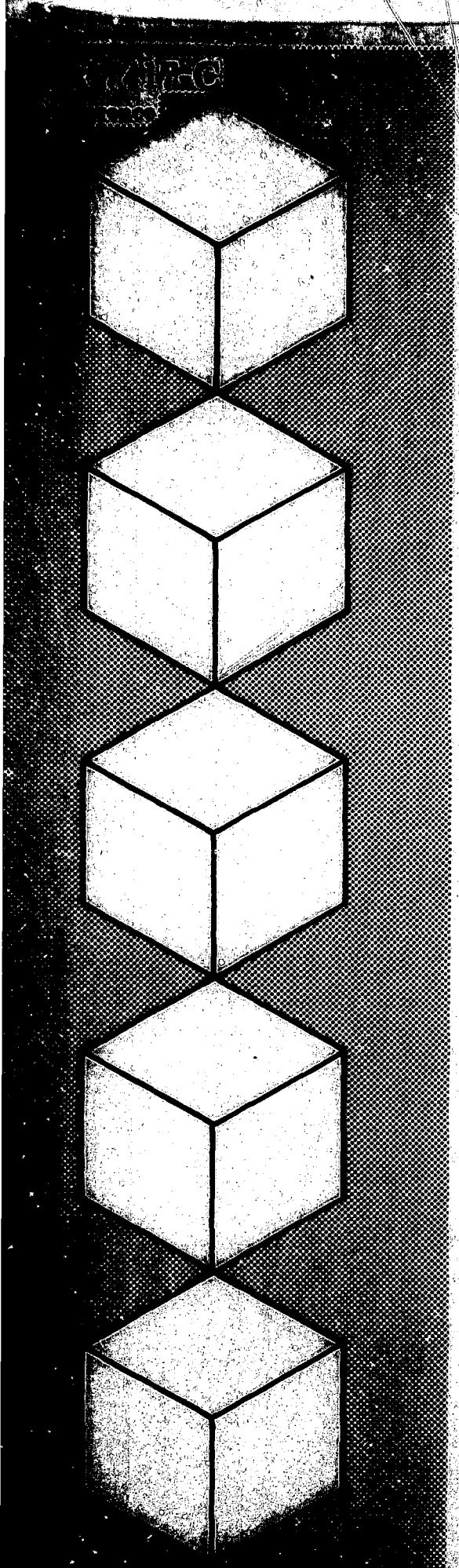

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MASTER

MASTER

CUBE

(COMPUTER USE BY ENGINEERS) SYMPOSIUM

ABSTRACTS

October 4–6, 1978

Los Alamos
Scientific Laboratory
Los Alamos, NM 87545

University of California

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Compiled by
John J. Ruminer

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CUBE SYMPOSIUM ABSTRACTS

Compiled by

John J. Ruminer

ABSTRACT

This report presents the abstracts for the CUBE (Computer Use by Engineers) Symposium, October 4 through 6, 1978. Contributors are from Lawrence Livermore Laboratory, Los Alamos Scientific Laboratory, and Sandia Laboratories.

Session O

Computer Graphics - An Essential Communications Tool

Industrial Tomography at the Los Alamos Scientific Laboratory

R. P. Kruger, T. M. Cannon, A. S. Lundy, and R. A. Morris, LASL

A computed tomography system designed to function in an industrial environment is being constructed. The modular design maintains the flexibility necessary in an environment where source strength and energy, as well as detector type, could change with each application. The static nature of industrial objects also allows economies of design not possible where dynamic objects are to be analyzed. Simulation of the device has been completed and expected image qualities obtained. Results from the system should be available for presentation at the symposium.

Color Graphic Controls For the $5MW_{th}$ Solar Thermal Test Facility

D. M. Darsey, SLA

The world's largest solar powered thermal facility is nearing construction completion near Albuquerque, New Mexico. Sandia Laboratories' Solar Thermal Test Facility is capable of producing 5 million watts of thermal energy from the sun to test components for future solar electric generating plants. Control of a field of 222 sun-tracking mirrors, or heliostats, a solar boiler, and a heat rejection and condensing system, as well as control and real-time display of a large volume of experiment data, is performed by a single operator using a distributed network of minicomputers.

A two-terminal, high-resolution, interactive color graphics system is an integral part of the Master Control System minicomputer network. The graphics system displays one of the pictures stored in the 12-plane internal refresh memory to each of the two terminals. One terminal is used by the facility operator; the other is used by the experimenter. Each terminal has an

associated 19-inch RGB monitor, keyboard and cursor joystick. An internal microprocessor not only controls data transactions between the system and the network, but also implements high-level commands, such as character generation, line or conic vector generation and various modes of reading or writing to the memory, including image and raster modes.

Logical partitioning of the memory planes into several pictures permits storing a basic display, such as the steam loop schematic, into the refresh memory once, then dynamically updating only the information that changes. This technique relieves the computer network of the refresh task. A RAM look-up table allows the memory partitioning as well as easily changing colors displayed.

The graphics controls are oriented around the real-time control aspects of the test facility and are human engineered for the operator interaction as well as the experimenter. Off-line data presentation is also used, and several examples of both real-time and off-line pictures are presented.

Computer-Generated Movies: Another Dimension

D. L. Vickers, LLL

There is no doubt that the age of computer graphics is upon us. One LLL division leader in a recent briefing said, "(C)omputer graphics has become essential to us. We simply could not do the job we now do without it." But what about computer-generated movies? Are they still toys with little scientific value? A look at some DOE laboratories indicates that color movies are a highly useful and heavily used medium. LLL, for instance, currently produces in excess of 1/4 million frames of color movies per month. Most of these movies are not for presentations, but are standard output from the daily production code runs. Many others are painstakingly made by people trying to better understand complicated multi-variate data.

Time (motion) is certainly one of the most important variables introduced by computer-generated movies, but there are others: color and gray scale, for

instance, and all the simultaneous tracking of several variables. Experiments have been done using computer-produced sound to increase further the number of variables available in computer-generated movies. Sound can depict variables which change according to pitch, volume, or modulation rate. Additional realism can be added to movies of 3-D surfaces by the use of highlights and stereo images.

The future of computer-generated movies looks far from stagnant. Increased awareness of the potential of movies will result in more of them being produced. But the major factor for increasing the use of movies as a scientific tool will be the availability of easy-to-use high-level software with which to produce them. Nor will film remain the common medium for movies. Current efforts suggest that videotape may prevail. Tape offers faster turnaround, eliminates processing, and makes it easier to edit a movie and to include sound. Whatever the format, computer-generated scientific movies are here to stay.

Graphics Applications in Systems Analysis

J. N. Rogers, SLA

This presentation will discuss the use of static and dynamic graphics display methods in systems analysis studies. The emphasis will be on using graphics techniques both for developing and understanding of methodologies and for presenting final results and conclusions. Particular examples will be drawn from both tactical and strategic systems studies areas.

A computer-generated movie will be used to illustrate the dynamic interaction of forces on the tactical nuclear battlefield. Additional map overlays will highlight particular segments of a breakthrough situation on a conventional battlefield. The examples from strategic studies will emphasize data analysis, model validation, and results presentation techniques. All of the graphic results presentation methods are designed to draw on a knowledgeable, but not necessarily expert, audience's intuition in understanding the methodologies and conclusions being discussed.

Visual Aids by Computer Graphics

R. H. Ewald, LASL

This presentation reviews a variety of methods for preparing visual aids with a computer. Several programs at LASL, LLL, and Sandia are discussed and examples of their graphical output are presented.

The systems discussed include programs that may be used to generate text slides, business and scientific graphs, and general drawings and graphics. Sample black-and-white and color slides from the programs at the different laboratories will be shown to demonstrate and compare the capabilities of the programs.

Shaded Graphics as a Research Tool

S. R. Levine

The recent rapid decrease in the costs of memory and other digital circuitry now makes computer generation of raster-scan shaded images economically attractive. Today's hidden surface, shading, and curved surface approximation algorithms allow production of very realistic shaded images, useful for displaying quite complex images in a comprehensible manner.

Use of raster scan also allows one to exploit thirty years of TV-video technology to produce low cost, interactive, color computer graphics displays. Such displays, when coupled with local processors, can provide interactive generation and modification of images. These are useful for computer aided design, for preparing and checking input data to analysis programs, and for immediate viewing of the results of such programs.

Computer Use in the Nuclear Weapons Program

T. S. Gold, SLL

The DOE office of Military Applications recently sponsored a report and series of presentations intended to explain to Washington audiences why computers are so important to the nuclear weapon program. The entire weapon complex is covered although the focus is upon the use of large scale computers to support design at the laboratories. Included in the presentation is a computer graphics movie highlighting the role of computers in nuclear weapon design.

This talk will provide an abridged version of the Washington presentations as well as show the movie.

Session 1a

Weapons Systems Structural Analysis

Structural Response of Earth Penetrators With Angle of Attack Impact

P. P. Stirbis, SLA

The Pershing II earth penetrator program has utilized sub-scale and full-scale penetrators impacting various targets at high velocity. Testing has included reverse ballistic techniques in which the target is propelled into a stationary instrumented penetrator. Full-scale penetrators have been launched from a 30-foot long, 12-inch bore, Davis gun.

Analytical predictions for the structural resonses have been made for various penetrators and test conditions. The predictions are for angles of attack of 2 and 3 degrees into various targets.

The SHELL SHOCK structural code was used for the analysis. The code is intended for analyzing three-dimensional axisymmetric structures. The modeling of the penetrator requires that the axial response of the components are uncoupled from the penetrator case, but lateral coupling is required between the components and case for the angle of attack loading.

Comparisons are made between the analytical predictions and the experimental results.

Modeling the Mk 12A/W78 Impulse Response

B. P. Shafer, LASL

A lumped parameter dynamic model with "few" (<100) degrees-of-freedom (DOF) for the Mk 12A reentry vehicle (RV) is described. Models with few DOF offer the advantages of computational economy and compactness of representation. Major disadvantages are limited frequency response and the related discretization

errors, as well as lack of standardization or reliable prescriptions for the formulation of few DOF models.

The Mk 12A model was constructed by dividing the RV into a small number (52) of point masses and inertias. The dynamic response was assumed to be separable into low and high frequency response regimes. Low frequency structural response was represented by 2-body (pair-wise) interactions of generalized mass points. High frequency response was assumed to be representable with local shell response models.

The modeling ground rules were as follows. LASL was to supply a lumped parameter model of the W78 to General Electric. General Electric then incorporated the subsystem models into a slightly modified Mk 12 RV model. The subsystem approach incurred some problems caused by an error in the stiffness matrix for the Mk 12 aft cover.

The total RV model consisted of uncoupled axial and lateral models. The lateral model was predominantly linear and contained 91 lateral and rotational DOF. The axial model was nonlinear and contained 69 axial and radial DOF. The nuclear system model contained 14 axial DOF and 27 lateral DOF.

Measured and calculated response results are presented for SVTP-4 impulse test. Correlation criteria of frequency, magnitude (amplitude and damping), and phase were used to evaluate the calculated results. Reasonably good correlation of lateral acceleration and strain responses were observed. Reasonably good correlations of axial acceleration and strain responses were observed after the aft cover problem was rectified. Internal resonance was observed in the axial response of the W78 pit.

Mk 12A/W78 Aft Support Evaluation

R. C. Keyser, LASL

An analytical and experimental evaluation of the aft support of the W78 payload in the Mk 12A Reentry Vehicle is presented. The critical loading for this evaluation was determined from predictions of vehicle quasi-static behavior

associated with low altitude roll-resonance at the upper left section of the vehicle [illegible] flight map. Geometry, material, and aft support functional philosophy is described.

Static stress analytical evaluation of the aft support structure was based upon the SAPIV finite element code. Synthesis of the aft support into a finite element model was accomplished using shell (Type 6) elements with an aspect ratio of approximately 1.0 combined with suitable boundary elements (Type 7) to artificially induce rotational constraint normal to each element surface. Boundary conditions and spatial pressure distributions to simulate the roll resonance loadings are described. Code predictions of element max./min. principal stresses plus an overall shear spring constant for the structure are also tabulated.

Experimental evaluation of the aft support structure to the same loading was performed at both LASL (WX-1) and at GE/RESD Philadelphia. The test configurations are described and strain/deflection measurements are shown for each test. Comparisons are made between experimental results and analytical predictions. The close comparison between analysis and experiment coupled with the demonstrated experimental behavior of the aft support verifies the adequacy of this structure to withstand both limit and ultimate design flight loads.

Computer Applications in the Engineering Design of the W80 Warhead

J. L. Langford, LASL

Weaponization of the W80 warhead has seen two functionally distinct designs of the outer case. One design, fabricated of titanium alloy Ti6Al4V, required comparatively elegant contouring of the case with tight manufacturing tolerances. An alternative approach utilized a simpler aluminum (6061-T6) case in series with a silastic compression pad for a less expensive, but less compact, design.

Regardless of the case design, mechanical loading of the outer case results from thermal expansion of the W80 during its exposure to the operational environment. The prediction of case stresses was accomplished with the SABOR

code, a linear, 2-D, shell analysis code. Calculations varied from a parameter study used to contour the titanium case to the iterative evaluation of the interaction of the compression pad and aluminum case. Comparison of calculated strains with measured strains consistently show good agreement in both designs.

Structural Analysis of the Harpoon Convertible Warhead

R. W. Werne, LLL

As part of the Joint Navy/ERDA Harpoon Phase 2A study, LLL is involved with the Navy in an effort to demonstrate that our Harpoon convertible warhead design concept is valid and functional. The Navy has developed a conventional warhead that is able to penetrate a ship hull structure without incurring any significant structural damage. Since a convertible warhead is required by definition to function as a conventional penetrating warhead, it was decided as part of this Phase 2A study to conduct the target penetration tests necessary to demonstrate the technical feasibility of the convertible concept for the Harpoon application.

The structural response of the proposed LLL convertible warhead has been calculated for loadings which simulate the penetration of a ship hull. These calculations simulate the warhead in its conventional mode and seek to answer questions as to the structural integrity of the case, the response of the H. E. as well as other internal components.

The DYNA2D and DYNA3D finite element codes were used for this analysis. The DYNA2D code has a slide-line and void capability thus allowing the various internal components to separate and slide relative to one another as they would in the real structure. The slide-lines used in the model are located such that virtually all of the internal components are partially decoupled.

Comparisons between the calculations and the test results show good qualitative and quantitative correlation.

Session 1b

General Topics in Thermal Fluids

Incompressible Free Surface Fluid Flow and Heat Transfer in a Spherical Annulus

D. B. Tuft, LLL

In this paper we will discuss the computation of incompressible fluid flow and heat transfer during the filling of a spherical annulus with a hot fluid. A spherical annulus is the cavity formed between two concentric spheres of different diameters. As a heat transfer geometry the sphere has the distinction of providing a maximum volume with a minimum surface area. The spherical shell finds applications as a heat exchanger in situations where this feature is required. Such a situation occurs in certain types of nuclear reactors and in guard heating or cooling such as guard cooling of cryogenic liquids. Transient flow applications of the spherical annulus are found in injection molding and in paste H.E. injection.

We are interested in predicting temperature profiles that arise as a result of the heat transfer from the fluid in the annulus to the sphere walls. To achieve this we have assumed axially symmetric flow and have adapted the Marker-and-Cell computational method to this problem in spherical coordinates. The momentum equations are solved explicitly for the radial and tangential velocity components and then these velocities are adjusted iteratively along with pressure until mass conservation is satisfied. The thermal solution is obtained by an explicit finite difference calculation of the energy transport equation. Our solution uses a single chain of marker particles to mark the fluid surface and allows the surface to break and fold over on itself.

Our calculations cover fill times on the order of 15-30 seconds for an annulus volume of approximately 8.5×10^{-3} M^3. The inlet pipe flow Reynolds number is about $1.0 - 1.5 \times 10^{-4}$ and is in the turbulent flow regime for pipe

flow. Our temperature solution is for an insulated outer sphere and a constant temperature inner sphere with heated water filling the annulus.

For simplicity we used an algebraic turbulence model to calculate the eddy viscosity and the eddy diffusivity. An algebraic model is used since the majority of the flow is steady except near the free surface.

We present results of flow velocity patterns and temperature profiles and discuss these along with some of the details and difficulties involved in obtaining the solution.

