COO-2245-53

MASTER

COOLANT MIXING IN LMFBR ROD BUNDLES AND OUTLET PLENUM MIXING TRANSIENTS

Progress Report

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DISCLAIMER

Reports and Papers Published under MIT Coolant Mixing in LMFBR Rod Bundles Project

A. Quarterly Progress Reports (Available from National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22151)

COO-2245-1	Period June 1, 1972 - November 30, 1972
COO-2245-2	Period December 1, 1972 - February 28, 1973
COO-2245-3	Period March 1, 1973 - May 31, 1973
COO-2245-6	Period June 1, 1973 - August 31, 1973
COO-2245-7	Period September 1, 1973 - November 30, 1973
COO-2245-8	Period December 1, 1973 - February 28, 1974
COO-2245-10	Period March 1, 1974 - May 31, 1974
COO-2245-13	Period June 1, 1974 - August 31, 1974
COO-2245-14	Period September 1, 1974 - November 31, 1974
COO-2245-15	Period December 1, 1974 - February 28, 1975
COO-2245-23	Period March 1, 1975 - May 31, 1975
COO-2245-25	Period June 1, 1975 - August 31, 1975
COO-2245-26	Period September 1, 1975 - November 30, 1975
COO-2245-28	Period December 1, 1975 - February 29, 1976
COO-2245-30	Period March 1, 1976 - May 31, 1976
COO-2245-31	Period June 1, 1976 - August 31, 1976
COO-2245-34	Period September 1, 1976 - November 30, 1976
COO-2245-38	Period December 1, 1976 - February 28, 1977
COO-2245-50	Period March 1, 1977 - May 31, 1977
COO-2245-53	Period June 1, 1977 - August 31, 1977

Reports Issued Under This Contract

B. Topical Reports (Available from National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22151)

E. Khan and N. Todreas, "A Review of Recent Analytical and Experimental Studies Applicable to LMFBR Fuel and Blanket Assembly Design," COO-2245-4TR, MIT, Sept. 1973.

E. Khan, W. Rohsenow, A. Sonin and N. Todreas, "A Simplified Approach for Predicting Temperature Distribution in Wire Wrapped Assemblies," COO-2245-5TR, MIT, Sept. 1973.

T. Eaton and N. Todreas, "Instrumentation Methods for Inter-channel Coolant Mixing Studies in Wire-Wrap Spaced Nuclear Fuel Assemblies," COO-2245-9TR, MIT, June 1974.

Y.B. Chen, K. Ip, N.E. Todreas, "Velocity Measurements in Edge Subchannels of Wire Wrapped LMFBR Fuel Assemblies," COO-2245-11TR, MIT, September 1974.

E. Khan, N. Todreas, W. Rohsenow, A.A. Sonin, "Analysis of Mixing Data Relevant to Wire-Wrapped Fuel Assembly Thermal-Hydraulic Design," COO-2245-12TR, MIT, September 1974.

E. Khan, W. Rohsenow, A. Sonin, N. Todreas, "A Porous Body Model for Predicting Temperature Distributions in Wire Wrapped Fuel and Blanket Assemblies of a LMFBR," COO-2245-16TR, MIT, March 1975.

E. Khan, W.M. Rohsenow, A. Sonin, N. Todreas, "Input Parameters to the ENERGY Code (To be used with the ENERGY Code Manual) COO-2245-17TR, MIT, May 1975.

E. Khan, W. Rohsenow, A. Sonin, N. Todreas, "Manual for ENERGY Codes I, II, III," COO-2245-18TR, MIT, May 1975

E. Khan, W. Rohsenow, A. Sonin, N. Todreas, "Manual for ENERGY Codes I, II, III Computer Programs," COO-2245-18TR Revision 1, MIT, July 1976.

P. Carajilescov and N. Todreas, "Experimental and Analytical Study of Axial Turbulent Flows in an Interior Subchannel of a Bare Rod Bundle," COO-2245-19TR, MIT.

B. Chen and N. Todreas, "Prediction of Coolant Temperature Field in a Breeder Reactor Including Interassembly Heat Transfer," COO-2245-20TR, MIT, May 1975.

B. Chen and N. Todreas, "Prediction of Coolant Temperature Field in a Breeder Reactor Inlcuding Interassembly Heat Transfer," COO-2245-20TR Revision 1, MIT, December 1976.

F. Carre and N. Todreas, "Development of Input Data to ENERGY Code for Analysis of Reactor Fuel Bundles," COO-2245-21TR, MIT, May 1975.

Reports Issued Under This Contract

B. Topical Reports, Continued

H. Ninokata and N.E. Todreas, "Turbulent Momentum Exchange Coefficients for Reactor Fuel Bundle Analysis," COO-2245-22TR, MIT, June 1975.

R. Anoba and N. Todreas, "Coolant Mixing in LMFBR Rod Bundles and Outlet Plenum Mixing Transients," COO-2245-24TR, August 1975.

B. Bosy, "Fabrication Details for Wire Wrapped Fuel Assembly Components," COO-2245-27TR, MIT, November 1975.

Ralph G. Bennett and Michael W. Golay, "Interferometric Investigation of Turbulently Fluctuating Temperature in an LMFBR Outlet Plenum Geometry," COO-2245-29TR, MIT, June 1976.

N.E. Todreas, "Analysis Methods for LMFBR Wire Wrapped Bundles," COO-2245-32TR, MIT, November 1976.

K.L. Basehore and N.E. Todreas, "Development of Stability Criteria and an Interassembly Conduction Model for the Thermal-Hydraulics Code SUPERENERGY," COO-2245-33TR, MIT December 1976.

Robert Masterson and Neil E. Todreas, "Analysis of the Feasibility of Implementing an Implicit Temporal Differencing Scheme in the SUPERENERGY Code," COO-2245-35TR, MIT, February 1977.

S. Glazer, C. Chiu and N. Todreas, "Collection and Evaluation of Salt Mixing Data with the Real Time Data Acquisition System," COO-2245-36TR, MIT, April 1977.

B. Mikic, E.U. Khan and N.E. Todreas "An Approximate Method for Predicting Temperature Distribution in Wire Wrapped Fuel Assemblies of a LMFBR," COO-2245-37TR, MIT, April 1977.

C. Chiu and N. Todreas, "Development of a Technique for Subchannel Flow Rate Measurements in LMFBR Wire Wrapped Assemblies," COO-2245-39TR, July 1977

C. Chiu and N. Todreas, "WARD Blanket Assembly Pre-Test Predictions by SUPERENERGY," COO-2245-40TR, July 1977

C. Chiu and N. Todreas, "Flow Split for a LMFBR 4" Wire Wrapped Blanket Assembly," COO-2245-41TR, July 1977

C. Chiu and N. Todreas, "Static Pressure and Pressure Drop for a LMFBR 4" Wire Wrapped Blanket Assembly," COO-2245-42TR, July 1977

Reports Issued Under This Contract

B. Topical Reports, Continued

C. Chiu and N. Todreas, "Mixing Experiments for a LMFBR 4" Wire Wrapped Blanket Assembly," COO-2245-43TR, July 1977

Yi Bin Chen and Michael W. Golay, "Coolant Mixing in the LMFBR Outlet Plenum," COO-2245-44TR, June 1977.

J. Kelly and N. Todreas, "Turbulent Interchange in Triangular Array Bare Rod Bundles," COO-2245-45TR, July 1977

K.L. Basehore and N.E. Todreas, "Assessment of the Need to Incorporate a Variable Swirl Flow Model into the ENERGY Code," COO-2245-46TR, July 1977.

K.L. Basehore and N. Todreas, "Analysis of the Thermal-Hydraulic Behavior in the CRBR Secondary Control Assembly, Including Interassembly Heat Transfer Effects," COO-2245-47TR, July 1977.

J.G. Bartzis and N.E. Todreas, "Hydrodynamic Behavior of a Bare Rod Bundle," COO-2245-48TR, June 1977.

M.R. Fakori-Monazah and N.E. Todreas, "Measurement and Analysis of Flow Wall Shear Stress in an Interior Subchannel of Triangular Array Rods," COO-2245-49TR, August 1977.

A.S. Hanson and N.E. Todreas, "Fluid Mixing Studies in an Hexagonal 61-Pin, Wire-Wrapped Rod Bundle," COO-2245-51TR, August 1977.

S. Glazer, N. Todreas, W. Rohsenow, and A. Sonin, "TRANSENERGY S,M - Computer Codes for Coolant Temperature Prediction in LMFBR Cores During Transient Events," COO-2245-52TR, January 1977.

C. Chiu, W.M. Rohsenow and N.E. Todreas, "Mixing Experiments in an Alternating Wire Wrapped Assembly," COO-2245-54TR, MIT, December 1977.

C. Chiu, W.M. Rohsenow and N. E. Todreas, "Sweeping Flow Mixing Model for Wire Wrapped LMFBR Assemblies," COO-2245-55TR, MIT, December 1977.

