CONTACTS AND THE NEXT RELAY TRANSFERS CONTACTS. THIS IS BECAUSE THE TIME SPACING OF THE LOADING IS CRITICAL (SO AS TO GIVE THE DIESEL GENERATORS TIME TO RECOVER FROM THE PREVIOUS LOADING).

BECAUSE OF THIS ARRANGEMENT, THE TIME SPACING BETWEEN RELAYS WILL BE CONSIDERED THE PARAMETER OF CONCERN AND THE ERRORS FROM EACH OF THE TWO SEQUENTIAL RELAYS WILL BE R.S.S.'d WITH EACH OTHER AND THIS VALUE SUBTRACTED FROM THE NOMINAL SPACING VALUE TO YIELD THE MINIMUM SPACING BETWEEN THE TWO RELAYS. THIS WILL BE DONE IN TURN FOR ALL RELAYS IN THE SEQUENCE. (SEE CALCULATIONS PAGE 29-32)

REV 0	PREP RC	DATE 5-11-87	CHECK RP	DATE 5-12-87	SHEET 25	C/O 26
REV 1	PREP	DATE	CHECK	DATE	SHEET	C/O
REV 2	PREP	DATE	CHECK	DATE	SHEET	C/O

126
136

BRANCH/PROJECT IDENTIFIER
DEMONSTRATED ACCURACY CALCULATION DG TIMER RELAYS

COMPUTATIONS/ANALYSES
C) ACCURACY DISCUSSION (CONTINUED)

✓ THE FOLLOWING DEVICES ARE CALIBRATED INDIVIDUALLY. THEIR ACCEPTANCE BANDS ARE AS FOLLOWS:

DEVICE	Ab	REFERENCE
ALL TIMERS	±5% of SP	REQUIREMENT OF THIS CALCULATION (SEE NOTE 7, SHEET 10)

___ THE FOLLOWING DEVICES ARE CALIBRATED TOGETHER. THE ACCEPTANCE BAND FOR THE COMBINATION OF THESE DEVICES IS AS FOLLOWS:

DEVICE	Ab	REFERENCE

17/

REV 0	PREP SC	DATE 5-11-97	CHECK RS	DATE 5-12-97	SHEET 26 C/O 27
REV 1	PREP	DATE	CHECK	DATE	SHEET C/O
REV 2	PREP	DATE	CHECK	DATE	SHEET C/O

BRANCH/PROJECT IDENTIFIER DG TIMER RELAYS
DEMONSTRATED ACCURACY CALCULATION

COMPUTATIONS/ANALYSES
D) ACCURACY CALCULATION INDEX

R_1

REV 0	PREP [illegible]	DATE 5-11-87	CHECK [illegible]	DATE 5-12-87	SHEET 27	C/O 28
REV 1	PREP [illegible]	DATE 8-24-87	CHECK [illegible]	DATE 8/24/87	SHEET	C/O
REV 2	PREP	DATE	CHECK	DATE	SHEET	C/O

COMPUTATIONS/ANALYSES

D) ACCURACY CALCULATIONS

A) DELAYS < 200 SEC

I) $A_n = A_s$ for RELAY TIMERS WITH DELAYS < 200 SEC.

$$A_n = A_s = \pm (Re^2 + De^2 + TNe^2 + Ab^2)^{1/2}$$

$$A_n = A_s = \pm (5\%^2 + 2.7\%^2 + 7.2\%^2 \quad 5\%^2)^{1/2}$$

$$A_n = A_s = \pm 10.4\% \text{ of SP}$$

B) DELAYS > 200 SEC

$A_m = A_s$ for RELAY TIMERS WITH DELAYS > 200 SEC

$$A_m = A_s = \pm (Re^2 + De^2 + TNe^2 + \quad + Ab^2)^{1/2}$$

$$A_m = A_s = \pm (10\%^2 + 2.7\%^2 + 7.2\%^2 \quad + 5\%^2)^{1/2}$$

$$A_m = A_s = \pm 13.6\% \text{ of SP}$$

C) DELAY for 1[ST] RELAY: (INCLUDES TNe (BIAS) ERROR)

$$A_n = A_s = \pm (Re^2 + De^2 + TNe_{(RANDOM)}^2 + Ab^2)^{1/2} \pm TNe_{(BIAS)}$$

$$A_n = A_s = \pm (5\%^2 + 2.7\%^2 + 7.2\%^2 + 5\%^2)^{1/2} \pm 5.6\%$$

$$A_m = A_s = \pm 10.4 \pm 5.6$$

$$A_m = A_s = \pm 16.0\% \text{ of SP}$$

REV 0	PREP [illegible]	DATE 5-19-87	CHECK RP	DATE 5-19-87	SHEET 25	C/O 29
REV 1	PREP	DATE	CHECK	DATE	SHEET	C/O
REV 2	PREP	DATE	CHECK	DATE	SHEET	C/O

BRANCH/PROJECT IDENTIFIER DG TIMER RELAYS
DEMONSTRATED ACCURACY CALCULATION

COMPUTATIONS/ANALYSES

D) ACCURACY CALCULATIONS

I) SEQUENCE 0^- TO 2 SEC

NOTE: ONLY ONE RELAY INCLUDED

DELAY TIME: 2 SEC

$A_N = A_S = 2 \times .16 = \pm .32$ sec   Nominal $- A_N = (2-0) - .32 = 1.68$ sec | R_1

II) SEQUENCE 2 TO 5 SEC

A) 2 SEC DELAY

$A_N = A_S = 2 \times (.104) = \pm .21$ sec

B) 5 SEC DELAY

$A_N = A_S = 5 \times (.104) = \pm .52$ sec

C) TIME SPACING

$A_N = A_S = \pm \left(A_{N_{2sec}}^2 + A_{N_{5sec}}^2 \right)^{1/2}$

$A_N = A_S = \pm \left(.21^2 + .52^2 \right)^{1/2}$

$A_N = A_S = \pm (.56)$ sec

Nominal $- A_N = (5-2) - .56 = 2.54$ sec | R_1

REV 0	PREP GC	DATE 5-14-87	CHECK RP	DATE 5-19-87	SHEET 30 C/O 30
REV 1	PREP GC	DATE 9-24-87	CHECK SIB	DATE 9/24/87	SHEET C/O
REV 2	PREP	DATE	CHECK	DATE	SHEET C/O

COMPUTATIONS/ANALYSES
D) ACCURACY CALCULATIONS

VI) SEQUENCE 15 TO 20 SEC

A) $A_m = A_s$ 15 SEC DELAY

$A_m = A_s = 15\,(.104) = \pm 1.56$ sec

B) 20 SEC DELAY

$A_m = A_s = 20\,(.104) = \pm 2.08$ sec

C) TIME SPACING

$A_m = A_s = \pm\left(A_{m_{15sec}}^2 + A_{m_{20sec}}^2\right)^{1/2}$

$A_m = A_s = \pm\left(1.56^2 + 2.08^2\right)^{1/2}$

$A_m = A_s = \pm 2.6$ sec

Nominal $- A_n = (20-15) - A_n = 2.4$ sec

R1

VII) SEQUENCE 20 TO 30 SEC

A) 20 SEC DELAY

$A_m = A_s = 20\,(.104) = \pm 2.08$ sec

B) 30 SEC DELAY

$A_m = A_s = 30\,(.104) = \pm 3.12$ sec

C) TIME SPACING

$A_m = A_s = \pm\left(A_{m_{20sec}}^2 + A_{m_{30sec}}^2\right)^{1/2}$

$A_m = A_s = \pm\left(2.08^2 + 3.12^2\right)^{1/2}$

$A_m = A_s = \pm 3.75$ sec

Nominal $- A_n = (30-20) - 3.75 = 6.25$ sec

R1

REV 0	PREP JC	DATE 5-11-87	CHECK RP	DATE 5-12-87	SHEET 31	C/O 32
REV 1	PREP JC	DATE 8-27-87	CHECK SJD	DATE 8/24/87	SHEET	C/O
REV 2	PREP	DATE	CHECK	DATE	SHEET	C/O

COMPUTATIONS/ANALYSES

D) ACCURACY CALCULATIONS

VIII) 30 TO 180 SEC SEQUENCE

A) 30 SEC DELAY

$A_M = A_S = 30(.104) = \pm 3.12$ sec

B) 180 SEC DELAY

$A_M = A_S = 180(.104) = \pm 18.72$ sec

C) TIME SPACING

$A_M = A_S = \pm(A_{M_{30\,sec}}^2 + A_{M_{180\,sec}}^2)^{1/2}$

$A_M = A_S = \pm(3.12^2 + 18.72^2)^{1/2}$

$A_M = A_S = \pm 18.97$ sec

Nominal $- A_n = (180-30) - A_n = 150 - 18.97 = 131.03$ sec

IX) 180 TO 240 SEQUENCE

A) 180 SEC DELAY

$A_M = A_S = 180(.104) = \pm 18.72$ sec

B) 240 SEC DELAY

$A_M = A_S = 240(.136) = \pm 32.64$ sec

C) TIME SPACING

$A_M = A_S = \pm(A_{M_{180\,sec}}^2 + A_{M_{240\,sec}}^2)^{1/2}$

$A_M = A_S = \pm(18.72^2 + 32.64^2)^{1/2}$

$A_M = A_S = \pm 37.63$ sec

Nominal $- A_n = (240-180) - 37.63 = 22.37$ sec

R_1

REV 0	PREP SC	DATE 5-11-87	CHECK RP	DATE 5-12-87	SHEET 32 C/O 33
REV 1	PREP TC	DATE 4-24-87	CHECK RP	DATE 4/24/87	SHEET ___ C/O ___
REV 2	PREP ___	DATE ___	CHECK ___	DATE ___	SHEET ___ C/O ___

COMPUTATIONS/ANALYSES

D) ACCURACY CALCULATIONS

D1		D2		F		
Before vs After [A]	After vs Next Before [B]	Before vs After [A]	After vs Next Before [B]	Before vs After [A]	After vs Next Before [B]	Before vs During [C]
0	0	+.4	-.3	-.1	0	0
0	+.1	0	0	0	0	-.05
-.1	+.1	0	0	+.1	0	+.1
0	+.1	+.2	+.2	+.1	-.3	-.1
-.2	0	-.4	+.3	+.2	0	+.1
+.2	-.1	-.2	-.3	0	0	+.1
-.1	0	-.2	0	+.1	-.1	0
+.1	0	-.2	0	-.1	-.1	-.1
-.1	+.2	+.1	-.1	+.2	-.1	0
-.1	-.1	+.2	0	+.2	-.1	+.1
0	+.2	+.1	-.3	-.1	0	+.1
-.2	-.2	0	0	-.1	-.2	+.3
-.2	0	-.1	0	-.2	+.2	+.1
+.2	+.1	-.1	0	-.1	0	-.1
-.1	0	+.2	+.2	-.1	-.1	0
-.2	0	-.4	+.3	-.2	-.2	+.2
-.2	-.1	-.2	+.3	-.2	0	0
-.1	0	-.2	+.1	+.1	-.1	0
-.1	-.2	0	-.1	-.1	+.1	-.1
+.2	-.2	+.2	-.3	0	-.1	+.1
+.1	0	+.2	-.3	0	0	+.3
-.1	-.2	+.3	-.3	0	-.1	0
-.1	0	+.2	-.1	+.2	-.1	+.2
-.1	0	-.1	0	+.1	0	+.2
0	+.1	+.3	0	0	0	-.1
0	+.1	-.1	0	-.1	+.1	-.1
0	-.1	-.2	0	-.2	+.3	-.1
0	-.1	+.1	+.2	0	-.1	0
+.2	-.2	-.2	-.1	-.1	0	0
0	0	+.1	-.1	0	0	+.1
+.1	0	+.1	-.1	0	+.1	+.2
0	-.1	0	+.3	-.1	+.1	-.1
+.1	0	-.1	+.1	-.2	+.1	-.2
+.1	-.1	-.2	+.1	+.1	0	0
-.1		-.2		0		-.1

SEISMIC ANALYSIS

(ALL VALUES IN SECONDS)

D1-A

$$\frac{\sum x}{n} = 0$$

$$\sqrt{\frac{n \sum x^2 - (\sum x)^2}{n(n-1)}} = .124$$

D1-B

$$\frac{\sum x}{n} = -.003$$

$$\sqrt{\frac{n \sum x^2 - (\sum x)^2}{n(n-1)}} = .111$$

D2-A

$$\frac{\sum x}{n} = -.006$$

$$\sqrt{\frac{n \sum x^2 - (\sum x)^2}{n(n-1)}} = .200$$

D2-B

$$\frac{\sum x}{n} = .009$$

$$\sqrt{\frac{n \sum x^2 - (\sum x)^2}{n(n-1)}} = .183$$

F-A

$$\frac{\sum x}{n} = .011$$

$$\sqrt{\frac{n \sum x^2 - (\sum x)^2}{n(n-1)}} = .123$$

F-B

$$\frac{\sum x}{n} = -.009$$

$$\sqrt{\frac{n \sum x^2 - (\sum x)^2}{n(n-1)}} = .116$$

F-C

$$\frac{\sum x}{n} = .03$$

$$\sqrt{\frac{n \sum x^2 - (\sum x)^2}{n(n-1)}} = .126$$

BRANCH/PROJECT IDENTIFIER DG TIMER RELAYS
DEMONSTRATED ACCURACY CALCULATION

COMPUTATIONS/ANALYSES
D) ACCURACY CALCULATIONS

XI) POWER SUPPLY EFFECT ANALYSIS

E7012PC001	E7022AC001	E7012PC001
-6.4	-5.6	-2.5
-.5	-.6	+1.6
+3.5	+2.0	0
+1.0	0	-.6
-.5	-1.1	-.6
-1.6	-1.2	-5.5
+.5	0	-6.7
+1.7	-1.9	-10.6
-.5	-.7	-12.2
E7022PC001	**E7014AC001**	**E7024AC001**
+5.4	+2.4	-4.8
+1.2	-5.1	0
0	-2.7	+7.4
+.6	-13.7	+3.1
+4.4	-11.6	-3.6
+3.7	-2.8	-.5
+1.0	-10.2	+4.4
0	-5.5	0
-.7	-7.4	-1.4
E7014PC001	**E7024PC001**	
-.6	+7.3	
+1.2	-1.3	
-1.5	+1.2	
0	+3.3	
-.8	+4.6	
-.8	+.7	
+2.0	+5.9	
+.6	+3.0	
-1.8	+3.1	

(ALL VALUES IN %)

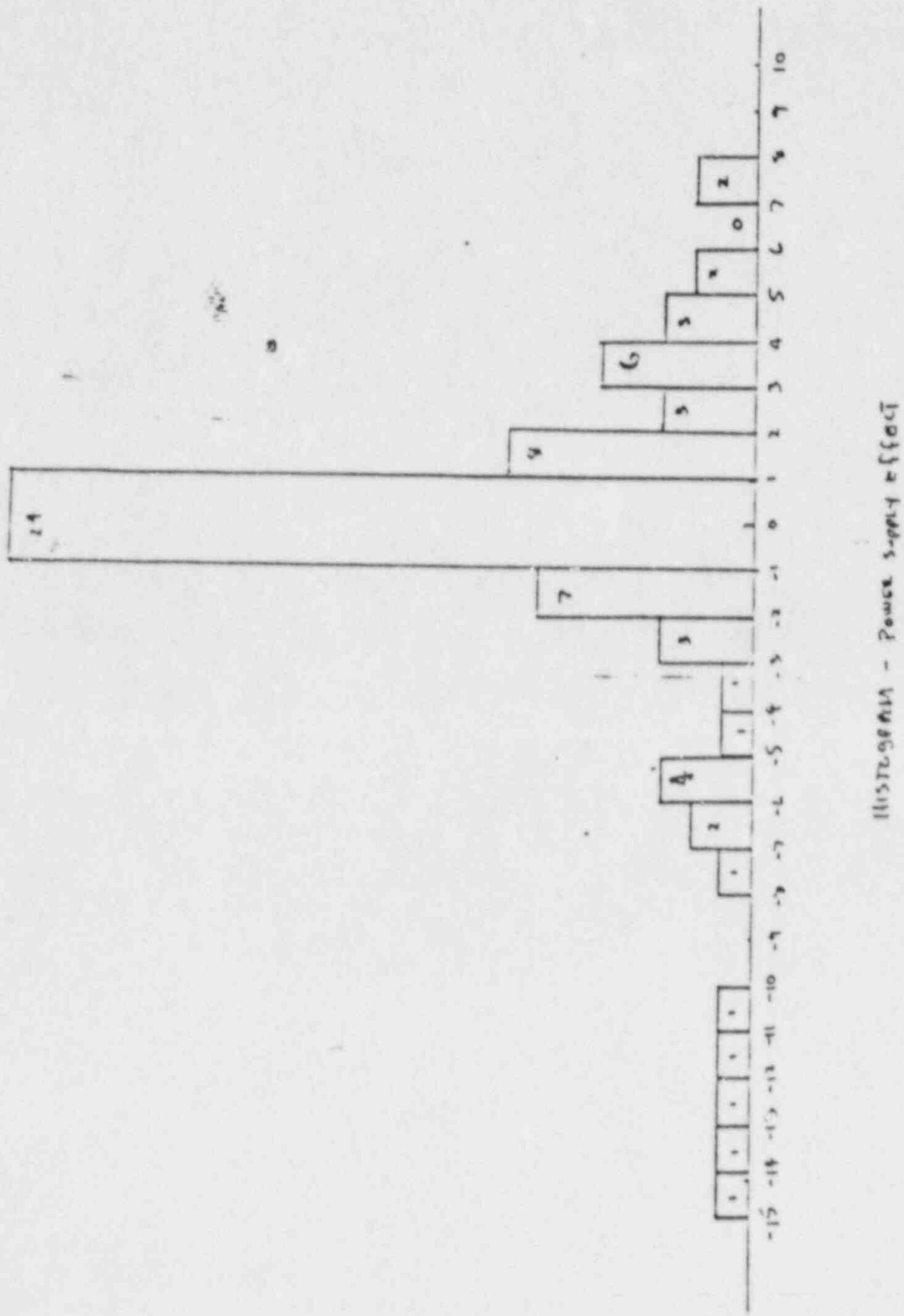
$$\frac{\sum x}{n} = -0.789\%$$

$$\sqrt{\frac{n\sum x^2 - (\sum x)^2}{n(n-1)}} = 4.47\%$$

REV 0 PREP FC DATE 5-11-87 CHECK R.P. DATE 5-12-87 SHEET 39 C/O 35
REV 1 PREP ____ DATE ____ CHECK ____ DATE ____ SHEET ____ C/O ____
REV 2 PREP ____ DATE ____ CHECK ____ DATE ____ SHEET ____ C/O ____

COMPUTATIONS/ANALYSES
D) ACCURACY CALCULATIONS

VI)



BRANCH/PROJECT IDENTIFIER DG [illegible]

DEMONSTRATED ACCURACY CALCULATION

COMPUTATIONS/ANALYSES

D) ACCURACY CALCULATIONS

XIII TEMPERATURE EFFECT ANALYSIS

% DEVIATION

40°F TO 50°F	-.49 +.3 +1.4 -1.1 +6.9 +4 -4.1 -3.0	+7.3 -.9 -4.3 +7.0 -1.9 0 -1.1 +3.4	mean = 1.0 σ = 3.86
50°F TO 70°F	-2.4 +.6 +11.5 +2.3 +8.4 +3.4 -2.6 +26.3*	+1.5 -.6 +8.3 +5.7 +11.2 +6.5 -4.2 +35.6*	mean = 3.6 σ = 5.2
70°F TO 90°F	-1.5 -1.8 -2.2 -4.0 -4.3 -6.8 -7.0 -6.8	+3.8 -4.7 -4.9 -7.8 -4.4 -5.3 -6.4 -4.4	mean = -4.4 σ = 3.5
90°F TO 110°F	-.5 +3.1 0 +1.1 -3.2 +.7 -2.8 0	-2.0 +7.5 +.8 0 -.9 +1.9 -2.4 -6.5	mean = -.23 σ = 3.1
110°F TO 130°F	-5.5 -1.2 -1.6 -2.3 -10.0 -2.0 +5.8 -4.6	-3.5 -2.3 -3.2 -2.3 -.9 -5.7 +.6 -1.6	mean = -2.5 σ = 3.1
130°F TO 150°F	-2.1 -5.5 -3.3 -4.6 +12.5 -4.4 -1.1 -1.6	-3.2 -7.1 -.6 -3.5 -.7 -4.7 -2.3 +3.3	mean = -2.5 σ = 3.3

$$\text{mean} = \frac{\Sigma x}{n}$$

$$\sigma = \sqrt{\frac{n\Sigma x^2 - (\Sigma x)^2}{n(n-1)}}$$

* SEE NOTE NEXT PAGE

REV 0	PREP [illegible]	DATE 5-11-87	CHECK R.P.	DATE 5-12-87	SHEET 36	C/O 37
REV 1	PREP	DATE	CHECK	DATE	SHEET	C/O
REV 2	PREP	DATE	CHECK	DATE	SHEET	C/O

COMPUTATIONS/ANALYSES

D) ACCURACY CALCULATIONS

TEMPERATURE EFFECT ANALYSIS

NOTE: this value (35.6) is inconsistent with the rest of the data. Including this value in the sample yields a σ of 10.65. For a >99% certainty (3σ), the limit of probable values would be 31.95, Therefore, a value of 35.6 is not probable. If this and its companion value (26.3) is deleted from the sample, the mean becomes +3.6 and σ = 5.2, These values are consistent with the values calculated for the other steps. Using a σ of 5.2, the 26.3 value is also improbable, therefore, these two points (26.3 & 35.6) will be excluded from the analysis on Page 36.

BRANCH/PROJECT IDENTIFIER DG timer relays
DEMONSTRATED ACCURACY CALCULATION

COMPUTATIONS/ANALYSES
D) ACCURACY CALCULATIONS

TEMPERATURE EFFECT ANALYSIS

% deviation

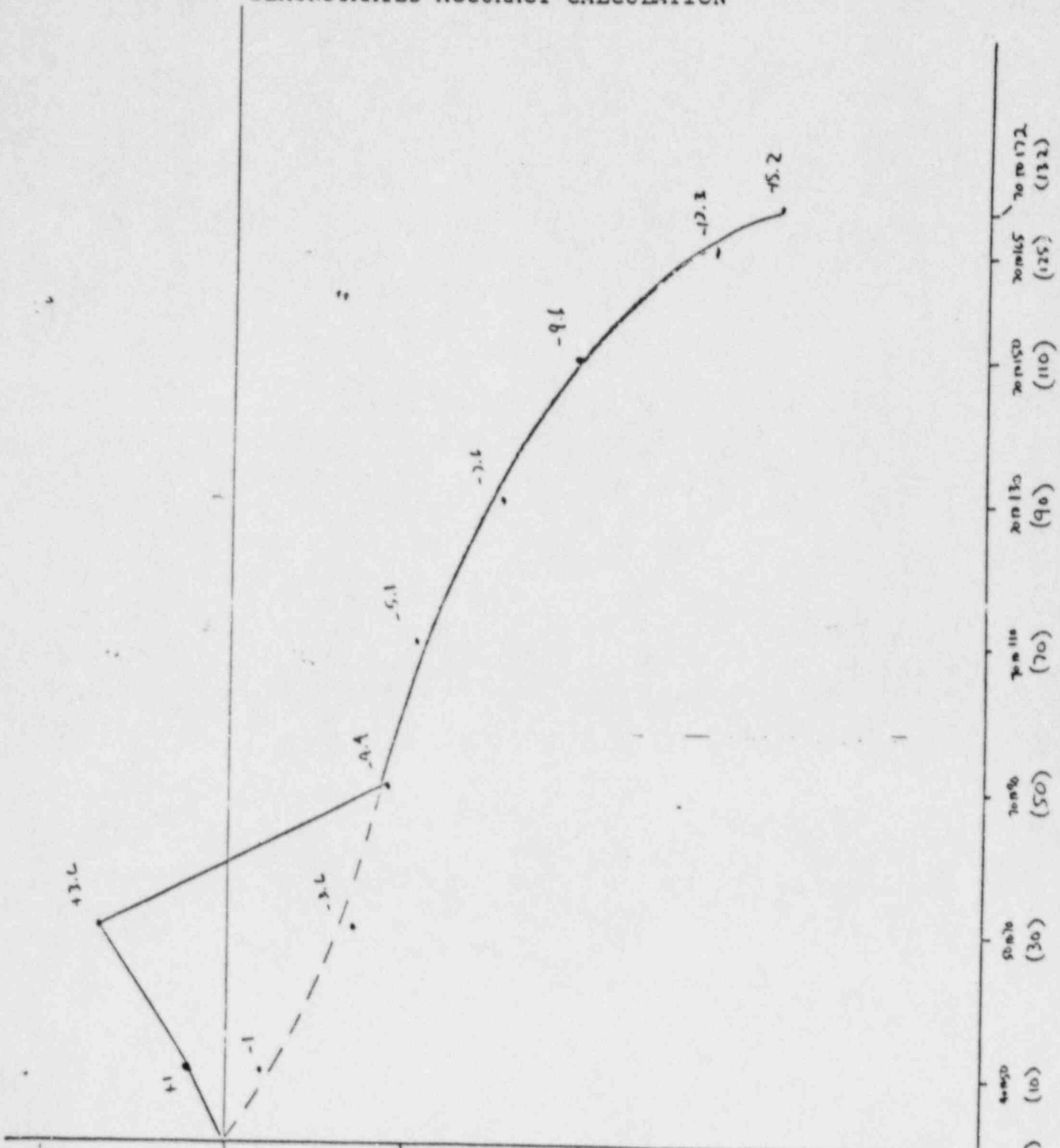
70°F to 110°F	-2.0 -1.1 -7.1 -9.1	-1.4 -4.0 -6.8 -6.2	-5.7 -4.9 -7.6 +0.6	-10.5 -13.8 -9.6 -3.0	mean: -5.1 σ = 3.6
70°F to 130°F	-7.4 -3.4 -1.6 -5.2	-11.3 -8.4 -8.3 -8.0	-10.1 -7.1 -7.1 -1.7	-11.9 -15.2 -7.6 -8.5	mean: -7.6 σ = 3.5
70°F to 150°F	-9.4 -7.8 -2.7 -10.5	-0.2 -9.9 -11.3 -16.7	-12.0 -10.3 -9.2 -8.7	-12.0 -12.4 -8.1 -12.8	mean: -9.625 σ = 3.9
70°F to 165°F	-13.9 -12.3 -2.2 -16.9	-10.9 -30.2* -11.5 -18.5	-19.8 -16.3 -12.5 -16.9	-13.5 -35.0* -9.7 -17.1	mean: -13.3 σ = 4.16
70°F to 172°F	-10.4 -15.6 -2.2 -18.6	-11.7 -30.7* -5.8 -21.0	-13.9 -18.5 -14.1 -19.2	-16.0 -36.4* -16.0 -19.5	mean: -15.2 σ = 4.8

* These values were taken from the same relay addressed in the note on page 37. The same situation is exhibited here in that these values are not probable (>26), therefore, will be excluded from the analysis.

REV 0	PREP	Fc	DATE 5-11-87	CHECK	[illegible]	DATE 5-12-87	SHEET 38	C/O 39
REV 1	PREP		DATE	CHECK		DATE	SHEET	C/O
REV 2	PREP		DATE	CHECK		DATE	SHEET	C/O

BRANCH/PROJECT IDENTIFIER DC Timer Relays

DEMONSTRATED ACCURACY CALCULATION



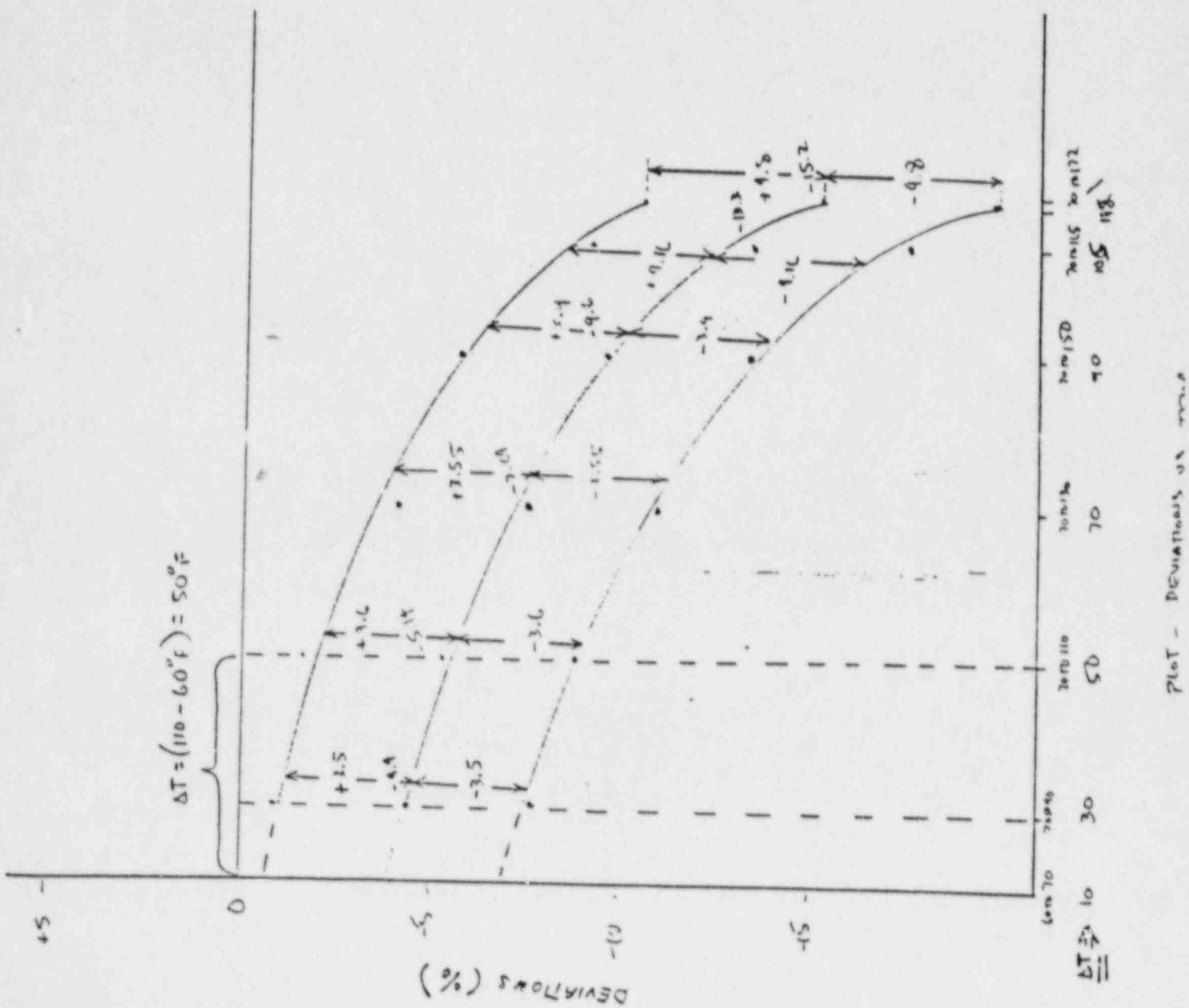
REV 0 PREP FC DATE 5-11-87 CHECK [illegible] DATE [illegible] SHEET 39 C/O 40

REV 1 PREP ____ DATE ____ CHECK ____ DATE ____ SHEET ____ C/O ____

REV 2 PREP ____ DATE ____ CHECK ____ DATE ____ SHEET ____ C/O ____

BRANCH/PROJECT IDENTIFIER DC Timer Relays

DEMONSTRATED ACCURACY CALCULATION



REV 0 PREP HC DATE 5-1-87 CHECK RF DATE 5-12-87 SHEET 40 C/O ~~40A~~ 41

REV 1 PREP ____ DATE ____ CHECK ____ DATE ____ SHEET ___ C/O ___

REV 2 PREP ____ DATE ____ CHECK ____ DATE ____ SHEET ___ C/O ___

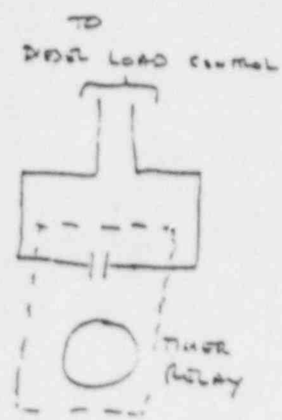
BRANCH/PROJECT IDENTIFIER DG Timer Relay
DEMONSTRATED ACCURACY CALCULATION

SUPPORTING GRAPHICS

A) LOOP DIAGRAM

✓ APPLICABLE TO ALL LOOPS LISTED ON SHEET 6.

__ APPLICABLE ONLY TO LOOPS: __________



REV 0	PREP FE	DATE 5-11-87	CHECK R.P.	DATE 5-12-87	SHEET 41	C/O 42
REV 1	PREP	DATE	CHECK	DATE	SHEET	C/O
REV 2	PREP	DATE	CHECK	DATE	SHEET	C/O

BRANCH/PROJECT IDENTIFIER DC TIMER RELAYS
DEMONSTRATED ACCURACY CALCULATION

SUMMARY OF RESULTS

I) A) DEMONSTRATED ACCURACY FOR TIMERS WITH DELAY. < 200 SEC = ± 10.1% of SP
B) DEMONSTRATED ACCURACY FOR 1ST RELAY ONLY: ±16.0% of SP

II) DEMONSTRATED ACCURACY FOR TIMERS WITH DELAYS > 200 SEC = ± 13.6 % of SP

III) MINIMUM TIME SPACING BETWEEN LOADINGS:

A) 0 TO 2 SEC : 1.68 SEC

B) 2 TO 5 SEC : 2.44 SEC

C) 5 TO 10 SEC : 3.84 SEC

D) 10 TO 15 SEC : 3.13 SEC

E) 15 TO 20 SEC: 2.4 SEC

F) 20 TO 30 SEC: 6.25 SEC

G) 30 TO 180 SEC: 131 SEC

H) 180 TO 290 SEC: 22.4 SEC

R1

92A

REV 0	PREP 24	DATE 5-4-87	CHECK GF	DATE 5-19-87	SHEET 42	C/O 43
REV 1	PREP 24	DATE 8-24-87	CHECK SJB	DATE 8/29/87	SHEET	C/O
REV 2	PREP	DATE	CHECK	DATE	SHEET	C/O

THIS SHEET ADDED BY REV 2.

BRANCH / PROJECT IDENTIFIER DG TIMER RELAYS
DEMONSTRATED ACCURCY CALCULATION

SUMMARY OF RESULTS (con't)

TITLE: DG TIMER RELAYS

REVISION: 2 #77

CALIBRATION FREQUENCY: 15 MONTHS

POST-SEISMIC RECAL. ~~IS~~ IS ✓ IS NOT REQUIRED GC 1-19-88

LOOP ANf: N/A

MODIFIER/INDICATOR ANf: N/A

INSTRUMENT	ANf	INSTRUMENT	ANf
ALL TIMERS WITH A SP < 200 SEC	+/- 16% of SP	ALL TIMERS WITH A SP > 200 SEC	+/- 19.2% of SP

1. ACCEPTANCE BAND FOR TIMERS IS +/- 5% OF SETPOINT.
2. THE CALIBRATION OF THE TIMERS MUST BE PERFORMED BY INITIATING THE TIMER DELAY AND THE CALIBRATION EQUIPMENT (TIMER) SIMULTANEOUSLY. HAVING ONE SWITCH START BOTH DEVICES SIMULTANEOUSLY IS PREFERRED. HAVING ONE TECHNICIAN VERBALLY OR VISUALLY SIGNAL ANOTHER AS TO THE START OF EITHER DEVICE IS NOT ACCEPTABLE.
   THE END OF THE DELAY PERIOD MUST BE SIMILARLY DETERMINED.
3. DIGITAL TIMER WITH A READOUT TO AT LEAST 1/100 TH OF A SECOND MUST BE USED.

REV 2 PREP [illegible] DATE 1-14-88 CHECK [illegible] DATE 1-14-88 SHEET 92A C/O 93
REV ___ PREP ___ DATE ___ CHECK ___ DATE ___ SHEET ___ C/O ___
REV ___ PREP ___ DATE ___ CHECK ___ DATE ___ SHEET ___ C/O ___

CONCLUSIONS

✓ APPLICABLE TO ALL LOOPS LISTED ON SHEET 6.

___ APPLICABLE ONLY TO LOOPS: ________

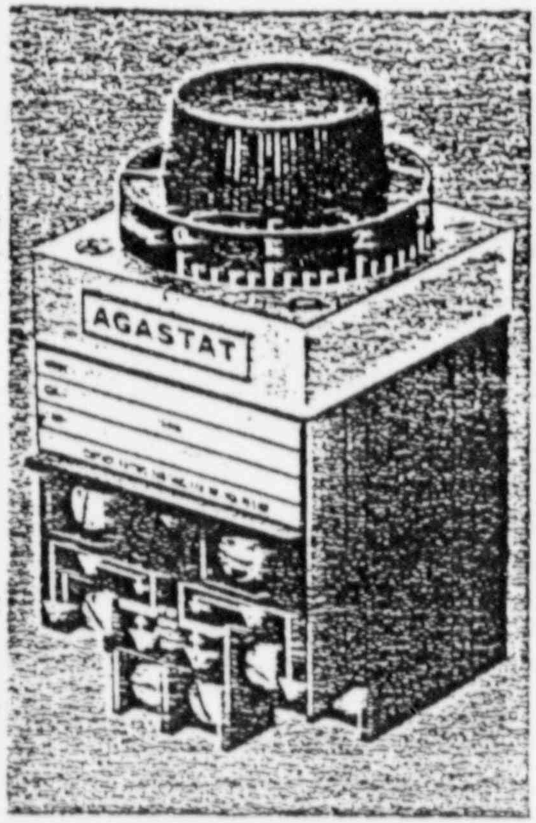
THIS CALCULATION DEFINED THE MINIMUM INTERVAL TIMES BETWEEN DG LOAD STEPS FOR THE SEQUENCE TIMERS AND INCORPORATED THE CHANGES TO SETPOINTS FOR AFW, CCSP AND ELECTRICAL Bd. RM. AHU. THE MINIMUM INTERVALS WILL BE EVALUATED IN THE DG VOLTAGE ANALYSIS TO ENSURE ACCEPTABILITY. A PRELIMINARY EXAMINATION OF DG TEST RESULTS INDICATES THAT THESE INTERVALS WILL BE ACCEPTABLE. THEREFORE, THE SETPOINT CHANGES PROPOSED IN ECN 7216 & 7222 WILL NOT ADVERSELY AFFECT THE DG LOADING. FAVORABLE RESULTS OF THE DG VOLTAGE ANALYSIS WILL SUBSTANTIATE ACCEPTABLE DG PERFORMANCE PRIOR TO LEAVING MODE 5.

INTERFACE REVIEW: [signature]
G.L. NICELY (EEB - AUXILIARY POWER)

REV 0	PREP JC	DATE 5-26-87	CHECK RP	DATE 5-26-87	SHEET 43	C/O –
REV 1	PREP JC	DATE 8-31-87	CHECK LJD	DATE 8/31/87	SHEET	C/O
REV 2	PREP	DATE	CHECK	DATE	SHEET	C/O

AGASTAT®

timing relays 7000 series



The AGASTAT 7000 Series timing relay provides performance features never before available in an electropneumatic timer. It represents over 35 years of research and development by the acknowledged leader in this specialized field. Using advanced design concepts and custom-produced components, this new generation of timers offers circuit designers a degree of accuracy and versatility matched only by the most sophisticated electronic controls. In addition, their economy and reliability under severe operating conditions make them the preferred choice for demanding industrial applications where timing is a critical function.

A number of significant design improvements characterize the 7000 Series. These include:

OVERSIZE TIME-CALIBRATED ADJUSTMENT KNOBS — all ranges from milliseconds to 60 minutes are fully calibrated in linear increments. Large serrated knobs with high-resolution markings visible from all angles make this the most practical, easily-set timer available.

2-WAY MOUNTING — can be ordered for surface or panel mounting, with minimum hardware change. "All-angle" dial calibrations.

LONGEST TIME RANGES — standard ranges from milliseconds to 60 minutes, with outstanding repeatability at all points.

FRONT TERMINALS — easy-to-reach screw terminals, all on the face of the unit, clearly identified.

MODULAR ASSEMBLY — timing head, coil assembly and switchblock all individual modules, with coils and switches field-replaceable. Auxiliary switches can be added for greater switching flexibility.

amerace

CONTROL PRODUCTS DIVISION

Attachment No. 1 Sheet 1 of 5
Loop #/Identifier DG TIMER RELAYS

Agastat timing relays 7000 series

design

Other manufacturers assemble timers using switches, solenoid coils or other parts originally designed for nontiming applications. Extensive research through the years has proven, however, that the proper balance of electrical, mechanical, and pneumatic forces required to produce a reliable timing instrument cannot be achieved in this manner. This is why every component of the AGASTAT timing relay has been expressly designed for its specific role in the overall timing function. These are the main components of the 7000 Series relays:

CALIBRATED TIMING HEAD uses no needle valve, recirculates air under controlled pressure through a variable orifice to provide linearly adjustable timing. Patented design provides instant recycling, easy adjustment and long service life under severe operating conditions.

PRECISION-WOUND POTTED COIL module supplies the initial motive force with minimum current drain. Total sealing without external leads eliminates moisture problems, gives maximum insulation value.

NEW SNAP-ACTION SWITCH ASSEMBLY — custom-designed over-center mechanism provides greater contact pressure up to transfer time for positive, no-flutter action. Standard switches are DPDT arrangement, with flexible beryllium copper blades and silver-cadmium oxide contacts. Special "timing-duty" design assures positive wiping action, sustained contact pressure and greater heat dissipation during long delay periods.

Each of these sub-assemblies forms a self-contained module which is then assembled at the factory with the other two to afford a wide choice of operating types, coil voltages, and timing ranges.

The modern squared design with front terminals and rear mounting permits the grouping of 7000 Series units side-by-side in minimum panel space. Auxiliary switches may be added in the base of the unit, without affecting the overall width or depth.

operation

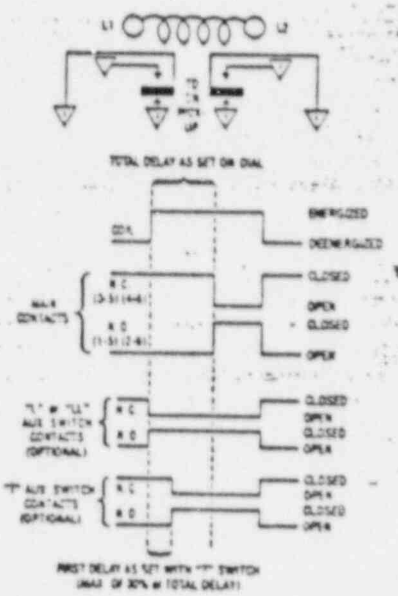
Two basic operating types are available. "On-delay" models provide a delay period on energization, at the end of which the switch transfers the load from one set of contacts to another. De-energizing the unit during the delay period immediately recycles the unit, readying it for another full delay period on reenergization.

In "off-delay" models the switch transfers the load immediately upon energization, and the delay period does not begin until the unit is deenergized. At the end of the delay period the switch returns to its original position. Reenergizing the unit during the delay period immediately resets the timing, readying it for another full delay period on deenergization. No power is required during the timing period.

In addition to these basic operating types, "Double Head" models offer sequential delays on pull-in and drop-out in one unit, as described on page 3. With the addition of auxiliary switches the basic models provide two-step timing, pulse actuation for interlock circuits, or added circuit capacity.

On-Delay Models, 7012 [redacted]

(Delay on pick-up)



Applying continuous voltage to the coil (L1-L2) starts a time delay lasting for the preset time. During this period the normally closed contacts (3-5 and 4-6) remain closed. At the end of the delay period the normally closed contacts break and the normally open contacts (1-5 and 2-6) make. The contacts remain in this transferred position until the coil is deenergized, at which time the switch instantaneously returns to its original position.

Deenergizing the coil, either during or after the delay period, will recycle the unit within .050 second. It will then provide a full delay period upon reenergization, regardless of how often the coil voltage is interrupted before the unit has been permitted to "time-out" to its full delay setting.

Auxiliary Switch Options

To increase the versatility of the basic timer models, auxiliary switches may be added to either on-delay or off-delay types. They switch additional circuits, provide two-step timing action, or furnish electrical interlock for sustained coil energization from a momentary impulse, depending on the type selected and its adjustment. Because of their simple attachment and adjustment features, they can be installed at the factory or in the field, by any competent mechanic. All auxiliary switches are SPDT with UL listings of 10A @ 125, 250, or 480 VAC. A maximum of one Code T or two Code L auxiliary switches may be added to each relay.

Instant Transfer (Auxiliary Switch Code L, maximum of 2 per relay)

1. Energizing coil begins time delay and transfers auxiliary switch.
2. Main switch transfers after total preset delay.
3. Deenergizing coil resets both switches instantly.

Auxiliary switch is non-adjustable.

Two-Step Timing (Auxiliary Switch Code T, maximum of 1 per relay)

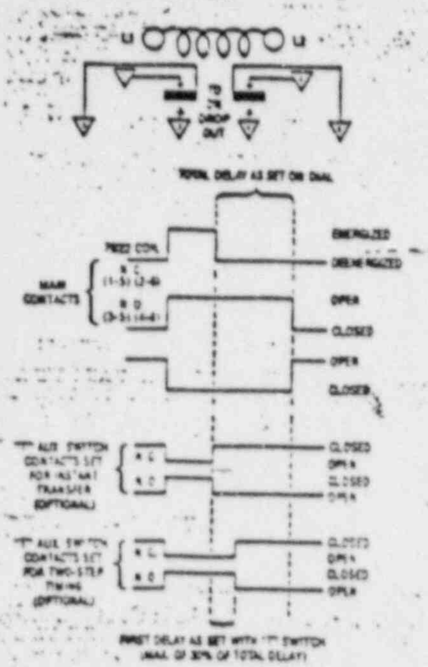
1. Energizing coil begins time delay.
2. After first delay auxiliary switch transfers.
3. Main switch transfers after total preset delay.
4. Deenergizing coil resets both switches instantly.

First delay is independently adjustable, up to 30% of overall delay. (Recommended maximum 100 seconds)

Attachment No. 1 Sheet 2 of 5
Loop #/Identifier DG DHCL RELAYS

operation

Off-Delay Models, 7022
(Delay on drop-out)



Applying voltage to the coil (for at least .050 second) will instantaneously transfer the switch, breaking the normally closed contacts (1-5 and 2-6), and making the normally open contacts (3-5 and 4-6). Contacts remain in this transferred position as long as the coil is energized. The time delay begins immediately upon deenergization. At the end of the delay period the switch returns to its normal position.

Reenergizing the coil during the delay period will immediately return the timing mechanism to a point where it will provide a full delay period upon subsequent deenergization. The switch remains in the transferred position.

Auxiliary Switch Options

In these models the same auxiliary switch provides either two step timing or instant transfer action, depending on the adjustment of the actuator.

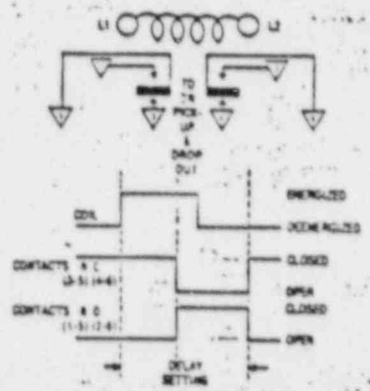
Two-Step Timing (Auxiliary Switch Code T, maximum of 1 per relay)

1. Energizing coil transfers main and auxiliary switches instantly.
2. Deenergizing coil begins time delay.
3. After first delay auxiliary switch transfers.
4. Main switch transfers after total preset delay. First delay is independently adjustable, up to 30% of overall delay. (Recommended maximum 100 seconds).

Instant Transfer (Auxiliary Switch Code T, maximum of 1 per relay)

1. Energizing coil transfers main and auxiliary switches instantly.
2. Deenergizing coil resets auxiliary switch and begins time delay.
3. Main switch transfers after total preset delay. Auxiliary switch is factory adjusted to give instant transfer operation, but may be easily adjusted in the field to provide two-step timing.

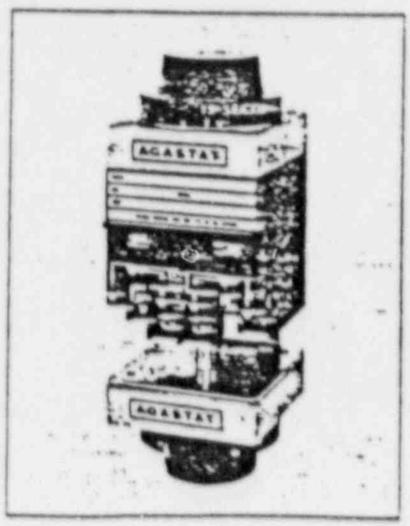
On-Delay, Off-Delay Models, 7032
(Double Head)



The Double Head model provides delayed switch transfer on energization of its coil, followed by delayed resetting upon coil deenergization. Each delay period is independently adjustable.

In new circuit designs or the improvement of existing controls now using two or more conventional timers, the Double Head unit offers distinct advantages.

Its compact design saves precious panel space, while the simplified wiring reduces costly interconnections.



Four Pole Models, 7014, 7024

With the addition of an extra switch block at the bottom of the basic unit, this version of the 7000 Series offers four pole switch capacity with simultaneous timing or two-step timing. The two-step operation is achieved by factory adjustment to your specifications.

For two-step operation, a maximum timing ratio between upper and lower switches of 3:2 is recommended. Once adjusted at the factory, this ratio remains constant regardless of changes in dial settings. (Ex: if upper switch transfer is set on dial at 60 sec., minimum time on lower switch should be 40 sec.)

This 7000 Series unit offers many of the performance features found in basic models in the series — voltage ranges, timing and switch capacities are virtually identical.

Four pole models add approximately 1¼" to the maximum height of the basic model, approximately ⅛" to the depth. They are designed for vertical operation only.

Timing Adjustment

The AGASTAT 7000 Series is the first electropneumatic timer to offer the ease of adjustment and resetting of a calibrated dial head. Discrete ranges covering a total span from .1 second to 60 minutes are available, as well as a cycle-calibrated range. (See table on page 4.) Each has its own calibrated, clearly identified dial.

Timing is set by simply turning the dial (in either direction) to the desired time value. In the zone of approximately 25° separating the high and low ends of timing ranges A, D, E, and K, instantaneous operation (no time delay) will occur. All other ranges produce an infinite time delay when the dial is set in this zone.

Attachment No. 1 Sheet 3 of 5
Loop #/Identifier DC Main Relays

Agastat timing relays 7000 series

— 11-4-76

specifications

(All values shown are at nominal operating voltage and 77°F unless otherwise noted.)

Linear Timing Ranges

Time Range Code	Models 7012, 7022, 7024	*Models 7014* 7032
A	.1 to 1 Sec.	.2 to 2 Sec.
B	.5 to 5 Sec.	.7 to 7 Sec.
C	1.5 to 15 Sec.	2 to 20 Sec.
D	5 to 50 Sec.	10 to 100 Sec.
E	20 to 200 Sec.	30 to 300 Sec.
F	1 to 10 Min.	1.5 to 15 Min.
H	3 to 30 Min.	3 to 30 Min.
I	6 to 60 Min.	Not avail.
J	3 to 120 Cycle	Not avail.
K	1 to 300 Sec.	Not avail.

Basic models are furnished with dials calibrated in linear increments covering the range selected. In addition, time-calibrated ranges B through K provide non-linear adjustment from .2 second to the beginning of the linear zone. For easiest adjustment and lowest cost, the shortest time range suitable for the application should be selected.

*Models 7014 and 7032 are available with letter-calibrated dials only. The upper end of the time ranges in these models may be twice the values shown.

Contact Ratings

Contact Capacity in Amperes (Resistive Loads)

Contact Voltage	Min. 100,000 Operations	Min. 1,000,000 Operations
30 vdc	15.0	7.0
110 vdc	1.0	0.5
120 v 60 Hz	20.0	15.0
240 v 60 Hz	20.0	15.0
480 v 60 Hz	12.0	10.0
250 DC	.5	.25

Contact Ratings as listed under the UL Component Recognition Program for 100,000 operations:

10 Amps. Resistive, 240 VAC
¼ Horsepower, 120 VAC/240 VAC
15 Amps. 30 VDC
5 Amps. General Purpose, 600 VAC
} Per Pole

Inductive and capacitive loads should not have inrush currents that exceed five times normal operating load.

All specifications listed here are for reference only and are subject to continuing revision. Verified drawings are available on request. If your requirements cannot be met by the standard production units described here, they may be filled by one of the many non-standard models not shown here. Many of these unusual configurations are available on a shorter-delivery, lower-cost basis than a purely custom model. We welcome your inquiry.

Coil Data

Coil Part Number	Code Letter	Rated Voltage @ 60 Hz	Operating Voltage Range @ 60 Hz	Rated Voltage @ 50 Hz	Operating Voltage Range @ 50 Hz
7000	A	120	102-132	110	93.5-121
	B	240	204-264	220	187-242
	C	480	408-528		
	D	550	468-605		
	E	24	20.5-26.5		
	F			127	108-140
	G			240	204-264
	H	12	10.2-13.2		
	I	6	5.1-6.6		
	J	208	178-229		
	K	Dual Voltage Coil (Combines A&B)			
	L	Special AC Coils (L1, L2, etc.)			
7010	M	28	22.5-33.5		
	N	48	38.5-57.5		
	O	24	19.2-28.8		
	P	120	96-144		
	Q	12	9.6-14.4		
	R	60	48-74		
	S	250	200-300		
	T	550	440-660		
	U	16	12.8-19.2		
	V	32	25.6-38.4		
	W	96	76.8-115		
	Y	6	4.8-7.2		
	Z	220	176-264		
	X	Special DC Coils (X1, X2, etc.)			

All units draw approximately 8 watts power at rated voltage. Minimum operating voltages are based on vertically mounted 7012 units. 7012 horizontally mounted or 7022 vertically or horizontally mounted units will operate satisfactorily at minimum voltages approximately 5% lower than those listed.

AC units drop out at approximately 50% of rated voltage. DC units drop out at approximately 20% of rated voltage.

All units may be operated on intermittent duty cycles at voltages 10% above the listed maximums. (Intermittent duty = maximum 50% duty cycle and 30 minutes "on" time.)

Repeat Accuracy

Repeat accuracy at any fixed temperature is defined as:

*The repeat accuracy deviation (A_a) of a time-delay relay is a measure of the maximum deviation in the time-delay that will be experienced in successive operations at any particular time setting of the relay and for any particular operating voltage or current.

Repeat accuracy is obtained from the following formula:

$$A_a = 100\frac{(T_1 - T_2)}{(T_1 + T_2)}$$

Where —
T_1 = Maximum observed time.
T_2 = Minimum observed time.

*NEMA part ICS 2-218.07

For delays of 200 seconds or less:

7012*, 7022, 7024	±5%
7014*	±10%
7032	±15%

For delays greater than 200 seconds:

7012*, 7022, 7014*, 7024	±10%
7032	±15%

*The first time delay afforded by Model 7012 with H (3 to 30 min.) and I (6 to 60 min.) time ranges or Model 7014 with H time range will be approximately 15% longer than subsequent delays due to coil temperature rise.

Attachment No. 1 Sheet 4 of 5
Loop #/Identifier DG Therm Relays

specifications

Temperature Range

Operating temperature range is −20°F to 165° F. The maximum shift in the average of three consecutive time delays at 77°F is −20% at −20°F; +20% at 165°F.

The storage temperature is −67°F to 165°F.

Dielectric

Withstands 1500 volts RMS 60 Hz between terminals and ground; 1,000 volts RMS 60 Hz between non-connected terminals.

For dielectric specifications on hermetically sealed models, consult factory.

Insulation Resistance

500 Megohms with 500 VDC applied.

Mounting/Terminals

Normal mounting of the basic unit is in a vertical position, from the back of the panel. Four tapped holes are provided in the back plate of the unit, making it interchangeable with earlier AGASTAT timer models. A front mounting bracket is also supplied with each basic unit, for installation from the front of the panel. All units are calibrated for vertical operation. Basic models (7012, 7022) may also be horizontally mounted, and will be adjusted accordingly *when Accessory Y1 is specified in your order.*

Standard screw terminals (8-32 truss head screws supplied) are located on the front of the unit, with permanent schematic markings. Barrier isolation is designed to accommodate spade or ring tongue terminals, with spacing to meet all industrial control specifications.

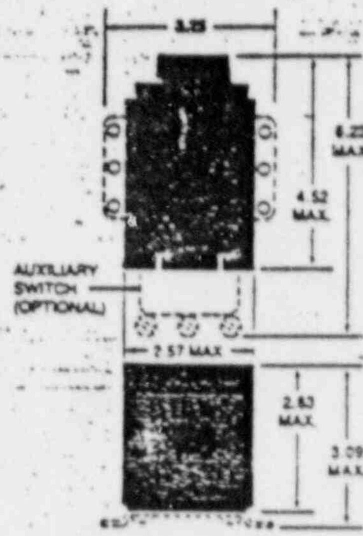
The basic 7000 Series may also be panel-mounted, with the addition of a panelmount kit that includes all necessary hardware and faceplate. This offers the convenience of "out-front" adjustment, with large calibrated dial skirt knob. The modern faceplate and knob blend with advanced equipment and console designs, while the body of the unit and its wiring are protected behind the panel.

Other mounting options include plug-in styles and special configurations to meet unusual installation requirements. Your inquiries are invited.

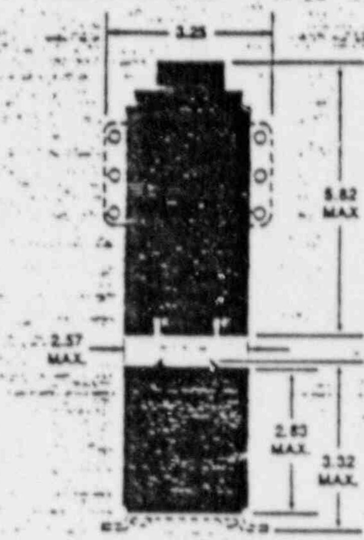
Panelmount Option "X"

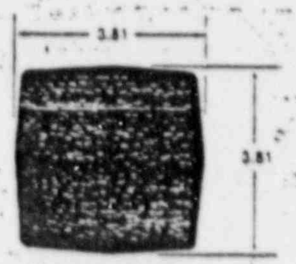
Dimensions

Basic Models 7012, 7022

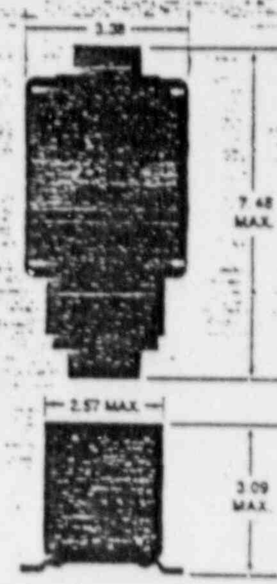


Models 7014, 7024

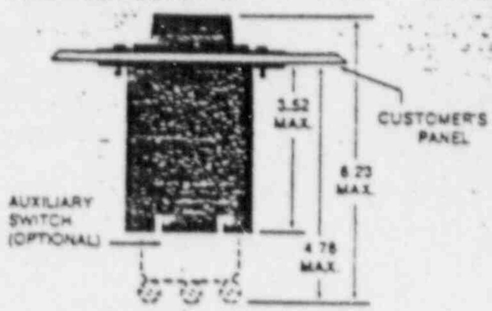




Model 7032



Panelmount Option "X"



UL Listed, CSA Certified, FM Approved

AGASTAT® 7000 Series basic models 7012, 7022, 7014 and 7024 are recognized under the Component Recognition Program of Underwriters Laboratories, Inc. under File No. E15631. They are Canadian Standards Association (CSA) certified under File No. LR-29186, and they are approved by Factory Mutual Engineering Corporation.

Approximate Weights

Models 7012, 7022 ....1 lb. 13 ozs.
7014, 7024 ....1 lb. 15 ozs.
7032 ....3 lbs. 5 ozs.

Weight may vary slightly with coil voltage.

Attachment No. 1 Sheet 5 of 6
Loop #/Identifier DG TIMER RELAYS

ordering information

ORDERING INFORMATION
Catalog Number Code

AGASTAT® 7000 Series timing relay

Operation

1 - On-Delay
2 - Off-Delay
3 - On-Delay, Off-Delay (Double head)

Contact Arrangement

2 — Double Pole, Double Throw
①⑥ 4 — Four Pole, Double Throw

Coil Voltage

Code	Voltage
A	120V 60 Hz 110 V 50 Hz
B	240 V 60 Hz 220 V 50 Hz
C	480 V 60 Hz
D	550V 60 Hz
E	24 V 60 Hz
F	127V 50 Hz
G	240 V 50 Hz
H	12V 60 Hz
I	6 V 60 Hz
J	208 V 60 Hz
K	Dual Voltage (combines A & B)
M	28 VDC
N	48 VDC
O	24 VDC
P	120 VDC
Q	12 VDC
R	60 VDC
S	250 VDC
T	550 VDC
U	16 VDC
V	32 VDC
W	96 VDC
Y	6 VDC
Z	220 VDC

Time Range

Models 7012, 7022, 7024

Code	Range
A	.1 to 1 sec.
B	.5 to 5 sec.
C	1.5 to 15 sec.
D	5 to 50 sec.
E	20 to 200 sec.
F	1 to 10 min.
H	3 to 30 min.
I	6 to 60 min.
J	3 to 120 cyc.
K	1 to 300 sec.