TACO: A General Two-Dimensional Thermal Analysis Code

W. E. Mason and G. L. Johnson, LLL

TACO is a nonlinear finite element computer program for general two-dimensional heat transfer analysis. The code was developed recently at LLL to give the analyst a successor for the TRUMP network analog code. TACO incorporates most of the features available in TRUMP, such as internal radiation, contact resistance, and Arrenhius kinetics. In addition, the TACO code has advantages over TRUMP. It is easily coupled with finite element stress analysis codes for thermomechanical calculations. It accepts meshes generated by several LLL finite element mesh generators (e.g., ZONE). It solves steady state problems by a one step process, whereas TRUMP requires a transient solution to reach a steady state solution. Unlike TRUMP, TACO maintains a description of the problem geometry allowing for internal calculation of view factors and for spatial temperature plotting. A companion post processor, POSTACO, was developed to plot nodal time histories, isotherms, and temperature profiles along an arbitrary cut line.

The presentation will include a description of the basic theory and structure of the TACO code. Several example calculations illustrating some of the special features of the code will be presented. Comparisons with both theory and TRUMP calculations will be given

Hydrodynamic Calculation of Jet Formation Hemispherical-Shaped Charges With Tantalum Liners

G. E. Cort and J. H. Fu, LASL

The collapse of hemispherical-shaped, tantalum liners and the subsequent jet formation have been calculated with a two-dimensional Eulerian code (2DE). The objective of the study is to understand the processes involved in the detonation wave, liner collapse, jet formation, and eventual jet breakup, so that shaped charges can be developed to produce optimum-sized particles of nearly uniform velocity. The study has included several sizes of confined, cylindrical, plane-initiated, explosive devices and a "levitated shell" jet generator of unique design. Where experimental data are available, the model calculations agree reasonably well. The conclusion thus far is that the jet breakup is caused by (or is related to) the axial velocity gradient in the jet and is not influenced by material properties. Various methods of reducing the velocity gradient are being explored, including effects of liner diameter, liner thickness, and detonation wave velocities. The 2DE computer program was originally written for the CDC 7600 computer under CROS, but currently is being used on the CRAY computer.

S2D - The Sesame Equation of State Display Code

J. D. Johnson, LASL

The equation of state group at the Los Alamos Scientific Laboratory provides tables of equations of state. These tables consist primarily of pressures and energies tabulated as functions of density and temperature for various physical materials. There was a long standing need to be able to display the physics of these tables graphically. In particular, with the advent of time sharing at LASL, one wanted to be able to interactively display such data at a CRT terminal.

Such an interactive display package, the code S2D, has been written, allowing a user to directly access the Sesame equations of state tables. The

code is very modular and fairly system independent. One can construct constant temperature curves (isotherms), constant entropy curves (adiabats), and hugoniots (shocks). One can output graphs to the CRT terminal, microfilm, and microfiche. The modular form of the coding allows other physics packages and output devices to be added at will.

We have allowed for fairly extensive graph manipulation capability. In particular, one is allowed any combination of linear-logarithmic axes, and through the use of appropriate windows it is possible to expand the resolution and examine fine details. The user can choose to have a grid placed over the plotted curves and can select either table points as the points being plotted or interpolate on the table.

The plot commands are input via a free format form. (There is no order for the commands and no formating for numbers.) Defaults are always to the last entered command with an internally generated set of initial defaults. While the complete set of commands is extensive, the defaulting allows the user to work with only the small set relevant to his needs.

Session 1c

System Modeling and Simulation: Energy Applications

Role of Storage in Determining the Value of a Solar Electric Plant in an Electric Power Grid

J. B. Woodard, SLL

Because insulation and the demand for electricity are imperfectly correlated in time, energy storage plays a key role in determining the value of a solar electric plant to an electric utility. This paper discusses how computer simulation may be used to identify desirable features of a storage unit and estimate their value to a utility. Attention is restricted to thermal storage and the central receiver solar thermal electric power plant concept. Alternate storage and solar electric concepts are not considered.

The value of a solar plant is defined to be the present value of the difference in the yearly conventional (non-solar) costs to supply the load with and without the solar plant over its life. Yearly conventional costs include the fuel, operation, maintenance and capital related costs for all the non-solar plants in the network. In each case, the non-solar generation is selected to supply the load most economically subject to the same reliability constraint.

The storage features investigated include the storage unit capacity, maximum charge rate, and the maximum discharge rate. Before the impact of these features on the value of a solar plant can be investigated, a solar storage dispatch strategy must be developed. A substantial portion of this paper is devoted to this development. Thermal storage should be dispatched to supply the load most economically subject to certain reliability and operating constraints. Dispatch strategies compared included sun-following, peak shaving and conventional (non-solar) variable cost minimization.

Using the best dispatch strategy, the value of a solar plant is presented as a function of field area, storage capacity, charge rate and solar

penetration. In addition, the penalty for derated power generation from storage is presented.

The Electromagnetics Transients Program and Its Application at LLL

A. M. Mihalka, T. Allison, F. Fong, and W. Magnuson, LLL

Since the 1920's power engineers have been faced with the problem of simulating their growing networks. Analysis of such complex systems by means of hand calculations is a very difficult, cumbersome task even when relatively simple models are assumed. Over the years the network analyzer has been perfected to the point where nearly all electric utilities have access to one and rely on it. The network analyzer is an analog device, but the manner in which it is used reminds one of a digital computer. Time steps are specified and voltage sources are varied. One takes down a barrage of meter readings in the scale model power system. These constants are then interpreted to adjust the system for the next round of readings. After much manual labor, the operator has the answer to his question.

Over the past ten years an alternative to the network analyzer has been the Electromagnetic Transients Program (EMTP), developed and maintained by the Bonneville Power Administration (BPA) of Portland, Oregon. This program, consisting of some 45,000 Fortran lines, is used by manufacturers and consultants as well as utilities. The program is based on direct solutions of sparse network equations by optimally ordered triangular factorization. The EMTP is capable of representing mutual coupling, three phase as well as single phase transformers, non-linear resistance and reactance, time varying resistance, switches, lightning arrestors, diodes, various types of sources, synchronous machines, saturable transformers, and analog control systems. The program is capable of giving output in the forms of node voltage, branch voltage, branch current and branch power or energy, depending on what the user asks for. Time steps can be as large or as small as desired, and plotting routines can specify the frequency of data points to be plotted. Experience with the program has shown it to be a very reliable and powerful means of

analyzing power systems, and no other developed programs are as versatile or as fast when dealing with three phase systems.

At LLL we are using the EMTP to give us some answers on our power supplies. We will study the twelve pulse rectifier system which gives us 80 kV dc for accelerating the neutral beams for the Mirror Fusion Test Facility (MFTF). In addition, we hope to tie together the arc and filament supplies of the neutral beam source to the accel supply and study the effects of one supply on another due to the common substation reactance. We also hope to compare our computer results with an 80 kV prototype of the accel supply being tested presently at LLL. The EMTP is relatively new at LLL, and in the ensuing months should give us much data on which to draw our decisions.

Oscillatory Stresses in the 10 MWe Solar Central Receiver

A. T. Jones, E. D. Eason, and D. E. Allison, SLL

For the 10 MWe solar central receiver, one of the primary design considerations is the fatigue life of the boiler tubes. The tubes will be subjected to both "diurnal" cycles during nightly cool down, cloud cover, etc. -- causing low cycle fatigue; and to hydraulic oscillations of the fluid surface in the tube -- causing high cycle fatigue. It is the latter which will be discussed here.

The boiler tubes are subjected to a constant incoming solar flux. At the saturated liquid - vapor interface the tube wall will undergo cyclic temperatures and stresses due to an axial oscillatory motion of the interface tube. In this discussion the oscillations are assumed to occur although their existence in the actual plant is still being questioned. Depending upon the magnitude of the various important parameters, the stresses generated can be very large, or quite small.

A series of four increasingly complex transient analyses have been developed to predict temperature and stresses. The first was a calculation of average tube temperature near the oscillation zone using a simple ordinary

differential equation model. The second model incorporated axial tube conduction and an oscillatory convective film coefficient in a one-dimensional partial differential equation model. This equation was solved for the average tube crown temperature using Eason's non-linear PDE solver LSQPDE. The bending of the tube was then calculated from this temperature profile. The third one-dimensional model was of the tube wall subjected to an oscillatory convective film coefficient internally and a constant flux externally. This combined problem was solved using the MARC general purpose program. Last, the tube was modeled as a two-dimensional body using MARC and applying a spatially variable oscillatory film coefficient.

There are a large number of important variables such as oscillation frequency, transition zone length, input solar flux levels, etc. Thus, a two level multi-factor experiment was designed and executed in the computer. This procedure allows the authors to more clearly display and understand the effects of the variables and their interaction. These calculations are now underway.

The Numerical Simulation of an Arc-Image Furnace

M. Abrams, SLL

In order to study the radiative transfer processes that occur in cavity-type solar receivers, an effort was initiated in 1974 to design and build an arc-image furnace that would introduce significant amounts of radiant energy into the apertures of various laboratory-scale cavities. A Monte Carlo ray trace program simulating furnace performance was written and used extensively to prove the feasibility of the selected design before fabrication was begun, and in interpreting measured energy distributions after the furnace was completed. The ray trace program and design decisions influenced by it are discussed.

The image furnace essentially consists of a commercial 20 KW xenon arc lamp located at the first focus of an ellipsoidal mirror. Energy emitted by the arc is collected by the mirror and focussed into the second focal region where the experimental cavities are placed. In assessing the feasibility of the design, the Monte Carlo program was used to quantify the effects of finite arc size,

lamp misalignment, and mirror contour errors upon the focussing capabilities of the furnace. It was concluded from this study that energy emitted by the arc would be focussed into the 7 cm. diameter cavity apertures if mirror slope errors were less than 10 minutes and if the arc's center were positioned to within 2 mm of the first focal point of the mirror. These requirements were judged achievable, and the decision was made to fabricate the furnace.

After the furnace was assembled, energy flux measurements made in planes parallel to the mirror's second focal plane were compared to corresponding Monte Carlo predictions. It was concluded from these comparisons that the spatial variation of energy density within the arc need be taken into account to produce good agreement between predicted and measured energies. An effort to determine that energy distribution is in progress.

Session 2a

Hydrodynamics and Heat Transfer Analysis for Weapons Applications

Nuclear Explosion Height of Burst Study

T. K. Bergstresser, SLA

We have conducted calculations of the effects of a nuclear explosion on the ground. The effects of interest are energy coupling, peak pressures, ground motion, etc. The independent variable of interest is height of burst (HOB). There have been previous such calculations, but this is the first such work clearly to isolate the HOB dependence by holding other variables fixed. We have used the code CSQ.

One purpose of this talk is to present an overview of the study. We will display a graphic presentation of the time-development of the problem. We will discuss the energy coupling into the ground. Another purpose of the talk will be to discuss some of the computational problems which have arisen. For higher heights of burst and for a limited region of problem time, the time step is severely limited by the Courant condition. The origin of this problem and several solutions will be discussed. For all heights of burst and for much of the problem time the time step is limited by the radiation time-step. An analysis of this problem will be presented.

Ground Shock From Near-Surface Nuclear Explosions

W. R. Davey, SLA

The code CSQ-II has been used to investigate the ground shock environment from near-surface nuclear explosions. A distinction is made between a hemispherical shock formed by prompt energy coupling and a roughly planar shock at greater ranges formed by fireball coupling to the ground. The effects of varying both the height of burst and the device radiating temperature are discussed.

Influence of Alien Structural Supports on the Implosion Dynamics of Small Warheads

A. J. Chabai and S. L. Thompson, SLA

Small diameter warheads are being considered for earth penetration weapon systems. Structural response calculations and experimental data have indicated that, under certain high deceleration conditions associated with penetration impacts, the structural integrity of the warhead cannot be maintained. The insertion of structural support members has been suggested as a remedy. Two specific configurations have been investigated. For each configuration two-dimensional calculations have been completed with the with the ten-material Eulerian code, CSO-II. Calculations have been carried to expected times of detonation. Influence of the structural supports on implosion dynamics has been examined and compared with an idealized configuration having no supports. Details of interest at various times during the implosion process will be presented.

Some Unique Heat Transfer Solutions in Weapon Systems Designs

D. L. Jaeger, LASL

This presentation describes several heat transfer problems and solutions related to weapon designs and experiments. Each of these problems has some aspect which does not lend itself to solution by standard conduction modeling. However, by special treatment of material properties and boundary conditions, solutions were obtained with conduction heat transfer codes.

The solution techniques include the treatment internal free connection and the use of temperature dependent properties to simulate fuel burn off. The effects of thermal environments on weapon systems is also discussed.

Thermal Analysis of a Rocky Flats Experiment

A. S. Vigil, LASL

TSAAS, a 2-D finite element code, and EXPLO, a 1-D finite difference code, have been used to analyze the heat transfer in an experiment conducted at Rocky Flats in which a chemical reaction was used to produce a large quantity of heat in materials adjacent to simulated high explosive (HE) components. The codes were used to assess the probability of thermal ignition of two different high explosives subjected to the extreme temperatures. The calculations indicate that a new TATB based insensitive HE, PBX 9502, would not thermally ignite but that X-0208, an RDX based HE, probably would.

Session 2b

Microprocessor Applications

Controlling a Fast Solid-State Camera With a Microcomputer

A. L. Criscuolo, LASL

The performance capabilities of a Fast Solid-State Camera (FSSC) used for detonation analysis and the design of its microprocessor-based controller are presented. The FSSC, a device which senses images with light-sensitive diodes and records the moving image in a semiconductor memory, offers advantages over high-speed film cameras. Features, such as, continuous recording with asynchronous stop trigger, extended recorded time interval, 100,000 frames per second recording rate, absence of moving parts, light sensor/electronics dynamic range of 2000:1, digitally formatted data, and low cost, are discussed.

Aspects of the microprocessor controller which are examined include a) the operator's command repertoire, b) image presentation on the console CRT, c) synchronization of multiple cameras, d) command recognition by multiple cameras, and e) software design.

Identification of areas for improvement and performance goals for future FSSC's are offered in conclusion.

Microcode Support of a Bit-Slice Hardware Design

J. F. Leighton, LLL

The engineering design group of the National Magnetic Fusion Computer Center (NMFECC) at Lawrence Livermore Laboratory has recently completed a hardware design which uses four AMD 2901A bit-slice microprocessor chips and a 44 bit microcode word length.

Bit-slice designs are generally characterized by the fact that they have "non-fixed" microinstructions, i.e. to formulate a working system the designer

must invent his own microinstruction format. It follows then that standard microcode support such as (cross) assemblers and debugging aids are not readily available.

After the designer begins to consider the required microinstruction set, a number of related problems come to mind:

1. Since cross-assembling is required, on what computer should it be done?
2. How can initial microcode development be done with reasonable turn-around?
3. How can the transistion from microcode RAM for development to ROM for production be handled?
4. How will the cross-assembled microcode be transported to the hardware system under development.

Generally, a solution to any question impacts another. An example was the availability of a generalized cross-assembler by the vendor on his computer system as an approach to the assembler problem. However, this would seriously affect turn-around as output is a paper-tape to be mailed to the user.

A set of implemented solutions with hopefully overall optimzation is presented.

The decision on the cross-assembler was to develop an in-house version running on the NMFECC 7600 under a timesharing system. The existence of a powerful Fortran like language (LRLTRAN) and applicable library subroutines significantly reduced the effort required. A generalized assembler was developed which allows the users to define the number and (bit) lengths of fields, width of microinstruction, and source op-codes.

The binary output format was chosen to be identical to that of the PDP-11 cross-assembler. This allows the output to be handled as a PDP-11 core image for loading. In particular, this gives the ability to directly down-load the microcode into the PDP-11 and hence into the microprocessor. Using this approach, turnaround on minor microcode iterations may be done in a few minutes.

The conclusion is that although some problems associated with bit-slice microprocessors seem formidable at first, but reasonable trade-offs are at hand, and the additional effort is warranted.

Microprocessor Control of a CCD Transient Digitizer - The Practical Alternative

J. C. Hill and J. C. Lawson, LLL

Microprocessors are now commonly used to increase the effectiveness and reliability of electronic instruments by the cost-effective implementation of features like "smart" front panels and self-test capability.

Less common, but more significant perhaps, is the use of the microprocessor for cost effective implementation of features like autocalibration and self-tuning - features that can improve the basic measurement capability of an instrument. As a case in point, an LLL project to advance the state of the art in transient digitizers was deemed practical for two reasons:

first the recording medium - a charge-coupled shift register - would be based on a new technology with very promising theoretical limits, and

second, it appeared that a microprocessor would make the application of these new CCD devices practical by ameliorating the difficult design problems engendered by the novelties and vagaries of an immature technology.