C. Chiu, W.M. Rohsenow and N.E. Todreas, "Lumped Subchannel Flow Model for LMFBR Wire Wrapped Assemblies," COO-2245-56TR MIT, December 1977.

Reports Issued under this Contract

C. Papers and Summaries

Yi Bin Chen, Ka-Lam Ip, Neil E. Todreas, "Velocity Measurements in Edge Channels of Wire-Wrapped LMFBR Fuel Assemblies," American Nuclear Society Transactions Vol. 19, 1974, pp. 323-324.

P. Carajilescov, N. Todreas, "Experimental and Analytical Study of Axial Turbulent Flows in an Interior Subchannel of a Bare Rod Bundle," J. of Heat Transfer, Vol. 98, No. 2, May 1976, pp. 262-268 (Included as Appendix to Quarterly Progress Report, COO-2245-15).

E. Khan, W. Rohsenow, A. Sonin, N. Todreas, "A Porous Body Model for Predicting Temperature Distribution in Wire-Wrapped Fuel Rod Assemblies," Nuclear Engineering and Design, 35 (1975) 1-12.

E. Khan, W. Rohsenow, A. Sonin, N. Todreas, "A Porous Body Model for Predicting Temperature Distribution in Wire-Wrapped Rod Assemblies Operating in Combined Forced and Free Convection," Nuclear Engineering and Design, 35 (1975) 199-211.

Ralph G. Bennett and Michael W. Golay, "Development of an Optical Method for Measurement of Temperature Fluctuation in Turbulent Flows," American Nuclear Society Transactions, Vol. 22, 1975, p. 581.

B. Chen and N. Todreas, "Prediction of the Coolant Temperature Field in a Breeder Reactor Including Interassembly Heat Transfer," Nuclear Engineering and Design 35, (1975) 423-440 (Included as Appendix to Quarterly Progress Report, COO-2245-23).

R. Bennett and M.W. Golay, "Interferometric Investigation of Turbulently Fluctuating Temperature in an LMFBR Outlet Plenum Geometry," Accepted for the ASME Winter Annual Meeting, Dec., 1976, (Included as Appendix in Quarterly Progress Report, COO-2245-30).

B.B. Mikic, E.U. Khan, N.E. Todreas, "An Approximate Method for Predicting Temperature Distribution in Wire Wrapped Fuel Assemblies of a Liquid Metal Fast Breeder Reactor," Mech. Res. Comm., Vol. 3, 353-360 (1976).

Reports Issued Under this Contract

C. Papers and Summaries (Continued)

L. Wolf, R. Karimi, I.Y. Kim, C.N. Wong, M.K, Yeung "2-D Thermoelastic Analysis of LMFBR Fuel Rod Claddings," Paper C4/d, 4th International Conf. Structural Mechanics in Reactor Technology, San Francisco, August 1977.

M. Yeung, L. Wolf, "Effective Conduction Mixing Lengths for Subchannel Analysis of Finite Hexagonal LMFBR Bundles," ANS Meeting, New York, June 1977.

C. Chiu and N. Todreas, "Flow Split Measurements In An LMFBR Radial Blanket Assembly," ANS Meeting, New York, June 1977.

Commencing with report COO-2245-30, a new task, TASK IV, which has been added to the contract, was reported. This TASK IV and TASK IID differ in that TASK IV is initially concentrated on thermal analyses using slug and laminar velocity profiles while TASK IID is concentrated on hydrodynamic analyses of turbulent velocity fields.

COOLANT MIXING IN LMFBR ROD BUNDLES AND OUTLET PLENUM MIXING TRANSIENTS

Contract AT(11-1)-2245

Quarterly Progress Report

June 1, 1977 - August 31, 1977

The work of this contract has been divided into the following Tasks:

TASK I: BUNDLE GEOMETRY (WRAPPED AND BARE RODS)

- TASK IA: Assessment of Available Data
- TASK IB: Experimental Bundle Water Mixing Investigation
- TASK IC: Experimental Bundle Peripheral Velocity Measurements (Laser Anemometer)
- TASK ID: Analytic Model Development - Bundles

TASK II: SUBCHANNEL GEOMETRY (BARE RODS)

- TASK IIA: Assessment of Available Data
- TASK IIB: Experimental Subchannel Water Mixing Investigation
- TASK IIC: Experimental Subchannel Local Parameter Measurements (Laser Anemometer)
- TASK IID: Analytic Model Development - Subchannels

TASK III: LMFBR OUTLET PLENUM FLOW MIXING

- TASK IIIA: Analytical and Experimental Investigation of Velocity and Temperature Fields

TASK IV: THEORETICAL DETERMINATION OF LOCAL TEMPERATURE FIELDS IN LMFBR FUEL ROD BUNDLES

TASK I: BUNDLE GEOMETRY (WRAPPED AND BARE RODS)

TASK IA: Assessment of Available Data and Codes (Kerry Basehore)

No work was performed this quarter.

TASK IB.2 Experimental Bundle Water Mixing Investigation

Repeat of Laminar and Transition Flow - 61 Pin Fuel Mixing Experiments (Stuart Glazer and Hafeez Khan)

No mixing data were obtained during this quarter due to electronic hardware problems in the Real Time Data Acquisition System (RTDAS). The computer system has been successfully repaired and tested, and is once again ready for use.

In preparation for further tests scheduled to begin immediately, the 61 pin fuel bundle was disassembled, cleaned, and reassembled. The special rods used for salt solution injection were tested, and installed in critical locations within the bundle prior to reassembly. The electrical conductivity probes used for measurement of local water salinity at the outlet plane were checked, and faulty probes replaced, so that a complete complement of 126 functioning probes is positional in the flow separator at the bundle exit.

A final draft of report entitled "Collection and Evaluation of Mixing Data with the Real Time Data Acquisition System," (COO-2245-36TR) was completed and released to selected project leaders within MIT for review and comment. The report will be released to the project during the current quarter.

TASK IB.3 217 Pin Mixing Experiments (Stuart Glazer and Hafeez Khan)

No work was performed this quarter due to the priority of the 61 pin fuel bundle tests, and temporary failure of the RTDAS.

TASK IB.4 61 Pin Blanket Bundle Experiment (Chong Chiu)

Progress in several aspects have been made in this quarter. First, the mixing experiment and the flow split experiment (subchannel flow rate measurement) for the two inch lead blanket test section have been done. Second, all the experimental data obtained over the past two years have been categorized and summarized into the following topical reports (will be issued by February 1, 1978):

(i) Flow Split Measurement in LMFBR Blanket Assemblies

(ii) Mixing Experiment in LMFBR Blanket Assemblies

(iii) Pressure Drop Experiment in LMFBR Blanket Assemblies

Finally, two models for the sweeping flow and the subchannel flow split parameters have been evolved and correlations for ε_1^*, C_1, x_1 and x_2 (under the turbulent condition) are suggested for bundles having geometric characteristics from low P/D and H/D ratios to high P/D and H/D ratios. These two models are reported in the following two topical reports (will be issued by February 1, 1978):

(i) Flow Sweeping Model for LMFBR Triangular-Array Wire-Wrapped Assemblies

(ii) Lumped Subchannel Flow Model for LMFBR Wire Wrapped Assemblies.

The abstracts of the above five reports are attached.

TASK IB.5 Shaved-Wire 61-Pin Blanket Bundle Experiment (Song-Feng Wang)

The following section reports the progress in the preparation of the mixing experiments during this quarter. The present status of test bundle set-up and familiarity with data processing systems are briefly described. Future plans and work are also described.

Technique Study

1) The subchannel flow area calculation for the shaved-wire rod bundle was carried out. A detailed review of the fundamental approaches in flow area calculations for various rod configurations will be available in November, 1977.

2) The experimental technique in flow and pressure distribution measurements has been reviewed. The experimental results are satisfactory: mass balance in flow split measurement is within $\pm 3\%$ and data scattering in pressure measurement is within $\pm 5\%$.

3) A modified interior subchannel flow sampler was designed to get more reliable experimental results. In the new design two pitot-tubes, instead of one, were used to monitor the static reference pressure at the exit of two adjacent subchannels. This new flow sampler eliminates a possible experimental error of improper orientation of flow-sampler. This can give less reliable readings in interior subchannel flow measurements.

4) The experimental techniques in salt injection mixing experiments are currently under study. Equipment and data processing methods will be examined carefully. The first run (in 12" lead fuel bundle) will be conducted within a few days.

Test Section Fabrication

Present Status

1) The modified flow housing for shaved-wire pin is available.

2) Edge- and corner-flow-sampler are available and need not be modified.

3) Fabrication of modified interior-flow-sampler is underway.

4) A half-wire file machine was designed and the fabrication is underway.

Future Work

1) Re-wrap the fuel rods — as soon as the other experiments are finished.

2) Shave the wrapped wire to half size — 24 peripheral rods only.

3) Re-platinumize the conductivity probe.

