COMPUTER OPERATIONAL SYSTEM REQUIREMENTS
TO UTILIZE FLAC AND MUDEC
FOR THERMOMECHANICAL ANALYSIS

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COMPUTER OPERATIONAL SYSTEM REQUIREMENTS TO UTILIZE FLAC AND MUDEC FOR THERMOMECHANICAL MODELING

The microcomputer codes FLAC and MUDEC have been adapted and tested for the purpose of thermomechanical modeling to assist the NRC in the reviews of studies performed by the DOE for high-level radioactive waste isolation in basalt, tuff and salt. These codes were specifically developed to operate on IBM-compatible microcomputers and are designed to take full advantage of this microcomputer system for both computation processing and display of graphical results.

In order to utilize these codes most effectively for the purpose of thermomechanical modeling, specific computer hardware equipment and peripherals and software support packages are required. These are listed in Table 1. This operational system provides a facility which is extremely efficient for computational analysis and is, in fact, more effective for conducting thermomechanical studies in support of NRC reviews than are the present computer systems available to NRC's Engineering Branch.

Justification Procedure

The justification for the recommended operational system is based on a comparison of "turn-around" times required for a typical thermomechanical analysis on different computer systems. The turn-around time is the total time required to complete a model simulation and includes the following components:

(1) model set-up time (i.e., the time required to generate the model for a specific problem);

(2) central processing units (CPU) time (required by the computer to perform the calculations in order to solve the problem);

(3) actual "clock time" (i.e., the total time from submission of the model run to the computer to receipt of the model results); and

(4) post-processing time (i.e., the time required for generation of printed and graphical output used for interpretation of results).

Table 1

SPECIFIC COMPUTER SYSTEM HARDWARE AND SOFTWARE
(and suggested vendors)

HARDWARE

1. Computer

IBM-AT or AT-compatible such as

(a) COMPAQ 286;

(b) HEWLETT-PACKARD VECTRA; or

(c) PC's LIMITED 286.

The IBM-AT, COMPAQ 286 and HP-VECTRA are available at most computer stores; PC's LIMITED 286 is available from PC's Limited, 1611 Headway Circle, Building 3, Austin, Texas, 78754).

Required Accessories

(a) 640K RAM (minimum);

(b) 80287 Math Co-processor;

(c) 20 Mbyte hard disk (30 Mbyte or larger, preferable);

(d) 1.2 Mbyte floppy disk drive; and

(e) accelerator board to speed calculations — the speed of FLAC and MUDEC runs on an IBM-AT can be increased by roughly 3.5 times by using the DSI/32, 32-bit accelerator processor board. The DSI/32 board is sold by

Definicon Systems
31324 Via Colinas
#108/9
Westlake Village, California 91372
(818) 889-1646

Table 1 (continued)

HARDWARE (continued)

<u>Required Accessories</u> (continued)

A second alternative is the Number Smasher board by

MicroWay, Inc.
P. O. Box 79
Kingston, Massachusetts 02364
(617) 746-7431

This co-processor board increase the speed of FLAC or MUDEC runs by roughly 2 to 3 times.

<u>Optional Accessories</u>

(a) additional 360 kbyte floppy disk drive; and

(b) streaming tape for backing up the hard drive. The streaming tape option should be obtained from and installed by the firm from which the computer is ordered.

2. <u>Graphics</u>

IBM Enhanced Graphics Adaptor Card and Enhanced Graphics Monitor or compatible, such as:

(a) EGA Graphics Cards

(i) AST-3G Plus EGA Graphics Card	AST Research Inc. 2121 Alton Avenue Irvine, California 92714
(ii) Orchid Technologies Turbo EGA Graphics Card	Orchid Technologies 47790 Westinghouse Drive Fremont, California 94536
(iii) Everex Enhancer EGA Graphics Card	Everex 4831 Milmont Drive Fremont, California 94538

Table 1 (continued)

Graphics (continued)

(b) EGA Monitors

(i) NEC Multisync	NEC Home Electronics, Inc. Computer Products Division 1255 Michael Drive Wood Dale, Illinois 60191
(ii) Taxan Model 840 EGA Monitor	Taxan 1805 Cortney Court City of Industry, California 91748
(iii) Amdek 722 EGA Monitor	Amdek 2201 Lively Boulevard Elk Grove Village, Illinois 60007
(iv) Princeton Graphics Systems HX-12E EGA Monitor	Princeton Graphics Systems 601 Ewing Street/Bldg. A Princeton, New Jersey 08540

3. Dot Matrix Printer

with Graphics ROM and and parallel connector cable for IBM-PC

(a) EPSON FX, MX or LX series printers (generally available at most computer stores);

(b) NEC LQ series printer; or

(c) OKIDATA 192 or 193 printer.

