Department of Energy
Washington, D.C. 20545

Docket No. 50-537
HQ:S:82:158

DEC 21 1982

Mr. Paul S. Check, Director
CRBR Program Office
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Check:

ADDITIONAL INFORMATION ON THE SECONDARY CONTROL ROD SYSTEM (SCRS)

Reference: Letter HQ:S:82:107, J. R. Longenecker to P. S. Check, "Meeting Summary for Reactor Mechanical Shutdown Systems Working Meeting, October 14, 1982," dated October 15, 1982

Enclosed is additional information on the SCRS that was identified in the reference letter.

If you have any questions, please call W. Pasko (FTS 626-6096) of the Project Office.

Sincerely,

John R. Longenecker

John R. Longenecker
Acting Director, Office of
Breeder Demonstration Projects
Office of Nuclear Energy

3 Enclosures

cc: Service List
Standard Distribution
Licensing Distribution

D001
s
1/40

The specific items ENCLOSED are:

ENCLOSURE A (Item 2) - Consequences of Beyond Design Life Operation of the Secondary Control Rod System

ENCLOSURE B (Item 3) - Design traceability from the SCRS prototype units to plant units.

ENCLOSURE C (Item 6) - A detailed basis for the decision to use a combination test/analysis on the SCRS seismic treatment.

ENCLOSURE A

CONSEQUENCES OF OPERATING THE SCRS DRIVELINE AND CONTROL ASSEMBLY BEYOND THEIR DESIGN LIFE

Introduction

This attachment summarizes the consequences of operating the SCRD and SCA beyond their design life due to the component remaining in service for two life times. Hence, the consequences of operating the driveline for 20 or 30 years, instead of the normal 10 years, and the control assembly for two years, instead of the normal one year, are discussed.

Consequences of Beyond Design Life Operation

Evaluation of the driveline for 20 or 30 years operation and the control assembly for 2 years operation has been completed. The results show the driveline to be sodium flow erosion and irradiation material embrittlement limited and the control assembly to be pin pressure limited. The consequences of the limiting conditions have been evaluated and found to have no significant influence on the SCRS scram performance.

Use of the driveline for 2 or 3 times its normal 10-year life could result in sodium flow erosion of the latch housing labyrinth seal and irradiation embrittlement of the latch parts. These conditions would have no significant effect on the ability of the driveline to release the control rod or on the control rod insertion speed. The seal flow erosion would reduce the pressure drop across the seal and slightly alter the flow distribution within the control assembly. The control rod insertion speed would be slightly reduced but not enough to significantly affect the negative reactivity insertion rate. The latch material embrittlement may cause the latch gripper fingers to break by brittle fracture. This would allow the control rod coupling head to be pulled free of the driveline and the rod would travel to the inserted position.

Extending the use of the control assembly to two years may result in a helium pressure induced rupture of the pin cladding. The consequences of a cladding break have been found to be of small significance. Limited ex-reactor experiments with defected pin cladding in flowing sodium showed no significant loss of absorber material either by flow erosion or by sodium B_4C reaction. Based on these findings, no significant loss of B^{10} loading would result and the required negative reactivity insertion capability would be maintained.

DESIGN TRACEABILITY FROM THE MOST RECENT SCRS PROTOTYPE UNIT TO THE PLANT UNITS

The design traceability of the SCRS Prototype P-4 (the most recent test unit) and the SCRS plant units is given in Table B-1. This table lists the General Electric Company drawings that define the configuration of these units.

The design differences between the SCRS Prototype P-4 and the plant units are summarized in Table B-2 for the SCRDM/SCRD and in Table B-3 for the SCA. These design differences were evaluated for wear characteristics effects, structural characteristics effects and scram performance effects. The evaluation determined no significant change would result and the validity of the test results are unaffected.

A majority of the design differences are due to the incorporation of producibility improvements, updated plant interface definitions and greater clearances, and deletion of features for interfacing with the test facility. These changes do not affect the SCRS performance and therefore have no effect on the validity of the prototype P-4 test results. The producibility changes improved the availability of the components to meet the plant units fabrication schedule. The shape of a few parts was slightly modified to maintain clearance to adjacent moving parts at worst-case dimensional conditions. Certain features and positional controls were added to the SCRDM connector plate and SCA hex duct to satisfy updated plant interface definitions. A limited number of features for interfacing with the test facility handling system, test vessel and instrument system were deleted. These features were away from sliding interfaces and their deletion has no effect on the prototype performance.