4) Check the conductivity probes and replace the failed ones.

5) Fabricate one more injection rod for possible corner subchannel injection.

6) Redesign the flow separator for possible corner injection experiments.

Future Plans

The experiment on the 4" lead shaved-wire rod bundle will be divided into 3 phases: flow split, pressure drop and sub-channel flow mixing measurements. Results from flow split measurements will be used to analyze the pressure drop and flow mixing behaviors in the shaved-wire rod bundle. Late salt injection in the mixing experiment will prevent the failure of the shaved-wires due to corrosion.

TASK IC: Experimental Bundle Peripheral Velocity Measurement (Laser Anemometer)

No work was performed this quarter.

TASK ID: Analytic Model Development - Bundles

TASK ID.1: Steady State SUPERENERGY (Kerry Basehore)

1. Code Development

A new version of the SUPERENERGY (steady state) code is being developed. A list of some of the important improvements are as follows:

i) Include a larger interassembly gap noding scheme and a stagnant flow approximation to increase the range of the code stability.

ii) Include a subroutine to precheck user selected axial step size against stability criteria before temperature calculations begin.

iii) Include a subroutine to check the input data against a modified Grashof number criteria to determine the validity of applying SUPERENERGY to the given input conditions.

iv) Include user determined variable radial mesh sizing so that a wider range of problems can be examined.

v) Include an option for an extra bypass flow region so that control and test assemblies can be properly modeled.

vi) Include the capability for gamma heating in the duct wall.

The code is presently functional on a CDC 7600 machine, though portions of it are still in the developmental stages. It is anticipated that a completed version will not be ready until January 1978.

2. G.E. Secondary Control Assembly

A topical report was issued this quarter discussing a method of modeling the thermal hydraulic behavior of the CRBR Secondary Control Assembly (SCA) (see Fig. 1). For the purpose of this model, the SCA is broken into two sections, the counter-flow section is evaluated by using a semi-analytical solution technique. The distribution in the poison bundle was found by using forward differenced numerical techniques. The wire wrap sweeping in the control bundle is represented by an enhanced eddy diffusion of heat as in the ENERGY model. The SCA modeling scheme allows complete user specification of the bundle heat transfer boundary conditions, including also the capability for interassembly coupling to fuel bundles modeled by the SUPER-ENERGY code. A further discussion of the governing equations and a listing of the computer program and the associated sample problems is found in the report.

TASK ID.2 Analytical Model Development - Transient SUPERENERGY (Stuart Glazer)

During the previous quarter, a computer code, designated TRANSENERGY-S, was completed. This code utilizes the SUPERENERGY model of known slug coolant velocity in the axial direction in 2 regions of LMFBR fuel and blanket bundles. Energy transfer within the coolant due to turbulent mixing and diversion cross-flow is modelled as occurring due to an "enhanced" eddy diffusivity, determined experimentally. The assumption of a known, unchanging velocity field therefore requires only the solution of the energy equation.

TRANSENERGY-S is the single bundle version of the transient codes written at MIT. It solves for coolant temperature as a function of time in each subchannel of a single LMFBR wire wrapped fuel or blanket assembly, consisting of 7 to 217 pins. General code capabilities include:

- gamma heating in the coolant, specified as a temporally and rodwise varying fraction of rod heat generation appearing directly in the coolant;
- gamma heating in the duct wall, specified as a temporally, axially and radially (across a duct face) varying magnitude of heat generation;
- the presence or absence of an interstitial gap surrounding the bundle containing flowing coolant;
- either heat flux or temperature boundary conditions applied outside the duct wall or gap region, specified by temporal, axial and radial (across a duct face) profiles;
- selection of from 1 to 10 radial nodes in the fuel and clad;
- selection of the number of axial fuel nodes, which may be different from the number of axial coolant nodes;

- input specified in SI units, output in either SI or British units

- output of coolant temperatures directly in map form, either degrees Fahrenheit or Celsius, and output, if desired, of local instantaneous fuel rod nodal temperatures and heat fluxes

- ability to analyze transient events involving variations in coolant flowrate, rod power, and inlet temperature, singly or in combination.

Test cases are currently being run at MIT to verify the accuracy of code predictions relative to other computer codes and actual experimental results of the Oak Ridge TWORS natural convection test. Preliminary test results indicate very close agreement for a 7 pin bundle test case between COBRA IIIC-MIT and TRANSENERGY-S. The test bundle was specified as 36" (.9144 m) in length, with fuel rods of identical geometry to typical CRBRP pins described in Ref. (1). The transient examined included variation of flowrate and rod heat generation, typical of the CRBRP E-16 transient. Forcing functions are shown in Fig. 2. Fuel rods were given a chopped cosine axial power distribution, and a radial power skew across the bundle, as shown in Fig. 3. With the exception of the radial power skew, the forcing functions and magnitudes of operating conditions were as specified in Ref. (2), for the case of 61 pin blanket bundle number C0302.

TRANSENERGY-S predictions presented here specifically excluded duct wall heat capacity since the COBRA IIIC-MIT code could not include this effect. Both codes were run to predict temperatures at times up to 35 seconds into the transient. The TRANSENERGY-S run to 35 seconds required less than 250K bytes of core storage, and approximately 9 minutes of computational time on an IBM 360/65. Estimates from Ref. (3), obtained by running benchmark computer codes on various computers, indicates that this would correspond to approximately 27 seconds on a CDC-6600, and approximately 9 seconds on a CDC-7600.

Five graphs representing partial prediction comparisons are presented as Figs. 4-8. Figure 4 shows comparison of fuel pin temperatures as a function of time for the central pin, at the bundle midpoint. The fuel model was only included in TRANSENERGY-S so that local heat flux to the coolant could be accurately modelled. Figure 5 indicates the excellent agreement in heat flux predictions from the same pin at the same position. Figure 6 compares the TRANSENERGY-S and COBRA-IIIC-MIT instantaneous heat flux predictions with the equivalent instantaneous heat flux which would occur due to the forcing function if rod heat capacity effects were neglected. Note the excellent agreement at the initial steady state calculation (time = 0), and at large times, where changes in rod power occur so slowly that conditions may be assessed to be quasi-steady. The difference between the predictions and the forcing function at intermediate times is the result of heat capacity within the rod. Figure 7 compares TRANSENERGY-S coolant temperature predictions with COBRA-IIIC-MIT predictions across the bundle at different axial heights at time = 0.0 seconds (refer to Fig. 3 for subchannel numbering). As can be seen agreement is generally very good, with the poorest match occurring at approximately the 27 inch axial level. Transient coolant temperature predictions of the two codes were compared at the 27 inch axial level specifically to highlight differences. This comparison appears in Fig. 8.

Additional code testing and verification will be carried out at MIT and probably at Westinghouse-ARD. Mr. Dan Spencer of that organization has requested code predictions from MIT (using TRANSENERGY-S) and Battelle Northwest (using a COBRA version) for selected 61 pin and 217 pin bundles for the purpose of code comparison. A second version fo the transient code, called TRANSENERGY-M, is being written and tested. This code will have the capability to analyze up to a 1/12 core sector or 41 coupled assemblies, by a fixed lumping, or homoginization of each bundle. The current model will lump each assembly into 12 distinct regions, and will retain the simplicity and the assumptions of the original ENERGY approach.

REFERENCES

(1) Carelli, M., and Markley, R., "Preliminary Thermal Hydraulic Design and Predicted Performance of the Clinch River Breeder Reactor Core," paper presented at the AIChE-ASME Heat Transfer Conference, San Francisco, Calif., August 11-13, 1975, paper number 75-HT-71.

(2) Dickson, P.W., Westinghouse Advanced Reactors Division, Waltz Mill, Pa., letter of N.E. Todreas, letter number RA-77-192, July, 1977.

(3) Covel, J., Sales Department, Control Data Corp., Boston, Mass., telephonic interview, October 21, 1977.

