Form 01077 (R7-92)

FORM 101.1	REVISION 14

CERTIFICATION OF ENGINEERING CALCULATION

STATION AND UNIT NUMBER Keowee Unit 1 + 2

TITLE OF CALCULATION Keowee Power Operating Restrictions for NSM-52966

CALCULATION NUMBER KC UNIT 1-2 - 0106

ORIGINALLY CONSISTING OF:

PAGES 1 THROUGH 10

TOTAL ATTACHMENTS 7 TOTAL MICROFICHE ATTACHMENTS

TOTAL VOLUMES 2 TYPE I CALCULATION/ANALYSIS YES ☐ NO ☒

TYPE I REVIEW FREQUENCY

THESE ENGINEERING CALCULATIONS COVER QA CONDITION 1 ITEMS. IN ACCORDANCE WITH ESTABLISHED PROCEDURES, THE QUALITY HAS BEEN ASSURED AND I CERTIFY THAT THE ABOVE CALCULATION HAS BEEN ORIGINATED, CHECKED OR APPROVED AS NOTED BELOW:

ORIGINATED BY John R. Beckman DATE 12/12/94

CHECKED BY Henry E. Harling DATE 12/20/94

APPROVED BY [signature] DATE 1/10/95

ISSUED TO DOCUMENT CONTROL John R. Beckman DATE 3/22/95

RECEIVED BY DOCUMENT CONTROL [signature] DATE 3/23/95

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Form 101.2 Revision 1
26164 (R9-89)

File/Calculation No. KC UNIT 1-2-0106

REVISION DOCUMENTATION SHEET

Revision Number	Review Frequency Changed Yes/No	Revision Description
01	NO	Revised Calc to incorporate New test Data &
		To include Better analysis of model Benchmarking,
		Instrumentation Accuracies, and new method.

I PURPOSE

The purpose of this calculation is to establish operating limits for Keowee Hydro Station when supplying power to the Duke Power Distribution Grid. These Limits will be based on the station configuration after it is modified by NSM ON-52966. The purpose of these limits is to insure that Keowee will be able to perform its safety related functions whenever it is in power production.

An additional purpose of this modification is to provide simulated unit start-up response as a design input for the electrical groups designs on NSM ON-52966.

II RELATION to NUCLEAR SAFETY

Since this calculation will identify operating limits for Keowee to ensure its operability, this calculation is designated as QA Condition 1.

III DESIGN METHOD

The design method for this calculation will be to review test data of load rejections performed in the past for acceptable initial conditions. This test data will also be used to verify a computer model developed by Voith Hydro Inc. The results of the test data and model predictions will be used to expand the acceptable test initial conditions to produce an acceptable operating range. These will be in the form of power, Keowee lake level and operating tailrace level restrictions.

IV APPLICABLE CODES and STANDARDS

ANSI N45.2.11 has been reviewed and all applicable design inputs are addressed in the appropriate sections of this calculation.

V OTHER DESIGN CRITERIA

EDM Section 101.4.5 and NSD 800 lists the requirements for Computer Program Verification.

VI FSAR CRITERIA

FSAR Chapter 8.3.1.1.1 Keowee must provide emergency power in 23 seconds.

VII ASSUMPTIONS

7.1 The accuracy of Lake elevations measurements used in this calculation are assumed to be accurate to within ± 1/2 foot. This is based on the measurement method. The water elevations for the testing performed for this calculation were measured manually. Observations of this method were made and this accuracy is considered to be conservative.

7.2 Data interpolations and extrapolations are assumed to be linear over the range of the interpolation or extrapolation.

VIII REFERENCES

8.1 TT/0/A/0620/05 Keowee Load Rejection Testing Performed 2/23/95

8.2 TT/0/A/0620/03 Keowee Load Rejection Testing Performed 3/6/93

8.3 Keowee Calculation KC-UNIT-1-2-0097 Rev.0 Turbine Generator Overspeed Set Point Calculation.

8.4 Drawing K-34 Rev. 0

8.5 Drawing K-130 Rev. 12

8.6 Keowee Vendor Drawing KM 200-126 Rev. DK

8.7 Calculation OSC-6003 Rev. 5

IX CALCULATION

Keowee can be in two different initial conditions prior to being needed to supply emergency power to Oconee Nuclear Station. These two initial conditions are power operation to the Duke grid and, at rest in standby. These two responses will be evaluated by this calculation.

In the first initial condition, power operation, the units are generating power in to the Duke System Grid. Following the initiation of the loss of power signal from Oconee, the response of the switching logic at Keowee is to separate the units from the Duke grid and then tie into the their respective emergency power supply paths. This operation, separation from the grid, causes the Keowee units to experience a load rejection (LR) transient. During this transient the unit speed increases significantly before governor control can return the unit speed to normal. The amount of this increase and the length of time the unit is in overspeed is dependent on several variables. The initial power output of the unit has the greatest effect on overspeed. The greater the load rejection the greater the overspeed. Headwater and Tailwater conditions also have an effect. Design restrictions from the electrical group designing NSM ON-52966 are such that the unit speed must be 110% or less and decreasing at a time of 22 seconds following the initiation of the LR. This is to prevent exposing the emergency power systems to excessive electrical frequency. Operation curves (Power, Head and Tailwater elevations) which meet this criteria will be developed herein.

The second initial condition is the Keowee units are at rest when the emergency start logic is activated by Oconee. This causes the units to start rapidly. If a governor failure were to occur that would cause one of the units to runaway, this unit must be detected and removed from service. As part of the design inputs for the electrical portion of this modification, the Electrical Group needs to know the slowest unit startup characteristics. A unit speed vs startup time curve will be produced by the model for the conditions that would produce the slowest response.

Since it is not practical to test the response of the Keowee units for all of the different combinations of the above design conditions, a computer simulation will be used. This model will allow the investigation of variables that would effect these restrictions. Limits for these variables can then be developed.

The calculation will be performed in the following sequence:

9.1 The LR test data will be reviewed and evaluated.

9.2 The Voith Hydraulic Transient Model for Keowee will be reviewed.

9.3 Acceptable operating conditions for power operation will be calculated.

9.4 The model will be used to simulate unit start-up with a governor failure on one unit, (input for Electrical group).

9.1 Review and Evaluation of Test Data

On February 23, 1995 load rejection (LR) testing was performed on the Keowee Hydro units (Ref 8.1). The purpose of this testing was to obtain data concerning the response of the Keowee units. This data will be presented here and evaluated. The following was recorded for each load rejecting unit:

Unit Speed vs Time
Wicket Gate Position vs Time
Forebay (Lake Keowee Level) Water Elevation
Tailrace Elevation
Initial Power

The test conditions and test results are included in Attachment 3. Also in Att. 3 a summary table is included with frequently used outputs. The time for Unit Speed vs Time data was recorded in milliseconds. This was converted to seconds on Attachment 3. The gate position (% Gate open) was calculated as follows:

$$\% \text{ Gate} = \frac{\text{Output Voltage}}{\text{Input Voltage}}$$

The Input voltage signal was recorded only following the initiation of the LR. This can be noted by observing a step change in Input Voltage. This step change indicates the initiation of the LR. Following the LR the input voltage is recorded. Therefore, the % Gate can only be accurately determined for gate positions following the trip.

Since the data recorded in Attachment 3 were recorded by two separate recorders, the times do not match. There

is no trip signal for the RPM record. The time that the LR occurred must be determined for the RPM data.

Using the information from LR testing performed in March 1993 (Ref 8.2), and comparing it with Voith Hydro Model runs (Attachment 1) for the same conditions, it can be seen that test speed, one second following the LR, is very close to the model predicted speed. The use of the Voith Model here will be justified in Section 9.2.

From Att. 1 Pg. 4
75 MW LR Test (RPM) @ 1 sec = 137.78 RPM

94 MW LR Test (RPM) @ 1 sec = 139.88 RPM

Model times @ 1 sec:

75 MW = 138.67 RPM
94 MW = 141.26 RPM

Comparing the test with the model:

Power MW	Model RPM	Test RPM	Difference
75	138.67	137.78	0.9 RPM
94	141.26	139.88	1.4 RPM

Using the model data, predict when the above test started, relative to the computer model, by interpolating model speed at 1 sec with test data and subtracting 1 sec from that time:

75 MW Data Interpolate 138.67 RPM with test data gives:

Time	RPM
1.0	137.78
T	138.67
2.0	147.89

T = 1.09 sec

Subtracting 1 second gives the model's estimate of when the test LR occurred:

T = 0@ 1.09 - 1 = 0.1 sec

94 MW Data Interpolate 141.26 RPM with test data gives a time of 1.11 sec. Subtracting 1 second gives the model's estimate when the test LR occurred:

T = 0@ 1.11 - 1 = 0.1sec

The above predictions are based on test data that is of unknown accuracy (Ref. 8.2). In addition, the above method predicts a starting time after the LR has begun. To compensate for this uncertainty, any starting time calculated using this method will be corrected by 0.25 sec. This amount is appropriate since the test date in Attachment 3 is recorded in approximately 0.5 sec intervals. The correction amount is 1/2 of this interval. This assumes a normal distribution of LR times within the time scan band.

For each of the 11 LR test, model runs were performed (Attachment 3 contains both test results and model results simulating the tests). Using the model speed estimate at 1 sec, a prediction of when the test LR occurred. By interpolating the test data at the model speed the time for each test one second into the LR can be found.

Model results for Model 1:

.996 sec 136.84 RPM

Test 1	Time sec	Speed RPM
	12.591	135.02
	13.086	139.469

Interpolating the test results at 136.84 RPM:

Test Time

$$@\ 0.996\ \text{sec} = (13.086-12.591)\frac{(136.84-135.02)}{(139.469-135.02)} + 12.591$$

$$= 12.793\ \text{sec}$$

Now to find the estimated starting time of the LR, 0.996 seconds must be subtracted:

T = 0 @ 12.793 - 0.996

= 11.797 sec

The correction of 0.25 sec is now added:

T = 11.797 - 0.25 = 11.547 sec

Repeating the above operation of the remaining 10 tests gives the following:

Test No.	Time @ T =0 sec
1	11.547
2	10.657
3	7.343
4	5.822
5	9.126
6 U1	9.101
6 U2	9.315
7 U1	10.33
7 U2	10.58
8 U1	9.135
8 U2	9.363
9	10.08
10	2.390
11 U1	10.043
11 U2	10.180

Now, the time that the Keowee units, following the initiation of the LR, passed through 110% rated speed decreasing must be determined. The accuracy of the RPM readings is ±0.44 RPM (Attachment 16). To be conservative, this amount will be rounded up to 0.5 RPM. This amount will be subtracted from the 110% speed value to give a conservative time at 110%. Rated speed for the turbine is 128.6 (Attachment 1). The speed which the unit needs to be equal to or below at 22 seconds is:

N = (1.1 X 128.6) -0.5 = 140.96 RPM

Using this speed and interpolating the test data, the time can be determined:

Example Test 1 (Att. 3)

Time when Test 1 reached 140.96 RPM decreasing

$$\text{Test Time} = (26.158-26.652)\frac{(140.96-142.308)}{(142.308-140.259)} + 26.158$$

$$= 26.483 \text{ sec}$$

Repeating the above operation of the remaining 10 tests gives the following:

Test No.	Time @ T =140.96 RPM sec
1	26.483
2	28.346
3	27.462
4	21.394
5	27.421
6 U1	24.498
6 U2	25.512
7 U1	27.914
7 U2	28.829
8 U1	28.525
8 U2	29.055
9	24.586
10	21.960
11 U1	27.419
11 U2	27.974

No correction has yet been made for the accuracy of the time keeping associated with the test data. The recorded time was kept by the data recording computer. (an IBM laptop) The accuracy of this measurement over this short of a time frame (22 sec) is expected to be very small. To be conservative, an accuracy of 0.1 sec over a 22 sec period will be assumed.

Now to find the elapsed time from the LR to reach 110% speed decreasing. Subtracting the time at initiation

from the times just calculated above gives (the time uncertainties will also be added):

Test 1 T = 26.483 - 11.547 + 0.1 = 15.04 sec

Repeating the above operation of the remaining 10 tests gives a conservative time for the LR speed to reach 110% RPM :

Test No.	Time @ Time to 110% sec
1	15.04
2	17.79
3	20.22
4	15.67
5	18.40
6 U1	15.50
6 U2	16.51 Note 1
7 U1	17.68
7 U2	18.60 Note 1
8 U1	19.49
8 U2	20.02 Note 1
9	14.61
10	19.67
11 U1	17.48
11 U2	18.03 Note 1

Note 1: For the double unit LR test the earliest time for the initiation of the LR was used to calculate the elapsed time for both units. This is conservative. The difference in time of Unit 2 compared to Unit 1 can be explained partially by the data acquisition program used to record the test data. The computer recorded data approximately ever 0.25 seconds (1/2 of every time interval). It would record Unit 1 first, then Unit 2. Therefore, the Unit 2 data is approximately 0.25 seconds behind Unit 1.

It can be concluded that all 11 tests produced times and speeds acceptable for the design requirement, 110% speed decreasing in less than 22 sec.

9.2 Evaluation of the Voith Hydro Model.

EDM Section 101.4.5 and NSD-800 lists the requirements for the verification of computer programs that will be used for the design of QA Condition items. This portion of this calculation will verify the validity of portions of CORA Version 1.1 for Keowee Hydro Station. This program belongs to and is operated by Voith Hydro Inc. (Voith).

Voith is a maker of large hydro turbines. Voith is considered to be the Original Equipment Manufacturer of the Keowee turbines after Voith Purchased the Allis-Chalmers Corporation, Hydro-Turbine Division in 1986. Both Voith and Allis-Chalmers have more than 120 years experience in the hydro turbine field. A requirement of EDM 101 is that the Vendor Verification must be performed. This verification is based on Voith's expertise and experience in this field. Voith has supplied many of the Turbines on the Duke Hydro System. Specifically, Voith's expertise is recognized in the industry through the presentation and publications of the CORA program used in this model. This program has been presented at the Joint ASCE-IAHR/AIHR-ASME Symposium on Design and Operation of Fluid Machinery June 1978 and most recently at the 1983 ASCE Water Power Convention. Copies of these presentations are included with the Voith model report in Attachment 1. Also included in Attachment 1, are summaries of 7 other model reports on other projects. These reports also compare actual test data and model data. The model shows good correlation with the actual test data.

Voith was contracted to develop a hydraulic transient model for Keowee. This model was based on information that Voith maintains as the OEM of the Keowee turbines and information specific to the Keowee installation. A model was developed using Version 1.1 of CORA (Attachment 1). The following is a list of input information that was used:

The Report of Model Tests for Duke Power Company, Keowee Development. October, 28 1966 by Allis-Chalmers Co. This report was created by Allis-Chalmers to define the

operating characteristics of the Keowee turbines. (Ref. 8.3). This is the report on the actual scale model tests that were performed by Allis-Chalmers to design the Keowee Units and should not be confused with the computer model being evaluated herein.

Index Test Report for Duke Power Co. Keowee Power Plant September, 1971 by Allis-Chalmers Co.. This is the report of the Index Test for the actual turbines. This report provided gate position to servo motor % stroke. (Ref 8.3)

Keowee Penstock and Layout Drawings (Ref 8.4 and 8.5) were used to define the configuration of the Penstock.

Tests (Ref 8.1 and 8.2) were used to help benchmark the model as well as to help define the gate closing characteristics. Test data (Ref 8.2) was also used to develop cavitation characteristics (Sigma) and is discussed in Att 1. The Allis-Chalmers model tests performed, produced Sigma characteristics mostly for runaway conditions. During the development of the Voith Computer model, this information was found to be inadequate for the conditions in this calculation. To resolve this problem, Voith modified the Sigma input to match the two tests in Ref. 8.2. These two Sigma responses were then averaged to produce a better simulation.

Unit startup information was obtained during the performance of PT/0/A/0610/22 on May 22, 1993. During the performance of this test a trace of the unit speed and gate opening vs. time was obtained (Attachment 7). This information provided gate opening timing as well as startup verification.

Verification of the computer model will be performed using the load rejection test performed for this purpose. TT/0/A/0620/05 was performed on February 23 , 1995 (Ref. 8.1). During this test, 11 load rejections (LR) were performed. These LR were evaluated in Section 9.1. The test results are included in Attachment 3.

Using the initial conditions, recorded in the test (Initial Power, No. of Units running, Forebay Level and Tailrace Level), Voith produced Time vs RPM model runs.

This model output data is included in Attachment 3. To help verify the model, graphs were generated using the actual test data and the model data. These are included in Attachment 8. The time used as T = 0 for the test data was calculated in Section 9.1. Reviewing these comparison curves, it can be seen that the model does not predict the response of the unit exactly. But, during the first few seconds of the LR, the model is accurate and maintains the same or smaller slope. This supports the use of the model to predict the T = 0 point for the test data as evaluated in Section 9.1 The model does show matching responses to changes in the operating variables. For example, as power increased, the model increased along with the test results (Tests 1,2 and 3). To better evaluate the model, direct comparisons and evaluations of the variables (when possible) will be performed. The variables to be evaluated are as follows:

- Tailrace Elevation Effects
- Initial Power Effects
- Difference in Unit Performance
- Forebay Elevation Effects
- Gate Timing

9.2.1 The effects of changes in Tailrace can be determined from comparing tests performed with other variables constant and varying the Tailrace elevation. The runs that can be used for this comparison are as follows (Att. 3):

Compare	Test	to	Test
Test	1		9
Pwr MW	60		60
Unit	1		1
Forebay	799.87′		799.44′
Tail	663.45′		670.4′
Test	3		10
Pwr MW	90		90
Unit	1		1
Forebay	799.85′		799.44′
Tail	664.25′		671.7′
Test	7		11
Pwr MW	70		70
Unit	1		1
Forebay	799.58′		799.56′
Tail	667.51′		672.5′
Test	7		11
Pwr MW	70		70
Unit	2		2
Forebay	799.58′		799.56′
Tail	667.51′		672.5′

To compare the effects of Tail elevation, the gross head across the unit is calculated:

Test 1 799.87′ - 663.45′ = 136.42′

Test 9 799.44′ - 670.4′ = 129.04′

Test 3 799.85′ - 664.25′ = 135.6′

Test 10 799.44′ - 671.7′ = 127.74′

Test 7 799.58′ - 667.51′ = 132.07′

Test 11 799.56′ - 672.5′ = 127.06′

Now calculate the difference in head for each comparison group. The differences in Forebay levels between comparison tests are small compared to the total change in head. Therefore, the effects of different Forebay levels will be ignored.

Test 1 compared to Test 9

136.42′ - 129.04′ = 7.38′

Test 3 compared to Test 10

135.6′ - 127.74′ = 7.86′

Test 7 compared to Test 11

132.07 - 127.06′ = 5.01′

Now the effects of the above changes in Tailrace elevations can be evaluated against the change in the amount of time for the units to reach 110%.

Test 1 time compared to Test 9

15.04 - 14.61 = 0.43 sec

Test 3 time compared to Test 10

20.22 - 19.67 = 0.55 sec

Test 7 time compared to Test 11

U1 17.68 - 17.48 = 0.2 sec
U2 18.60 - 18.03 = 0.57 sec

Now compare the change in time to reach 110% speed to the change in Tail elevation:

Test 1-9 .43 / 7.38 = 0.06 sec/ft

Test 3-10 .55 / 7.86 = 0.07 sec/ft

Test 7-11 U1 .2 / 5.01 = 0.04 sec/ft

U2 .57 / 5.01 = 0.11 sec/ft

The accuracy of the above conclusions needs to be considered. The accuracy for each time measurement was developed in Section 9.1. This accuracy was ± 0.1 sec. The accuracy of the water elevation measurements are ± 0.5'. For each addition or subtraction of these times and elevations the uncertainty is doubled. Therefore the uncertainty of the time difference above is :

0.1 X 2 = 0.2 sec Uncertainty

The uncertainty of the Tail elevation was calculated by subtracting twice:

0.5 X 2 X 2 = 2 feet Uncertainty

The most severe effect noted above was the double unit LR Test 7 to 11 comparison for Unit 2. Using the above

calculated uncertainties the maximum effect can be calculated:

$$\frac{0.57\pm.2}{5.01\pm2} = \text{Worst case } \frac{0.77}{3.01} = 0.26 \text{ sec/ft}$$

It should be noted here that as the Tailrace elevation increased, the time to 110% speed decreased.

Comparison with the Voith model data needs to be performed. The model was run at the same elevations as the tests. The model data in Attachment 3 needs to be evaluated to determine the model time to 110% speed. Interpolation of the model data is as follows:

Model 1 110% speed is 1.1 X 128.6 = 141.46 RPM

10.957 sec	144.75 RPM
11.953 sec	140.94 RPM

Interpolating to 141.46 gives a time of 11.82 sec

Repeating for the other 10 model runs:

Model No.	Time to 141.46 RPM sec
1	11.82
2	14.49
3	18.87
4	11.78
5	14.46
6	12.82
7	14.74
8	17.95
9	12.44
10	20.10
11	15.80

Performing the same comparisons for Tailrace effects as before:

Model 1-9 $\frac{11.82 - 12.44}{7.38'} = -0.084$ sec/ft

Model 3-10 $\frac{18.87 - 20.1}{7.86'} = -0.156$ sec/ft

Model 7-11 $\frac{14.74 - 15.8}{5.01'} = -0.212$ sec/ft

It should be noted here that the model does not correctly predict the effects of raising the Tail water elevation. The model predicts that as the Tail elevation increases the gross head across the machine decreases. This requires that the wicket gates be open more for the higher Tailrace runs. This would expose the unit, following a LR, to the gates being open more and for a longer period of time. For the model, this increases the time it takes for the unit to reach 110% decreasing. Test data shows that the higher Tailrace elevation causes the time to 110% to decrease. Additional insight into this problem can be gained by further examination of the test data for the above tests. From Attachment 3 the maximum attained LR speeds are:

Test	Test Max RPM.	Mdl Max RPM
1	165.764	157.45
9	165.819	158.32
3	185.427	181.48
10	186.505	183.39
7 U1	177.589	167.41
11 U1	176.848	169.78
7 U2	178.569	167.41
11 U2	178.878	169.78

It is noted that these comparisons agree, since both the Test data and the model obtain higher maximum RPM when compared to the higher Tailrace run on 3 of the 4 comparisons. The higher the Tailrace the higher the

maximum speed achieved. These phenomena are due to different braking characteristics of the two tests. When the Tailwater is high, more of the turbine runner in under water (Attachment 9). As the wicket gates close, air is admitted to the turbine area by the air admission valve. The water level in the turbine is then dependant on the Tailrace elevation. The higher the Tailrace elevation the more water in the turbine blade area and the more braking effect this would have. This braking effect would not come into play until the wicket gates are almost closed. This accounts for the higher max speeds seen for the higher Tailrace tests. The units are performing as predicted by the Voith model until the gates are almost closed. Then the increased braking action comes into play. This accounts for the decrease in time to 110%. The Voith model does not take into account any braking effect differences due to Tailrace elevation changes. Therefore, the Voith model should not be used to predict any changes due to Tailrace elevation changes.

9.2.2 The effects of changes in Power can be determined from comparing tests performed with other variables constant and varying the Power. The runs that can be used for this comparison are as follows (Att. 3):

Compare

Test	1	2	3
Pwr MW	60	75	90
Unit	1	1	1
Forebay ft	799.87′	799.9	799.85
Tail ft	663.45	663.6	664.25
Tst T to 110%↓	15.04	17.79	20.22
Mdl T to 110%↓	11.82	14.49	18.87

Test	4	5
Pwr MW	60	75
Unit	2	2
Forebay ft	799.85′	799.82
Tail ft	663.02	663.13
Tst T to 110%↓	15.67	18.40
Mdl T to 110%↓	11.78	14.46

Test	6	7	8
Pwr MW	60	70	80
Unit	1	1	1
Forebay ft	799.83′	799.58	799.72
Tail ft	666.65	667.51	668.1
Tst T 110%↓	15.5	17.68	19.49
Mdl T 110%↓	12.82	14.74	17.95

Test	6	7	8
Pwr MW	60	70	80
Unit	2	2	2
Forebay ft	799.83′	799.58	799.72
Tail ft	666.65	667.51	668.1
Tst T 110%↓	16.51	18.6	20.02
Mdl T 110%↓	12.82	14.74	17.95

Test	9	10
Pwr MW	60	90
Unit	1	1
Forebay ft	799.44′	799.44
Tail ft	670.4	671.7
Tst T 110%↓	14.61	19.67
Mdl T 110%↓	12.44	20.1

Using the above information, graphs were made plotting Power vs Time to 110% (Attachment 10). Using the least squares method, the linear slope of these lines were calculated (Attachment 10):

Test curves slope:	Test 1-2-3	0.173 sec/MW
	Test 4-5	0.182 sec/MW
	Test U1 6-7-8	0.200 sec/MW
	Test U2 6-7-8	0.176 sec/MW
	Test 9-10	0.169 sec/MW
Model curves slope:	Test 1-2-3	0.235 sec/MW
	Test 4-5	0.179 sec/MW
	Test 6-7-8	0.257 sec/MW
	Test 9-10	0.255 sec/MW

Reviewing the curves in Attachment 10 and the above slopes it can be determined that the Voith model does predict the proper response of the Keowee Units to a LR. However, the model is more sensitive to power changes than the actual units.

9.2.3 One of the assumptions in the Voith model is that both Keowee units will perform the same following a LR. Review of the test data included in Attachment 3, shows that the response of the units is slightly different for each unit. Comparing the time to 110% for the following runs:

Compare Similar Test Different Units

Unit 1 Run		Unit 2 Run	Time Difference (sec)
1 15.04	-	4 15.67	= -0.63 sec
2 17.79	-	5 18.4	= -0.61 sec
6 15.5	-	6 16.51	= -1.01 sec
7 17.68	-	7 18.6	= -0.92 sec
8 19.49	-	8 20.02	= -0.53 sec
11 17.48	-	11 18.03	= -0.55 sec

It is noted that Unit 2 is anywhere from 1/2 to 1 sec slower in recovering following from the LR. Up to 0.5 seconds of this difference is explained in Sect 9.1 in Note 1. This difference will not be subtracted out for additional conservatism. If Unit 1 test data is used to develop restrictions, then additional corrections will have to be added to correct for differences in the Unit 2's performance.

9.2.4 The Voith model needs to be evaluated for effects of changes in Forebay elevation. The Voith model predicts that as the Forebay elevation is decreased, the time to 110% is increased. This is due to the decreased gross head available to the turbine. With a lower head the

wicket gates on the turbines must open more to maintain the same power output. When the LR occurs the turbine must deal with a longer time for the gates to close, due to them being open wider. Also the velocity of the water is greater causing a greater pressure surge as the gates go closed. These factors combine to produce higher and longer speed response. Some of these effects can be seen in the Test data in Attachment 3. Although these test only varied Tail elevation, they did reduce the gross head available to the turbines. Since Maximum RPM occurred at approximately 8-10 sec into the LR, the wickets gates were still open significantly. Therefore, braking effects mentioned in Section 9.2.1 had not come into play yet. Any difference in RPM would be due to differences in gross head. To compare these tests against the model, the difference in maximum RPM will be divided by the change in gross head:

From Attachment 3

Test No.	Tst Max RPM	Gross Head ft	Mdl Max RPM
	±0.44	±1.0	±0.44
1	165.764	136.42	157.45
9	165.819	129.04	158.32

Tst $\frac{(165.764 - 165.819)}{(136.42 - 129.04)} = -0.01 \pm 0.16$ RPM/ft

Mdl $\frac{(157.45 - 158.32)}{(136.42 - 129.04)} = -0.12$ RPM/ft

3	185.427	135.6	181.48
10	186.505	127.74	183.39

Test - -0.14 ±0.2 RPM/ft
Mdl - -0.24 RPM/ft

7 U1	177.589	132.07	167.41
11 U1	176.848	127.06	169.78

Test - +0.15 ±0.39 RPM/ft
Model - -0.47 RPM/ft

7 U2	178.569	132.07	167.41
11 U2	178.878	127.06	169.78

Test - -0.06 ±0.34 RPM/ft
Model - -0.47 RPM/ft

As can be seen from the above comparisons, the model predicts the effects of gross head changes on maximum overspeed. The model predicted effect is within the accuracy of two of the above test and predict a greater effect compared to the remaining two. The addition of a safety factor is warranted here. A safety factor of 1.5 will be employed whenever the model is used to predict changes in gross head. These comparisons were made using changes in gross head using Tailwater elevation changes. Any use of this portion of the model should be limited to a narrow band around known data. Since the above comparisons were made in the range of 7 to 5 feet differences, predictions within 4 feet will be conservative.

9.2.5 Gate timing is a design input characteristic that was determined originally by the March 6, 1993 testing (Ref 8.1). Since this information is of unknown accuracy, this input characteristic needs to be evaluated using the test data in Attachment 3. Gate timing on the Keowee Turbines is controlled by the Governor. Closing gate speeds are limited to different rates. The unit has a nominal closing rate that is in effect from 100% to approximately 10% closed. From Approximately 10% to full closed, the gates close at a slower rate to reduce the closing pressure transient. These rates and the transition point need to be determined. Using the data in Attachment 3, graphs of the gate closing position vs time were made (Attachment 11). Using this data, linear slopes of the normal closing and slow closing can be calculated (Attachment 11). Straight lines with these slopes were drawn on these curves to demonstrate their appropriateness. The accuracy of the gate position indication was found to be ±.07% (Att 16) and time accuracy for this duration is again estimated to be ±.1 sec.

From Attachment 11:

Slope Tst 1 Nominal $\frac{38\pm.07-0\pm.07}{0 - 9.5\pm.1}$ = -4.0± 0.06 %/sec

Slope Tst 1 Slow Closure $\frac{8\pm.07 - 0\pm.07}{(8-13.4)\pm.1}$ = -1.48 ±.06 %/sec

Unit 1 Tests	Nominal Timings %/sec ±0.06	Slow Close Timings %/sec ±0.06
1	-4.00	-1.48
3	-4.16	-1.45
6	-4.03	-1.47
7	-4.11	-1.42
8	-4.21	-1.48
9	-4.04	-1.40
10	-4.22	-1.54
11	-4.12	-1.53
Unit 2 Tests		
4	-4.17	-1.68
5	-4.16	-1.62
6	-4.20	-1.62
7	-4.20	-1.62
8	-4.21	-1.58
11	-4.28	-1.65

In the Voith Model this information is input in the form of "Nominal" Gate Time. This is defined as the time for the gates to travel from 100% to 0% without any slow closure. Using the above information to calculate this nominal gate time:

Unit 1 Tests

Test 1	100/4.000 ±.06 = 25.0±0.4 sec Nom. Gate Time
Test 3	24.0 sec
Test 6	24.8 sec
Test 7	24.3 sec
Test 8	23.8 sec
Test 9	24.8 sec
Test 10	23.7 sec
Test 11	24.3 sec

Average Nominal Gate Time = 24.3 ±0.4 sec

Maximum Gate Time = 25.00 ±0.4 sec

Unit 2	
Test 4	24.0 sec
Test 5	24.0 sec
Test 6	23.8 sec
Test 7	23.8 sec
Test 8	23.8 sec
Test 11	23.4 sec

Average Nominal Gate Time = 23.8 ±0.4 sec

Maximum Gate Time = 24 ±0.4 sec

The slow closure rate used in the model is input in the form of what % Gate Opening the slow closure begins and the amount of time for the gates to go full closed from that point. The model used a slow closure starting position of 11%. Therefore, using the graphs in Att. 11 and the closure rates listed above, the slow closure rates from the tests can be calculated as above:

Unit 1	Slow Closure Time (Model)
Test 1	11/1.48 ±.06 = 7.4 ±0.3 sec
Test 3	7.6
Test 6	7.5
Test 7	7.7
Test 8	7.4
Test 9	7.9
Test 10	7.1
Test 11	7.2
Average	7.5 ±0.3 sec

Maximum Gate Time 7.9 ±0.3 sec

Unit 2	Slow Closure Time (Model)
Test 4	6.5
Test 5	6.8
Test 6	6.8
Test 7	6.8
Test 8	7.0
Test 11	6.7
Average	6.8 ±0.3 sec

Maximum Gate Time = 7.0 ±0.3 sec

To verify the initiation point of the slow closure the graphs in Att. 11 were reviewed to determine the

approximate point where slow closure begins. The selection of these points will be by observing the graph and selecting the first point after the slope changes. The actual point where the transition from nominal to slow closure rates occurred most likely within the 1/2 sec period before this point.

Unit 1	Slow Closure Starting % ±0.07
Test 1	7.3
Test 3	7.9
Test 6	7.6
Test 7	7.6
Test 8	7.9
Test 9	8.2
Test 10	7.3
Test 11	8.2
Average	7.8 ±.07 % Gate

Unit 2	Slow Closure Starting % ±.07
Test 4	9.2
Test 5	9.3
Test 6	8.2
Test 7	8.2
Test 8	8.5
Test 11	9.6
Average	8.8 ±.07 % Gate

From Attachment 1 the closing Gate timing used in the model is:

1/2 sec delay
24.7 sec Nominal Gate Timings
11 % gate Slow Closure begins
6.8 sec Slow Closure time.

A graph of the above model closing rates was made comparing the above model rates with the maximum(Test 11 U2) and minimum (Test 1 U1) nominal closing test rates (Attachment 13). The Test Data curves used the gate position and time just prior to the initiation of the trip signal as the starting point (Att 3). This produces test gate curves that may be as much as 1/2 sec conservative. It can be seen that for both of these cases the model is ultimately slower to close. This is mainly due to the model slow closure starting at 11%. The slower the closing rate used in the model, the longer the LR overspeeds take to reach 110%. Therefore

the gate closing times used in the model are conservative. In addition, if the model is used only for comparison purposes (comparing small changes in initial conditions, ie. a 135′ head LR to a 130′ head LR), the difference in results (times to 110%) between two models using slightly different gate times would be very small.

The above evaluation of test gate closing times can be used to gain some insight into the overall repeatability of the Keowee units to produce repeatable LR responses. Conversations with Voith (Attachment 12) indicate that repeated testing of turbine LR's, at constant initial conditions, produce maximum overspeeds that vary by no more than 1 RPM. This variance can be attributed to slight changes in governor control over gate closing timing. As can be seen by the above gate timings, the gate timing varies from the average by as much as:

Average Nominal Gate Timing = 24.3 ±0.4 sec
Maximum Gate Timing = 25 ±0.4 sec

Gate timing varies 25±.4 - 24.3 ±0.4 = maximum of 1.5 sec

Voith made a model run for a 89 MW LR using gate closing times that varied by 1 sec (Attachment 14). The longer gate closing time produced a slightly higher maximum RPM and a time to 110% longer by 1/2 second.

Since gate closing times for the Keowee units vary by as much as 1.5 sec from the average, any use of test data based on one sample needs to be adjusted for variances in gate speed by 0.75 sec (ie, add 0.75 sec to the "Time to reach 110% speed decreasing")

9.3 Development of Restrictions

To meet the design criteria of 110% speed and decreasing by 22 seconds, the above variables need to be controlled. Review of the conservative times for the tests evaluated in Section 9.1 indicate that all of those test met the design criteria. If the units could be operated at the same exact conditions it could be expected to produce the same results. If these test

results are expanded, using the effects of the variables on time to 110%, limits and restrictions for unit operation to the grid can be developed.

Double Unit 80 MW

Reviewing the tests in Section 9.1, test 8 is for a double unit 80 MW LR. Test 8 has the following LR times to 110%:

Test 8 U1 19.49 sec
U2 20.02 sec

The Unit 2 time will be used since it is closer to 22 sec and is more restrictive. This time needs to adjusted for the repeatability as evaluated in 9.2.5. Variances in repeatability were identified as 0.75 seconds

20.02 + 0.75 = 20.77 sec

These test were performed at 80 MW using the Keowee Control board MW meter. This meter has an accuracy of ±2.71 MW (Ref. 8.7). Therefore, this test could have been:

80 - 2.71 = 77.29 MW

If this gage is used to set the operating limits the accuracy must be subtracted again:

77.22 - 2.71 = 74.58 MW

This is the restriction on the power variable. For LR overspeeds to be below 110% speed in 22 seconds the load must be at or below 74 MW.

Other variables must now be controlled. It is known from the test data that an increase in Tailrace elevation will shorten the time to 110% speed. Therefore, operation with a Tailrace elevation above the test elevation is conservative. The Tailrace elevation for Test 8 was 668.1 feet ±0.5. The effects of decreasing the Tailrace elevation were evaluated from test data in Section 9.2.1 and were found to be (worst case) 0.26

sec/ft decreasing. Using this rate to extrapolate the test Tailrace elevation:

$$22 - 20.77 = 1.2 \text{ sec}$$

$$\frac{1.2 \text{ sec}}{0.26 \text{ sec/ft}} = 4.6 \text{ ft}$$

Keowee could operate at 74 MW with a Tailrace elevation 4.6 feet below the test data and still have its speed at or below 110% in 22 seconds. This level reduction is based on Assumption 7.2. Since this is an extrapolation, Some additional conservatism needs to be added. Extrapolations of this kind should not exceed 4ft. Therefore, the minimum Tailrace elevation for this power will be limited to the following.

From Att. 3

Above: 668.1 - 4 = 664.1 ft

Operation will be based on the same measurement method, with the same accuracy (±0.5ft). Accuracy of the test measurement has already been considered in the rate used above. The following is added:

Tailrace Elevation Restriction:

Above: 664.1 + 0.5 = 664.6 ft

This is the minimum Tailrace elevation allowed, for the given power, with the Forebay Elevation at or above 799.72 ft.

Now Results of Test 8 need to be expanded concerning changes in Forebay Elevation. Operation with Forebay elevations above the test elevation will produce shorter times to 110% speed. But, operation with lower Forebay elevations, will produce longer times. In Section 9.2.4 the Voith model was shown to closely predict effects caused by changes in gross head. This Section also required the use of a safety factor of 1.5 when using the model to predict effects of changes in gross head. Voith made a model run based on Test 8 conditions except

the Forebay elevation was lowered 5 feet (Attachment 4). The model produced the following:

Forebay 794.72 ft
Tailrace 668.1
Initial Power 80.4
Double Unit LR

Interpolating Time to 110% speed gives 19.12 sec.

Compared to the model time results for Test 8 (17.95 sec) from Section 9.2.1:

$$\frac{19.12\ sec - 17.95\ sec}{5\ ft} = 0.23\ sec/ft$$

Calculating the Maximum Allowable decrease in Forebay level:

$$22 - 20.8 = 1.2\ seconds$$

$$\frac{1.2\ sec}{(0.23 \times 1.5)\ sec/ft} = 3.48\ ft$$

This is within the extrapolation limit of 4 feet so:

$$799.72 - 3.48 = 796.24\ ft$$

In addition, correction for Forebay elevation measurements need to be made as before:

$$796.24 + 0.5 = 796.74\ ft$$

This is the minimum Forebay Elevation allowed, for the given power, with Tailrace elevation at or above 668.1'.

A graph of Tailrace Elevation vs Forebay Elevation (Attachment 15) was constructed using the above limits. This graph makes the combinations of these limits usable.

Double Unit 70 MW

Now repeating the above for a 70 MW double unit LR. Test 7 will be used for the starting point for this evaluation.

Time to 110% for Test 7 Unit 2 18.60 sec

Adding correction for repeatability:

18.60 + 0.75 = 19.35 sec

Correcting Power:

70 - 2.71 - 2.71 = 64.58 MW Use **64 MW as LIMIT**

Adjustment for Tailwater Elevation

22 - 19.35 = 2.65 sec

$$\frac{2.65 \text{ sec}}{.26 \text{ sec/ft}} = 10.2 \text{ ft}$$

This is beyond the limit (4 ft) for extrapolating. Tailrace Limit is:

667.51 - 4 = 663.51 ft

Measurement corrections

663.51 + 0.5 = 664.01 ft

Forebay Adjustments:

The Voith model only uses Gross head, therefore, Model 11 can be used here.

From Model 7	From Model 11
Forebay 799.58′	799.56′
Tailrace 667.51′	672.5′
Gross H 132.07′	127.06′
Initial Power 70 MW	70MW
Time to 110% 14.74 sec	15.8 sec
Double Unit LR	

Compare to Model 7 to Model 11

$$\frac{15.8 - 14.74 \text{ sec rs}}{132.07 - 127.06 \text{ ft rs}} = .21 \text{ sec/ft}$$

Max decrease in Forebay:

22 - 19.35 = 2.65 sec

$$\frac{2.65 \text{ sec rs}}{(0.21 \times 1.5) \text{ sec/ft rs}} = 8.41 \text{ ft}$$

Model extrapolation limits is restricted to 4 feet. The Forebay Limit is:

799.58 - 4 = 795.58ft

Correcting for measurement accuracies:

795.58 + 0.5 + = 796.08 ft

Using the above the limits, the Double Unit 64 MW Restriction Graph can be made (Attachment 15)

Single Unit 90 MW

Now repeating the above for a single unit LR. Test 3 will be used for the starting point for this evaluation. Since Unit 2 produces longer (greater time to 110% speed) LR transients, this limit will be applicable to **Unit 1 only.**

Time to 110% for Test 3   20.22 sec

Adding correction for repeatability:

20.22 + 0.75 = 20.97 sec

Correcting Power:

90 - 2.71 - 2.71 = 84.58 MW   Use **84 MW as LIMIT**

Adjustment for Tailwater Elevation

22 - 20.97 = 1.03 sec

$$\frac{1.03 \text{ sec}}{.26 \text{ sec/ft}} = 4.0 \text{ ft}$$

This is the limit (4 ft) for extrapolating. Tailrace Limit is:

664.25 - 4 = 660.25 ft

Measurement corrections

660.25 + 0.5 = 660.75 ft

Forebay Adjustments:

The Voith model only uses Gross head, therefore, Model 10 can be used here.

From Mdl 10	From Model 3
Forebay 799.44'	799.85'
Tailrace 671.7'	664.25'
Gross H 127.74'	135.6'
Initial Power 90 MW	90 MW
Time to 110% 20.1 sec	18.87 sec
Single Unit LR	

Compare to Model 3 to Model 10

$$\frac{20.1 - 18.87 \text{ sec}}{135.6 - 127.74 \text{ ft}} \quad .156 \text{ sec/ft}$$

Max decrease in Forebay:

$$22 - 20.97 = 1.03 \text{ sec}$$

$$\frac{1.03}{0.156 \times 1.5} = 4.40 \text{ ft}$$

Model extrapolation limits is restricted to 4 feet. The Forebay Limit is:

$$799.85 - 4 = 795.85\text{ft}$$

Correcting for measurement accuracies:

$$795.85 + 0.5 = 796.35 \text{ ft}$$

Using the above the Unit 1 limits graph can be made (Attachment 15)

9.4 Unit Startup Model

An additional requirement for the modified control circuitry is to protect Oconee from a Keowee unit that has experienced a runaway unit governor failure during a startup. In this case, both units are at rest in standby. At the initiation of the event, both units start. One unit is under governor control and one unit

experiences a governor failure that causes it to run away. For this scenario, the Keowee unit that has experienced the failure must be detected and removed from service to protect Oconee. The circuitry that is being designed for this purpose needs to know unit startup speed characteristics. The failure will be detected by monitoring the Governor Ball Head Motor speed, internal to the Governor Cabinet. The electrical group needs some insight into the unit speed startup characteristics so that the timing of this check can be determined.

For this model the most conservative set of conditions would be those that would produce the slowest start. These conditions would be where the available head to the unit would be at the minimum and where both units start. The lowest Headwater level allowed for Lake Keowee is conservatively set at 785'. This is based on FSAR Chapter 16 SLC 16.9.7. The highest Tailrace level would be the maximum expected level for lake Hartwell. This level is 665 ft (Attachment 6). If the governor failed and caused a unit to runaway, the wicket gates would not move uninterrupted to 100% open. The governor is equipped with several speed switches that temporarily over ride the governor during startup. Keowee Speed switches 14/1 and 13/1 (Ref. 8.6) perform the following functions.

14/1 operates at 52 RPM. This switch operates the Partial Shutdown Solenoid. This over rides the governor and limits the wicket gates to 25 % open. If the gates are open greater than this at the initiation of this switch, then the gates would close, at the nominal gate speed, to 25 %.

13/1 operates at 122 RPM. This switch picks up the Partial Shutdown Solenoid and restores full control to the governor. The full range of motion is restored to the governor.

The effects of these two switches is such that if the governor failure caused the unit to runaway, the gates would operate as follows: The gates would open at full speed until the unit reached 52 RPM. The gates would then begin to close until the gates reached 25 % open.

When the unit reached 122 RPM, The gates would then open until they reached 100% open.

The gate closing rates would be the same as determined earlier. Unit startup information was obtained during the performance of PT/0/A/0610/22 on May 22, 1993. During the performance of this test a trace of the unit speed and gate opening vs. time was obtained (Attachment 7). This information provided gate opening timing as well as startup verification.

During PT/0/A/0610/22, Unit startup data was recorded (Attachment 7). The accuracy of this data is unknown. This test involved an emergency start of both Keowee Units. The Initial conditions for this test were:

Initial Power:	0 MW (Standby)
Headwater Elevation	799.2' Ref 8.5
Tailwater Elevation	661.0' Ref 8.5

Voith used these initial conditions in the model and the results are shown in Attachment 2. Actual data vs Model data are plotted together. The two curves correlate very closely especially in the first few seconds of the startup.

Using the low head conditions given above (HW = 785', TW = 665') Voith ran a model with both units starting from rest. One unit operated normally and one unit simulated a governor failure. The results of this model are shown in Attachment 5. Although the accuracy of the Voith model at these conditions is unknown, the Electrical group can use this curve to gain insight into the unit's operation at low heads.

X CONCLUSION

The results of testing performed in February, 1995 were evaluated and of the eleven load rejection tests performed, all were ~~within~~ acceptable within the Design Criteria of 110% decreasing at 22 seconds. These acceptable test results were expanded using trends of variables developed from the test data and from the Voith model. All instrument uncertainties and unit performance characteristics were taken into account to develop conservative restrictions for future operation.

The requirements of EDM Section 101.4.5 (Computer Program Verification) were reviewed and the information provided herein demonstrates that Voith has the necessary expertise and is qualified to perform this model analysis. The model simulations were verified by eleven benchmark runs. These benchmarks were actual Keowee test results. The results of these verification runs showed that although, it did not predict turbine response exactly, it did, for several variables, conservatively predict relative changes from one case to another. Test data coupled with the model can be used to develop operational curves for the Keowee Units.

Operation of the unit in the acceptable operating region shown on the curves in Attachment 15 will ensure that the load rejection unit's speed will be below the 110% at 22 seconds. The use of the curves are as follows:

10.1 Use of the **2 Units 74 MW Curve**

Operation of **both** Keowee units to the grid is allowed at a power of 74 MW or less. Forebay and Operating Tailrace Elevations must be inside the Acceptable Operating Area shown on the curve. This curve takes into account all operating instrument uncertainness. The curve does not take into account any unit power drift.

Operation of a **single** Keowee Unit (Unit 1 or 2) alone to the grid is allowed at a power of 74 MW or less. This is allowed since, double unit LR's are limiting conditions. If it is acceptable for double LR, then single unit operation is acceptable. Forebay and Operating Tailrace Elevations must be inside the Acceptable Operating Area shown on the curve. This curve takes into account all operating instrument uncertainties. The curve does not take into account any unit power drift.

10.2 Use of the **2 Units 64 MW Curve**

Operation of **both** Keowee units to the grid is allowed at a power of 64 MW or less. Forebay and Operating Tailrace Elevations must be inside the

Acceptable Operating Area shown on the curve. This curve takes into account all operating instrument uncertainties. The curve does not take into account any unit power drift.

Operation of a **single** Keowee Unit (Unit 1 or 2) alone to the grid is allowed at a power of 64 MW or less. This is allowed since, double unit LR's are limiting conditions. If it is acceptable for double LR, then single unit operation is acceptable. Forebay and Operating Tailrace Elevations must be inside the Acceptable Operating Area shown on the curve. This curve takes into account all operating instrument uncertainties. The curve does not take into account any unit power drift.

10.3 Use of the **Unit 1 ONLY 84 MW Curve**

Operation of Keowee unit 1 only to the grid is allowed at a power of 84 MW or less. Forebay and Operating Tailrace Elevations must be inside the Acceptable Operating Area shown on the curve. This curve takes into account all operating instrument uncertainties. The curve does not take into account any unit power drift.

An additional curve (Att. 5) was generated for the use of the Electrical group. This curve shows the slowest possible unit startup characteristics.

XI ATTACHMENTS

Attachment 1 — HYDRAULIC TRANSIENT ANALYSIS FOR KEOWEE HYDROELECTRIC SITE Reported by: Voith Hydro, Inc. Field Engineering Department.

Attachment 2 — Keowee Startup Verification Curve.

Attachment 3 — Test Results from Keowee Testing on Feb. 23 1995 and Voith Model Runs Simulating these test load Rejections

Attachment 4 — Voith model results for Double Unit LR at 80.4 MW, 794.72 H and 668.1 T

Attachment 5	Keowee Model Run for Startup with Runaway Governor.
Attachment 6	Telephone Conversation Report with Alvin Christian, US Army Corp. Engineers
Attachment 7	Strip Chart of Unit Speed and Gate Position VS time for two unit Emergency Start. Taken 5/22/93 during PT/0/A/0610/22.
Attachment 8	Graphs comparing Test results and Model simulations for data in Attachment 3
Attachment 9	Information from Voith Hydro concerning effects of Tailwater elevation on LR braking effects.
Attachment 10	Graphs showing Time vs LR Power
Attachment 11	Graphs of Att. 3 Gate Timing Data vs Time
Attachment 12	Phone Conversation Report with Voith Hydro concerning LR repeatability
Attachment 13	Graph comparing Test Gate Timing with Model Timing
Attachment 14	Graph of Voith results showing effects of slight changes in Gate Timing.
Attachment 15	Keowee Power Level and Lake Restriction Curves
Attachment 16	Test and Operation Instrument uncertainties analysis.

Attachment # 1

VOITH

Voith Hydro, Inc.
York, Pennsylvania

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792-7155

March 28, 1994

Duke Power Company
Oconee Nuclear Site
7812 Rochester Highway
Mail Stop ONO 2ME
Seneca, SC 29679

ATTENTION: John Beckman

Subject: Keowee Hydro Station Hydraulic Modeling
DPCo P.O. E 39447-K2
Voith S/B Number 15448

Dear John:

Enclosed is a summary report of the results of our hydraulic transient analysis along with computer program verification documentation.

Please let us know if you have any questions or require clarification on any of the submitted materials and also keep us informed should you require any additional hydraulic transient analysis for the Keowee site.

Sincerely,

Michael Byrne
Field Engineering Department

cc: VY- G. Snyder

Purpose
The following information is presented to document the calculation process used to analyze the transient behavior for the hydro turbines at the Keowee Plant.

Method
A computer program "CORA" was used to predict the transient behavior of the hydro turbines at the Keowee Plant. The Computer program was developed in 1976 and was specifically designed for hydro turbine applications. The program is based on the method of characteristics. This technique converts the partial differential equations describing the conditions of pressure and velocity into finite difference equations solvable by digital computers. The program used for the Keowee analysis is Version 1.1 which is designed to operate on an IBM PC computer.

Applications
The program was introduced to the Hydro Turbine Industry in a paper titled " 'CORA' Hydraulic Transients 'PLUS' " written by S. A. Chacour and R. E. Deitz was presented at a Joint Symposium on Design and Operation of Fluid Machinery June 12 - 14, 1978 sponsored by ASCE - IAHR/AIHR - ASME. Another paper titled "Computer Analysis and Field Correlation from the Hydraulic Transient Program 'CORA' " was written by R. E. Deitz and presented at WATERPOWER 1983. Since the program was developed, it has been applied to well over 300 different hydro turbine systems.

Verification
The predicted transient results from the "CORA" program have been compared to many different type hydro turbines. Appendix A contains comparisons of predicted transient behavior to measured prototype data for nine (9) different plants demonstrating good correlation. Included in the Keowee analysis report are comparisons of predicted to site measurements for two different load rejections.

HYDRAULIC TRANSIENT ANALYSIS
FOR KEOWEE HYDROELECTRIC SITE

Report by: Voith Hydro, Inc.
Field Engineering Department
March 1994

Calculations by:
Michael Byrne
Field Engineer

Checked and Approved by:
Ronald E. Deitz
Manager, Field Engineering

PURPOSE

This hydraulic transient analysis was performed in order to determine the transient speed characteristics of the two mixed flow turbines at the Keowee hydroelectric plant. These two units supply emergency power to the Oconee Nuclear Station.

CONCLUSION

This Keowee hydraulic transient model simulation used Duke Power supplied field data for a 75 and ~~93~~ 94 MW generator load rejection to establish a working model which could then be used to simulate additional transient cases requested by Duke Power. The correlation of the simulated data to the field data can be found on figures 6 and 7. The primary area of concern of this study was the time versus turbine generator shaft speed curve following load rejection and the time at which the unit speed went below 145 RPM. The field data shows the unit returning to 145 RPM at 16.43 and 18.86 seconds where as the simulation data returns to 145 RPM at 15.03 and 18.42 seconds.

INPUT DATA

Machine Type	8X Mixed Flow Turbine
Rated Speed	128.6 RPM
Rated Conditions	96,000 horsepower turbine output at 99 foot net head
Runner Diameter	214 inches
Model Data Used	Allis Chalmers Model Test 3294 Report of October 1966
Headwater Elevation	808.0 feet(maximum)
	785.0 feet(minimum)
Tailwater Elevation	672.5 feet(maximum)
	655.0 feet(minimum)
Centerline Elevation	667.0 feet(distributor centerline)
Turbine Inertia	2,480,000 pounds-feet squared
Generator Inertia	102,500,000 pounds-feet squared
Penstock Drawings	Duke Power Company K-34 and K-130
Friction Factors	0.009 for steel lined penstock
(Darcy-Weisbach)	0.010 for concrete lined tunnel
Pressure Wave Vel.	3,900 feet per second

DISCUSSION

Hydraulic transient turbine work was previously undertaken and submitted to Duke Power in November 1993. The shape of the time versus unit speed curves from that computer simulation did not match field data taken by Duke Power at the Keowee hydroelectric facility during a single unit 93MW generator load rejection.

The next step was to look at the influence of sigma on the model data. Sigma which is a measure for the conditions which cause cavitation can be calculated several different ways so the

following equation is enclosed to show a trend of how sigma influences runaway speed:

$$\frac{Hb - Hv - Hs}{\text{Net Head}}$$

Where: Hb is barometric pressure in feet
Hv is vapor pressure in feet
Hs is the static suction head on the runner in feet
Net Head is in feet

An example calculation for Keowee based on the following conditions yields the following sigma value:

Hb = 33.1 feet
Hv = 1.0 feet for 75 degrees F water
Hs = (667 - 672.5) = -5.5 feet
Net Head = 128 feet
Sigma = 0.29

The preceding example is based on the distributor centerline elevation of 667 feet and a tailwater elevation of 672.5 feet. The sigma information shown on figure 1 which is extracted from the Keowee model test report and is concerned with cavitation damage to the runner blades is based on a reference elevation of the bottom of the runner blades of 657.17 feet.

A new model data file was formed and attempts were made to match the simulated transient output data to field data obtained from Duke Power in their submittal dated January 13, 1994. The two transient cases studied were a 75 and a 94 MW generator output single unit load rejection conducted on Keowee unit 2 by Duke Power on March 6, 1993. Two transient data files were formed that matched the time versus shaft speed data submitted by Duke Power. The only problem was that if the 75 MW simulation file was used to simulate the 94 MW load rejection and the 94 MW simulation file was used to simulate the 75 MW load rejection exhibited some variation from the field test results. The next step was to create a blended transient data file which was an arithmetic average of the 75 and 94 MW transient data files.

This blended transient data file was used to study the 17 runs submitted by telefax from Duke Power on February 17, 28, March 11 and 15, 1994. The wicket gate servomotor stroke closing rate was established from the 75 and 94 MW load rejection data obtained by Duke at Keowee on the curves labelled chart 3 and chart 6. First there is a 0.5 second dead time which means there is no wicket gate movement for the first 0.5 seconds after the units main breaker is opened. A straight line was drawn through the gate position(Gp) data to established the nominal wicket gate closing time. Chart 3 shows the gates go from 55 to 0% in 13.7 seconds and chart 6 from 64 to 0% in 15.7 seconds which yield nominal closing

rates of 24.91 and 24.53 seconds an average value of 24.7 seconds was used for the transient simulations. The slow closure rate which initiates at 11% servomotor stroke took 6.6 seconds for chart 3 and 7.0 seconds for chart 6. The average slow closure time of 6.8 seconds was used for the transient simulations.

The wicket gate setting in the transient model is based on wicket gate opening and the wicket gate position closing scheme outlined in the preceding paragraph is based on wicket gate servomotor stroke. Unit 2 wicket gate servomotor stroke versus wicket gate opening calibration data taken during index testing is tabulated below and shown graphically on figure 4.

Wicket Gate Servomotor Stroke (Inches)	Wicket Gate Opening (In.)
0	0
2.375	2.725
4.672	5.552
6.953	8.533
9.219	11.448
11.531	14.331
13.844	17.088
16.156	19.813
18.453	22.231
20.781	24.606
23.141	26.785
23.172	26.792

The wicket gate servomotor stroke closing scheme used during this transient study is shown on figure 5. The transient simulation is based on turbine output and the field data from Duke is based on generator output. A generator efficiency of 97.7% was used in this transient study to convert turbine output to generator output.

A comparison of the Duke field data and the simulated transient results for the 75 and 93 MW generator output single unit load rejections are presented in the following table:

75 MW Generator Load Rejection (TEST)		(MODEL)		93 MW Generator Load Rejection (TEST)		(MODEL)	
Time Seconds	Speed RPM	Time Seconds	Speed RPM	Time Seconds	Speed RPM	Time Seconds	Speed RPM
0.0	128.6	0.0	128.6	0.0	128.6	~~0.0~~	~~128.6~~
1.0	137.78	1.0	138.67	1.0	139.88	~~1.0~~	~~140.69~~
2.0	147.89	1.99	148.05	2.0	152.52	~~1.99~~	~~151.75~~
3.0	156.16	2.99	156.06	3.0	162.44	~~2.99~~	~~161.42~~
4.0	163.05	3.98	162.07	4.0	169.66	~~3.98~~	~~169.52~~
5.0	167.54	4.98	165.97	5.0	175.98	~~4.98~~	~~175.54~~
6.0	169.93	5.98	167.92	6.0	180.04	~~5.98~~	~~179.46~~
7.0	172.23	6.97	168.62	7.0	180.94	~~6.97~~	~~181.46~~
8.0	172.23	7.97	168.69	8.0	181.39	~~7.97~~	~~181.88~~
9.0	171.77	8.96	167.64	9.0	181.39	~~8.96~~	~~181.53~~
10.0	169.93	9.96	165.44	10.0	180.04	~~9.96~~	~~180.71~~

Rev 1 JBB

See 4B Pg's 4A

VOITH HYDRO, INC. TELEFAX

DATE: April 24, 1995

TO: Duke Power

ATTN: John Beckman

RE: Keowee Data

TELEFAX #: (803) 885-4028

SENT BY: Michael Byrne

FROM: VOITH HYDRO, INC.
East Berlin Road
P.O. Box 712
York, PA 17405

Tel: (717) 792-7155
Tfx: (717) 792-7263
Tlx: 4764013

NO. OF PAGES: 1
(incl. cover page)

If you do not receive all the pages, or if trouble occurs during transmission, please call (717) 792-7852 as soon as possible

Hello John:

Enclosed is a table listing time versus unit speed that results from a 1 unit 93 and 94 MW generator load rejection with the unit subject to a headwater elevation of 798.16 feet and a tailwater elevation of 672.5 feet:

Time (Seconds)	Test Unit Speed (RPM)	Mdl Unit Speed (RPM)
0.0	128.6	128.6
0.996	139.88	141.26
1.992	152.52	152.73
2.988	162.44	162.67
3.984	169.66	170.98
4.980	175.98	177.45
5.976	180.04	181.84
6.973	180.94	184.24
7.969	181.39	184.91
8.965	181.39	184.57
9.961	180.04	183.76
10.957	178.24	182.17
11.953	175.98	179.38
12.949	172.38	175.56
13.945	168.76	170.90
14.941	164.70	165.70
15.937	160.18	160.54
16.933	155.67	155.42
17.930	149.81	150.33
18.926	144.39	145.27
19.922	139.88	140.23
20.918	134.46	135.29

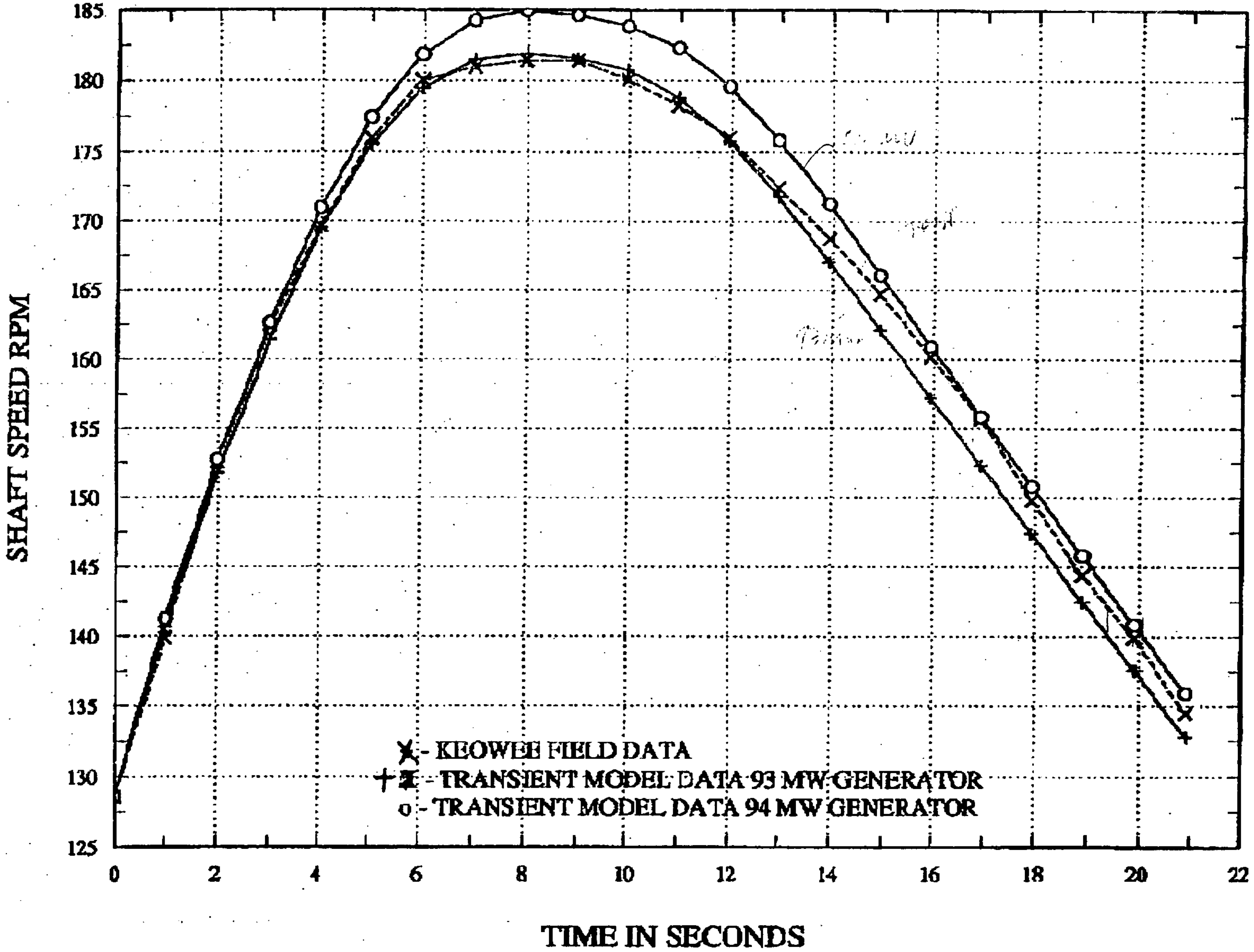
These numbers were used to produce the figure telefaxed to you on January 25, 1995.

Regards,
Michael Byrne
Michael Byrne

4B 4A JTB Rev 1

KEOWEE 1 UNIT 93 MW GENERATOR LOAD REJECTION

HW = 798.6 TW = 664.8 FEET USING BLENDED MODEL DATA



4B 93B Rev 1

01-25-95

75 MW Generator Load Rejection

Time Seconds	Speed RPM	Time Seconds	Speed RPM
11.0	167.64	10.96	162.26
12.0	163.50	11.95	158.31
13.0	160.29	12.95	154.05
14.0	156.16	13.94	149.74
15.0	151.57	14.94	145.39
16.0	146.98	15.94	141.00
17.0	142.37	16.93	136.55
18.0	136.87	17.93	132.07
19.0	133.19	18.93	127.67

9~~3~~4 MW Generator Load Rejection

Time Seconds	Speed RPM	Time Seconds	Speed RPM
11.0	178.24	~~10.96~~	~~178.79~~
12.0	175.98	~~11.95~~	~~175.76~~
13.0	172.38	~~12.95~~	~~171.77~~
14.0	168.76	~~13.94~~	~~167.05~~
15.0	164.70	~~14.94~~	~~162.13~~
16.0	160.18	~~15.94~~	~~157.22~~
17.0	155.67	~~16.93~~	~~152.31~~
18.0	149.81	~~17.93~~	~~147.40~~
19.0	144.39	~~18.93~~	~~142.48~~
20.0	139.88	~~19.92~~	~~137.56~~
21.0	134.46	~~20.92~~	~~132.79~~

Rev 1 JBB

The transient cases requested by Duke to be studied are listed in the following table:

Run Number	Initial Generator Power(MW)	Headwater Elev.(ft)	Tailwater Elev.(ft)	Number of Units Rejecting	Special Conditions
1	90	800	662	1	
2	90	800	662	1	10MW LoadOn 2s Before
3	90	800	662	1	10MW Load On 2s After
4	90	800	662	1	20MW LoadOn 2s Before
5	90	800	662	1	20MW Load On 2s After
6 *	90	800	672.5	2	
7	90	790	672.5	2	
8	90	790	660	2	
9	90	790	672.5	2	Duplicate of Run 7
10	90	800	660	2	
11	85	790	672.5	2	
12	80	790	672.5	2	
13	90	800	670	1	
14	90	790	660	1	
15	80	790	660	2	
16	80	800	660	2	
17	80	800	672.5	2	

The special conditions used in Runs 2-5 add a constant load either two seconds before or after the unit achieved its top speed based on the output of Run 1.

The major area of concern in this transient analysis is the time versus unit speed data. The following tables contain the shaft speed versus one second increments of time with time zero being when the unit trips off the line this information is also shown graphically on figures enclosed with this report:

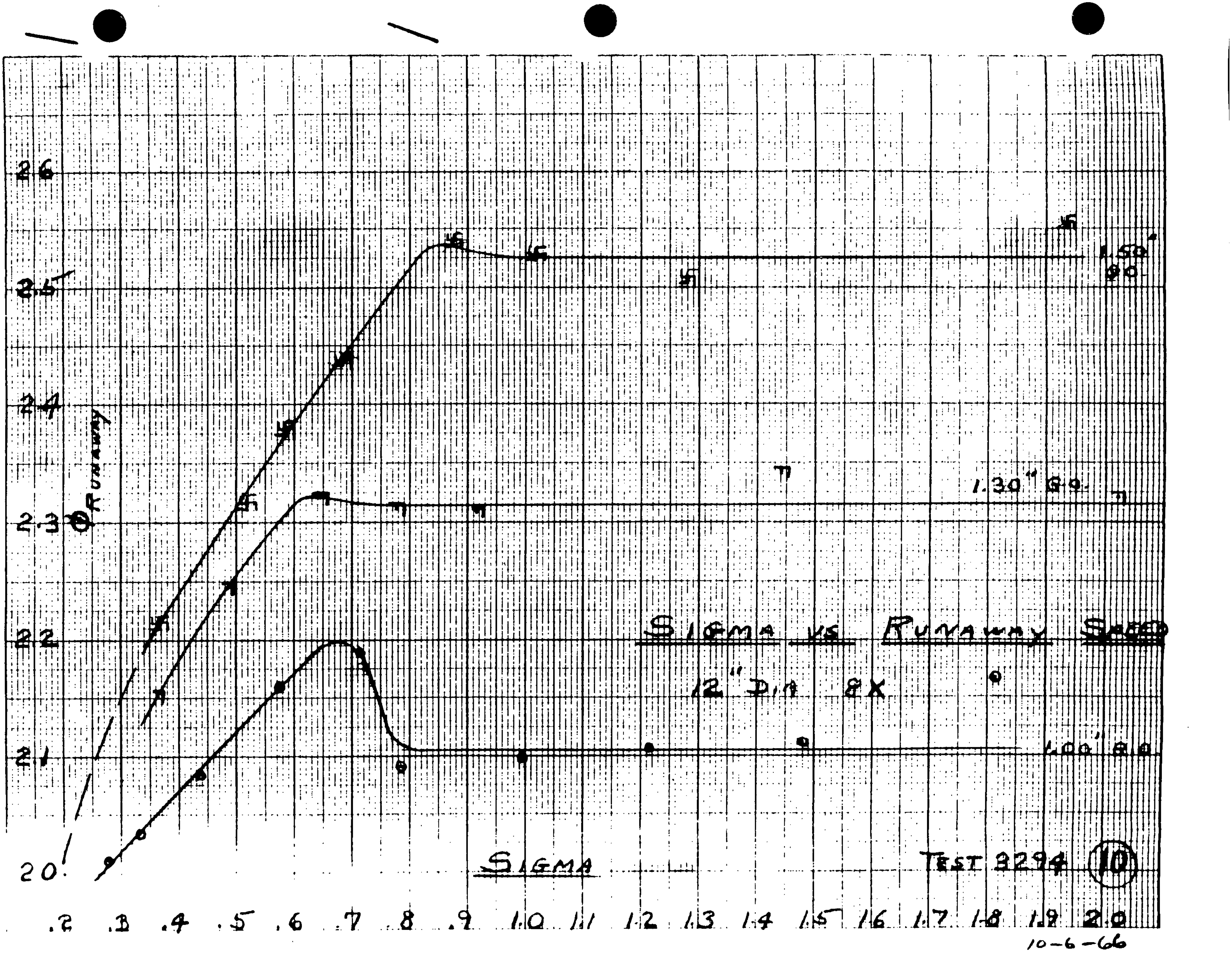
* NOTE These Run # are For This att. ONLY | Rev 1 JBB

Time Seconds	Turbine Generator Shaft Speed in RPM Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
0.0	128.6	128.6	128.6	128.6	128.6	128.6	128.6	128.6	128.6
1.00	140.8	140.8	140.8	140.8	140.8	140.8	140.5	140.8	140.5
1.99	151.9	151.9	151.9	151.9	151.9	151.7	150.3	151.8	150.3
2.99	161.6	161.6	161.6	161.6	161.6	161.3	159.0	161.4	159.0
3.98	169.6	169.6	169.6	169.6	169.6	169.4	167.1	169.8	167.1
4.98	175.4	175.4	175.4	175.4	175.4	176.3	174.5	176.7	174.5
5.98	179.1	179.1	179.1	179.1	179.1	181.7	181.2	182.0	181.2
6.97	180.9	180.1	180.9	179.2	180.9	185.4	187.0	185.5	187.0
7.97	181.3	179.6	181.3	177.9	181.3	187.6	191.4	187.5	191.4
8.96	181.0	178.5	181.0	176.0	181.0	188.3	194.7	188.0	194.7
9.96	180.3	177.0	180.3	173.6	180.3	188.0	197.1	187.6	197.1
10.96	178.5	174.5	177.6	170.3	176.8	187.2	198.4	186.8	198.4
11.95	175.6	170.9	173.9	166.1	172.1	186.0	198.4	185.4	198.4
12.95	171.9	166.5	169.2	160.9	166.5	183.8	197.5	182.8	197.5
13.94	167.4	161.4	163.9	155.0	160.3	180.5	195.8	179.3	195.8
14.94	162.4	155.8	158.2	148.7	153.7	176.4	193.9	174.9	193.9
15.94	157.5	150.2	152.4	142.4	147.1	171.6	191.9	169.8	191.9
16.93	152.6	144.6	146.7	136.0	140.5	166.3	189.4	164.5	189.4
17.93	147.7	139.0	141.0	129.6	133.8	161.0	185.7	159.2	185.7
18.93	142.7	133.4	135.2			155.8	181.6	154.0	181.6
19.92	137.8		129.5			150.6	176.6	148.8	176.6
20.92	133.0					145.4	171.0	143.6	171.0
21.91						140.3	165.4	138.5	165.4
22.91						135.3	159.9	133.7	159.9
23.91						130.7	154.5	129.2	154.5
24.90							149.2		149.2
25.90							144.0		144.0
26.89							138.8		138.8
27.89							133.9		133.9
28.89							129.4		129.4

Time Seconds	Turbine Generator Shaft Speed in RPM Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Run 16	Run 17
0.0	128.6	128.6	128.6	128.6	128.6	128.6	128.6	128.6
1.00	140.8	139.8	139.9	140.8	140.8	139.5	139.6	139.5
1.99	152.1	150.1	149.3	151.8	151.8	149.7	149.8	149.6
2.99	162.3	159.4	157.9	161.3	161.3	158.9	158.6	158.8
3.98	170.8	167.4	165.4	169.3	169.3	166.7	165.4	166.7
4.98	177.1	174.2	171.7	175.6	175.6	172.5	169.9	172.8
5.98	181.4	179.7	176.6	179.9	179.9	176.4	172.3	177.0
6.97	183.6	184.2	180.0	182.3	182.3	178.3	173.4	179.4
7.97	184.3	187.5	181.8	183.1	183.1	179.0	173.2	180.2
8.96	184.3	189.4	182.3	182.8	182.8	179.0	171.5	180.2
9.96	183.3	190.0	181.9	182.0	182.0	177.7	168.6	179.5
10.96	180.9	189.6	181.1	180.7	180.7	175.3	164.6	177.5
11.95	177.3	188.5	179.6	178.3	178.3	171.7	160.1	174.4
12.95	172.9	187.1	176.9	174.8	174.8	167.2	155.5	170.2
13.94	167.8	185.4	173.2	170.5	170.5	162.4	150.9	165.4
14.94	162.7	182.6	168.7	165.6	165.6	157.5	146.2	160.5
15.94	157.6	179.0	163.7	160.6	160.6	152.6	141.5	155.6

Time	Turbine Generator Shaft Speed in RPM							
Seconds	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Run 16	Run 17
16.93	152.6	174.5	158.7	155.7	155.7	147.8	136.7	150.7
17.93	147.4	169.4	153.8	150.8	150.8	142.9	132.0	145.7
18.93	142.3	164.2	148.8	145.8	145.8	138.0		140.8
19.92	137.3	159.0	143.9	140.9	140.9	133.2		135.9
20.92	132.5	153.8	139.0	136.0	136.0			131.2
21.91		148.7	134.2	131.4	131.4			
22.91		143.7	129.7					
23.91		138.6						
24.90		133.8						
25.90		129.3						

FIGURE 1



SIGMA VS RUNAWAY SPEED
12" DIA 8X
Φ RUNAWAY
SIGMA
TEST 3294
10
1.30"
2.0
2.1
2.2
2.3
2.4
2.5
2.6
.2 .3 .4 .5 .6 .7 .8 .9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0
10-6-66

KW, 75MW LR, Gp

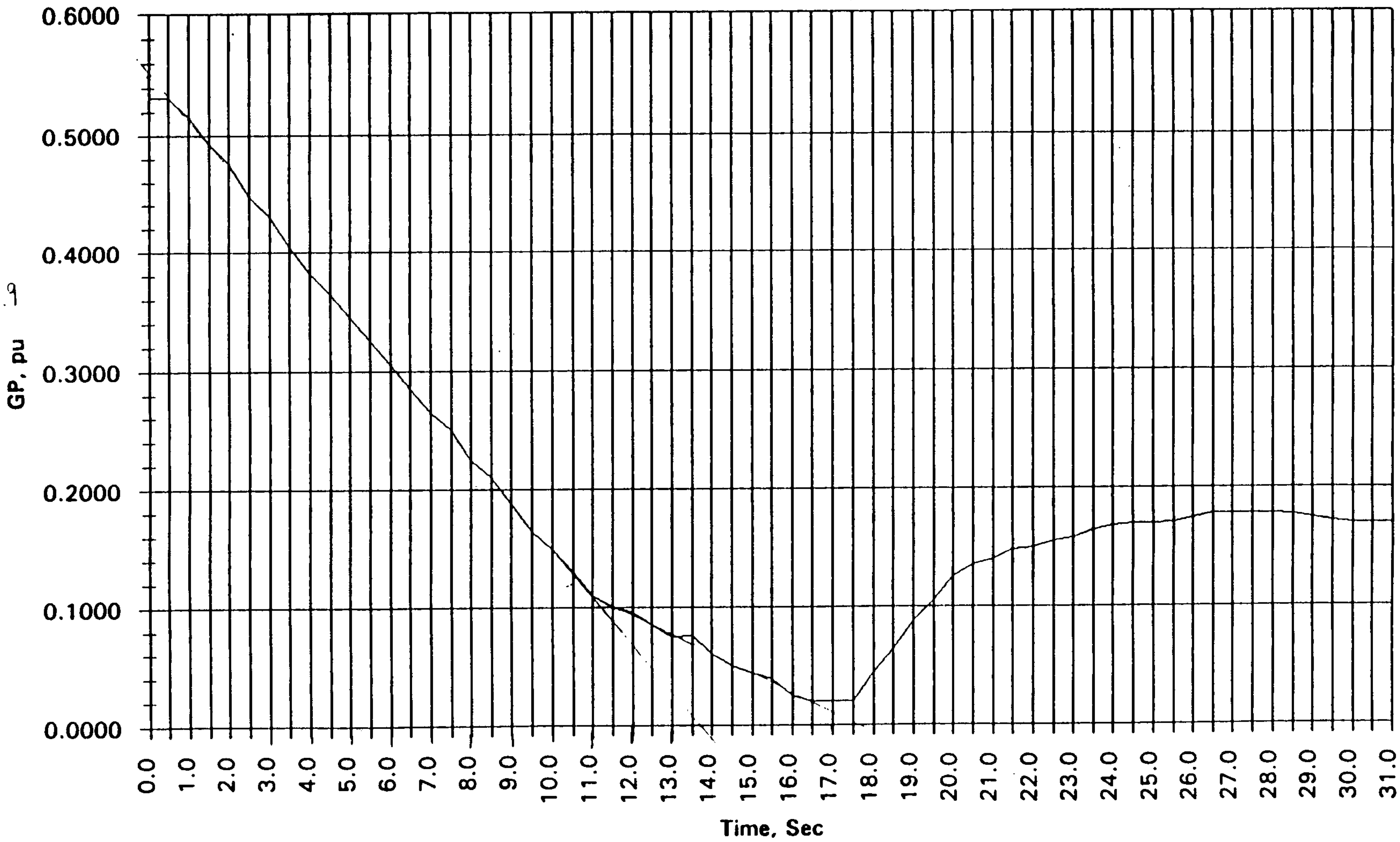
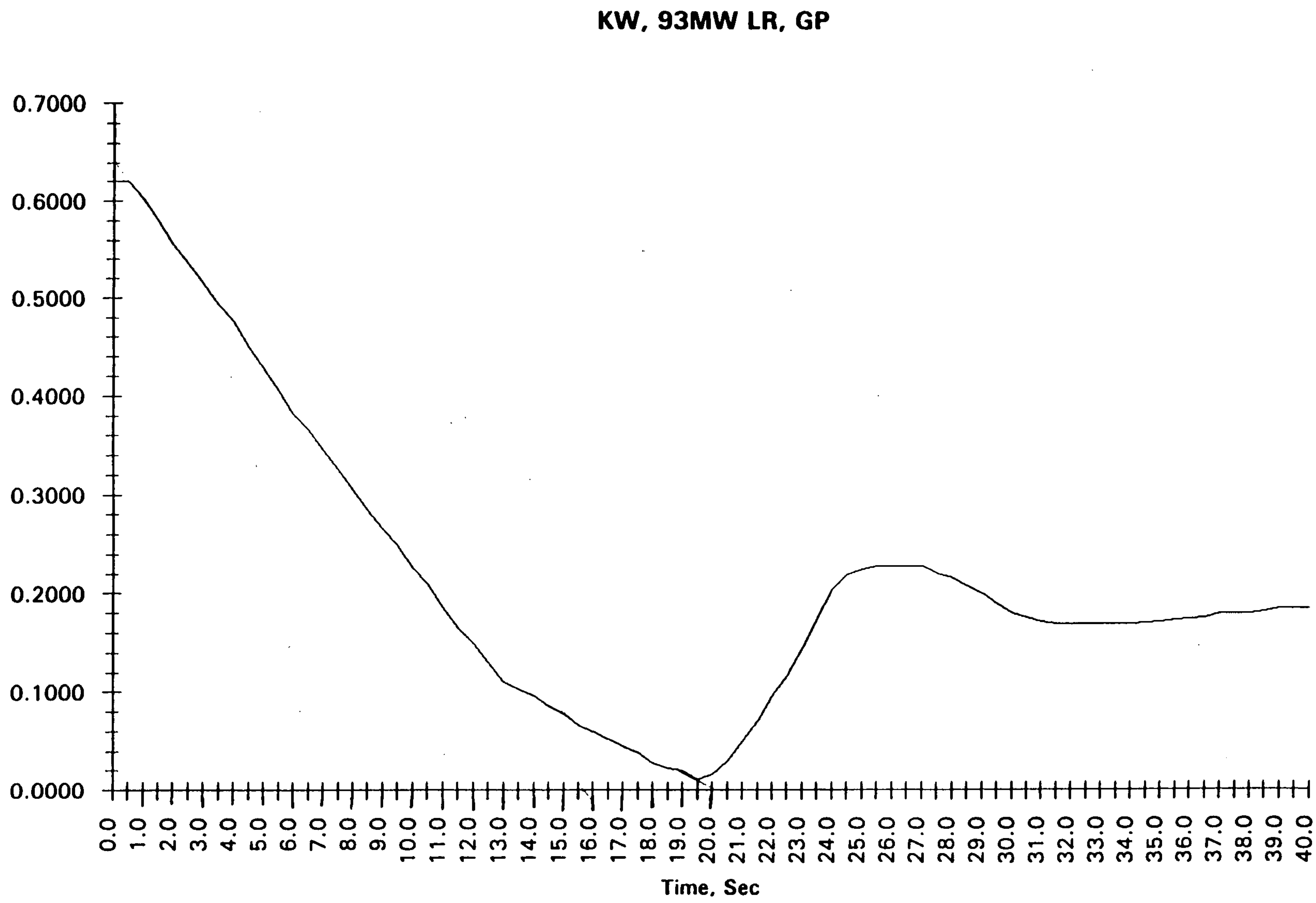


FIGURE 2

FIGURE 3


KW, 93MW LR, GP
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
Gp, pu
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0 13.0 14.0 15.0 16.0 17.0 18.0 19.0 20.0 21.0 22.0 23.0 24.0 25.0 26.0 27.0 28.0 29.0 30.0 31.0 32.0 33.0 34.0 35.0 36.0 37.0 38.0 39.0 40.0
Time, Sec