The material specification change described in Table B-2, Item 8 and Table B-3, Item 1 is a conversion from industrial material standards to corresponding ASME and RDT material standards. The same type of material is specified with expanded quality assurance requirements imposed on the material supplier. This will provide greater assurance that the specification chemistry and mechanical limits are met.

The addition of material chemistry controls (Table B-2, Item 9 and Table B-3, Item 1) for carbon, cobalt, titanium, tantalum, and columbium were evaluated for material wear characteristics effects and structural properties effects and concluded to be insignificant. These additional chemistry controls improve the in-reactor material performance. Their addition does not affect the validity of the test results.

The piston assembly (Table B-3, Item 7) and the down stop (Table B-3, Item 8) dimensional changes were made to satisfy the control rod to guide tube/hex duct clearance criteria at worst-case conditions. The dimensional changes are relatively small and have no significant effect on the SCA hydraulic characteristics and therefore on the control rod insertion speed.

The scram valve with the modified pilot valve configuration (Table B-2, Item 5) will be tested using a complete valve and cylinder assembly. The modification was made to enhance the valve reliability. The single ball pilot valve was replaced with a double ball arrangement to convert to a pressure assist actuation versus the prototype spring against pressure actuation. The key pilot valve features - valve seats, ball size and material types - remained the same. The testing of the plant valve/cylinder assembly will provide a data base for evaluating its performance. It is expected that this modification will not affect the performance of the valve/cylinder assembly.

TABLE B-1

SCRS PROTOTYPE P-4 AND PLANT UNITS DRAWINGS

	General Electric Drawings & Revision Numbers	
Description	SCRS Prototype P-4	Plant Units*
Secondary Control Rod System Design Layout Drawing	273R225, Rev.14	273R225, Rev.18
Secondary Control Rod Drive Mechanism and Driveline Assembly (SCRDM/SCRD)	273R290G005 Rev. 7	273R309G001 Rev.3
Extension Nozzle	908E947P001 Rev. 6	909E315G001 Rev.1 or 909E311G001 Rev.2 **
Hold Down Ring	908E957P001 Rev. 0	909E307G001 Rev.1
Support Ring	145D6310P001 Rev.0	145D6484G001 Rev.0
Hold Down Screw	215B2668P001 Rev.0	227B4026P001 Rev.0
Secondary Control Assembly	273R237G006 Rev.14	273R312G001 Rev.0

* As of 11/01/82

** Two drawing numbers are given due to two fabrication options--(single-piece or three-piece welded constructions)

TABLE B-2

DESIGN DIFFERENCES AS OF 11/1/82 BETWEEN SCRS PROTOTYPE P-4 SCRDM/SCRD AND PLANT UNITS SCRDM/SCRD

Component	Design Difference
1) Frame Assembly Mid Bearing Support	Radiused in-board corners for added clearance with carriage assembly
2) Position Indicator Electrical Cable Assemblies	Combined three cable assemblies into a single assembly for improved producibility
3) Electrical Connectors	Added nickel plate coating to connector shells and cable clamp for imrpoved corrosion protection
4) Sensing Tube and Tension Rod LVDT Linkage Clamps	Slight shape change for added clearance with interfacing parts at worst case tolerance conditions
5) Pneumatic Valve and Cylinder Assembly	Modified single ball pilot valve to double ball configuration for pressure assist opening actuation to enhance reliability
	Added centering shoulder for poppet valve return springs to avoid potential spring/housing contact
	Connector type and size change to improve availability
6) Connector Plate Assembly	Increased shell size of two penetrations to allow use of #16 size pins to improve availability and added azimuthal control for all penetrations for alignment with plant cables
7) Extension Nozzle	Replaced test flange mounting configuration with plant thread-sealweld configuration
	Added one-piece construction option in addition to existing 3-piece welded configuration
8) SCRDM/SCRD Pressure Boundary Parts Shield Plug and Driveline Parts (except Latch Housing & Gripper)	Changed material specification from ASTM and AMS standards to ASME and RDT Standards; used same material types and no change in material properties

TABLE B-2 (Cont'd)

Component	Design Difference
9) SCRDM Shield Plug and Driveline Parts (Except Latching Housing and Gripper)	Added material chemistry controls for carbon, cobalt, titanium, tantalum, and columbium for in-reactor operation, no change in material properties
10) SCRDM Housing	Added pressure relief valve to satisfy ASME Code overpressure protection criteria
11) SCRD Threeshaft Coupling Region	On tension rods end, at three shaft coupling, increased rod diameter and number of coupling lands from 2 to 3 to satisfy stress rupture-creep criteria