③ Models 7014, 7032

For Model 7032 specify separate time range code for each head. Any two ranges may be selected.

Code	Range
A	.2 to 2 sec.
B	.7 to 7 sec.
C	2 to 20 sec.
D	10 to 100 sec.
E	30 to 300 sec.
F	1.5 to 15 min.
H	3 to 30 min.

Factory Installed Options

- ②④ A1—Quick-Connect Terminals Single, Male, .250 ± .032
- ②④ A2—Quick-Connect Terminals Double, Male, .250 ± .032
- ②⑤⑥ B—Plug-in Connector, Male
- ①⑥ GZ—Total Enclosure with Bottom Connection
- ①②④ H—Herm. Sealed (Consult Factory)
- ① I1—Tamperproof Cover — Opaque green
- ① I2—Tamperproof Cover — Transparent
- ① K—Explosionproof enclosure
- ⑥ L—Auxiliary Switch One instantaneous Form C contact, (on-delay models only)
- ④⑥ LL—Auxiliary Switch Two instantaneous Form C contacts (on-delay models only)
- ②④⑤ M—Dustight
- ②⑤⑥ P—Octal Plug Adapter
- S—Dial Stops — Specify minimum & maximum settings
- ⑥ T—Auxiliary Switch One Form C contact (timed on on-delay models; timed or instantaneous on off-delay models)
- ①⑥ W—Watertight Enclosure
- ⑥ X—Panelmount Kit (Relay is calibrated for horizontal mounting)
- ② Y1—Calibration for Horizontal Mounting.
- ②④⑤⑥ Y2—Compensating Spring for 2-way mounting. Factory installed for vertical operation; remove for horizontal operation.

① Not suitable for Panelmounted models
② Not available on Four Pole models
③ Models 7014 and 7032 available with letter calibrated dials only. Upper end of time range may be twice the value shown
④ Factory installed only
⑤ Not available if unit is equipped with L, LL or T Auxiliary Switch or any type of enclosure
⑥ Not available on On-Delay, Off-Delay (Double head) models

| = Revised Since Last Printing

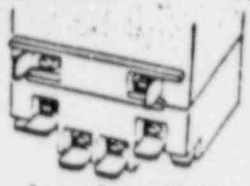
AGASTAT 7000 Series timing relays are also manufactured to MIL-SPEC requirements, and are QPL listed, conforming to requirements of MIL-C-2212D (SHIPS). Consult Control Products Division Regional Information Center for drawings and model numbers of available configurations.

Attachment No. 1 Sheet 6 of 6
Loop #/Identifier DG TIMING RELAYS

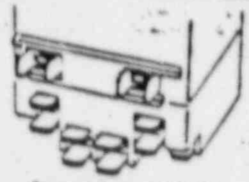
options

Factory installed when ordered as part of the Catalog Number Code

A SINGLE — QUICK-CONNECT TERMINALS — DOUBLE **A2**

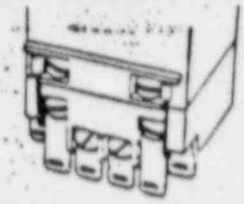


Request Drawing SS-625



Request Drawing SS-626

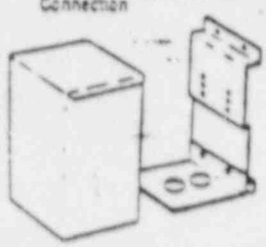
B PLUG-IN CONNECTORS



May be ordered separately as Part No. 7000-77

Request Drawing SS-627

G TOTAL ENCLOSURE with Knockouts for Bottom Connection

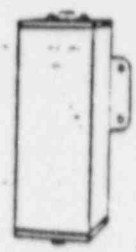


May be ordered separately as part No. 1675-42

3.18" W. x 3.84" D. x 7.63" H.

Request drawing SS-633

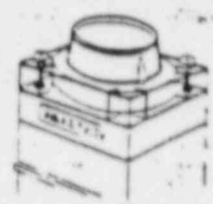
H HERMETICALLY SEALED ENCLOSURE



with Solder Hook Terminals. Consult Factory for connector styles available

Request drawing SS-626

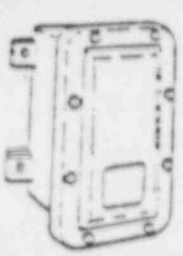
I TAMPER-PROOF COVER



May be ordered separately as Part Number 7000-62 (opaque green) or 7000-71 (transparent)

Request Drawing SS-634

K EXPLOSIONPROOF ENCLOSURE



(Meets requirements for Class I, Groups C & D locations.) May be ordered separately as part no. 2412-224 7.50" W. x 6.02" D. x 10.38" H.

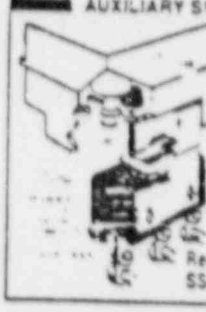
Request drawing 32807-00

L AUXILIARY SWITCH

May be ordered separately as Part No. 7000-47. Mounting hardware included.

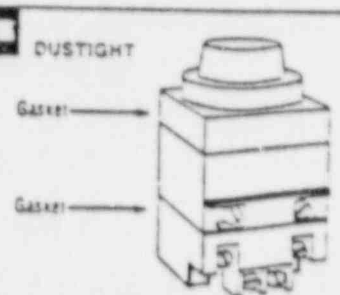
Request Drawing SS-638

L AUXILIARY SWITCH



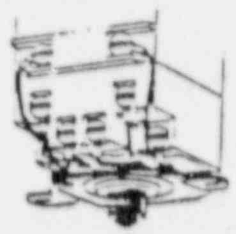
Request Drawing SS-621

M DUSTIGHT



Request Drawing SS-631

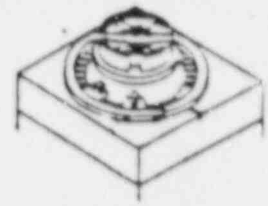
P OCTAL PLUG ADAPTER



May be ordered separately as Part No. 2412-97

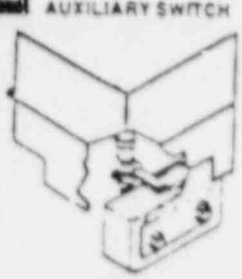
Request Drawing SS-630

S DIAL STOPS



Request Drawing SS-632

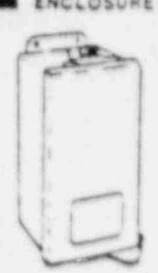
T AUXILIARY SWITCH



May be ordered separately as Part No. 2412-121. Mounting hardware included.

Request Drawing SS-641

W WATERTIGHT ENCLOSURE (NEMA-4)



4.75" W. x 4.44" D. x 9.75" H. May be ordered separately as Part No. 2025-01

Request drawing SS-...

X PANELMOUNT KIT

Mounting hardware included. May be ordered separately as Part No. 7000-41

Request Drawing SS-583

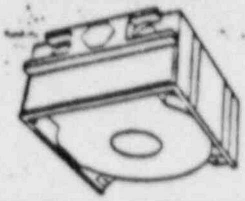
Attachment No. ____
Loop #/Identifier ____

Agastat timing relays 7000 series

accessories

order separately by part number

COIL ASSEMBLIES

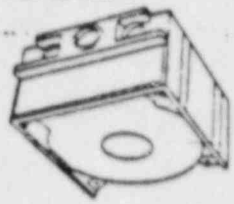


AC ASSEMBLY
Part No. 7000-(insert coil voltage code)

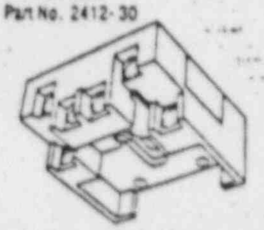
DC ASSEMBLY
Part No. 7010-(insert coil voltage code)

DC ASSEMBLY-550 VDC
Part No. 7010-T

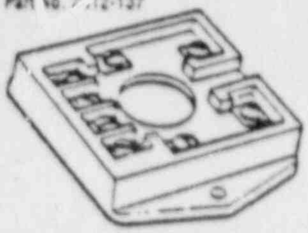
AC DUAL VOLTAGE COIL ASSEMBLY
Part No. 7000-K



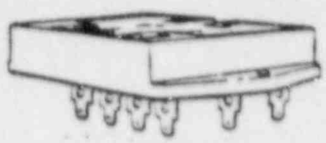
SWITCHBLOCK ASSEMBLY
Part No. 2412-30



PLUG-IN RECEPTACLE
Screw Terminals
Part No. 2412-137



PLUG-IN RECEPTACLE
Quick-connect Terminals
Part No. 2412-141



NOTE

Control Products Division of Amerace Corporation cannot recommend the use of its Products in the containment areas of Nuclear Power Generating Stations.

Attachment No. 1 Sheet 5 of 5
Loop #/Identifier DC TIME RELAYS

Agastat® timing relays are now marketed by

amerace CONTROL PRODUCTS DIVISION

Amerace Corporation, Control Products Division, 2330 Vauxhall Road, Union, New Jersey 07083
Telex 138 978

Seismic Test Procedure
on
6900 - Volt Shutdown Board Logic Panels
for
Sequoyah Nuclear Plant Units 1 & 2

TVA 72C2-83403
Westinghouse #CO-31704
Shop Order 17672

Prepared by R. F. Filer

Date 5/30/75

Approved by Westinghouse Electric Corp.

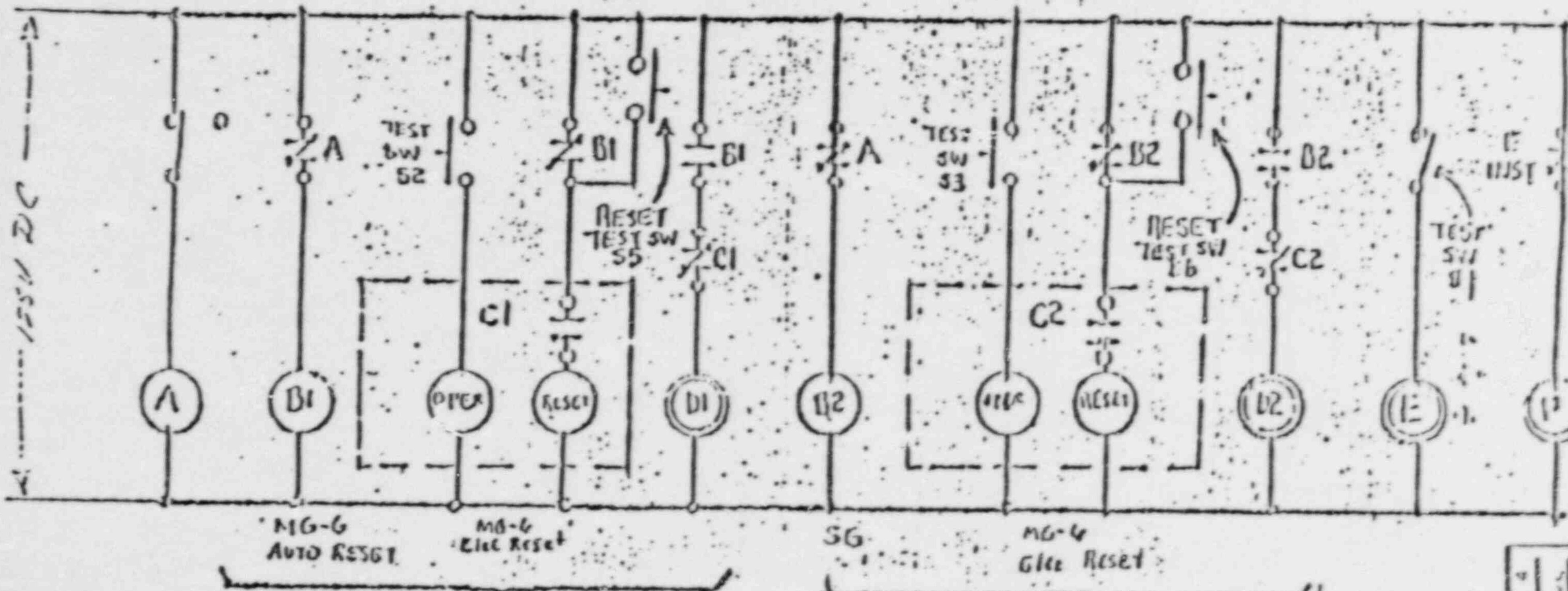
5/30/75 Date D. J. Cadillac
D. J. Cadillac

Approved by Westinghouse Electric Corp.

Date 5/30/75 R. P. Ballman, QA

Date: 10/30/73
Rev. 1 Date: 3/10/75
Rev. 2 Date: 5/30/75

Attachment No. 2 Sheet 1 of 4
Loop #/Identifier D.C. TIMER RELAYS



1 DS3-6-75A

Attachment No. ___ Sheet 2 of 4
Loop #/Identifier DC Dist. Relays

TVA CONTRA

E OF TEST — SINE BEAT
RELAY TEST II
PER FIG. 10

FREQ	ACCELERATION IN G's									TIME TO CLOSE WITH TEST SWITCH CLOSED			TIME TO CLOSE			
	A	B1	B2	CF	C3	F1										
1	[illegible]			1.3H		1.35H				31.6	31.6	31.5	20.1	20.1	20.0	20.4
2	[illegible]			1.0H		1.15H				31.95	31.5	31.5	20.1	20.1	20.1	20.1
3	[illegible]			1.05H		1.4H				31.6	31.5	31.6	20.2	20.1	20.1	20.1
4	[illegible]			1.09H		1.45H				31.5	31.6	31.7	20.2	20.2	20.1	20.3
5	[illegible]			1.16H		1.3H				31.9	31.4	31.6	20.3	20.1	20.5	20.1
6	[illegible]			1.13H		1.3H				31.7	31.6	31.6	20.1	20.3	20.4	20.2
7	[illegible]			1.1H		1.25H				31.6	31.6	31.7	20.2	20.1	20.5	20.3
8	[illegible]			1.7H		1.35H				31.5	31.6	31.5	20.1	20.2	20.3	20.1
9	[illegible]			1.78H		1.2H				31.4	31.4	31.6	20.2	20.1	20.1	20.3
10	[illegible]			1.4H		1.05H				31.6	31.8	31.7	20.3	20.2	20.1	20.3
11	[illegible]			1.55H		1.35H				31.7	31.6	31.5	20.1	20.1	20.3	20.4
[illegible]	[illegible]			1.75H		1.26H				31.8	31.5	31.4	20.3	20.1	20.1	20.1
[illegible]	[illegible]			1.44H		1.23H				31.7	31.6	31.4	20.3	20.1	20.1	20.2
[illegible]	[illegible]			1.48H		1.3H				31.5	31.6	31.5	20.1	20.3	20.2	20.1
[illegible]	[illegible]	—		1.87H		1.05H				31.5	31.5	31.6	20.2	20.3	20.1	20.3
[illegible]	[illegible]			1.78H		1.15H				31.7	31.5	31.7	20.3	20.1	20.5	20.1
[illegible]	[illegible]			1.11H		1.3H				31.7	31.7	31.6	20.1	20.3	20.4	20.3
[illegible]	[illegible]			1.4H		1.3H				31.5	31.6	31.7	20.2	20.1	20.5	20.3
[illegible]	[illegible]			1.64H		1.3H				31.5	31.6	31.8	20.1	20.3	20.<	20.4
[illegible]	[illegible]			1.5H		1.3H				31.7	31.6	31.6	20.1	20.3	20.3	20.5
[illegible]	[illegible]	SAME AS A	SAME AS B1	1.0H	SAME AS CF	1.3H	SAME AS F1	SAME AS D1	SAME AS [illegible]	31.3	31.5	31.5	20.1	20.2	20.2	20.4
[illegible]	[illegible]			1.08H		1.2H				31.[illegible]	31.5	31.5	20.2	20.1	20.1	20.4
[illegible]	[illegible]			1.86H		1.3H				31.6	31.4	31.6	20.3	20.3	20.1	20.3
[illegible]	[illegible]			1.51H		1.16H				31.7	31.5	31.6	20.2	20.1	20.3	20.1
[illegible]	[illegible]			1.6H		1.2H				31.5	31.6	31.6	20.1	20.1	20.1	20.4
[illegible]	[illegible]			1.59H		1.21H				31.5	31.6	31.5	20.2	20.2	20.4	20.3
[illegible]	[illegible]			1.49H		1.13H				31.5	31.6	31.4	20.3	20.3	20.3	20.1
[illegible]	[illegible]			1.76H		1.3H				31.5	31.7	31.7	20.2	20.2	20.1	20.2
[illegible]	[illegible]			2.1H		1.3H				31.6	31.6	31.5	20.1	20.3	20.4	20.2
[illegible]	[illegible]			1.98H		1.9H				31.6	31.5	31.5	20.1	20.1	20.1	20.1
[illegible]	[illegible]			2.0H		1.1H				31.7	31.5	31.5	20.1	20.2	20.1	20.2
[illegible]	[illegible]			1.95H		1.16H				31.7	31.6	31.5	20.3	20.3	20.1	20.1
[illegible]	[illegible]			1.12H		1.08H				31.4	31.6	31.4	20.1	20.3	20.4	20.3
										31.5	31.5	31.6	20.2	20.3	20.4	20.3
										31.8	31.6	31.6	20.2	20.1	20.3	20.1

Attachment No. 2 Sheet 3 of
Loop #/Identifier DC [illegible]

TVA CONTRACT
72C2-83403

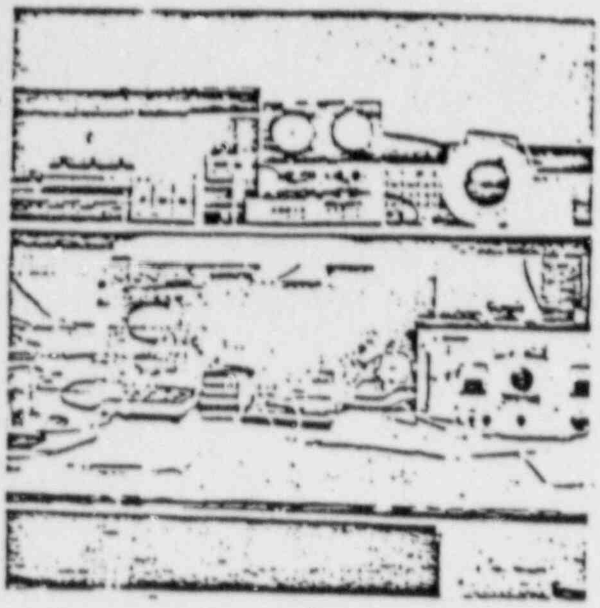
TYPE OF TEST — SINE BEAT RELAY TEST II PER FIG. II

FREQ	ACCELERATION IN G's A									TIME TO CLOSE C WHEN [illegible] CLOSED			TIME TO CLOSE			
		SAME AS 'A'	SAME AS 'A'	VERTICAL SAME AS 'A'	SAME AS 'C'	VERTICAL SAME AS 'A'	SAME AS '[illegible]'	SAME AS '[illegible]'	SAME AS '[illegible]'							
1	[illegible]			[illegible]		[illegible]				31.5	31.6	31.5	20.2	20.1	20.1	[illegible]
2	[illegible]			[illegible]		[illegible]				31.6	31.5	31.6	20.1	20.1	20.1	20.2
3	[illegible]			[illegible]		[illegible]				31.5	31.5	31.6	20.1	20.1	20.2	20.1
4	[illegible]			[illegible]		[illegible]				31.4	31.5	31.6	20.1	20.2	20.1	20.1
5	[illegible]			[illegible]		[illegible]				31.5	31.4	31.5	20.1	20.1	20.2	20.1
6	[illegible]			[illegible]		[illegible]				31.6	31.5	31.6	20.1	20.2	20.1	20.1
7	[illegible]			[illegible]		[illegible]				31.7	31.6	31.7	20.2	20.2	20.2	20.1
8	[illegible]			[illegible]		[illegible]				31.4	31.5	31.4	20.2	20.3	20.2	20.1
9	[illegible]			[illegible]		[illegible]				31.4	31.4	31.7	20.3	20.1	20.2	20.1
10	[illegible]			[illegible]		[illegible]				31.4	31.5	[illegible]	20.2	20.2	20.1	20.2
11	[illegible]			[illegible]		[illegible]				31.5	[illegible]	31.5	20.2	20.1	20.1	20.2
12	[illegible]			[illegible]		[illegible]				31.6	31.5	31.4	20.2	20.3	20.1	20.2
13	[illegible]			[illegible]		[illegible]				31.5	31.4	31.5	20.1	20.1	20.1	20.1
14	[illegible]			[illegible]		[illegible]				31.6	31.4	31.5	20.1	20.2	20.1	20.2
15	[illegible]			[illegible]		[illegible]				31.7	31.4	31.5	20.2	20.1	20.1	20.1
16	[illegible]			[illegible]		[illegible]				31.6	31.4	31.5	20.2	20.1	20.2	20.2
17	[illegible]			[illegible]		[illegible]				31.5	31.4	31.5	20.2	20.1	20.1	20.2
18	[illegible]			[illegible]		[illegible]				31.5	31.5	31.6	20.2	20.2	20.2	20.2
19	[illegible]			[illegible]		[illegible]				31.6	31.5	31.5	20.2	20.1	20.1	20.2
20	[illegible]			[illegible]		[illegible]				31.4	31.4	31.6	20.1	20.1	20.1	20.1
21	[illegible]			[illegible]		[illegible]				31.4	31.6	31.5	20.2	20.1	20.1	20.2
22	[illegible]			[illegible]		[illegible]				31.5	31.5	31.6	20.2	20.2	20.1	20.1
23	[illegible]			[illegible]		[illegible]				31.5	31.7	31.6	20.1	20.2	20.2	20.2
24	[illegible]			[illegible]		[illegible]				31.6	31.6	31.7	22.1	20.2	20.1	20.1
25	[illegible]			[illegible]		[illegible]				31.5	31.5	31.5	20.1	20.3	20.2	20.2
26	[illegible]			[illegible]		[illegible]				31.4	31.7	31.4	20.1	20.2	20.1	20.1
27	[illegible]			[illegible]		[illegible]				31.6	31.6	31.6	20.2	20.2	20.2	20.2
28	[illegible]			[illegible]		[illegible]				31.4	31.7	31.7	20.1	20.2	20.1	20.1
29	[illegible]			[illegible]		[illegible]				31.5	31.5	31.5	20.1	20.2	20.2	20.2
30	[illegible]			[illegible]		[illegible]				31.7	31.5	31.5	20.2	20.2	20.1	20.1
31	[illegible]			[illegible]		[illegible]				31.6	31.4	31.6	20.2	20.1	20.2	20.1
32	[illegible]			[illegible]		[illegible]				31.6	31.5	31.5	20.2	20.2	20.1	20.1
33	[illegible]			[illegible]		[illegible]				31.6	31.5	31.5	20.1	20.1	20.2	20.1
										31.5	31.6	31.6	20.1	20.2	20.3	20.2
										31.5	31.6	31.5	20.1	20.1	20.1	20.2

TVA CONTRACT
72C2-83403

Attachment No. 2 Sheet 6 of 6
Loop #/Identifier DC [illegible] RELAYS

Hutch Coleman
6450



NEQ
Nuclear Environmental Qualification
Test Report

REPORT NO. 43706-2 REVISION B

WYLE JOB NO. 43706

CUSTOMER P. O. NO. 20175

PAGE 1 OF VOL. I - 364 VOL. II - 411 PAGE REPORT

DATE August 23, 1978

SPECIFICATION (S) Wyle Qualification Plan 545/5614-3/ES, REVISION A

Attachment No. 3 Sheet 1 of 2
Loop #/Identifier DC Timer Relays

1.0 CUSTOMER Amerace Corporation, Control Products Division

ADDRESS 1000 Hickory Street, Grafton, Wisconsin 53024

2.0 TEST SPECIMEN Thirty-Eight (38) Agastat Relays, Series 7000, GP, ML, & TR

3.0 MANUFACTURER Amerace Corporation, Control Products Division, Grafton, Wisconsin

4.0 SUMMARY

Thirty-eight (38) Agastat Relays, consisting of seventeen (17) different types, were subjected to a Qualification Test Program to confirm the adequacy of design to perform their required functions under normal and abnormal conditions specified herein.

The test program was performed to satisfy the requirements of IEEE 323-1974, "IEEE Standard for Qualifying Class IE Equipment for Nuclear Power Generating Stations" including IEEE 344-1975, "IEEE Recommended Practice for Seismic Qualification of Class IE Equipment for Nuclear Power Generating Stations".

Attachment No. 5 Sheet 1 of 9
Loop #/Identifier DC Timer Relays

STATE OF ALABAMA } ss. Alabama Professional
COUNTY OF MADISON Engineers License #6363

James W. Foreman, being duly sworn, deposes and says: The information contained in this report is the result of complete and carefully conducted tests and is to the best of his knowledge true and correct in all respects.

SEAL James W. Foreman

SUBSCRIBED and sworn to before me this 23 day of August, 1978

Notary Public in and for the County of Madison, State of Alabama at large

My Commission expires June 3, 1980

Wyle shall have no liability for damages of any kind to person or property, including special or consequential damages, resulting from Wyle's providing the services covered by this report.

TEST BY Special Projects

PROJ. ENGINEER Richard C. Bridge
R. C. Bridge

WYLE Q. A. L. M. Davies
L. M. Davies

WYLE LABORATORIES
SCIENTIFIC SERVICES AND SYSTEMS GROUP
HUNTSVILLE, ALABAMA

4.0 SUMMARY (CONTINUED)

The test program was performed as specified in References 5.2 through 5.7 and in accordance with Reference 5.1. A summary of the tests performed and the results obtained is shown in Table I. There was a total of thirteen (13) Notices of Anomaly written during the test program. These anomalies are discussed in detail in the body of this report.

This final test report contains the following sections. The qualification program was performed in the sequence indicated by the section numbers.

VOLUME I:	Section I	Baseline Functional Tests
	Section II	Radiation Aging Test
	Section III	Post-Radiation Functional Tests
	Section IV	Cycling With Load Aging Test
	Section V	Post-Cycle/Load Aging Functional Tests
	Section VI	Temperature Aging Test
	Section VII	Post-Temperature Aging Functional Tests
	Section VIII	Seismic Tests
	Section IX	Post-Seismic Functional Tests
	Section X	Hostile Environment Tests
	Section XI	Post-Hostile Environment Functional Tes
	Section XII	Post-Test Inspection
	Section XIII	Qualification Plan 545/5614-3/ES, REV A
VOLUME II:	Section I	Baseline Functional Data
	Section II	Post-Radiation Functional Data
	Section III	Post-Cycle/Load Aging Functional Data
	Section IV	Post-Temperature Aging Functional Data
	Section V	Post-Seismic Functional Data
	Section VI	Hostile Environment Test Data
	Section VII	Post-Hostile Environment Functional Dat
	Section VIII	Post-Test Inspection Data

Attachment No. 3 Sheet 2 of 5
Loop #/Identifier DS [illegible]

SECTION I

BASELINE FUNCTIONAL TESTS

1.0 REQUIREMENTS

The thirty-eight (38) Agastat Relays will be subjected to a series of Baseline Functional Tests. The data from these tests will be measured and recorded. This data will be used for comparison to functional data throughout the Qualification Test Program to measure any degradation of performance of the relays.

Each test will be measured and recorded five (5) times, except insulation resistance and dielectric strength. The following tests will be conducted on all relays at room ambient temperature and humidity:

- Pull-In Voltage
- Drop-Out Voltage
- Dielectric Strength
- Insulation Resistance
- Operate Time
- Recycle Time
- Time Delay
- Repeat Accuracy
- Contact Bounce
- Contact Resistance

Operating specifications and test values are shown in Figures 1 and 2 of Reference Paragraph 5.2.

2.0 PROCEDURES

Pull-In Voltage - Each relay coil was connected to a power supply and voltmeter. Contact operation was monitored by indicating lamps. The power supply voltage was slowly increased until the lamps indicated all contacts were in the energized position. The minimum voltage to operate the relay was then measured and recorded.

Drop-Out Voltage - The setup for each relay was identical to the procedure used for Pull-in Voltage. The power supply was set at the rated voltage of the relay. The voltage was decreased until the lamps indicated all contacts were in the deenergized position. The maximum voltage to deenergize the relay was measured and recorded.

Dielectric Strength - Each relay was connected to a high electrical potential (hi-pot) power supply. The relays were tested for breakdown or current leakage at the test points described in Test 1 through Test 4, below. The results were recorded on data sheets. The applied electrical potential for relays was 2420 VAC, 60 Hz.

Attachment No. 3 Sheet 3 of 5
Loop #/Identifier DG [illegible]

Attachment No. ______ Sheet ____ of ____
Loop #/Identifier ____________

2.0 PROCEDURES (CONTINUED)

Operate Time (Continued)

The operate time measurement started upon energizing the relay coil at rated voltage and ended upon closure of the normally open contacts.

Time delay relays were set at zero or at their minimum values. All required operate times were measured and recorded.

Recycle Time - The relays were subjected to the Recycle Time Test using the test equipment setup required for the Operate Time, except normally closed contacts were wired in series and energized at 5 VDC. Rated voltage was then applied to the relay coil. The recycle time measurement began upon deenergizing the coil and ended upon closure of all the normally closed contacts.

Time Delay - The twenty-nine (29) Agastat Relays with the time delay feature were subjected to the Time Delay Test.

On-Delay Relays - Time delay measurements were performed using the Operate Time setup with one exception--contacts were energized at 110 VAC.

Off-Delay Relays - Time delay measurements were performed using the Recycle Time setup with one exception--contacts were energized at 110 VAC.

Repeat Accuracy - The repeat accuracy was calculated from the time delay measurements and then recorded, using the following formula:

$$A_r = 100 \frac{(T_1-T_2)}{(T_1+T_2)}$$

A_r = Repeat Accuracy

T_1 = Maximum time delay of five measurements

T_2 = Minimum time delay of five measurements

Contact Bounce - The relays were subjected to two (2) Contact Bounce Tests using the following test setup.

The coil of each relay was connected to a power supply. All normally open contacts were connected in series and all normally closed contacts were also connected in series. In the first test, the contact bounce measurements were taken from the normally open contacts. The contacts were connected to a power supply and oscilloscope. The relay coil was energized and the contacts closed. The last set of contacts to close yielded a time trace on the oscilloscope. The contact bounce time was measured from the first contact closure until the contact voltage dropped to dynamic contact resistance (minimum voltage drop values).

SECTION IV

CYCLING WITH LOAD AGING TEST

1.0 REQUIREMENTS

The thirty-eight (38) Agastat Relays will be operated 27,500 cycles at ambient temperature and humidity. The cycling rate will be 20 ± 2 cycles per minute. The duty cycle will be 1.5 ± 0.2 seconds energized and 1.5 ± 0.2 seconds deenergized. A resistive load will be applied to one set of contacts for each relay. The load type and contact designations can be found in Paragraph 6.0, Test Item Description, located in the beginning of this report.

2.0 PROCEDURES

The relays were mounted on panels for the cycling test. The 7000 Series Relays were mounted in their normal operating positions. Resistive loads, monitor lamps, and power supplies were connected to one set of contacts on each relay. Power supplies, cycling equipment, and an automatic shutdown counter were connected in order to energize and deenergize the relay coils 27,500 cycles.

3.0 RESULTS

The relays were cycle aged for 27,500 operations with attached electrical loads, as specified in Paragraph 2.0. After 304 cycles, Relay 7012 ACLLE, Item 2, failed to operate. The relay was removed from further testing. Notice of Anomaly No. 2 describes this deviation and is located in Appendix of this section. The remaining thirty-seven (37) relays successfully completed the cycling test.

Equipment used for the cycling test is shown on Instrumentation Equipment Sheets located in Appendix III of this section.

Photographs 1 and 2 show the setup of the relays, loads, and test equipment and are located in Appendix II of this section.

Attachment No. 3 Sheet 5 of 9
Loop #/Identifier DC [illegible]

SECTION VI

TEMPERATURE AGING TEST

1.0 REQUIREMENTS

The thirty-seven (37) Agastat Relays will be subjected to a simulated aging life of 20 years, as defined by Amerace Corporation. The relays will be temperature aged based upon the 10°C rule.

The relays will be temperature aged to a simulated qualified life of 20 years with an anticipated baseline service temperature of 24°C (75°F). The aging temperature will be 100°C (212°F). The number of days for aging the relays is calculated below.

The time at elevated temperature is expressed as:

100°C - 24°C = 76°C Rise

76°C equivalent to reducing life by one-half 7.6 times

$$\frac{20 \text{ years}}{(2)^{7.6}} = 0.1030 \text{ year} = 37.6 \text{ days} \times 1.1 \text{ margin per IEEE 323-1974}$$

= 41.4 days

2.0 PROCEDURES

The relays were placed in a temperature chamber. They were arranged in the chamber so as to avoid the direct radiant heat effects from the heating element. The air velocity inside the chamber was distributed uniformly around the relays.

The chamber temperature was then increased to and stabilized at 212°F. This temperature was maintained for 42 days.

3.0 RESULTS

The thirty-seven (37) Agastat Relays were subjected to the Temperature Aging Test as specified in Paragraph 2.0.

All the relays successfully completed the Temperature Aging Test.

Equipment used in the test is shown on an Instrumentation Equipment Sheet located in Appendix II of this section.

A photograph showing the relays in the temperature aging test chamber is located in Appendix I of this section.

APPENDIX IX

INSTRUMENTATION LOG SHEETS

AND

INSTRUMENTATION EQUIPMENT SHEETS

SECTION IX

POST-SEISMIC FUNCTIONAL TESTS
(1st Test)

1.0 REQUIREMENTS

The relays will be subjected to a Post-Seismic Functional Test. The test items shall comply with the requirements specified in Section I, Paragraph 1.0, of this report.

2.0 PROCEDURES

The test procedures used are defined in Paragraph 2.0, Section I, of this report.

3.0 RESULTS

The relays were subjected to the tests specified in Paragraph 2.0. Twenty-one (21) relays successfully completed the Post-Seismic Functional Tests.

During the Post-Seismic Functional Testing, Relay 7014ACE, Item 1, was inadvertently damaged, causing loss of operation. This was not a test failure. The relay was replaced by 7014ACE, Item 2. Item 2 completed all tests prior to the Seismic Test. The Seismic Test and Post-Seismic Functional Tests were repeated on 7014ACE, Item 2. This replacement unit successfully completed the Post-Seismic Functional Tests. This anomaly is described in Notice of Anomaly No. 5, located in Appendix I of this section.

Data sheets for the Post-Seismic Functional Tests are located in Section VI, Volume II, of this report.

The equipment used for these tests is shown on Instrumentation Equipment Sheets located in Appendix II of this section.

Attachment No. 3 Sheet 5 of 5
Loop #/Identifier DG [illegible]

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NUCLEAR ENVIRONMENTAL
QUALIFICATION TEST REPORT
ON
AGASTAT® E7000 SERIES TIMING RELAYS
BY
CONTROL PRODUCTS DIVISION
AMERACE CORPORATION

APPROVED
4/11/86
24E004T
TENNESSEE VALLEY AUTHORITY

	DATE	SIGNATURE
PREPARED BY:	4/3/80	E. J. LESZCZAK PRODUCT ENGINEER
APPROVED BY:	4/3/80	R. J. MALECKI CHIEF ENGINEER
APPROVED BY:	4/7/80	J. TONINI PRODUCT MANAGER
APPROVED BY:	4/3/80	M. MARTIN QUALITY ASSURANCE MANAGER
COMPANY OFFICIAL:	4/10/80	R. J. BERTLING PLANT GENERAL MANAGER

STATE OF WISCONSIN
COUNTY OF OZAUKEE

On this 14th day of April 1980 personally appeared before me the above named R. J. Bertling to me known or known to me to be the person described in and who executed the foregoing instrument and he acknowledged that he executed the same.

(Seal) (Notary Public)
Notary Public of Wisconsin
My Commission Expires

PROJECT SQN
CONTRACT 86PLB-834407
DRAWING NUMBER ES-1000
SHEET 1—105
REVISION A
UNIT 1 & 2

CONTROL PRODUCTS DIVISION	AMERACE CORPORATION CONTROL PRODUCTS DIVISION UNION, N.J. 07083	TEST REPORT NO. ES-1000 REV A SHEET 01

Attachment No. 4 Sheet 1 of 20
Loop #/Identifier

211516

PREFACE

This test report (number ES-1000) complements Wyle Test Report Number 43706-2, Volume I, and replaces Volume II (which is the raw data volume for baseline, hostile environment and post test inspection tests).

Together, these two documents contain results from a generic qualification test program which was performed on representative samples from a family of timing relays which are coded E7000 series. The tests performed were part of a larger qualification test program conducted at Wyle Laboratories in Huntsville, Alabama which consisted of a total of thirty-eight (38) relays including various other models and types.

Some parts of Wyle Test Report Number 43706-2, Volume I do not pertain entirely or in part to the E7000 series timing relays. This is because the Wyle test report reflects the total test program which included the testing of other products (as stated above).

ES-1000 addresses only the E7000 series timing relays and will act as a guide to the applicable portions of the Wyle test report for these particular relays. This document also replaces Volume II of the Wyle test report which contains raw data from the baseline, hostile environment and post test inspection portions of the test program. This was done in order to present this data in a more reduced, meaningful and understandable form. Certain data will be stated in terms of min. or max. value rather than a specific value of performance. The original raw test data is on file at Amerace Corporation and is available if necessary.

The relay model numbers have been revised from those as stated in the accompanying Wyle Test Report Number 43706-2, Volume I and Qualification Test Plan Number 545/5614-3/ES. This was done in order to facilitate the handling of certain requirements of Federal Regulation 10CFR part 21. The "E" (nuclear safety related) designator was moved from the end of the model code to the front and a three digit numerical suffix was added in order to provide configuration control capabilities. If and/or when a design change is required, which effects form, fit and/or function with respect to qualification test status, the configuration code number will advance (001 to 002, etc.) and this report [illegible] amended to justify the change either by test or analysis. [illegible] ES-1000 Test Report reflects the new model numbering system [illegible] the Wyle test report expresses the old model numbers, the following [illegible] reference will correlate the old to the new numbering systems.

PREFACE: (cont'd)

211517

AS STATED IN WYLE TEST REPORT NO. 43706-2	AS STATED IN AMERACE TEST REPORT NO. ES-1000
OLD CATALOG MODEL NO.	NEW CATALOG MODEL NO.
7012ACE	E7012AC001
7022ACE	E7022AC001
7012PCE	E7012PC001
7022PCE	E7022PC001
7014ACE	E7014AC001
7024ACE	E7024AC001
7014PCE	E7014PC001
7024PCE	E7024PC001

7012PCLE
7012ACLLE
7012ACTE
7022PCTE

These relays were engineering prototypes and are not available as Class 1E qualification tested timing relays.

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TEST PROGRAM SUMMARY TABLE

	WYLE TEST REPORT NO. 43706-2 VOLUME I	AMERACE TEST REPORT ES-1000
QUALIFICATION TEST PLAN & DEVIATIONS	SECTION XIII	PAGES 2-8
ESTABLISHED AND/OR VERIFIED SPECIFICATIONS FOR BASELINE TESTS	N/A	PAGES 12-14
INITIAL BASELINE FUNCTIONAL TESTS AND DATA	SECTION I	PAGES 15-33
RADIATION AGING TEST	SECTION II	N/A
POST RADIATION FUNCTIONAL TESTS AND DATA	SECTION III	PAGES 15-33
CYCLING WITH LOAD AGING TEST	SECTION IV	N/A
POST-CYCLE/LOAD AGING FUNCTIONAL TESTS AND DATA	SECTION V	PAGES 15-33
TEMPERATURE AGING TEST	SECTION VI	N/A
POST TEMPERATURE FUNCTIONAL TESTS AND DATA	SECTION VII	PAGES 15-33
SEISMIC AGING & FRAGILITY-TYPE TESTS AND DATA	SECTION VIII	PAGES 34-48
POST SEISMIC FUNCTIONAL TESTS & DATA	SECTION IX	PAGES 15-33
HOSTILE ENVIRONMENT TESTS AND DATA	SECTION X	PAGES 49-57
POST HOSTILE ENVIRONMENT FUNCTIONAL TESTS AND DATA	SECTION XI	PAGES 15-33
POST TEST INSPECTION	SECTION XII	PAGES 58 & 59
ESTABLISHED AND/OR VERIFIED NUCLEAR SAFETY RELATED PERFORMANCE CHARACTERISTICS FOR:		
MODELS E7012/E7022	N/A	PAGES 60-82
E7014/E7024	N/A	PAGES 83-105

CONTROL PRODUCTS DIVISION | AMERACE CORPORATION CONTROL PRODUCTS DIVISION UNION, N.J. 07083 | TEST REPORT NO. ES-1000 | REV. A | SHEET ___ OF ___

Attachment No. 6 Sheet 4 of 29
Loop #/Identifier DG [illegible] Relays

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ZS 7-8

ZS 12-14

ZS 15-33

/A

ZS 15-33

/A

ZS 15-33

ZS 34-48

ZS 15-33

ZS 49-57

ZS 15-33

ZS 58 & 59

S 60-82

S 83-105

211526

ESTABLISHED AND/OR VERIFIED OPERATING SPECIFICATIONS FOR BASELINE TESTS

THE FOLLOWING CROSS REFERENCE CORRELATES OLD TO NEW NUMBERING SYSTEMS:

AS STATED IN WYLE TEST REPORT NO. 43706-2 (OLD CATALOG MODEL NO.)	AS STATED IN AMERACE TEST REPORT NO. ES-1000 (NEW CATALOG MODEL NO.)
7012ACE	E7012AC001
7022ACE	E7022AC001
7012PCE	E7012PC001
7022PCE	E7022PC001
7014ACE	E7014AC001
7024ACE	E7024AC001
7014PCE	E7014PC001
7024PCE	E7024PC001

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UNION N J 07083

TEST REPORT NO. ES-1000

REV. A | SHEET 12 OF 105

Attachment No. 4 Sheet 5 of 20

Loop #/Identifier DG

Sheet 4 of 20

211527

OPERATING SPECIFICATIONS FOR BASELINE TESTS (E7012 & E7022 SERIES)

BASELINE FUNCTIONAL TESTS	E7012AC001 (7012ACE)	E7012PC001 (7012PCE)	E7022AC001 (7022ACE)	E7022PC001 (7022PCE)
	OPERATING SPECIFICATIONS BY RELAY CATALOG NUMBERS			
COIL OPERATING VOLTAGE, NOMINAL RATED VOLTAGE	120 VAC	125 VDC	120 VAC	125 VDC
PULL-IN % RATED VALUE	85% MIN	80% MIN	85% MIN	80% MIN
DROP-OUT % RATED VALUE	50% APPROX	10% APPROX	50% APPROX	10% APPROX
OPERATING FREQUENCY	60 HZ	N/A	60 HZ	N/A
DIELECTRIC STRENGTH (VRMS, 60 HZ)				
BETWEEN TERMINALS AND GROUND	1,500	1,500	1,500	1,500
BETWEEN NON-CONNECTED TERMINALS	1,000	1,000	1,000	1,000
INSULATION RESISTANCE (MEGOHMS AT 500 VDC)	500 MIN	500 MIN	500 MIN	500 MIN
RELAY OPERATE TIME (MILLISECONDS)	NOTE 1	NOTE 1	50 MAX	50 MAX
RELAY RELEASE (RECYCLE) TIME (MILLISECONDS)	50 MAX	50 MAX	NOTE 2	NOTE 2
TIME DELAY (SECONDS)	NOTE 3	NOTE 3	NOTE 3	NOTE 3
* TIME DELAY REPEATABILITY (PERCENT)	±10%	±10%	±10%	±10%
** CONTACT BOUNCE (MILLISECONDS) AT 28 VDC, 1 AMP	10 MAX	10 MAX	10 MAX	10 MAX
** CONTACT RESISTANCE (MILLIOHMS) AT 28 VDC, 1 AMP	200 MAX	200 MAX	200 MAX	200 MAX

* THE REPEAT ACCURACY DEVIATION (Ar) OF A TIME-DELAY RELAY IS A MEASURE OF THE MAXIMUM DEVIATION IN THE TIME-DELAY THAT WILL BE EXPERIENCED IN FIVE (5) SUCCESSIVE OPERATIONS AT ANY PARTICULAR TIME SETTING OF THE RELAY AND FOR ANY PARTICULAR OPERATING VOLTAGE OR CURRENT.

REPEAT ACCURACY IS OBTAINED FROM THE FOLLOWING FORMULA:

$$Ar = 100 \frac{(T_1 - T_2)}{(T_1 + T_2)}$$

WHERE T_1 = MAXIMUM TIME DELAY
T_2 = MINIMUM TIME DELAY

** MAXIMUM CONTACT BOUNCE AND RESISTANCE AS STATED IS AVERAGE OF FIVE (5) CONSECUTIVE READINGS.

NOTE #1 SINCE THIS IS THE TIME DELAY MODE FOR ON DELAY RELAY (SERIES E7012) THE OPERATE TIME IS NOT APPLICABLE. HOWEVER, TIME DELAY AT ZERO TIME DELAY SETTING SHOULD NOT EXCEED 200 MILLISECONDS.

NOTE #2 SINCE THIS IS THE TIME DELAY MODE FOR OFF DELAY RELAY (SERIES E7022) RELEASE (RECYCLE) TIME IS NOT APPLICABLE. HOWEVER, TIME DELAY AT ZERO TIME DELAY SETTING SHOULD NOT EXCEED 200 MILLISECONDS.

NOTE #3 THE TIME DELAY VALUES AS STATED IN THE BASE LINE TEST SUMMARY SHEETS DO NOT REFLECT TRUE SET POINT DRIFT. THIS IS BECAUSE, IN ORDER TO PROPERLY CONDUCT MANY OF THE OTHER BASELINE FUNCTIONAL TESTS, IT WAS NECESSARY TO REMOVE THE TIME DELAY BY TURNING THE (TIME DELAY) REGULATING DIAL TO THE ZERO SETTING, THEN RETURNING BACK TO ITS APPROXIMATE PREVIOUS SETTING FOR THE NEXT TEST SEQUENCE. DUE TO THE INTRODUCTION OF THE DIAL SETTING ERROR THE ACTUAL TIME DELAYS WERE RECORDED ONLY.

FIGURE 1

CONTROL PRODUCTS DIVISION	AMERACE CORPORATION CONTROL PRODUCTS DIVISION UNION N.J. 07083	TEST REPORT NO. ES-1000
		REV A | SHEET __ OF 103

FIGURE 1

Attachment No. 4 Sheet 6 of 29
Loop #/Identifier DC [illegible]

OPERATING SPECIFICATIONS FOR BASELINE TESTS (E7014 & E7024 SERIES)

BASELINE FUNCTIONAL TESTS	OPERATING SPECIFICATIONS BY RELAY CATALOG NUMBERS E7014ACC001 (7014ACE)	E7014PC001 (7014PCE)	E7024ACC001 (7024ACE)	E7024PC001 (7024PCE)
COIL OPERATING VOLTAGE, NOMINAL RATED VOLTAGE	120 VAC	125 VDC	120 VAC	125 VDC
PULL-IN % RATED VALUE	90% MIN	85% MIN	90% MIN	85% MIN
DROP-OUT % RATED VALUE	50% APPROX	10% APPROX	50% APPROX	10% APPROX
OPERATING FREQUENCY	60 HZ	N/A	60 HZ	N/A
DIELECTRIC STRENGTH (VRMS, 60 HZ)				
BETWEEN TERMINALS AND GROUND	1,500	1,500	1,500	1,500
BETWEEN NON-CONNECTED TERMINALS	1,000	1,000	1,000	1,000
INSULATION RESISTANCE (MEGOHMS AT 500 VDC)	500 MIN	500 MIN	500 MIN	500 MIN
RELAY OPERATE TIME (MILLISECONDS)	NOTE 1	NOTE 1	75 MAX	75 MAX
RELAY RELEASE (RECYCLE) TIME (MILLISECONDS)	75 MAX	75 MAX	NOTE 2	NOTE 2
TIME DELAY (SECONDS)	NOTE 3	NOTE 3	NOTE 3	NOTE 3
* TIME DELAY REPEATABILITY (PERCENT)	±10%	±10%	±10%	±10%
** CONTACT BOUNCE (MILLISECONDS) AT 28 VDC, 1 AMP	10 MAX	10 MAX	10 MAX	10 MAX
** CONTACT RESISTANCE (MILLIOHMS) AT 28 VDC, 1 AMP	200 MAX	200 MAX	200 MAX	200 MAX

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* THE REPEAT ACCURACY DEVIATION (Ae) OF A TIME-DELAY RELAY IS A MEASURE OF THE MAXIMUM DEVIATION IN THE TIME-DELAY THAT WILL BE EXPERIENCED IN FIVE (5) SUCCESSIVE OPERATIONS AT ANY PARTICULAR TIME SETTING OF THE RELAY AND FOR ANY PARTICULAR OPERATING VOLTAGE OR CURRENT.

REPEAT ACCURACY IS OBTAINED FROM THE FOLLOWING FORMULA:

$$Ae = 100 \frac{(T_1 - T_2)}{(T_1 + T_2)}$$

WHERE T_1 = MAXIMUM TIME DELAY

T_2 = MINIMUM TIME DELAY

** MAXIMUM CONTACT BOUNCE AND RESISTANCE AS STATED IS AVERAGE OF FIVE (5) CONSECUTIVE READINGS.

NOTE #1 SINCE THIS IS THE TIME DELAY MODE FOR ON DELAY RELAY (SERIES E7014) THE OPERATE TIME IS NOT APPLICABLE. HOWEVER, TIME DELAY AT ZERO TIME DELAY SETTING SHOULD NOT EXCEED 200 MILLISECONDS.

NOTE #2 SINCE THIS IS THE TIME DELAY MODE FOR OFF DELAY RELAY (SERIES E7024) RELEASE (RECYCLE) TIME IS NOT APPLICABLE. HOWEVER, TIME DELAY AT ZERO TIME DELAY SETTING SHOULD NOT EXCEED 200 MILLISECONDS.

NOTE #3 THE TIME DELAY VALUES AS STATED IN THE BASE LINE TEST SUMMARY SHEETS DO NOT REFLECT TRUE SET POINT DRIFT. THIS IS BECAUSE, IN ORDER TO PROPERLY CONDUCT MANY OF THE OTHER BASELINE FUNCTIONAL TESTS, IT WAS NECESSARY TO REMOVE THE TIME DELAY BY TURNING THE (TIME DELAY) REGULATING DIAL TO THE ZERO SETTING, THEN RETURNING BACK TO ITS APPROXIMATE PREVIOUS SETTING FOR THE NEXT TEST SEQUENCE. DUE TO THE INTRODUCTION OF THE DIAL SETTING ERROR THE ACTUAL TIME DELAYS WERE RECORDED ONLY.

FIGURE 2

FIGURE 2

CONTROL PRODUCTS DIVISION

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UNION, N.J. 07083

TEST REPORT NO. ES-1000

REV. A | SHEET 22 OF 122

Attachment No. 6 Sheet 7 of 29
Loop #/Identifier DC time delays

211529

DATA - BASELINE FUNCTIONAL TESTS FOR ACTUAL TEST DEVICES

NOTE: 1. SEE FIGURES 1 AND 2, PAGES 13 AND 14 OF THIS REPORT FOR OPERATING SPECIFICATIONS FOR BASELINE TESTS.

2. FOR PROCEDURE AND ADDITIONAL INFORMATION SEE WYLE TEST REPORT NO. 43706-2, VOLUME I, SECTIONS I, III, V, VII, IX, AND XI.

THE FOLLOWING CROSS REFERENCE CORRELATES OLD TO NEW NUMBERING SYSTEMS:

AS STATED IN WYLE TEST REPORT NO. 43706-2 (OLD CATALOG MODEL NO.)	AS STATED IN AMERACE TEST REPORT NO. ES-1000 (NEW CATALOG MODEL NO.)
7012ACE	E7012AC001
7022ACE	E7022AC001
7012PCE	E7012PC001
7022PCE	E7022PC001
7014ACE	E7014AC001
7024ACE	E7024AC001
7014PCE	E7014PC001
7024PCE	E7024PC001

CONTROL PRODUCTS DIVISION | AMERACE CORPORATION CONTROL PRODUCTS DIVISION UNION, N.J. 07083 | TEST REPORT NO. ES-1000 | REV. A | SHEET 15 OF 101

Attachment No. 6 Sheet 8 of 24
Loop #/Identifier DG timing relays

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SYSTEMS:

NO. ES-1000

SHEET 13 OF [illegible]

BASELINE TEST DATA SUMMARY

PAGE 22 OF [illegible]

RELAY CATALOG NO. [illegible] (Table [illegible])

TEST ITEM NO. [illegible]

PREPARED BY [illegible] DATE [illegible]

Baseline Functional Tests	Initial Functionals	Radiation Aging	Post-Radiation Functionals	Cycling with Load Aging	Post-Cycling/Load Aging Functionals	Temperature Aging	Post-Temperature Aging Functionals	Seismic Tests	Post-Seismic Functionals	Hostile Environment Test	Post-Hostile Env Functionals	Post-Test Inspection
PULL-IN VOLTS VAC RMS	Passed [illegible]	[illegible] (Gamma) [illegible]	Passed [illegible]	[illegible]	Passed [illegible]	100°C [illegible] for 42 Days	Passed [illegible]	[illegible]	Passed [illegible]	[illegible]	Passed [illegible]	[illegible]
DROP-OUT VOLTS VAC RMS	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
DIELECTRIC STRENGTH VOLTS RMS	Passed @ [illegible]		Passed @ [illegible]		Passed @ [illegible]		Passed @ [illegible]		Passed @ [illegible]		Passed @ [illegible]	
INSULATION RESISTANCE @ 500 VDC	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
OPERATE TIME MILLISECONDS	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
RECYCLE TIME MILLISECONDS	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
TIME DELAY SECONDS	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	
REPEATABILITY PERCENT	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
CONTACT BOUNCE @28 VDC, 1 AMP	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
CONTACT RESISTANCE @28 VDC, 1 AMP	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
DATE TEST CONDUCTED	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	

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CONTROL PRODUCTS DIVISION

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CONTROL PRODUCTS DIVISION
UNION N.J. 07083

TEST REPORT NO. ES-1000

REV. A | SHEET 12 OF [illegible]

Attachment No. 4 Sheet 8 of 2[illegible]

Loop #/Identifier DG [illegible]

Attachment No. 4 Sheet 9 of 22

Loop #/Identifier DG [illegible]

211532

BASELINE TEST DATA SUMMARY

RELAY CATALOG NO. [illegible] (Gree Sel) — PAGE 18 OF 20

TEST ITEM NO. 2 — PREPARED BY [illegible] — DATE [illegible]

Baseline Functional Tests	Initial Functionals	Radiation Aging	Post-Radiation Functionals	Cycling with Load Aging	Post-Cycle/Load Aging Functionals	Temperature Aging	Post-Temperature Aging Functionals	Seismic Tests	Post-Seismic Functionals	Hostile Environment Test	Post-Hostile Env Functionals	Post-Test Inspection
PULL-IN VOLTS AC 60Hz	Passed [illegible]	[illegible] (Gamma) Time [illegible]	Passed [illegible]	[illegible]	Passed [illegible]	[illegible] for 42 days.	Passed [illegible]	[illegible]	Passed [illegible]	[illegible]	Passed [illegible]	[illegible]
DROP-OUT VOLTS AC 60Hz	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
DIELECTRIC STRENGTH VOLTS RMS	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
INSULATION RESISTANCE @ 500 VDC	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
OPERATE TIME MILLISECONDS	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
RECYCLE TIME MILLISECONDS	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
TIME DELAY SECONDS	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	
REPEATABILITY PERCENT	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
CONTACT BOUNCE @28 VDC, 1 AMP	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
CONTACT RESISTANCE @28 VDC, 1 AMP	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
DATE TEST CONDUCTED	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	

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		REV. A — SHEET [illegible] OF [illegible]

Attachment No. [illegible] Sheet 19 of 24

Loop #/Identifier DG [illegible]

211533

BASELINE TEST DATA SUMMARY

RELAY CATALOG NO. [illegible]

TEST ITEM NO. [illegible]

PAGE [illegible] OF [illegible]

PREPARED BY [illegible] DATE [illegible]

Baseline Functional Tests	Initial Functionals	Radiation Aging	Post-Radiation Functionals	Cycling with Load Aging	Post-Cycle/Load Aging Functionals	Temperature Aging	Post-Temperature Aging Functionals	Seismic Tests	Post-Seismic Functionals	Hostile Environment Test	Post-Hostile Env Functionals	Post-Test Inspection
PULL-IN VOLTS VDC	Passed [illegible]	[illegible]	Passed [illegible]	[illegible]	Passed [illegible]	100° Continuous [illegible]	Passed [illegible]	[illegible]	Passed [illegible]	[illegible]	Passed [illegible]	Visual Inspection [illegible]
DROP-OUT VOLTS VDC	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
DIELECTRIC STRENGTH VOLTS RMS	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
INSULATION RESISTANCE @ 500 VDC	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
OPERATE TIME MILLISECONDS	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
RECYCLE TIME MILLISECONDS	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
TIME DELAY SECONDS	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	
REPEATABILITY PERCENT	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
CONTACT BOUNCE @28 VDC,1 AMP	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
CONTACT RESISTANCE @28 VDC,1 AMP	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
DATE TEST CONDUCTED	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	

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		REV. A SHEET [illegible] OF [illegible]

Attachment No. 4 Sheet 11 of 29
Loop #/Identifier DG [illegible]

BASELINE TEST DATA SUMMARY

RELAY CATALOG NO. [illegible]

TEST ITEM NO. 1

PAGE [illegible] OF [illegible]

PREPARED BY [illegible] DATE [illegible]

[illegible]	INITIAL FUNCTIONALS	RADIATION AGING	POST-RADIATION FUNCTIONALS	CYCLING WITH LOAD AGING	POST-CYCLING/LOAD AGING FUNCTIONALS	TEMPERATURE AGING	POST-TEMPERATURE AGING FUNCTIONALS	SEISMIC TESTS	POST-SEISMIC FUNCTIONALS	POSTULATED ENVIRONMENT TEST	POST-POSTULATED ENV FUNCTIONALS	POST-TEST INSPECTION
PULL-IN VOLTS VDC	Passed [illegible]	[illegible] (Gamma) Total Integrated Dose	Passed [illegible]	[illegible]	Passed [illegible]	100° Centigrade [illegible] days	Passed [illegible]	[illegible]	Passed [illegible]	[illegible]	Passed [illegible]	[illegible]
DROP-OUT VOLTS VDC	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
DIELECTRIC STRENGTH VOLTS RMS	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
INSULATION RESISTANCE @ 500 VDC	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
OPERATE TIME MILLISECONDS	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
RECYCLE TIME MILLISECONDS	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
TIME DELAY SECONDS	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	
REPEATABILITY PERCENT	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
CONTACT BOUNCE @28 VDC, 1 AMP	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
CONTACT RESISTANCE @28 VDC, 1 AMP	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
DATE TEST CONDUCTED	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	

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CONTROL PRODUCTS DIVISION	AMERACE CORPORATION CONTROL PRODUCTS DIVISION UNION, N.J. 07083	TEST REPORT NO. ES-1000
		REV. A SHEET [illegible] OF [illegible]

Attachment No. 4 Sheet 12 of 20

Loop #/Identifier DC [illegible]

BASELINE TEST DATA SUMMARY

RELAY CATALOG NO. [illegible] | PAGE [illegible] OF [illegible]

TEST ITEM NO. 1 | PREPARED BY [illegible] | DATE [illegible]

Baseline Functional Tests	Initial Functionals	Radiation Aging	Post-Radiation Functionals	Cycling with Load Aging	Post-Cycle/Load Aging Functionals	Temperature Aging	Post-Temperature Aging Functionals	Seismic Tests	Post-Seismic Functionals	Hostile Environment Test	Post-Hostile Env Functionals	Post-Test Inspection
Pull-In Volts VAC 60	Passed [illegible]	[illegible] Dose	Passed [illegible]	[illegible]	Passed [illegible]	100°C [illegible]	Passed [illegible]	See [illegible]				[illegible]11535
Drop-Out Volts VAC 60	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]					
Dielectric Strength Volts RMS	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]					
Insulation Resistance @ 500 VDC	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]					
Operate Time Milliseconds	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]					
Recycle Time Milliseconds	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]					
Time Delay Seconds	[illegible]		[illegible]		[illegible]		[illegible]					
Repeatability Percent	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]					
Contact Bounce @ 28 VDC, 1 AMP	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]					
Contact Resistance @ 28 VDC, 1 AMP	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]					
Date Test Conducted	[illegible]		[illegible]		[illegible]		[illegible]					

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AMERACE CORPORATION
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UNION N.J. 07083

TEST REPORT NO. ES-1000

REV. A | SHEET [illegible] OF [illegible]

Attachment No. 4 Sheet 13 of 29

Loop #/Identifier [illegible]

211536

BASELINE TEST DATA SUMMARY

PAGE 22 OF 105

RELAY CATALOG NO. [illegible]

TEST ITEM NO. 6

PREPARED BY [illegible] DATE [illegible]

BASELINE FUNCTIONAL TESTS	INITIAL FUNCTIONALS	RADIATION AGING	POST-RADIATION FUNCTIONALS	CYCLING WITH LOAD AGING	POST-CYCLE/LOAD AGING FUNCTIONALS	TEMPERATURE AGING	POST-TEMPERATURE AGING FUNCTIONALS	SEISMIC TESTS	POST-SEISMIC FUNCTIONALS	HOSTILE ENVIRONMENT TEST	POST-HOSTILE ENV FUNCTIONALS	POST-TEST INSPECTION
PULL-IN VOLTS [illegible]	Passed [illegible]	[illegible] (Gamma) [illegible]	Passed [illegible]	[illegible]	Passed [illegible]	100°C [illegible] for [illegible]	Passed [illegible]	[illegible]	Passed [illegible]	[illegible]	Passed [illegible]	[illegible]
DROP-OUT VOLTS [illegible]	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
DIELECTRIC STRENGTH VOLTS RMS	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
INSULATION RESISTANCE @ 500 VDC	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
OPERATE TIME MILLISECONDS	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
RECYCLE TIME MILLISECONDS	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
TIME DELAY SECONDS	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	
REPEATABILITY PERCENT	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
CONTACT BOUNCE 28 VDC, 1 AMP	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
CONTACT RESISTANCE 28 VDC, 1 AMP	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
DATE TEST CONDUCTED	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	

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CONTROL PRODUCTS DIVISION	AMERACE CORPORATION CONTROL PRODUCTS DIVISION UNION, N.J. 07083	TEST REPORT NO. ES-1000
		REV. A — SHEET 22 OF 105

Attachment No. C Sheet 19 of 20

Loop #/Identifier [illegible]

211537

BASELINE TEST DATA SUMMARY

PAGE [illegible] OF [illegible]

RELAY CATALOG NO. [illegible]

TEST ITEM NO. 1

PREPARED BY [illegible] DATE [illegible]

[illegible]	INITIAL FUNCTIONALS	RADIATION AGING	POST-RADIATION FUNCTIONALS	CYCLING WITH LOAD AGING	POST-CYCLE/LOAD AGING FUNCTIONALS	TEMPERATURE AGING	POST-TEMPERATURE AGING FUNCTIONALS	SEISMIC TEST	POST-SEISMIC FUNCTIONALS	HOSTILE ENVIRONMENT TEST	POST-HOSTILE ENV FUNCTIONALS	POST-TEST INSPECTION
PICK-IN VOLTS [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	100° Continuous for [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
DROP-OUT VOLTS [illegible]	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	
DIELECTRIC STRENGTH VOLTS RMS	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	
INSULATION RESISTANCE @ 500 VDC	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	
DE-ENERGIZE TIME MILLISECONDS	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	
RECYCLE TIME MILLISECONDS	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	
TIME DELAY SECONDS	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	
REPEATABILITY PERCENT	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	
CONTACT BOUNCE @28 VDC, 1 AMP	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	
CONTACT RESISTANCE @28 VDC, 1 AMP	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	
DATE TEST CONDUCTED	[illegible]		[illegible]		[illegible]		[illegible]		7-6-79		[illegible]	

* NOTES: [illegible]

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		REV. A	SHEET [illegible] OF [illegible]

Attachment No. 4 Sheet 15 of 20

Loop #/Identifier [illegible]

BASELINE TEST DATA SUMMARY

RELAY CATALOG NO. [illegible]

TEST ITEM NO. 1

PREPARED BY [illegible] DATE [illegible]

Baseline Functional Tests	Initial Functionals	Radiation Aging	Post-Radiation Functionals	Cycling with Load Aging	Post-Cycle/Load Aging Functionals	Temperature Aging	Post-Temperature Aging Functionals	Seismic Tests	Post-Seismic Functionals	Hostile Environment Test	Post-Hostile Env Functionals	Post-Test Inspection
PULL-IN VOLTS VDC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
DROP-OUT VOLTS VDC	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	
DIELECTRIC STRENGTH VOLTS RMS	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	
INSULATION RESISTANCE @ 500 VDC	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	
OPERATE TIME MILLISECONDS	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	
RECYCLE TIME MILLISECONDS	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	
TIME DELAY SECONDS	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	
REPEATABILITY PERCENT	[illegible]		[illegible]		0%		[illegible]		[illegible]		[illegible]	
CONTACT BOUNCE 28 VDC, 1 AMP	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	
CONTACT RESISTANCE 28 VDC, 1 AMP	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	
DATE TEST CONDUCTED	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	

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CONTROL PRODUCTS DIVISION
UNION, N.J. 07083

TEST REPORT NO. ES-1000

REV. A | SHEET [illegible] OF [illegible]

Attachment No. 4 Sheet [illegible] of [illegible]

Loop #/Identifier [illegible]

211539

BASELINE TEST DATA SUMMARY

PAGE [illegible] OF [illegible]

RELAY CATALOG NO. [illegible]

TEST ITEM NO. 1

PREPARED BY [illegible] DATE [illegible]

Baseline Functional Tests	Initial Functionals	Radiation Aging	Post-Radiation Functionals	Cycling with Load Aging	Post-Cycling Aging Functionals	Temperature Aging	Post-Temperature Aging Functionals	Seismic Tests	Post-Seismic Functionals	Hostile Environment Test	Post-Hostile Env. Functionals	Post-Test Inspection
PICK-IN VOLTS VDC	Passed [illegible]	[illegible]	Passed [illegible]	[illegible]	Passed [illegible]	[illegible]	Passed [illegible]	[illegible]	Passed [illegible]	[illegible]	Passed [illegible]	[illegible]
DROP-OUT VOLTS VDC	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
DIELECTRIC STRENGTH VOLTS RMS	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
INSULATION RESISTANCE @ 500 VDC	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
OPERATE TIME MILLISECONDS	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
RECYCLE TIME MILLISECONDS	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
TIME DELAY SECONDS	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	
REPEATABILITY PERCENT	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
CONTACT BOUNCE @28 VDC, 1 AMP	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
CONTACT RESISTANCE @28 VDC, 1 AMP	Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]		Passed [illegible]	
DATE TEST CONDUCTED	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	

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CONTROL PRODUCTS DIVISION	AMERACE CORPORATION CONTROL PRODUCTS DIVISION UNION, N.J. 07083	TEST REPORT NO. ES-1000
		REV. A / SHEET [illegible] OF [illegible]

Attachment No. 4 Sheet 17 of 29

Loop #/Identifier [illegible]

211540

DATA - BASELINE FUNCTIONAL TESTS FOR ACCOMPANING SPARES

NOTE: 1. THESE DEVICES ARE SPARES AND WERE AGED TO POINT SHOWN FOR USE IN CASE OF ACCIDENTAL DAMAGE OF ACTUAL TEST DEVICES. ALSO, THESE DEVICES MIGHT BE USED BY AMERACE IN POSSIBLE F[illegible]TURE TEST PROGRAMS.

