DATA PROCESSING FOR THE 1/5-SCALE BOILING WATER REACTOR MARK I PRESSURE SUPPRESSION EXPERIMENT

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CONTENTS

Abstract	1
Introduction	1
Processing the Raw Data	1
Reformatting the Taped Data	1
Processing Details	3
Analysis and Processing of Engineering Files	8
Interactive Programs	8
Production Codes	8
Acknowledgments	13
References	14

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ABSTRACT

In this report are described the methods used at Lawrence Livermore Laboratory (LLL) for data reduction and post-processing of reduced data for the 1/5-scale Boiling Water Reactor (BWR) Mark I pressure suppression experiment. Output from approximately 200 transducers, recorded onto analog magnetic tape, were reduced to engineering quantities with an analog-to-digital, COBOL-like conversion code. The reduced data were analyzed with conversational FORTRAN codes and mass-processed for reports with batch-processing FORTRAN codes.

INTRODUCTION

The 1/5-scale BWR Mark I facility used for pressure suppression experiments at LLL produces data in the form of low-level signals from approximately 200 transducers per test. These data signals are amplified, conditioned, formatted, and recorded onto analog magnetic tape by special techniques and equipment.¹ However, the recorded transducer data signals are not useful for analysis until reduced to physical (engineering) data. Because there are so many signals produced by the transducers, their rapid reduction requires computer processing.

Figure 1 shows the data-processing steps (heavy boxes) and their relationship to the mass-processing steps required to produce a report. In this scheme, data quality is maintained by three error-correcting loops (A, B, C). Accuracy is also maintained in post-processing the data, which include pre-test post-analysis and inter-test post-analysis steps. Presented in this report are the methods used to process the raw signals into engineering data, post-processing analysis, and post processing for report production.

PROCESSING THE RAW DATA

The data were recorded on seven tracks of a 14-track analog magnetic tape recorder using biphase-level (B1Φ-L) shift Pulse Code Modulation (PCM) operating at 1.228 megabits/s. This technique tightly packs the information but is not compatible with the Livermore Time Shared System (LTSS).² All data for a test were contained on one magnetic tape. After recording the measurements, the tapes were first restructured for LTSS processing.

Reformatting the Tape Data

The analog tape was reformatted at LLL's L-Division Analog/Digital Data Center into a form

suitable for the LLL Octopus computer system. Figure 2 illustrates some of the data center equipment; only a fraction of the center's capabilities were needed for reformatting. In Fig. 3, the required components are shown as loops bounded by heavy boxes and arrows. The data tape from a test was read into the system, sorted into proper order by the synchronizers, and queued in the controller and disc file for final storage on digital magnetic tape.

From one digital data tape, four tapes were produced. In early tests the data were reblocked into as many as seven digital tapes, which later proved unnecessary. The data were reformatted into a tape containing data from (1) all of the transducer calibration; (2) the Low-Frequency Acquisition

Figure 1. Flow diagram emphasizing data processing steps (heavy boxes) required before test results can be reported.

are presented in the air test results report.⁴ Calculated load functions and mass flow rates are stored in the LLL photostore system.

Processing Details

To reduce the digitized data from LOFAU units into engineering quantities, we used ATD, a compiler-type code written in a COBOL-like computer language.³ ATD was also used to process data for input into the Fortran codes TORUS and MF.⁴ TORUS takes the processed, selected-pressure data to compute the hydrodynamic vertical load; MF takes the processed, selected-temperature and -pressure, and differential-pressure data to compute the mass flow rate in the vent lines. Results from TORUS and MF

Whether used for general or selected processing, an instruction set was first prepared for ATD. The ATD instruction set for general data reduction from LOFAU units (60 channels per LOFAU) is described below; the instruction sets for use with TORUS and MF are similarly written. Instruction sets contain identifiers, calibration constants, scaling parameters, and directions for storing the reduced data.

Figure 5 illustrates part of a typical instruction set for Test 2.4, LOFAU 4. PRINT (Fig. 5) saves the indicated 14 engineering data files, one for each channel 2 through 15, and names them by appending the two-digit, data-processing channel numbers (beginning with 02) to the identifier WL2441. PLOT (Fig. 5) calls for a graphic readout of the engineering data for each of the 14 channels.

Figure 2. Working area of the L-Divisor analog/digital data center.

Figure 4. EMR graphics display terminal.

•
•
•
•
•
END

- A Data processing channel number.
B Instrumentation channel number.
C Calibration constant.
D Ordinate title for graph.

Figure 5. Typical ATD instruction set.