TABLE B-3

DESIGN DIFFERENCES AS OF 11/01/82 BETWEEN SCRS PROTOTYPE P-4 SCA AND PLANT UNITS SCA

Component	Design Differences
1) Materials	Changed material specifications from AMS and ASTM standards to RDT standards, used same material types and no change of material properties.
	Added material chemistry controls for carbon, cobalt, titanium, tantalum, and columbium for in-reactor operation, no change in material properties.
2) Top Handling Socket	Deleted cross-hole used for prototype test handling.
3) Hex Duct	Located load pads per plant configuration and added load pad hard facing.
4) Control Rod Damper Assembly	Added chamfer to leading edge to prevent potential control rod withdrawal hangup.
	Deleted test use bellows/whistle assembly.
	Changed coupling head attachment from male/female arrangement to female/male to improve producibility.
5) Guide Tube	Increased tube wall thickness to maintain large margin with tube buckling criteria.
6) Absorber Pin Assembly	Increased tube ID to plant unit dimensions.
	Replace simulated internals with plant configuration absorber pellets, spacers, springs, and insulator pellets.
	Replaced 316 SST tube with plant cladding tube.
7) Piston Assembly	Deleted test use position indicator CO-60 source.
	Reduced piston cross-section to allow meeting 20% cold work requirement and maintain temperature and thermal expansion limits.
	Added sodium drain hole.
	Added cooling holes to maintain piston seal ring temperature limits.

TABLE B-3 (Cont'd)

Component	Design Difference
7) Piston Assembly (Cont'd)	Increased piston/seal ring clearance to allow more seal ring float to satisfy control rod no-three-point contact criteria
8) Down Stop	Increased ID to delete undercuts and obtain required control rod clearance to satisfy control rod no-three-three point contact criteria

ENCLOSURE C

BASIS FOR THE DECISION TO USE A COMBINATION OF TEST/ANALYSIS FOR SCRS SEISMIC QUALIFICATION

1.0 Introduction

This document presents the rationale and basis for choosing the seismic qualification method of the CRBRP Secondary Control Rod System (SCRS). The methods of demonstrating adequacy are described and a summary of the results obtained to date are included.

2.0 Basis for Qualification Method

The guidelines and requirements for verifying structural integrity and operability of structures, systems and components of the CRBRP during a seismic event are given in Reference 1. The secondary control rod system is designated as a Seismic Category I System and is required to perform its safety function for OBE and SSE events. The general requirements and guidelines applicable to the SCRS are as follows:

- o Seismic Category I Systems shall be analyzed by a detailed dynamic analysis using either time history methods or the response spectra method.
- o Testing shall be employed for complex equipment that cannot be adequately modeled for a dynamic analysis to correctly predict its response.

3.0 Description of Qualification Method

Based upon the Reference 1 requirements for seismic qualification as summarized in Section 2.0, the Secondary Control Rod System seismic qualification method uses a combination of testing and analysis. The structural integrity of the SCRS is determined by a detailed dynamic analysis. Scram performance is determined by a combination of testing and analysis.

For the purpose of seismic qualification, the SCRS scram performance is separated into three parts -- valve/cylinder operation, control rod unlatching, and control rod insertion -- as illustrated in Figure C-1. The valve/cylinder assembly, being the key SCRDM component for the scram function, is qualified by an extensive seismic test as part of the valve/cylinder 1E qualification. The balance of the scram performance is determined by a driveline functional analysis and a control assembly seismic insertion analysis.

This methodology is consistent with the guidelines established in Reference 1. The valve/cylinder assembly which does not lend itself to modeling is verified by test. The balance of the system, composed of simple shapes (cylinders within cylinders), is qualified through conservative analysis. Dynamic coefficients of frictions used in the analysis are based on dynamic friction tests.

4.0 Analysis for Structural Integrity

The reactor system seismic analysis is used to determine the loads on the SCRS during seismic conditions for the reactor system configurations. 'Stick-models' are used in the finite element linear elastic dynamic analysis of the reactor system. The reactor subsystems, such as the SCRS, are represented by pipe and beam approximations in sufficient detail to reproduce the dynamic response of the subsystem. The reactor system seismic analysis provides the time histories of the displacements, acceleration and forces at the SCRS reactor system interfaces. These time-histories are used in the SCRS seismic analysis with a more detailed representation of the SCRS.