KEOWEE UNIT 2 WICKET GATE CALIBRATION DATA OF 9/26/71

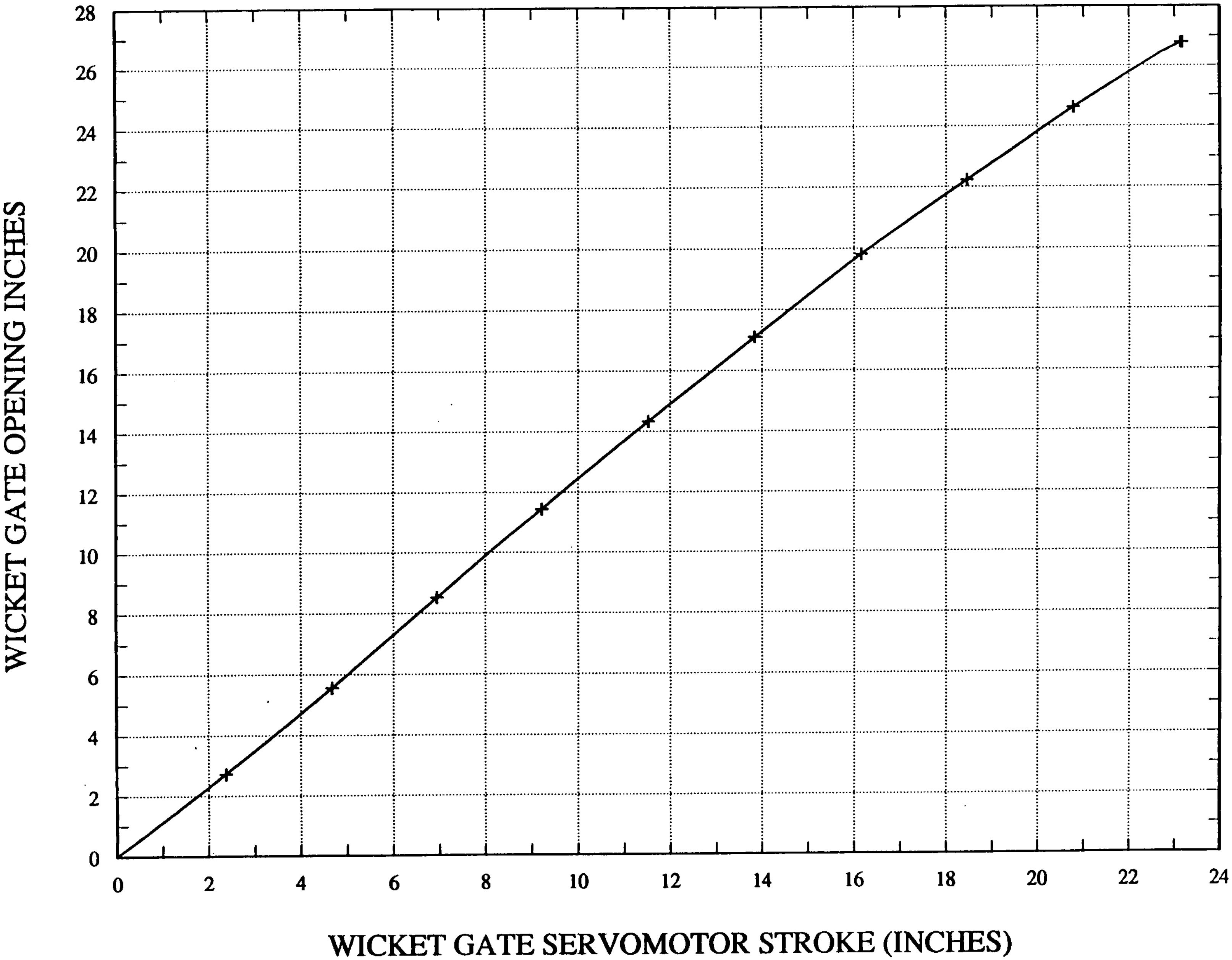


FIGURE 4

3-23-94

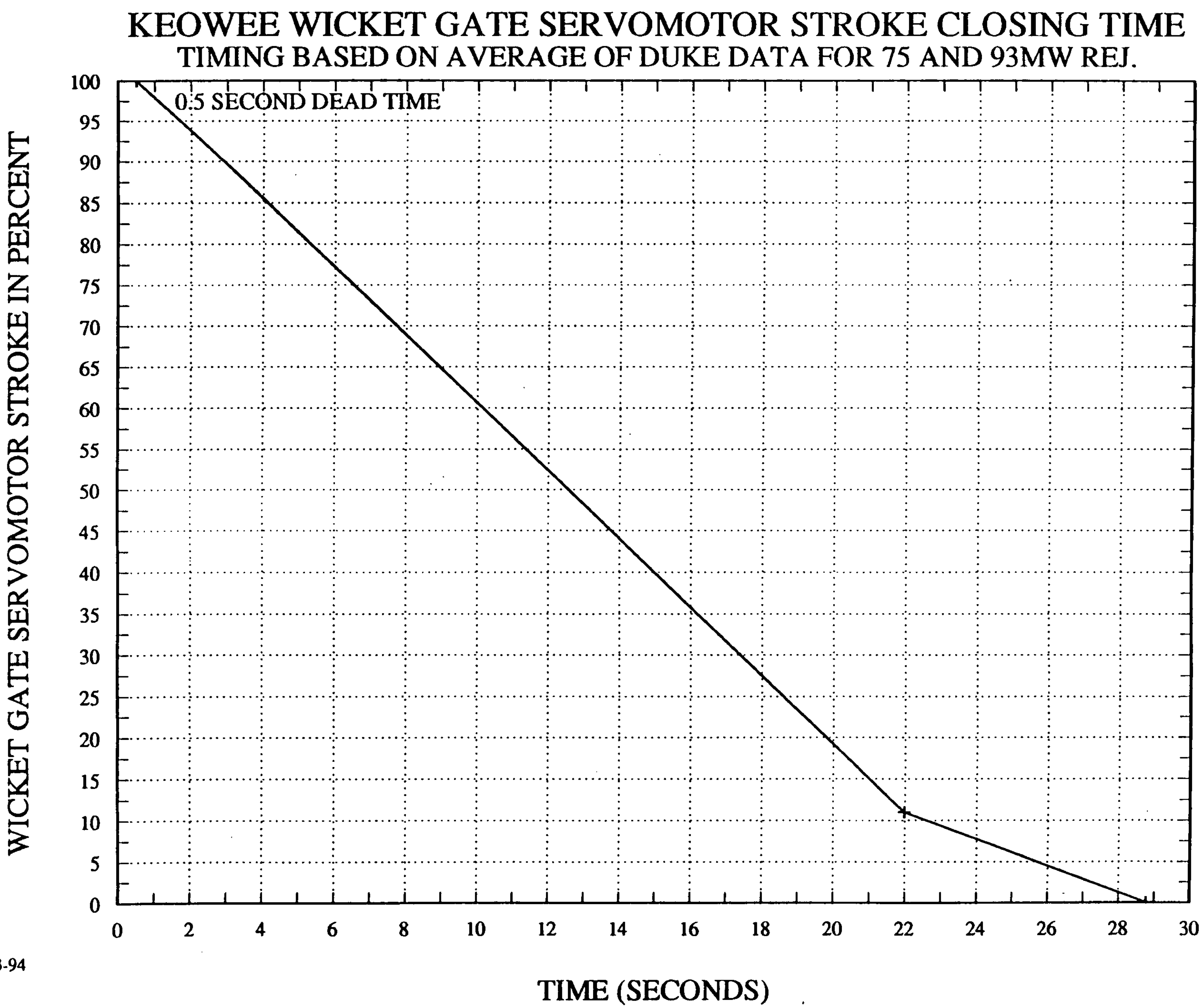


FIGURE 5

03-23-94

KEOWEE 93MW GENERATOR LOAD REJECTION
BLENDED TRANSIENT MODEL DATA FILE

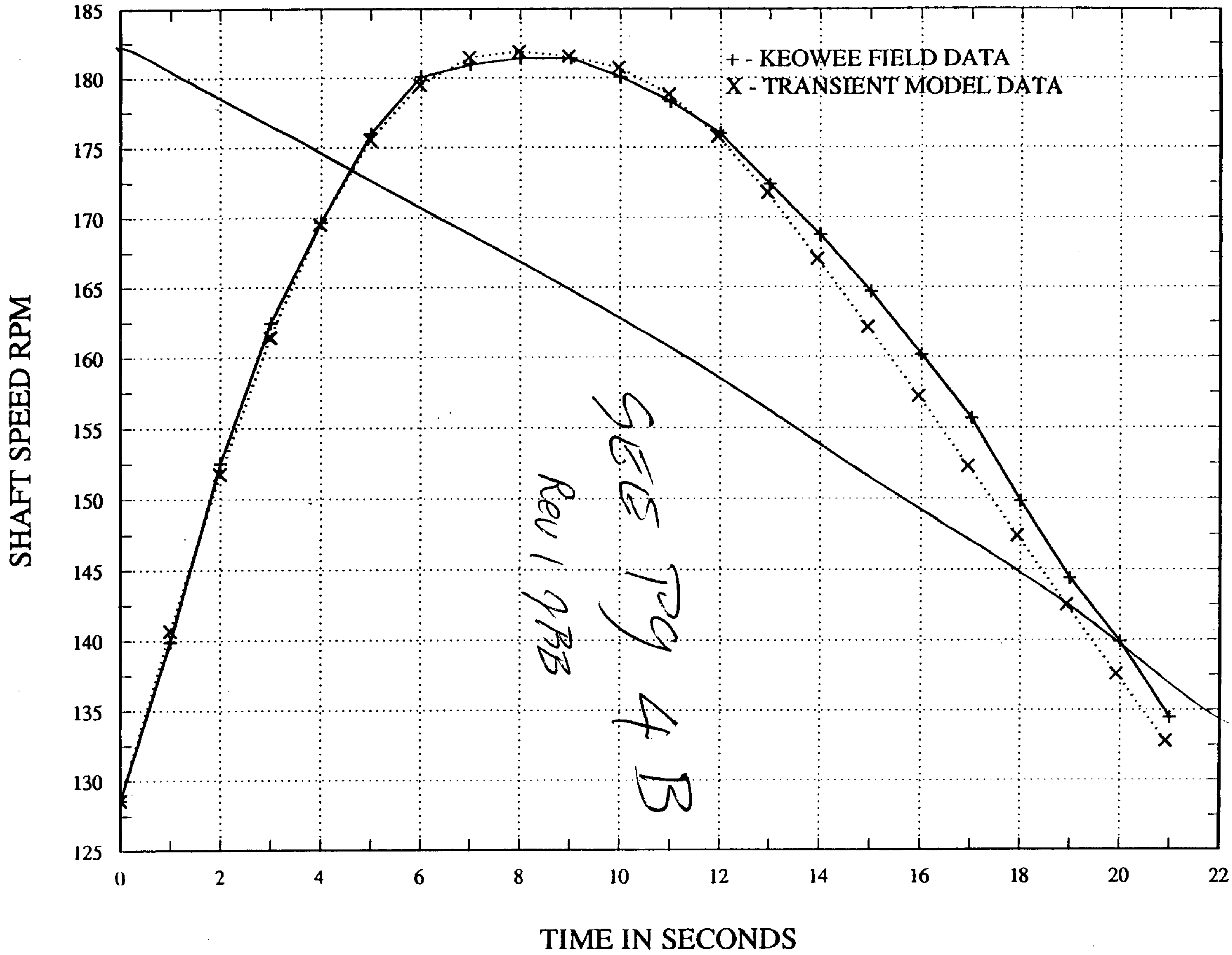


FIGURE 6

03-25-94

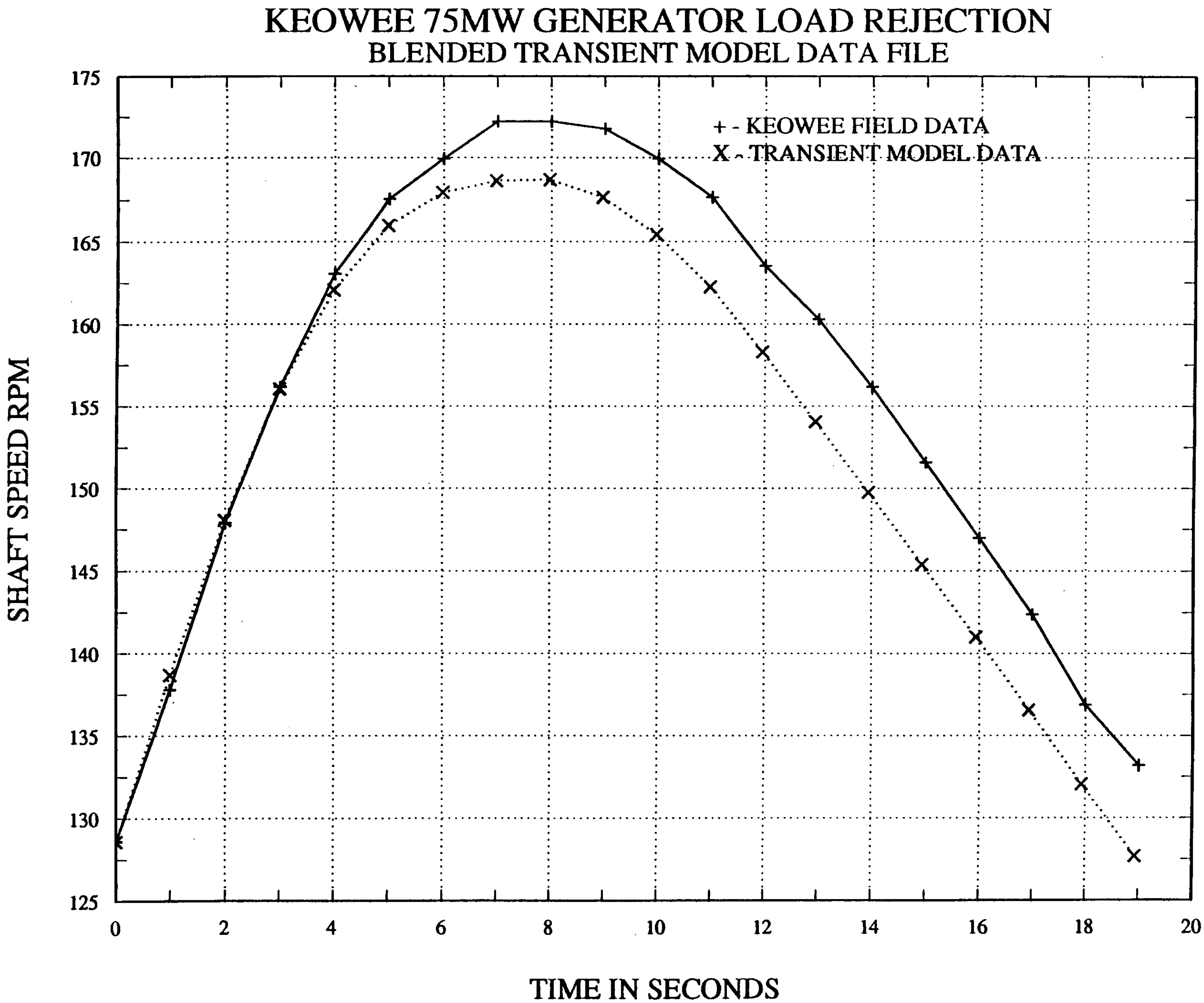


FIGURE 7

03-25-94

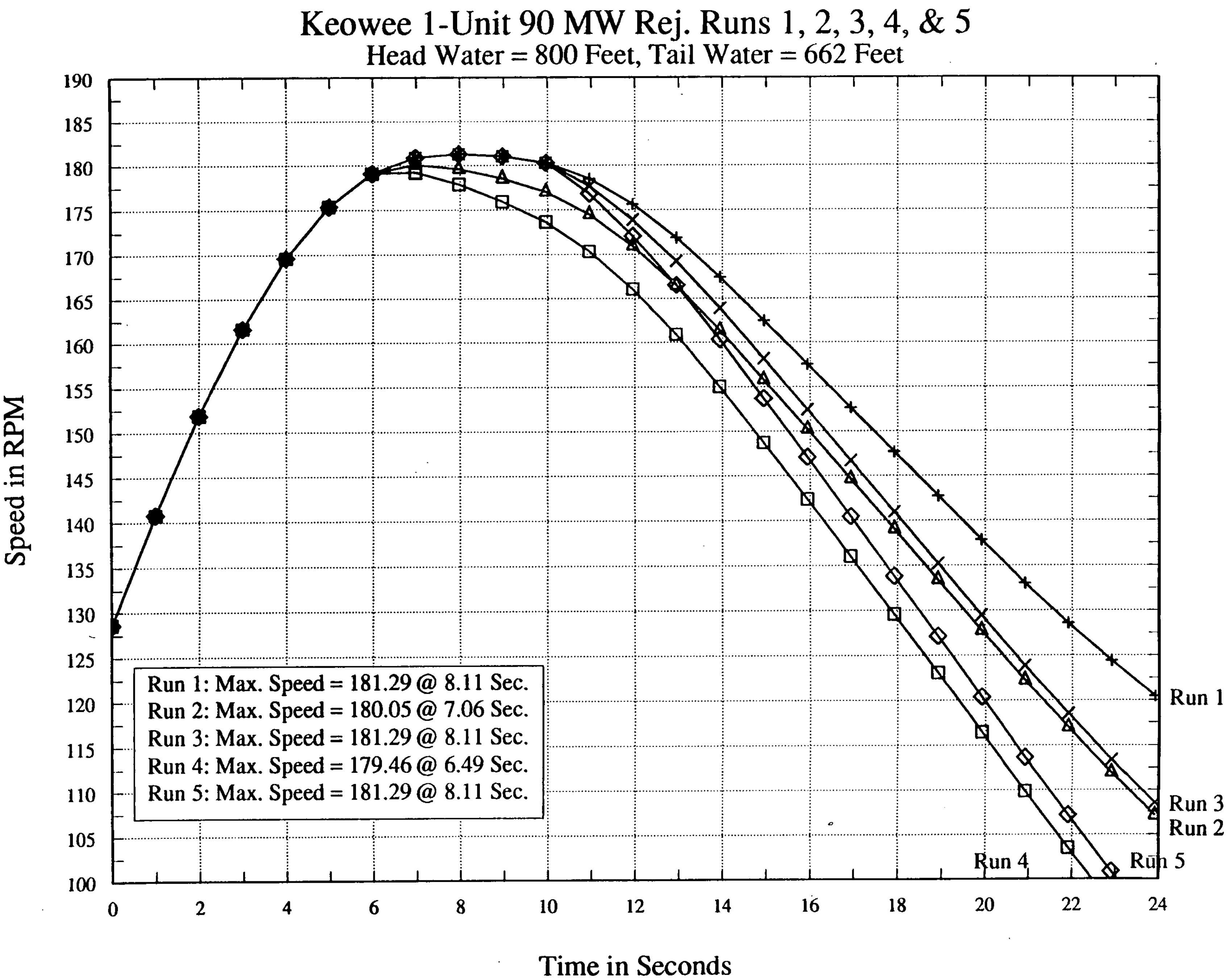


FIGURE 8

3- 3-94 16.21

KEOWEE 2 UNIT 90 MW GENERATOR LOAD REJECTION RUN 6

HW = 800 TW = 672.5 FEET USING BLENDED MODEL DATA

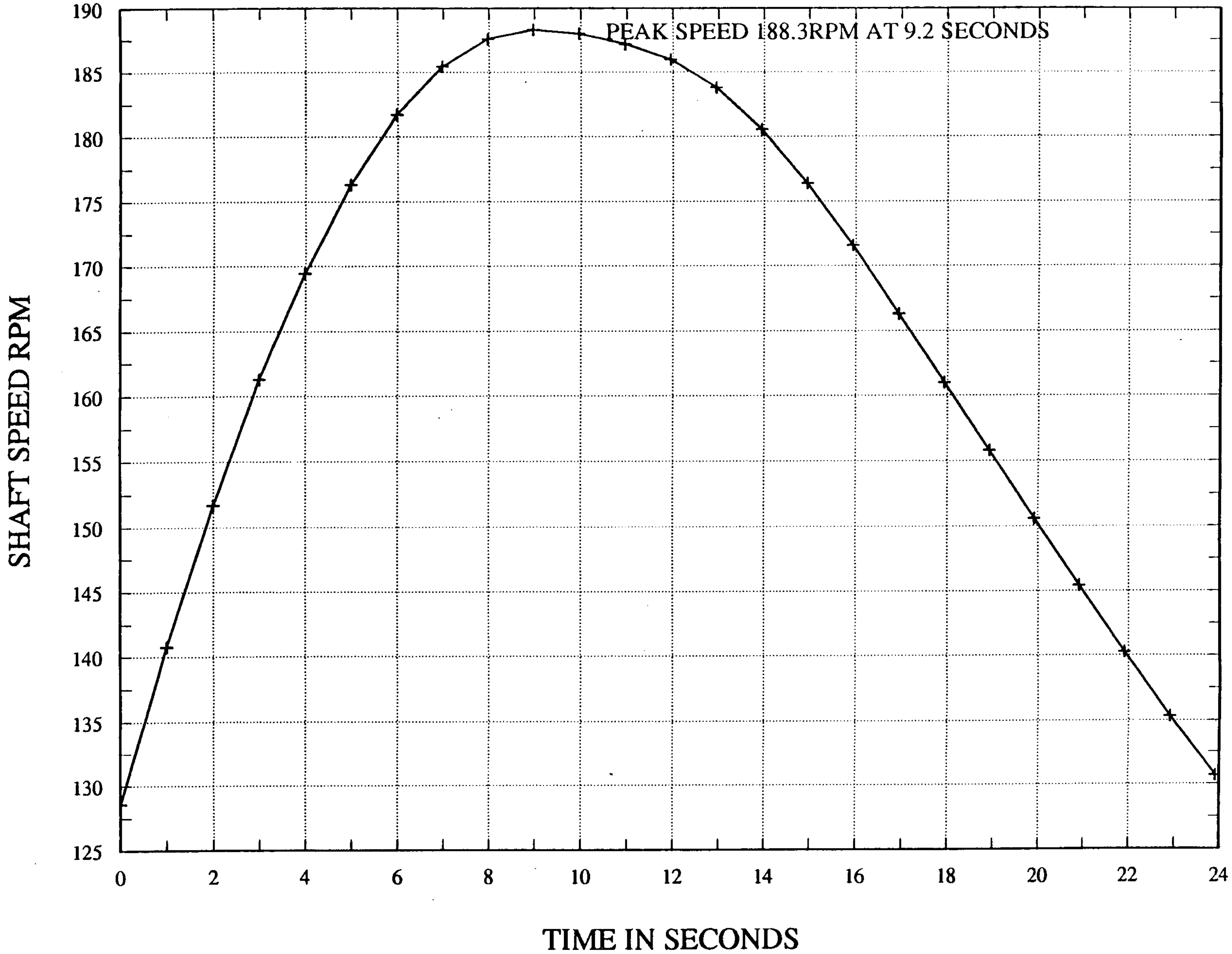


FIGURE 9

2-25-94

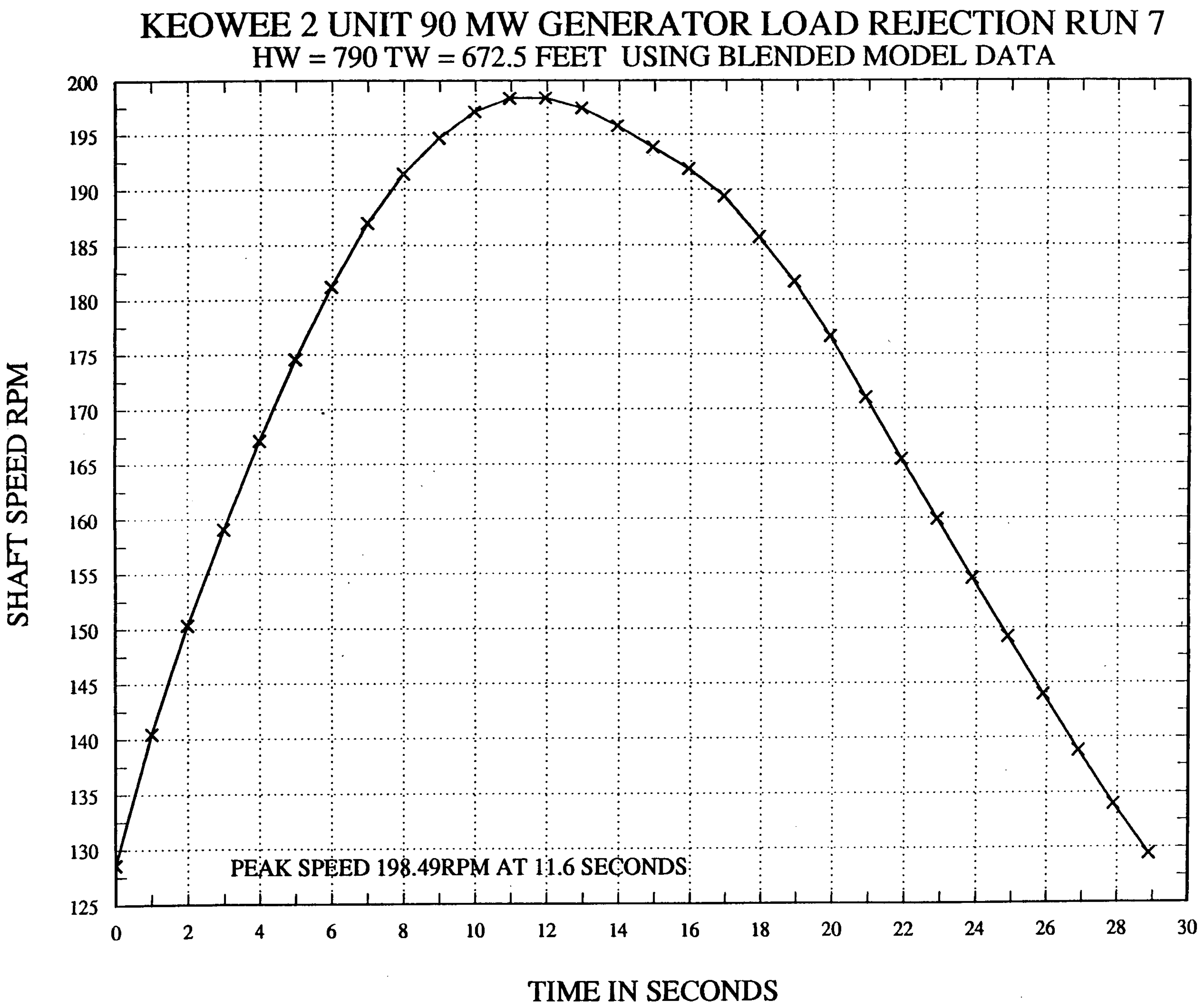


FIGURE 10

03-25-94

KEOWEE 2 UNIT 90 MW GENERATOR LOAD REJECTION RUN 8
HW = 790 TW = 660 FEET USING BLENDED MODEL DATA

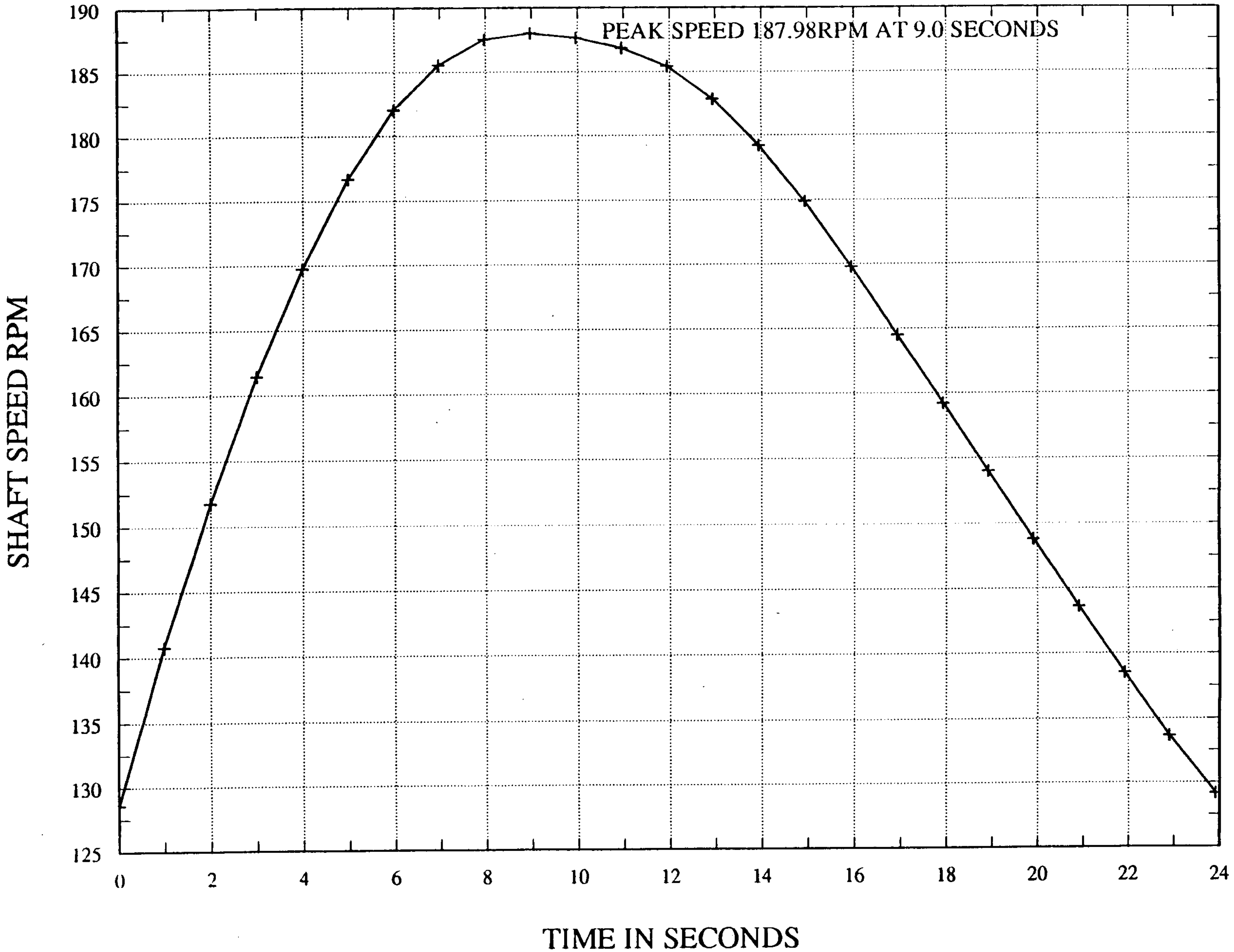
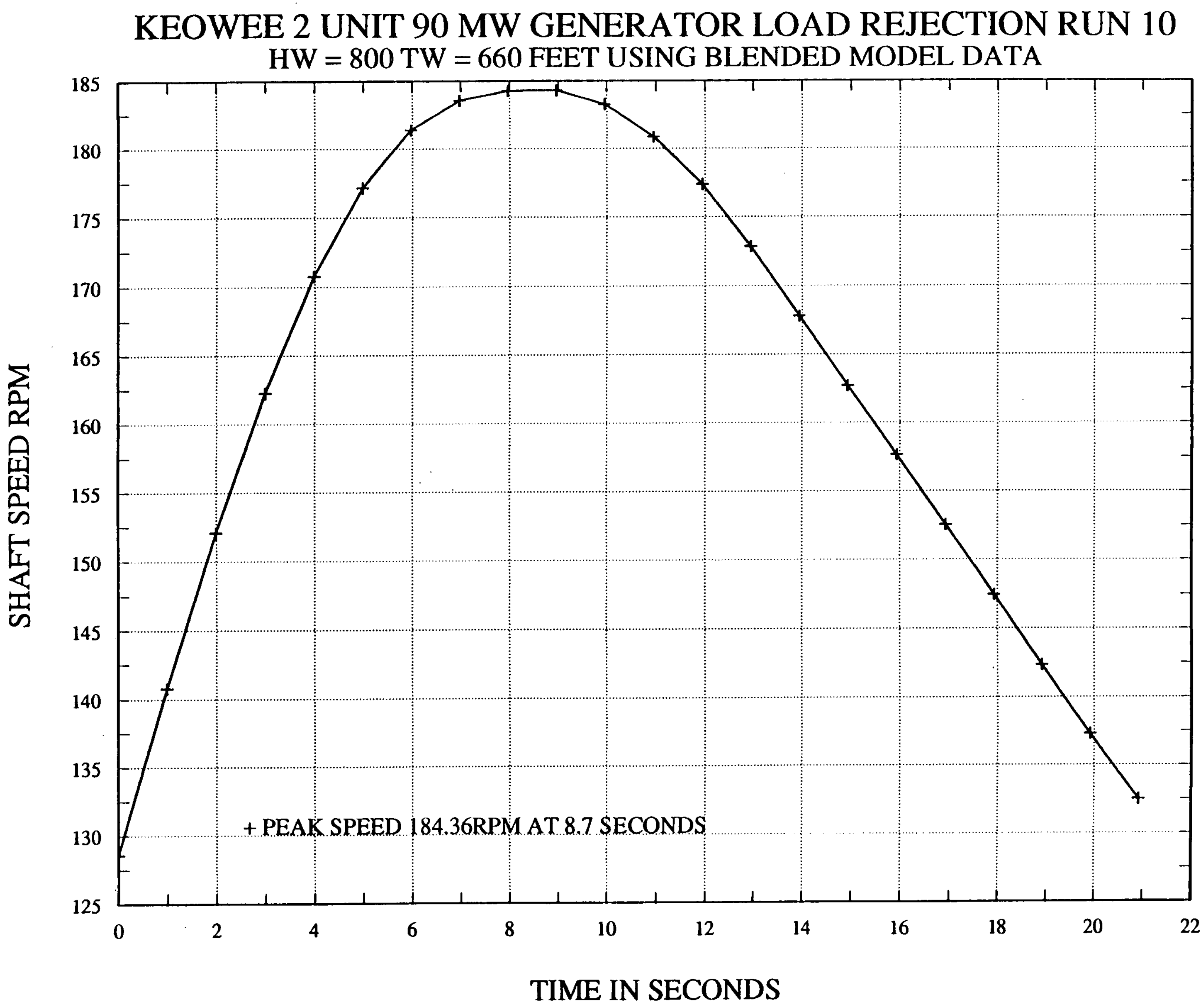


FIGURE 11

2-25-94

FIGURE 12



3- 9-94

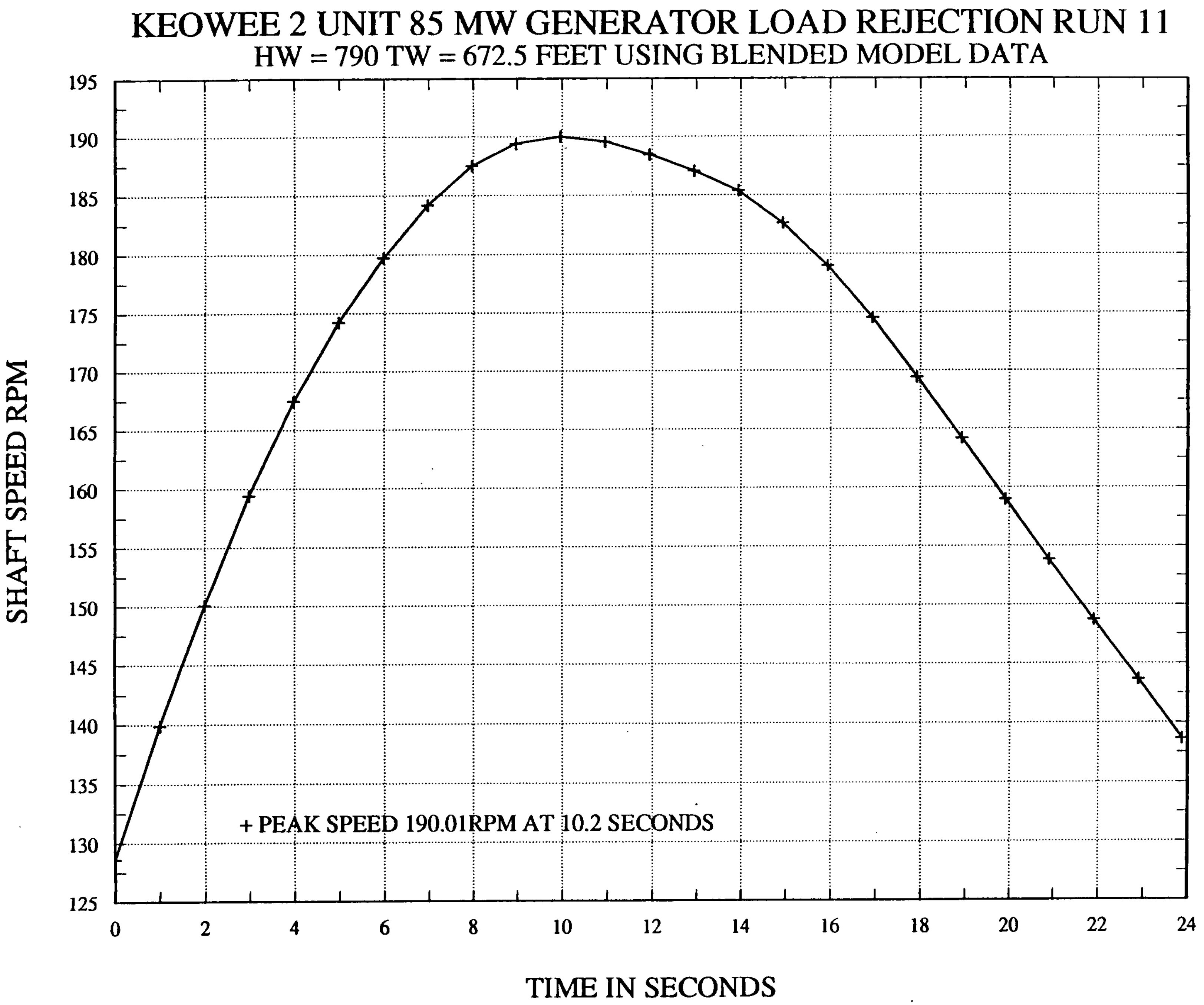


FIGURE 13

3-9-94

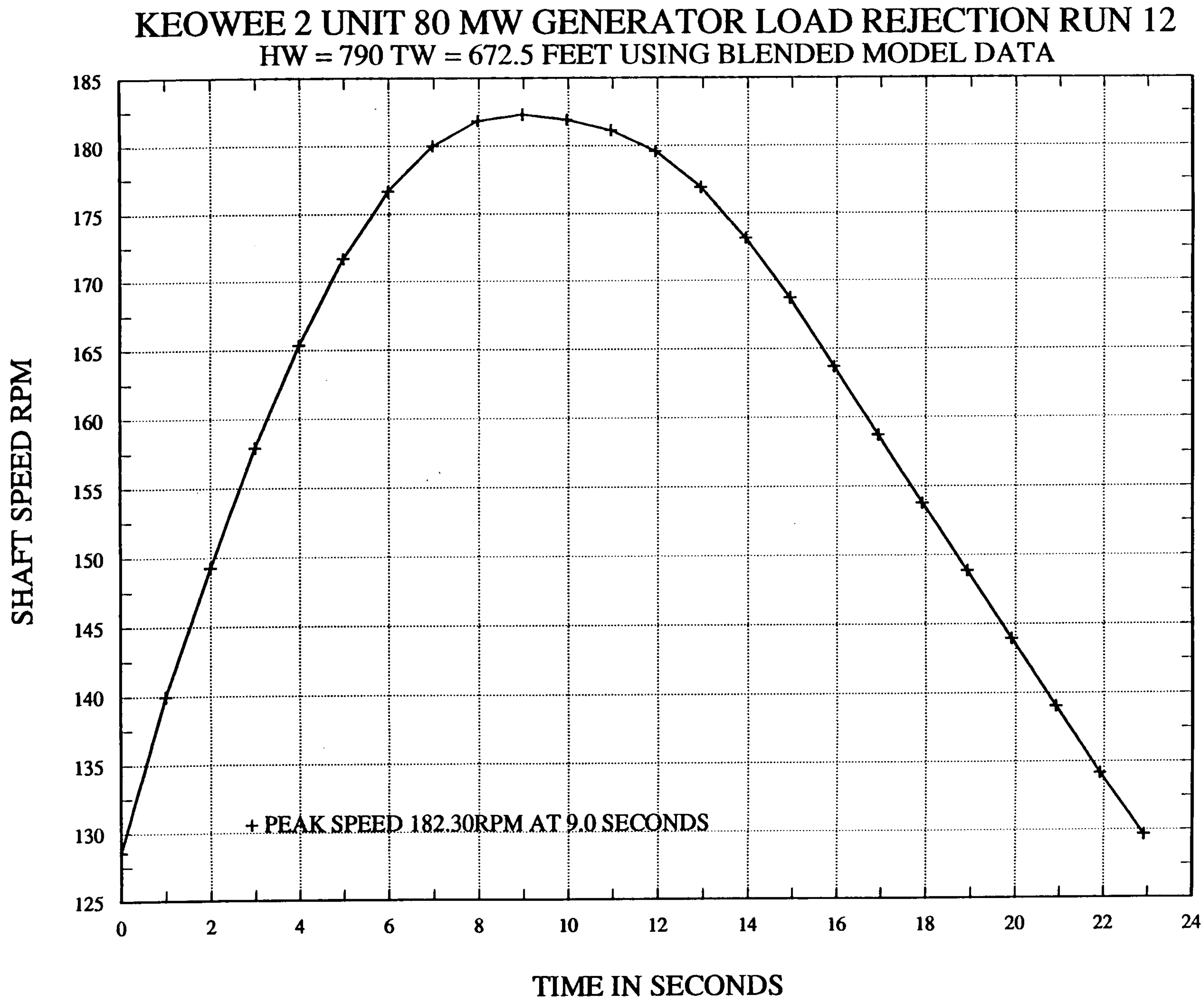


FIGURE 14

3-18-94

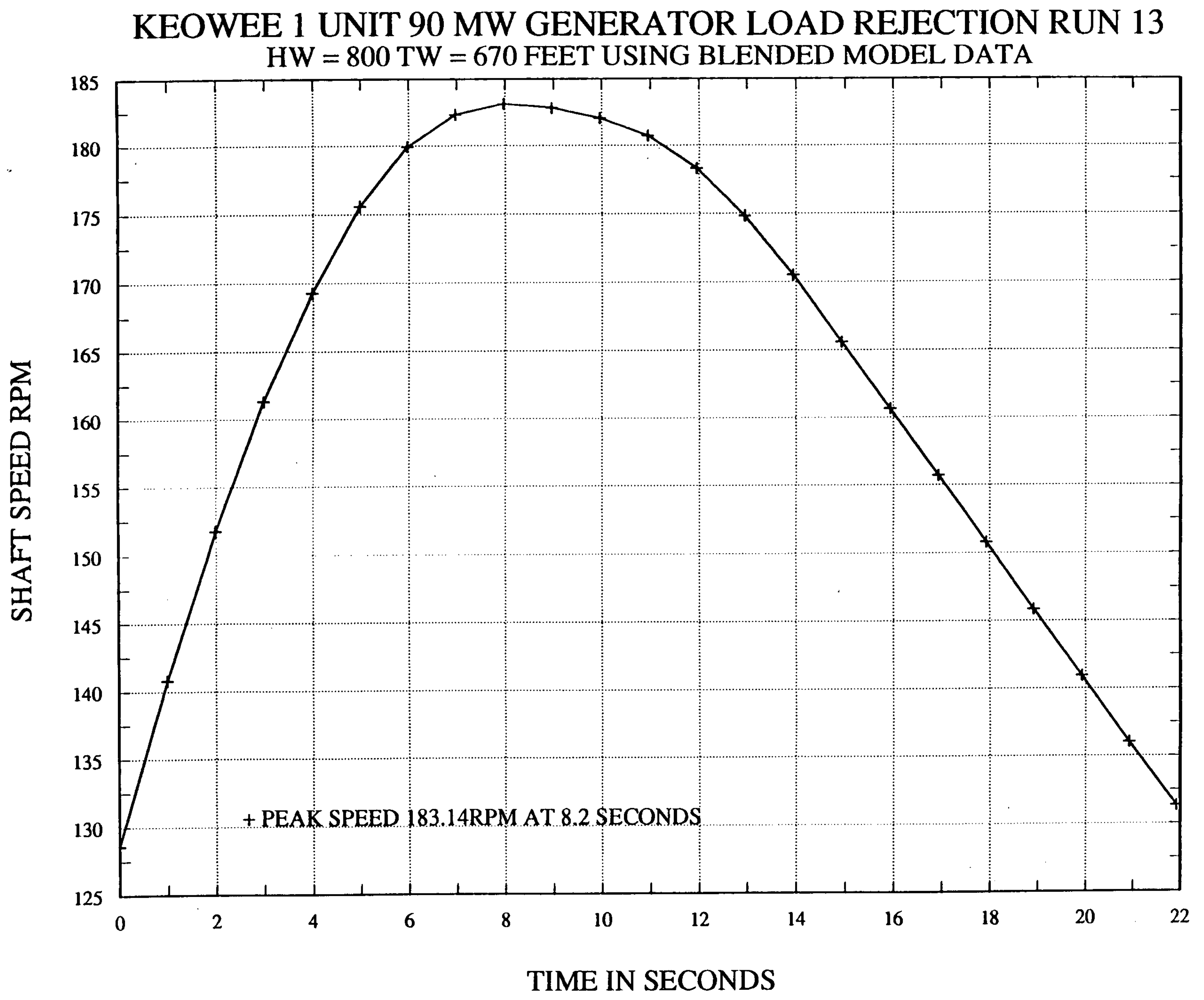


FIGURE 15

3-11-94

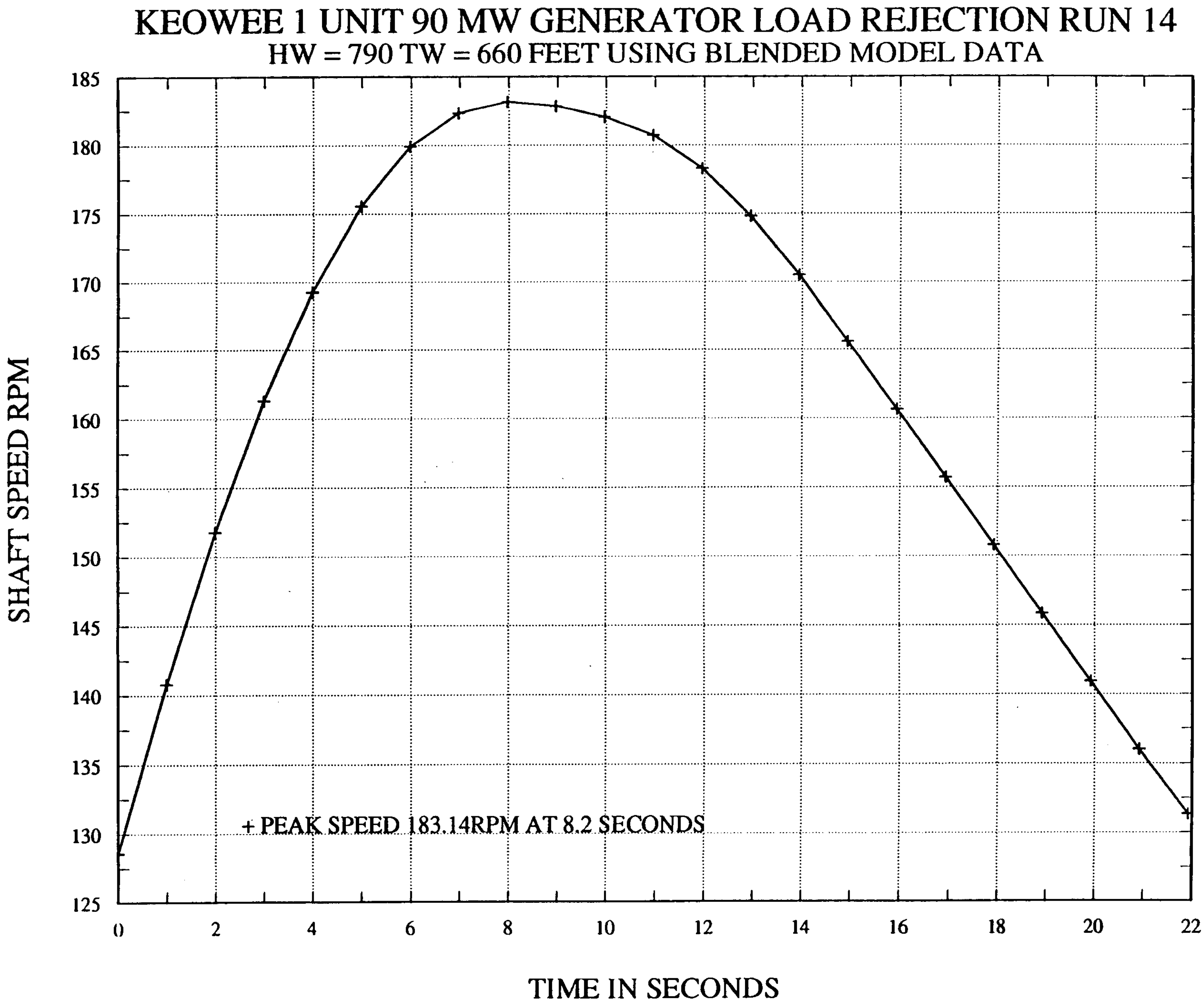


FIGURE 16

3-11-94

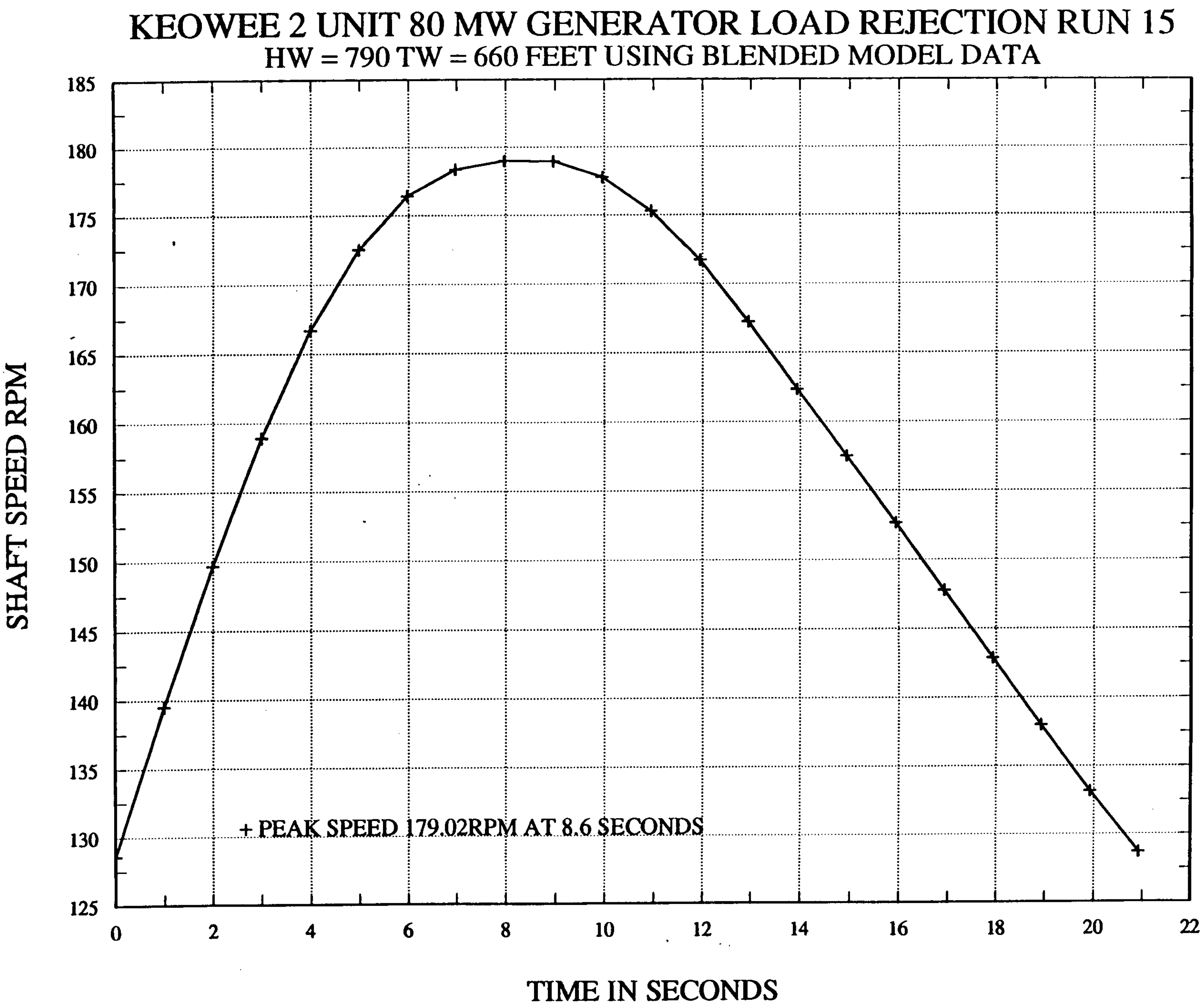


FIGURE 17

3-18-94

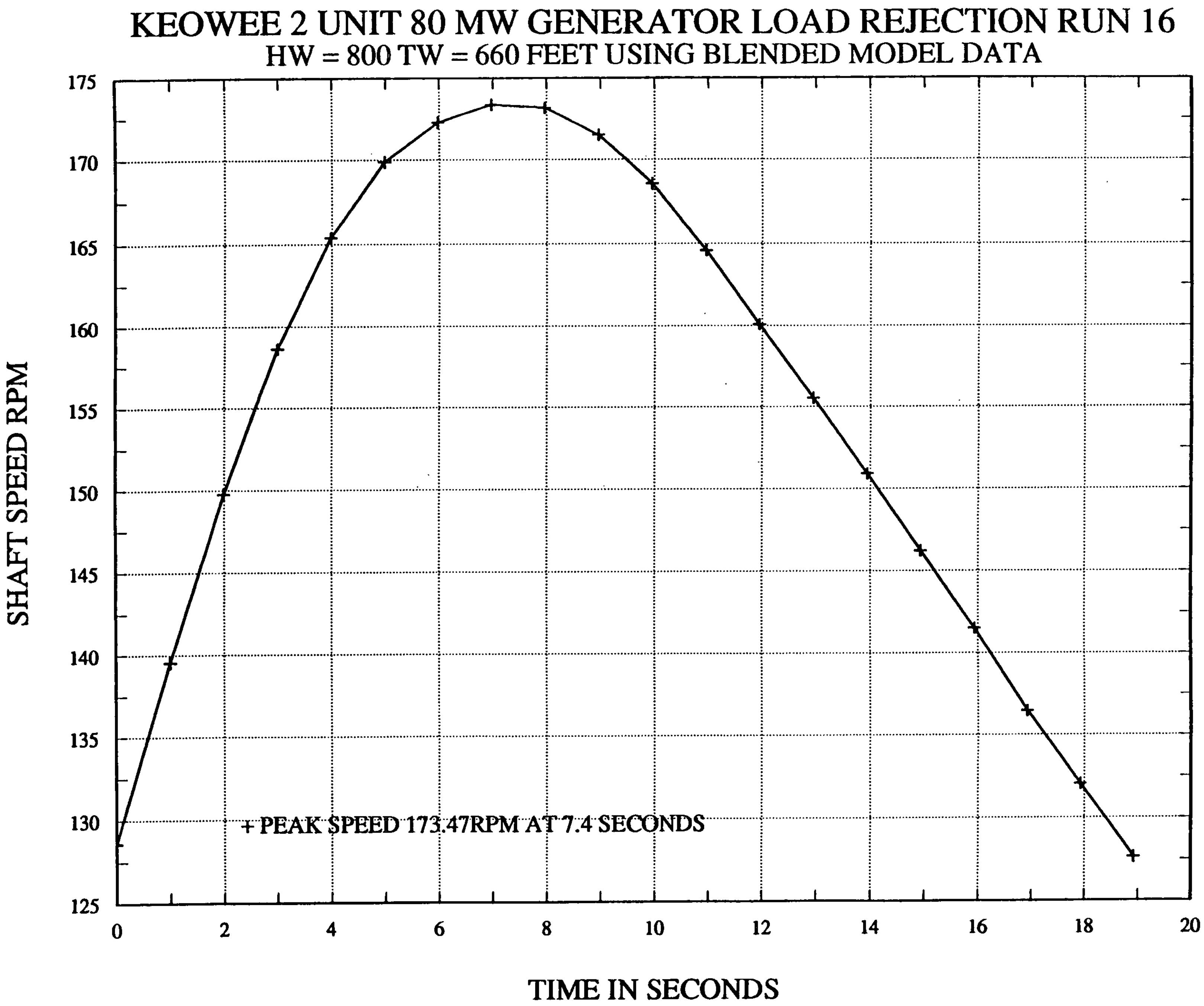


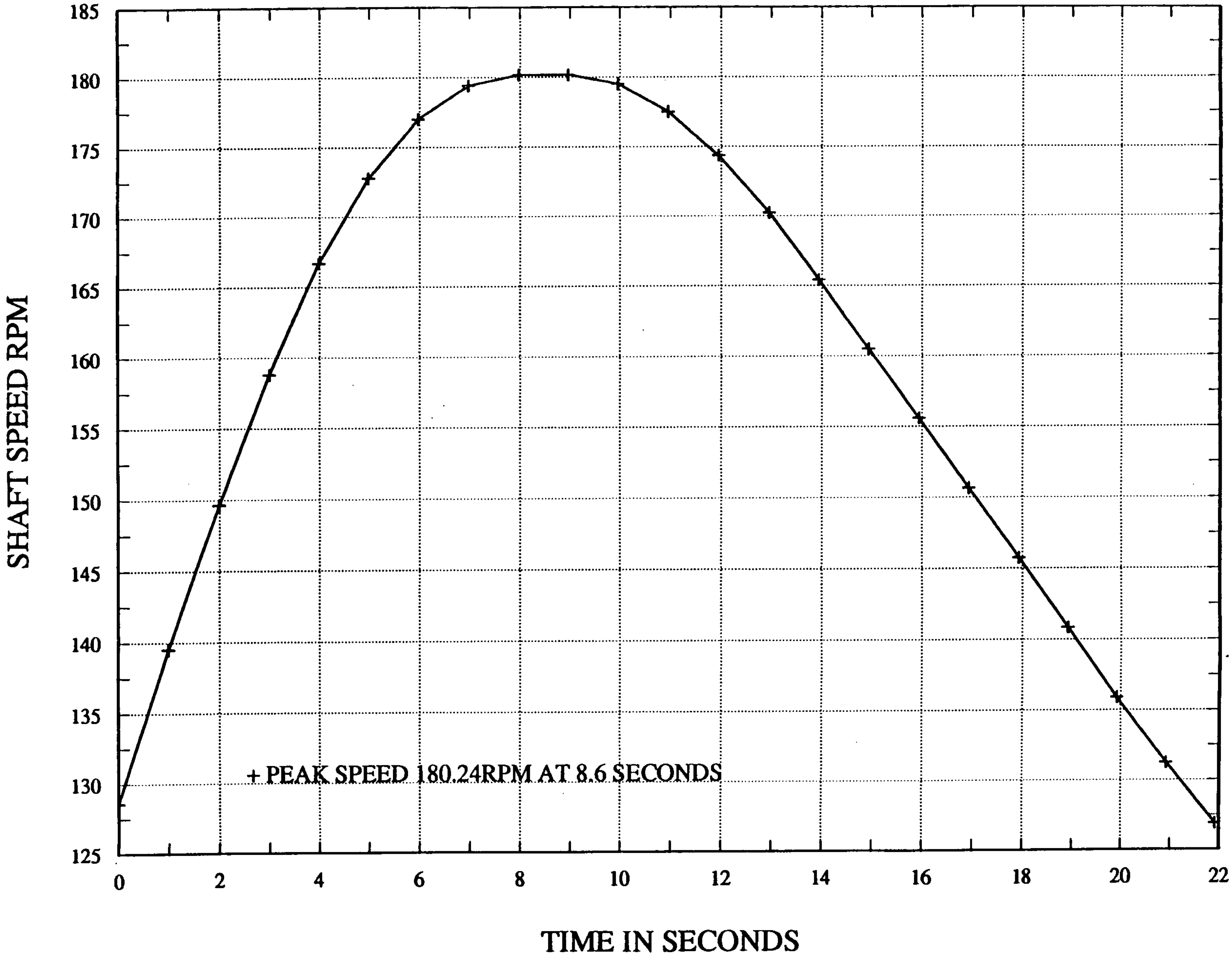
FIGURE 18

3-18-94

FIGURE 19

KEOWEE 2 UNIT 80 MW GENERATOR LOAD REJECTION RUN 17

HW = 800 TW = 672.5 FEET USING BLENDED MODEL DATA



3-18-94

Hydraulic Transient Program

Used For

Transient Calculation

At

Keowee Hydroelectric Site

Ronald E. Deitz

Submitted By: Ronald E. Deitz
Mgr. Field Engr.
VOITH Hydro, Inc.

VOITH HYDRO, INC.

P.O. BOX 712
YORK, PENNSYLVANIA 17405

CORA HYDRAULIC TRANSIENT PLUS

Presented at the

Joint Symposium on Design and Operation
of Fluid Machinery — June 12 - 14, 1978
ASCE — IAHR/AIHR — ASME

"CORA" HYDRAULIC TRANSIENT "PLUS"

SUMMARY

Due to the great impact of hydraulic transients on the structural design of high head reversible pump/turbines, "CORA" was developed to predict, in addition to the typical head, discharge, torque, and R.P.M. data, the static and dynamic loading of various mechanical components. Excellent field verification confirms the accuracy of the program.

SYNOPSIS

Hydraulic transients are generated in closed piping systems by a sequence of events resulting in time dependent variable flow conditions. This phenomenon is observed in hydraulic power stations during valve closure or during the voluntary or accidental passage of the hydraulic machine from an operating condition to another one.

A good evaluation of transients in a hydraulic power project is essential to the proper layout of the distribution system (penstock, valves, surge tanks, etc.) and to the mechanical design of the hydraulic machine and related equipment. This paper describes a new hydraulic transient program "CORA" developed specifically for the analysis of complex systems found in modern reversible pump turbine installations and its application to the evaluation and solution of different problems.

INTRODUCTION

The calculation of transients in hydraulic power projets has traditionally been the responsibility of the civil engineer with the turbine manufacturer providing the necessary machine characteristics. The recent development of the high head reversible pump/turbine and the great impact of hydraulic transients on the structural design and dynamic behavior of nearly all major components of the machines such as stay ring, spiral case, wicket gate and servomotor system, runner and runner seals, head cover, discharge ring, shaft and bearing system. Thrust bearing, spherical valve, etc. had induced the turbine manufacturers to develop sophisticated computer programs which could, in addition to the typical head, discharge, torque, R.P.M. calculations, predict the static and dynamic loadings on different mechanical components and calculate their effect on the safety and longevity of the machine. The definition of operation limits and the optimization of governor characteristics and wicket gate closure laws are achieved by analyzing the "total picture" depicting the effect of the transients on the civil and mechanical aspects of the project.

"CORA" PROGRAM DESCRIPTION

The solution process used in the "CORA" program is based on the method of characteristics; this technique converts the partial differential equations describing the conditions of pressure and velocity in the system into finite difference equations solvable directly by digital computers (Ref. 1). The whole process is completely transparent to the user; the choice of proper incremental time and the subdivision of the length of pipes into a suitable number of segments is done automatically.

The present capabilities of the program are as follows:

PIPE SEGMENTS

Up to 40 pipe segments having different diameters (or areas), friction factors, wave speed, length and orientations can be accommodated by the program. The length can be entered or calculated automatically from the end coordinates; the wave speed can be calculated automatically by entering shell thickness, modulus of elasticity and support conditions or entered independently.

RESERVOIRS

Four different reservoirs having fixed or time dependent elevations can be considered in the system.

VALVES

Up to eight different valves can be accommodated in the system and operated independently. The valve can discharge into a pipe, reservoir or atmosphere. The time dependent operating sequence can be specified through linear interpolation or cubic spline fitting.

Some typical valves used frequently in hydraulic power stations and of known characteristics can be called directly by the program. The program will calculate the torque, axial and lateral load acting on a spherical valve rotor during a closing or opening sequence.

SURGE TANKS

Up to four different surge tanks can be modelled; they can be of simple orifice, differential or pressurized design with variable area vs. elevation distribution.

HYDRAULIC TURBINES

Up to four hydraulic turbines or pump/turbines having the same characteristics but operating completely independently can be modelled. The necessary four quadrant data are the Discharge vs. Unit Speed and Shaft Torque vs. Unit Speed for different gate openings. In addition, we can optionally input the following:

Static Gate Torque
Dynamic Gate Torque (peak to peak)
Static Runner Side Load
Dynamic Runner Side Load
Static Thrust
Static Runner Chamber Pressure
Dynamic Runner Chamber Pressure
Governor Characteristics

All these data are nowadays recorded routinely during model testing for all medium or high head pump/turbines. They are normalized for a runner of unit diameter operating under a unit head. The transformation from model characteristics to prototype is done automatically by the program. Two efficiency step up ratios affecting the discharge in the pump or turbine direction respectively can be specified.

INITIAL CONDITIONS

The initial conditions are generated automatically by the program. Thus eliminating tedious and lengthy manual calculations.

A manual input is possible and is economical for multiple cases starting from the same initial conditions.

OUTPUT OPTIONS

A printed and plotted output can be specified describing the evolution of selected parameters of the system and the hydraulic turbines.

To demonstrate the output generated by "CORA", a hypothetical hydraulic system will be used consisting of two reservoirs, one vented surge tank, two spherical valves, and two reversible pump/turbines (Figure 1). The first transient condition is a pump power failure with the wicket gates stuck in the full open position (Figure 2). Both pump/turbines are initially pumping 96.5 cubic meters per second against a 340 meter head when at time zero, the pump/turbines experience a power failure. Output parameters selected to be plotted are the water elevation in the surge tank, flowrate through the pump/turbines, main shaft rotation speed and torque, a model data, steady and dynamic wicket gate torque, hydraulic axial thrust of the runner, steady and dynamic side loads of the runner, dynamic runner chamber pressure, spiral case and draft tube pressure. The dynamic runner chamber pressure is the peak to peak pressure fluctuations in the chamber between the wicket gates and the runner. The steady term of runner side load and wicket gate torque is the average value while the dynamic term is one-half of the peak to peak fluctuating values.

The second transient condition is a load rejection with the wicket gates stuck in their full open position (Figure 3). Initially, both pump/turbines are generating at full capacity when at time zero, the pump/turbines experience a load rejection. The same parameters were selected to be plotted.

The third transient condition is a load rejection with the wicket gates stuck and the spherical valve initiates its 60 second closing cycle starting closure at 15 seconds into the transient and fully closed at 75 seconds into the transient (Figure 4). The new parameters selected for plotting are the torque required to operate the valve, both axial (horizontal) and lateral (vertical) load imposed on the spherical valve rotor, and the differential head across the valve.

SPHERICAL VALVE AUTO-OSCILLATIONS

The cross section of a typical medium to high head spherical valve is shown in Figure 5. The downstream seal "a" is the normal working seal while the upstream seal "b" is used only for maintenance purposes.

These seals consist of a stationary component bolted and dowelled to the valve rotor and a movable piston seal sliding in a special cavity machined in the valve body.

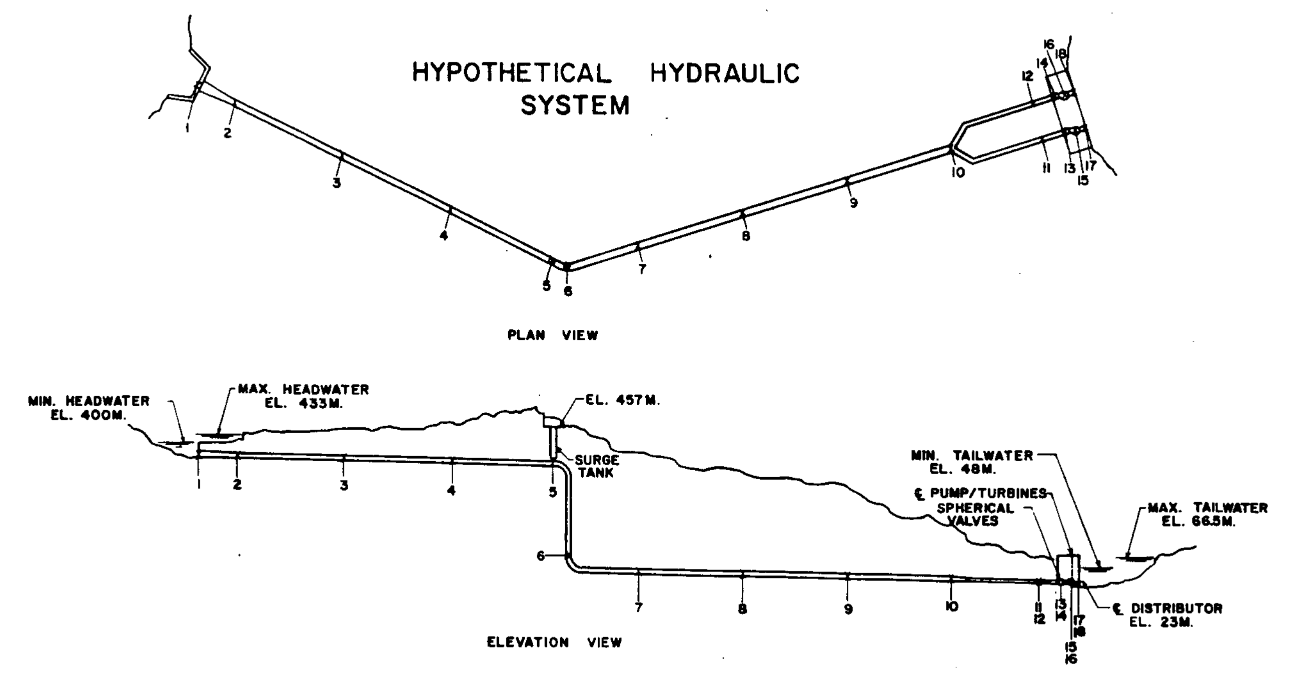


FIGURE 1

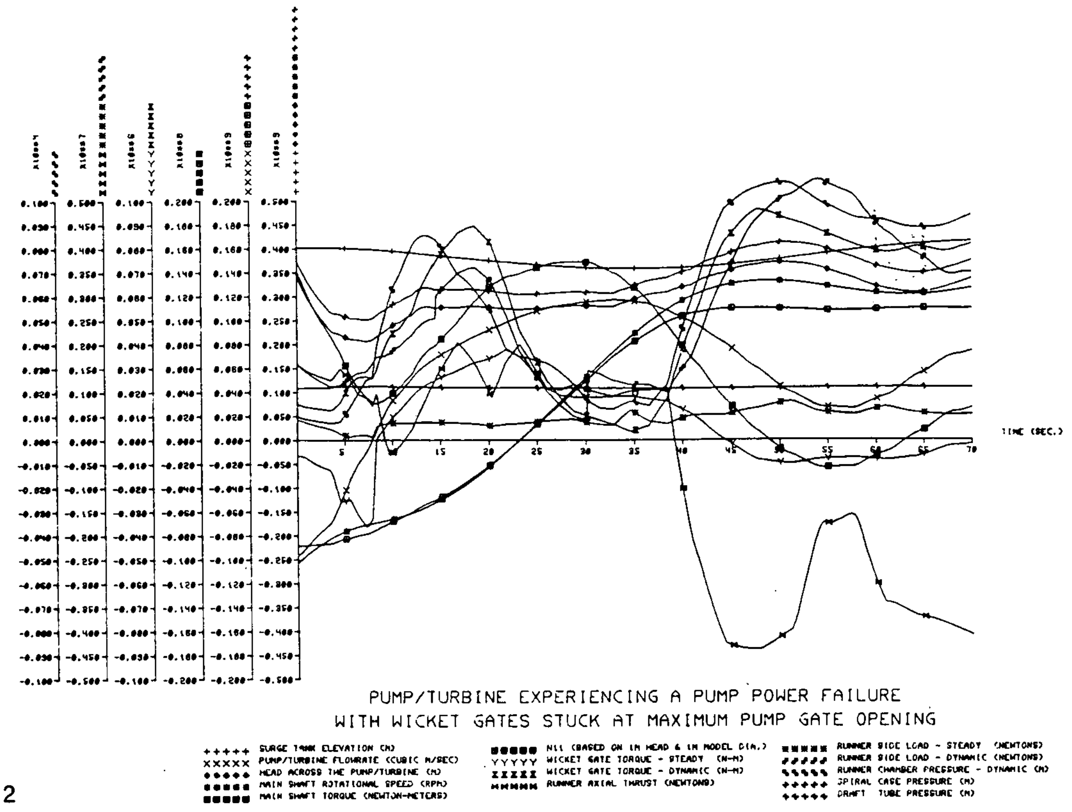


FIGURE 2

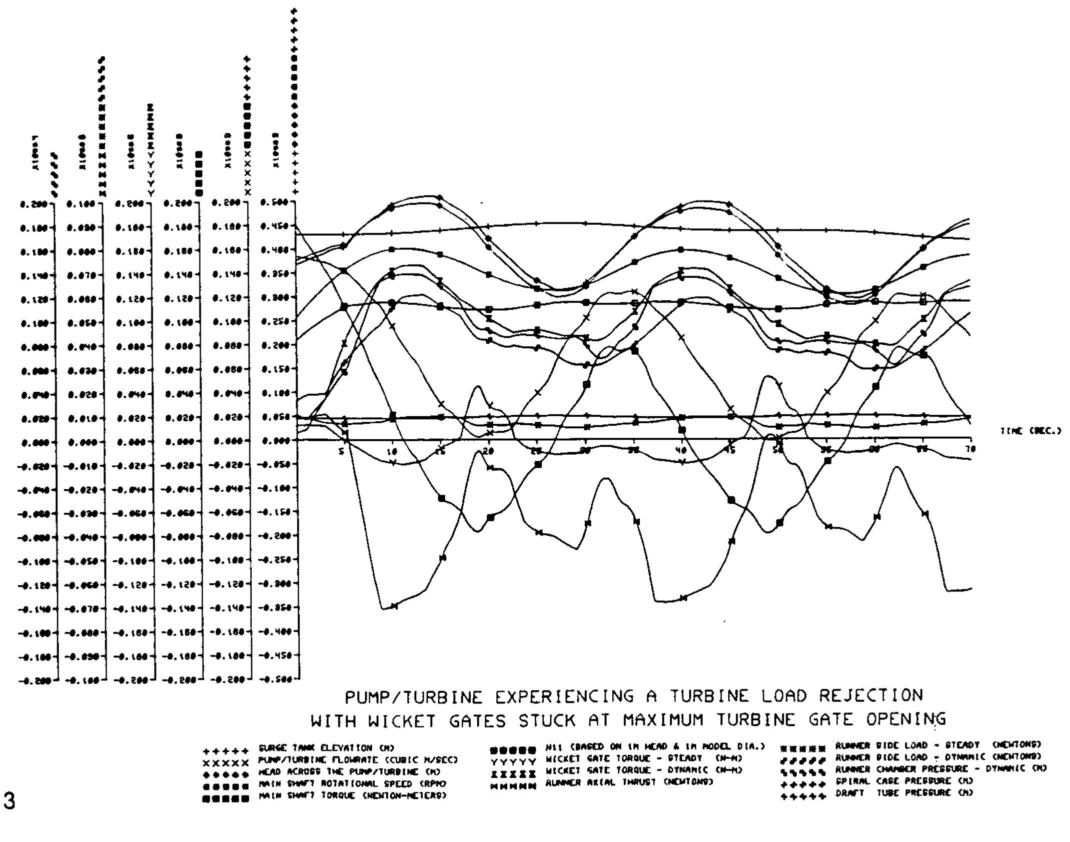


FIGURE 3

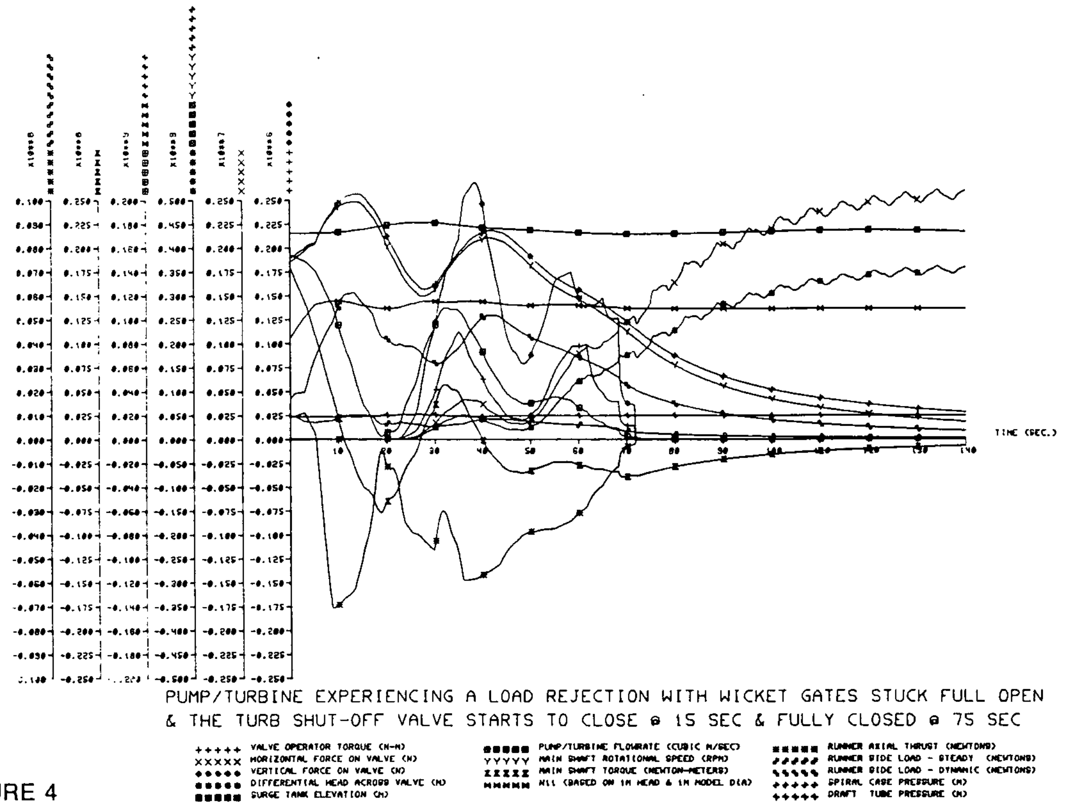


FIGURE 4

When the valve rotor is in the closed position with both piston seals retracted, the differential pressure "h" across the valve deflects the rotor in the downstream direction relative to the valve body increasing the leakage area across the upstream emergency seal and decreasing it across the downstream seal.

If the reduced downstream seal leakage area is the flow controlling element, the rotor deflection could create a negative rate of leakage with respect to the differential head i.e. $dQ/dh<0$ where Q is the leakage flow. This unstable condition can induce dangerous self-energized pressure fluctuations called "auto-oscillations", which could lead to a spherical valve or penstock rupture.

This condition can be made possible by an improper original design or more often by the jamming of the downstream seal piston at a near closed position due to "O" ring extrusion or to an accumulation of dirt or debris.

The following mathematical analysis will study the conditions necessary to induce auto-oscillations and the means of avoiding them.

MATHEMATICAL MODEL

Definitions

Hu = Upstream head (m)
Hv = Valve body head (m)
Hd = Downstream head (m)
h = Valve differential head (m)

$$h = Hu - Hd$$

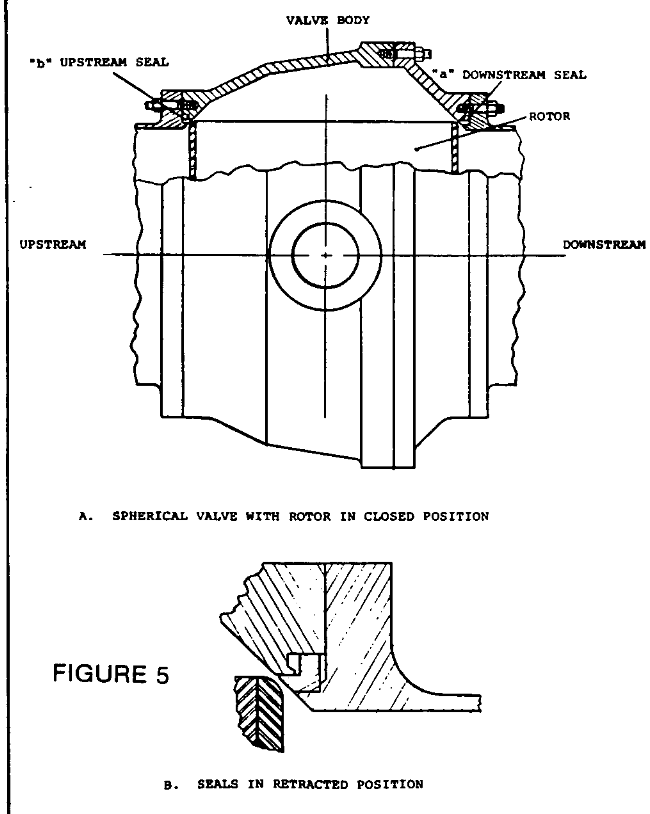


FIGURE 5

*CDu = Upstream seal discharge coefficient
*Au = Upstream seal unloaded area (Area of flow with rotor closed and seal retracted M^2)
*Ku = Upstream seal area coefficient

$$Ku = \frac{\Delta Au}{\Delta h} \text{ (Absolute Value)}$$

*CDd = Downstream seal discharge coefficient
*Ad = Downstream seal unloaded area (m^2)
*Kd = Downstream seal area coefficient

$$Kd = \frac{\Delta Ad}{\Delta h} \text{ (Absolute Value)}$$

*Cb = Bypass flow coefficient (with bypass connecting downstream penstock with valve body)

$$Cb = \frac{Qb}{\sqrt{2g\ (hv - Hd)}}$$

Where Qb - bypass flow (m^3/Sec)

NOTE: Terms preceded by an asterisk * are needed for the "CORA" program.

Upstream seal leakage Qu

$$Qu = CDu \times (Au + (Ku \times h)) \times \sqrt{2g\ (Hu - Hv)} \qquad 1$$

Downstream seal leakage Qd

$$Qd = CDd \times (Ad + (Kd \times h)) \times \sqrt{2g\ (Hv - Hd)} \qquad 2$$

Bypass leakage Qb

$$Qb = Cb\sqrt{2g\ (Hv - Hd)} \qquad 3$$

Continuity equation:

$$Qu = Qd + Qb = Q \qquad 4$$

or

$$(a + (b \times h)) \times \sqrt{Hu - Hv} = (c - (d \times h)) \times \sqrt{Hv - Hd} \qquad 4'$$

Where

$$a = CDu \times Au \times \sqrt{2g}$$

$$b = CDu \times Ku \times \sqrt{2g}$$

$$c = ((CDd \times Ad) + CB) \times \sqrt{2g}$$

$$d = CDd \times Kd \times \sqrt{2g}$$

or

$$T \times \sqrt{Hu - Hv} = S \times \sqrt{Hv - Hd} \qquad 4''$$

with

$$T = a + (B \times h)\ \&\ S = c - (d \times h)$$

Solving equation 4″ for Hv

$$Hv = \frac{T^2\ Hu + S^2\ Hd}{T^2 + S^2} \qquad 5$$

Expanding Hv by its value in equation 1

$$Q = \frac{T \times S \times \sqrt{h}}{\sqrt{T^2 + S^2}} \qquad 6$$

Expanding 6 in terms of a, b, c, d, h

$$Q = \frac{(a + (b \times h)) \times (c - (d \times h)) \times \sqrt{h}}{\sqrt{(a + (b \times h))^2 + (c - (d \times h))^2}} \qquad 6'$$

$$\text{or } Q = \frac{u}{v}$$

where $u = (a + (b \times h)) \times (c - (d \times h)) \times \sqrt{h}$

and $v = \sqrt{(a + (b \times h)) + (c - (d \times h))^2}$

$$\frac{dQ}{dh} = \frac{d\,(u/v)}{dh} = \frac{v\frac{du}{dh} - u\frac{dv}{dh}}{v^2}$$

$$\frac{dQ}{dh} = \frac{1}{2v} \times \frac{ac}{\sqrt{h}} + 3\,(cb - ad)\sqrt{h} - 5\ bdh^{3/2} - \frac{U}{V}(ab - cd) + (b^2 + d^2)\ h$$

To avoid possible auto-oscillation

$$\frac{dQ}{dh} > 0$$

VALVE STRUCTURAL ANALYSIS

The upstream and downstream seals unloaded areas, Av and Ad and area coefficients Ku and Kd are determined from the results of the valve rotor and valve body finite element structural analyses (Ref. 2 and 3 Figure 6A and Figure 6B). Graphs showing the differential deflection of the rotor and body as a function of angular position are drawn for the upstream and downstream seals and the deflected areas estimated (Figure 7).

"CORA" PREDICTION OF AUTO-OSCILLATIONS

In order to determine the system's susceptibility to auto-oscilliation, the following parameters describing the valve system are input in the program:

Both upstream and downstream seal discharge coefficients.

Both upstream and downstream seal unloaded areas.

Both upstream and downstream seal area coefficients.
Bypass flow coefficient.

The first example is an improperly designed spherical valve closing in 60 seconds after closure both upstream and downstream seals remain retracted (Figure 8). From the plot of the penstock pressures directly upstream and downstream of the valve, it is evident auto-occillation does exits. The second example is a properly designed spherical valve operating under identical conditions. (Figure 9).

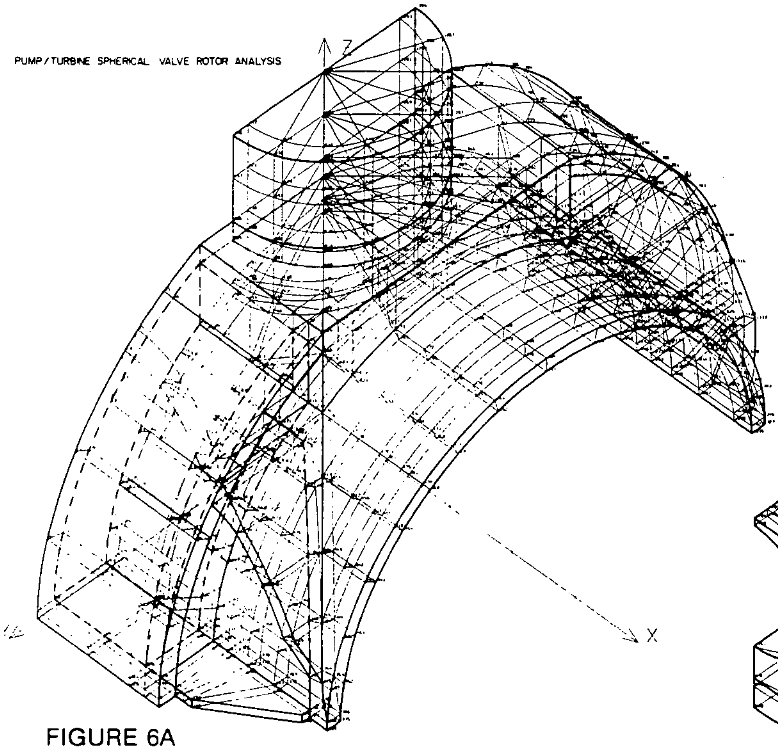


FIGURE 6A

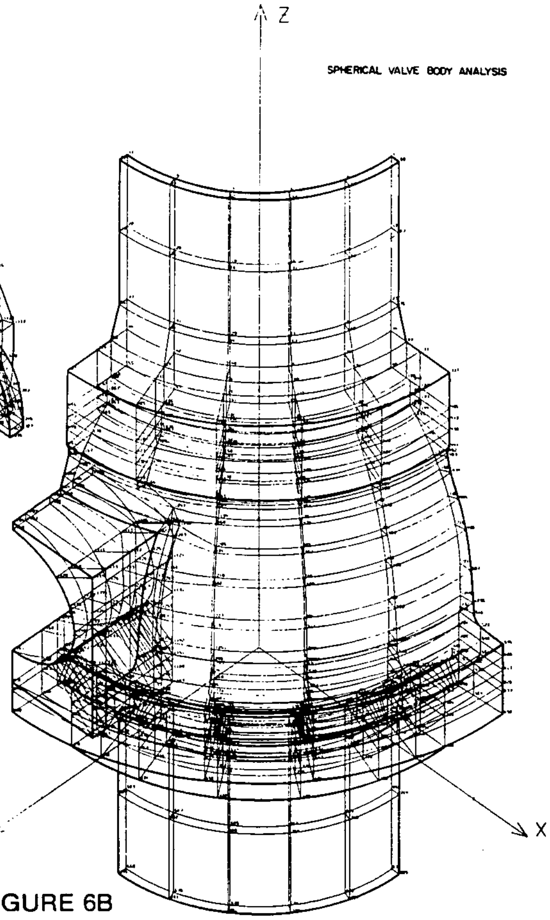


FIGURE 6B

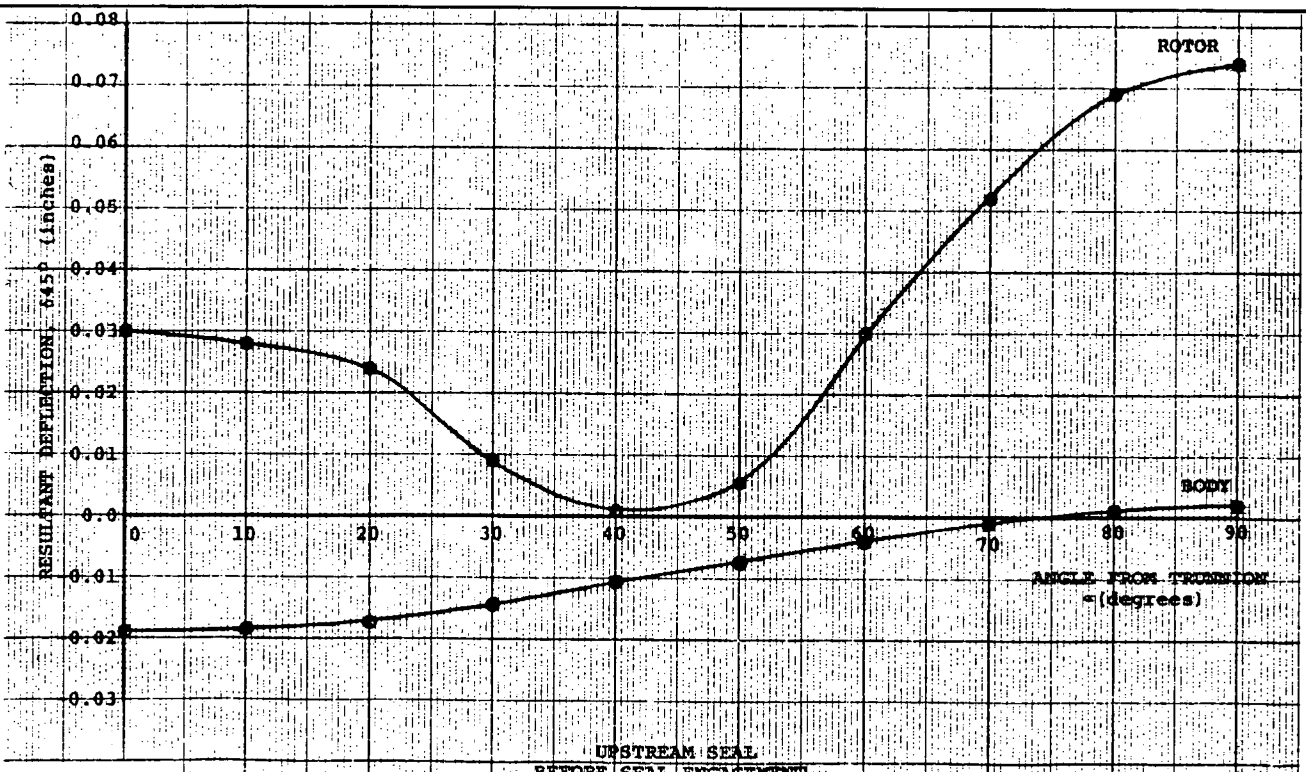
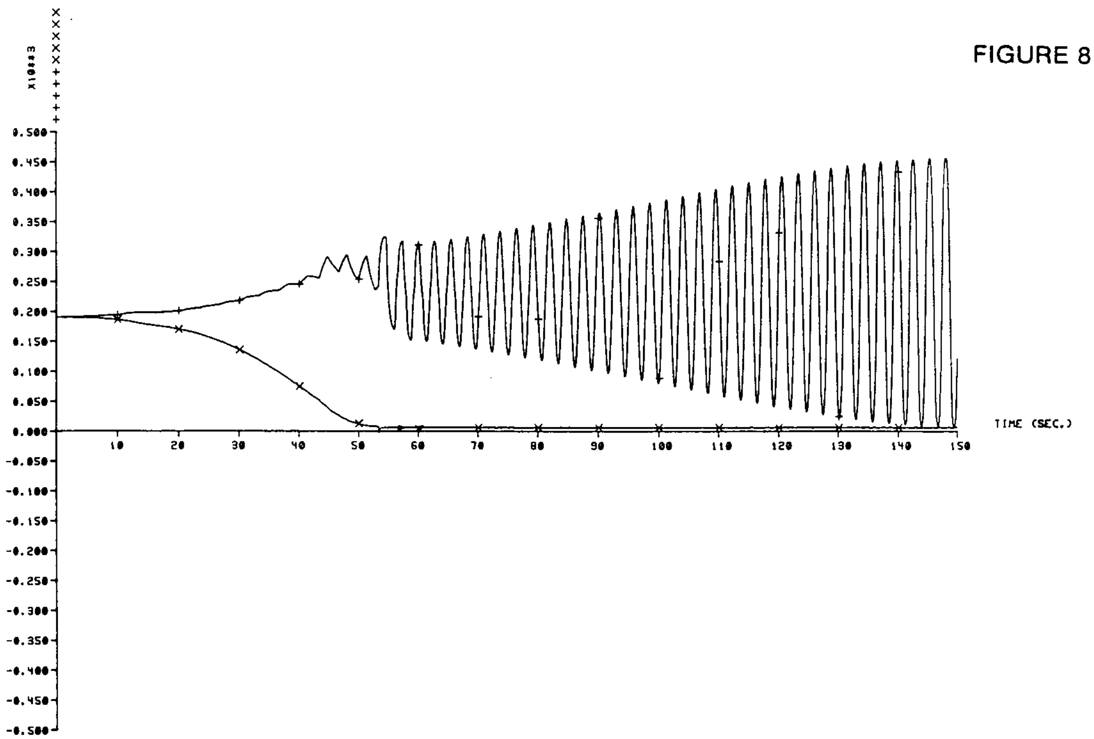


FIGURE 7

FIGURE 8

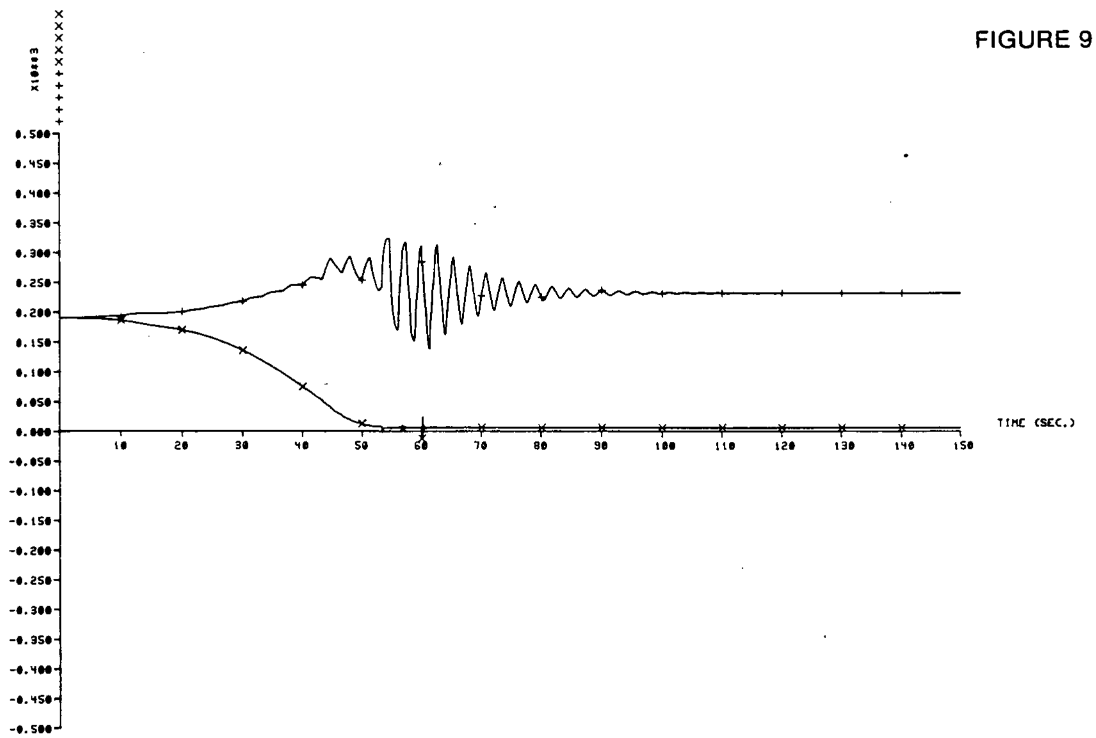


IMPROPERLY DESIGNED SPHERICAL VALVE - AUTO-OSCILLATION DOES EXIST

+++++ HEAD DIRECTLY UPSTREAM OF VALVE - METERS

xxxxx HEAD DIRECTLY DOWNSTREAM OF VALVE-METERS

FIGURE 9



PROPERLY DESIGNED SPHERICAL VALVE - AUTO-OSCILLATION DOES NOT EXIST

+++++ HEAD DIRECTLY UPSTREAM OF VALVE - METERS

xxxxx HEAD DIRECTLY DOWNSTREAM OF VALVE-METERS

WICKET GATE FATIGUE ANALYSIS AND CUMULATIVE DAMAGE CALCULATION

As an obvious prerequisite to wicket gate fatigue design and life expectancy analysis, the working loads, their mode and frequencies of application and the resultant stress field must be known to the required degree of completeness and precision. Also, an accurate knowledge of the fatigue properties of the material under the environmental condition of the application is required.

There are numerous methods for the prediction of the fatigue life. Fundamentally, they all involve the concept of the gradual accumulation of damage during the process of loading. The Miner's linear cumulative damage rule is typically used in the fatigue analysis of wicket gates. This rule is based on the linear summation of the fractions of fatigue damage expressed in terms of the cycle ratio (n/Nf) where n = number of cycles experienced for each mode of loading. Nf = number of cycles required to cause fatigue failure at any point of the component under the evaluated mode of loading. Failure is thus hypothesized when $\Sigma n/Nf = 1$.

The process of calculating the wicket gates cummulative fatigue damage during transients has been completely computerized in the "Cora" program using the following procedure:

A. An accurate finite element analysis of the wicket gate is done, the gate is loaded by a representative pressure distribution on the leaf generating a known torque in the stem (Figure 10).

B. The high stressed points are recorded and entered into the "Cora" program.

C. For each incremental time Δt during a transient, the following procedure is followed:

1. The number of cycles is calculated

$$n = \frac{\Delta t \times RPM \times NB}{60}$$

Where NB is the number of runner blades.

2. The static and fluctuating torque is calculated from the model data.

3. The static and dynamic stress levels are calculated by rationing the torques to the standards torque used in the finite element analyses.

4. The number of cycles expected to generate a fatigue failure (Nf) is calculated from the material properties.

5. The ratio n/NF is calculated and accumulated.

At the end of the transient, the summation $\Sigma n/NF$ is obtained and used in the life expectancy calculation.

The qualitative results are as important as the quantitative ones. The engineer can see immediately the effect of changes in the closure laws on the fatigue life of the wicket gates and enter this consideration into his optimization of wicket gate closure.