2. SEE FIGURE 1 AND 2, PAGES 13 AND 14 OF THIS REPORT FOR OPERATING SPECIFICATION FOR BASELINE TESTS.

3. FOR PROCEDURE AND ADDITIONAL INFORMATION SEE WYLE TEST REPORT NO. 43706-2, VOLUME I, SECTIONS I, III, V, AND VII.

THE FOLLOWING CROSS REFERENCE CORRELATES OLD TO NEW NUMBERING SYSTEMS:

AS STATED IN WYLE TEST REPORT NO. 43706-2 (OLD CATALOG MODEL NO.)	AS STATED IN AMERACE TEST REPORT NO. ES-1000 (NEW CATALOG MODEL NO.)
7012ACE	E7012AC001
7022ACE	E7022AC001
7012PCE	E7012PC001
7022PCE	E7022PC001
7014ACE	E7014AC001
7024ACE	E7024AC001
7014PCE	E7014PC001
7024PCE	E7024PC001

CONTROL PRODUCTS DIVISION | AMERACE CORPORATION CONTROL PRODUCTS DIVISION UNION, N.J. 07083 | TEST REPORT NO. ES-1000 | REV. A | SHEET 26 OF 105

Attachment No 4 Sheet 4 of 29
Loop #/Identifier DC [illegible]

[illegible] TEST DATA SUMMARY

RELAY CATALOG NO. [illegible]   PAGE [illegible]

TEST ITEM NO. 2   PREPARED BY [illegible]   DATE [illegible]

[illegible] Functional Tests	Initial Functionals	Radiation Aging	Post-Radiation Functionals	Cycling with Load Aging	Post-Cycling Functionals	Temperature Aging	Post-Temperature Aging Functionals	Seismic Tests	Post-Seismic Functionals	Post-LOCA Test	Post-LOCA Functionals	Post-Test Inspection
PULL-IN VOLTS [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					
DROP-OUT VOLTS [illegible]	[illegible]		[illegible]		[illegible]		[illegible]					
DIELECTRIC STRENGTH VOLTS RMS	[illegible]		[illegible]		[illegible]		[illegible]					
INSULATION RESISTANCE @ 500 VDC	[illegible]		[illegible]		[illegible]		[illegible]					
OPERATE TIME MILLISECONDS	[illegible]		[illegible]		[illegible]		[illegible]					
RECYCLE TIME MILLISECONDS	[illegible]		[illegible]		[illegible]		[illegible]					
TIME DELAY SECONDS	[illegible]		[illegible]		[illegible]		[illegible]					
REPEATABILITY PERCENT	[illegible]		[illegible]		[illegible]		[illegible]					
CONTACT BOUNCE 28 VDC, 1 AMP	[illegible]		[illegible]		[illegible]		[illegible]					
CONTACT RESISTANCE 28 VDC, 1 AMP	[illegible]		[illegible]		[illegible]		[illegible]					
DATE TEST CONDUCTED	[illegible]		[illegible]		[illegible]		[illegible]					

211511

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TEST REPORT NO. ES-1000

REV. A | SHEET [illegible] OF [illegible]

Attachment No 6 Sheet 14 of 29
Loop #/Identifier DC time delays

211549 SEISMIC TESTS SUMMARY

The artificially aged devices were subjected to simulated seismic vibration, which verified each individual device's ability to perform its required function, before, during, and/or following design basis eathquakes.

Using a Generic Required Response Spectra (RRS) for control systems purposes for the majority of nuclear power plant locations in the continental United States as a Guideline, the devices should have met, exceeded, and/or established their own fragility levels.

The relays were tested in the following electrical states.

(a) Non-operating Mode (Relay coil deenergized - off-delay relays timed out).

(b) Operating Mode (Relay coils energized - on-delay relays timed out).

(c) Transistional Mode (Relay time delay) with nominal rated voltage, less 10%, applied to coils. Relays timed out twice during seismic test.

CONDITIONS OF SEISMIC TESTS:

Value of Damping used - 5%
Device Mounting - Vertical only (Rigid Test Fixture)
Mode of Vibration - Identical (Dependent) biaxial inputs (45° Thrustar)
Seismic Input - Random multifrequency (Spaced at 1/3 octaves over a range of 1—0 Hz). 30 second duration.

SEISMIC RESPONSE

The three figures for each type relay as specified below represent the actual vertical and horizontal test response of the relays in their three (3) electrical states. Using the Failure Criteria specified, these values were derived by combining the lowest Test Response Spectrum (TRS) values from the four (4) test orientations and multiplying that composite value by .707 due to the 45-degree inclination of the test machine. Also, superimposed on the graphs are: (1) The Standard Response Spectrum (SRS) for relays per IEEE Standard 501-1978 which gives a specific zero period acceleration "G" level for each of the relay states, and, (2) The Required Response Spectrum (RRS) which was used as a guideline and artificially created by Control Products Div. as a goal or maximum test level.

Figures: 3, 4 & 5	Model E7012
6, 7 & 8	Model E7022
9, 10 & 11	Model E7014
12, 13 & 14	Model E7024

211530

BRIEF TEST DESCRIPTION

The test machine was inclined at 45° to the horizontal plane to simulate two-axes excitation. In order to orient the test articles to their normal service position, they were placed on a 45° Rigid Test Fixture. This arrangement gave the input motion equal vectors in the vertical plane and in one horizontal direction. The relays were tested in four horizontal orientations. This was done to test for the in-phase and out-of-phase conditions of the test items. This method of test input is recognized as an acceptable alternative to true biaxial excitation in Section 6.6.6 of IEEE Standard 344-1975.

FAILURE CRITERIA (CLASS 1E FUNCTIONS MONITORED DURING SEISMIC TESTS)

(A) Non-Operating Mode (Relay coils de-energized) Normally closed contacts for chatter in excess of 1 millisecond with 28 vdc at 1 amp applied to contacts. Normally open contacts for false transfer of 1 millisecond or greater with 28 vdc at 1 ampere applied to contacts.

(B) Operate Mode (Relay coils energized) Normally open contacts for chatter in excess of 1 millisecond with 28 vdc at 1 amp applied to contacts. Normally closed contacts for false transfer of 1 millisecond or greater with 28 vdc at 1 ampere applied to contacts.

(C) Transitional Mode (Relay operated for time delay) Failure of the relays to time-out twice. Note: Relays set for approximately 10 seconds time delay.

NOTE: Nominal rated voltage less 10% applied to relays coils during operate and transitional modes..

FRAGILITY LEVEL

Device fragility level was obtained in the following manner:

Using the Failure Criteria as described, all relays were first subjected to the artificial RRS acceleration level. If a relay failed to meet its Class1E function the testing was continued, but at regressive increments (of approximately 10% levels) until the malfunction ceased. The level at which fault free operation of the relay had been established was documented as the fragility level of that relay.

TEST RESPONSE

The test responses which exceed the artificial RRS level and stated as such are not device fragility levels but are highest values tested to.

3/26/87
no leave slip
4C on TS

HOSTILE ENVIRONMENT TEST DATA

SUMMARY SHEET

211564

MODEL NO. E7012AC001 (7012ACE)

TEST ITEM NO. 2

TEMPERATURE	MINIMUM VOLTAGE TEST		MAXIMUM VOLTAGE TEST	
AT 95% R.H. (DEGREES FAHRENHEIT)	AVERAGE TIME DELAY (SECONDS)	REPEAT ACCURACY (PERCENT)	AVERAGE TIME DELAY (SECONDS)	REPEAT ACCURACY (PERCENT)
40°F	2.06 sec	1.8 %	1.92 sec	9.4 %
50°F	2.07	3.7	2.06	2.9
70°F	2.02	2.6	2.09	2.7
90°F	1.97	3.1	2.01	4.5
110°F	1.98	4.5	1.97	2.1
130°F	1.87	6.9	1.90	[illegible]
150°F	1.83	1.4	1.87	1.0
165°F	1.75	1.8	1.78	0.8
172°F	1.81	0.7	1.80	1.9

NOTES:

1. TEMPERATURES STATED ARE AT 95% RELATIVE HUMIDITY.
2. AVERAGE TIME DELAY IS AVERAGE OF FIVE (5) CONSECUTIVE READINGS.
3. FOR REPEAT ACCURACY DEFINITION SEE FIGURES 1 AND 2, PAGES 13 AND 14 RESPECTIVELY OF THIS REPORT.

MINIMUM VOLTAGE USED 102 vac

MAXIMUM VOLTAGE USED 140 vac

PREPARED BY [signature]

DATE 2-25-80

CONTROL PRODUCTS DIVISION | AMERACE CORPORATION CONTROL PRODUCTS DIVISION UNION N.J. 07083 | TEST REPORT NO. ES-1000 | REV A | SHEET 22 OF 103

Attachment No. 4 Sheet 22 of 29
Lopp #/Identifier DG Time Delays

211865

HOSTILE ENVIRONMENT TEST DATA

SUMMARY SHEET

MODEL NO. E7022AC001 (7022ACE)

TEST ITEM NO. 2

TEMPERATURE	MINIMUM VOLTAGE TEST		MAXIMUM VOLTAGE TEST	
AT 95% R.H. (DEGREES FAHRENHEIT)	AVERAGE TIME DELAY (SECONDS)	REPEAT ACCURACY (PERCENT)	AVERAGE TIME DELAY (SECONDS)	REPEAT ACCURACY (PERCENT)
40°F	1.77 sec	0.6 %	1.67 sec	10.1 %
50°F	1.75	0.6	1.74	1.2
70°F	1.79	2.6	1.84	0.8
90°F	1.75	0.9	1.75	0.6
110°F	1.77	0.9	1.75	0.3
130°F	1.73	0.8	1.71	0.7
150°F	1.65	0.9	1.65	1.1
165°F	1.57	0.9	1.54	1.0
172°F	1.51	2.1	1.50	0.9

NOTES:

1. TEMPERATURES STATED ARE AT 95% RELATIVE HUMIDITY.
2. AVERAGE TIME DELAY IS AVERAGE OF FIVE (5) CONSECUTIVE READINGS.
3. FOR REPEAT ACCURACY DEFINITION SEE FIGURES 1 AND 2, PAGES 13 AND 14 RESPECTIVELY OF THIS REPORT.

MINIMUM VOLTAGE USED 102 VAC

MAXIMUM VOLTAGE USED 145 VAC

PREPARED BY [illegible signature]

DATE [illegible]

CONTROL PRODUCTS DIVISION | AMERACE CORPORATION CONTROL PRODUCTS DIVISION UNION N J 07083 | TEST REPORT NO. EP-1000 | REV. [illegible] SHEET __ OF __

Attachment No. 4 Sheet 23 of 29

Loop #/Identifier DC Time Delays

211509

HOSTILE ENVIRONMENT TEST DATA

SUMMARY SHEET

MODEL NO. E7012AC001 (7012ACE)

TEST ITEM NO. 1

TEMPERATURE	MINIMUM VOLTAGE TEST		MAXIMUM VOLTAGE TEST	
AT 95% R.H. (DEGREES FAHRENHEIT)	AVERAGE TIME DELAY (SECONDS)	REPEAT ACCURACY (PERCENT)	AVERAGE TIME DELAY (SECONDS)	REPEAT ACCURACY (PERCENT)
40°F	1.77 sec	2.5 %	1.72 sec	7.4 %
50°F	1.87	1.5	1.76	5.0
70°F	1.84	0.2	1.84	0.8
90°F	1.76	1.6	1.75	1.4
110°F	1.71	1.3	1.70	1.3
130°F	1.81	2.0	1.71	1.3
150°F	1.77	2.1	1.67	1.6
165°F	1.80	3.7	1.61	1.5
172°F	1.80	2.0	1.58	3.5

NOTES:

1. TEMPERATURES STATED ARE AT 95% RELATIVE HUMIDITY.
2. AVERAGE TIME DELAY IS AVERAGE OF FIVE (5) CONSECUTIVE READINGS.
3. FOR REPEAT ACCURACY DEFINITION SEE FIGURES 1 AND 2, PAGES 13 AND 14 RESPECTIVELY OF THIS REPORT.

MINIMUM VOLTAGE USED 96 VDC

MAXIMUM VOLTAGE USED 154 VDC

PREPARED BY [signature]

DATE 8-25-80

CONTROL PRODUCTS DIVISION	AMERACE CORPORATION CONTROL PRODUCTS DIVISION UNION N.J. 07083	TEST REPORT NO. ES-1000
		REV A SHEET __ OF __

Attachment No. 6 Sheet 24 of 29

Loop #/Identifier DG Time delays

211507

HOSTILE ENVIRONMENT TEST DATA

SUMMARY SHEET

MODEL NO. E7022PC001 (7022PCP)

TEST ITEM NO. 1

TEMPERATURE	MINIMUM VOLTAGE TEST		MAXIMUM VOLTAGE TEST	
AT 95% R.H. (DEGREES FAHRENHEIT)	AVERAGE TIME DELAY (SECONDS)	REPEAT ACCURACY (PERCENT)	AVERAGE TIME DELAY (SECONDS)	REPEAT ACCURACY (PERCENT)
40°F	1.66 sec	9.6%	1.75 sec.	0.3%
50°F	1.71	0.2	1.73	0.7
70°F	1.72	0.6	1.72	0.5
90°F	1.60	1.6	1.61	0.2
110°F	1.65	3.6	1.73	1.9
130°F	1.63	2.2	1.69	1.3
150°F	1.59	0.4	1.57	0.6
165°F	1.43	1.0	1.43	0.7
172°F	1.40	0.3	1.39	0.3

NOTES:

1. TEMPERATURES STATED ARE AT 95% RELATIVE HUMIDITY.
2. AVERAGE TIME DELAY IS AVERAGE OF FIVE (5) CONSECUTIVE READINGS.
3. FOR REPEAT ACCURACY DEFINITION SEE FIGURES 1 AND 2, PAGES 13 AND 14 RESPECTIVELY OF THIS REPORT.

MINIMUM VOLTAGE USED 96 VDC

MAXIMUM VOLTAGE USED 154 VDC

PREPARED BY [signature]

DATE 2-25-80

CONTROL PRODUCTS DIVISION | AMERACE CORPORATION CONTROL PRODUCTS DIVISION UNION N.J. 07083 | TEST REPORT NO. ES-1000 | REV. A | SHEET 22 OF 117

Attachment No. 6 Sheet 25 of 29

Loop #/Identifier DC time relays

211009

HOSTILE ENVIRONMENT TEST DATA

SUMMARY SHEET

MODEL NO. E7014AC001 (7014ACE)

TEST ITEM NO. 2

TEMPERATURE	MINIMUM VOLTAGE TEST		MAXIMUM VOLTAGE TEST	
AT 95% R.H. (DEGREES FAHRENHEIT)	AVERAGE TIME DELAY (SECONDS)	REPEAT ACCURACY (PERCENT)	AVERAGE TIME DELAY (SECONDS)	REPEAT ACCURACY (PERCENT)
40°F	4.31 sec	5.5%	4.31 sec	12.9%
50°F	4.50	9.6	4.47	1.9
70°F	4.88	11.0	4.25	5.1
90°F	4.97	22.5	4.29	1.7
110°F	4.81	8.7	4.25	1.7
130°F	4.33	14.2	4.21	1.3
150°F	4.37	6.6	4.18	1.4
165°F	4.35	14.4	4.11	2.7
172°F	4.31	13.0	3.99	0.6

NOTES:

1. TEMPERATURES STATED ARE AT 95% RELATIVE HUMIDITY.
2. AVERAGE TIME DELAY IS AVERAGE OF FIVE (5) CONSECUTIVE READINGS.
3. FOR REPEAT ACCURACY DEFINITION SEE FIGURES 1 AND 2, PAGES 13 AND 14 RESPECTIVELY OF THIS REPORT.

MINIMUM VOLTAGE USED 102 VAC

MAXIMUM VOLTAGE USED 145 VAC

PREPARED BY C.J. Raymond

DATE [illegible]

CONTROL PRODUCTS DIVISION	AMERACE CORPORATION CONTROL PRODUCTS DIVISION UNION N.J. 07083	TEST REPORT NO. ES-1000
		REV. A | SHEET __ OF __

Attachment No. 4 Sheet 26 of 26

Loop #/Identifier 26 Time delays

211575 **HOSTILE ENVIRONMENT TEST DATA**

SUMMARY SHEET

MODEL NO. E702YAC001 (702YACP)

TEST ITEM NO. 1

TEMPERATURE	MINIMUM VOLTAGE TEST		MAXIMUM VOLTAGE TEST	
AT 95% R.H. (DEGREES FAHRENHEIT)	AVERAGE TIME DELAY (SECONDS)	REPEAT ACCURACY (PERCENT)	AVERAGE TIME DELAY (SECONDS)	REPEAT ACCURACY (PERCENT)
40°F	1.65 sec	0.2%	1.67 sec	9.2%
50°F	1.60	0.5	1.60	0.6
70°F	2.02	0.7	2.17	6.4
90°F	1.94	0.8	2.0	3.6
110°F	1.94	1.9	1.87	6.4
130°F	1.85	0.6	1.84	1.2
150°F	1.82	0.5	1.90	3.1
165°F	1.41	1.0	1.41	0.4
172°F	1.40	3.0	1.38	0.5

NOTES:

1. TEMPERATURES STATED ARE AT 95% RELATIVE HUMIDITY.
2. AVERAGE TIME DELAY IS AVERAGE OF FIVE (5) CONSECUTIVE READINGS.
3. FOR REPEAT ACCURACY DEFINITION SEE FIGURES 1 AND 2, PAGES 13 AND 14 RESPECTIVELY OF THIS REPORT.

MINIMUM VOLTAGE USED 102 VAC

MAXIMUM VOLTAGE USED 145 VAC

PREPARED BY E.J. [illegible]

DATE 2-25-80

CONTROL PRODUCTS DIVISION

AMERACE CORPORATION CONTROL PRODUCTS DIVISION UNION N.J. 07083

TEST REPORT NO. [illegible]

REV [illegible]

Attachment No. 4 Sheet 27 of 29

Loop #/Identifier 25 Tran relays

211578

HOSTILE ENVIRONMENT TEST DATA

SUMMARY SHEET

MODEL NO. E7014PC001 (7014PCF)

TEST ITEM NO. 1

TEMPERATURE	MINIMUM VOLTAGE TEST		MAXIMUM VOLTAGE TEST	
AT 95% R.H. (DEGREES FAHRENHEIT)	AVERAGE TIME DELAY (SECONDS)	REPEAT ACCURACY (PERCENT)	AVERAGE TIME DELAY (SECONDS)	REPEAT ACCURACY (PERCENT)
40°F	3.53 sec	0.8 %	3.51 sec	1.3 %
50°F	3.58	1.6	3.63	1.8
70°F	3.77	1.4	3.73	2.7
90°F	3.72	1.6	3.72	0.8
110°F	3.72	1.0	3.75	0.8
130°F	3.66	1.0	3.63	0.8
150°F	3.64	1.0	3.61	1.2
165°F	3.53	1.4	3.55	0.9
172°F	3.36	1.1	3.30	0.8

NOTES:

1. TEMPERATURES STATED ARE AT 95% RELATIVE HUMIDITY.
2. AVERAGE TIME DELAY IS AVERAGE OF FIVE (5) CONSECUTIVE READINGS.
3. FOR REPEAT ACCURACY DEFINITION SEE FIGURES 1 AND 2, PAGES 13 AND 14 RESPECTIVELY OF THIS REPORT.

MINIMUM VOLTAGE USED 96 VDC

MAXIMUM VOLTAGE USED 154 VDC

PREPARED BY R.J. Bernard

DATE 8-15-80

HOSTILE ENVIRONMENT TEST DATA

SUMMARY SHEET

211572

MODEL NO. E702XAC001 (702XACE)

TEST ITEM NO. 1

TEMPERATURE	MINIMUM VOLTAGE TEST		MAXIMUM VOLTAGE TEST	
AT 95% R.H. (DEGREES FAHRENHEIT)	AVERAGE TIME DELAY (SECONDS)	REPEAT ACCURACY (PERCENT)	AVERAGE TIME DELAY (SECONDS)	REPEAT ACCURACY (PERCENT)
40°F	1.50 sec.	5.7 %	1.61 sec.	1.2 %
50°F	1.56	2.1	1.54	0.8
70°F	1.62	0.4	1.64	1.5
90°F	1.51	0.5	1.56	1.3
110°F	1.52	0.7	1.57	1.2
130°F	1.47	1.3	1.50	0.3
150°F	1.35	0.3	1.43	0.5
165°F	1.32	0.4	1.36	0.3
172°F	1.28	0.2	1.32	1.2

NOTES:

1. TEMPERATURES STATED ARE AT 95% RELATIVE HUMIDITY.
2. AVERAGE TIME DELAY IS AVERAGE OF FIVE (5) CONSECUTIVE READINGS.
3. FOR REPEAT ACCURACY DEFINITION SEE FIGURES 1 AND 2, PAGES 13 AND 14 RESPECTIVELY OF THIS REPORT.

MINIMUM VOLTAGE USED 96 VDC

MAXIMUM VOLTAGE USED 154 VDC

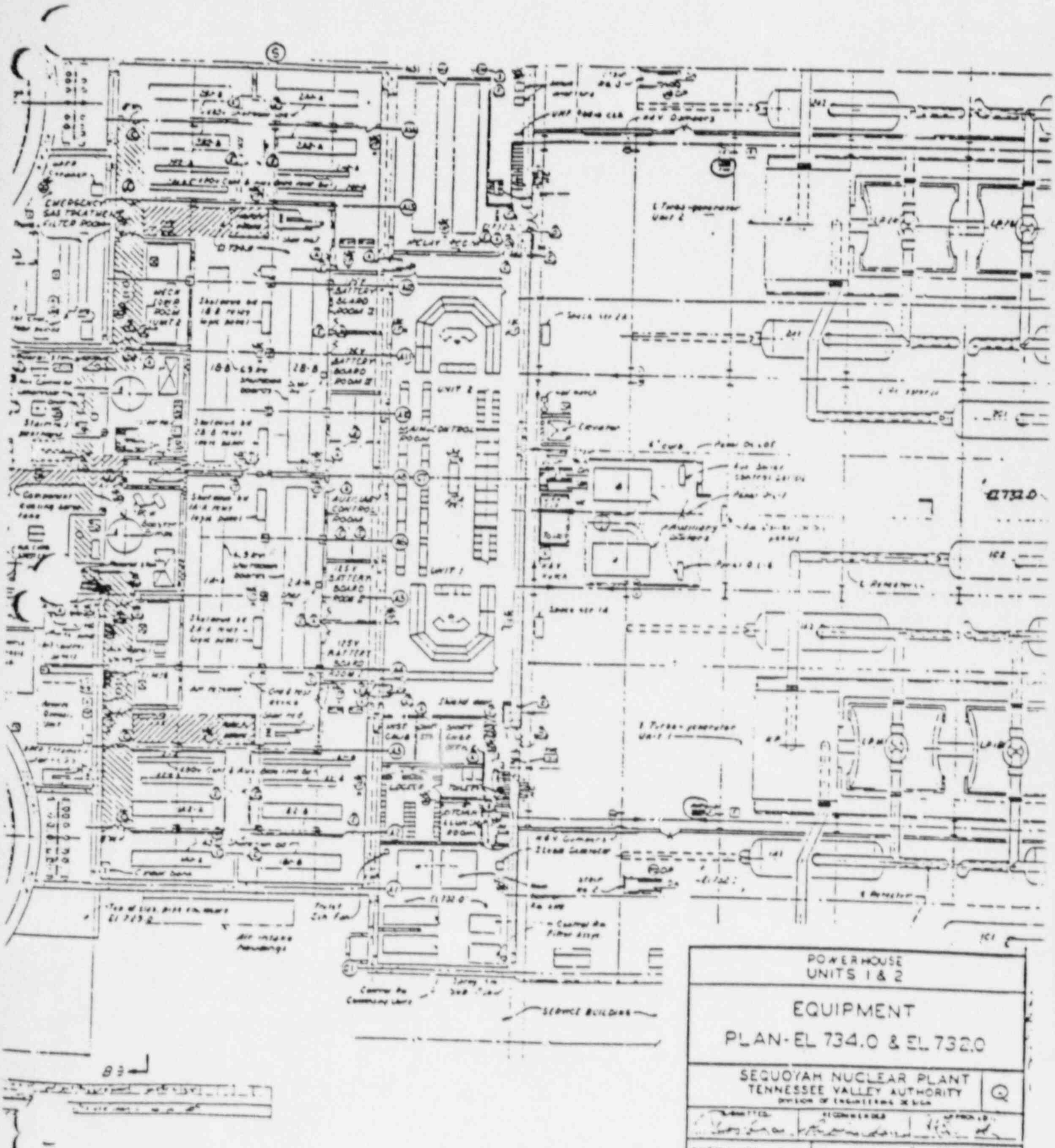
PREPARED BY [illegible signature]

DATE 8-25-80

CONTROL PRODUCTS DIVISION	AMERACE CORPORATION CONTROL PRODUCTS DIVISION UNION N.J. 07083	TEST REPORT NO. ES-1000
		REV. 0 SHEET [illegible] OF [illegible]

Attachment No. 7 Sheet 29 of 29

Loop #/Identifier DC [illegible]



POWERHOUSE
UNITS 1 & 2

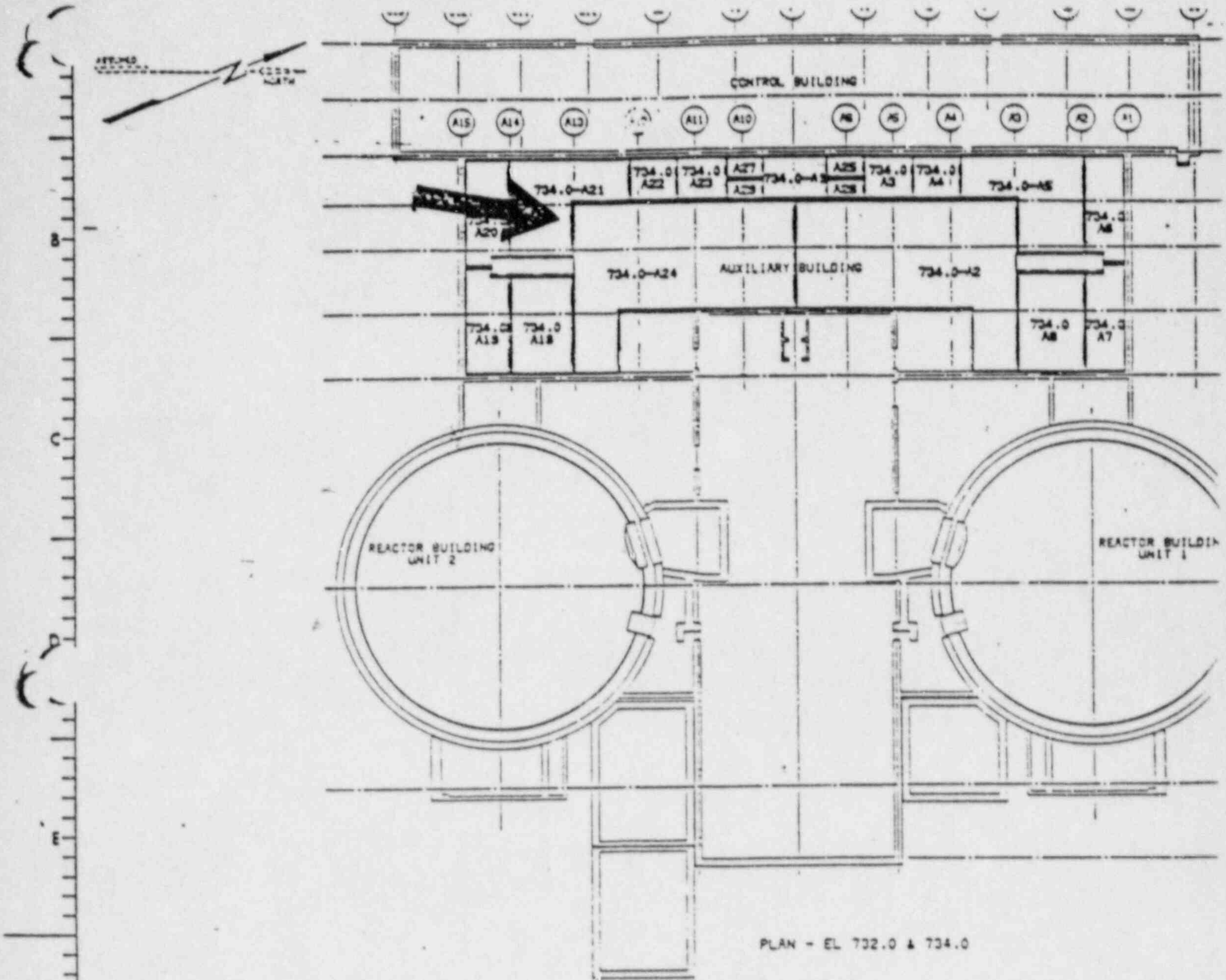
EQUIPMENT
PLAN-EL 734.0 & EL 732.0

SEQUOYAH NUCLEAR PLANT
TENNESSEE VALLEY AUTHORITY
DIVISION OF ENGINEERING DESIGN

Q

KNOXVILLE 47W200-3

Attachment No. 5 Sheet 1 of 1
Loop #/Identifier DG [illegible] relays



PLAN - EL 732.0 & 734.0

BUILDING LOCATION AND ROOM NUMBER	OPERATIONAL CONDITION (NOTE A)		TEMPERATURE (°F)	RELATIVE HUMIDITY (%) (NOTE G)	PRESSURE (PSIA) (NOTE B & H)	TOTAL 40 YEAR INTEGRATED DOSE (RADS) (NOTE C)	INTEGRATED ACCIDENT DOSE (RADS) (NOTES F & C)	AREA TYPE (NOTE J)
AUXILIARY BUILDING [illegible] EL 734.0	1	AVG MAX MIN	[illegible]	50 60 40	ATM (1) ATM (1) ATM (1)	NA 1.8 x 10[illegible] NA	NA NA NA	A
	2	MAX MIN	104 60 NOTE D	90 10	ATM (1) ATM (1)	NA NA	<1 x 10[illegible] NA	
	3		NA	NA	MODE 20	NA	NA	

ENVIRONMENTAL DATA
ENVIRONMENT - MILD
EL 734.0

SEQUOYAH NUCLEAR PLANT
TENNESSEE VALLEY AUTHORITY
DIVISION OF ENGINEERING DESIGN

Q

SUBMITTED	RECOMMENDED	APPROVED
[signature]	[signature]	[signature]

KNOXVILLE | [illegible] | 45 | W | 47E235-07 | R[illegible]

Attachment No. 6 Sheet 1 of 1
Loop #/Identifier DC Train Relays

Attachment No. 7 Sheet 1 of 2 This block to be completed by TVA
Loop #/Identifier

EE VALLEY AUTHORITY
ON OF PURCHAS
nooga, Tennessee 37401
— Area Code 615/265-3551
73 5274

AND ACCEPTANCE

State or Country Code	12
Vendor Code	
Buying Code	S A
Commodity Code	
Account Number	N2 39
TVA Refer. No.	7208-83738
Contract Date	May 19, 1972
Total Amount $	22,440 .00
Performance Date	August 1, 1972

Date April 4, 1972

IE is requested on the items listed, subject. Quotations will be received at this office DST, April 25, 1972*
read in public. Bids not physically received be returned unopened to the bidder.

ORITY, By John P. Cop
Purchasing Agent

ICLES OR SERVICES AND WHICH FORM PART OF CONTRACT

e, Chattanooga, Tennessee

ital Battery Charger

F Prices
ata (form 5053)
a (Appendix B)
Performance Data
t C)
Data (Appendix D)
nditions
nditions (form 5052)
ey Act
(forms 9923 & 9995)
for 125-Volt Vital
harger for Sequoyah Nuclear
its 1 and 2 (including
Assurance Program of
urers and Suppliers of
Materials and Equipment
t A)

minimum acceptance period
quired.

CAB PAB Specs. 7
TB Sisk Contr. 2

APPROVED
5/3/72

Requisition Ref. No. N2E-144 Project Sequoyah Units 1 and 2

BID — Date April 21, 1972 Bidder's Reference Number CFS-4-21-72

In compliance with the invitation for bids, and subject to all the conditions thereof, the undersigned offers, and agrees if this bid be accepted within *60 days from the date of the opening, to furnish the services and/or sell and deliver the articles listed in any or all of the items at the price quoted opposite each. Bids may not be withdrawn after bid opening without the consent of the Contracting Officer.

Discounts will be allowed for payments as follows: net 30 days
Unless otherwise qualified by the bidder on this form: (1) discounts will be deducted from the gross contract price; and (2) time in connection with discounts offered will be computed from date of delivery of the supplies at destination, or from date of receipt of correct bill, whichever date is later.

The bidder represents:

That he is X, is not ___, a small business concern as defined in Code of Federal Regulations, Title 13, Chapter 1, Part 121, Section 121.3-8. In connection with supply contracts, if bidder is a nonmanufacturer, he also represents that the products to be furnished hereunder will X, will not ___, be produced by a small business concern. In construction and construction-related nonpersonal service contracts, the preceding sentence is not applicable.

(Complete only when the aggregate amount of bid is $10,000 or more.)
That he is X a manufacturer of the articles, equipment, material or supplies quoted upon herein. That he is ___ a regular dealer in, and maintains a stock for sale to the general public of articles, equipment, materials, or supplies of the general character of that or those upon which he bids herein.

(Complete only when (a) the aggregate amount of bid in response to advertising is $25,000 or more, or (b) the aggregate amount of bid on a negotiated purchase is more than $1,000.)
That (a) he has X, has not ___ employed or retained any company or person (other than bona fide employees or bona fide established commercial or selling agencies maintained by the bidder for contractor) for purposes of securing business) to solicit or secure this contract, and (b) he has ___, has not X, paid or agreed to pay any company or person (other than bona fide employees of bona fide established commercial or selling agencies maintained by the bidder for contraction for purposes of securing business) any fee, commission, percentage, or brokerage fee, contingent upon or resulting from the award of this contract, and agrees to furnish information relating thereto as requested by the Contracting Officer.

Bidder: Power Conversion Products Inc. — Number 513 — Zip Code 60014
Street: 42 East St. — Telephone No. 815/459-9100
City, State, and Zip Code: Crystal Lake, Illinois 60014
MAY 30 1972
Person authorized to sign bid — Name and title (print or type) and signature: C.F. Seyer, Sales Manager

accepted only as to:

1A and 2. Addendums I and II
de a part of this award.

Destination. Ship by Prepaid
Freight.

gs to be submitted by June 19,

John P. Cop, Purchasing Agent

CONSIGN TO — TENNESSEE VALLEY AUTHORITY
Sequoyah Nuclear Plant, near Daisy, Tennessee
MARK: Contract 7208-83738
For: Sequoyah Units 1 and 2
Attn: Chief Storekeeper

MAIL INVOICE in DUPLICATE to — TENNESSEE VALLEY AUTHORITY
Construction Accounting Branch
400 Northshore Building
Knoxville, Tennessee 37902

Invoices must show contract number, discount or terms of payment, item number, description of article or service, quantity, unit price and total amount.

Person receiving material	Date Material Received	G.B.L. No.	Carrier's Charges Paid $	
Approved as reported above	Truck: Vendor / TVA	Common Carrier: Express / Freight / Par. Post	Purchase Cost	
			Cash Discount	
			Carrier's Charges	
			Total Cost	

of 2

TENNESSEE VALLEY AUTHORITY

APPENDIX C

GUARANTEED PERFORMANCE DATA   Item 1a(alternate)

(To be Made a Par‘ the Contract)

The bidder hereby guarantees that the performance and characteristics of the equipment bid upon will be as stated in the following tabulation. In the case of conflicts between data furnished below and any other data furnished with the bid, that furnished below shall govern. Include a separate tabulation for alternate proposal where applicable.

TVA considers this information so material to its decision on whether or not a bid meets the specifications that the omission of any one or more of them could make impossible such decision and cause the bid to be nonresponsive. If the omission of items of information renders a bid nonresponsive, such bid will be rejected.

Input requirement: 36 kva input at 19.6 kw output (rated)
23.4 kw input at 19.6 kw output (rated)
80 percent efficiency

Regulation: ± 1 percent from no load to full load with a simultaneous ± 7.5 percent line voltage variation and ± 2 percent frequency variation

Output voltage ripple: 100 mv volts rms, or .5 percent without battery connected

Current limit: 125 max. percent rated at nominal input (480 volts, 60 Hz)

130 max. percent rated value at nominal +10 percent input

125 max. percent rated value at nominal -10 percent input

Ambient temperature: 45^0 C maximum

Attachment No. 7 Sheet 2 of 2
Loop #/Identifier DG [illegible]

Power Conversion Products Inc.

Sheet 1 of 2

Date [illegible]

Rev. R1

SEQUOYAH NUCLEAR DIESEL GENERATOR LOADING SEQUENCE

FOR BO AND SI-PHASE B ON POWER TRAIN 2B

SQN E^3 002

Component	Load Rating	Time* (Sec)	Starting P.F.	Acc Time (Sec)	Remarks	Running P.F.	Running Eff.
Random Loads	190 HP	--	.496	5 Max. @** Min. Volt	1047 Kva Starting	0.85**	0.9**
6.9kV to 480V transformers	3 @ 1500 kVA, 1 @ 300 kVA	0	.578	5 Max @** Minimum Volts	572 Conn. HP 2351 Kva Starting	.85**	.9**
Centrifugal Charging Pump	600 hp rated 690 ,687 hp actual	2	.29 ,2868	4.5 @ 100% Volt, 11.5 @ 80% Volt	3601 kVA Δ Starting	.929	.939 | R6
Safety Injection Pump	400 hp rated 410 hp actual	5	.25	2.7 @ 100% Volt, 6.8 @ 80% Volt	2458 kVA Δ Starting	.895	.933
Residual Heat Removal Pump	400 hp rated 425 hp actual	10	.2928	1.6 @ 100% Volt, 3.8 @ 80% Volt	2401 kVA Δ Starting	.937	.938
Essential Raw Cooling Water Pump	700 hp	15	.17**	1.4 @ 100% Volt, 1.98 @ 90% Volt	3852 kVA Δ Starting	.856	.925
Component Cooling Pump	2 @ 350 hp rated 355 hp actual	20	.2098	3.6 @ 100% Volt, 6.0 @ 80% Volt	3541 kVA Starting	.875	.928
Auxiliary Feedwater Pump	500 hp rated 540 hp actual	25	.18**	5 Max @** Minimum Voltage	2789 kVA Δ Starting	.915	.93
Containment Spray Pump	700 hp rated 690 hp actual	~~30~~ 180	.2711	3.1 @ 100% Volt, 11 @ 80% Volt	4058 kVA Δ Starting	.934	.949

Attachment No. 8 Sheet 1 of 2

Loop #/Identifier DG [illegible]

Prepared RLL
Checked [illegible]
Reviewed [illegible]
Date 2-10-86
Rev R1

SQN E3 002

FOR BO AND SI-PHASE A ON POWER TRAIN 2B

Component	Load Rating	Time* (Sec)	Starting P.F.	Acc Time (Sec)	Remarks	Running P.F.	Running Eff.
Fire Pumps	200 hp rated	≥ 120 / 220	.32	2 @ 85% Volt	876 kVA Δ Starting	.815	.895

*Time is measured from closing of circuit breaker connecting the diesel generator to the power train with 5 percent timing accuracy.

**Assumed values

Δ Kva was calculated at 6.6 Kv.

Attachment No. 8 Sheet 2 of 2
Loop #/Identifier [illegible]

0663A

CONTROL PRODUCTS DIVISION
AMERACE CORPORATION, 2330 VAUXHALL ROAD
UNION, NEW JERSEY 07083 USA
TELEX — 138-978 TWX — 710-985-4687
TELE: (201) 964-4400

amerace

January 17, 1984 EEB '84 0119 028

Mr. F.W. Chandler
Chief, Electrical Engineering Support Branch
Tennessee Valley Authority
400 West Summit Hill Drive, W8C126
Knoxville, Tennessee 37902

Re: Your letter of January 10, 1984

Dear Mr. Chandler: Subject: Agastat Time Delay Relays
2400, 7000 and E7000 series

This is to certify that the Agastat series 2400, 7000 and E7000 are electro pneumatic or solenoid time delay devices -

These series have a diaphragm in a sealed timing chamber. A one way valve traps air in the timing chamber, and is forced through a variable orifice. It's dial position setting determines the time delay.

The attached sheets outline it's basic operation for both on and off delay models.

Very truly yours,

CONTROL PRODUCTS DIVISION

D.P. Alexander
Customer Service Manager
DPA/ie

encl.

1/19/84 - FWC:PAD
cc: MEDS, W5B63 C-K, w/attachments

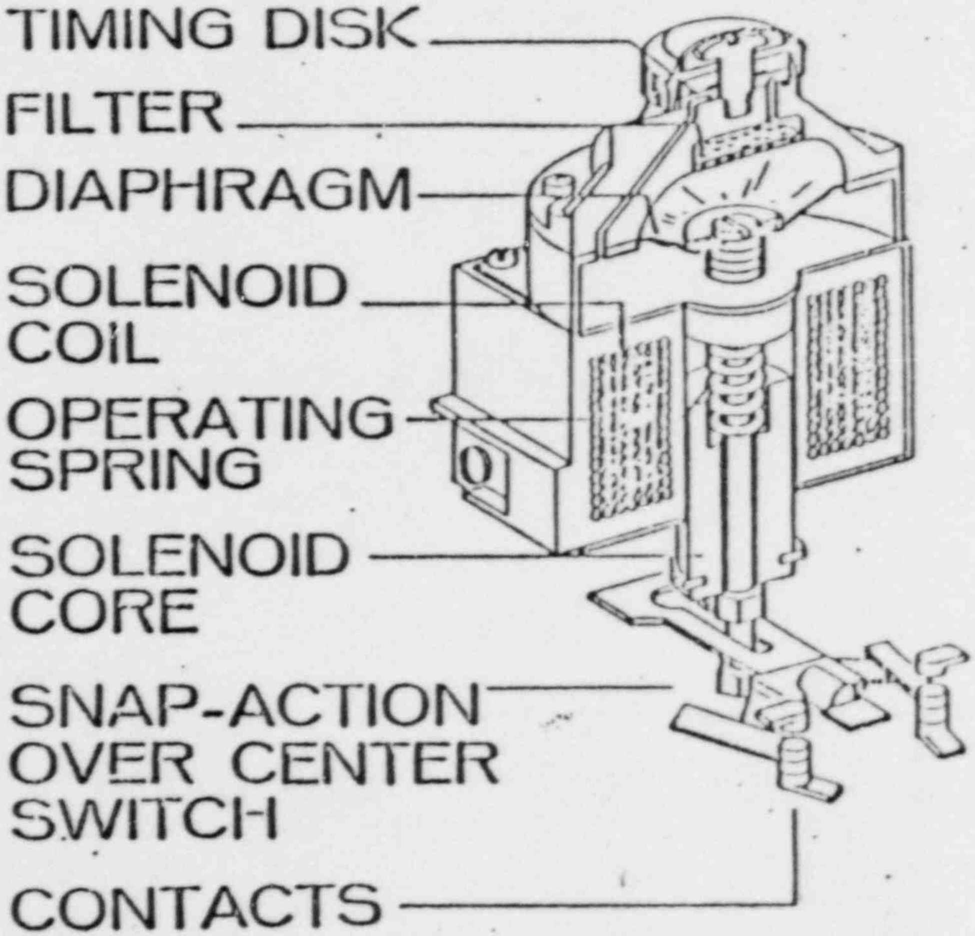
ELECT ENGR BRANCH
JAN 20 '84

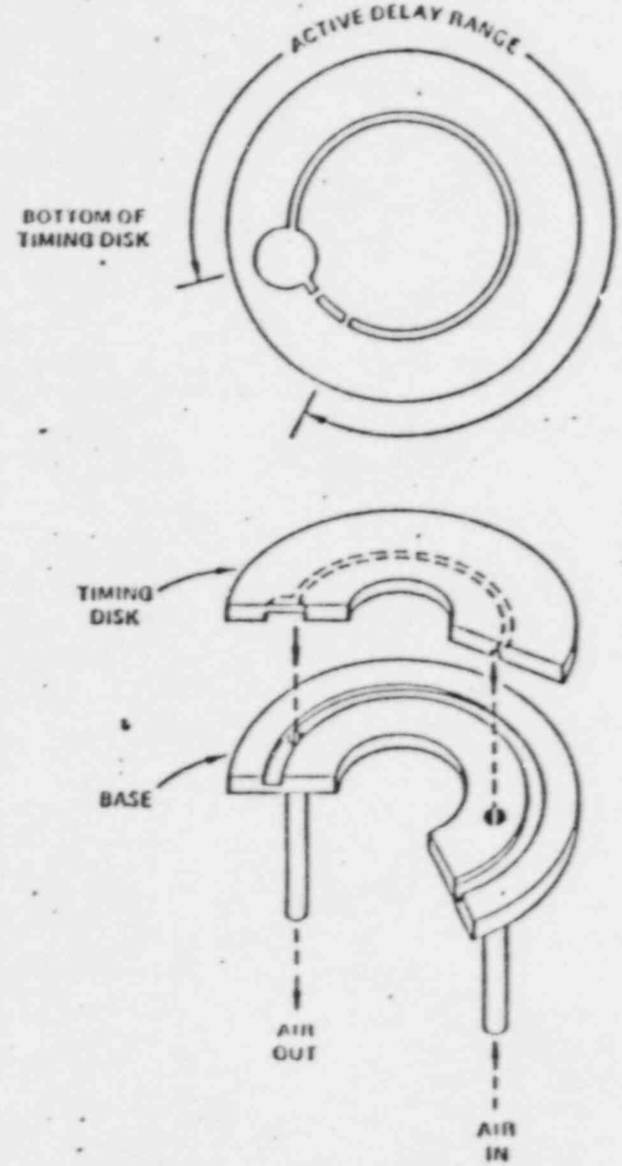
Attachment No. 9 Sheet 1 of 4
Loop #/Identifier DG TIME RELAYS

1 891

Series 2400, 7000, E7000

"A"





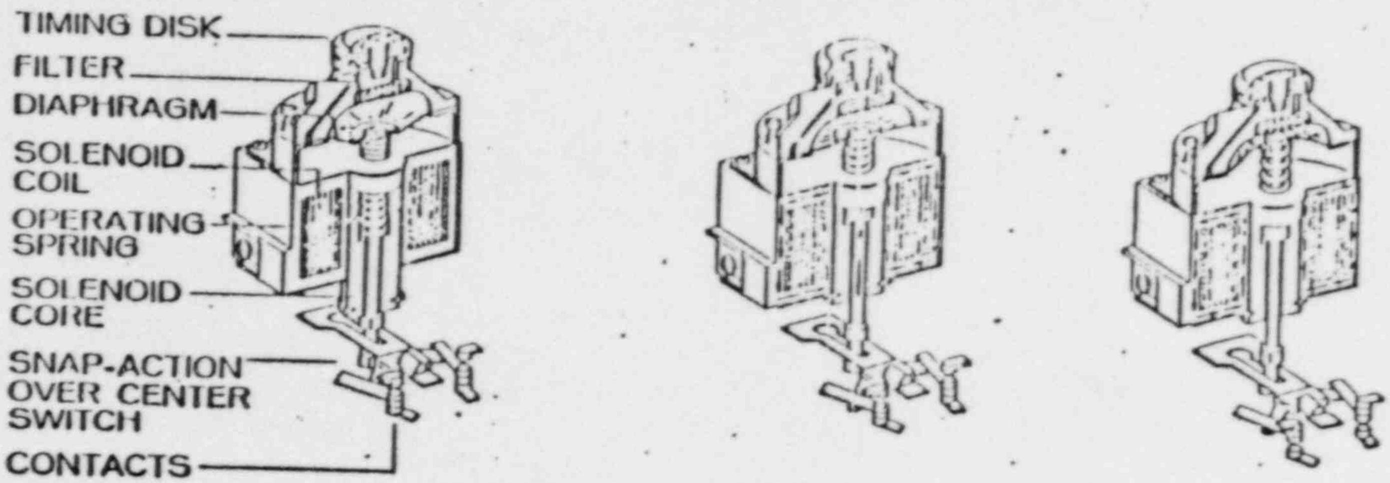
DETAIL OF TIMING HEAD

Attachment No. ___ Sheet ___ of ___
Loop #/Identifier ___

"B"

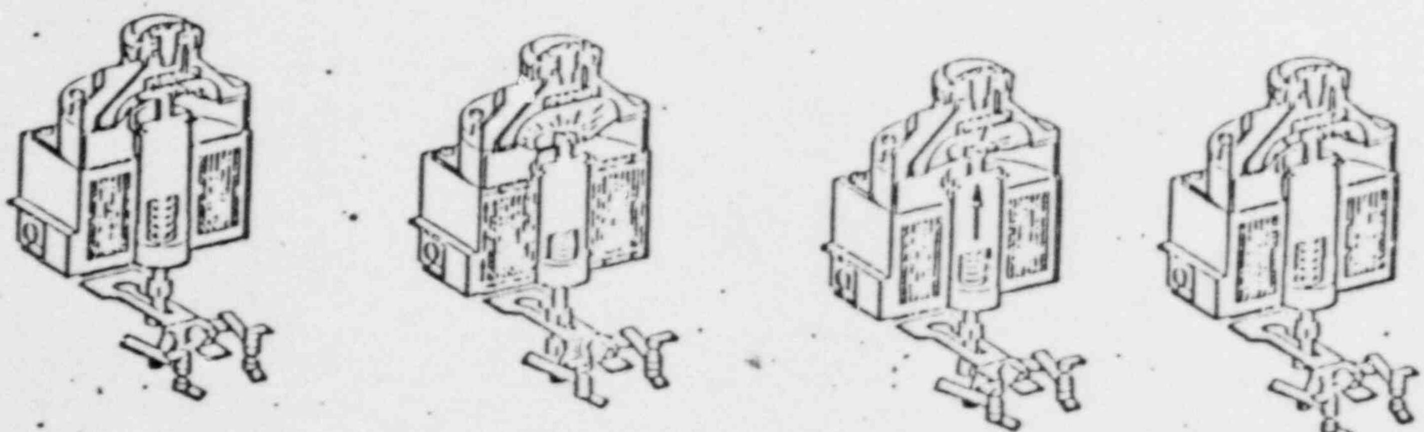
Attachment No. 9 Sheet 3 of 7
Loop #/Identifier DC [illegible]

Series 2400, 7000, E7000



ON delay

off delay



"C"

The 7000 series time delay relays are electropneumatic or solenoid operat devices. A spindle is affixed through the center of the core. One end (bottom) of the spindle actuates the switch block. The other end (top) of the spindle forces air through a controlled orifice.

BASIC OPERATION OF AN ON-DELAY 7000 E7000 2400

Applying voltage to coil terminals, L1 and L2, initiates the preset time delay and creates an invisible magnetic field that draws the magnetic core to the magnet core stop closing the one-way valve in the diaphragm assembly. Captured air in the timing chamber is then forced through the variable orifice (timing disk). At the end of the preset delay the captive air is totally exhausted through the variable orifice and the bottom portion of the spindle transfers the contacts and they (contacts) remain in this position as long as the unit is energized. To reset (start a new time delay) the unit voltage must be removed from the coil. With the help of gravity and spring forces the magnetic core breaks away from the magnet core stop allowing the one-way valve to open and the contacts to transfer to their normal deenergized state within .050 seconds.

BASIC OPERATION OF AN OFF-DELAY 7000 E7000 2400

Applying voltage to coil terminal, L1 and L2, (for a minimum of .050 seconds) creates an invisible magnetic field that draws the magnetic core to the magnet core stop opening the one-way valve in the diaphragm assembly and simultaneously transfers the contacts on the switch block. Removing voltage from coil terminals, L1 and L2, initiates the preset time delay and closes the one-way valve in the diaphragm assembly. Captured air in the timing chamber is then forced through the variable orifice (timing disk). At the end of the preset delay the captive air is totally exhausted through the variable orifice and the bottom of the spindle transfers the contacts to their normal rest position.