The CCD seems an ideal medium for transient recording since it is effectively an analog shift register that can be operated at hundreds of megahertz for recording but only a few tens of kilohertz for readout and digitization. However, there are several characteristics of CCD's which make them difficult to use:

Their clock inputs (a capactive load) must be driven with large (10 V p-p), high frequency, voltage swings with precise phase relationships,

they are not a permanent medium since thermal electrons continually add to the recorded charge (signal),

they are non-linear,

their characteristics are not repeatable from unit-to-unit.

However, by allowing a microprocessor to control the bias voltages of the CCD s, vary electronically controlled delay elements, and sense clock phase differences with a rudimentary time-interval circuit; the CCD's within a particular instrument at a particular time (temperature) can be tuned, and held, to a functional operating point. This electronic control is effected with a single, multiplexed D to A converter and holding op-amps for the various parameters to be controlled.

With a precision DAC in the instruments the microprocessor has the means to generate precise calibration voltages. Therefore, by allowing the microprocessor to control the calibrate-measure sequence of the instrument and manage the attendant data files it is possible to compensate for device non- linearity, unit-to-unit variations, variations over temperature, and the thermal current addition to the recorded signal. Thus microprocessor control is the key element in the implementation of practical, high performance transient recorders using CCD's.

A Microprocessor Supported Delay Generator

J. C. Lawson, J. B. Kaser, and S. R. Trost, LLL

This paper describes a new programmable delay generator which uses microprocessor control to improve reliability, maintainability, and operation. Instrument specifications include eight channels of delay, range from 100 nsec. to 10 msec., and jitter of less than 5 nsec. The unit may be programmed either locally through a front panel keyboard or remotely via the General Purpose Interface Bus (GPIB-IEEE-488, 1975). Forty-eight numeric indicators on the front panel display the delay values.

The microprocessor (an 8085) has responsibility for receiving keyboard inputs, driving the front panel displays, processing all GPIB operations, and controlling instrument self-test diagnostics. In order to minimize hard wired logic the 48 seven segment displays are refreshed by the microprocessor; only one set of segment drivers is used. All GPIB protocols have been implemented in the microprocessor's software.

The delay generator also incorporates self-test diagnostics. Each channel has a status bit to indicate when an input trigger has been received and when an output pulse has been generated. Thus the microprocessor verifies correct trigger operation. Further, by counting its own clock cycles the microprocessor can determine the correctness of the generated delay time. This generator will play an important role in our hydrodiagnostic work. The microprocessor has allowed us to produce an instrument which is more flexible, more reliable, and more cost effective than previous models.

Session 2c

Software Techniques

Big Codes and Little Computers

L. A. Glenn, LLL

It is shown that large scale scientific computation via minicomputer is a practical and economically advantageous supplement to maxicomputer usage. 2D finite difference calculations, with state-of-the-art codes and mesh densities of order 10^4, can be made at costs from 4 to 20 times less than at present.

These results are not based on hypothetical performance data or estimated costs, but on a 3 year experiment with a 16-bit, disc based machine operated on a 24 hour day, 7 day week schedule. However, the machine was located in a relatively remote location, in Europe, so that maintenance opportunities were far from optimum. Cost comparisons assume an identical system in the USA at 1978 prices, and including maintenance and operating expenses, in competition with CDC 7600.

Typical problems addressed included the interaction of hypervelocity fluid jets with solid boundaries and the dynamic response of geologic materials to intense impulsive loading. The code employed was a variant of AFTON 2A, a 2D explicit, axisymmetric, finite difference code, which solves the equations of motion in an arbitrary generalized coordinate frame and is thus a superset of both Lagrangian and Eulerian algorithms. It was written in FORTRAN and was designed initially for the CDC 6600.

The most recent "version," used to model a dynamic fracture experiment, is capable of running a 50xN mesh (where N is typically, but not limited to, 200). The simulation consumed 17 ms/zone-cycle of clock time on the minicomputer. The 7600 version used 0.82 ms/zone-cycle system charge, so that the equivalent of 43 minutes on the 7600 could be run overnight on the mini.

Structured Development of Wavecodes

W. Herrmann, SLA

A number of wavecodes have been written in the Laboratories with capabilities for providing excellent computer simulations of extremely complex weapons related problems. Many of these are routinely used as an integral part of the system or component design procedure. Most of them represent many man years of developmental effort and involve a number of people in their use, further development and maintenance.

Unfortunately, many of these codes were developed in a relatively unstructured manner by evolutionary growth, are relatively poorly documented, require very specialized knowledge for their use and maintenance and are difficult to transport from one computer system to another. In some cases, these factors can be so bad that loss of a vital programmer or change of computer system can be traumatic.

At the same time, changing requirements at the Laboratories are generating increasing demands for ever more complex codes. Three-dimensional codes, coupled fluid-structure codes, multi-fluid diffusion codes, coupled electrodynamic or plasma dynamics codes are all of interest. In fact, the number of combinations of coupled effects which are demanded far outstrips our development capabilities if traditional methods are considered.

ACSYS is an acronym for a feasibility study to see if alternate means of developing wavecode software might not prove more efficient. Some of the concepts which underlie it will be described. In particular, the following factors are addressed.

The commonality in the partial differential equations arising from balance laws for various physical processes is exploited. This commonality and the commonality in general initial and boundary conditions suggests that general partial-differential equation solvers for hyperbolic and parabolic (and perhaps

elliptic) systems be considered, instead of developing these for each specific problem separately over and over.

Efficient finite-difference and finite-element algorithms are known. Many of these imply very similar data structures. This commonality suggests the development of a single general data structure, and the software for its efficient management. An integral consideration involves substructuring, that is, dividing a large complex problem into smaller pieces with mutual interfaces. Several methods of substructuring have been developed. A common data structure and substructuring facilitates coupling different methods, for example Eulerian and Lagrangian, either sequentially in time, or simultaneously in different regions.

Another basic concept is operator splitting in which the algebraic difference operator is split into sequential operations. Familiar examples are the alternating direction method in which a multidimensional operator is split into sequential one-dimensional operators or the splitting of a radiation hydrodynamics operator into sequential radiation and hydrodynamics operators. The splitting process can be carried much farther, however, to structure the difference operators into pieces which are much simpler to implement separately than the original operator.

A common data structure makes possible the development of common code for initial shape generation, automatic mesh or element generation, automatic rezoning, and display functions. Since these functions now have widespread application, proper attention can be paid to the design of a context-free user language and interactive capabilities which should remove from the engineering analyst most of the burden associated with discretization and computer idiosyncracies.

The ACSYS system is largely unimplemented, although most of the concepts have been tested, and top level design and data structure definition have been started. This will be a progress report to stimulate discussion.

A Fast, Efficient Equation Solver for Large Finite Element Codes

S. J. Sackett, LLL, and R. L. Taylor, University of California

We describe a set of subroutines which assemble and solve large systems of equations generated by the finite element method. The technique used is based on the Crout algorithm with compact profile storage and out-of-core blocking. Working array space and I/O buffers are dynamically allocated for maximum efficiency. Key loops are optimized by using COMPASS for the CDC 7600 version and CAL vector instructions for the CRAY version. Timings are given for both the CDC 7600 under LTSS and the CRAY-I under COS.

On the Structure of Computer Codes for Solving Partial Differential Equations

J. M. Hyman, LASL

An analysis of effective strategies will be presented for the so-called method of lines solution of the initial-boundary-value problem for partial differential equations. We also describe the structure and implementation of two user oriented FORTRAN subroutine packages called MOL1D and PDE1D for the numerical solution of a large class of equations of this type using the method of lines.

The PENAP Earth Penetration Program: An Example of the Use of Structured Programming Techniques

P. Yarrington and N. K. Ruiz, SLA

PENAP is an interactive computer program for calculating surface loads on conical- and ogival-nosed earth penetrators, penetrator deceleration as a function of depth, and final depth of penetration. It is based on a one-dimensional approximate technique developed by P. Yarrington for describing the penetration process. PENAP was developed using top-down design and structured programming. The program is coded in FLECS, a Fortran extension

which supports structured programming concepts and which translates into ANSI standard Fortran.

Session 3a

System Modeling and Simulation: System Simulation Techniques

Design Optimization and Trade-Off Analysis Using Numerical Optimization Techniques

E. D. Eason, SLL

A common procedure for selecting the best design for a system or component is to vary the parameters affecting the design and choose the combination giving the best value of one or more merit functions. This procedure can be improved by the use of numerical optimization techniques, particularly in cases involving more than two or three parameters. Compared to parameter variation, an optimization approach often leads to a clearer definition of all the competing objectives and constraints in the problem. The numerical results guide the analyst's intuition on general trends, design concepts, and parameter sensitivities. In complicated multi-parameter cases, optimization will generally provide a more accurate estimate of the optimal design with less computation and much less human labor than a parameter study would require.

The presentation will describe the steps involved in expressing a design problem in the standard numerical optimization form. Available optimization codes will be briefly discussed, along with the practical limitations and difficulties inherent in nonlinear optimization. The emphasis will be on practical application, with examples of recent optimization efforts at Sandia Livermore. These include weight and reliability trade-offs in a multi-layer explosive containment design and cost and performance trade-offs in the heliostats and receiver of the solar central receiver power plant.

LASAN: A General Purpose Transient Systems Analysis Program

P. A. Secker and R. B. Lazarus, LASL

The Los Alamos Systems Analysis code (LASAN) is a general purpose systems analysis program developed by LASL as part of the High Temperature Gas Cooled Reactor Safety Program. The code consists of a model-independent systems analysis framework with steady-state, transient, and frequency-response solution capabilities. LASAN is similar in concept to digitial simulation codes, such as CSMP, MIMIC, DSL/90, and others which are in wide use. LASAN is not, however, a new simulation language. Mathematical models of dynamic systems, subsystem components, or phenomena are user coded in FORTRAN, and, with the exception of only a few rules, any FORTRAN feature may be involved by the modeler. Both overlay and non-overlay versions of the code are available.

We have developed a modular approach for LASAN, which allows system models to be represented as a set of subroutines, or "modules," each representing a separate component, feature, or subsystem of the overall simulation model. A few standard rules have been established for modularizing a problem. Models are developed using a state-variable approach where dynamic response variables are described by their time rate of change as nonlinear ordinary first order differential equations and algebraic relationships.

An implicit predictor-corrector time integration technique based on the optimal integrating factor method is used to solve the time-dependent equations. The method is asymptotically stable, is applicable to "stiff" systems of equations, utilizes efficient storage and solution algorithms, and has a self-adjusting solution step size to achieve a user specified error criterion. The method is also used to rapidly achieve system steady states.

LASAN uses a flexible free-format input/output package. The code is written in standard FORTRAN and follows closely guidelines established for exportable codes. This presentation will describe in greater detail many aspects of the special solution algorithms and user features with simple examples.

PARET: A Parameter Estimation Technique for Physical Applications

A. J. Poggio, LLL

A parameter estimation technique (PARET) based on Prony's method, anti-aliasing filtering, and statistical averaging has been developed. This method is used to obtain the parameters in a complex exponential sum (damped sinusoidal series) which represents a time domain waveform. We can thus extract the natural oscillation frequencies and damping constants of the damped sinusoidal oscillations which are very common in many natural phenomena. This is particularly important since the complex natural frequencies often characterize the processes.

The method has been applied to many areas in the physical sciences. Among the applications are

Data compression

Curve filtering

Linear prediction

Radar target identification

Radar and acoustic array processing and synthesis

Exponential decay parameterization

Physical phenomena description

Structural dynamics

Structure modification detection

In the latter area, for instance, we have obtained the natural frequencies and damping for buildings using data from seismically induced oscillations.

The digital processing algorithm will be described in detail and its strengths and weaknesses will be illustrated. The user oriented computer program, which is available with detailed documentation will be summarized. To highlight the wide range of utility of this program, examples will be given of

many applications with specific emphasis on those where the parameters are characteristic of a physical process.

The areas of present research such as noise effects, mode shape determination, and the evaluation of other potentially useful system identification methods will be described.

Using SETS to Find Minimal Cut Sets in Large Fault Trees

R. B. Worrell and D. W. Stack, SLA

An efficient algebraic algorithm for finding the minimal cut sets for a large fault tree has been defined and a new procedure which implements the algorithm has been added to the Set Equation Transformation System (SETS). The algorithm includes the identification and separate processing of independent subtrees, the coalescing of consecutive gates of the same kind, the creation of additional independent subtrees, and the derivation of the fault tree stem equation in stages. The computer time required to determine the minimal cut sets using these techniques is shown to be substantially less than the computer time required to determine the minimal cut sets when these techniques are not employed. It is shown for a given example that the execution time required to determine the minimal cut sets can be reduced from 7,686 seconds to 7 seconds when all of these techniques are employed.

Session 3b

Structural Analysis/Design Interaction

The Prediction of Low Cycle Fatigue Failure In a 20,000 psi Pressure Vessel

J. J. Ruminer and J. W. Neudecker, Jr., LASL

Hydrostatic pressing is one method used to fabricate plastic bonded high explosives. The high explosive (HE) powder is pre-mixed with a plastic binder, then pressed into rough shapes under a 20,000 psi pressure. Because the pressing process can involve considerable quantities of HE, it is critical from a safety standpoint that no structural failures occur during the life of the press.

This paper describes a series of stress analyses which were performed on a press design of this type. Axisymmetric finite element calculations accounted for material yielding and included one-way surfaces. The model approximated certain three-dimensional features of the design by use of orthotropic material properties. These calculations predicted low cycle fatigue failure of the vessel clamps.

The calculational model was subsequently used to design a fatigue test specimen which closely simulates the stress state in the actual clamp. Fatigue tests were conducted, and they verified the fatigue failure at the locations predicted. A comparison between the analysis and photoelastic stress measurements will be included in the presentation.

NEDS Door Design and Analysis

L. I. Weingarten, SLL

The NEDS (nonviolent explosive destruct system) was being developed to meet military requirements for the complete command destruction of certain nuclear

weapons. Upon command, high explosives within a weapon in the NEDS container is detonated. The container must contain all by-products of such an explosion.

The success of the NEDS concept is dependent on the design of a quick-access blast resistant container door which will provide a metal-to-metal seal after its use. The development of the seal is dependent upon fragment impact loading of a door diaphragm. As the diaphragm is hit, it expands radially, deforming an outer door lip which in turn compresses a soft material (e.g., aluminum or lead) in the door sleeve. If there is sufficient extrusion of the door sleeve material, a metal-to-metal seal is formed.

A set of scale-model and full-scale tests of the NEDS container were planned to verify containment and door design. However, due to test planning times and costs, only a few tests could be devoted to door diaphragm design. This mandated that the diaphragm design would be controlled by analysis.

The HONDO computer code was used in the analysis. This is a finite element structural code incorporating Langrangian finite deformation, plastic flow, and sliding interfaces with friction. The effect of varying several geometric and material parameters on door sealing was studied with the code. The resultant door design arrived at with the aid of HONDO was then tested. Actual door deformations were in good agreement with code predictions.

This exercise has shown that hardware which experience large plastic strains can be designed with the aid of computer codes.

Explosive Valve Analysis

L. E. Voelker, SLL

Sandia Laboratories Livermore is evaluating several different explosive valve concepts in an attempt to improve current valve design. As part of this effort, finite element analyses are being performed to study the deformation and stresses in the valves under various loadings. The valve is initiated by the explosive which drives a plunger down the bore of the valve housing to cut the

transfer tubes. After the tubes are cut, the plunger's remaining kinetic energy is absorbed by a soft collar which deforms into recesses creating a pressure seal.

The dynamic, large deformation finite element computer program HONDO is being used to evaluate the stresses during the tube-cutting, during collar deformation and while sealing against pressure. The major effort has been the analysis of the dynamic, large deformation process of collar compression and extrusion into the recesses for plunger velocities on the order of 100 meters/second.

At first a relatively simple model was used to determine the applicability of the computer code to the collar deformation problem. Encouraged by the initial results, this simple model was used for parametric studies of the collar material and plunger velocity resulting in the choice of aluminum as the collar material and insight into the mechanics of the collar deformation and the resultant strains of several hundreds of percent. Results of these studies are presented.

Secondly a more complex, more realistic finite element model was used to study experimental hardware. The qualitative agreement shown between the test and analysis led to further refinement in the model to more carefully examine a more optimum design.