Response spectrum and time history methods are used in the SCRS dynamic analyses. The dynamic analysis results are supplemented with static analyses for regions with geometric irregularities which use the predicted dynamic loads to calculate local stress levels. The calculated stresses are compared with appropriate design criteria to verify structural integrity. The time-history analysis results are also used to develop design response spectra for SCRS sub-components and the required response spectra for the scram cylinder/valve seismic tests.

The ANSYS general purpose finite element code (Reference 3) is used for all the SCRS dynamic analysis and the reactor system seismic analysis. It is a nationally recognized code and very suitable for these types of analysis.

The results of the SCRS seismic analysis and the component structural analysis show that the combined stresses in the components are well within the SCRS structural design criteria. The resulting deflections or displacements at any structural element are small and the SCRS scram function is unaffected.

5.0 Scram Performance Qualification

The scram performance of the SCRS for seismic conditions is determined by a combination of testing and analysis. The methods chosen are the scram valve/cylinder seismic test, the driveline functional analysis, and control assembly seismic insertion analysis. Each method verifies the scram performance of the particular portion of the SCRS as illustrated in Figure [illegible]-1. The three methods are discussed in detail in the following subsections.

5.1 Scram Valve/Cylinder Seismic Test

The test method of the SCRDM scram valve/cylinder meets the guidelines and objectives defined in IEEE 344-75. A complete scram valve/cylinder assembly is tested to verify performance during and following an SSE preceded by a number of OBE's. The test unit is identical to those used in the plant. Prior to the seismic tests, the unit is thermally aged and then functionally tested. The assembly is oriented and mounted in a manner duplicating the conditions in the SCRDM. The unit is subjected to 5 OBE and 3 SSE simulations with biaxial excitation using a synthesized time history corresponding to the Required Response Spectra (RRS). The test unit mounting conditions and the number of OBE and SSE simulations satisfies the requirements of IEEE 344-75. The test response spectra for each OBE and SSE are required to envelope the RRS. Three of the OBE's and one SSE are with the unit at its reference position. The equipment is rotated 90° about the vertical axis and the remaining OBE and SSE simulations are performed. Functional testing of the valve/cylinder is performed during and after each simulation. The cylinder piston drop time, which corresponds to the SCRDM control rod release function, is measured. The cylinder piston rod is instrumented and its downward motion is timed during the scramming of the valve. In addition to the OBE and SSE simulation, the fundamental frequency of the unit in its three orthogonal directions is obtained. This is done by searching for the maximum response amplification during a sine sweep using a constant excitation, but varying the frequency of the input.

A prototype scram valve/cylinder assembly has been subjected to the seismic testing just described. The test showed that the required valve/cylinder scram performance during each OBE and SSE simulation was obtained. The seismic excitation had no significant influence on the prototype unit performance.

5.2 Driveline Functional Analysis

Control rod release during seismic and non-seismic conditions is determined by a driveline functional analysis. The driveline is made up of three concentric cylinders - a stiff outer tube (driveshaft), and a relatively flexible middle tube (sensing tube) and a flexible center rod (tension rod). This arrangement is illustrated in Figure C-2. The function of the driveline is to release the control rod. This is accomplished by a tension rod "drop" of less than .25 inches at the latch. The driveline functional analysis considers all the forces acting on the tension rod during a seismic event. An analysis of this type is adequate for predicting control rod release due to the simple driveline shapes and uniaxial loading conditions.

The analysis shows that there is a large margin for a positive downward force on the tension rod for control rod unlatching at worst case conditions (including seismic). The forces acting on the tension rod and the net downward force are summarized in Table C-1. The drag load on the tension rod is small due to the combination of the stiff outer driveshaft and the flexible tension rod. The driveshaft stiffness limits the driveline bending during an OBE or SSE excitation. This lack of significant bending, combined with the tension rod flexibility, limits the downward drag force to 5.1 lbs for a conservative friction coefficient of 1.5.

In addition to the functional analysis, a failure mode and effects analysis (FMEA) performed on the driveline has yielded no credible failure modes for preventing the required downward tension rod motion for control rod release. A key basis for this finding is the redundancy available for achieving the required tension rod movement. This movement can occur in two ways - the tension rod can move relative to the sensing tube, or, the sensing tube and tension rod as a unit can be moved relative to the driveshaft.

5.3 Control Assembly Seismic Insertion Analysis

The control rod insertion time during seismic conditions is determined by a control assembly seismic insertion analysis using the DYNALSS code, a control rod drag load-time history analysis, and the dynamic friction test results. The analysis method is comprehensive and models all aspects of the control assembly. The control assembly is made up of simple shapes, cylindrical control rod within a cylindrical guide tube. This cylinder within cylinder arrangement can be conservatively modeled to determine loads on the rod during insertion. Friction coefficients are based on dynamic friction tests.