Attachment No. __ Sheet __ of __
Loop #/Ident: __ DS TIMER RELAYS

WESTINGHOUSE ELECTRIC CORPORATION

MILWAUKEE SPECIAL PROJECTS

205 BISHOPS WAY
ELM GROVE, WI. 53122

Secuoyan Nuclear Plant Tennessee Valley Authority Division of Engineering Design	Logic Relay Panels Bill of Material
7107-17672 | CO-31704-4KE-3M	REV. 3 | SHEET NO. 1

IT.	QTY	DESCRIPTION	STYLE NO.
1	16	G.E. Type 1AV54F Relay, 120V A.C., Range 2-30 Sec., 60 HZ (27S)	121AV54F1A
2	3	G.E. Type 1AV54E Relay, 120V A.C., Range 0.3-5 Sec., 60 HZ (27D)	121AV54E1A
3	192	Type MG-6 Relay, 125V D.C., 6-CC Contacts	289B359A20
4	128	Type MG-6 Relay, 125V D.C., Electric & Hand Reset, with Op. Coil Cutoff Contact	289B361A15
5	120	Type SG Relay, 125V D.C., DPDT	1162952
6	38	Type EZC Indicating Lamp, 125V D.C. Lens - Red Bulb - 25V D.C., .75 Watts Resistor - 3200 Ohms Hardware Receptacle Assembly	449D187G14
7	74	Type EZC Indicating Lamp, 125V D.C. Lens - Amber Bulb - 24V D.C., .75 Watts Resistor - 3200 Ohms Hardware Receptacle Assembly	449D187G54
		Lens - Bulb - V D.C., Watts Resistor - Ohms Hardware Receptacle Assembly	

AS BUILT

APPROVED
TENNESSEE VALLEY AUTHORITY

Attachment No. 10 Sheet 1 of 4
Loop #/Identifier MG Type Relays

WESTINGHOUSE ELECTRIC CORPORATION
MILWAUKEE SPECIAL PROJECTS

205 BISHOPS WAY
ELM GROVE, WI. 53122

Sequoyan Nuclear Plant
Tennessee Valley Authority
Division of Engineering Design

Logic Relay Panels
Bill of Material

7107-17672 | CO-31704-MKE-RM | REV. 3 | SHEET NO. 2

IT.	QTY	DESCRIPTION	STYLE NO.	
3	40	Westinghouse Type OT Selector Switch, 3 Position, 2 N.C. & 2 N.O. Contacts, with Extra Large Nameplate Engraved "Normal - Reset - Test", Bat Lever Handle, 4 Contact Blocks Ea. (2-OT2N, 2-OT2M) (43T)	OT2S6	
9	8	Type W-2 Control Switch Escutcheon 12 - "Normal", 1 - "Test" Handle - Oval Basic Switch Sw. Assembly (43-MT)	 501B787H01 508A106G01	
10	4	Type W-2 Control Switch Escutcheon 12 - "Cont. Room" 1 - "Aux. Cont. Room" Handle - Oval Basic Switch Sw. Assembly (43 L/R)	 501B787H01 508A104G01	
11	56	Westinghouse Type OT Test Pushbutton, 4 N.O. & 4 N.C. Contacts, Std. Nameplate Engraved "Test" Operator 4 Contact Blocks (1 NO - 1NC)	 OT2B1 OT2A	
13	88	Cutler-Hammer Press-to-Test Indicating Light, 125V D.C. Lens - White Assembly	 E-29KP60 E-29WM	
14	46	Agastat Timing Relay, 125V D.C. Range (Time) 0.2-5 Sec. 1 - SPDT Instantaneous 1 - DPDT Time Delay on Pick-Up	7012PBL	
15	36	Agastat Timing Relay, 125V D.C. Range (Time) 2.5-50 Sec., DPDT Time Delay on Pick-Up	7012PD	

AS BUILT

APPROVED
TENNESSEE VALLEY AUTHORITY
Date APR 27 1977

7E-93403

Attachment No. 10 Sheet 2 of 4
Loop #/Identifier [illegible]

WESTINGHOUSE ELECTRIC CORPORATION
MILWAUKEE SPECIAL PROJECTS

205 BISHOPS WAY
ELM GROVE, WI. 53122

Sequoyan Nuclear Plant Tennessee Valley Authority Division of Engineering Design	Logic Relay Panels Bill of Material
7107-17672 / CD-31704-MKE-3M	REV. 1 / SHEET NO. 3

IT.	QTY	DESCRIPTION	STYLE NO.	
16	9	Agastat Timing Relay, 125V D.C. Range (Time)' 10-200 Sec., DPDT Time Delay on Pick-Up	7012PE	
17	100	3A. Epoxy Diode 600 Volt, 3 Amp	--	
18	4	Westinghouse Type OT Selector Switch 3 Position, with Extra Large Nameplate Engraved "Normal-Reset-Test", Bat Lever Handle, with 4 - OT2M & 2OT2N Contact Blocks	OT26	
19	4	Agastat Timing Relay, 125V D.C. Range (Time) 2.5-50 Sec. DPDT Time Delay on Pick-Up with 1 - SPDT Instantaneous Pair of Contacts	7012PD	
20	8	Type EZC Indicating Lamp, 125V D.C. Lens - White Bulb - 24V D.C. .75 Watts Resistor - 3200 Ohm Hardware Receptacle Assembly	449D137G14	
21	4	Westinghouse Type OT Selector Switch 3 Position (Spring Return to 12 O'Clock with Extra Large Nameplate Engraved "27D AB TEST - NOR - 27D CD TEST") Bat Lever Handle 2 Contact Block (OT2N) per Operator	OT2V6	
22	4	Westinghouse Type OT Selector Switch 2 Position Maintained, with Extra Large Nameplate Engraved "NORMAL-TEST" Bat Lever Handle 3 Contact Block (OT2N) per Operator	OT2S1	

AS BUILT

APPROVED
TENNESSEE VALLEY AUTHORITY
APR 27 1977

74-53-03

Attachment No. 10 Sheet 3 of 4
Loop #/Identifier DG TIMER RELAYS

MILWAUKEE SPECIAL PROJECTS

205 BISHOPS WAY
ELM GROVE, WI. 53122

Sequoyah Nuclear Plant Tennessee Valley Authority Division of Engineering Design	Logic Relay Panels Bill of Material
7107-17677 / CO-31704-WKE-RM / REV. 3	SHEET NO. 4

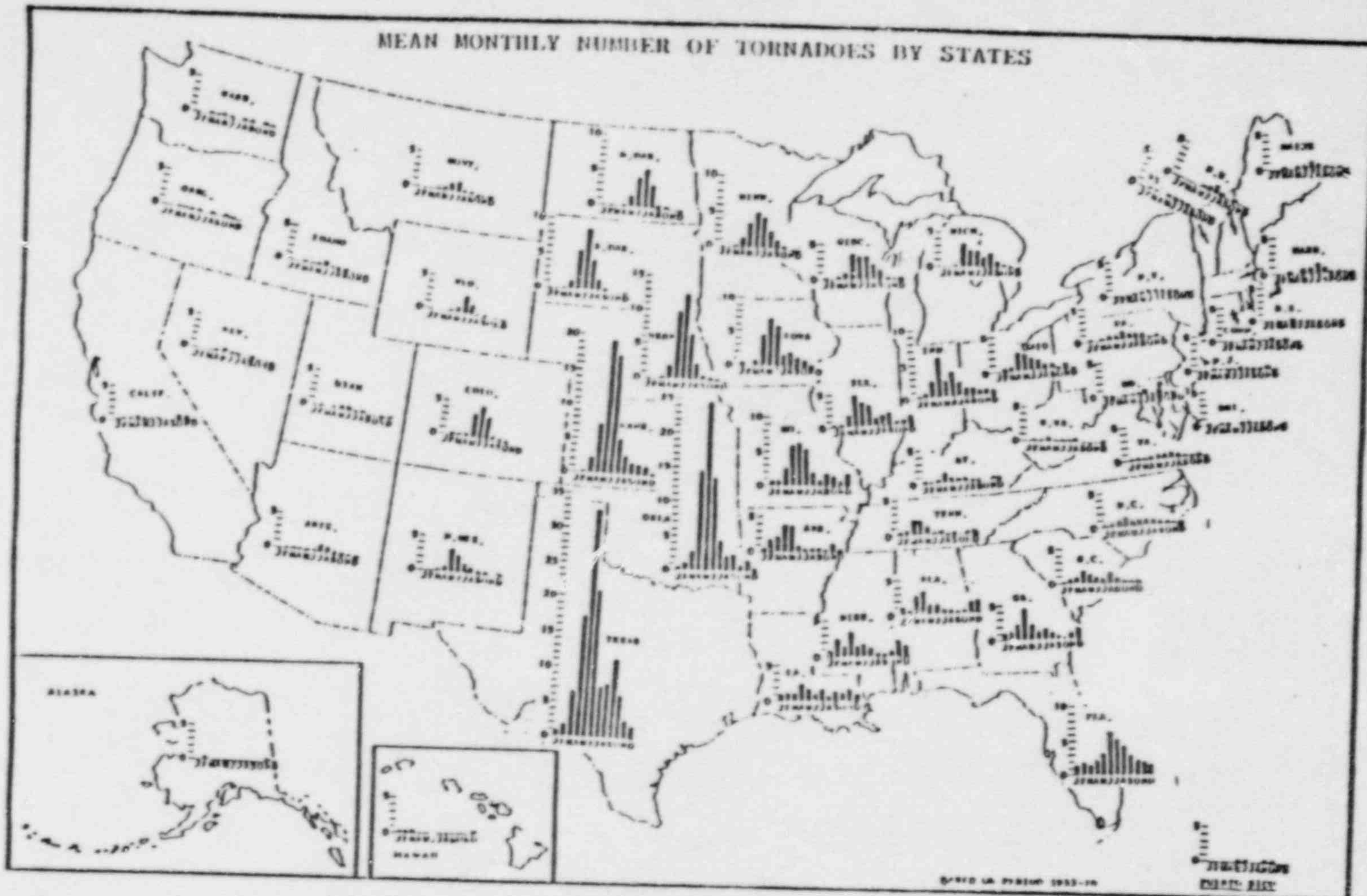
IT.	QTY	DESCRIPTION	STYLE NO.	
23	40	Fuse, Buss Type KAZ Activator		
24	20	Fuse Block - Buss Block #2837 2 Pole, 5-5/16" x 4-13/16"		

AS BUILT 7-1-83403

AS BUILT

TENNESSEE VALLEY AUTHORITY
APR 27 1977

Attachment No. 10 Sheet 4 of 4
Loop #/Identifier DG INPUT RELAYS



DATA OBTAINED FROM CLIMATE ANALYSIS CENTER
WASHINGTON, D.C.

Attachment No. 11 Sheet 1 of 1
Loop #/Identifier [illegible]

9-16 OCT

QUALITY INFORMATION REQUEST / RELEASE (QIR)
DIVISION OF NUCLEAR ENGINEERING
(INTERNAL USE ONLY)

QA Record

RIMS ACC NO: B43 '87 0924 902

TO: Roberta Galante SEB W4A24C-K	DOCUMENT NUMBER QIR EEB 87461
FROM: P.K. Guha EEB W8D223C-K	PAGE 1 OF 1
TYPE OF DOCUMENT: [X] REQUEST NEED DATE 24 Sept 87 / [ ] RELEASE REF. QIR Esl.84 (10/16)	DATE 24 Sept 87 / PLANT AND UNIT Sequoyah 1+2

REFERENCED DOCUMENTS

AVAILABLE IN ONE OF THE RIMS SYSTEMS		ATTACHMENT TO THIS QIR	
DOCUMENT	IDENTIFYING NUMBER	DOCUMENT	ATTACHMENT NUMBER

SUBJECT: Sequoyah N.P. Tornado Depressurization & Time Delay Relays

SYSTEMS AFFECTED: Emergency Power System (Diesel Gen) | UNID / SYSTEM ID:

QUALITY INFORMATION REQUESTED / RELEASED: AGASTAT Pneumatic time delay relays used to Sequence on Diesel/Generator loads are affected by atmospheric pressure (depressurization shortens time delay)

Please provide the probability of the following sequence of events occurring and justification for not replacing the time delay relays before restart.

A) a Tornado occurs on Sequoyah site

B) All offsite Power is lost.

C) Aux Building 6.9KV shutdown board room (see 47E 235-07) is depressurized. Depressurization is still in effect 10 seconds after Loss of offsite Power. (Note: the timers don't start to function until D.G. is up to speed and this takes approximatly 10 seconds after Loop.)

D. Depressurization causes timers to malfunction and prevent successful Loading of Diesels. — Diesels trip.

-Note Diesels may be restarted and reloaded at some time after the trip.

PREPARED: W. C. Thomas W8D197 x 3097

REVIEWED (RELEASES ONLY):

APPROVED (BRANCH CHIEF, PROJECT ENGINEER): PGuha for W.S. Raughley

Attachment No. 12 Sheet 1 of 1
Loop #/Identifier DG TIMER RELAYS

TVA 10829 (DNE 6-86)

cc (Attachment): RIMS, SL-26 C-K

TVA 64 (OS-9-63)

UNITED STATES GOVERNMENT

Memorandum

B81 '870928 001

TENNESSEE VALLEY AUTHORITY

TO : J. B. Hosmer, Project Engineer, Sequoyah Engineering Project, DNE, DSC-E, Sequoyah

FROM : L. W. Lau, Chief, Systems Engineering Branch (RAM), W4 A4 C-K

DATE :

SUBJECT: SEQUOYAH NUCLEAR PLANT - DIESEL GENERATOR PNEUMATIC SEQUENCE TIMERS

References: 1. DNE Calculation (EEB), "DG Timer Relays," Revision 1 (B43 870831 902)
2. QIR EEB87461 (B43 870924 902)

The purpose of this memorandum is to provide engineering judgment for the removal of the requirement to replace the diesel generator pneumatic sequence timers before January 1988 as stated on 25A of reference 1.

The reason for the existing requirement is that the accuracy of the pneumatic timers is affected by tornado depressurization in the 6.9-kV shutdown board rooms where the relays are located. See Sequoyah Nuclear Plant (SQN) environmental drawing 47E235-07.

For the tornado depressurization effect to adversely affect the loading of the diesel generators, the following sequence of events must occur:

1. a tornado occurs onsite,
2. all offsite power is lost,
3. the diesel loading sequence progresses to the point that the timers are timing, and
4. the depressurization occurs between two non-SI loads which are already closed spaced.

The probability of the above sequence of events occurring is sufficiently low as to justify removing the requirement to replace the timers from the calculation. The quantitative values for the probability and a description of the sequence, however, will be provided at a later date (by October 15, 1987) to support this engineering judgment and the referenced calculation will be revised accordingly.

L. W. Lau

PKG:JMW

cc: RIMS, SL 26 C-K
W. S. Raughley, W8 C126 C-K
R. A. Sessoms, W12 A6 C-K

0005L

Attachment No 13 Sheet 1 of 1
Loop #/Identifier DG Timer Relays

QA Record

QUALITY INFORMATION REQUEST/RELEASE (QIR)
DIVISION OF NUCLEAR ENGINEERING
(INTERNAL USE ONLY)

	RIMS ACCNO B31 871014 001
TO W. S. Raughley, Chief, Electrical Engineering Branch, W8 C126 C-K	DOCUMENT NUMBER
FROM L. W. Lau, Chief, Systems Engineering Branch, W7 C126 C-K	QIR SEB 87003
TYPE OF DOCUMENT	PAGE 1 OF 2
( ) REQUEST NEED DATE	DATE OCT 14 1987
(X) RELEASE REF. QIR EEB87461	PLANT AND UNIT Sequoyah Nuclear Plant Units 1 & 2

REFERENCED DOCUMENTS

Available in One of the RIMS Systems

Document	Identifying Number

Attachment to This QIR

Document	Attachment Number
Final Environmental Statement SQN Units 1 and 2, Appendix A, p. A-3	1
Reliability of Emergency Diesel Generators at US Nuclear Power Plants, NSAC-108, Sept 1986, p. 3-1	2

SUBJECT

SEQUOYAH NUCLEAR PLANT TORNADO DEPRESSURIZATION OF TIME DELAY RELAYS

SYSTEMS AFFECTED

emergency power system (diesel generator)

UNID/SYSTEM ID

QUALITY INFORMATION REQUESTED/RELEASED

This QIR provides the probability of the following sequence of events:

a) A tornado strikes the SQN plantsite
b) All offsite power is lost (LOOP)
c) Auxiliary building 6.9-kV shutdown board room is depressured
d) Depressurization causes sequence timers to malfunction thereby tripping the diesel generators (DGs)
e) The DGs are not successfully restarted

The yearly probability of a tornado striking any point in the plantsite area is 8.4E-5 (attachment 1).

This QIR conservatively assumes (due to insufficient data) that a tornado causing the auxiliary building 6.9-kV shutdown board room to depressure would also damage the plant switchyards thereby initiating a nonrecoverable LOOP (facilities damaged). Therefore, for purposes of this QIR events b and c are postulated for a tornado strike of the immediate plant area. Additionally when depressured, the sequence timers are assumed to malfunction and initiate a diesel trip.

Either a DG hardware failure or an operator failure to start the DG will result in the failure to restart the DGs. The probability of hardware failure preventing the start of a single DG is 1.4E-2 (attachment 2) (assumes independence from previous start and trip).

PREPARED Darrel Cain 10/14/87

REVIEWED (RELEASES ONLY) Mark A. Sisco for A. D. Proctor

APPROVED (BRANCH CHIEF/PROJECT ENGINEER)

Attachment No. 14 Sheet 1 of 4
Loop #/Identifier DG TIMER RELAYS

TVA 10829 (DNE-QA-6-86)

cc (Attachments): RIMS, SL 26 C-K
C. W. Beachler, W5 D182 C-K
J. B. Hosmer, DNE, DSC-E, Sequoyah

Manually starting a DG is an operator practiced procedure. Although there would be increased stress levels associated with an onsite tornado, failure of an operator to conduct a DG start procedure is considered insignificant in comparison to the probability of DG hardware failure. For the success criteria (two out of four DGs required for safe shutdown) of two DGs restarting (three single DG start failures assumed total failure) the failure probability for the DGs to start is 4 * $(1.4E-2)^3$ or 2.7E-6.

Using the above data this QIR calculates the yearly probability of events a, b, c, d, and e as approximately:

8.4E-5 * 2.7E-6 or 2.3E-10

Acceptable methods for calculating these conditional probabilities have been used. The probabilities calculated are extremely small and can never by demonstrated in the lifetime of TVA nuclear power plants. Their validity for decisionmaking should be based on the extremely low relative probability of these events versus other more frequency events calculated using acceptable methods. The probabilities calculated are specific to the site characteristics at SQN.

Attachment No. 14	Sheet 2 of 4
Loop #/Identifier DG TIMER RELAYS	

ATTACHMENT 1

From: Final Environmental Statement SQN Units 1 and 2, Appendix A

hourly wind speed recorded at the Sequoyah meteorological facility during the first 24 months of operation, April 2, 1971, through March 31, 1973, was 40 mi/h. High wind may accompany moderate-to-strong cold frontal passages about 20 to 30 times a year with the maximum frequency in March and April. High wind may also accompany thunderstorms about 56 times a year with maximum frequency in July.[1]

The probability of tornado occurrence is extremely low. Statistics show that during the period, 1916-73, no tornadoes were reported in the vicinity of the Sequoyah site.[1,2] Using the principles of geometric probability described by H.C.S. Thom,[3] the probability of a tornado striking any point in the plant site area is 8.4×10^{-5}, or about one in 11,905 years.

Tornadoes in the eastern Tennessee area generally move northeasterly and cover an average surface path 5 miles long and 100 yards wide (0.284 mi^2).[4] Winds of 150 to 200 mi/h are common in the whirl and are estimated to occasionally reach 300 mi/h.[4,5]

Days of high air pollution potential have been depicted by G. C. Holtzworth.[6] Over a 5-year period, his data show that there would be about 30 days, or about 6 days annually, that such conditions would likely affect the site area, with most of the days occurring in the fall.

The highest monthly average rainfall occurs during the winter and early spring months with March usually having the greatest amount. The maximum 24-hour rainfall reported near the plant site was 7.56 inches in August of 1954.[7] Other months with high precipitation are June and July when air mass thunderstorm activity is common. Minimum precipitation is normally in October when the Azores-Bermuda anticyclonic circulation is most predominant.

Attachment No. 14 Sheet 3 of 4

Loop #/Identifier [illegible]

ATTACHMENT 2

From: Reliability of Emergency Diesel Generators at US Nuclear Power Plants
NASC-108, Sept 1986

Section 3

RESULTS AND DISCUSSION

Tests and Real Demands

Appendix A shows the overall nationwide reliability results for U.S. nuclear power plant EDG operations. The values in Appendix A include both test and real (unplanned) demands as one class for the years 1983, 1984, and 1985.

Industry-wide EDG unreliability results for tests and unplanned demands as a class is excerpted from Appendix A and shown below:

EDG UNRELIABILITY
TEST & UNPLANNED DEMANDS

YEAR	Start Phase		Load-Run Phase		Unreliability (Failures/Demand)		
	Demands	Failures	Demands	Failures	Start	Load-run	Total
1983	6642	31	4126	40	0.005	0.010	0.014
1984	7335	27	4391	42	0.004	0.010	0.013
1985	8127	25	5291	56	0.003	0.011	0.014
3 Yrs	22104	83	13808	138	0.004	0.010	0.014

The results in Appendix A are based on 22,104 start demands and 13,808 load-run demands. The appendix indicates that overall, after being called on to start, EDGs are further called on to carry load only about 60% of the time. The difference between the number of start demands and load-run demands comes about for a number reasons. For one there are various anticipatory signals (for example the opening of certain switchyard breakers or tripping of the main turbine generator) that at various plants are programmed to start the EDGs, however the EDGs will go on to assume load only if a safety bus actually becomes deenergized. Also, certain Action Statement tests are performed to confirm that

Attachment No. 14 Sheet 4 of 4
Loop #/Identifier DG TIMER ACT. AMS

Attachment 3

Demonstrated Accuracy Calculation 27S1A

(B25 880126 456)

Itl 94

ORIGINAL

QA Record

TVA 10697 (DNE-QA-6-86) DNE CALCULATIONS

Title: DEMONSTRATED ACCURACY CALCULATION 27SIA			Plant/Unit: SEQUOYAH / 1 & 2
Preparing Organization: EEB-I&C	KEY NOUNS (Consult RIMS Descriptors List): I&C, INSTR, CALIBRATION, SETPOINT, ACCURACY		
Branch/Project Identifiers: 27SIA	Each time these calculations are issued, preparers must ensure that the original (RO) RIMS accession number is filled in.		
	Rev	(for RIMS' use)	rims accession number
	R0		B25 '88 0126 456
Applicable Design Document(s)	R		
	R		
SAR Section(s): [illegible] / UNID System(s): NA	R		FOR INFORMATION ONLY

Revision 0	R1	R2	R3	Safety-related? Yes (X) No ( )
ECN No. (or indicate Not Applicable): ~~[illegible]~~ N/A RDH				Statement of Problem
Prepared: Felix Chomicki				Determine the accuracy of the subject instrument loop(s) and demonstrate that the accuracy is adequate for the intended purpose. Primary elements are located in a MILD environment. Subject devices /_/are /X/are not part of PAM.
Checked: Vinod Wakudkar				
Reviewed: R D Hall				
Approved: Michael [illegible]				
Date: 1-24-88				
USE FORM TVA 10534 IF MORE SPACE REQUIRED — List all pages added by this revision				
List all pages deleted by this revision				
List all pages changed by this revision				

ABSTRACT [These calculations contain an unverified assumption(s) that must be verified later. Yes ( ) No (X)]

Calculations were performed to determine the accuracy of the subject instrument loop(s). The determined accuracies were compared to the required accuracies, setpoints, safety limits and/or operating limits and the accuracy for the loop(s) listed below were demonstrated to be acceptable for the intended function of the instrument loop(s). This calculation applies to the instrument loop(s) listed below:

6.9KV SHUTDOWN BOARD RELAY LOGIC PANEL:

1A-A, 2A-A, 1B-B & 2B-B

R0 FSAR COMPLIANCE REVIEW Michael [illegible] 1/24/88 LE/ABC

R0 of this calculation consists of 41 pages and 16 attachments for a total of 102 pages.

Return to G. Hunley
P-17S SB-K X-[illegible]

( ) Microfilm and store calculations in RIMS Service Center

(✓) Microfilm and return calculations to: ~~J. D. Hutson~~ ~~RE Hall~~

Microfilm and destroy. ( )

Address: ~~WB [illegible]~~ ~~W2 ALL C-K~~

cc: RIMS, SL 26 C-K
F. Chomicki W8B84C-K

DNEI - 2548k

FSAR COMPLIANCE REVIEW (PER PM 87-31)

Sections reviewed:

Chapter 7,8, & Technical Specifications (section 3/4 8 in particular)

Results of review:

Change to Table 8.3.1-2 required (see attached ECN data sheets).

PREPARER ________________ DATE 11-23-87

MODIFICATION CRITERIA NO. N2-72/C-01

6.0 CHECKLIST OF POTENTIAL EFFECTS ON DESIGN DOCUMENTS

Y = YES N = NO

	Affected Y/N	Data Sheet Required Y/N
1. Safety Analysis Report (SAR) affected? If yes, Figure No.: ______ ~~Section~~ No.: 8.3.1-? TABLE ([illegible] ATTACHMENT 1)	Y ~~N~~	N
2. Technical specification affected? If yes, Section No.: ______	N	N
3. Latest scoping document required?	N	N
4. Seismic analysis required (Reference CES-DI-121.03)?	N	N
5. Condition Adverse to Quality (CAQ) report (~~[illegible]~~) required (existing) Number: SEE [illegible]	Y	N
6. Security system modification?	N	N
7. Human factor review required?	N	N
8. Vendors involved (new/existing)?	N	N
9. Appendix R analysis affected?	N	N
10. Equipment EQ analysis affected?	N	N
11. Electrical or physical separation analysis affected?	N	N
12. Flooding evaluation required?	N	N
13. Radiation shielding and/or As Low As Reasonably Achievable (ALARA) considered?	N	N
14. Revision to Environmental Impact Statement (EIS) required?	N	N

ECN 1216

SNP-1

TABLE 8.3.1-2

DIESEL GENERATOR LOAD SEQUENTIALLY APPLIED FOLLOWING A LOSS OF NUCLEAR UNIT AND PREFERRED (OFFSITE) POWER

Equipment Name	Time in Seconds*	Total HP Load	Starting kVA	Load Applied: Nonaccident Condition	Load Applied: Accident Condition
Miscellaneous Loads	0	1100	5132	Yes	Yes
Centrifugal Charging Pump & AHU	2	680	4079	Yes	Yes
Safety Injection Pump & AHU	5	410	2632	No	Yes
Residual Heat Removal Pump & AHU	10	425	2499	No	Yes
Essential Raw Cooling Water Pump	15	700	3788	Yes	Yes
Component Cooling System Pump	~~20~~**	710	4000	Yes	Yes
Auxiliary Feedwater Pump	~~15~~ 20	486	2386	Yes	Yes
Containment Spray Pump & AHU	30	690	3572	No	Yes
Pressurizer Heaters	90	485 kw	485 kw	Yes	No
Fire Pump	120	200	865	Yes	Yes

1

Diesel Generator Rating: 4000 kw continuous or 4400 kw for 2 hours

* Time is measured from the time of closing of the breaker which connects the diesel generator to the power train. Values given are nominal times. Actual times are consistent with the diesel generator loading analyses and will be verified during preoperational testing.

** Diesel generator 1A or 2B will have two component cooling system pumps loaded (see Table 8.3.1-3, Loads Having Manual Transfer Between Power Trains)

AHU - Air Handling Unit

Revised by Amendment 1

PROPOSED FSAR CHANGE

ATTACHMENT 1 TO AEL-1216-01

CALCULATION INDEPENDENT REVIEW VERIFICATION FORM

~~778~~ EJB 2751A — Calculation No.

R0 — Revision

Method of independent review used (check one or more):

1. Alternate calculation method ________
2. Testing method ________
3. Other method ✓ - Review

Justification (explain below):

Method 1: Identify the pages where the alternate calculation has been included in the calculation package and explain why this method is adequate.

Method 2: Identify the QA documented source(s) where testing adequately demonstrates the adequacy of this calculation and explain.

Method 3: Justify the technical adequacy of the calculation and explain how the adequacy was verified (calculation is similar to another, based on accepted handbook methods, appropriate sensitivity studies included for confidence, etc.).

The calculation was performed per the NEI requirements with all input data referenced. The methodology appears to be reasonable therefore the calculation is considered to be adequate.

[signature] — Design Verifier (Independent Reviewer)

1-23-85 — Date

TVA

Title: 275IA

REVISION LOG

Revision No.	DESCRIPTION OF REVISION	Date Approved

TVA 10534 (EN DES-4-78)

BRANCH/PROJECT IDENTIFIER 275IA · -
DEMONSTRATED ACCURACY CALCULATION

TABLE OF CONTENTS

REV 0 PREP JC DATE 9-15-87 CHECK VC DATE 9.15.87 SHEET 1 C/O 2
REV 1 PREP ____ DATE ____ CHECK ____ DATE ____ SHEET ____ C/O ____
REV 2 PREP ____ DATE ____ CHECK ____ DATE ____ SHEET ____ C/O ____

BRANCH/PROJECT IDENTIFIER 2751A

DEMONSTRATED ACCURACY CALCULATION

P U R P O S E

The purpose of this calculation is a) to determine the accuracy of the instrumentation covered by this calculation, and b) to demonstrate that the instrumentation is sufficiently accurate to perform its intended function without safety or operational limits being exceeded.

A S S U M P T I O N S

✓ This calculation contains no assumptions.

___ The following assumptions were used in the performance of this calculation. These assumptions require further analysis. This calculation may require revision if the assumptions below are shown to be invalid.

REQUIREMENTS:

1) NOTE 3 & 5 PAGE 1C PLACES REQUIREMENTS ON CALIBRATION PROCEDURES.

SCOPE:

THIS CALCULATION IS VALID ONLY FOR THE FOLLOWING CHANGES PROPOSED ON ECN 7216 & 7222. IF THESE CHANGES ARE NOT MADE OR ADDITIONAL CHANGES ARE MADE, THEN THIS CALCULATION MUST BE REVIEWED TO ENSURE APPLICABILITY.

1) CHANGE AUX FEEDWATER PUMP TIMER TO 20 SEC

2) CHANGE COMPONENT COOLING PUMP TIMER TO 30 SEC.

REMAINDER OF DG LOAD SEQUENCE DOES NOT CHANGE RDH 1/23/88

REV 0	PREP FC	DATE 11-4-87	CHECK VC	DATE 11-4-87	SHEET 2	C/O 3
REV 1	PREP	DATE	CHECK	DATE	SHEET	C/O
REV 2	PREP	DATE	CHECK	DATE	SHEET	C/O

BRANCH/PROJECT IDENTIFIER 2751A

DEMONSTRATED ACCURACY CALCULATION

SOURCE OF DESIGN INPUT INFORMATION (REFERENCES)

REF #	ATT #	REFERENCE (RIMS#)
1	1	GE PRODUCT LITERATURE (GEH-1768B)
2	2	RELAY SETTING SHEETS
3	3	SEISMIC TEST PROCEDURE ON 6900-VOLT SHUTDOWN BOARD LOGIC PANELS FOR SEQUOYAH NUCLEAR PLANT UNITS 1 & 2
4	4	A) TVA DWG 47W200-3 R15 "EQUIPMENT PLAN"
		B) TVA DWG. 47E235-07 R2 "ENVIRONMENTAL DATA"
		C) TVA DWG 45N724-1 R25 "SINGLE LINE"
5	5	"THE ART & SCIENCE OF PROTECTIVE RELAYING", C. RUSSELL MASON; JOHN WILEY & SONS, INC., NEW YORK, 1956.
6	6	"POWER SYSTEM PROTECTION AND SWITCHGEAR", B. RAVINDRANATH & M. CHANDER; JOHN WILEY & SONS, 1977.
7		DNE CALCULATION "A REVIEW OF ELECTRONIC COMPONENTS IN A RADIATION ENVIRONMENT OF ≤ 5X10⁴ RADS" (B43860721903)
8	7	TEST RECORDS OF RELAY LOGIC PNL RELAY SETTINGS
9	8	LETTER FROM GE TO TVA DATED MAY 11, 1987
10		DNE CALCULATION "DG TIMER RELAYS" (RIMS NO. B43870615905), RC
11	9	"SEQUOYAH NUCLEAR DIESEL GENERATOR LOADING SEQUENCE" FROM DNE CALC SQN E3002 (NON-ACCIDENT LOADS)
12	10	ITE PRODUCT LITERATURE (BULLETIN 8.2-1C)

REV 0 PREP 4C DATE 9-15-87 CHECK VC DATE 9-15-87 SHEET 3 C/O 3A

REV 1 PREP ____ DATE ____ CHECK ____ DATE ____ SHEET ____ C/O ____

REV 2 PREP ____ DATE ____ CHECK ____ DATE ____ SHEET ____ C/O ____

BRANCH/PROJECT IDENTIFIER 27SIA -
DEMONSTRATED ACCURACY CALCULATION

SOURCE OF DESIGN INPUT INFORMATION
(REFERENCES)

REF #	ATT #	REFERENCE (RIMS#)
13	11	"SEQUOYAH NUCLEAR DIESEL GENERATOR LOADING SEQUENCE" from DNE CALC SQNE3002 (ACCIDENT LOADS).
14	12	FSAR, chapter 8, page 8.3-9, "STANDBY DIESEL GENERATOR OPERATION
15	13	LETTER from TVA to NRC, "SEQUOYAH - DIESEL GENERATOR LOADING SEQUENCE
16		ECN 6715
17		ECN 7216
18	14	QIRS: EEB 87329, EEB 87330, MEB SQN 87139, SQP-87-921
19	15	FSAR figure 15.2.9-1
20	16	QIR EEB 87447 ; QIR SQP 87-468

REV 0 PREP JC DATE 9-15-87 CHECK VC DATE 11-4-87 SHEET 3A C/O 4
REV 1 PREP ____ DATE ____ CHECK ____ DATE ____ SHEET ____ C/O ____
REV 2 PREP ____ DATE ____ CHECK ____ DATE ____ SHEET ____ C/O ____

DESIGN INPUT DATA

A) DEFINITIONS & ABBREVIATIONS

Aa	ACCIDENT ACCURACY-ACCURACY OF A DEVICE IN A HARSH ENVIRONMENT CAUSED BY AN ACCIDENT
Aas	COMBINED ACCIDENT AND SEISMIC ACCURACY
Ab	ACCEPTANCE BAND-THE RANGE OF VALUES AROUND THE CORRECT VALUE DETERMINED TO BE ACCEPTABLE WITHOUT RECALIBRATION
AB	AUXILIARY BOILER LINE BREAK
AF	AFW PUMP TURBINE STEAM SUPPLY LINE BREAK
An	NORMAL ACCURACY-ACCURACY OF A DEVICE LOCATED IN A ENVIRONMENT NOT AFFECTED BY AN ACCIDENT OR PRIOR TO AN ACCIDENT
As	POST SEISMIC ACCURACY
AV	ALLOWABLE VALUE-SAFETY LIMIT/REQUIRED ACCURACY MINUS NON-MEASUREABLES; USED FOR THE PURPOSE OF DETERMINING REPORTABILITY ONLY.
CV	CVCS LETDOWN LINE BREAK
De	DRIFT INACCURACY
HELB	HIGH ENERGY LINE BREAK
IAD	INTEGRATED ACCIDENT DOSE
ICRe	INPUT TEST INSTRUMENT READING INACCURACY
ICTe	INPUT TEST INSTRUMENT CALIBRATION INACCURACY
INDRe	INDICATOR READING ERROR
IRe	INACCURACY DUE TO CABLE LEAKAGE
L	LOSS OF COOLANT ACCIDENT
M	MARGIN-THE DIFFERENCE BETWEEN THE SAFETY LIMIT/OPERATING LIMIT AND THE NORMAL/ACCIDENT ACCURACY (Mn=NORMAL MARGIN Ma=ACCIDENT MARGIN)
N/A	NOT APPLICABLE
OCRe	OUTPUT TEST INSTRUMENT READING INACCURACY

D E S I G N   I N P U T   D A T A

A) DEFINITIONS & ABBREVIATIONS CONTINUED

OCTe	OUTPUT TEST INSTRUMENT CALIBRATION INACCURACY
PRCSe	PROCESS UNCERTAINTY
PSEe	INACCURACY DUE TO POWER SUPPLY VARIATIONS
PV	PROCESS VALUE (ACTUAL)
RADe	INACCURACY DUE TO ACCIDENT RADIATION EXPOSURE
Rc	REPEATABILITY INACCURACY
RH	RHR LINE BREAK
RNDe	NORMAL RADIATION DOSE BETWEEN CALIBRATION
Se	INACCURACY FOLLOWING A SEISMIC EVENT
SECu	SPAN ERROR CORRECTION UNCERTAINTY
SL	SAFETY LIMIT
SP	SETPOINT
SPEe	ZERO ERROR DUE TO EFFECTS OF OPERATING PRESSURE
TAe	TEMPERATURE EFFECT AT ACCIDENT CONDITIONS
TID	TOTAL 40 YEARS INTEGRATED DOSE
TNe	TEMPERATURE EFFECT IN THE MAXIMUM/MINIMUM ABNORMAL TEMPERATURE RANGES
TPRe	TEST POINT RESISTOR ERROR
WLe	WATERLEG UNCERTAINTY
WLHP	WATERLEG HIGH POINT
WLLP	WATERLEG LOW POINT
TD	TIME DELAY
LOOP	LOSS OF OFF SITE POWER
LOCA	LOSS OF COOLANT ACCIDENT

BRANCH/PROJECT IDENTIFIER 27SIA

DEMONSTRATED ACCURACY CALCULATION

D E S I G N   I N P U T   D A T A

B) LOOP COMPONENT LIST

LOOP ID#	COMPONENT ID#	
RELAY LOGIC PNLS:	27SIA (Aφ & Cφ)	ONE EACH PER PANEL
1A-A, 2A-A, 1B-B & 2B-B	27SIA (Aφ & Cφ)	

REV 0	PREP FC	DATE 9-5-87	CHECK VC	DATE 9.15.87	SHEET 6	C/O 7
REV 1	PREP	DATE	CHECK	DATE	SHEET	C/O
REV 2	PREP	DATE	CHECK	DATE	SHEET	C/O

BRANCH/PROJECT IDENTIFIER 27SIA

DEMONSTRATED ACCURACY CALCULATION

DESIGN INPUT DATA

C) LOOP FUNCTION

SEE NEXT PAGE

C) LOOP REQUIREMENTS AND LIMITS (BISTABLE)

RESPONSE TIME: THE PARAMETER of INTEREST IN THIS CALCULATION IS TIME DELAY, THEREFORE, THIS CALCULATION IS CALCULATING THE ACCURACY of THE RESPONSE TIME.

SAFETY LIMITS: 27SIA (LOAD SHED): 10 SECONDS following LOOP/AFTER THIS CALCULATION. SEE "LOOP FUNCTION," SHEET 7B.

function 2 & 3 (LOOP & LOOP w/ SI): SEE ATTACHMENT 14 & 16

OPERATING LIMITS:

SETPOINT: 27SIA RELAYS: 5 SEC per REF. 4C

27DIA RELAYS: 1.5 SEC per REF. 4C

SEQUENCE TIMERS: SEE "ACCURACY CALCULATION" SECTION of THIS CALCULATION (VALUES per Ref 10, 16, & 13 & 11)

REV 0	PREP JC	DATE 9-5-87	CHECK VC	DATE 9.15.87	SHEET 7	C/O 7A
REV 1	PREP	DATE	CHECK	DATE	SHEET	C/O
REV 2	PREP	DATE	CHECK	DATE	SHEET	C/O

L O O P F U N C T I O N

There are (3) functions covered by this calculation:

1) Load shedding following a LOOP (initiated by 27SIA relays).
2) DG start and load sequencing following a LOOP only (27DIA relays).
3) DG start and load sequencing following a concurrent LOOP and LOCA initiation.

Function 1) is initiated by the 27SIA relays after sensing zero volts on the 6.9 KV Shutdown Buss. These relays have a voltage and time setpoint. The voltage setpoint is nominal and as such is not considered since the function of the relay is to transfer contacts on zero volts (LOOP). Therefore, this calculation will consider only the time delay inaccuracies following LOOP.

Function 2) is initiated by the 27DIA relays which send a start signal to the DG. After the DG's have come up to speed and voltage the load sequencing relays will start to apply non-accident loads. The 27DIA relays have a nominal voltage setpoint which will not be considered, only the delay from LOOP to closing of the non-accident load breakers will be addressed (see attachment 9 for non-accident loading sequence).

For function 3) the 27DIA relays are by-passed by the LOCA initiation signal (SI signal) which immediatley sends a signal to start the DG's. After the DG's are up to speed and voltage the load sequencing relays will start to apply accident loads (see attachment 11 for accident loading sequence). Therefore, this calculation will calculate time delay errors from a concurrent initiation of LOOP and LOCA to closing of the accident load breakers.

Function 2) and 3) requires calculation of inaccuracies for both the 27DIA relays and the DG sequence timers relays. The inaccuracies of the tha timer relays is calculated in DNE calculation "DG timer relays." and will be incorporated into this calculation by reference (reference no. 10). Timing diagrams for function 2) and 3) start on page 29.

L O O P   F U N C T I O N (con't)

The 27SIA relay initiates a load shed while the DG's are coming up to speed, therefore, this function requires loads to be shed before the DG's are ready to connect to the 6.9 KV Shutdown Buss. The DG's are allowed 10 seconds to attain rated speed and voltage(reference A), therefore the load shed must occur within 10 seconds of LOOP.

A delayed LOCA after a LOOP or a delayed LOOP after a LOCA are not considered due to the information contained in attachment 13.

BRANCH/PROJECT IDENTIFIER 27S1A -
DEMONSTRATED ACCURACY CALCULATION

DESIGN INPUT DATA

D) COMPONENT DATA

VALID FOR DEVICES IDENTIFIED ON SHEET(S): 6

COMPONENT: VOLTAGE RELAY CONTRACT #: 54499 REFERENCE #: —

MANUFACTURER/MODEL: GE / 12IAV54E1A & 12IAV54F1A REFERENCE #: 2, 8

INPUT RANGE & UNITS: NA NOTE #: ___ REFERENCE #: ___

OUTPUT RANGE & UNITS: NA NOTE #: ___ REFERENCE #: ___

OVERRANGE LIMIT: NA NOTE #: ___ REFERENCE #: ___

CALIBRATED SPAN: NA NOTE #: ___ REFERENCE #: ___

ROOM #/ PANEL #: SEE NOTE 1 NOTE #: 1 REFERENCE #: 4

ELEVATION/ COORDINATE: 734 / SEE NOTE 1 NOTE #: 1 REFERENCE #: 4

MIN/MAX ABNORMAL TEMP: 60 / 104 °F, 75°F NORMAL NOTE #: ___ REFERENCE #: 4

ACCIDENT TEMPERATURE: N/A NOTE #: ___ REFERENCE #: 4

RADIATION TID (RAD): 1.8×10^3 NOTE #: ___ REFERENCE #: 4

RADIATION IAD (RAD): $< 1 \times 10^4$ NOTE #: ___ REFERENCE #: 4

INSTRUMENT TAP INFORMATION REFERENCE #: NA

WLHP TAP ELEVATION: NA WLHP CONDENSING POT ELEVATION: NA

WLLP TAP ELEVATION: NA WLLP CONDENSING POT ELEVATION: NA

EVENT/CATEGORY/OPERATING TIME: NA (MILD ENVIRONMENT) NOTE #: ___ REFERENCE #: ___

___ / ___ / ___

___ / ___ / ___

___ / ___ / ___

___ / ___ / ___

___ / ___ / ___

REV 0	PREP FC	DATE 9-15-87	CHECK VC	DATE 9-15-87	SHEET 8 C/O 9
REV 1	PREP ___	DATE ___	CHECK ___	DATE ___	SHEET ___ C/O ___
REV 2	PREP ___	DATE ___	CHECK ___	DATE ___	SHEET ___ C/O ___

BRANCH/PROJECT IDENTIFIER 27S1A'

DEMONSTRATED ACCURACY CALCULATION

DESIGN INPUT DATA

D) COMPONENT DATA CONTINUED

COMPONENT: VOLTAGE RELAY

PARAMETER	VALUE/UNITS	NOTE #	REFERENCE #
Re	± 4% of setting	7	9
De	± 5.2% of setting	6	5, 6 & 8
TNe	± 10% of setting	6	
SPEe	NA		
SECu	NA		
PSEe	NA		
RNDe	NEGLIGIBLE	2	7
TPRe	NA		
ICTe	NEGLIGIBLE	3	
ICRe	NA	3	
OCTe	NA	4	
OCRe	NA	4	
Ab	± 4% of setting	5	
Se	NEGLIGIBLE	6	3, 5, & 6
RADe	NEGLIGIBLE	2	7
TAe	NA		
WLe	NA		
PRCSe	NA		
INDRe	NA		
IRe	NA		

REV 0 PREP Jc. DATE 9-15-87 CHECK VC DATE 9-15-87 SHEET 9 C/O 10

REV 1 PREP ___ DATE ___ CHECK ___ DATE ___ SHEET ___ C/O ___

REV 2 PREP ___ DATE ___ CHECK ___ DATE ___ SHEET ___ C/O ___

DESIGN INPUT DATA

E) COMPONENT DATA NOTES

COMPONENT: VOLTAGE RELAY

\# NOTE

1)

SHUTDOWN BD RELAY LOGIC PNL ID	ELEVATION	COL	ROOM
1A-A	734	A6-S	6.9KV SHUTDOWN BD. RM.
2A-A	)	A4-S	(
1B-B	)	A11-S	(
2B-B	d.	A8-S	do

2) PER INFORMATION CONTAINED IN REFERENCE # 7, RADIATION EFFECTS FOR DOSES < 5×10^4 RADS ARE NEGLIGIBLE.

3) A REQUIREMENT OF THIS CALCULATION IS A CALIBRATION TIMER W/A A DIGITAL READOUT TO $1/100^{th}$ OF A SEC. IT IS EXPECTED THAT A TIME PIECE OF THIS NATURE WILL HAVE NEGLIGIBLE INACCURACY COMPARED TO THE OTHER INACCURACIES IN THIS CALCULATION THEREFORE, PER ENGINEERING JUDGEMENT, ICT_e IS NEGLIGIBLE. ALSO, SINCE A DIGITAL TIMER IS USED, ICR_e IS NA.

4) OUTPUT IS A CONTACT TRANSFER, THEREFORE OCT_e & OCR_e ARE NA.

5) A REQUIREMENT OF THIS CALCULATION IS THAT A_b = ±4% OF SETTING.

DESIGN INPUT DATA

E) COMPONENT DATA NOTES

COMPONENT: VOLTAGE RELAY

\# ✓ NOTE

6) These relays are a variation of the shaded-pole induction relay (see ref. 1, 5 & 6). The principle of operation is that two magnetic fluxes produced by an electromagnet and differing in time phase penetrate through a disc. The current produced by one flux reacts with the other flux, and vice versa, so that a force is produced which rotates the disc shaft. The disc shaft carries a contact that completes a circuit when it touches a stationary contact. The disc shaft is restrained by a spiral spring that counter-balances the electro-magnetically induced rotating torque. The time delay is obtained by a " drag magnet " which is a permanent magnet that retards motion in either direction by interacting with eddy currents within the disc. The disc shaft rests on a jewel bearing for relatively friction free operation.

For the function addressed in this calculation, i.e., time delay following a complete loss of voltage, the only mechanisim involved in providing the delay function is the return of the disc shaft to its de-energized position by the spiral spring. Because of this type of construction and the simple operation required to accomplish the relay's function, some engineering judgements can be made regarding accuracy of operation:

1) DRIFT: Since the spiral spring is metallic, there would be little significant time-temperature induced aging, therefore, drift would be negligible. Mechanical wear would also be minimal since the relays are normally only cycled for testing and calibration.

   Attachment 7 is calibration data for the relays addressed in this calculation. Starting on page 19 is a statistical analysis of this data. The mean value deviation of 6 relays on 4 boards (24 total) for a calibration cycle of 6 months was approximately zero (-0.279%) indicating that there was no bias shift. The standard deviation for the 24 samples was 2.6% of setting. For a 95% confidence level, (2σ), the deviation was 5.2% of setting. Considering that the repeatability of the relays is +/- 4%, most of the " drift " value of 5.2% is more than likely attributable to repeatability. However, for conservatisim in this calculation, a drift error, (De), of +/-5.2% of setting will be used.

REV 0	PREP Fc	DATE 8-15-87	CHECK Ve	DATE 9.15.87	SHEET 11	C/O 12
REV 1	PREP	DATE	CHECK	DATE	SHEET	C/O
REV 2	PREP	DATE	CHECK	DATE	SHEET	C/O

BRANCH/PROJECT IDENTIFIER 2751A

DEMONSTRATED ACCURACY CALCULATION

DESIGN INPUT DATA

E) COMPONENT DATA NOTES

COMPONENT: voltage relays

#	NOTE
6) (con't)	2) SEISMIC: As long as the disc shaft remains on its pivot and the spiral spring remains intact, the time delay following seismic vibration would not affect time delay on complete loss of voltage. The relays were seismically qualified by reference 3, therefore, the relay will remain intact and perform its function following a seismic event.
	3. TEMPERATURE EFFECTS: since the time delay is produced by the magnetic flux of the drag magnet interacting with the disc, and the pivot about which the shaft rotates is relatively friction free, the time delay for short periods (1.5 sec 5.0 in this case) would seem to be immune to normal temperature variations (104° to 60°F) this is used as the basis for the engineering judgement that temperature effects are minimal. However, for conservatism in this calculation, the value of ±10% of setting will be included for TNE.
7.	Per attachment 8, Time delay repeatability = ± 4% of setting

REV 0	PREP 7C	DATE 9-15-87	CHECK VC	DATE 9-15-87	SHEET 12	C/O 13
REV 1	PREP	DATE	CHECK	DATE	SHEET	C/O
REV 2	PREP	DATE	CHECK	DATE	SHEET	C/O

BRANCH/PROJECT IDENTIFIER 27 S1A

DEMONSTRATED ACCURACY CALCULATION

COMPUTATIONS/ANALYSES

A) PROCESS UNCERTAINTY DISCUSSION/CALCULATION

_√_ NO PROCESS UNCERTAINTY EXISTS FOR THIS CALCULATION BECAUSE:

_√_ THE MEASURED PARAMETER IS THE PARAMETER OF CONCERN; THEREFORE, PROCESS VARIATIONS ARE ACCOUNTED FOR IN THE DETERMINATION OF SAFETY AND/OR OPERATIONAL LIMITS.

___ OTHER: SEE DISCUSSION BELOW.

___ PROCESS UNCERTAINTY DOES EXIST AND IS DETAILED IN THE FOLLOWING DISCUSSION/CALCULATION.

REV 0 PREP JC DATE 9-15-87 CHECK VC DATE 9.15.87 SHEET 13 C/O 14
REV 1 PREP ___ DATE ___ CHECK ___ DATE ___ SHEET ___ C/O ___
REV 2 PREP ___ DATE ___ CHECK ___ DATE ___ SHEET ___ C/O ___

COMPUTATIONS/ANALYSES

B) WATERLEG UNCERTAINTY DISCUSSION/CALCULATION

✓ APPLICABLE TO ALL LOOPS LISTED ON SHEET 6.

___ APPLICABLE ONLY TO LOOPS: ___

✓ WATERLEG UNCERTAINTY IS NOT CONSIDERED FOR THE CALCULATION BECAUSE:

✓ NO WATERLEG EXISTS FOR THIS CALCULATION.

___ THE EFFECTS OF WATERLEG CHANGES ARE INSIGNIFICANT. SEE DISCUSSION/CALCULATION BELOW.

___ OTHER. SEE DISCUSSION/CALCULATION BELOW.

___ A WATERLEG UNCERTAINTY DOES EXIST FOR THIS LOOP. SEE CALCULATION/DISCUSSION BELOW.

___ SEE SENSING LINE DIAGRAM ON SHEET ___ OF THIS CALCULATION.

COMPUTATIONS/ANALYSES

C) ACCURACY DISCUSSION

___ The accuracy of this instrument for normal, post seismic and accident conditions will be determined by considering the parameters tabulated in the design input section of this calculation.

The accuracy calculation for seismic (As) is bounding for all seismic events.

✓ The square root of the sum of the squares method shall be used in this calculation for calculating accuracy since the factors affecting accuracy are independent variables.

___ Bi-directional errors and uni-directional errors will be combined in a manner such that the sum of the positive uni-directional errors will be added to the positive portion of the bi-directional error (obtained from the square root of the sum of the squares method), and the sum of the negative uni-directional errors will be added to the negative portion of the bi-directional error.

This method is conservative. Therefore, it will be used in this calculation.

Example: (+/-)10 = bi-directional error
+5 = first uni-directional error
-2 = second uni-directional error

Total Error = (+10 +5) to (-10 -2) = +15 to -12

___ other: ______________________

For the purpose of this calculation, accuracy is defined as the range of actual process values that may exist for a given indicated or bistable trip value, e.g. an accuracy of +10 psig to -5 psig means that for a indicated or bistable trip value of 100 psig, the actual process pressure may be anywhere between 95 and 110 psig.

All system analysis based on or using accuracy values from this calculation should take into account the fact that operator action and/or automatic initiations may occur at a process value differing from the indicated or setpoint values by the amount of the calculated inaccuracies.

COMPUTATIONS/ANALYSES

C) ACCURACY DISCUSSION (CONTINUED)

✓ THE FOLLOWING DEVICES ARE CALIBRATED INDIVIDUALLY. THEIR ACCEPTANCE BANDS ARE AS FOLLOWS:

DEVICE	Ab ±	REFERENCE
VOLTAGE RELAY	± 4% of SETTING	PER THIS CALCULATION (SEE NOTE 5, PAGE 10)

___ THE FOLLOWING DEVICES ARE CALIBRATED TOGETHER. THE ACCEPTANCE BAND FOR THE COMBINATION OF THESE DEVICES IS AS FOLLOWS:

DEVICE	Ab	REFERENCE

BRANCH/PROJECT IDENTIFIER 27SIA

DEMONSTRATED ACCURACY CALCULATION

COMPUTATIONS/ANALYSES

D) ACCURACY CALCULATION INDEX

REV	PREP	DATE	CHECK	DATE	SHEET	C/O
0	ZC	9-15-87	VC	9-15-87	17	17A
1						
2						

BRANCH/PROJECT IDENTIFIER 27 SIA -
DEMONSTRATED ACCURACY CALCULATION

COMPUTATIONS/ANALYSES

D) ACCURACY CALCULATION INDEX

REV	PREP	DATE	CHECK	DATE	SHEET	C/O
0	JC	9-5-87	VC	9-15-87	17A	18
1						
2						

COMPUTATIONS/ANALYSES

D) ACCURACY CALCULATIONS

I) A) $Am = As = \pm(Re^2 + De^2 + Ab^2 + Tne^2)^{1/2}$

$An = As = \pm(4\%^2 + 5.2\%^2 + 4\%^2 + 10\%^2)^{1/2}$

$An = As = \pm$ 12.61% of setting

B) 27SIA SETTING = 5 SEC

$Am = As =$ (5 sec) ($\pm$ 12.6% of setting)

$Am = As = \pm$ 0.63 SEC

c) 27DIA SETTING = 1.5 SEC

$Am = As =$ (1.5 sec) ($\pm$ 12.6% of setting)

$Am = As = \pm$ 0.19 sec

d) $AV = SP \pm Anf$ $(Anf = Am)$

$AV = 5 \pm .63$ (27SIA)

$AV = 1.5 \pm .19$ (27DIA)

REV 0	PREP ZC	DATE 9-15-87	CHECK VC	DATE 9-15-87	SHEET 18 C/O 19
REV 1	PREP	DATE	CHECK	DATE	SHEET C/O
REV 2	PREP	DATE	CHECK	DATE	SHEET C/O

BRANCH/PROJECT IDENTIFIER 27S1A

DEMONSTRATED ACCURACY CALCULATION

COMPUTATIONS/ANALYSES

D) ACCURACY CALCULATIONS

II) DRIFT ANALYSIS

(DATA TAKEN FROM ATTACHMENT 7)

BOARD 1A-A

DEVICE	AS FOUND (SEC)	AS LEFT (SEC)
27S11A/Aφ	4.96	5
27S11A/Cφ	5.2	5
27D1A/Aφ	1.54	1.5
27D1A/Cφ	1.54	1.5
27S21A/Aφ	4.85	5
27S21A/Cφ	4.85	5
DATE	3/14/86	9/27/85

BOARD 1B-B

DEVICE	AS FOUND (SEC)	AS LEFT (SEC)
27S11A/Aφ	4.86	5
27S11A/Cφ	4.91	5
27D1A/Aφ	1.49	1.5
27D1A/Cφ	1.48	1.5
27S21A/Aφ	5.12	5
27S21A/Cφ	5.08	5
DATE	4/4/86	9/13/85

BOARD 2A-A

DEVICE	AS FOUND (SEC)	AS LEFT (SEC)
27S11A/Aφ	5.0	5
27S11A/Cφ	5.0	5
27D1A/Aφ	1.46	1.5
27D1A/Cφ	1.48	1.5
27S21A/Aφ	5.1	5
27S21A/Cφ	4.9	5
DATE	3/14/86	9/27/85

BOARD 2B-B

DEVICE	AS FOUND (SEC)	AS LEFT (SEC)
27S11A/Aφ	5.14	5
27S11A/Cφ	4.9	5
27D1A/Aφ	1.46	1.5
27D1A/Cφ	1.5	1.5
27S21A/Aφ	5.13	5
27S21A/Cφ	5.13	5
DATE	4/7/86	9/13/85

19

COMPUTATIONS/ANALYSES

D) ACCURACY CALCULATIONS

II) cont'

DRIFT ANALYSIS

% of SETTING, DEVIATIONS

BOARD 1A-A	BOARD 1B-B	BOARD 2A-A	BOARD 2B-B
-0.8	-2.8	0	+2.8
+2.0	-1.8	0	-2.0
+2.7	-0.7	-2.7	-2.7
+2.7	-5.3	-1.3	0
-3.0	+2.4	+2.0	+2.6
-3.0	+1.6	-2.0	+2.6

(ALL VALUES IN % OF SETTING)

MEAN VALUE $= \frac{\Sigma x}{n} = -0.279\%$

$$\sigma = \sqrt{\frac{n\Sigma x^2 - (\Sigma x)^2}{n(n-1)}} = 2.6\%$$

$2\sigma = 5.2\%$

COMPUTATIONS/ANALYSES
D) ACCURACY CALCULATIONS

III A_N/A_S CAL TIME DELAY > 200 SEC
(ELEC. BD. RM. AHU TIMER)

A) PER REFERENCE 10:
$Re = \pm 10$
$De = \pm 2.7$
$TNe_{(RANDOM)} = \pm 7.2$
$Ab = \pm 5$
$TNe_{(BIAS)} = \pm 5.6$
Se = NEGLIGIBLE

$$A_N = A_S = \pm (Re^2 + De^2 + TNe^2_{(RANDOM)} + Ab^2)^{1/2} \pm TNe_{(BIAS)}$$

$$A_N = A_S = \pm (10^2 + 2.7^2 + 7.2^2 + 5^2)^{1/2} \pm 5.6$$

$$A_N = A_S = \pm (13.57) \pm 5.6$$

$A_N = A_S = \pm 19.2\%$ of SETPOINT

B) FOR ELEC. BD. RM. AHU TIME DELAY of 220 SEC:

$A_N = A_S$ = (TIME DELAY SETTING) $\times$ ($\pm 19.2\%$)

$A_N = A_S = 220\ (.192)$

$A_N = A_S = \pm 46\ \pm 10$ SEC

COMPUTATIONS/ANALYSES
D) ACCURACY CALCULATIONS

IV MISCELLANEOUS LOADS

TD = (27DIA ± ERROR) + (DIESEL GENERATOR TIME DELAY) + (SEQUENCE TIMER) + (BKRS)

= 1.5 ± .19 + 10** + 0 + .25

TD = 11.93 sec / 11.56 sec

V CCP (CENTRIFUGAL CHARGING PUMP)

TD = (27 DIA ± ERROR) + (DIESEL GENERATOR TIME DELAY) + [(SEQUENCE TIMER) ± ERROR] + (BKRS)

TD = 1.5 ± .19 + 10** + 2 ± .32* + .25

TD = 14.26 / 13.24 sec

VI ERCW PUMP

TD = (27DIA ± ERROR) + (DIESEL GENERATOR TIME DELAY) + [(SEQUENCE TIMER) ± ERROR] + (BKRS)

TD = 1.5 ± .19 + 10** + 15 ± 2.4* + .25

TD = 29.34 / 24.16 sec

* PER DNE CALCULATION "DG TIMER RELAYS" ERROR = ± 16% of SP for TIME DELAYS ≤ 200 SEC & ±19.2% for TIME DELAYS ≥ 200 SEC.

** PER SEQUOYAH FSAR, PAGE 8.3-9, "STANDBY DIESEL GENERATOR OPERATION," A MAXIMUM of 10 SEC IS ALLOWED FOR DG START AND LOAD ONTO THE 6.9 KV SHUTDOWN BOARD BUS. (ATTACH #12)

REV 0	PREP JC	DATE 9-15-87	CHECK VC	DATE 9.15.87	SHEET 22	C/O 23
REV 1	PREP	DATE	CHECK	DATE	SHEET	C/O
REV 2	PREP	DATE	CHECK	DATE	SHEET	C/O

C O M P U T A T I O N S / A N A L Y S E S
D) ACCURACY CALCULATIONS

VII CCS PUMP (COMPONENT COOLING SYSTEM PUMP)

TD = [(27DIA) ± ERROR] + (DIESEL GENERATOR TIME DELAY) + [(SEQUENCE TIMER) ± ERROR] + (BKRS)

TD = 1.5 ± .19 + 10** + 30 ± 4.8* + .25

TD = 46.74 / 36.76 SEC

VIII AFW PUMP

TD = [(27DIA) ± ERROR] + (DIESEL GENERATOR TIME DELAY) + [(SEQUENCE TIMER) ± ERROR] + (BKRS)

TD = 1.5 ± .19 + 10** + 20 ± 3.2* + .25

TD = 35.14 / 28.36 SEC

* SEE "*" PAGE 22

** SEE "**" PAGE 22

COMPUTATIONS/ANALYSES
D) ACCURACY CALCULATIONS

IX PRESSURIZER HEATERS

TD = (27D1A ± ERROR) + (DIESEL GENERATOR TIME DELAY) + [(SEQUENCE TIMER) ± ERROR] + (BKRS)

TD = 1.5 ± .19 + 90 ± 19.4* + 10** + .25

TD = 116.34 / 87.16 SEC

X FIRE PUMPS

TD = [(27D1A) ± ERROR] + (DIESEL GENERATOR) + [(SEQUENCE TIMER) ± ERROR] + (BKI

TD = 1.5 ± .19 + 10** + 120 ± 19.2* + .25

TD = 151.14 / 112.36 SEC

* PER DWE CALCULATION "DG TIMER RELAYS" ERROR = ±16% of SP FOR DELAYS ≤ 200 SEC AND ±19.2% of SP FOR DELAYS > 200 SEC

** SEE "**" PAGE 22

BRANCH/PROJECT IDENTIFIER 27SIA -
DEMONSTRATED ACCURACY CALCULATION

COMPUTATIONS/ANALYSES
D) ACCURACY CALCULATIONS

XI MISCELLANEOUS LOADS

TD = (DG START UP TIME DELAY) + (BKRS)

TD = 10** + .25

TD = 10.25 SEC

NOTE: INACCURACY OF BKR CLOSING TIME IS NOT CONSIDERED SINCE FOR A 7.5 CYCLE NOMINAL CLOSURE TIME ANY INACCURACIES WOULD BE NEGLIGIBLE WITH REGARD TO THE FINAL RESULT.