LIX LXENG42.4 / 1 1.1 Utility routine LIX operating on engineering library LXENG42.4
 Z1758 FRI MAY 27.77 LXENG42.4 OK RW
 OK. LL. Instruction to list contents of library

ADDRESS	LENGTH	NAME
8	11123	WL244102
11123	11123	WL244103
22246	11123	WL244104
33371	11123	WL244105
44514	11123	WL244106
55637	11123	WL244107
66762	11123	WL244108
100105	11123	WL244109
111230	11123	WL244110
122353	11123	WL244111
133476	11123	WL244112
144621	11123	WL244113
155744	11123	WL244114
167067	11123	WL244115

Engineering file names corresponding to block of transducers shown in Fig. 5.

Figure 7 is the plot of this file.

Figure 6. Example of an engineering library. Data from LOFAU 4, Test 2.4.

MRC TEST NO. 2.4 Test number.
 MPX CHANNEL: 15 Data reduction channel
 TIME PER POINT: 2.06350E-03
 NUMBER OF POINTS: 3492
 LOAD, LBS. (L-50), TORUS TRUNION, 4-270 DEG. Transducer identification

-9.4116E+00	3.7647E+01	-9.4116E+00	-9.4116E+00	-9.4116E+00	-9.4116E+00
-9.4116E+00	8.4705E+01	-9.4116E+00	-5.6470E+01	-9.4116E+00	-9.4116E+00
-9.4116E+00	3.7647E+01	-9.4116E+00	-9.4116E+00	-9.4116E+00	-1.0353E+02
-9.4116E+00	3.7647E+01	-5.6470E+01	3.7647E+01	3.7647E+01	-9.4116E+00
-9.4116E+00	-9.4116E+00	-9.4116E+00	-9.4116E+00	-9.4116E+00	3.7647E+01
3.7647E+01	-9.4116E+00	3.7647E+01	8.4705E+01	-9.4116E+00	3.7647E+01
3.7647E+01	-9.4116E+00	-9.4116E+00	3.7647E+01	-9.4116E+00	3.7647E+01
3.7647E+01	3.7647E+01	3.7647E+01	3.7647E+01	-9.4116E+00	3.7647E+01
-9.4116E+00	-1.5059E+02	-9.4116E+00	-9.4116E+00	-9.4116E+00	3.7647E+01
-9.4116E+00	-9.4116E+00	3.7647E+01	-5.6470E+01	-9.4116E+00	-9.4116E+00
-5.6470E+01	3.7647E+01	3.7647E+01	-9.4116E+00	-9.4116E+00	-9.4116E+00
-9.4116E+00	8.4705E+01	3.7647E+01	-9.4116E+00	3.7647E+01	3.7647E+01
-5.6470E+01	3.7647E+01	3.7647E+01	-9.4116E+00	3.7647E+01	8.4705E+01
3.7647E+01	8.4705E+01	3.7647E+01	-1.0353E+02	-5.6470E+01	3.7647E+01
-9.4116E+00	3.7647E+01	-5.6470E+01	-9.4116E+00	3.7647E+01	3.7647E+01
3.7647E+01	3.7647E+01	-9.4116E+00	3.7647E+01	3.7647E+01	-9.4116E+00
-9.4116E+00	-9.4116E+00	-9.4116E+00	3.7647E+01	3.7647E+01	-9.4116E+00
3.7647E+01	3.7647E+01	3.7647E+01	3.7647E+01	3.7647E+01	-9.4116E+00

Figure 7. Example of an engineering data file: first 25 lines of WL244115.

showing the first 14 files as defined in the instruction set of Fig. 5. For each test, there are four libraries, one for each LOFAU unit. The files listed in Fig. 6 are saved by the PRINT instruction (Fig. 5). Each engineering file contains 10 s of data (3,492 data points) with 2.8635 ms between points. Figure 7, a portion of WL244115, illustrates a characteristic data file. The identifying lines at the beginning of the file are the identifiers in the instruction set (Fig. 5).

Calibration and engineering plots for a LOFAU unit and a particular test are stored together in a

master plot file on magnetic tape. The master plot file is identified by the prefix FX; the plot file for WL244115 is contained in the master plot file FX035/1500 stored on a magnetic tape labeled Test 2.4, LOFAU 4. For each test, there were four master plot files, one for each of the approximately 60 data sets from the four LOFAU units. Figure 8 illustrates a typical plot file (WL244115). Note the identifiers on this plot and their agreement with those in the data file (Fig. 7) and instruction set (Fig. 5). In Fig. 8, the block of data on the left between the graph and the identifier NRC TEST

Figure 8. Example of an engineering plot file (WL244115).

NO. 2.4 contain data-processing information used for quality control. This information means:

CE TIME—date and time data processing controller was made.

SA RATE—sampling rate (the rate is encoded).