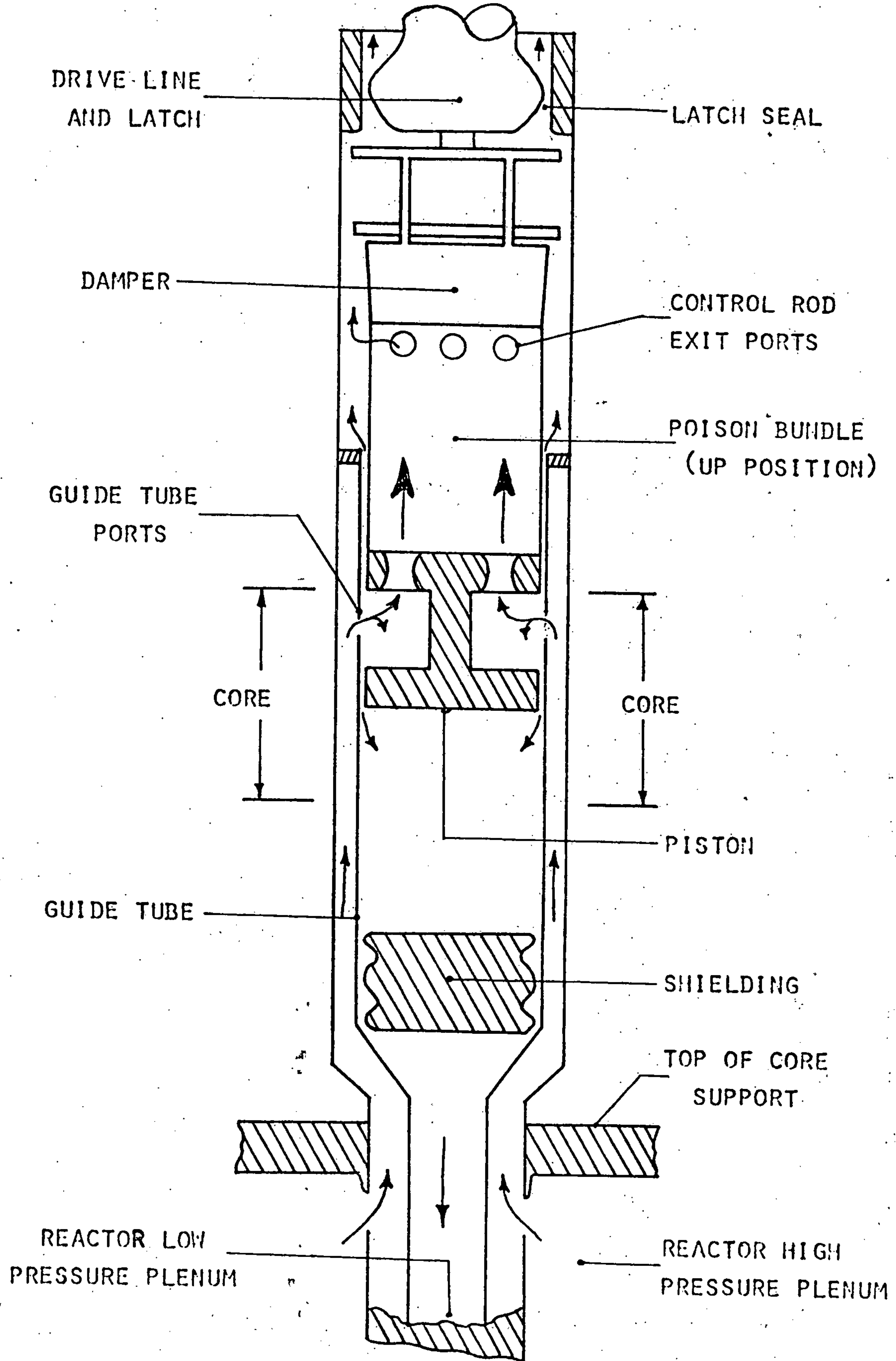


FIG. 1: DETAILS OF ASSEMBLY

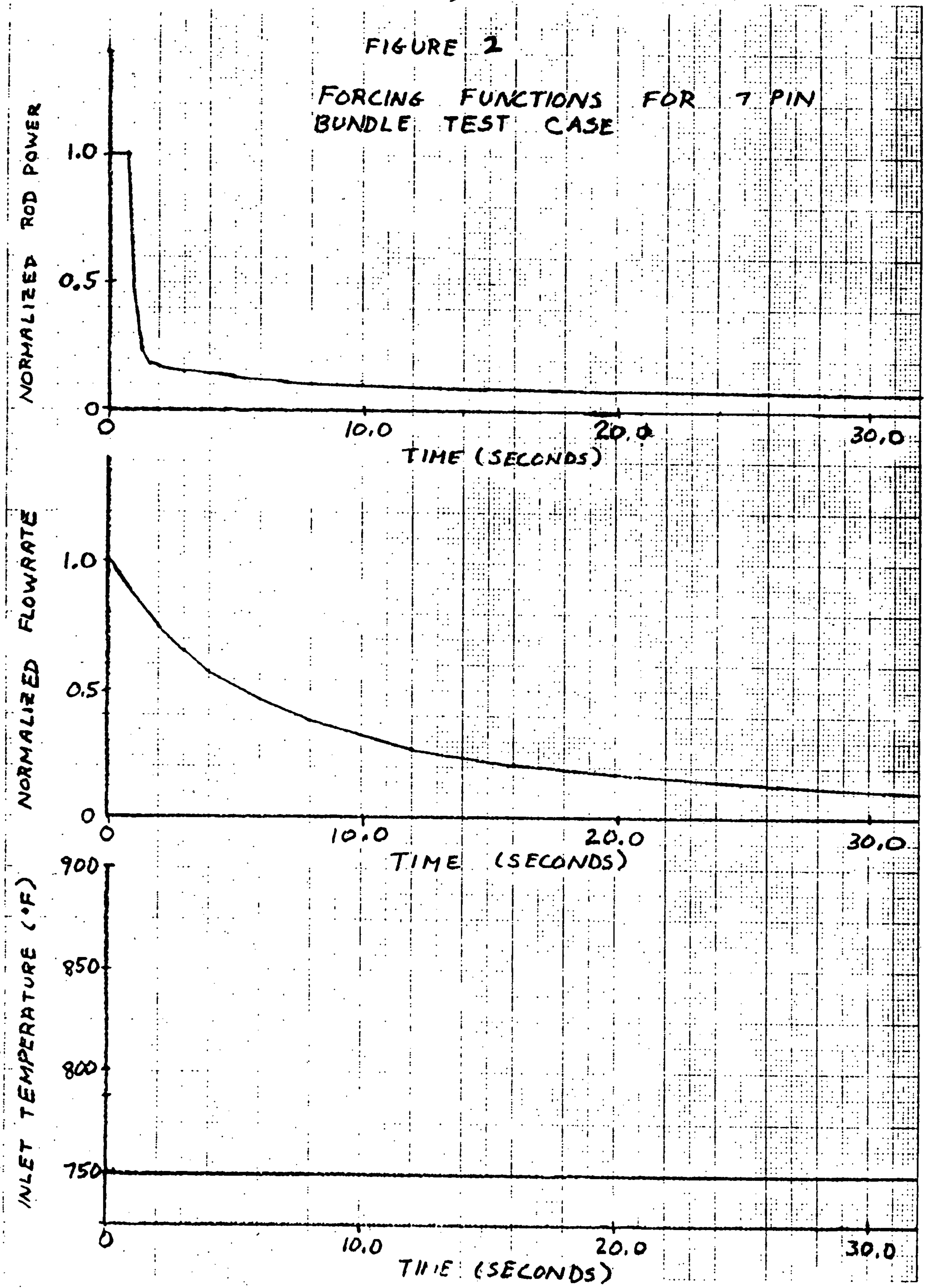


FIGURE 2
FORCING FUNCTIONS FOR 7 PIN BUNDLE TEST CASE
NORMALIZED ROD POWER
1.0
0.5
0
0
10.0
20.0
30.0
TIME (SECONDS)
NORMALIZED FLOWRATE
1.0
0.5
0
0
10.0
20.0
30.0
TIME (SECONDS)
INLET TEMPERATURE (°F)
900
850
800
750
0
10.0
20.0
30.0
TIME (SECONDS)