II CENTRIFUGAL CHARGING PUMP

TD: (DG START UP TIME DELAY) + (SEQUENCE TIMER ± ERROR) + (BKRS)

TD = 10** + 2 ± .32* + .25

TD = 12.57 SEC / 11.93 SEC

XIII SAFETY INJECTION PUMP

TD = 10** + 5 ± 0.8* + .25

TD = 16.05 / 14.95 SEC

* SEE "*" SHEET 22
** SEE "**" SHEET 22

REV 0	PREP Jc	DATE 9-15-87	CHECK VC	DATE 9-15-87	SHEET 25 C/O 26
REV 1	PREP	DATE	CHECK	DATE	SHEET C/O
REV 2	PREP	DATE	CHECK	DATE	SHEET C/O

COMPUTATIONS/ANALYSES
D) ACCURACY CALCULATIONS

XIV RHR PUMPS

TD = 10** + 10 ± 1.6* + .25

TD = 21.85 / 18.65 SEC

XV ERCW PUMP

TD = 10** + 15 ± 2.4* + .25

TD = 27.15 / 22.85 SEC

XVI COMPONENT COOLING PUMP

TD = 10** + 30 ± 4.8* + .25

TD = 45.05 / 35.45 SEC

XVII AUX FEEDWATER PUMP

TD = 10** + 20 ± 3.2* + .25

TD = 33.45 / 27.05 SEC

XVIII CONTAINMENT SPRAY PUMP

TD = 10** + 180 ± 28.8* + .25

TD = 219.05 / 161.45 SEC

XIX ELEC. BD. RM AHU

TD = 10** + 240 ± 46.10+ + .25

TD = 296.35 / 204.15 SEC

* SEE "*" SHEET 22

** SEE "**" SHEET 22

\+ PER CALCULATION # III PAGE 21

REV	PREP	DATE	CHECK	DATE	SHEET	C/O
0	JC	9-15-87	VC	9-15-87	26	27
1						
2						

BRANCH/PROJECT IDENTIFIER 27SIA

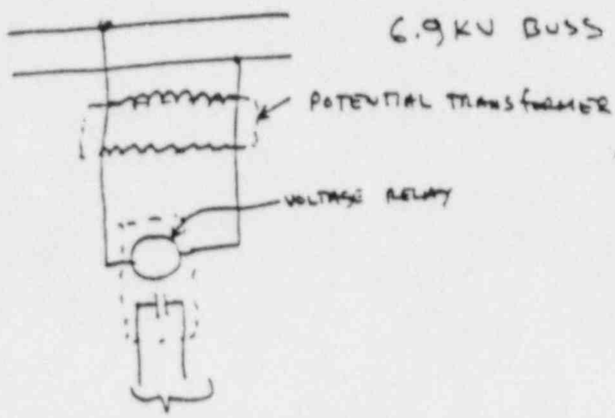
DEMONSTRATED ACCURACY CALCULATION

S U P P O R T I N G   G R A P H I C S

A) LOOP DIAGRAM

___ APPLICABLE TO ALL LOOPS LISTED ON SHEET _.

✓ APPLICABLE ONLY TO LOOPS: 27SIA



TO LOAD SHED CIRCUITRY (27SIA)

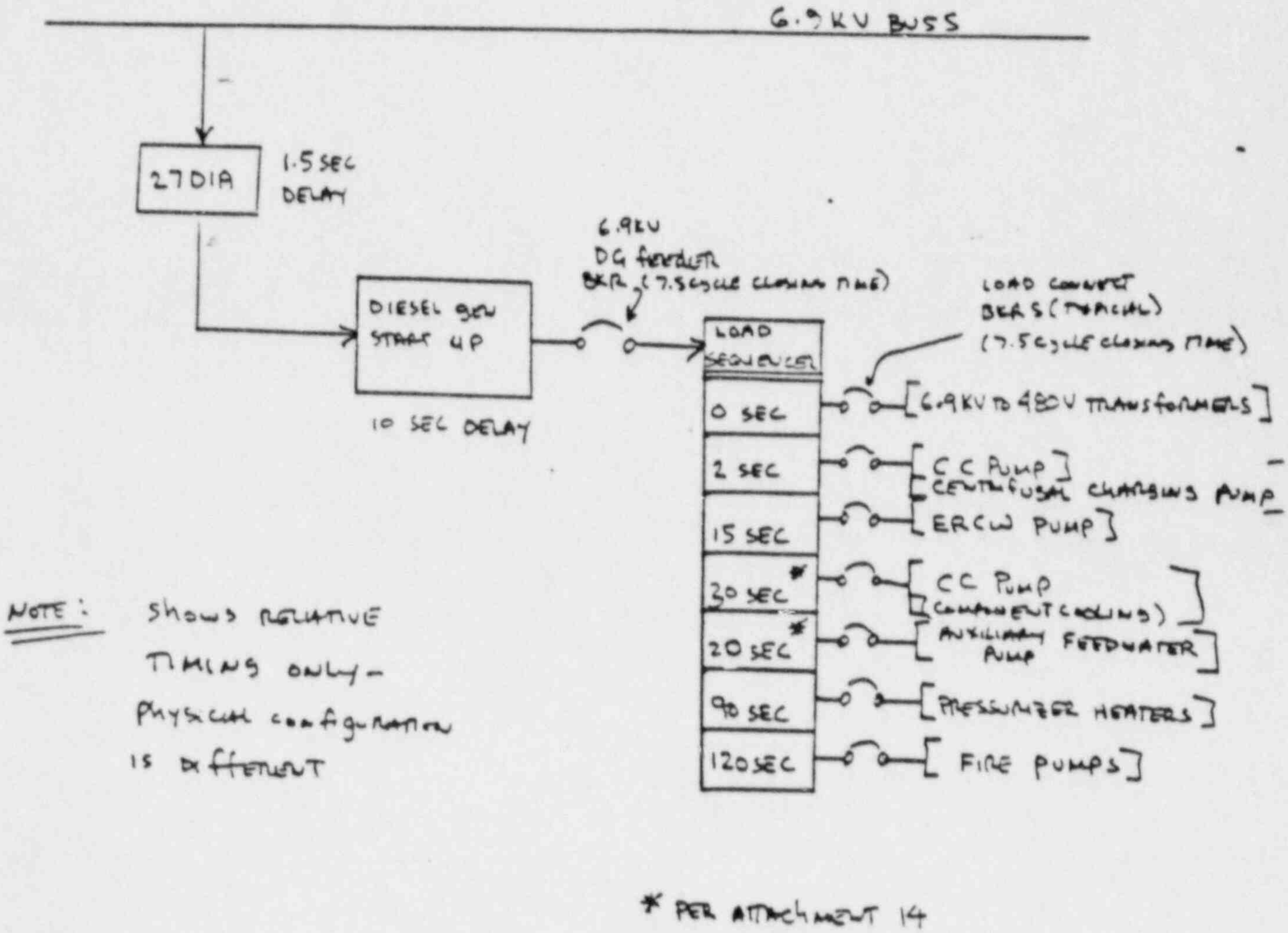
REV	0	PREP	JC	DATE	9-15-87	CHECK	VC	DATE	9.15.87	SHEET 27	C/O 28
REV	1	PREP		DATE		CHECK		DATE		SHEET	C/O
REV	2	PREP		DATE		CHECK		DATE		SHEET	C/O

S U P P O R T I N G   G R A P H I C S

A) LOOP DIAGRAM

___ APPLICABLE TO ALL LOOPS LISTED ON SHEET ___.

✓ APPLICABLE ONLY TO LOOPS: 27DIA (LOOP ONLY)



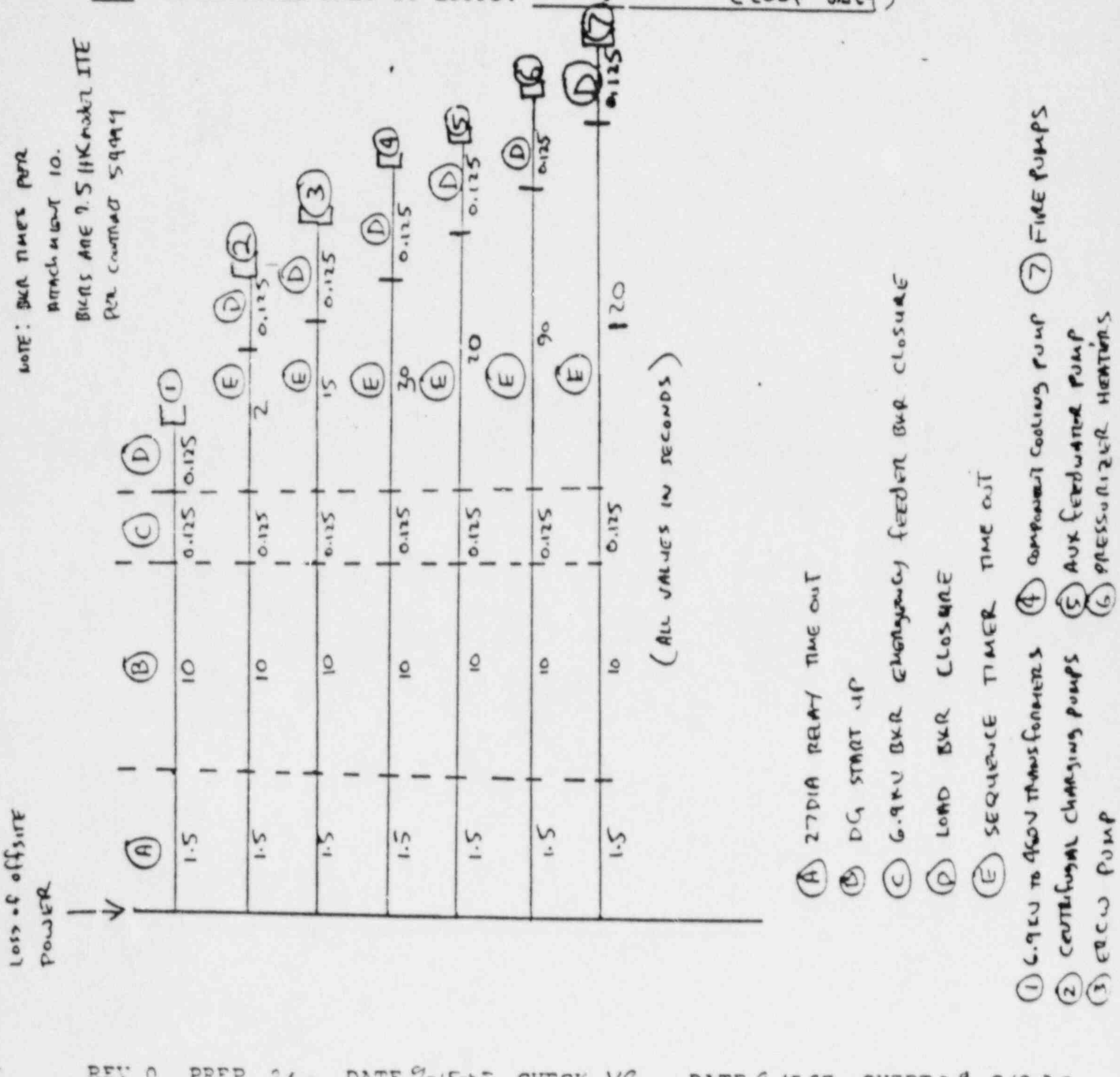
REV 0	PREP JC	DATE 9-15-87	CHECK VC	DATE 9-15-87	SHEET 28	C/O 29
REV 1	PREP	DATE	CHECK	DATE	SHEET	C/O
REV 2	PREP	DATE	CHECK	DATE	SHEET	C/O

BRANCH/PROJECT IDENTIFIER 27SIA
DEMONSTRATED ACCURACY CALCULATION

S U P P O R T I N G   G R A P H I C S
B) TIMING DIAGRAM

___ APPLICABLE TO ALL LOOPS LISTED ON SHEET ___.

✓ APPLICABLE ONLY TO LOOPS: 27DIA (LOOP ONLY)



REV 0	PREP JC	DATE 9-15-87	CHECK VC	DATE 9-15-87	SHEET 2a	C/O 30
REV 1	PREP	DATE	CHECK	DATE	SHEET	C/O
REV 2	PREP	DATE	CHECK	DATE	SHEET	C/O

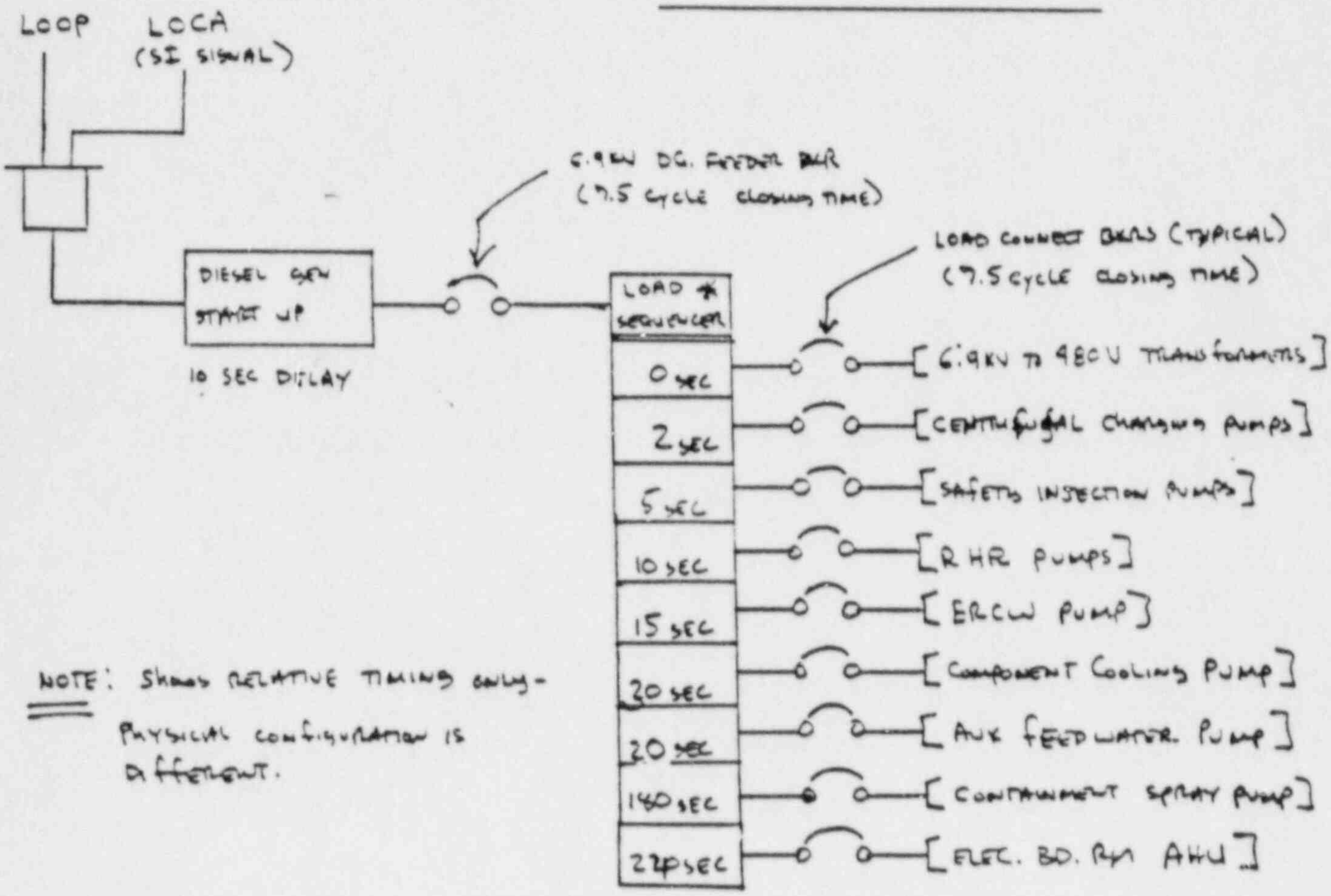
BRANCH/PROJECT IDENTIFIER 27SIA · -
DEMONSTRATED ACCURACY CALCULATION

SUPPORTING GRAPHICS

A) LOOP DIAGRAM

___ APPLICABLE TO ALL LOOPS LISTED ON SHEET __.

✓ APPLICABLE ONLY TO LOOPS: LOOP WITH LOCA



NOTE: SHOWS RELATIVE TIMING ONLY - PHYSICAL CONFIGURATION IS DIFFERENT.

* TIME DELAY PER ATTACHMENT 14

REV 0	PREP TC	DATE 9-15-87	CHECK VC	DATE 9-15-87	SHEET 30	C/O 31
REV 1	PREP	DATE	CHECK	DATE	SHEET	C/O
REV 2	PREP	DATE	CHECK	DATE	SHEET	C/O

BRANCH/PROJECT IDENTIFIER 27SIA

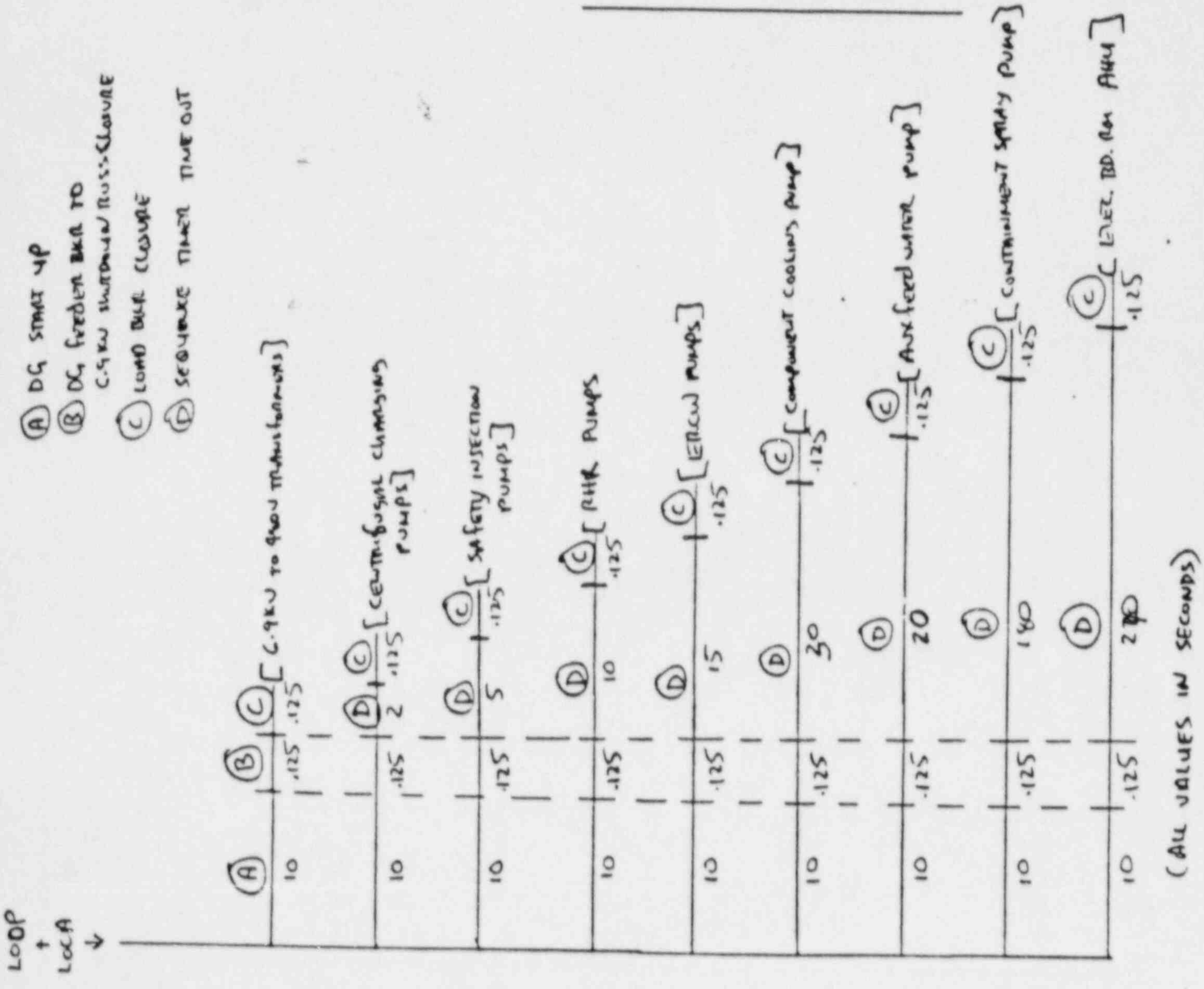
DEMONSTRATED ACCURACY CALCULATION

SUPPORTING GRAPHICS

A) TIMING DIAGRAM

___ APPLICABLE TO ALL LOOPS LISTED ON SHEET ___.

✓ APPLICABLE ONLY TO LOOPS: LOOP WITH LOCA



REV 0	PREP 2c	DATE 7-15-87	CHECK VC	DATE 9.15.87	SHEET 31 C/O 32
REV 1	PREP	DATE	CHECK	DATE	SHEET C/O
REV 2	PREP	DATE	CHECK	DATE	SHEET C/O

BRANCH/PROJECT IDENTIFIER 27SIA

DEMONSTRATED ACCURACY CALCULATION

SUMMARY of RESULTS

APPLICABLE ONLY TO LOOPS: 27DIA (LOOP ONLY)

TIME FROM LOOP TILL LOAD BKR CLOSES:

	MAX	MIN*
(1) MISCELLANEOUS LOADS:	11.94	11.56 sec
(2) CENTRIFUGAL CHARGING PUMPS:	14.26	13.24 sec
(3) ERCW PUMP:	29.34	24.16 sec
(4) COMPONENT COOLING SYSTEM PUMP:	46.74	36.76 sec
(5) AFW PUMP:	35.14	28.36 sec
** (6) PRESSURIZER HEATERS:	116.34	87.16 sec
** (7) FIRE PUMPS:	151.19	112.36 sec

* MIN TIMES ARE BASED ON 10 SEC MAX DG START UP TIME. DG's WILL MOST PROBABLY START QUICKER, THEREFORE, MIN VALUES ARE FOR REFERENCE ONLY.

** THESE LOADS ARE NOT AUTOMATICALLY SEQUENCED ON. THE OUTPUT OF THE SEQUENCER IS A PERMISSIVE WHICH ALLOWS APPLING THESE LOADS AS NEEDED.

REV 0 PREP Jc DATE 9-15-87 CHECK VC DATE 9-15-87 SHEET 32 C/O 33
REV 1 PREP ____ DATE ____ CHECK ____ DATE ____ SHEET ____ C/O ____
REV 2 PREP ____ DATE ____ CHECK ____ DATE ____ SHEET ____ C/O ____

SUMMARY of RESULTS:

APPLICABLE ONLY TO LOOP with LOCA

TIME FROM LOOP CONCURRENT WITH A LOCA TILL LOAD BKR CLOSES:

	MAX	MIN *
(1) MISCELLANEOUS LOADS:	10.25	10.25 SEC
(2) CENTRIFUGAL CHARGING PUMP:	12.5	11.9 SEC
(3) SAFETY INJECTION PUMP:	16.05	14.95 SEC
(4) RHR PUMPS:	21.85	18.65 SEC
(5) ERCW PUMPS:	27.65	22.85 SEC
(6) COMPONENT COOLING PUMP:	45.05	35.45 SEC
(7) AUX FEEDWATER PUMP:	33.95	27.05 SEC
(8) CONTAINMENT SPRAY PUMP:	219.05	161.95 SEC
(9) ELEC. BD. RM AHU:	296.35	204.15 SEC

* MIN TIMES ARE BASED ON 10 SEC MAX DG START UP TIME. DG's WILL MOST PROBABLY START QUICKER, THEREFORE, MIN VALUES ARE FOR REFERENCE ONLY.

BRANCH/PROJECT IDENTIFIER 27SIA · -

DEMONSTRATED ACCURACY CALCULATION

SUMMARY OF RESULTS (BISTABLE- INCREASING SETPOINT)

___ APPLICABLE TO ALL LOOPS LISTED ON SHEET ___.

✓ APPLICABLE ONLY TO LOOPS: 27SIA RELAYS ONLY (LOAD SHED RELAYS)

SAFETY LIMIT	10	MARGIN 0.37
PV = SP + Aa	NA	
PV = SP + As	5.63	
PV = SP + An	5.63	
SETPOINT (SP)	5	
PV = SP - An	4.37	
PV = SP - As	4.37	
PV = SP - Aa	NA	
OPERATIONAL LIMIT	NA	

ALL VALUES SHOWN ARE SECONDS

(REFER TO ACCURACY DISCUSSION, SHEET 15 FOR CLARIFICATION OF ABOVE)

AV: 5.63 + Aas NA

REV 0 PREP [illegible] DATE 7-15-87 CHECK VC DATE 9-15-87 SHEET 34 C/O 35
REV 1 PREP ___ DATE ___ CHECK ___ DATE ___ SHEET ___ C/O ___
REV 2 PREP ___ DATE ___ CHECK ___ DATE ___ SHEET ___ C/O ___

BRANCH/PROJECT IDENTIFIER 2751A
DEMONSTRATED ACCURACY CALCULATION

CONCLUSIONS

✓ APPLICABLE TO ALL LOOPS LISTED ON SHEET 6.

___ APPLICABLE ONLY TO LOOPS: ______

(REFER TO SHEET 7A FOR EXPLANATION OF LOOP FUNCTIONS)

FUNCTION 1: LOAD SHEDDING FOLLOWING A LOOP:

THE DEMONSTRATED ACCURACY FOR NORMAL AND POST SEISMIC CONDITIONS IS ACCEPTABLE BASED ON DISCUSSION IN "LOOP FUNCTION" AND "SUMMARY OF RESULTS" PORTION OF THIS CALCULATION.

FUNCTION 2: DG START & LOAD SEQUENCING FOLLOWING A LOOP (NON-ACCIDENT):

A) THE DEMONSTRATED ACCURACY FOR INSTRUMENTS ASSOCIATED WITH miscellaneous loads, centrifugal charging pumps, ERCW pumps, component cooling system pumps, and AFW pump is acceptable based on the information contained in attachment 14.

REV 0	PREP JC	DATE 9-15-87	CHECK VC	DATE 9-15-87	SHEET 35	C/O 36
REV 1	PREP	DATE	CHECK	DATE	SHEET	C/O
REV 2	PREP	DATE	CHECK	DATE	SHEET	C/O

BRANCH/PROJECT IDENTIFIER 27SIA

DEMONSTRATED ACCURACY CALCULATION

CONCLUSIONS

v APPLICABLE TO ALL LOOPS LISTED ON SHEET 6.

___ APPLICABLE ONLY TO LOOPS: __________

B) THE DEMONSTRATED ACCURACY FOR THE INSTRUMENTS ASSOCIATED WITH THE PRESSURIZER HEATERS IS ADEQUATE DUE TO THE FOLLOWING:

THE SAFETY ANALYSIS, SECTION 15.2.9 OF THE SQN FSAR, STATES THAT LOSS OF OFFSITE POWER RESULTS IN LOSS OF NORMAL FEEDWATER (ANALYZED IN SECTION 15.2.8) AND COMPLETE LOSS OF FORCED REACTOR COOLANT FLOW (ANALYZED IN SECTION 15.3.4).

LOSS OF NORMAL FEEDWATER RESULTS IN A REDUCTION IN CAPABILITY OF THE SECONDARY SYSTEM TO REMOVE THE HEAT GENERATED IN THE REACTOR CORE. ATTACHMENT 15 SHOWS REACTOR COOLANT PRESSURE AND TEMPERATURE CONDITIONS FOLLOWING A LOSS OF NORMAL FEEDWATER. LOSS OF FORCED REACTOR COOLANT FLOW WILL ALSO IMMEDIATELY INCREASE THE COOLANT TEMPERATURE.

DUE TO THE ABOVE DISCUSSION, THE PRESSURIZER HEATERS ARE NOT NEEDED IMMEDIATELY FOLLOWING A LOOP.

ADDITIONALLY, SINCE THE TIMER OUTPUT IS ONLY A PERMISSIVE WHICH ALLOWS THE OPERATOR TO MANUALLY ACTUATE THE PRESSURIZER HEATERS, OPERATOR RESPONSE WITHIN 117 SECONDS OF LOOP IS UNLIKELY.

INTERFACE REVIEW: [signature] 11/3/87

E. J. SHEEHY (NEB - SAFETY ANALYSIS)

REV 0	PREP Fc	DATE 9-15-87	CHECK Vc	DATE 11-4-87	SHEET 36	C/O 37
REV 1	PREP	DATE	CHECK	DATE	SHEET	C/O
REV 2	PREP	DATE	CHECK	DATE	SHEET	C/O

CONCLUSIONS

✓ APPLICABLE TO ALL LOOPS LISTED ON SHEET 6.

___ APPLICABLE ONLY TO LOOPS: ______

c) THE DEMONSTRATED ACCURACY FOR THE INSTRUMENTS ASSOCIATED WITH THE FIRE PUMPS IS ADEQUATE DUE TO INFORMATION CONTAINED IN REF. 20

FUNCTION 3: DG START AND LOAD SEQUENCING FOLLOWING CONCURRENT SI & LOOP:

THE DEMONSTRATED ACCURACY FOR THE INSTRUMENTS ASSOCIATED WITH THIS FUNCTION IS ADEQUATE BASED ON THE INFORMATION CONTAINED IN ATTACHMENT 19.

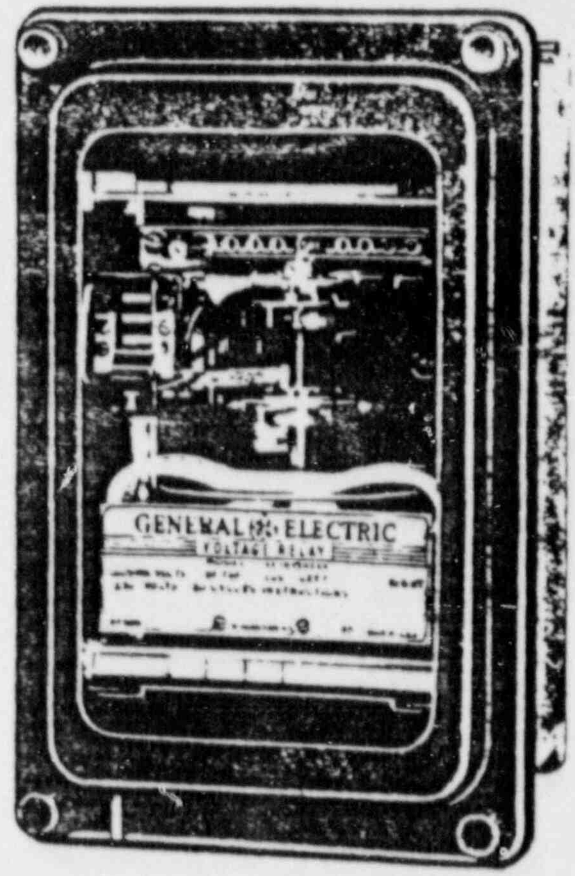
INSTRUCTIONS

GEH-1768B
Supersedes GEH-1768A

PROCUREMENT
300 UB - K

SUPERSEDED

UNDERVOLTAGE RELAYS



Types

IAV54E

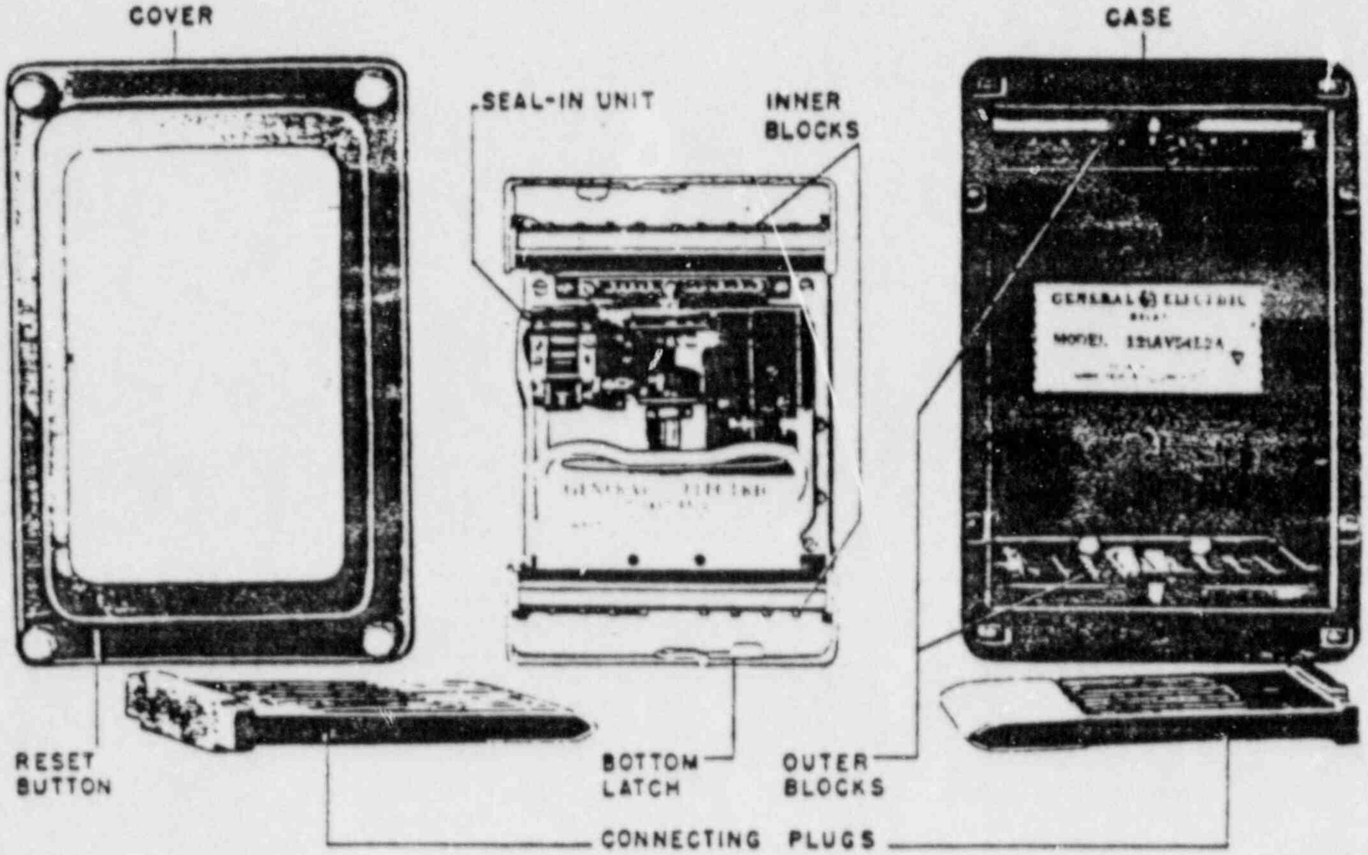
IAV54F	IAV55F
IAV54H	IAV55H
IAV55C	IAV55J

POWER SYSTEMS MANAGEMENT DEPARTMENT

GENERAL ELECTRIC

PHILADELPHIA, PA.

Attachment No: 1 Sheet 1 of 12
Loop #/Identifier: 2751A



Attachment No. 1 Sheet 2 of 12
Loop #/Identifier 27 S1A

Figure 1. (8007477) The Type IAV54E Relay Disassembled

UNDERVOLTAGE RELAYS

TYPE IAV

INTRODUCTION

These relays are of the induction-disk construction. The disk is actuated by a potential operating coil on a laminated U-magnet. The disk shaft carries the moving contact which completes the trip or alarm circuit when it touches the stationary contact or contacts. The disk shaft is restrained by a spiral spring to give the proper contact-closing voltage and its motion is retarded by permanent magnets acting on the disk to give the correct time delay.

There is a seal-in unit mounted to the left of the shaft as shown in Fig. 1. This unit has its coil in series and its contacts in parallel with the main contacts such that when the main contacts close, the seal-in unit picks up and seals in. When the seal-in unit picks up, it raises a target into view which latches up and remains exposed until released by pressing a button beneath the lower-left corner of the cover.

The relays are all mounted in single-unit double-end cases. The case has studs for external connections at both ends. The electrical connections between the relay and the case are made through stationary molded inner and outer blocks between which rests a removable connecting plug which completes the circuits. The molded outer blocks carry the studs for the external connections while the inner blocks carry the terminals for the internal connections. The operating coil is connected in parallel with both the upper and the lower inner molded blocks while the trip circuit is connected in series with these blocks. In this way, insertion of either the upper or lower connecting plug will energize the operating coil but the trip circuit will not be completed until the second connecting plug is inserted. For relays which have contacts closed when the relay is de-energized but open under normal operating conditions, the double connecting plug feature allows the relay contacts to open before the trip circuit is completed, thus minimizing the possibility of incorrect tripping when returning the relay to service after tests and inspection.

APPLICATION

These relays are protective devices designed to close trip or alarm circuits whenever the voltage applied to their operating coils reaches some predetermined value. The functions are described in greater detail in the following paragraphs.

OPERATING CHARACTERISTICS

The Type IAV54E relay has a single circuit-closing contact which closes when the voltage is reduced to some predetermined value. Thus, the contacts are closed at zero volts. This relay is a time undervoltage relay with inverse time characteristics which are shown in Fig. 2.

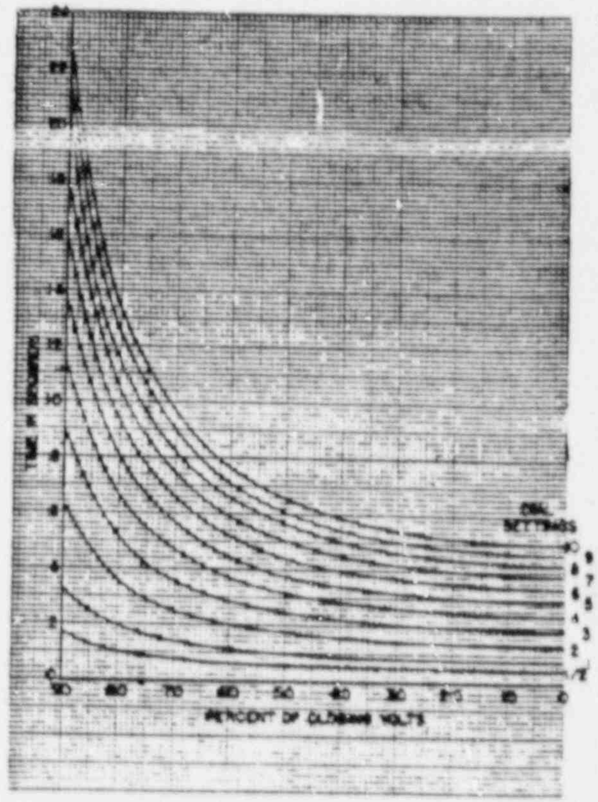


Figure 2. (362A648-0) Time-Voltage Curves for Relay Types IAV54E and IAV55C

The Type IAV54F relay is similar to the Type IAV54E relay except that it has a longer operating time. The time characteristics are shown in Fig. 3.

The Type IAV54H relay is also similar to the Type IAV54F relay except that it has much longer operating time than either the Type IAV54E or the Type IAV54F relays. The time characteristics are shown in Fig. 4.

The Type IAV55C relay is similar to the Type IAV54E relay except that it has two circuit-closing contacts.

The Type IAV55F relay is similar to the Type IAV54F relay except that it has two circuit-closing contacts.

The Type IAV55H relay is similar to the Type IAV54H relay except that it has two circuit-closing contacts.

The Type IAV55J relay is similar to the Type IAV55H relay except that it is provided with two separate seal-in units; one for each set of normally closed contacts.

Attachment No. 1 Sheet 3 of 12
Loop #/Identifier 37 S1A

(8007476) Cover

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes, the matter should be referred to the General Electric Company.

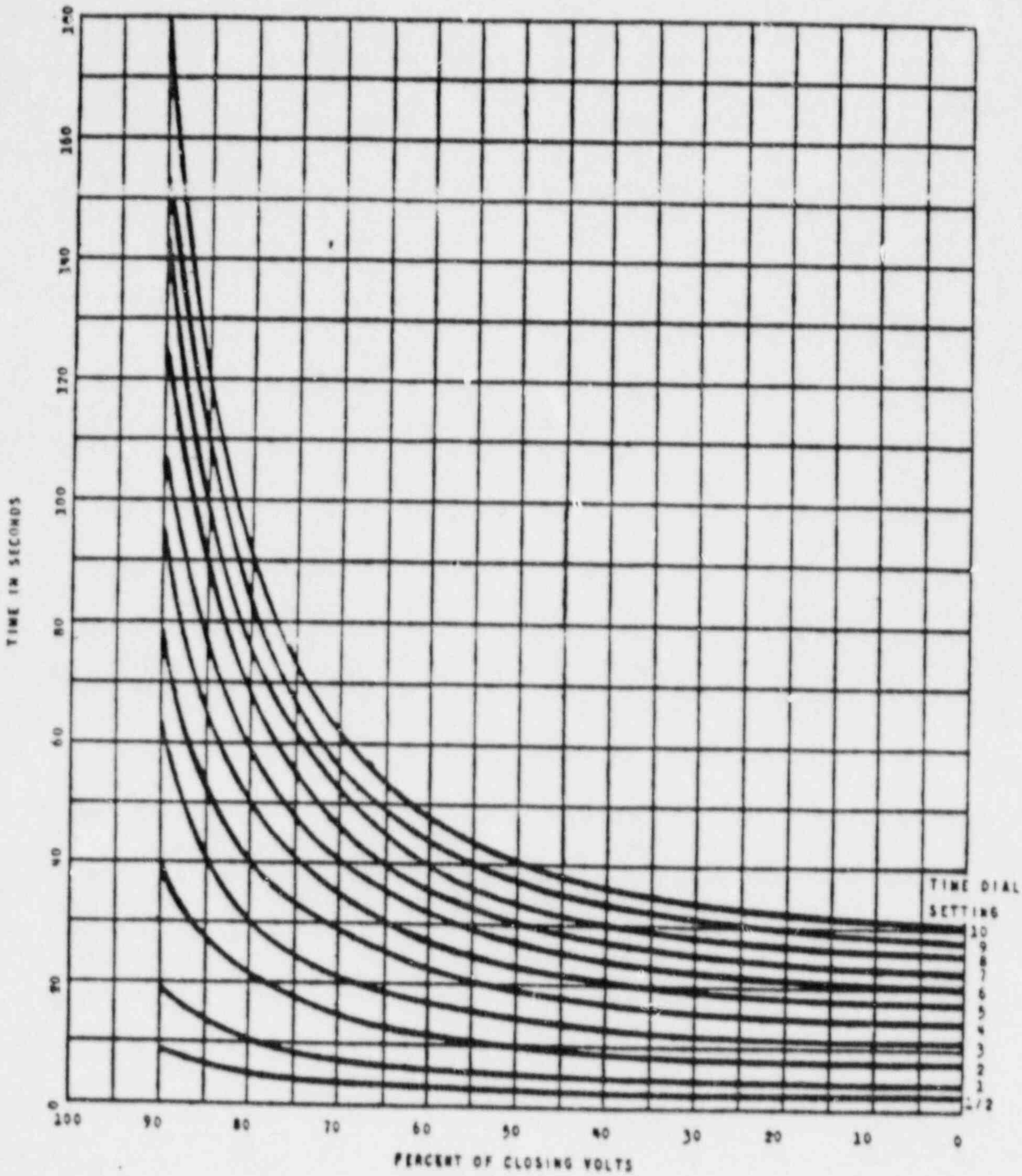


Figure 3. (362A668-0) Time-Voltage Curves for Types IAV54F and IAV55F

Attachment No 1 Sheet 9 of 12
Loop #/Identifier 27S1A

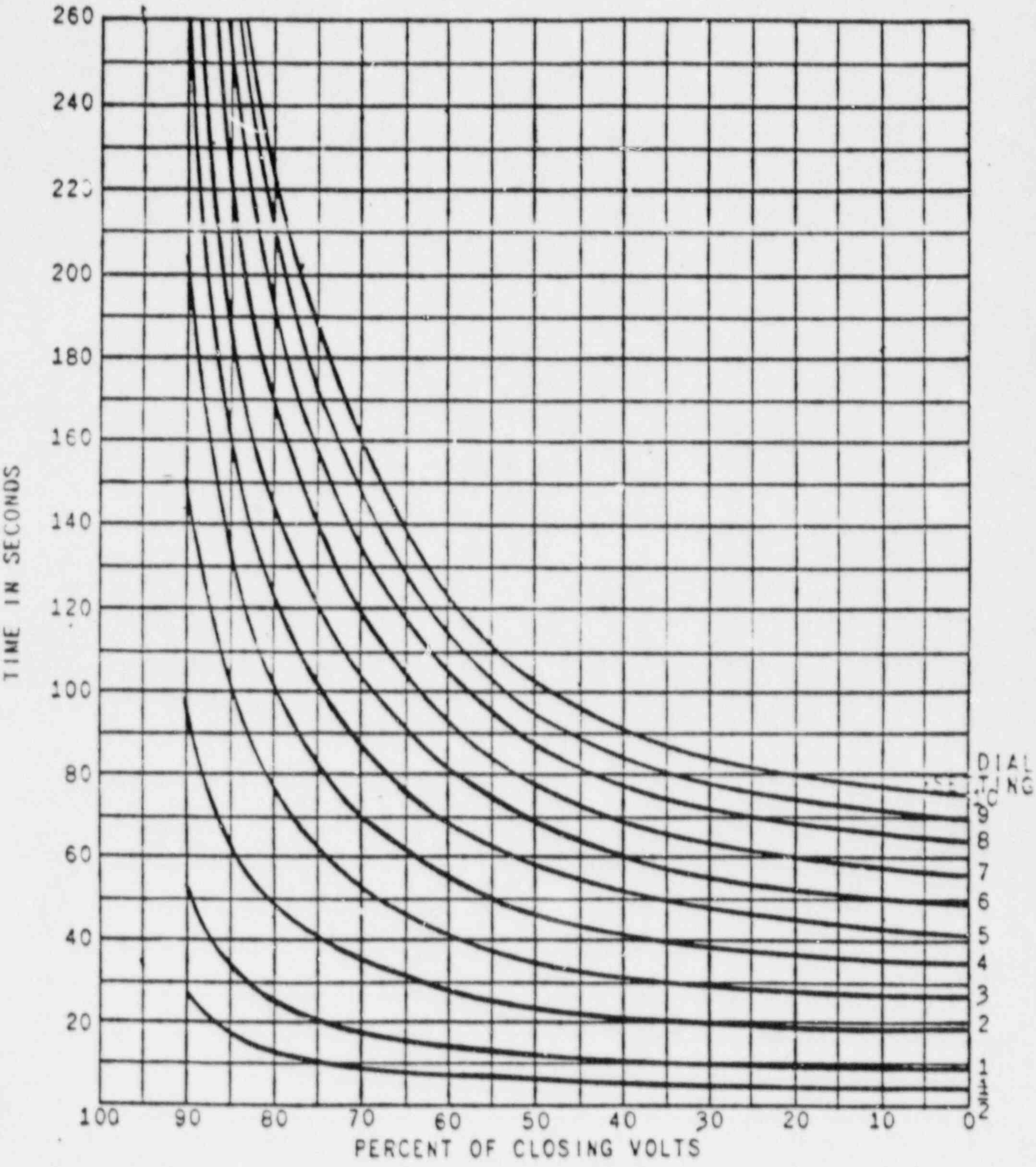


Figure 4. (362A650-1) Time-Voltage Curves for Relay Types IAV54H and IAV55H

Attachment No. 1 Sheet 5 of 12
Loop #/Identifier 27 S1A

RATINGS

The operating circuit ratings available are 115, 230 or 460 volts at 60, 50, or 25 cycles. The operating coil will stand rated voltage continuously on any tap and will stand tap voltage continuously on the taps above rated voltage.

The current-closing rating of the contacts is 30 amperes for voltages not exceeding 250 volts. The current-carrying ratings are affected by the selection of the tap on the seal-in coil as indicated in the following table:

Function	Amperes, A-C or D-C	
	2 Amp Tap	0.2 Amp Tap
Tripping Duty	30	5
Carry Continuously	4	0.8

The 2-ampere tap has a d-c resistance of 0.13 ohms and a 60 cycle impedance of 0.53 ohms, while the 0.2-ampere tap has a 7 ohm d-c resistance and 52 ohm 60 cycle impedance. The tap setting used on the seal-in element is determined by the current drawn by the trip coil.

The 0.2-ampere tap is for use with trip coils that operate on currents ranging from 0.2 up to 2.0 amperes at the minimum control voltage. If this tap is used with trip coils requiring more than 2 amperes, there is a possibility that the 7 ohm resistance will reduce the current to so low a value that the breaker will not be tripped.

The 2-ampere tap should be used with trip coils that take 2 amperes or more at the minimum control voltage, provided the tripping current does not exceed 30 amperes at the maximum control voltage. If the tripping current exceeds 30 amperes, an auxiliary relay should be used; the connections being such that the tripping current does not pass through the contacts or the target and seal-in coil of the protective relay.

BURDENS

Burdens at rated voltage for the various relay types are given in Table I.

TABLE I

Relay	Tap Settings 115V Coil	Tap Settings 230V Coil	Tap Settings 460V Coil	Volt-Amps	Power Factor	Watts
			60-Cycle Burdens			
IAV54E and IAV55C	140	280	560	3.0	0.26	0.8
	120	240	480	4.0	0.26	1.0
	105	210	420	5.2	0.26	1.4
(Burdens for IAV54F and IAV55F are approximately 60% of these values)	93	186	372	6.8	0.28	1.9
	82	164	328	8.9	0.28	2.5
	70	140	280	12.4	0.29	3.6
	64	128	256	15.1	0.30	4.5
	55	110	220	21.6	0.31	6.6
			50-Cycle Burdens			
	140	280	560	2.5	0.28	0.7
(Burdens for IAV54H and IAV55H are approximately 40% of these values)	120	240	480	3.3	0.24	0.8
	105	210	420	4.3	0.28	1.2
	93	186	372	5.7	0.28	1.6
	82	164	328	7.4	0.28	2.1
	70	140	280	10.3	0.29	3.0
	64	128	256	12.6	0.30	3.8
	55	110	220	18.0	0.31	5.5
			25-Cycle Burdens			
	140	280	560	2.3	0.26	0.6
	120	240	480	3.1	0.24	0.75
	105	210	420	4.0	0.28	1.1
	93	186	372	5.2	0.27	1.4
	82	164	328	6.8	0.28	1.9
	70	140	280	9.5	0.30	2.8
	64	128	256	11.6	0.30	3.5
	55	110	220	16.5	0.31	5.1

Attachment No. 1 Sheet 6 of 12
Loop #/Identifier 27 S1A

RECEIVING, HANDLING AND STORAGE

These relays, when not included as a part of a control panel will be shipped in cartons designed to protect them against damage. Immediately upon receipt of a relay, examine it for any damage sustained in transit. If injury or damage resulting from rough handling is evident, file a damage claim at once with the transportation company and promptly notify the nearest General Electric Apparatus Sales Office.

Reasonable care should be exercised in unpacking the relay in order that none of the parts are injured or the adjustments disturbed.

If the relays are not to be installed immediately, they should be stored in their original cartons in a place that is free from moisture, dust and metallic chips. Foreign matter collected on the outside of the case may find its way inside when the cover is removed and cause trouble in the operation of the relay.

DESCRIPTION

CASE

The case is suitable for either surface or semi-flush panel mounting and an assortment of hardware is provided for either mounting. The cover attaches to the case and also carries the reset mechanism when one is required. Each cover screw has provision for a sealing wire.

The case has studs or screw connections at both ends or at the bottom only for the external connections. The electrical connections between the relay units and the case studs are made through spring backed contact fingers mounted in stationary molded inner and outer blocks between which nests a removable connecting plug which completes the circuits. The outer blocks, attached to the case, have the studs for the external connections, and the inner blocks have the terminals for the internal connections.

The relay mechanism is mounted in a steel framework called the cradle and is a complete unit with all leads being terminated at the inner block. This cradle is held firmly in the case with a latch at the top and the bottom and by a guide pin at the back of the case. The cases and cradles are so constructed that the relay cannot be inserted in the case upside down. The connecting plug, besides making the electrical connections between the respective blocks of the cradle and case, also locks the latch in place. The cover, which is fastened to the case by thumbscrews, holds the connecting plug in place.

To draw out the relay unit the cover is first removed, and the plug drawn out. Shorting bars are provided in the case to short the current transformer circuits. The latches are then released, and the relay unit can be easily drawn out. To replace the relay unit, the reverse order is followed.

A separate testing plug can be inserted in place of the connecting plug to test the relay in place on the panel either from its own source of current and voltage, or from other sources. Or, the relay unit can be drawn out and replaced by another which has been tested in the laboratory.

INSTALLATION

LOCATION

The location should be clean and dry, free from dust and excessive vibration, and well lighted to facilitate inspection and testing.

MOUNTING

The relay should be mounted on a vertical surface. The outline and panel drilling dimensions are shown in Fig. 11.

CONNECTIONS

The internal connection diagrams are shown in Figs. 5 and 6. Typical external connections are shown in Fig. 7.

One of the mounting studs or screws should be permanently grounded by a conductor not less than No. 12 B&S gage copper wire or its equivalent.

ADJUSTMENTS

TARGET AND SEAL-IN UNIT

For trip coils operating on currents ranging from 0.2 up to 2 amperes at the minimum control voltage, set the target and seal-in tap plug in the 0.2 ampere tap.

The tap plug is the screw holding the right-hand stationary contact of the seal-in unit. To change the tap setting, first remove the connecting plugs. Then take a screw from the left-hand stationary contact and place it in the desired tap. Next, remove the screw from the other tap, and place it in the left-hand contact. This procedure is necessary to prevent the right-hand stationary contact from getting out of adjustment. Screws should not be in both taps at the same time, as d-c pickup will have a higher tap value, whereas a-c pickup will be increased.

Attachment No. 1 Sheet 7 of 12
Loop #/Identifier 27 S1A

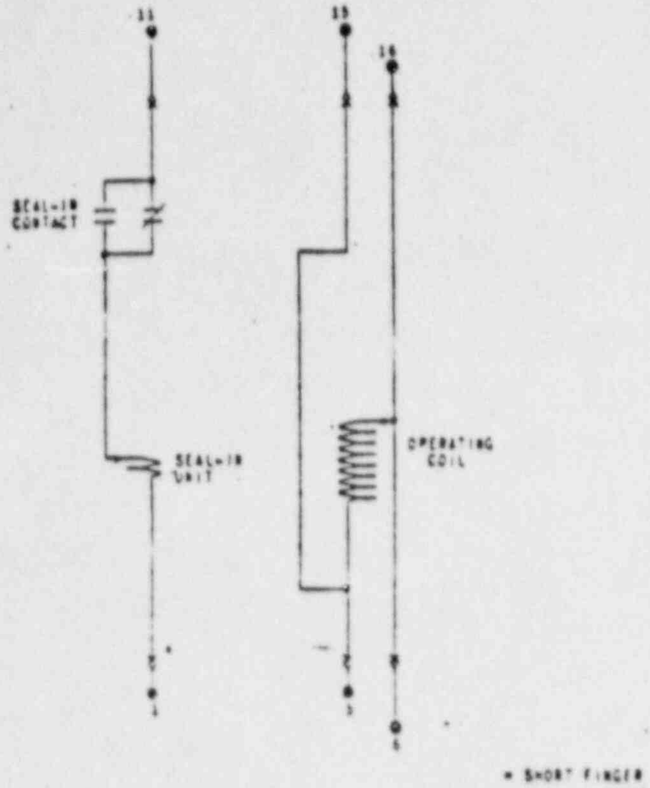


Figure 5. (6209253-3) Internal Connections for Relay Types IAV54E, IAV54F, and IAV54H (Front View)

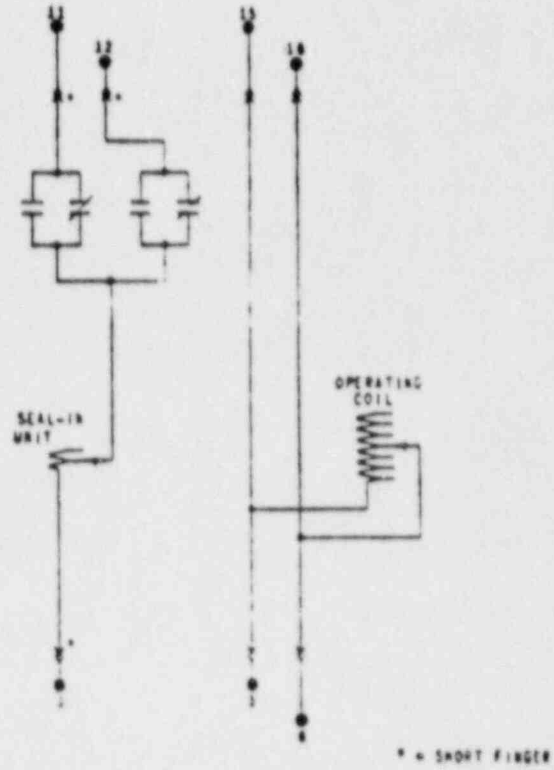
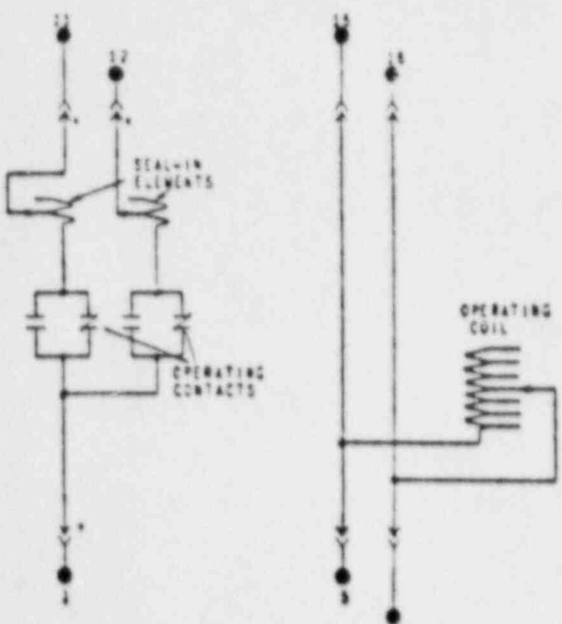


Figure 6. (6400515-3) Internal Connections for Relay Types IAV56C, IAV55F, and IAV55H (Front View)



Attachment No. 1 Sheet 8 of 12
Loop #/Identifier 27 S1A

Figure 7. (K-6375840-0) Internal Connections for Relay Type IAV55J (Front View)

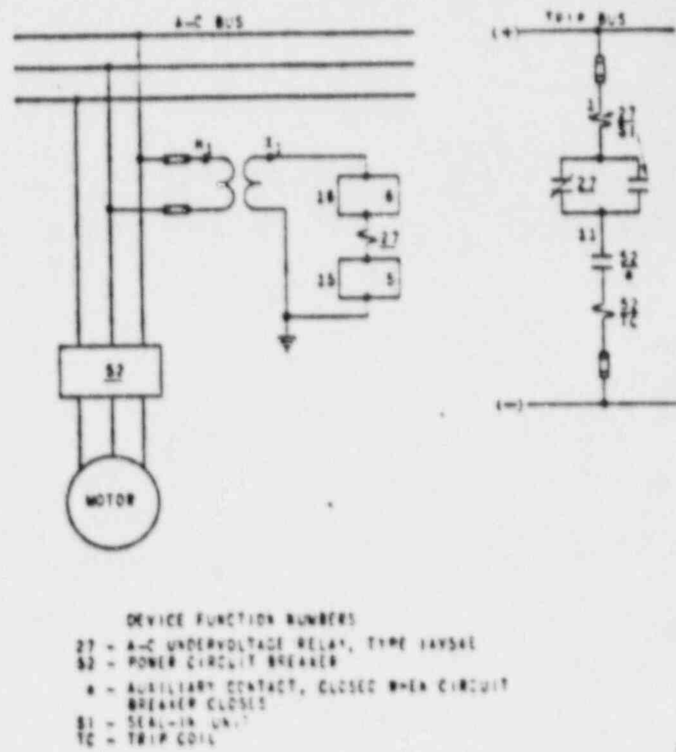


Figure 8. (6209277-2) Typical External Connections using an IAV54E Relay for the Undervoltage Protection of an A-C Motor

VOLTAGE SETTINGS

The voltage at which the contacts operate may be changed by changing the position of the tap plug in the tap block at the top of the relay. The range of this adjustment is from 55 to 140 volts on the 115 volt ratings, 110 to 280 volts on the 230 volt ratings, and 220 to 560 volts on the 460 volt ratings. Screw the tap plug firmly into the tap marked for the desired voltage (above which the relay is not to operate).

The tap settings indicate voltage values at which the contacts will close. A spring adjusting ring is provided for a sensitive adjustment of the relay operation. If the factory adjustment has been disturbed; the desired operating value may be obtained by inserting a tool in the notches around the edge of the ring (see Fig. 9) and turning the ring to the desired position. This adjustment also permits any desired setting between the taps. The relay has been adjusted at the factory to close its contacts, from any time-dial position, at a voltage within 5 per cent of the tap-plug setting. For example: If the tap plug setting is 55 volts, the contacts will close when the voltage is reduced from a higher value down to 55 volts. The relay contacts will open at 110 per cent of the tap setting. For the 55 volt tap setting, the contacts will open when the voltage is increased approximately 61 volts.

TIME SETTINGS

The time of operation of the relay is determined primarily by the setting of the time dial. Further adjustment is obtained by moving the permanent magnet along its supporting shelf; moving the magnet in toward the back of the relay decreases the time while moving it out increases the time.

Figs. 2, 3, and 4 show the time-voltage characteristics of the various relays with the time-dial settings for obtaining each characteristic. To make time settings, set the time dial to the number required (to give the desired characteristics) by turning it until the number lines up with the notch in the adjacent frame. The time indicated by the curves is the time required to close the relay contacts when the voltage is suddenly decreased from operating value or above to the value on the curve.

The time voltage curves are plotted in per cent thus making them applicable for all tap settings.

INSPECTION

At the time of installation, the relay should be inspected for tarnished contacts, loose screws, or other imperfections. If any trouble is found, it should be corrected in the manner described under MAINTENANCE.