This third generation model presents some computational difficulties as a result of the large deformation and the geometry of the recesses which are described. This model, in turn, is to be used to study all pertinent phases of the problem for initiation of the explosive to sealing against transfer pressure. Motion pictures show the evolution of the finite element models and the dynamic deformation of the collar material. It is felt that the problem is adequately modeled, the calculational approach is valid, and the design models can be ultimately fine-tuned to some relative optimum.

Dynamic Response of a Cylindrical Shell Immersed in a Potential Fluid

G. E. Cummings, LLL

A numerical solution technique is presented for determining the dynamic response of a thin, elastic, circular, cylindrical shell of constant wall thickness and density, immersed in a potential fluid. The shell may be excited by an arbitary radial forcing function with a specified time history and spatial distribution. In addition, a pressure history may be specified over a segment of the fluid outer boundary. Any of the natural shell end conditions may be prescribed.

The shell equations are formulated using Sander's solution method. The fluid is represented by Laplace's equation in cylindrical coordinates. The dependent variables of the governing differential system are expanded in Fourier series in the circumferential direction and the resulting equations are then expressed in finite difference form. The basic strategy of the computational method is to solve the finite difference representations of the shell and fluid equations separately and account for the interaction between the two by forcing a match of the radial velocities at the fluid-shell interface.

A numerical instability prevented direct solutions where the ratio of the hydrodynamic forces to shell inertial forces is greater than two. This instability is believed to be the result of the weak coupling between the equations describing the fluid and those describing the shell. To circumvent this instability and obtain a solution, an effective mass can be calculated and added to tne shell.

Comparison of numerical to experimental results are made using a 1/12 scale model of a nuclear reactor core support barrel. Natural frequencies and modes are determined for this model in air, water, and soil. Both impact and harmonic methods were used to identify modes and natural frequencies. The harmonic method involved the excitation of the model core barrel by means of pressure

pulses generated by an electro-magnetic exciter and introduced through inlet ports. The experimental frequencies compared to computed results to within 15 .

Session 3c

Information Management and Computer Security

On-Line Accountability of Special Nuclear Material (DYMAC)

P. F. Ford, LASL

DYMAC is a real time inventory control system used for the safeguard accountability and process monitoring of special nuclear material in a plutonium reprocessing facility at the Los Alamos Scientific Laboratory. The system is a network of transaction terminals and nondestructive assay instruments connected to an on-line data base via a powerful minicomputer. The major purpose of the DYMAC system is to facilitate DOE's goal of maintaining accurate accounting for special nuclear material. A secondary goal realized is more efficient processing by providing process supervisors with the ability to perform on-line inquiries of the data base. Some of the topics covered are: a) various methods used to allow many users apparent simultaneous access to the one data base; b) a packet and image method of programming the various process transactions so as to obviate the need for reprogramming when the process changes; c) techniques used to insure the integrity of the information in the data base; d) the measurement control program used to determine the accuracy of the various instruments used; and e) methods used to allow the network to be reconfigured without the need for reprogramming.

SECSIM--A Computer Security Simulation Code

E. P. Schelonka, LASL

In the process of designing secure information systems for nuclear facilities, a series of simulation programs have been developed to model the effectiveness of computer security. From modules for analysis and their interrelationships, a security simulation profile is generated indicating strengths and weaknesses. Parameters are changed and the process is repeated

until desired requirements are met. Models used in this study to characterize candidate systems security behavior are comprehensive in accommodating the full range of threats and protection levels. They are tailored to each facility by weighting input parameters in accordance with the design configuration and environment selected. This method of analysis is applicable to centers in the conceptual design, detailed design, construction, and operational stages of evolution.

Emphasis is placed on providing as much structure as possible for the parameters associated with computer security. Barrier evaluation is similar to security in general in which subjective as well as objective judgements must be made to determine its effectiveness. The range of 0 to 1 is chosen, where 1 represents a totally effective barrier. The individual facility threat environmental factors are incorporated as weighted inputs along with the corresponding attributes of each barrier, and a numerical value or range of values is assigned. These are then introduced into the appropriate segment of the model, and a composite effectiveness is computed for the sublevel. This is repeated for the next event sequence level until an index is generated in that respective category. A two-dimensional horizontally layered and vertically structured network decomposition methodology is used.

A Scientific Data Base for Safeguards Components

R. C. Hall and R. D. Jones, SLA

The need to store and maintain vast amounts of data and the desire to avoid nonfunctional redundancy have provided an impetus for modern data base technology. Large scale data base management systems have emerged during the past two decades evolving from earlier generalized file processing systems. This evolution has primarily involved certain business applications (e.g., production control, payroll, order entry) because of their high volume data processing characterization. Current data base technology, however, is becoming increasingly concerned with generality. Many diverse applications, including

scientific ones, are benefiting from the generalized data base management software which has resulted.

The concept of a data base management system is examined. The three common modules which have been proposed for organizing data and relationships are identified: the network model, the hierarchical model, and the relational model. A specific implementation using a hierarchical data base management system is described. This is the data base for safeguards components which has been developed at Sandia Laboratories using the System 2000 developed by MRI Systems Corporation. Its organization, components, and functions are presented. The various interfaces it permits to user programs (e.g., safeguards automated facility evaluation software) and interactive terminal users are described.

The Meta-Machine - A New Way of Making a Mini-Computer Do a Maxi-Job in Data Management

V. E. Hampel, L. E. Gallo, S. K. McGrogan, and J. E. Swanson, LLL

We have implemented a new technique which permits access to a large collection of dissimilar data files in a responsive, flexible manner. In this unique approach, all of the instructions for the man-machine dialogue and directions for the manipulation of each data file are deposited in a data file rather than being embedded in a computer program. Our technique makes the task of generalized database management practical on a mini-computer as the memory requirements are reduced substantially. Memory contains only the necessary number of primitive operations to simulate what we call the Integrated Information System Meta-Machine.

The concept for this Meta-Machine results from our work for the Division of Energy Storage Systems where we are under contract to establish a database consisting of numerous administrative, project-oriented, and technological data files in support of Energy Storage RD and D.

The Meta-Machine, which is written in the programming language 'C', interfaces with the user and the database management program INGRES, which was developed at the Electronics Research Laboratory of the University of California, Berkeley. This combination of software runs on a PDP-11/70 using the UNIX operating system.

Session 4a

System Modeling and Simulation: Weapons and Safeguards

A Method for Determining the Susceptibility of a Facility To Sensor System Nullification by Insiders

B. D. Boozer and R. B. Morrell, SLA

One strategy for insiders attempting the theft of special nuclear material (SNM) from a nuclear facility, is to attempt to nullify a sufficient set of sensor system elements to create an unprotected exit path through the personnel control system. A qualitative method for determining the susceptibility of a nuclear facility to this strategy is described. The method yields all combinations of insiders whose collusion could result in the theft of SNM. An extension of the method determines all of the ways of restricting authorized access so that at least n insiders must work in collusion to create an unprotected exit path. The method is illustrated with an example.

Interactive Combat Simulation for Evaluating Transportation Physical Protection Strategies

P. De Laquil III, SLL

The Division of Safeguards, Fuel Cycle and Environmental Research within the Nuclear Regulatory Commission (NRC) has created a program to establish appropriate methodologies for structuring and evaluating physical protection systems. To assess the overall effectiveness of a transportation physical protection system, computer codes which simulate armed attacks have been developed by Sandia Laboratories. These tools are currently being used to examine a range of issues associated with road transportation systems.

This paper describes the SABRES II model, which simulates the combat between an adversary force and the defending force following the initial ambush of a road convoy. SABRES II is a time-stepped stochastic simulation model which

includes (1) a detailed terrain and vegetation model, (2) a detection model which simulates the human eye, (3) a target characterization model which represents specific body parts for casualty assessment and (4) a stochastic state-transition combat suppression model to account for non-casualty effects of weapons fire.

An interactive version of SABRES II, which allows user-directed movement of all forces, has been developed to explore possible strategies and tactics which the defending force might employ. The SABRES II interactive combat model combines the features of a game and a simulation. Positioning of the SNM transporter and members of the adversary and defending forces takes place on a computer-drawn map of the terrain surface. The map identifies major relief features and vegetation regions. Combat is simulated for a predetermined time period, and a gamer report summarizes the status of all personnel at the end of the period. Between the combat simulation periods, movement objectives may be redefined for all combat participants. During the simulation, individual movement is conducted toward objectives at a rate which is consistent with the terrain, vegetation, and each combatant's casualty status and suppression level.

Presented in the paper are example combat simulations which emphasize the interactive capabilities of SABRES II. The techniques used in each of the four major submodels are briefly described and illustrative comparisons are presented.

Analysis of Oblique Impact by Earth Penetrators

P. Yarrington, F. R. Norwood, and N. K. Ruiz, SLA

A computer program has been developed for calculating the distribution of stress on a conical- or ogival-nosed projectile resulting from oblique impact and subsequent nose embedment in a geologic target. In addition, the code provides time histories of the axial and lateral forces acting on the penetrator. This code is based to a large extent on the equations of the earth penetration program PENAP, which treats the case of normal impact. In PENAP, the penetration of each infinitesimal layer of the target is approximated by the

one-dimensional expansion of a circular cavity in an infinite sheet. Then, with specific assumptions on the constitutive response of the target medium, the equation of motion is integrated in the region between the radially propagating shock front and the cavity formed by the penetrator. The displacement and velocity boundary conditions for the problem are completely determined by the geometry of the penetrator and its velocity.

For the case of oblique impact, the penetration of each infinitesimal layer is again approximated by the plane-strain expansion of a cavity in an infinite sheet· however. in this case the displacement and velocity boundary conditions on the problem are allowed to vary with arc length around the cavity. The variation of these conditions with both arc length and time is, again, completely determined by the geometry of the penetrator, the obliquity of the impact and the impact velocity. Solution of a specific problem is effected by partitioning the arc length around the cavity and then proceeding to solve, at each partition, PENAP equations with boundary conditions appropriate to that partition.

PENAP solutions are typically obtained in several orders of magnitude less computer time than is required for wavecode analysis of a penetration problem, and since the present code is merely an extension of the PENAP method, solutions for the oblique impact problem also proceed quickly. A complete calculation generally takes less than 10 seconds on a CDC-6600 machine. Both codes are set up on the interactive network operating system (NOS) at Sandia, and thus provide a further convenience over the wavecodes which, in general, must be run in batch mode. It should also be noted that PENAP predictions have shown good agreement with both wavecode (WONDY and TOODY) solutions and experimental data from penetration tests.

The manner in which target material is characterized for calculations will be demonstrated using laboratory test data for a particular geologic medium. The stress distribution on the penetrator and both axial and lateral force histories will also be presented for a specific oblique impact penetration event.

Assessing Nonnuclear Interceptor Lethality To Ballistic Missile Warheads

J. L. Merson, E. K. Tucker, and B. M. Wheat, LASL

A multidisciplinary team at the Los Alamos Scientific Laboratory (LASL) is developing solutions to problems in assessing a nonnuclear interceptor's lethality to a ballistic missile warhead. Although the vulnerability of nuclear warheads to high-velocity fragments has been recognized for some time, analytical demonstration of the lethality of a fragment-generating interceptor to a warhead has been difficult. LASL is developing a fragment-generating device for such an interceptor. This development project made the team aware of the need for a lethality analysis capability. Using a versatile method for mathematically representing a target and experimentally validated material-penetration parameters, the team has developed SCORE, a computer code that facilitates lethality assessment. Using data from an empirical characterization of experimentally-generated fragments, SCORE analyzes in detail the damage inflicted by such fragments on a modeled target in simulated engagements. SCORE can now aid the team in a variety of fragment-lethality investigations.

Vulnerability of Reentry Vehicles Subjected to Hypervelocity Fragment Impact

G. Min, LLL

Non-nuclear fragment kill mechanisms of reentry vehicle and warhead are studied using theoretical calculations coupled with experiments. The impact phenomenon is calculated using a hydrodynamic code BBC to obtain the local, short-time interaction of the fragment and target while a dynamic finite element code was used to obtain the structural, long-time response of the target. The calculations are then verified with a series of experiments which subject mock reentry vehicles, having simulated warheads, to hypervelocity fragment impact.

The theoretical results accurately predicted the damage sustained by the reentry vehicle and warhead.

Five reentry vehicles, three with single fragment impact and two with multiple fragment impacts, were tested in the NRL two-stage gas gun and the LLL hypervelocity explosive device from 5.35 km/sec to 6.4 km/sec. The projectile geometry (with mass of 50, 133, and 286 grams) includes a steel step-cone (ρ = 7.85 g/cc) and a magnesium-lithium cylindrical disk (ρ = 1.38 g/cc). A theoretical nose-on, frontal impact on the RV will be used for the BBC hydrodynamic impact penetration calculation. The 286 gram steel step-cone projectile moving at 5.55 km/sec delivered an energy of 4.4 MJ to the RV. The BBC calculated penetration profile was confirmed by radiography. The residual velocity, energy and momentum transferred from the fragment to the warhead provides valuable information for lethality evaluations.

Using the proven model, the physics of kill mechanisms are evaluated with parametric studies. The results establish criteria for RV destruction and warhead dismemberment. This calculational process provides a reliable technique to model a future threat reentry vehicle for non-nuclear fragment engagement without an actual testing program.

Session 4b

Evaluation of Computational Procedures in Structural Mechanics

Experiences With Finite Element Programs On the CRAY-1 Computer

W. R. Oakes, Jr. and R. V. Browning, LASL

Several finite element computer programs - including NONSAP, ADINA, and ADINAT - have been converted and used on the CRAY-1 computer at the Los Alamos Scientific Laboratory. Discussion of conversion, optimization, timing comparisons with CDC 7600 machines and operation experiences for the CRAY-1 is presented.

In particular, the effects of memory size, input-output buffer size, and of vectorizing portions of the programs are examined. Timing comparisons between the CDC 7600 and the CRAY-1 versions of these programs show a range of 2:1 to greater than 10:1 advantage for the CRAY-1. Typical advantage for production problems is 5:1 demonstrating the effectiveness of the CRAY-1.

Evaluation of a Large Three-Dimensional Finite Element Analysis

M. L. Callabresi and V. K. Gabrielson, SLL

For large three-dimensional finite element models, the analyst not only encounters many computational difficulties but also has the formidable task of evaluating the numerical model. The usual procedure for verifying a particular model is to compare the analytical data to a discrete set of experimental strain gage and displacement data. To complement this usual procedure, a much larger experimental data set may be obtained from photostress fringe patterns representing surface strain distribution over a large region of the structure. This photoelastic information is usually converted to a discrete set of strain data, however, the laborious conversion task may be eliminated by converting the analytical strain data to the pertinent photoelastic parameter and pictorially

displaying the results in the form of analytical fringe patterns. These fringe patterns can then be directly compared to the experimental fringe patterns. This technique was used on the aft case of the B77 and a comparison of the analytical data to the experimental data will be shown in this presentation.

The large three-dimensional finite element model used to analyze the B77 aft case resulted in 17,000 degrees of freedom to be solved. Initially when solving this large system of equations by the direct equation solver in the SAP-IV code, several computational difficulties were encountered. Due to these difficulties, a new generalized conjugate gradient method was used. At this time a solution has been obtained by both methods and this talk will also review these results.

Rezoning - An Adaptive Refinement Technique

F. M. Guerra, LASL

In the application of the finite element method to regularly elliptic boundary value problems, the user is often faced with the modeling of large regions that may contain one or more subregions that need a finer mesh. One technique that is often used in this class of problems is to lay a coarse grid on the entire grid, solve this problem, and to then compute boundary conditions from the coarse grid solution to apply to a finer mesh of the subregions of interest. This technique has been called the coarse-to-fine mesh method, windowing-in, "substructuring," or rezoning.

The main criticism associated with this technique is that an error is introduced at the refined boundary and that if applied successively, the error will grow. In this presentation a brief mathematical analysis of this technique shows that, for the class of problems considered, the error that is introduced by the approximate rezone boundary data decays into the interior of the refined region because of the ellipticity of the problem. Thus, for "small" enough boundary errors and for regions "sufficiently" distant from the rezone boundaries, the rezoned finite element solution is acceptable. Several numerical examples are used to illustrate these analytical results.

Since the quality of the finite element solution (coarse and fine grids) is desired, a posteriori error estimate shows that element residuals computable from the finite element approximation can be used as upper bounds on the error. Results for several examples with known solutions are also presented. Linear regressions of various errors of interest on the element residuals show the numerical correlations, and contour plots show the spatial correlation.