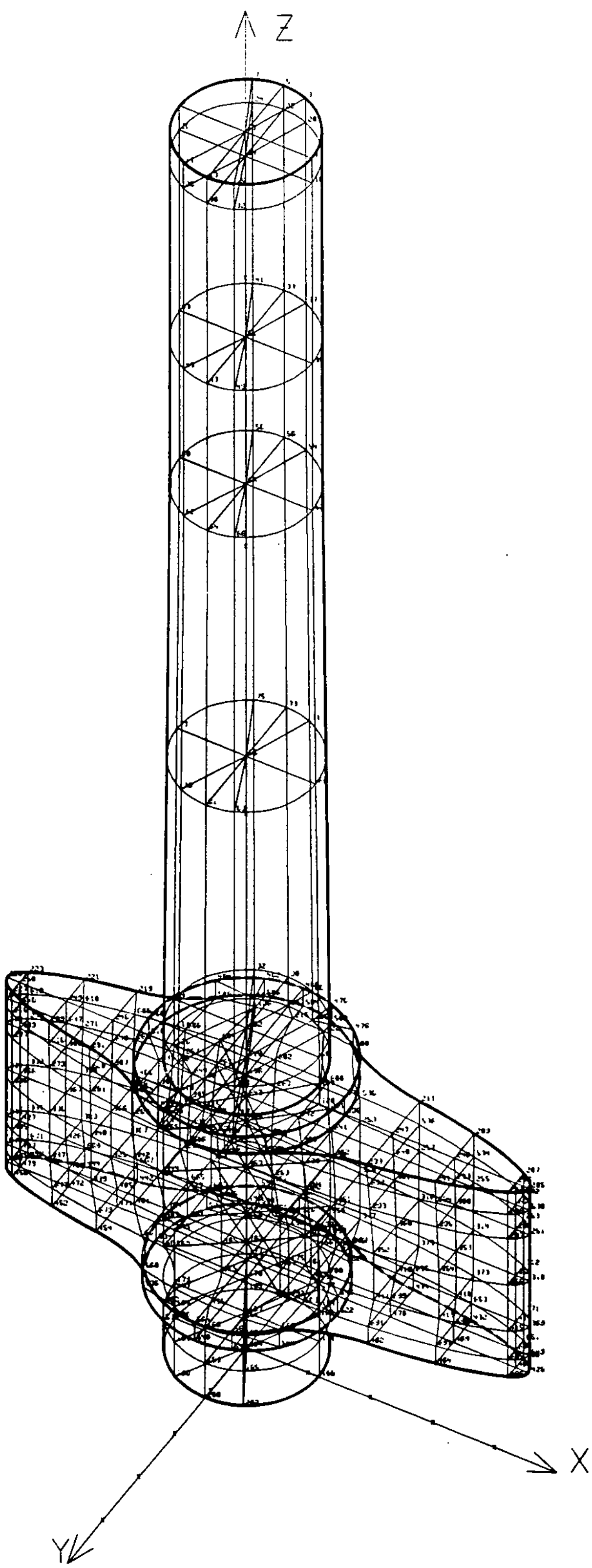


FIGURE 10

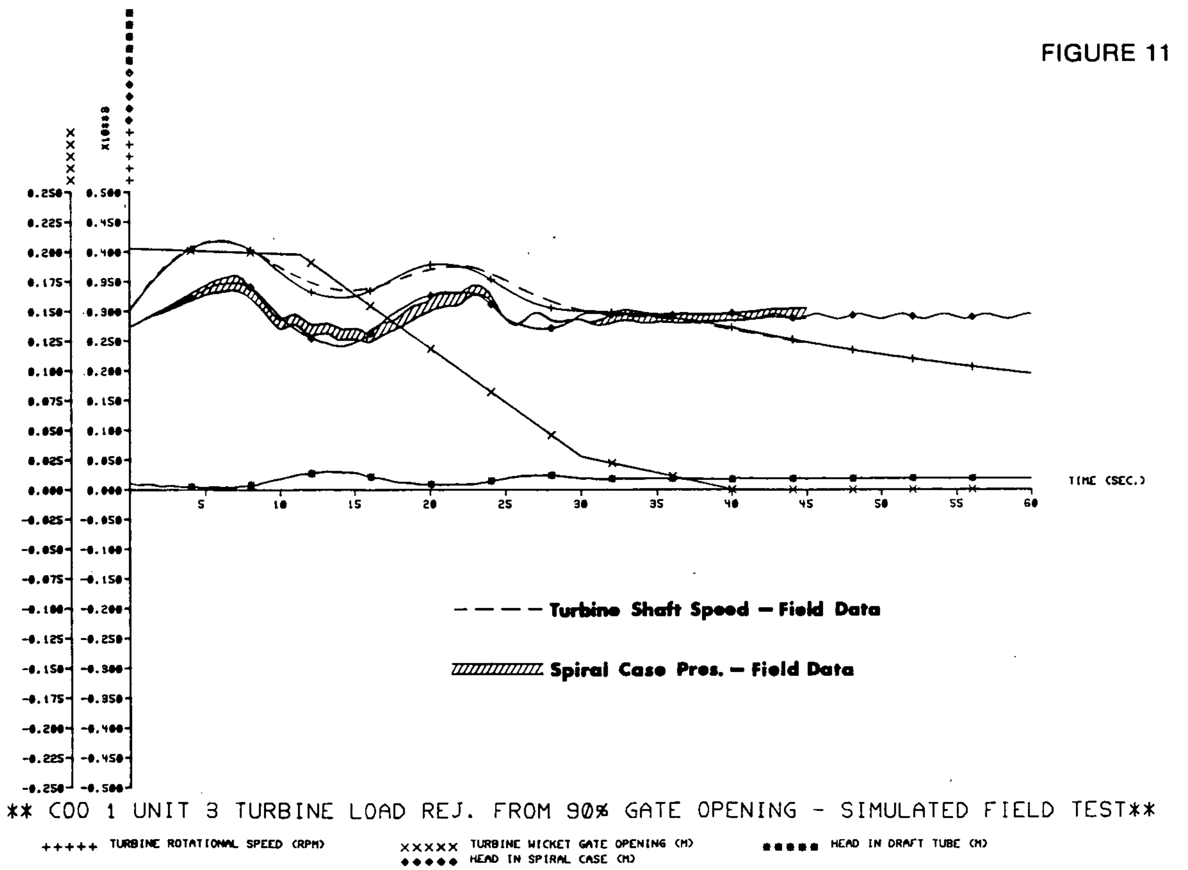
FIELD CORRELATION

The ultimate test of any analytical solution is how well the predicted values compare with actual measured data. Correlation of main shaft speed and spiral case pressure from reversible pump turbines at Coo 1 powerhouse is shown for a load rejection from 90% gate opening (Figure 11) and a pump power failure from 68% gate opening (Figure 12). Correlation of spiral case pressure and draft tube pressure from reversible pump turbines at Carters powerhouse is shown for a load rejection from 60% gate opening (Figure 13) and pump power failure from 62% gate opening (Figure 14). Excellent correlation is seen for main shaft speed, spiral case pressure, and draft tube pressure.

CONCLUSION

The large loads found in high head pump turbines during transient conditions and their large impact on the mechanical design of the machine has necessitated the development of new tools capable of predicting their evolution. The "CORA" program has been developed to provide both the data necessary for the proper design of high head pump turbines and sizing of their mechanical components and the necessary information for the proper design of the civil structure.

FIGURE 11



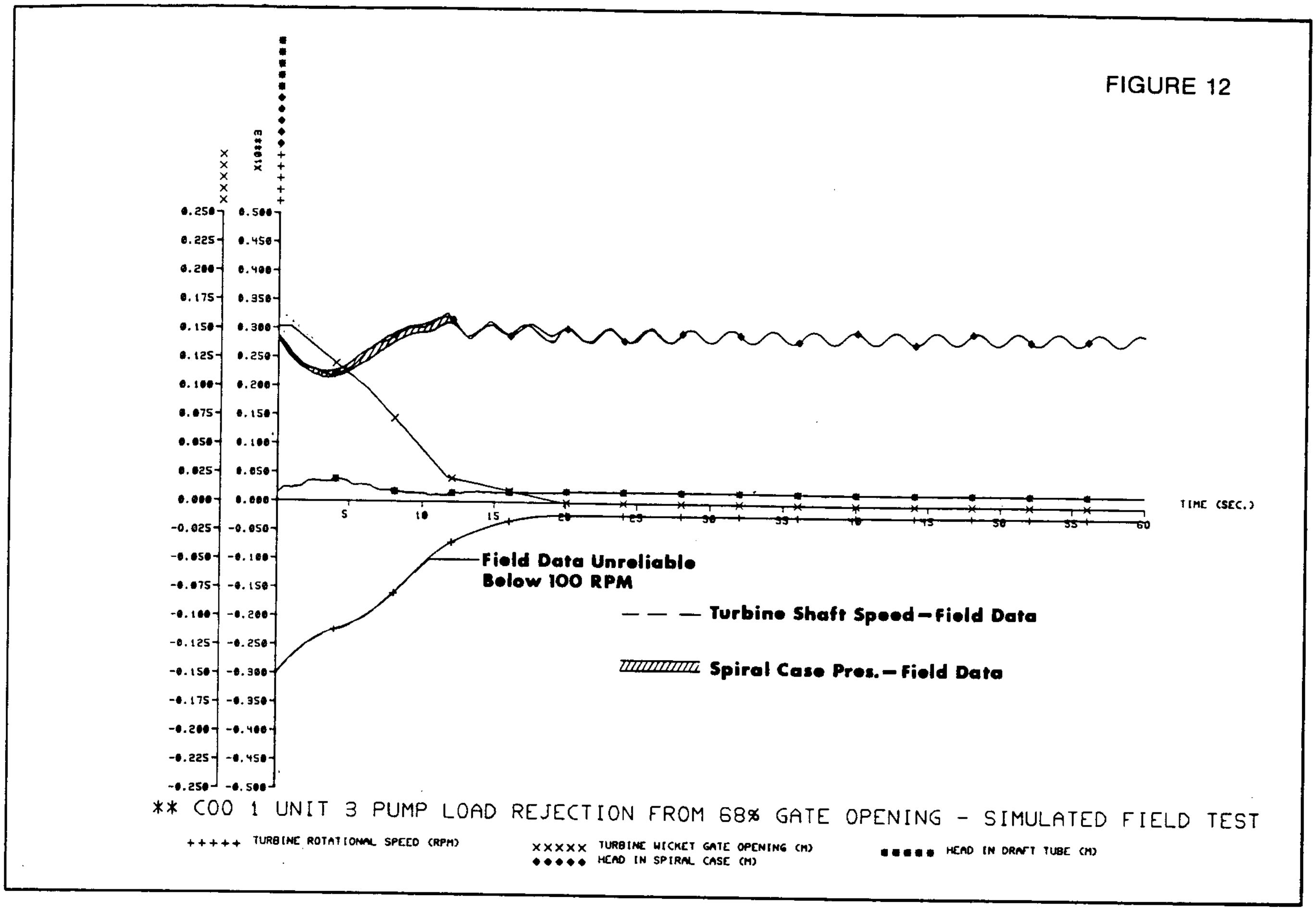


FIGURE 12
Field Data Unreliable Below 100 RPM
Turbine Shaft Speed—Field Data
Spiral Case Pres.—Field Data
TIME (SEC.)
** COO 1 UNIT 3 PUMP LOAD REJECTION FROM 68% GATE OPENING - SIMULATED FIELD TEST
+++++ TURBINE ROTATIONAL SPEED (RPM)
XXXXX TURBINE WICKET GATE OPENING (M)
◆◆◆◆◆ HEAD IN SPIRAL CASE (M)
■■■■■ HEAD IN DRAFT TUBE (M)

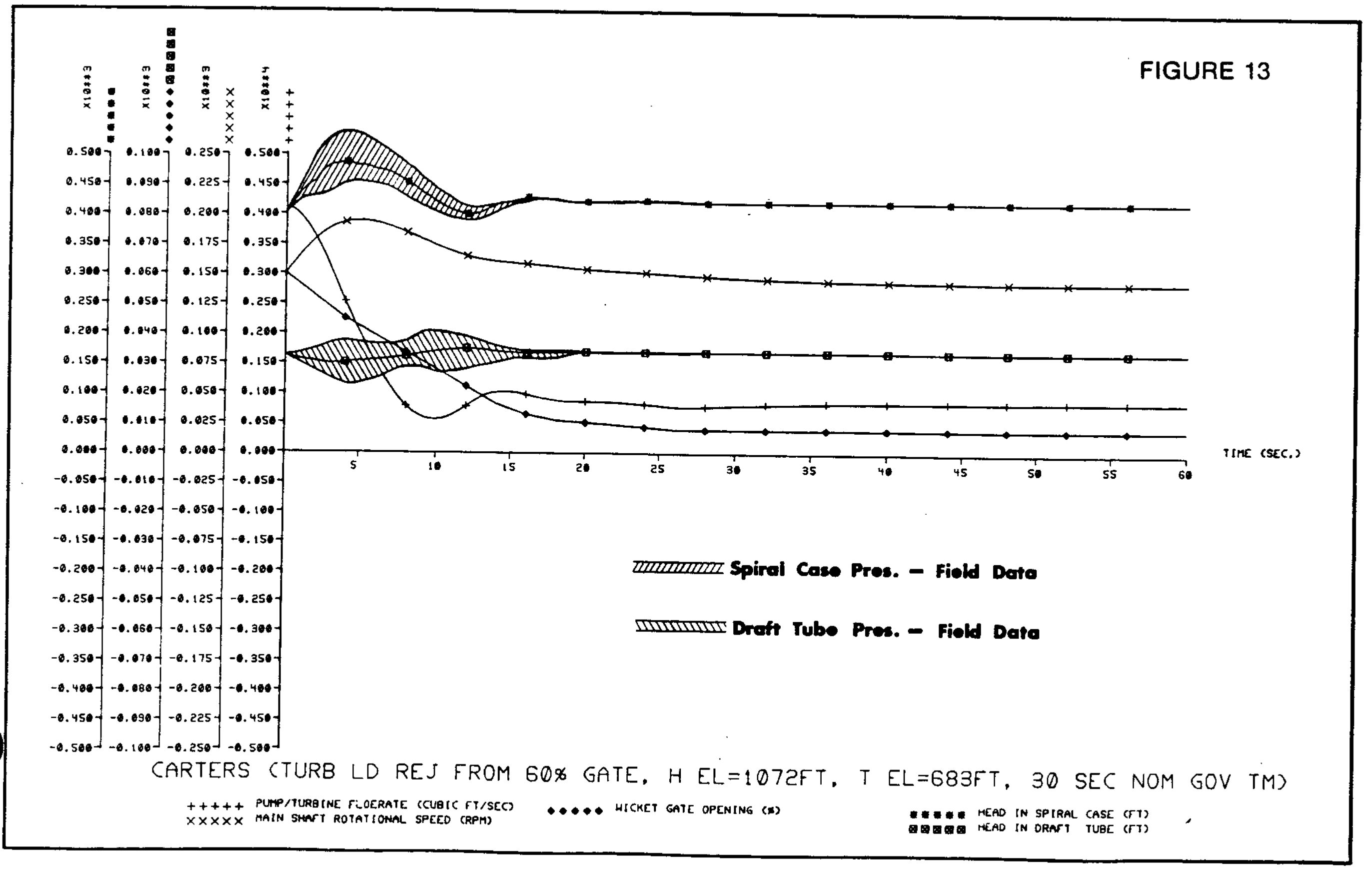


FIGURE 13
Spiral Case Pres. — Field Data
Draft Tube Pres. — Field Data
TIME (SEC.)
CARTERS (TURB LD REJ FROM 60% GATE, H EL=1072FT, T EL=683FT, 30 SEC NOM GOV TM)
+++++ PUMP/TURBINE FLOERATE (CUBIC FT/SEC)
XXXXX MAIN SHAFT ROTATIONAL SPEED (RPM)
◆◆◆◆◆ WICKET GATE OPENING (%)
■■■■■ HEAD IN SPIRAL CASE (FT)
▣▣▣▣▣ HEAD IN DRAFT TUBE (FT)

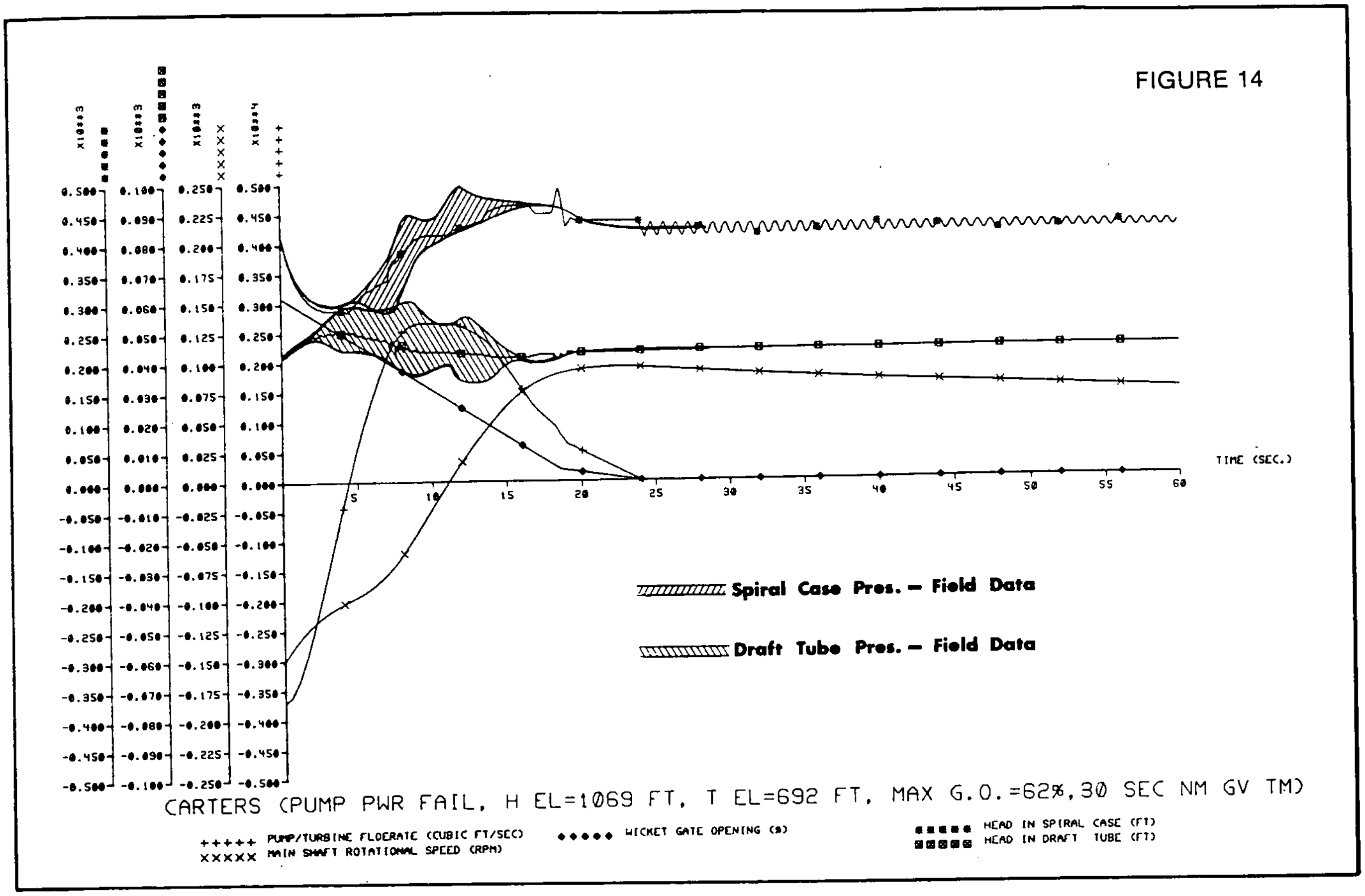


FIGURE 14

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2. Chacour, S., "DANUTA, A Three-Dimensional Finite Element Program Used in The Analysis of Turbo-Machinery", ASME Paper.
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COMPUTER ANALYSIS AND FIELD CORRELATION
FROM THE HYDRAULIC TRANSIENT PROGRAM "CORA"

RONALD E. DEITZ[1]

ABSTRACT

In 1976, a sophisticated computer program "CORA" was developed to analyze the hydraulic transients generated in complex penstock systems.

More than 200 various hydraulic systems have been analyzed using "CORA", with over 40 field correlations. Some of the more interesting applications and results are discussed in this paper. The specific topics are:

— Determination of the total flow passing through a valve during opening stroke with the valve connected to a pressurized system.

— An unusual interaction of two reversible pump/turbines connected to a common penstock during a load rejection.

— Influence of a surge tank on the transient behavior of a low head hydro-turbine.

— Hydraulic system response to the low frequency draft tube surges which are normally found in a hydraulic turbine.

— Isolated load operation problems with a hydro-generating unit having a low inertia constant.

— Turbine mode pumping phenomena of a reversible pump/turbine and field correlation from the commissioning tests.

— Two reversible pump/turbines using the same penstock and draft tube tunnel with one unit pumping and the other unit starting in the generation mode.

Computer plots of the various analyses and some field correlations are included.

INTRODUCTION

The computer program "CORA"(1) is used to analyze penstock and hydro machinery systems to provide both static and dynamic loads anticipated on the various machinery components, as well as to supply design information for the hydro machinery and the civil structure.

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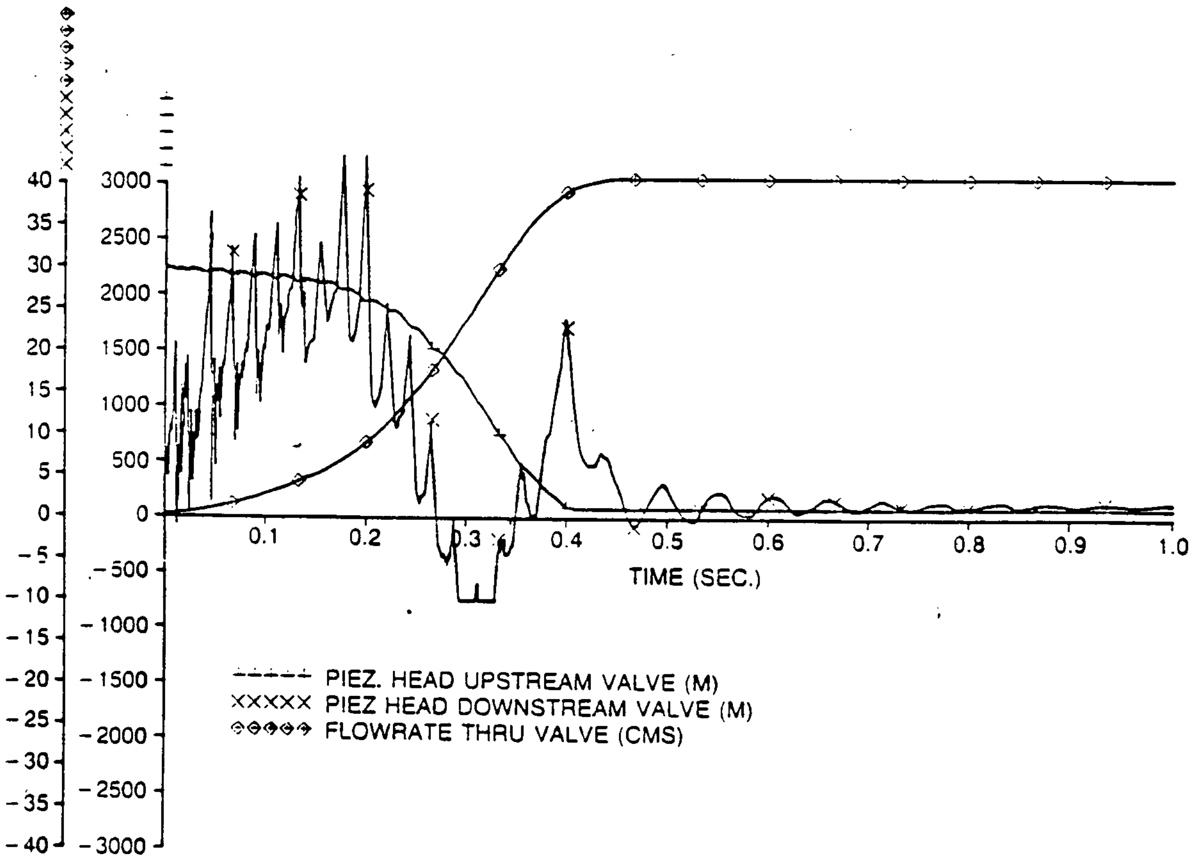
Since its development, the program has been used to study more than 200 different hydraulic systems with pipe sizes ranging from 0.006 meter diameter to 410 square meters of area, pressure ranges from 4 to 2250 meters of water and penstocks which range from 15 meters to 9000 meters in length. This paper discusses a few of the more interesting applications and results of the "CORA" program.

Landing Sled Test Stand

In this case, the "CORA" program was used to analyze an unusual hydraulic system. The system was an aircraft landing sled test stand consisting of an air over water pressure tank from which water with 2250 meters of pressure discharges against a sled in order to duplicate landing conditions on aircraft tires. A 0.5 meter conical plug valve was being considered to control the water flow from the pressure tank. The points of interest were how much time would be required for the system to reach full flow with a 0.4 second opening time; and, what volume of water would pass through the valve during the opening stroke. The computer simulation of this condition (Figure 1) showed that full flow of 40 cubic meters per second was achieved in 0.45 seconds. By integrating the flow curve, the volume of water that passed through the valve during opening was evaluated as 5.5 cubic meters. The answers to this unique problem demonstrated the flexibility of the "CORA" program.

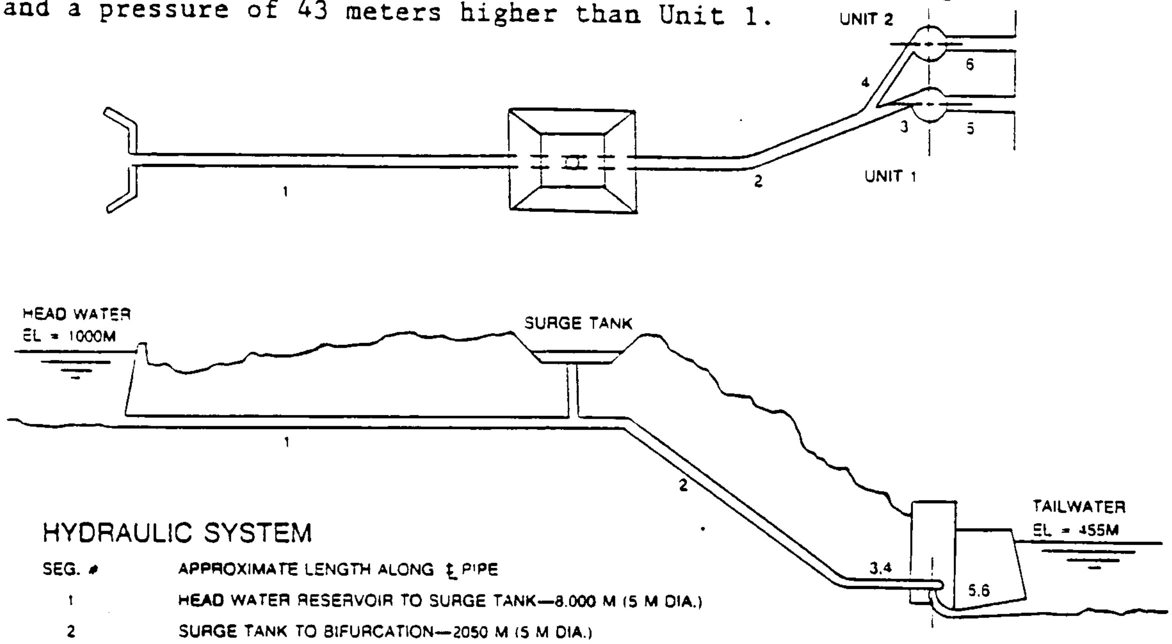


LANDING SLED—0.4 SEC. VALVE OPENING TIME

FIGURE 1

Common Penstock Potential Problem

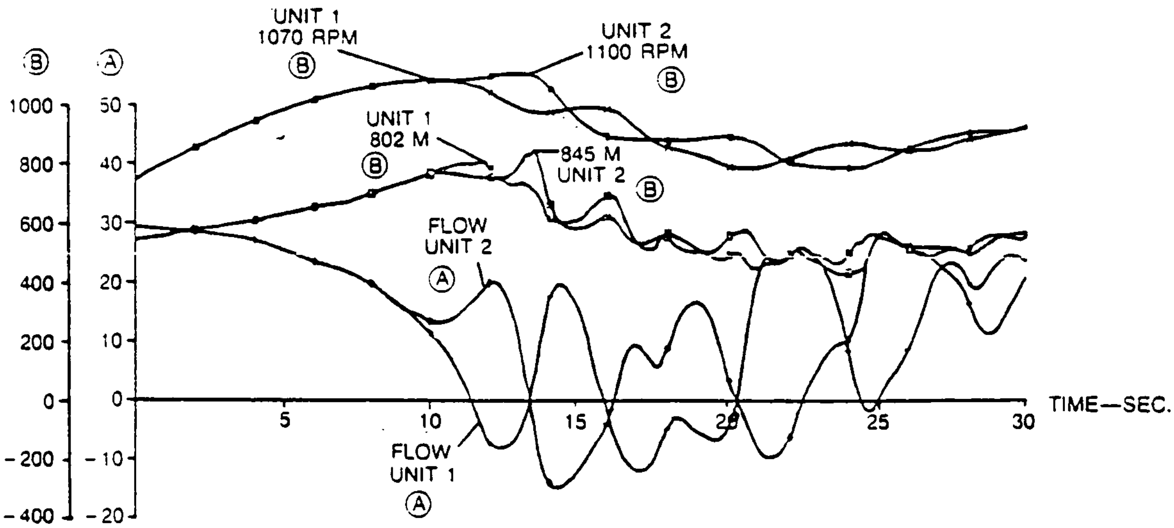
The computer program has helped to identify many possible problems where the hydraulic machinery and penstock are not compatible. One possible mis-match was identified in the proposal stage of two single stage reversible pump/turbines. The 545 meter gross head hydraulic system is shown in Figure 2. During a simultaneous load rejection from maximum power and head (Figure 3), Unit 2 peaked at a speed of 30 RPM and a pressure of 43 meters higher than Unit 1.



HYDRAULIC SYSTEM

SEG. #	APPROXIMATE LENGTH ALONG ℄ PIPE
1	HEAD WATER RESERVOIR TO SURGE TANK—8.000 M (5 M DIA.)
2	SURGE TANK TO BIFURCATION—2050 M (5 M DIA.)
3	FROM BIFURCATION TO SP. CASE OF UNIT 1—31 M (3.5 M DIA.)
4	FROM BIFURCATION TO SP. CASE OF UNIT 2—34 M (3.5 M DIA.)
5 & 6	DRAFT TUBE AND TAILRACE OF BOTH UNITS—100 M (3.75 M DIA.)

FIGURE 2



SIMULTANEOUS LD REJ—
2 UNITS FROM MAX. LOAD & HEAD

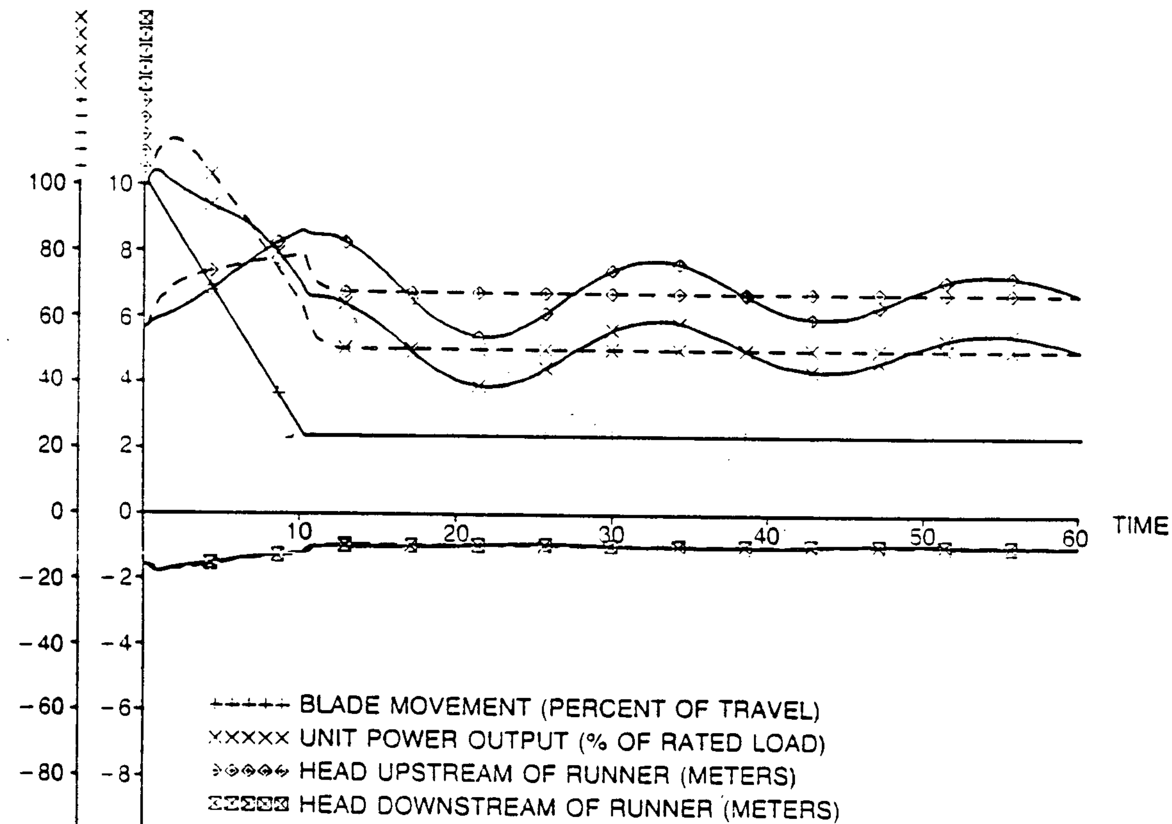
FIGURE 3

With this combination of penstock and hydro machinery characteristics, Unit 1, having a penstock 3 meters shorter, went into the reverse pumping quadrant (pumping with shaft rotation in generating direction) before Unit 2. This potentially dangerous phenomena would be eliminated by increasing the total unit inertia of both units by 30%.

Surge Tank on Low Head Unit

Surge tanks are used in hydraulic penstock systems to decrease pressure fluctuations and improve the regulating capabilities of hydro units. A rule of thumb indicates the possible need for a surge tank when the Σ(length x velocity)/head is greater than 5. This study of a 7.6 meter low head penstock system has a $\Sigma(LV)/H = 30$. With the unit synchronized, a 50% load swing was computer simulated (Figure 4). Note that the surge tank (solid lines) minimizes the pressure fluctuations in the first 10 seconds. After 10 seconds, the normal pressure oscillations inherent to the surge tank are a large percentage of the head on this unit, which has a major influence on both pressure and load swings.

This is basic to surge tank stability which is covered in text books[3]. Care should be taken when planning penstock systems of low head units with surge tanks so that the normal pressure oscillations of the surge tank do not have an adverse influence on the generating system.

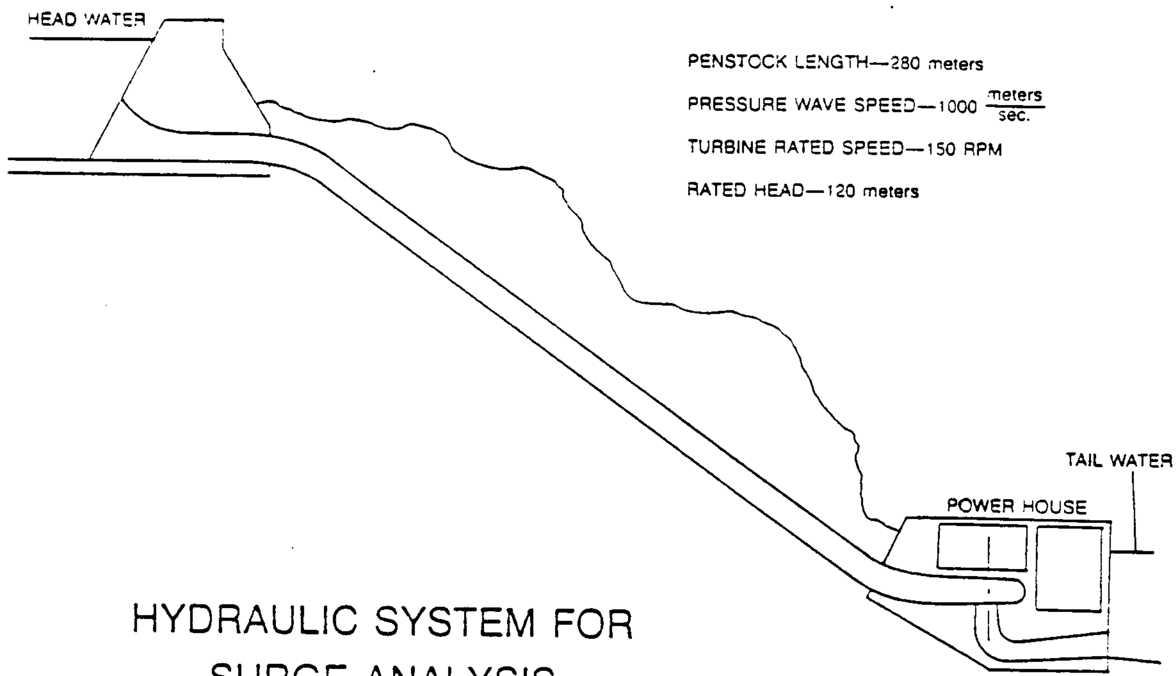


UNLOADING UNIT
FROM FULL TO 50% OUTPUT IN 10 SECONDS
SOLID LINES—WITH SURGE TANK DASHED LINES—WITHOUT SURGE TANK

FIGURE 4

Water Passage Frequency Study

This analysis was conducted to determine the response of the penstock to the normal draft tube pressure surges of the turbine. The hydraulic system was a single penstock 280 meters long connected to a Francis turbine subject to a head of 120 meters (Figure 5). The reason for concern was that the penstock natural frequency (4L/A = 0.9 Hz) was in range of the normal part load draft tube pressure surging frequency of 0.6 to 1.2 Hz (Rheingans frequency).



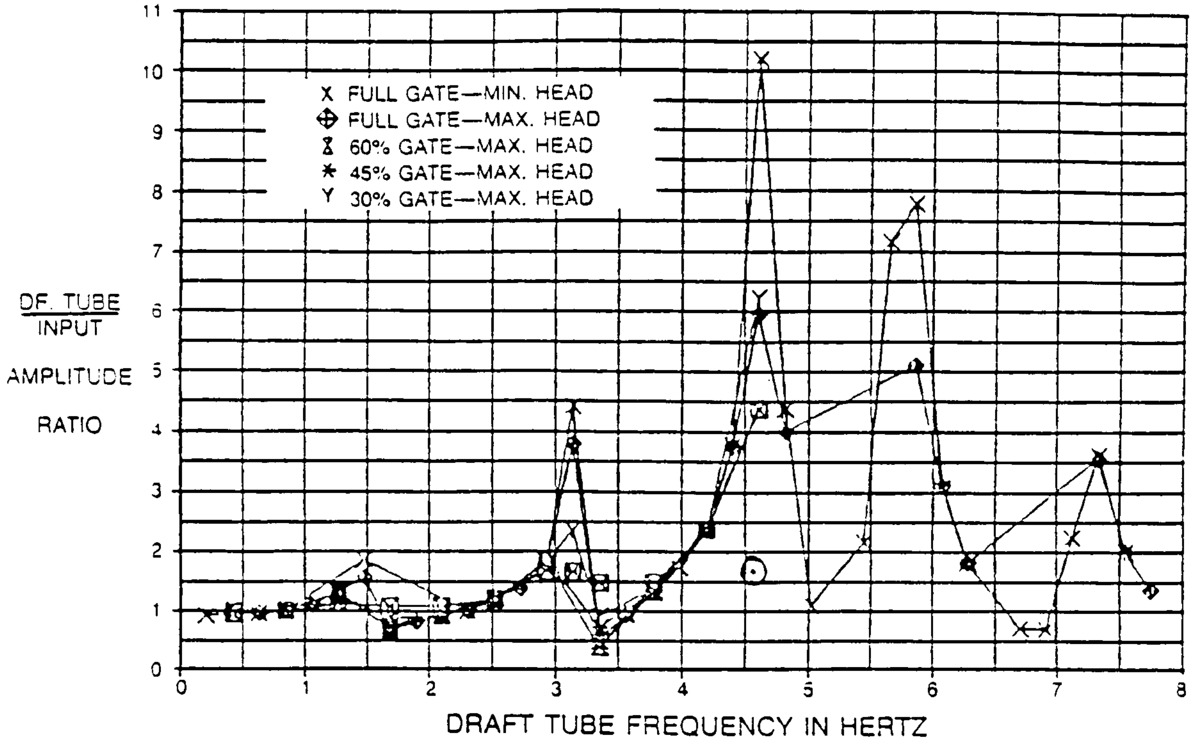
HYDRAULIC SYSTEM FOR SURGE ANALYSIS

FIGURE 5

The "CORA" program was used for a computer simulation of dynamic pressures at the top of the draft tube just below the runner, at the bend, and the draft tube exit; with the most adverse response used for expected prototype behavior. Figure 6 demonstrates the response of the draft tube to the excitation, and Figure 7 demonstrates the spiral case dynamic pressure response with respect to the draft tube. It should be noted that the spiral case dynamic pressure was never greater than the draft tube dynamic pressure indicating no penstock resonance problems.

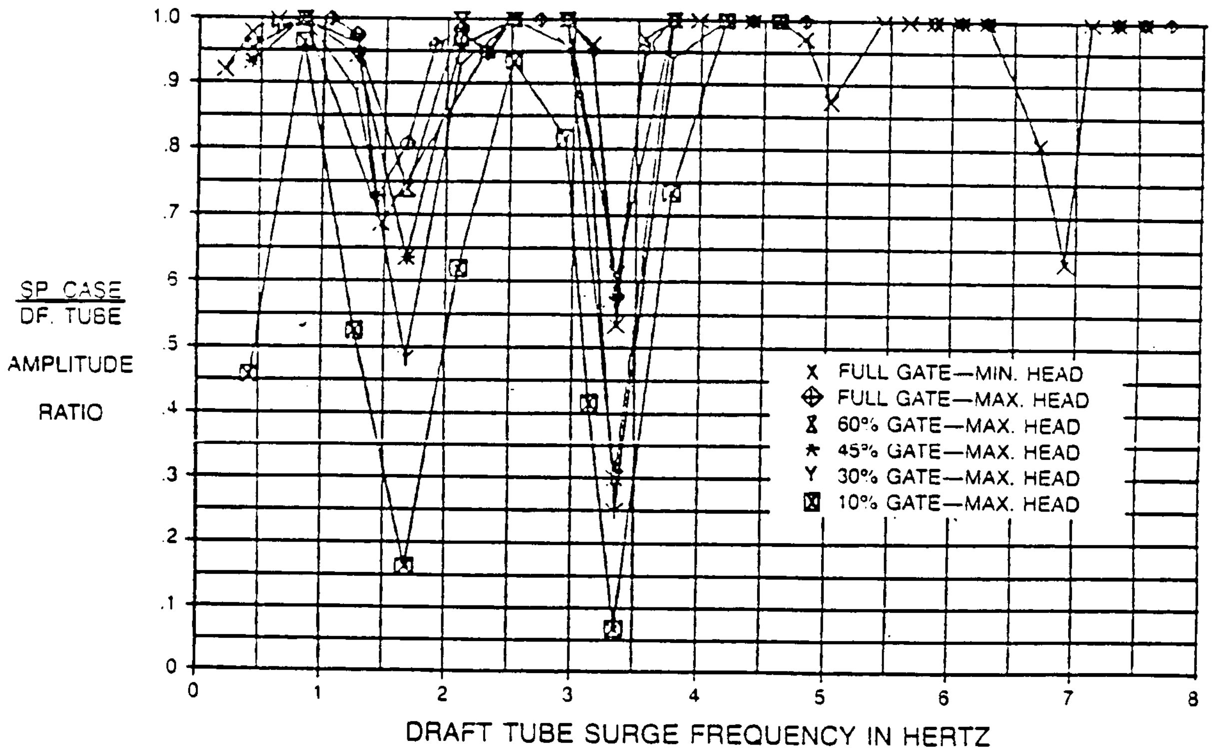
Isolated System Operation

This case involved a low head hydro-turbine that was intended to supply energy to an established electrical system, with the added option of operating as an isolated system. The hydro project had a gross head of 7 meters and a turbine output of 800 kW. The water starting time (Tw), or the time to accelerate the water flow in the system from zero to rated velocity when subject to rated head, was 1.1 seconds; while the mechanical starting time (Tm), or the time required to accelerate the turbine and generator from stop to rated speed with rated torque applied, was 0.5 seconds.



SURGE ANALYSIS

FIGURE 6



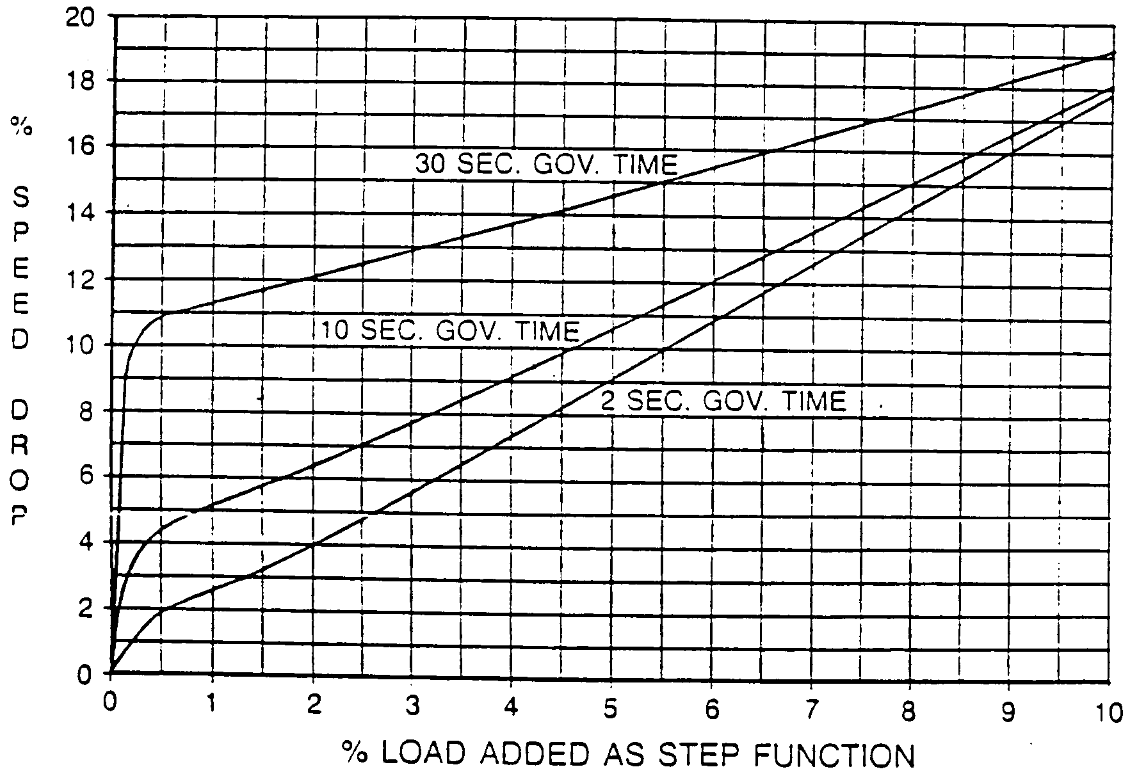
SURGE ANALYSIS

FIGURE 7

With these system and unit characteristics, the response of the unit to different step load changes was computer simulated for various governor times (Figure 8). Note that for a 10% load change (about 100 HP), the unit had an 18% change in speed.

It is evident that this unit is not suitable for isolated load operation in its present configuration. For good regulating capabilities, the U.S. Bureau of Reclamation[(2)] recommends a ratio greater than 8 for mechanical starting time (Tm) to water starting time (Tw) (Tm/Tw > 8). The planned unit had a Tm/Tw ratio of .45 which also indicates the unit would not suitable for load regulation. To obtain an appropriate Tm/Tw ratio, the mechnical starting time is the only parameter which could be changed since the water starting time is a function of fixed penstock dimensions (length and diameter). In this case the mechanical starting time must be 8.8 seconds which would require an increase in unit WR^2 of 17.6 times. Increases in rotating inertia of these magnitudes are not practicable, and isolated load operation would not be possible.

When isolated load operation is required, all parametrs such as penstock dimensions, turbine, generator, governor, etc., must be considered in the planning stages; and in some cases isolated operation may not be practical.



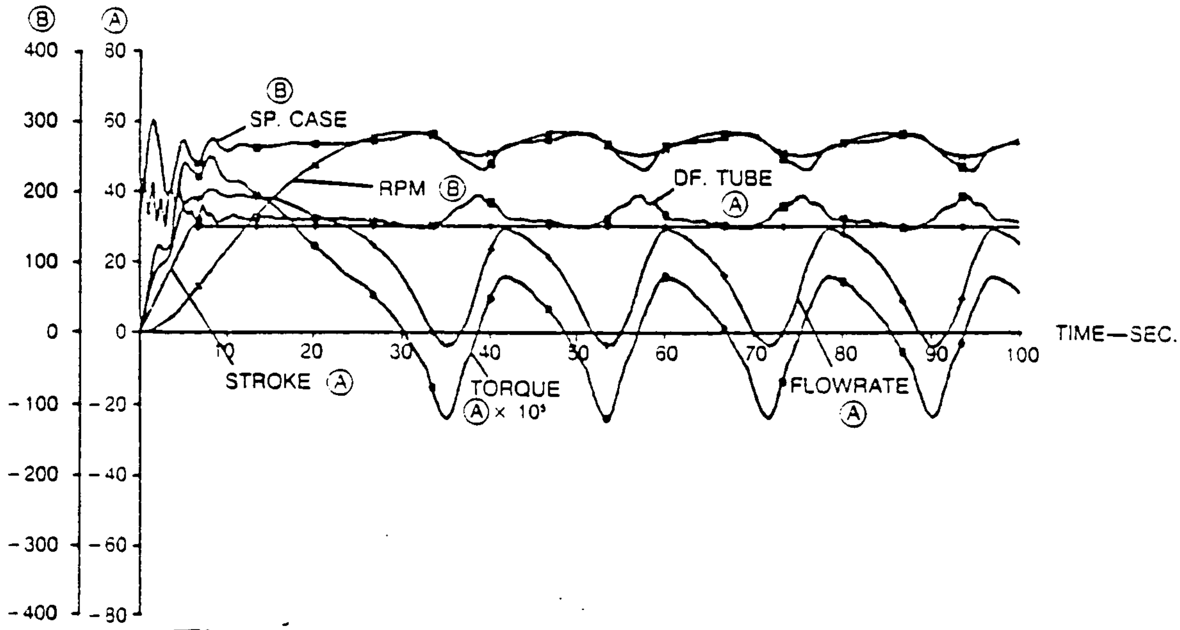
ISOLATED LOAD OPERATION—UNIT AT 50% LOAD

FIGURE 8

Commissioning

During the commissioning of a pump/turbine manufactured by one of our licensees, a synchronizing problem was reported for normal turbine operation which occurred only at low head. The site conditions were simulated to analyze the problem (Figure 9). From various computer simulations, it was determined that the unit could be synchronized if the gates were opened at a slow rate, which was confirmed by prototype tests.

Once synchronized, the turbine began pulling power from the electrical grid and continued to pull power as the gates were opened. Under this condition, the unit was pumping from the tailwater to the headwater while the shaft rotation was in the generating direction. Computer simulations determined the best method for loading the machine would be to open the gates rapidly after synchronization. This was also confirmed by prototype tests.

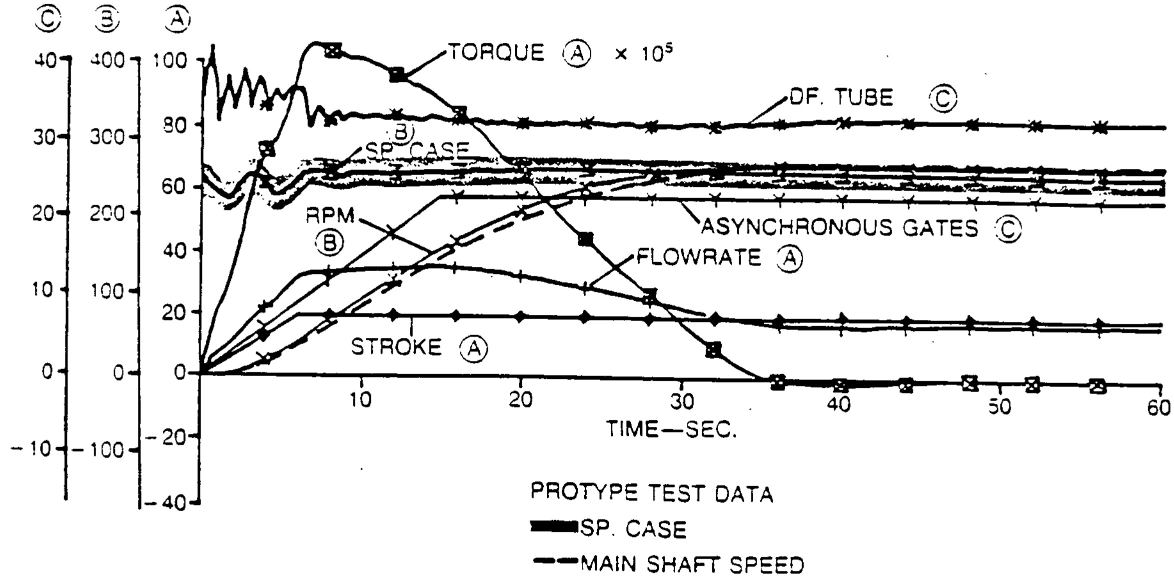


TURBINE START—MINIMUM HEAD

FIGURE 9

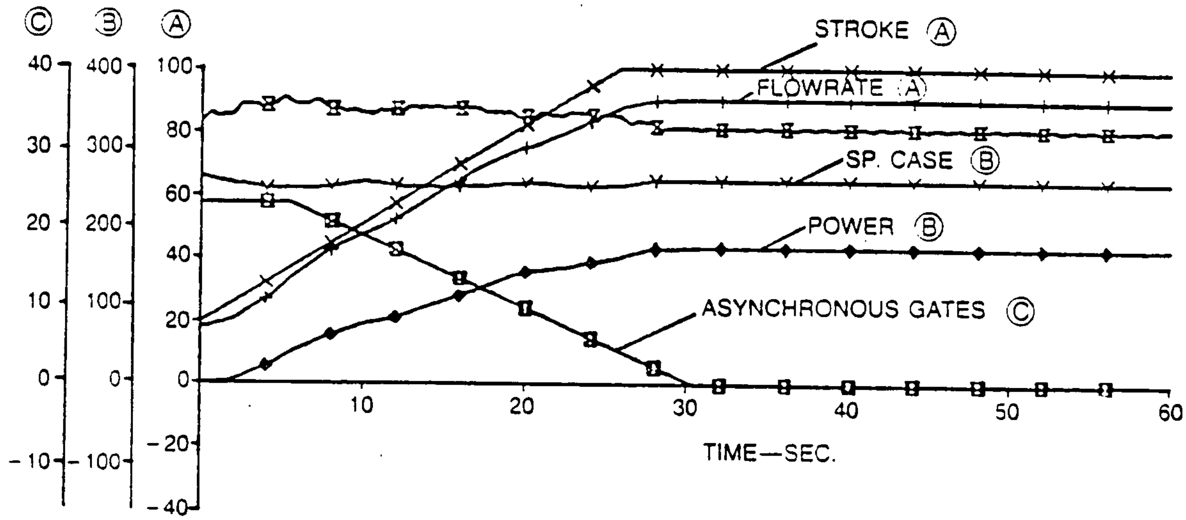
While permanent solutions were being investigated using model tests, satisfactory temporary operation was obtained by following the recommendation based on the computer simulations.

One of the permanent solutions investigated involved some asynchronous gate operation. All phases of the pump/turbine operations were simulated to determine optimum timing and settings. Figure 10 is a simulation of the turbine start using asynchronous gate operation with Figure 11 being the loading condition. Field test data of spiral case pressure and main shaft speed was overlayed on Figure 10 which shows good correlation of predicted asynchronous gate operation to the prototype test data.



TURBINE START—MINIMUM HEAD

FIGURE 10

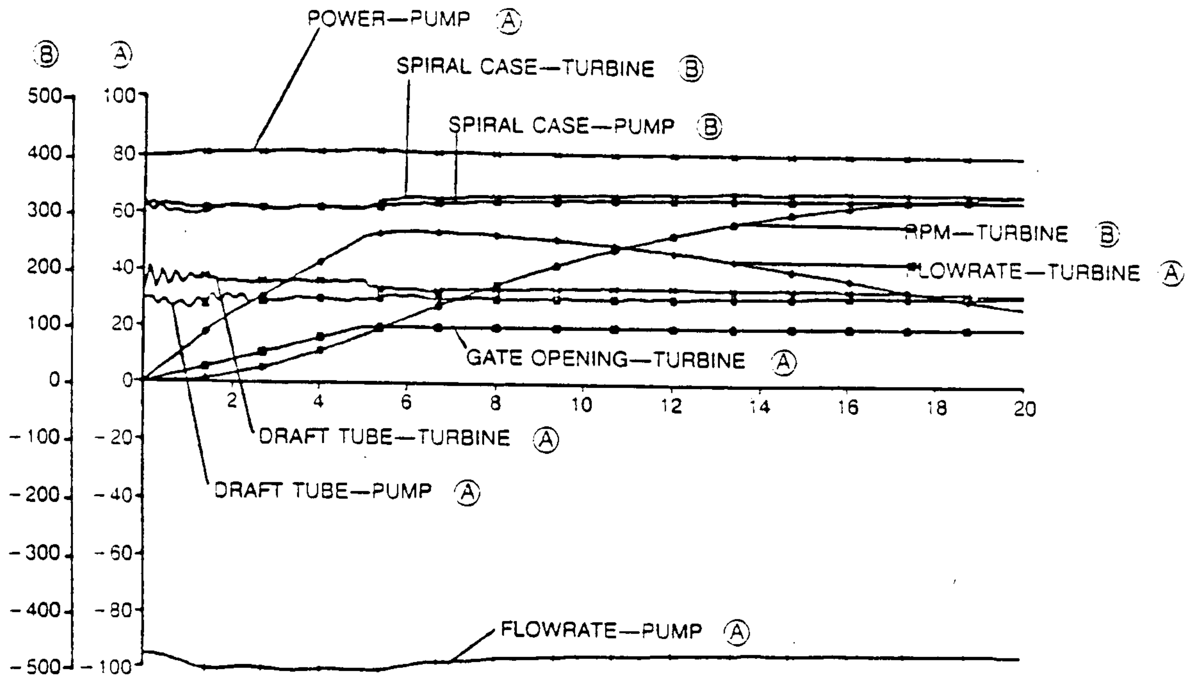


TURBINE LOADING—LOW HEAD

FIGURE 11

Simultaneous Pump and Turbine Operation on Common Penstock

The last item to be discussed concerns back to back starting of pump/-turbines. The power plant consisted of four reversible pump/turbines which shared a common penstock tunnel as well as a common draft tube tunnel. The secondary pump starting method was back-to-back starting with a turbine. With this method, the question was asked: if one or more units are already pumping, could another unit be started in the pump mode? Concerns arose from having one unit passing flow in the generating direction while other units on the same penstock system were pumping. No adverse effects could be identified from the computer simulation of this condition (Figure 12). This condition was successfully practiced in actual operation.



1 UNIT PUMPING—1 UNIT TURBINE START
SAME PENSTOCK

FIGURE 12

CONCLUSIONS

A good evaluation of hydraulic transients can be extremely helpful in solving some field associated problems as well as identifying and resolving potential problems in the planning stages of hydro machinery projects. The "CORA" program permits a wide range of applications involving valves, surge tanks, hydro-turbines, pumps, and closed loop systems. The program can be used for the traditional speed and pressure rise calculations as well as determining the dynamic response of the penstock and other systems. Good correlation of the computer simulation to the prototype measurements demonstrates the accuracy of the predictions.

REFERENCES

(1) Chacour, S. A. and Deitz, R. E., "'CORA' Hydraulic Transient 'Plus'," Proceedings Volume II of the Joint Symposium of Design and Operation of Fluid Machinery — June 12-14, 1978, ASCE-IAHR/AIHR-ASME.

(2) Krueger, R., "Selecting Hydraulic Reaction Turbines", Engineering Monograph No. 20, United States Bureau of Reclamation, 1966.

(3) Chaudhry, M. H., "Applied Hydraulic Transients", Litton Educational Publishing Inc., Copyright 1979.

Appendix A

Field Correlation

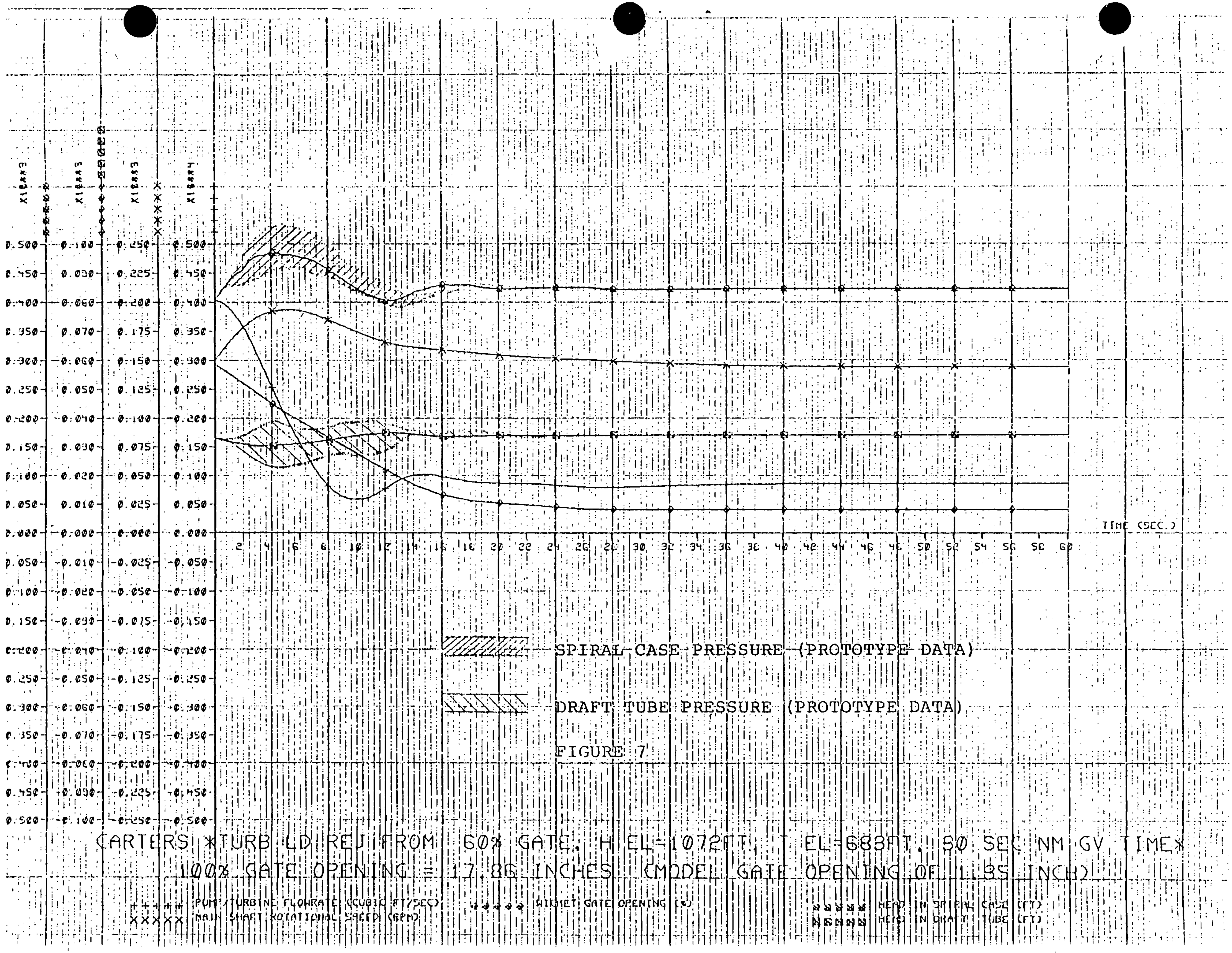

TIME (SEC.)
SPIRAL CASE PRESSURE (PROTOTYPE DATA)
DRAFT TUBE PRESSURE (PROTOTYPE DATA)
CARTERS *TURB LD REJ FROM 60% GATE, H EL=1072FT, T EL=683FT, 50 SEC NM GV TIME*
100% GATE OPENING = 17.86 INCHES (MODEL GATE OPENING OF 1.35 INCH)
PUMP/TURBINE FLOWRATE (CUBIC FT/SEC)
MAIN SHAFT ROTATIONAL SPEED (RPM)
WICKET GATE OPENING (%)
HEAD IN SPIRAL CASE (FT)
HEAD IN DRAFT TUBE (FT)

FIGURE 7

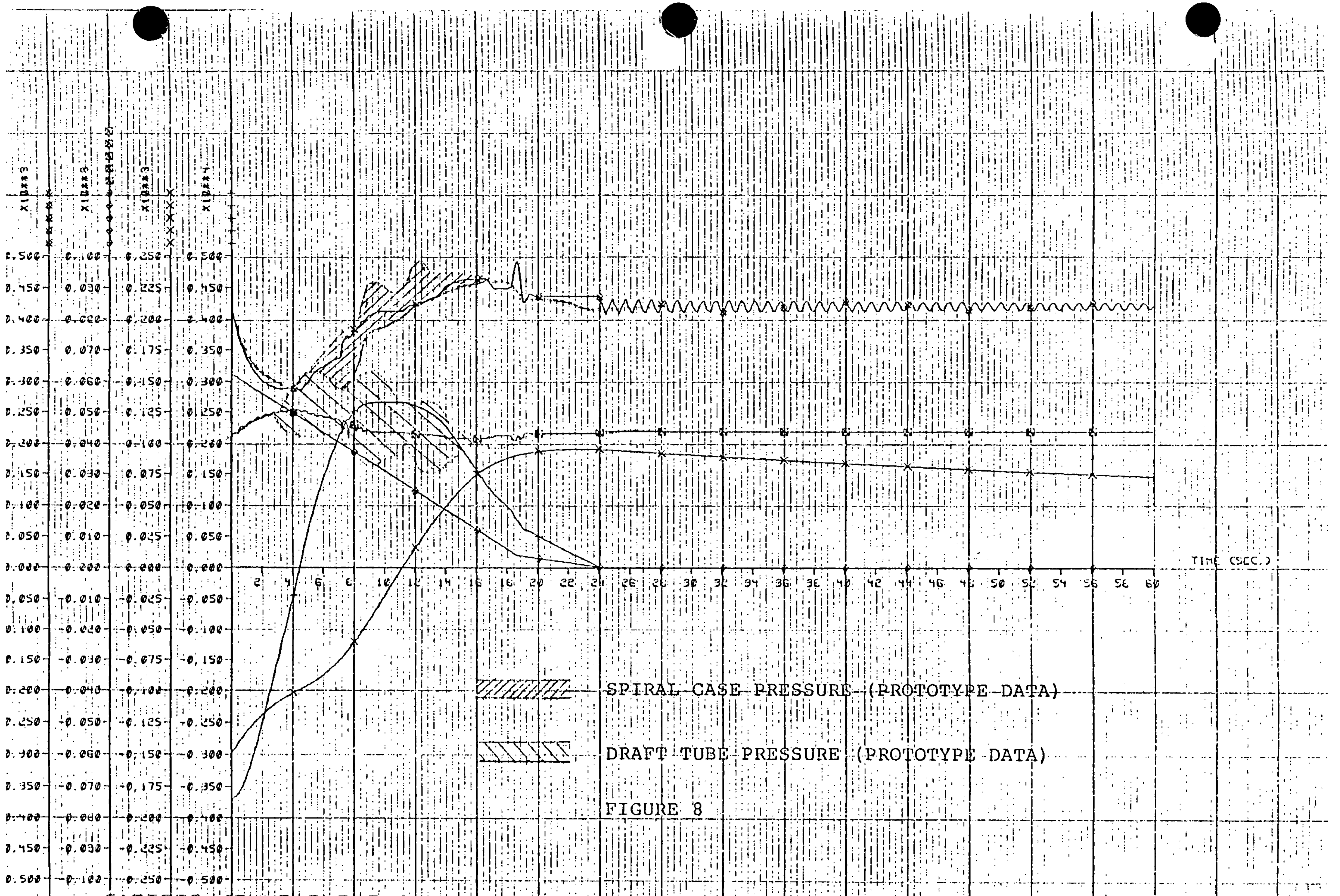
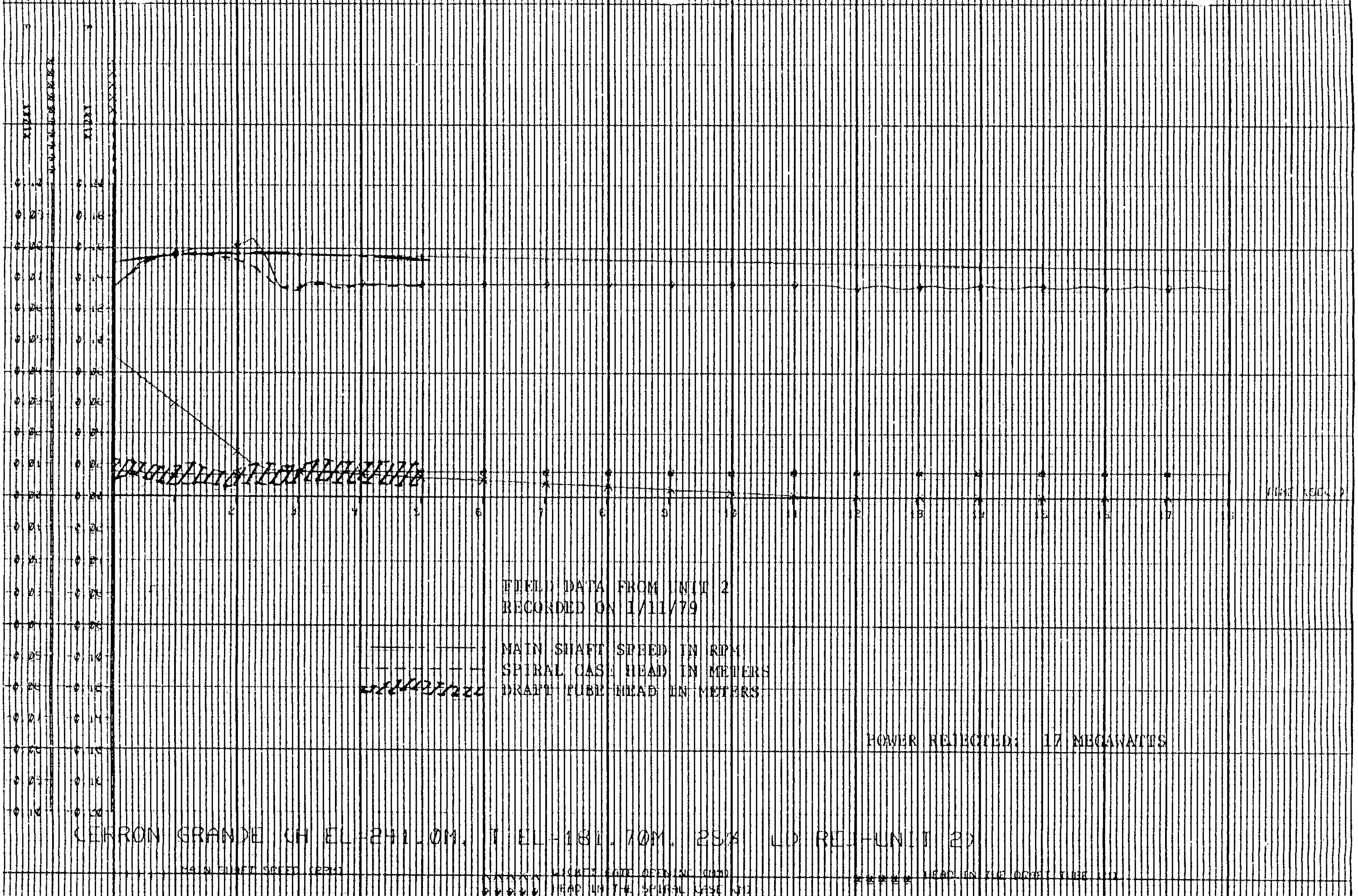


FIGURE 8

CARTERS (PUMP PWR FAIL, H EL=1069 FT, T EL=692 FT, MAX G.O.=62%,30 SEC NM GV TM)

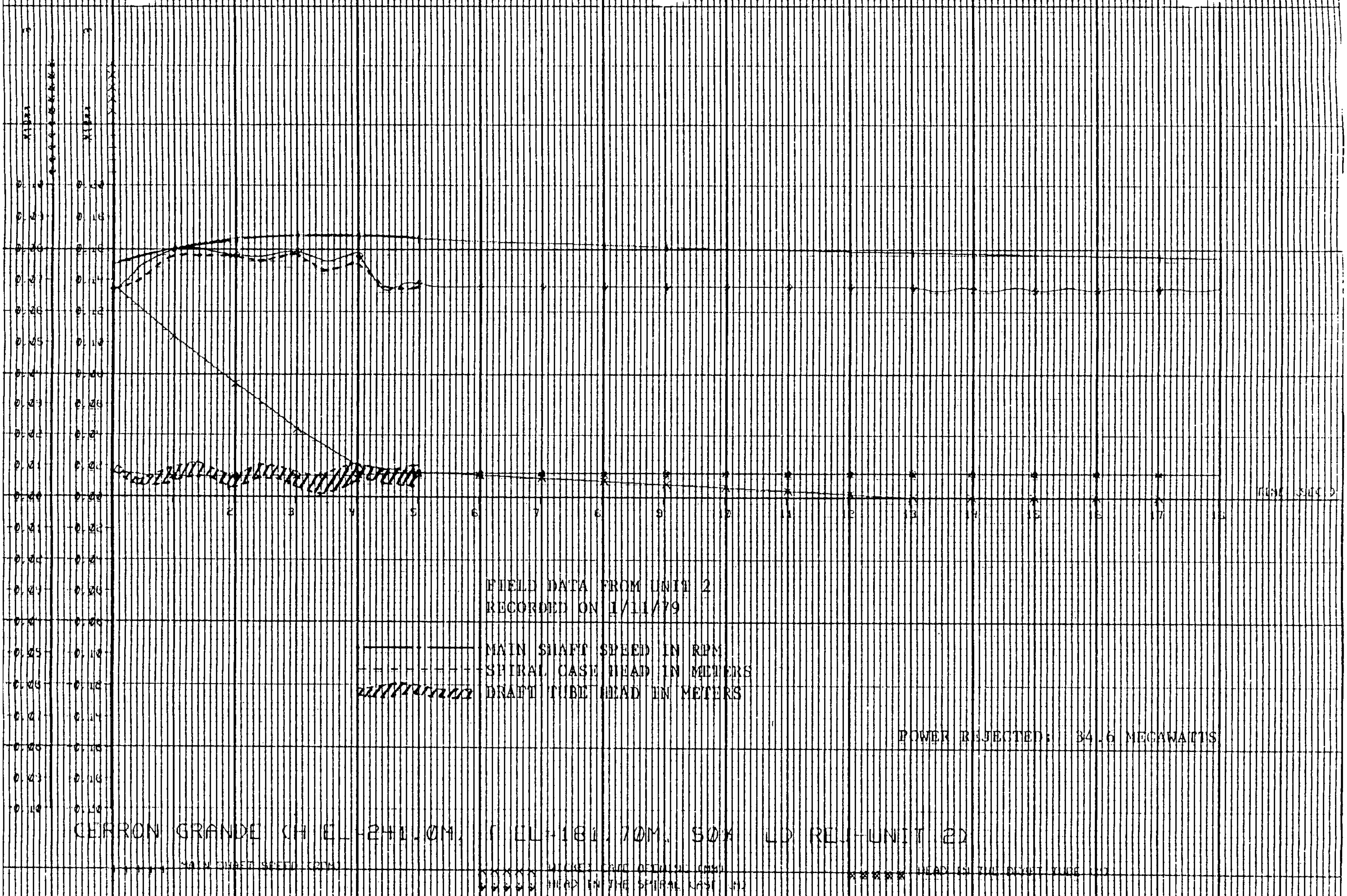
100% GATE OPENING = 17.86 INCHES (MODEL GATE OPENING OF 1.35 INCH)

++++ PUMP/TURBINE FLOWRATE (CUBIC FT/SEC)
XXXXX MAIN SHAFT ROTATICNAL SPEED (RPM)
◇◇◇◇◇ WICKET GATE OPENING (%)
▣▣▣▣▣ HEAD IN SPIRAL CASE (FT)
▣▣▣▣▣ HEAD IN DRAET TUBE (FT)



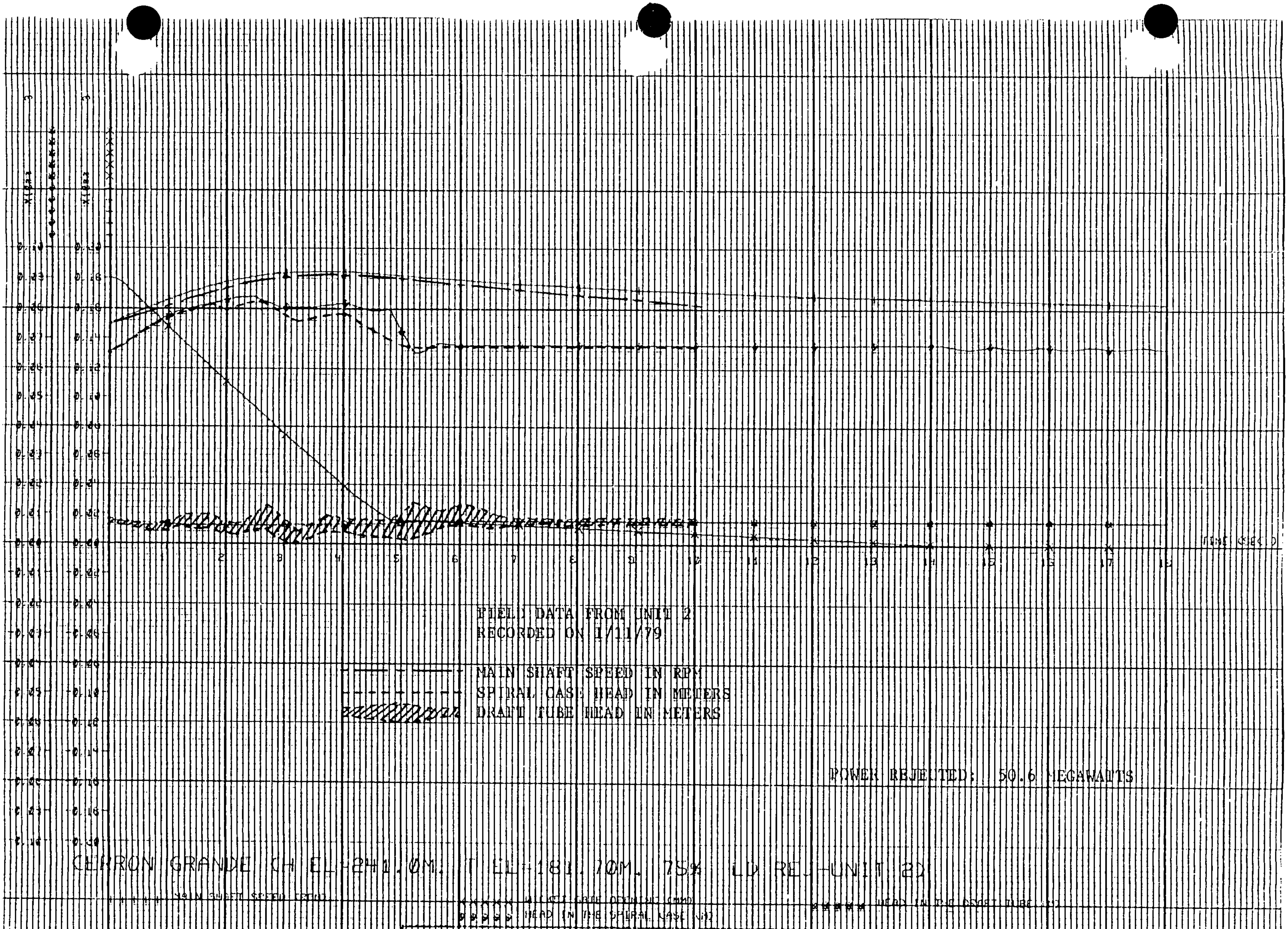
TRANSIENT CALCULATIONS VERSUS FIELD RESULTS

FIGURE 26



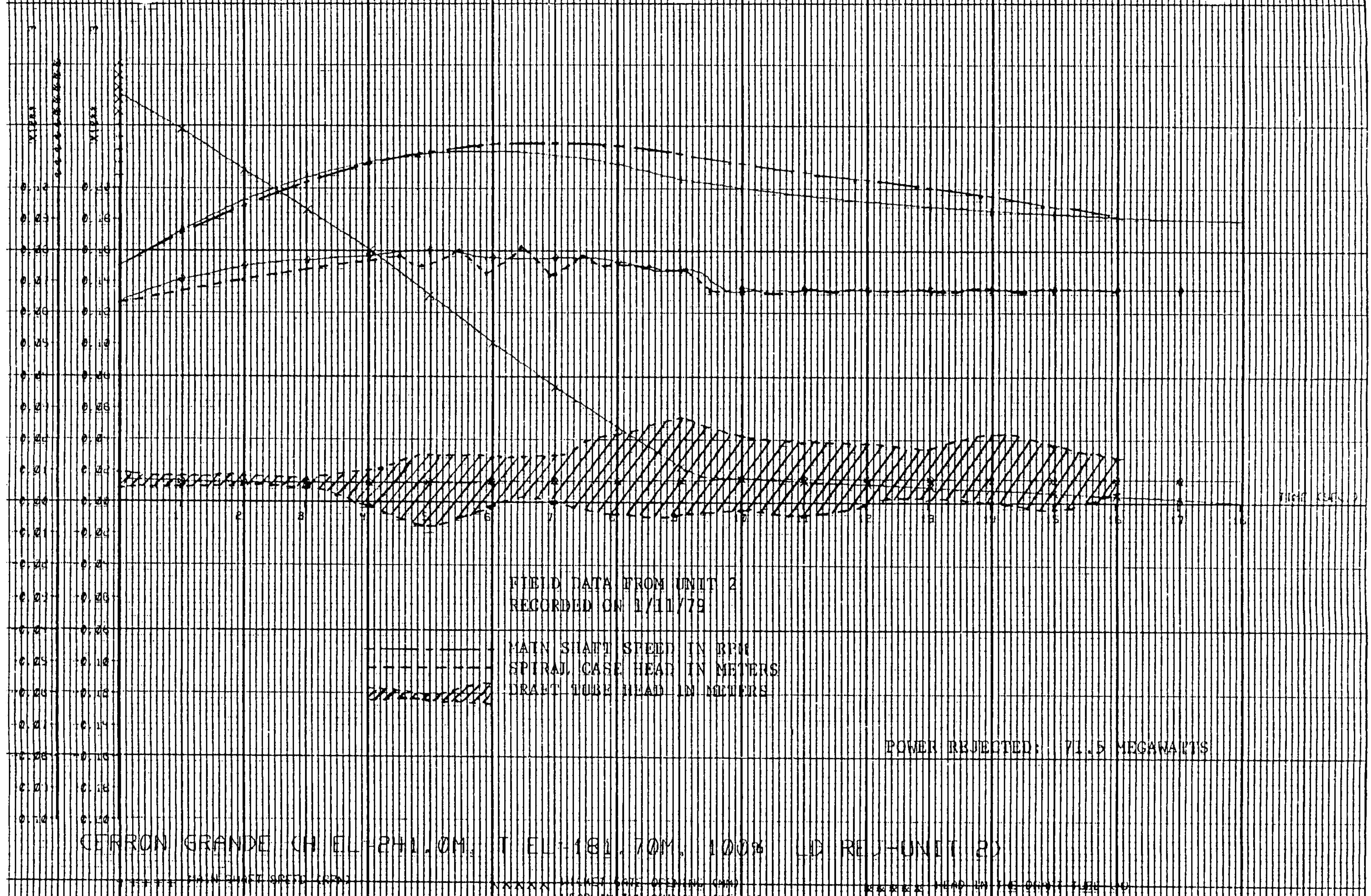
TRANSIENT CALCULATIONS VERSUS FIELD RESULTS

FIGURE 27



TRANSIENT CALCULATIONS VERSUS FIELD RESULTS

FIGURE 28



TRANSIENT CALCULATIONS VERSUS FIELD RESULTS

FIGURE 29

INTER-OFFICE CORRESPONDENCE

To: Mr. L. F. Henry

Date: December 17, 1979

Copies To: Mr. G. Fintak

From: M. Byrne

Subject: CORA Correlation With Field Data
From Chongpyong P/T

PURPOSE:

CORA runs were made to compare with test results from a 200 MW turbine load rejection and a pump power failure with a 204 MW input load. Both of these field tests took place October 20, 1979.

INITIAL CONDITIONS:

Head Water Elevation: 530.3 M

Tail Water Elevation: 49.9 M

Rated Speed: 450 RPM

Elevation ℄ of Distributor: -6.0 M

Kt (Turbine Torque coeffecient for unit spinning in water with closed gates) = .000477

Kt (Pump Torque coeffecient for unit spinning in water with closed gates) = .000876

Wave Speed : 1200 M/Sec. (Turbine Run)

Wave Speed: 1064 M/Sec. (Pump Run)

DISCUSSION:

The first turbine load rejection was run with the following values: wave speed - 1064.0 M/Sec.; Kt - .00477. Figure 1 shows the field data plotted on the CORA output plot. A second turbine load rejection was made changing the following input values: wave speed - 1200 M.Sec.; Kt - .00047. Figure 2 shows the results of the second run. The increased wave speed did little to change the time when the maximum spiral case

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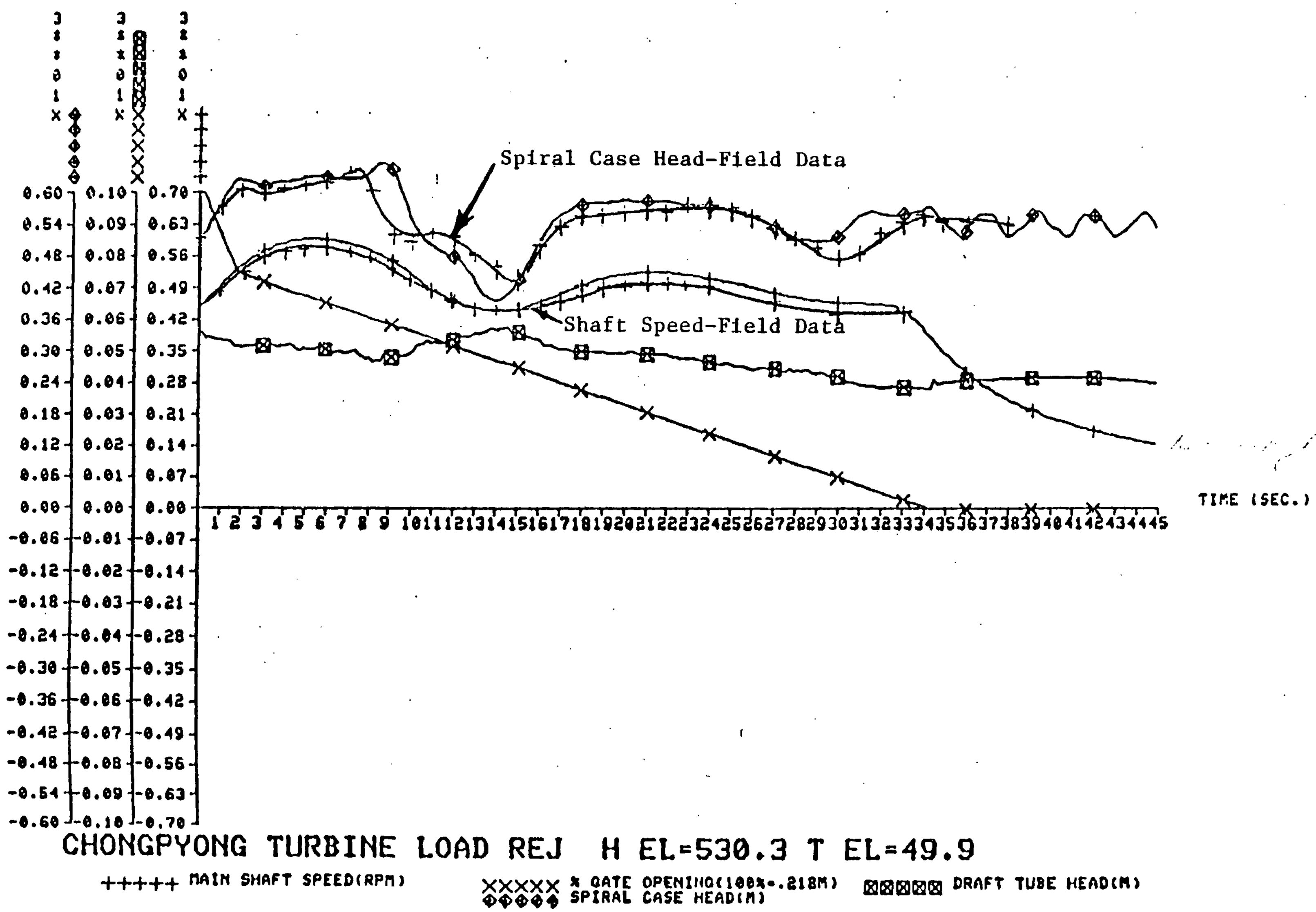
pressure occured. The maximum pressure occured at 8.74 seconds for Figure 1, 8.82 seconds for Figure 2, and 7.5 seconds during the field test. The effect of the increased torque coeffecient can be seen by comparing the main shaft speed trace after the gates are closed on Figure 1 and 2 ($KtN^2=T$).

The results of the pump power failure with 204 MW of input can be seen on Figure 3. The computer predicted results correlate very well with the field data. The only area of weakness appears to be the result of to high torque values for the smaller gate openings of the model input data. This can be seen in the 7 to 14 second range of Figure 3.