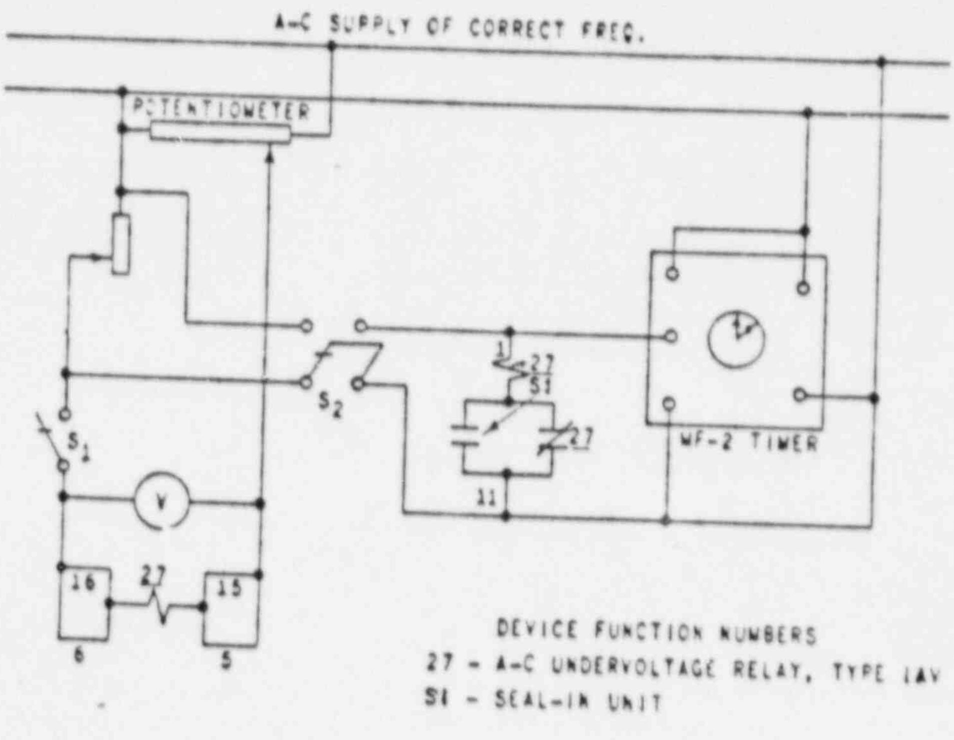


Figure 9. (6154392-3) Connections for Testing Relay Types IAV54 and IAV55

Attachment No. 1 Sheet 9 of 12
Loop #/Identifier 27 S1A

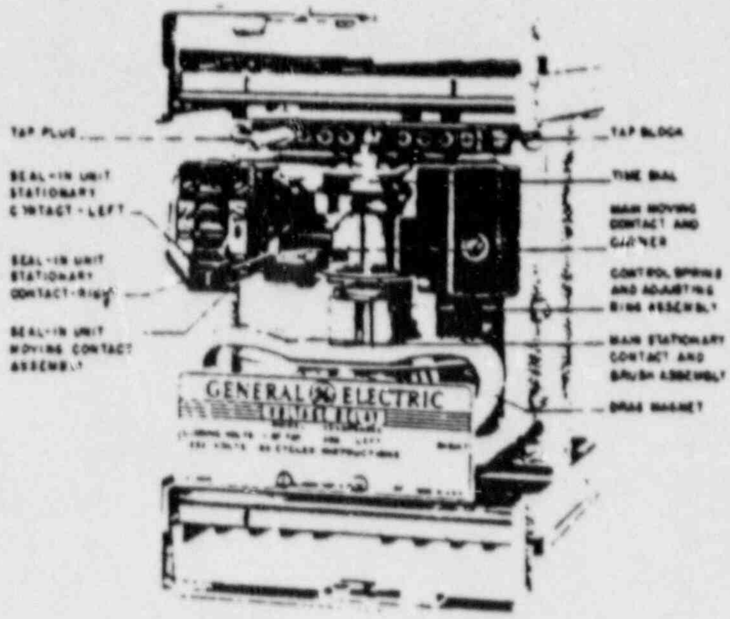


Figure 10. (8007475) Type IAV54E Relay Removed From Case (Front View)

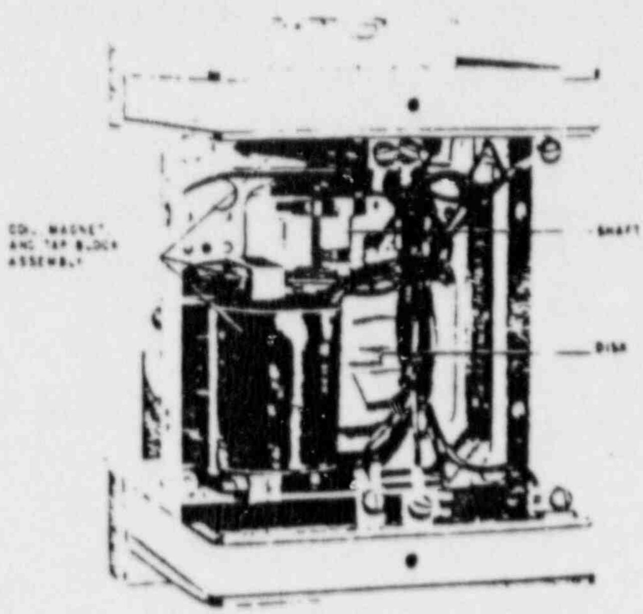


Figure 11. (8007478) Type IAV54E Relay Removed from Case (Back View)

Attachment No. 1 Sheet 10 of 12
Loop #/Identifier 27 S1A

OPERATION

Before the relay is put in service, it should be given a partial check to determine that factory adjustments have not been disturbed. On relays which have time dials, the dials will be set at zero before the relay leaves the factory. It is necessary to change this setting so that the relay contacts may be opened.

The drop-out voltage should be checked on one or more taps making certain that the contacts close.

The time voltage curves should be checked for one or more settings.

Recommended test connections for the above tests are shown in Fig. 8.

The relay may be tested while mounted on the panel, either from its own or another source of power, by inserting separate testing plugs in place of the connecting plugs. Or, the cradle can be drawn out and replaced by another which has been laboratory tested.

MAINTENANCE

These relays are adjusted at the factory and it is advisable not to disturb the adjustments. If for any reason, they have been disturbed, the following points should be observed in restoring them:

DISK AND BEARINGS

The lower jewel may be tested for cracks by exploring its surface with the point of a fine needle. The jewel should be turned up until the disk is centered in the air gap, after which it should be locked in position by the set screw provided for the purpose.

CONTACT CLEANING

For cleaning fine silver contacts, a flexible burnishing tool should be used. This consists of a flexible strip of metal with an etched roughened surface, resembling in effect, a superfine file. The polishing action is so delicate that no scratches are left, yet corroded material will be removed rapidly and thoroughly. The flexibility of the tool insures the cleaning of the actual points of contact. Sometimes an ordinary file cannot reach the actual points of contact because of some obstruction from some other part of the relay.

Fine silver contacts should not be cleaned with knives, files, or abrasive paper or cloth. Knives or files may leave scratches which increase arcing and deterioration of the contacts. Abrasive paper or cloth may leave minute particles of insulating abrasive material in the contacts and thus prevent closing.

The burnishing tool described above can be obtained from the factory.

RENEWAL PARTS

It is recommended that sufficient quantities of renewal parts be carried in stock to enable the prompt replacement of any that are worn, broken, or damaged.

When ordering renewal parts, address the nearest Sales Office of the General Electric Company, specifying the quantity required and describing the parts by catalogue numbers as shown in Renewal Parts Bulletin No. GEF-3897.

Attachment No. 1 Sheet 11 of 12
Loop #/Identifier 27 S1A

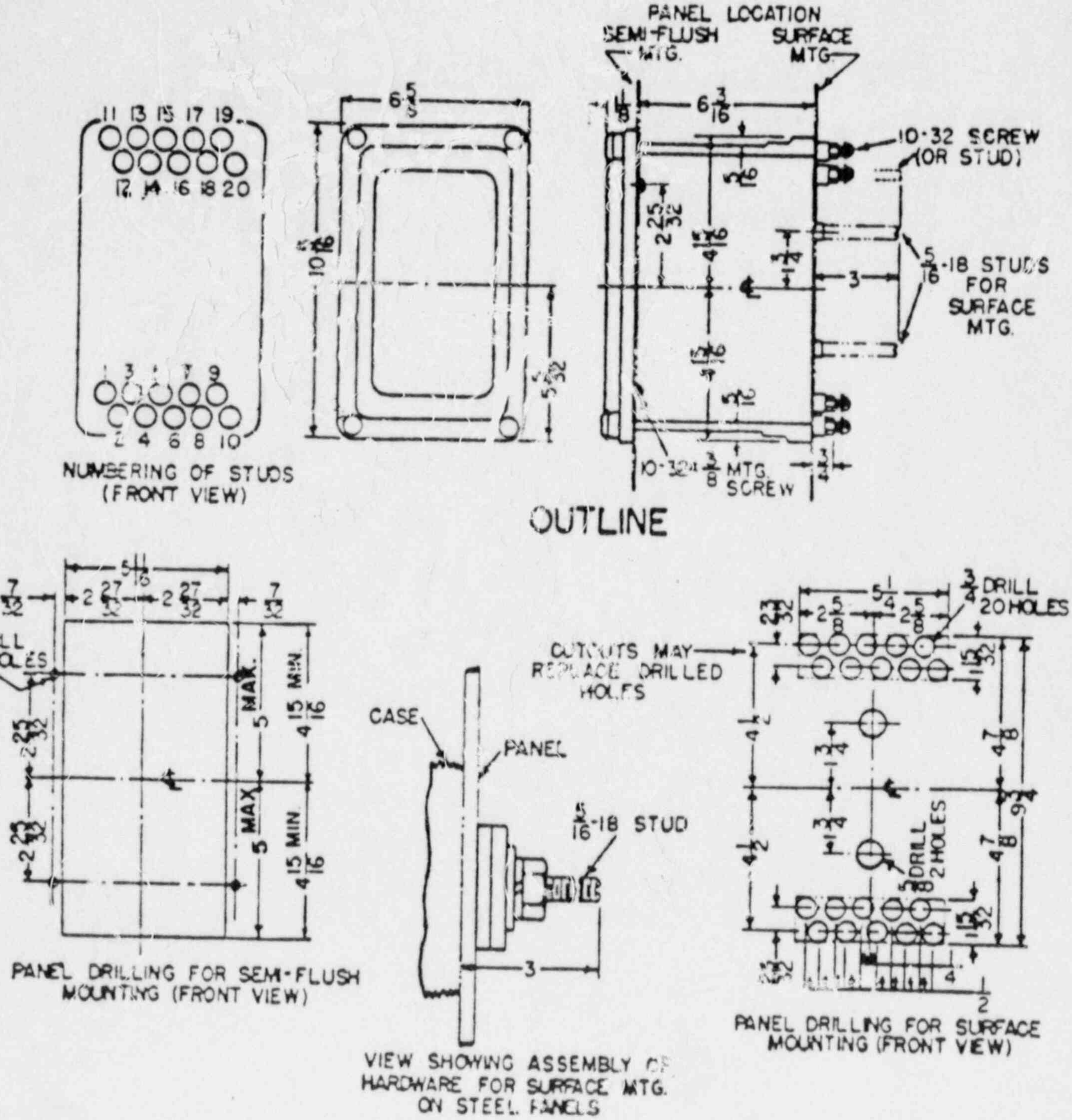


Figure 12. (K-6209272-2) Outline and Panel Drilling Dimensions for the Type IAV54 and IAV55 Relays

TVA 6789 (PO-6-64)

No. 8116 Date 11-29-79

Supersedes No. 7597 Date 9-19-79

RELAY INFORMATION AND SETTING - GENERAL

Location: Sequoyah Nuclear Plant
Settings By: H. M. Shuh
Date:

Line or Equipment Protected: 6.9-kV Shutdown Board 1A-A

Breaker No.: 1716, 1718, All motor breakers and all electrically operated breakers on 480-volt shutdown boards
Relays Trip:

Breaker Time (cycles) Close:
Open:
Total (C.C.C.):

Reclosing Relay Type:
Operating Cycle:

Time Delay Relay Type:
Setting:

RELAY DATA

Service	Range	Make	Type	Style Number		Device No.
6 - Undervoltage Relays	115V, 60 C.,	GE	IAV	12IAV54F1A	AØ	27S1A
	55, 64, 70,				AØ	
	82, 93, 105,				CØ	
	120, and				CØ	
	140V taps			12IAV54E1A	AØ	27D1A
					CØ	

INSTRUMENT TRANSFORMER DATA

Location and Circuit Voltage	Make and Available Ratios	Ratio and Conn. Used	Type	Effective Ratio
2 - PTs on 6.9-kV Shutdown Board 1A-A	7200-120V	7200-120V	PT	60/1

RELAY SETTINGS

Relay Function	Setting Sec.	Setting Pri.	Setting Time	Test Values and Time in Cycles
2 - AØ 27S1A and 2 - CØ 27S1A U.V. Relays	81V*	4860V	1.5	Apply P.U. voltage and adjust relay to close contacts in 5 seconds on complete loss of voltage.
1 - AØ and 1 - CØ 27D1A Relays	81V*	4860V	2.5	Apply pickup voltage and adjust relay to close contacts in 1.5 seconds on complete loss of voltage.

APPROVED BY EN DES

Remarks: Ref. 45N724-1, 45N765-3

*Set on 82V tap and adjust the spring to pick up 81V.

Change 27S1A relay style number and time lever from 10 to 1.5

Attachment No. 2 Sheet 1 of 1

Loop #/Identifier 27S1A

Seismic Test Procedure
on
6900 - Volt Shutdown Board Logic Panels
for
Sequoyah Nuclear Plant Units 1 & 2

TVA 72C2-83403
Westinghouse #CO-31704
Shop Order 17672

Prepared by R. F. Filer

Date 5/30/75

Approved by Westinghouse Electric Corp.

5/30/75 Date D. J. Cadillac

D. J. Cadillac

Approved by Westinghouse Electric Corp.

Date 5/30/75 R. P. Ballman, QA

Date: 10/30/73
Rev. 1 Date: 3/10/75
Rev. 2 Date: 5/30/75

Attachment No. 3 Sheet 1 of 9
Loop #/Identifier 2751A

TEST METHOD (RELAYS)

Two separate seismic tests were performed on the relays and are described below.

Relay Test 1

It would be meaningless to test the relays and devices under the same conditions as the panels. The maximum acceleration recorded on the panels during the beat test from 1 to 20 hertz is 1.6 g's horizontal and .16 g's vertical as determined from Graphs 4, 5, 6 and 10. The graphs show the maximum acceleration outputs with a ZPAX2 input to the panels. The IEEE 344-1971 rev. 5, page 33 section 6.61 under point 3 states that the test should not include frequencies above the ZPA asymptote; and as seen on Graph 13 the RRS is basically asymptotic at 14 hertz. The relays and devices were tested, however, with the ZPAX2 values from 20 to 35 hertz to increase conservatism.

Based on the above, the relays must withstand values listed below:

1.6 g's horizontal	0 - 20 hertz
.16 g's vertical	0 - 20 hertz
.44 g's horizontal	20 - 35 hertz
.13 g's vertical	20 - 35 hertz

A representative sample of the relays for the logic panels were ...ened to the seismic test table as shown in the figures listed below.

Test Set Up	Description
Fig. 8	Relays mounted for front to back acceleration
Fig. 9	Relays mounted for side to side acceleration

The relays were all subjected to a sine beat input of 5 beats with cycles per beat at each unit frequency from 1.0 to 35 cps.

First the table was run at maximum acceleration. The acceleration the relays that did not fail was recorded. The different levels of imum acceleration shown on tables 1 thru 8 attached is due to the ...ience in fixture amplification at the different relay locations.

Second the relays that failed were retested by bringing the accelera-...n up gradually and determining the point of failure and this level ...orded. Tables 1 thru 8 attached contain the results. The relay ...acts were monitored during the test with an oscilloscope for both

...ct 7202-83403
...ghouse G.O. CO-31704
No. 7107-17672

Attachment No. 3 Sheet 2 of 4
Loop #/Identifier 27SIA

contact opening and closing. A 10 microsecond opening or closing of a contact was considered a failure. Relay contacts were checked in all possible configurations; normally open, normally closed, energized and de-energized. In the range of accelerations required excluding the IAV relay there was no contact chatter detected in any of the relays under test except the normally closed contact of a de-energized SG or MG-6. These relays were loaded with an Agastat relay to determine if the chatter was meaningful and would cause failures of the shutdown logic. The criteria for pass or fail of the normally closed contacts was based on the Agastat as a load. Tables 1 thru 8 show accelerations which relays were subjected to during beat test. These values meet or exceed values required for the logic panels with the exception of the General Electric IAV relay which must be operated with ICS disconnected and the chattering of a de-energized relay must not affect essential shutdown.

The devices tested are listed below.

Device (for Cat. No. see Fig. 8 & 9)

Agastat Time Relay
Westinghouse Oil Tite Pushbutton
Westinghouse Oil Tite Switch
Westinghouse Type W Switch
Westinghouse EZC Light
Cutler-Hammer Press to Test Light
Westinghouse MG-6
Westinghouse SG
General Electric IAV Relay

Relay Test II

This test was requested by TVA to make certain no possible failure modes were overlooked and is outlined below.

General

This test procedure was designed to test for those seismic-induced relay maloperations which can cause unacceptable circuit malfunctions.

Unacceptable circuit malfunctions are:

1. Uncontrolled reset of electrical reset MG-6 relay.
2. Failure of a timing circuit to time properly or to remain in timed position.

Attachment No. 3 Sheet 3 of 4
Loop #/Identifier 27 S1A

The devices tested are listed below. (For devices cat. numbers see Fig. 10 & 11).

A-Westinghouse MG-6 (automatic reset)

B1-Westinghouse MG-6 (automatic reset)

B2-Westinghouse SG (automatic reset)

C1&C2-Westinghouse MG-6 (electric reset)

D1, D2, & F - Agastat (time delay on energizing)

E - Agastat with instantaneous auxiliary contacts (time delay on energizing)

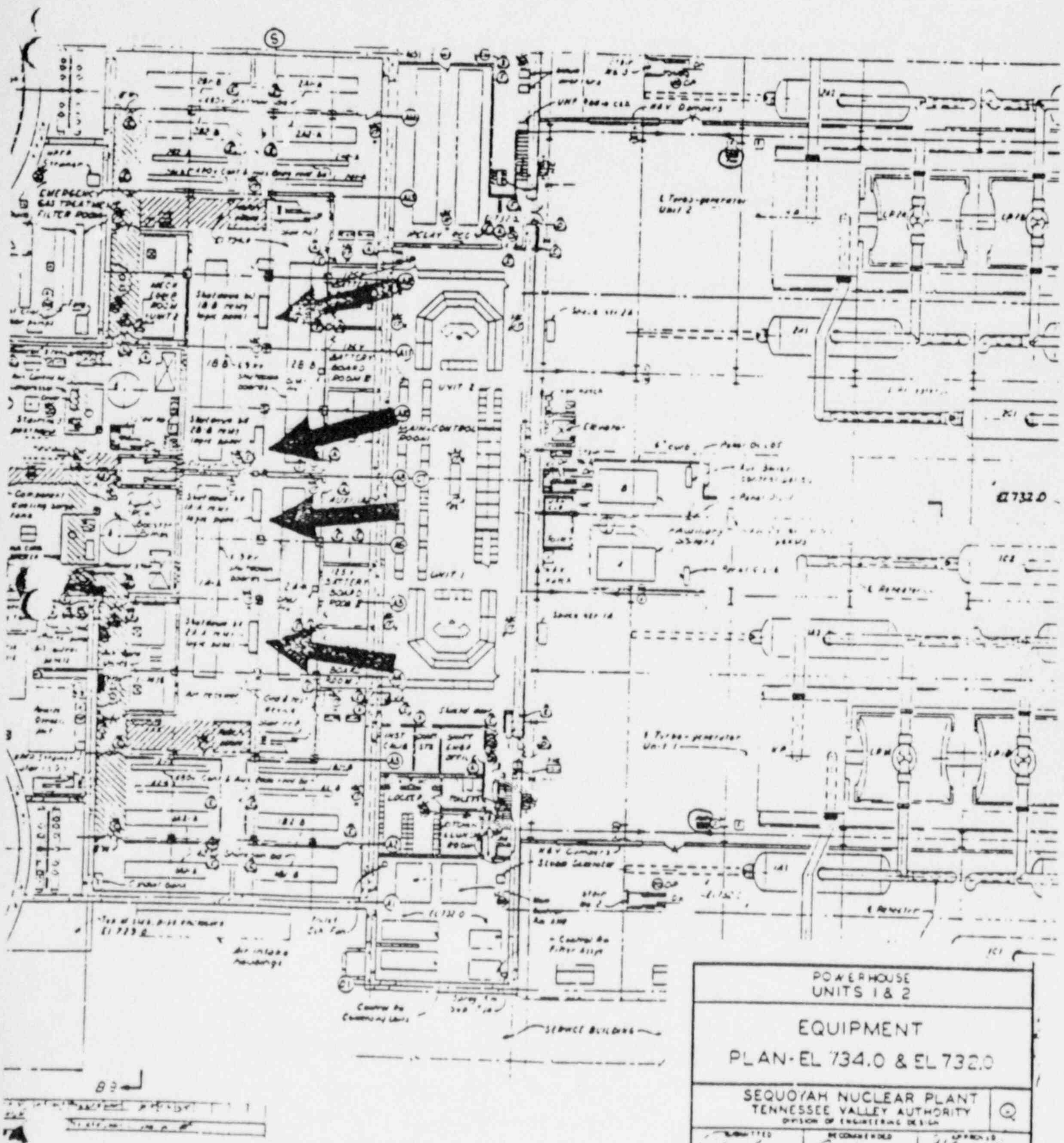
The relays were all subjected to a sine beat input of 5 beats with 10 cycles per beat at each unit frequency from 1.0 to 33 hz. The relays were positioned on the table per Fig. 10 & 11 and a complete sine beat test performed in each position. Table 9 & 10 give accelerations at relays. No relay failures occurred during test.

CONCLUSION

The relays and devices on the logic panels are seismically qualified for use in the panels structurally tested in this report. Based on the results of the relay test described in this report, the relays were conservatively tested and meet the requirements for seismic approval on the 6900 Volt Shutdown Board Logic Panels at Sequoyah Nuclear Plant.

Contract 7202-83403
Westinghouse G.O. CO-31704
S.C. No. 7107-17672

Attachment No. 3 Sheet 4 of 4
Loop #/Identifier 27 S/A



POWERHOUSE
UNITS 1 & 2

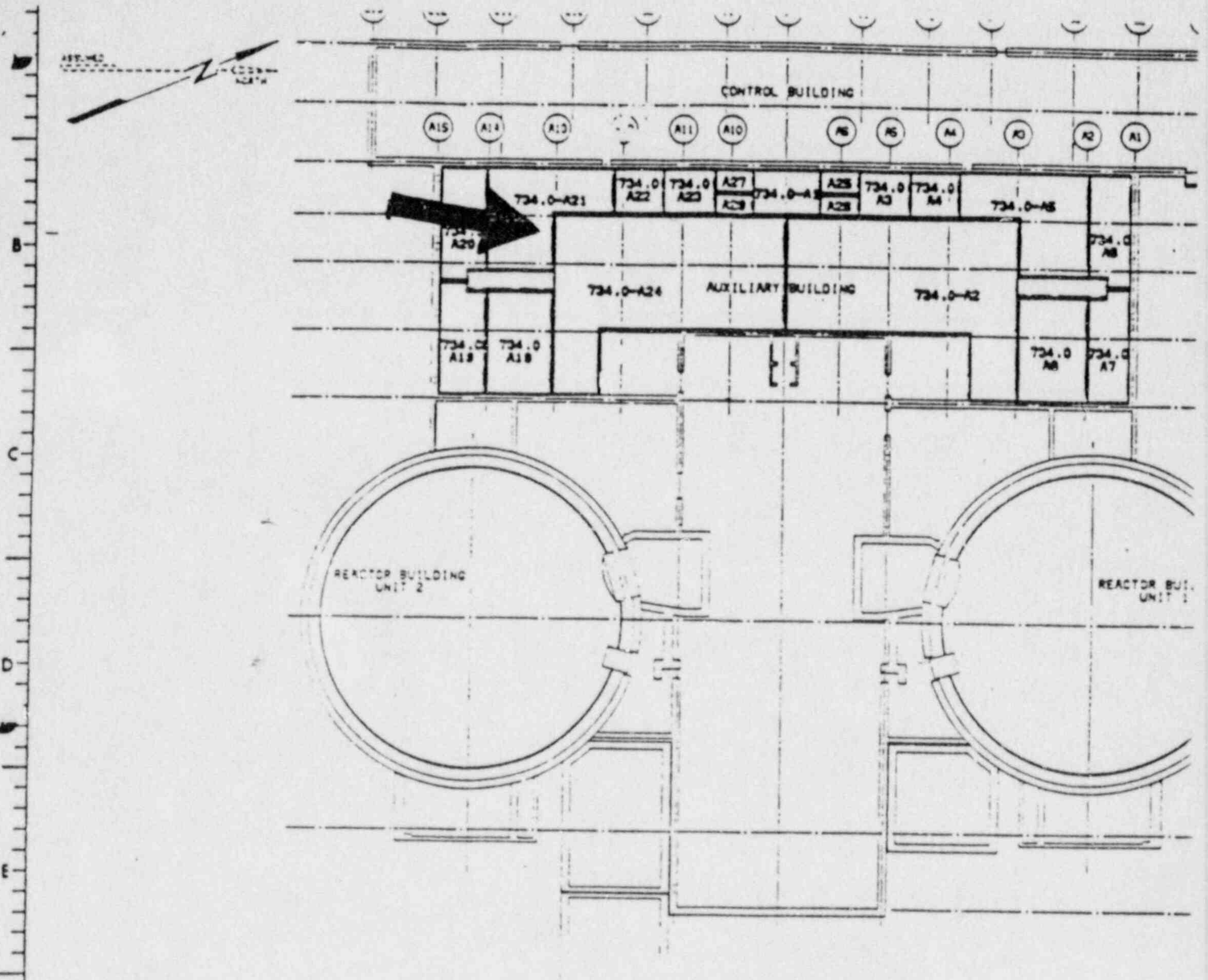
EQUIPMENT
PLAN-EL 734.0 & EL 732.0

SEQUOYAH NUCLEAR PLANT
TENNESSEE VALLEY AUTHORITY
DIVISION OF ENGINEERING DESIGN

SUBMITTED | RECOMMENDED | APPROVED

KNOXVILLE | 47W200-3

Attachment No. 4A Sheet 1 of 1
Loop #/Identifier - 27519



PLAN - EL 732.0 & 734.0

BUILDING LOCATION AND ROOM NUMBER	OPERATIONAL CONDITION (NOTE A)		TEMPERATURE (°F)	RELATIVE HUMIDITY (%) (NOTE G)	PRESSURE (PSIA) (NOTE B & H)	TOTAL 40 YEAR INTEGRATED DOSE (RADS) (NOTE C)	INTEGRATED ACCIDENT DOSE (RADS) (NOTES F & C)	AREA TYPE (NOTE J)
AUXILIARY BUILDING AUX CONTROL ROOM, AUX CONT INST RMS [illegible] BATT BD ROOMS [illegible] 6.9 KV SHUTDOWN BD ROOMS A & B 480V SHUTDOWN BD ROOMS [illegible] ROOM NUMBERS [illegible] EL 734.0	1	AVG MAX MIN	[illegible]	50 50 40	ATM (+) ATM (+) ATM (+)	NA 1.8 x 10[illegible] NA	NA NA NA	A
	2	MAX MIN	104 50 NOTE D	90 10	ATM (+) ATM (+)	NA NA	<1 x 10[illegible] NA	
	3		NA	NA	MODE 29	NA	NA	

ENVIRONMENTAL DATA
ENVIRONMENT - MILD
EL 734.0

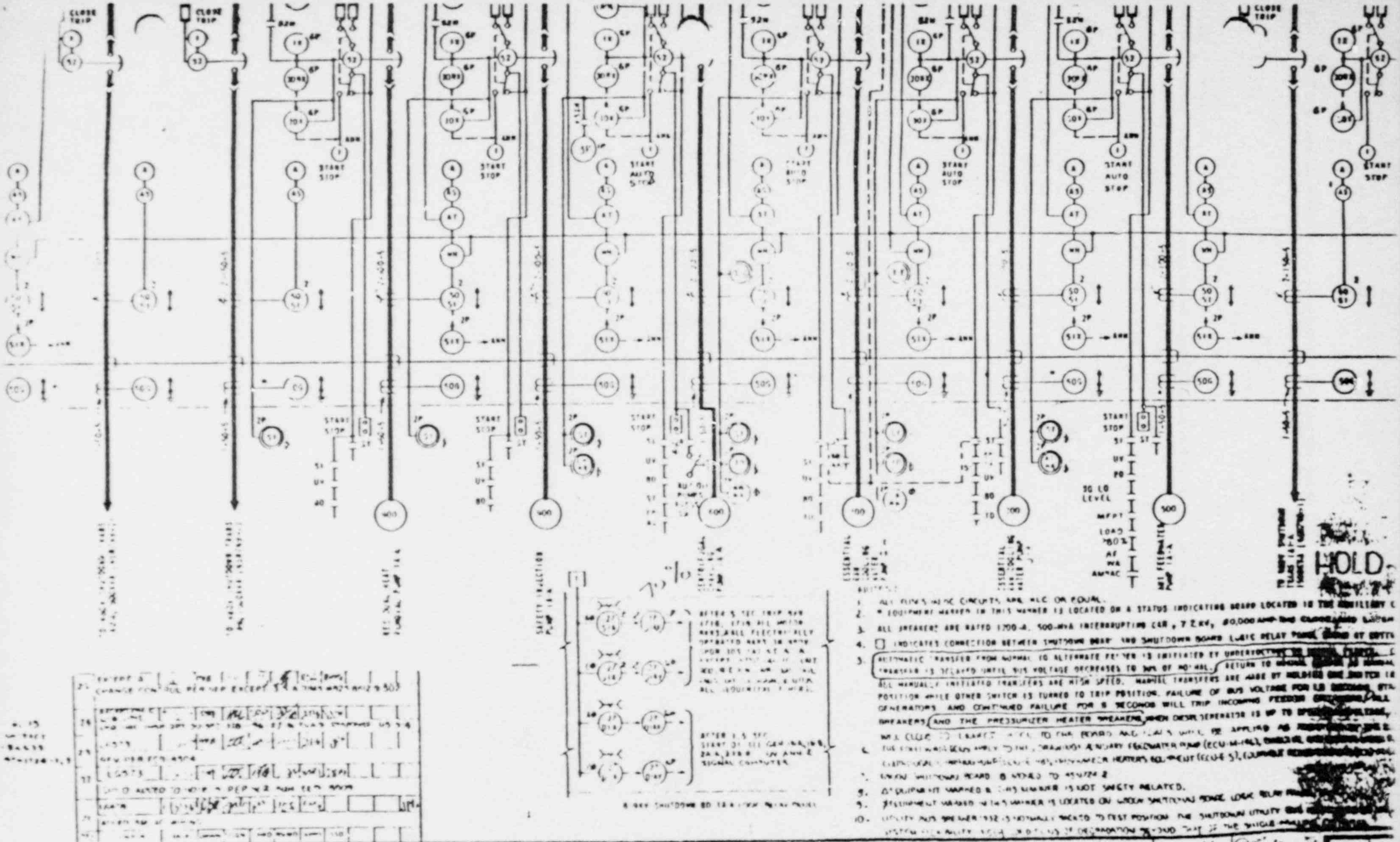
SEQUOYAH NUCLEAR PLANT
TENNESSEE VALLEY AUTHORITY
DIVISION OF ENGINEERING DESIGN

Q

SUBMITTED	RECOMMENDED	APPROVED
[signature]	[signature]	[signature]

KNOXVILLE | [illegible] | 45 | W | 47E235-07 | R

Attachment No. 45 Sheet 1 of 1
Loop #/Identifier 2751A



Attachment No 4C Sheet 1 of 1

Loop #/Identifier 27519

in order to differentiate such relays from the earlier, slower types. This book will use the term "instantaneous" for general reference to either instantaneous or high-speed relays, reserving the term "high-speed" for use only when the terminology is significant.

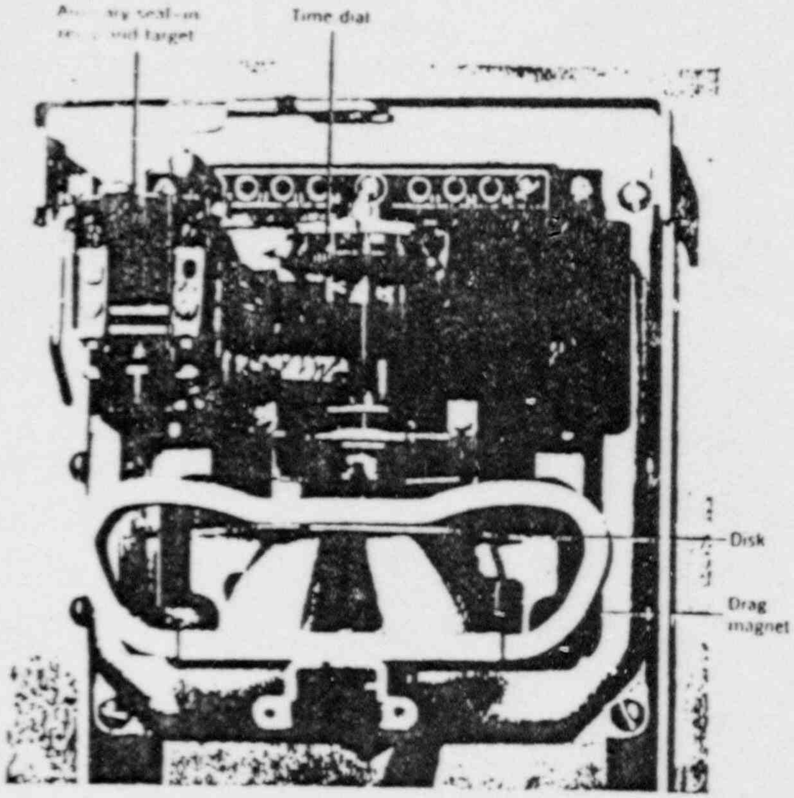


Fig. 4. Close-up of an induction-type overcurrent unit, showing the disc rotor and the drag magnet.

Occasionally, a supplementary auxiliary relay having fixed time delay may be used when a certain delay is required that is entirely independent of the magnitude of the actuating quantity in the protective relay.

Time delay is obtained in induction-type relays by a "drag magnet," which is a permanent magnet arranged so that the relay rotor cuts the flux between the poles of the magnet, as shown in Fig. 4. This produces a retarding effect on motion of the rotor in either direction. In other relays, various mechanical devices have been used, including dash pots, bellows, and escapement mechanisms.

The terminology for expressing the shape of the curve of operating time versus the actuating quantity has also been affected by developments throughout the years. Originally, only the terms "definite time" and "inverse time" were used. An inverse-time curve is one in which the operating time becomes less as the magnitude of the actuating quantity is increased, as shown in Fig. 5. The more pro-

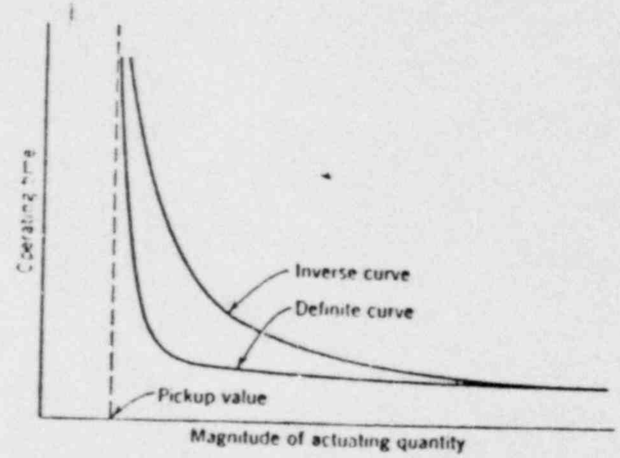


Fig. 5. Curves of operating time versus the magnitude of the actuating quantity.

nounced the effect is, the more inverse is the curve said to be. Actually, all time curves are inverse to a greater or lesser degree. They are most inverse near the pickup value and become less inverse as the actuating quantity is increased. A definite-time curve would strictly be one in which the operating time was unaffected by the magnitude of the actuating quantity, but actually the terminology is applied to a curve that becomes substantially definite slightly above the pickup value of the relay, as shown in Fig. 5.

As a consequence of trying to give names to curves of different degrees of inverseness, we now have "inverse," "very inverse," and "extremely inverse." Although the terminology may be somewhat confusing, each curve has its field of usefulness, and one skilled in the use of these relays has only to compare the shapes of the curves to know which is best for a given application. This book will use the term "inverse" for general reference to any of the inverse curves, reserving the other terms for use only when the terminology is significant.

Thus far, we have gained a rough picture of protective relays in general and have learned some of the language of the profession.

RATIO OF CONTINUOUS THERMAL CAPACITY TO PICKUP

As a consequence of greater efficiency, the actuating coil of this type of relay has a high ratio of continuous current or voltage capacity to the pickup value, from the thermal standpoint.

TIME CHARACTERISTICS

Relays of this type are instantaneous in operation, although a slug may be placed around the armature to get a short delay.

Induction-Type Relays—General Operating Principles

Induction-type relays are the most widely used for protective-relaying purposes involving a-c quantities. They are not usable with d-c quantities, owing to the principle of operation. An induction-type relay is a split-phase induction motor with contacts. Actuating force is developed in a movable element, that may be a disc or other form of rotor of non-magnetic current-conducting material, by the interaction of electromagnetic fluxes with eddy currents that are induced in the rotor by these fluxes.

THE PRODUCTION OF ACTUATING FORCE

Figure 7 shows how force is produced in a section of a rotor that is pierced by two adjacent a-c fluxes. Various quantities are shown

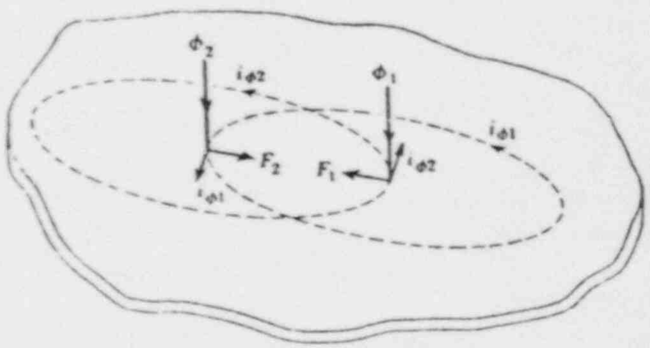


Fig. 7. Torque production in an induction relay.

at an instant when both fluxes are directed downward and are increasing in magnitude. Each flux induces voltage around itself in the rotor, and currents flow in the rotor under the influence of the two voltages. The current produced by one flux reacts with the other flux, and vice versa, to produce forces that act on the rotor.

The quantities involved in Fig. 7 may be expressed as follows:

$$\phi_1 = \Phi_1 \sin \omega t$$

$$\phi_2 = \Phi_2 \sin (\omega t + \theta),$$

where θ is the phase angle by which ϕ_2 leads ϕ_1. It may be assumed with negligible error that the paths in which the rotor currents flow have negligible self-inductance, and hence that the rotor currents are in phase with their voltages:

$$i_{\phi 1} \propto \frac{d\phi_1}{dt} \propto \Phi_1 \cos \omega t$$

$$i_{\phi 2} \propto \frac{d\phi_2}{dt} \propto \Phi_2 \cos (\omega t + \theta)$$

We note that Fig. 7 shows the two forces in opposition, and consequently we may write the equation for the net force (F) as follows:

$$F = (F_2 - F_1) \propto (\phi_2 i_{\phi 1} - \phi_1 i_{\phi 2}) \qquad (1)$$

Substituting the values of the quantities into equation 1, we get:

$$F \propto \Phi_1 \Phi_2 [\sin (\omega t + \theta) \cos \omega t - \sin \omega t \cos (\omega t + \theta)] \qquad (2)$$

which reduces to:

$$F \propto \Phi_1 \Phi_2 \sin \theta \qquad (3)$$

Since sinusoidal flux waves were assumed, we may substitute the rms values of the fluxes for the crest values in equation 3.

Apart from the fundamental relation expressed by equation 3, it is most significant that the net force is the same *at every instant*. This fact does not depend on the simplifying assumptions that were made in arriving at equation 3. The action of a relay under the influence of such a force is positive and free from vibration. Also, although it may not be immediately apparent, the net force is directed from the point where the leading flux pierces the rotor toward the point where the lagging flux pierces the rotor. It is as though the flux moved across the rotor, dragging the rotor along.

In other words, actuating force is produced in the presence of out-of-phase fluxes. One flux alone would produce no net force. There must be at least two out-of-phase fluxes to produce any net force, and the maximum force is produced when the two fluxes are 90° out of phase. Also, the direction of the force—and hence the direction of motion of the relay's movable member—depends on which flux is leading the other.

Attachment No. 5 Sheet 2 of 4
Loop #/Identifier 2751A

A better insight into the production of actuating force in the induction relay can be obtained by plotting the two components of the expression inside the brackets of equation 2, which we may call the "per-unit net force." Figure 8 shows such a plot when θ is assumed to be 90°. It will be observed that each expression is a double-frequency sinusoidal wave completely offset from the zero-force axis.

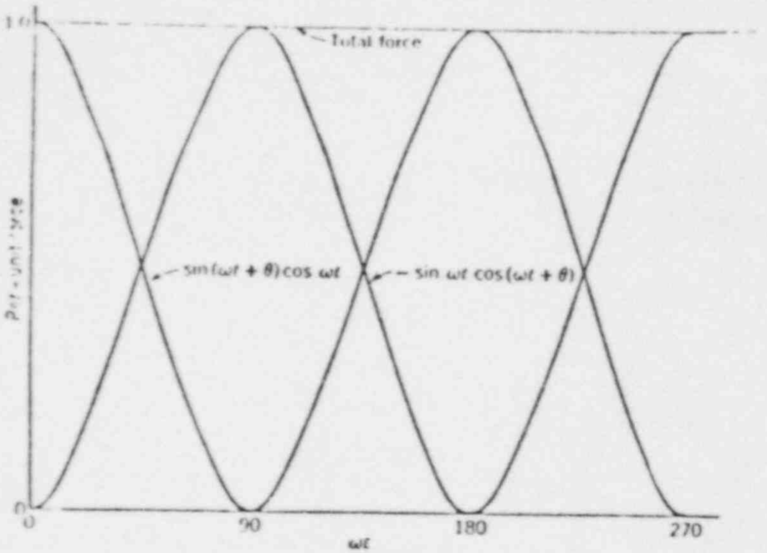


Fig. 8. Per-unit net force.

The two waves are displaced from one another by 90° in terms of fundamental frequency, or by 180° in terms of double frequency. The sum of the instantaneous values of the two waves is 1.0 at every instant. If θ were assumed to be less than 90°, the effect on Fig. 8 would be to raise the zero-force axis, and a smaller per-unit net force would result. When θ is zero, the two waves are symmetrical about the zero-force axis, and no net force is produced. If we let θ be negative, which is to say that ϕ_2 is lagging ϕ_1, the zero-force axis is raised still higher and net force in the opposite direction is produced. However, for a given value of θ, the net force is the same at each instant.

In some induction-type relays one of the two fluxes does not react with rotor currents produced by the other flux. The force expression for such a relay has only one of the components inside the brackets of equation 2. The *average* force of such a relay may still be expressed by equation 3, but the instantaneous force is variable, as

shown by omitting one of the waves of Fig. 8. Except when θ is 90° lead or lag, the instantaneous force will actually reverse during parts of the cycle; and, when $\theta = 0$, the average negative force equals the average positive force. Such a relay has a tendency to vibrate, particularly at values of θ close to zero.

Reference 2 of the bibliography at the end of this chapter gives more detailed treatment of induction-motor theory that applies also to induction relays.

TYPES OF ACTUATING STRUCTURE

The different types of structure that have been used are commonly called: (1) the "shaded-pole" structure; (2) the "watthour-meter" structure; (3) the "induction-cup" and the "double-induction-loop" structures; (4) the "single-induction-loop" structure.

Shaded-Pole Structure. The shaded-pole structure, illustrated in Fig. 9, is generally actuated by current flowing in a single coil on a magnetic structure containing an air gap. The air-gap flux produced by this current is split into two out-of-phase components by a

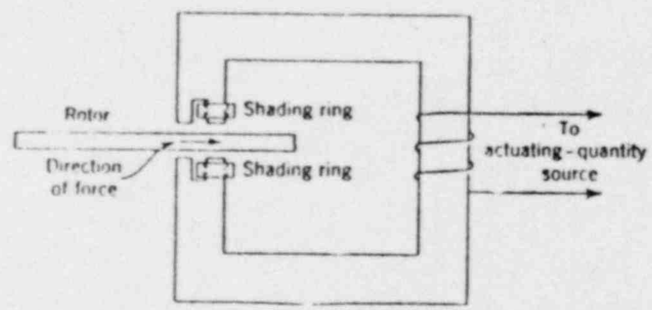


Fig. 9. Shaded-pole structure.

so-called "shading ring," generally of copper, that encircles part of the pole face of each pole at the air gap. The rotor, shown edgewise in Fig. 9, is a copper or aluminum disc, pivoted so as to rotate in the air gap between the poles. The phase angle between the fluxes piercing the disc is fixed by design, and consequently it does not enter into application considerations.

The shading rings may be replaced by coils if control of the operation of a shaded-pole relay is desired. If the shading coils are short-circuited by a contact of some other relay, torque will be produced; but, if the coils are open-circuited, no torque will be produced because there will be no phase splitting of the flux. Such torque control is employed where "directional control" is desired, which will be described later.

Watthour-Meter Structure. This structure gets its name from the fact that it is used for watthour meters. As shown in Fig. 10, this structure contains two separate coils on two different magnetic circuits, each of which produces one of the two necessary fluxes for driving the rotor, which is also a disc.

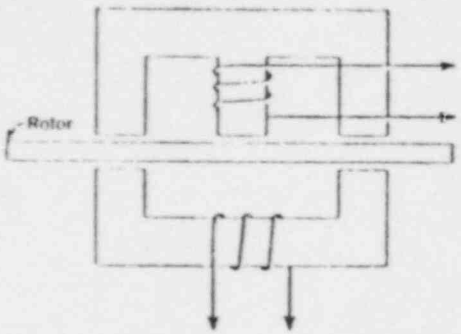


Fig. 10 Watthour-meter structure.

Induction-Cup and Double-Induction-Loop Structures. These two structures are shown in Figs. 11 and 12. They most closely resemble an induction motor, except that the rotor iron is stationary, only the rotor-conductor portion being free to rotate. The cup structure employs a hollow cylindrical rotor, whereas the double-loop structure

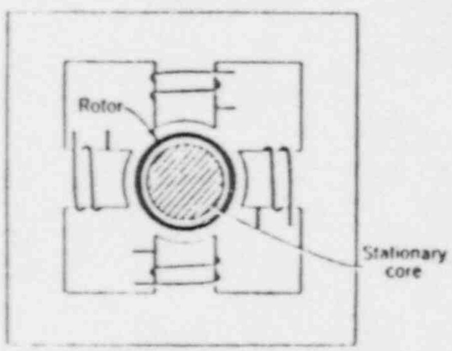


Fig. 11 Induction-cup structure.

employs two loops at right angles to one another. The cup structure may have additional poles between those shown in Fig. 11. Functionally, both structures are practically identical.

These structures are more efficient torque producers than either the shaded-pole or the watthour-meter structures, and they are the type used in high-speed relays.

Single-Induction-Loop Structure. This structure, shown in Fig. 13, is the most efficient torque-producing structure of all the induction types that have been described. However, it has the rather serious disadvantage that its rotor tends to vibrate as previously described for a relay in which the actuating force is expressed by only one component inside the brackets of equation 2. Also, the torque varies somewhat with the rotor position.

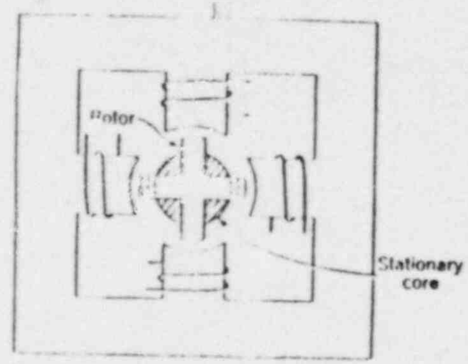


Fig. 12 Double-induction-loop structure.

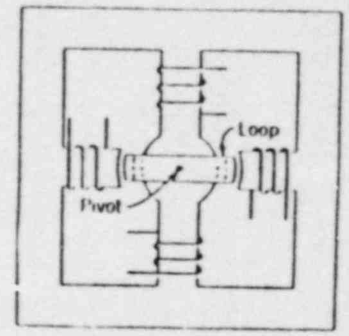


Fig. 13. Single-induction-loop structure.

ACCURACY

The accuracy of an induction relay recommends it for protective-relaying purposes. Such relays are comparable in accuracy to meters used for billing purposes. This accuracy is not a consequence of the induction principle, but because such relays invariably employ jewel bearings and precision parts that minimize friction.

Single-Quantity Induction Relays

A single-quantity relay is actuated from a single current or voltage source. Any of the induction-relay actuating structures may be used. The shaded-pole structure is used only for single-quantity relays. When any of the other structures is used, its two actuating circuits are connected in series or in parallel; and the required phase angle between the two fluxes is obtained by arranging the two circuits to have different X/R (reactance-to-resistance) ratios by the use of auxiliary resistance and/or capacitance in combination with one of the circuits. Neglecting the effect of saturation, the torque of all such relays may be expressed as:

$$T = K_1 I^2 - K_2$$

where I is the rms magnitude of the total current of the two circuits.

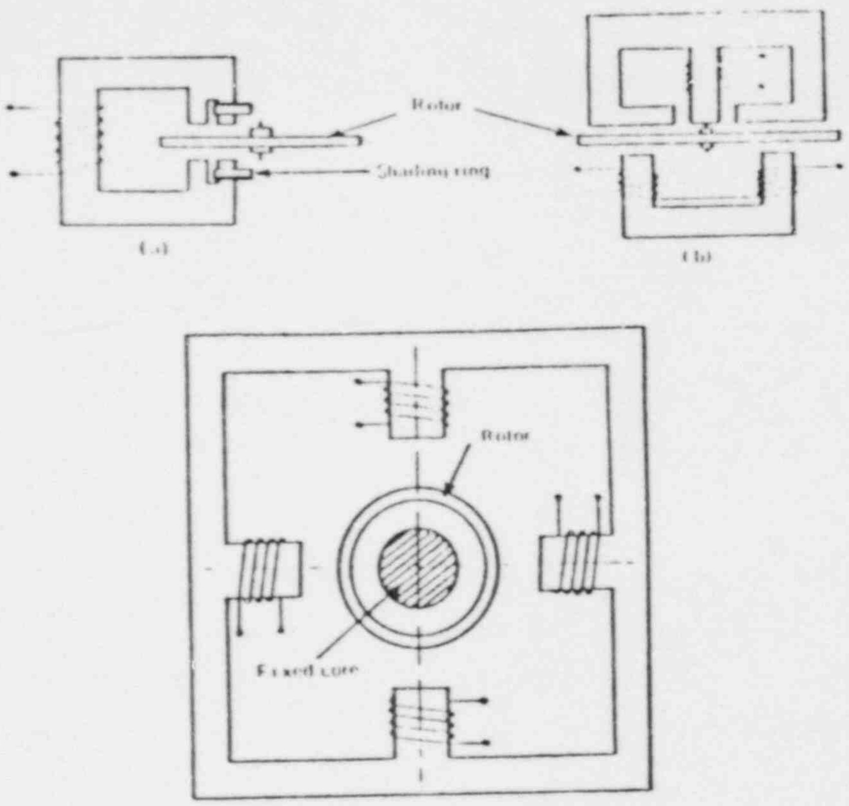


FIGURE 3.5 Induction relays: (a) shaded pole type induction disc relay; (b) wattmetric type induction disc relay; (c) induction cup relay.

a comparatively high speed and the contacts are driven through gears.

The distance of travel of the arm carrying the bridging contact to the relay contacts can be adjusted with the help of the time multiplier setting. Taps are provided on the input side of the operating quantity which can be adjusted with the help of inserting the plug. This is known as the plug multiplier setting. A permanent magnet is provided to give eddy current breaking to the disc. This is necessary to reduce to a minimum the overrun of the disc in case the current or voltage providing the driving torque stops before the operation has been completed. A modern induction disc relay will have an overrun of not more than 2 cycles on interruption of 20 times the setting quantity.

Induction cup relays operate on the same principle as the induction motor. A rotating field is produced by the two pairs of coils shown in Fig. (3.5c). The rotating field induced currents in the cup causing it to

ing of the contacts carried on an arm attached to the spindle of the cup, prevent continuous rotation. The rotation depends on the direction of rotation of the field and the magnitude of the applied voltage and/or currents and the phase angle between them. This type is very fast in operation owing to the light rotor and minimum magnetic leakages in the magnetic circuit. Relays of this type may have an operating time of less than 0.010 second. They can be made to have linear operating characteristics and a very high ratio of resetting to operating values. These are best suited where normal and abnormal conditions are very close together, so that it can be set to trip instantaneously up to 90% of the protected section as a distance relay. These are also ideal as directional relays because of their high sensitivity, speed and nonvibrating steady torque, the parasitic torques due to current or voltage alone are small.

3.3 Theory of Induction Relay Torque

Two magnetic fluxes ϕ_1 and ϕ_2 differing in time phase penetrate through a disc. These alternating fluxes induce emfs e_1 and e_2 in the disc which lag their respective fluxes by 90°. These emfs lead to the flow of eddy currents i_1 and i_2. By the interaction of ϕ_1 with i_2 and ϕ_2 with i_1 a driving torque is produced. The currents i_1 and i_2 lag the voltages e_1 and e_2 by the impedance angle λ of the disc. Figure (3.6) shows the vector diagram.

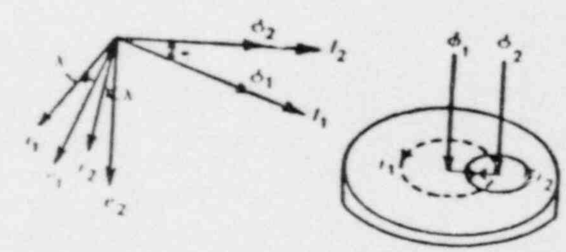


FIGURE 3.6 Principle of induction relay torque.

Attachment No. 6 Sheet 1 of 2
Loop #/Identifier 2251A

$$\phi_1 \propto |I_1| \sin \omega t \tag{3.2}$$

$$\phi_2 \propto |I_2| \sin (\omega t + \alpha) \tag{3.3}$$

$$e_1 \propto \frac{d\phi_1}{dt} \propto \omega |I_1| \cos \omega t \tag{3.4}$$

$$e_2 \propto \frac{d\phi_2}{dt} \propto \omega |I_2| \cos (\omega t + \alpha) \tag{3.5}$$

$$i_1 \propto \omega |I_1| \cos (\omega t - \lambda) \tag{3.6}$$

Therefore, the resultant torque is given by

$$T \propto \phi_2 i_1 - \phi_1 i_2$$

$$\propto \omega |I_1||I_2| [\sin(\omega t + \alpha)\cos(\omega t - \lambda) - \sin \omega t \cos(\omega t + \alpha - \lambda)]$$

$$\propto \omega |I_1||I_2| \sin\alpha \cos\lambda$$

or $$T \propto \omega |I_1||I_2| \sin\alpha \tag{3.8}$$

Thus the induction relay is a sine comparator in which the maximum torque is developed when α is 90° or 270° and zero torque when α is 0° or 180°.

3.4 Relay Design and Construction

The design of protective relay is normally divided into the following stages:

(a) Selection of the operating characteristics.
(b) Selection of proper construction.
(c) Design of the contact movement from the point of view of utmost reliability.

The relay operating characteristic must match with the abnormal operating characteristic of the system. In other words it should clearly show the conditions for tripping under various abnormal operating conditions.

The most important considerations in the design for construction are reliability, simplicity of construction and circuitry. The construction of the relay is divided into the following: (i) contacts; (ii) bearings; (iii) electro-mechanical design; and (iv) terminations and housing.

Contacts. Contact performance is probably the most important item affecting reliability of the relay. Corrosion or dust deposition can cause nonoperation of relay, consequently the material and shape of the contacts are of considerable importance.

A good contact system design provides restricted contact resistance as well as reduced contact wear. The contact materials used are gold, gold alloys, platinum, palladium and silver. The selection of the contact material depends on a number of factors like the voltage per contact break, the current to break as well as the type of atmospheric pollution under which these contacts are operated. However there is no one ideal contact material which can be used universally under all conditions. There is also no method by which the suitability of contact material for use under any condition can be derived. The following factors are to be considered

1. The nature of the current to be interrupted, i.e., direct or alternating.
2. Voltage at break and make operations.
3. The value of the currents to be interrupted.
4. Frequency of operation.
5. The actual speed of contact at make or break (this covers the arc duration and contact bounce).
6. The contact shape.
7. The contact closing force.

On the basis of practical experience the following are some of the rules recommended in the design of contact system of a relay:

(a) The contacts should be bounce proof to avoid arcing at the contacts thereby reducing the maintenance which ultimately results in increasing its life.
(b) Contact pressure is another very important factor to be kept in view. An increase in contact pressure leads to decrease in voltage drop or contact resistance.
(c) To promote accuracy and avoid sticking after long periods of inaction, the relay should be designed to maximum torque/friction ratio.
(d) The value of current that can be interrupted by a pair of contact in a.c. circuit is 2 to 8 times than that in a d.c. circuit.

In general domed shaped contacts or the cylindrical contacts at right angles give the best performace.

Bearing. The various arrangements in use are:

(i) *Single ball bearings*: Used for high sensitivity and low friction, a single ball bearing between two cup-shaped sapphire jewels is in use.
(ii) *Multi-ball bearings*: Miniature types of less than 1.6 mm diameter are available. These provide low friction and greater resistance to shock and combine side-thrust and end-thrust in a single bearing.
(iii) *Pivot and jewel bearings*: This is the most common type for precision relays, e.g. induction relays. Modern relays have spring-mounted jewels so that shocks are taken on a shoulder and not on the jewel.
(iv) *Knife edge bearings*: These are used for hinged armature relays which normally operate many contacts.

Electromechanical Design. It consists of the design of the magnetic circuit and the mechanical fixtures of core, yoke and the armature.

The reluctance of the magnetic path is kept to a minimum by enlarging the pole face which makes the magnetic circuit more efficient.

FOR	NAME: Fabio Chumicki	DATE: 5-22-87	
	ADDRESS: WBB 84 C-K		
FROM	NAME: Bobbye G Malone	EXTENSION: 6541	
	ADDRESS: DPSO DSC-J		

This is the test data you ask for per phone conversation.