NCHANS—number of channels.

LO FREQ—inverse of the data time span.

HI FREQ—inverse of twice the time between points.

ANALYSIS AND PROCESSING OF ENGINEERING FILES

The primary data base for analysis of our results were the engineering data. Because of the high sampling rate (2.8635 ms between points), these numerical data files cannot be examined or manipulated effectively without computer software. Interactive computer codes were developed for the LTSS to plot and manipulate these files. When analyses with these codes revealed pertinent characteristics, relevant plot and manipulations were incorporated into production codes. The production codes were then used to reprocess all library files into a new form. The codes discussed in this section rely on utility routines available in the LLL computer system.

Interactive Programs

Three conversational FORTRAN programs accessed from a teletype, were written for engineering data manipulation: NUPLOT, PRPLOT, and CLCPLOT. These routines manipulate files as instructed and plot selected portions of the file as described below.

NUPLOT performs two basic functions. One is to plot selected portions of several engineering data files on an expanded time scale; up to eight files may be overlaid on the same frame. Figure 9 is an example of a single file (WL244115) plotted on an expanded time scale, comparable with that shown in Fig. 8. Figure 10 shows a simultaneous overlay and expanded time plot. The second NUPLOT function is to plot up to eight data files side by side; the same time window and ordinate apply to all files on the same frame. Figure 11 is an example of a side by

side plot with an expanded time scale for 7.5° sector boundary pressure histories from Test 2.4. Each history is plotted for 0.32 s.

PRPLOT adds or multiplies the data by a constant number, shifting and expanding the data vertically. By properly applying NUPLOT to a file with PRPLOT, we can compare any portion of the data from the original or other files by overlay plotting, thereby adding a new dimension to the analysis.

CLCPLOT incorporates PRPLOT and NUPLOT to correct load-cell data for forces from the pressurization of the torus vent lines.⁴ CLCPLOT contains the static calibration used to correct for this pressure effect. When files from the ullage pressure and load cell are specified, CLCPLOT will correct the load-cell file and produce a corrected plot, shown in Fig. 12. The most noticeable change between the corrected (Fig. 12) and the uncorrected plot (Fig. 8) is the removal of the apparent zero shift shortly after the maximum upload. Figure 9 is an expanded-time plot of Fig. 12. The data beyond 4.5 s was not corrected because the ullage pressure transducers became saturated after this time.

Production Codes

Mass processing of data files was required for the Air Test Results report.⁴ Six FORTRAN codes using features of NUPLOT, PRPLOT, and CLCPLOT were written for this purpose. The function of each code,⁴ is summarized in Table 1. These codes search for the proper library file (Fig. 6) and process the file in selected order.

Table 1. Summary of computer programs used for mass processing of engineering data files.

Code name	Function
FOURPLOT	Plots data files four per page with proper identification.
DEFPLOT	Computes starting time and drywell pressurization rate from the drywell pressure (P73 and P74) data files; overplots the computed results onto the P73 and P74 graphs.
APLOT	Produces side by side plots from a given library of files.
PCPLOT	Produces overlay plots from a given library of files.
CLCPLOT137 CLCPLOT14	Corrects load cell data for pressurization forces.
PRPLOT1	Adds data files from CLCPLOT to produce the vertical load function.

CORRECTED LOAD CELL NO. 5B TEST NO. 2.4

ORD. SHIFT

P43 WL244115

MIN=-2.3059E+04 MAX= 1.1884E+04

Figure 9. Example of an expanded-time plot, Load Cell 5B, Test 2.4.

REPLOT RUN U 12/16/77 14:21:51
 A B
 HYDRO VLF TEST131 RESPONSE VLF TEST131

Figure 10. Example of an overlay plot response vertical load function and hydrodynamic vertical load function, Test 1.3.1.

PSE AIR TEST NO. 2.4
TOTAL PRESSURE 7.5 DEG. TORUS
THETA = 45 128 155 160 165 180

Figure 11. Example of side-by-side plot boundary-pressure histories in the 7.5° TORUS sector, Test 2.4.

CORRECTED LOAD CELL NO. 5B TEST NO. 2.4

ORD. SHIFT

P43 WL244115

MIN=-2.3059E+04 MAX= 1.1884E+04

Figure 12. Corrected response vertical load function, Test 2.4, WL244115.

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The ATD system for data processing was developed by A. W. Shannon; he trained R. Lum and J. E. Mellor to implement ATD. The post-

processing software routines were written by R. W. Martin.

John E. Mellor took over the data processing task near the beginning of the test series because of the reassignment of other personnel. He not only processed the some 5000 data files but, through his own initiative, created an effective method for retaining the engineering files for future reference.

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