FIGURE 3 - ROD POWER IN 7 PIN BUNDLE

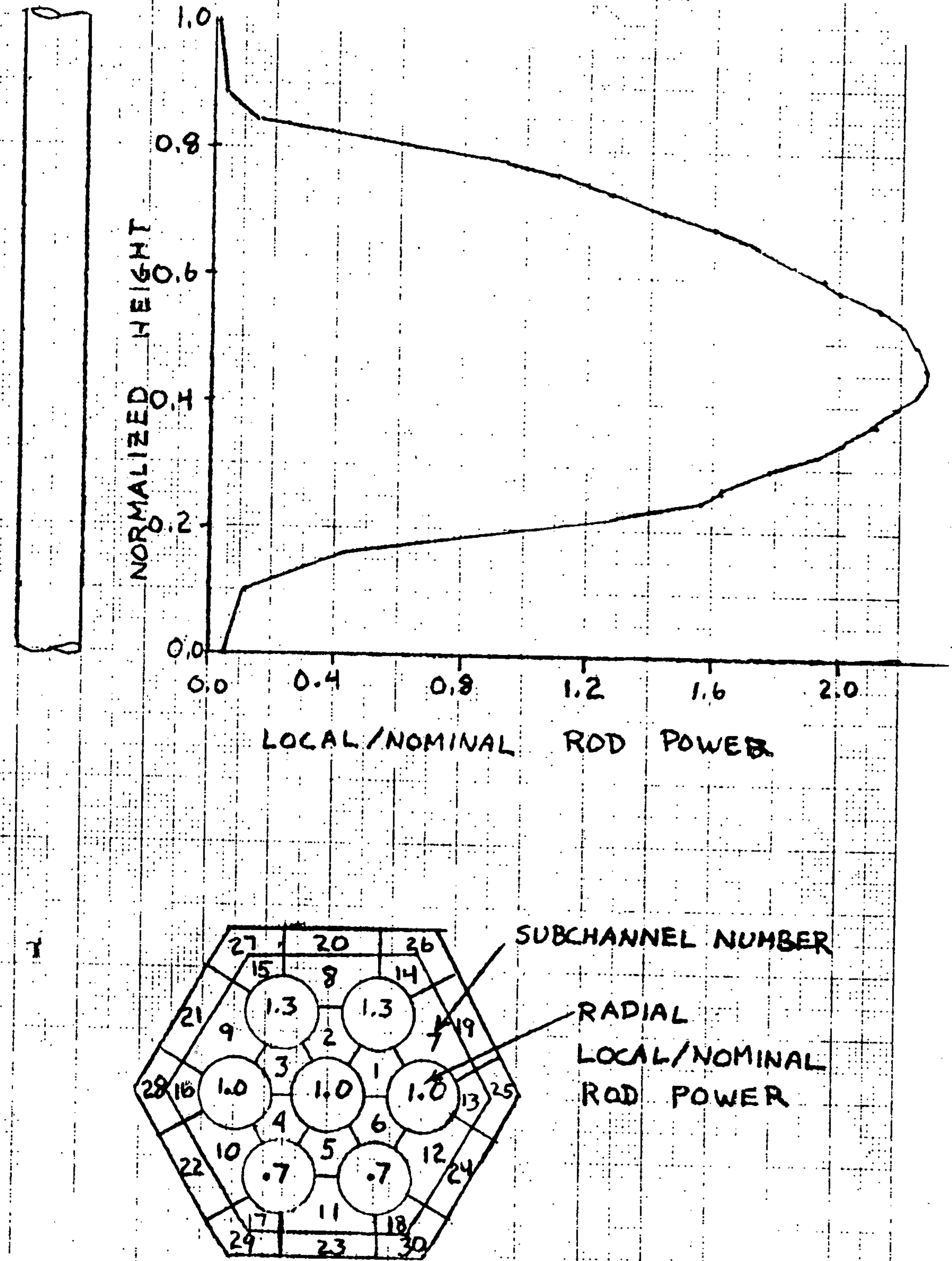


FIG. 4
RADIAL PIN TEMPERATURES VS. TIME
FOR CENTRAL PIN, HEIGHT = 18.0"

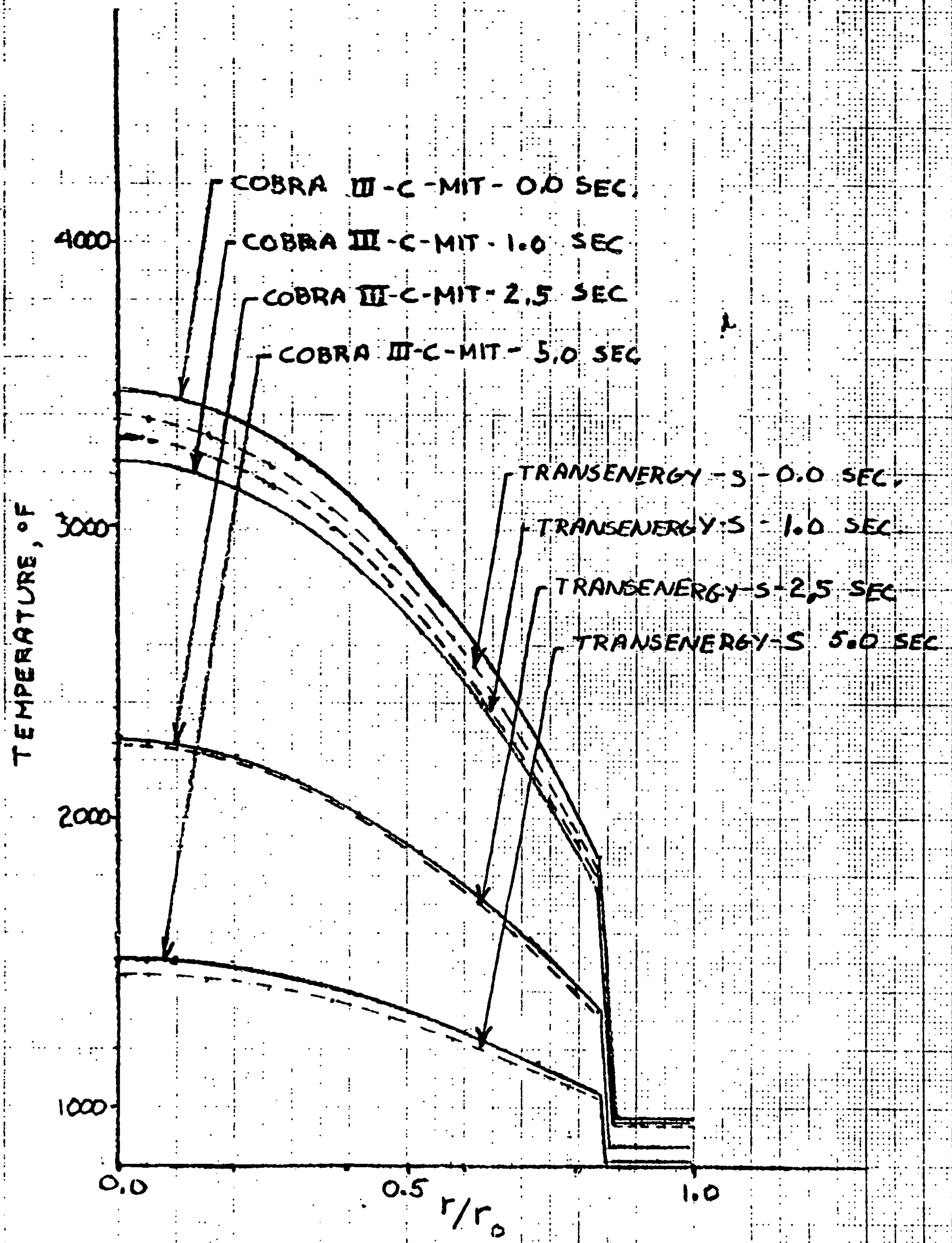
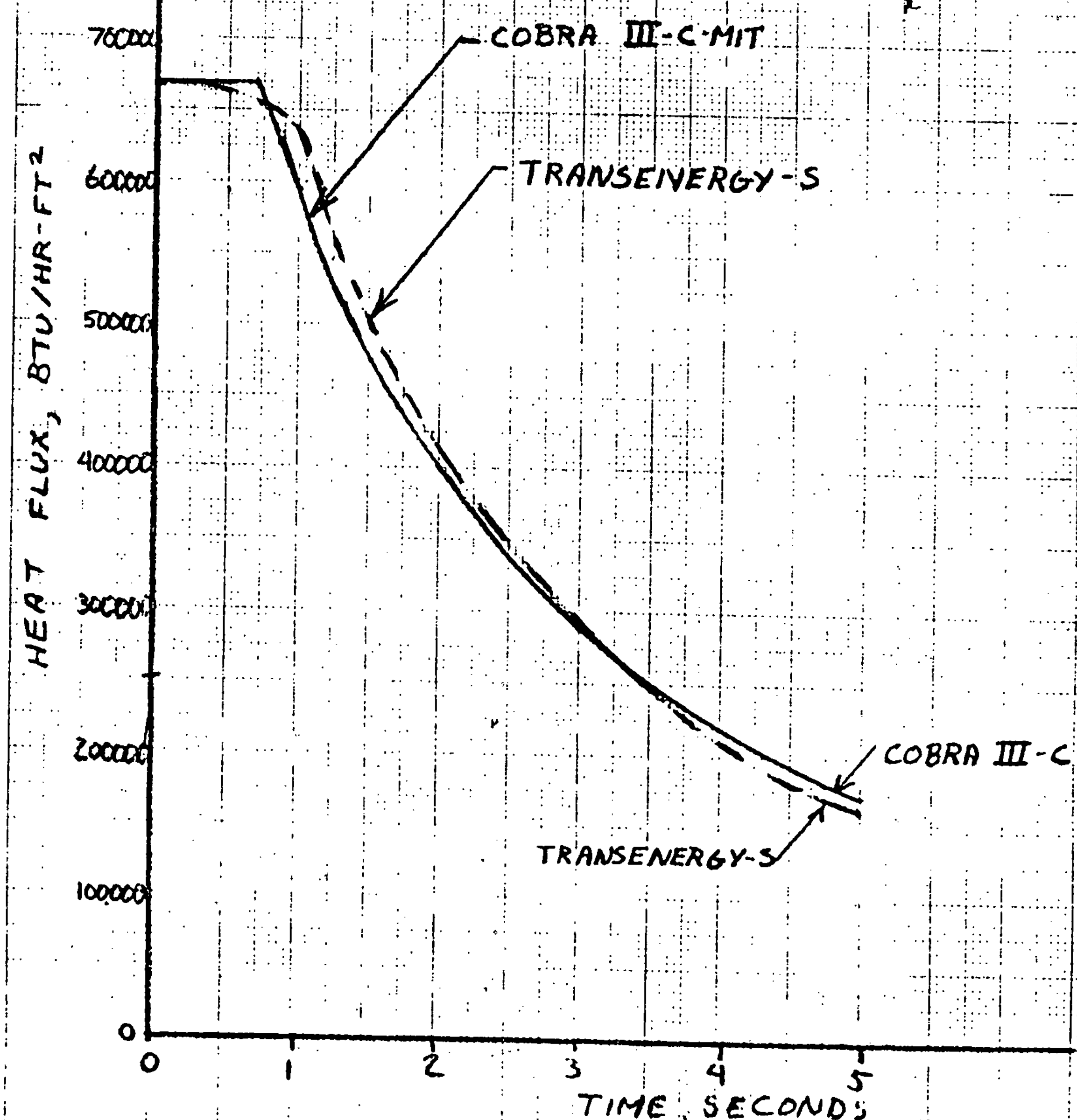