TM 45C IOS 9 80 INTEROFFICE MAILING SLIP

Attachment No. 7 Sheet 1 of 9

Loop #/Identifier 27 S1A

TEST RECORD -- GENERAL

REPORT NO.: SI-235
SHEET NO.: ___ OF ___ SHEET

LOCATION: SEQUOYAH NUCLEAR PLANT
SUBJECT: 6.9 KV SHUTDOWN BOARD 1A-A LOGIC PANELS
GENERAL DATA: G.E. UNDERVOLTAGE RELAYS 12IAV54E1A & 12IAV54F1
DATE OF TEST: 3/14/86
DATE OF REPORT: 3/14/86

SETTING SHEET # 811[illegible] DATE OF SETTING SHEET 11-29-7[illegible]

COPIES SENT TO: UNIT FILE, SI-235 DATA PACKAGE

TESTED BY: Hooper & McLane
CHECKED BY:
APPROVED BY:

DEVICE	PHASE	PANEL	PICKUP (AS FOUND)	PICKUP (AS LEFT)	SECONDS TO CLOSE CONTACTS ON LOSS OF POTENTIAL (AS FOUND)	SECONDS TO CLOSE CONTACTS ON LOSS OF POTENTIAL (AS LEFT)	TARGET	TIME DIAL	* PERCENT OFF SET POINT (AS FOUND) P.U.	* PERCENT OFF SET POINT (AS FOUND) TIM
27S11A	A Φ	1	80.5	81	4.96	4.96	OK	1.9	.6%	.8%
27S11A	C Φ	1	83	81	5.0	5.0	OK	1.7	2.5%	4%
27D1A	A Φ	2	80.5	81	1.54	1.5	OK	[illegible]	.6%	2.67
27D1A	C Φ	2	81	81	1.54	1.5	OK	2.2	0%	2.67
27S21A	A Φ	3	81.5	81	4.85	5.0	OK	[illegible]	.6%	3%
27S21A	C Φ	3	82	81	4.85	5.0	OK	1.75	1.2%	3%

EQUIPMENT	TVA #	CALIBRATION DUE DATE
TEST SET [illegible]	[illegible]	[illegible]
FLUKE	KK 453	5-31-86

* FORMULA FOR PERCENT OFF SET POINT

$$\frac{(\text{AS FOUND VALUE}) - (\text{SET POINT VALUE})}{(\text{SET POINT VALUE})} \times 100 = \% \text{ OFF SET POINT}$$

Attachment No. 7 Sheet 2 of 9
Loop #/Identifier 27S1A

TVA 6472 (PO-4-68)

TEST RECORD -- GENERAL

REPORT NO.: SI-235
SHEET NO.: ___ OF ___ SHEETS
DATE OF TEST: 4/4/86
DATE OF REPORT:

LOCATION: SEQUOYAH NUCLEAR PLANT
SUBJECT: 6.9 KV SHUTDOWN BOARD 1B-B LOGIC PANELS
GENERAL DATA: G.E. UNDERVOLTAGE RELAYS 12IAV54E1A & 12IAV54F1A

SETTING SHEET # 8117 DATE OF SETTING SHEET 11-29-79

COPIES SENT TO: UNIT FILE, SI-235 DATA PACKAGE

TESTED BY: Cox & NICHOLS
CHECKED BY:
APPROVED BY:

DEVICE	PHASE	PANEL	PICKUP (AS FOUND)	PICKUP (AS LEFT)	SECONDS TO CLOSE CONTACTS ON LOSS OF POTENTIAL (AS FOUND)	SECONDS TO CLOSE CONTACTS ON LOSS OF POTENTIAL (AS LEFT)	TARGET	TIME DIAL	* PERCENT OFF SET POINT (AS FOUND) P.U.	* PERCENT OFF SET POINT (AS FOUND) TIME
27S11B	AØ	1	80V	81V	4.86	4.91	.19	1.8	1.25	2.8%
27S11B	CØ	1	81V	81V	4.91	4.91	.19	1.4	0%	1.8%
27D1B	AØ	2	81.2V	80.9V	1.49	1.51	.19	2.4	.25	.67
27D1B	CØ	2	82.5	80.9V	1.42	1.49	.19	2.3	1.85	1.6%
27S2B	AØ	3	80.2V	80.2	5.12	5.07	.12	1.5	.99	[illegible]
27S2B	CØ	3	80.4V	80.5	5.08	5.12	.19	1.6	.74	1.6%

EQUIPMENT	TVA #	CALIBRATION DUE DATE
EPOCH 1	531818	6-25-86
EPOCH 1	531820	6-25-86
Poly Phase meter	512777	4-16-86

* FORMULA FOR PERCENT OFF SET POINT

$$\frac{(\text{AS FOUND VALUE}) - (\text{SET POINT VALUE})}{(\text{SET POINT VALUE})} \times 100 = \%\ \text{OFF SET POINT}$$

Attachment No. 7 Sheet 3 of 9
Loop #/Identifier 27 S1A

TEST RECORD -- GENERAL

REPORT NO.: SI-235

SHEET NO.: ___ OF ___ SHEETS

LOCATION: SEQUOYAH NUCLEAR PLANT

DATE OF TEST: 3/14/86

SUBJECT: 6.9 KV SHUTDOWN BOARD ~~2A-A~~ LOGIC PANELS

DATE OF REPORT: 3/14/86

GENERAL DATA: G.E. UNDERVOLTAGE RELAYS 12IAV54E1A & 12IAV54F1

SETTING SHEET # 8118 DATE OF SETTING SHEET 11/29/79

COPIES SENT TO: UNIT FILE, SI-235 DATA PACKAGE

TESTED BY: MHH & BGM

CHECKED BY:

APPROVED BY:

DEVICE	PHASE	PANEL	PICKUP (AS FOUND)	PICKUP (AS LEFT)	SECONDS TO CLOSE CONTACTS ON LOSS OF POTENTIAL (AS FOUND)	SECONDS TO CLOSE CONTACTS ON LOSS OF POTENTIAL (AS LEFT)	TARGET	TIME DIAL	* PERCENT OFF SET POINT (AS FOUND) P.U.	* PERCENT OFF SET POINT (AS FOUND) TIM
27S12A	A Φ	1	81	81	5.0	5.0	OK	1.7	0%	0%
27S12A	C Φ	1	82	81	5.0	5.0	OK	1.55	1.2% ~~0%~~ MHH	0% BGM
27D2A	A Φ	2	80	81	1.46	1.50	OK	1.55	1.2%	2.6%
27D2A	C Φ	2	81	81	1.48	1.50	OK	2.7	0%	1.3%
27S22A	A Φ	3	81	81	5.1	5.0	OK	1.65	0%	2%
27S22A	C Φ	3	81	81	4.8	5.0	OK	1.65	0%	4%

EQUIPMENT	TVA #	CALIBRATION DUE DATE
EIL Test Set	486215	12-31-86
Fluke	486433	7-31-86

* FORMULA FOR PERCENT OFF SET POINT

$$\frac{(\text{AS FOUND VALUE}) - (\text{SET POINT VALUE})}{(\text{SET POINT VALUE})} \times 100 = \% \text{ OFF SET POINT}$$

Attachment No. 7 Sheet 4 of 9

Loop #/Identifier 27S1A

TVA 6472 (PO-4-68)

TEST RECORD -- GENERAL

REPORT NO.: SI-235
SHEET NO.: ______ OF ______ SHEETS

LOCATION: SEQUOYAH NUCLEAR PLANT
DATE OF TEST: 4-7-86
SUBJECT: 6.9 KV SHUTDOWN BOARD 2B-B LOGIC PANELS
DATE OF REPORT:
GENERAL DATA: G.E. UNDERVOLTAGE RELAYS 12IAV54E1A & 12IAV54F1

SETTING SHEET # 8119   DATE OF SETTING SHEET 11-29-79

COPIES SENT TO: UNIT FILE, SI-235 DATA PACKAGE

TESTED BY: Cox & Nichols
CHECKED BY:
APPROVED BY:

DEVICE	PHASE	PANEL	PICKUP (AS FOUND)	PICKUP (AS LEFT)	SECONDS TO CLOSE CONTACTS ON LOSS OF POTENTIAL (AS FOUND)	SECONDS TO CLOSE CONTACTS ON LOSS OF POTENTIAL (AS LEFT)	TARGET	TIME DIAL	* PERCENT OFF SET POINT (AS FOUND) P.U.	* PERCENT OFF SET POINT (AS FOUND) TIM
27S12B	AG	1	82V	80.9V	5.14	4.95	.2	1.4	1.2	.82
27S12B	CG	1	82.5V	81.V	4.9	4.90	.2	1.7	1.9	2
27D2B	AG	2	81.8V	81V	1.46	1.55	.2	2.5	.25	2.60
27D2B	CG	2	80.8V	81V	1.5	1.5	.2	2.2	.24	0
27S22B	AG	3	82.2V	81V	5.13	5.1	.2	1.4	1.48	2.6
27S22B	CG	3	80V	80.9	5.13	4.95	.2	1.6	1.2	2.6

EQUIPMENT	TVA #	CALIBRATION DUE DATE
EPOCH 1	531818	6-25-86
EPOCH 1		
RELAY TEST SET	239664	4-2-87

* FORMULA FOR PERCENT OFF SET POINT

$$\frac{(\text{AS FOUND VALUE}) - (\text{SET POINT VALUE})}{(\text{SET POINT VALUE})} \times 100 = \%\ \text{OFF SET POINT}$$

Attachment No. 7 Sheet 5 of 9
Loop #/Identifier 27 S1A

TEST RECORD -- GENERAL

REPORT NO.: SI-235
SHEET NO.: ___ OF ___ SHEET

LOCATION: SEQUOYAH NUCLEAR PLANT
SUBJECT: 6.9 KV SHUTDOWN BOARD 1AA LOGIC PANELS
GENERAL DATA: G.E. UNDERVOLTAGE RELAYS 12IAV54E11A
115V 60~

DATE OF TEST: 9-27-85
DATE OF REPORT: 9-30-85

COPIES SENT TO:

TESTED BY: JFN & MHH
CHECKED BY:
APPROVED BY:

SI-235

DEVICE	PHASE	PANEL	PICKUP	TIME TO CLOSE CONTACTS ON LOSS OF POTENTIAL SECONDS	TIME DIAL	TARGET
2751	AΦ	1	81V	5	1.9	OK
2751	CΦ	1	81V	5	1.9	OK
27D1	AΦ	2	81V	1.5	2.4	OK
27D1	CΦ	2	81V	1.5	2.3	OK
2752	AΦ	3	81V	5	1.5	OK
2752	CΦ	3	81V	5	1.6	OK

EQUIPMENT	TVA #	DUE DATE
EPOCH I	52,920	6-25-86
EPOCH I	52,915	6-25-86
[illegible]METER	52030	3-22-86
KEITHLEY VOLTMETER	537774	11-15-85

Attachment No. 7 Sheet 6 of 9
Loop #/Identifier 27S1A

TEST RECORD -- GENERAL

REPORT NO.: SI-235
SHEET NO.: ___ OF ___ SHEETS

LOCATION: SEQUOYAH NUCLEAR PLANT
SUBJECT: 6.9KV SD BD 1BB LOGIC RelAYS
GENERAL DATA: G.E. UNDERVOLTAGE RelAYS 12IAV54E1A 115V. 60Hz

DATE OF TEST: 9-13-85
DATE OF REPORT:

COPIES SENT TO:

TESTED BY: CLC - BGM
CHECKED BY:
APPROVED BY:

SS# 8117

SI-235

Key C415A

Device	Phase	Panel	Decrease Voltage Pickup	Time to close Contacts on Loss of Potential in Secs.	Target
27511B	A	1	81 V	5	.2
27511B	C	1	81 V	5	.2
27D1B	A	2	81 V	1.5	.2
27D1B	C	2	81 V	1.5	.2
27521B	A	3	81 V	5	.2
27521B	C	3	81 V	5	.2

EQUIPMENT	TVA #	Due Date
EIL FTS300 Set	486218	7-12-86
Keithley Voltmeter	537776	11-15-85

Attachment No. 7 Sheet 2 of 9
Loop #/Identifier 2751A

TVA 6472 (PO-4-68)

TEST RECORD -- GENERAL

REPORT NO.: SI-235
SHEET NO.: ____ OF ____ SHEETS

LOCATION: SEQUOYAH NUCLEAR PLANT
DATE OF TEST: 9-27-85
SUBJECT: 6.9 KV SHUTDOWN BOARD 2AA LOGIC PANELS
DATE OF REPORT: 9-30-85
GENERAL DATA: G.E. UNDER VOLTAGE RELAYS 12IAV54E11A 115V 60C~

COPIES SENT TO:

TESTED BY: JFN & MHH
CHECKED BY:
APPROVED BY:

SI-235

DEVICE	PHASE	PANEL	PICKUP	TIME TO CLOSE CONTACTS ON COMPLETE LOSS OF POTENTIAL	TIME DIAL	TARGET
27S1	Aϕ	1	91V	5 sec	1.7	OK
27S1	Cϕ	1	91V	5 sec	1.5	OK
27D	Aϕ	2	91V	1.5 sec	2.7	OK
27D	Cϕ	2	91V	1.5 sec	2.7	OK
27S2	Aϕ	3	91V	5sec	1.7	OK
7S2	Cϕ	3	91V	5sec	1.5	OK

EQUIPMENT	TVA#	DUE DATE
EPOCH I	531820	6-25-86
EPOCH I	531815	6-25-86
POLYMETER	529301	3-22-86
KEITHLEY VOLTMETER	537774	11-18-85

Attachment No. 7 Sheet 8 of 9
Loop #/Identifier 27S1A

TVA 6472 (PO-4-68)

TEST RECORD -- GENERAL

REPORT NO.: SI-235
SHEET NO.: ___ OF ___ SHEETS

LOCATION: SEQUOYAH NUCLEAR PLANT
SUBJECT: 6.9KV SD BD 2BB LOGIC RelAYS
GENERAL DATA: G.E. UNDERVOLTAGE RelAYS 12IAV54E1A 115V. 60 HZ

DATE OF TEST: 9-12-85
DATE OF REPORT:

COPIES SENT TO:

TESTED BY: CLC-BGM
CHECKED BY:
APPROVED BY:

SS#8119

SI-235

Key C415A

Device	Phase	Panel	Decrease voltage Pickup	Time to close Contacts on Loss of Potential in Secs.	Target
27S12B	A	1	81 V	5	.2A
27S12B	C	1	81 V	5	.2A
27D12B	A	2	81 V	1.5	.2A
27D12B	C	2	81 V	1.5	.2A
27S22B	A	3	81 V	5	.2A
27S22B	C	3	81 V	5	.2A

EQUIPMENT	TVA #	Due Date
EIL FTS-300 Set	486218	7-12-86
Keithley Voltmeter	537776	11-15-85

Attachment No. 2 Sheet 9 of 9
Loop #/Identifier 27 SIA

TVA 6472 (PO-4-68)

GENERAL ELECTRIC

UTILITY & INDUSTRIAL SALES DIVISION
GENERAL ELECTRIC COMPANY • 141 PROVIDENCE ROAD • P.O. BOX 30697 • CHARLOTTE, NORTH CAROLINA 28230 • (704) 371-3300

May 11, 1987

J. C. Arnett
Tennessee Valley Authority
400 West Summit Hill
Location W8C
Knoxville, TN 37902

Dear Tim:

In response to your question on the repeatability of 12IAV54E1A and F1A relays, our factory has the following information:

REPEATABILITY

The operating voltage (pick-up voltage) will repeat within ± 2% if the frequency and ambient temperature are held constant.

The operating (pick-up) time will repeat within ± 4% if the frequency and ambient temperature are held constant.

ACCURACY

The relay will operate at the tap value voltage ± 2%.

The relay will match published time curves within ± 7% or ± 0.01 times the time dial setting, whichever is larger.

Since our factory has not qualified these models of relays for Class 1 E service, we have no data on the effects of temperature or aging.

Sincerely,

R. D. Dartnall
Senior Application Engineer

CC: E. D. DeBoer-Chattanooga, TN

RDD87018W:pw

Attachment No. 8 Sheet 1 of 1
Loop #/Identifier 27 S1A

Prepared: [signature]
Checked: [signature]
Reviewed: [signature]
Date: 2-10-86
Rev R1

Sheet 1 of 1

SQN E3 002

SEQUOYAH NUCLEAR DIESEL GENERATOR LOADING SEQUENCE

FOR BO (LOSS OF OFF-SITE POWER) ON POWER TRAIN 2B

Component	Load Rating	Time* (Sec)	Starting P.F.	Acc Time (Sec)	Remarks	Running P.F.	Running Eff.
Random Loads	229 HP	-	0.523	5 Max. @** Min. Volts	1294 Kva Starting	.85**	.9**
6.9kV to 480V transformers	3 @ 1500 kVA, 1 @ 300 kVA	0	0.483	5 Max @** Minimum Volts	679 HP 2699 Kva Starting	.85**	.9**
Centrifugal Charging Pump	600 hp rated 690 ~~687~~ hp actual	2	.29 ~~.2868~~	4.5 @ 100% Volt, 11.5 @ 80% Volt	3601 kVA Δ Starting	.929	.939 | RG
Essential Raw Cooling Water Pump	700 hp	15	.17**	1.4 @ 100% Volt, 1.98 @ 90% Volt	3852 kVA Δ Starting	.856	.925
Component Cooling Pump	2 @ 350 hp rated 355 hp actual	20	.2098	3.6 @ 100% Volt, 6.0 @ 80% Volt	5541 kVA Δ Starting	.875	.928
Auxiliary Feedwater Pump	500 hp rated 540 hp actual	25	.18**	5 Max @** Minimum Voltage	2789 kVA Δ Starting	.915	.93
Pressurizer Heaters	485 kw	≥ 90	-		-	-	-
Fire Pumps	200 hp rated	≥ 120	.32	2 @ 85% Volt	876 kVA Δ Starting	.815	.895

*Time is measured from closing of circuit breaker connecting the diesel generator to the power train with 5% timing accuracy.
**Assumed values
Δ Kva was calculated at 6.6 Kv.

Attachment No. 9 Sheet 1 of 1
Loop #/Identifier 275.1A

0671A

THE FULL LINE OF I-T-E TYPE HK CIRCUIT BREAKERS ARE RATED ON A TRUE SYMMETRICAL BASIS

APPLICATION DATA

TABLE 7 AIR-MAGNETIC POWER CIRCUIT BREAKERS—Ratings on a symmetrical basis.

Type of Breaker	Nominal Rating: Three Phase MVA	Nominal Rating: Voltage KV RMS	Rated Cont. Current 60 Hertz AMPS RMS	Rated Voltages: Maximum Voltage KV RMS	Rated Voltages: K Factor Max KV / Min KV	Rated Voltages: Minimum Voltage KV RMS	Insulation Level Rated Withstand: Low Frequency KV RMS	Insulation Level Rated Withstand: Impulse Δ 1.2 x 50 MS KV Crest	Interrupting Ratings† AMPS Symmetrical: Maximum KV AMPS RMS	Interrupting Ratings† AMPS Symmetrical: Nominal KV AMPS RMS	Interrupting Ratings† AMPS Symmetrical: Minimum KV AMPS RMS	Asymmetrical ○ Rating Factor	Short Time Rating 3 Sec AMPS RMS	Close and Latch Rating AMPS RMS	Interrupting Time Cycles
5 HK 75	[illegible]	4.16	1.200	4.76	1.36	3.50	19	60	9.100	10.500	12.500	1.2	12.500	20.000	5
5 HK 250	250	4.16	1.200	4.76	1.24	3.85	19	60	30.300	35.000	37.500	1.2	37.500	60.000 ‡	5
5 HK 250	250	4.16	2.000	4.76	1.24	3.85	19	60	30.300	35.000	37.500	1.2	37.500	60.000 ‡	5
5 HK 350	350	4.16	1.200	4.76	1.19	4.00	19	60	42.400	48.600	50.000	1.2	50.000	80.000	5
5 HK 350	350	4.16	2.000	4.76	1.19	4.00	19	60	42.400	48.600	50.000	1.2	50.000	80.000	5
5 HK 350	350	4.16	3.000	4.76	1.19	4.00	19	60	42.400	48.600	50.000	1.2	50.000	80.000	5
7.5 HK 500	500	7.20	1.200	8.25	1.25	6.6	36	95	35.000	40.000	44.000	1.2	44.000	70.000	5
7.5 HK 500	500	7.20	2.000	8.25	1.25	6.6	36	95	35.000	40.000	44.000	1.2	44.000	70.000	5
15 HK 500	500	13.8	1.200	15.0	1.30	11.5	36	95	19.300	21.000	25.000	1.2	25.000	40.000	5
15 HK 500	500	13.8	2.000	15.0	1.30	11.5	36	95	19.300	21.000	25.000	1.2	25.000	40.000	5
15 HK 750	750	13.8	1.200	15.0	1.30	11.5	36	95	28.900	31.500	37.500	1.2	37.500	60.000‡	5
15 HK 750	750	13.8	2.000	15.0	1.30	11.5	36	95	28.900	31.500	37.500	1.2	37.500	60.000‡	5
15 HK 1000	1.000	13.8	1.200	15.0	1.30	11.5	36	95	38.500	42.000	50.000	1.2	50.000	80.000	5
15 HK 1000	1.000	13.8	2.000	15.0	1.30	11.5	36	95	38.500	42.000	50.000	1.2	50.000	80.000	5
15 HK 1000	1.000	13.8	3.000	15.0	1.30	11.5	36	95	38.500	42.000	50.000	1.2	50.000	80.000	5

Notes: †—For operating voltages other than those listed the interrupting Current = Amps at Max. KV $\frac{\text{Max. KV}}{\text{Operating KV}}$ but in no case can this current exceed the interrupting Current at Minimum KV.
‡—60.000 Amp also available.
‡—80.000 Amp also available.
○—Rating factor is based on breaker speed from initiation to contact parting with ½ cycle relay time. Multiply factor x symmetrical current to obtain asymmetrical current interrupting capability of breaker.
Δ—These values apply with circuit breaker in or out of switchboard.

TABLE 8

CONTROL POWER REQUIREMENTS						
	Closing Coil		Tripping Coil		Charging Motor	
Nominal Control Voltage	Voltage Range Volts	Average Current A	Voltage Range Volts	Average Current A	Voltage Range Volts	Average Current A
24V D.C.Δ	—	—	14-30	22.0	—	—
48 V D.C.	35-50	10.7	28-60	10.7	35-50	20
125 V D.C.	90-130	6.7	70-140	6.7	90-130	10
250 V D.C.	180-260	2.2	140-280	2.2	180-260	5
115 V A.C.	95-125	4.5	95-125	4.5	95-125	10
230 V A.C.	190-250	2.3	190-250	2.3	190-250	5

ΔUnless the circuit breaker is located close to the battery and relay and adequate electrical connections are provided between the battery and trip coil 24-volt tripping is not recommended.

TABLE 10

STANDARD CURRENT TRANSFORMERS						
RATIO*	RELAYING† ACCURACY	METERING ACCURACY†				
	10H	B0.1	B0.2	B0.5	B1	B2
75/5	10	0.6	1.2	—	—	—
100/5	10	0.6	1.2	—	—	—
150/5	20	0.3	0.6	1.2	—	—
200/5	20	0.3	0.6	1.2	—	—
300/5	50	0.3	0.3	0.3	0.6	1.2
400/5	50	0.3	0.3	0.3	0.3	0.6
600/5	100	0.3	0.3	0.3	0.3	0.3
800/5	100	0.3	0.3	0.3	0.3	0.3
1200/5	200	0.3	0.3	0.3	0.3	0.3
1500/5	200	0.3	0.3	0.3	0.3	0.3
2000/5	200	0.3	0.3	0.3	0.3	0.3
2500/5	200	0.3	0.3	0.3	0.3	0.3
3000/5	200	0.3	0.3	0.3	0.3	0.3
4000/5	200	0.3	0.3	0.3	0.3	0.3

*Front mounted CT's are available only up to 2000/5A.
†For higher accuracies refer to the nearest I-T-E district sales office.

TABLE 12

Standard Single Phase Control Power Transformers	
KVA	Voltage
5	2400—240/120
	4160—240/120
10	4800—240/120
	7200—240/120
15	8400—240/120
	13200—240/120
25	13800—240/120

TABLE 9

HK BREAKER TIME CHARACTERISTICS				
Breaker	Av. Closing	Av. Tripping	Av. Spring Charging	Interrupting Time 0-100% of Rating
5 HK	4.5 Cycles	1.5 Cycles	2 Seconds	5 Cycles
7.5 & 15 HK	7.5 Cycles			
15 HK 1000	6 Cycles	2.0 Cycles	2 Seconds	5 Cycles

Closing Time—Between energizing closing coil and making of arcing contacts
Tripping Time—Between energizing of trip coil and parting of arcing contacts
Interrupting Time—Between energizing trip coil and complete interruption

TABLE 11

Space Heaters for Outdoor Equipment*		
Type Unit	No. of Heaters Per Frame	Total Watts Per Frame
5 HK	2	300
7.5 & 15 HK	3	450

*Space heaters on indoor equipment are an optional addition.

TABLE 13

Standard Potential Transformers
2400/4160y—120
2400—120
4200—120
4800—120
7200—120
8400—120
12000—120
14400—120

Attachment No. 10 Sheet 1 of 2
Loop #/Identifier 27 SIA

SPECIAL APPLICATION CONSIDERATIONS

HK air-magnetic power circuit breakers are capable of switching reactive load current up to their full continuous current rating. Reactor switching applications wherein the reactor(s) are in close proximity (within ten feet) of the circuit breaker(s) should be referred to the nearest I-T-E district sales office for consideration.

Standard HK circuit breakers are capable of switching capacitors, single or back-to-back, in accordance with the data outlined in Table 4 below.

Capacitor installations are generally applied on both utility and industrial power systems to improve voltage regulation, enhance system stability and to provide for system expansion.

The shunt bank or back-to-back capacitor switching application means either connecting or disconnecting a capacitor bank to or from a bus to which a single bank, equal to or less than the switching bank, is already connected. Generally, HK air-magnetic circuit breakers can switch any capacitor bank as long as the breaker continuous current rating equals or exceeds 1.35 times the nominal current rating of the capacitor bank. However, for complex capacitor switching applications or where frequent switching is contemplated, contact the nearest I-T-E district sales office for recommendations.

Table 4 — MAXIMUM 3-PHASE SINGLE-CAPACITOR-BANK SWITCHING

Capacitor Voltage, Volts	HK BREAKER CONTINUOUS CURRENT RATING*			
	1200A		2000A	
	Capacitor Bank KVAR	Capacitor Switching Capability, A	Capacitor Bank KVAR	Capacitor Switching Capability, A
2400	3700	890	6200	1480
4160	6400	890	10700	1480
4800	7400	890	12300	1480
7200	11100	890	18500	1480
12470	19200	890	32000	1480
13800	21500	890	35400	1480

NOTES: Ratings are subject to the following conditions:

1. The transient voltage from line to ground shall not exceed 3 times maximum design line-to-ground crest voltage measured at the breaker terminals.
2. The number of restrikes or reignitions shall not be limited as long as the transient voltage to ground does not exceed the value given in Note 1.
3. The capacitor rating applies only to "Single Bank Switching" as noted herein.
4. Interrupting time is in accordance with the rated interrupting time of the circuit breaker.

*For 3,000 A, refer to the nearest I-T-E district sales office.

AUTOMATIC BUS TRANSFER TIMES FOR STATION AUXILIARIES

Bus transfer can be initiated under two conditions. The first condition is called **routine transfer** and is done when the generating unit is started up or shut down. The second condition is called **emergency transfer** and is necessary upon failure of the normal source of power. Routine transfer can be handled in many ways and the problems incurred are generally minor. However, automatic bus transfer of station auxiliaries under emergency conditions, whether for conventional steam or nuclear stations, must be accomplished with a minimum dead bus time. Dead bus time is more critical for nuclear stations because coolant pump motors are involved. If the coolant pumps are lost, the nuclear reactor must be shut down!

Bus transfer times should be held to some low value because motors slow down and go out of phase. With these conditions, if the emergency source is energized, there will be large inrush currents. This is undesirable and could result in total loss of the bus under certain circumstances. Consequently, there must be a coordinated bus transfer time to keep these conditions to a minimum.

There seems to be two prevalent choices of required dead bus time: 50ms (three cycles) or 100ms (six cycles). Of these, 100ms (six cycles) is indicated to be generally preferred. Accordingly, this can be thought of as a significant level of comparison with the dead bus transfer times of the HK air-magnetic circuit breakers listed in Table 5.

Table 5 lists the dead bus transfer times of HK air-magnetic circuit breakers normally applied on generating station auxiliary circuits:

Table 5—HK BREAKER DEAD BUS TRANSFER TIMES

Breaker		DEAD BUS TRANSFER TIME, ms (cycles)‡†				
Type	Continuous Current Rating, A	Simultaneous Trip & Close (No arcing)	Simultaneous Trip & Close (With arcing)	Trip then Close using Standard "b" Contact (With arcing)	Trip then Close using Early "b" Contact (With arcing)	Trip then Close using Early "b" Contact (No arcing)
5 HK 350	1200 2000 3000	50(3) 50(3) 55(3.3)	20(1.2) 20(1.2) 25(1.5)	85(5.1) 85(5.1) 120(7.2)	45(2.7) 45(2.7) 80(4.8)	75(4.5) 75(4.5) 110(6.6)
7.5 HK 500	1200 2000	95(5.7)	55(3.3)	130(7.8)	90(5.4)	130(7.8)
15 HK 500	1200 2000	95(5.7)	60(3.6)	145(8.7)	105(6.3)	140(8.4)
15 HK 750	1200 2000	95(5.7)	55(3.3)	130(7.8)	90(5.4)	130(7.8)

‡All times shown are nominal.
†Tolerance on dead time is ± 16.7 ms (1 cycle).

Attachment No. 10 Sheet 2 of 2
Loop #/Identifier 27 SIA

Rev. R14

SQN E3 002

Attachment No. 11 Sheet 1 of 2
Lisp #/Identifier 27 S 1A

SEQUOYAH NUCLEAR DIESEL GENERATOR LOADING SEQUENCE

FOR LO AND SI-PHASE B ON POWER TRAIN 2B

Component	Load Rating	Time* (Sec)	Starting P.F.	Acc Time (Sec)	Remarks	Running P.F.	Running Eff.
Random Loads	190 HP	--	.496	5 Max. @** Min. Volt	1047 Kva Starting	0.85**	0.9**
6.9kV to 480V transformers	3 @ 1500 KVA, 1 @ 300 kVA	0	.578	5 Max @** Minimum Volts	572 Conn. HP 2351 Kva Starting	.85**	.9**
Centrifugal Charging Pump	600 hp rated 690 687 hp actual	2	.22 .2068	4.5 @ 100% Volt, 11.5 @ 80% Volt	3601 kVA Δ Starting	.929	.939 | R6
Safety Injection Pump	400 hp rated 410 hp actual	5	.25	2.7 @ 100% Volt, 6.8 @ 80% Volt	2458 kVA Δ Starting	.895	.933
Residual Heat Removal Pump	400 hp rated 422 hp actual	10	.2928	1.6 @ 100% Volt, 3.8 @ 80% Volt	2401 kVA Δ Starting	.937	.938
Essential Raw Cooling Water Pump	700 hp	15	.17**	1.4 @ 100% Volt, 1.98 @ 90% Volt	3852 kVA Δ Starting	.856	.925
Component Cooling Pump	2 @ 350 hp rated 355 hp actual	20	.2098	3.6 @ 100% Volt, 6.0 @ 80% Volt	3541 kVA Δ Starting	.875	.928
Auxiliary Feedwater Pump	500 hp rated 540 hp actual	25	.19**	5 Max @** Minimum Voltage	2709 kVA Δ Starting	.915	.93
Containment Spray Pump	700 hp rated 690 hp actual	~~30~~ 180	.2711	3.1 @ 100% Volt, 11 @ 80% Volt	4050 kVA Δ Starting	.934	.945

Prepared [illegible]
Checked [illegible]
Reviewed [illegible]
Date 2-10-86
Rev R1

SQN E3 002

FOR BO AND SI-PHASE A ON POWER TRAIN 2B

Component	Load Rating	Time* (Sec)	Starting P.F.	Acc Time (Sec)	Remarks	Running P.F.	Running Eff.
Fire Pumps	200 hp rated	≥ ~~120~~ 210	.32	2 @ 85% Volt	876 KVA Δ Starting	.815	.895

*Time is measured from closing of circuit breaker connecting the diesel generator to the power train with 5 percent timing accuracy.

**Assumed values

Δ Kva was calculated at 6.6 Kv.

0663A

Attachment No. 11 Sheet 2 of 2
Loop #/Identifier 275.6

Standby Diesel Generator Operation

The diesel generator system is shown on single line diagram, Figure 8.3.1-17. The schematic of the engine start and stop circuits is shown in Figure 8.3.1-18. Remote control of the engine from the main control room is accomplished through interposing relays located in the diesel building. The schematic for this control is shown in Figure 8.3.1-19.

The 6.9-kV shutdown boards in each power train derive power from either of two circuits from the 6.9-kV unit boards, or from their respective standby power source. During conditions where neither the nuclear unit nor preferred (offsite) power are available, each 6.9-kV shutdown board is energized from a separate, 1
independent dedicated standby diesel generator unit. See Table 8.2.1-1 for complete description of board transfer schemes.

The connection of the diesel generators to the 6.9-kV shutdown boards is initiated by either the loss-of-voltage relays on the 6.9-kV bus or the degraded voltage relays. The loss-of-voltage 1
relays are set to dropout at 80 percent of nominal whereas the degraded voltage relays are set to dropout at 95 percent of nominal. A sustained voltage below these setpoints will initiate starting the diesel generators, tripping the normal or alternate feeder breaker, all 6.9-kV loads except the 480V shutdown board transformers, and the major 480V loads. Table 8.3.1-1 lists the loads that are automatically tripped. For a complete description of the voltage relay logic, see the system description of this section (page 8.3-4). When the diesel generator set has reached accelerated to a speed of 850 rpm and voltage of 80 percent of nominal (maximum of 10 seconds from initiation of automatic start signal), it is automatically connected to the 6.9-kV shutdown board bus. The return of voltage to the 6.9-kV shutdown board initiates logic which connects the required loads in the proper sequence. Table 8.3.1-2 shows the order in which the loads are applied.

The loss of voltage shedding relays remain in the circuit at all times. If the load shedding relays voltage (≤ 70 percent) and 1
time delay (5 seconds at 0 volts) setpoint is reached, the proper operation is:

1. To shed loads to prevent overloading the diesel generator.
2. Allow the diesel generator to recover to rated speed and voltage.
3. Reconnect the loads in the proper sequence.

Since the load shedding relays recognize loss of voltage, the starting of the largest driven load will not cause actuation of the load shedding feature.

As shown in Table 8.3.1-2, there are two loading sequences. One,

Attachment No. 12 Sheet 1 of 1
Loop #/Identifier 27 S1A

37 ... 05

L44 870312 303

5N 157B Lookout Place

MAR 12 1987

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Office of Nuclear Reactor Regulation
Washington, D.C. 20555

Attention: Mr. Stewart Ebneter

In the Matter of) Docket Nos. 50-327
Tennessee Valley Authority) 50-328

SEQUOYAH NUCLEAR PLANT - DIESEL GENERATOR LOADING SEQUENCES

NRC requested information regarding the Sequoyah diesel generator loading sequence analyses during a meeting between TVA and NRC on January 21, 1987. TVA evaluated three diesel generator loading sequences: loss of offsite power, loss of offsite power coincident with safety injection and Phase A containment isolation, and loss of offsite power coincident with safety injection and Phase B containment isolation. Plant modifications required to meet these sequences are being implemented before restart of the respective units.

Presently, the Sequoyah Final Safety Analysis Report (FSAR) identifies two additional diesel generator loading sequences in addition to those listed above: loss of offsite power with a delayed safety injection and safety injection with a delayed loss of offsite power. TVA is not evaluating these sequences because the delayed loss of offsite power and safety injection cases do not significantly contribute to the probability of core melt. TVA will revise the FSAR to identify that only the coincident diesel generator loading sequences are design basis events. This revision is scheduled for the 1988 annual update.

The current TVA position on design basis diesel generator loading sequences is consistent with NRC Power Systems Branch review reminder No. 11. NRC has also reviewed the loss of offsite power following safety injection reset and determined that TVA had adequate procedures to recover from such an event. NRC's review was documented in sections 6.3.3 and 7.3.2 of their safety evaluation report.

The enclosure to this letter lists the commitments made in this letter.

Very truly yours,

TENNESSEE VALLEY AUTHORITY

Original Signed By
R. L. Gridley

R. Gridley, Director
Nuclear Safety and Licensing

Enclosure
cc: see page 2

Attachment No. 13 Sheet 1 of 1
Loop #/Identifier 2751A

QUALITY INFORMATION REQUEST / RELEASE (QIR)
DIVISION OF NUCLEAR ENGINEERING
(INTERNAL USE ONLY)

QA Record

RIMS ACC NO. B43 '87 0721 902

TO C.A. Chandley W7C127 C-K

FROM W.S. Raughley W8C127 C-K

DOCUMENT NUMBER QIR EEB 87330 21 1987

PAGE 1 OF 2

TYPE OF DOCUMENT
[X] REQUEST NEED DATE 7-22-87
[ ] RELEASE REF. QIR

DATE Prepare Reply

PLANT AND UNIT Sequoyah Unit 2

REFERENCED DOCUMENTS

AVAILABLE IN ONE OF THE RIMS SYSTEMS		ATTACHMENT TO THIS QIR	
DOCUMENT	IDENTIFYING NUMBER	DOCUMENT	ATTACHMENT NUMBER
DG Timer Relays	B43870615905		

SUBJECT Diesel Generator Sequence Timers

SYSTEMS AFFECTED 3B, 63, 67, 70, 72, 74, 82

UNID / SYSTEM ID

QUALITY INFORMATION REQUESTED / RELEASED

Results of Demonstrated Accuracy Calculation "DG Timer Relays" (B43870615 905) show the inaccuracies of the sequence timers to be greater than the ±5% originally assumed. This presents a problem in two areas. If the timing intervals are too short they could impact the reliability of D.G. loading. If the sequence times are too long they could cause the ESF loads to be sequenced on later than previously assumed.

Due to the relationship between motor acceleration times and possible sequence intervals, it is desirable to change the loading sequence as noted in the attached table in order to increase D.G. loading reliability.

The attached table shows the relationship between existing nominal sequence times with tolerences and Proposed sequence times with tolerences.

Please Confirm that the Proposed loading sequence maximum times are adequate to support Process System Requirements under your Discipline's responsibility. Confirmation is required by 7-22-87. This information has also been Requested from D.W. Wilson on ~~EES~~ QIR EEB 87329

PREPARED
W. Cecil Thomas, Jr. W8C197 3097

REVIEWED (RELEASES ONLY)

APPROVED (BRANCH CHIEF/PROJECT ENGINEER)
PGuha 7/17/87 for W.S. Raughley

TVA 10829 (DNE 6-86)

cc (Attachments): RIMS, SL 26 C-K
R.C. Williams DSC P107 SQN

Attachment No. 14 Sheet 1 of 15
Loop #/Identifier 2751A

LOADING SEQUENCE TABLE

Existing Sequence

Load	Nominal time	max time
misc. Loads	t_0	0
Cent Chg Pmp	2 sec	2.32 sec
SI Pmp	5 sec	5.8 sec
RHR Pmp	10 sec	11.6 sec
ERCW Pmp	15 sec	17.4 sec
Comp Cool. Pmp	20 sec	23.2 sec
Aux FW Pmp	25 sec	29 sec
Contmnt Spray	180 sec	209 sec
**Elec Bd Rm AHU	220 sec	255 sec

Proposed Sequence

Load	Nominal time	max time
misc. Loads	t_0	0
Cent Chg Pmp	2 sec	2.32 sec
SI Pmp	5 sec	5.8 sec
RHR Pmp	10 sec	11.6 sec
ERCW Pmp	15 sec	17.4 sec
*Aux FW Pmp	20 sec	23.2 sec
*Comp. Cool. Pmp	30 sec	34.8 sec
Cont. Spray	180 sec	209 sec
**Elec Bd Rm AHU	240 sec	286 sec

*NOTE this is a proposed change

** Electric Board Room AHU will be "permissive to start" at this time but actual start will be determined by Process.

Note. t_0 is the time at which the Diesel Generator is Connected to the Shutdown Board. t_0 will occur no later than 10.25 seconds after the the closure of the S.I. initiation contact (which will also start the Diesel).

For Loss of offsite Power without S.I., t_0 will occur not more than 12 seconds after Loss of offsite Power.

Attachment No. 19 Sheet 2 of 15
Loop #/Identifier 2851A

QUALITY INFORMATION REQUEST / RELEASE (QIR)
DIVISION OF NUCLEAR ENGINEERING
(INTERNAL USE ONLY)

QA Record

TO D. W. Wilson W10 C127 C-K	RIMS ACCNO B43 '87 0721 903
	DOCUMENT NUMBER QIR EEB 87329
FROM W. S. Raughley W8 C127 C-K	PAGE 1 OF 2
TYPE OF DOCUMENT ☒ REQUEST NEED DATE 7-22-87	DATE
☐ RELEASE REF. QIR	PLANT AND UNIT Sequoyah Unit 2

REFERENCED DOCUMENTS

AVAILABLE IN ONE OF THE RIMS SYSTEMS		ATTACHMENT TO THIS QIR	
DOCUMENT	IDENTIFYING NUMBER	DOCUMENT	ATTACHMENT NUMBER
DG Timer Releys	B43870615905		

SUBJECT Diesel Generator Sequence Timers

SYSTEMS AFFECTED 36, 63, 67, 70, 72, 74, 82 UNID / SYSTEM ID

QUALITY INFORMATION REQUESTED / RELEASED Results of Demonstrated Accuracy Calculation "DG Timer Relays" (B43870615 905) show the inaccuracies of the sequence timers to be greater than the ±5% originally assumed. This presents a problem in two areas. If the timing intervals are too short they could impact the reliability of D.G. loading. If the sequence times are too long they could cause the ESF loads to be sequenced on later than previously assumed.

Due to the relationship between motor acceleration times and possible sequence intervals, it is desirable to change the loading sequence as noted in the attached table inorder to increase D.G. loading reliability.

The attached table shows the relationship between existing nominal sequence times with tolerences and Proposed sequence times with tolerences.

Please Confirm that the Proposed loading sequence maximum times are adequate to support Process System Requirements under your Discipline's responsibility. Confirmation is required by 7-22-87. This information has also been requested from C.A. Chandley on QIR EEB 87330

PREPARED W. Cecil Thomas Jr. W8 D97 3097

REVIEWED (RELEASES ONLY)

APPROVED (BRANCH CHIEF/PROJECT ENGINEER)
P Enha 7 17 87 for W. S. Raughley

TVA 10829 (DNE 6-86)

cc (Attachments): RIMS, SL 26 C-K
R.C. Williams OSC P107 SQN

Attachment No. 14 Sheet 3 of 15
Loop #/Identifier 2751A

TVA

QUALITY INFORMATION REQUEST
EEB 87329

LOADING SEQUENCE TABLE

Existing Sequence			Proposed Sequence		
Load	Nominal time	max time	Load	Nominal time	max time
misc. Loads	t_0	0	misc. Loads	t_0	0
Cent Chg Pmp	2 sec	2.32 sec	Cent Chg Pmp	2 sec	2.32 sec
SI Pmp	5 sec	5.8 sec	SI Pmp	5 sec	5.8 sec
RHR Pmp	10 sec	11.6 sec	RHR Pmp	10 sec	11.6 sec
ERCW Pmp	15 sec	17.4 sec	ERCW Pmp	15 sec	17.4 sec
Comp Cool. Pmp	20 sec	23.2 sec	*Aux Fw Pmp	20 sec	23.2 sec
Aux FW Pmp	25 sec	29 sec	*Comp. Cool. Pmp	30 sec	34.8 sec
Contmnt Spray	180 sec	209 sec	Cont. Spray	180 sec	209 sec
**Elec Bd Rm AHU	220 sec	255 sec	**Elec Bd Rm AHU	240 sec	286 sec

*NOTE this is a proposed change

** Electric Board Room AHU will be "permissive to start" at this time but actual start will be determined by Process.

Note. t_0 is the time at which the Diesel Generator is Connected to the Shutdown Board. t_0 will occur no later than 10.25 seconds after the the closure of the S.I. initiation contact (which will also start the Diesel).

For Loss of Offsite Power without S.I., t_0 will occur not more than 12 seconds after Loss of offsite Power.

Attachment No. 14 Sheet 4 of 15
Loop #/Identifier 27 SIA

QUALITY INFORMATION REQUEST / RELEASE (QIR)
DIVISION OF NUCLEAR ENGINEERING
(INTERNAL USE ONLY)

QA Record

TO W. S. Raughley W8 C126	RIMS ACCNO B44 '870724 006
FROM C. H. Chandley	DOCUMENT NUMBER QIR MEB SQN 87139
	PAGE 1 OF 2
TYPE OF DOCUMENT ☐ REQUEST NEED DATE	DATE 7/24/87
☒ RELEASE REF. QIR EEB 87330	PLANT AND UNIT SQN-2

REFERENCED DOCUMENTS

AVAILABLE IN ONE OF THE RIMS SYSTEMS		ATTACHMENT TO THIS QIR	
DOCUMENT	IDENTIFYING NUMBER	DOCUMENT	ATTACHMENT NUMBER
DG Timer Relays	B43 870615 905		

SUBJECT: Diesel/Generator Sequence Times

SYSTEMS AFFECTED: 67

UNID / SYSTEM ID:

QUALITY INFORMATION REQUESTED / RELEASED

We have reviewed the revised Loading Sequence Table and have the following comments:

Reducing the Auxillary Feedwater (AFW) Pump starting sequence time from 29 sec. to 23.2 sec. is acceptable. Reducing this time will help establish AFW flow to the Steam Generators by 60sec. as assumed in the accident analysis.

The timers that control the Electric Board Room AHU motors starters operate independently from the recycle timers in the associated condensing units. The recycle timers are set between 15 and 20 minutes. Therefore, increasing the AHU fan start time from 255 sec. to 286 sec. (less than 5 min.) has no impact on the system and is acceptable. (Coordinated between MEB's Dennis Schatte and EEB's Wade Holbrook on 7/23/87)

PREPARED: Richard K Freeman 7/24/87

REVIEWED (RELEASES ONLY): K R Corbett

APPROVED (BRANCH CHIEF/PROJECT ENGINEER): C H Chandley

TVA 10829 (DNE 6-86)

cc (Attachment): RIMS ...

Attachment No 19 Sheet 5 of 5
Loop #/Identifier 27.31A

Quality Information Release

Document Number
QIR MEB SQN 87139

The loading time for the Component Cooling System (CCS) pumps comes from the Westinghouse accident analysis. This change in CCS pump starting time will be addressed by NEB in their reply to your QIR EEB 87329.

QUALITY INFORMATION REQUEST / RELEASE (QIR)

DIVISION OF NUCLEAR ENGINEERING

(INTERNAL USE ONLY)

	RIMS ACCNO
TO R.C. Williams	DOCUMENT NUMBER QIR - SOP-87-421
FROM H.L. Jones	PAGE 1 OF 6
TYPE OF DOCUMENT ☐ REQUEST NEED DATE	DATE 14 August 1987
☒ RELEASE REF. QIR EEB 87329	PLANT AND UNIT Sequoyah Unit 2

REFERENCED DOCUMENTS

AVAILABLE IN ONE OF THE RIMS SYSTEMS **		ATTACHMENT TO THIS QIR	
DOCUMENT	IDENTIFYING NUMBER	DOCUMENT	ATTACHMENT NUMBER
QIR EEB 87329	B43870721903	ECN L7216	#1
W LTR TVA-86-738	B45861208600	ECN L7221	#2
W LTR TVA-86-743	B45861204600	QIR EEB 87329	#3
W LTR TVA-87-625	B25870414011	W LTR TVA-87-720	#4
W LTR TVA-87-636	B25870428021		

SUBJECT Diesel Generator Sequence Timers

SYSTEMS AFFECTED 38, 63, 67, 70, 72, 74 & 82

UNID / SYSTEM ID

QUALITY INFORMATION REQUESTED / RELEASED

This QIR is in response to QIR EEB87329 from W.S. Raughley to D.W. Wilson (principally prepared by W. Cecil Thomas Jr.) The request requires NEB review and confirmation of a proposed loading sequence with maximum loading times resulting from the "DG Timer Relay Calculation" and tests conducted under SI-220. Two separate issues must be addressed in the NEB response

1) Affect on the Safety evaluation by interchanging the auxiliary feedwater pump with the component cooling pump in the sequence.

* "BASIS FOR DELAYING THE START TIME FOR CONT. SPRAY" #5
ENGINEERING STUDY "RHR PUMPS: PUMP START UP TIME" #6

** W LTR TVA-178 (April 21, 1969) "COMPONENT COOLING WATER SYSTEM DESIGN"
W LTR TVA-87-734 (B25870720001)
SIS Design Criteria SQN-DC-V-27.3 Rev 2 (B45870722252)

PREPARED [signature] 8/14/87	REVIEWED (RELEASES ONLY) WR Mangiante/ksu 8/19/87

APPROVED (BRANCH CHIEF/PROJECT ENGINEER)
[signature] 8/20/87

TVA 10829 (DNE 6-86)

cc (Attachments): RIMS, SL 26 C-K

Attachment No. 14 Sheet 7 of 15
Loop #/Identifier 27SIA

2) Affect on the Safety Analysis due to maximum Sequence times.

Interchange AFWS and CCW pumps in DG load sequence

Although the relative times for loading each of the pumps (AFWS & CCW) on the DG do not change significantly from a system standpoint (vs DG for an electrical standpoint), a review of various documents to justify such a change is nevertheless required. Since the Centrifugal Charging, Safety Injection and Residual Heat Removal pumps require Component Cooling water, researching the documentation to determine if an additional 10 seconds delay for that service would affect the Safeguards pumps yielded no adverse conditions to deny this change. W Ltr TVA-178" Component Cooling Water System Design, Conversations with Pump Engineer D. M. Kitch W ELECTRIC Corporation (8/11/87), W Ltr TVA-87-625, CCS Design Criteria SQN-DC-V-13.9.9 (B05 16 07 21 5 19) & W Ltr TVA-86-743 provide the required background to justify approval to interchange the CCS and AFWS pumps on the load sequence.

The various documents, plus discussions with the W pump engineer (for clarification) and also the pump specification for the W supplied Auxiliary pumps #677125 rev 0 and #678786 rev 1, indicate the requirements for CCW to the pump mechanical seal coolers can be (and has been traditionally used by W) zero "0" up to one (1) minute, therefore covering the range of the loading sequence previously or now proposed. The CCW pumps are not modeled in the Appendix K analysis, and the sequence change therefore causes no affect in this regard.

Attachment No. 14 Sheet 8 of 15
Loop #/Identifier: 2751A

The RHR pump uses CCW for the oil cooler circuit however the same criteria of 1 minute applies, and the requirements for "Bearing Oil Cooling water" are adequately covered in the pump specifications previously referenced.

Reference to AFWS Design Criteria SQN-DC-V-13.9.8 and W Letters on the subject indicate the requirement of 1 min (60 sec) for Auxiliary Feedwater with no indication that loading the pump on the DG 5 seconds sooner will affect analysis. Since the AFWS pump(s) are being loaded in the proposed sequence at 20 secon vs the original 25 seconds the change in sequence with the CCS pump also is justified.

Other users for CCW such as the RHR Hx occurs during Recirculation and are not a matter of consideration.

Loading Sequence (Maximum loading times)

Testing of the timers (SI-220) supports the Demonstrated Accuracy Calculation for the timers (B43870615705) such that the accuracies exceeding ± 5% in the proposed DG loading list must be considered as being required. Review of W Ltr TVA-87-720, Design criteria SQN-DC-V-27.3 rev 2, and clarifying conversations with Mr. H. J. Cordle of W (reviewer and author of Appendix C of SQN-DC-V-27.3 rev 2) indicates that due to the early design considerations of the SIS that the "Event Sequence" indicated in the DC provides the limit data directly tied to the Safety Analysis. e.g Sequence "Loss of Coolant Accident/Secondary Accidents" the limit is 27 seconds for initiating event to "Full" pum "System injection Capability established" for a LOCA. Combinations of accuracies of various equipment in the sequence can vary in response times when deviations occur, or when equipment is changed, such that TVA can revise the structure to satisfy overall functions

Attachment 19 Sheet 9 of 15
Loop #/Ide 2251A

requirements without modification to the upper tier document so long as the data shown for limiting time is met. Since these times are not explicitly defined in the FSAR, and there is no indication either from the telecon with Mr Cordle (Originally the Manager of Reactor Fluid Systems throughout the major part of the design of the W 2, 3 & 4 loop plants including Sequoyah) or in other documents, that W has or has not done a sensitivity study on exceeding the limiting injection times for the SI, CCP and RHR pumps, it is concluded at present TVA must also abide by the data given in SQN-DC-V-27.3 rev 2 Appendix C.

Therefore in view of both positions, accepting 16% inaccuracy of the DG timers, and not exceeding the limits imposed by the event sequence in SQN-DC-V-27. the continued review of the potential to exceed full injection by ≈ 2 seconds leads to two alternate solutions.

1. Verify that the RHR pumps* (based on actual plant data) will accelerate to full flow in ≅ 3.4 seconds after the breaker closure to start.
2. Request W to analyze the current analyses to confirm that TVA Sequoyah will still meet the FSAR, with the additional delay for "full" injection.

Since the time frame, and probable success for the second alternative, precludes current TVA requirement QIR-SQP-87-443 (B25870819013) from MEB has verified + the RHR pumps will accelerate in ≅ 3.4 seconds and alternate 1 prevails. (See attachment 6 for text of QIR)

* The SI and CCPs have already sequenced on to the DG and should be at full injection capability within the bounds of the 27 seconds, thus the RHR sequence is limiting

Attachment No. 19 Sheet 10 of 15
Loop #/Identifier 27 JIA

Further review of the sequence loading times, led to the extensive report relative to Containment pressure calculations with extended spray pump loading delay, W LTR-86-738. The W study initiate by TVA desire to sequence the Containment Spray pumps on the D.G. at 180 seconds rather than 30 seconds, assumes an additional 28 seconds (or 208 seconds total) until actual spray occurs. Accepting the 16% error for the sequence start time will push the actual spray time to 237 seconds (209 seconds plus 28 seconds to come to full speed and flow and transport time to fill the piping to the ring headers and to spray nozzles). Two alternatives exist for approval of this maximum sequence time also

1. Review by the "Severe Accident & T/Hydraulics" organization in Knoxville (K. Kieth) of the W report, and any other supporting documents to confirm that 237 seconds to achieve spray flow will not obviate the results of the analysis (or with W assistan
2. Reset the 180 second timer to account for the error in order not to exceed 208 seconds to achieve full CS pump flow.

Attachment No. 19 Sheet 4 of 5
Loop #/Identifier 2751m

Since the time frame, and probable success for the second alternative precludes current TVA requirements, A basis for delaying the start time has been provided by APS 2 Severe Accident & Thermal Hydraulics (see attachment #5 for text, QIR to be revised to add RIM# later) which justifies a delay to 209 seconds and subsequent spray at 237 seconds.

Conclusions

(1. Switch of load sequence on DG between AFWS and CCW pumps is acceptable as proposed.

2. Maximum potential load times for the AFWS, ERCW pumps are acceptable as they relate to system analysis, and interface with the CCP, SI & RHR pumps respectively.

3. Maximum potential load times for the CCP, SI and RHR pumps is acceptable as long as the RHR pumps are at full injection flow capability in ≤ 3.4 seconds i.e D.G sequence time for the RHR pump is at 11.6 seconds (16% error)

(4. Maximum potential load sequence time for the containment spray pump is acceptable if the TVA review of the W analysis (change to 180 seconds) still results in satisfactory margin.

5. ECN L7221 must be implemented (8.5 seconds ± 1.36 seconds for the setpoint) in order not to exceed 10 Otherwise the resulting potential error will also contribute to exceeding the full flow injection limit. A alternate to implementing L7221 is to install a new state of the art timer with the ± 5% accuracy initially intended, retaining the 10 second set point.

(* Attachment #5 & #6, texts of a memo from T/H group Knoxv. and QIR-SQO-87-443 from MEB confirm acceptability.

Principally prepared by [signature] 8/14/87

Attachment No. 19 Sheet 13 of 13
Loop #/Identifier 27 J14

Attachment #5

BASIS FOR DELAYING THE START TIME FOR CONTAINMENT SPRAY

TVA has submitted a second proposed technical specification change regarding the loading sequence of the containment spray pumps on the emergency diesel generators. This change extended the delay of spray delivery from the previous change to 208 seconds, which includes timer delay, pump start-up time, and instrument inaccuracies, to 238 seconds due to additional delays associated with Agastat relays. The containment peak pressure and temperature analyses were examined to determine if this change would invalidate the analyses currently presented in the FSAR. The delay time in the current FSAR analysis assumed for loading the spray pumps on the diesels is 30 seconds. The proposed change would be to make this delay time 180 seconds plus an additional 16.5% error margin resulting in a 210 second delay. This error was not considered in the previous assessment of spray delay (see B45 861126 261). An additional of 28 seconds is included in the delay time to account for additional signal processing and pump startup to full flow.

The important parameters for evaluating the acceptability of this change are what energy removal role the sprays have before ice bed meltout and the time of containment spray switchover from RWST to the containment sump relative to the time of ice bed meltout. Because Sequoyah is an ice condenser plant, the sprays have little effect on the analysis while ice remains. The sprays do not actively remove energy from the containment atmosphere until the majority of the ice has melted. The peak containment pressure is the result of a large break LOCA. Figure 1 (FSAR Figure 6.2.1-21) shows a plot of upper compartment temperature versus time for this event. This figure shows that when the sprays are turned on, the upper compartment actually increases in temperature from the initial value of 80°F to the RWST temperature of 105°F. This temperature remains constant until the sprays are shut down to switchover to the containment sump. At this time, the containment temperature drops sharply because the cold air exiting the ice condenser is no longer being warmed by the spray water. The temperature recovers and stabilizes at the outlet temperature of the spray heat exchangers at about 2800 seconds once the spray pumps have been restarted. After ice bed meltout, the temperature of the upper compartment rises due to the hot steam from the lower compartment finally reaching the upper compartment. If the sprays had been actively removing energy from the upper compartment, the temperature would have increased rather than decreased when the sprays were shut off during the switchover to the emergency sump. In the FSAR chapter 6.2.1 LOCA analysis the current time of completion of switchover to the sump is 2516 seconds. The time of ice bed meltout is 3000 seconds. Changing the diesel loading sequence would change the time of switchover by a maximum of 180 seconds, including delays associated with the relays, to 2696 seconds. This change still leaves a substantial margin before ice bed meltout. Thus, the current FSAR analysis would not be affected by the change and is still valid.

The main steam line break results in the peak containment temperature. For these events, the ice bed does not melt before all mass and energy releases from the broken steam line to the containment are terminated. Thus, the change in the containment spray pump loading sequence has no affect on the current design analysis.

The current FSAR containment analyses supports the change in the diesel generator loading sequence. These analyses show the proposed change is not detrimental to the health and safety of the public.

Attachment No. 14 Sheet 13 of 15
Loop #/Identifier 2731A

TOTAL P.02

ENGINEERING STUDY
SEQUOYAH NUCLEAR PLANT

J. Hanevich
6/14/87

RHR PUMPS--PUMP START-UP TIME
UNIT 1 & 2

Determine the RHR pump's start-up time. This period is defined as the length of time needed for the pump to get to operating speed when it's motor breaker is energized.

REFERENCES

1. Westinghouse motor data, provided by EEB-Central Staff. Curve number 557934-1 and 665589-E.

2. Ingersoll-Rand pump instruction manual.

3. Pre-op test data W-2.2 (unit 1 8/29/78), (unit 2 3/6/81). Response time testing, RHR pumps.

4. SI-247.100A & B, IMI-99 RT-608A & B, IMI-99 RT-699A & B. Response time testing of ESF slave relays K-608, K-618.

   MasterFiles microfilm rolls:

453	2066	K-608A	1A-A pump	12/17/82
702	2925	K-608A	2A-A pump	10/4/84
621	1732	K-608B	2B-B pump	8/17/83
677	4054	K-608B	1B-B pump	4/6/84
677	4240	K-618B	1B-B pump	12/5/83

5. Interviews with Rich Mooney and Keith Weller of Systems Engineering, Bill McKay of Mechanical Test, and John Edwards of I&C.

6. ECN L-7216.

INFORMATION

- Motor synch. speed - 1800rpm (ref. 2)
- Full load rpm - 1783 (ref .2)
- Full torque of 2900 Ft-lbs @ 1705rpm (ref. 1)
- Motor acceleration time @ 6600V, 30 to 180A - 1.6 to 1.5 seconds.

DETERMINATION

The pre-op test graphs and the IMI response time graphs were used to extract the RHR pump start-up times. The pumps were aligned for mini-flow recirculation and then a test SI signal was input to the solid state protection system relays. This relay (125VDC on the 6.9KV shutdown boards) tells the pump to auto start. A strip chart records the time of the input signal vs the output pressure of the pump. In recirc, the

system pressure oscillates at first but is dampened-out in 2 to 3 seconds. The pressure oscillations are considered not to affect the pump speed. The pump is assumed to be at operating speed when the first maximum pressure peak is reached. The pressure is monitored at the discharge of the pump. These centrifugal pumps reach their rated head at operating speed. Since there is no record of when the motor breaker actually closes, the next closest recorded situation is the actuation of the SSPS slave relay K-608. This logic train has a maximum allowable time response ~~time~~ of 11 seconds. These times would be maximum pump start-up times since the breakers are energized during this time interval. The test instrument accuracies are 1.5% by procedure and .6% in practice. The pump start-up times extracted from the graphs are as follows:

Pump	Time(A)	Time(B)
1A-A	1.80	1.64-2.56
1B-B	1.80	1.48
2A-A	1.84	NA
2B-B	1.60-1.88	1.68-2.64

A=time in seconds, pre-op tests
B=time in seconds, IMI-SS RT-608 tests
The 2nd time is when a 2nd pressure peak occurred.

CONCLUSION

From the test data, MEB concluded that the RHR pumps reach operating speed in 1.8 to 2.5 seconds on the average.