4. Pen Plotter

Hewlett-Packard 7475A 6-pen plotter with RS-232 cable for IBM-PC (generally available)

Table 1 (concluded)

SOFTWARE

1. IBM Storyboard (available from IBM) — a program for capturing screen graphics and creating graphical images and text (to be used for development of presentations of modeling results)

2. Data Base Manager — a data base manager program such as REFLEX by Borland (available at most software retail stores) to organize and manipulate data from modeling runs

NRC Standard Computer System Configuration

The NRC-supported standard system configurations are described in the following references:

"Policy and Procedures for Acquiring Microcomputer Equipment, Software, and Support Service," United States Nuclear Commission NRC Manual, Bulletin 0904-1, October 15, 1985.

Scroggins, R. M. "(NRC) Memorandum for Those on Attached List of 'Draft Bulletin 0904.5, NRC Computer Software Policy,'" February 20, 1986.

It is our understanding that the primary mainframe computer system available to the NRC Engineering Branch for performing numerical analysis is the Idaho National Energy Laboratories Computer System (INEL), which has a CYBER 176 mainframe computer. This machine is accessed by the Engineering Branch via a 1200 baud modem communications link. The Engineering Branch presently also has access to IBM-XT microcomputers with 640 kb RAM memory and 10 mbyte hard disk.

Computer Systems Comparison

The following thermomechanical analysis is posed as an illustration of the improvement in modeling capability which can be achieved with the recommended computer system. The analysis involves the simulation of the response of a room excavation in bedded salt with a thermal loading produced by a radioactive waste canister beneath the floor of the excavation. The simulated time frame of thermal loading is for 50 years following canister emplacement. The bedded salt is characterized in the numerical model by an empirical relation for salt creep and a slip line model which represents the behavior of inhomogeneous zones (e.g., clay seams) in the salt. This problem represents the most detailed analysis that would generally be anticipated for review by the Engineering Branch.

A typical model geometry for this type of analysis is shown in Fig. 1. The model consists of 600 zones, which is considered to be a reasonable discretization for modeling the non-linear behavior of the rock mass and calculating the influence of bedded salt creep on room closure and stability.