Michael Byrne

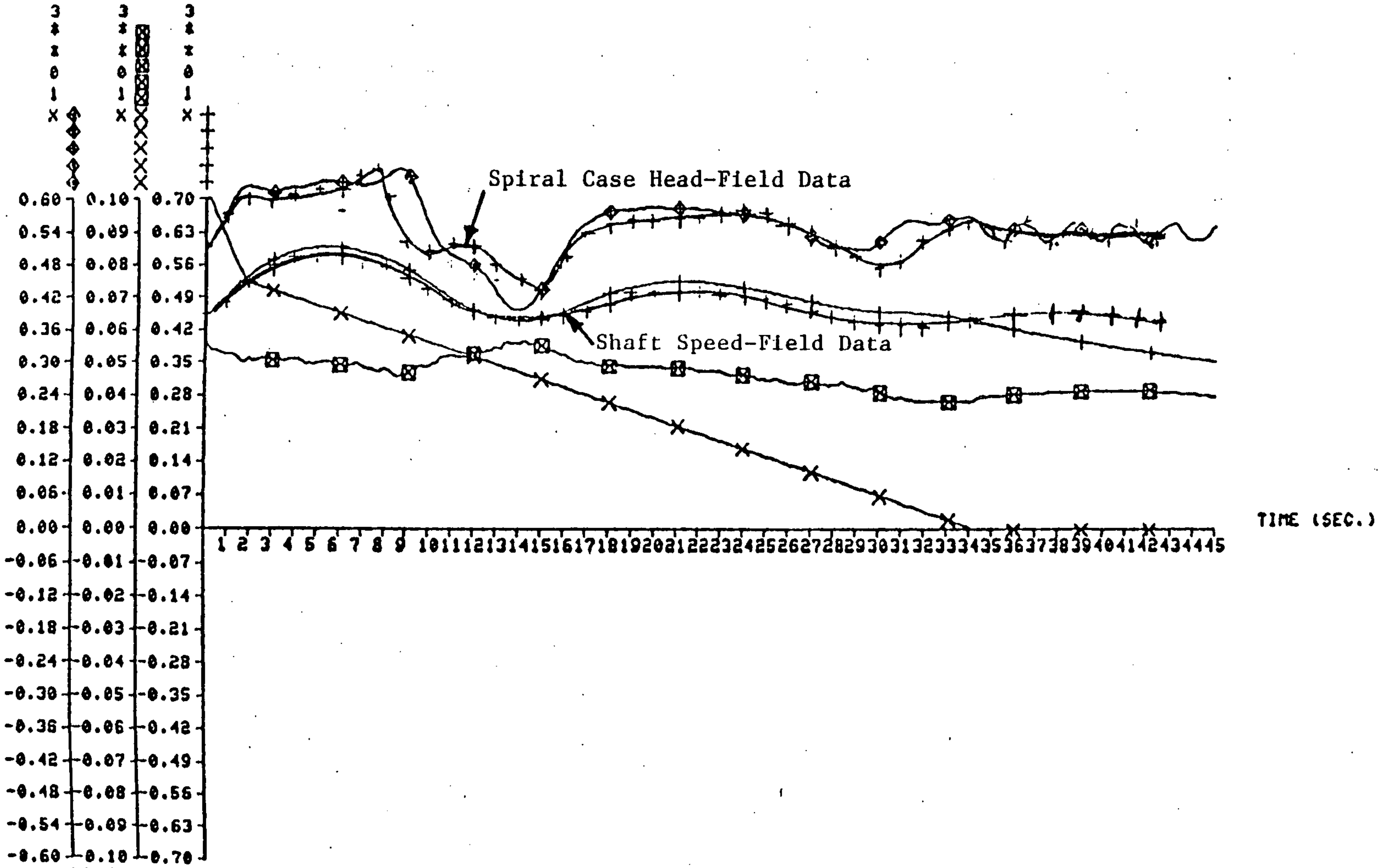
Michael Byrne
Field Engineer

MB/jew



Spiral Case Head-Field Data
Shaft Speed-Field Data
TIME (SEC.)
CHONGPYONG TURBINE LOAD REJ H EL=530.3 T EL=49.9
+++++ MAIN SHAFT SPEED(RPM)
XXXXX % GATE OPENING(100%=.218M)
SPIRAL CASE HEAD(M)
DRAFT TUBE HEAD(M)

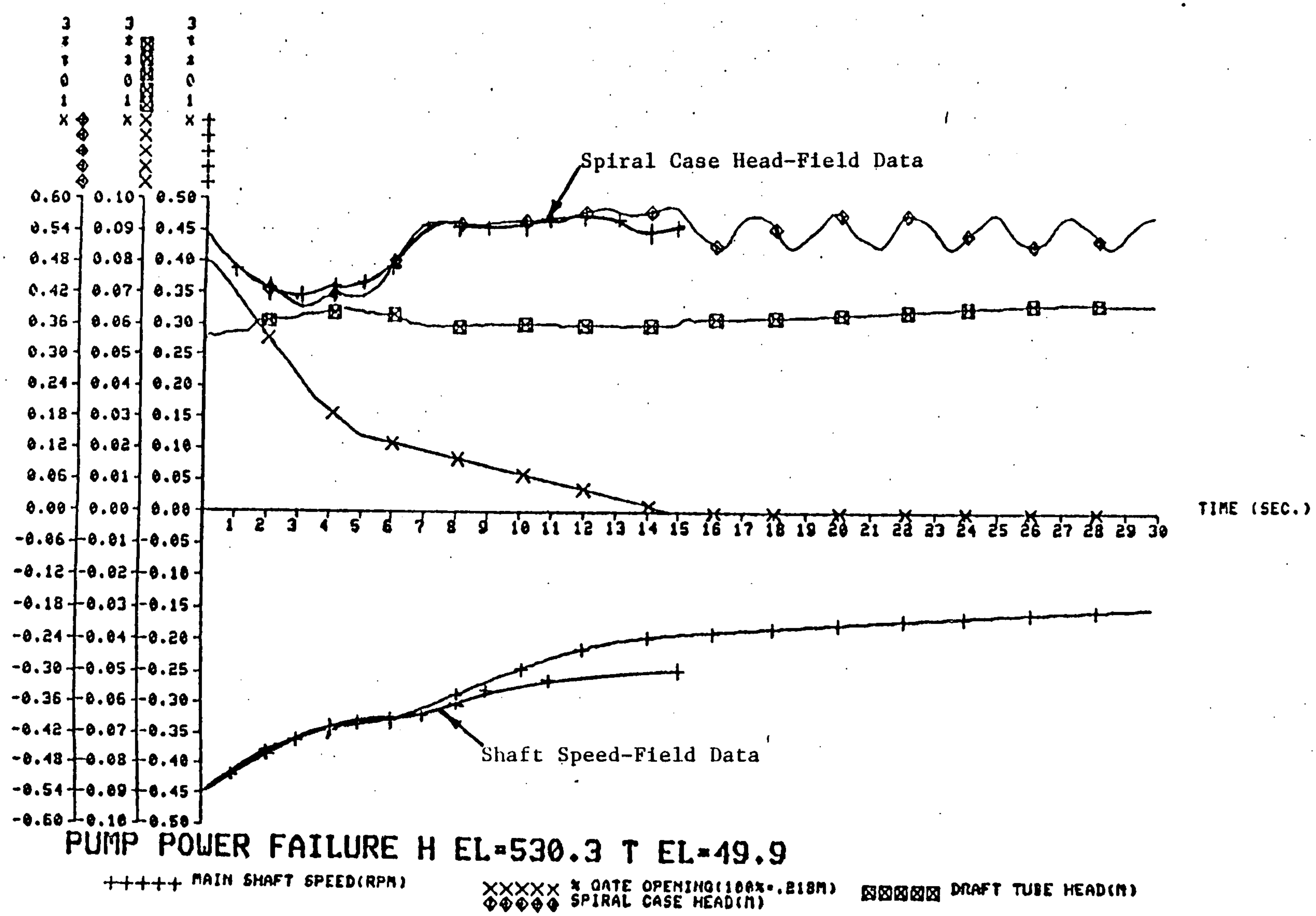
Figure 1



CHONGPYONG TURBINE LOAD REJ H EL=530.3 T EL=49.9

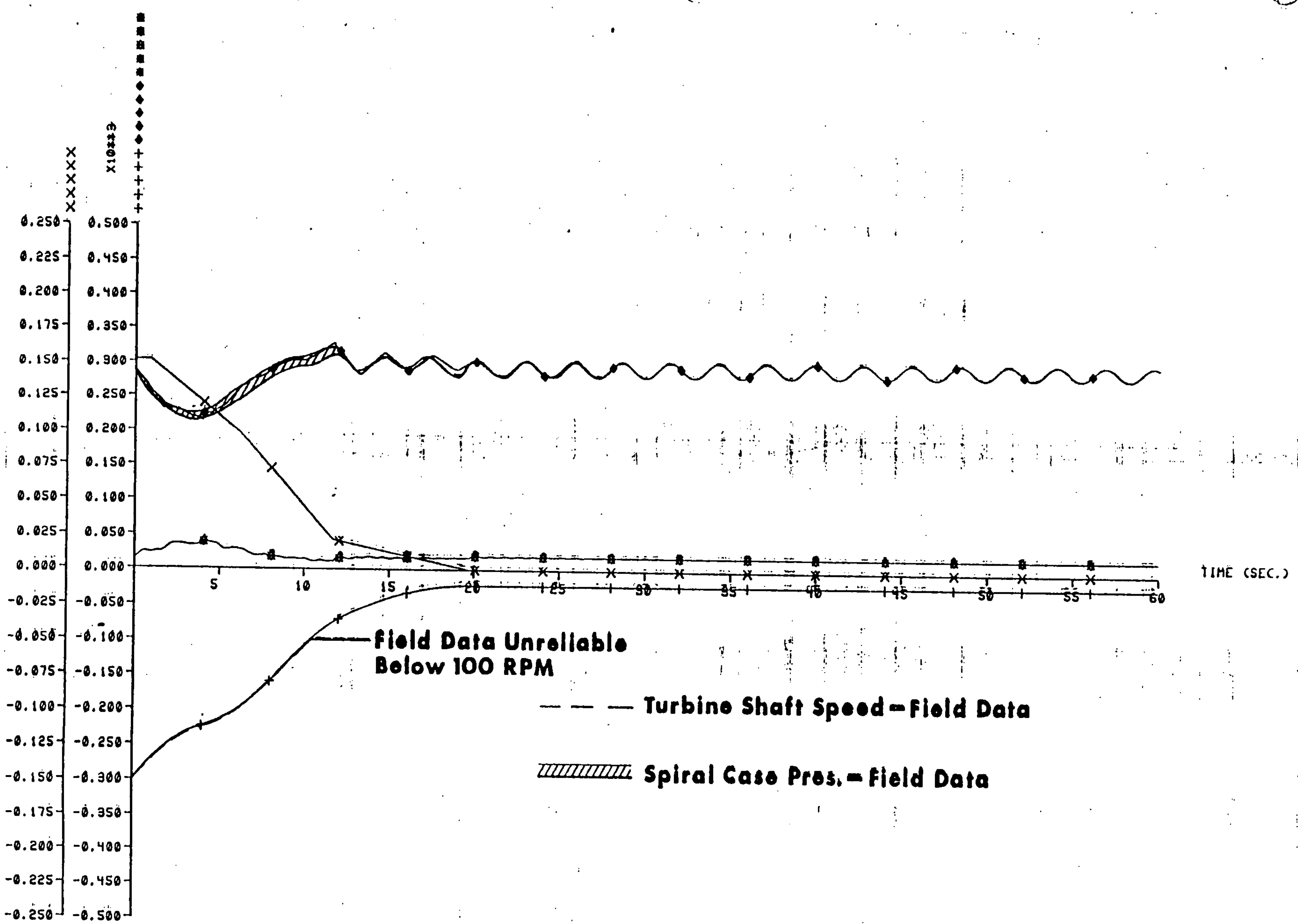
+++++ MAIN SHAFT SPEED(RPM) XXXXX % GATE OPENING(100%=.218M) ⊠⊠⊠⊠⊠ DRAFT TUBE HEAD(M)
◇◇◇◇◇ SPIRAL CASE HEAD(M)

Figure 2



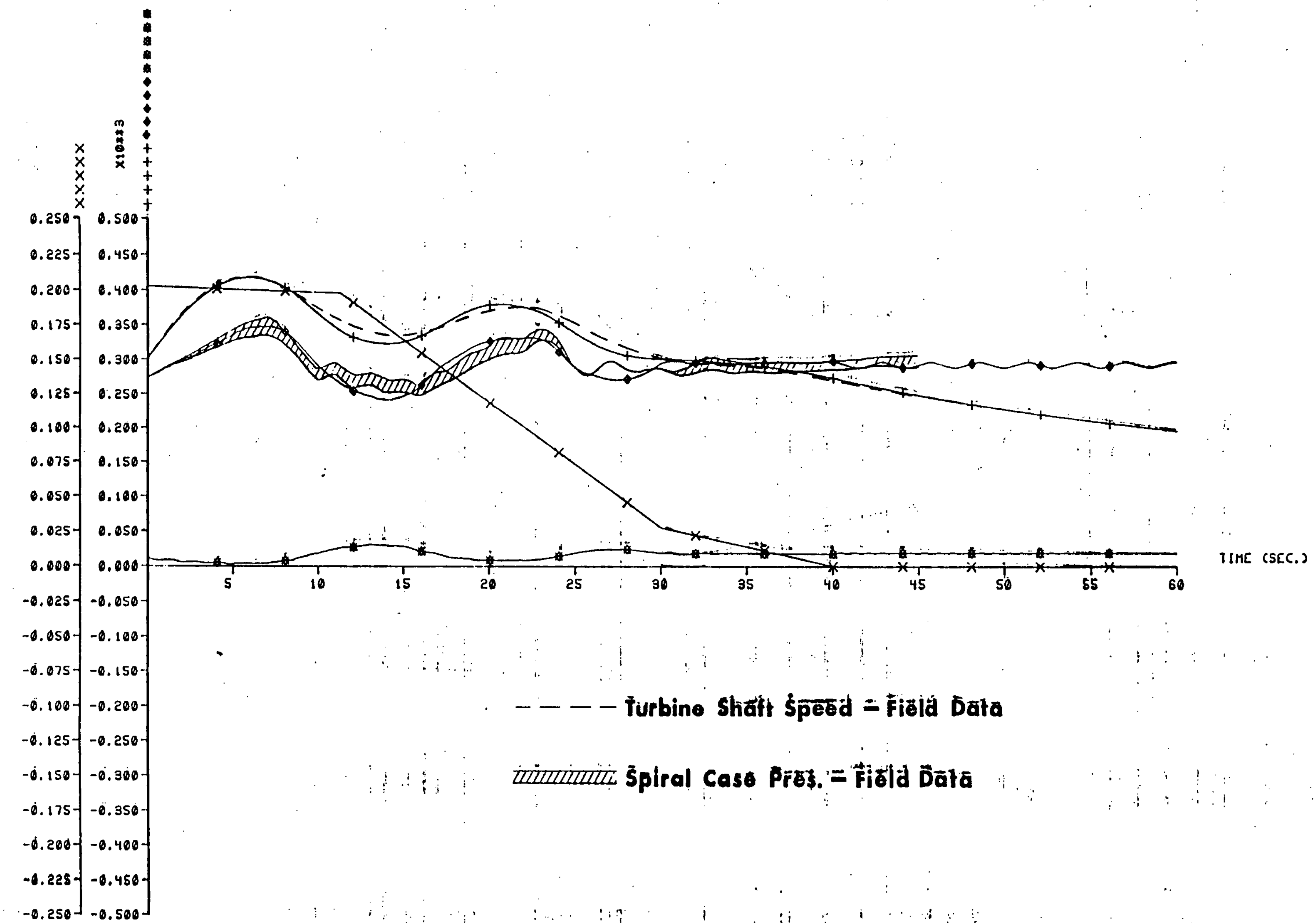
Spiral Case Head-Field Data
Shaft Speed-Field Data
TIME (SEC.)
PUMP POWER FAILURE H EL=530.3 T EL=49.9
+++++ MAIN SHAFT SPEED(RPM)
XXXXX % GATE OPENING(100%=.218M)
◇◇◇◇◇ SPIRAL CASE HEAD(M)
⊠⊠⊠⊠⊠ DRAFT TUBE HEAD(M)

Figure 3



** C00 1 UNIT 3 PUMP LOAD REJECTION FROM 68% GATE OPENING = SIMULATED FIELD TEST

+++++ TURBINE ROTATIONAL SPEED (RPM)
XXXXX TURBINE WICKET GATE OPENING (M)
◆◆◆◆◆ HEAD IN SPIRAL CASE (M)
■■■■■ HEAD IN DRAFT TUBE (M)



** COO 1 UNIT 3 TURBINE LOAD REJ. FROM 90% GATE OPENING - SIMULATED FIELD TEST**

+++++ TURBINE ROTATIONAL SPEED (RPM) XXXXX TURBINE WICKET GATE OPENING (M) ◆◆◆◆◆ HEAD IN SPIRAL CASE (M) ▪▪▪▪▪ HEAD IN DRAFT TUBE (M)

INTER-OFFICE CORRESPONDENCE

To: L. F. Henry

Date: October 5, 1978

Copies To:

From: R. E. Deitz

Subject: Coo 1A Transient Analysis

PURPOSE:

The purpose of this analysis is to predict the maximum shaft speed and spiral case pressure experienced during simultaneous load rejections of all three units under high head conditions. Maximum power output limitations are recommended from these calculated values.

INPUT CONDITIONS:

- Maximum Permissible Shaft Speed - 450 RPM
- Maximum Permissible Spiral Case Head - 408 Meters (40 Bars)
- Head Water Range - 483.25-509.1 Meters
- Tail Water Range - 233.75-248.45 Meters
- Elevation of ℄ Distributor - 216 Meters
- GD^2 = 4700 Ton Meters

DISCUSSION:

To determine the maximum safe operating limits, it was necessary to calculate the maximum shaft speed and maximum spiral case pressure experienced during a simultaneous load rejection of all three units. These values were calculated for outputs of 75% to full wicket gate opening over the gross head range of 255 to 275 meters. Results of the 12 transient conditions are summarized in Table 1. Figure 1 is a plot of the calculated maximum main shaft speed and spiral case head during the simultaneous load rejection of all three units.

transducer should be about 281 meters (501.36-215-3.5-2≈281 meters). The pressure recorded by the spiral case transducer was 298 meters.

With a static check (no flow) the pressure transducer should indicate 286.36 meters (501.36-215 = 286.36 meters).

Therefore the recorded spiral case pressure is wrong and was corrected for both the 200 MW and 300 MW simultaneous load rejection by Equation 3.

$$H_C = H_M - (H_I - H_T) + (EL_T - EL_{CORA}) \qquad \text{Equation 3}$$

H_C = Corrected Spiral Case Pressure

H_M = Measured Spiral Case Pressure

H_I = Initial Spiral Case Pressure (Before Load Rejection)

H_T = Expected Pressure Experienced by The Spiral Case Transducer (Calculated by Equation 1)

EL_T = Elevation of the Transducer (215 M)

EL_{CORA} = Elevation that CORA Uses to Predict Spiral Case Pressure (216 M)

RECOMMENDATIONS:

With 450 RPM the maximum allowable shaft speed and 408 meter (40 bars) the maximum spiral case head, the power output limit per machine would be 138 MW (gate opening of 104% or 0.2213 meters) up to and including 255 meter gross head and increasing to 149 MW (gate opening of 89% or 0.197 meters) at the maximum gross head of 275 as shown in Figure 8.

It should be noted that these values are based on the actual numbers calculated. We would recommend decreasing these units by 1% based on the correlation of both the 200 and 300 MW simultaneous load rejections.

If the maximum allowable shaft speed can be increased to 464 RPM, the maximum power output per machine would be limited to 154 MW (gate opening of 104% or 0.2213 meters) up to and including a gross head of 270 meters and 154 MW (gate opening of 97% or 0.2147 meters) at the maximum gross head of 275 meters.

Ronald E. Deitz

Ronald E. Deitz
Field Engineer

RED/pjm

COQ 1A

PREDICTED MAXIMUM SHAFT SPEED
AND SPIRAL CASE PRESSURE VALUES FOR
SIMULTANEOUS LOAD REJECTION OF 3 UNITS
FOR VARIOUS GROSS HEAD

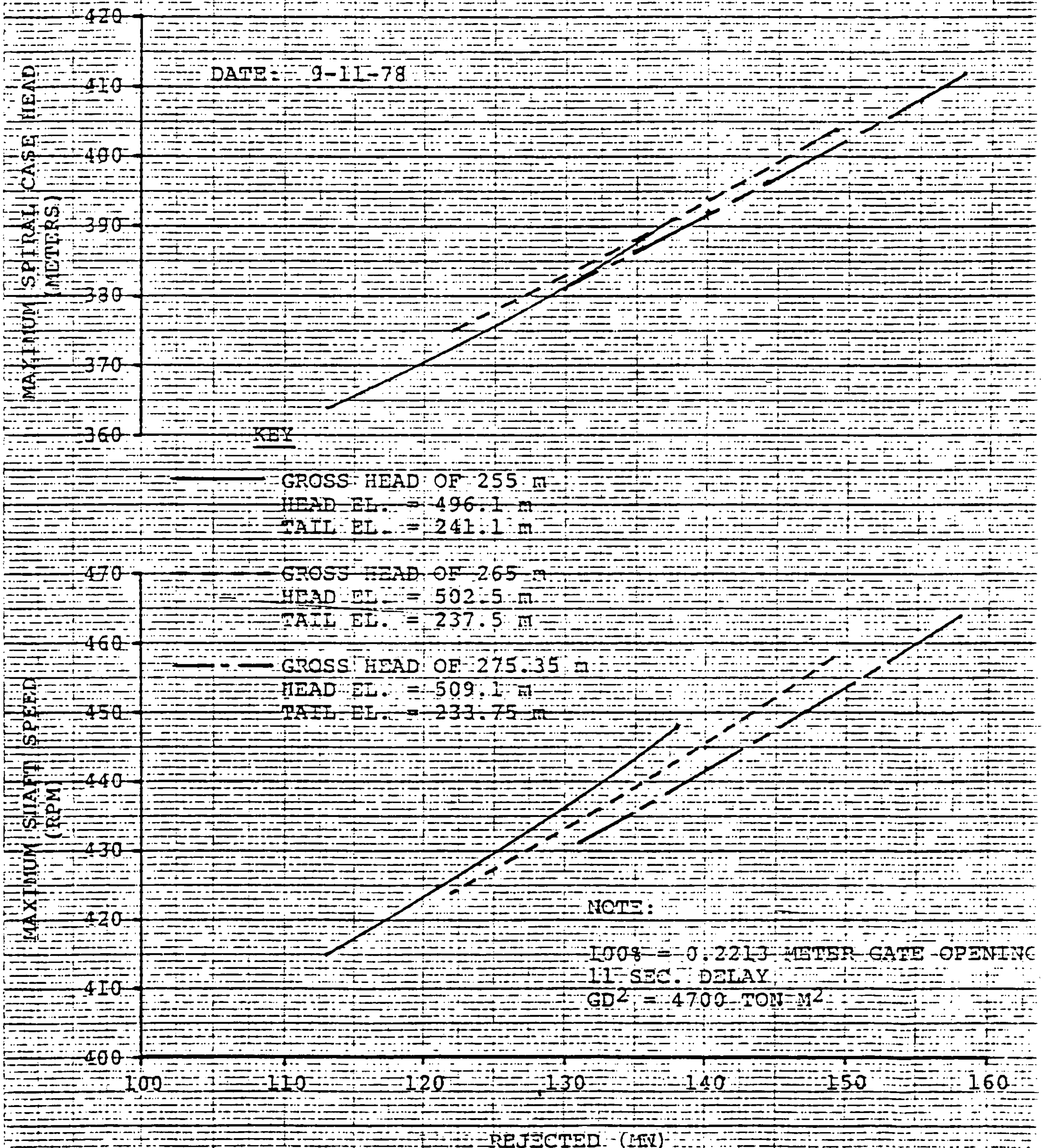


FIGURE 1

COO 1A

SIMULTANEOUS LOAD REJ. OF 3 UNITS

Maximum Gate Opening (%)	Initial Power (MW)	Gross Head (M)	Head Water Elevation (M)	Tail Water Elevation (M)	Maximum Shaft Speed (RPM)	Maximum Spiral Case Head (M)
75	131	275.35	509.1	233.75	431	383
82	140	275.35	509.1	233.75	442	392
90	150	275.35	509.1	233.75	452	401
104	158	275.35	509.1	233.75	464	412
75	122	265	502.5	237.5	424	375
82	130	265	502.5	237.5	435	385
90	140	265	502.5	237.5	445	394
104	149	265	502.5	237.5	458	404
75	113	255	496.1	241.1	415	364
82	121	255	496.1	241.1	425	372
90	130	255	496.1	241.1	436	381
104	138	255	496.1	241.1	448	391

NOTE: GD^2 = 4700 Ton-M^2
104% G.O. = .2213 Meters

TABLE 1

CO[illegible]A

COMPARISON OF FIELD MEASUREMENTS TO THE PREDICTED
MAIN SHAFT SPEED FOR THE 200 MW
SIMULTANEOUS LOAD REJECTION (3 - UNITS)
RECORDED ON JANUARY 20, 1978

Time Seconds	UNIT 1 From Field Data	UNIT 1 Predicted Based On Gate Opening	UNIT 1 Predicted Based On Power	UNIT 2 From Field Data	UNIT 2 Predicted Based On Gate Opening	UNIT 2 Predicted Based On Power	UNIT 3 From Field Data	UNIT 3 Predicted Based On Gate Opening	UNIT 3 Predicted Based On Power
0	300	300	300	300	300	300	300	300	300
1	313	311	314	313	309	314	315	311	314
2	326	321	327	324	319	328	325	322	328
3	334	328	337	335	328	340	339	331	340
4	341	333	344	343	335	349	348	339	349
5	346	337	348	351	340	356	356	344	356
6	350	340	352	355	342	359	360	347	359
7	353	341	354	356	343	359	362	347	360
8	355	341	354	355	342	358	363	346	359
9	356	340	353	351	340	355	361	344	356
10	355	338	351	347	337	352	357	341	353
11	350	335	347	345	335	348	352	339	350
12	343	330	340	343	333	346	346	337	347
13	331	322	328	340	332	344	341	336	344
14	320	315	319	334	331	341	336	335	341
15	311	309	312	325	328	337	330	333	338

NOTE: Head Water Elev. = 501.36 M; Tail Water Elev. = 237.39 M; Shaft Speed in RPM

CONCLUSION: The predicted based on the initial power output correlates best with the measured values.

TABLE 2

COO 1A

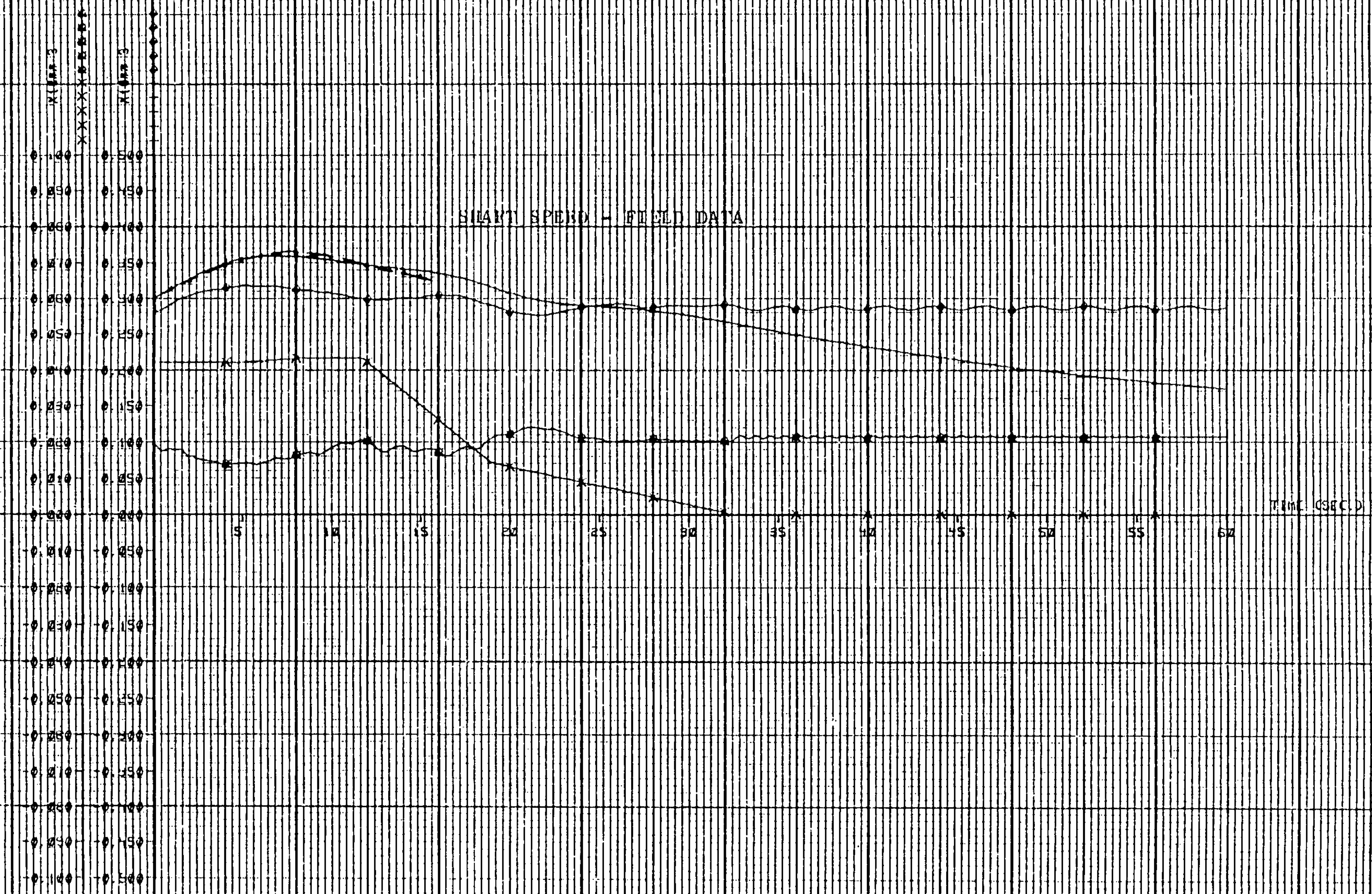
COMPARISON OF FIELD MEASUREMENTS TO THE PREDICTED SPIRAL CASE PRESSURE FOR THE 200 MW SIMULTANEOUS LOAD REJECTION OF 3-UNITS (RECORDED 1-20-78)

UNIT 1

Time Seconds	From Field Data Meters	Corrected Field Data Meters	Predicted Based On Gate Opening Meters	Predicted Based On Power Meters
0	298	280	282	280
1	308	290	292	294
2	323	305	304	307
3	325	307	307	312
4	325	307	307	314
5	325	307	307	316
6	325	307	307	315
7	330	312	306	314
8	333	315	304	314
9	335	317	300	310
10	335	317	300	309
11	335	317	302	311
12	323	305	300	307
13	320	302	294	294
14	314	296	295	297
15	308	290	297	295

NOTE: H. El. = 501.36 M; T. El. = ~~501.36~~ 237.39 M; El. ℄ Dist. = 216 M

TABLE 3



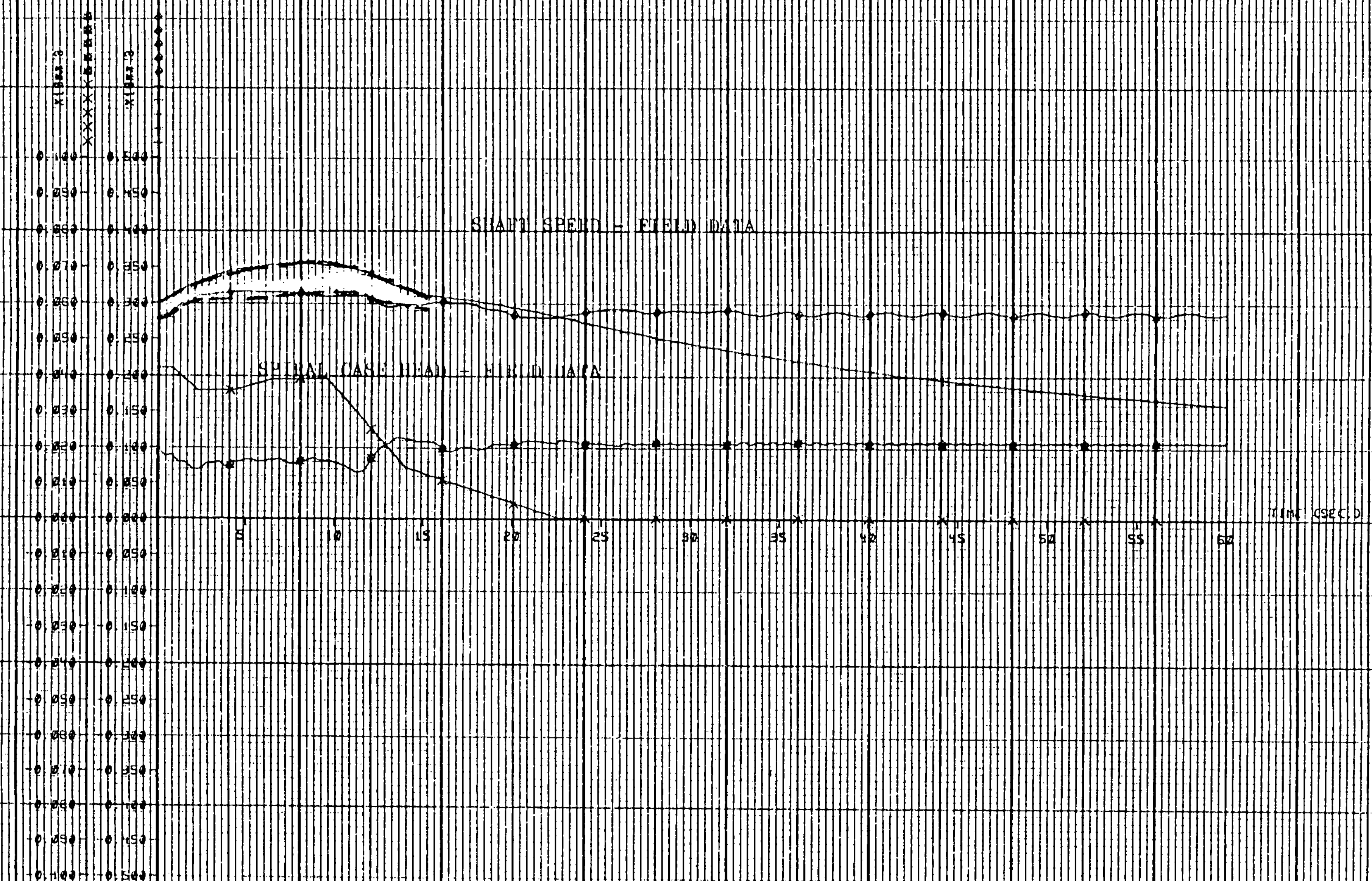
COO 1A SIMULTANEOUS LOAD REJECTION OF 3 UNITS (200 MW TOTAL OUTPUT, 1-20-78)
UNIT 3 HEAD ELEV=501.36M, TAIL ELEV=237.39M, GD2=4700 TON-METERS-METERS

+ + + + + MAIN SHAFT ROTATIONAL SPEED (RPM)

X X X X X % GATE OPENING (100%= 2813M)

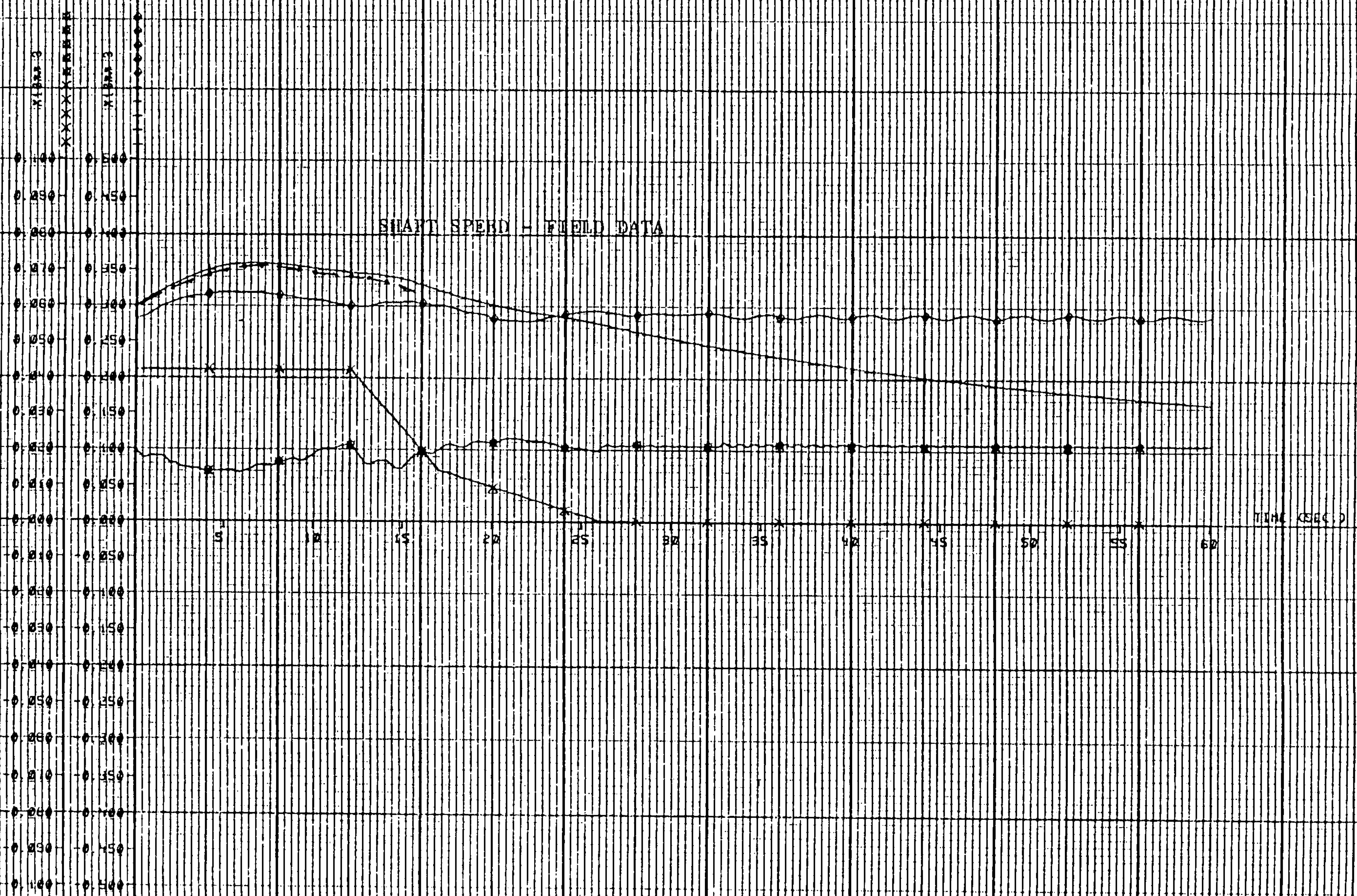
◆ ◆ ◆ ◆ ◆ HEAD IN THE SPIRAL CASE (METERS)

◆ ◆ ◆ ◆ ◆ HEAD IN THE DRAFT TUBE (METERS)



(00 1A SIMULTANEOUS LOAD REJECTION OF 3 UNITS (800 MW TOTAL OUTPUT, 1-20-78)
UNIT 1 HEAD ELEV=501.36M, TAIL ELEV=237.39M, GD2=4700 TON-METERS-METERS

+++++ MAIN SHAFT ROTATIONAL SPEED (RPM)
XXXXX % GATE OPENING (100%= 2313M)
♦♦♦♦♦ HEAD IN THE SPIRAL CASE (METERS)
♦♦♦♦♦ HEAD IN THE DRAFT TUBE (METERS)



COO 1A SIMULTANEOUS LOAD REJECTION OF 3 UNITS (200 MW TOTAL OUTPUT, 1-20-78)
UNIT 2 HEAD ELEV=501.36M, TAIL ELEV=237.39M, GDD=4700 TON-METERS-METERS

+ + + + + MAIN SHAFT ROTATIONAL SPEED (RPM)
X X X X X % GATE OPENING (100% = 22.13M)
◆ ◆ ◆ ◆ ◆ HEAD IN THE SPIRAL CASE (METERS)
▣ ▣ ▣ ▣ ▣ HEAD IN THE DRAFT TUBE (METERS)

COC

COMPARISON OF FIELD MEASUREMENTS THE PREDICTED MAIN SHAFT SPEED
FOR THE 300 MW SIMULTANEOUS LOAD REJECTION (3-UNITS)
RECORDED ON JANUARY 20, 1978

	UNIT 1			UNIT 2			UNIT 3		
Time Seconds	From Field Data	Predicted Based On Gate Opening	Predicted Based On Power	From Field Data	Predicted Based On Gate Opening	Predicted Based On Power	From Field Data	Predicted Based On Gate Opening	Predicted Based On Power
0	300	300	300	300	300	300	300	300	300
1	324	320	322	323	319	322	313	320	322
2	342	337	342	342	336	343	338	339	343
3	357	351	357	358	351	362	359	355	362
4	370	362	370	369	364	377	377	368	377
5	378	370	380	373	374	388	389	377	388
6	385	375	386	384	379	393	396	381	394
7	389	378	389	386	380	394	399	381	396
8	389	378	390	385	378	392	398	378	393
9	388	376	387	381	375	388	395	373	388
10	384	371	382	378	370	382	390	368	382
11	376	366	375	373	364	375	380	362	375
12	366	356	360	365	357	369	370	357	368
13	355	341	343	358	351	362	360	352	361
14	344	329	331	351	344	353	350	346	353
15	332	321	323	340	334	339	341	341	345

NOTE: Head Water Elev. = 500.5 M; Tail Water Elev. = 237.62 M; Shaft Speed in RPM

CONCLUSION: Prediction based on the initial power correlates best with data recorded.

TABLE 4

COO 1A

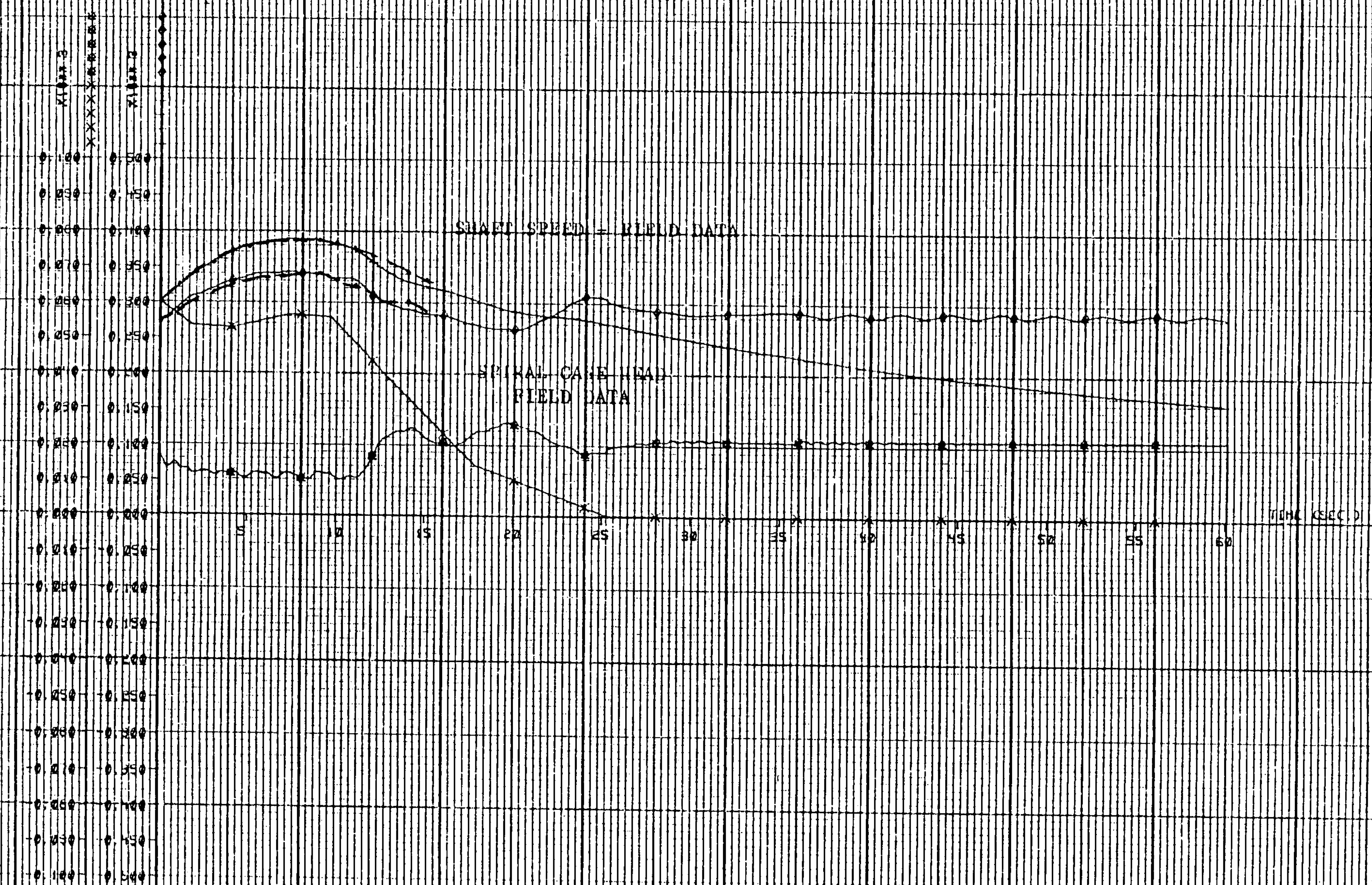
COMPARISON OF FIELD MEASUREMENTS TO THE PREDICTED SPIRAL CASE PRESSURE FOR 300 MW SIMULTANEOUS LOAD REJECTION OF 3-UNITS (RECORDED 1-20-78)

UNIT 1

Time Seconds	From Field Data Meters	Corrected Field Data Meters	Predicted Based On Gate Opening Meters	Predicted Based On Power Meters
0	293	274	276	274
1	307	288	293	289
2	321	302	308	310
3	335	316	318	320
4	344	325	325	330
5	350	331	331	337
6	352	333	332	342
7	356	337	334	343
8	360	341	331	342
9	360	341	329	340
10	353	334	323	338
11	345	326	321	332
12	335	316	313	313
13	320	301	296	299
14	322	303	288	291
15	306	287	280	285

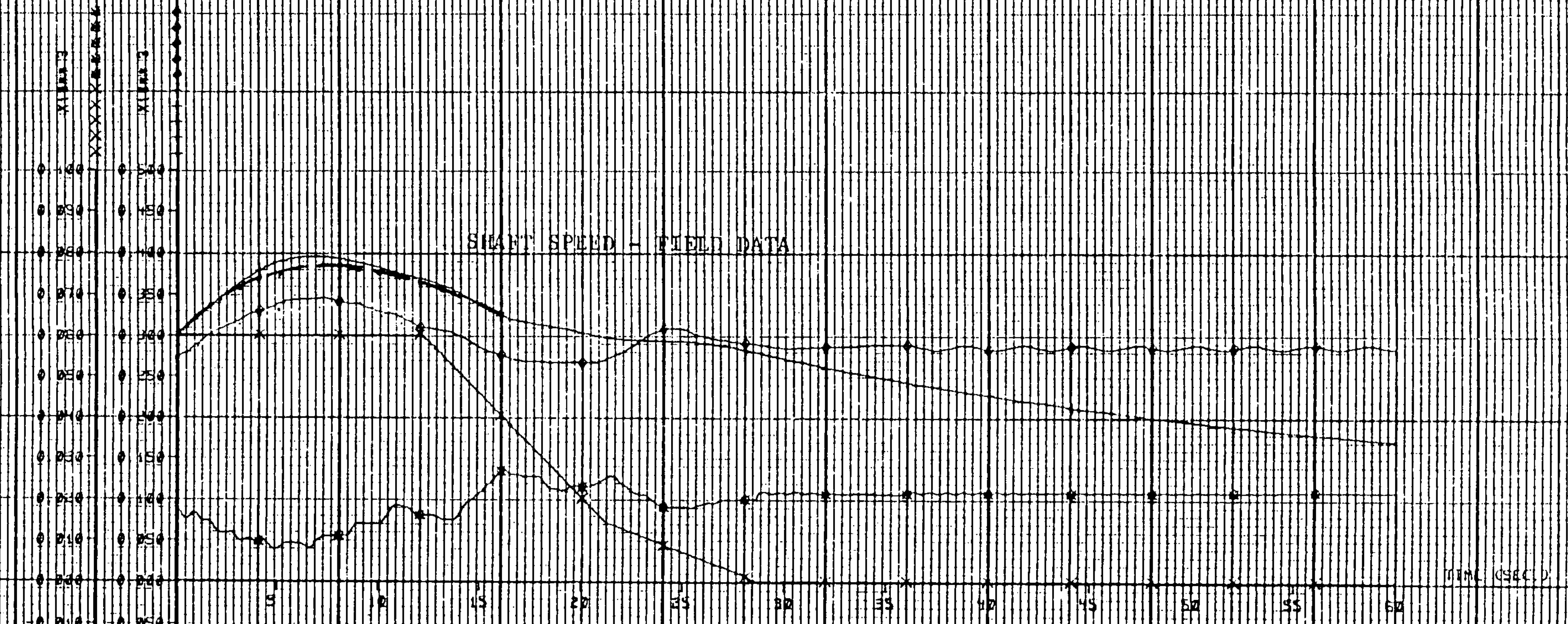
NOTE: H. El. = 505.5 M; T. El. = 237.62 M; El. ℄ = 216 M

TABLE 5



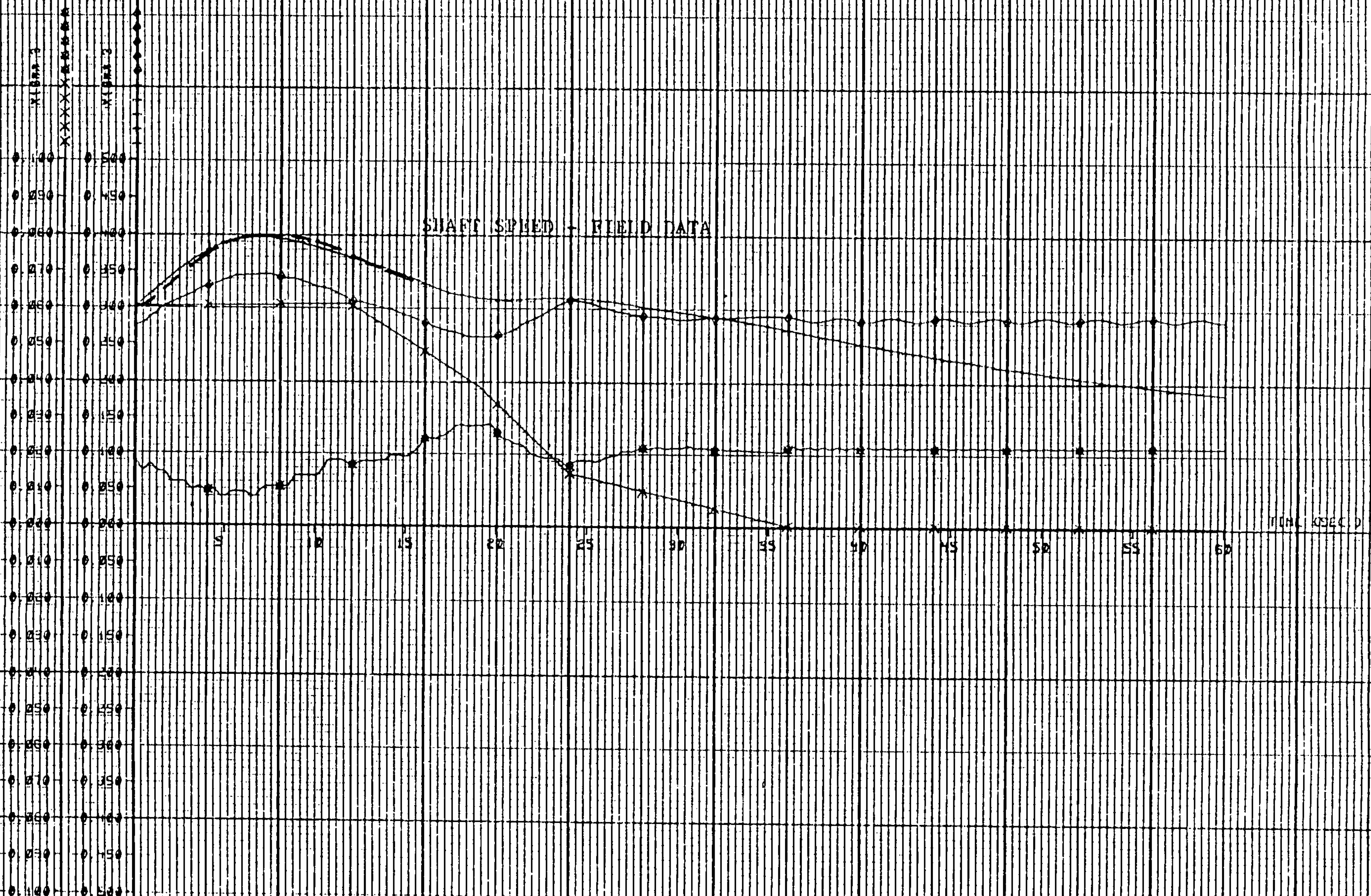
COO 1A SIMULTANEOUS LOAD REJECTION OF 8 UNITS (300 MW TOTAL OUTPUT, 1-20-78)
UNIT 1 HEAD ELEV=500.SM. TAIL ELEV=237.62M. GD2=4700 TON-METERS-METERS

+++++ MAIN SHAFT ROTATIONAL SPEED (RPM)
XXXXX % GATE OPENING (100%=.2213M)
HEAD IN THE SPIRAL CASE (METERS)
HEAD IN THE DRAFT TUBE (METERS)



(00 1A SIMULTANEOUS LOAD REJECTION OF 3 UNITS (300 MW TOTAL OUTPUT, 1-20-78)
UNIT 2 HEAD ELEV=500.5M, TAIL ELEV=237.62M, GD2=4700 TON-METERS METERS

+ + + + + MAIN SHAFT ROTATIONAL SPEED (RPM)
X X X X X % GATE OPENING (100% = 22(3M)
HEAD IN THE SPIRAL CASE (METERS)
HEAD IN THE DRAFT TUBE (METERS)



COO 1A SIMULTANEOUS LOAD REJECTION OF 3 UNITS (300 MW TOTAL OUTPUT, 1-20-78)
UNIT 3 HEAD ELEV=501.36M, TAIL ELEV=237.39M, GD2=4700 TON-METERS-METERS

+ + + + + MAIN SHAFT ROTATIONAL SPEED (RPM)
X X X X X % GATE OPENING (100% = 2213M)
◆ ◆ ◆ ◆ ◆ HEAD IN THE SPIRAL CASE (METERS)
■ ■ ■ ■ ■ HEAD IN THE DRAFT TUBE (METERS)

COQ 1A
RECOMMENDED MAX. POWER OUTPUT PER UNIT
VS. GROSS HEAD TO LIMIT
THE MAIN SHAFT SPEED TO
450 RPM IN THE EVENT OF
A SIMULTANEOUS LOAD REJ. OF 3 UNITS

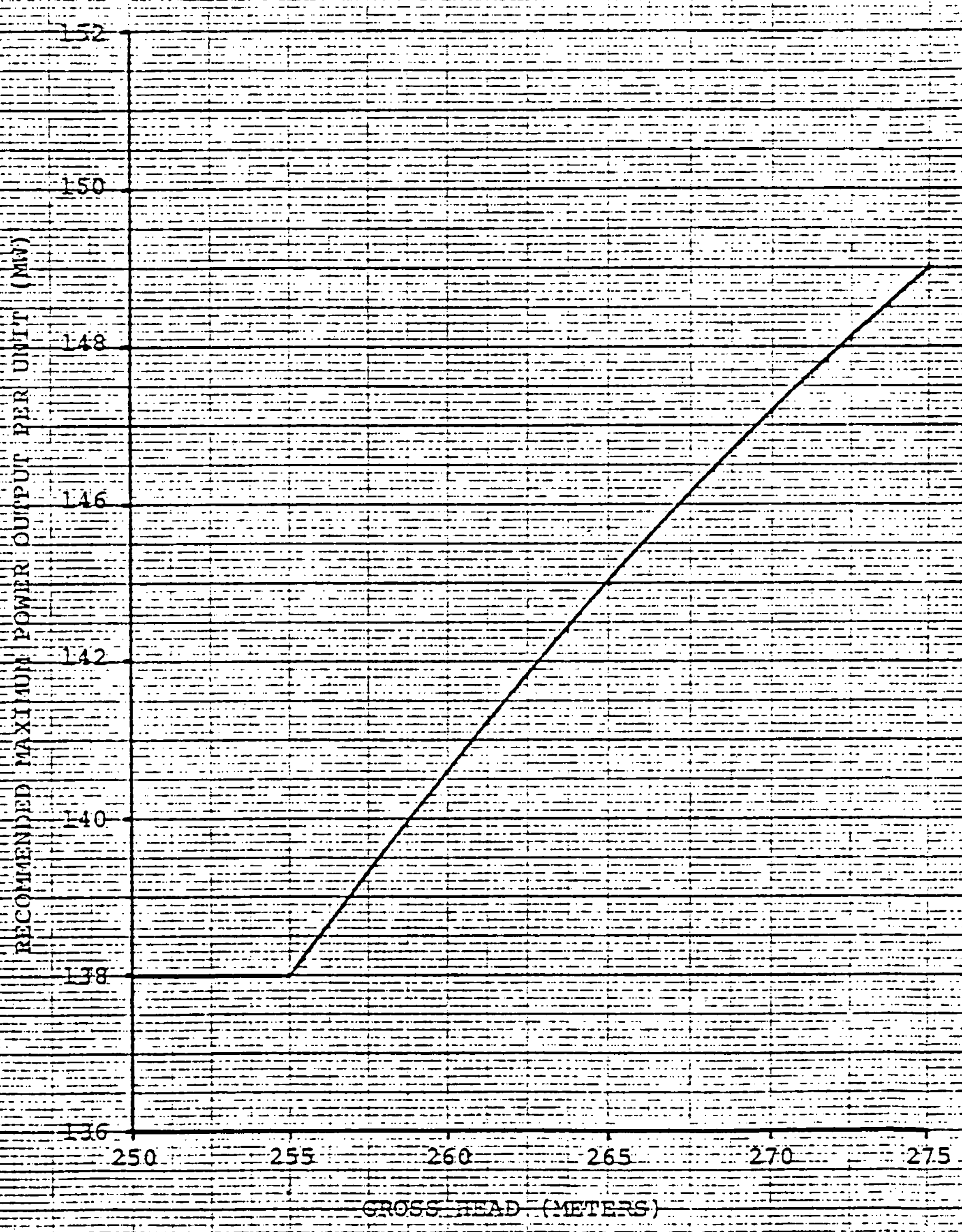


FIGURE 8

60% LOAD REJECTION

FAIRFIELD - UNIT 1

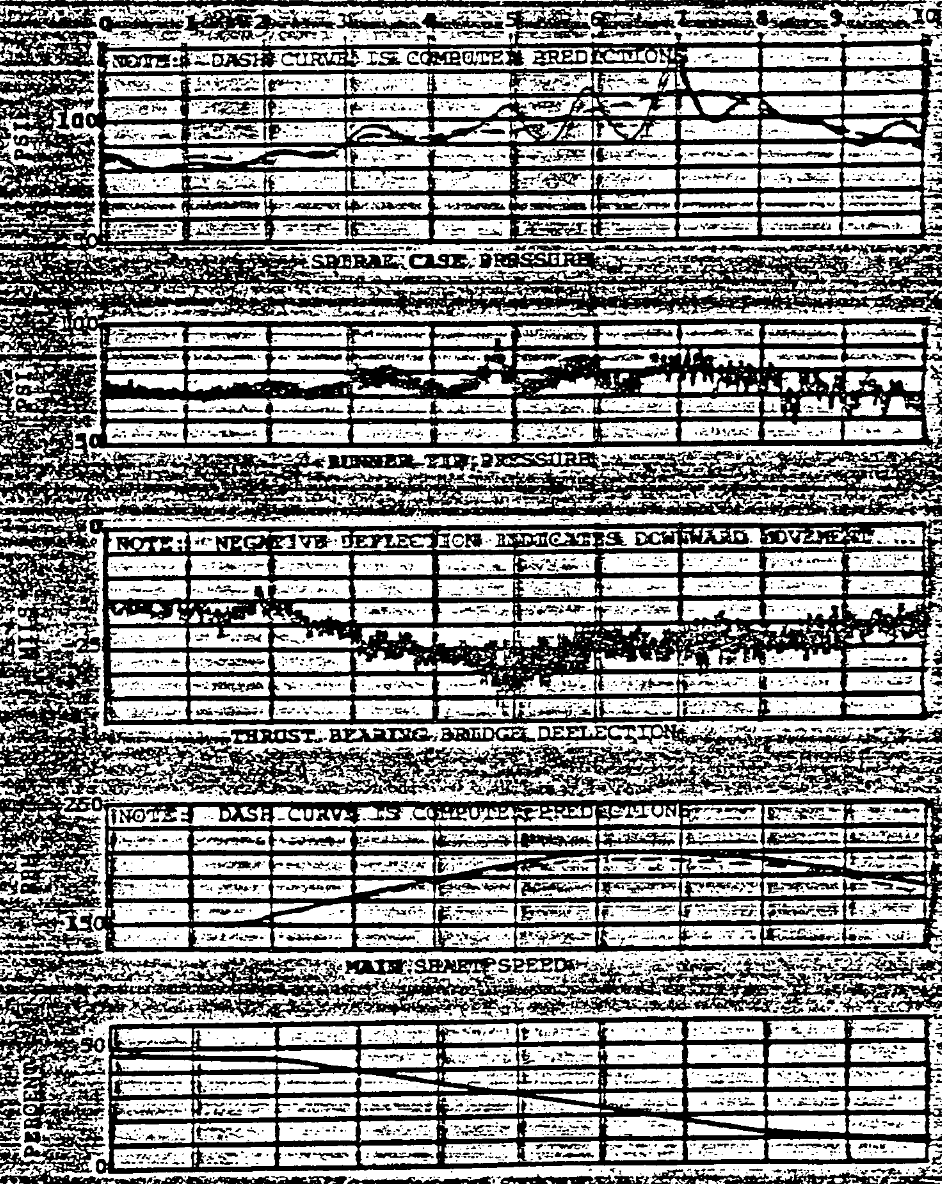


FIGURE 8

INTER-OFFICE CORRESPONDENCE

To: G. G. Fintak

Date: August 31, 1978

Copies To: L. F. Henry

From: R. E. Deitz

Subject: Grand Coulee Hydraulic Transient Analysis
S.O. 20374

PURPOSE:

The purpose of this analysis is to determine the following:

1. Expected speed and spiral case pressure rises during load rejection at the high head water conditions.

2. Effect of nominal governor time on speed and pressure rise values during load rejection.

INPUT DATA:

Head Water Elevation Range	1290 to 1208 Feet
Tail Water Elevation Range	1011 to 931 Feet
Elevation of ℄ Distributor	946 Feet
Spiral Case Design Pressure	438 Feet (190 PSI)
Maximum Speed of Generator	128.5 RPM
Rated Speed	85.7 RPM
Maximum Wicket Gate Opening	26 Inches
Nominal Governor Timing of Unit 22 When Commissioned	14.5 Seconds
Slow Closure of 8 Seconds From 1.3 Inch Wicket Gate Opening	
Model Data From Witnessed Model Test Report	
Performance Data Step-Up Ratio 27.6967	

GEN. WR^2 = 2,110,000,000 LB-FT^2
RUNNER WR^2 = 135,000,000 LB-FT^2

DISCUSSION:

A total of 28 various load rejections were investigated with the results summarized in Table 1. The 28 runs consist of load rejections from 50 to 100% wicket gate opening, tail water elevations from 931 to 990 feet, and various nominal governor times between 6 and 14.5 seconds. All runs had a head water elevation of 1290 feet.

Figures 1, 2, and 3 are plots of the predicted maximum speed and spiral case pressure for load rejections from outputs corresponding to half to full wicket gate openings for tail water elevation 990, 958, and 931 feet respectively.

The accuracy of the predicted values can be indicated by the comparison of the enclosed simulation of the 760 MW load rejection of Unit 22 on March 28, 1978 and the 700 MW load rejection of Unit 22 on June 1, 1978.

760 MW LOAD REJECTION (3-28-78)

Parameter	Actual Measured Value	Predicted Value	Percent Difference
Initial Load	760 MW	766 MW	.8%
Max. Shaft Speed	134.5 RPM	130 RPM	3.5%
Max. Spiral Case Head	346 Feet	340 Feet	1.8%

NOTE: A plot of the 760 MW load rejection is shown in Figure 4.

700 MW LOAD REJECTION (6-1-78)

Parameter	Actual Measured Value	Predicted Value	Percent Difference
Intial Load	700 MW	707 MW	1%
Max. Shaft Speed	125 RPM	121 RPM	3.3%
Max. Spiral Case Head	353 Feet	350 Feet	.9%

NOTE: A plot of the 700 MW load rejection is shown in Figure 5.

Ronald E. Deitz

Ronald E. Deitz
Field Engineer

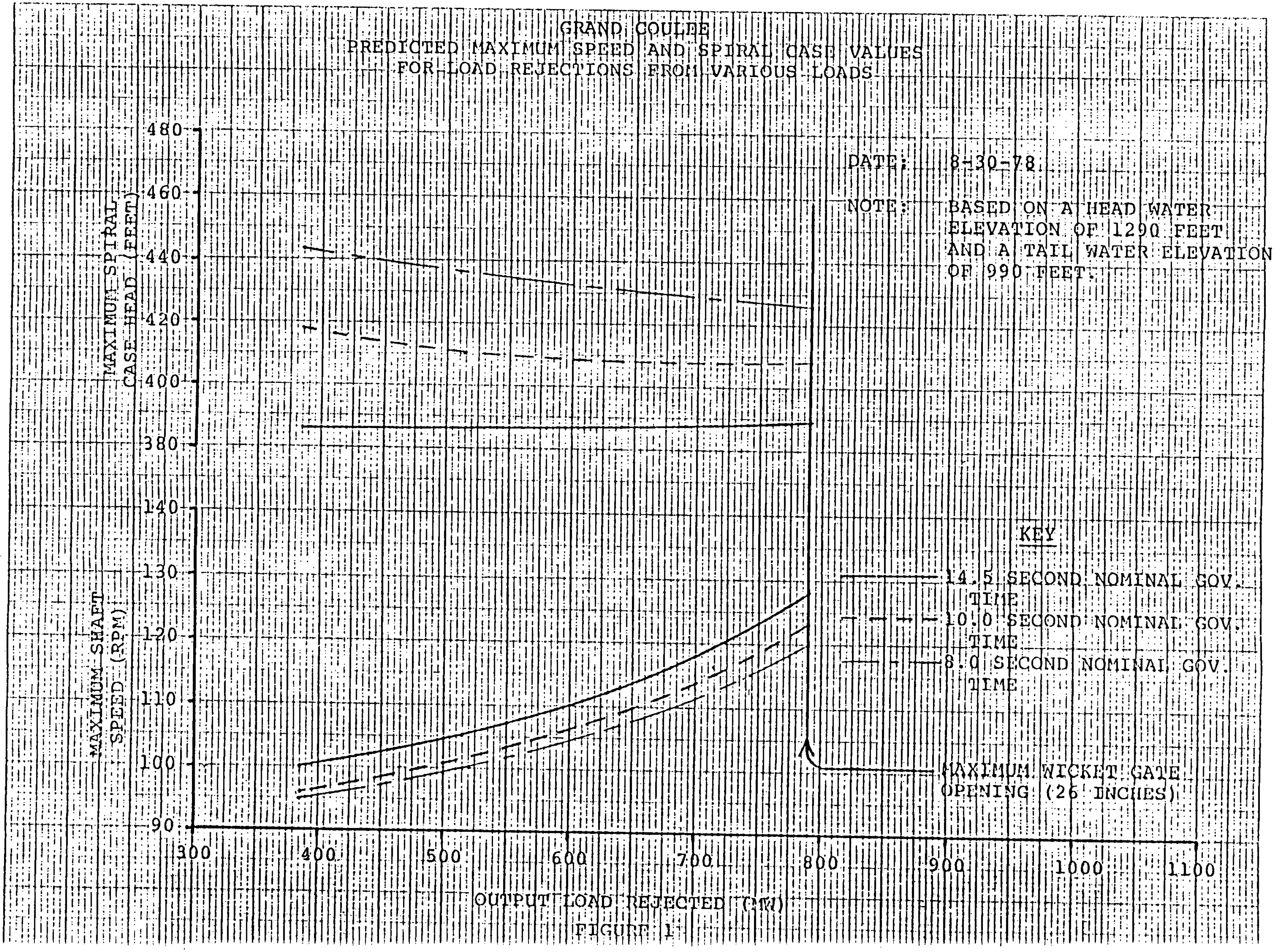
RED/pjm

SUMMARY OF RESULTS

Nominal Governor Time (Sec)	Max. Gate Opening (Inches)	Power Ouput (MW)	Tail Water Elevation (Feet)	Max. Shaft Speed (RPM)	Max. Spiral Case Head (Feet)
14.5	13.0	385	990	100	386
14.5	19.5	640	990	113	387
14.5	26.0	790	990	128	389
10.0	13.0	385	990	96	418
10.0	19.5	640	990	109	408
10.0	26.0	790	990	123	408
8.0	13.0	385	990	95	443
8.0	19.5	640	990	107	431
8.0	26.0	790	990	120	426
14.5	13.0	465	958	102	388
14.5	19.5	750	958	118	389
14.5	26.0	915	958	133	391
10.0	13.0	465	958	98	422
10.0	19.5	705	958	113	412
10.0	26.0	915	958	128	411
8.0	13.0	465	958	97	449
8.0	19.5	750	958	111	437
8.0	26.0	915	958	125	429
14.5	13.0	530	931	104	389
14.5	19.5	845	931	122	390
14.5	26.0	1030	931	138	392
10.0	13.0	530	931	100	427
10.0	19.5	845	931	116	415
10.0	26.0	1030	931	132	414
8.0	13.0	530	931	98	451
8.0	19.5	845	931	114	443
8.0	26.0	1030	931	129	434
6.0	26.0	1030	931	124	470

NOTE: Head water elevation for all the above case was 1290 feet.

TABLE 1


GRAND COULEE
PREDICTED MAXIMUM SPEED AND SPIRAL CASE VALUES
FOR LOAD REJECTIONS FROM VARIOUS LOADS
DATE: 8-30-78
NOTE: BASED ON A HEAD WATER ELEVATION OF 1290 FEET AND A TAIL WATER ELEVATION OF 990 FEET.
MAXIMUM SPIRAL CASE HEAD (FEET)
480
460
440
420
400
380
140
130
120
110
100
90
MAXIMUM SHAFT SPEED (RPM)
KEY
14.5 SECOND NOMINAL GOV. TIME
10.0 SECOND NOMINAL GOV. TIME
8.0 SECOND NOMINAL GOV. TIME
MAXIMUM WICKET GATE OPENING (26 INCHES)
300
400
500
600
700
800
900
1000
1100
OUTPUT LOAD REJECTED (MW)
FIGURE 1

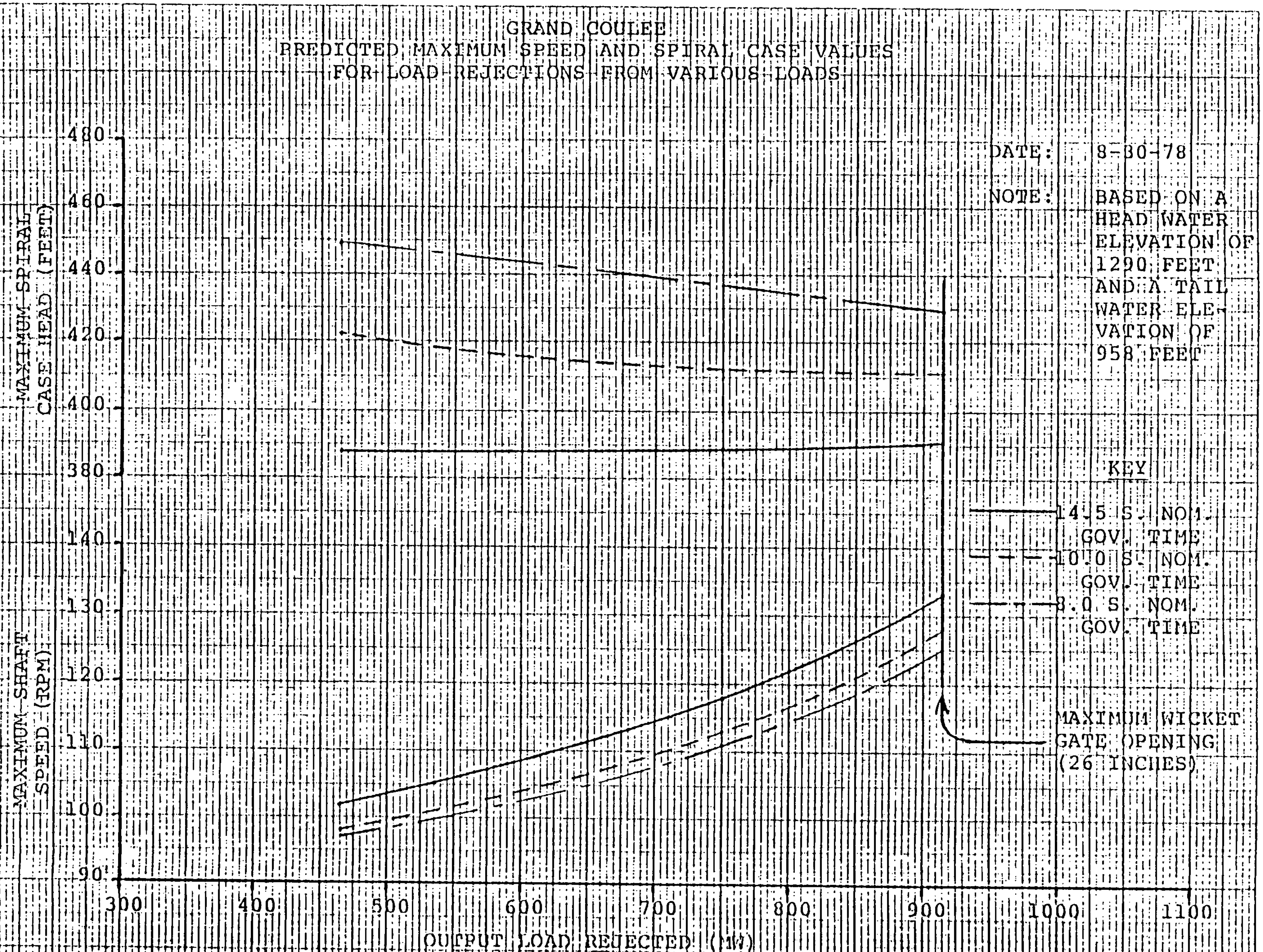

GRAND COULEE
PREDICTED MAXIMUM SPEED AND SPIRAL CASE VALUES
FOR LOAD REJECTIONS FROM VARIOUS LOADS
MAXIMUM SPIRAL CASE HEAD (FEET)
480
460
440
420
400
380
MAXIMUM SHAFT SPEED (RPM)
140
130
120
110
100
90
300
400
500
600
700
800
900
1000
1100
OUTPUT LOAD REJECTED (MW)
DATE: 8-30-78
NOTE: BASED ON A HEAD WATER ELEVATION OF 1290 FEET AND A TAIL WATER ELEVATION OF 958 FEET
KEY
14.5 S. NOM. GOV. TIME
10.0 S. NOM. GOV. TIME
8.0 S. NOM. GOV. TIME
MAXIMUM WICKET GATE OPENING (26 INCHES)

FIGURE 2

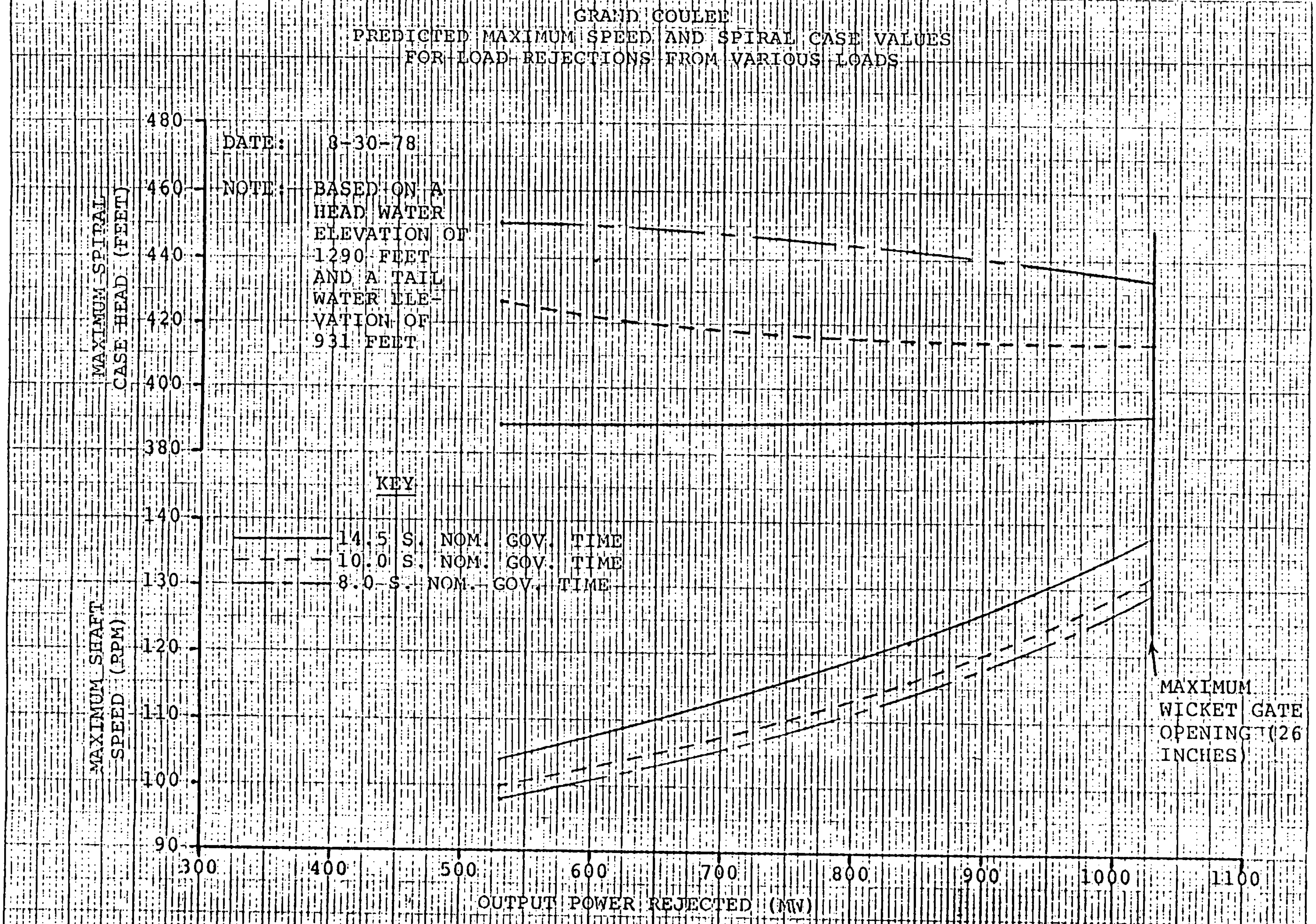

GRAND COULEE
PREDICTED MAXIMUM SPEED AND SPIRAL CASE VALUES
FOR LOAD REJECTIONS FROM VARIOUS LOADS
DATE: 8-30-78
NOTE: BASED ON A HEAD WATER ELEVATION OF 1290 FEET AND A TAIL WATER ELE-VATION OF 931 FEET
MAXIMUM SPIRAL CASE HEAD (FEET)
480
460
440
420
400
380
KEY
14.5 S. NOM. GOV. TIME
10.0 S. NOM. GOV. TIME
8.0 S. NOM. GOV. TIME
MAXIMUM SHAFT SPEED (RPM)
140
130
120
110
100
90
MAXIMUM WICKET GATE OPENING (26 INCHES)
300
400
500
600
700
800
900
1000
1100
OUTPUT POWER REJECTED (MW)

FIGURE 3

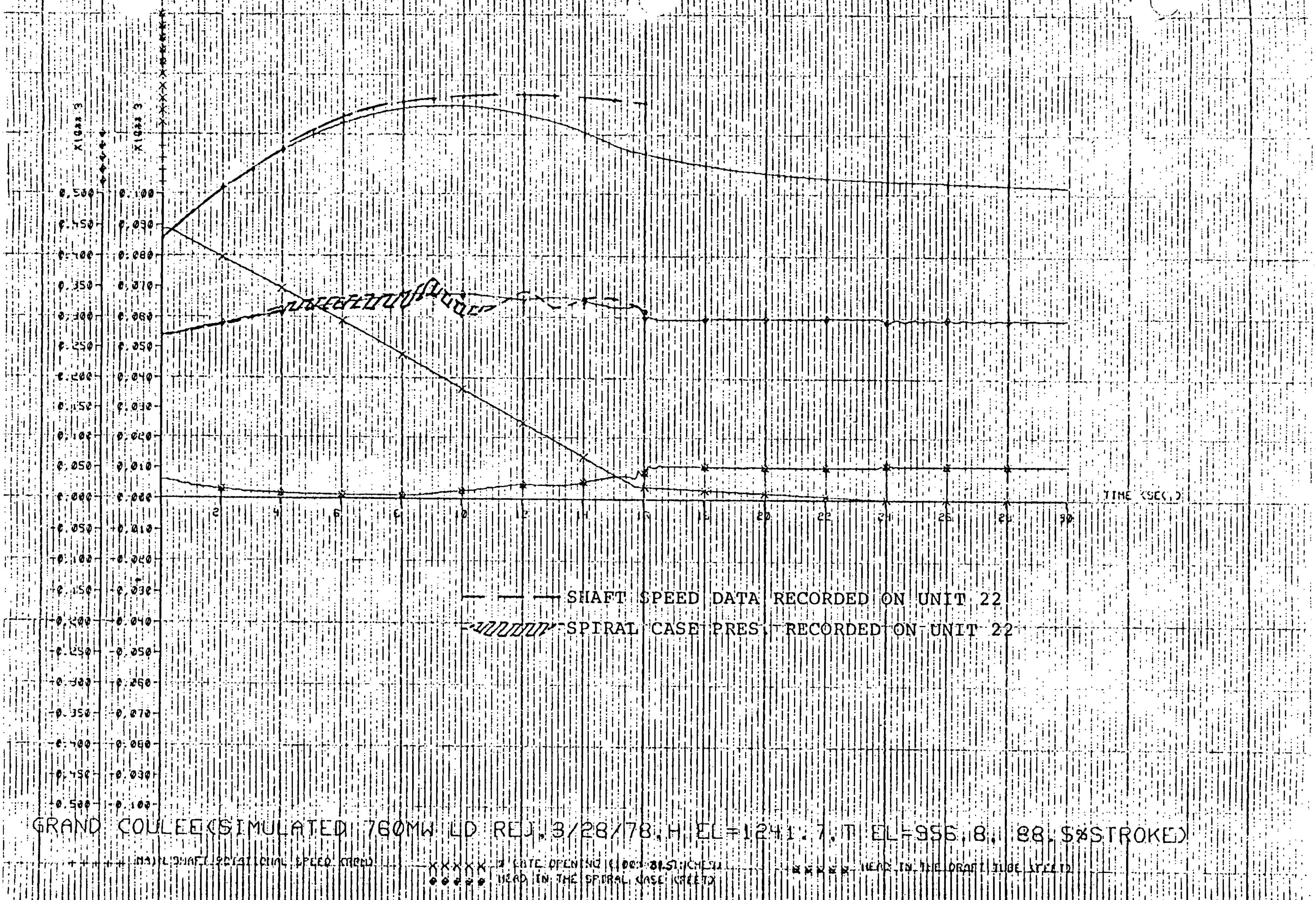

SHAFT SPEED DATA RECORDED ON UNIT 22
SPIRAL CASE PRES. RECORDED ON UNIT 22
TIME (SEC.)
GRAND COULEE(SIMULATED 760MW LD REJ.3/28/78.H EL=1241.7.T EL=956.8. 88.5%STROKE)
HEAD IN THE SPIRAL CASE (FEET)

FIGURE 4

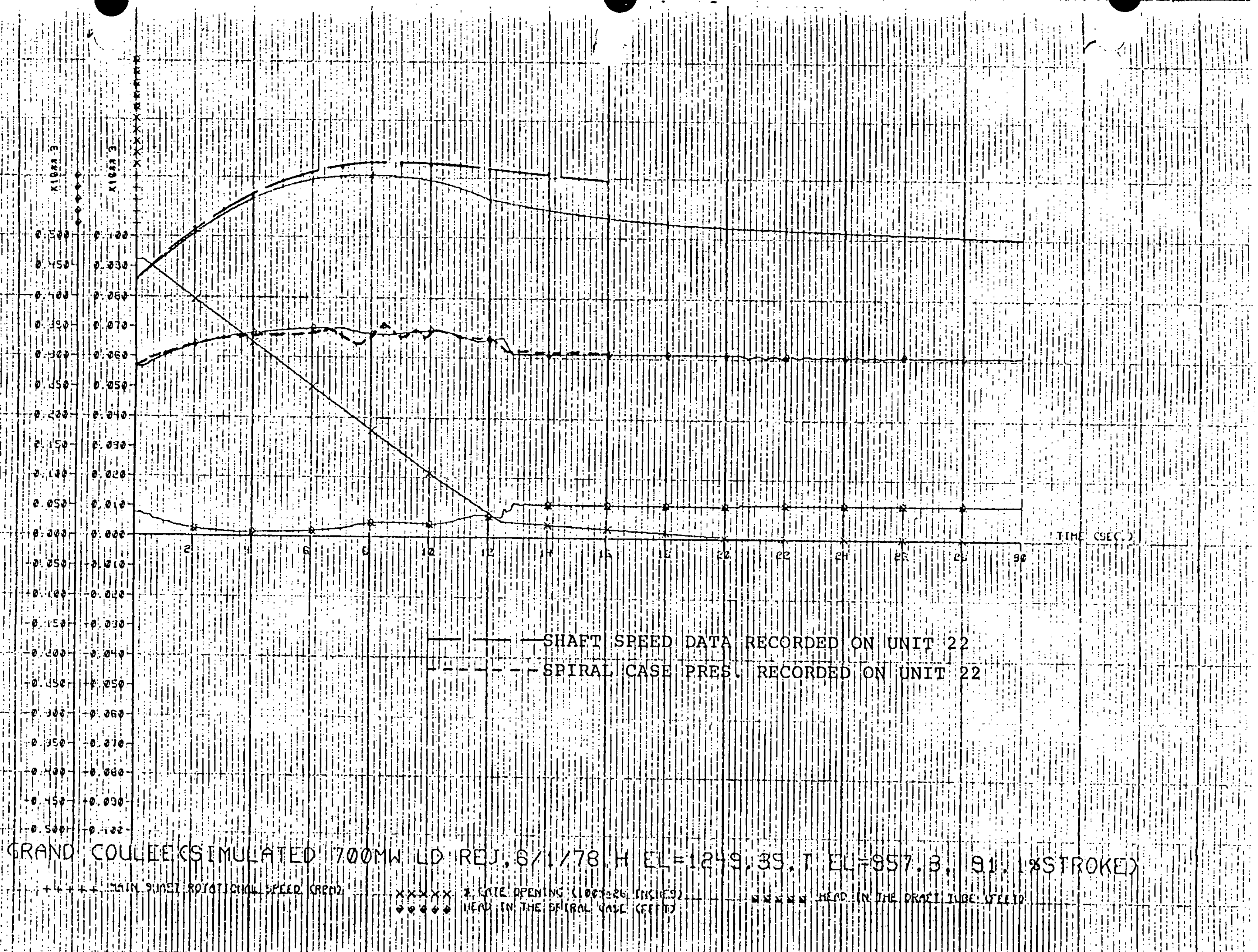

SHAFT SPEED DATA RECORDED ON UNIT 22
SPIRAL CASE PRES. RECORDED ON UNIT 22
TIME (SEC.)
GRAND COULEE(SIMULATED 700MW LD REJ,6/1/78,H EL=1249.39,T EL=957.3, 91.1%STROKE)
HEAD IN THE SPIRAL CASE (FEET)

FIGURE 5

INTER-OFFICE CORRESPONDENCE

To: Mr. L. F. Henry

Date: December 17, 1979

Copies To: Mr. M. H. Turnbull

From: M. Byrne

Subject: CORA Correlation with Field Data for Lewiston P/T

PURPOSE:

A CORA run was made to compare with field test results from a 32 MW load rejection taken during the index tests of 11/79.

INITIAL CONDITIONS:

- Head Water Elevation = 654.47 Feet
- Tail Water Elevation = 544.70 Feet
- Rated Speed = 112.5 RPM
- Elevation ℄ of Distributor = 550.0 Feet
- Kt (Turbine Torque coeffecient for unit = .0185 spinning in water with closed gates)
- Wave Speed = 3937 ft/sec

DISCUSSION:

Figure 1 shows the correlation of the computer predicted values and the actual field test data for shaft speed and spiral case head during the 32 MW load rejection.

The field values for the spiral case pressure had to be corrected due to a head loss created by leakage from a crack in one of the net head pipes. A sample calculation of this correction follows:

$V=\sqrt{2gH}$ $\quad H=\frac{V^2}{2g}$ $\quad Q=KH$

3/4" Sch. 80 Pipe ID=.742 inches Area=.003 $Ft.^2$

FORM 989-13 PRINTED IN U.S.A.

STATIC CONDITION:

Static Value	104.47 ft.
Chart Value	- 89.315 ft.
	15.155 ft.

$$H = \frac{V^2}{2g}$$

$$15.155 = \frac{V^2}{2(32.2)}$$

V= 31.24 ft/sec

$Q = VA = (31.24)\ (.003) = .0938\ ft.^3/sec$

$Q = KH$

$$K = \frac{.0938}{89.315} = .00105$$

Max value from chart = 104.08 ft.

$Q = KH = (.00105)\ (104.08) = .1093\ ft^3/sec$

$$V = \frac{Q}{A} = \frac{.1093}{.003} = 36.4\ ft/sec$$

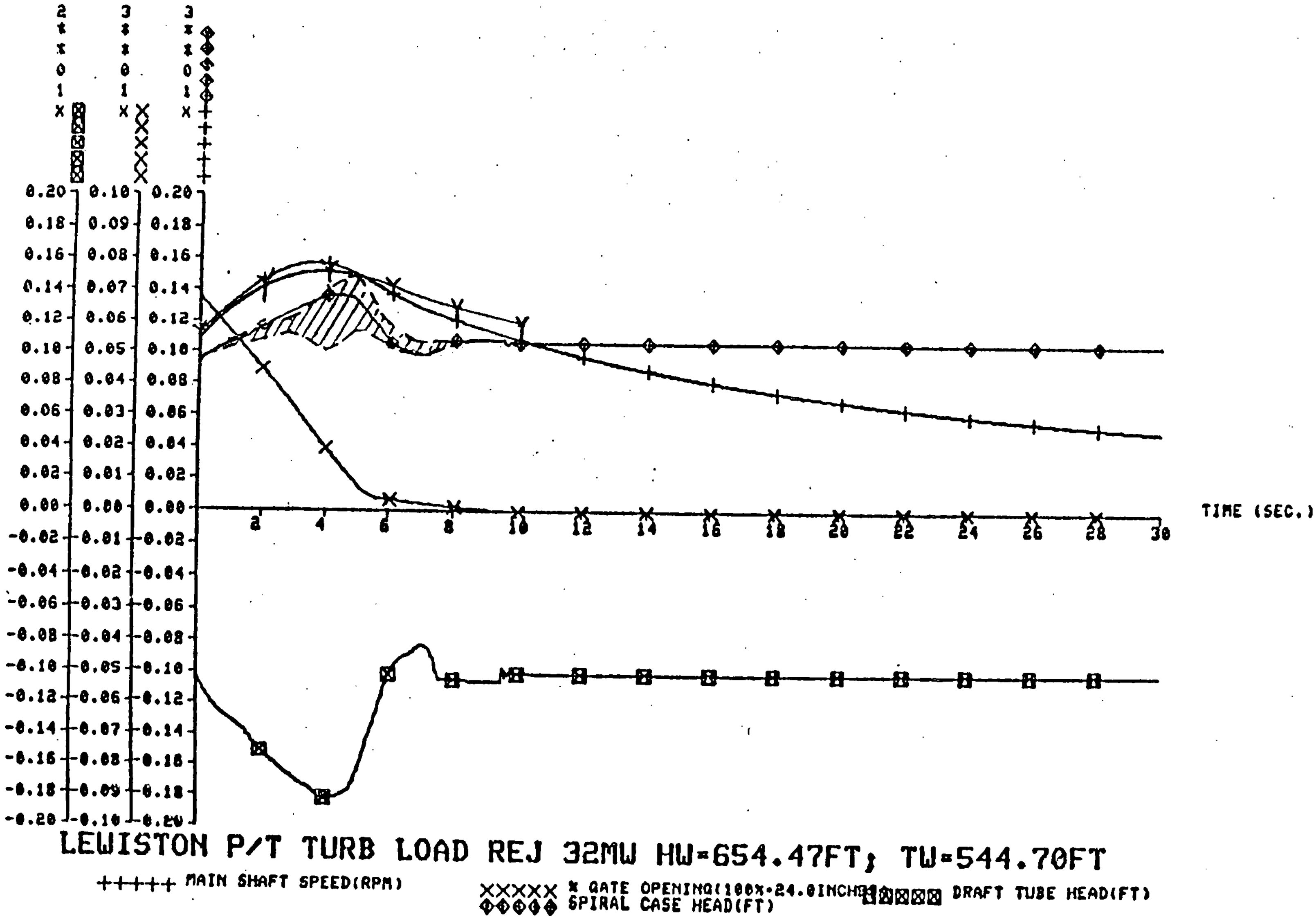
$$H = \frac{V^2}{2g} = \frac{(36.4)^2}{2\ (32.2)} = 20.58\ ft.$$

Corrected Head = 104.08 + 20.58 = 124.66 feet

All chart values were corrected in the same way based on the discharge coeffecient of .00105.