Finite Element Linear Models for Symmetrically Loaded Shells of Revolution

W. A. Cook, LASL

Three finite element models for linear axisymmetric shells will be presented. These models have been developed for a version of NONSAP for analysis of energy materials shipping systems. These models are:

1. a potential energy model which approximates equilibrium and uses two displacements and meridional rotation for the nodal variables,
2. a mixed model which approximates force equilibrium and the meridional bending moment constitutive relation. This model uses two displacements and meridional bending moments for the nodal variables, and
3. a potential energy model which approximates equilibrium and the basic thin shell assumption (normals to the reference surface remain normal). This model uses two displacements and meridional rotation as the nodal variables.

These models have both two- and three-node elements and include curvature terms. They also have the option to input curvature data. Thus, for two node elements the elements can be conical or curvature data is required while for three node elements the curvature can either be calculated or input.

Three example problems will be discussed: a plate with a shear load, a cylindrical shell with a shear load, and a hemispherical shell with an applied

moment. Each of these models can adequately predict the stress resultants and bending moments required for an analysis of a shell of revolution if enough elements are used. The aim of this presentation is to demonstrate this with these example problems and to discuss the advantages and disadvantages of each model.

Session 4c

Electronics Design and Analysis

Automated Design Verification and Optimization of Combinational Logic Circuits

L. H. Goldstein, SLA

This paper presents a method for automatically verifying the functional correctness of combinational circuit designs without simulation and generating an optimal equivalent realization. Starting with the standard cell net list for a combinational circuit in SALOGS-compatible format and a functional description of the circuit in some form, a computer code named TRANSI produces an equivalent net list in terms of AND-gates, OR-gates, buffers, and inverters. This fundamental-gate net list defines a set of equations that characterizes the logical functions performed by the circuit. A program called SETS, originally developed at Sandia Laboratories for fault tree analysis through boolean equation manipulation, can be used to prove that the equations derived from the net list are logically equivalent to the original functional description of the circuit, thus verifying the design. The correctness of a redesign can be verified in a similar manner.

In an optimization mode, the circuit output equations produced by SETS are input to a program named MINI, developed at the University of Illinois, which generates a set of equivalent equations containing a minimum number of terms. These optimized equations can then be realized in terms of standard cells. Note that the optimal realization of the circuit can be functionally verified in the same manner as any other redesign.

Eight Level Digital Logic Simulation Using SALOGS-IV

J. D. Stauffer, SLA

A digital logic circuit in the process of design must be checked for compliance with the design objectives of the circuit. This is most often accomplished with a digital logic simulator such as SALOGS (SAndia LOGic Simulator) which models the propagation of idealized waveforms through the circuit under development.

Since actual solution of waveform equations at each active device within an integrated circuit would prove too costly, simulation codes such as SALOGS idealize the waveforms to only a few states -- typically three or four, to allow for on, off, undefined, and perhaps the high-impedance state.

While this approach greatly reduces the amount of time necessary to verify the operation of a given circuit, it constitutes a gross simplification of the true state of the voltage-time relationship, with an attendant loss in accuracy of the simulation. Additional accuracy in the waveform model would greatly enhance the ability of the designer to locate problems.

SALOGS-IV utilizes eight logic states during simulation, adding to the traditional states four states representing transitions to the other four. The added accuracy in simulation appears to justify the increased simulation time. Conditions which would be invisible to a four-state simulator are easily noted.

Circuit examples illustrating the capabilities of this code and the importance of eight-state simulation are presented. The use of the code to perform eight-state modeling and the SALOGS-IV code structure are described.

Analysis of Transient Upset in CMOS Integrated Circuits

G. W. Brown, SLA

Ionizing radiation results in the generation of primary photocurrent through the PN junctions in integrated circuits. This photocurrent can result in transient upset in digital circuits. The size and complexity of large-scale integrated (LSI) circuits has made computer analysis indispensable. A circuit simulation code, such as SPICE, is an important aid in the LSI design sequence. This code, with modifications for radiation-induced photocurrents, has been used to analyze a critical 1480 flip-flop and associated circuitry in a metal-gate CMOS timer circuit.

Modeling of the circuit consisted of representing all MOS transistors and diodes in the flip-flop as well as the inclusion of diodes representing the diffused tunnels. In addition, all line parasitic capacitances and resistances were included. The amplitude and shape of the radiation induced photocurrents produced for various dose rates were determined for experimental data and were modeled as current generators for each PN junction. The simulation circuit consisted of over 360 nodes and over 1,100 elements. Typical run times ranged from 30 to 45 minutes on the CDC 6600 computer, with core requirements of $254K_8$.

Simulations were performed for both non-gold and gold-doped processes to verify experimental measurements and to predict ultimate ionizing dose rate sensitivities for the metal-gate CMOS technology using the RCA standard cell family. Three different photocurrent levels were simulated corresponding to approximately 2×10^9, 5×10^9, and 1×10^{10} Rads (si)/sec.

For the non-gold process, the agreement between analysis and experiment is excellent when the full simulation model is used. For the gold-doped process, reasonably good agreement with experiment could only be obtained by eliminating the external resistors associated with the tunnel interconnects.

The photoresponse of a large circuit is quite complex. Changing the resistivity of the P-well and the gains of the parasitic verticle NPN tran-

sistors can affect the photo-response, but the interactions are complex and not amenable to simple calculations. The calculations indicate that such processing changes may result in a factor of two improvement in radiation hardness.

A Unified Time Domain Electromagnetic and Circuit Analysis Code

J. A. Landt, LASL

Recent interest in the broadband response of antennas has led to development and refinement of numerical time-domain techniques capable of high efficiency and accuracy. These techniques are easily modified to handle simple non-linear loads, and this work has been reported earlier. Hybrid approaches have been employed to assess the response of antennas connected to more complicated circuits. These techniques have found widespread use in the assessment of electromagnetic pulse effects, electromagnetic compatibility, radio frequency interference, and other applications.

A unified numerical procedure is discussed in this paper. The antenna portion of the computer code is based on the thin wire approximation of a time domain electric field integral equation. The circuit portion of the code is based on a simple time-domain nodal analysis. Application of the technique is demonstrated by consideration of several simple types of antennas connected to circuits containing linear and non-linear elements.

Recent Advances in LLL PCB Layout Automation

W. G. Magnuson and R. J. Smith, LLL

The DASLL printed circuit board layout system has been in use at LLL for more than two years. We have recently added capabilities for automatic documentary drawing generation, component placement, interactive (graphics) editing, and diagonal wiring optimization. Our presentation briefly discusses each of these new facilities and their impact on the design of printed circuit boards at LLL.

Session 5a

Data Acquisition and Control

Master Control and Data System For the 5MW Solar Thermal Test Facility

D. M. Darsey, SLA

Sandia's Solar Thermal Test Facility, the world's largest solar experiment facility, is controlled by a network of nine minicomputers. Five minicomputers are used solely for controlling the field of 222 heliostats, or sun-tracking mirrors. The other four minicomputers form the Master Control System (MCS) an overall command, control and data system. An interactive color graphic terminal is used for the operator's and experimenter's consoles. Over 1500 channels of analog and digital data may be acquired from the solar experiments, analyzed and displayed in real time or stored for post-test analysis. The facility controls are designed for automatic operation using the MCS, MCS-assisted manual operation via the operator's console, or manual operation locally at each subsystem. In any of these modes, the MCS provides data presentation to the operator and the experimenter, permitting on-line modification of pre-programmed test sequences while the test is running.

The design philosophies of the MCS are discussed as well as the system itself. Many of the features of Sandia's MCS will be used in the first Solar Power Plant to be built near Barstow, California.

An Overview of CTR-Division Control and Data Acquisition Computer Usage at the Los Alamos Scientific Laboratory

G. I. Chandler, J. W. Lillberg, and R. W. Wilkins, LASL

Computers have become an integral part of the control and data acquisition systems of several different fusion experiments in the CTR Division. These systems must 1) monitor and/or control approximately 200-500 signals, 2) process from 40 to 250 diagnostic channels with a maximum plasma discharge

repetition rate of once every five minutes, and 3) operate in an electrically noisy environment. Small to medium sized minicomputers interfaced to the experiment through CAMAC modules have been used to meet these requirements. System shielding and grounding have been given special consideration. These systems are also used for on-line data analysis and are linked to the local CTR network User Service Center where more sophisticated off-line analysis can be performed.

DAISY A Data Acquisition and IO Control System

A. Demuth, J. Robinson, J. D. Schneider, and B. Barnett, LASL

A data acquisition system has been designed and installed for use with a simulation of a neutron source consisting of a proton beam and a hydrogen gas target. This prototype test facility at the Los Alamos Scientific Laboratory (LASL) uses a multi-microprocessor configuration as the base for the data acquisition system. The purpose of the system is to monitor analog data from all of the subsystems of the Beam-On-Target prototype (B-O-T). This system performs data reduction for on-line displays of experiments being monitored, and it writes the data on magnetic tape for detailed analysis at the LASL Central Computing Facility.

The entire data acquisition system consists of three subsystems: the Digital Data System (DDS), the CAMAC Executive System (EXEC), and the Ion Source CAMAC crate. The primary collection module is the CAMAC EXEC, which collects the analog data, performs the analog-to-digital conversion, formats the data for transmitting to the DDS, then sends the data to the DDS. The EXEC displays the B-O-T real-time data on a DECscope in engineering units. The DDS receives the formatted data and records the data on magnetic tape. The third microprocessor processes data for the Ion Source control in the high voltage dome and sends it to the DDS.

The CAMAC Executive System consists of the crate, which houses an intelligent crate controller that uses an INTEL 8080 microprocessor, AD converters, a binary-to-BCD converter, and three communication interfaces to a DECscope, the DDS, and the ion source controller. The primary command terminal for the EXEC system is the DECscope. Displays from the DECscope are sent to a VERSATEC printer plotter. The software for the EXEC system is based on CAMAC protocol.

The main function of the DDS is to write the data on magnetic tape. A microcontroller designed at LASL performs this function. It is organized around an INTEL 8080 microprocessor and is the DDS hardware controller. Besides the microcontroller, the DDS includes a serial input/output communication interface, a clock, a Kennedy 1600 Incremental tape recorder and a Texas Instruments 700 command terminal. The software for the DDS is hardware-interrupt driven.

The third element of this multiple system is the microprocessor that serves as the High-Voltage Crate Controller (HVCC). It is a Motorola 6800, and it can function as a stand-alone control and monitoring unit as well as answer queries for data from the CAMAC unit. Data comes from an electrically isolated CAMAC crate floating at 200 kV to the HVCC via an optic fiber link. New data is displayed on a DECscope every half second. The link to the EXEC 8080 is through a standard serial link. No data is ever sent if the requests do not come through the serial link. This stand-alone capability enabled us to read significant data before the rest of the system was developed.

Using a Microcomputer System to Control Data Collection Instrumentation of a Laser Damage Experiment

T. H. Kuckertz and D. H. Gill, LASL

Thermonuclear reactions, which are to be started by bombarding deuterium pellets with intense laser light, will require selection of optical systems which can transmit light of great energy densities. A data collection and analysis system to measure damage parameters of optical components has been designed using a microcomputer as its central processing unit. The data

acquisition system, which is based on a Digital Equipment Corporation (DEC) microcomputer (PDP-11/03), was designed to measure damage parameters every time a pulsed laser was fired at a selected optical test sample. A fundamental design philosophy was to let the microprocessor control, via a stored program, as much of the instrumentation as possible, excluding the laser itself. The experimental signals measured by the microcomputer are those associated with (1) a calorimeter, (2) an energy meter, (3) a diode array, (4) a transient digitizer, and (5) a spark (not laser light) intensity measurement circuit. The first two items give a measure of the energy in a laser shot, while the diode array gives the spatial distribution of the laser pulse. The transient digitizer records the intensity of the laser pulse as a function of time. The spark intensity gives a measure of damage above a threshold. Suitable mathematical manipulation of the measured quantities yields the peak energy and power densities of the laser pulse, which are of primary importance. The software for the microcomputer was developed on a minicompuer with the transfer media being cassette tapes. The software consists of three tasks: (1) a keyboard monitor and accounting program, (2) an interrupt-driven routine to initialize the experiment for a laser shot, and (3) an interrupt-driven routine to collect the data and calculate the report quantities.

Session 5b

Developments and Applications in Fluid Mechanics and Heat Transfer

Application of a General Parametric Differentiation Procedure to Map Solutions of the Compressible Boundary Layer Equations

J. G. Taylor, SLA

For many problems the laminar compressible boundary layer equations are reducible to ordinary differential equations. Even so, these similar flows often present a rather difficult non-linear two-point boundary value problem. Solution of these problems is usually accomplished by employing some kind of shooting technique. Because of the asymptotic nature of the far boundary, the shooting technique depends on an asymptotic solution (in this region) of the problem at hand. In addition, difficulty with stability is frequently encountered.

The method of parametric differentiation resolves these difficulties. The method was developed by Rubbert, and Rubbert and Landahl to solve transonic flow problems. Rubbert and Landahl also applied the method to solve the Falkner-Skan equations. Naranya and Ramamoorthy used this method to solve the usual compressible boundary layer equations but did not take advantage of the problems linearity to eliminate iteration. This was pointed out by T. Y. Na.

The present study extends these earlier works to obtain a more general parametric differentiation procedure. The parametric differentiation procedure obtains a solution for a small perturbation from a known solution. This is accomplished by making Taylor series expansions of the dependent variables (to fourth order) about the known solution. Substitution of these expansions into the governing equations and collecting separately terms of the same order yields the utility of this approach. Solution of the zeroith order problem is known. The first and all higher order sets of equations are linear with variable, but known, coefficients. Thus, superposition is applied to convert these linear equations from two point boundary value to initial value type. This effects a

transformation of the entire problem to initial value type, eliminating the need for iteration. This numerically accurate perturbed solution is, in turn, perturbed again and step-by-step the solution is obtained over the range of the parameter of interest.

Details of solutions of the compressible boundary layer equations are given for different (a) wall temperatures and (b) blowing rates.

Calculation of Intake Flow

W. T. Ashurst, SLL

In the car engine, the intake flow produces thin shear layers that mix the residual exhaust gas with the new charge. The details of this mixing are important for pollutant calculations. Numerical solutions using the standard Eulerian finite-difference method do not resolve these thin shear layers. A Lagrangian vorticity model has been developed for unsteady intake flow that does provide the required detailed spatial resolution.

Vorticity is equal to twice the local rigid-body rotation speed. Thus the relationship between vorticity and velocity is purely geometrical. Each one can be defined in terms of the other. The Eulerian method defines a continuous velocity field only at discrete node points and one must difference these node values in order to advance the solution in time. The Lagrangian vorticity method distributes "node-points" of vorticity only in shear regions and moves this vorticity by calculating a continuous velocity field. By converting the continuous vorticity field into discrete vortices, the Lagrangian vorticity, or vortex dynamic method has corrected two disadvantages of the Eulerian method: (1) the node points are no longer needed over the complete flow field but are only used in regions with shear; and (2) the "node-points" move with the shear region and thus spatial details will not be limited by a fixed grid spacing.

Beginning computer calculations have been done for an axisymmetric piston-cylinder intake flow. The vorticity motion is most easily understood by

generating computer movies of the vortex motion. During the intake stroke the vorticity from the valve-lip shear layer forms into a large ring vortex between the valve and piston faces; whereas, the vorticity from the valve-seat shear layer remains confined to the upper cylinder corner region. Thus the mixing effects will differ in these two regions. The calculated flow pattern agrees with hydraulic intake flow experiments. Detailed comparisons of measured and calculated velocities will be done.

Monte Carlo Computer Simulation of Flow Through Porous Media

R. R. Eaton and R. L. Fox, SLA

Recent developments, for example in the in-situ gasification of coal, the removal of hydrocarbons from oil shale, and the extraction of oil and gas, require an in-depth understanding of flow in porous geologic media. The purpose of this paper is to develop a particle tracing scheme for calculating flows in porous media which will reduce the number of required empirical properties, such as permeability.

A Monte Carlo particle tracing technique (referred to as the tracer- fluid method) has been extended to continuum flows by employing a combination of particle dynamics and fluid equations. In this paper two methods are developed for applying the Monte Carlo method to porous flows--geometric and statistical.

The tracer-fluid computational method predicts the motion of a fluid using a combination of (a) dynamically following a hypothetical set of tracer particles, and (b) solving the fluid dynamic equations.

In the geometric method, we model the porous media by "rocks" as specifically located obstacles in the path of the flow. The statistical modeling of the porous media for a tracer fluid calculation is accomplished by determining a free path for the interaction of each tracer with the rocks.