The DYNALSS code (described in Reference 2) is written specifically for the secondary control rod system to predict control rod insertion times under non-seismic and seismic conditions. The code traces the control rod position, calculates the resistances and flow distributions and determines the detailed hydrodynamic response of the control rod as it moves into the reactor core. The code uses time-dependent pressures or time-dependent flows as input boundary conditions for the dynamic calculation. Mass and momentum balances are written for the control volumes. Control rod drag forces from the seismic condition are determined from a separate drag load time history analysis. A force balance is written for the control rod. These are combined to solve for the control rod acceleration and velocity.

The DYNALSS code is being verified by the SCRS prototype tests for non-seismic conditions. Test data, available to date, has been compared with the code predictions. The agreements between the predictions and the test data are very good as shown in Figures C-3 and C-4.

The effect of a seismic event on the control rod insertion speed is determined by a control rod drag load-time history analysis. The control rod, guide tube, and duct are modeled and the control rod contact load-time history is determined using the time histories determined from the reactor system analysis. Given the cylindrical shapes of the control rod and guide tube (cylinder within a cylinder), the lateral control rod movement within the guide tube can be readily modeled and contact loads predicted. The contact load-time history is combined with a conservative dynamic friction coefficient to develop the control rod drag load-time history. These data are input to the DYNALSS code for predicting control rod insertion times under seismic conditions. The dynamic friction coefficient used is based on extensive dynamic friction tests using the same type of material as used for the control rod and guide tube.

DYNALSS control rod insertion predictions for non-seismic and seismic conditions have been completed. The predicted times are within the design criteria.

6.0 References

1) "CRBRP; Seismic Design Criteria for the Clinch River Breeder Reactor Plant," WARD-D-0037, Rev. 1, May 1977.

2) "DYNALSS: A Computer Code to Analyze the Response of a Control Rod With Hydraulic Scram-Arrest," CRBRP-GEFR-14040, February 1975.

3) "ANSYS; Engineering Analysis System User's Manual," Rev. 2 (1975) and Rev. 3 (1979).