J. Hamrick

Attachment No. 14 Sheet 15 of 15
Loop #/Identifier 2731A

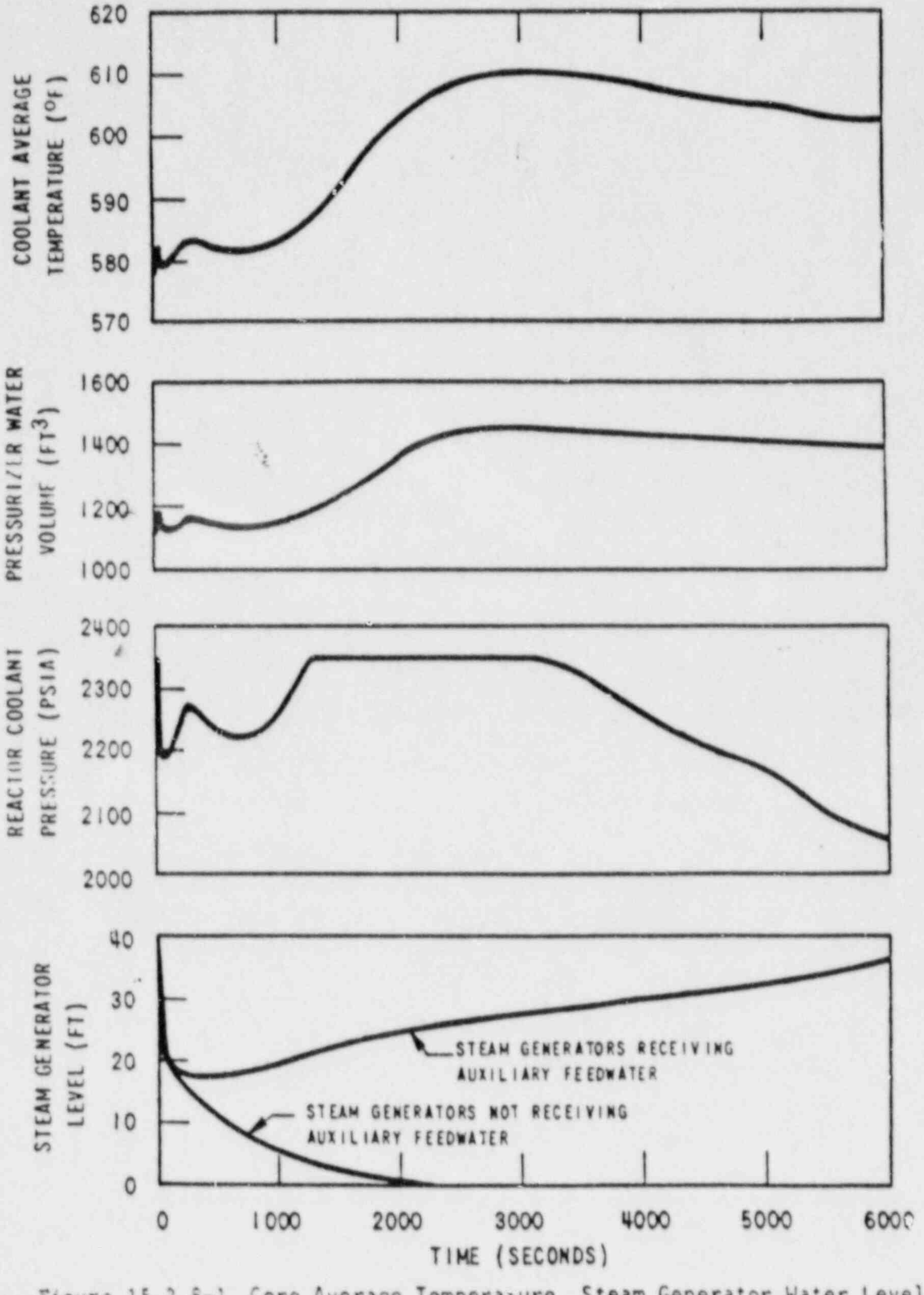


Figure 15.2.8-1 Core Average Temperature, Steam Generator Water Level and Pressurizer Water Volume as a Function of Time, Loss of Normal Feed Accident

Attachment No. 15 Sheet 1 of 1
Loop #/Identifier 27S1A

QUALITY INFORMATION REQUEST / RELEASE (QIR)
DIVISION OF NUCLEAR ENGINEERING
(INTERNAL USE ONLY)

	RIMS ACCNO
TO: RICK DANIELS H23 SQN-P	DOCUMENT NUMBER: QIR EEB 87447
FROM: R.C. WILLIAMS, DSC-P, SQN-P	PAGE 1 OF 1
TYPE OF DOCUMENT: ☑ REQUEST NEED DATE 9-28-87	DATE: 8-26-87
☐ RELEASE REF QIR	PLANT AND UNIT: SQN 1+2

REFERENCED DOCUMENTS

AVAILABLE IN ONE OF THE RIMS SYSTEMS		ATTACHMENT TO THIS QIR	
DOCUMENT	IDENTIFYING NUMBER	DOCUMENT	ATTACHMENT NUMBER

SUBJECT: FIRE PUMP LOAD SEQUENCE

SYSTEMS AFFECTED: FIRE PROTECTION | UNID SYSTEM ID

QUALITY INFORMATION REQUESTED RELEASED

EEB is performing demonstrated accuracy calculations which will determine the maximum time it will take to make electric power available to the fire pumps following a loss of offsite power (LOOP). It is assumed that the safety function is to supply electric power to these pumps as quickly as possible, therefore, EEB is not addressing a minimum time limit (please confirm).

Per FSAR Table 8.3.1-2 the setpoint of the diesel generator fire pump sequence timer is 120 sec. Per EEB's demonstrated accuracy calculations the maximum delay time from LOOP initiation to closure of the load breaker supplying electric power to the fire pumps is 152 sec. (considering timer errors, breaker closure times and Diesel Generator run up time).

Please confirm that the 152 seconds maximum delay is acceptable for the fire pumps (considering a LOOP). If the 152 sec is not acceptable, provide the maximum allowable time that is acceptable.

PREPARED: Fabio Chomicki (FABIO CHOMICKI)

REVIEWED (RELEASES ONLY)

APPROVED (BRANCH CHIEF/PROJECT ENGINEER)

Attachment No 16 Sheet 1 of 2
Loop #/Identifier 2751A

TVA 10529 (DNE 6-86)

cc (Attachments): RIMS SL 26 C-K CC: F. Chomicki W8B59 C-K

QUALITY INFORMATION REQUEST / RELEASE (QIR)
DIVISION OF NUCLEAR ENGINEERING
(INTERNAL USE ONLY)

QA Record

B25 '87 0928 007

TO R. C. Williams, DSC-P, SQN	DOCUMENT NUMBER QIR - SQP-87-468
FROM R. E. Daniels, DSC-N39, SQN	PAGE 1 OF 1
TYPE OF DOCUMENT ☐ REQUEST NEED DATE	DATE 8-29-87
☒ RELEASE REF. QIR EEB 87447	PLANT AND UNIT Sequoyah units 1 & 2

REFERENCED DOCUMENTS

AVAILABLE IN ONE OF THE RIMS SYSTEMS		ATTACHMENT TO THIS QIR	
DOCUMENT	IDENTIFYING NUMBER	DOCUMENT	ATTACHMENT NUMBER
		871002R0069	(1)

SUBJECT
Fire Pump Loading Sequence to the Diesel Generators

SYSTEMS AFFECTED: 26- HPFP

UNID / SYSTEM ID: N/A

QUALITY INFORMATION REQUESTED / RELEASED

The FSAR table 8.3.1-2 lists 120 seconds before the fire pumps are loaded to the diesel generators following a loss of off-site power. Sequoyah design criteria SQN-DC-V-24.0 section 6.6 requires a fire to be postulated concurrent with a loss of off-site power. No maximum time delay is mentioned in the design criteria for fire pump sequencing to the diesel generators.

The proposed time delay increase to 152 seconds would add 32 seconds to the time which is listed in the FSAR table 8.3.1-2 and would require a revision to the FSAR.

The 32 second delay would not adversely affect the safety related aspects of the fire protection system for the following reasons:

1. Only a loss of off-site power is postulated concurrent with a fire.
2. A brief interruption of auxiliary feed water during flood mode operation would not adversely affect reactor temperatures since the rector would be in cold shutdown during flood mode operation.
3. If a fire was in progress at the time of the loss of off-site power, the raw service water head tanks would still supply some water to the system at a lower pressure and flow rate until the fire pumps are loaded to the diesel generators.

The 152 second delay time before the fire pumps are loaded to the diesel generators is acceptable, provided the FSAR is revised accordingly.

PREPARED: David O. Bost 8-29-87

REVIEWED (RELEASE ONLY): [signature]

APPROVED (BRANCH CHIEF/PROJECT ENGINEER): [signature] for JBH

TVA 10639 (DNE 6-86)

cc: RIMS, SL 26 C-K

G. T. Hall, DSC-P, Sequoyah
J. B. Hosmer, DSC-E, Sequoyah
J. C. Key, P-104 SB-K
L. Tunnel, DSC-E, Sequoyah
H. X. Jones, DSC-A, SQN

Attachment No. N Sheet 2 of 2
Loop #/Identifier 2731A

Attachment 4

NEI Peebles Electric Products, Inc., Report

TRANSIENT VOLTAGE RESPONSE

ANALYSIS

VERSUS

TEST RESULTS

ESTIMATING TRANSIENT VOLTAGE RESPONSE OF A VOLTAGE-REGULATED, SALIENT POLE, SYNCHRONOUS GENERATOR TO SWITCHED IMPEDANCE LOADING

When a balanced 3-phase impedance load is suddenly connected across the terminals of an isolated synchronous generator operating at its rated frequency and voltage, currents begin to flow in all 3 armature circuits so established. Magnitude of these currents depends on the impedance of each respective circuit and, as a rule, varies with time due to the everpresent inductance in the synchronous machine armature (internal) part of each circuit. It is customary to postulate certain conditions under which a single set of variables representing 3-phase average quantities can be used in lieu of 3 separate quanitities for each variable on a "per circuit" (per phase) basis. It is, therefore, possible to analyze the behavior of the 3-phase circuit described by observing the behavior of only one set of phasors, which greatly simplifies the process. Phasor diagram normally used is such as shown in Figure 1.

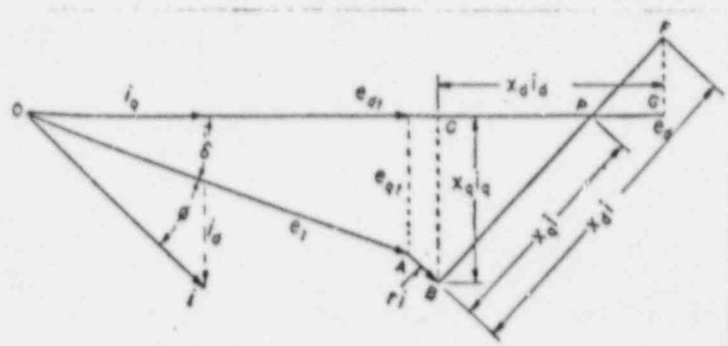


Fig. 1 —Determination of internal angle, δ, and excitation of an unsaturated salient-pole machine when loading is known.

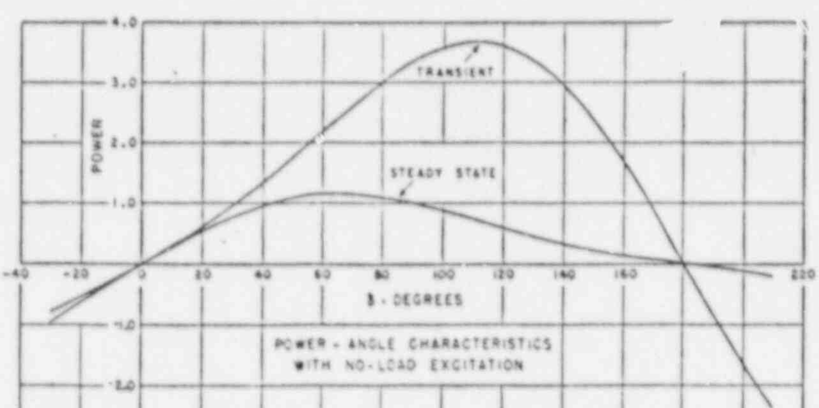
When the current is established, it is accompanied by certain other effects which depend on the circuit parameters and the conditions preceding the circuit closure. Since a current flow through an impedance consumes power (real and/or reactive), a power demand is established and some form of energy conversion (and/or transfer) must take place. In the case of an isolated synchronous machine feeding a load impedance, the everpresent resistance demands the real (kW) power and the everpresent inductance demands the reactive (kVAR) power. These demands, in turn, are satisfied by the conversion of mechanical energy supplied by the prime mover and of magnetic energy supplied by the exciter, respectively. Certain amounts of both these energy forms are stored within the generator operating at a steady state. Since every steady state operating condition must satisfy its own prerequisites of energy equilibria, neither form of the stored energy can be released or absorbed without an appropriate quantitative (and/or qualitative) change in the steady state operating parameters. Of course, nearly all of these

parameters have time as their common independent variable and can be perceived as functionally interrelated. While their funcational relationships are predominantly exponential or logarithmic, the time rates of their variations cover a very wide range (several orders of ten) leading to time constants from a few milliseconds up to several seconds in duration. Needless to say, this causes some of the effects to appear as instantaneous while some others (ten thousand times slower) resemble steady state conditions. Although this makes most rigorous studies of transient conditions between any two steady states much more difficult, it enables us to construe reasonably accurate methods of approximate solutions based on treating fast phenomena as instantaneous and slowly varying parameters as constants, thereby greatly simplifying the mathematics involved. Keeping this in mind, it is well justified to postulate that a real power (kW) demand is satisified from the kinetic energy stored in the rotating mass of the motor-generator and a reactive power (kVAR) demand is satisfied from the magnetic energy stored in the iron cores of the generator stator and rotor, for it is virtually impossible to supply either power component from the external sources at the rates comensurate with those of the current rise. Since the kinetic energy can be freed only by decreasing the velocity of the rotating mass and the magnetic energy can be freed only by decreasing the magnetic saturation of the iron core, it is evident that a frequency change and a voltage change must accompany any load switching as inevitable consequences in all cases. Unfortunately, the voltage change is also frequency-dependent through the magnetic flux of the generator.

Although a transient response of an isolated synchronous generator to switched-on (and -off) load impedance must always consist of a frequency and a voltage change, it is the load impedance itself that determines the detail nature of these effects and the appropriate methods of their analysis. Other important determinants are the prime mover and excitation system characteristics. Concentrating on the load impedance first, we can deduce quite intuitively two limiting conditions. If the load impedance is very small, there is practically no voltage drop due to the current flowing through it and the machine terminals appear short-circuited. With no external voltage drops, the terminal voltage must be zero and the internal voltage is determined solely by the internal machine impedance with the short-circuit current. If, on the other hand, the load impedance is very large, practically no current can flow through it and no external circuit is established, thereby making the machine appear to operate under an open-circuit condition. Understanding the transient response under both of these conditions is essential in order to analyze conditions of more general nature.

A load impedance in its more general sense is any device connected to generator terminals whose power demand is being satisfied by electrical form of energy supplied to it "by wire". This implies electric current relative to the terminal voltage and it is of no major consequence whether the energy supplied is consumed in the device or transmitted further in various other forms. Thus a load impedance can be a heater, a light, a motor, a radio transmitter, an arc welder, a capacitor bank, an oscillator, or even an unloaded distribution grid with its own inherent distributed resistance, inductance and capacitance parameters. Regardless of the kind of device connected, in the real world, every energy transmission and/or conversion process is imperfect and a certain

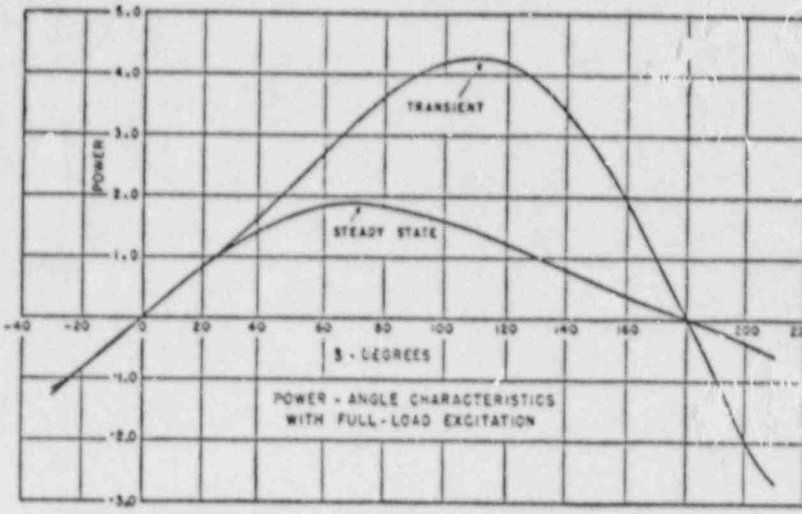
fraction of the total energy is irretrievably lost in the form of heat. Thus a real power demand is always present whenever a load current exists, regardless how large or small. This leads to a very important concept of the "power angle" which makes it possible to relate the load current to the internal, rather than the terminal voltage of the generator, and thereby establish an analytical link between the excitation and the load. Although the symbolics used in the literature varies, the power angle is usually designated as θ and consists of two parts designated as ϕ and δ. The angle ϕ is recognized as the familiar phase angle between the load current and the terminal voltage, sometimes referred to as "power factor angle" as determined from the load impedance. The angle δ is the rotor angle, sometimes referred to as "load angle" or "torque angle" and can be identified as the angle between the terminal voltage and the direct axis internal voltage phasors in Figure 1. It depends entirely on the quadrature-axis reactance of the generator and the load current at the rated terminal voltage (taken as 1.0 P.U.). In the physical sense, it is an angle by which the generator rotor field must lead the EMF induced in the stator conductors in order to generate power. Of course, the amount of power generated at any given angle is affected by the field excitation available as illustrated in Figure 2, a. and b. For a generator operating at a steady state condition, a constant magnetic flux linkage must exist between the rotor and stator in order to satisfy the conditions of equilibrium at each specific load. Thus, at a steady state, each specific angle δ is associated with a specific magnitude of magnetic flux (per pole) linking the rotor and stator cores. If the angle is changed due to a load (or excitation) change, the magnitude of flux must also change in order to satisfy the new set of equilibrium conditions. Since the power generation takes place in a synchronous manner and the rotor providing the magnetization must lead the induced EMF by a specific "time phase" angle δ before the specific power demanded by the load impedance can be generated, the physical rotor displacement angle is achieved by "displacing" the reference point among the distributed stator conductors at which the induced EMF is observed rather than "advancing" the rotor itself. Thus the specific angle δ is established



(a)

Figure 2, Load angle dependence on excitation

SUBJECT	TRANSIENT VOLTAGE RESPONSE ANALYSIS V/S TEST RESULTS	S.O. NO. T-1049 ID. NO. EF-3348
NEI	NEI PEEBLES—ELECTRIC PRODUCTS, INC. 17045 EUCLID AVENUE • CLEVELAND, OHIO 44112	BY JVP Date 2-10-88 REVISION ____ Date ____ SHEET NO. 3 OF 17



(b)

Figure 2, Load angle dependence on excitation

as soon as the load current required to satisfy the power demand is reached, which, with suddenly switched loads, happens very fast and can be considered nearly instantaneous. On the other hand, the magnetic flux linking the rotor and stator, which must also change, cannot be changed instantaneously. In fact, it may require as much as thousand times longer interval to change sufficiently to establish a new equilibrium corresponding to the steady state angle δ dictated by the switched-on (or -off) load. Even if it were only hundred times slower than the load current rate of change, it would be well justified to consider the flux linkages constant when dealing with the current and voltage changes due to switched loads. This then becomes the key principle of any transient response analysis.

Having postulated constant magnetic flux linkages during an abrupt load change, it becomes immediately obvious that a new steady state equilibrium cannot be reached and other phenomena of transient nature must take place during the transition from one steady state equilibrium to the other, potentially reached at a much later time. As all energy conversion (or transfer) devices, the generator has a propensity to operate within the law of "energy conservation" and any action tending to disturb its energy balance is accompanied by a reaction tending to restore it or, stated differently, effects of transient phenomena in a generator oppose the effects causing such phenomena in the first place. It is readily apparent from Figure 2, a. and b. that substantially more power can be delivered by a generator momentarily under transient conditions than at a steady state (at the same δ) regardless of the excitation level. This, of course, is partly due to the salient-pole construction of the rotor and its inherently high reluctance effects caused by different flux densities in the direct and the quadrature axes. Other than that, the increased

transient power capability is due to reaction phenomena mentioned above which can be best illustrated by considering a very low impedance load extreme-namely, a 3-phase short circuit.

As already mentioned, when the terminals of a synchronous generator operating at its rated voltage and frequency are connected together with no impedance between them, their potential differences disappear and the generator continues to operate under a 3-phase short-circuit condition. The terminal voltage drops instantaneously to zero and currents begin to flow in the 3 armature circuits. Since the instantaneous potentials at the time of "shorting" are not equal at all 3 terminals (3-phase sinewaves), unidirectional equalizing currents begin to flow in the armature circuits in accord with the Kirchhoff's Laws. Since the flux linkage between the rotor and the stator needed to generate the rated voltage at the terminals prior to their shorting remains constant, rather high alternating currents are generated in the armature circuits which tend to demagnetize the core thereby reducing the internal voltage generated to a value needed to just overcome the internal voltage drops. This demagnetization results in reducing the voltage-related nonlinear saturation effects and releases a sizeable amount of magnetic energy previously stored in the saturated cores. This excess energy must either be converted to some other form and dissipated as losses or returned back to the source of its origin (or both). Since the armature conductors are magnetically linked with the damper cage and field coils located in the rotor, a transformer effect exists between the current carrying armature conductors and each of the other two circuits, whereby currents are induced in both in directions opposing the effects that are creating them. Although the currents in both circuits are magnetizing currents (being caused by demagnetizing armature currents), they help to re-distribute the excess energy by converting it to heat and excitation current (returning it back to the source of origin). Both of these currents decay logarithmically, although at different rates, and eventually disappear. Different decrements of decay are due to the obvious difference in inductances of a multiturn field winding on one hand and a short-circuited damper cage (half-turn) on the other. This effect is partly apparent form the oscillogram of a 3-phase short-circuit at a constant excitation shown in Figure 3. Since the cage-induced current is difficult to measure (and record) directly, its presence has to be deduced from its effects on the field and armature currents recorded in Figure 3.

The sudden increase in the field current as a reaction to a sudden armature current change is very important in optimizing the transient response of voltage-regulated systems to switched impedance loading. However, certain functional relationships between the armature (e.g. load) current and both of these "transient reaction" currents must be understood first. This is best accomplished by analyzing what happens with the fixed excitation, such as shown in Figure 3 oscillogram.

Next Figure shows a 3-phase average RMS armature current (not including the unidirectional equalizing currents) as could be derived from an oscillograph similar to Figure 3. It is apparent that this current is at its maximum at the instant of short-circuiting the generator terminals (t = o) and begins to decay immediately thereafter, asymptotically approaching a sustained steady-state value.

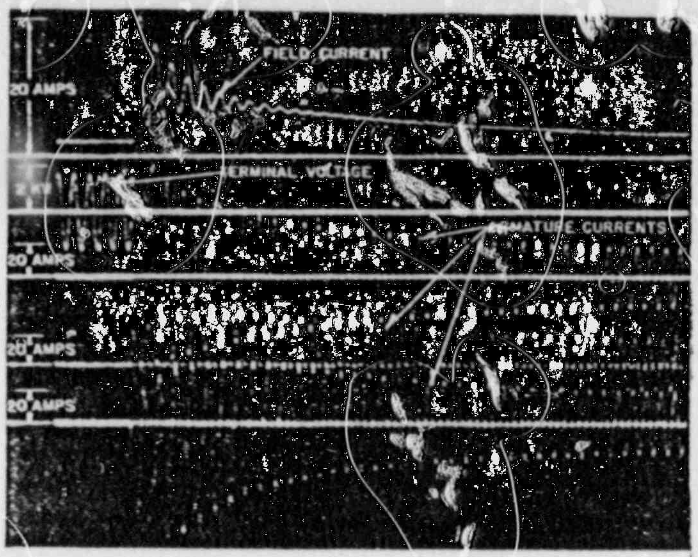


Fig. 3 —Three-phase short circuit in salient-pole machine with damper windings.

If plotted on a semi-log paper (linear time), two logarithmic decrements of decay (straight lines) become readily apparent, one being a whole order of ten (or more) steeper than the other. Since the steeper decrement line already has a "zero time" (t = 0) intercept, only the "zero time" intercept of the other decrement needs to be established, which, on semi-log paper, requires just projecting a straight line to "zero time" (t = 0). Of course, in a linear plot, such as Figure 4, both decrements are curved. It is readily apparent that the 3-phase average (RMS) armature current resulting from a sudden short circuit at the generator terminals at a rated voltage and frequency condition is composed of three distinct components defined by their "zero time" intercepts and decaying each at its own rate defined by its own logarithmic decrement (a time constant). Since the initial condition of magnetic flux is known to correspond

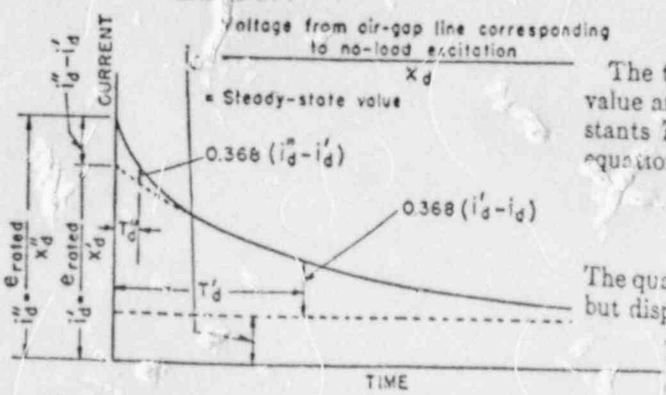


Fig. 4 —Symmetrical component of armature short-circuit current (three-phase short circuit from no-load rated voltage). Values are rms.

The total armature current consists of the steady-state value and the two components that decay with time constants T_d' and T_d''. It can be expressed by the following equation

$$i_{ac} = (i_d'' - i_d')\,\epsilon^{-\frac{t}{T_d''}} + (i_d' - i_d)\,\epsilon^{-\frac{t}{T_d'}} + i_d$$

The quantities are all expressed as rms values and are equal but displaced 120 electrical degrees in the three phases.

SUBJECT: TRANSIENT VOLTAGE RESPONSE ANALYSIS V/S TEST RESULTS	S.O. NO. T-1059 ID. NO. EF-3348
NEI PEEBLES—ELECTRIC PRODUCTS, INC. 17045 EUCLID AVENUE • CLEVELAND, OHIO 44112	BY JVP Date 2-10-88 REVISION ____ Date ____ SHEET NO. 6 OF 17

to a steady-state equilibrium at the rated open-circuit voltage and the excitation is constant, the internal voltage is equal to the terminal voltage and can be taken as 1.0 per unit (on the air-gap line). Recognizing that the flux cannot change at the instant of short-circuit, it becomes readily evident from Ohm's Law that the reciprocal value of each "zero time" current component is a constant impedance of the equivalent circuit through which that particular current must flow. As any other impedance of an electromagnetic device, even these have a resistive and an inductive part each. However, since the current components associated with them are nearly totally demagnetizing currents, their power factor is near zero and the resistive parts of their characteristic impedances can be neglected. It is, therefore, customary to treat them as "positive sequence reactances" in the "direct axis" (magnetic field structure is not isotropic). They are known under the following terms and symbolized as follows:

X"d = direct-axis subtransient reactance (P.U., rated voltage)

X'd = direct-axis transient reactance (P.U., rated voltage)

Xd = direct-axis synchronous reactance (P.U., rated voltage referred to air-gap line, e.g. unsaturated)

Having determined the characteristic parameters of the short-circuit current components, it is possible to determine the rates of their decay simply by observing at what time after the instant of short-circuiting each current component reaches $1/\mathcal{E}$ = .368 = 36.8% of its initial value. This time interval is then defined as the "time constant" of that particular current component, designated by the letter T (or τ) suffixed in a manner consistent with the symbolics used above. Knowing the initial value of all components as well as the rates of their decay, it is possible to calculate the short-circuit armature current at any time after shorting the generator terminals by means of the equation shown in Figure 4. All variables are as defined therein.

As already mentioned, the different rates of decay of the subtransient and the transient current components are caused by the reaction currents induced in the other circuits linked by the magnetic flux with the armature circuit. Therefore, the number of armature current components decaying at different rates (e.g. the number of logarithmic decrements defined by different time constants) must be equal to the number of flux-linked circuits, excluding the armature. In most synchronous generators, there are two such circuits: the damper cage and the field winding, although three-decrement short-circuit current oscillograms are not that uncommon. In such cases, the third circuit is not intentional but it is created by currents induced in some structural members of laminated rotor poles, such as rivets or welds located near the air gap which are also flux-linked with the armature circuits. Since the rate of decay is characterized by the "time constant" which is defined as a ratio of circuit inductance to its resistance, the current decay in multi-turn circuits must be slower. Although the inductance and the resistance of a circuit are both functions of the number of its turns, the resistance varies directly with it while the inductance varies with its square and, being in the numerator, tends to increase the time constant rather dramatically. Since the field circuit

always consists of multi-turn windings, its time constant will always be at least one order of ten longer than that of the damper cage circuit in spite of the rather low cage resistance. Thus, the subtransient current component is dominated by the damper cage circuit characteristics while the transient current component is field circuit-dominated. Reactances and time constants associated with either can be determined from geometries of their respective dominant circuits and other parameters. With these known, short-circuit current magnitude at any instant following the shorting of generator terminals can be calculated by the equation of Figure 4.

All considerations so far were based on the constant excitation applied to the generator field, that is, a constant voltage applied between the field circuit terminals (slip rings). Under a steady state operation, the field current due to that voltage flowing through a fixed number of turns of the field winding represents a constant magnetizing force (ampere-turns) required to maintain magnetic flux equilibrium dictated by the output conditions. Upon switching of the load impedance, the flux equilibrium is disturbed and transient change in the magnetizing force must follow. Since the number of turns is fixed, the field current must change while the field voltage remains constant. This, of course, is possible only if the impedance of the field circuit changes. Although the field circuit impedance under steady state operating conditions is practically a pure D.C. resistance, its inductive character becomes obvious under transient conditions. As seen in the field current trace of the short-circuit oscillogram in Figure 3, the field current profile, the field circuit impedance change and their common parameters are analogical to the armature current features already analyzed in Figure 4. Similar approach can be followed when analyzing transient impedance changes of the field circuit. In order to establish limits of the field circuit impedance variation, it is only necessary to short-circuit the field circuit of a generator operating at a steady state under one and the other load impedance extreme. That is with its armature circuits open as well as with its armature circuits shorted while operating at its rated frequency and a constant excitation adjusted to produce the rated terminal voltage under the open-circuit conditions.

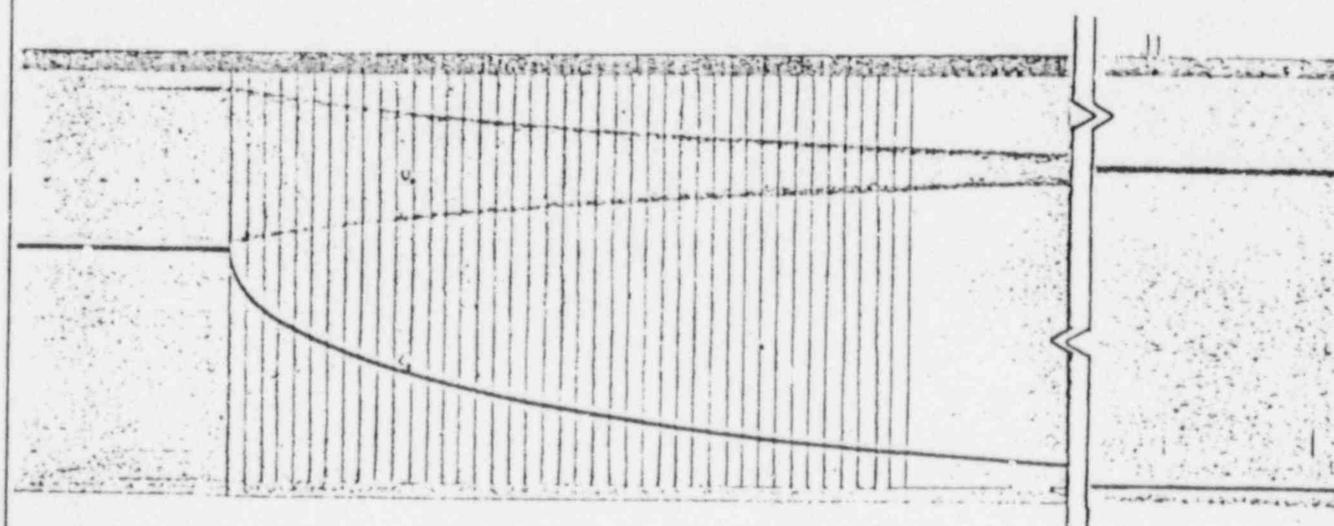


Figure 5, Generator field short circuit with open-circuit armature

SUBJECT	TRANSIENT VOLTAGE RESPONSE ANALYSIS V/S TEST RESULTS	S.O. NO. T-1049 ID. NO. EF-3348
NEI	NEI PEEBLES—ELECTRIC PRODUCTS, INC. 17045 EUCLID AVENUE • CLEVELAND, OHIO 44112	BY JVP Date 2-10-88 REVISION ___ Date ___ SHEET NO. 8 OF 17

Figure 5 shows an oscillogram of the generator terminal voltage (one of 3 phases) and the field current supplied from a constant voltage excitation source. With the generator operating at a steady state equilibrium at the rated voltage and frequency, the field circuit is suddenly shorted while the armature circuits remain open. Proceeding as already outlined in connection with Figure 4, a time interval is found at the end of which the magnitude of voltage is equal to $1/\mathcal{E}$ = .368 = 36.8% of the initial value. This time interval is defined as:

T'do = direct-axis transient open-circuit time constant (sec.)

The field current decay can also be analyzed in a similar manner and the rapidly decaying component of the field current segregated from the rest by a straight line projection on a semi-log paper. As already mentioned, this component is caused by damper cage effects and is short-lived. It leads to defining:

T"do = direct-axis subtransient open-circuit time constant (sec.)

Figure 6 is another oscillogram, this time, of the generator 3-phase short-circuit current (one of 3 phases) and the field current supplied from a constant voltage excitation source. With the generator operating at a steady state equilibrium at the rated frequency and excitation (same as before), its field circuit is again shorted but, this time, while a 3-phase "bolted" short circuit remains at its armature terminals. Proceeding as outlined before, the rapidly decaying current component can be separated from the slower one and the following time constants defined by the process already explained:

T'd - direct-axis transient short-circuit time constant (sec.)

for the slowly decaying current component related to the field circuit and:

T"d = direct-axis subtransient short-circuit time constant (sec.)

for the rapidly decaying current component related to the damper cage circuit.

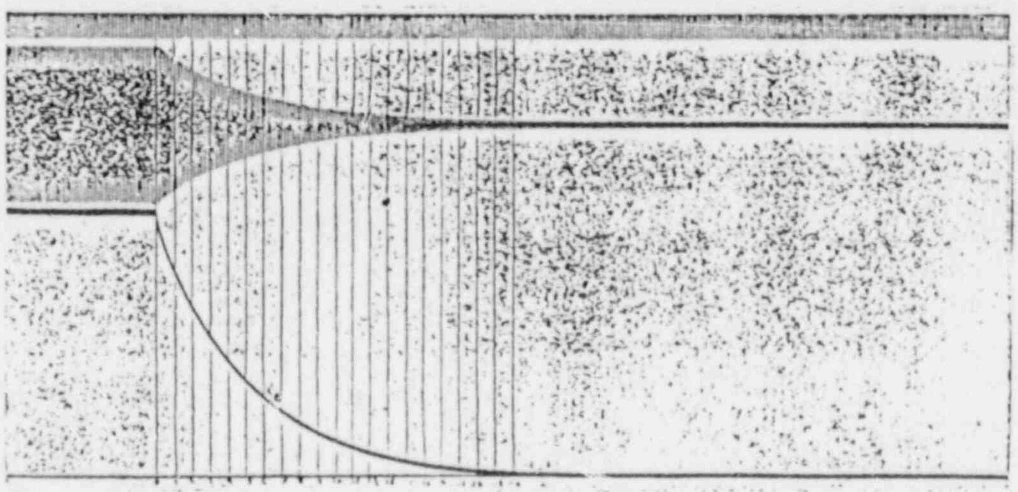


Figure 6, Generator field short circuit with short-circuit armature

It should be noted that the values of T'd and T"d derived from the armature current decay and the field current decay match reasonably well if the sustained short-circuit current due to residual magnetization of the iron cores is extracted from the total armature current. It is also noteworthy that both of these parameters are in a close agreement with their counterparts obtained by the sudden short-circuiting of armature terminals with a constant field excitation maintained, such as shown in Figure 4. As long as the steady state excitation current preceding the test is the same, the parameters derived by either of these three methods fall within a "less than 5% error" band. This confirms quite well the validity of the mathematical model of the synchronous machine just formulated.

Since the above time constants were defined under both extremes of loading, specifically: $R_{ext} = X_{ext} \rightarrow 0$ (short-circuit)

and: $R_{ext} = X_{ext} \rightarrow \infty$ (open-circuit),

it follows that time constants associated with any finite load impedances falling between 0 and ∞ must fall between the short-circuit (T"d, T'd) and the open-circuit (T"do, T'do) values defined above. It is, therefore, customary to express the time constants under a finite impedance load condition as products of open-circuit time constants and equivalent impedance coefficient derived as appropriate for each respective condition. Thus, for any load impedance Z:

T"dz = K"T"do and T'dz = K'T'do, where K" and K' depend on Z

For the transient condition, which is of primary interest here:

$$K' = [(R_{ext}+R_a)^2+(X_{ext}+X'd)(X_{ext}+Xq)][(R_{ext}+R_a)^2+(X_{ext}+Xd)(X_{ext}+Xq)]^{-1}$$

If the armature resistance R_a (usually less than 1%) is neglected, K' = 1.0 for $R_{ext} = X_{ext} \rightarrow \infty$ and T'dz = T'do, as it must for the open-circuit condition. analogically, K' = (X'd/Xd) for $R_{ext} = X_{ext} \rightarrow 0$ and T'dz = (X'd/Xd)T'do = T'd, as it must for the short-circuit condition.

Having established the transient response of the field current to a sudden change of the armature current at a constant excitation voltage, it is now necessary to address the transient response of the field current to a sudden change of the excitation voltage. It is apparent from field current oscillogram in Figure 5 that the field circuit behaves like an inductive impedance. It is, therefore, justified to conclude that the field voltage-current relationship follows the Helmholtz' Law. Thus:

$I_f = e_x/r_f\ [1 - \varepsilon^{-t/T'do}]$ where:

- e_x = exciter voltage (volts, D.C.)
- r_f = field circuit resistance (ohms)
- T'do = direct axis transient o-c time constant (sec.)
- t = time (sec.)
- I_f = field current (amps, D.C.)

If the exciter voltage is fixed (e_x = constant), the current I_f will vary as an exponential function of time only. If, however, the exciter voltage varies as some other function of time, a much more complicated condition arises. This, of course, is the usual situation encountered when dealing with the voltage-regulated synchronous generators operating as isolated power supplies.

Figure 7 shows a typical exciter voltage build-up characteristic of a relatively slow exciter-regulator system obtained from an oscillogram and also approximated analytically b· a relatively simple exponential function shown on the right. Although considerably faster systems are now commonplace, Figure 7 is a good illustration of the fundamental system features present in the majority of exciter-regulators. The straight line on the left of the graph (negative time) is a delay caused by the regulator sensing the generator terminal voltage and, consequently, developing an appropriate signal to trigger (and control) the exciter voltage change in order to maintain the generator terminal voltage constant. This time delay depends on the type of regulator used. In a typical case of a Mag-Amp type this would include the total time elapsed from the instant of the generator terminal voltage change to the instant at which the proper Mag-Amp output voltage controlling the exciter output appears at the exciter terminals. It does not include the exciter voltage build-up time which, typically, is included in the exponential portion of the characteristic curve beginning at t = 0 in the graph. Since most exciters contain some magnetic cores which saturate, be it the rotating exciter poles and armature or the static exciter power transformers (PTs and/or CTs), the slope of the exponential build-up curve must reverse before the maximum exciter output (ceiling) voltage is reached. Thus the portion of the build-up curve on the right of the graph is asymptotic to the ceiling voltage e_C. It is customary to neglect this part in most analytical representations and such is the case here, as apparent from the function shown on the right.

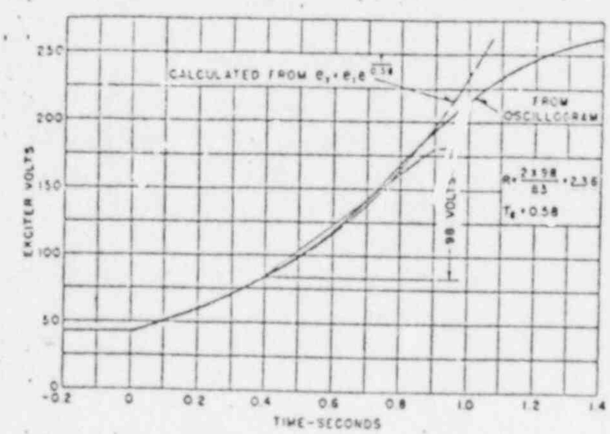
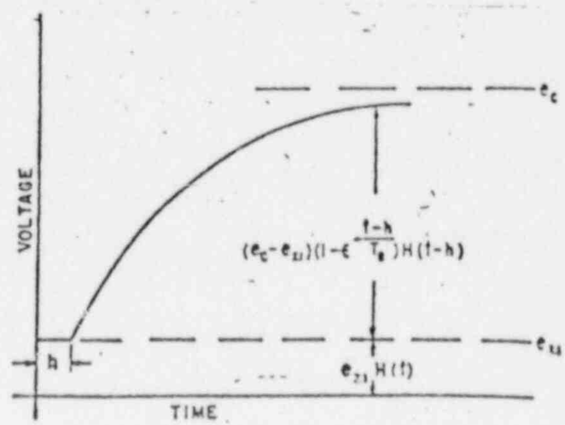


Figure 7. Voltage build-up curve of a self-excited exciter, showing method of calculating response



Exciter build-up curve, including delay caused by regulator operating time, *h*

Since the rate of the exciter voltage build-up is usually faster than the rate of the generator field current build-up ($T_e <$ T'dz) even for relatively slow response exciters, the error so introduced is not significant. Unfortunately, the same is not true about the regulator delay, which is quite significant and must be included. Thus the exciter voltage buildup function remains composed of two nonhomogeneous parts, such as shown on the right of Figure 7, thereby complicating its further analytical treatment. Different authors resorted to different approaches that eventually lead to the same end results. For instance, C. Concordia treats the two parts separately combining their results later, while E.L. Harder and R.C. Cheek utilize a "delayed Heaviside unit function" approach leading to a differential equation of the transient internal voltage as a time-dependent function of the exciter voltage corrected for the generator saturation. Its solution, utilizing the time constants as defined above and saturation derived from the O.C. saturation curve of the generator by the Potier voltage method yields the following expression:

$$e_d' = \frac{T_d'}{T_{do}'}(e_e - s) + \left[\frac{(e_e - e_{s1})T_d' e^{\frac{t}{T_d'}} - (e_{s1} - s)}{T_{do}'(T_e - T_d')} \times \frac{(T_e - T_d')T_d' + e_{d1}' T_{do}'(T_e - T_d')}{T_{do}'(T_e - T_d')}\right] e^{-\frac{t}{T_d'}} - \left[\frac{(e_e - e_{s1})T_d' T_e e^{\frac{t}{T_e}}}{T_{do}'(T_e - T_d')}\right] e^{-\frac{t}{T_e}}$$

Setting the first derivative of this expression equal to zero and solving for t, the minimum terminal voltage is determined from the above and the combined generator-load impedances.

$$t = \frac{T_d' T_e}{0.434(T_e - T_d')} \log_{10} \left[\frac{e_{d1}' \frac{T_{do}'}{T_d'}(T_e - T_d') + (e_e - e_{s1})T_d' e^{\frac{t}{T_d'}}}{(e_e - e_{s1})T_d' e^{\frac{t}{T_e}}} - \frac{(e_{s1} - s)(T_e - T_d')}{(e_e - e_{s1})T_d' e^{\frac{t}{T_e}}}\right]$$

It should be noted that the symbol T'd used in both above expressions is not for "direct-axis transient short-circuit time constant" but for "direct-axis transient closed-circuit time constant" and should be correctly T'dz because it contains finite load impedance parameters R_{ext} and X_{ext}.

Effects of magnetic saturation of generator cores on the transient voltage response are significant but rather difficult to account for analytically. Since the total magnetic flux also contains the so called "leakage flux", the saturation effects appea. to be dependent on the flux density and on the permeance of the magnetic paths. Therefore, they are voltage, frequency and excitation-dependent. Given the non-isotropic magnetic circuit structure of salient pole synchronous machines, the task of accounting for them individually is quite formidable. However, they all have one thing in common - they must be compensated for by the excitation. Thus the saturation effects in total can be considered as an unusable part of the exciter output. In that sense, they can be considered a function of a fictitious internal voltage, called Potier voltage customarily used by machine designers to relate the "open circuit" saturation to various conditions of saturation under different loads. Figure 8 illustrates the method of determining saturation(s) for different load impedances in relation to the terminal voltage.

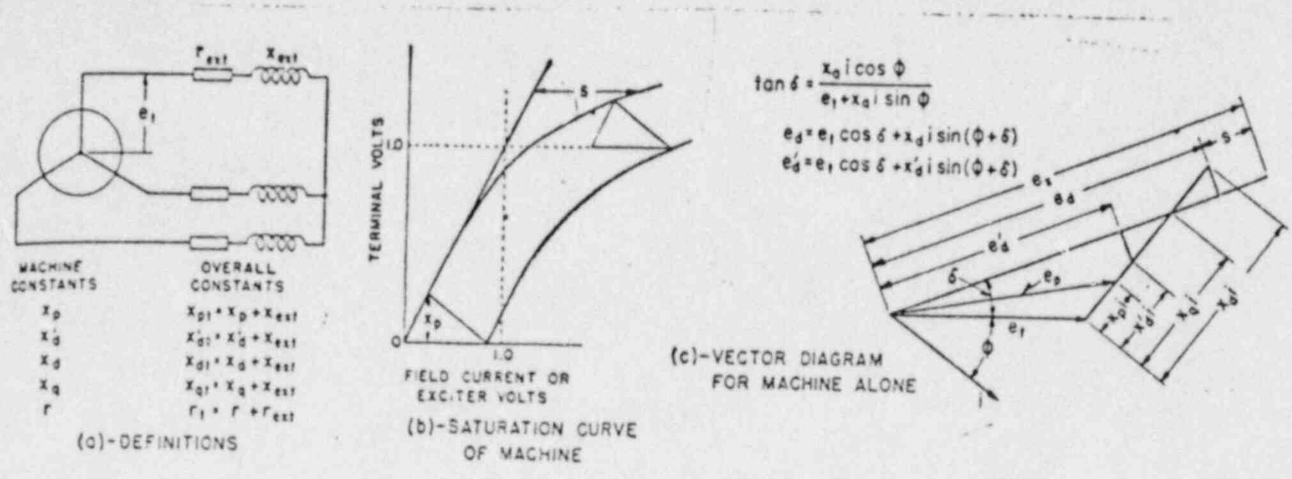


Figure 8, Phasors of loaded generator including saturation

Since this involves iterative process in order to account for the simultaneous variations of voltage and current with time, intervals near the inflection points must be small. It should be noted that the armature resistance (usually less than 1%) is neglected in the above phasor diagram in order to simplify the Potier voltage (e_p) relationship to the terminal votlage (e_t).

The 3-phase short-circuit current characteristic shown in Figure 4 was obtained under the condition of fixed excitation. If the same kind of short-circuit test were performed on a voltage-regulated system and the oscillographic traces of current analyzed in a similar manner, there would be a noticeable reversal of the current decay in response to the exciter voltage build-up. Such a case is illustrated in Figure 9 where the current is seen to have reached its minimum

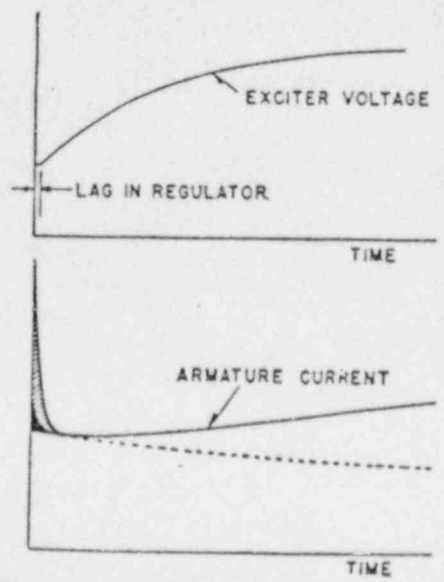
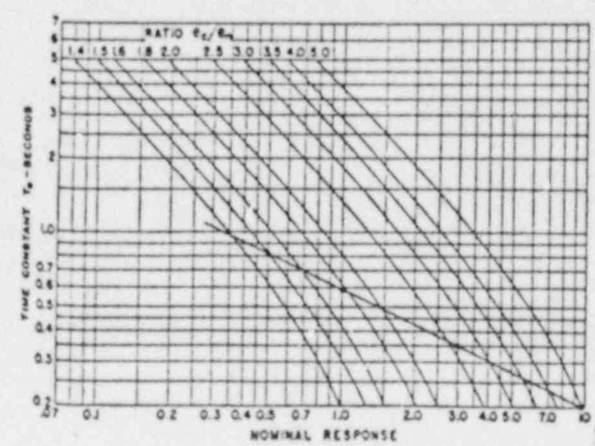


Fig. 9—Illustration showing relative importance of different components of armature short-circuit current and response of transient component to the exciter voltage.



Exciter time constant, T_e, versus response for various ratios of ceiling voltage, e_c, to nominal voltage, e_n

SUBJECT TRANSIENT VOLTAGE RESPONSE ANALYSIS V/S TEST RESULTS	S.O. NO. T-1049 ID. NO. EF-3348
NEI PEEBLES—ELECTRIC PRODUCTS, INC. 17045 EUCLID AVENUE • CLEVELAND, OHIO 44112	BY JVP Date 2-10-88 REVISION Date SHEET NO. 13 OF 17

in a relatively short time and begun to rise relatively slowly thereafter, rather than following the slow downward trend indicated by the dotted line. It can be deduced quite intuitively that the faster the exciter voltage build-up (shown in the upper part of Figure 9), the steeper the armature current recovery path. On the other hand, the minimum armature current value appears to be more affected by the time delay due to the lag in the regulator response to the instantaneous terminal voltage drop at the time of short-circuit ($t = 0$) rather than by the rate of the exciter voltage build-up. Of course, there is a good reason for it which can be best illustrated by returning to the oscillographic field current trace in Figure 3. As already mentioned, the current flowing in the generator field circuit is undergoing rather dramatic changes in response to redistribution of the magnetic flux linkages among the individual circuits without accompanying changes in the total flux magnitude, which remains at its pre-short circuit level. Thus the field current is "magnetic flux-driven" rather than "voltage-driven" until such time when the voltage applied at the field circuit terminals (slip rings) matches the internal voltage drop due to the current flow through the field circuit impedance. This can occur only when the new "steady state" flux regime is established and the field current decays to its pre-short circuit level or when the exciter voltage is increased sufficiently to achieve an equilibrium at any intermediate field current level. This can be viewed as a Norton/Thevenin transformation of the field circuit behavior (and viceversa). In the voltage regulated system, the net result is that the armature current decay cannot be intercepted in the "subtransient region" shown by the crosshatched area in Figure 9 (except with extremely fast response solid state exciter-regulators). Thus, in usual application, the minimum armature current occurs in the "transient region" (or later) when the field current (as in Figure 3) has had already decayed to only a fraction of its initial magnitude. The longer the regulator time lag and the slower the rate of exciter voltage build-up, the lower will be the minimum armature current value reached. Therefore, it is obvious that the limiting positive sequence reactance value which determines this minimum will vary with the exciter-regulator response time from an initial (saturated) transient reactance X'd to its unsaturated value X'du and, possibly, even to some kind of "time-prorated" value between X'du and Xd, if the response is very slow or delayed by other causes. Although the regulator time lag effect is readily apparent, the "slow response" effect of the regulated excitation system is not so simple to visualize. The response effect depends on two independent parameters, specifically the Exciter time constant (T_e) and the Ceiling voltage (e_c), sometimes called "forcing" which is indicative of the maximum exciter voltage 95% of which can be reached in three time constants (after $3T_e$). Relationship of the Exciter time constant and the Nominal exciter response ratio is shown on the right of Figure 9 for those exciters whose build-up characteristics can be approximated by the function shown in Figure 7. It is apparent that the same response can be obtained with different ceiling voltages, however, the response effects can be different because of the different voltage margin available to "drive" the field current build-up.

All that has been said about the behavior of the voltage-regulated system under a 3-phase short circuit is equally valid for any other load impedance switching. Since the transient voltage and current time profiles are both functions of the same internal voltage time profile, it is apparent that they must

be geometrically similar, of course, allowing for different levels of saturation which must be much lower under the short-circuit condition. However, since the saturation is treated as an "instantaneous adjustment" of the exciter voltage derived by a separate process of iteration described in Figure 8, all expressions defined so far remain unaffected. If the proper initial exciter voltage (e_{x1}) is substituted in the expressions quoted, valid results will be obtained for any switched load impedance as long as the time to reach the minimum voltage will be longer than the regulator time lag ($t > h$). Analytical results will always be conservative when compared with actual measurements.

Figure 10 shows the transient response of a voltage-regulated synchronous machine to starting of an induction motor driving a pump. An across-the-line starting induction motor can be considered a constant impedance load practically up to its "break-down speed" which occurs just slightly (5% to 10%) below its operating speed. At that point, its highly inductive input current starts to drop sharply and its initially low power factor begins to dramatically improve (as illustrated by the graph on the right of Figure 10). At a constant voltage, the motor draws practically constant kVA (inrush kVA) at a low power factor and can be reasonably well represented by its "locked-rotor impedance" for the majority of transient voltage response studies whenever frequency effects are of no major significance. This is especially true about NEMA Design B motors, whose current characteristics are flatter than those shown in the graph, and which are the most widely used motors in pump and compressor drives. It should be noted that the starting motor torque and, therefore, its kW demand is independent of the load coupled to its shaft (a pump) but is determined solely by its impedance (and losses) as long as the motor keeps on accelerating. The excess kW input is simply used up in accelerating the rotating mass.

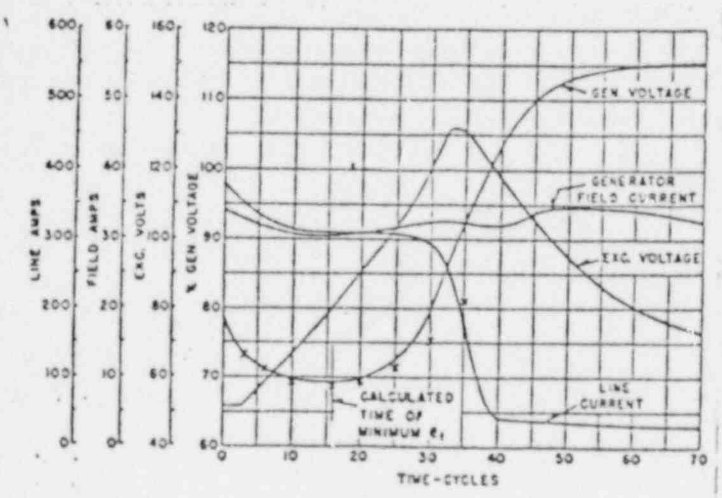
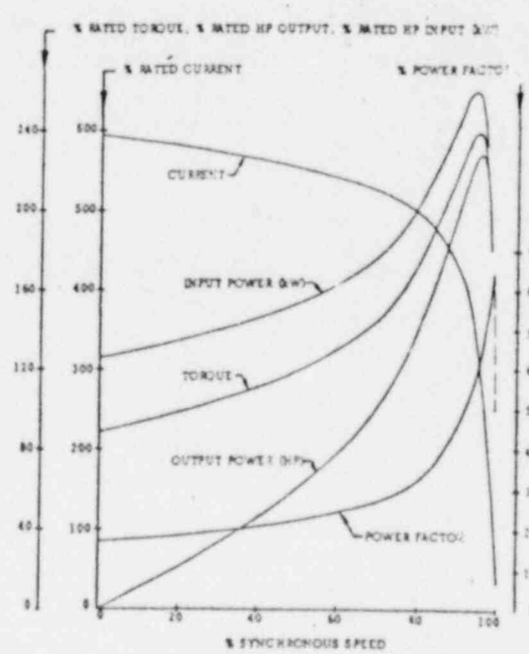


Figure 10 Comparison of calculated voltage-dip curve (crosses) with voltage-dip curve obtained from test



Typical asynchronous characteristics of motors

SUBJECT	TRANSIENT VOLTAGE RESPONSE ANALYSIS V/S TEST RESULTS	S.O. NO. T-1049 ID. NO. EF-3348
NEI	NEI PEEBLES—ELECTRIC PRODUCTS, INC. 17045 EUCLID AVENUE • CLEVELAND, OHIO 44112	BY JVP Date 2-10-88 REVISION ____ Date ____ SHEET NO. 15 OF 17

As apparent from Figure 10, when the motor starting contactor is closed, the motor inrush current begins to flow in the previously open armature circuits of the generator whose terminal voltage drops nearly instantaneously from its rated to some intermediate value (80%). This voltage drop is sensed by a voltage regulator which, after certain time interval, initiates the exciter voltage build-up. Meanwhile the generator field current decays, thereby allowing further terminal voltage decrease, albeit at much slower rate, until a minimum voltage point is reached (at about 267 m sec.). At the same time, however, the armature current is also decreasing as a consequence of the voltage decrease. At the minimum terminal voltage point, the exciter voltage has been built-up sufficiently to "drive" the field current upward, thereby initiating the terminal voltage recovery trend accompanied by the armature current increase. Meanwhile, of course, the motor apparently accelerated to its "breakdown" speed and its "locked-rotor" impedance began to increase rather abruptly, thereby causing a dramatic reduction of the armature current and improvement of power factor. Consequently, the terminal voltage recovery rate began to increase although the generator field current remained nearly constant (for next 167 m sec.). It is not clear whether an exciter ceiling voltage was reached or the exciter voltage build-up was stopped by some kind of "regulator feedback" about 33 cycles (.55 sec.) after the contactor closure but a few cycles thereafter, the exciter voltage began to decline. Meanwhile, of course, the generator terminal voltage continued to climb, reaching its rated value about 38 cycles (.63 sec.) after the contactor closure. As must be expected in any highly inductive circuit, the generator field current continued to increase up to about 50 cycles (.83 sec.) past the contactor closure, although the exciter voltage continued in its decline, before beginning its own downward trend. In response to that, generator terminal voltage continued its climb at a gradually decreasing rate, reaching its maximum (15%) overshoot in about 60-65 cycles (1.0 - 1.1 sec.) after the contactor closure.

It is quite obvious that analytical methods discussed will not be capable to completely simulate all the events depicted in Figure 10 and described above. The transient characteristics shown include the effects of motor impedance change as the motor exceeds its "break-down" speed prior to the full recovery of the terminal voltage. The analytical methods, on the other hand, are based on the <u>constant load impedance</u> and will be valid only up to that point in time when the "break-down" speed is reached (at about 20-25 cycles). From that point on, the terminal voltage recovery calculated will be slower than that actually measured and depicted in the graph. Nevertheless, the accuracy of calculated values (as indicated by crosses) is good where the postulated condition of constant impedance exists and, where it does not, the analytical results tend to be conservative. As for the suspected "regulator feedback" effect, no attempt is made to account for it because it is usually adjustable in order to insure stability of the system. Since the system is assumed to be stable, only the asymptotic approach to the exciter ceiling voltage (e_c) is considered in usual applications.

With a rather slow exciter-regulator system, it is possible to encounter a situation when a motor starting contactor is closed while the generator terminal voltage is high but the voltage regulator already started to "drive" the exciter voltage down, such as would be the condition following a "load shedding".

This condition would roughly correspond to what can be seen in Figure 10 after the 40th cycle (.67 sec.) up to the instant of the contactor closure. At that instant, however, say at the 45th cycle (.75 sec.), the terminal voltage will again dip nearly instantaneously down to about the same level as if the initial voltage were at the rated rather than 110% of the rated value because of the proportionately higher inrush current. Of course, the armature current will follow the voltage as described before and the field current will also decay in a similar fashion. The voltage regulator, sensing the instantaneous voltage drop, would react to it as already described before but, this time, its output would have to change from "full-off" to "full-on" (e.g., from some maximum to some minimum control current in a Mag-Amp regulator controlling an SCPT). This, of course, would take nearly twice as long as the control current change from some midrange point to either extreme. It is fair to say, therefore, that while the regulator would recognize the sudden terminal voltage drop as quickly as before, it will take much longer to react to it. Meanwhile, of course, the field current would continue to decay to even lower values than reached before and, consequently, the terminal voltage and the armature (load) current would follow until such time when a sufficient exciter voltage is reached to reverse this decaying field current trend. Exactly when this will happen will now depend on the type of exciter much more than when the motor was started at the stabilized rated terminal voltage of the generator. With rotating exciters (either self- or separately excited from a source indepedent of the generator), the rate of the exciter voltage build-up will be nearly the same as observed before. However, with most static excitation systems deriving their power from the generator output through PTs and CTs, the exciter voltage build-up will be slower due to lower generator voltage and current available, as both of these were allowed to decay deeper than before. This effect can be easily visualized with the aid of the exciter build-up curve shown in Figure 7 when the regulator time lag (h) is increased and the ceiling voltage (e_c) is decreased in proportion to the generator output decrease. Even if there is no significant change in the exciter time constant (T_e), the same voltage output is reached in a considerably longer time interval than before. The net result of all of this is the fact that the decaying field current may not be intercepted any more in the "transient" time range but somewhere between it and the sustained condition (pre-existent steady state). Thus the "positive sequence reactance" limiting the terminal voltage dip, having already changed from the "subtransient" (X"d) to "transient" (X'd) was allowed to increase past its "unsaturated" (X'du) value (consuming nearly all excess magnetic energy freed from the saturated iron cores) further, to some value defined by $1/(1/X'd - 1/Xd)\varepsilon^{-t/T'd}$, but not quite Xd. Exactly what, depends on the time (t) elapsed from the instant of the contactor closure up to the instant when "field circuit voltage drop-exciter voltage" equilibrium is reached and the field current becomes "voltage-" rather than "flux driven", thereby reversing its trend. It is apparent that, unless appropriately corrected, the analytical methods outlined above may substantially underestimate the actual transient voltage dip experienced during a motor start under the conditions just described. Whether or not the error will be significant depends primarily on the type of the exciter-regulator system used. Experience has shown that with "fast responding" solid state static exciter-regulator systems, the analytical results are still conservative, while some correction of the "positive sequence reactance" must be made for all other types.

Enclosure 2

Commitments

1. TVA will commit to revise the appropriate sections of the SQN FSAR in the next annual update to change the existing RG 1.9 commitments (specifically section 8.3.1) based upon the results of the DG tests and analysis.