Michael Byrne
Michael Byrne
Field Engineer

MB/jew



Y Turbine Shaft Speed - Field Data

(hatched) - Spiral Case Pressure - Field Data

Figure 1

INTER-OFFICE CORRESPONDENCE

To: S. A. Chacour

Date: May 30, 1979

Copies To:

From: L. F. Henry

Subject: RACCOON MOUNTAIN TRANSIENTS

On an unofficial basis, I have tried to find out whether or not the T.V.A. will perform simultaneous load rejections on all four Raccoon Units when they are operational.

It is normal procedure for operations of T.V.A. to do full load rejections on an entire plant. In exploring the reason for this I find:

1. There are no federal, state or local regulations that require entire plant rejections.

2. The reason given for such trips is to insure that all plant protective devices do function and to gain operator confidence.

Since we always require transient testing on each individual unit, my question is if the entire plant must be tripped, why not be satisfied with a low load plant trip? I do not know whether or not my unofficial comments made any impression on T.V.A. personnel to encourage or discourage plant rejections.

(Naturally a simultaneous trip on units sharing the same penstock does impose higher transient conditions on the machinery than a single unit trip, but from the contractor's point of view I'm in favor of discouraging a multitude of transient tests on our machinery.)

Attached are Figures 6-9 from our field engineering report (F5 Advanced Technology Department) on the single unit transient tests on Unit 1. The red pencil line shows the Cora predictions on the plot of the field test results.

Run G-1 and G-14 are T.V.A. computations of 4 unit transients with Cora predictions in red and green color. Our Cora runs predict about 2% more pressure rise and 9% more speed rise than the T.V.A. calculations.

Larry

L. F. Henry
Manager, Field
Engineering

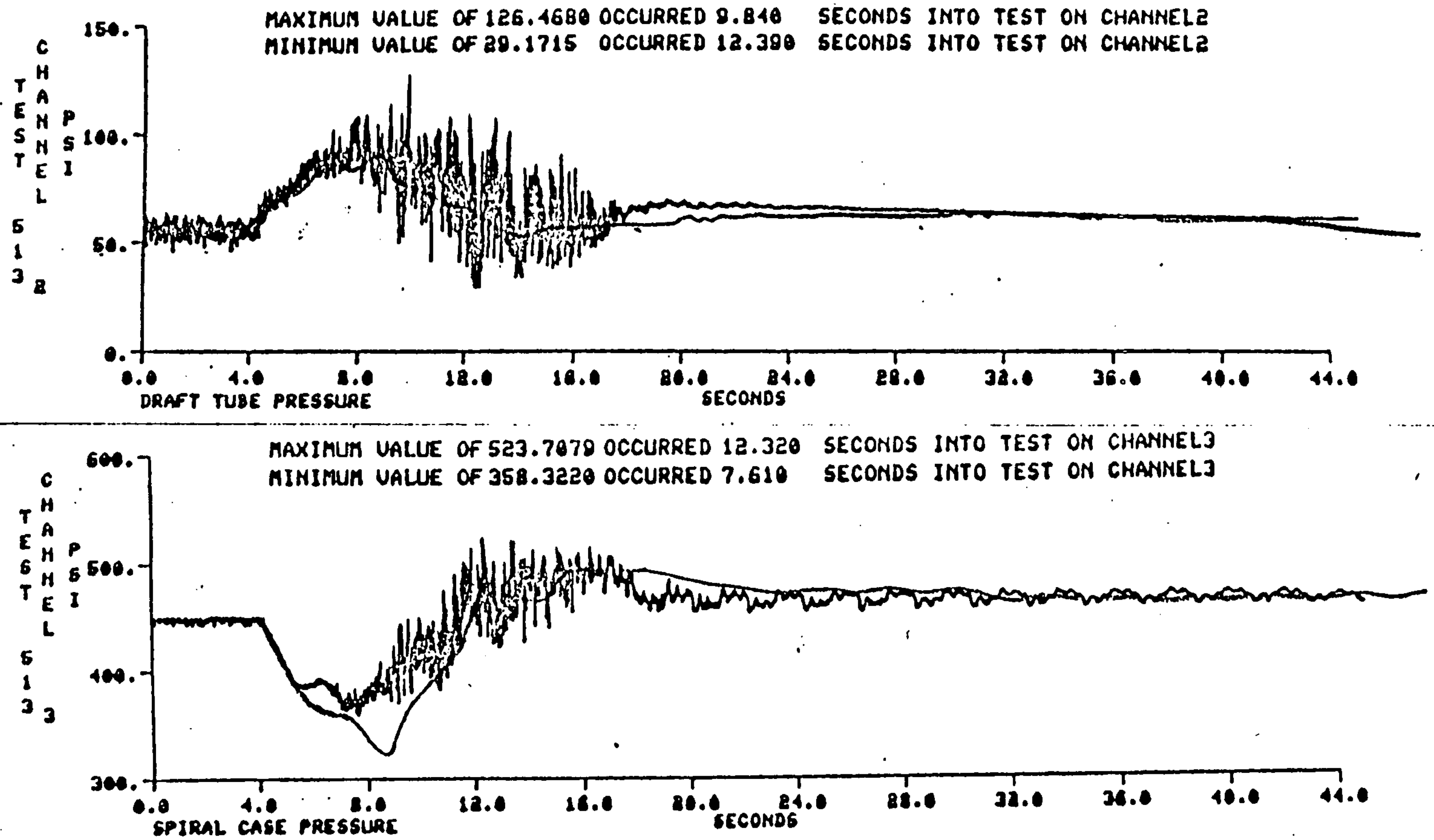
LFH/pjm

FORM 989-13 PRINTED IN U.S.A.

RACCOON MOUNTAIN

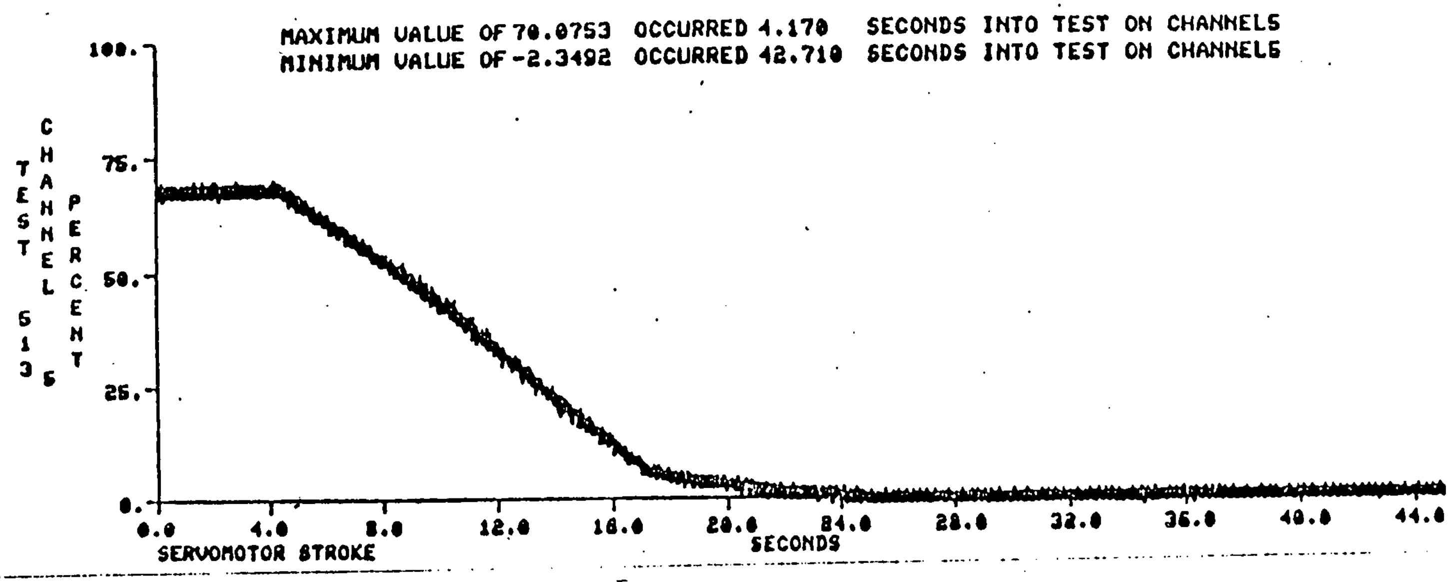
Turbine full load rejections at maximum head.

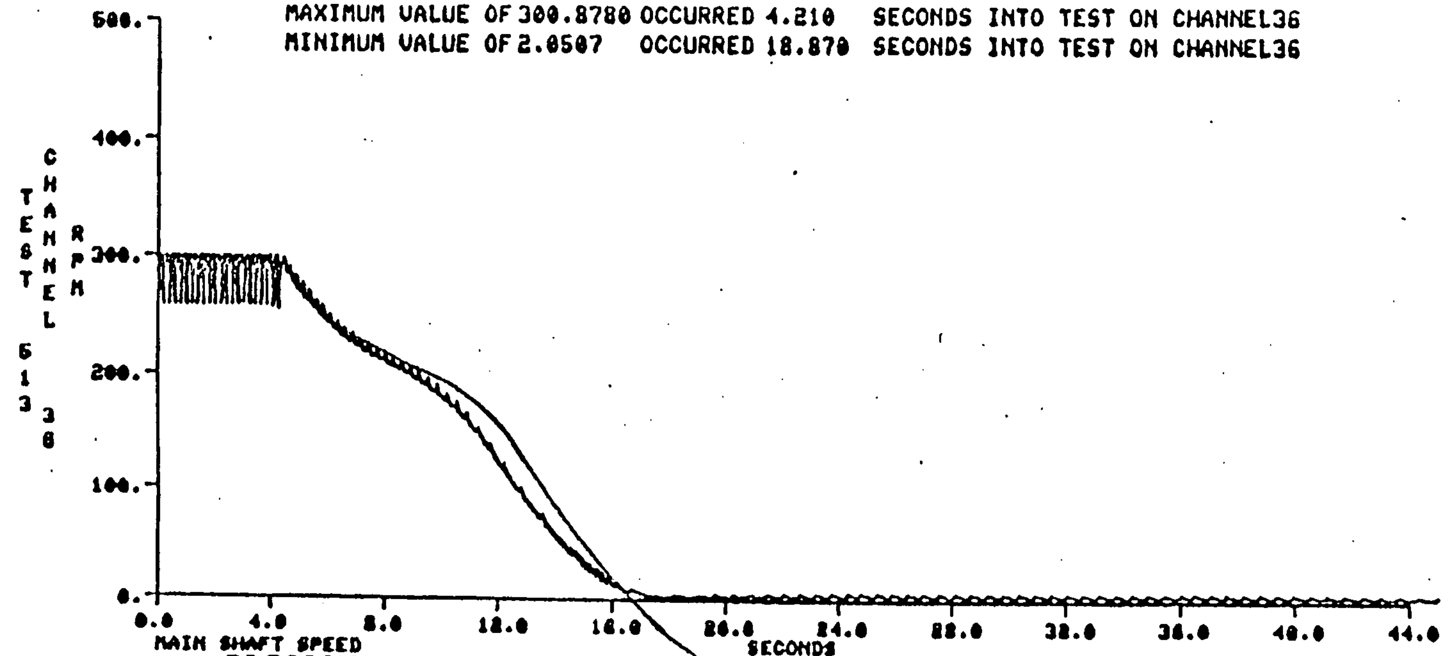
Calculated For One Unit Only		Calculated For Four Units Simultaneously
424 RPM	Shaft Speed	446 RPM
1847 FT	Spiral Case Pressure	2000 FT



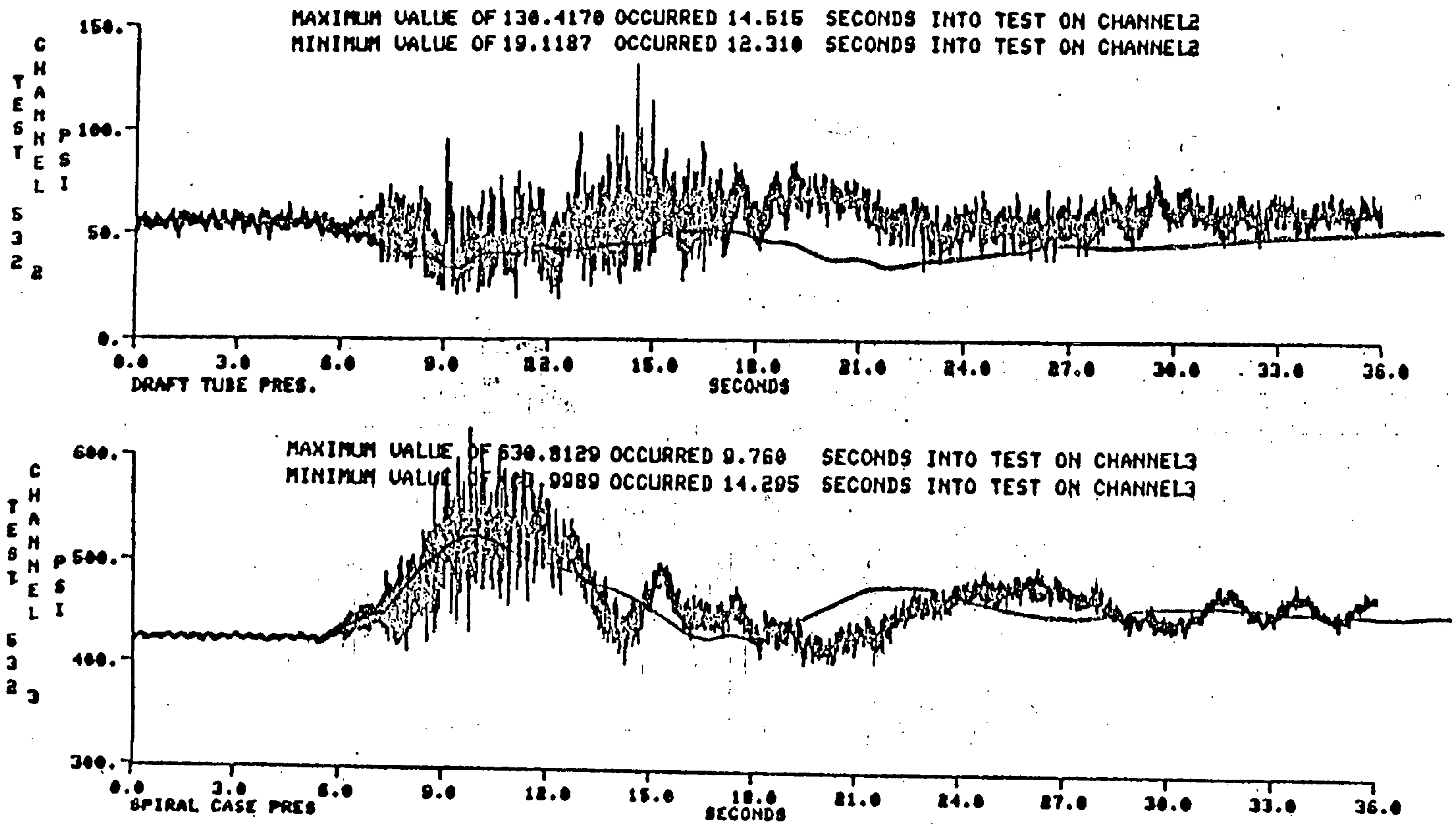
RACCOON MOUNTAIN - UNIT 1 - PUMP POWER FAILURE FROM 70% GATE
COMPARISON OF FIELD DATA AND CORA OUTPUT (RED LINE)

FIGURE 6



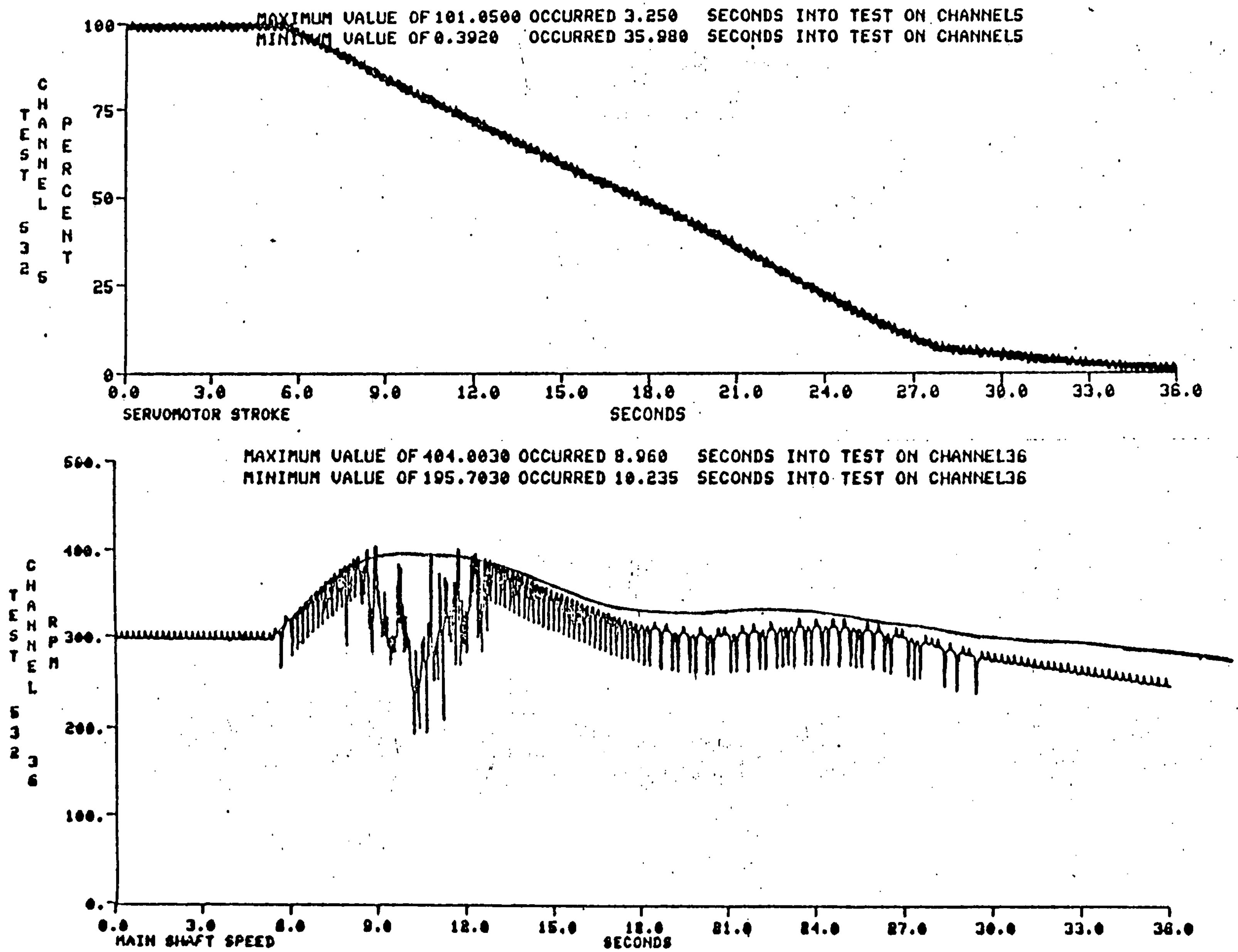


RACCOON MOUNTAIN - UNIT 1 - PUMP POWER FAILURE FROM 70% GATE
COMPARISON OF FIELD DATA AND CORA OUTPUT (RED LINE)



RACCOON MOUNTAIN - UNIT 1 - 390 MW LOAD REJECTION
COMPARISON OF FIELD DATA AND CORA OUTPUT (RED LINE)

FIGURE 8



RACCOON MOUNTAIN - UNIT 1 - 390 MW LOAD REJECTION
COMPARISON OF FIELD DATA AND CORA OUTPUT (RED LINE)

FIGURE 9

Attachment #2

VOITH HYDRO, INC. TELEFAX

DATE: June 27, 1994

TO: Duke Power

ATTN: John Beckman

RE: Keowee Transients

TELEFAX #: (803) 885-4028

SENT BY: Michael Byrne

FROM: VOITH HYDRO, INC.
East Berlin Road
P.O. Box 712
York, PA 17405

Tel: (717) 792-7155
Tfx: (717) 792-7263
Tlx: 4764013

NO. OF PAGES: 2
(incl. cover page)

If you do not receive all the pages, or if trouble occurs during transmission, please call (717) 792-7852 as soon as possible

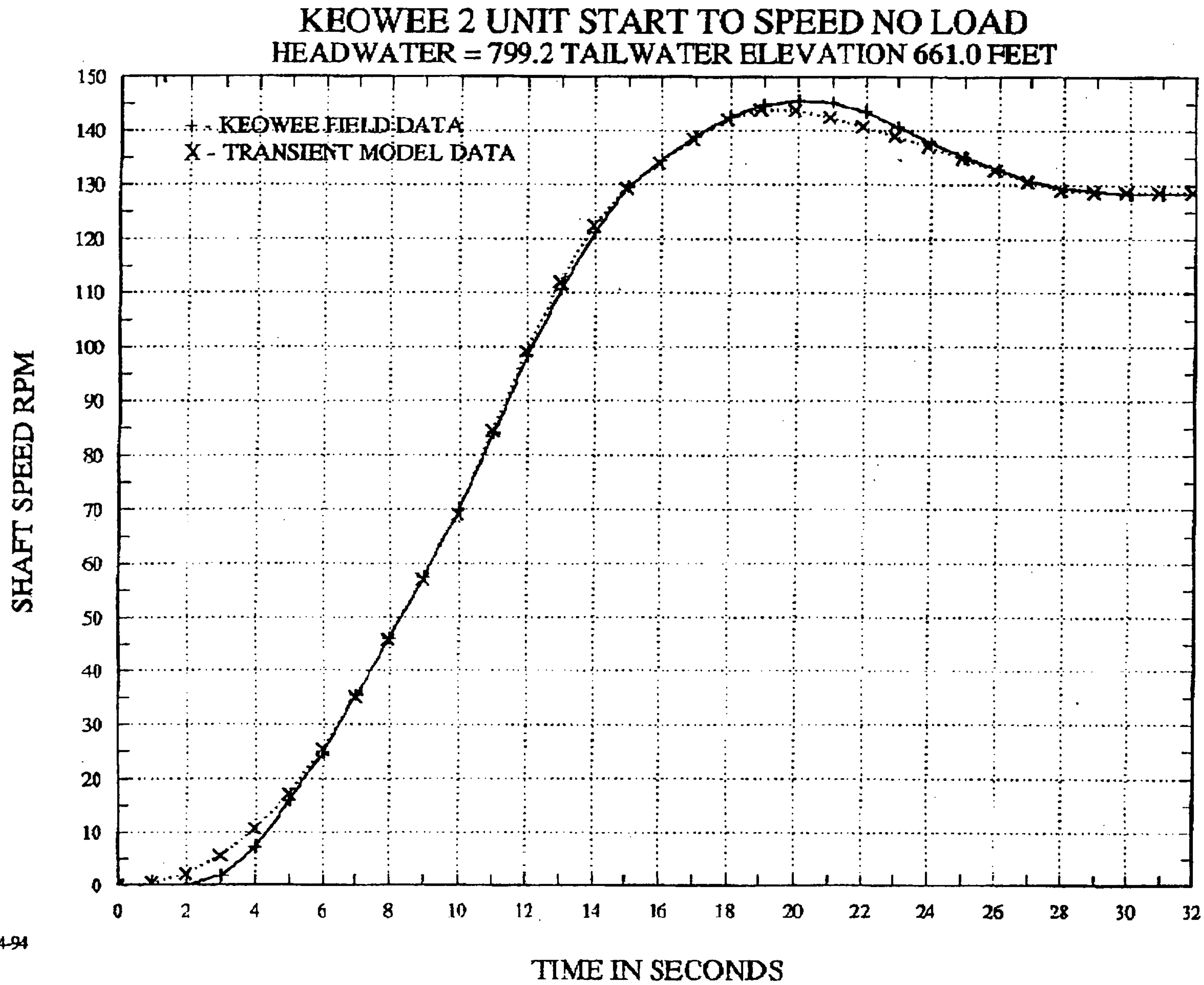
Hello John:

Enclosed is the comparison of field data versus computer simulation for two unit simultaneous start to speed no load position. The simulation modelled straight line servomotor openings from 0 to 17, 17 to 26, 26 to 49, 49 to 30, 30 to 32, 32 to 11.5, 11.5 to 8.4, hold at 8.4 for a second, and then go from 8.4 to 16.5 percent servomotor stroke. The preceding simulation of gate movement was based on trying to model the tabulated data you faxed on June 23, 1994.

Regards,

Michael Byrne

SENT BY:VOITH HYDRO ; 6-27-94 ; 8:32AM ; VOITH HYDRO→ CMD SOUTHERN DIV.;# 1/ 2


KEOWEE 2 UNIT START TO SPEED NO LOAD
HEADWATER = 799.2 TAILWATER ELEVATION 661.0 FEET
+ - KEOWEE FIELD DATA
X - TRANSIENT MODEL DATA
SHAFT SPEED RPM
TIME IN SECONDS
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32

06-24-94

	Keowee Emergency Startup Test			
	Double Unit Startup to Speed-No-Load			
	Keowee Elevation 799.2'			
		Initial Tail Elev. 661'		
	Time (Sec)	Unit Speed (PRM)	Gate Position (%)	
	0	0	0	
	1	0	5	
	2	0	9	
	3	1.77	13	
	4	7.08	17	
	5	15.93	26	
	6	24.78	32	
	7	35.4	37.5	
	8	46.02	42.4	
	9	57.525	49	
	10	69.915	46	
	11	84.075	42	
	12	98.235	38	
	13	110.625	34	
	14	121.245	30	
	15	129.6525	32	
	16	134.52	31	
	17	138.945	27	
	18	142.485	23	
	19	144.786	18.6	
	20	145.494	15	
	21	145.14	11.5	
	22	143.547	10.4	
	23	140.715	8.4	
	24	137.706	8.4	
	25	135.051	10.5	
	26	132.75	12.5	
	27	130.5375	14.4	
	28	129.387	15.5	
	29	128.7675	16	
	30	128.325	16.5	
	31	128.325	16.5	
	32	128.325	16.5	

Attachment #3

TEST AND MODEL SUMARY

Test No.	Unit No.	Forebay ft	Tailwater ft	Gross Head ft	Power MW	Tst T to 110% sec	Mdl T to 110% sec
1	1	799.87	663.45	136.42	60	15.04	11.82
2	1	799.9	663.6	136.3	75	17.79	14.49
3	1	799.85	664.25	135.6	90	20.22	18.87
4	2	799.85	663.02	136.83	60	15.67	11.78
5	2	799.82	663.13	136.69	75	18.4	14.46
6	1	799.83	666.65	133.18	60	15.5	12.82
6	2	799.83	666.65	133.18	60	16.51	12.82
7	1	799.58	667.51	132.07	70	17.68	14.74
7	2	799.58	668.1	131.48	70	18.6	14.74
8	1	799.72	670.4	129.32	80	19.49	17.95
8	2	799.72	670.4	129.32	80	20.02	17.95
9	1	799.44	670.4	129.04	60	14.61	12.44
10	1	799.44	671.7	127.74	90	19.67	20.1
11	1	799.56	672.5	127.06	70	17.48	15.8
11	2	799.56	672.5	127.06	70	18.03	15.8

VOITH HYDRO, INC. TELEFAX

DATE: March 12, 1995

TO: Duke Power

ATTN: John Beckman

RE: Keowee Transients

TELEFAX #: (803) 885-4028

SENT BY: Michael Byrne

FROM: VOITH HYDRO, INC.
East Berlin Road
P.O. Box 712
York, PA 17405

Tel: (717) 792-7155
Tfx: (717) 792-7263
Tlx: 4764013

NO. OF PAGES: 3
(incl. cover page)

If you do not receive all the pages, or if trouble occurs during transmission, please call (717) 792-7852 as soon as possible

Hello John:

Enclosed are the transient simulation results for you to compare to the transient test results you obtained from the Keowee field tests.

Time	Rotating Speed of the Turbine and Generator in RPM						
Seconds	Case 1	Case 2	Case 2A	Case 3	Case 4	Case 5	Case 5A
0.0	128.6	128.6	128.6	128.6	128.6	128.6	128.6
0.996	136.84	138.84	139.1	140.75	136.84	138.84	139.10
1.992	144.54	148.23	148.77	151.89	144.55	148.22	148.76
2.988	150.57	155.89	156.78	161.64	150.55	155.88	156.73
3.984	154.47	161.33	162.58	169.73	154.55	161.30	162.47
4.980	156.68	164.44	166.01	175.62	156.65	164.40	155.85
5.976	157.45	165.91	167.64	179.36	157.40	165.86	167.45
6.973	156.84	166.42	168.27	181.15	156.75	166.35	168.06
7.969	154.96	165.62	167.76	181.48	154.85	165.53	167.49
8.965	152.03	163.56	165.95	181.13	151.90	163.34	165.62
9.961	148.46	160.43	163.01	180.17	148.32	160.28	162.63
10.957	144.75	156.49	159.18	178.00	144.62	156.32	158.76
11.953	140.94	152.35	154.95	174.73	140.81	152.19	154.55
12.949	137.02	148.13	150.67	170.54	136.89	147.97	150.27
13.945		143.85	146.33	165.71		143.69	145.93
14.941		139.51	141.93	160.82		139.35	141.54
15.938			137.47	155.92			137.08
16.933				151.02			
17.930				146.11			
18.926				141.19			
19.922				136.26			

Attachment #4

VOITH HYDRO, INC. TELEFAX

DATE: April 18, 1995

TO: Duke Power

ATTN: John Beckman

RE: Keowee Data

TELEFAX #: (803) 885-4028

SENT BY: Michael Byrne

FROM: VOITH HYDRO, INC.
East Berlin Road
P.O. Box 712
York, PA 17405

Tel: (717) 792-7155
Tfx: (717) 792-7263
Tlx: 4764013

NO. OF PAGES: 1
(incl. cover page)

If you do not receive all the pages, or if trouble occurs during transmission, please call (717) 792-7852 as soon as possible

Hello John:

Enclosed is a table listing time versus unit speed that results from a 2 unit simultaneous 80.4 MW generator load rejection with the units subject to a headwater elevation of 794.72 feet and a tailwater elevation of 668.1 feet:

Time (Seconds)	Unit Speed (RPM)
0.0	128.6
0.996	139.56
1.992	149.71
2.988	158.85
3.984	166.81
4.980	173.04
5.976	177.44
6.973	180.03
7.969	180.95
8.965	181.00
9.961	180.47
10.957	178.74
11.953	175.81
12.949	171.88
13.945	167.16
14.941	162.19
15.937	157.24
16.933	152.29
17.930	147.35
18.926	142.41
19.922	137.47
20.918	132.70

The proceding replaces information given to you by telephone and telefax on April 10, 1995.

Regards,
Michael Byrne
Michael Byrne

Attachment #5

VOITH HYDRO, INC. TELEFAX

DATE:	June 28, 1994	FROM:	VOITH HYDRO, INC. East Berlin Road P.O. Box 712 York, PA 17405
TO:	Duke Power		
ATTN:	John Beckman		Tel: (717) 792-7155 Tfx: (717) 792-7263 Tlx: 4764013
RE:	Keowee Transients		
TELEFAX #:	(803) 885-4028		NO. OF PAGES: 2 (incl. cover page)
SENT BY:	Michael Byrne		

If you do not receive all the pages, or if trouble occurs during transmission, please call (717) 792-7852 as soon as possible

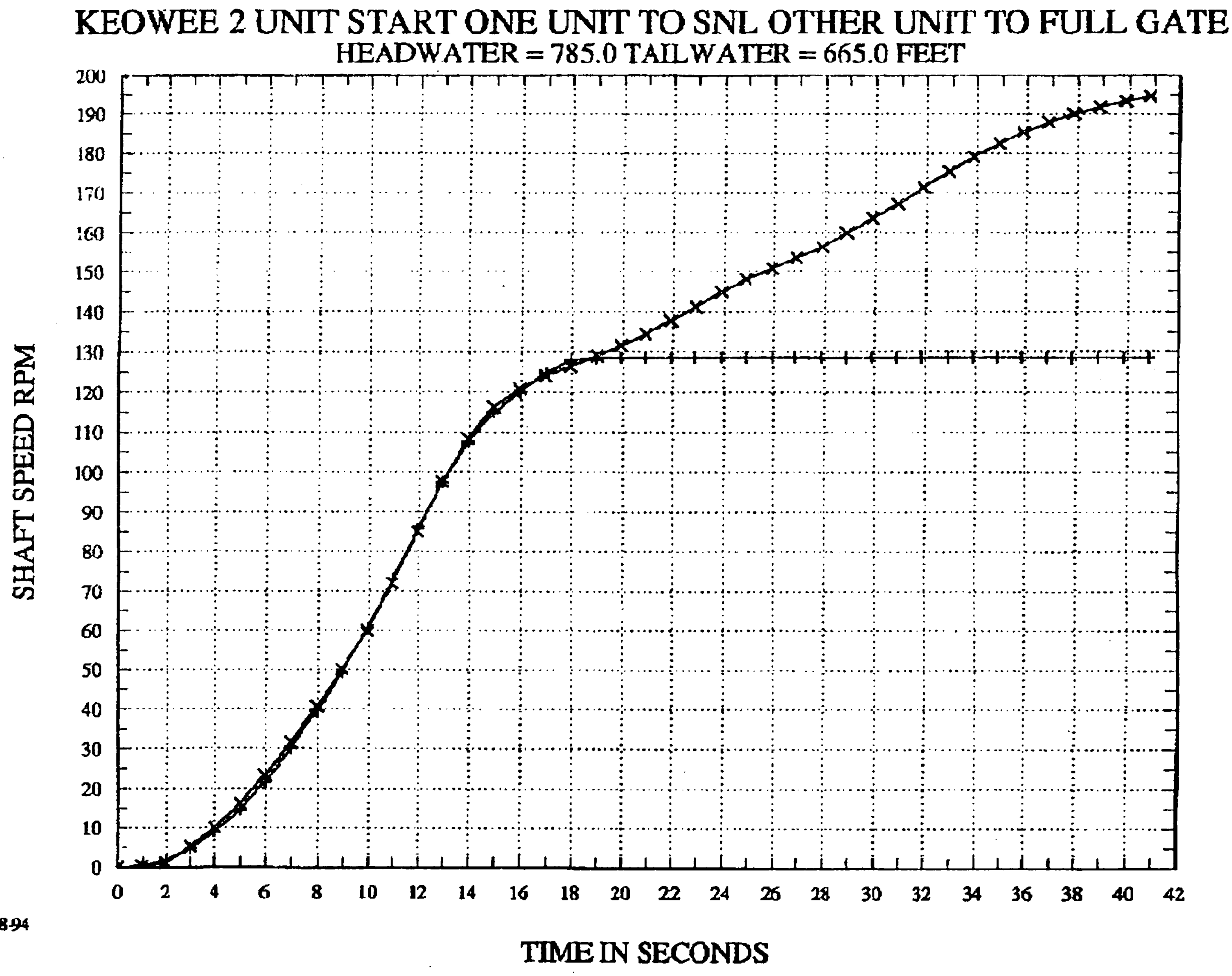
Hello John:

Enclosed is the transient simulation output for a 2 unit start while subject to a headwater elevation of 785.0 feet and a tailwater elevation of 665.0 feet. The one unit goes to synchronous speed while the other unit opens to 100 percent opening. The second unit was controlled by the speed switch settings at 52 and 122 RPM. The unit went from 0 to 48.8% gate servomotor stroke then from 48.8% to 28% to 100% position. The opening rate was set at 5.33% per second and the closing rate was 4.05% per second.

Regards,

Michael Byrne

Michael Byrne


KEOWEE 2 UNIT START ONE UNIT TO SNL OTHER UNIT TO FULL GATE
HEADWATER = 785.0 TAILWATER = 665.0 FEET
SHAFT SPEED RPM
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
TIME IN SECONDS
06-28-94

Attachment # 6

Form 1021

DUKE POWER COMPANY

TELEPHONE CONVERSATION REPORT

PROJECT Keowee FILE NO.

SUBJECT Lake Hartwell Operating Levels

PERSON CALLED Alvin Christrian Power Systems Operator Operations Center U. S. ARMY Corp Engineers @ Lake Hartwell

DATE 7/11/94 TIME

PERSON CALLING John Beckman

SPECIFICATION NUMBER

SUBJECT DISCUSSED Normal + Full pond Lake Levels For Lake Hartwell

RECOMMENDATION OR RESOLUTION Normal Full pond for Lake Hartwell is different ~~for~~ Than Keowee. Lake Hartwell is Full Pond at elev. 660' but maintains a 5 Foot surge or Flood Pool. The "Top of The Flood gates is 665'. Lake Hartwell should never go above This Level. The Flood gates would be used To maintain The Level at or below 665' if necessary

SIGNED: John R. Beckman

Attachment #7

Keowee Unit 2 Emergency Start 5/22/93

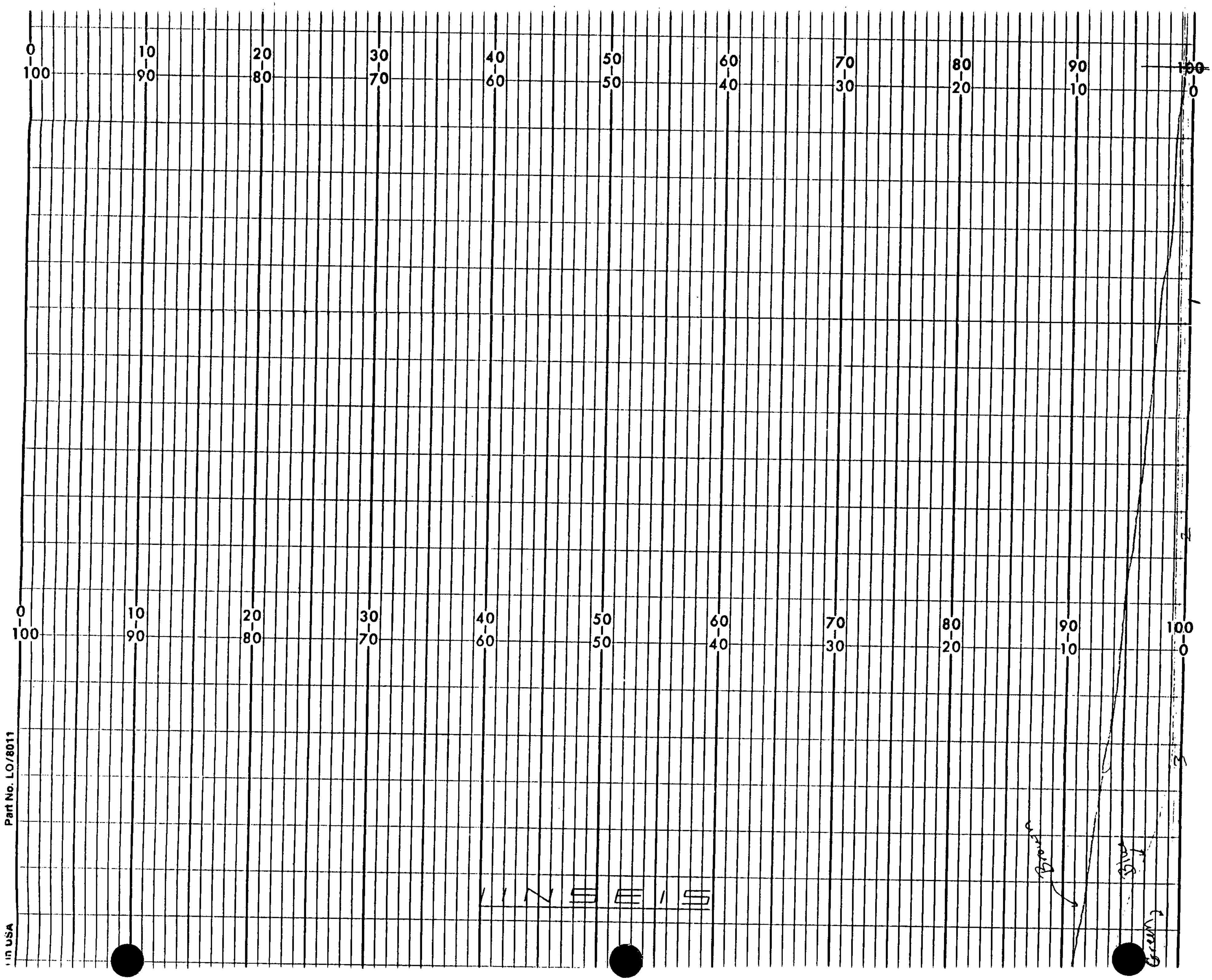
PT/0/A/0610/22
From Keowee Log
5/22/93
Keowee L/L 799.21'
Gross Head 138.23'
(Not Running)
JBB

0	10	20	30	40	50	60	70	80	90	100
100	90	80	70	60	50	40	30	20	10	0

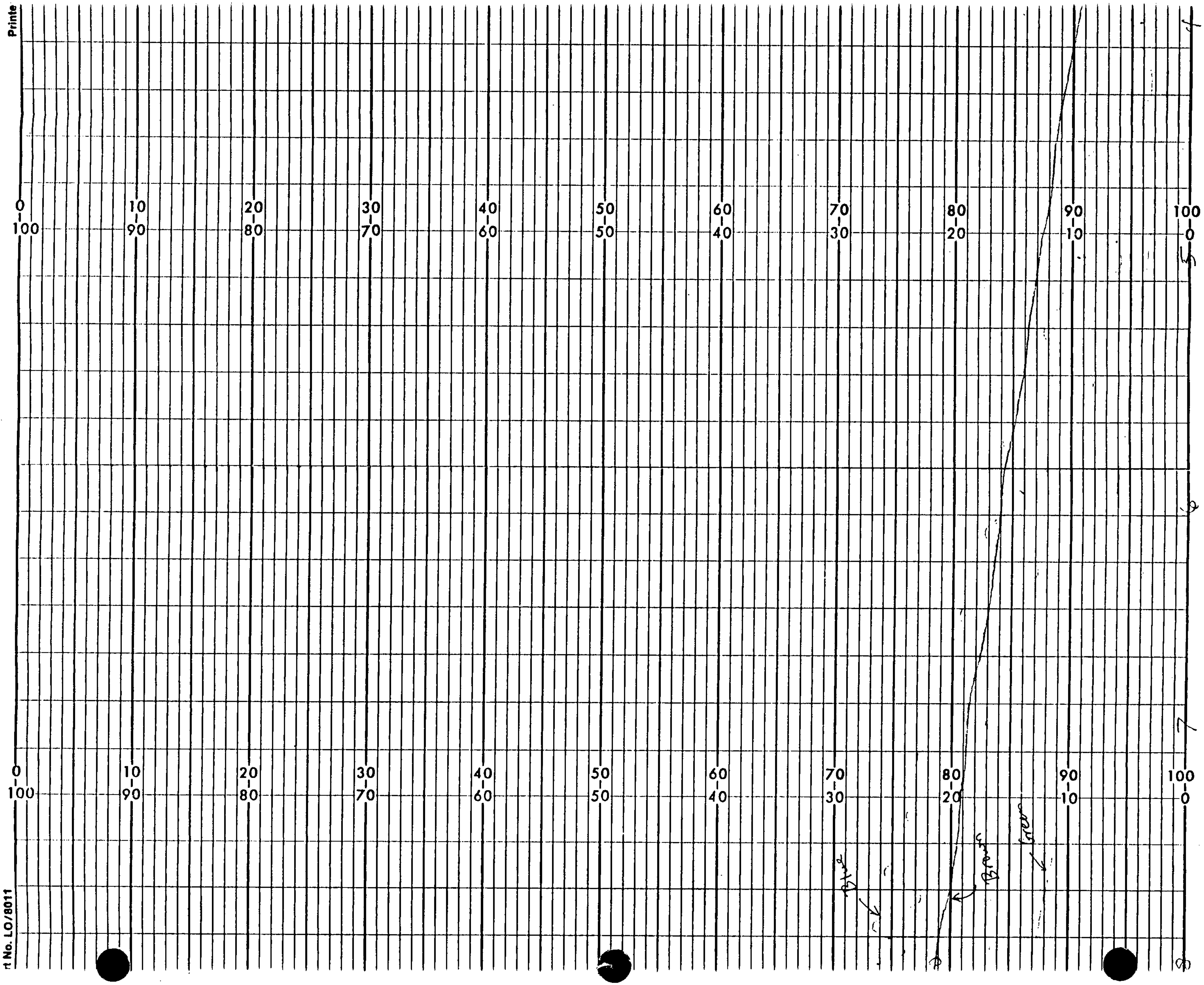
Blue = Speed (1.77 RPM/div)
Green = Gen. Voltage (2.5 V/div) (373V/div)
Brown = Gate Position (2%/div)
300 cm/min (5 cm/sec)

LINSEIS

Printed in USA
Part No. LO/8011


0 10 20 30 40 50 60 70 80 90 100
100 90 80 70 60 50 40 30 20 10 0
LINSEIS
Part No. LO/8011
in USA
Brown
Blue
Green

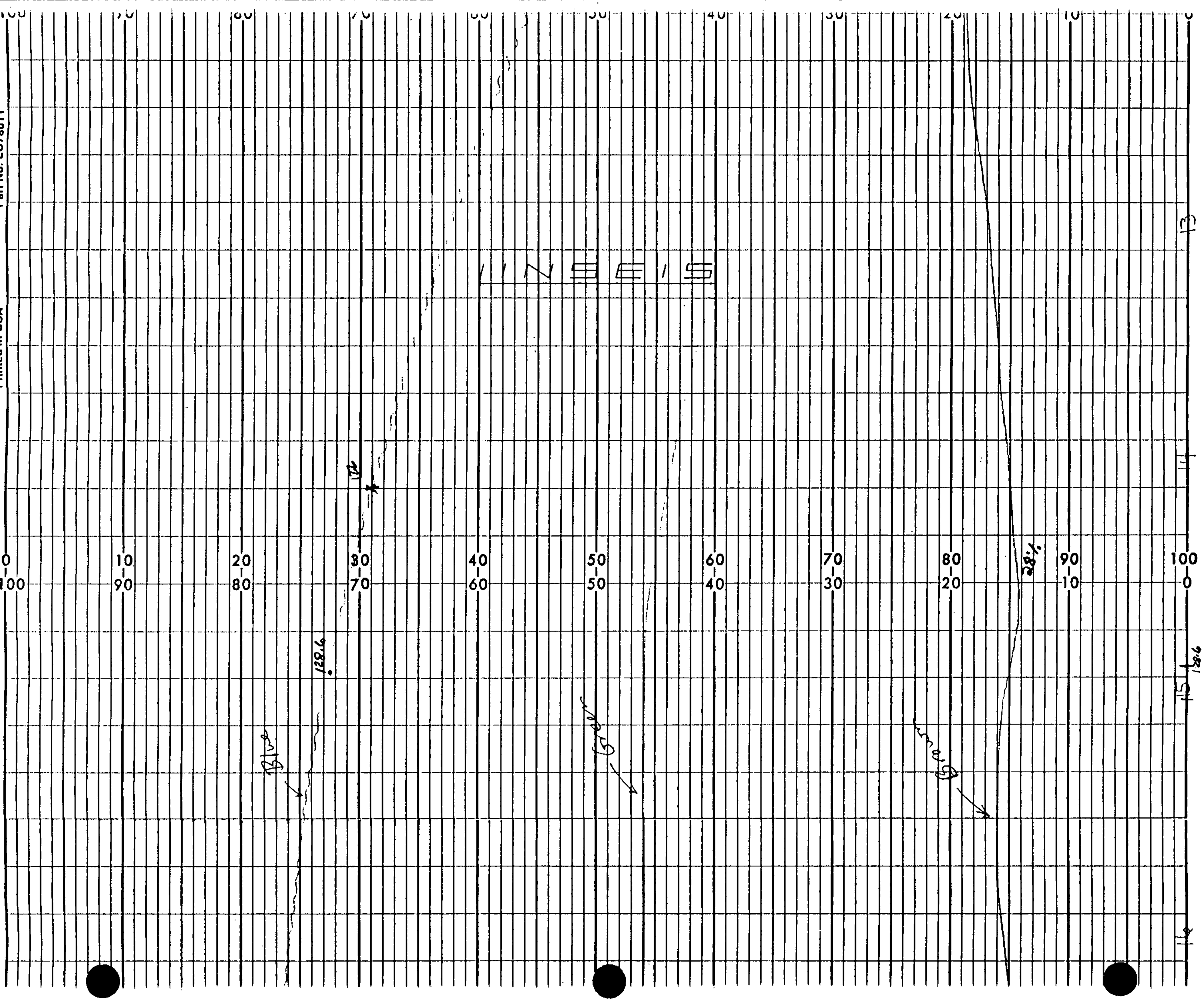
Printe

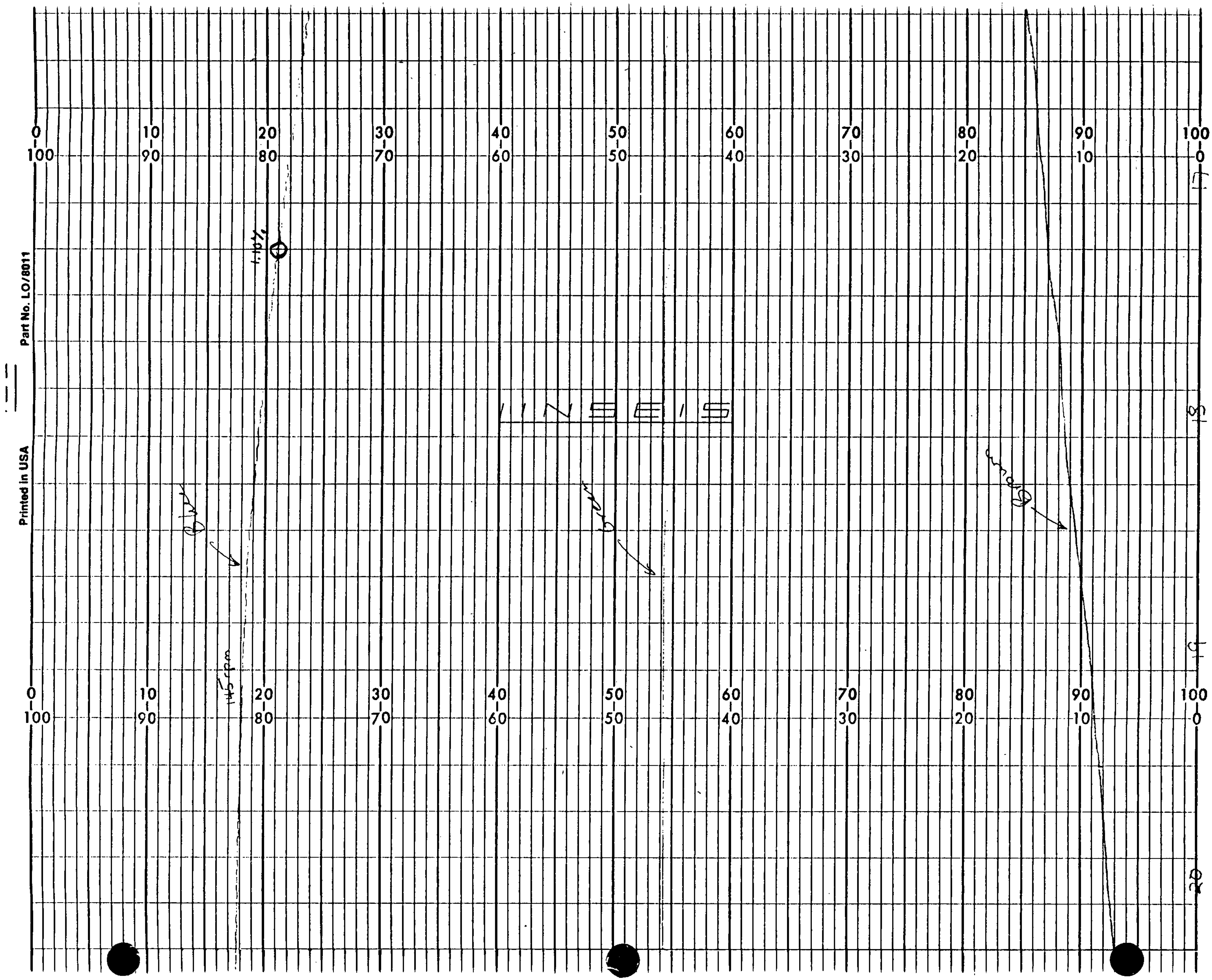


rt No. LO/8011

Printed in USA
LINSEIS
50rpm
50%
8.18 KV
84rpm
Blue
Green
Brown

Printed in USA Part No. LO/8011

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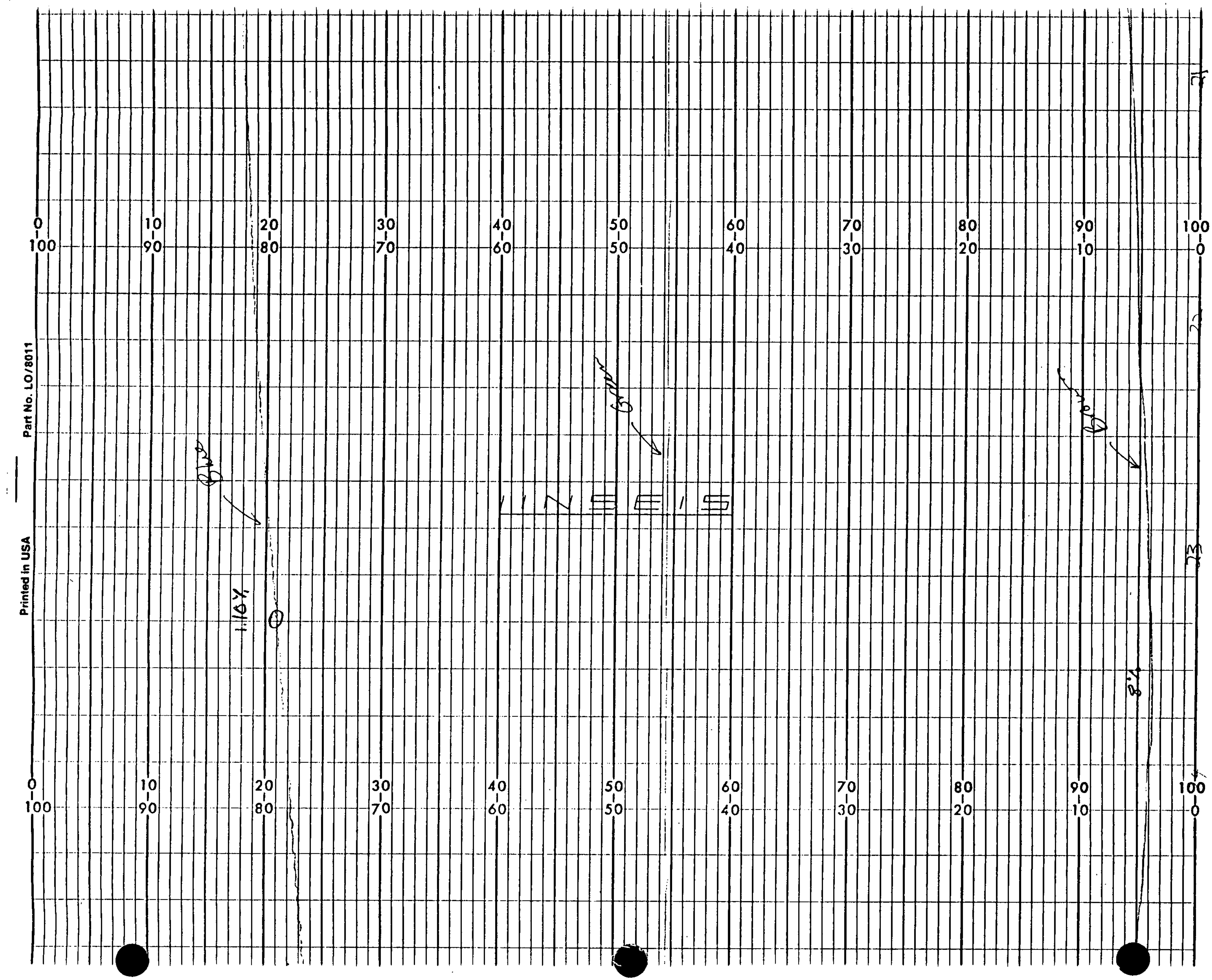
Part No. LO/8011
Printed in USA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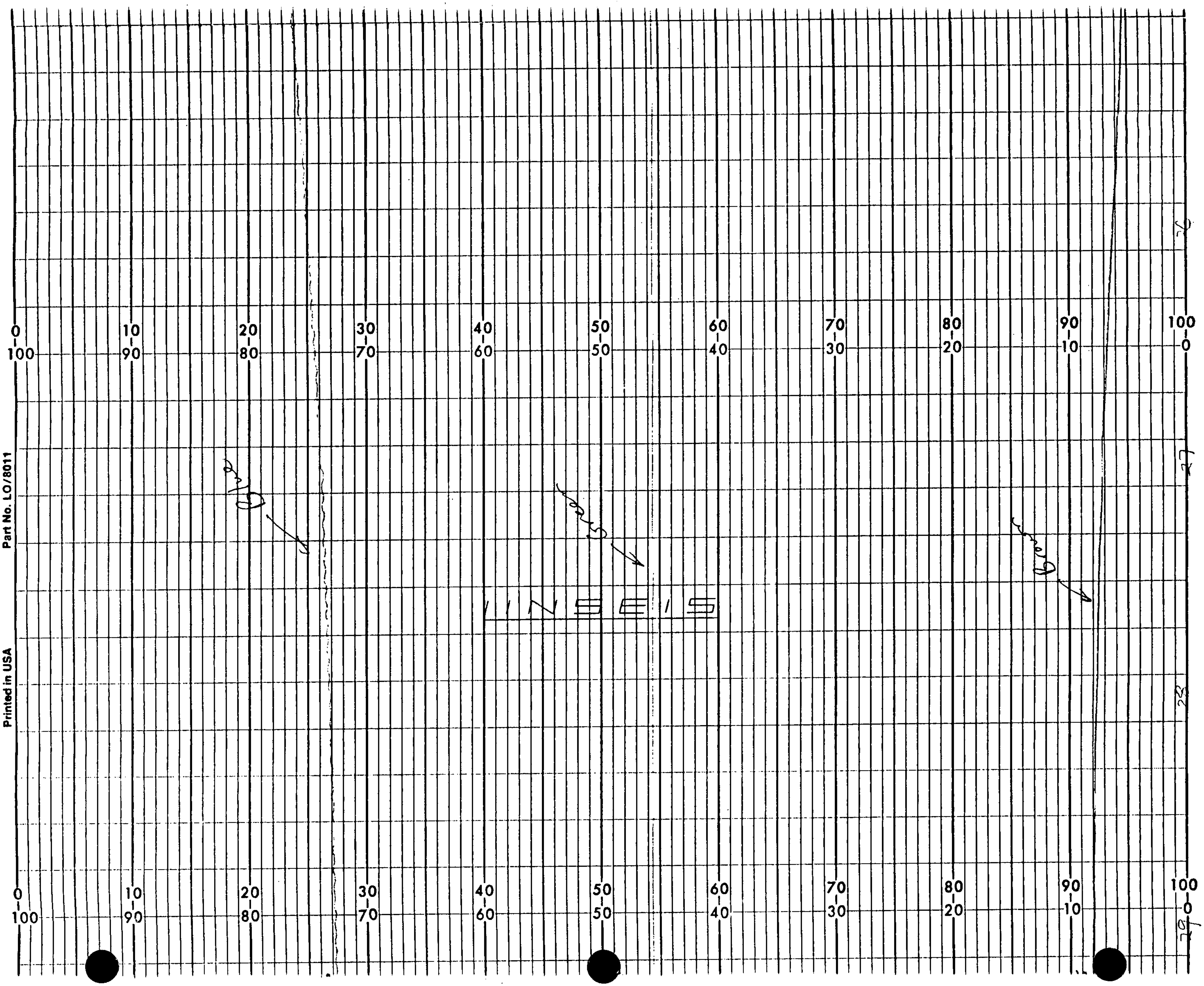
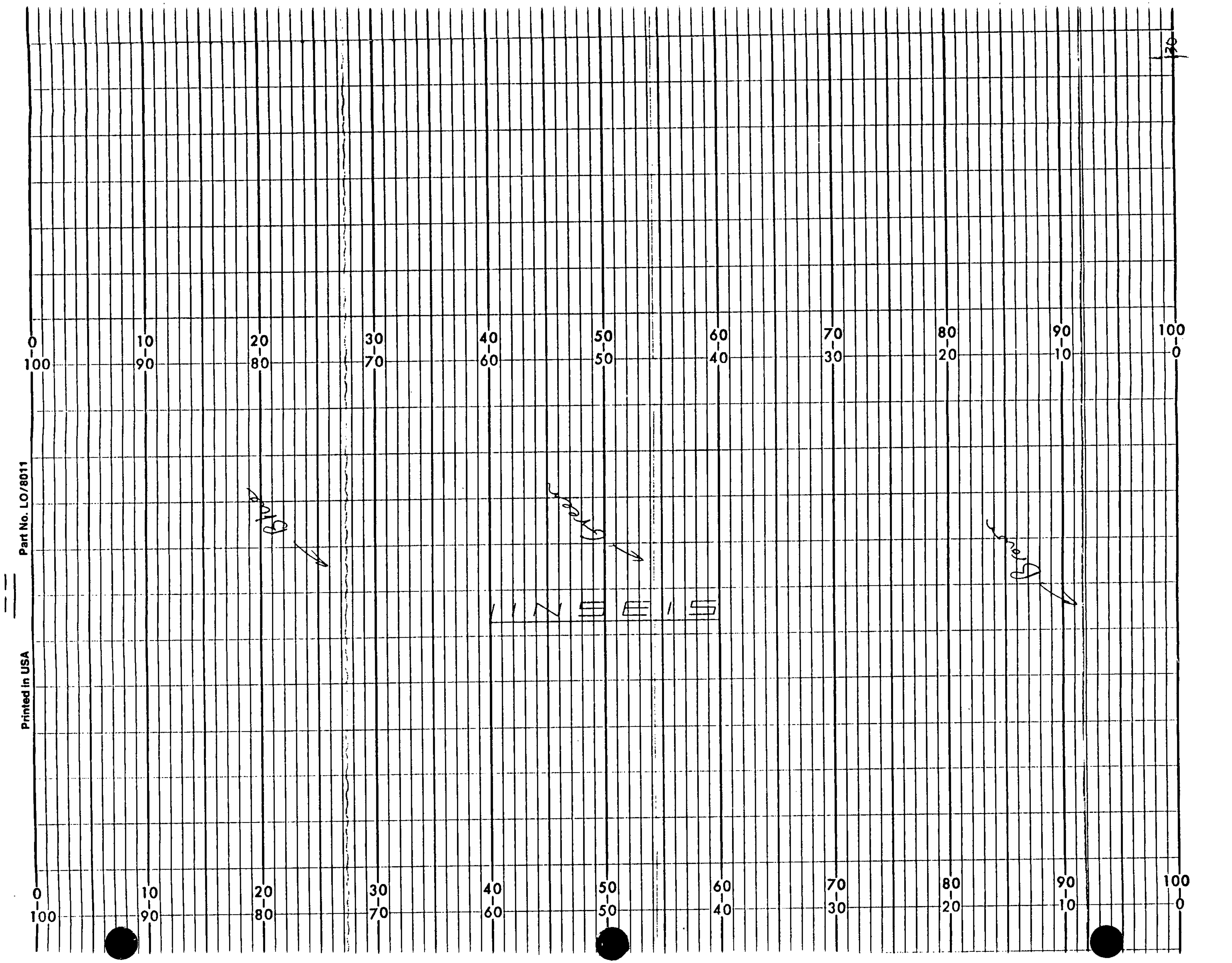
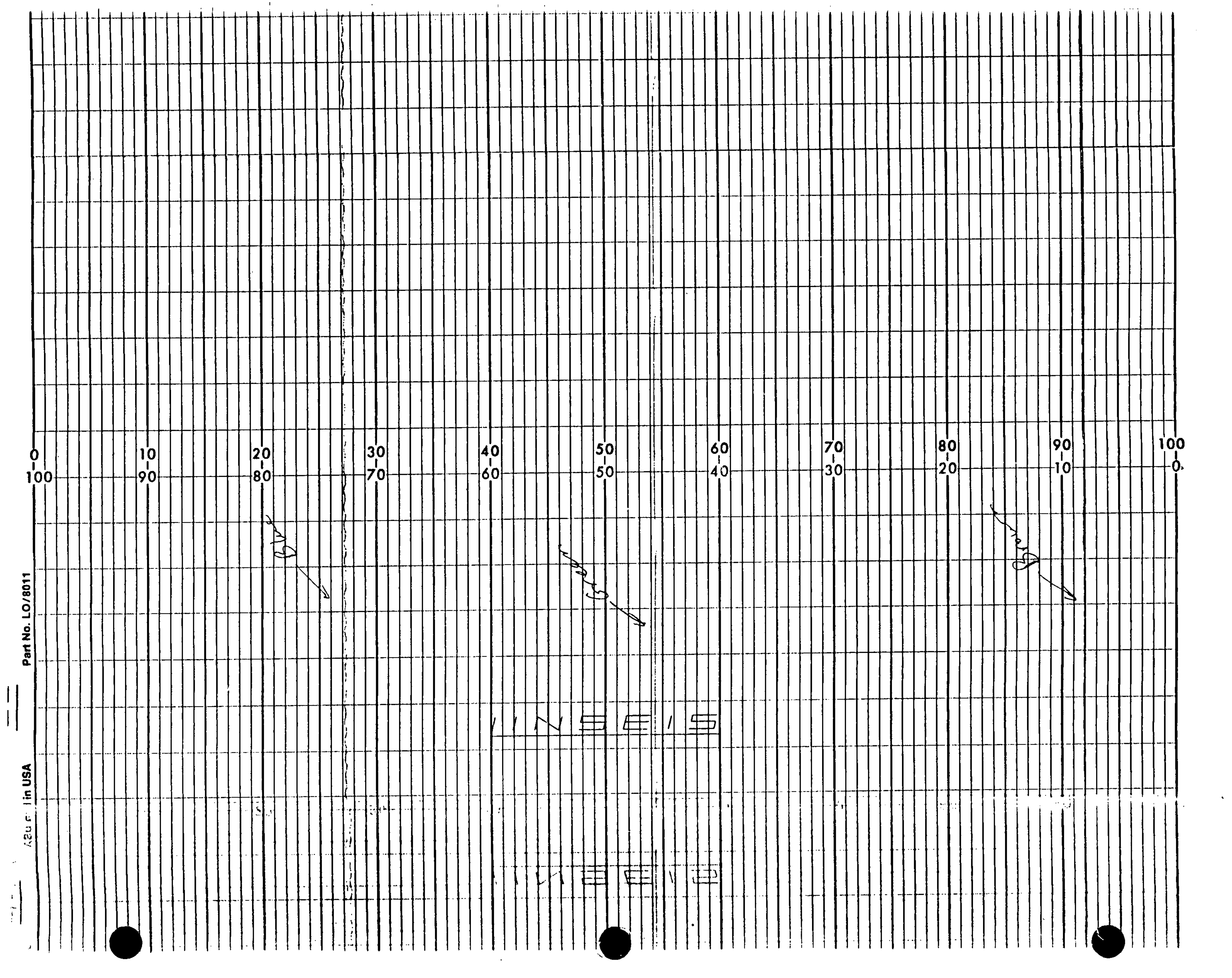
Printed in USA
LINSEIS
0 10 20 30 40 50 60 70 80 90 100
100 90 80 70 60 50 40 30 20 10 0

Printed in USA Part No. LO/8011



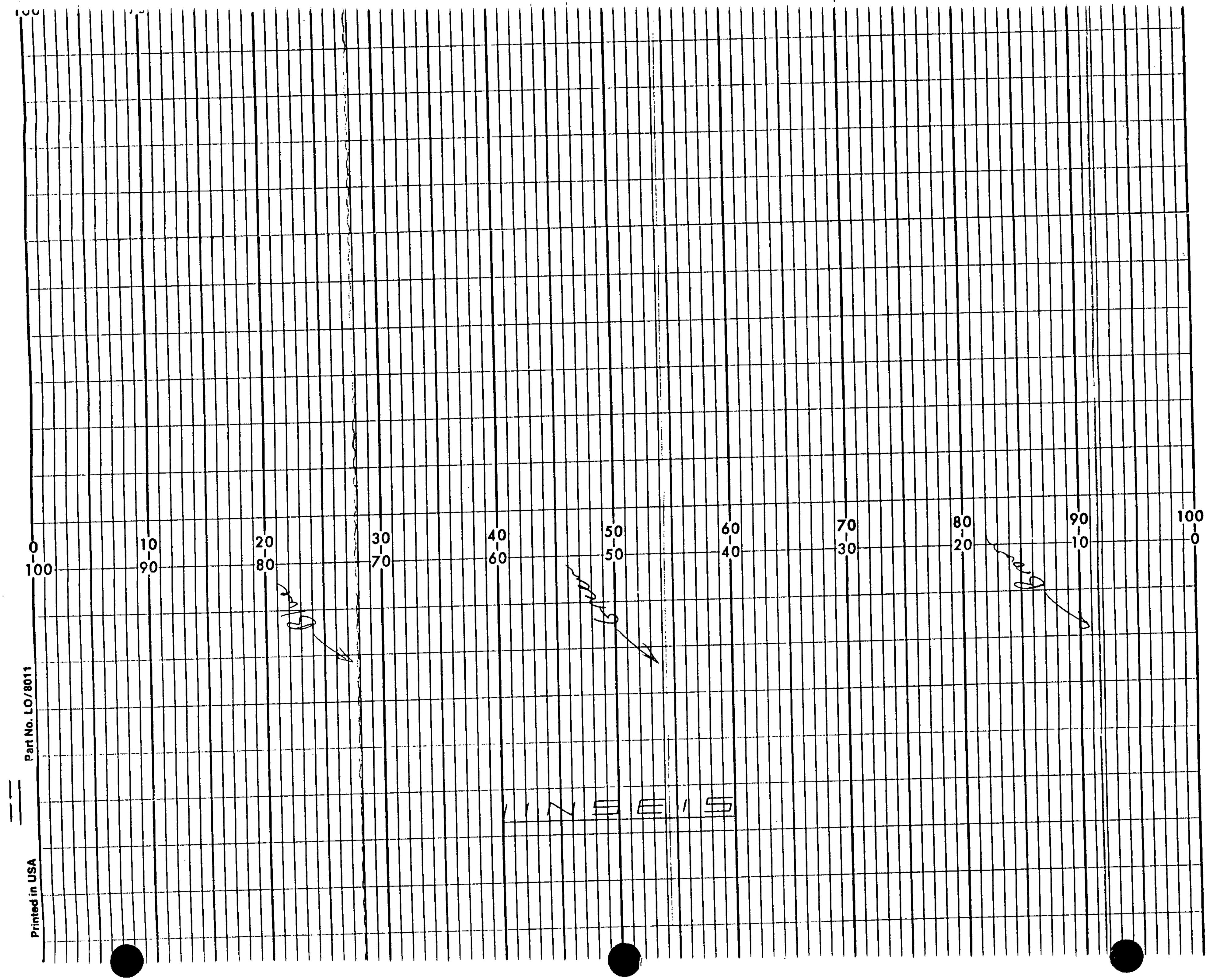


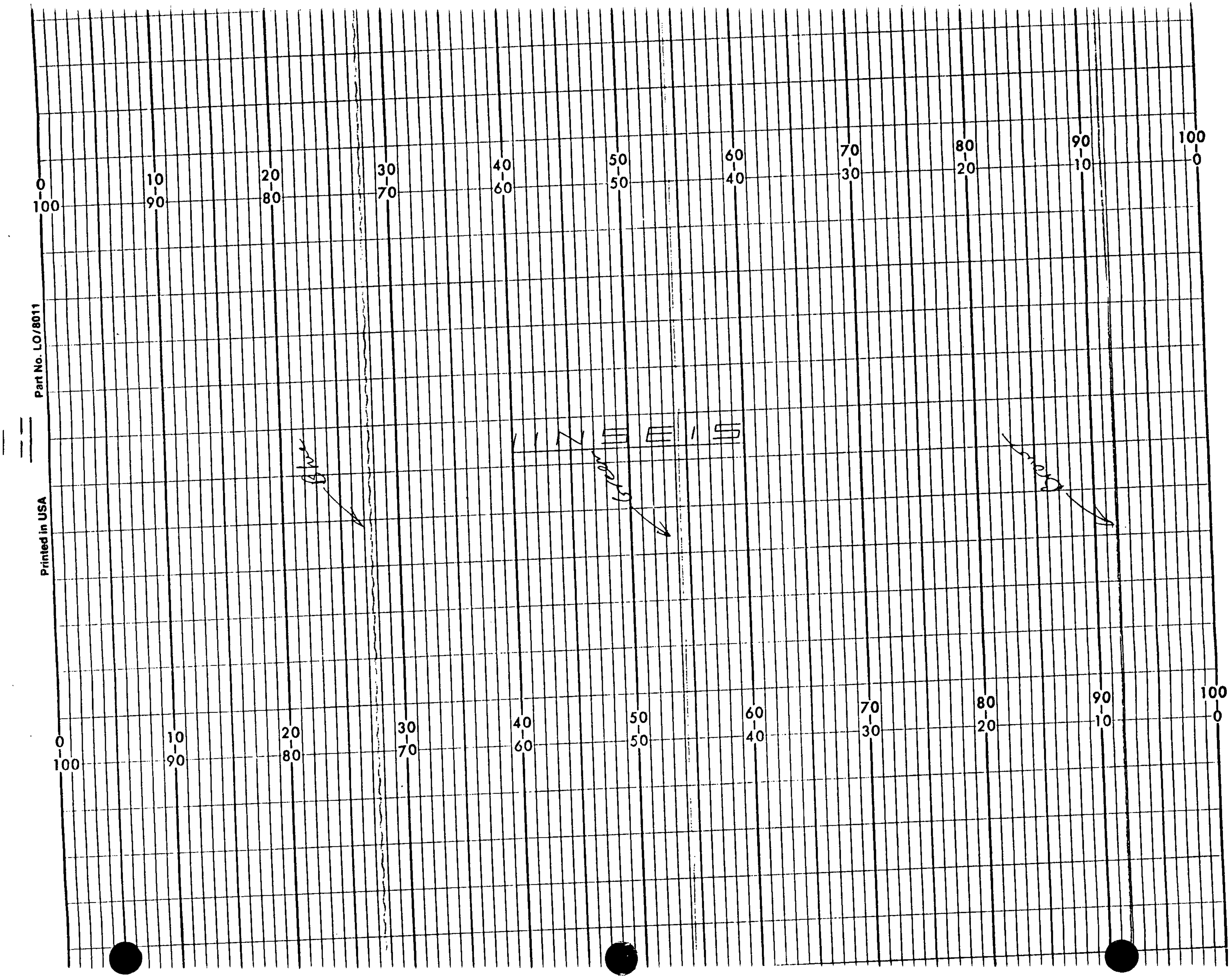
130


0 10 20 30 40 50 60 70 80 90 100
100 90 80 70 60 50 40 30 20 10 0
Part No. LO/8011
in USA
LINSEIS

0 10 20 30 40 50 60 70 80 90 100

100 90 80 70 60 50 40 30 20 10 0


0
100
10
90
20
80
30
70
40
60
50
50
60
40
70
30
80
20
90
10
100
0
LINSEIS
Part No. LO/8011
Printed in USA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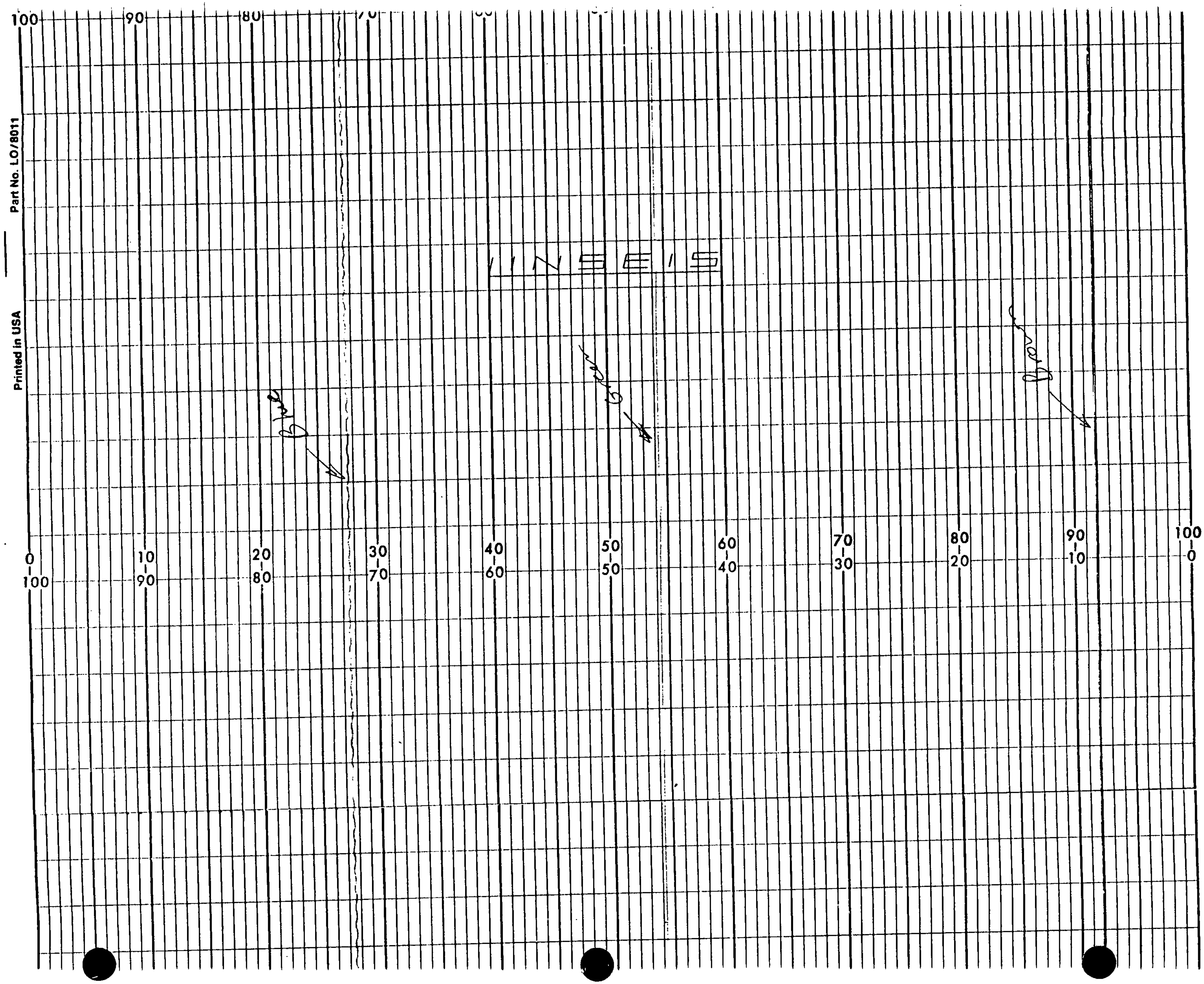
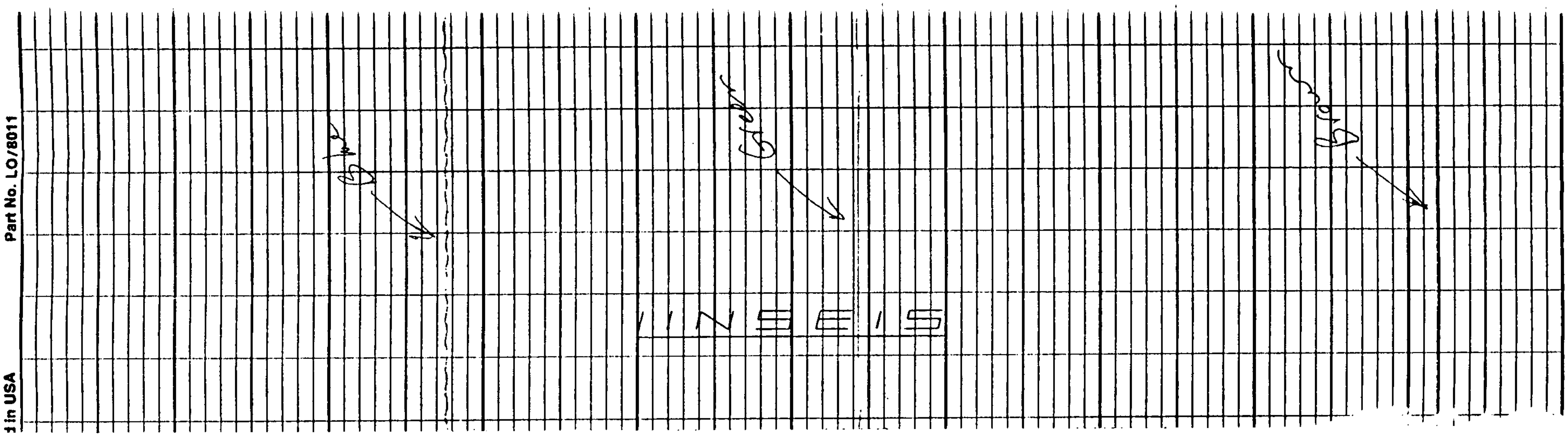
Printed in USA


Part No. LO/8011
Printed in USA
LINSEIS
100 90 80 70
0 10 20 30 40 50 60 70 80 90 100
100 90 80 70 60 50 40 30 20 10 0

Part No. LO/8011

d in USA



Time Seconds	Rotating Speed of the Turbine and Generator in RPM Case 6	Case 7	Case 8	Case 9	Case 10	Case 11	Case 11A
0.0	128.6	128.6	128.6	128.6	128.6	128.6	128.6
0.996	136.84	138.15	139.57	136.84	140.76	138.09	138.26
1.992	144.79	147.18	149.81	144.56	151.70	147.16	147.47
2.988	151.49	154.95	159.09	150.77	161.12	155.19	155.75
3.984	156.27	160.86	166.80	154.93	168.96	161.56	162.38
4.980	159.21	164.58	172.51	157.24	175.26	165.99	167.07
5.976	160.68	166.60	176.21	158.32	179.76	168.45	169.70
6.973	160.61	167.41	177.96	158.21	182.38	169.54	170.86
7.969	159.16	166.87	178.53	156.83	183.39	169.78	171.22
8.965	156.49	164.96	178.40	154.34	183.16	168.66	170.31
9.961	152.90	161.89	176.96	150.97	182.34	166.29	168.10
10.957	149.00	157.92	174.25	147.22	181.19	162.86	164.80
11.953	145.02	153.68	170.47	143.39	179.04	158.67	160.61
12.949	140.95	149.37	165.87	139.48	175.86	154.27	156.15
13.945	136.79	145.00	161.04		171.78	149.82	151.65
14.941		140.57	156.20		167.01	145.34	147.12
15.938		136.08	151.34		162.04	140.82	142.55
16.933			146.47		157.09	136.26	137.95
17.930			141.58		152.17		
18.926			136.68		147.25		
19.922					142.35		
20.918					137.43		

During each transient condition simulated the breaker opens at time 0.0 seconds, there is a 0.5 second delay before wicket gate closing motion is started. The nominal wicket gate closure time of 24.7 seconds and a slow closure of 6.8 seconds from 11 percent to zero percent servomotor stroke were used. The cases simulated the following transient conditions based on your faxes of February 24 and March 6, 1995:

Case Number	Headwater Elev. (ft)	Tailwater Elev. (ft)	Generator Output (MW)
1	799.87	663.45	60
2	799.9	663.6	75
2A	799.9	663.6	76.8
3	799.85	664.25	90
4	799.85	663.02	60
5	799.82	663.13	75
5A	799.82	663.13	76.8
6	799.83	666.65	60 (U1&U2)
7	799.58	667.51	70 (U1&U2)
8	799.72	668.1	80.4 (U1&U2)
9	799.44	670.4	60
10	799.44	671.7	90
11	799.56	672.5	69.6 (Unit 1)
11A	799.56	672.5	70.8 (Unit 2)

The transient simulation as it is presently configured does not have any performance difference between unit 1 and 2. The transient simulation results for case 6 and 7 produce the same speed rise curve for unit 1 and 2. I'm still in California and

will be here probably the rest of this week. I can be reached at (909)886-5028 or 886-2514(fax).