The geometric method and the statistical method were used to predict the velocity and mass flux profiles for the flow in a 2-D porous channel modeled by cylindrical rocks. The number of obstacles in the media were varied

parametrically, such as to keep the porosity constant. The resulting profiles demonstrate that when only a few particles are present in the media, the statistical method is not valid. However, as the number of particles is increased, the statistical prediction comes into agreement with the geometric calculation.

Computer Use For Predicting Tornado-Induced Flow and Re-Entrainment In Nuclear Facilities

R. W. Andrae, K. H. Duerre, W. S. Gregory, and R. A. Martin, LASL

A preliminary analytical procedure that may be used to calculate tornado-induced flow and material re-entrainment within nuclear fuel cycle facilities is described. The procedure involves the following four steps: (1) a computer code models the overall ventilation pathways and predicts tornado-induced flows and pressures, (2) a second computer code models individual rooms or cells and predicts velocities within the room induced by the flows from step (1), (3) these velocities are then used to predict re-entrainment and suspension of particulate material, and (4) the possibility of release is predicted from the flow patterns calculated in (1). For illustrative purposes only, the head-end ventilation system of the Nuclear Fuel Services, West Valley, New York, plant was analyzed using the proposed procedure.

Session 5c

Software Tools

Debugging Aids

C. Kazek, LASL

"Optimal, logistical programming is hampered by non-functional first-generation concepts and can only be cured by a synchronized, monitored capability." The above statement makes as much sense as present-day debugging techniques, and is as difficult to understand as error messages, exchange packages, and memory dumps. An automatic debugging code that uses simple English and compiler language explanations to tell a user exactly where and how an error occurred can save a user hours of searching for errors. This paper describes the work being done at the Los Alamos Scientific Laboratory (LASL) to develop and perfect such a code.

A Library of Portable Mathematical Functions

L. W. Fullerton, LASL

A library of mathematical functions that works on every major North American computer is under development. The library currently contains over 150 documentable routines of interest to scientists and engineers, and portions of the library have been in use for a year and a half. The library has been implemented on CDC, CRAY, IBM, and Honeywell equipment, and portions of the library have been tested on several minicomputers. A version of the library should be available for general release in early 1979.

LLL's BASIC-II Interpreter

P. R. McGoldrick, LLL

The LLL BASIC interpreter was designed to operate with LLL's MCS-80 microprocessor. It consists of an 8K-byte ROM resident interpreter used for program generation and debug.

The goal in developing the 8080 BASIC was to provide high-level, easy-to-use language for performing both control and computation functions in the MCS-80. All numerical operations and functions use the Am9511 arithmetic processor chip or a software simulation of the chip. To minimize system size and cost, the interpreter was constrained to fit into 8K-bytes. It was necessary, therefore, to limit the interpreter commands and BASIC statements to those considered the most useful in microprocessor applications. With not too many exceptions, LLL BASIC conforms to the standards expressed by the ANSI committee, X3J2, on MINIMAL BASIC.

Some features of LLL's BASIC are:

Device independent I/O for ease of interfacing BASIC to different I/O devices.

Special functions to allow access from BASIC to any I/O port.

Formatted printing.

Special INPUT/OUTPUT and proceed statements to allow I/O without interrupting BASIC program execution.

Full arithmetic expressions.

ABS, SQR, SIN, COS, TAN. ATN, INT and many more functions.

Limited string manipulation.

Shorthand forms for common BASIC keywords.

Immediate mode BASIC statement execution.

Can run a BASIC program that is contained in ROM.

Computer Algebra and Its Applications

J. A. Howell, LASL

Systems for computer algebra enable one to manipulate symbols as well as numbers on a computer. This means that the user of such systems will be able to find closed-form analytical solutions to many problems. MACSYMA is the name of one such computer system. We give a brief introduction to computer algebra systems. Then the facilities of MACSYMA are discussed and the usage of many of its commands is illustrated. We also give brief descriptions of applications of such systems in science, engineering, and mathematics.

Session 6a

Computer Aided Design/Computer Aided Manufacturing

Microprocessor Based Machine Tool Safety Modifications

L. Newton, LLL

This report describes two MCS48 microprocessor implemented modifications of a commercially purchased precision lathe that will enhance the high explosives (HE) machining capabilities at the Lawrence Livermore Laboratory (LLL) Site 300. The facility will provide for technological advancement in remote controlled machining with complete containment of an accidental explosion during the machining operation. The lathe computer numerical control (CNC) design and modifications are predicated on modern principles for safe HE machining including protection of personnel in adjacent work areas.

The lathe was purchased from LeBlond as a production model and delivered to LLL where extensive capabilities were designed into the control system to enhance the system safety and reliability concept which was reviewed by a quality assurance committee. These system modifications consist of the following:

1. Remote control capability
2. Safety circuits
   a. Chip thickness calculator (CTC) -- Intel MCS48 μP
   b. Surface feet per minute calculator (SFMC) -- Intel MCS48 μP
   c. Tool force monitor
   d. RPM limit detector
   e. Aux encoders
   f. Aux displays
   g. Stored program memory

h. Safe distance limit switches

i. Air purge

j. Vacuum monitor

k. Coolant flow monitor

My paper will address the CTC and SFM modifications only. The CTC was designed to calculate the real time value of chip thickness during the actual machining operation. An Intel MCS48 microprocessor on a chip was programmed to make the calculation, take care of the necessary overhead, and process an action command if a preset limit is exceeded.

The program safeware was written in assembly language and consists of about 300 instructions. The MCS48 microprocessor and TTL chips necessary to implement this function are mounted on a small universal Augat card which is interfaced to the General Electric model 1050 CNC.

The SFM calculator was designed to continuously calculate the real time value of the tool speed. The calculated value is compared with a stored limit of 210 FPM and appropriate safety action is automatically taken if that value is exceeded. The design procedure and implementation comments are similar to those taken on the CNC modification.

Since the G.E. CNC consists of TTL logic and a cluster of three microprocessors talking to each other, these modifications were easily interfaced to the control system.

The lathe became operational at Site 300 in March 1978 and had been cutting chips since that date. We are now in the process of modifying a milling machine with the same general constraints and expect to have 7 to 8 machines fully operational in the HE machining facility at Site 300 by 1982.

AD-2000 - A Case Study of the Antares Laser Lens System

T. L. Dixon, LASL

A brief explanation of the lens system and the computer code which generates the basic data for input to AD-2000, an interactive graphics design, drafting and manufacturing code.

The case study explains the impact of AD-2000 on lens design layout optimization, data verification and manipulation, and various other design options prior to manufacturing. A list is presented detailing cost savings, design man-hours saved, and saved manufacturing costs.

Computer Control in Chemical Vapor Deposition Plating Process

F. Y. Shimamoto, LLL

Using an LSI-11 based system, a method has been developed to improve the plating of spherical surfaces with a metal alloy. Computer control of the multi-axis system provides absolute control of the mandrel speed and position during the four-to-eight hour process. A stepping motor, driven by the LSI-11, is the key control element. The ability to consistently determine position has produced dramatic results in plating homogeneity and surface smoothness. Plating repeatability is required for parametric control of the process.

Control of all system parameters is currently being implemented. These include temperature, pressure, and gas flow control.

Finite Element as Design Layout Tools Applied to MFTF

J. Horvath, LLL

To optimize the neutral-beam current incident on the fusion plasma and limit the heat load on exposed surfaces of the Mirror Fusion Test Facility (MFTF) magnet coils, impingement of the neutral beams on the magnet structure must be minimized. Placement of the neutral-beam injectors must

comply with specifications for neutral-current heating of the plasma and should allow maximum flexibility to accommodate alternate beam aiming patterns without significant hardware replacement or experiment downtime. Also, diagnostic lines-of-sight and stay-out zones must be maintained in the crowded MFTF vacuum vessel.

Injector placement and subsequent aimings as well as structural member locations are analyzed by means of either the Structural Analysis Movie Post Processor (SAMPP) or a program called EUTERPE, both being general purpose graphics codes which display three-dimensional finite element models. These programs are used to visually assemble, disassemble or cut away sections of a complex three-dimensional apparatus which is characterized by an assemblage of finite elements. The resulting pictures are used to detect and quantify interactions between the neutral or charged particle beams, diagnostic stay-out zones and solid structural members.

Finite structural-modeling elements are proving to be useful geometric layout tools. They can be used to define surfaces and can be displayed by application of finite-element display codes. With outside surfaces rather than neutral surfaces defined, the undisplaced (zero displacement state) views can be interpreted as surface layouts for line-of-sight determinations and physical clearance measurements.

Complete automated drafting capability is not easily accessible to most engineers. However, finite-element display codes are more readily available and quite adaptable to design layout problems.

Application of Computers and Graphics to Physical Inspection Problems

B. A. Pentecost, LASL

The Physical Inspection problems at Group WX-3 are somewhat unusual. The operation is non-production, i.e. job shop oriented, and the materials are mostly HE, plastics or foam. Also the parts are very complex, and we are mainly concerned with exactly how parts will fit together.

The need to determine fits between parts, especially between surfaces, requires three-dimensional inspection of surfaces and features located on the surfaces. The part types range from normal geometric shapes such as spherical or conical, to point defined surfaces to revolution and complex geometric shapes. Many parts also have various features machined into the surfaces.

The problem can be broken down into three main areas, data acquistion, data reduction and meaningful display of results. The approach that we have chosen is to use a manually operated X-Y-Z coordinate measuring machine interfaced to a computer for the data acquisition. A ball probe is normally used to take a large number of readings on the part surface. The data reduction is accomplished using a family of general subroutines that perform fits of X-Y-Z coordinate points to spheres, planes, and two-dimensional point defined curves, and give results as deviations normal to the surface. The data display is graphical, usually in the form of perspective plots or stereo pairs.

We are approaching what we call "Instant Versatility" using these techniques. This makes it possible to do inspection of complex parts without precision fixtures, part alignment or special gaging equipment and display the results in an understandable form.

Session 6b

Developments and Applications in Hydrodynamics

Computer Code Design of Shaped Charges

C. S. Godfrey and L. L. Edwards, LLL

A shaped charge is an explosive charge constructed to implode a metal linear and project a high-velocity "jet" of the metal into some object. Shaped charges were first designed and used during World War II; since then they have been used effectively as warheads for penetrating military armament and as explosives for making underground cavities in rock, soil, or coal.

Current shaped-charge weapons, though highly effective, were designed mainly by trial and error.

The CHPOODSC computer code uses the coupled Eulerian-Lagrangian polygonal line interface methodology of the CHAMP code to produce an economical shaped-charge jet calculational tool. Here the liner and enclosing case are treated as mass segments coupled to an Eulerian calculation of the high explosive. As segments collapse on the axis an analytic approximation computes the jet. An automated iteration scheme is allowed to adjust the mass associated with each segment to achieve a prescribed desired collapse velocity.

Following the initial somewhat crude design, a complete multifluid Eulerian treatment using the CHAMP code is employed to compute the full hydrodynamics of the liner collapse and jet formation.

Calculational results will be compared with both theoretical and experimental results.

Self Forming Fragment Calculations

D. Hanner, LLL

Calculations to predict the velocity and final shape of self forging fragments are being made at LLL. DYNA2D, a hydrodynamic finite element and finite difference code has been developed and includes features which makes a more realistic modeling of this problem possible. The most important feature of DYNA2D over other codes used for this type of problem is two-way slide-line capability. Also, the code permits the redefining of slide-lines on restart. This is important where a surface folds over, and areas of the surface come into contact.

A high-strain-rate constitutive model which gives the flow stress and shear modulus as a function of temperature and hydrostatic pressure has also been included in DYNA2D as a material option. As the self-forming fragment experiences effective plastic strains of well over 100%, this option gives the user a great deal of latitude in modeling materials.

Results thus far have given reasonably good shape predictions of experimental flash x-rays and excellent velocity predictions.

One-Dimensional Code Calculations of the Containment of Blast Waves

R. R. Karpp and T. A. Duffey, LASL

The ability to completely contain the products of experiments involving detonation of high explosives is a subject of current concern for a variety of applications. To better understand and interpret experimental data from tests on vessels that provide this containment, a series of one-dimensional, finite-difference calculations that simulate the blast loading and subsequent response of spherical containment vessels was performed. These calculations treat the motion of the explosive products, the propagation of the blast wave from the explosive to the vessel wall, and the motion of the containment vessel.

A common Lagrangian finite-difference technique is used to compute the motion of the explosive products and the filler material. The motion of the vessel wall is computed, as part of the overall finite-difference routine, by solving the equation describing the motion of a thin spherical shell. The calculation is begun with the explosive completely burned. The initial distribution of properties within the explosive products is determined from the Taylor similarity solution by a prior calculation.

When the vessel contains air at about one atmosphere of pressure or air at near vacuum conditions, agreement between the calculated pressure loading and the measured pressure is good. Also, the early portion of the strain history is adequately simulated by the calculations. Since the test vessel is not perfectly spherical, two- and three-dimensional effects will influence the later stages of motion. Calculations and tests were also performed when the vessel was filled with a highly compactable material. The material was modelled with a purely mechanical equation of state based upon static compaction data. A comparison between calculations and test results using vermiculite as the filler indicates that the measured pressure pulse is somewhat lower and acts over a longer period of time than the calculated pressure pulse. A somewhat more sophisticated material model is probably required to adequately describe the behavior of vermiculite. However, these calculations were still found useful for estimating the sensitivity to various parameters. For example, code calculations were used to study the variation of pulse shape as a function of the compacting materials density.

Explosive-Filled Hydrofrac Simulations

M. E. Kipp, SLA

The creation of a region of rubble in an oil shale formation may be obtained by filling parallel hydrofracs with liquid explosive, and detonating the explosive at the center of the hydrofrac. The radially propagating detonation waves eventually interact, producing a region of tension that will cause fracture of the oil shale. The two-dimensional simulation of this event with a

[illegible] considerably less than a [illegible] that develops in this [illegible] point, increases with [illegible] in the one-dimensional [illegible]

[illegible] Model for Porous Materials with Strength

[illegible]

A three-dimensional computational model is being developed to describe isotropic porous materials which are capable of supporting deviatoric stresses. In contrast to previous models which have added a separate deviatoric stress calculation to a hydrodynamic pressure-porosity calculation, the present model incorporates the complete stress tensor into the porosity calculation. The model is based on the physical concept of a yield surface for the porous material in principal stress space which is a function of both the first and second invariants, J_1 and J_2, of the stress tensor. Thus the dependence of the porosity on the stress state is given by reversible compression curves and irreversible compaction curves, both of which may be functions of J_1 and J_2. The model will describe such phenomena as shear-enhanced pore compaction and rate dependent pore collapse. Calculations with the model show good agreement with experimental data.

Session 6

Microprocessor Applications II

WISE (Warhead In-Service Status Estimator)

P. K. McCue, III

The WISE (Warhead In-Service Status Estimator) feasibility package is a first generation of unattended, microcomputer based black boxes designed to log, over extended periods, the stockpile environments of individual warheads. Currently, the WISE package monitors warhead temperature and shipping container % RH. During the logging period the WISE box is located within the warhead shipping and handling container. At each sampling time, WISE reads the sensors, processes the readings, and stores the results. The WISE box processes temperature readings into two formats: % Time-at-temperature and time history, % RH is available in time history form. A CMOS microcomputer and data compression algorithm minimize the stored data and energy requirements for the time history format. At the end of the logging period, WISE writes the recorded data onto a tape cassette. This cassette is read directly into the Livermore Timeshare System (LTS) without going through tedious, manual inputting. Once into LTS, the warhead data is formatted into database, plots, and listing files; the time history data is reconstructed (uncompressed) at this stage. Under typical conditions, the WISE package has a one year logging capacity. The temperature time history has a maximum error of $\pm 2^{o}F$; the % RH time history has a maximum error of $\pm 7\%$. The WISE box, except for % RH sensor, is designed to operate from $-65^{o}F$ to $+165^{o}F$. Weights, volume, and energy consumption are minimized through the use of LSI CMOS technology, power management, and date compression. The electronics and batteries, excluding the case and sensors, have a volume of 100 cubic inches and weighs under 4 pounds, conventional packaging techniques are used. The average power dissipation is ~1mW; all power used by WISE is supplied by internally carried Li/SO_2 batteries. The WISE package also has a computer terminal mode for data communications.