TABLE C-1

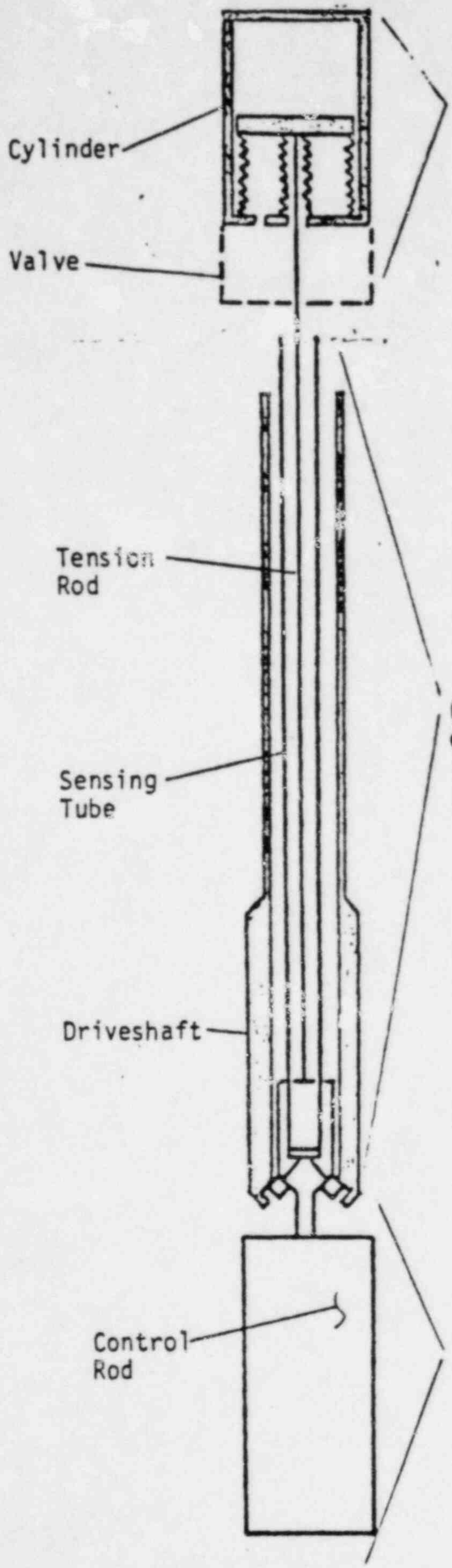
TENSION ROD FORCE BALANCE

DESCRIPION	LOAD VALUE*, Lbs 40% FLOW	100% Flow
Tension Rod Weight	34.0	34.0
Drag Force on Tension Rod	-5.1	-5.1
Bellow Spring and Pressure Load on Tension Rod	3.2	3.2
Sensing Tube Weight	75.0	75.0
Control Rod Weight Times Coupling Head Mechanical Advantage (81x1.5)	141.5	141.5
Hydraulic Assist Force Times Coupling Head Mechanical Advantage	60.0	330.0
Net Downward Load on Tension Rod	308.6 lbs.	578.6 lbs.

*Positive Values for Down Direction

Figure C-1

SCRS SCRAM FUNCTION ILLUSTRATION



Function	Verification Method
Scram Valve/Cyl. Operation • Valve Actuation • Cylinder Gas Venting • Piston Rod Drop	Scram Valve/Cyl. Seismic Test
Control Rod Unlatch • Tension Rod Drop	Driveline Functional Analysis
Control Rod Insertion	Control Assembly Seismic Insertion Analysis • DYNALSS Code • Drag Load Time History Analysis • Dynamic Friction Test