FIGURE 5

HEAT FLUX FROM ROD 1, HEIGHT = 18.00 INCHES

7 PIN BUNDLE, TEST CASE 0.1, FLOW & POWER TRANSIENT



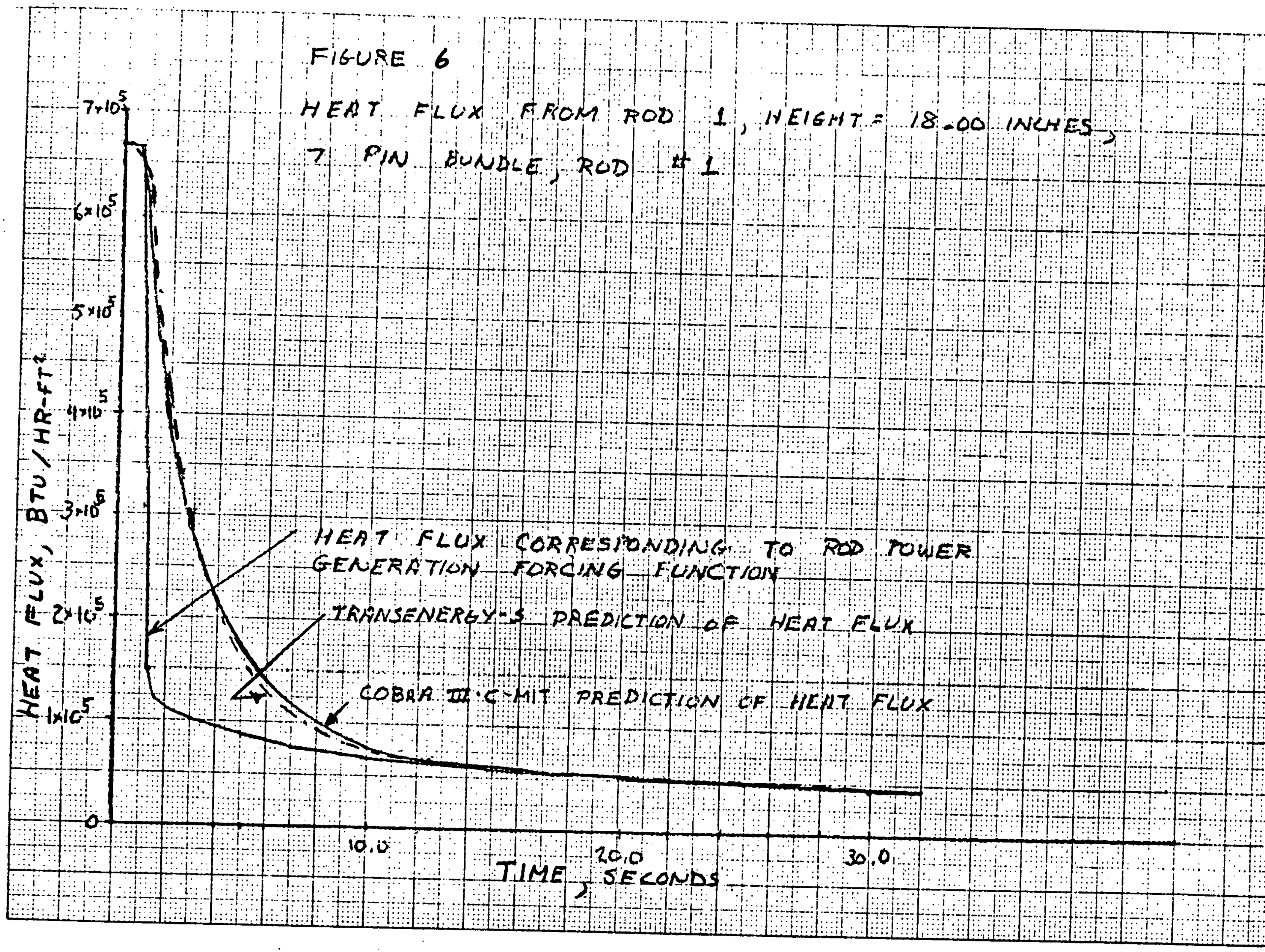


FIGURE 6

HEAT FLUX FROM ROD 1, HEIGHT = 18.00 INCHES, 7 PIN BUNDLE, ROD #1

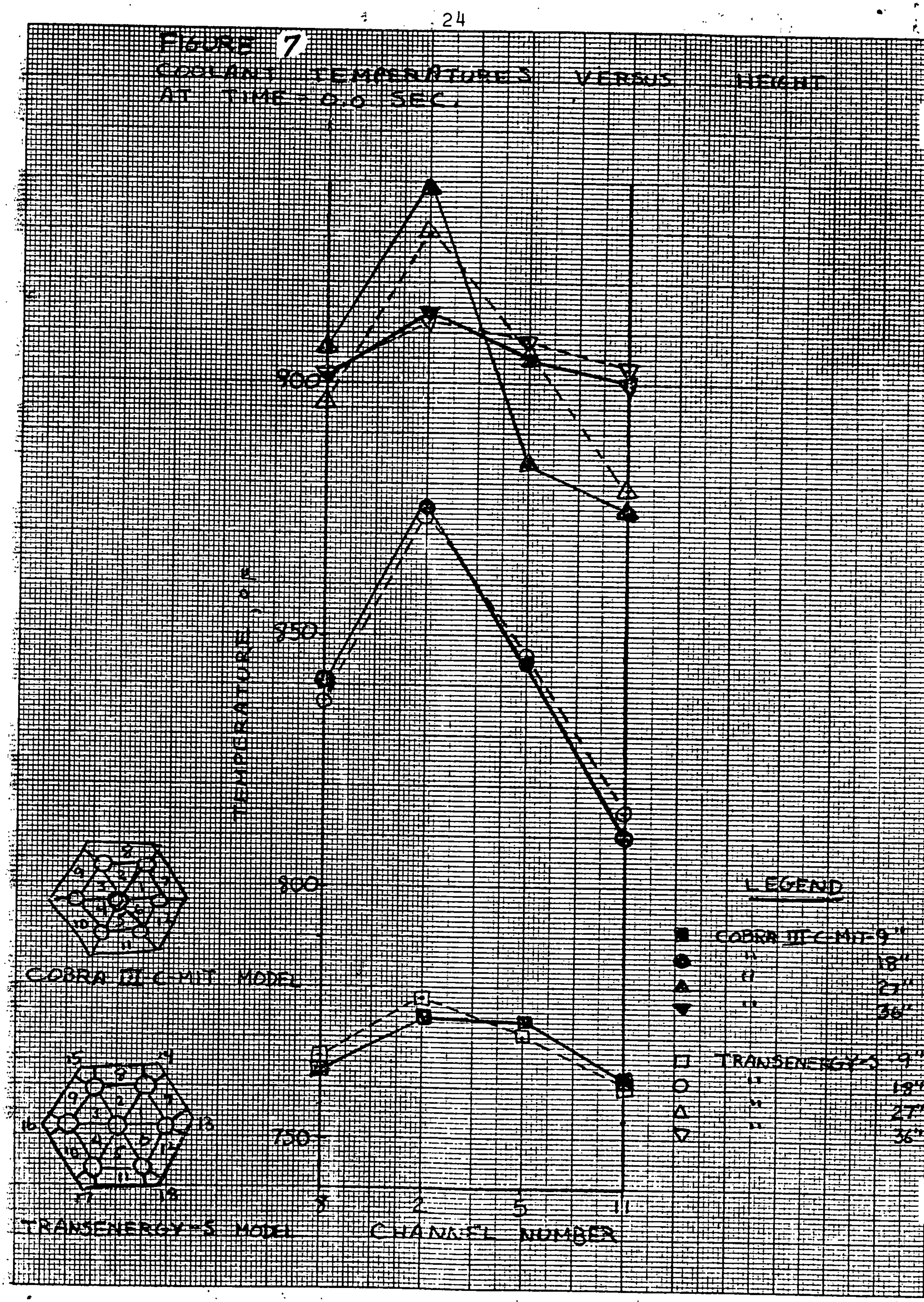


FIGURE 7
COOLANT TEMPERATURES VERSUS HEIGHT
AT TIME = 0.0 SEC.
TEMPERATURE, °F
900
850
800
750
8
2
5
11
CHANNEL NUMBER
COBRA III C-MIT MODEL
TRANSENERGY-S MODEL
LEGEND
COBRA III C-MIT-9"
18"
27"
36"
TRANSENERGY-S 9"
18"
27"
36"