[illegible]

[illegible]

The Fire Control System was designed as a part of a complete upgrading of electronic instrumentation used at hydrodynamic test facilities at Kappa Site (M-Y) and Anvil Canyon (M-6). Major factors in the decision were increasing cost of maintaining the antiquated, existing equipment and the need for a control system incorporating equipment interlocking and data logging functions due to the increasing complexity of shot instrumentation.

The function of the fire control syster is to provide personal safety interlocks, warning syster control, instrumentation control and interlock, and interface a future optional CAMAC based data acquisition system. Improved human engineering of the micro-based fire control chassis front panel provides easy human interface to the syster. Interface between the fire control chassis and the syster instrumentation such as oscilloscopes, flash x-ray, rotating mirror cameras, high-speed movie camera, etc. The modules provide pre-event triggers to open shuttering, start motors, trigger flash x-ray, etc. at proper time prior to the shot as well as provide status interlocks and rotating mirror camera coincidence. Each module is controlled by an 8035 processor.

All software is non-volatile. The main program is an interpreter which sequentially fetches commands from the control program which is written with a custom control language. Device interface module software constants subroutine which are entered by interrupts. The main program is a display driver routine.

Graphics Made Easier With a Microprocessor-Based Cursor

H. H. Bell and F. L. Sindelar, LLL

This paper describes an 8080 based cursor for use with the TMDS TV monitors on the Livermore Time Sharing System (LTSS). The speed of the microprocessor and its associated hardware insure that the point of interest can be accurately

identified, and its coordinates transmitted to the central computer. These functions are especially important in an interactive graphics environment.

Among other things, the LTSS provides a softcopy output in a TV-like format for both text and graphics. In many applications, such as mesh and hydrocode work, it is necessary to identify points of a display either to rescale for closer examination or to change parameters. To do this effectively, the user must accurately identify points in his data, and convey that information back to the main computer that is running his code.

The IMLS produces data on a TV monitor that has been designed to display 512 (interlaced) lines of 512 points each. By counting lines and pulses across a line, the cursor unit can place its figure anywhere on the screen with an accuracy of less than 1 point, both vertically and horizontally. When the user is satisfied that he has the proper point, he instructs the microprocessor to send the coordinate, in proper format, to the main computer.

The microprocessor adds versatility to the cursor by allowing the user to select several special characters to send along with the coordinate data. In addition, the user can select the 1 of 8 cursor figures that meets his fancy or need at the time. Other figures can be substituted for those preprogrammed, if necessary.

The speed, accuracy, and versatility of the microprocessor-based cursor make it ideally suited to the LTSS, and is being used extensively to rezone meshes and hydrocodes.

A Multiprocessor LSI-11 High Speed Data Capture System

F. D. Lee, LLL

At Lawerence Livermore Laboratory we are using systems of interconnected LSI-11's to accomplish high speed data capture from nuclear tests. The systems reside in mobile bunkers and are subjected to high levels of shock, vibration and electrical noise. Each system consists of a master LSI-11 and up to 32 slave LSI-11's tied together by a common bus. The function of the master LSI-11

[illegible] commands to and receive responses and data from each LSI-11 and send the data collected to a central processing point. The function of the slave LSI-11 is to control and read data from a digital measurement system and to respond to commands from the master LSI-11.

The system of LSI-11's is tied together by a common bus. The bus consists of two unidirectional, 16-bit buses plus necessary control signals. All bus signals are differential to increase noise immunity. The unidirectional bus structure allows the master LSI-11 to remain bus master at all times reducing the possibility of the bus being used by a slave LSI-11. The master LSI-11 is interfaced to the bus by a controller which allows both programmed word transfers and high speed DMA block transfers to and from the bus.

A set of six external control lines are also bused to each LSI-11. These signals originate from the Test Site control room and are used to synchronize the data capture system with other aspects of firing the nuclear device. When these lines become active, each slave LSI-11 logically disconnects from the system bus and operates as a stand alone machine. In this mode, each slave LSI-11 drives its own dedicated data acquistion unit to acquire data. After ground shock, the external control signals are released and the system resumes the original master/slave configuration in order to format and transport the data to a PDP-10 via a high speed encrypted microwave link for further processing.

Mirror Position Display Equipment For the Target Chamber Mirror Mounts of the 8-Beam Laser Fusion Research Facility

F. E. Wells and D. A. Remington, LASL

The Laser Fusion Research Facility employs sixteen mirrors within a target chamber to direct eight laser beams onto a target. Each mirror mount contains three stepping motors which drive lead screws to move the mirror. A motor controller has been fabricated which steps the motors to control mirror position relative to the target. To augment this equipment, a mirror position display system has been designed containing memory to store the positions of the 48

stepping motors. Motor motion is sensed by 48 incremental optical encoders, coupled to the drive shafts. Outputs from the encoder tracks are multiplexed to [illegible] which is programmed to address the mirror mount being moved and transmit step information to the display chassis located in the control room. Data transmission is accomplished by a type 8251 USART and a fiber-optic data link.

Processing and display of the encoder data is accomplished by the Mirror Position Display chassis in the control room. This unit contains a type 8085 microprocessor and type 2716 EPROM. Type 5101 RAM with standby battery power stores the position of 48 stepping motors. Scratchpad memory is provides by a type 8155 RAM. Two type 8251 USART's communicate with the target chamber circuits and the facility computer.

The programmed control algorithms provide means for storing and updating motor position data, for communicating with the target chamber and the facility computer, for generating the front panel display, and monitoring the front panel switches. For a selected mirror mount, motor position data is processed and displayed in either absolute motor steps, or FOCUS, TILT AND ROTATE position. Programs were written in assembly language and translated by a cross assembler, which produced necessary outputs for an EPROM programmer.

Session 7a

Inelastic Solids and Fracture

Plastic-Fracture Research at Lawrence Livermore Laboratory

D. M. Norris, Jr., B. Moran, and D. F. Quinones, LLL

We developed a computer model of ductile fracture that correctly predicts fracture initiation in five different fracture-test geometries. Fracture occurs when the time-integrated product of the equivalent plastic strain rate and a function of the mean tensile stress exceeds a critical value over a critical dimension. Material constants of the model are set by computer simulations of small specimen tests. Four calibration geometries were used: two different circumferentially notched-tension specimens, a simple-tension specimen and a precracked compact-tension specimen. The calibrated model was then used to predict crack initiation and initial flat propagation in dynamic Charpy V-notch test specimens. The calculations show the importance of damage history and the need to weight plastic strain with mean stress to obtain agreement with fracture data.

A Computer Simulation of the Tension Test

B. Moran, D. F. Quinones, and D. M. Norris, Jr., LLL

The HEMP computer program is used to calculate the quasi-static necking deformation of a round tensile bar to 71% reduction in area. Finite strain and rotation are accounted for. We modelled the behavior of A-533 Grade B Class 1 nuclear-pressure-vessel steel as elastic work-hardening plastic material, using J_2-flow theory and a flow curve obtained from a simple tension test. Up to the time of fracture, computed results of neck radius vs load and elongation, load vs elongation, and neck profile vs neck radius compare faborably with experimental results. We present the macroscopic stress and strain state at fracture and compare these results with those of Bridgman and other caiculators.

Our calculated neck stress shows monotonically decreasing stress in the radial direction and does not show the sharp stress peaks on axis or the rounder stress peaks off axis that these earlier calculations show. We find considerable differences from the Bridgman solution. An iterative computer method is introduced to allow correction of simple tension-test data to a universal flow-stress curve valid for large strain.

Nonlinear J-Integral Calculations of Two-Dimensional Crack Problems With Large Scale Yielding by Finite-Element Analysis

Y. R. Kan, SLL

The nonlinear J-contour integral evaluation of two-dimensional fracture problems with large scale plasticity has been added to the general nonlinear finite-element code GNATS. The nonlinear finite-element analysis results, using an incremental plasticity formulation, have shown that the J-integral is nearly path-independent (which is exact only under the nonlinear elasticity or deformation plasticity theory) for two-dimensional crack problems with Rambera-Osgood type material stress-strain relationship. The only restriction on the contour integration is that it must be evaluated at several elements away from the crack tip.

Very good correlation between the present analysis results and existing numerical J-integral values in literature was obtained for a center cracked specimen with large scale plasticity. This technique was also used to analyze a non-standard C-shaped fracture specimen with large scale yielding. Very good correlation is obtained between the elastic-plastic finite-element analysis results and the experimentally measured "apparent" critical stress- intensity factor. The effects of material yield strength on the 'apparent" critical J-integral of stress-intensity factor for the undersized C-shaped fracture specimen are also studied in detail. The results will be graphically presented.

A Comparison of Several Finite Element Codes on Problems of Soil and Rock Analysis

E. C. Greenlaw, LLL

To assist the needs of several on-going programs at LLL, it is necessary from time to time to produce finite element analyses of soil and rock formations, extracting such information as stress and displacement due to excavation, rock bolting, thermal loading, or all of the above.

While many excellent finite element codes exist for linear and non- linear analysis of metals and similar materials due to steady and rapid loading, the availability of efficient codes for earth materials is not so well established. The loading of natural formations for the problems at hand is generally slow, quasi-static rather than dynamic, and the material properties are not well defined, let alone adequately modeled in finite element codes.

This paper discusses the relative merits and experiences with several programs used for the purpose in the nuclear test engineering division at LLL and draws some conclusions as to suitability and efficiency.

Session 7b

Data Analysis and Support

A Computer Simulation and Performance Evaluation of the Smith Predictor-Controller

C. L. Pomernacki and R. P. Brand, LLL

One of the more difficult system elements to cope with in the design of feedback controller is pure time delay. Nevertheless, the appearance of time delay is universal wherever mass transport is involved such as in chemical processes. An approach which has been used to design controllers for systems having large time delays utilizes a model of the process and is called the Smith Predictor-Controller. Although the method has been used in practical situations, the authors know of no statements relating to the performance sensitivity of the controller with respect to model parameter variations. This presentation examines the influence of parameter variations on the performance of the controller.

Performance measures of importance are: steady-state error, overdamping or underdamping characteristics, percentage overshoot, and settling time to various final levels. The system model used in this effort is a second-order lag plus time delay structure. The principle parameters of the model are the system gain, time constant, and time delay. A performance sensitivity analysis is developed for all performance measures of interest for each parameter at several levels above and below its normal value.

The simulation is performed on a Tektronics Model 4051 graphics calculator using an extended form of BASIC, and the program occupies approximately 150 lines of code. Numerical values for the parameters were obtained experimentally by step-response measurements on a chemical reactor. The results of the simulation will be used in implementing a digital computer time delay controller for the control of a complex chemical process.

Experimental Modal Analysis Using a Minicomputer System

M. R. Posehn, LLL

Modal analysis is the process of experimentally determining the vibration natural frequencies, mode shapes, and damping coefficients of a mechanical structure. A transportable minicomputer system provides an integrated data acquisition/reduction capability that facilitates the rapid modal analysis of complex structures. Data is obtained by exciting the structure with a force input and simultaneously measuring the vibration response. A set of input and response measurements is used to compute point-to-point frequency response functions. An interactive algorithm is then used to extract modal parameters from the frequency response functions. The results of the modal analysis are displayed on a CRT screen as an animated three-dimensional line drawing of the vibrating structure.

Artificial People

M. S. Maiten

Artificial People are small computers used for controlling large computers. They appear to the large machine as a human on a teletype. The Artificial People do jobs that are required, but for which no personnel are available to perform, and for which is difficult to reliably automate by a user on the large machine. This is a pragmatic approach used to improve the apparent reliability of the LLL computer center in the eyes of the user. He now no longer need concern himself with the details of making sure his job completes, since he knows that all he need do is to issue commands to the Artificial Person and his task will be monitored and massaged, where needed, automatically. If a particular large machine should fail, the Artificial Person can move the task to an alternate computer. If the Artificial Person is unable to correct the problem, it then calls humans on the telephone, using a Votrax speech synthesis device. The unit also will call a preset telephone number and transmit a "Beep"

signal if it itself fails. This makes the large computer system to which the Artificial Person is connected seem much more reliable to the user.

Manufacturer Independent Software Development/Debug for Microprocessors

E. P. Fisher, LLL

The microprocessor industry is spending large sums of money to sell the idea of in-circuit microprocessor emulation. Processor emulation is not only expensive, but it always follows the state-of-the-art by six months or a year. For example, most new single-chip microprocessors are still not supported by in-circuit emulators.

This paper describes a new approach to hardware and software debug. This technique uses hardware emulation of the only standard element in the microcomputer industry, memory. The paper shows how it is possible to use a standard MACRO assembler to provide the software for any microprocessor for a fraction of the cost of the current industry approach and in a fraction of the time.

In using this approach, it is possible to use the same development system, possibly an existing system, to develop software for almost any processor. The change to a new processor requires less than 40 hours of programming time without learning a new operating system and no additional hardware.

This paper will show examples of how memory emulation can be used on SBC80, F8/3970, and other microprocessors.

Session 7c

System Modeling and Simulation Transient Systems Analyses

A Modularized Simulation of Electric Car Performance

J. Nachamkin, P. Bobbett, C. Derouin, D. Lynn, and B. McCormick, LASL

The computer code THECAR was written to simulate all of the components that contribute to the performance of an electric car. Input data for wheel-road friction, aerodynamic drag and drive train losses were obtained from roll-down data on a test vehicle. Separate subroutines describe the differential, transmission, motor, and battery charge-discharge cycles. Idealized strategies for acceleration using least amounts of battery charge are derived from a variational principle. These are compared with simulated real driving conditions. Results concerning differential and transmission gear ratios will be presented.

An Investigation of Occupant Ride Quality in the Safe-Secure Tractor-Trailer

T. G. Carne and L. T. Wilson, SLA

A combined analytical and experimental approach is used to examine the severe ride which the courier-drivers experience in the Safe-Secure Tractor. Laboratory modal tests, on-the-road vibration measurements, and finite element modeling are used in conjunction to develop a verified analytical model and a physical understanding of the dynamics of the vehicle.

A three-dimensional finite element model of the vehicle has been created using the code NASTRAN and including the tractor, the trailer, the suspension systems and tires, and human occupants. The modal characteristics of the vehicle, obtained from laboratory tests, are compared with corresponding results from an analysis of the model. Unquantified parameters in the model are then adjusted so that the analytical results correlate with the experimental data.

To completely verify the accuracy of the model, the analysis must be able to reproduce the acceleration reponses measured on the road. To analytically simulate the road environment, the variation in the road surface is taken as a random variable. These random road displacements are applied to the tire patches in the model, taking into account the appropriate phase shifts along the length of the vehicle and the partial correlation between the two tire tracks on each side of the vehicle.

In computing the response of the vehicle due to the random road roughness, one can identify the contributions that each particular mode makes to the overall response. Understanding the modes which contribute to the poor ride and how they are excited directs one toward changes to improve the quality of the ride.

CHAP-II: A Transient Simulation Code for the Fort St. Vrain High Temperature Gas Cooled Reactor

P. A. Secker and R. B. Lazarus, LASL

The LASAN simulation code has been used to model a composite of subsystems, phenomena, and controls for the Fort St. Vrain High Temperature Gas Cooled (HTGR) nuclear/electric generating plant. The CHAP-II models have been developed for the U. S. Nuclear Regulatory Commission to aid in the assessment of normal, anticipated, and accident transients for safety and licensing purposes. This paper describes the models developed and the transient scenarios obtained in validating model behavior and assessing plant performance.

Sixteen separate modules have been coded for CHAP-II. They are used to describe the mass, momentum, and energy transport of the primary reactor coolant (helium) and the secondary nuclear steam supply coolant (water), the neutronic and fission product heat generation in the reactor core, energy transport in solid materials within the plant adjacent to fluids, and the control dynamics. Best estimate modeling of all dynamic and static behavior has been used throughout the code. The CHAP-II modules include the reactor core and side reflector, the primary coolant containment vessel including structural insulated

liners, support posts, plenum voids, and ducts. The reactor neutron kinetics may be treated as spatially independent or regionally coupled point dynamics. The nuclear steam supply components include the feedwater components of condenser, pumps, feedwater heaters, deareator, and feedpump turbines, the main steam generators and steam reheaters, the helium circulator compressor and turbines, the high, intermediate, and low pressure electrical generation turbines, with associated piping, valves, and bypass components. An overall plant control module was developed containing the three main plant control loops, and the plant protection and operator protection control strategies. A separate module is included to predict the fuel failure and hazardous radiation release from the reactor core into the primary containment and ultimately to the atmosphere.

Scenarios performed by the code will be presented for a variety of problems. For example, containment depressurization studies with natural convection effects were investigated. Anticipated transients without reactor scram have been studied. Spatial oscillations of neutron power in FSY were also studied.