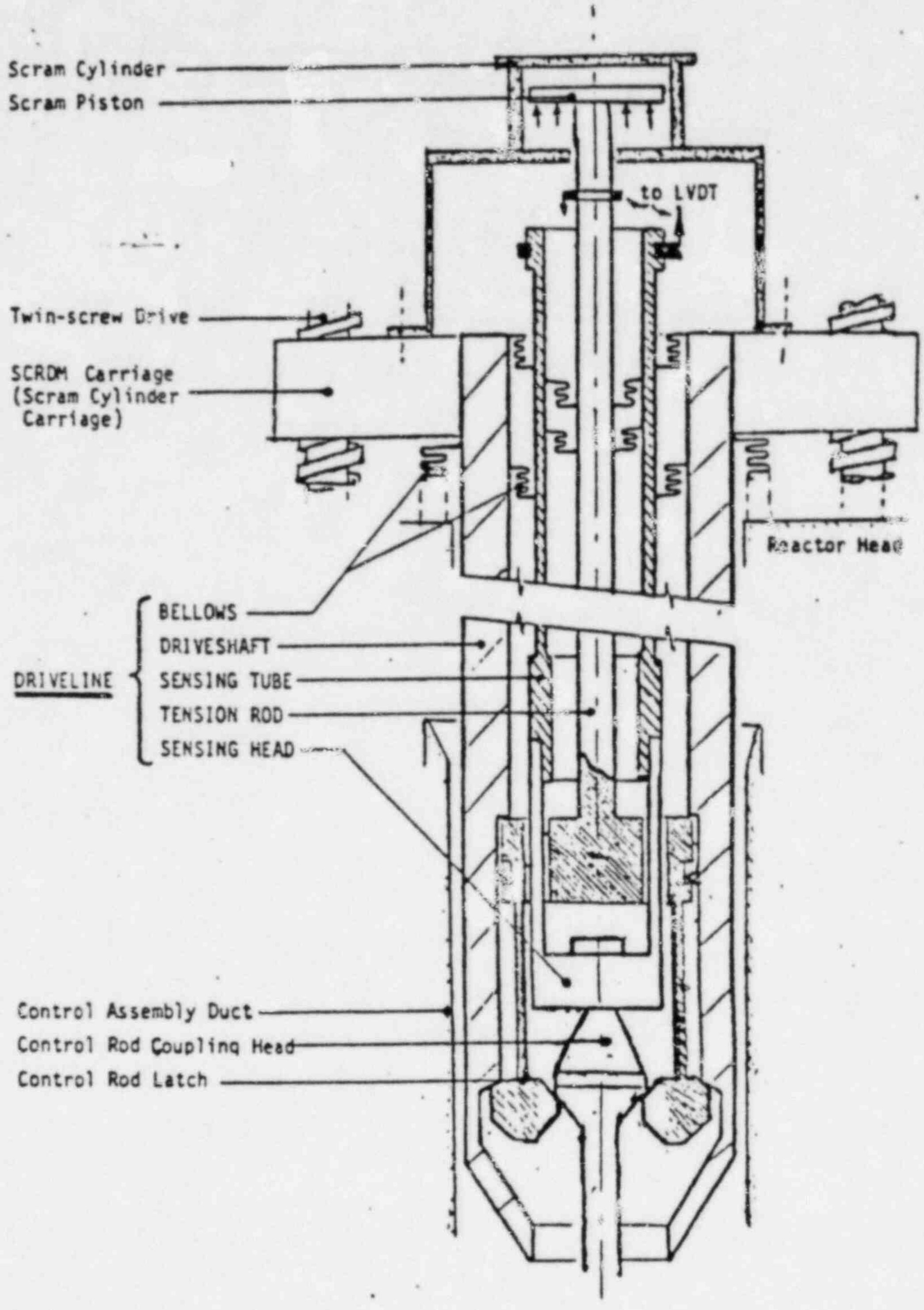


FIGURE C-2

SECONDARY CONTROL ROD DRIVELINE (SCRD)

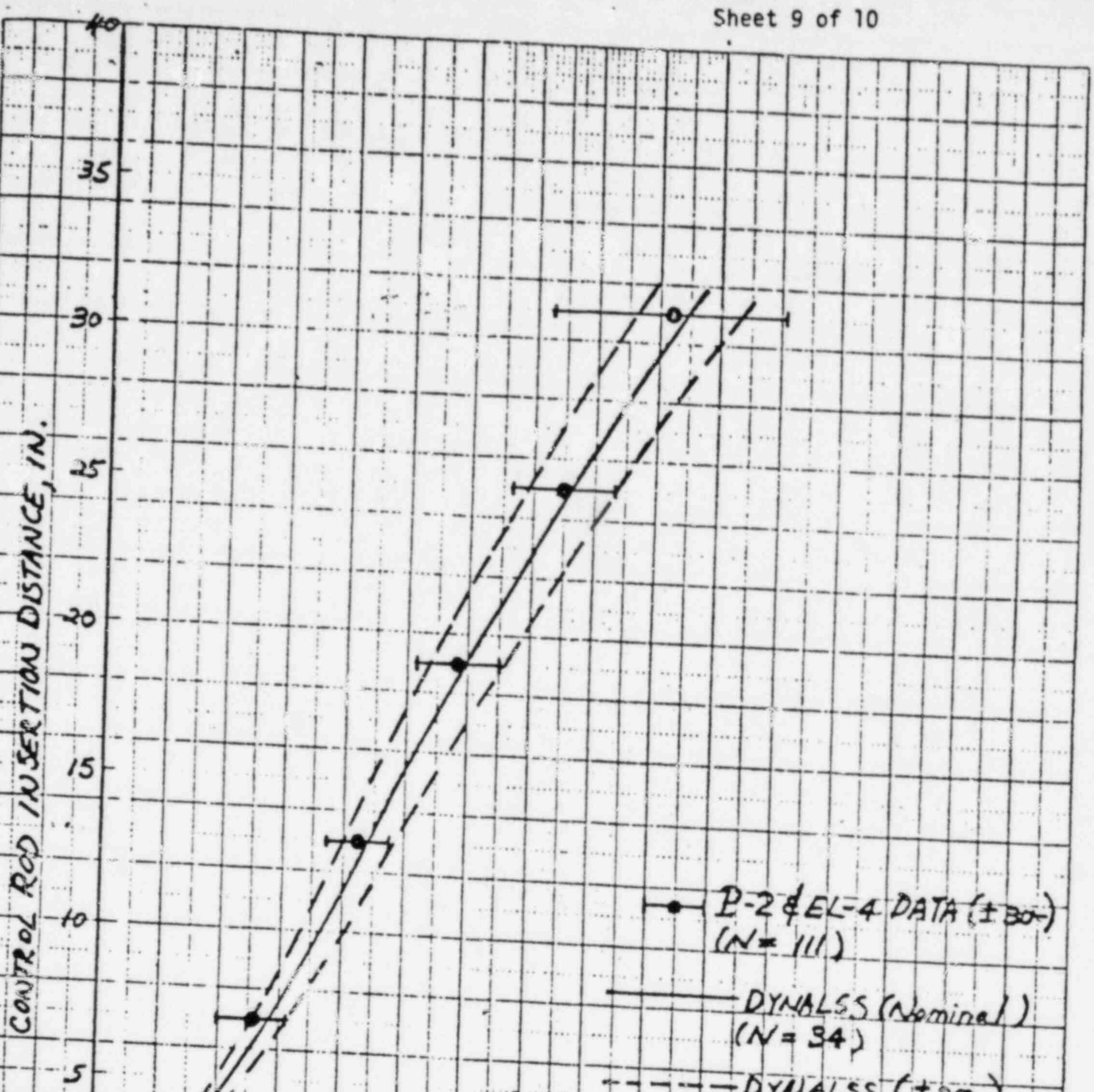


FIGURE C-3 Scram Insertion Data vs. Prediction for 40% Flow with Temperature Range 400°F to 550°F