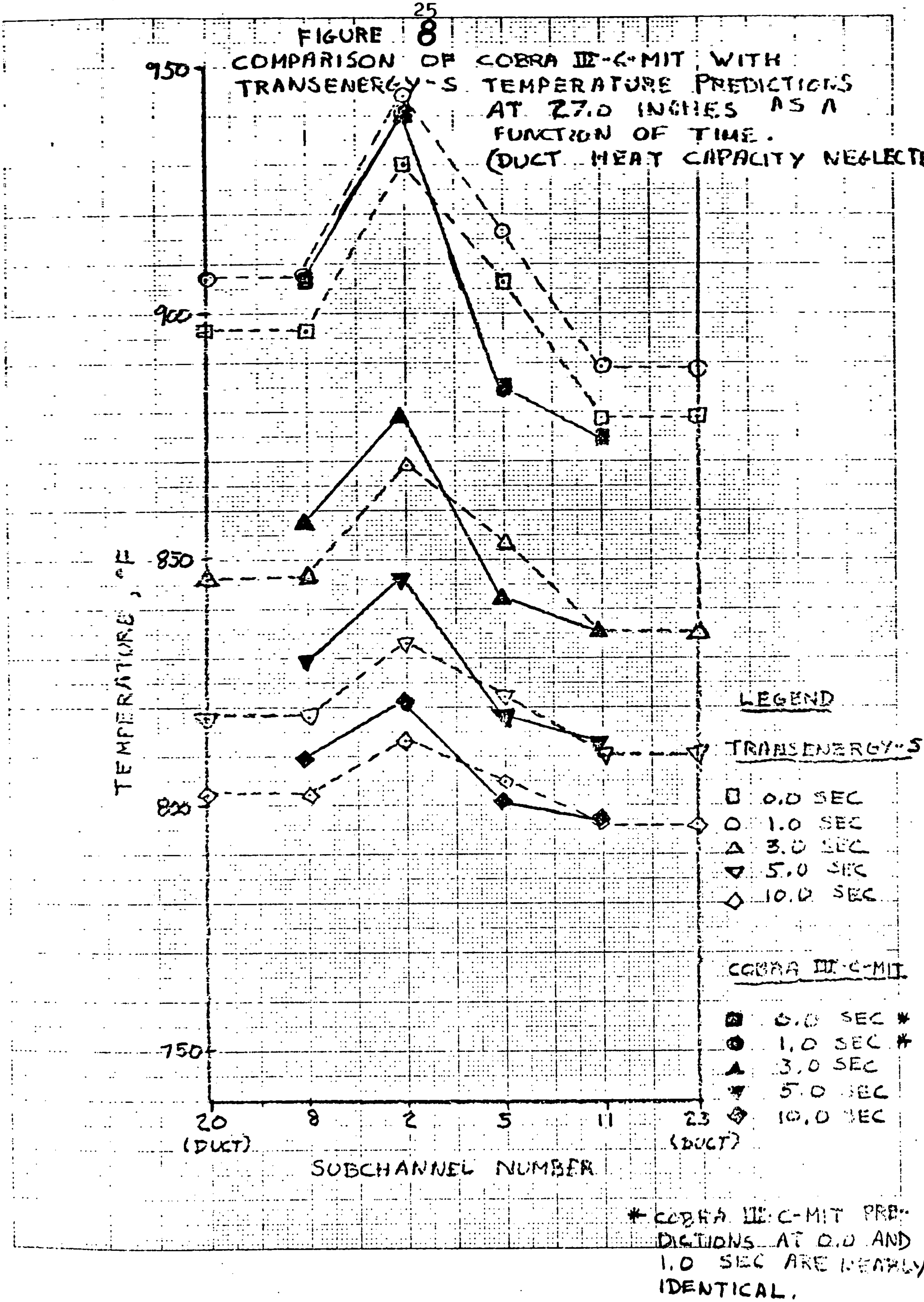


FIGURE 8
COMPARISON OF COBRA III-C-MIT WITH TRANSENERGY-S TEMPERATURE PREDICTIONS AT 27.0 INCHES AS A FUNCTION OF TIME.
(DUCT HEAT CAPACITY NEGLECTE
950
900
850
800
750
TEMPERATURE, °F
20
(DUCT)
8
2
5
11
23
(DUCT)
SUBCHANNEL NUMBER
LEGEND
TRANSENERGY-S
0.0 SEC
1.0 SEC
3.0 SEC
5.0 SEC
10.0 SEC
COBRA III-C-MIT
0.0 SEC *
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* COBRA III-C-MIT PREDICTIONS AT 0.0 AND 1.0 SEC ARE NEARLY IDENTICAL.

TASK III: LMFBR Outlet Plenum Flow Mixing

III.A. Combined Temperature and Velocity Measurements (Vincent P. Manno)

During the past quarter, the remaining components of the overall temperature-velocity experimental system were acquired and efforts centered around preliminary measurements coupled with system optimization. The chief task first undertaken was to test the various electronic and optical components. Unfortunately during the testing procedure an electronic problem developed which necessitated replacing a crucial component. A brief explanation of the problem will add insight into the system's mode of operation. The laser anemometer being utilized consists of devices built by two different manufacturers. In particular the photomuliplier which detects the frequency shifted scattered light is produced by DISA Electronics while the remainder of the LDA consists of electronics and optics designed by Thermo Systems Inc. (TSI). The DISA photomultiplier signal output is an anode current with a maximum value of roughly 50 microamperes. The signal of the photomultiplier is received by the TSI signal processing units which require a voltage input. Therefore, a transimpedance amplifier is employed as an interface between the two. The major working component of this amplifier is an integrated circuit (TIXL 150) which was discovered to be malfunctioning. Hence, time was taken up in both diagnosing the problem and acquiring a replacement.

Once the repairs were completed, preliminary mean velocity measurements were begun concentrating on the CRBR (Clinch River Breeder Reactor) outlet plenum geometry. Prior to the actual data acquisition measurement stations were chosen for both geometries (CRBR and FFTF). The location of these positions are illustrated in Fig. III.1. The choice of these positions was determined from the flow pattern observed in the test cell. As has been previously discussed, a seeding material (particles) are introduced into the flow circuit as part of the LDA requirements. These seeding particles have a tendancy to adhere to the internal faces of the test cell in a very short time. The heaviest clouding occurs in the regions of lowest velocity. Therefore, the positions chosen represent the areas where the clouding rate is lower than average. Unfortunately even at some of these locations, especially those on the outer sides of the chimneys become clouded fairly quickly and data acquisition in those areas suffer to various degrees. In fact the test cell must be dismantled and cleaned after roughly 30 minutes of seeded flow operation. This clouding problem is not caused by poor choice of material but is a difficulty intrinsic to the narrowness of the cell (which must exist for meaningful temperature data) and high seeding rates necessitated by the flow high velocities.

The most significant data gathered to date concern the flow field of the chimney regions in the CRBR geometry. First of all, unsurprisingly, the mean velocity in the vertical direction is basically constant in the region as measured at stations A, B, C and D. The mean velocity measured was 36.5 m/sec. This value corresponds to the ambient temperature flow mode, that is the flow is unheated. The magnitude of the velocity observed during actual temperature mixing situations will no doubt be different. Another flow parameter investigated was the magnitude and fluctuating nature of the horizontal velocity components at the same four stations. A distinct pattern of increasing mean value was observed in ascending stations. This is also expected since significant flow redirection should occur in the upper chimney regions. Further, the horizontal velocity components experience severe temporal fluctuations. The magnitude of the mean horizontal component however is never more than 0.2 to 0.3% of the mean vertical velocity. Figure III.2 is a plot of the velocity measurements (in arbitrary velocity units) at station C along with horizontal lines indicating the mean values of the horizontal component at both stations A and C to illustrate the increasing values as one ascends the chimney.

At present, the system is being re-optimized on the basis of our preliminary data as preparation for the correlation measurements which will begin shortly in the CRBR geometry. The first measurements will be that of the <u'T'> values and then the <v'T'> and <u'v'> terms. The initial data will be used primarily to check the characteristics of the integrated system which has never been tested and further give a feeling for the more sensitive experimental parameters involved. Subsequent to that analysis, data gathering for both the CRBR and FFTF configurations will be the primary task.