Dynamic Computer Simulation of a Tritium System Test Assembly in Support of Fusion Reactors

J. G. Grundmann, LASL

The dynamic computer simulation of a tritium system test assembly (TSTA) is presented. The model was created using LASAN, a general computer code developed at LASL to provide dynamic simulation of systems. The code can solve combinations of ordinary nonlinear differential equations and algebraic equations using a state variable approach to modeling. The LASAN code, written entirely in FORTRAN IV provides steady state, frequency response, and transient response outputs for complete design analysis for the TSTA.

The TSTA facility, which is primarily a gas and liquid process loop used to separate the isotopes of hydrogen through cyrogenic distillation, was divided into major modules. Each module was then modeled separately to ensure correct

steady-state operation, acceptable stability of control systems, and acceptable transients during failure modes. The LASAN code has a modular structure, and once the TSTA modules were complete they were easily interconnected allowing analysis of the effects of module interactions upon steady-state and transient behavior of the facility process loop. Sample results of the facility simulations are presented and discussed in this paper.

Session 8a

Graphics Software

The Application of Computer Graphics to Three Dimensional Engineering Geometry and Analysis

B. E. Brown, LLL

There are many uses of computer graphics in the engineering of three-dimensional objects. The uses are broken into two major areas. The first is descriptive geometry, and the second is looking at the results of the analysis. The primary three-dimensional graphics code at the Lawrence Livermore Laboratory is called GRAPE. GRAPE is a much enhanced and reworked combination of the codes known as SAMPP and MOVIE.BYU.

The scan line oriented Watkins' algorithm is used to remove the hidden portions of the models. Much of the work of the last year has been devoted to enhancing the output of the Watkins's algorithm. The resolution (number of scan lines) used to calculate the visibility of the model is the major factor in the cost of using the code for both the line drawing and continuous tone color output. Since no anti-aliasing algorithm is used in the Watkin's algorithm the quality of the output is also controlled by the resolution. A study has been made to determine the minimum acceptable output resolution for line drawings and color output. The size of the film for output of the color images on the DICOMED D-48 film recorder has also been taken into account. These results plus the timing data will be presented.

The capacity of the code for display (i.e., the size of the model), has been increased to about 5 times the previous capacity. A new binary data-base for the results of the engineering analysis was developed for GRAPE. This new data-base will be used by all other post processors (time history plotters, etc.) of the three-dimensional analysis.

Examples of the current work at LLL include display of reentry vehicle components and a movie of a vehicle in flight, the components of the B-77 and

results of analysis of a portion of the weapon, the components of the W-82 AFAP and thermal analysis results, several models of the Safety Release Valve (SRV) work and their analysis results. A movie of the MFTF magnet will also be presented.

Energy Flow Diagrams

D. R. Koenig, LASL

A computergraphics program was developed to display energy-flow patterns for each of the states and for the entire United States. The diagrams, which can be displayed in color, illustrate 1) the production of various kinds of energy, 2) the storage, import or export of each type of energy and 3) subsequent distribution and consumption of the energy in various sectors of society.

Basically, the diagrams are generated by providing to the computer the chart title, the content of the legend, the names of each energy source and consuming sector, and the amount of energy flow in each path. The computer calculates a scaling factor and generates a diagram. If desired, alterations can be made to the diagram on subsequent passes.

MAPPER

D. A. Dahl, LASL

MAPPER is an easy to learn program designed to make report quality visual aids for presentations and reports. The user with no previous programming experience can output presentation slides, graphs, maps, and tables to both color and BW microfilm, Tektronix terminals, and Zeta plotters (10 mil.)

MAPPER reads command files that the user has generated. An interactive editor allows Tektronix users to add features on the scope and have the additions automatically added to the command file. The Tektronix Graphics Tablet can be used to generate MAPPER command files directly. MAPPER can draw

boxes, circles, connected line segments, and roads in selected line formats. There are six types of label commands and two lettering styles to cover the spectrum of labeling requirements. Label options include manual or automatic labeling requirements. Label options include manual or automatic sizing and location, rotation to a specified angle, and multiple line capabilities. The user has a choice of seven colors. Special features permit selective shading of specific areas. Symbols may be defined, located, rotated, and shaded as desired. Additional features include the LASL logo, skipping, projection ports, contouring three types of support files, ten layers of file subroutining, and FORTRAN support capabilities.

An Interactive Computer Graphics Program For Preparation of Visual Aids

B. E. Barker, SLL

TEXT is an interactive computer program designed to prepare visual aids based on the DISSPLA plotting system. It combines the quality of a technical art layout with the flexibility and ease of use of a handwritten or typewritten alternative.

In operation a user sitting at an interactive graphics terminal prepares a file consisting of a mixture of text lines and instruction directives. The file is read by the TEXT program which plots the text as specified in the input file.

Use of directives which is entirely optional enables a user of TEXT with several degrees of sophistication to select various character fonts and character sets, to specify shading and sizing, to position and justify text and to draw or plot lines. Several directives may, at the users discretion specify interactive positioning of text or line drawing.

Session 8b

Applications in Energy of Structural Mechanics

CRASHC - A Two-Dimensional Code to Compute the Reponse of Axisymmetric Shipping Containers to End-On Impacts

T. A. Butler, E. G. Endebrock, and J. B. Payne, LASL

A two-dimensional, finite element computer code is developed to calculate the response of shipping containers to end-on impacts. The code is made easy to use and relatively economical by specifically designing it to analyze container structural configurations. Thus it meets the needs of the Department of Energy as a tool for analyzing shipping containers for environmental and safety risk assessments and for performing parametric and sensitivity studies on variables influencing container response.

The finite element method is used to develop the mass and nonlinear stiffness matrices. The basic numerical solver was adapted from the NONSAP computer code. The nonlinear equations of motion are solved implicitly using the Newmark equations and an equilibrium iteration approach. An eight-node isoparametric element formulation, also derived from NONSAP code, simulates the container-shielding material. A three-node isoparametric element simulates the shell and plate components, and an eight-node isoparametric compressible fluid element simulates fluid contents of the container. A preprocessor automatically creates the finite element mesh and sliding interfaces from basic geometric data provided by the user.

Model accuracy is verified by comparing its predicted strain histories with strain histories obtained in test programs at the Los Alamos Scientific Laboratory (LASL) and Battelle Columbus Laboratories (BCL). Results are compared for several cases ranging from an empty steel shell to an actual shipping container model.

The code is specifically designed to simulate the response of nuclear material shipping containers. However, the computer code has been written so that most containers that can be represented as axisymmetric structures can be analyzed.

Design Considerations-Central Receiver Solar Tower

J. E. Grant, SLL

The design criteria being used to evaluate the tower in the solar central receiver program is presented and related to more traditional design criteria provided in the Uniform Building Code (UBC). Particular emphasis will be devoted to comparing seismic response as computed by a response spectrum model analysis method to that provided by the UBC. Generally, the UBC uses peak acceleration values much less than that known to exist during major earthquakes. The use of lower values is justified by the reduction in frequency when yielding occurs and by the energy dissipated at the points of local yielding.

This paper examines the reduction in acceleration due to (1) frequency modification due to nonlinear behavior and (2) local yielding or ductility built into the structure. A reduction factor, based on these two parameters, is presented that can be used with response spectrum techniques that will result in more realistic and less costly designs.

Comparison of Finite Element Predictions of Blade Stresses With Measurements on a Vertical Axis Wind Turbine

W. N. Sullivan and D. W. Lobitz, SLA

Sandia Laboratories has been operating an instrumented 17 meter diameter vertical axis wind turbine since the spring of 1977. The blades of this machine were analyzed with the aid of a non-linear, finite element model to assess stresses and displacements under a range of operating conditions. The blades are equipped with strain gages which have been monitored since the machine was installed.

The strain gage readings have been compared with the finite element model, with particular emphasis on performance in very high winds. The data are in good agreement with predictions in most cases. Areas of disagreement, believed to be due to unaccounted for dynamic effects, are discussed.

Optimization Studies For the Design of Superconducting Magnetic Energy Storage Vacuum Vessels

J. G. Bennett and C. A. Anderson, LASL

The conceptual design and feasibility studies for superconducting magnetic energy storage (SMES) facilities indicate that the energy storage cost rates decrease rapidly with increasing facility capacity. Thus, present studies have focused attention on 10-GWh capacity plants. In the large SMES plant concept the proposed vacuum vessel is about 100 m in height and about 300 m in diameter. Because of the large dimensions of the vessel, significant cost savings can be effected by relatively small decreases in vessel wall thickness that can be brought about in an optimized structural design.

The main structural problem that is formulated is that of the deformation of a point-supported shell liner under an external pressure of one atmosphere. Because of desirability of large support spacing and thinness of the shell, the deflections are large with respect to the thickness. Hence, even though the material remains linearly elastic, the problem is basically one of nonlinear deformation.

In order to carry out the structural optimization, an approximate solution is obtained. This solution is then used to parametrically investigate, via the computer, the structural design of the vacuum vessel for the large underground SMES concept. Vacuum vessel designs are evaluated by varying such parameters as shell thickness, support spacing, material properties and physical configuration to keep the amount of material used and construction cost to a minimum.

Session 8c

Developments and Applications in Thermo Fluid Dynamics

PEBBLE - A Thermal-Hydraulic Analysis Code For Axisymmetric Pebble Bed Nuclear Reactor Cores

K. R. Stroh, LASL

The pebble bed reactor cylindrical core volume contains a random bed of small, spherical, fuel-moderator elements. These graphite spheres, containing a central region of dispersed coated-particle fissile and fertile material, are cooled by high pressure helium flowing through the connected interstitial voids. Program PEBBLE is based on a mathematical model which macroscopically treats the bed as a generating, conducting, porous medium. The steady-state model uses a nonlinear Forchheimer-type relation between the coolant pressure gradient and mass flux, with newly derived coefficients for the viscous and inertial loss terms. The remaining equations in the model make use of mass continuity, and thermal energy balances for the solid and fluid phases. None of the usual simplifying assumptions, such as constant properties, constant velocity flow, or negligible conduction and/or radiation are used.

PEBBLE solves a coupled set of nonlinear finite difference equations, derived by integrating the corresponding nonlinear elliptic partial differential equations over a finite area, based on assumptions about the distribution of the variables between the nodes of the grid. This approach ensures that conservation laws are obeyed over arbitrarily large or small portions of the field. In addition, this approach is most appropriate for a macroscopic porous medium model of the packed sphere bed, which already includes the assumption that the variables in a given bed volume are well characterized by macroscopic averaged values. The finite difference equations are solved by a successive substitution technique.

A comparison of coolant flow predictions with those measured on a full-scale mockup of a pebble bed reactor core will be presented. Results of coupled thermal-hydraulic calculations for large pebble bed reactors will also be discussed.

Computer Simulation of LMFBR Accident Sequences by SIMMER-II

W. R. Bohl, LASL

One of the safety problems in the study of Liquid Metal Fast Breeder Reactors (LMFBRs) is the assessment of the residual risk to the public as a consequence of an accident beyond the containment design basis. At steady-state the fuel in an LMFBR is not in its most reactive configuration. A rapid change in core geometry could lead to significant energy production. One technique to obtain insight for use in addressing this safety problem is the computer simulation of hypothetical accident sequences. This paper describes the scope and some of the general features of the SIMMER-II computer program, which is designed to follow the neutronic behavior, the material motions, and the associated mass, momentum, and energy transport which occurs in a disrupted LMFBR core.

The neutronic calculation in SIMMER-II employs the quasistatic method combined with standard finite difference techniques to solve either the multigroup diffusion or transport equations in two space dimensions and time. As an option the point kinetics equations may be solved. The fluid dynamics calculation treats three separate velocity fields--structure, liquid, and vapor. The structure field is stationary and contains nine density and five energy components. The liquid field is assumed to be in a dispersed flow regime with eight density and six energy components. The vapor field is assumed to possess a uniform temperature and contains six density components. A combination of explicit and implicit time differencing and standard spatial finite differencing techniques are used. In particular, following an update of the component energies, the coupled continuity and momentum equations are solved simultaneously and implicitly by matrix inversion.

Results using SIMMER-II on a variety of problems have been obtained. In particular, a recent study examined the partition of energy within the reactor containment following a possible energetic core disassembly event, and work is in progress to assess the potential for recriticality, or the recompaction of fuel following an initial but modest degree of fuel dispersal.

The TRAC (Transient Reactor Analysis Code) Hydrodynamics

D. R. Liles, J. H. Mahaffy, and K. A. Williams, LASL

The Transient Reactor Analysis Code is an advanced best estimate system code for analyzing accidents in light water nuclear reactors. The talk will emphasize only the hydro-dynamic features of the code without describing the neutronics, heat transfer, or code structure.

The reactor vessel is described using a six-field equation, two-fluid model in cylindrical coordinates (fully three dimensional). Flow area blockages are permitted so that large-scale restrictions such as a downcomer wall can be explicitly modeled. The smaller-scale restrictions, such as fuel rod arrays, are treated using a porous matrix formulation.

The remainder of the system components (pumps, steam generators, piping, etc.) are modeled using a one-dimensional, five-field equation, drift-flux model. Any number of one-dimensional pipes can be connected anywhere within the vessel module with the restriction that no more than one connection per mesh cell exists.

The one- and three-dimensional field equations are approximated using a staggered finite difference mesh. The use of energy equations for both phases in conjunction with a thermodynamics package, which allows either phase to exist in a metastable state, permits complete thermal nonequilibrium. The drift terms (1-D) or added momentum equations (3-D) accommodate relative motion between the phases. A flow-regime-dependent constitutive package provides estimates of the necessary interfacial interaction terms.

A comparison of the TRAC results with experimental data will be shown.

Computer Modeling of Scale Formation in Geothermal Fluid Heat Exchange Equipment

T. J. Merson, R. C. Feber, W. J. Parkinson, and G. A. Baca, LASL

A computer program has been developed to predict scale deposition in heat exchangers using geothermal fluids. The program combines a chemical equilibrium calculation modified to simulate deposition rates with an engineering calculation of equipment performance.

The chemical equilibrium calculations are done in a subroutine based on a code by Ma and Shipman that has been modified to treat aqueous solutions. The amount of scale deposited is predicted by empirical rate models based on various parameters including the supersaturation of scale-forming precipitates as calculated in the equilibrium subroutine.

The engineering calculation assumes the heat exchanger to be divided into an arbitrary number of segments. The amount of scale predicted to be formed at the temperature, pressure, and fluid composition in each segment is applied to the exposed surface in that segment, and a degradation of heat exchanger performance is calculated.

Because chemical reactions are temperature dependent and degradation of equipment performance by scale affects the fluid temperatures, the coupling of engineering and chemical calculations permits a quasi-transient prediction of scale buildup during the life the equipment.

To date, primary emphasis has been on the modeling of a tube-and-shell heat exchanger in an experimental test facility at the Dow Chemical Company, Freeport, Texas. This facility adds scale-forming chemical species to diluted and heated salt dome brine and passes the simulated geothermal fluid through a series of instrumented tube-and-shell heat exchangers. A number of experiments have been run in this facility with varying chemical compositions and engineering parameters to provide data to test the computer model. Comparisons of predicted and experimental results have been encouraging.

Feed solution depositing silica and calcium carbonate are being emphasized at present. Extension to include sulfides of interest in geothermal fluids is planned.

COUPLEFLO - Formulation and Applications

P. R. Dawson and P. F. Chavez, SLA

COUPLEFLO is a two-dimensional finite element code for plane strain or axisymmetric analyses of thermomechanically coupled systems. It is capable of analyzing the creeping flow of non-Newtonian fluids or the secondary creep of solids. COUPLEFLO solves equations for conductive-convective heat transfer to determine the thermal response of a system. Thermomechanical coupling between the flow field and temperature distribution can exist in terms of temperature dependent material properties, temperature dependent body forces, viscous dissipation, material convection, and changing system geometry. Either transient or steady-state problems can be analyzed in Eulerian or quasi-Lagrangian reference frames. This presentation will focus on the equations for creeping flow and heat transfer solved by COUPLEFLO. Emphasis will be placed on the class of problems that can be analyzed using COUPLEFLO and the program features that are especially useful in the analysis of particular types of problems. Examples of the application of COUPLEFLO to several engineering applications will also be discussed. Applications to date include creep of geological materials resulting from thermally induced buoyancy, creep of mine room and pillar configurations accelerated by concurrent heating of the pillar material, and flow of metals during forming processes that generate large amounts of heat.

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