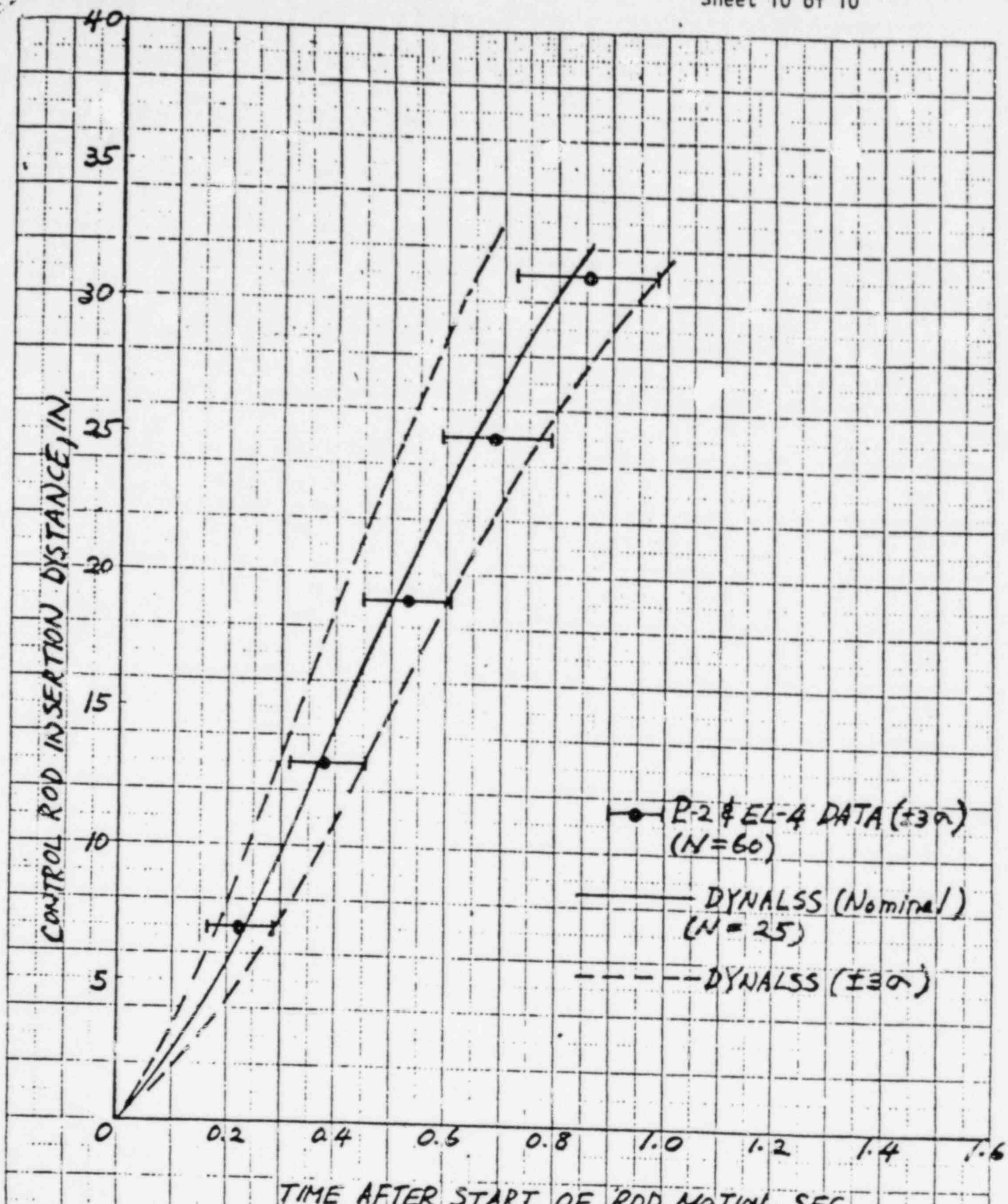


FIGURE C-4 Scram Insertion Data vs Prediction for 100% Flow with Temperature Range 400°F to 1050°F