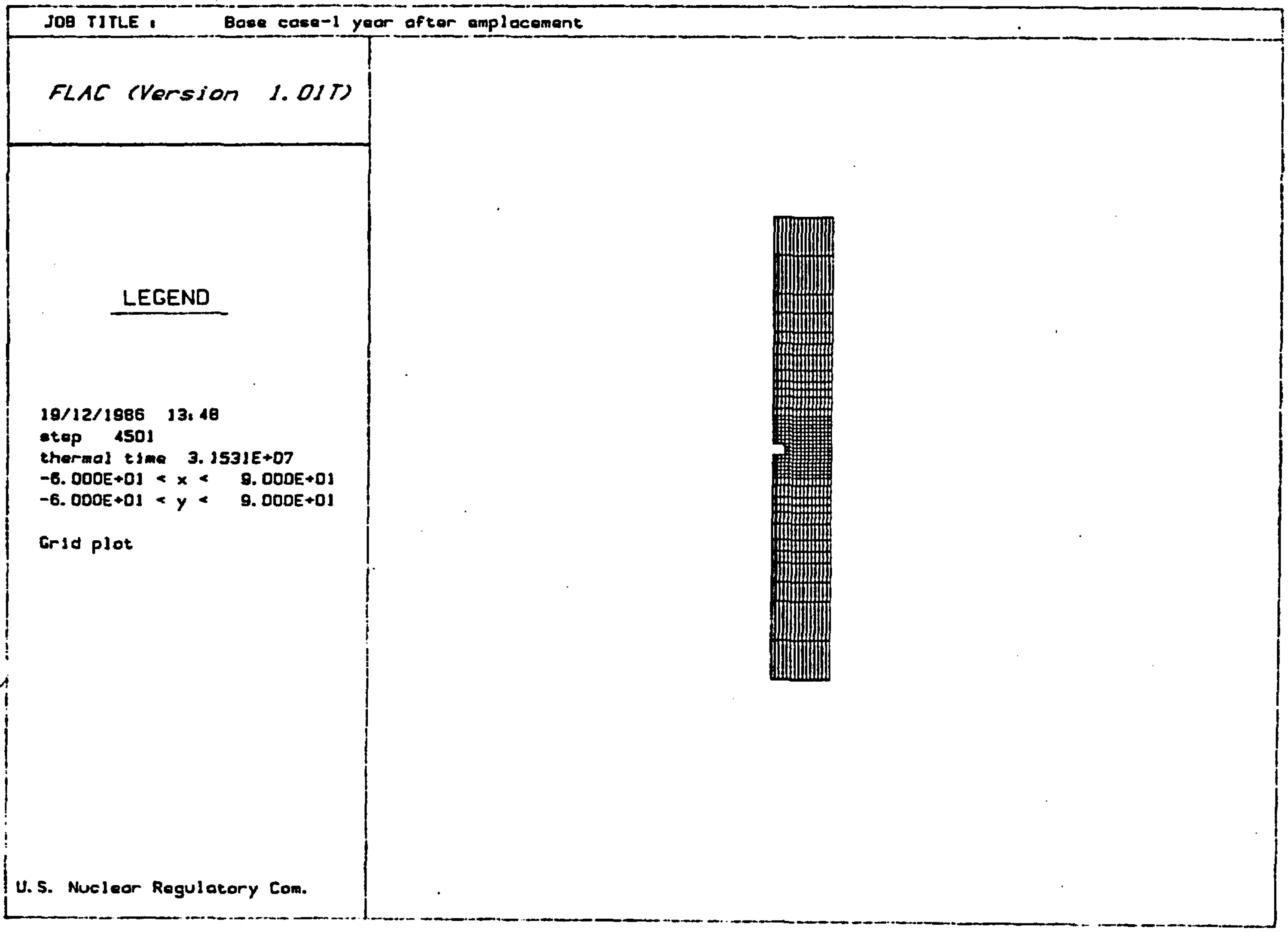

Fig. 1 Example Model Grid for Thermomechanical Model

The total turn-around time for this model case includes the time for generation of the model conditions, execution of the simulation from the room excavation stage through the 50-year heating period, and post-processing of results for graphical representation.

Components (2) and (3) of the turn-around time for this analysis are the predominant factors because of the great number of calculations required to simulate the long time period of transient heating. The CPU time required for the 50-year simulation is summarized for various computer systems in Table 2. These times are estimates based on our experience with comparable model simulations with FLAC and with similar computer codes. As shown in Fig. 2, the CPU time varies by as much as a factor of 150 between the IBM-XT and the CYBER 176. By using an accelerator board (the DSI-32) in an IBM-AT, this factor is reduced to approximately 25 compared to the CYBER 176.

The actual clock time is a function of the number of users using the computer at the same time. For the single-user microcomputer, the clock time is the CPU time. For a multi-user mainframe, the clock time usually is directly related to the number of users on the system—i.e., for a computer with two users, the clock time is double the CPU time. In addition, many mainframes assign priorities for processing based on the length of the runs (i.e., the longer the required CPU time for a run, the lower the priority). Run times can vary considerably depending on the number of users and the time of day the run is submitted. It is our experience that model runs of the order of 1 to 2 CPU hours require 1 to 2 days of actual clock time on large, multi-user mainframes. Therefore, we estimate that the example analysis run on a multi-user CYBER 176 (such as that at INEL) will require approximately 30 to 40 hours of clock time.

Table 2

ESTIMATED CPU TIME FOR THE 50-YEAR THERMOMECHANICAL CALCULATION

Computer	CPU Time (hours)
IBM PC-XT	230
IBM PC-AT	113
IBM PC-AT with DSI-32 Board	35
PRIME 750	8
CYBER 176	1.5