Regards

Michael Byrne

Unit	1					
Initial Power	60					
Head Water Level	799.87					
Tailrace Level	663.45			Trip Sig		
				Input		Output
Time	RPM		Gov. Gate Timing	Voltage	% GAte	Voltage
8.692	129.075		FEB 23 13:55:17.006499	18.5	41.47501983	52.3
9.186	129.125		FEB 23 13:55:17.506749	18.5	41.47501983	52.3
9.68	129.383		FEB 23 13:55:18.006999	18.5	41.55432197	52.4
10.12	129.378		FEB 23 13:55:18.507249	126.9	41.21355398	52.3
10.614	129.036		FEB 23 13:55:19.007499	126.8	40.45741325	51.3
11.108	128.997		FEB 23 13:55:19.507749	126.9	38.37667455	48.7
11.548	129.183		FEB 23 13:55:20.007999	126.8	36.04100946	45.7
12.097	130.758		FEB 23 13:55:20.508249	126.9	34.04255319	43.2
12.591	135.02		FEB 23 13:55:21.008499	126.8	31.78233438	40.3
13.086	139.469		FEB 23 13:55:21.508749	126.8	29.49526814	37.4
13.525	143.411		FEB 23 13:55:22.008999	126.9	27.81717888	35.3
14.019	147.25		FEB 23 13:55:22.509249	126.8	27.20820189	34.5
14.514	150.922		FEB 23 13:55:23.009499	126.8	23.42271293	29.7
15.008	154.291		FEB 23 13:55:23.509749	126.9	21.9070134	27.8
15.447	156.939		FEB 23 13:55:24.009999	126.9	19.5429472	24.8
15.997	159.225		FEB 23 13:55:24.510249	126.8	17.42902208	22.1
16.491	161.064		FEB 23 13:55:25.010499	126.9	15.44523247	19.6
16.985	162.817		FEB 23 13:55:25.510749	126.9	13.86918834	17.6
17.425	164.091		FEB 23 13:55:26.010999	126.9	12.214342	15.5
17.919	165.137		FEB 23 13:55:26.511249	126.9	10.24428684	13
18.413	165.764		FEB 23 13:55:27.011499	126.8	8.438485804	10.7
18.908	165.661		FEB 23 13:55:27.511749	126.8	7.255520505	9.2
19.347	165.434		FEB 23 13:55:28.011999	126.9	6.619385343	8.4
19.896	164.845		FEB 23 13:55:28.512249	126.8	5.914826498	7.5
20.391	164.003		FEB 23 13:55:29.012499	126.9	5.437352246	6.9
20.83	162.877		FEB 23 13:55:29.512749	126.9	5.279747833	6.7
21.324	161.502		FEB 23 13:55:30.012999	126.8	4.495268139	5.7
21.819	159.95		FEB 23 13:55:30.513249	126.9	2.915681639	3.7
22.313	158.298		FEB 23 13:55:31.013499	126.8	1.971608833	2.5
22.752	156.42		FEB 23 13:55:31.513749	126.8	1.340694006	1.7
23.247	154.656		FEB 23 13:55:32.013998	126.8	0.867507886	1.1
23.796	152.606		FEB 23 13:55:32.514248	126.8	0.70977918	0.9
24.29	150.488		FEB 23 13:55:33.014498	126.9	1.33963751	1.7
24.73	149.258		FEB 23 13:55:33.514748	126.8	4.100946372	5.2
25.224	146.678		FEB 23 13:55:34.014998	126.8	5.678233438	7.2
25.718	144.417		FEB 23 13:55:34.515248	126.8	7.176656151	9.1
26.158	142.308		FEB 23 13:55:35.015498	126.8	9.936908517	12.6
26.652	140.259		FEB 23 13:55:35.515748	126.8	12.53943218	15.9
27.146	137.944		FEB 23 13:55:36.015998	126.9	14.81481481	18.8
27.696	135.691		FEB 23 13:55:36.516248	126.9	16.07565012	20.4
28.135	133.898		FEB 23 13:55:37.016498	126.9	16.78486998	21.3

Time	RPM		Gov. Gate Timing	Voltage	% GAte	Voltage
28.629	132.266		FEB 23 13:55:37.516748	126.9	16.86367218	21.4
29.179	131.108		FEB 23 13:55:38.016998	126.9	16.94247439	21.5
29.673	130.086		FEB 23 13:55:38.517248	126.8	16.95583596	21.5
30.112	129.558		FEB 23 13:55:39.017498	126.9	16.86367218	21.4
30.607	128.831		FEB 23 13:55:39.517748	126.9	15.99684791	20.3
31.101	129.184		FEB 23 13:55:40.017998	126.9	15.28762805	19.4
31.595	129.486		FEB 23 13:55:40.518248	126.9	14.89361702	18.9
32.09	129.919		FEB 23 13:55:41.018498	126.9	14.5784082	18.5
32.584	130.525		FEB 23 13:55:41.518748	126.9	14.18439716	18
33.023	131.172		FEB 23 13:55:42.018998	126.9	13.94799054	17.7
			FEB 23 13:55:42.519248	126.7	13.89108129	17.6
			FEB 23 13:55:43.019498	126.7	13.89108129	17.6
			FEB 23 13:55:43.519748	126.7	13.89108129	17.6
			FEB 23 13:55:44.019998	126.7	13.89108129	17.6
			FEB 23 13:55:44.520248	126.6	13.90205371	17.6
			FEB 23 13:55:45.020498	126.5	13.91304348	17.6
			FEB 23 13:55:45.520748	126.6	13.90205371	17.6
			FEB 23 13:55:46.020998	126.5	13.91304348	17.6
			FEB 23 13:55:46.521248	126.5	13.91304348	17.6
			FEB 23 13:55:47.021498	126.5	13.91304348	17.6
			FEB 23 13:55:47.521748	126.5	13.91304348	17.6
			FEB 23 13:55:48.021998	126.5	14.15019763	17.9
			FEB 23 13:55:48.522248	126.5	14.22924901	18
			FEB 23 13:55:49.022498	126.5	14.22924901	18

Unit	1				
Initial Power	75MW				
Head Water Level	799.9				
Tailrace Level	663.6				
Time	RPM				
7.804	129.137				
8.244	129.253				
8.74	128.945				
9.232	129.152				
9.672	129.395				
10.168	129.439				
10.66	129.13				
11.212	130.866				
11.65	136.317				
12.144	141.244				
12.64	146.653				
13.132	151.506				
13.572	155.53				
14.068	159.637				
14.56	163.369				
15.11	166.422				
15.55	168.687				
16.044	170.669				
16.538	172.719				
16.978	174.756				
17.472	175.75				
17.966	176.391				
18.46	176.283				
18.956	176.947				
19.448	176.283				
19.944	175.861				
20.438	175.531				
20.876	174.036				
21.372	172.784				
21.866	171.57				
22.36	169.848				
22.856	167.894				
23.348	165.816				
23.844	163.561				
24.284	161.02				
24.776	158.886				
25.272	156.512				
25.766	154.005				
26.204	151.786				
26.754	149.305				
27.248	147.064				

Time	RPM				
27.744	144.358				
28.182	141.669				
28.676	139.533				
29.172	137.094				
29.664	135.208				
30.104	133.505				
30.654	132.18				
31.148	130.784				
31.644	129.783				
32.082	129.319				
32.632	128.825				
33.126	128.902				
33.564	128.825				
34.06	129.503				
34.554	130.242				
35.048	130.992				
35.542	131.717				
36.036	132.422				
36.532	132.981				
36.97	133.389				
37.464	133.373				
37.96	133.406				
38.452	133.348				
-18040	0				
-18040	0				
-18040	0				
-18040	0				
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-18040	0				

Unit	1					
Initial Power	90					
Head Water Level	799.85					
Tailrace Level	664.25			Trip Sig		
				Input		Output
Time	RPM		Gov. Gate Timing	Voltage	% GAte	Voltage
6.678	129.244		FEB 23 03:54:00.518829	19	56.85963521	71.7
7.172	129.355		FEB 23 03:54:01.019162	19.1	56.93893735	71.8
7.668	129.433		FEB 23 03:54:01.519495	19	56.93893735	71.8
8.16	134.189		FEB 23 03:54:02.019828	19	56.85963521	71.7
8.6	140.923		FEB 23 03:54:02.520161	19.1	56.93893735	71.8
9.096	146.756		FEB 23 03:54:03.020494	127	56.45669291	71.7
9.588	152.503		FEB 23 03:54:03.520827	126.9	56.50118203	71.7
10.084	158.123		FEB 23 03:54:04.021160	127	54.01574803	68.6
10.524	162.556		FEB 23 03:54:04.521493	126.9	51.61544523	65.5
11.072	166.988		FEB 23 03:54:05.021826	127	49.21259843	62.5
11.568	170.681		FEB 23 03:54:05.522158	127	46.92913386	59.6
12.06	174.239		FEB 23 03:54:06.022491	126.9	44.52324665	56.5
12.5	176.692		FEB 23 03:54:06.522824	126.9	42.00157604	53.3
12.996	178.937		FEB 23 03:54:07.023157	126.9	40.11032309	50.9
13.488	180.731		FEB 23 03:54:07.523490	126.9	37.98266351	48.2
13.984	182.491		FEB 23 03:54:08.023823	127	36.06299213	45.8
14.424	183.756		FEB 23 03:54:08.524156	126.9	33.56973995	42.6
14.972	184.516		FEB 23 03:54:09.024489	127	31.18110236	39.6
15.466	184.881		FEB 23 03:54:09.524822	126.9	29.07801418	36.9
15.96	185.102		FEB 23 03:54:10.025155	126.9	27.81717888	35.3
16.4	185.427		FEB 23 03:54:10.525488	126.8	25.70977918	32.6
16.894	184.958		FEB 23 03:54:11.025821	126.8	23.10725552	29.3
17.388	184.272		FEB 23 03:54:11.526154	126.8	21.60883281	27.4
17.884	183.548		FEB 23 03:54:12.026487	126.8	19.32176656	24.5
18.322	182.552		FEB 23 03:54:12.526820	126.7	16.96921863	21.5
18.816	181.152		FEB 23 03:54:13.027153	126.6	15.24486572	19.3
19.366	179.869		FEB 23 03:54:13.527486	126.6	13.66508689	17.3
19.804	178.178		FEB 23 03:54:14.027819	126.6	11.76935229	14.9
20.3	176.242		FEB 23 03:54:14.528152	126.6	10.11058452	12.8
20.794	174.266		FEB 23 03:54:15.028485	126.6	7.898894155	10
21.288	171.964		FEB 23 03:54:15.528818	126.6	7.266982622	9.2
21.728	169.75		FEB 23 03:54:16.029150	126.6	6.556082148	8.3
22.222	167.192		FEB 23 03:54:16.529483	126.6	5.924170616	7.5
22.716	164.819		FEB 23 03:54:17.029816	126.7	5.44593528	6.9
23.266	162.684		FEB 23 03:54:17.530149	126.6	5.292259084	6.7
23.704	160.45		FEB 23 03:54:18.030482	126.6	4.502369668	5.7
24.2	157.753		FEB 23 03:54:18.530815	126.6	2.922590837	3.7
24.694	155.375		FEB 23 03:54:19.031148	126.6	1.974723539	2.5
25.132	153.05		FEB 23 03:54:19.531481	126.6	1.342812006	1.7
25.628	150.752		FEB 23 03:54:20.031814	126.6	0.789889415	1
26.122	148.006		FEB 23 03:54:20.532147	126.6	0.473933649	0.6

Time	RPM		Gov. Gate Timing	Voltage	% GAte	Voltage
26.616	145.133		FEB 23 03:54:21.032480	126.6	0	0
27.11	142.552		FEB 23 03:54:21.532813	126.6	0	0
27.604	140.317		FEB 23 03:54:22.033146	126.6	0	0
28.1	137.922		FEB 23 03:54:22.533479	126.6	0.078988942	0.1
28.592	135.333		FEB 23 03:54:23.033812	126.6	1.342812006	1.7
29.032	133.805		FEB 23 03:54:23.534145	126.6	4.107424961	5.2
29.528	132.197		FEB 23 03:54:24.034478	126.6	5.845181675	7.4
30.02	130.753		FEB 23 03:54:24.534811	126.6	7.266982622	9.2
30.516	129.661		FEB 23 03:54:25.035144	126.7	9.944751381	12.6
31.01	129.111		FEB 23 03:54:25.535477	126.6	12.63823065	16
			FEB 23 03:54:26.035809	126.7	14.91712707	18.9
			FEB 23 03:54:26.536142	126.7	17.28492502	21.9
			FEB 23 03:54:27.036475	126.7	19.33701657	24.5
			FEB 23 03:54:27.536808	126.7	20.44198895	25.9
			FEB 23 03:54:28.037141	126.6	20.5371248	26
			FEB 23 03:54:28.537474	126.7	20.28413575	25.7
			FEB 23 03:54:29.037807	126.6	19.66824645	24.9
			FEB 23 03:54:29.538140	126.6	18.2464455	23.1
			FEB 23 03:54:30.038473	126.7	17.20599842	21.8
			FEB 23 03:54:30.538806	126.7	16.10102605	20.4
			FEB 23 03:54:31.039139	126.7	15.15390687	19.2
			FEB 23 03:54:31.539472	126.6	14.61295419	18.5
			FEB 23 03:54:32.039805	126.7	13.97000789	17.7
			FEB 23 03:54:32.540138	126.7	13.89108129	17.6
			FEB 23 03:54:33.040471	126.6	13.74407583	17.4
			FEB 23 03:54:33.540804	126.7	13.7332281	17.4
			FEB 23 03:54:34.041137	126.7	13.7332281	17.4
			FEB 23 03:54:34.541470	126.7	13.8121547	17.5
			FEB 23 03:54:35.041803	126.7	13.7332281	17.4
			FEB 23 03:54:35.542136	126.7	13.7332281	17.4
			FEB 23 03:54:36.042469	126.7	13.97000789	17.7
			FEB 23 03:54:36.542801	126.7	13.97000789	17.7

Unit	2					
Initial Power	60					
Head Water Level	799.85					
Tailrace Level	663.02			Trip Sig		
				Input		Output
Time	RPM		Gov. Gate Timing	Voltage	% GAte	Voltage
4.664	128.461		FEB 23 04:57:00.008339	19	44.80570975	56.5
5.16	128.811		FEB 23 04:57:00.508756	19	44.8850119	56.6
5.708	128.798		FEB 23 04:57:01.009173	19	44.80570975	56.5
6.148	129.212		FEB 23 04:57:01.509590	19	44.8850119	56.6
6.642	132.834		FEB 23 04:57:02.010007	19	44.8850119	56.6
7.136	137.48		FEB 23 04:57:02.510424	19	44.8850119	56.6
7.632	141.919		FEB 23 04:57:03.010841	19	44.8850119	56.6
8.07	145.817		FEB 23 04:57:03.511258	126.8	44.55835962	56.5
8.564	149.356		FEB 23 04:57:04.011675	126.7	43.96211523	55.7
9.06	153.084		FEB 23 04:57:04.512092	126.7	42.30465667	53.6
9.552	155.764		FEB 23 04:57:05.012509	126.7	39.62115233	50.2
10.048	158.267		FEB 23 04:57:05.512926	126.8	37.69716088	47.8
10.542	160.334		FEB 23 04:57:06.013343	126.8	35.6466877	45.2
11.036	162.344		FEB 23 04:57:06.513760	126.7	33.54380426	42.5
11.53	164.25		FEB 23 04:57:07.014260	126.7	31.49171271	39.9
11.97	165.675		FEB 23 04:57:07.514760	126.7	28.96606156	36.7
12.464	166.864		FEB 23 04:57:08.015260	126.8	26.97160883	34.2
12.96	167.178		FEB 23 04:57:08.515760	126.8	24.84227129	31.5
13.452	167.22		FEB 23 04:57:09.016260	126.8	23.02839117	29.2
13.948	166.909		FEB 23 04:57:09.516760	126.8	20.50473186	26
14.442	166.119		FEB 23 04:57:10.017260	126.8	18.76971609	23.8
14.936	165.031		FEB 23 04:57:10.517760	126.8	16.48264984	20.9
15.43	163.769		FEB 23 04:57:11.018260	126.8	15.14195584	19.2
15.87	162.252		FEB 23 04:57:11.518760	126.8	13.09148265	16.6
16.364	160.453		FEB 23 04:57:12.019260	126.8	10.56782334	13.4
16.858	158.619		FEB 23 04:57:12.519760	126.8	9.227129338	11.7
17.352	156.898		FEB 23 04:57:13.020260	126.8	8.123028391	10.3
17.848	155.083		FEB 23 04:57:13.520760	126.8	7.176656151	9.1
18.34	153.178		FEB 23 04:57:14.021260	126.8	6.309148265	8
18.836	151.789		FEB 23 04:57:14.521760	126.8	5.441640379	6.9
19.276	150.03		FEB 23 04:57:15.022260	126.8	4.889589905	6.2
19.768	148.105		FEB 23 04:57:15.522760	126.8	3.627760252	4.6
20.264	145.898		FEB 23 04:57:16.023260	126.7	3.314917127	4.2
20.758	143.677		FEB 23 04:57:16.523760	126.8	2.129337539	2.7
21.252	141.667		FEB 23 04:57:17.024260	126.8	1.498422713	1.9
21.748	139.192		FEB 23 04:57:17.524760	126.8	0.94637224	1.2
22.24	136.855		FEB 23 04:57:18.025259	126.7	0.236779795	0.3
22.736	134.531		FEB 23 04:57:18.525759	126.8	0.23659306	0.3
23.176	132.769		FEB 23 04:57:19.026259	126.8	1.498422713	1.9
23.668	131.192		FEB 23 04:57:19.526759	126.8	3.627760252	4.6
24.164	129.941		FEB 23 04:57:20.027259	126.8	5.678233438	7.2

Time	RPM		Gov. Gate Timing	Voltage	% GAte	Voltage
24.658	129.052		FEB 23 04:57:20.527759	126.8	7.649842271	9.7
25.152	128.83		FEB 23 04:57:21.028259	126.8	9.936908517	12.6
25.646	128.731		FEB 23 04:57:21.528759	123.5	14.41295547	17.8
26.14	128.666		FEB 23 04:57:22.029259	126.6	15.48183254	19.6
26.636	129.239		FEB 23 04:57:22.529759	126.7	15.70639305	19.9
27.074	129.648		FEB 23 04:57:23.030259	126.7	15.86424625	20.1
27.568	129.809		FEB 23 04:57:23.530759	126.6	16.11374408	20.4
28.064	130.345		FEB 23 04:57:24.031259	126.6	16.11374408	20.4
28.556	130.647		FEB 23 04:57:24.531759	126.6	16.11374408	20.4
29.052	130.863		FEB 23 04:57:25.032259	126.5	16.12648221	20.4

Unit	2					
Initial Power	75 MW					
Head Water Level	799.82					
Tailrace Level	663.13			Trip Sig		
				Input		Output
Time	RPM		Gov. Gate Timing	Voltage	% GAte	Voltage
8.324	129.441		FEB 23 05:23:49.510749	19	53.13243458	67
8.82	129.633		FEB 23 05:23:50.010999	19	53.13243458	67
9.312	129.395		FEB 23 05:23:50.511249	19	53.13243458	67
9.752	132.489		FEB 23 05:23:51.011499	19	53.13243458	67
10.248	137.484		FEB 23 05:23:51.511749	19.1	53.05313243	66.9
10.74	142.861		FEB 23 05:23:52.011999	19	53.13243458	67
11.236	148.002		FEB 23 05:23:52.512249	19.1	53.13243458	67
11.73	152.363		FEB 23 05:23:53.012499	19	53.13243458	67
12.224	156.745		FEB 23 05:23:53.512749	19	53.05313243	66.9
12.718	160.467		FEB 23 05:23:54.012999	19.1	53.13243458	67
13.158	163.839		FEB 23 05:23:54.513249	19	53.05313243	66.9
13.652	166.486		FEB 23 05:23:55.013499	126.8	52.76025237	66.9
14.146	168.873		FEB 23 05:23:55.513749	126.9	52.71867612	66.9
14.64	171.114		FEB 23 05:23:56.013998	126.8	50.47318612	64
15.136	172.523		FEB 23 05:23:56.514248	126.8	48.26498423	61.2
15.628	174.177		FEB 23 05:23:57.014498	126.8	46.37223975	58.8
16.124	175.398		FEB 23 05:23:57.514748	123.1	43.94800975	54.1
16.618	176.07		FEB 23 05:23:58.014998	126.6	42.10110585	53.3
17.056	176.236		FEB 23 05:23:58.515248	126.6	39.65244866	50.2
17.552	176.398		FEB 23 05:23:59.015498	126.6	37.51974724	47.5
18.046	176.689		FEB 23 05:23:59.515748	126.6	35.62401264	45.1
18.54	175.966		FEB 23 05:24:00.015998	126.6	33.49131122	42.4
19.036	175.75		FEB 23 05:24:00.516248	126.5	31.38339921	39.7
19.528	174.767		FEB 23 05:24:01.016498	126.5	28.93280632	36.6
20.024	173.209		FEB 23 05:24:01.517332	126.5	26.95652174	34.1
20.464	171.83		FEB 23 05:24:02.018166	126.5	24.82213439	31.4
20.956	170.387		FEB 23 05:24:02.519000	126.5	23.08300395	29.2
21.452	168.512		FEB 23 05:24:03.019834	126.5	20.55335968	26
21.946	166.402		FEB 23 05:24:03.520668	126.5	18.81422925	23.8
22.44	164.437		FEB 23 05:24:04.021502	126.5	16.52173913	20.9
22.934	162.081		FEB 23 05:24:04.522336	126.5	15.17786561	19.2
23.428	159.823		FEB 23 05:24:05.023170	126.5	13.12252964	16.6
23.924	157.706		FEB 23 05:24:05.524004	126.4	10.5221519	13.3
24.362	155.608		FEB 23 05:24:06.024838	126.5	9.328063241	11.8
24.856	153.458		FEB 23 05:24:06.525672	126.5	7.984189723	10.1
25.352	150.795		FEB 23 05:24:07.026506	126.5	7.193675889	9.1
25.79	148.806		FEB 23 05:24:07.527340	126.5	6.482213439	8.2
26.34	146.561		FEB 23 05:24:08.028174	126.5	5.533596838	7
26.834	144.139		FEB 23 05:24:08.529008	126.5	4.901185771	6.2
27.328	141.48		FEB 23 05:24:09.029842	126.5	3.636363636	4.6
27.768	139.023		FEB 23 05:24:09.530676	126.4	3.32278481	4.2

Time	RPM		Gov. Gate Timing	Voltage	% GAte	Voltage
28.262	136.645		FEB 23 05:24:10.031510	126.5	2.134387352	2.7
28.756	134.284		FEB 23 05:24:10.532344	126.5	1.422924901	1.8
29.252	132.277		FEB 23 05:24:11.033178	126.5	1.027667984	1.3
29.69	130.736		FEB 23 05:24:11.534012	126.4	0.237341772	0.3
30.184	129.591		FEB 23 05:24:12.034846	126.6	0.157977883	0.2
30.734	128.68		FEB 23 05:24:12.535680	126.8	0.078864353	0.1
31.172	127.467		FEB 23 05:24:13.036514	126.6	0.157977883	0.2
31.668	127.239		FEB 23 05:24:13.537348	126.3	1.425178147	1.8
32.162	127.308		FEB 23 05:24:14.038182	126.4	3.560126582	4.5
32.656	127.187		FEB 23 05:24:14.539016	126.7	5.367008682	6.8
			FEB 23 05:24:15.039850	126.6	7.187993681	9.1
			FEB 23 05:24:15.540684	126.3	9.580364212	12.1
			FEB 23 05:24:16.041518	126.5	12.72727273	16.1
			FEB 23 05:24:16.542352	126.5	15.49407115	19.6
			FEB 23 05:24:17.043186	126.5	15.49407115	19.6
			FEB 23 05:24:17.544020	126.5	15.49407115	19.6
			FEB 23 05:24:18.044854	126.5	15.65217391	19.8
			FEB 23 05:24:18.545271	126.6	15.79778831	20
			FEB 23 05:24:19.045688	126.6	15.71879937	19.9
			FEB 23 05:24:19.546105	126.6	15.71879937	19.9
			FEB 23 05:24:20.046522	126.5	15.7312253	19.9
			FEB 23 05:24:20.546939	126.5	15.49407115	19.6
			FEB 23 05:24:21.047356	126.5	15.33596838	19.4
			FEB 23 05:24:21.547773	126.5	14.94071146	18.9
			FEB 23 05:24:22.048190	126.5	14.86166008	18.8
			FEB 23 05:24:22.548607	126.6	14.61295419	18.5
			FEB 23 05:24:23.049024	126.5	14.62450593	18.5
			FEB 23 05:24:23.549441	126.5	14.62450593	18.5
			FEB 23 05:24:24.049858	126.5	14.54545455	18.4
			FEB 23 05:24:24.550275	126.5	14.54545455	18.4
			FEB 23 05:24:25.050692	126.5	14.62450593	18.5
			FEB 23 05:24:25.551109	126.5	14.7826087	18.7
			FEB 23 05:24:26.051526	126.5	15.01976285	19
			FEB 23 05:24:26.551943	126.5	15.09881423	19.1
			FEB 23 05:24:27.052360	126.5	15.17786561	19.2

KTEST6.XLS

Unit	1	2			1	2	1	2
Initial Power	60	60						
Head Water Level	799.83							
Tailrace Level	666.65			Trip Sig				
Time	RPM	RPM	Gov. Gate Timing	Input Voltage	% GAte	% GAte	Output Voltage	Output Voltage
7.56	128.809	129.042	FEB 23 06:15:31.007229	19.1	44.17129262	47.66058684	55.7	60.1
8.052	128.709	129.081	FEB 23 06:15:31.507479	19.1	44.17129262	47.66058684	55.7	60.1
8.548	128.466	128.967	FEB 23 06:15:32.007729	19.1	44.17129262	47.66058684	55.7	60.1
8.988	128.531	129.216	FEB 23 06:15:32.507979	19.1	44.17129262	47.66058684	55.7	60.1
9.48	129.8	129.114	FEB 23 06:15:33.008229	19.1	44.17129262	47.66058684	55.7	60.1
10.03	133.863	131.822	FEB 23 06:15:33.508479	19.1	44.17129262	47.66058684	55.7	60.1
10.524	138.497	136.47	FEB 23 06:15:34.008729	19.1	44.17129262	47.66058684	55.7	60.1
10.964	142.302	140.875	FEB 23 06:15:34.508979	19.1	44.17129262	47.66058684	55.7	60.1
11.458	146.548	145.378	FEB 23 06:15:35.009229	19.1	44.17129262	47.66058684	55.7	60.1
11.952	150.734	149.12	FEB 23 06:15:35.509479	126.7	43.88318863	47.35595896	55.6	60
12.448	154.161	153.064	FEB 23 06:15:36.009729	126.8	43.45425868	47.31861199	55.1	60
12.94	157.198	156.767	FEB 23 06:15:36.509979	126.8	41.32492114	45.58359621	52.4	57.8
13.38	159.975	159.939	FEB 23 06:15:37.010229	126.8	39.27444795	43.21766562	49.8	54.8
13.93	162.334	162.572	FEB 23 06:15:37.510479	126.8	37.14511041	40.93059937	47.1	51.9
14.424	164.411	165.081	FEB 23 06:15:38.010729	126.7	35.28018942	39.14759274	44.7	49.6
14.918	165.844	167.136	FEB 23 06:15:38.510979	126.8	32.88643533	36.67192429	41.7	46.5
15.358	166.586	168.806	FEB 23 06:15:39.011229	126.7	30.62352013	34.49092344	38.8	43.7
15.852	167.414	169.705	FEB 23 06:15:39.511479	126.8	28.23343849	32.2555205	35.8	40.9
16.348	168.1	170.778	FEB 23 06:15:40.011729	126.8	27.60252366	29.81072555	35	37.8
16.84	168.212	171.542	FEB 23 06:15:40.511979	126.8	24.44794953	27.99684543	31	35.5
17.28	167.908	171.586	FEB 23 06:15:41.012229	126.8	22.87066246	25.63091483	29	32.5
17.83	167.531	171.658	FEB 23 06:15:41.512479	126.7	20.75769534	23.59905288	26.3	29.9
18.324	166.667	170.866	FEB 23 06:15:42.012729	126.7	18.3898974	21.70481452	23.3	27.5
18.818	165.552	170.062	FEB 23 06:15:42.512979	126.7	16.17995264	19.33701657	20.5	24.5
19.258	164.234	169.034	FEB 23 06:15:43.013229	126.7	14.60142068	17.36385162	18.5	22
19.752	162.502	167.767	FEB 23 06:15:43.513479	126.7	12.70718232	15.46961326	16.1	19.6
20.246	160.384	165.956	FEB 23 06:15:44.013729	126.8	11.11987382	13.95899054	14.1	17.7
20.686	158.341	163.928	FEB 23 06:15:44.514480	126.7	9.313338595	11.12865036	11.8	14.1
21.18	156.38	161.772	FEB 23 06:15:45.015231	126.8	7.570977918	9.621451104	9.6	12.2
21.728	154.116	159.759	FEB 23 06:15:45.515982	126.7	6.629834254	8.208366219	8.4	10.4
22.224	152.27	157.617	FEB 23 06:15:46.016733	126.7	6.235201263	7.340173639	7.9	9.3
22.718	149.531	155.18	FEB 23 06:15:46.517484	126.8	5.678233438	6.466876972	7.2	8.2
23.156	147.398	152.414	FEB 23 06:15:47.018235	126.7	5.44593528	5.603788477	6.9	7.1
23.652	145.056	150.72	FEB 23 06:15:47.518986	126.7	4.972375691	4.972375691	6.3	6.3
24.146	142.736	148.312	FEB 23 06:15:48.019737	126.7	4.10418311	3.709550118	5.2	4.7
24.64	140.242	145.62	FEB 23 06:15:48.520488	126.2	1.980982567	3.328050713	2.5	4.2
25.08	137.866	143.036	FEB 23 06:15:49.021239	126.5	1.660079051	2.134387352	2.1	2.7
25.628	135.833	140.402	FEB 23 06:15:49.521990	126.5	1.027667984	1.422924901	1.3	1.8
26.124	133.675	138.164	FEB 23 06:15:50.022741	126.5	0.711462451	0.948616601	0.9	1.2
26.618	131.958	135.558	FEB 23 06:15:50.523492	126.4	0.791139241	0.237341772	1	0.3
27.112	130.391	133.033	FEB 23 06:15:51.024243	126.3	1.979414093	0.079176564	2.5	0.1
27.552	129.278	130.952	FEB 23 06:15:51.524994	126.5	5.296442688	0.158102767	6.7	0.2

Time	RPM	RPM	Gov. Gate Timing	Voltage	% GAte	% GAte	Voltage	Voltage
28.046	128.166	129.303	FEB 23 06:15:52.025745	126.5	6.561264822	1.501976285	8.3	1.9
28.54	127.473	127.927	FEB 23 06:15:52.526496	126.4	9.018987342	3.560126582	11.4	4.5
28.98	127.141	126.884	FEB 23 06:15:53.027247	126.3	11.55977831	5.30482977	14.6	6.7
29.474	126.402	125.917	FEB 23 06:15:53.527998	126.3	14.17260491	7.2050673	17.9	9.1
30.024	126.923	125.244	FEB 23 06:15:54.028749	126.2	16.56101426	9.667194929	20.9	12.2
30.516	127.073	124.769	FEB 23 06:15:54.529500	126.4	18.75	13.92405063	23.7	17.6
30.956	127.647	124.734	FEB 23 06:15:55.030251	126.5	20.4743083	15.88932806	25.9	20.1
31.452	127.977	124.588	FEB 23 06:15:55.531002	126.5	21.18577075	18.97233202	26.8	24
31.944	128.687	125.686	FEB 23 06:15:56.031753	126.4	21.59810127	22.94303797	27.3	29
			FEB 23 06:15:56.532504	126.4	21.91455696	25.39556962	27.7	32.1
			FEB 23 06:15:57.033255	126.3	21.77355503	27.31591449	27.5	34.5
			FEB 23 06:15:57.534006	126.3	21.6152019	27.63262074	27.3	34.9
			FEB 23 06:15:58.034757	126.4	21.0443038	27.45253165	26.6	34.7
			FEB 23 06:15:58.535508	126.4	20.25316456	26.50316456	25.6	33.5
			FEB 23 06:15:59.036259	126.4	19.0664557	24.6835443	24.1	31.2
			FEB 23 06:15:59.537010	126.4	17.87974684	22.94303797	22.6	29
			FEB 23 06:16:00.037761	126.4	16.7721519	20.49050633	21.2	25.9
			FEB 23 06:16:00.538512	125.7	15.51312649	18.61575179	19.5	23.4
			FEB 23 06:16:01.039263	126.2	14.89698891	16.40253566	18.8	20.7
			FEB 23 06:16:01.539596	126.3	13.93507522	15.12272367	17.6	19.1
			FEB 23 06:16:02.039929	126.2	13.39144216	13.23296355	16.9	16.7
			FEB 23 06:16:02.540262	126.2	12.99524564	12.20285261	16.4	15.4
			FEB 23 06:16:03.040595	126.2	12.67828843	11.17274168	16	14.1
			FEB 23 06:16:03.540928	126.1	12.68834259	11.26090404	16	14.2
			FEB 23 06:16:04.041261	126	12.6984127	11.26984127	16	14.2
			FEB 23 06:16:04.541594	126.1	12.68834259	12.60904044	16	15.9
			FEB 23 06:16:05.041927	126.1	13.40206186	15.06740682	16.9	19
			FEB 23 06:16:05.542260	126.1	13.95717684	15.38461538	17.6	19.4
			FEB 23 06:16:06.042593	126	14.28571429	15.79365079	18	19.9
			FEB 23 06:16:06.542926	126.2	14.89698891	17.11568938	18.8	21.6
			FEB 23 06:16:07.043259	126.1	15.2260111	18.31879461	19.2	23.1
			FEB 23 06:16:07.543592	126	15.55555556	18.33333333	19.6	23.1
			FEB 23 06:16:08.043925	126	15.79365079	18.49206349	19.9	23.3
			FEB 23 06:16:08.544258	126.1	16.09833466	18.55670103	20.3	23.4

Unit	1	2				1	2	1	2
Initial Power	70	70							
Head Water Level	799.58								
Tailrace Level	667.51				Trip Sig				
					Input			Output	Output
Time	RPM	RPM		Gov. Gate Timing	Voltage	% GAte	% GAte	Voltage	Voltage
8.824	129.355	129.025		FEB 23 06:45:37.503749	19	49.88104679	52.49801745	62.9	66.2
9.372	129.323	128.745		FEB 23 06:45:38.003999	19	49.88104679	52.49801745	62.9	66.2
9.812	129.011	128.977		FEB 23 06:45:38.504249	19	49.88104679	52.49801745	62.9	66.2
10.36	129.223	128.78		FEB 23 06:45:39.004499	19	49.88104679	52.49801745	62.9	66.2
10.856	130.891	129.066		FEB 23 06:45:39.504749	19	49.88104679	52.49801745	62.9	66.2
11.296	135.164	133.07		FEB 23 06:45:40.004999	19	49.88104679	52.49801745	62.9	66.2
11.79	140.373	137.689		FEB 23 06:45:40.505249	19	49.88104679	52.49801745	62.9	66.2
12.284	145.408	142.797		FEB 23 06:45:41.005499	19	49.88104679	52.49801745	62.9	66.2
12.778	149.748	147.386		FEB 23 06:45:41.505749	126.2	49.44532488	52.53565769	62.4	66.3
13.272	153.975	152.419		FEB 23 06:45:42.005999	122.7	48.65525672	51.34474328	59.7	63
13.768	158.103	156.562		FEB 23 06:45:42.506249	126	46.58730159	48.73015873	58.7	61.4
14.26	161.781	160.791		FEB 23 06:45:43.006499	125.9	44.16203336	47.02144559	55.6	59.2
14.756	164.811	164.723		FEB 23 06:45:43.506749	126	41.34920635	44.92063492	52.1	56.6
15.196	167.291	168.036		FEB 23 06:45:44.006999	126	39.28571429	42.53968254	49.5	53.6
15.688	169.608	170.484		FEB 23 06:45:44.507249	125.9	37.25178713	40.42891183	46.9	50.9
16.184	171.597	173.2		FEB 23 06:45:45.007499	125.9	35.34551231	38.68149325	44.5	48.7
16.678	173.373	175.298		FEB 23 06:45:45.507749	125.8	32.90937997	36.24801272	41.4	45.6
17.116	175.403	176.591		FEB 23 06:45:46.007999	125.8	30.6836248	33.9427663	38.6	42.7
17.666	176.741	177.861		FEB 23 06:45:46.508249	125.8	28.29888712	31.87599364	35.6	40.1
18.16	176.958	178.453		FEB 23 06:45:47.008916	125.8	27.58346582	29.49125596	34.7	37.1
18.656	177.192	178.533		FEB 23 06:45:47.509583	125.5	24.46215139	27.56972112	30.7	34.6
19.096	177.105	178.569		FEB 23 06:45:48.010250	125.6	22.85031847	25.31847134	28.7	31.8
19.588	177.589	178.48		FEB 23 06:45:48.510917	125.7	20.84327765	23.30946698	26.2	29.3
20.084	176.919	177.541		FEB 23 06:45:49.011584	125.6	18.47133758	21.17834395	23.2	26.6
20.578	175.083	176.648		FEB 23 06:45:49.512251	125.6	16.40127389	19.10828025	20.6	24
21.072	174.267	175.028		FEB 23 06:45:50.012918	125.5	14.66135458	17.21115538	18.4	21.6
21.566	172.514	173.861		FEB 23 06:45:50.513585	125.5	12.90836653	15.45816733	16.2	19.4
22.06	170.652	172.619		FEB 23 06:45:51.014252	125.5	11.23505976	13.54581673	14.1	17
22.556	168.055	170.891		FEB 23 06:45:51.514919	125.5	9.322709163	10.99601594	11.7	13.8
23.048	165.939	168.689		FEB 23 06:45:52.015586	125.5	7.569721116	9.561752988	9.5	12
23.488	163.492	166.572		FEB 23 06:45:52.516253	125.5	6.613545817	8.207171315	8.3	10.3
23.984	161.219	164.395		FEB 23 06:45:53.016920	125.5	6.294820717	7.330677291	7.9	9.2
24.476	158.744	162.314		FEB 23 06:45:53.517587	125.5	5.737051793	6.454183267	7.2	8.1
24.972	156.256	160.172		FEB 23 06:45:54.018254	125.5	5.418326693	5.816733068	6.8	7.3
25.466	153.684	158.069		FEB 23 06:45:54.518921	125.5	5.019920319	5.019920319	6.3	6.3
25.96	151.477	155.594		FEB 23 06:45:55.019587	125.6	4.140127389	3.662420382	5.2	4.6
26.454	148.686	153.455		FEB 23 06:45:55.520254	125.6	2.070063694	3.423566879	2.6	4.3
26.948	146.133	150.772		FEB 23 06:45:56.020921	125.5	1.673306773	2.629482072	2.1	3.3
27.388	143.858	148.408		FEB 23 06:45:56.521588	125.5	1.035856574	1.513944223	1.3	1.9
27.884	141.108	146.017		FEB 23 06:45:57.022255	125.6	0.71656051	1.433121019	0.9	1.8
28.376	138.7	143.344		FEB 23 06:45:57.522922	125.5	0.15936255	0.239043825	0.2	0.3
28.872	136.078	140.736		FEB 23 06:45:58.023589	125.5	0	0.15936255	0	0.2
29.366	134.148	138.055		FEB 23 06:45:58.524256	125.6	0.557324841	0.079617834	0.7	0.1
29.86	132.133	135.527		FEB 23 06:45:59.024923	125.6	1.671974522	0.159235669	2.1	0.2
30.354	130.587	133.097		FEB 23 06:45:59.525590	125.6	5.015923567	0.238853503	6.3	0.3
30.794	128.731	130.828		FEB 23 06:46:00.026257	125.5	6.294820717	1.832669323	7.9	2.3
31.288	128.1	128.689		FEB 23 06:46:00.526924	125.4	8.612440191	3.668261563	10.8	4.6

Time	RPM	RPM		Gov. Gate Timing	Voltage	% GAte	% GAte	Voltage	Voltage
31.782	127.366	127.614		FEB 23 06:46:01.027591	125.3	11.17318436	5.905826018	14	7.4
32.276	126.689	126.294		FEB 23 06:46:01.528258	125.5	13.94422311	8.764940239	17.5	11
32.772	126.002	124.878		FEB 23 06:46:02.028925	125.6	16.08280255	10.82802548	20.2	13.6
33.264	125.889	123.542		FEB 23 06:46:02.529592	125.6	19.10828025	15.20700637	24	19.1
				FEB 23 06:46:03.030259	125.5	21.67330677	16.4940239	27.2	20.7
				FEB 23 06:46:03.530759	125.4	22.56778309	18.42105263	28.3	23.1
				FEB 23 06:46:04.031259	125.3	22.74541101	18.59537111	28.5	23.3
				FEB 23 06:46:04.531759	125.4	22.80701754	18.97926635	28.6	23.8
				FEB 23 06:46:05.032259	125.4	22.72727273	19.05901116	28.5	23.9
				FEB 23 06:46:05.532759	125.5	22.15139442	19.20318725	27.8	24.1
				FEB 23 06:46:06.033259	125.4	20.89314195	19.13875598	26.2	24
				FEB 23 06:46:06.533759	125.5	19.20318725	19.20318725	24.1	24.1
				FEB 23 06:46:07.034259	125.5	17.60956175	18.48605578	22.1	23.2
				FEB 23 06:46:07.534759	125.5	16.09561753	17.4501992	20.2	21.9
				FEB 23 06:46:08.035259	125.5	15.21912351	16.1752988	19.1	20.3
				FEB 23 06:46:08.535759	125.4	14.27432217	15.55023923	17.9	19.5
				FEB 23 06:46:09.036259	125.4	13.71610845	15.3907496	17.2	19.3
				FEB 23 06:46:09.536759	125.5	13.30677291	14.98007968	16.7	18.8
				FEB 23 06:46:10.037259	125.5	13.30677291	14.90039841	16.7	18.7
				FEB 23 06:46:10.537759	125.5	13.30677291	14.90039841	16.7	18.7
				FEB 23 06:46:11.038259	125.5	13.30677291	14.98007968	16.7	18.8
				FEB 23 06:46:11.538758	125.5	13.86454183	15.21912351	17.4	19.1
				FEB 23 06:46:12.039258	125.5	14.02390438	15.21912351	17.6	19.1
				FEB 23 06:46:12.539758	125.4	14.51355662	15.3907496	18.2	19.3
				FEB 23 06:46:13.040258	125.4	14.9122807	15.55023923	18.7	19.5
				FEB 23 06:46:13.540758	125.5	15.21912351	15.37848606	19.1	19.3
				FEB 23 06:46:14.041258	125.5	15.53784861	15.45816733	19.5	19.4
				FEB 23 06:46:14.541758	125.5	15.77689243	15.45816733	19.8	19.4
				FEB 23 06:46:15.042258	125.5	15.85657371	15.45816733	19.9	19.4
				FEB 23 06:46:15.542758	125.5	15.77689243	15.45816733	19.8	19.4
				FEB 23 06:46:16.043258	125.6	15.76433121	15.52547771	19.8	19.5
				FEB 23 06:46:16.543758	125.5	15.77689243	15.45816733	19.8	19.4
				FEB 23 06:46:17.044258	125.6	15.76433121	15.44585987	19.8	19.4
				FEB 23 06:46:17.544758	125.6	15.76433121	15.44585987	19.8	19.4

Unit	1	2				1	2	1	2
Initial Power	80 Gage 1 80.4 Gage 2	80 Gage 1 80.4 Gage 2							
Head Water Level	799.72								
Tailrace Level	668.1				Trip Sig				
					Input			Output	Output
Time	RPM	RPM		Gov. Gate Timing	Voltage	% GAte	% GAte	Voltage	Voltage
6.152	128.461	128.777		FEB 23 07:13:03.012499	19	55.67010309	56.93893735	70.2	71.8
6.648	128.933	128.512		FEB 23 07:13:03.512749	19	55.67010309	56.85963521	70.2	71.7
7.14	128.797	128.786		FEB 23 07:13:04.012999	19	55.67010309	56.93893735	70.2	71.8
7.58	128.972	128.68		FEB 23 07:13:04.513249	19	55.67010309	56.85963521	70.2	71.7
8.076	128.755	128.748		FEB 23 07:13:05.013499	19	55.67010309	56.93893735	70.2	71.8
8.568	129.153	128.566		FEB 23 07:13:05.513749	19	55.67010309	56.93893735	70.2	71.8
9.064	129.15	128.916		FEB 23 07:13:06.013998	19	55.67010309	56.93893735	70.2	71.8
9.558	130.344	128.906		FEB 23 07:13:06.514248	19	55.67010309	56.85963521	70.2	71.7
10.052	135.648	132.733		FEB 23 07:13:07.014498	19	55.67010309	56.93893735	70.2	71.8
10.546	141.53	138.766		FEB 23 07:13:07.514748	19	55.67010309	56.85963521	70.2	71.7
10.986	146.886	144.353		FEB 23 07:13:08.014998	126.2	55.54675119	56.89381933	70.1	71.8
11.48	152.083	149.586		FEB 23 07:13:08.515248	126.1	54.63917526	55.82870738	68.9	70.4
11.974	157.048	154.756		FEB 23 07:13:09.015498	126.2	52.13946117	53.88272583	65.8	68
12.468	161.772	159.788		FEB 23 07:13:09.515748	126.1	49.40523394	52.18080888	62.3	65.8
12.908	165.548	164.166		FEB 23 07:13:10.015998	126	47.14285714	49.68253968	59.4	62.6
13.456	169.261	167.842		FEB 23 07:13:10.516248	126	44.76190476	47.53968254	56.4	59.9
13.952	172.328	171.428		FEB 23 07:13:11.016498	126	42.85714286	45.79365079	54	57.7
14.446	175.598	174.434		FEB 23 07:13:11.516915	126	40.3968254	43.33333333	50.9	54.6
14.94	177.692	176.973		FEB 23 07:13:12.017332	126	38.33333333	41.11111111	48.3	51.8
15.38	179.305	178.961		FEB 23 07:13:12.517749	125.9	36.13979349	39.15806195	45.5	49.3
15.874	180.659	180.823		FEB 23 07:13:13.018166	125.9	33.83637808	36.69579031	42.6	46.2
16.368	181.922	182.075		FEB 23 07:13:13.518583	125.8	31.71701113	34.49920509	39.9	43.4
16.808	182.989	182.789		FEB 23 07:13:14.019000	125.9	29.30897538	32.32724384	36.9	40.7
17.356	183.853	183.473		FEB 23 07:13:14.519417	125.9	27.87926926	30.18268467	35.1	38
17.852	183.85	184.292		FEB 23 07:13:15.019834	125.9	26.92613185	28.11755361	33.9	35.4
18.346	183.63	184.512		FEB 23 07:13:15.520251	125.9	23.19301033	26.13185068	29.2	32.9
18.784	183.258	183.994		FEB 23 07:13:16.020668	125.8	21.62162162	23.84737679	27.2	30
19.28	183.202	183.481		FEB 23 07:13:16.521085	125.9	19.30103257	22.08101668	24.3	27.8
19.774	182.762	182.814		FEB 23 07:13:17.021502	125.9	17.15647339	19.77760127	21.6	24.9
20.268	181.366	181.991		FEB 23 07:13:17.521919	125.7	15.19490851	17.97931583	19.1	22.6
20.708	180.036	180.698		FEB 23 07:13:18.022336	125.7	13.60381862	15.75178998	17.1	19.8
21.256	178.472	179.083		FEB 23 07:13:18.522753	125.7	11.85361973	14.55847255	14.9	18.3
21.752	176.639	177.806		FEB 23 07:13:19.023170	125.7	10.10342084	12.01272872	12.7	15.1
22.244	175.002	175.628		FEB 23 07:13:19.523587	125.6	7.882165605	9.792993631	9.9	12.3
22.684	172.738	174.062		FEB 23 07:13:20.024004	125.5	7.250996016	8.525896414	9.1	10.7
23.18	170.191	171.728		FEB 23 07:13:20.524421	125.5	6.613545817	7.490039841	8.3	9.4
23.672	167.653	169.539		FEB 23 07:13:21.024838	125.5	5.976095618	6.693227092	7.5	8.4
24.168	164.93	167.128		FEB 23 07:13:21.525255	125.6	5.334394904	5.891719745	6.7	7.4
24.608	162.314	164.653		FEB 23 07:13:22.025672	125.4	5.023923445	5.183413078	6.3	6.5
25.156	160.111	162.205		FEB 23 07:13:22.526089	125.5	4.143426295	3.984063745	5.2	5
25.652	157.53	159.606		FEB 23 07:13:23.026506	125.4	2.312599681	3.349282297	2.9	4.2
26.144	154.655	156.858		FEB 23 07:13:23.526923	125.5	1.673306773	2.788844622	2.1	3.5
26.584	151.759	154.311		FEB 23 07:13:24.027340	125.5	1.354581673	1.832669323	1.7	2.3
27.08	149.589	152.056		FEB 23 07:13:24.527757	125.5	0.717131474	1.434262948	0.9	1.8
27.572	146.573	148.919		FEB 23 07:13:25.028174	125.5	0.15936255	0.637450199	0.2	0.8
28.068	143.842	146.417		FEB 23 07:13:25.528591	125.5	0	0.15936255	0	0.2
28.508	141.044	143.575		FEB 23 07:13:26.029008	125.5	0	0.079681275	0	0.1
29.056	138.366	140.956		FEB 23 07:13:26.529425	125.5	0	0.079681275	0	0.1
29.55	135.792	138.042		FEB 23 07:13:27.029842	125.6	0.159235669	0.159235669	0.2	0.2
30.044	133.35	135.166		FEB 23 07:13:27.530259	125.5	1.354581673	0.079681275	1.7	0.1

Time	RPM	RPM		Gov. Gate Timing	Voltage	% GAte	% GAte	Voltage	Voltage
30.484	131.219	132.625		FEB 23 07:13:28.030676	125.5	4.701195219	1.513944223	5.9	1.9
				FEB 23 07:13:28.531343	125.4	5.980861244	3.668261563	7.5	4.6
				FEB 23 07:13:29.032010	125.4	7.575757576	5.661881978	9.5	7.1
				FEB 23 07:13:29.532677	125.4	10.52631579	7.575757576	13.2	9.5
				FEB 23 07:13:30.033344	125.4	13.31738437	9.888357257	16.7	12.4
				FEB 23 07:13:30.534011	125.5	15.61752988	14.34262948	19.6	18
				FEB 23 07:13:31.034678	125.6	18.23248408	16.08280255	22.9	20.2
				FEB 23 07:13:31.535345	125.6	21.65605096	18.55095541	27.2	23.3
				FEB 23 07:13:32.036012	125.6	22.92993631	18.94904459	28.8	23.8
				FEB 23 07:13:32.536679	125.5	23.10756972	19.6812749	29	24.7
				FEB 23 07:13:33.037346	125.4	23.12599681	19.85645933	29	24.9
				FEB 23 07:13:33.538013	125.4	23.12599681	19.93620415	29	25
				FEB 23 07:13:34.038680	125.4	23.04625199	19.85645933	28.9	24.9
				FEB 23 07:13:34.539347	125.4	21.92982456	19.93620415	27.5	25
				FEB 23 07:13:35.040014	125.5	20.23904382	19.12350598	25.4	24
				FEB 23 07:13:35.540681	125.5	18.16733068	18.4063745	22.8	23.1
				FEB 23 07:13:36.041348	125.5	16.65338645	17.21115538	20.9	21.6
				FEB 23 07:13:36.542015	125.5	15.13944223	16.09561753	19	20.2
				FEB 23 07:13:37.042682	125.5	13.94422311	15.61752988	17.5	19.6
				FEB 23 07:13:37.543349	125.4	13.31738437	15.31100478	16.7	19.2
				FEB 23 07:13:38.044016	125.5	12.74900398	14.98007968	16	18.8
				FEB 23 07:13:38.544683	125.5	12.66932271	14.90039841	15.9	18.7
				FEB 23 07:13:39.045350	125.5	12.66932271	14.82071713	15.9	18.6
				FEB 23 07:13:39.546017	125.5	12.66932271	14.82071713	15.9	18.6
				FEB 23 07:13:40.046684	125.5	12.74900398	14.98007968	16	18.8
				FEB 23 07:13:40.547351	125.5	13.30677291	15.21912351	16.7	19.1
				FEB 23 07:13:41.048017	125.5	13.94422311	15.37848606	17.5	19.3
				FEB 23 07:13:41.548684	125.5	14.26294821	15.53784861	17.9	19.5
				FEB 23 07:13:42.049351	125.5	14.74103586	15.45816733	18.5	19.4
				FEB 23 07:13:42.550018	125.5	14.98007968	15.37848606	18.8	19.3
				FEB 23 07:13:43.050685	125.5	15.21912351	15.45816733	19.1	19.4

Unit	1					
Initial Power	60					
Head Water Level	799.44					
Tailrace Level	670.4			Trip Sig		
				Input		Output
Time	RPM		Gov. Gate Timing	Voltage	% GAte	Voltage
8.052	128.592		FEB 23 08:43:11.120573	18.9	47.58128469	60
8.544	128.333		FEB 23 08:43:11.659075	19.1	45.59873117	57.5
9.04	128.672		FEB 23 08:43:12.197577	18.5	47.9777954	60.5
9.536	128.52		FEB 23 08:43:12.736079	19.5	45.04361618	56.8
10.028	128.808		FEB 23 08:43:13.274581	129.5	46.48648649	60.2
10.52	130.052		FEB 23 08:43:13.813083	123.7	45.109135	55.8
11.016	133.93		FEB 23 08:43:14.351585	126.1	42.90245837	54.1
11.512	138.581		FEB 23 08:43:14.890087	125.3	40.38308061	50.6
11.952	143.116		FEB 23 08:43:15.428589	126	38.25396825	48.2
12.444	147.339		FEB 23 08:43:15.967091	129.2	36.06811146	46.6
12.94	150.802		FEB 23 08:43:16.505593	122	33.36065574	40.7
13.38	154.103		FEB 23 08:43:17.044095	125.1	31.01518785	38.8
13.928	157.437		FEB 23 08:43:17.582597	129.9	28.5604311	37.1
14.476	159.616		FEB 23 08:43:18.121098	122	27.70491803	33.8
14.916	161.47		FEB 23 08:43:18.659600	129.1	24.4771495	31.6
15.412	163.019		FEB 23 08:43:19.198102	124	22.82258065	28.3
15.904	164.511		FEB 23 08:43:19.736604	124.9	20.81665332	26
16.344	164.959		FEB 23 08:43:20.275106	130.2	18.04915515	23.5
16.84	165.386		FEB 23 08:43:20.813608	124.6	15.8105939	19.7
17.332	165.819		FEB 23 08:43:21.352110	121.9	14.10992617	17.2
17.828	165.812		FEB 23 08:43:21.890612	129.9	12.39414935	16.1
18.32	165.137		FEB 23 08:43:22.429114	123.1	10.3168156	12.7
18.816	164.389		FEB 23 08:43:22.967616	127	8.188976378	10.4
19.312	163.462		FEB 23 08:43:23.506118	127.3	7.227022781	9.2
19.804	162.116		FEB 23 08:43:24.043174	123.3	6.326034063	7.8
20.244	160.595		FEB 23 08:43:24.580230	129.2	5.959752322	7.7
20.74	158.603		FEB 23 08:43:25.117286	121.9	5.332239541	6.5
21.232	156.852		FEB 23 08:43:25.654342	130	5	6.5
21.728	154.836		FEB 23 08:43:26.191398	123.2	3.733766234	4.6
22.22	152.117		FEB 23 08:43:26.728454	126.1	2.299762094	2.9
22.716	150.206		FEB 23 08:43:27.265510	128.2	4.134165367	5.3
23.208	147.855		FEB 23 08:43:27.802566	123.6	5.987055016	7.4
23.648	145.458		FEB 23 08:43:28.339622	128.6	7.542768274	9.7
24.144	143.067		FEB 23 08:43:28.876678	122.8	10.66775244	13.1
24.64	140.705		FEB 23 08:43:29.413734	128.6	13.84136858	17.8
25.08	138.395		FEB 23 08:43:29.950790	124.1	16.11603546	20
25.628	136.152		FEB 23 08:43:30.487846	126.5	18.97233202	24
26.12	134.186		FEB 23 08:43:31.024902	126.9	21.19779354	26.9
26.616	132.478		FEB 23 08:43:31.561958	123.2	22.07792208	27.2
27.056	130.891		FEB 23 08:43:32.099014	129.9	22.40184758	29.1
27.548	129.333		FEB 23 08:43:32.636070	122.5	22.44897959	27.5

Time	RPM		Gov. Gate Timing	Voltage	% GAte	Voltage
28.044	128.734		FEB 23 08:43:33.173126	127.5	22.03921569	28.1
28.536	127.633		FEB 23 08:43:33.710182	127.3	21.60251375	27.5
28.976	127.948		FEB 23 08:43:34.247238	122.4	20.50653595	25.1
29.528	128.155		FEB 23 08:43:34.784294	129.7	19.12104857	24.8
30.02	128.363		FEB 23 08:43:35.321350	126.2	17.90808241	22.6
30.46	129.145		FEB 23 08:43:35.858406	122.1	17.28091728	21.1
30.956	129.833		FEB 23 08:43:36.395462	123.6	16.90938511	20.9
31.448	130.488		FEB 23 08:43:36.932518	127.9	16.34089132	20.9
31.944	131.325		FEB 23 08:43:37.469573	129.8	16.10169492	20.9
32.384	131.906		FEB 23 08:43:38.006629	123.4	16.12641815	19.9

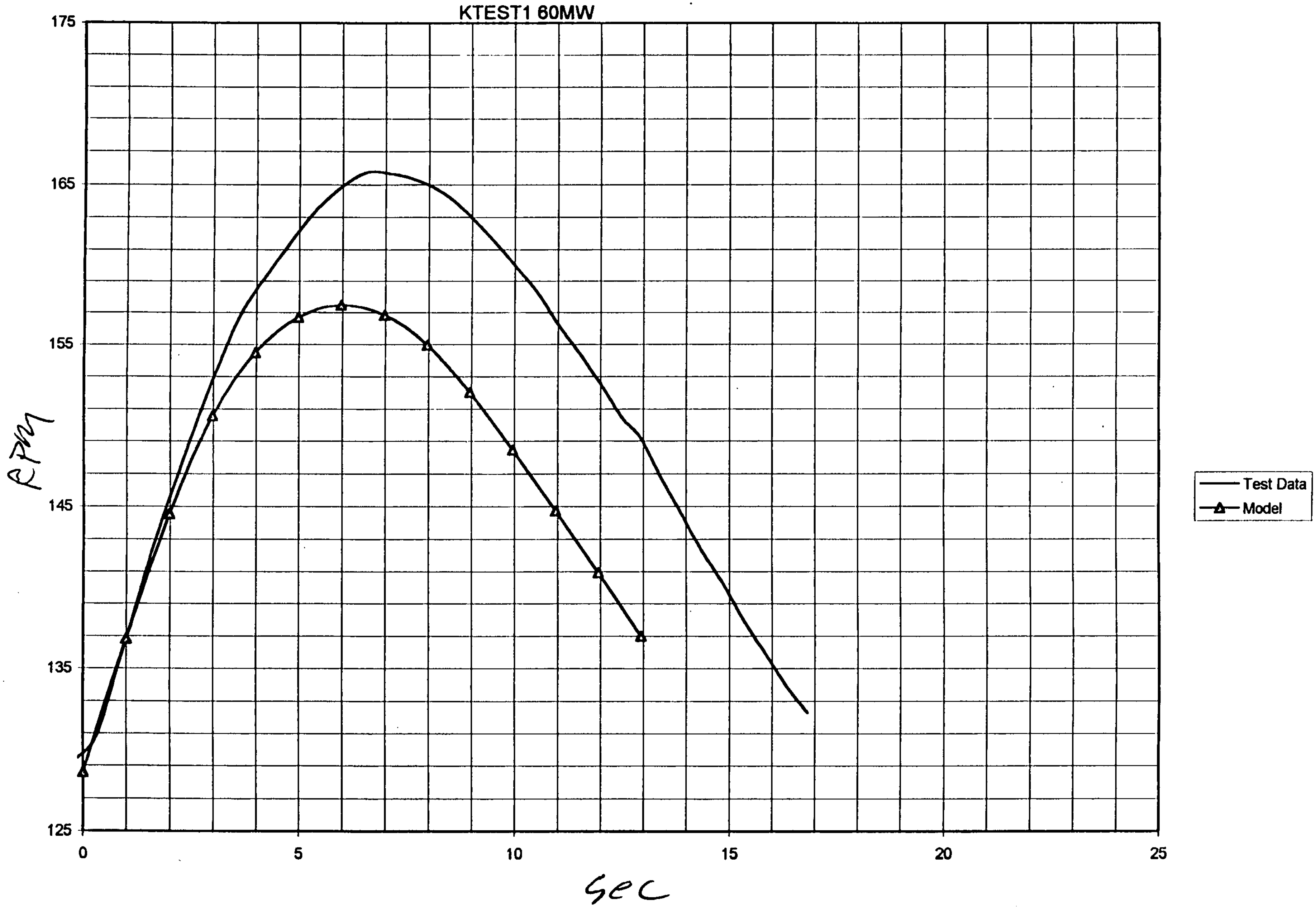
Unit	1					
Initial Power	90					
Head Water Level	799.44					
Tailrace Level	671.7			Trip Sig		
				Input		Output
Time	RPM		Gov. Gate Timing	Voltage	% GAte	Voltage
0.692	128.925		FEB 23 09:15:03.950946	18.8	61.77636796	77.9
1.188	128.973		FEB 23 09:15:04.487426	19.4	60.42823156	76.2
1.68	129.358		FEB 23 09:15:05.023906	19.4	61.4591594	77.5
2.176	129.347		FEB 23 09:15:05.560386	19.1	62.8072958	79.2
2.616	129.503		FEB 23 09:15:06.096866	19	62.88659794	79.3
3.164	134.444		FEB 23 09:15:06.633346	129.1	62.35476375	80.5
3.66	141.086		FEB 23 09:15:07.169826	130	62.07692308	80.7
4.096	147.033		FEB 23 09:15:07.706305	127.9	59.3432369	75.9
4.592	152.648		FEB 23 09:15:08.242785	123.9	56.57788539	70.1
5.088	158.091		FEB 23 09:15:08.779265	122.5	54.04081633	66.2
5.58	163.352		FEB 23 09:15:09.315745	127.1	51.77025964	65.8
6.02	167.328		FEB 23 09:15:09.852225	130.2	49.15514593	64
6.516	171.498		FEB 23 09:15:10.388705	128.1	46.99453552	60.2
7.064	174.581		FEB 23 09:15:10.925185	123.9	44.30992736	54.9
7.56	177.914		FEB 23 09:15:11.461665	122.3	41.3736713	50.6
8	180.386		FEB 23 09:15:11.996424	126.3	39.27157561	49.6
8.492	182.252		FEB 23 09:15:12.531183	129.8	36.82588598	47.8
8.988	183.977		FEB 23 09:15:13.065942	130	34.46153846	44.8
9.48	185.042		FEB 23 09:15:13.600701	128.1	32.24043716	41.3
9.92	185.605		FEB 23 09:15:14.135460	124.8	29.80769231	37.2
10.416	185.769		FEB 23 09:15:14.670219	122.5	27.91836735	34.2
10.964	186.039		FEB 23 09:15:15.204978	122.8	27.19869707	33.4
11.404	186.505		FEB 23 09:15:15.739737	124.8	23.23717949	29
11.896	186.209		FEB 23 09:15:16.274497	126.1	21.57018239	27.2
12.392	185.567		FEB 23 09:15:16.809256	127.3	18.9316575	24.1
12.888	184.783		FEB 23 09:15:17.344015	129.4	16.84698609	21.8
13.328	183.937		FEB 23 09:15:17.878774	129.9	14.78060046	19.2
13.82	182.636		FEB 23 09:15:18.413533	122.3	12.75551922	15.6
14.312	180.825		FEB 23 09:15:18.948292	123.2	10.95779221	13.5
14.864	179.491		FEB 23 09:15:19.483051	122.2	9.083469722	11.1
15.304	177.808		FEB 23 09:15:20.017810	125	7.28	9.1
15.796	175.648		FEB 23 09:15:20.552569	129.7	6.630686199	8.6
16.292	173.361		FEB 23 09:15:21.087328	126.7	6.235201263	7.9
16.784	170.858		FEB 23 09:15:21.622087	121.9	5.660377358	6.9
17.224	168.547		FEB 23 09:15:22.156846	124	5.161290323	6.4
17.72	165.872		FEB 23 09:15:22.691605	126.8	4.416403785	5.6
18.216	163.066		FEB 23 09:15:23.226364	128.3	2.33826968	3
18.708	160.483		FEB 23 09:15:23.761123	129.1	1.704105345	2.2
19.204	157.625		FEB 23 09:15:24.295882	129.7	1.310717039	1.7
19.696	154.622		FEB 23 09:15:24.830641	129.5	0.694980695	0.9
20.192	151.895		FEB 23 09:15:25.365400	127.9	0.54730258	0.7

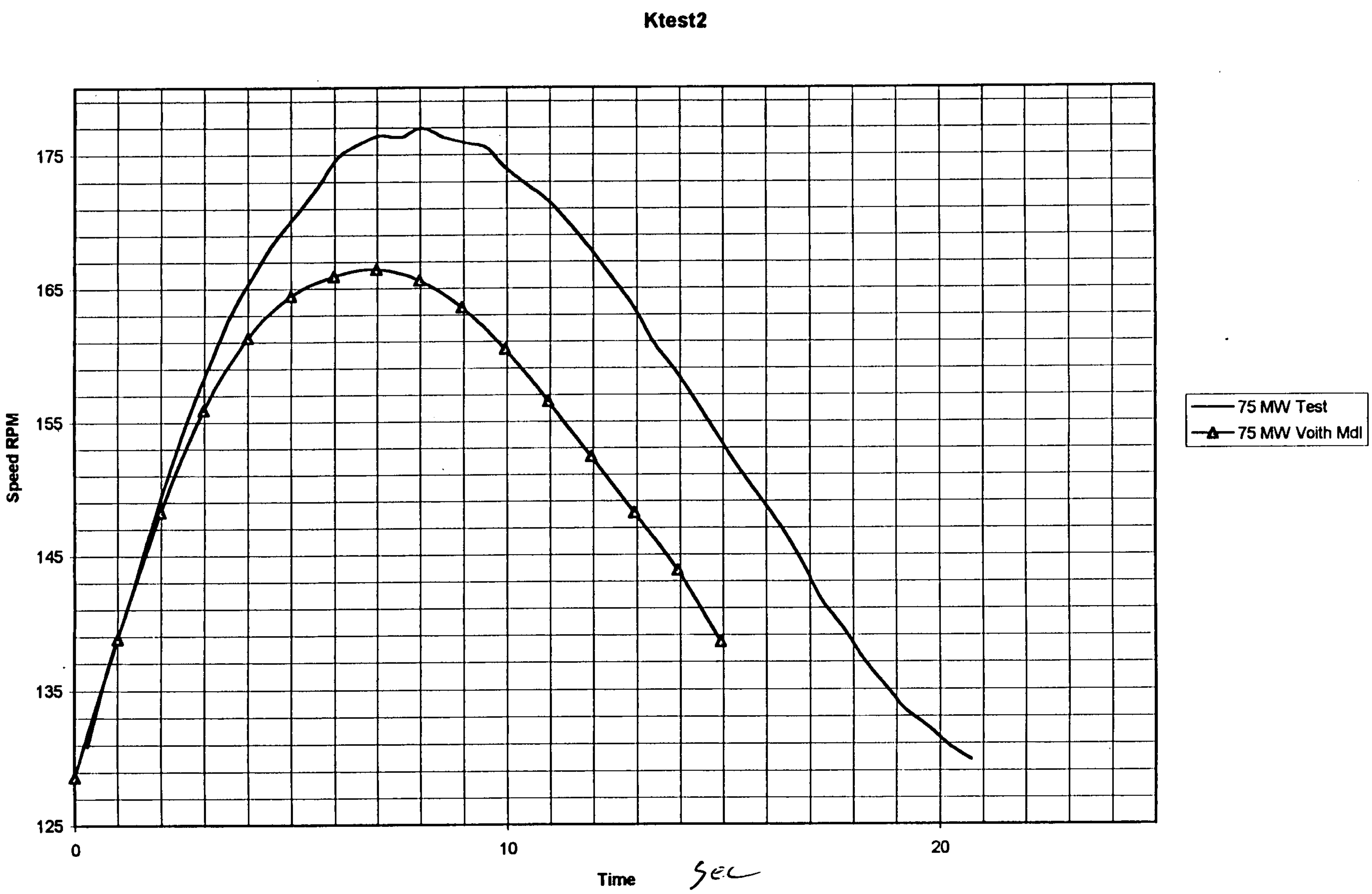
Time	RPM		Gov. Gate Timing	Voltage	% GAte	Voltage
20.632	148.852		FEB 23 09:15:25.900159	126.7	1.34175217	1.7
21.124	145.895		FEB 23 09:15:26.434918	124.5	4.096385542	5.1
21.62	142.991		FEB 23 09:15:26.969677	122	5.901639344	7.2
22.112	140.05		FEB 23 09:15:27.504436	123	7.56097561	9.3
22.608	137.655		FEB 23 09:15:28.039196	126.2	10.61806656	13.4
23.104	134.939		FEB 23 09:15:28.573955	128.9	13.49883631	17.4
23.596	132.562		FEB 23 09:15:29.108714	129.5	16.13899614	20.9
24.036	130.606		FEB 23 09:15:29.643473	128	19.296875	24.7
24.528	129.297		FEB 23 09:15:30.177946	127.2	22.48427673	28.6
25.024	127.408		FEB 23 09:15:30.712419	125.6	23.88535032	30
25.52	126.261		FEB 23 09:15:31.246891	124.1	24.41579371	30.3
25.96	125.18		FEB 23 09:15:31.781364	123.2	24.43181818	30.1
26.508	125.505		FEB 23 09:15:32.315837	122.4	24.18300654	29.6
27	125.128		FEB 23 09:15:32.850310	122.1	23.34152334	28.5
27.496	125.428		FEB 23 09:15:33.384783	122.2	22.17675941	27.1
27.936	125.533		FEB 23 09:15:33.919256	122.5	20.48979592	25.1
28.432	126.65		FEB 23 09:15:34.453729	122.4	18.46405229	22.6
28.924	127.961		FEB 23 09:15:34.988202	122.5	17.2244898	21.1
29.42	129.288		FEB 23 09:15:35.522675	122.2	16.12111293	19.7
29.856	130.625		FEB 23 09:15:36.057148	122.2	15.79378069	19.3

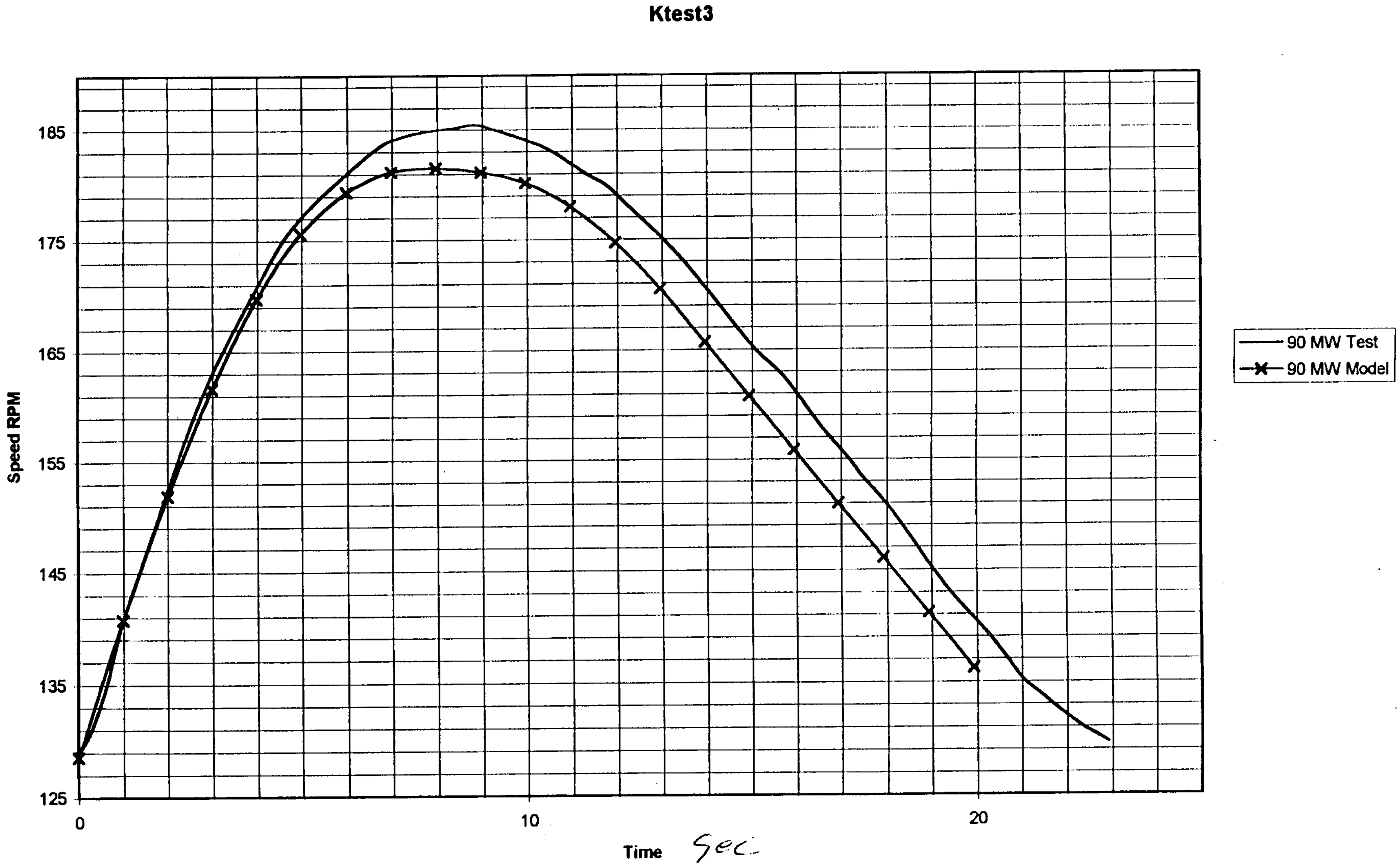
Unit	1	2				1	2	1
Initial Power	70 MW	70 MW						
Head Water Level	799.56							
Tailrace Level	672.5				Trip Sig			
					Input			Output
Time	RPM	RPM		Gov. Gate Timing	Voltage	% GAte	% GAte	Voltage
9.348	128.802	128.667		FEB 23 08:08:55.559106	18.9	52.1808089	54.48057	65.8
9.844	128.784	129.12		FEB 23 08:08:56.059439	18.9	52.1808089	54.40127	65.8
10.284	129.442	129.114		FEB 23 08:08:56.559772	18.8	52.1015067	54.40127	65.7
10.832	133.312	132.212		FEB 23 08:08:57.060105	18.8	52.1015067	54.32197	65.7
11.328	138.5	137.027		FEB 23 08:08:57.560438	18.8	52.0222046	54.32197	65.6
11.82	143.372	142.206		FEB 23 08:08:58.060771	18.8	52.0222046	54.32197	65.6
12.26	148.281	146.925		FEB 23 08:08:58.561104	124.8	52.5641026	54.88782	65.6
12.752	153.216	151.913		FEB 23 08:08:59.061437	124.8	52.0032051	54.24679	64.9
13.248	157.123	156.42		FEB 23 08:08:59.561770	125	49.28	52.32	61.6
13.744	161.355	160.092		FEB 23 08:09:00.062103	125	47.12	49.84	58.9
14.184	164.803	163.805		FEB 23 08:09:00.562436	125.2	44.6485623	47.76358	55.9
14.732	167.933	167.058		FEB 23 08:09:01.062769	125.2	42.7316294	45.76677	53.5
15.224	170.422	169.827		FEB 23 08:09:01.563102	125.3	40.3830806	43.4158	50.6
15.72	172.5	171.883		FEB 23 08:09:02.063435	125.3	38.3080607	41.10136	48
16.16	174.283	174.109		FEB 23 08:09:02.563768	125.3	36.1532322	39.18595	45.3
16.656	175.442	175.334		FEB 23 08:09:03.064101	124.6	33.8683788	36.67737	42.2
17.148	176.375	176.88		FEB 23 08:09:03.564434	125.2	31.7092652	34.50479	39.7
17.644	176.822	178.061		FEB 23 08:09:04.064767	125.2	29.313099	32.26837	36.7
18.08	176.848	178.686		FEB 23 08:09:04.565100	125.2	27.8753994	30.03195	34.9
18.632	176.827	178.788		FEB 23 08:09:05.065433	125.1	26.7785771	27.97762	33.5
19.128	176.462	178.878		FEB 23 08:09:05.565765	125	23.44	25.76	29.3
19.62	175.905	178.52		FEB 23 08:09:06.066098	125	21.68	23.68	27.1
20.06	175.505	177.773		FEB 23 08:09:06.566431	125	19.36	21.84	24.2
20.552	173.786	176.609		FEB 23 08:09:07.066764	124.9	17.2938351	19.3755	21.6
21.048	172.952	175.311		FEB 23 08:09:07.567097	124.9	15.2121697	17.53403	19
21.544	171.127	173.686		FEB 23 08:09:08.067430	124.7	13.6327185	15.55734	17
21.984	169.423	171.988		FEB 23 08:09:08.567763	124.6	11.8780096	14.36597	14.8
22.532	167.792	169.519		FEB 23 08:09:09.068096	124.5	10.2811245	11.16466	12.8
23.024	165.366	167.286		FEB 23 08:09:09.568429	124.5	8.19277108	9.558233	10.2
23.52	162.772	164.783		FEB 23 08:09:10.068762	124.4	7.23472669	8.279743	9
23.96	160.322	162.038		FEB 23 08:09:10.569095	124.4	6.59163987	7.395498	8.2
24.452	157.952	159.303		FEB 23 08:09:11.069428	124.3	5.9533387	6.516492	7.4
24.948	155.433	156.778		FEB 23 08:09:11.569761	124.3	5.39018504	5.792438	6.7
25.44	152.331	154.152		FEB 23 08:09:12.070094	124.4	5.22508039	4.983923	6.5
25.88	149.606	151.827		FEB 23 08:09:12.570427	124.5	4.09638554	3.694779	5.1
26.432	146.491	148.967		FEB 23 08:09:13.070760	124.6	2.40770465	3.370787	3
26.924	143.762	146.673		FEB 23 08:09:13.571427	124.7	1.6840417	2.485966	2.1
27.42	140.952	144.367		FEB 23 08:09:14.072094	124.8	1.36217949	1.442308	1.7
27.86	138.07	141.608		FEB 23 08:09:14.572761	124.9	0.72057646	1.200961	0.9
28.352	135.197	138.814		FEB 23 08:09:15.073428	124.8	0.72115385	0.240385	0.9
28.848	132.811	136.067		FEB 23 08:09:15.574095	124.9	1.36108887	0.160128	1.7
29.344	130.85	133.478		FEB 23 08:09:16.074762	124.9	4.40352282	1.120897	5.5
29.836	129.048	131.378		FEB 23 08:09:16.575429	124.9	5.92473979	2.96237	7.4
30.328	127.436	129.239		FEB 23 08:09:17.076096	125	7.52	5.2	9.4
30.824	125.359	127.231		FEB 23 08:09:17.576763	125	10.64	6.8	13.3
31.32	124.806	125.045		FEB 23 08:09:18.077430	125	13.36	9.6	16.7
31.812	123.858	123.259		FEB 23 08:09:18.578096	125	15.84	12.88	19.8
32.252	123.316	121.961		FEB 23 08:09:19.078763	121.8	18.226601	15.76355	22.2

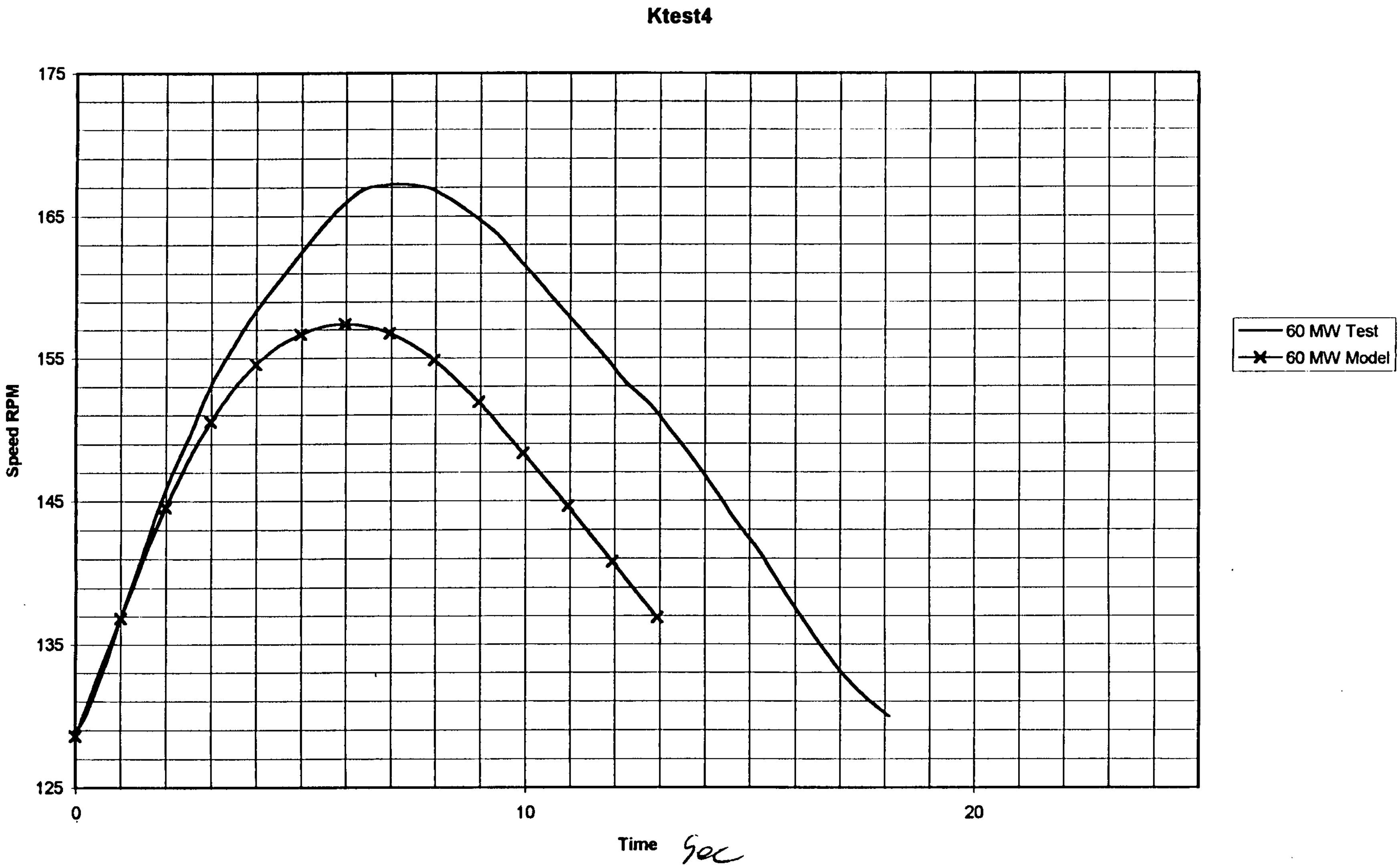
Time	RPM	RPM		Gov. Gate Timing	Voltage	% GAte	% GAte	Voltage
32.748	122.484	121.094		FEB 23 08:09:19.579430	125	21.92	18.64	27.4
33.24	122.53	120.625		FEB 23 08:09:20.080097	125	23.76	20.16	29.7
33.736	123.537	120.848		FEB 23 08:09:20.580764	124.9	27.2217774	22.33787	34
34.232	124.145	121.069		FEB 23 08:09:21.081431	124.9	27.6220977	22.97838	34.5
34.724	124.845	122.041		FEB 23 08:09:21.582098	124.7	27.6663994	23.09543	34.5
35.22	126.223	122.764		FEB 23 08:09:22.082765	124.5	27.7108434	23.13253	34.5
35.712	128.233	124.255		FEB 23 08:09:22.583432	124.3	27.5140788	23.16975	34.2
36.152	129.564	125.308		FEB 23 08:09:23.084099	124.2	27.2141707	23.02738	33.8
36.648	130.93	125.998		FEB 23 08:09:23.584766	124.1	23.8517325	22.56245	29.6
37.14	131.975	127.381		FEB 23 08:09:24.085433	123.8	22.5363489	21.48627	27.9
37.636	132.956	128.389		FEB 23 08:09:24.586100	123.8	20.7592892	20.35541	25.7
38.128	133.598	128.747		FEB 23 08:09:25.086767	123.7	18.7550525	19.32094	23.2
38.624	134.091	129.445		FEB 23 08:09:25.587434	123.6	17.1521036	18.3657	21.2
39.12	134.036	129.702		FEB 23 08:09:26.088101	123.6	15.776699	17.47573	19.5
39.612	133.875	129.783		FEB 23 08:09:26.588768	123.6	15.210356	16.42395	18.8
40.052	133.516	129.611		FEB 23 08:09:27.089435	123.7	14.9555376	16.08731	18.5
40.544	133.266	129.352		FEB 23 08:09:27.590102	123.9	14.6085553	15.81921	18.1
41.04	132.764	129.455		FEB 23 08:09:28.090769	124	14.5967742	15.80645	18.1
41.536	132.139	129.064		FEB 23 08:09:28.591436	124.1	14.9073328	15.79371	18.5
42.028	131.633	128.655		FEB 23 08:09:29.092103	124.2	15.0563607	15.781	18.7
42.524	131.197	128.727		FEB 23 08:09:29.592770	124.2	15.7809984	15.781	19.6
43.016	130.895	128.411		FEB 23 08:09:30.093187	124.3	16.1705551	15.84875	20.1

Attachment #8

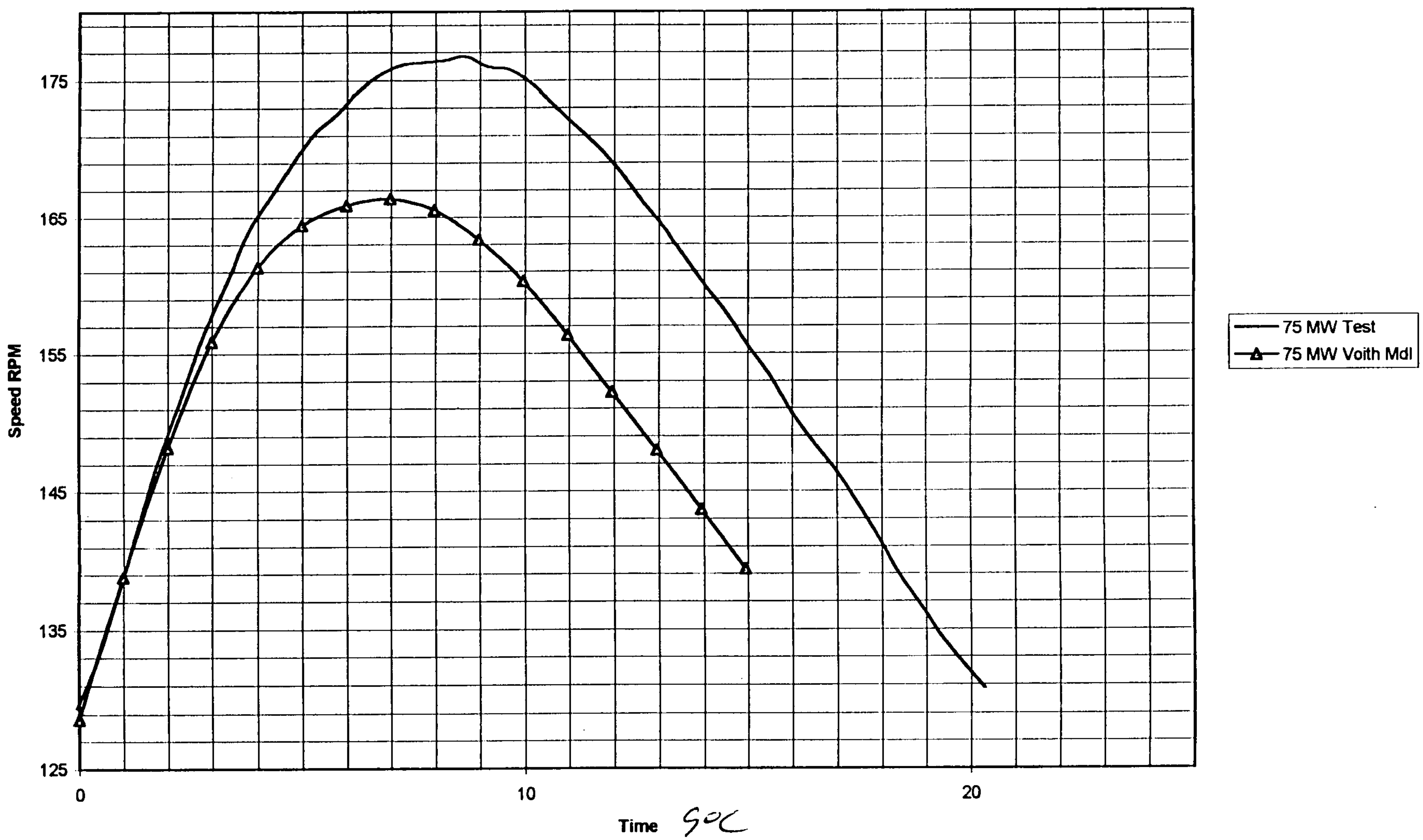

KTEST1 60MW
175
165
155
145
135
125
0
5
10
15
20
25
RPM
Sec
Test Data
Model

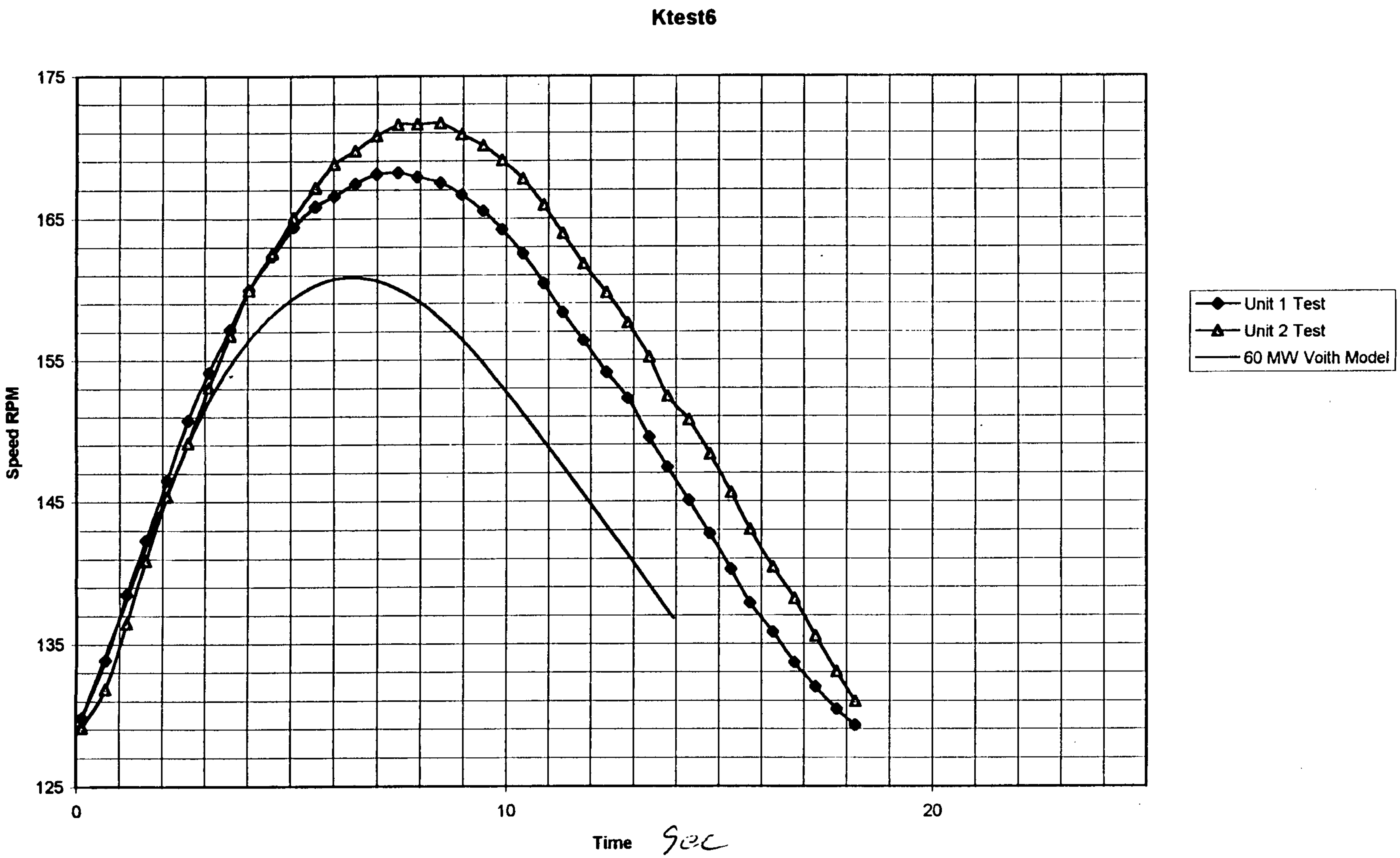

Ktest2
Speed RPM
175
165
155
145
135
125
0
10
20
Time
sec
75 MW Test
75 MW Voith Mdl

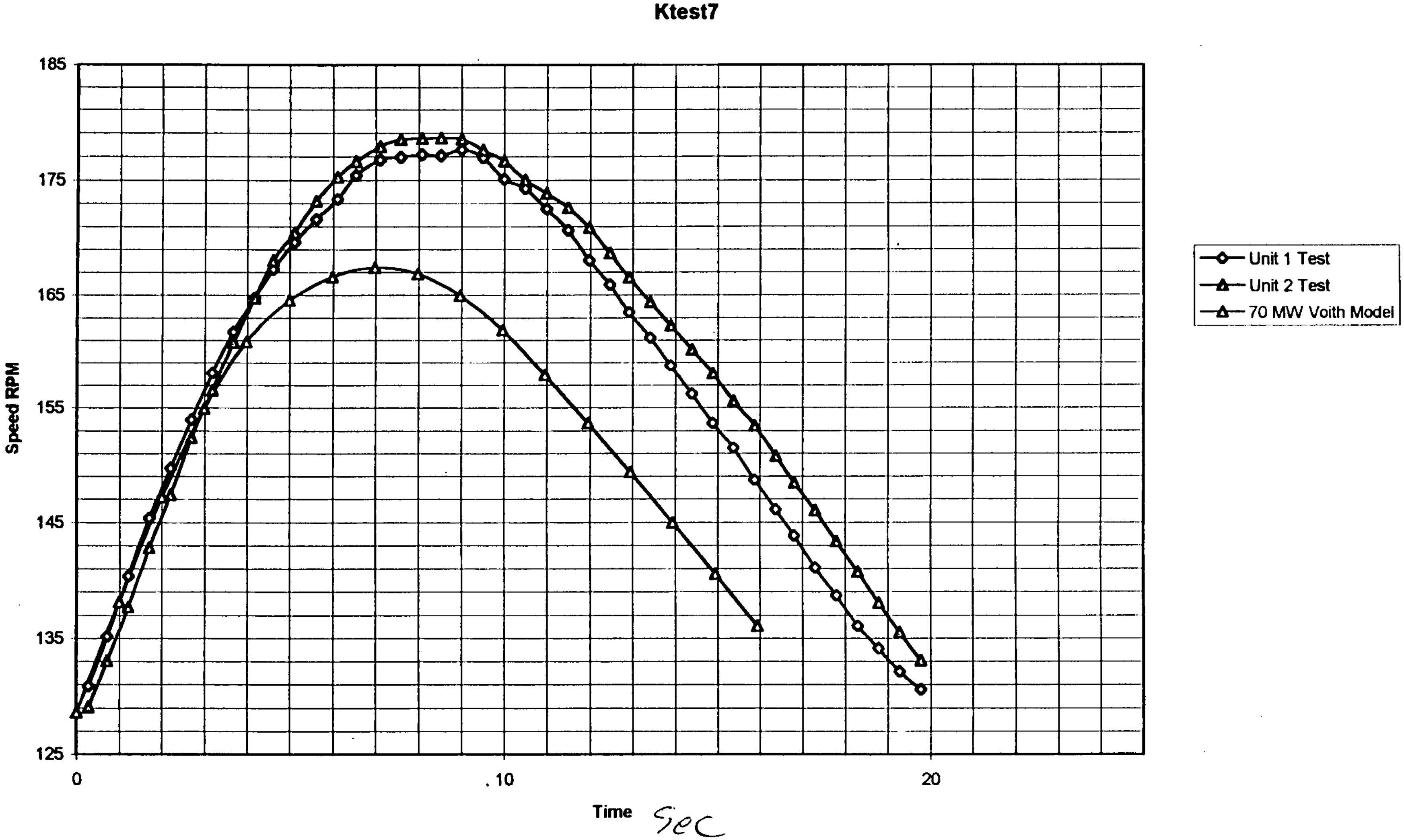

Ktest3
185
175
165
155
145
135
125
Speed RPM
0
10
20
Time
Sec.
90 MW Test
90 MW Model