KEY FC BR

	Above inlet	From ℄
A	1"	1"
B	2"	1"
C	4"	1"
D	6"	1"
E	6"	4"
F	4"	4"
G	2"	4"
H	1"	4"
I	1"	5"
J	2"	5"
K	1½"	6½"

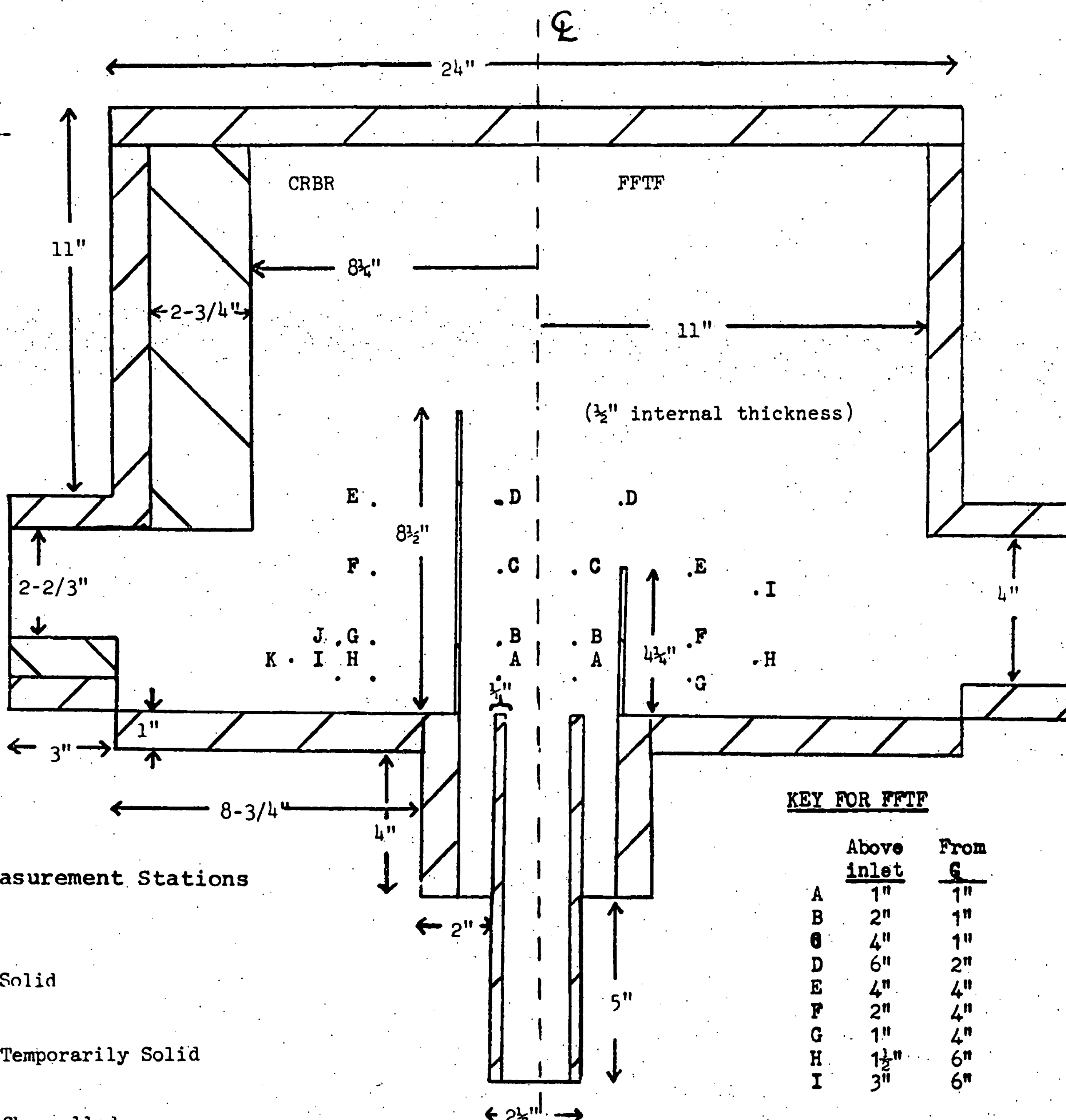

Fig. III.1: Measurement Stations

KEY FOR FFTF

	Above inlet	From ℄
A	1"	1"
B	2"	1"
C	4"	1"
D	6"	2"
E	4"	4"
F	2"	4"
G	1"	4"
H	1½"	6"
I	3"	6"

-- Solid

-- Temporarily Solid

-- Channelled

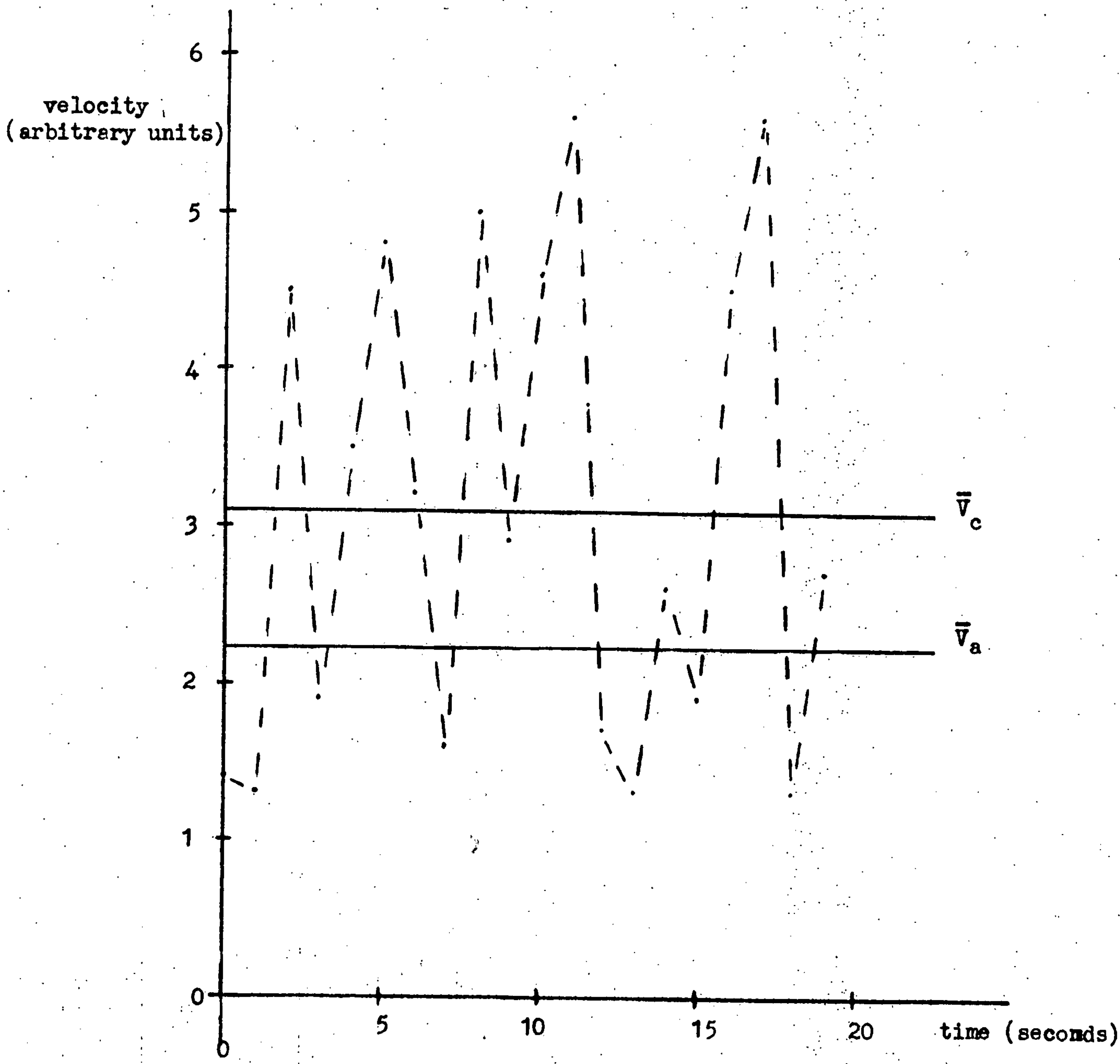

Fig. III.2: Horizontal Velocity Components at Stations A and C in CRBR geometry

TASK IV: THEORETICAL DETERMINATION OF LOCAL TEMPERATURE FIELDS IN LMFBR FUEL ROD BUNDLES

TASK IVA: Code Development for Solving the 2-D Multicell, Multiregion Energy Equations

TASK IVB: 3-D Coupled Cell Heat Transfer Analysis

No work has been performed for TASK IV during this report period due to lack of funding. Research will continue with the beginning of the next Fiscal Year.

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