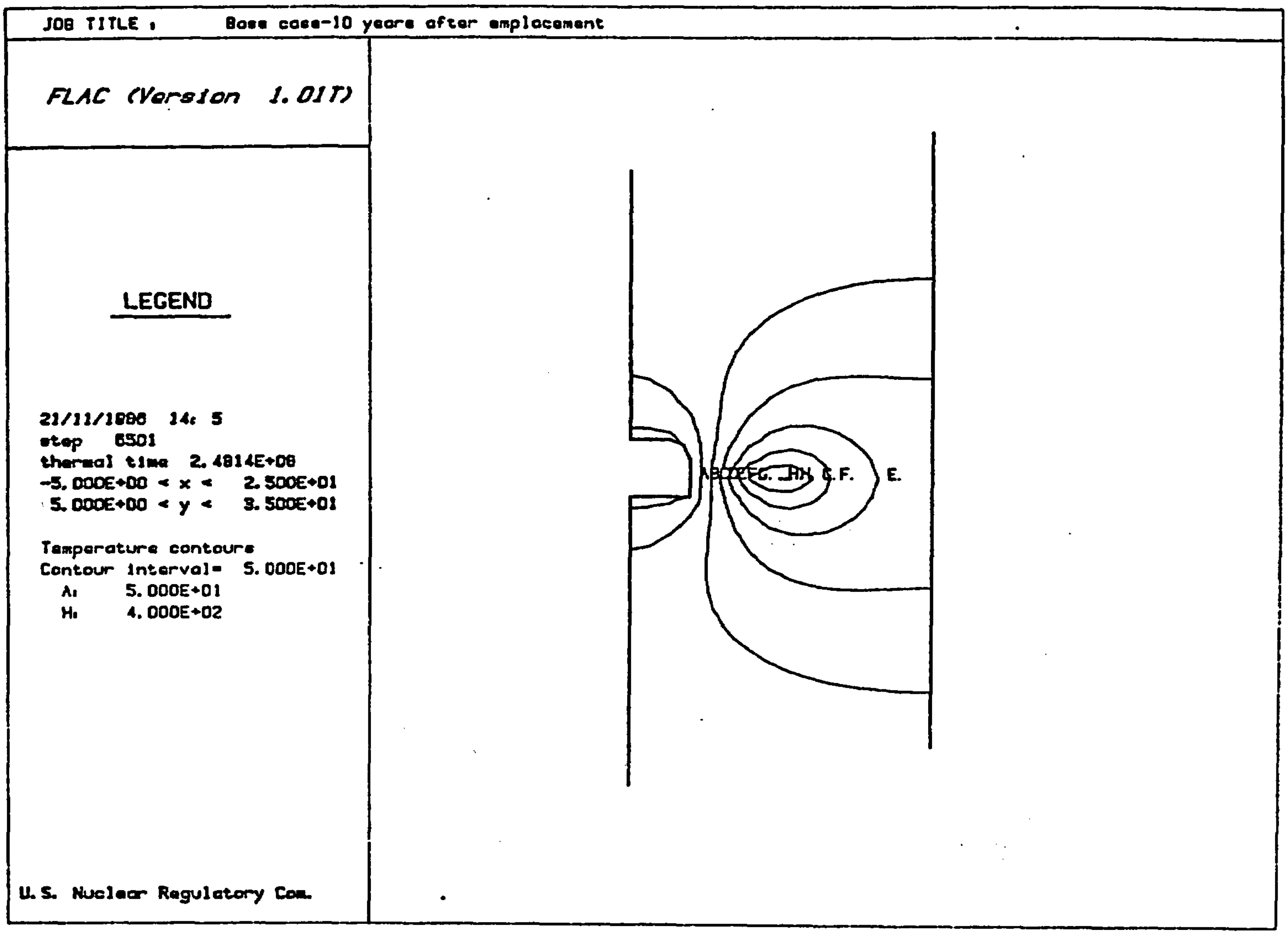

Fig. 2 Example Output from Thermomechanical Model

Based on factors (2) and (3) alone, the IBM-AT with the DSI-32 board is comparable in total turn-around time for the given model analysis to a multi-user CYBER 176. When model set-up time and post-processing output time are included in the turn-around time, the microcomputer shows a clear advantage over the mainframe if the mainframe must be accessed via a telephone communications link. Model grids such as that shown in Fig. 1 can be viewed immediately on the microcomputer graphics monitor, allowing the user to correct or modify during model set-up. Likewise, output from the model run (e.g., see Fig. 2) can be readily viewed on the monitor and revised for presentation as hard-copy plots. The same process with an off-site mainframe is considerably slowed by the time required to transmit files to and from the computer. It is our experience that the transmission of a single plot file similar to that in Fig. 2 may require some 10 to 20 minutes to send via a 1200 baud modem. This factor alone can have a significant effect on turn-around time when several output plots are generated for a run.

A hidden cost which will greatly outweigh the PC hardware cost is the necessary conversion of the FLAC and MUDEC codes for operation on the CYBER 176. Both codes are written in Standard FORTRAN 77, but the graphics used is specific to the personal computer. To rewrite, recompile, set-up and test the codes on the CYBER would require roughly one month of engineer time.

Conclusions

It is our opinion that the operations system requirements listed in Table 1 provide the most efficient configuration for the NRC to conduct thermomechanical analyses in support of the reviews of DOE documents. This system allows the user to perform simulations both efficiently and at the highest level of detail anticipated to be required for review. Furthermore, by being immediately available for calculation purposes, the system is even more efficient that an off-site system for less detailed scoping and cross-checking analyses.