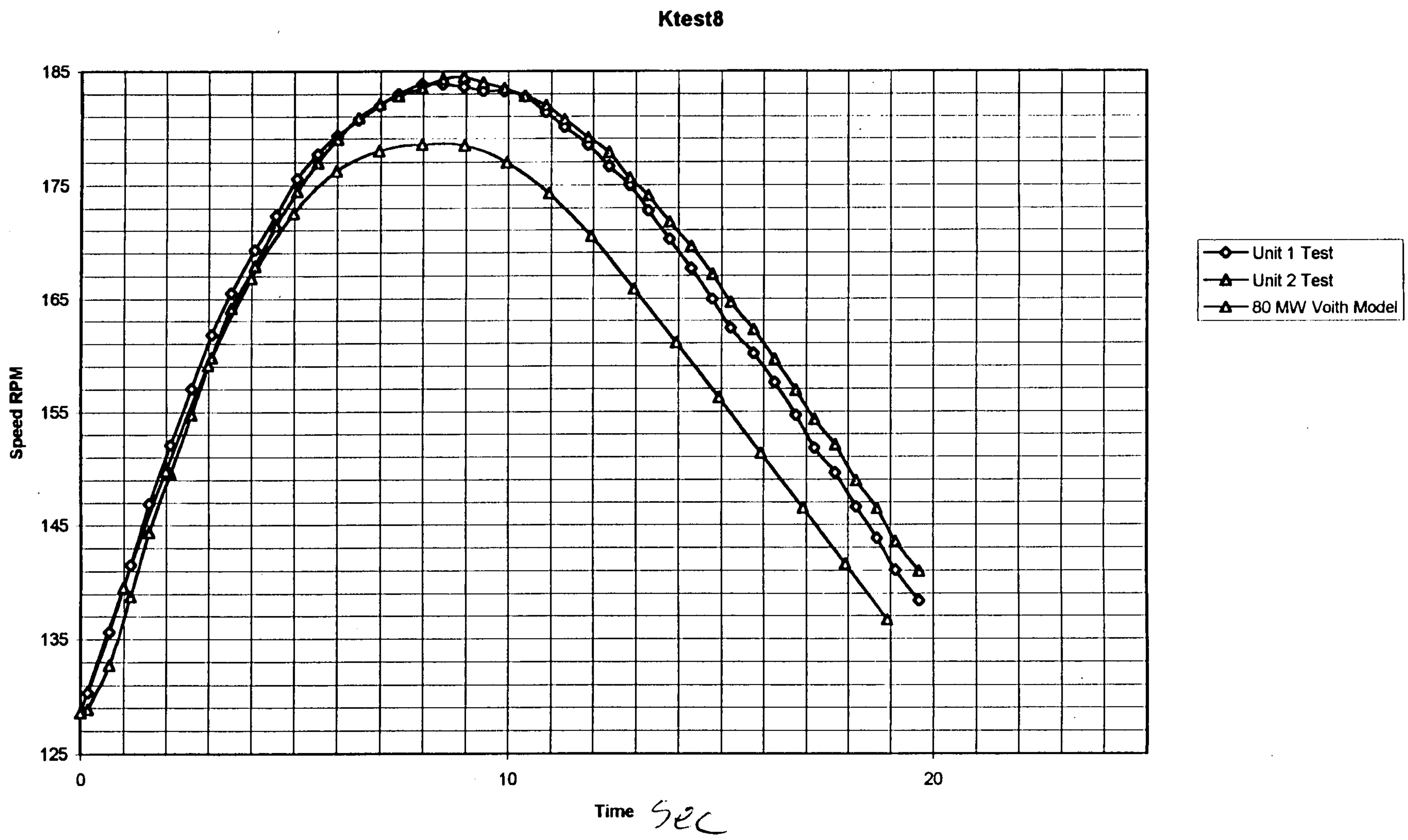

Ktest4
175
165
155
145
135
125
Speed RPM
0
10
20
Time
Sec
60 MW Test
60 MW Model

Ktest 5

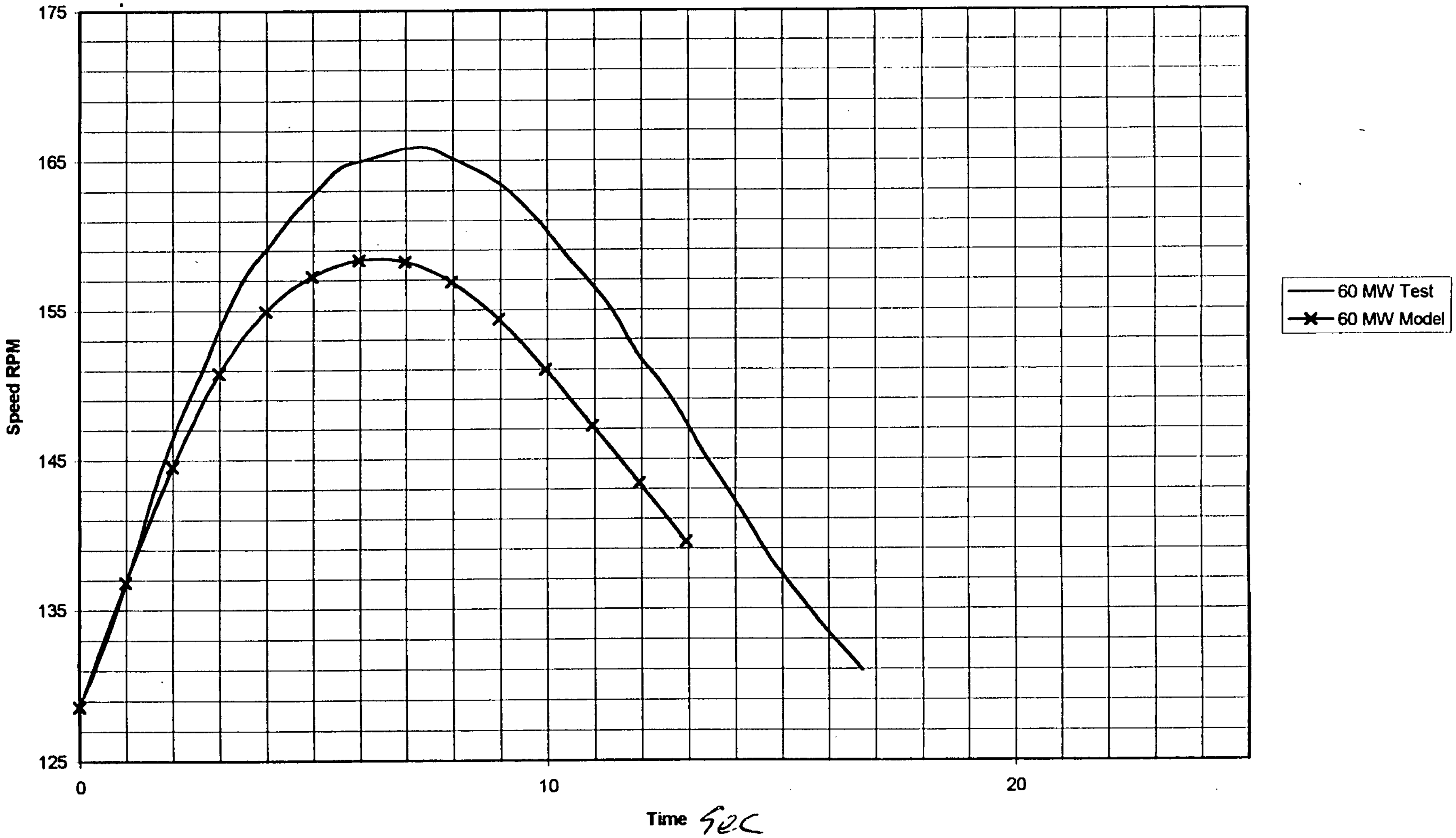

175
165
155
145
135
125
Speed RPM
0
10
20
Time
75 MW Test
75 MW Voith Mdl

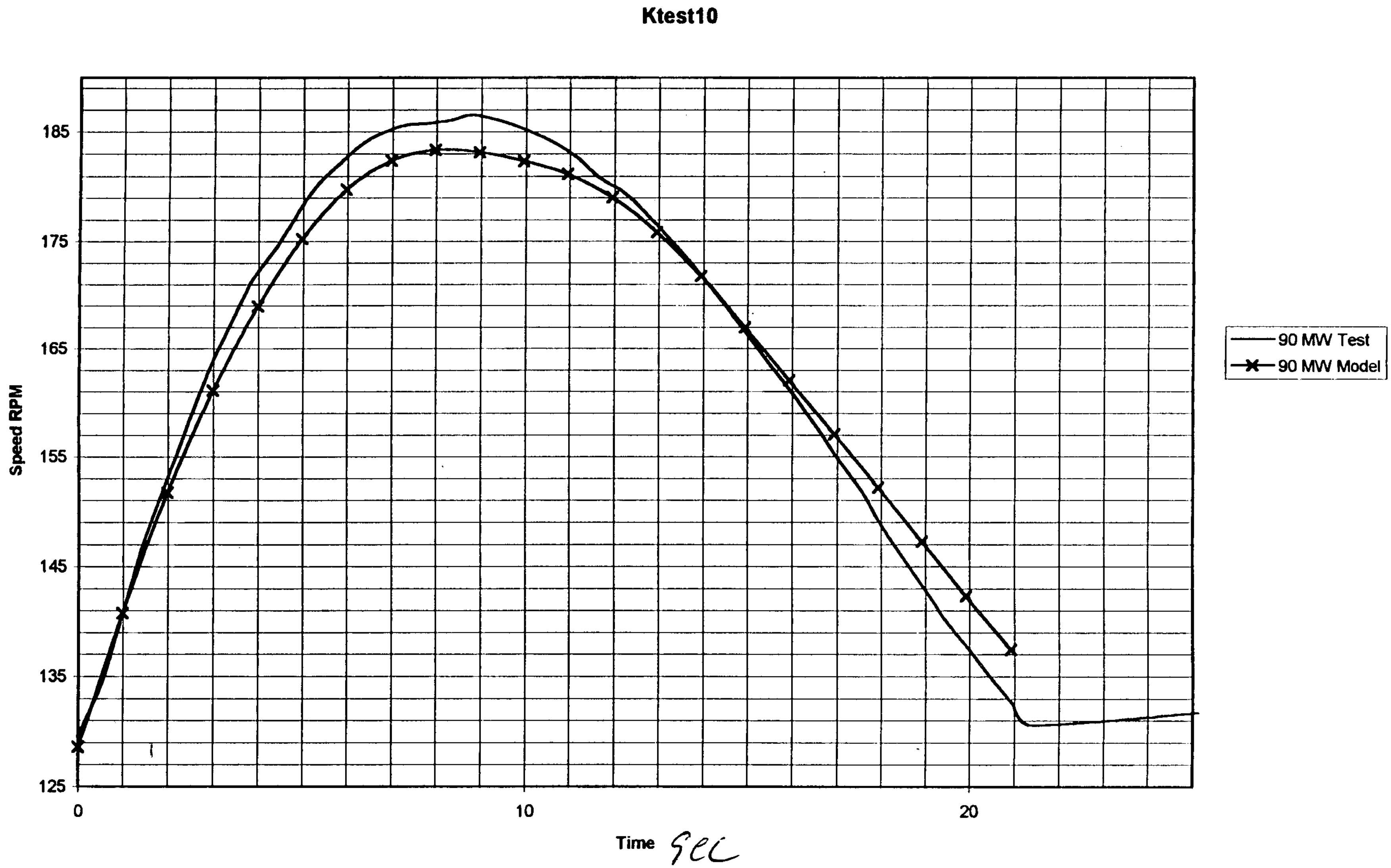

Ktest6
175
165
155
145
135
125
0
10
20
Speed RPM
Time
sec
Unit 1 Test
Unit 2 Test
60 MW Voith Model

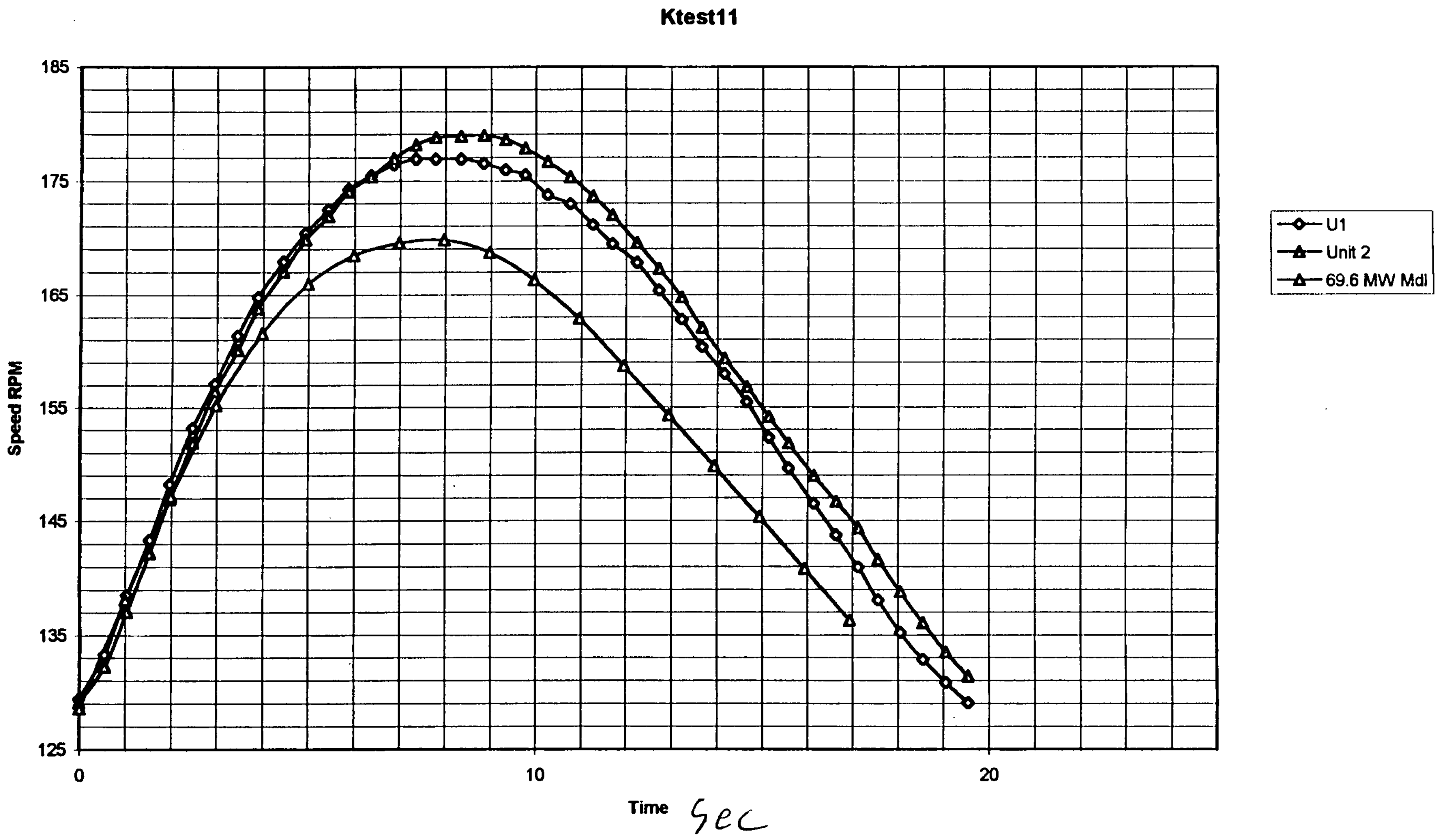

Ktest7
185
175
165
155
145
135
125
Speed RPM
0
10
20
Time
Sec
Unit 1 Test
Unit 2 Test
70 MW Voith Model


Ktest8
185
175
165
155
145
135
125
0
10
20
Speed RPM
Time Sec
Unit 1 Test
Unit 2 Test
80 MW Voith Model

Ktest9


175
165
155
145
135
125
Speed RPM
0
10
20
Time Sec
60 MW Test
60 MW Model


Ktest10
185
175
165
155
145
135
125
0
10
20
Speed RPM
Time sec
90 MW Test
90 MW Model


Ktest11
185
175
165
155
145
135
125
Speed RPM
0
10
20
Time
sec
U1
Unit 2
69.6 MW Mdl

Attachment #9

VOITH HYDRO, INC. TELEFAX

DATE:	April 10, 1995	FROM:	VOITH HYDRO, INC. East Berlin Road P.O. Box 712 York, PA 17405
TO:	Duke Power		
ATTN:	John Beckman		
RE:	Keowee Data		Tel: (717) 792-7155 Tfx: (717) 792-7263 Tlx: 4764013
TELEFAX #:	(803) 885-4028		
SENT BY:	Michael Byrne		NO. OF PAGES: 3 (incl. cover page)

If you do not receive all the pages, or if trouble occurs during transmission, please call (717) 792-7852 as soon as possible

Hello John:

Enclosed is a plot showing the results of the case you faxed dated April 8, 1995. Based on our phone call of April 8, 1995 and a review of the distributor section drawing 4450-FO-1 the runner will produce a varying braking effect due to the influence of tailwater elevation. The braking effect is non existent when the runner is rotating in air and will vary depending on whether the runner is rotating in a air/water mixture and will achieve a maximum braking effect when the runner is completely submerged by tailwater elevation. Based on the distributor section drawing the bottom of the runner at the periphery is at elevation 657.17 feet. The top of the runner at the periphery is at elevation 662.01 feet. The bottom of the runner at the hub is at approximately elevation 660.68 feet. The top of the runner at the hub is at approximately elevation 666.5 feet. The transient program can attempt to model these changes by varying two input variables the first being the unit inertia and the second being the closed gate torque coefficient.

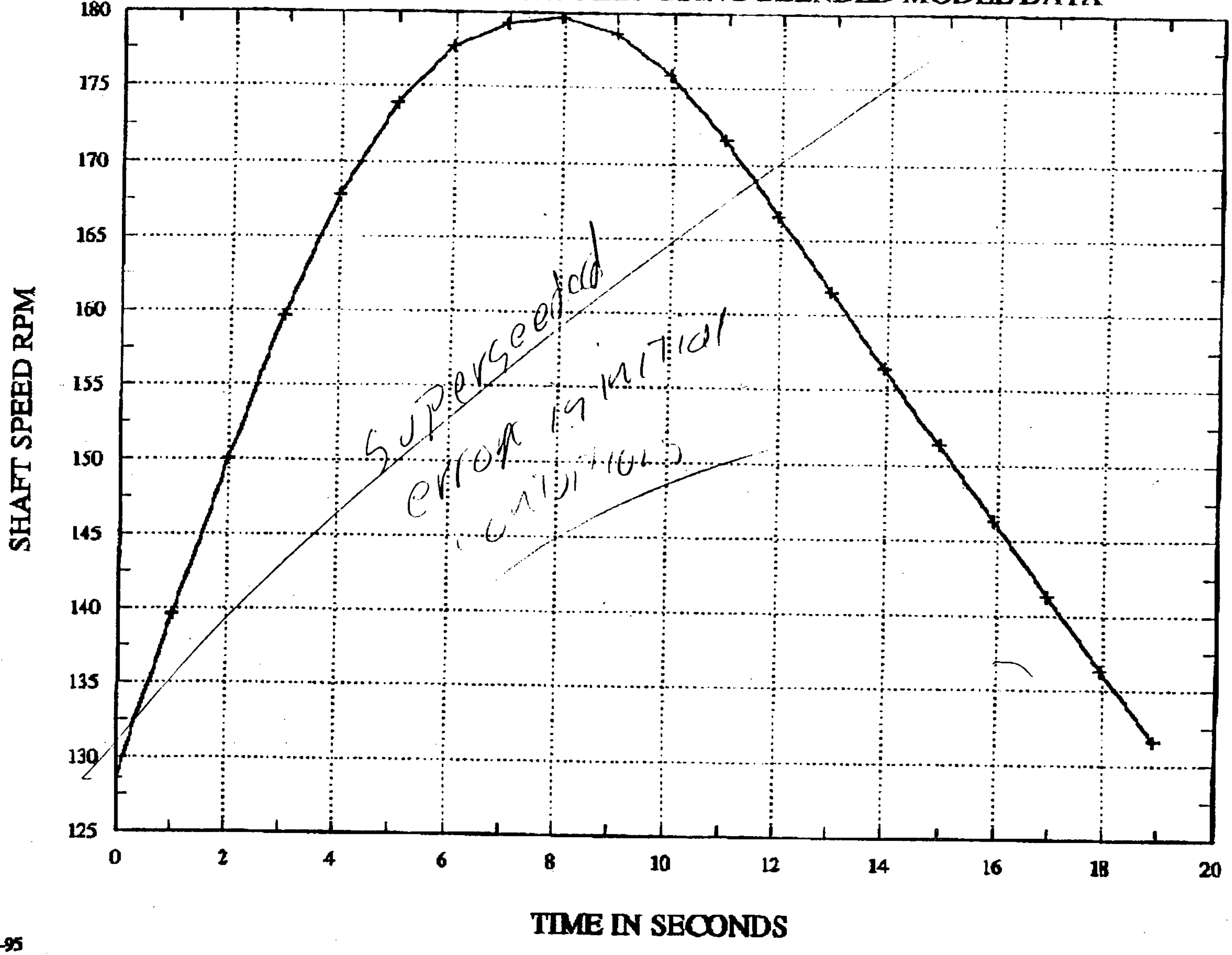
Regards,

Michael Byrne

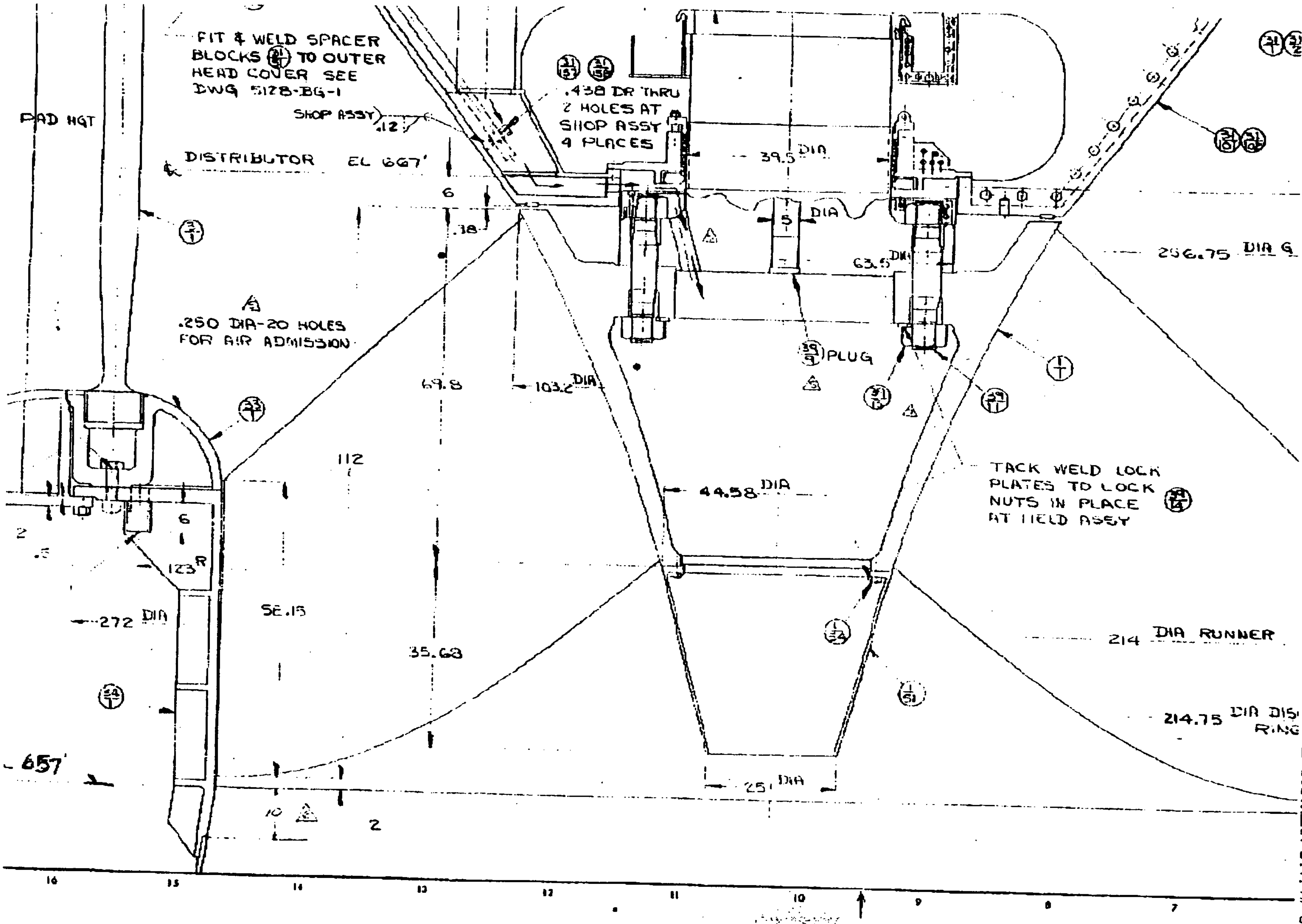
Michael Byrne

SENT BY:VOITH HYDRO : 4-10-95 : 3:48PM : VOITH HYDRO- CMD SOUTHERN DIV.:# 2/ 3

KEOWEE 2 UNIT 80.4 MW GENERATOR LOAD REJECTION 4/8/95 FAX
HW = 794.72 TW = 668.1 FEET USING BLENDED MODEL DATA



04-10-95


FIT & WELD SPACER BLOCKS TO OUTER HEAD COVER SEE DWG 5128-BG-1
SHOP ASSY
.12
PAD HGT
DISTRIBUTOR EL 667'
.438 DR THRU 2 HOLES AT SHOP ASSY 4 PLACES
39.5 DIA
5 DIA
63.5 DIA
256.75 DIA G
.250 DIA-20 HOLES FOR AIR ADMISSION
PLUG
6
.18
69.8
103.2 DIA
112
44.58 DIA
TACK WELD LOCK PLATES TO LOCK NUTS IN PLACE AT FIELD ASSY
123 R
272 DIA
35.63
214 DIA RUNNER
214.75 DIA DIS RING
657'
25 DIA
2

VOITH HYDRO, INC. TELEFAX

DATE:	May 1, 1995	FROM:	VOITH HYDRO, INC. East Berlin Road P.O. Box 712 York, PA 17405
TO:	Duke Power		
ATTN:	John Beckman		
RE:	Keowee Data		Tel: (717) 792-7155 Tfx: (717) 792-7263 Tlx: 4764013
TELEFAX #:	(803) 885-4028		
SENT BY:	Michael Byrne		NO. OF PAGES: 2 (incl. cover page)

If you do not receive all the pages, or if trouble occurs during transmission, please call (717) 792-7852 as soon as possible

Hello John:

Based on your phone request of earlier today here is a brief discussion of braking torque due to the runner spinning in water. Please also refer to the telefax of April 10, 1995 which referenced the tailwater elevations where this braking torque will have some influence at Keowee. Looking at this topic from a different perspective think of a unit in the synchronous condense mode. Normally on hydroelectric turbines either the unit is set above tailwater or the plant is equipped with a compressed air system for the purpose of depressing the tailwater elevation below the bottom of the rotating runner. The reason for this is that it requires additional input power to rotate a unit at synchronous speed with the wicket gates closed and the runner spinning in water versus the runner spinning in air. For example on Grand Coulee it required 135 MW of input power to rotate this unit at synchronous speed with the wicket gates closed and the runner in water. If that unit was designed for synchronous condense operation with the runner spinning in air the input power would probably be in the 15 to 20 MW range. The preceding example makes it clear that it requires a tremendous amount of additional torque to spin a unit at synchronous speed in water versus air.

Looking at this on the flip side during normal turbine shutdowns and load rejections this phenomena of water in the runner will have a decelerating or braking effect on the unit speed. Your field data taken at high tailwaters at Keowee also supports this. One way to model the braking effect during hydraulic transient simulations is to calculate the volume of water rotating with the runner ~~water~~ and multiply it by the specific weight of water(62.4 pounds per cubic foot) arriving at a mass of water. Then a radius of gyration is determined for the mass of water and then an inertia (WRR) for the water can be calculated. This value is added to the inertia of the rotating turbine generator parts which also acts as a braking effect. This water inertia is a difficult number to calculate but Duke could measure it at the Keowee site, if the electrical system can withstand the reverse power loading, by

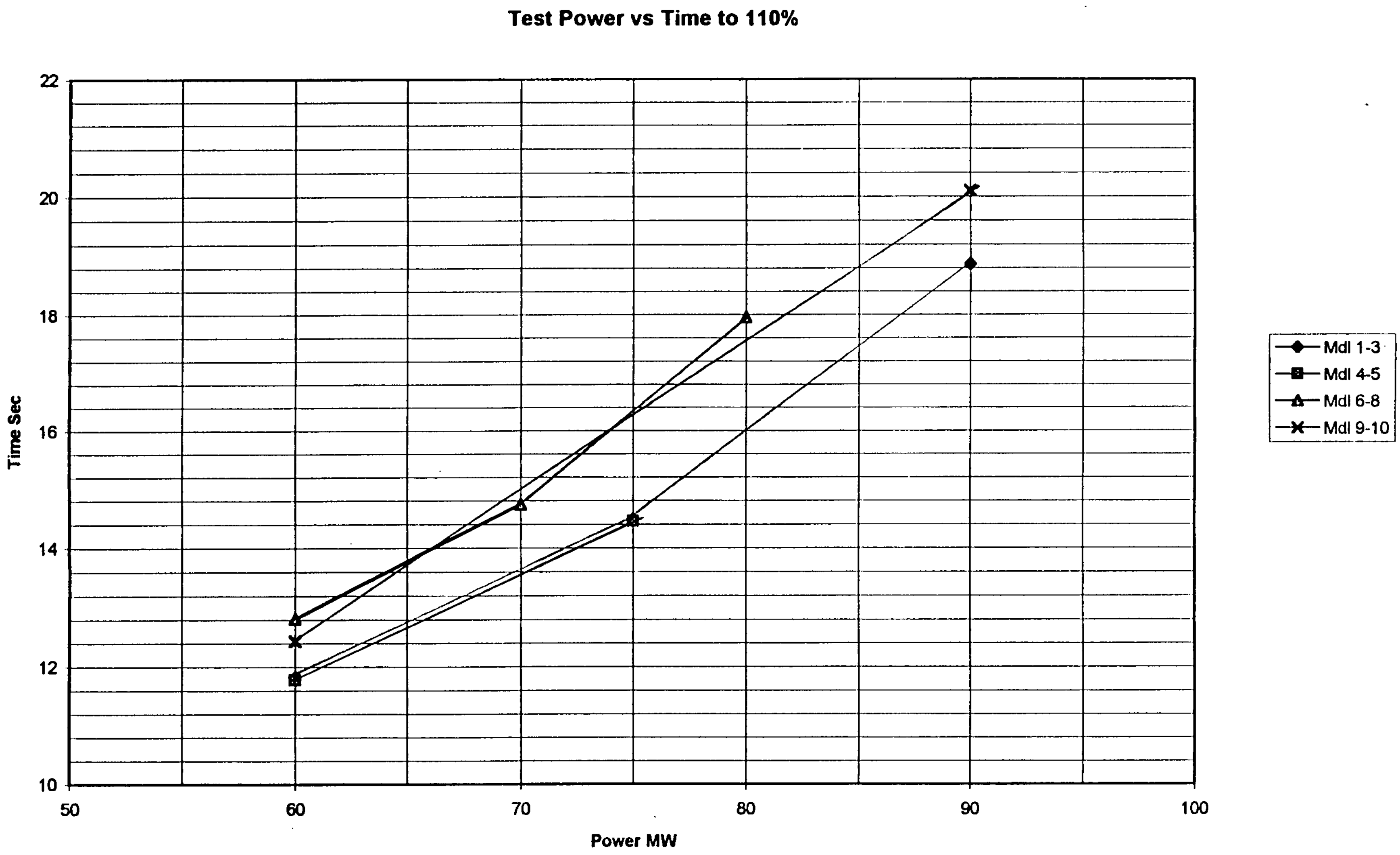
performing synchronous condenser operation at a variety of tailwater elevations.

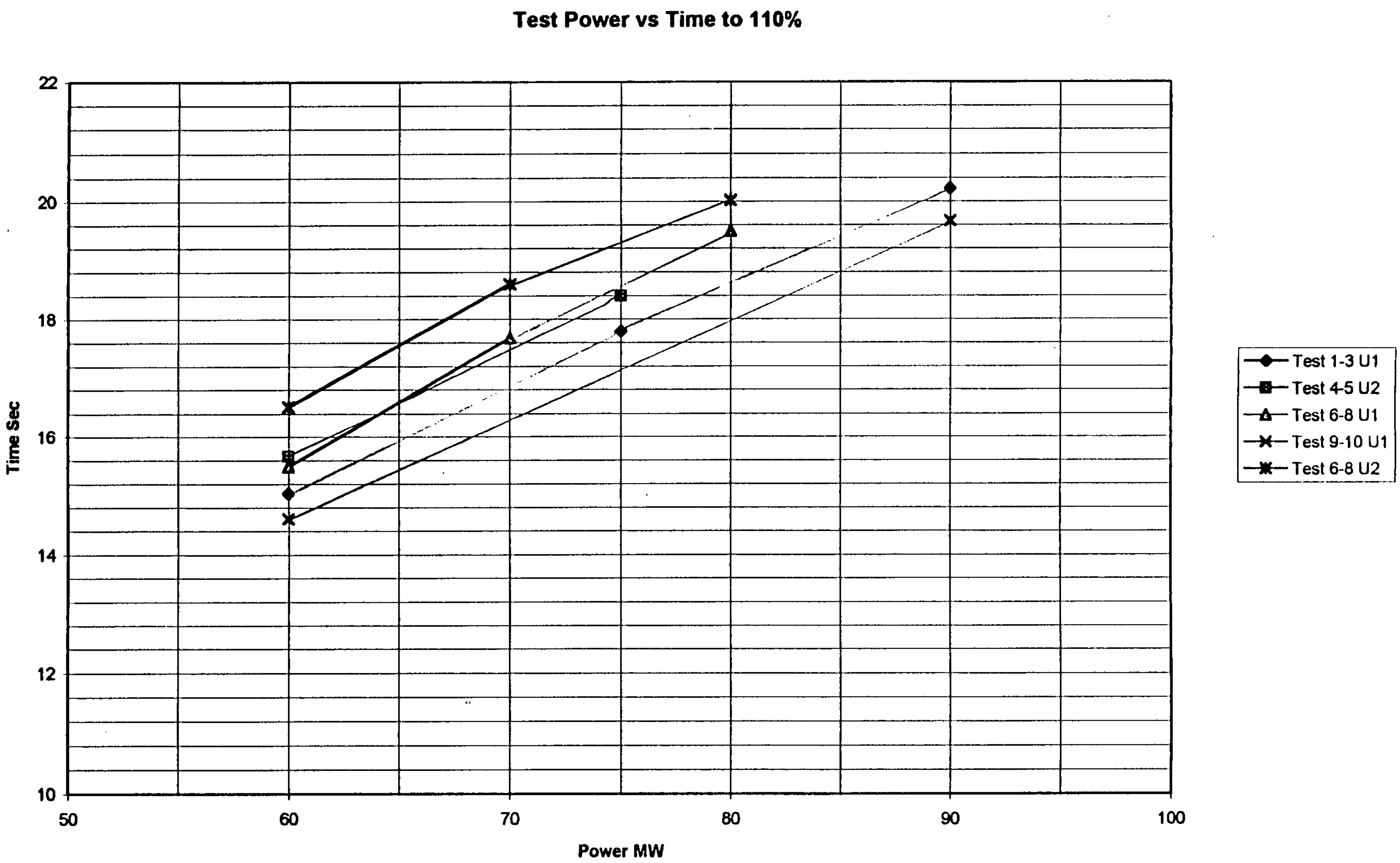
I hope this discussion sheds additional light on the subject. I will be out of the office till May 5, 1995 but you can reach me in Phoenix at (602)943-2341 or 371-8470(fax).

Regards,

Michael Byrne

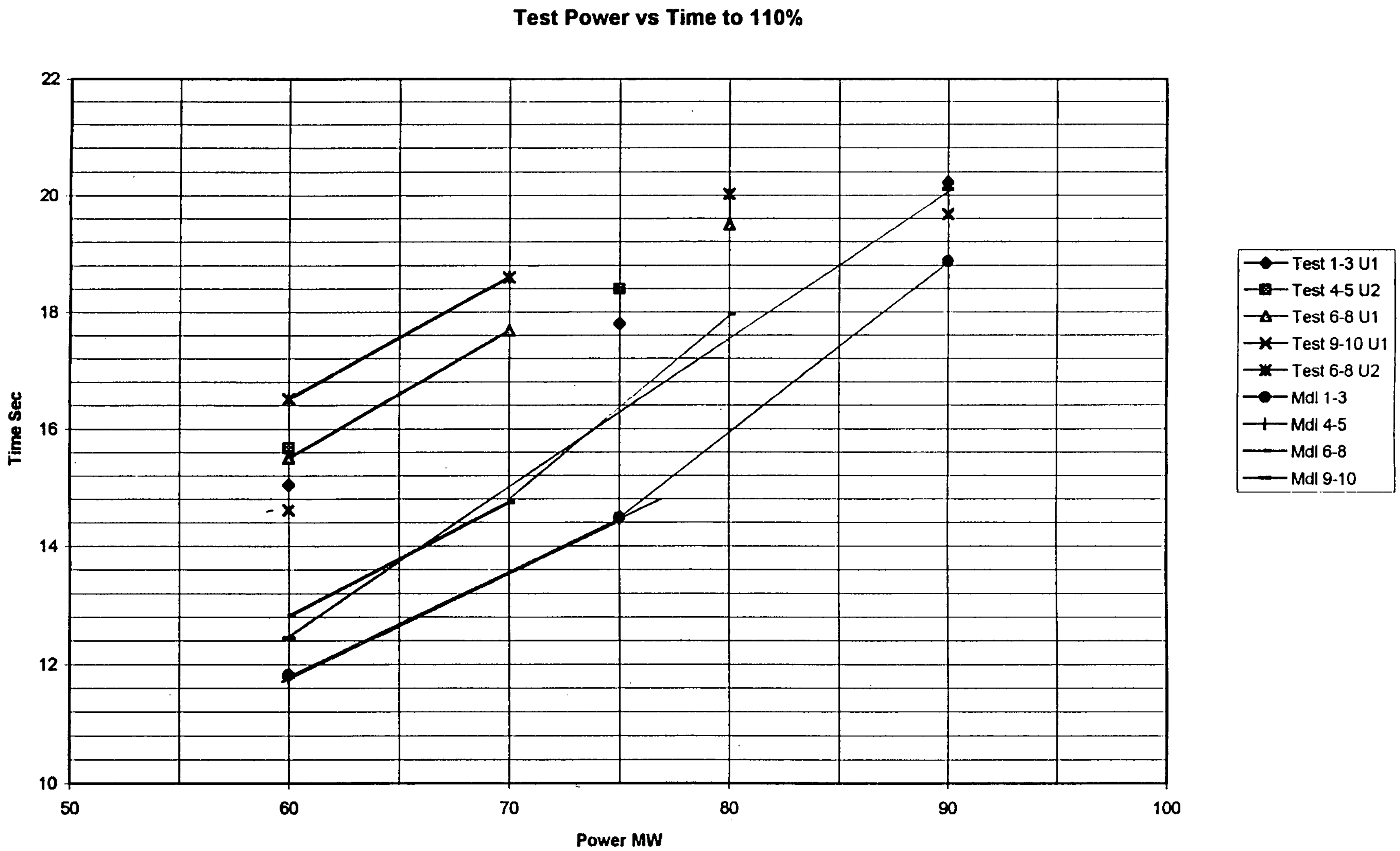
Attachment #10


Test Power vs Time to 110%
22
20
18
16
14
12
10
Time Sec
50
60
70
80
90
100
Power MW
Mdl 1-3
Mdl 4-5
Mdl 6-8
Mdl 9-10



Test Power vs Time to 110%
Time Sec
22
20
18
16
14
12
10
50
60
70
80
90
100
Power MW
Test 1-3 U1
Test 4-5 U2
Test 6-8 U1
Test 9-10 U1
Test 6-8 U2

Sheet1 Chart 2

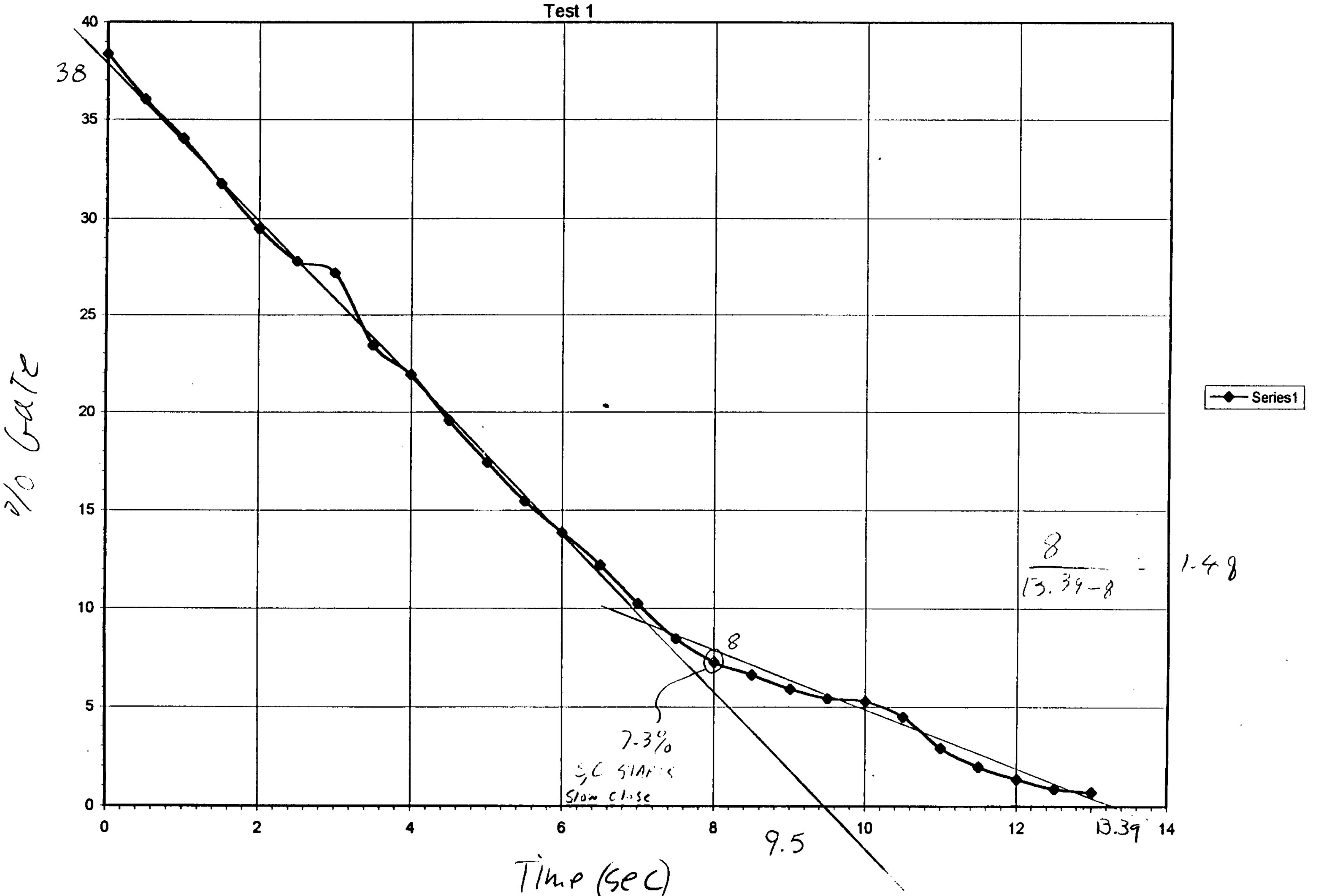


	A	B	C	D	E	F	G	H	I
1		Test		1	2	3			
2		Pwr		60	75	90			
3		Unit		1	1	1			
4		Forbay		799.87'	799.9	799.85			
5		Tail		663.45	663.6	664.25	Slope, Power vs Time		
6		Tst T		15.04	17.79	20.22	0.172666667		
7		Mdl T		11.82	14.49	18.87	0.235		
8									
9		Test		4	5				
10		Pwr		60	75				
11		Unit		2	2				
12		Forbay		799.85'	799.82				
13		Tail		663.02	663.13		Slope, Power vs Time		
14		Tst T		15.67	18.4		0.182		
15		Mdl T		11.78	14.46		0.178666667		
16									
17		Test		6	7	8			
18		Pwr		60	70	80			
19		Unit		1	1	1			
20		Forbay		799.83'	799.58	799.72			
21		Tail		666.65	667.51	668.1	Slope, Power vs Time		
22		Tst T		15.5	17.68	19.49	0.1995		
23		Mdl T		12.82	14.74	17.95	0.2565		
24									
25		Test		6	7	8			
26		Pwr		60	70	80			
27		Unit		2	2	2			
28		Forbay		799.83'	799.58	799.72			
29		Tail		666.65	667.51	668.1	Slope, Power vs Time		
30		Tst T		16.51	18.6	20.02	0.1755		
31		Mdl T		12.82	14.74	17.95	0.2565		
32									
33		Test		9	10				
34		Pwr		60	90				
35		Unit		1	1				
36		Forbay		799.44'	799.44				
37		Tail		670.4	671.7		Slope, Power vs Time		
38		Tst T		14.61	19.67		0.168666667		
39		Mdl T		12.44	20.1		0.255333333		

	A	B	C	D	E	F	G
1		Test		1	2	3	
2		Pwr		60	75	90	
3		Unit		1	1	1	
4		Forbay		799.87'	799.9	799.85	
5		Tail		663.45	663.6	664.25	Slope, Power vs Time
6		Tst T		15.04	17.79	20.22	=LINEST(D6:F6,D2:F2)
7		Mdl T		11.82	14.49	18.87	=LINEST(D7:F7,D2:F2)
8							
9		Test		4	5		
10		Pwr		60	75		
11		Unit		2	2		
12		Forbay		799.85'	799.82		
13		Tail		663.02	663.13		Slope, Power vs Time
14		Tst T		15.67	18.4		=LINEST(D14:E14,D10:E10)
15		Mdl T		11.78	14.46		=LINEST(D15:E15,D10:E10)
16							
17		Test		6	7	8	
18		Pwr		60	70	80	
19		Unit		1	1	1	
20		Forbay		799.83'	799.58	799.72	
21		Tail		666.65	667.51	668.1	Slope, Power vs Time
22		Tst T		15.5	17.68	19.49	=LINEST(D22:F22,D18:F18)
23		Mdl T		12.82	14.74	17.95	=LINEST(D23:F23,D18:F18)
24							
25		Test		6	7	8	
26		Pwr		60	70	80	
27		Unit		2	2	2	
28		Forbay		799.83'	799.58	799.72	
29		Tail		666.65	667.51	668.1	Slope, Power vs Time
30		Tst T		16.51	18.6	20.02	=LINEST(D30:F30,D26:F26)
31		Mdl T		12.82	14.74	17.95	=LINEST(D31:F31,D26:F26)
32							
33		Test		9	10		
34		Pwr		60	90		
35		Unit		1	1		
36		Forbay		799.44'	799.44		
37		Tail		670.4	671.7		Slope, Power vs Time
38		Tst T		14.61	19.67		=LINEST(D38:E38,D34:E34)
39		Mdl T		12.44	20.1		=LINEST(D39:E39,D34:E34)

Attachment #11

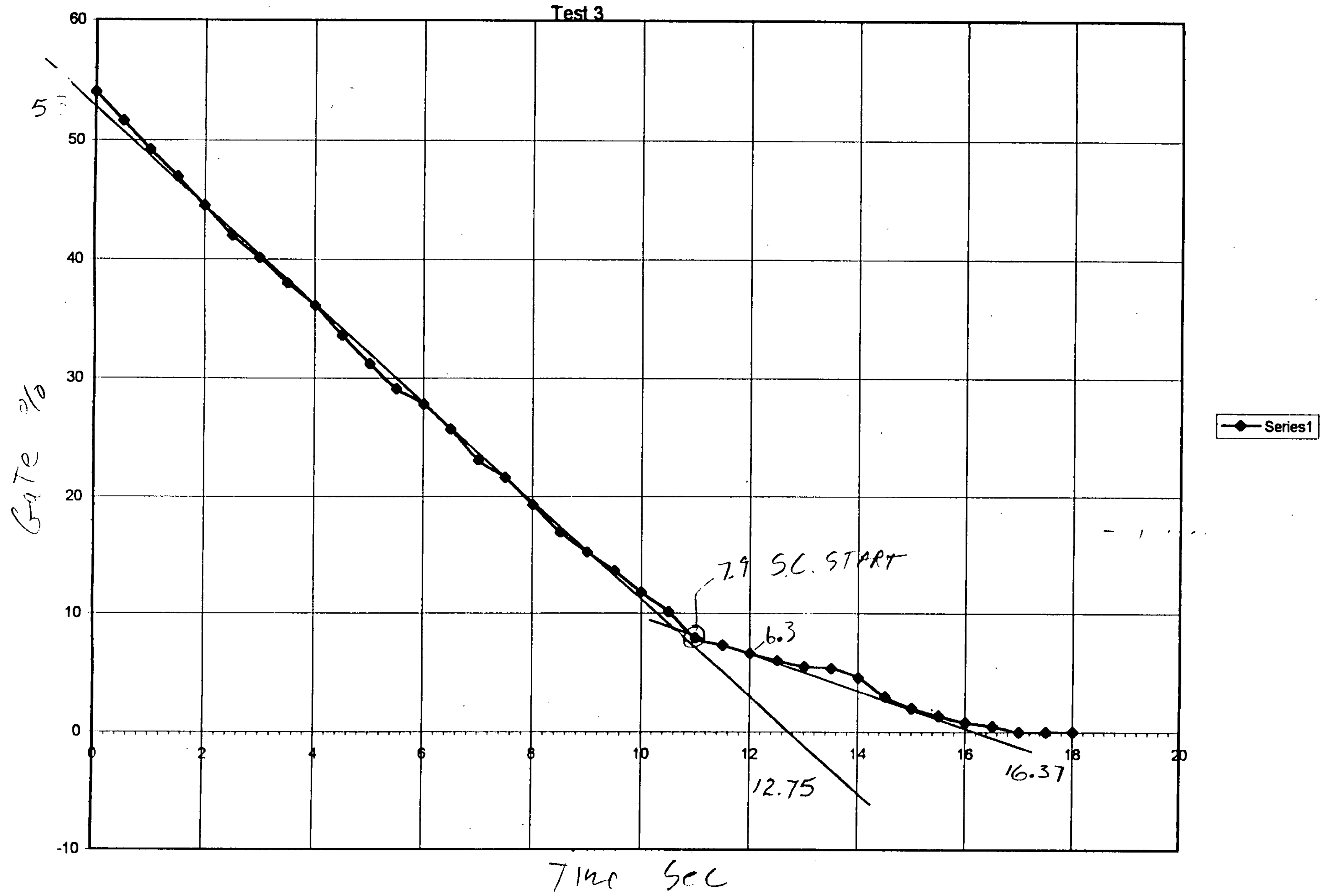
Sheet1 Chart 1



	D	E	F
1	Test 1		
2	sec	% Gate	Slpoe
3	0	38.37667	-3.99965
4	0.50025	36.04101	
5	1.0005	34.04255	
6	1.50075	31.78233	
7	2.001	29.49527	
8	2.50125	27.81718	
9	3.0015	27.2082	
10	3.50175	23.42271	
11	4.002	21.90701	
12	4.50225	19.54295	
13	5.0025	17.42902	
14	5.50275	15.44523	
15	6.003	13.86919	
16	6.50325	12.21434	
17	7.0035	10.24429	
18	7.50375	8.438486	
19	8.004	7.255521	-1.48421
20	8.50425	6.619385	
21	9.0045	5.914826	
22	9.50475	5.437352	
23	10.005	5.279748	
24	10.50525	4.495268	
25	11.0055	2.915682	
26	11.50575	1.971609	
27	12.006	1.340694	
28	12.50625	0.867508	

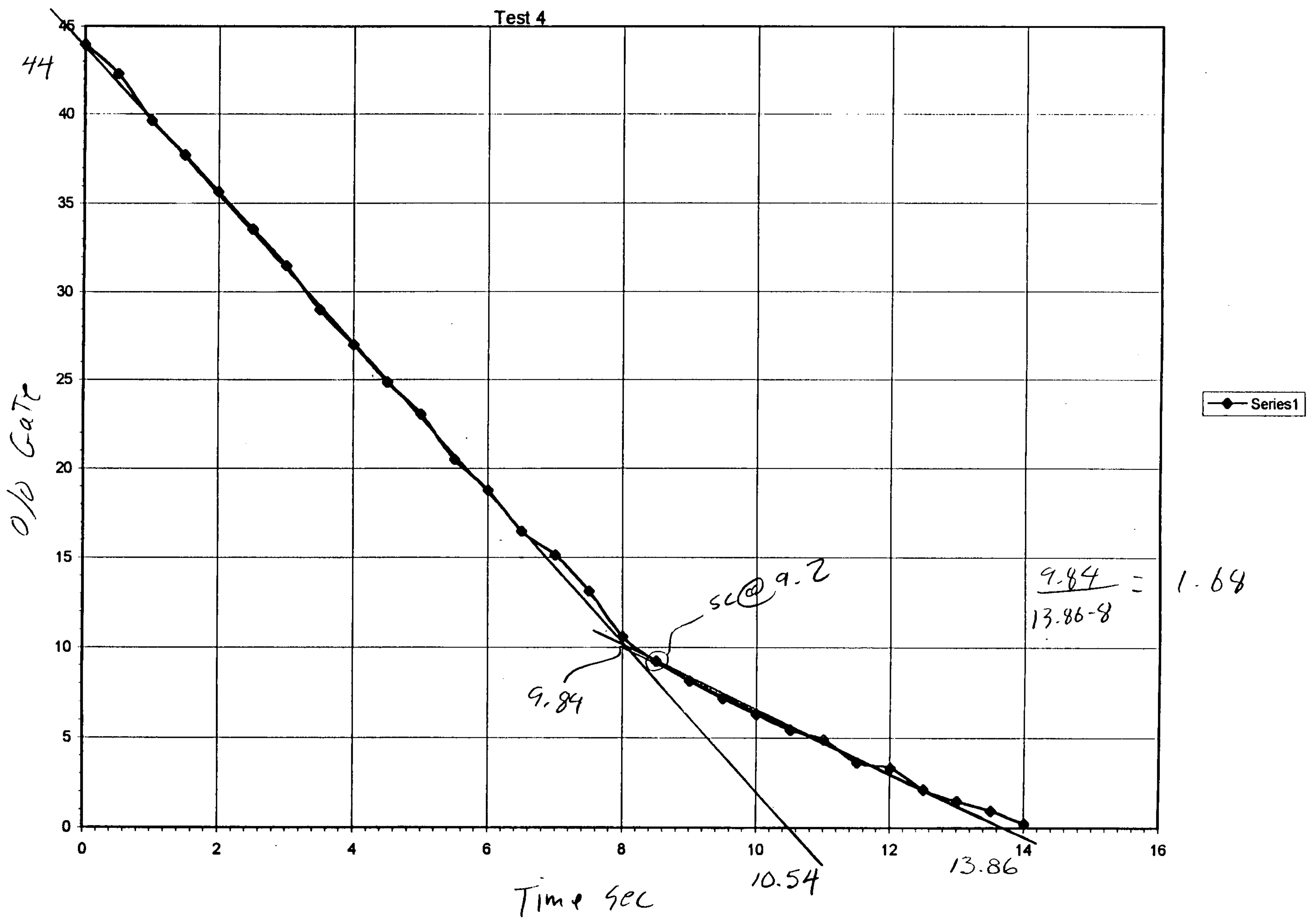
	D	E	F
1	Test 1		
2	sec	% Gate	Slpoe
3	0	38.3766745468873	=LINEST(E3:E18,D3:D18)
4	0.500250000000001	36.0410094637224	
5	1.0005	34.0425531914894	
6	1.50075	31.782334384858	
7	2.001	29.4952681388013	
8	2.50125	27.8171788810087	
9	3.0015	27.2082018927445	
10	3.50175	23.4227129337539	
11	4.002	21.9070133963751	
12	4.50225	19.5429472025217	
13	5.0025	17.4290220820189	
14	5.50275	15.4452324665091	
15	6.003	13.8691883372734	
16	6.50325	12.214342001576	
17	7.0035	10.2442868400315	
18	7.50375	8.4384858044164	
19	8.004	7.25552050473186	=LINEST(E19:E28,D19:D28)
20	8.50425	6.6193853427896	
21	9.0045	5.91482649842271	
22	9.50475	5.43735224586288	
23	10.005	5.27974783293932	
24	10.50525	4.49526813880126	
25	11.0055	2.91568163908589	
26	11.50575	1.97160883280757	
27	12.006	1.34069400630915	
28	12.506249	0.867507886435331	

Sheet1 Chart 1



	D	E	F
1	Test 3		
2	sec	%Gate	slope
3	0	54.01575	-4.16317
4	0.500333	51.61545	
5	1.000666	49.2126	
6	1.500998	46.92913	
7	2.001331	44.52325	
8	2.501664	42.00158	
9	3.001997	40.11032	
10	3.50233	37.98266	
11	4.002663	36.06299	
12	4.502996	33.56974	
13	5.003329	31.1811	
14	5.503662	29.07801	
15	6.003995	27.81718	
16	6.504328	25.70978	
17	7.004661	23.10726	
18	7.504994	21.60883	
19	8.005327	19.32177	
20	8.50566	16.96922	
21	9.005993	15.24487	
22	9.506326	13.66509	
23	10.00666	11.76935	
24	10.50699	10.11058	
25	11.00733	7.898894	-1.45235
26	11.50766	7.266983	
27	12.00799	6.556082	
28	12.50832	5.924171	
29	13.00866	5.445935	
30	13.50899	5.292259	
31	14.00932	4.50237	
32	14.50966	2.922591	
33	15.00999	1.974724	
34	15.51032	1.342812	
35	16.01065	0.789889	

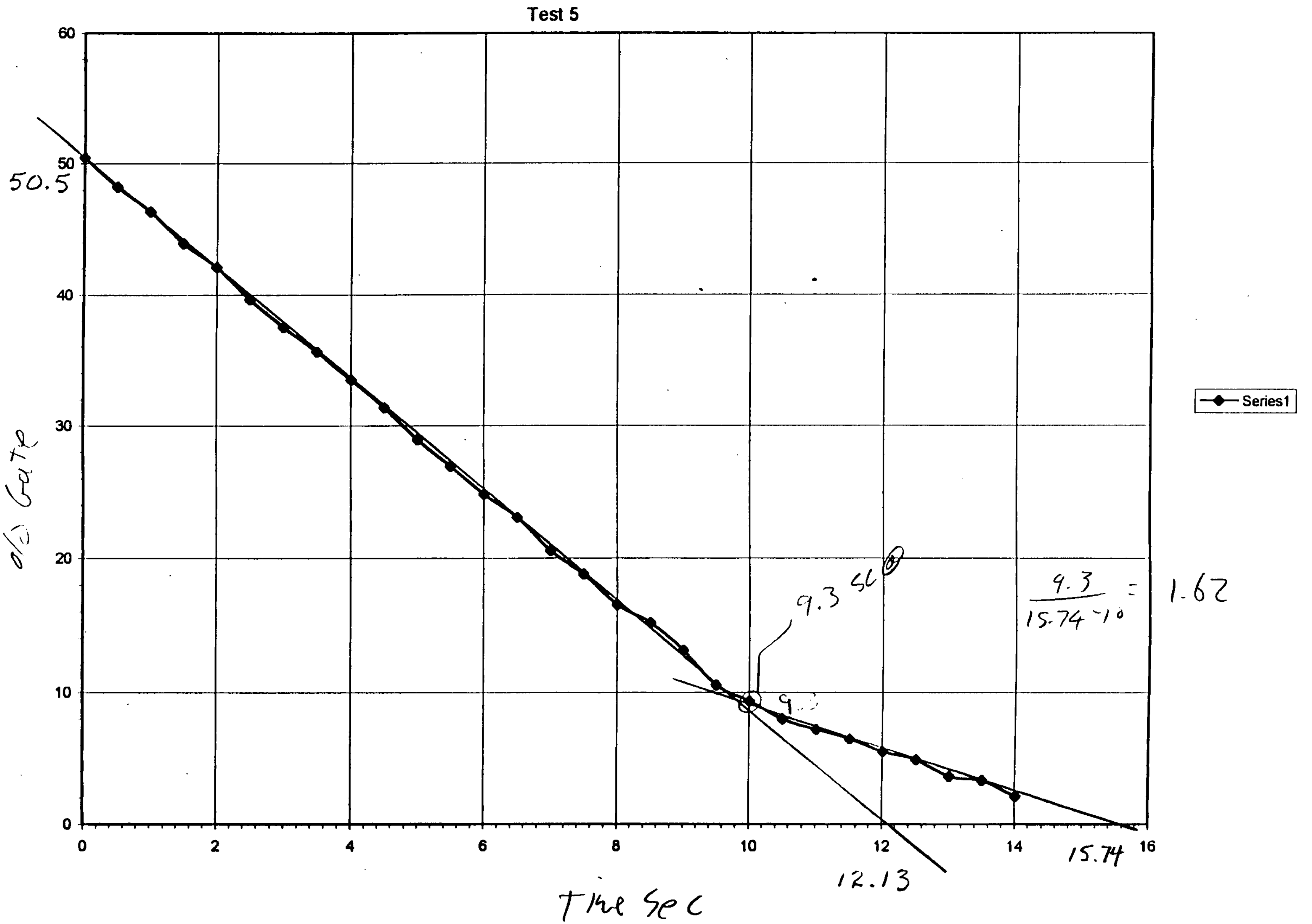
	D	E	F
1	Test 3		
2	sec	%Gate	slope
3	0	54.0157480314961	=LINEST(E3:E25,D3:D25)
4	0.500333	51.6154452324665	
5	1.000666	49.2125984251969	
6	1.500998	46.9291338582677	
7	2.001331	44.5232466509062	
8	2.501664	42.0015760441292	
9	3.001997	40.1103230890465	
10	3.50233	37.9826635145784	
11	4.002663	36.0629921259843	
12	4.502996	33.5697399527187	
13	5.003329	31.1811023622047	
14	5.503662	29.0780141843972	
15	6.003995	27.8171788810087	
16	6.504328	25.7097791798107	
17	7.004661	23.1072555205047	
18	7.504994	21.608832807571	
19	8.005327	19.3217665615142	
20	8.50566	16.9692186266772	
21	9.005993	15.2448657187994	
22	9.506326	13.6650868878357	
23	10.006659	11.7693522906793	
24	10.506992	10.1105845181675	
25	11.007325	7.89889415481833	=LINEST(E25:E35,D25:D35)
26	11.507658	7.26698262243286	
27	12.00799	6.55608214849921	
28	12.508323	5.92417061611374	
29	13.008656	5.44593528018942	
30	13.508989	5.29225908372828	
31	14.009322	4.50236966824645	
32	14.509655	2.92259083728278	
33	15.009988	1.97472353870458	
34	15.510321	1.34281200631912	
35	16.010654	0.789889415481833	


Test 4
44
45
40
35
30
25
20
15
10
5
0
% Gate
0
2
4
6
8
10
12
14
16
Time sec
Series1
sc@9.2
9.84
10.54
13.86
9.84 / 13.86-8 = 1.68

	D	E	F
1	Test 4		
2	sec	gate	slope
3	0	43.96212	-4.17379
4	0.500417	42.30466	
5	1.000834	39.62115	
6	1.501251	37.69716	
7	2.001668	35.64669	
8	2.502085	33.5438	
9	3.002585	31.49171	
10	3.503085	28.96606	
11	4.003585	26.97161	
12	4.504085	24.84227	
13	5.004585	23.02839	
14	5.505085	20.50473	
15	6.005585	18.76972	
16	6.506085	16.48265	
17	7.006585	15.14196	
18	7.507085	13.09148	
19	8.007585	10.56782	-1.6778
20	8.508085	9.227129	
21	9.008585	8.123028	
22	9.509085	7.176656	
23	10.00959	6.309148	
24	10.51009	5.44164	
25	11.01059	4.88959	
26	11.51109	3.62776	
27	12.01159	3.314917	
28	12.51209	2.129338	
29	13.01259	1.498423	
30	13.51309	0.946372	
31	14.01358	0.23678	

	D	E	F
1	Test 4		
2	sec	gate	slope
3	0	43.9621152328335	=LINEST(E3:E19,D3:D19)
4	0.500417	42.3046566692976	
5	1.000834	39.6211523283347	
6	1.501251	37.6971608832808	
7	2.001668	35.6466876971609	
8	2.502085	33.5438042620363	
9	3.002585	31.4917127071823	
10	3.503085	28.9660615627466	
11	4.003585	26.9716088328076	
12	4.504085	24.8422712933754	
13	5.004585	23.0283911671924	
14	5.505085	20.5047318611987	
15	6.005585	18.7697160883281	
16	6.506085	16.4826498422713	
17	7.006585	15.1419558359621	
18	7.507085	13.0914826498423	
19	8.007585	10.5678233438486	=LINEST(E19:E31,D19:D31)
20	8.508085	9.22712933753943	
21	9.008585	8.12302839116719	
22	9.509085	7.17665615141956	
23	10.009585	6.30914826498423	
24	10.510085	5.4416403785489	
25	11.010585	4.88958990536278	
26	11.511085	3.62776025236593	
27	12.011585	3.31491712707182	
28	12.512085	2.12933753943218	
29	13.012585	1.49842271293375	
30	13.513085	0.946372239747634	
31	14.013584	0.236779794790844	

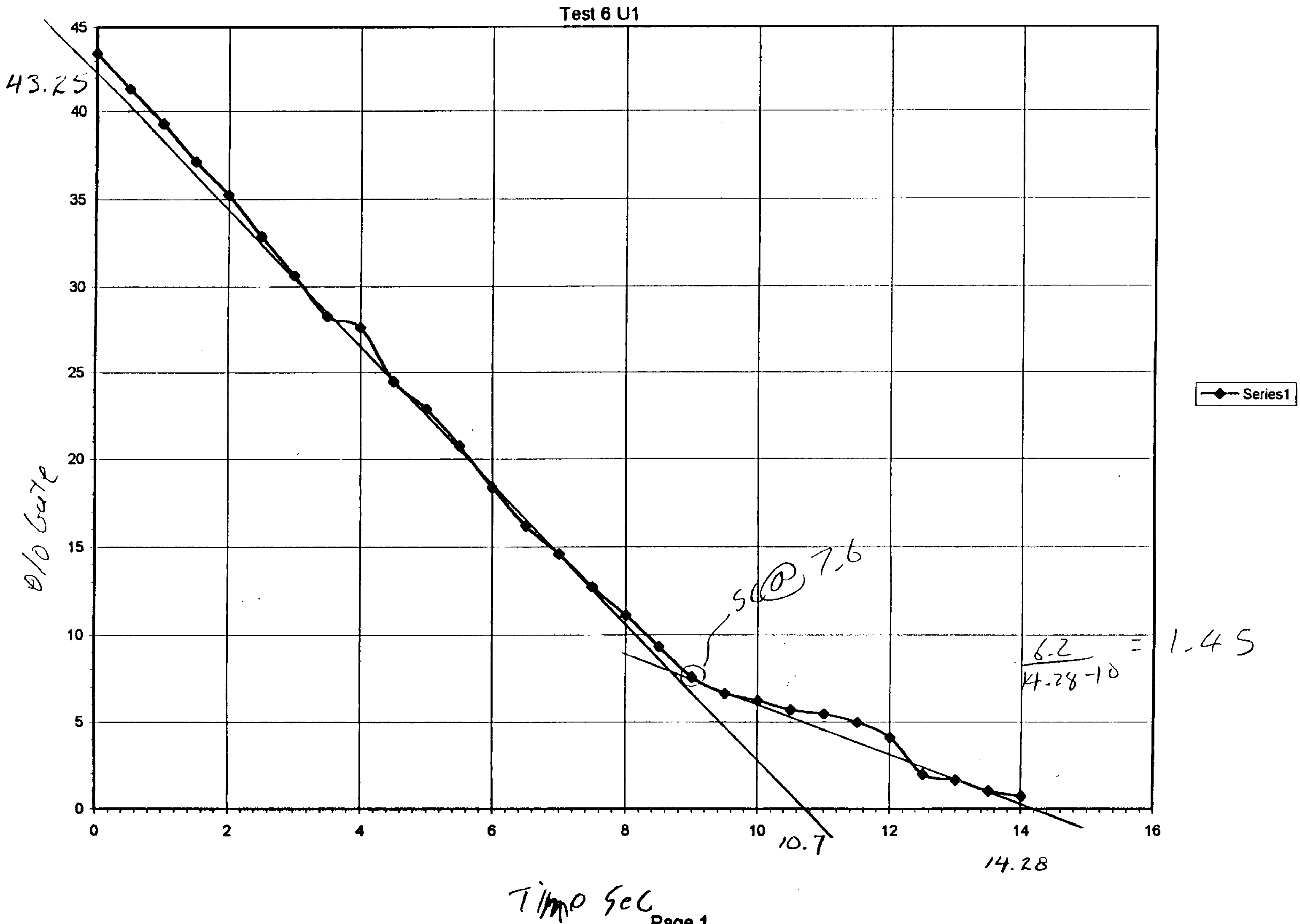
Sheet1 Chart 1



	D	E	F
1	Test 5		
2	sec	%gate	slope
3	0	50.47319	-4.16026
4	0.50025	48.26498	
5	1.0005	46.37224	
6	1.50075	43.94801	
7	2.001	42.10111	
8	2.50125	39.65245	
9	3.0015	37.51975	
10	3.50175	35.62401	
11	4.002	33.49131	
12	4.50225	31.3834	
13	5.0025	28.93281	
14	5.503334	26.95652	
15	6.004168	24.82213	
16	6.505002	23.083	
17	7.005836	20.55336	
18	7.50667	18.81423	
19	8.007504	16.52174	
20	8.508338	15.17787	
21	9.009172	13.12253	
22	9.510006	10.52215	
23	10.01084	9.328063	-1.62413
24	10.51167	7.98419	
25	11.01251	7.193676	
26	11.51334	6.482213	
27	12.01418	5.533597	
28	12.51501	4.901186	
29	13.01584	3.636364	
30	13.51668	3.322785	
31	14.01751	2.134387	
32	14.51835	1.422925	
33	15.01918	1.027668	
34	15.52001	0.237342	

	D	E	F
1	Test 5		
2	sec	%gate	slope
3	0	50.4731861198738	=LINEST(E3:E23,D3:D23)
4	0.50025000000	48.2649842271293	
5	1.0005	46.3722397476341	
6	1.50075	43.9480097481722	
7	2.001	42.1011058451817	
8	2.50125	39.652448657188	
9	3.0015	37.519747235387	
10	3.50175	35.6240126382307	
11	4.002	33.4913112164297	
12	4.50225	31.3833992094862	
13	5.0025	28.9328063241107	
14	5.503334	26.9565217391304	
15	6.004168	24.8221343873518	
16	6.505002	23.0830039525692	
17	7.005836	20.5533596837945	
18	7.50667	18.8142292490119	
19	8.007504	16.5217391304348	
20	8.508338	15.1778656126482	
21	9.009172	13.1225296442688	
22	9.510006	10.5221518987342	
23	10.01084	9.32806324110672	=LINEST(E23:E34,D23:D34)
24	10.511674	7.98418972332016	
25	11.012508	7.19367588932806	
26	11.513342	6.48221343873518	
27	12.014176	5.53359683794466	
28	12.51501	4.90118577075099	
29	13.015844	3.63636363636364	
30	13.516678	3.32278481012658	
31	14.017512	2.13438735177866	
32	14.518346	1.42292490118577	
33	15.01918	1.02766798418972	
34	15.520014	0.237341772151899	

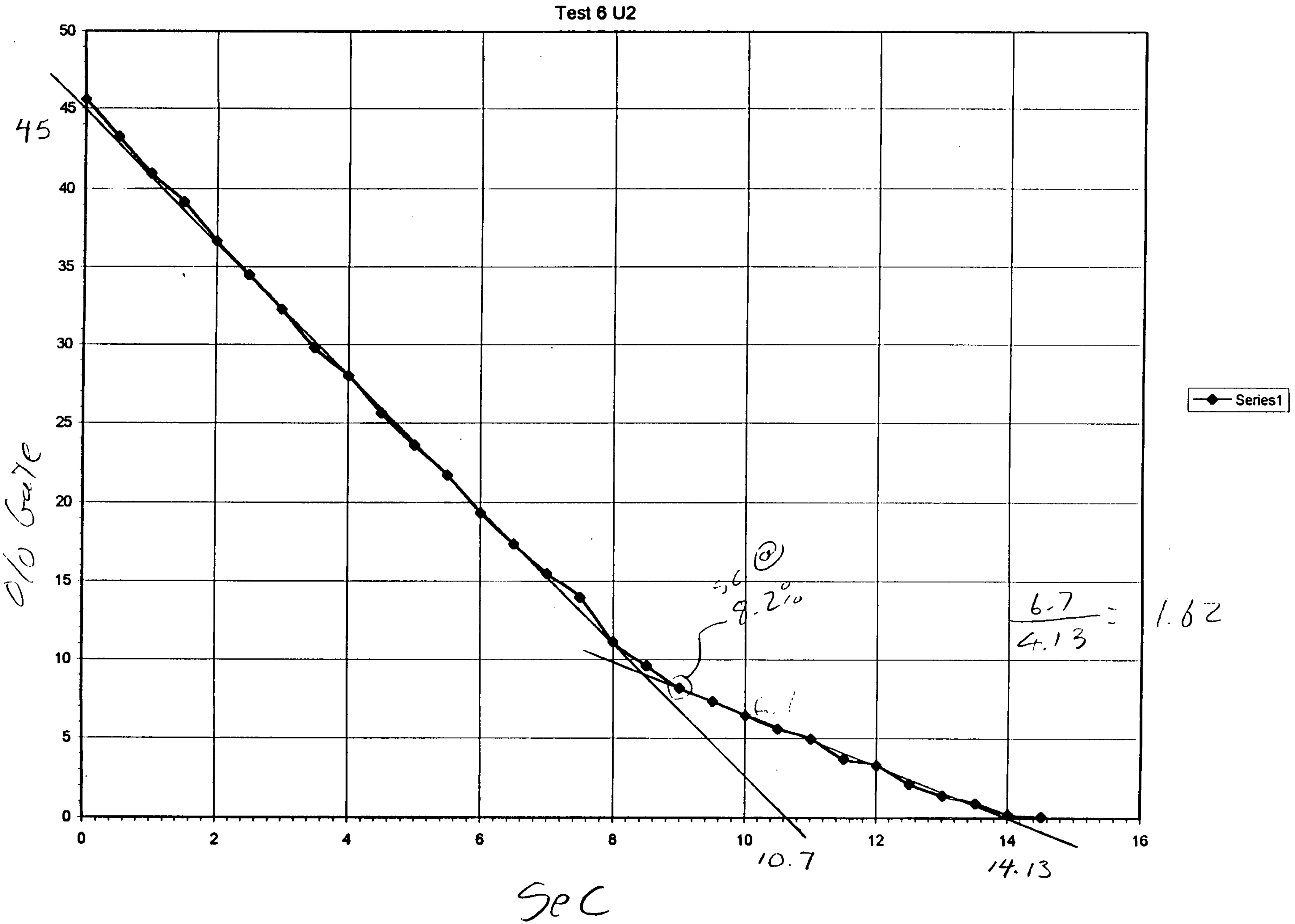
Sheet1 Chart 1



	D	E	F
1	Test 6 U1		
2	sec	gate	slope
3	0	43.45426	
4	0.50025	41.32492	-4.03062
5	1.0005	39.27445	
6	1.50075	37.14511	
7	2.001	35.28019	
8	2.50125	32.88644	
9	3.0015	30.62352	
10	3.50175	28.23344	
11	4.002	27.60252	
12	4.50225	24.44795	
13	5.0025	22.87066	
14	5.50275	20.7577	
15	6.003	18.3899	
16	6.50325	16.17995	
17	7.0035	14.60142	
18	7.50375	12.70718	
19	8.004	11.11987	
20	8.504751	9.313339	
21	9.005502	7.570978	
22	9.506253	6.629834	-1.46534
23	10.007	6.235201	
24	10.50776	5.678233	
25	11.00851	5.445935	
26	11.50926	4.972376	
27	12.01001	4.104183	
28	12.51076	1.980983	
29	13.01151	1.660079	
30	13.51226	1.027668	
31	14.01301	0.711462	

	D	E	F
1	Test 6 U1		
2	sec	gate	slope
3	0	43.4542586750789	
4	0.500250000000001	41.3249211356467	=LINEST(E3:E21,D3:D21)
5	1.0005	39.2744479495268	
6	1.50075	37.1451104100946	
7	2.001	35.2801894238358	
8	2.50125	32.8864353312303	
9	3.0015	30.6235201262826	
10	3.50175	28.2334384858044	
11	4.002	27.602523659306	
12	4.50225	24.4479495268139	
13	5.0025	22.8706624605678	
14	5.50275	20.7576953433307	
15	6.003	18.3898973954223	
16	6.50325	16.179952644041	
17	7.0035	14.6014206787687	
18	7.50375	12.707182320442	
19	8.004	11.1198738170347	
20	8.504751	9.31333859510655	
21	9.005502	7.57097791798107	
22	9.506253	6.62983425414365	=LINEST(E22:E31,D22:D31)
23	10.007004	6.23520126282557	
24	10.507755	5.6782334384858	
25	11.008506	5.44593528018942	
26	11.509257	4.97237569060773	
27	12.010008	4.10418310970797	
28	12.510759	1.98098256735341	
29	13.01151	1.6600790513834	
30	13.512261	1.02766798418972	
31	14.013012	0.711462450592885	

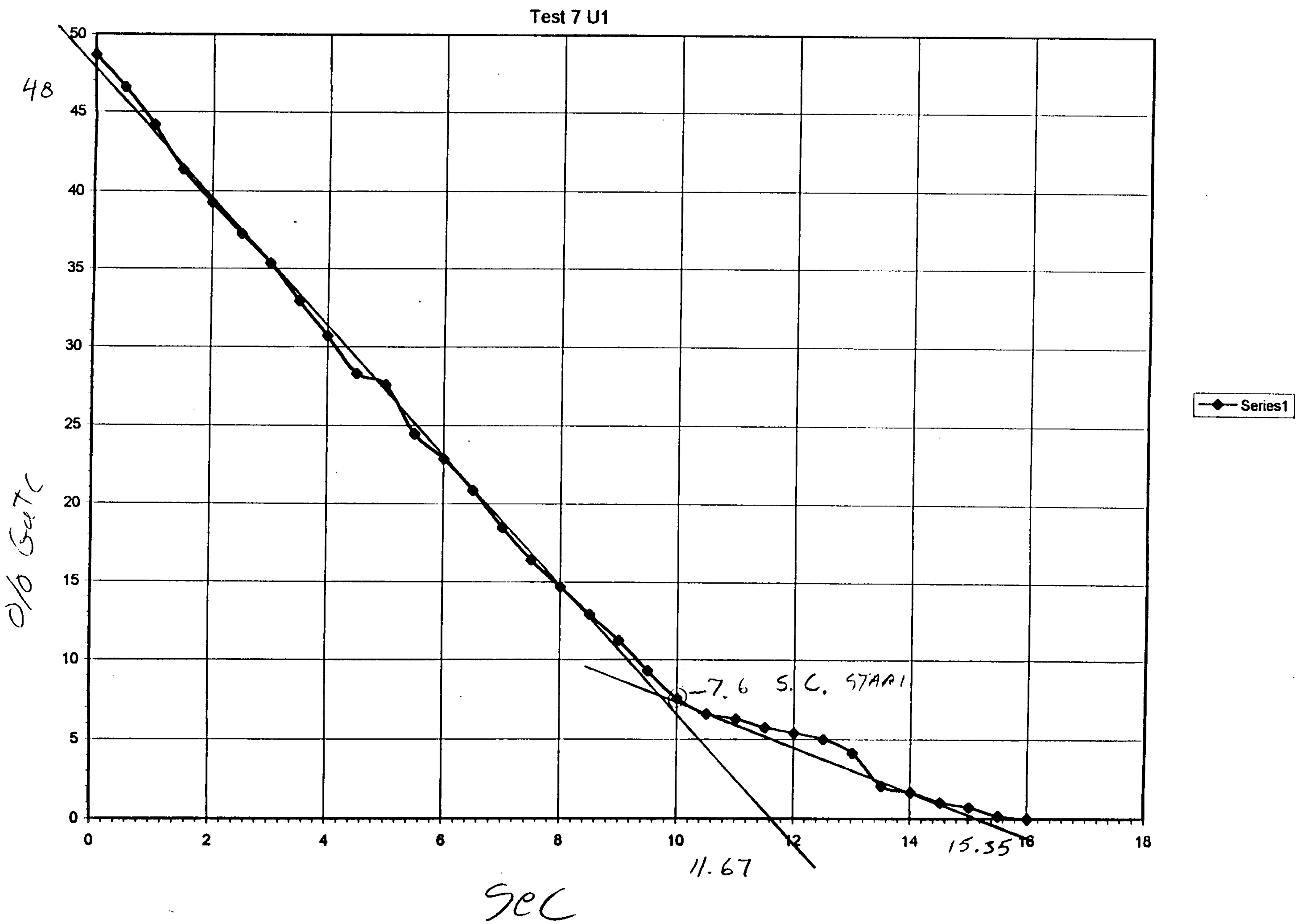
Sheet1 Chart 1



	D	E	F
1	Test 6 U2		
2	sec	%gate	slope
3	0	45.5836	
4	0.50025	43.21767	-4.20375
5	1.0005	40.9306	
6	1.50075	39.14759	
7	2.001	36.67192	
8	2.50125	34.49092	
9	3.0015	32.25552	
10	3.50175	29.81073	
11	4.002	27.99685	
12	4.50225	25.63091	
13	5.0025	23.59905	
14	5.50275	21.70481	
15	6.003	19.33702	
16	6.50325	17.36385	
17	7.0035	15.46961	
18	7.50375	13.95899	
19	8.004501	11.12865	
20	8.505252	9.621451	
21	9.006003	8.208366	-1.61823
22	9.506754	7.340174	
23	10.00751	6.466877	
24	10.50826	5.603788	
25	11.00901	4.972376	
26	11.50976	3.70955	
27	12.01051	3.328051	
28	12.51126	2.134387	
29	13.01201	1.422925	
30	13.51276	0.948617	
31	14.01351	0.237342	

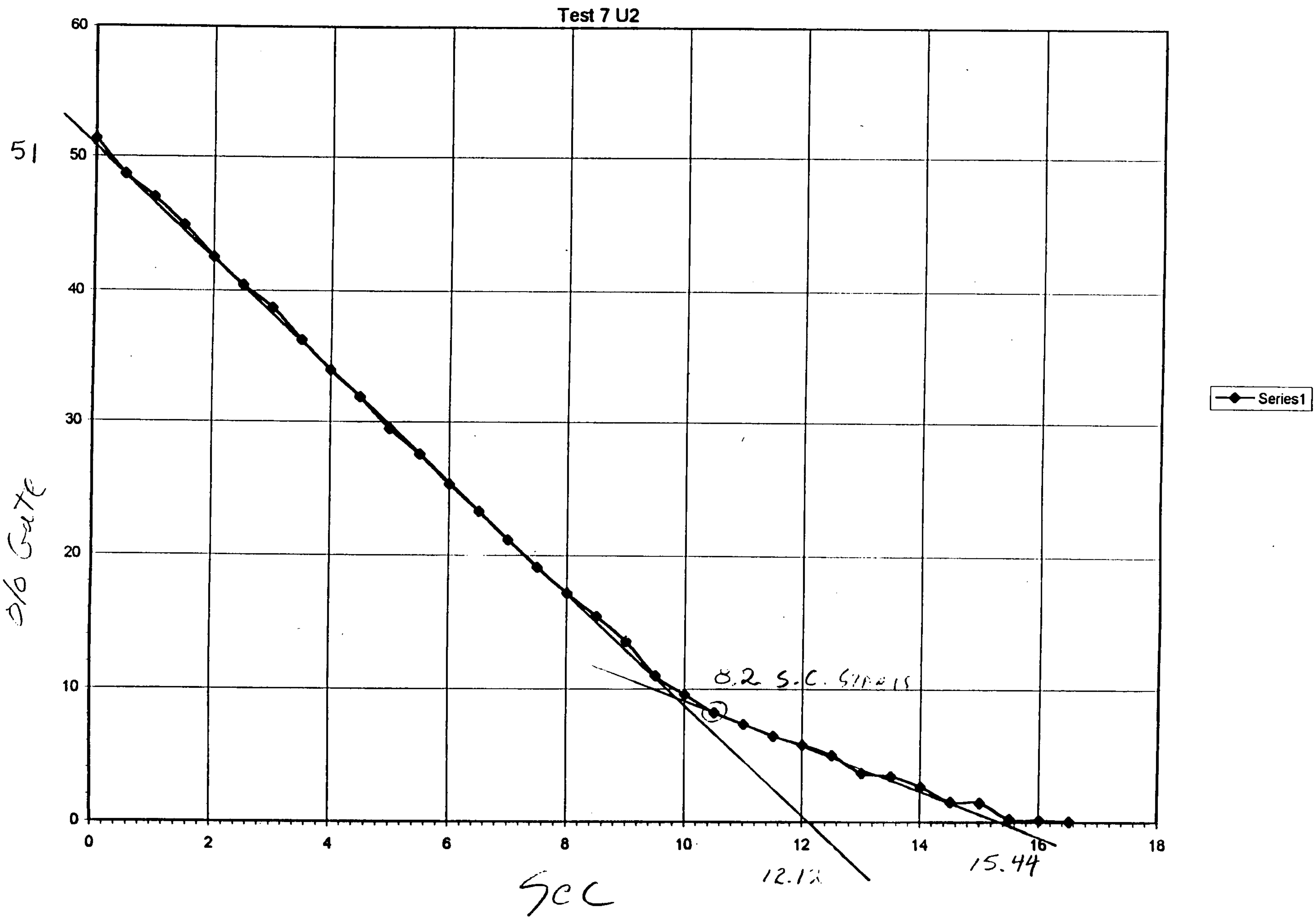
	D	E	F
1	Test 6 U2		
2	sec	%gate	slope
3	0	45.583596214511	
4	0.500250000000001	43.217665615142	=LINEST(E3:E21,D3:D21)
5	1.0005	40.9305993690852	
6	1.50075	39.147592738753	
7	2.001	36.6719242902208	
8	2.50125	34.4909234411997	
9	3.0015	32.2555205047319	
10	3.50175	29.8107255520505	
11	4.002	27.9968454258675	
12	4.50225	25.6309148264984	
13	5.0025	23.5990528808208	
14	5.50275	21.7048145224941	
15	6.003	19.3370165745856	
16	6.50325	17.3638516179953	
17	7.0035	15.4696132596685	
18	7.50375	13.9589905362776	
19	8.004501	11.1286503551697	
20	8.505252	9.62145110410095	
21	9.006003	8.20836621941594	=LINEST(E21:E31,D21:D31)
22	9.506754	7.34017363851618	
23	10.007505	6.46687697160883	
24	10.508256	5.60378847671665	
25	11.009007	4.97237569060773	
26	11.509758	3.7095501183899	
27	12.010509	3.32805071315372	
28	12.51126	2.13438735177866	
29	13.012011	1.42292490118577	
30	13.512762	0.948616600790514	
31	14.013513	0.237341772151899	

Sheet1 Chart 1



	D	E	F
1	Test 7 U1		
2	sec	gate	slope
3	0	48.65526	
4	0.50025	46.5873	-4.11007
5	1.0005	44.16203	
6	1.50075	41.34921	
7	2.001	39.28571	
8	2.50125	37.25179	
9	3.0015	35.34551	
10	3.50175	32.90938	
11	4.002	30.68362	
12	4.50225	28.29889	
13	5.002917	27.58347	
14	5.503584	24.46215	
15	6.004251	22.85032	
16	6.504918	20.84328	
17	7.005585	18.47134	
18	7.506252	16.40127	
19	8.006919	14.66135	
20	8.507586	12.90837	
21	9.008253	11.23506	
22	9.50892	9.322709	
23	10.00959	7.569721	-1.4152
24	10.51025	6.613546	
25	11.01092	6.294821	
26	11.51159	5.737052	
27	12.01226	5.418327	
28	12.51292	5.01992	
29	13.01359	4.140127	
30	13.51426	2.070064	
31	14.01492	1.673307	
32	14.51559	1.035857	
33	15.01626	0.716561	
34	15.51692	0.159363	

	D	E	F
1	Test 7 U1		
2	sec	gate	slope
3	0	48.6552567237164	
4	0.500249999999994	46.5873015873016	=LINEST(E3:E23,D3:D23)
5	1.0005	44.1620333598094	
6	1.50075	41.3492063492064	
7	2.001	39.2857142857143	
8	2.50125	37.251787132645	
9	3.0015	35.3455123113582	
10	3.50174999999999	32.9093799682035	
11	4.002	30.6836248012719	
12	4.50225	28.2988871224165	
13	5.002917	27.5834658187599	
14	5.503584	24.4621513944223	
15	6.004251	22.8503184713376	
16	6.504918	20.843277645187	
17	7.005585	18.4713375796178	
18	7.506252	16.4012738853503	
19	8.006919	14.6613545816733	
20	8.507586	12.9083665338645	
21	9.008253	11.2350597609562	
22	9.50892	9.32270916334661	
23	10.009587	7.56972111553785	=LINEST(E23:E34,D23:D34)
24	10.510254	6.61354581673307	
25	11.010921	6.29482071713147	
26	11.511588	5.73705179282869	
27	12.012255	5.41832669322709	
28	12.512922	5.0199203187251	
29	13.013588	4.14012738853503	
30	13.514255	2.07006369426752	
31	14.014922	1.67330677290837	
32	14.515589	1.03585657370518	
33	15.016256	0.71656050955414	
34	15.516923	0.159362549800797	


Test 7 U2
60
50
40
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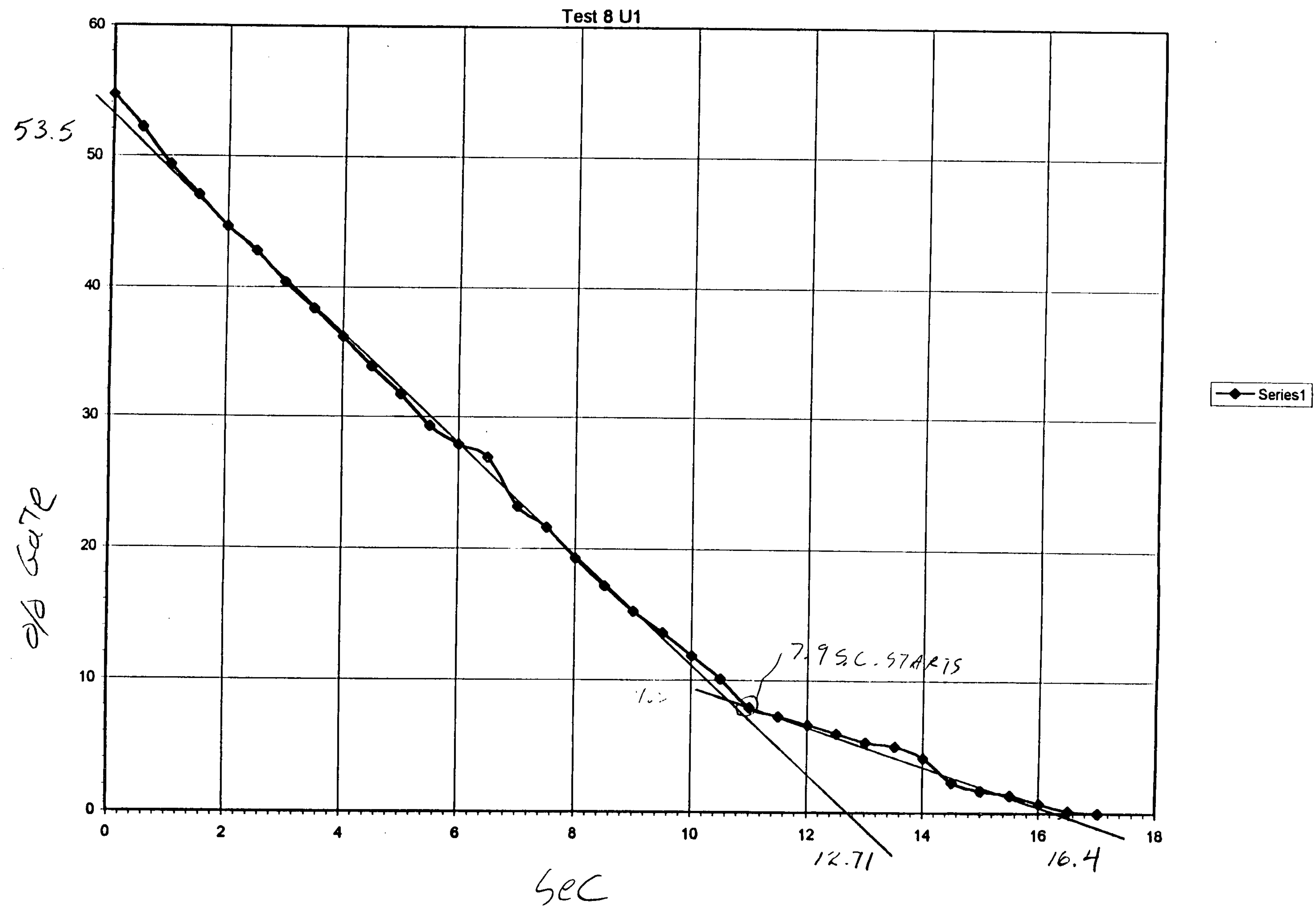
20
10
0
0
2
4
6
8
10
12
14
16
18
Series1
51
% Gate
Sec
8.2 S.C.
15.44

	D	E	F
1	Test 7 U2		
2	sec	% Gate	Slope
3	0	51.34474	
4	0.5	48.73016	-4.204806943
5	1	47.02145	
6	1.5	44.92063	
7	2	42.53968	
8	2.5	40.42891	
9	3	38.68149	
10	3.5	36.24801	
11	4	33.94277	
12	4.5	31.87599	
13	5	29.49126	
14	5.5	27.56972	
15	6	25.31847	
16	6.5	23.30947	
17	7.01	21.17834	
18	7.51	19.10828	
19	8.01	17.21116	
20	8.51	15.45817	
21	9.01	13.54582	
22	9.51	10.99602	
23	10	9.561753	-1.619475613
24	10.5	8.207171	
25	11	7.330677	
26	11.5	6.454183	
27	12	5.816733	
28	12.5	5.01992	
29	13	3.66242	
30	13.5	3.423567	
31	14	2.629482	
32	14.5	1.513944	
33	15	1.433121	
34	15.5	0.239044	

	D	E	F
1	Test 7 U2		
2	sec	% Gate	Slope
3	0	51.3447432762836	
4	0.50024999	48.7301587301587	=LINEST(E3:E23,D3:D23)
5	1.0005	47.0214455917395	
6	1.50075	44.9206349206349	
7	2.001	42.5396825396825	
8	2.50125	40.4289118347895	
9	3.0015	38.68149324861	
10	3.50174999	36.248012718601	
11	4.002	33.9427662957075	
12	4.50225	31.8759936406995	
13	5.002917	29.4912559618442	
14	5.503584	27.5697211155378	
15	6.004251	25.3184713375796	
16	6.504918	23.3094669848846	
17	7.005585	21.1783439490446	
18	7.506252	19.1082802547771	
19	8.006919	17.2111553784861	
20	8.507586	15.4581673306773	
21	9.008253	13.5458167330677	
22	9.50892	10.996015936255	
23	10.009587	9.56175298804781	=LINEST(E23:E34,D23:D34)
24	10.510254	8.20717131474104	
25	11.010921	7.33067729083665	
26	11.511588	6.45418326693227	
27	12.012255	5.81673306772908	
28	12.512922	5.0199203187251	
29	13.013588	3.6624203821656	
30	13.514255	3.42356687898089	
31	14.014922	2.62948207171315	
32	14.515589	1.51394422310757	
33	15.016256	1.43312101910828	
34	15.516923	0.239043824701195	

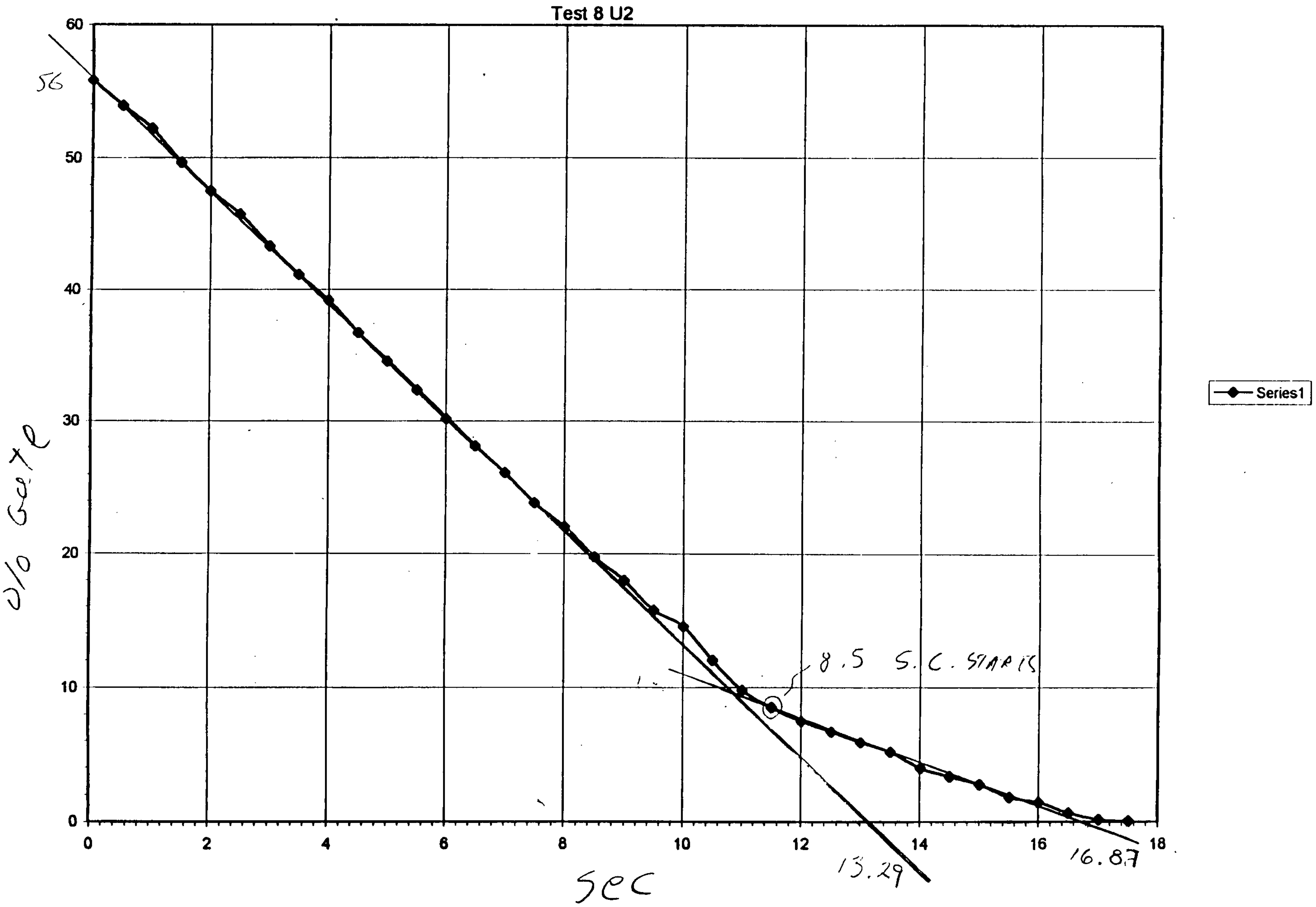
Sheet1 Chart 1



	D	E	F
1	Test 8 Unit 1		
2	sec	% Gate	slope
3	0	54.63918	
4	0.50025	52.13946	-4.20807
5	1.0005	49.40523	
6	1.50075	47.14286	
7	2.001	44.7619	
8	2.50125	42.85714	
9	3.001667	40.39683	
10	3.502084	38.33333	
11	4.002501	36.13979	
12	4.502918	33.83638	
13	5.003335	31.71701	
14	5.503752	29.30898	
15	6.004169	27.87927	
16	6.504586	26.92613	
17	7.005003	23.19301	
18	7.50542	21.62162	
19	8.005837	19.30103	
20	8.506254	17.15647	
21	9.006671	15.19491	
22	9.507088	13.60382	
23	10.00751	11.85362	
24	10.50792	10.10342	
25	11.00834	7.882166	-1.48148
26	11.50876	7.250996	
27	12.00917	6.613546	
28	12.50959	5.976096	
29	13.01001	5.334395	
30	13.51042	5.023923	
31	14.01084	4.143426	
32	14.51126	2.3126	
33	15.01168	1.673307	
34	15.51209	1.354582	
35	16.01251	0.717131	
36	16.51293	0.159363	

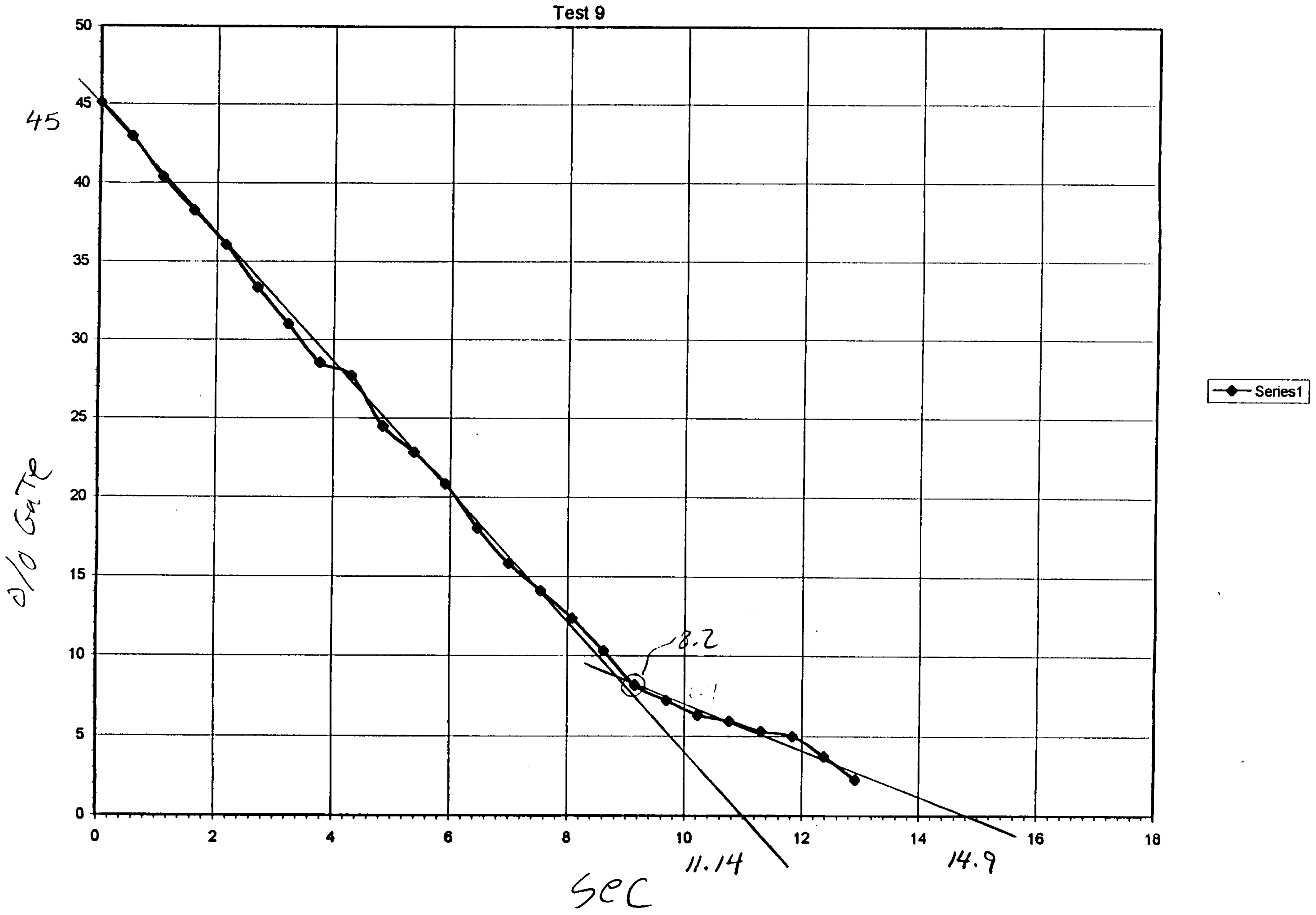
	D	E	F
1	Test 8 Unit 1		
2	sec	% Gate	slope
3	0	54.639175257732	
4	0.500249999999999	52.1394611727417	=LINEST(E3:E25,D3:D25)
5	1.0005	49.4052339413164	
6	1.50075	47.1428571428571	
7	2.001	44.7619047619048	
8	2.50125	42.8571428571429	
9	3.001667	40.3968253968254	
10	3.502084	38.3333333333333	
11	4.002501	36.1397934868944	
12	4.502918	33.8363780778396	
13	5.003335	31.7170111287758	
14	5.503752	29.3089753772836	
15	6.004169	27.8792692613185	
16	6.504586	26.9261318506751	
17	7.005003	23.1930103256553	
18	7.50542	21.6216216216216	
19	8.005837	19.3010325655282	
20	8.506254	17.1564733915806	
21	9.006671	15.1949085123309	
22	9.507088	13.6038186157518	
23	10.007505	11.8536197295147	
24	10.507922	10.1034208432776	
25	11.008339	7.88216560509554	=LINEST(E25:E36,D25:D36)
26	11.508756	7.25099601593625	
27	12.009173	6.61354581673307	
28	12.50959	5.97609561752988	
29	13.010007	5.3343949044586	
30	13.510424	5.02392344497608	
31	14.010841	4.14342629482072	
32	14.511258	2.31259968102073	
33	15.011675	1.67330677290837	
34	15.512092	1.35458167330677	
35	16.012509	0.717131474103586	
36	16.512926	0.159362549800797	

Sheet1 Chart 1



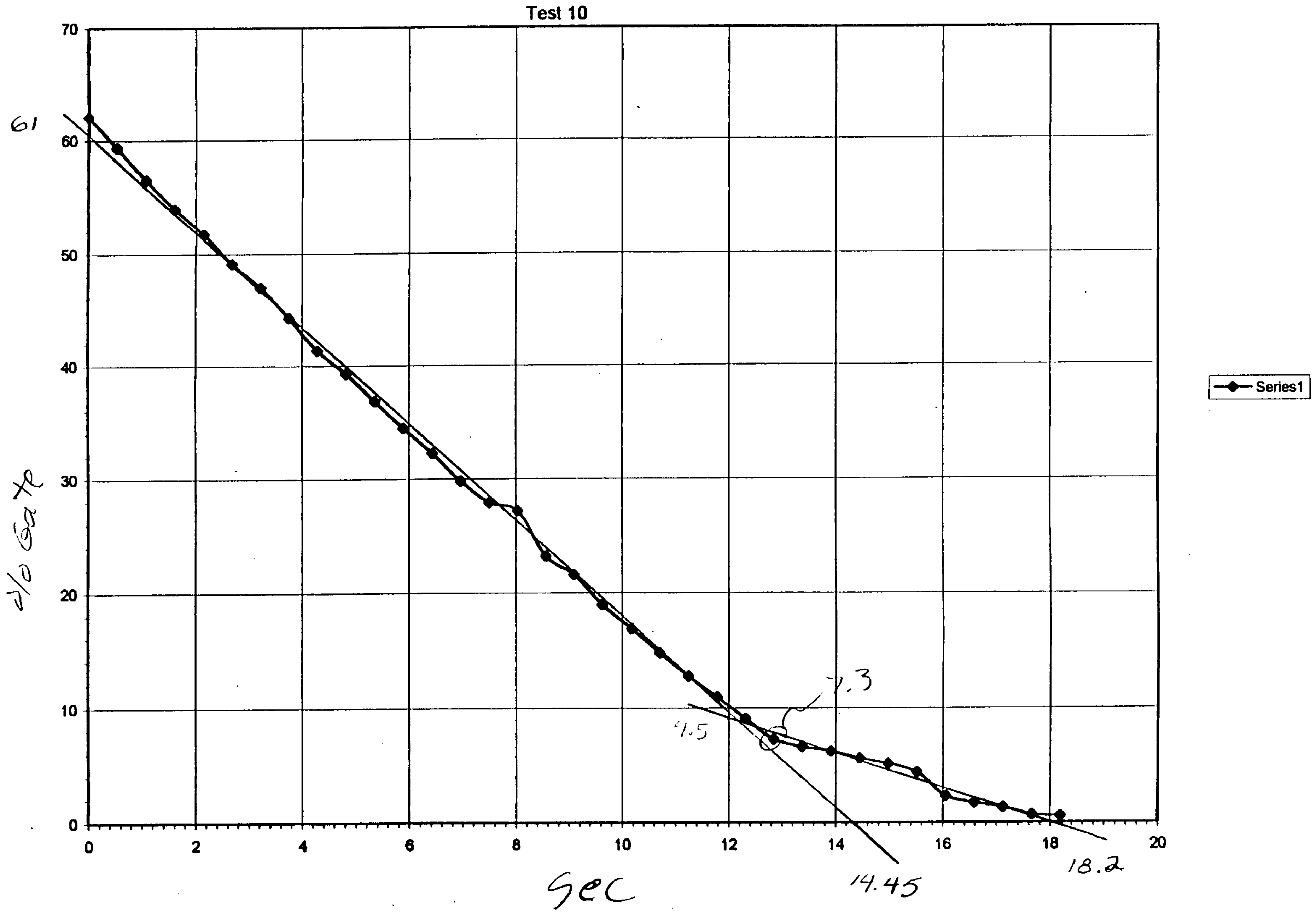
	D	E	F
1	Test 8	Unit2	
2	sec	%gate	slope
3	0	55.82871	
4	0.50025	53.88273	-4.21413
5	1.0005	52.18081	
6	1.50075	49.68254	
7	2.001	47.53968	
8	2.50125	45.79365	
9	3.001667	43.33333	
10	3.502084	41.11111	
11	4.002501	39.15806	
12	4.502918	36.69579	
13	5.003335	34.49921	
14	5.503752	32.32724	
15	6.004169	30.18268	
16	6.504586	28.11755	
17	7.005003	26.13185	
18	7.50542	23.84738	
19	8.005837	22.08102	
20	8.506254	19.7776	
21	9.006671	17.97932	
22	9.507088	15.75179	
23	10.00751	14.55847	
24	10.50792	12.01273	
25	11.00834	9.792994	-1.58207
26	11.50876	8.525896	
27	12.00917	7.49004	
28	12.50959	6.693227	
29	13.01001	5.89172	
30	13.51042	5.183413	
31	14.01084	3.984064	
32	14.51126	3.349282	
33	15.01168	2.788845	
34	15.51209	1.832669	
35	16.01251	1.434263	
36	16.51293	0.63745	
37	17.01334	0.159363	

	D	E	F
1	Test 8	Unit2	
2	sec	%gate	slope
3	0	55.8287073750991	
4	0.50024999	53.8827258320127	=LINEST(E3:E25,D3:D25)
5	1.0005	52.1808088818398	
6	1.50075	49.6825396825397	
7	2.001	47.5396825396825	
8	2.50125	45.7936507936508	
9	3.001667	43.3333333333333	
10	3.502084	41.1111111111111	
11	4.002501	39.1580619539317	
12	4.502918	36.6957903097697	
13	5.003335	34.4992050874404	
14	5.503752	32.3272438443209	
15	6.004169	30.1826846703733	
16	6.504586	28.1175536139793	
17	7.005003	26.131850675139	
18	7.50542	23.8473767885533	
19	8.005837	22.0810166799047	
20	8.506254	19.7776012708499	
21	9.006671	17.9793158313445	
22	9.507088	15.7517899761337	
23	10.007505	14.5584725536993	
24	10.507922	12.0127287191726	
25	11.008339	9.79299363057325	=LINEST(E25:E37,D25:D37)
26	11.508756	8.52589641434263	
27	12.009173	7.49003984063745	
28	12.50959	6.69322709163347	
29	13.010007	5.89171974522293	
30	13.510424	5.18341307814992	
31	14.010841	3.98406374501992	
32	14.511258	3.34928229665072	
33	15.011675	2.78884462151394	
34	15.512092	1.83266932270916	
35	16.012509	1.43426294820717	
36	16.512926	0.637450199203187	
37	17.013343	0.159362549800797	


Test 9
50
45
40
35
30
25
20
15
10
5
0
0
2
4
6
8
10
12
14
16
18
Series1
45
% Gate
sec
8.2
11.14
14.9

	D	E	F
1	Test 9		
2	sec	gate	slpoe
3	0	45.10914	
4	0.538502	42.90246	-4.0375
5	1.077004	40.38308	
6	1.615506	38.25397	
7	2.154008	36.06811	
8	2.69251	33.36066	
9	3.231012	31.01519	
10	3.769514	28.56043	
11	4.308015	27.70492	
12	4.846517	24.47715	
13	5.385019	22.82258	
14	5.923521	20.81665	
15	6.462023	18.04916	
16	7.000525	15.81059	
17	7.539027	14.10993	
18	8.077529	12.39415	
19	8.616031	10.31682	
20	9.154533	8.188976	-1.40276
21	9.693035	7.227023	
22	10.23009	6.326034	
23	10.76715	5.959752	
24	11.3042	5.33224	
25	11.84126	5	
26	12.37832	3.733766	
27	12.91537	2.299762	

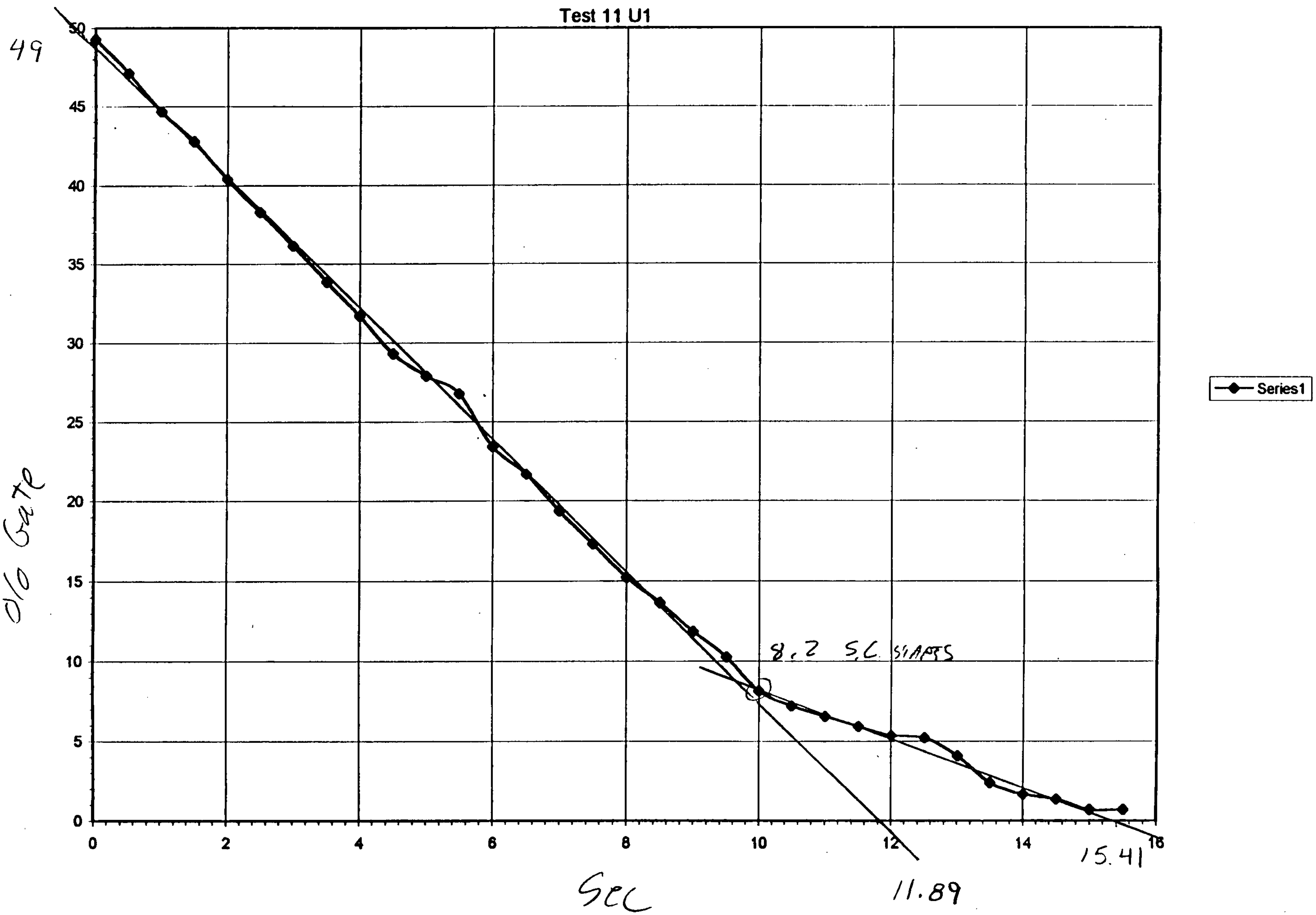
	D	E	F
1	Test 9		
2	sec	gate	slpoe
3	0	45.109135004042	
4	0.538501999999999	42.9024583663759	=LINEST(E3:E20,D3:D20)
5	1.077004	40.3830806065443	
6	1.615506	38.2539682539683	
7	2.154008	36.0681114551084	
8	2.69251	33.3606557377049	
9	3.231012	31.0151878497202	
10	3.769514	28.5604311008468	
11	4.308015	27.7049180327869	
12	4.846517	24.4771494965143	
13	5.385019	22.8225806451613	
14	5.923521	20.8166533226581	
15	6.462023	18.0491551459293	
16	7.000525	15.8105939004815	
17	7.539027	14.109926168991	
18	8.077529	12.3941493456505	
19	8.616031	10.3168155970755	
20	9.154533	8.18897637795276	=LINEST(E20:E27,D20:D27)
21	9.693035	7.22702278083268	
22	10.230091	6.32603406326034	
23	10.767147	5.95975232198142	
24	11.304203	5.33223954060705	
25	11.841259	5	
26	12.378315	3.73376623376623	
27	12.915371	2.29976209357653	


Test 10
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
Series1
61
% Gate
Sec
9.5
7.3
14.45
18.2

	D	E	F
1	Test 10		
2	sec	% Gate	slope
3	0	62.07692	
4	0.536479	59.34324	-4.22273
5	1.072959	56.57789	
6	1.609439	54.04082	
7	2.145919	51.77026	
8	2.682399	49.15515	
9	3.218879	46.99454	
10	3.755359	44.30993	
11	4.291839	41.37367	
12	4.826598	39.27158	
13	5.361357	36.82589	
14	5.896116	34.46154	
15	6.430875	32.24044	
16	6.965634	29.80769	
17	7.500393	27.91837	
18	8.035152	27.1987	
19	8.569911	23.23718	
20	9.104671	21.57018	
21	9.63943	18.93166	
22	10.17419	16.84699	
23	10.70895	14.7806	
24	11.24371	12.75552	
25	11.77847	10.95779	
26	12.31323	9.08347	
27	12.84798	7.28	
28	13.38274	6.630686	-1.53502
29	13.9175	6.235201	
30	14.45226	5.660377	
31	14.98702	5.16129	
32	15.52178	4.416404	
33	16.05654	2.33827	
34	16.5913	1.704105	
35	17.12606	1.310717	
36	17.66082	0.694981	

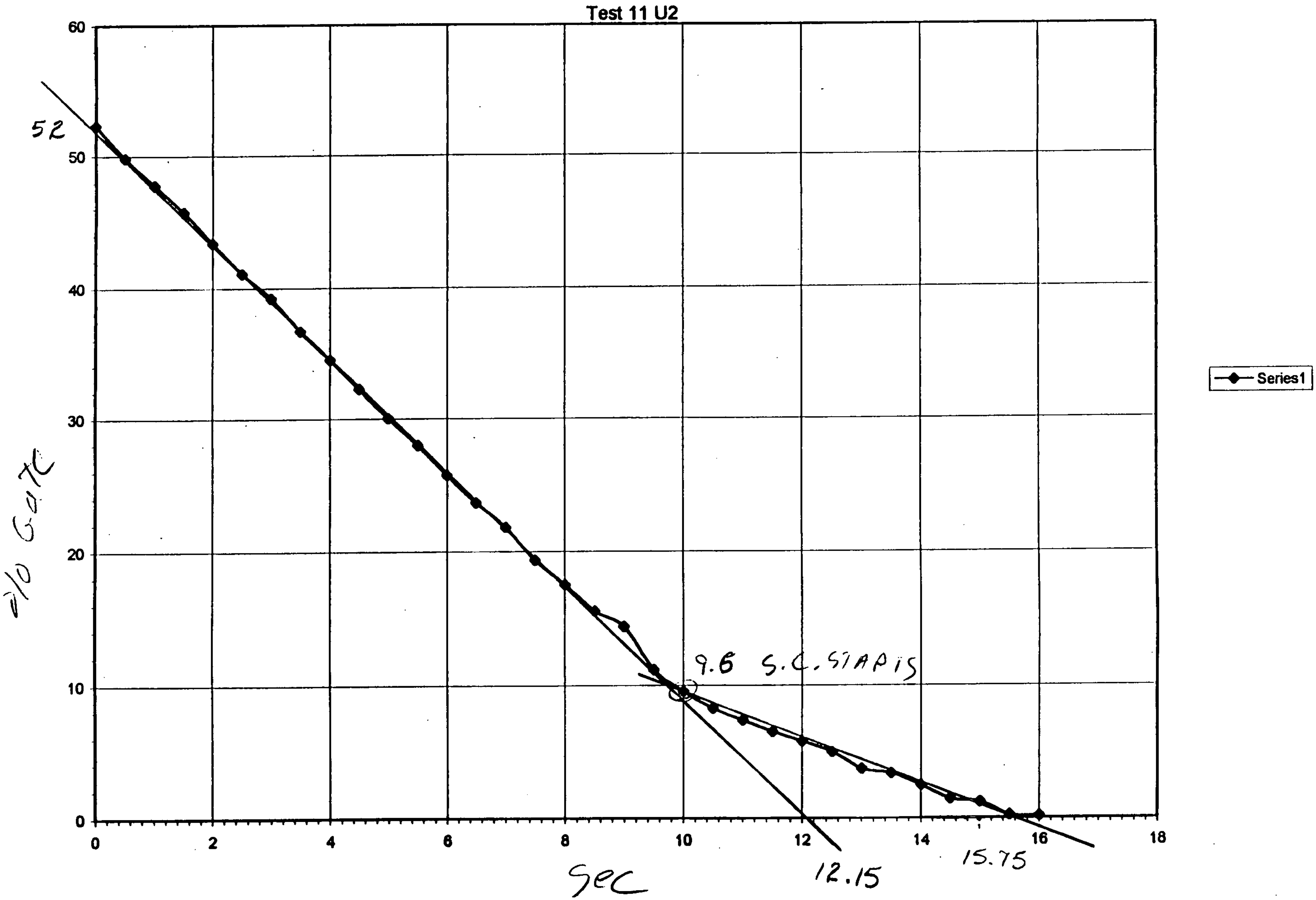
	D	E	F
1	Test 10		
2	sec	% Gate	slope
3	0	62.0769230769231	
4	0.536479000000001	59.3432369038311	=LINEST(E3:E28,D3:D28)
5	1.072959	56.5778853914447	
6	1.609439	54.0408163265306	
7	2.145919	51.7702596380803	
8	2.682399	49.1551459293395	
9	3.218879	46.9945355191257	
10	3.755359	44.3099273607748	
11	4.291839	41.3736713000818	
12	4.826598	39.2715756136184	
13	5.361357	36.8258859784283	
14	5.896116	34.4615384615385	
15	6.430875	32.2404371584699	
16	6.965634	29.8076923076923	
17	7.500393	27.9183673469388	
18	8.035152	27.1986970684039	
19	8.569911	23.2371794871795	
20	9.104671	21.5701823949247	
21	9.63943	18.9316575019639	
22	10.174189	16.8469860896445	
23	10.708948	14.7806004618938	
24	11.243707	12.755519215045	
25	11.778466	10.9577922077922	
26	12.313225	9.08346972176759	
27	12.847984	7.28	
28	13.382743	6.63068619892059	=LINEST(E28:E36,D28:D36)
29	13.917502	6.23520126282557	
30	14.452261	5.66037735849057	
31	14.98702	5.16129032258065	
32	15.521779	4.41640378548896	
33	16.056538	2.33826968043648	
34	16.591297	1.70410534469404	
35	17.126056	1.31071703932151	
36	17.660815	0.694980694980695	

Sheet1 Chart 1



	D	E	F
1	test 11 U 1		
2	sec	% Gate	slpoe
3	0	49.28	
4	0.500333	47.12	-4.11982
5	1.000666	44.64856	
6	1.500999	42.73163	
7	2.001332	40.38308	
8	2.501665	38.30806	
9	3.001998	36.15323	
10	3.502331	33.86838	
11	4.002664	31.70927	
12	4.502997	29.3131	
13	5.00333	27.8754	
14	5.503663	26.77858	
15	6.003996	23.44	
16	6.504328	21.68	
17	7.004661	19.36	
18	7.504994	17.29384	
19	8.005327	15.21217	
20	8.50566	13.63272	
21	9.005993	11.87801	
22	9.506326	10.28112	
23	10.00666	8.192771	-1.52538
24	10.50699	7.234727	
25	11.00733	6.59164	
26	11.50766	5.953339	
27	12.00799	5.390185	
28	12.50832	5.22508	
29	13.00866	4.096386	
30	13.50899	2.407705	
31	14.00932	1.684042	
32	14.50999	1.362179	
33	15.01066	0.720576	

	D	E	F
1	test 11 U 1		
2	sec	% Gate	slpoe
3	0	49.28	
4	0.50033300000	47.12	=LINEST(E3:E23,D3:D23)
5	1.000666	44.6485623003195	
6	1.500999	42.7316293929712	
7	2.001332	40.3830806065443	
8	2.501665	38.3080606544294	
9	3.001998	36.1532322426177	
10	3.50233100000	33.868378812199	
11	4.002664	31.7092651757189	
12	4.502997	29.3130990415335	
13	5.00333000000	27.8753993610224	
14	5.503663	26.7785771382894	
15	6.003996	23.44	
16	6.504328	21.68	
17	7.004661	19.36	
18	7.504994	17.2938350680544	
19	8.005327	15.2121697357886	
20	8.50566000000	13.6327185244587	
21	9.005993	11.8780096308186	
22	9.506326	10.281124497992	
23	10.006659	8.19277108433735	=LINEST(E23:E33,D23:D33)
24	10.506992	7.23472668810289	
25	11.007325	6.59163987138264	
26	11.507658	5.95333869670153	
27	12.007991	5.39018503620274	
28	12.508324	5.22508038585209	
29	13.008657	4.09638554216867	
30	13.50899	2.40770465489567	
31	14.009323	1.68404170008019	
32	14.50999	1.36217948717949	
33	15.010657	0.720576461168935	


Test 11 U2
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
Series1
52
% Gate
9.6 S.C. STARTS
12.15
15.75
Sec

	D	E	F
1	Test 11 U2		
2	sec	% Gate	slpoe
3	0	52.32	
4	0.500333	49.84	-4.27876
5	1.000666	47.76358	
6	1.500999	45.76677	
7	2.001332	43.4158	
8	2.501665	41.10136	
9	3.001998	39.18595	
10	3.502331	36.67737	
11	4.002664	34.50479	
12	4.502997	32.26837	
13	5.00333	30.03195	
14	5.503663	27.97762	
15	6.003995	25.76	
16	6.504328	23.68	
17	7.004661	21.84	
18	7.504994	19.3755	
19	8.005327	17.53403	
20	8.50566	15.55734	
21	9.005993	14.36597	
22	9.506326	11.16466	
23	10.00666	9.558233	-1.65298
24	10.50699	8.279743	
25	11.00733	7.395498	
26	11.50766	6.516492	
27	12.00799	5.792438	
28	12.50832	4.983923	
29	13.00866	3.694779	
30	13.50899	3.370787	
31	14.00966	2.485966	
32	14.51032	1.442308	
33	15.01099	1.200961	
34	15.51166	0.240385	

	D	E	F
1	Test 11 U2		
2	sec	% Gate	slpoe
3	0	52.32	
4	0.500332999999998	49.84	=LINEST(E3:E23,D3:D23)
5	1.000666	47.7635782747604	
6	1.500999	45.7667731629393	
7	2.001332	43.41580207502	
8	2.501665	41.1013567438148	
9	3.001998	39.1859537110934	
10	3.502331	36.677367576244	
11	4.002664	34.5047923322684	
12	4.50299699999999	32.2683706070287	
13	5.00333	30.0319488817891	
14	5.503663	27.9776179056755	
15	6.003995	25.76	
16	6.504328	23.68	
17	7.004661	21.84	
18	7.504994	19.3755004003203	
19	8.00532699999999	17.5340272217774	
20	8.50566	15.5573376102646	
21	9.005993	14.3659711075441	
22	9.506326	11.1646586345382	
23	10.006659	9.55823293172691	=LINEST(E23:E34,D23:D34)
24	10.506992	8.27974276527331	
25	11.007325	7.39549839228296	
26	11.507658	6.51649235720032	
27	12.007991	5.79243765084473	
28	12.508324	4.98392282958199	
29	13.008657	3.69477911646586	
30	13.50899	3.37078651685393	
31	14.009657	2.485966319166	
32	14.510324	1.44230769230769	
33	15.010991	1.20096076861489	
34	15.511658	0.240384615384615	

Attachment #12

Form 1021

DUKE POWER COMPANY

TELEPHONE CONVERSATION REPORT

PROJECT Oconee FILE NO.

SUBJECT KC-UNIT 1-2-0106 Rev 1

PERSON CALLED Mike Byrne Voith Hydro Inc.

DATE 4/25/95 TIME

PERSON CALLING John Beckman ONS/Mods

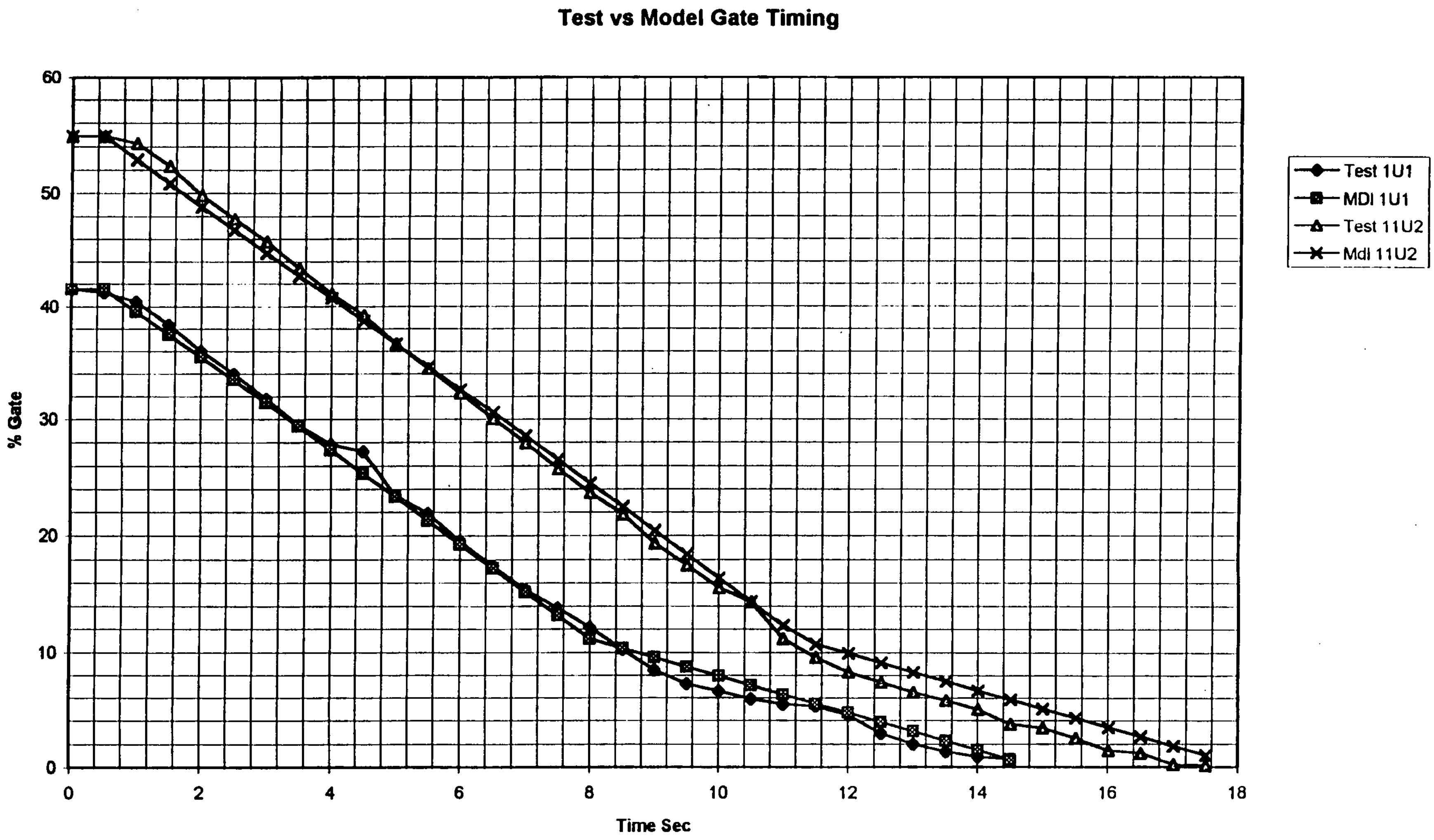
SPECIFICATION NUMBER

SUBJECT DISCUSSED Repeatability of LR on Large Turbines

RECOMMENDATION OR RESOLUTION Mike said That his experience on Field Testing Turbines has shown That repeated Load rejections of Turbines with Identical initial Conditions usually produce Max overspeeds within ± 1 RPM. This variance is due mostly to variances in governor closing times.

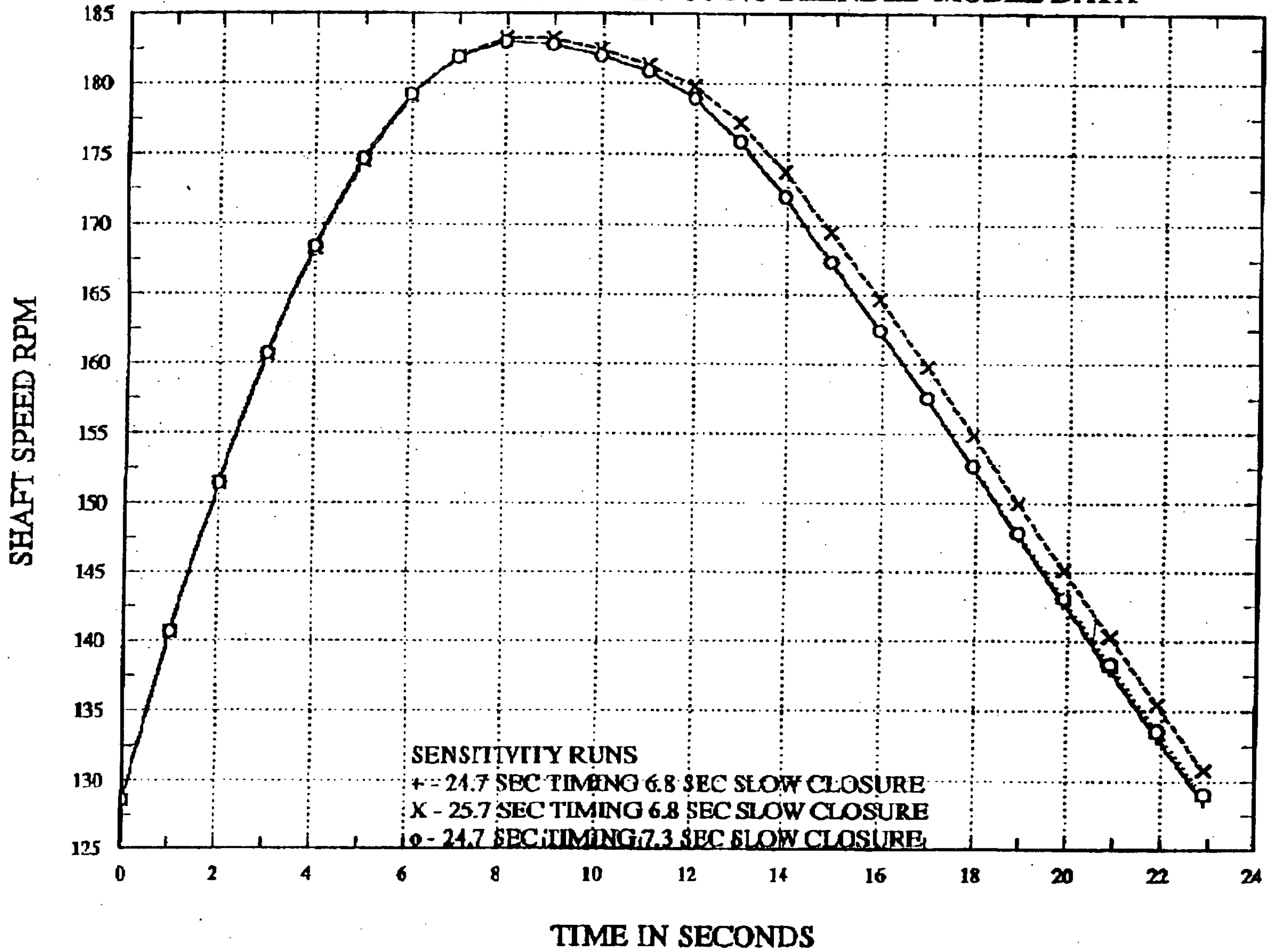
SIGNED: John B. Beckman

Attachment #13


Test vs Model Gate Timing
% Gate
Time Sec
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
Test 1U1
MDl 1U1
Test 11U2
Mdl 11U2

Attachment #14

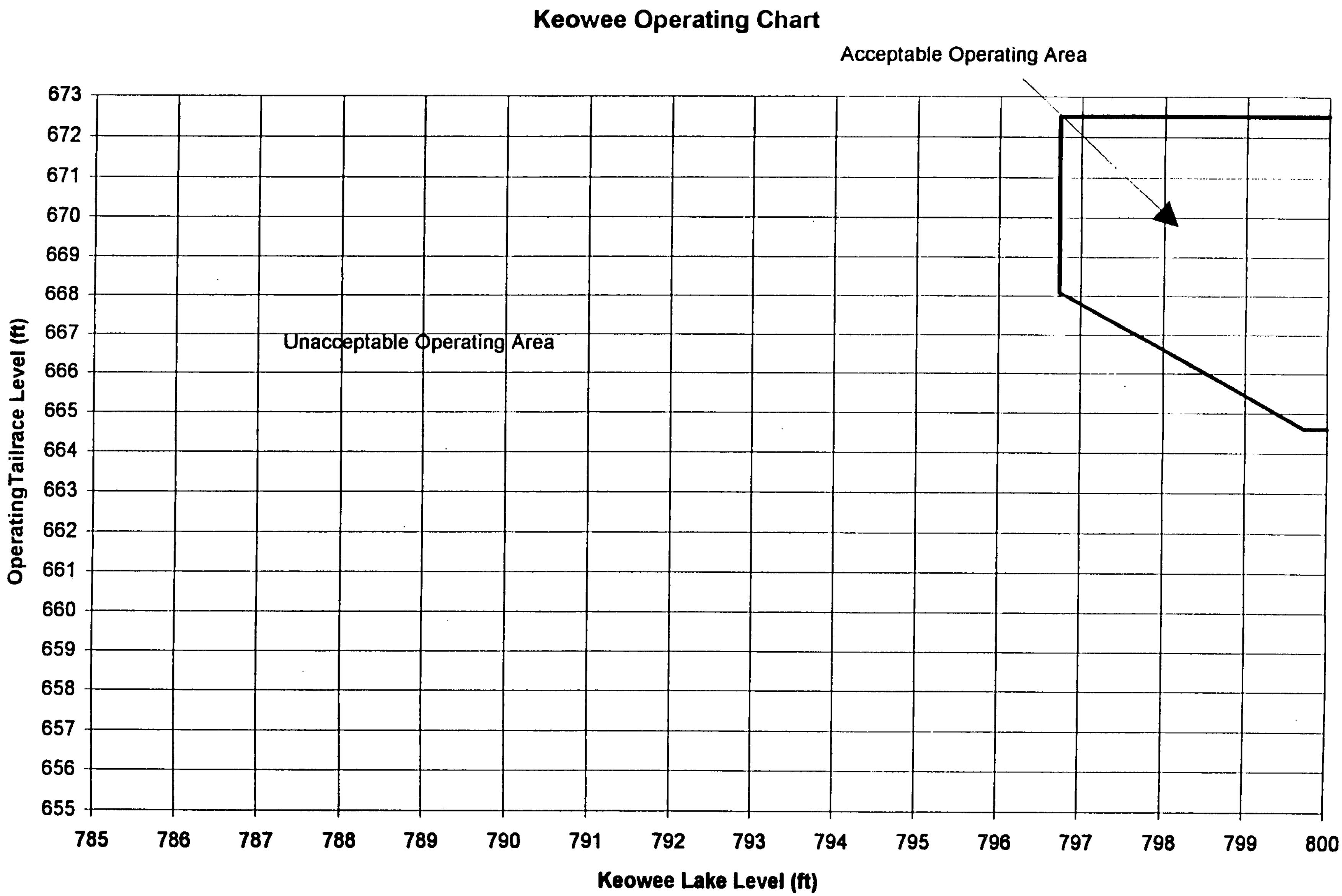
KEOWEE 1 UNIT 89 MW GENERATOR LOAD REJECTION
HW = 798.16 TW = 672.5 FEET USING BLENDED MODEL DATA



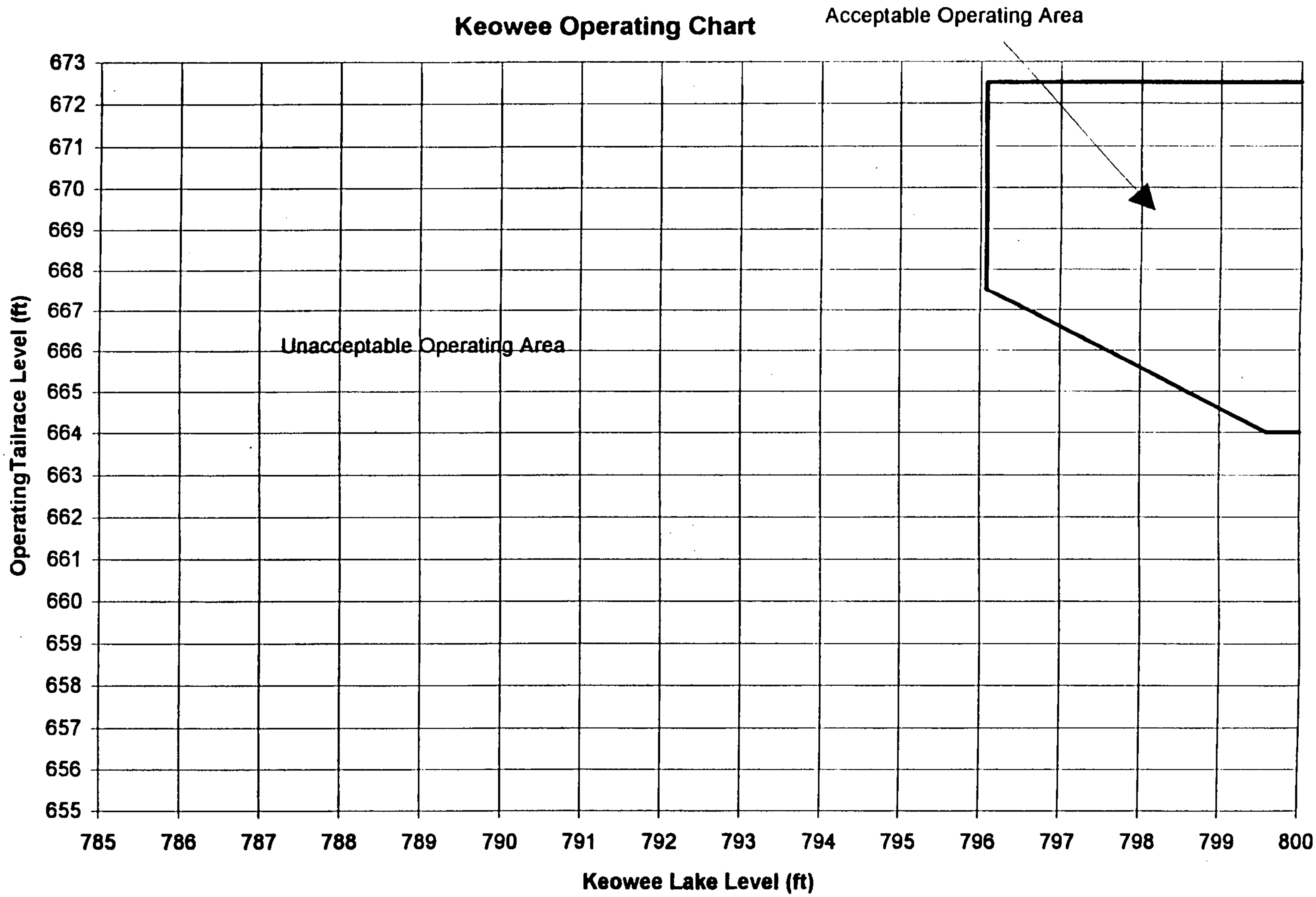
01-25-95

Attachment 15

2 Units 74 Mw

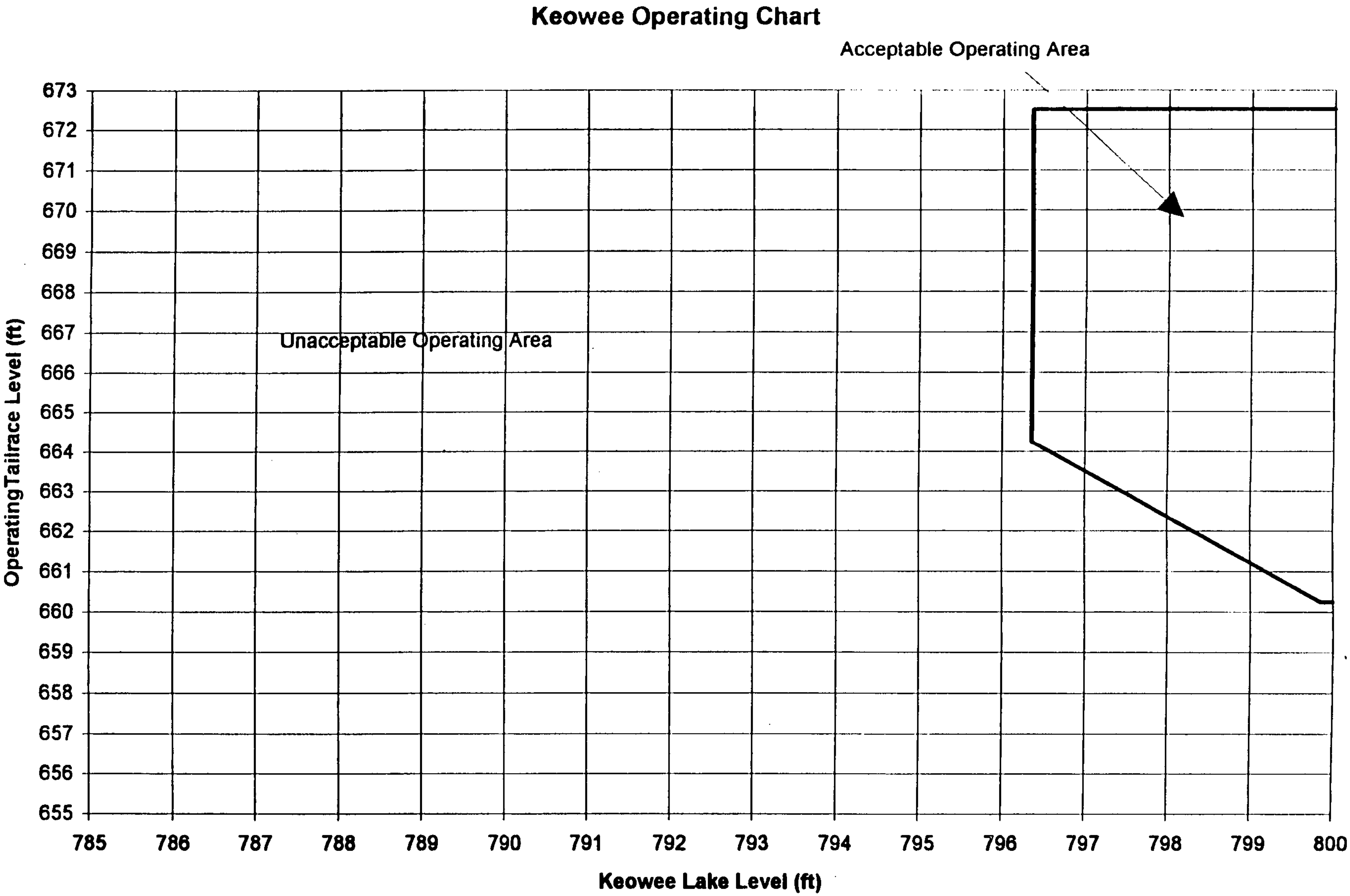

Keowee Operating Chart
Acceptable Operating Area
Unacceptable Operating Area
Operating Tailrace Level (ft)
673
672
671
670
669
668
667
666
665
664
663
662
661
660
659
658
657
656
655
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
Keowee Lake Level (ft)

2 Unit 64 Mw



Keowee Operating Chart
Acceptable Operating Area
Unacceptable Operating Area
673
672
671
670
669
668
667
666
665
664
663
662
661
660
659
658
657
656
655
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
Operating Tailrace Level (ft)
Keowee Lake Level (ft)

Unit 1 ONLY 84 Mw



Attachment #16

GATE POSITION ACCURACY

STATEMENT OF PROBLEM

The purpose of this evaluation is to determine the uncertainty in the measurement of gate position data for the Keowee Hydro units during load rejection testing. The output was monitored by the installed rheostat on the Governor Actuator Cabinet output to an Angus Series D Recorder. The data was saved in the Angus Recorder and transferred to a laptop computer after a load rejection.

RELATION TO QA CONDITION

Based on the function of the various meters, this calculation is non-safety related, however the results are inputs to a safety ~~realted~~ related calculation.

CALCULATION METHOD

The methodology for this calculation uses Reference 1 as a guideline although it is not specifically applicable to this instrumentation. The methodology accounts for random-independent (x,y), random-dependent (w,u), and non-random/bias (v,t) uncertainty terms differently in determining the total loop uncertainty (TLU) as follows:

$$\pm TLU = \pm \sqrt{x^2 + y^2 + (w + u)^2} \pm v \pm t$$

Uncertainty terms considered to be applicable to this instrumentation are listed below. All terms are considered to be random-independent except for CTE and MTE which are considered to be random-dependent.

CTE	-	Calibration tolerance
A	-	Reference accuracy
D	-	Drift
MTE	-	Measuring and test equipment
RES	-	Resolution / readability
TE	-	Temperature effect
B	-	Bias

DESIGN INPUTS

1. Accuracy of the Angus meter is based on Reference 3.

FSAR/TECHNICAL SPECIFICATION APPLICABILITY

Section 8.3.1.1.1, Keowee Hydro Station

REFERENCES

1. EDM-102: Instrument Setpoint / Uncertainty Calculations

2. Work Order 95016259-01

3. Specifications for Angus Series D Recorder (Attachment A)

4. Maintenance Directive 4.4.1, Measuring and Test Equipment Control

ASSUMPTIONS

1. Drift for the Angus is assumed to be embedded in the accuracy tolerance for calculation of total loop uncertainty. The value assigned to drift is therefore 0.

2. A value of 0.25 times the calibration tolerance is assumed for the measuring and test equipment used for calibrating the This is based on Reference 4 using 4:1 ratio for calibration equipment. This value is considered to be dependent with CTE.

3. The temperature effect on the rheostat and Angus is assumed to be zero based on the duration of the test. Equipment was not in a harsh environment, nor did conditions change measurably during the test. Calibration of the Angus is assumed to have been performed at close to the same temperature as the Keowee Mechanical Equipment Gallery during the test.

4. Readability of the string output is considered to be ± 0.1 VAC based on the resolution of the Angus.

5. Measuring and Test Equipment Calibration tolerance is assumed to be the same as the accuracy of the Angus.

6. The rheostat is assumed to have a bias of 0.3VAC based on data review indicating an output from the rheostat when the gates were closed. Reference test data in Attachment 2 of the calculation for dual unit 70 MW at tailrace of 667.51 and 80 MW load rejection.

7. The output of the rheostat is 0 to 100% of input voltage, assumed to correspond linearly to 0 to 100% gate opening based on field observation prior to the test. Gate openings at various percentages were compared to rheostat output, however this was not data taken on the test procedure.

8. The specification sheet for the Angus states a range of 0-300 VAC. The unit used had a range of 0-600 VAC. Since the specification sheets are those which were provided with the unit, it is assumed that the specifications are the same regardless of range.

CALCULATION

Prior to testing, the Angus output was verified using the scale on the servomotor piston and the output of the gate position indicator as references for the output of the Angus. The Angus read gate position in VAC should be divided by the input voltage, nominally 126.1 VAC. It should be noted that if the input voltage varied from 126.1 VAC, which it did, the output of the Angus should be divided by the corresponding voltage input for a true gate position measure.

The voltage input to the Angus may be read from the voltage reading for the Emergency Start signal. For this reason, the Angus voltage uncertainties will be taken twice, once for the voltage reading as gate opening, and once for the input voltage reading.

Uncertainty term allowances:

CTE

Angus (gate) = 0.5% or (0.005)(600 VAC)(1% gate/126.1 VAC)
= 0.02379 %gate

Angus (volts)= 0.5% or (0.005)(600 VAC)(1% gate/126.1 VAC)
= 0.02379 %gate

A

Angus (gate) = 0.5% or (0.005)(600 VAC)(1% gate/126.1 VAC)
= 0.02379 %gate

Angus (volts)= 0.5% or (0.005)(600 VAC)(1% gate/126.1 VAC)
= 0.02379 %gate

D = 0 (Assumption 1)

MTE

Angus (gate) = 0.25% or
(0.0025)(0.005)(600VAC)(1%gate/126.1VAC)
= 0.00006 %gate

Angus (volts)= 0.25% or
(0.0025)(0.005)(600VAC)(1%gate/126.1VAC)
= 0.00006 %gate

RES

Angus (gate) = (0.1VAC)(1%gate/126.1VAC)
= 0.00079 %gate

Angus (volts)= 0.1VAC subtracted from the
denominator = 1%gate/(126.1VAC - 0.1VAC)
= 0.00794 %gate

TE = 0 (Assumption 3)

B

Rheostat = 0.3VAC or (0.3VAC)(1%gate/126.1VAC) = 0.00238 %gate (Assumption 6)

$$TLU = \sqrt{(CTE + MTE)^2 + A^2 + D^2 + RES^2 + TE^2} + B$$

TLU = ± 0.0703 %gate

CONCLUSION

The uncertainty of the gate position test equipment is ± 0.0703 % gate.

ATTACHMENT A page 1 of

SPECIFICATIONS

GENERAL SPECIFICATIONS

Frequency Range: (Operational and measurement) 45 - 65 Hz fundamental.

Response Time: 1 Reading every half cycle, 0.5% accuracy, true RMS.

Sampling Rate: 256 samples per cycle (50 or 60 Hz) per channel.
15.3 kHz per channel at 60 Hz.

Operating Temp: Mounted units: 32°F (0°C) to 122°F (50°C).

Storage Temp: Main battery installed...5°F (-15°C) to 104°F (40°C).
Main battery removed...-4°F (20°C) to 150°F (70°C).

Memory: Static RAM, battery-backed.
16K reading capacity standard.
Expandable to 277k readings.

Battery Backup: Instrument Operation - Supports operation if AC power is lost through up to three successive 15 minute outages before recharge is required. AC power constantly recharges battery. Recharge time for fully discharged battery - 12 hours. Rear panel switch allows the battery to be turned off.
Clock/Memory Backup - Maintains the instrument's clock measurement storage memory for one week. Recharge is in 48 hours. Cock is set with P.C.

Size: Portable: 12.4"h x 10.4"w x 7.7"d.
Panelmount: 10.4"h x 8.4"w x8.3"d.
Cutout dimensions for new installation: 7.75"w x 10.19"h.

Clock: Battery backed, time/date stamps all data, 0.01% accuracy.

Weight: Portable: 18lbs.
Panel mounts: 18lbs

Display: Backlit LCD, 14.54 mm characters display phase, value, engineering units, mode and setup parameters.

VOLTMETER SPECIFICATIONS

Channels: One on DV1.
Four on DV4.

Input Range: 0 - 150 V AC, or 0 - 300 V AC, 45 - 65 Hz

SPECIFICATIONS

ATTACHMENT A page 2 of -

Measure Range: 0 - 300 VAC, direct AC input, 0 - 300 kV with PT's and programmable K factor. Ratio from 0.1 to 999.9.

Accuracy: 0.5% of FS ± 1 digit in the presence of harmonics.

Operating Power: 80 - 150 VAC or 160 to 300 VAC.

Burden: CH A portable less than 12.5 VA.
CH B, C, and D less than 1.0 VA each.

THE RECORDER WE HAVE IS RANGED TO 600 VAC.

AMMETER SPECIFICATIONS

Channels: One on DA1, four on DA4.

Input Range: 0 - 1 amp AC, or 0 - 5 amps AC from CT secondaries.

Measure Range: 0 - 1000 amps with programmable K factor and CTs. Ratios from 0.1 to 999.9.

Accuracy: 0.5% F.S. ± 1 digit.

Operating Power: AC voltage source of 120 or 240 VAC ± 15%, 45 - 65 Hz.

Burden: Less than 1.0 VA.

POWERMETER SPECIFICATIONS

Channels: 4 voltage and 4 current channels.

Input Range: 0 - 300 VAC or 0 - 600 VAC direct.
0 - 1 amp AC or 0 - 5 amps AC from CT secondaries.

Measure Range: 0 - 300 or 0 - 600 kV with PT's and programmable K factor.
0 - 1000 amps with programmable K factor.
Ratios from 0.1 to 999.9.

Accuracy: Sum of tolerances on voltage and current.

Operating Power: AC voltage source of 120 or 240 VAC ± 15%, 45 - 65 Hz.

Burden: Less than 1.0 VA.

SOFTWARE SPECIFICATIONS

PC Support Software: Requires IBM PC or compatible (minimum AT class) with minimum 1 MBytes RAM, hard disk, 3.5 inch drive, 1.44 MByte, VGA card, VGA color monitor, one serial port, and DOS 3.0 or higher. Optional modem use requires Hayes compatible with AT command set.

ATTACHMENT A pag

MEMORY FILL RATE TABLE

Examples of memory fill rate at various programmed setups:	16K Readings	272K Readings
1 instantaneous reading (single phase) every 15 minutes	168.7 days	2833.3 days
1 instantaneous and average reading (single phase) every 15 minutes	83.3 days	1416.7 days
1 instantaneous and average reading (single phase) every 5 minutes	27.8 days	472.2 days
1 instantaneous, average and max/min reading (single phase) every minute	2.2 days	37.8 days
Memory is selectable for LINEAR MODE (fill and stop) or CIRCULAR MODE (newest data replaces oldest data when memory i s full)		

OPTIONS

Alarms: Form C relays on rear panel, non-latching, rated at 2 amp, 250 VAC or 2 amp, 24 VDC non inductive. Front panel high and low LED alarm indicators with alarm acknowledge pushbutton. High and low programmable setpoints and hysteresis. Alarm status recordable.

Analog Output: Optically isolated, 0 - 1 mA DC output, 0.5% FS accuracy.
Output updated interval 160 milliseconds.
Max loop resistance - 10k ohms.
Available in 1 channel and 4 channel versions.

RS232 Serial Com: Optically isolated interface, 9600, 4800, 2400, or 1200 baud selectable.
8 bits, 1 stop bit, even parity.
9 pin connector on rear panel.

Modem: Internally mounted. Setup allows for party line operation with programming of priority answering schemes based on number of rings to answer and emergency answering capability. Connection to RJ-11 jack on rear panel. Conforms to CCITT V.22, Bell 212A/103. 1200 baud typical transfer time of 16k readings in 11.4 minutes.

NOTE: Specifications subject to change without notice

SPEED ACCURACY

STATEMENT OF PROBLEM

The purpose of this evaluation is to determine the uncertainty in the measurement of the speed of the Keowee Hydro units during load rejection testing. The turbine speed was monitored by Dynalco speed switches, Fluke 8842A multimeters, and a laptop computer. A Fluke 87 was utilized in the initial setup of the equipment.

RELATION TO QA CONDITION

Based on the function of the various meters, this calculation is non-safety related, however the results are inputs into a safety related calculation.

CALCULATION METHOD

The methodology for this calculation uses Reference 1 as a guideline although it is not specifically applicable to this instrumentation. The methodology accounts for random-independent (x,y), random-dependent (w,u), and non-random/bias (v,t) uncertainty terms differently in determining the total loop uncertainty (TLU) as follows:

$$\pm TLU = \pm \sqrt{x^2 + y^2 + (w + u)^2} \pm v \pm t$$

Uncertainty terms considered to be applicable to this instrumentation are listed below. All terms are considered to be random-independent except for CTE and MTE which are considered to be random-dependent.

CTE	-	Calibration tolerance
A	-	Reference accuracy
D	-	Drift
MTE	-	Measuring and test equipment
RES	-	Resolution / readability
TE	-	Temperature effect

DESIGN INPUTS

1. Accuracy of the Fluke 87 Multimeter is based on Reference 7.
2. Accuracy of the Fluke 8842A Multimeter is based on Reference 5.
3. Accuracy of the Dynalco Speed Switch is based on Reference 2.
4. Calibration tolerance of the multimeters are based on their respective calibration procedures, References 3 and 4.

5. Calibration tolerance of the speed switch is based on Reference 2.

FSAR/TECHNICAL SPECIFICATION APPLICABILITY

Section 8.3.1.1.1, Keowee Hydro Station

REFERENCES

1. EDM-102: Instrument Setpoint / Uncertainty Calculations

2. Work Order 95016259-01

3. IP/0/B/1602/012: Fluke 87 Digital Multimeter Calibration (Attachment E)

4. IP/0/B/1602/010: Fluke 8842A Digital Multimeter Calibration (Attachment D)

5. Specifications for Fluke 8842A Multimeter (Attachment A)

6. Specifications for Dynalco Speed Switch (Attachment B)

7. Specifications for Fluke 87 Multimeter (Attachment C)

8. Maintenance Directive 4.4.1, Measuring and Test Equipment Control

ASSUMPTIONS

1. Drift for the Dynalco speed switch is considered to be zero due to the switch being new and being calibrated prior to the testing.

2. Drift for the Fluke 8842A Multimeter is included in the reference accuracy of 0.003% of reading for 1 year. The meter is calibrated annually.

3. Drift for the Fluke 87 Multimeter is included in the accuracy of 0.005% of reading for 1 year. The meter is calibrated annually.

4. A value of 0.25 times the calibration tolerance is assumed for the measuring and test equipment used for calibrating the Fluke multimeters. This is based on Reference 4 using 4:1 ratio for calibration equipment. This value is considered to be dependent with CTE.

5. The temperature effect is assumed to be zero based on the duration of the test. Equipment was not in a harsh environment, nor did conditions change measureably during the test. The temperature during the test and the temperature during the instrument calibration are assumed to be about the same. The Dynalco Speed Switch was calibrated in the test

area. The multimeters typically do not have any temperature associated uncertainty until 28 C or 82.4 F is exceeded. The temperature in the area during March and Febraury is not this high, based on local temperature indication.

6. Readability of the string output is considered to be 100% based on the analog to digital conversion for the computer, and the data being saved as discrete data points on a spreadsheet.

7. The Dynalco output is influenced by ripple and noise. These factors are introduced by the power supplied to the device. They will be considered readability effects due to the oscillation induced to the devices downstream.

CALCULATION

Inherent to the analysis, are the physical characteristics of the setup. The Permanent Magnet Generator (PMG) gear has 192 teeth. One revolution per minute will therefore see 192 pulses or cycles. ~~Dividing by a time constant~~: Converting to a frequency:

$$\frac{192 \text{ pulses/rev}}{60 \text{ min/sec}} = \frac{3.2 \text{ cycles min}}{\text{sec rev}} = 3.2 \text{ Hz/1 rpm}$$

The Dynalco Speed Switch used had output ranges from 0 to 10 VDC correlating to inputs of 0 to 5000 Hz.

$$\frac{5000 \text{ Hz}}{10 \text{ VDC}} = 500 \text{ Hz/ 1 VDC}$$

Combining these factors yields the correlation from the magnetic pickup pulses to the voltage read by the Fluke 8842A and the computer.

$$\frac{3.2 \text{ Hz/1 rpm}}{500 \text{ Hz/1 VDC}} = 0.0064 \text{ VDC/ 1 rpm}$$

Uncertainty term allowances:

CTE

Fluke 87 = (0.1 Hz)(1rpm/3.2Hz) = 0.03125 rpm
Fluke 8842A = (0.0001VDC)(1rpm/0.0064VDC) = 0.01563 rpm
Dynalco = (0.002VDC)(1rpm/0.0064VDC) = 0.3125 rpm

A

Fluke 87 = 0.005% of reading or (0.005%)(1000 Hz)(1rpm/3.2Hz) = 0.01563 rpm
Fluke 8842A = 0.003% of reading or (0.003%)(1 VDC)(1rpm/0.0064VDC) = 0.00469 rpm
Dynalco = (0.001VDC)(1rpm/0.0064VDC) = 0.15625 rpm

D = 0 (Assumptions 1,2,3)

MTE

Fluke 87 = (0.25)(0.1Hz)(1rpm/3.2Hz) = 0.00781 rpm
Fluke 8842A = (0.25)(.0001VDC)(1rpm/0.0064VDC) = 0.00391 rpm

RES

Fluke 87 = 0.01Hz or (0.01Hz)(1rpm/3.2Hz) = 0.00313 rpm
Dynalco = 0.1% or (0.001V)(1rpm/0.0064VDC) = 0.15625 rpm

TE = 0 (Assumption 5)

$$TLU = \sqrt{(CTE + MTE)^2 + A^2 + D^2 + RES^2 + TE^2}$$

TLU = 0.4408 rpm

CONCLUSION

The uncertainty of the speed measuring equipment is ± 0.4408 rpm.

ATTACHMENT A page 1 of

8842A

DIGITAL MULTIMETER

Instruction Manual

P/N 765313
OCTOBER 1985 Rev. 2 6/86

FLUKE ®

Attachment A page 2 of 2

Table 1-1. Specifications

DC VOLTAGE

Input Characteristics

RANGE	FULL SCALE 5½ DIGITS	RESOLUTION 5½ DIGITS	4½ DIGITS*	INPUT RESISTANCE
20 mV	19.9999 mV	0.1 µV	1 µV	≥10,000 MΩ
200 mV	199.999 mV	1 µV	10 µV	≥10,000 MΩ
2V	1.99999V	10 µV	100 µV	≥10,000 MΩ
20V	19.9999V	100 µV	1 mV	≥10,000 MΩ
200V	199.999V	1 mV	10 mV	10 MΩ
1000V	1000.00V	10 mV	100 mV	10 MΩ

*4½ digits at the fastest reading rate.

Accuracy

NORMAL (S) READING RATE .... ±(% of Reading + Number of Counts).

RANGE	24 HOUR[1] 23±1°C	90 DAY 23±5°C	1 YEAR 23±5°C	2 YEAR 23 ±5°C
20 mV[2]	0.0050 + 20	0.0070 + 30	0.0100 + 30	0.0120 + 40
200 mV[2]	0.0030 + 2	0.0045 + 3	0.0070 + 3	0.0100 + 4
2V	0.0015 + 2	0.0025 + 2	0.0030 + 2	0.0050 + 3
20V	0.0015 + 2	0.0030 + 2	0.0035 + 2	0.0060 + 3
200V	0.0015 + 2	0.0030 + 2	0.0035 + 2	0.0060 + 3
1000V	0.0020 + 2	0.0035 + 2	0.0045 + 2	0.0070 + 3

[1] Relative to calibration standards.

[2] Within one hour of dc zero, using offset control.

MEDIUM AND FAST RATES: .... In medium rate, add 2 counts (20 counts on 20mV range) to number of counts. In fast rate, use 2 (4½ digit mode) counts (20 counts on 20mV range) for the number of counts.

Operating Characteristics

TEMPERATURE COEFFICIENT .... <±(0.0006% of Reading + 0.3 Count) per °C from 0°C to 18°C and 28°C to 50°C.

MAXIMUM INPUT .... 1000V dc or peak ac on any range.

NOISE REJECTION .... Automatically optimized at power-up for 50, 60, or 400 Hz.

RATE	READINGS/ SECOND[1]	FILTER	NMRR[2]	PEAK NM SIGNAL	CMRR[3]
S[5]	2.5	Analog & Digital	>98 dB	20V or 2x FS[4]	>140 dB
M[6]	20	Digital	>45 dB	1x FS	>100 dB
F	100	None	—	1x FS	>60 dB

[1] Reading rate with internal trigger and 60 Hz power line frequency. See "Reading Rates" for more detail.

[2] Normal Mode Rejection Ratio, at 50 or 60 Hz ±0.1%. The NMRR for 400 Hz ±0.1% is 85 dB in S rate and 35 dB in M rate.

[3] Common Mode Rejection Ratio at 50 or 60 Hz ±0.1%, with 1 kΩ in series with either lead. The CMRR is >140 dB at dc for all reading rates.

[4] 20 volts or 2 times Full Scale whichever is greater, not to exceed 1000V.

[5] Reading rate — 1/3 rdg/sec. in the 20 mV, 20Ω, 200 mA dc ranges

[6] Reading rate — 1.25 rdg/sec. in the 20 mV, 20Ω, 20 mA dc ranges

SPECIFICATIONS

ATTACHMENT B

page 1 of 1

Input Signal Frequency Range: Full scale range is field selectable from 0-80 Hz to 0-20,000 Hz. Ranges as low as 0 - 0.1 Hz and up to 0 - 50,000 Hz are available options. The waveform can be pulsed, sinusoidal, square, TTL, CMOS.

Full scale frequency adjusted by a calibration potentiometer and switches underneath the front cover plate.

Input Signal Sensitivity: Field-adjustable from approximately 5 mVRMS to 100 mVRMS by internal sensitivity potentiometer; normally factory adjusted to 25 mVRMS. Jumpering terminal 30 to 11 desensitizes the unit to a 1 volt threshhold for operation from logic levels, shaft encoders, Dynalco PG278 pulser, or contact closure. Maximum permissible signal is 50 VRMS for the standard unit.

Input Impedance: Nearly infinite at low signal levels; a minimum of 10,000 ohms at signal levels exceeding + 15 volt peak or −1 volt peak.

Power: 115 Vac ± 10%, 47 - 420 Hz; or 22-30 Vdc; 5 watts, or 150 mA dc maximum. Optionally available: 230 Vac, 50 Hz.

Proportional Output: 4 - 20 mAdc into 1000 ohms maximum load resistance is standard. Switches beneath the cover plate allow selection of 0 - 5 Vdc or 0 - 10 Vdc for use into an external load resistance of 20,000 ohms or higher. Other custom ranges are available. The output current is independent of load resistance up to the rated load resistance specified. Span and zero adjustment potentiometers are reached beneath the front cover plate and have a minimum adjustment range of ± 5% of full scale.

Auxiliary Meter Output: Proportional 0 - 1 mAdc, filtered, for meter or recorder loads up to 750 ohms. This meter output is normally calibrated into an external load of 60 ohms. A meter adjustment potentiometer allows calibration to the particular meter used. If a meter is not connected, these terminals yield an unloaded proportional output of 0 - 10 Vdc with an internal resistance of approximately 10K.

Supply Output: The regulated 14 Vdc supply is brought out at terminals 11 (+) and 4 (−) to power active pickups such as the M910, and other dc powered devices such as Dynalco models DPM-105, 705, etc. Load not to exceed 40 mAdc.

Repeater Output: Square wave 14 volt peak to peak, positive going, is brought out at terminals 29 and 4 to operate self-powered digital tachometers SPD-100, SPD-700, MTH-103A, or to use as a high level signal source into counters, etc.

Output Ripple and Noise: 0.1% RMS of full scale maximum over 10% to 100% of full scale.

Verifying/Setting of Setpoints: Jumpering designated terminals overrides the auxiliary meter output at 8 (+) and 7 (−) and sends out a signal that corresponds to the value of the setpoint. Jumpering 12 to 16 displays setpoint 1; 13 to 16 displays setpoint. 2; 14 to 16 displays setpoint. 3; 15 to 16 displays setpoint 4.

Response Time: 150 milliseconds, 10% to 90% rise, is standard. Full scale frequency ranges below 80 Hz are generally proportionally slower. Ranges above 80 Hz can be custom ordered with proportionally faster response.

Temperature Range: −40°F to +160°F (−40°C to +70°C) operating. −40°F to +180°F (−40°C to +80°C) storage.

Linearity: 0.1% of full scale (0.05% typical), all outputs.

Output and Setpoint Stability: Less than 0.05% of full scale change with a 10% change in supply voltage. Typical temperature coefficient of ± 0.01%/°F (.015%/°C).

Alarm Setpoints (SPDT relay contacts): Adjustable over 3-100% of full scale range with infinite resolution using 25 turn cermet potentiometers. Potentiometer adjustments are accessible through access holes at the top of the chassis.

Relays: Sealed heavy-duty plastic case with contact rating of 5 amperes at 28 Vdc or 115 Vac, resistive, (2A at 230 Vac).

Relay Logic: Field-programmable by switches for overspeed, underspeed, energize, deenergize, latch and auto-reset. Hysteresis (differential between pull-in and dropout) is typically 1% of full scale frequency.

Internal Commons, Isolation: Signal input low side (6) is common to the auxiliary output low side (7), to the dc supply (4) and to the main proportional output low side (9). Relay contacts are always isolated. When powered from ac, all circuitry is isolated from the power line by the built-in supply transformer. When powered from dc, the transmitter output is not isolated from the dc power source and any load driven by the transmitter (i.e. recorder, controller, etc.) should have the same common as the negative side of the dc supply or should have an isolated and floating input circuit totally isolated from the dc power source powering the transmitter.

A signal isolation transformer option is available for use when there is a need to isolate the transmitter input from the probe or sensor.

Weight:

Series SST-2000	4.0 lbs. Max.	1.81 Kg
Series SST-3000	5.0 lbs. Max.	2.27 Kg
Series SST-4000	7.0 lbs. Max.	3.17 Kg
Series SST-5000	32.5 lbs. Max.	14. 7 Kg
Series SST-6000	25.0 lbs. Max.	11.34 Kg

Alarm Disable: Jumpering terminal 31 to terminal 7 disables all alarms, allowing for start-up conditions and special functions.

Alarm Reset: Momentary jumpering of terminal 32 to terminal 7 resets all latched alarms; permanent jumpering converts all latching alarms into auto-reset alarms.

Open Pickup Option: Causes relay No. 1 to alarm in case of an open or disconnected magnetic pickup. Relay No. 1 will still alarm when its setpoint is traversed.

Pneumatic Trip Option: Pulses relay No. 1 for 100 milliseconds; trips optional Dynalco SPV-200 Solenoid Pneumatic Valve on overspeed.

Underspeed Class "C" Logic Option: Arms relay No. 2 as setpoint No. 2 (only) is traversed on increasing speed. Pulses relay No. 2 as setpoint No. 2 is traversed on decreasing frequency. Use for tripping the pneumatic SPV-200 on underspeed or for general underspeed electrical shutdown.

ATTACHMENT C page 1 of 2

Table 1-2. Specifications, Model 87 (cont)

Display	Digital: 4000 counts, updates 4/sec 19,999 counts (4 ½-digit mode), updates 1/sec Analog: 4 x 32 segments (equivalent to 128), updates 40/sec Frequency: 19,999 counts, updates 3/sec @ > 10 Hz Backlight: On for 68 seconds when selected.
Operating Temperature	-20°C to 55°C
Storage Temperature	-40°C to 60°C
Temperature Coefficient	0.05 x (specified accuracy)/°C (<18°C or >28°C)
Relative Humidity	0% to 90% (0°C to 35°C) 0% to 70% (35°C to 55°C)
Battery Type	9V, NEDA 1604 or 6F22 or 006P
Battery Life	400 hrs typical with alkaline
Shock, Vibration	Per MIL-T-28800 for a Class 2 Instrument
Size (HxWxL)	1.25 in x 3.41 in x 7.35 in (3.1 cm x 8.6 cm x 18.6 cm)
With Holster and Flex-Stand:	2.06 in x 3.86 in x 7.93 in (5.2 cm x 9.8 cm x 20.1 cm)
Weight	12.5 oz (355g)
With Holster and Flex-Stand:	22.0 oz (624g)
Safety	Designed to Protection Class II per IEC 348, ISA-DS82, and UL1244

Attachment C page

Table 1-2. Specifications, Model 87 (cont)

FUNCTION	RANGE	RESOLUTION	ACCURACY	BURDEN VOLTAGE TYPICAL
$\widetilde{\mu A}$ (45 Hz to 2 kHz)	400.0 μA	0.1 μA	±(1.0% + 2)	100 μV/μA
	4000 μA	1 μA	±(1.0% + 2)	100 μV/μA
$\overline{\mu A}$	400.0 μA	0.1 μA	±(0.2% + 2)	100 μV/μA
	4000 μA	1 μA	±(0.2% + 2)	100 μV/μA

FUNCTION	RANGE	RESOLUTION	ACCURACY
Frequency (0.5 Hz to 200 kHz, pulse width >2 μs)	199.99	0.01 Hz	±(0.005% + 1)
	1999.9	0.1 Hz	±(0.005% + 1)
	19.999 kHz	0.001 kHz	±(0.005% + 1)
	199.99 kHz	0.01 kHz	±(0.005% + 1)
	>200 kHz	0.1 kHz	Unspecified

FREQUENCY COUNTER SENSITIVITY AND TRIGGER LEVEL			
INPUT RANGE	MINIMUM SENSITIVITY (RMS SINEWAVE)		APPROXIMATE TRIGGER LEVEL (DC VOLTAGE FUNCTION)
(Maximum input for specified accuracy = 10X Range or 1000V)	5 Hz-20 kHz	0.5 Hz-200 kHz	
400 mV dc	70 mV (to 400 Hz)	70 mV (to 400 Hz)	40 mV
400 mV ac	150 mV	150 mV	—
4V	0.3V	0.7V	1.7V
40V	3V	7V	4V
400V	30V	70V (≤140 kHz)	40V
1000V	300V	700V (≤14 kHz)	400V

Duty Cycle 0.0 to 99.9% (0.5 Hz to 200 kHz, pulse width >2 μs)

Accuracy: Within ±(0.05% per kHz + 0.1%) of full scale for a 5V logic family input on the 4V dc range.

Within ±((0.06 x Voltage Range/Input Voltage) x 100%) of full scale for sine wave inputs on ac voltage ranges.

SPEED SWITCH OUTPUT KEOWEE 1

ENCLOSURE 11.3.1
AS FOUND CHECK

ATTACHMENT D page 1 of

Item Fluke 8842A
Instrument No. OCIAC 30802
Tolerance AS Listed Below
Span ± 1000 VDC and 2 Amps DC
Location M&TE Issue Area

Test Equipment Used

Item	OCIAC#	Cal Due Date
calibrator	31033	6-16-95

(10.1.1) Remove from service [initials]

Range (DC)	Required Input (DC)	Required Reading (DC)		AS FOUND Reading (DC)	Error (DC)
20mV	10 mV	10 mV	9.9960mV / 10.0040mV	10.0004	0.0004
200mV	10 mV	10 mV	9.996mV / 10.004mV	10.000	0.0
200mV	190 mV	190 mV	189.984mV / 190.016mV	189.994	0.006
200mV	-190 mV	-190 mV	-189.984mV / -190.016mV	-189.992	0.008
2 V	0.1 V	0.1 V	0.09998V / 0.10002V	0.09999	0.00001
2 V	0.3 V	0.3 V	0.29997V / 0.30003V	0.29999	0.00001
2 V	0.5 V	0.5 V	0.49997V / 0.50003V	0.49999	0.00001
2 V	0.7 V	0.7 V	0.69996V / 0.70004V	0.69998	0.00002
2 V	1.0 V	1.0 V	0.99995V / 1.00005V	0.99999	0.00001
⇒ 2 V	1.9 V	1.9 V	1.89992V / 1.90008V	1.89999	0.00001
2 V	-1.9 V	-1.9 V	-1.89992V / -1.90008V	-1.89999	0.00001
20 V	1.9 V	1.9 V	1.8997 V / 1.9003 V	1.8999	0.0001
20 V	19 V	19 V	18.9991V / 19.0009V	19.0000	0.0
20 V	-19 V	-19 V	-18.9991V / -19.0009V	-19.0002	0.0002
200 V	190 V	190 V	189.991V / 190.009V	190.000	0.0
2000 V	1000 V	1000 V	999.94V / 1000.06V	1000.00	0.0

SPEED SWITCH OUTPUT KEOWEE 2

ENCLOSURE 11.3.1
AS FOUND CHECK

Item Fluke 8842A
Instrument No. OCIAC 31162
Tolerance AS Listed Below
Span ± 1000 VDC and 2 Amps DC
Location M&TE Issue Area

Test Equipment Used

Item	OCIAC#	Cal Due Date
Calibrator	31033	6-16-95

(10.1.1) Remove from service JB

Range (DC)	Required Input (DC)	Required Reading (DC)		AS FOUND Reading (DC)	Error (DC)
20mV	10 mV	10 mV	9.9960mV / 10.0040mV	9.9999	0.0001
200mV	10 mV	10 mV	9.996mV / 10.004mV	10.001	0.001
200mV	190 mV	190 mV	189.984mV / 190.016mV	189.995	0.005
200mV	-190 mV	-190 mV	-189.984mV / -190.016mV	-189.992	0.008
2 V	0.1 V	0.1 V	0.09998V / 0.10002V	0.10000	0.0
2 V	0.3 V	0.3 V	0.29997V / 0.30003V	0.30000	0.0
2 V	0.5 V	0.5 V	0.49997V / 0.50003V	0.49999	0.00001
2 V	0.7 V	0.7 V	0.69996V / 0.70004V	0.69998	0.00002
2 V	1.0 V	1.0 V	0.99995V / 1.00005V	0.99999	0.00001
2 V	1.9 V	1.9 V	1.89992V / 1.90008V	1.89998	0.00002
2 V	-1.9 V	-1.9 V	-1.89992V / -1.90008V	-1.89998	0.00002
20 V	1.9 V	1.9 V	1.8997 V / 1.9003 V	1.9000	0.0
20 V	19 V	19 V	18.9991V / 19.0009V	19.0000	0.0
20 V	-19 V	-19 V	-18.9991V / -19.0009V	-18.9999	0.0001
200 V	190 V	190 V	189.991V / 190.009V	189.997	0.003
2000 V	1000 V	1000 V	999.94V / 1000.06V	999.99	0.01

ENCLOSURE 11.3.4
AS FOUND CHECK

Item Fluke 87
Instrument No. OCIAC 31245
Tolerance As Listed Below
Span Frequency 0.5 Hz - 200 kHz

Location M&TE Issue Area

Test Equipment Used

Item	OCIAC#	Cal Due Date
Calibrator	31372	12-8-9(

Frequency

RANGE	Required Input	Required Reading		AS FOUND Reading	~~Error~~
400 mV	150 mV 100.0 Hz	100 Hz	99.985 Hz 100.015 Hz	99.99	
4 V	300 mV 1000.0 Hz	1000.0 Hz	999.85 Hz 1000.15 Hz	999.9	
40 V	3 V 10 kHz	10 kHz	9.9985 kHz 10.0015 kHz	9.999	
400 V	30 V 100.0 kHz	100 kHz	99.985 kHz 100.015 kHz	99.99	

ch1

~~Maximum error~~ ______

Performed by John Gambrell Date 9-8-94