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Progress Report

MASTER

E-Division Semiannual Report

January 1--June 30, 1978

University of California

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E-Division Semiannual Report

January 1—June 30, 1978

P. W. Keaton
Division Leader

Compiled by
Patricia A. Kelley

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E-DIVISION SEMIANNUAL REPORT

January 1-June 30, 1978

Compiled by

Patricia A. Kelley

P. W. Keaton, Division Leader

ABSTRACT

We report the status of the programs and projects of the Electronics Division for the period of January through June 1978. The presentation is divided into three sections: Research, Engineering Support, and Technical Services. Each of these sections presents the activities and accomplishments of the corresponding branch within the Division. The primary goal of the Research and Development branch is to advance technology for future applications. The primary goal of the Engineering Support branch is to apply advanced technology to Los Alamos Scientific Laboratory (LASL) and material problems. The primary goal of the Technical Services branch is to provide a technical base and support for LASL programs. These goals are reflected in this report.

1. RESEARCH, P. W. KEATON, DIVISION LEADER

A. Detector Research and Development [Gruhn, E-10]

1. Introduction. Group E-10 does basic and developmental research on a variety of radiation detectors and materials for radiation detection. The work is applicable to a variety of programs including weapons, nuclear physics, high-energy physics, nuclear medicine, laser fusion, geothermal, nuclear safeguards, solar power, and environmental radiation detection.

2. Ionization Energy Loss of Relativistic Electrons in Thin Silicon Detectors. [Ogle, WPC-2; Goldstone, L-9; Gruhn, Maggiore, E-10]. The results of this experiment have been published in the May 8, 1976, issue of Physical Review Letters. The abstract follows:

We have measured the ionization loss of electrons with Lorentz factors $\gamma = 2.91$ and $1.6 \times 10^4 \leq \gamma < 10^5$ passing through a $(100.71 \pm 0.15)\text{-}\mu\text{m}$ silicon detector. Our results are in agreement with accepted theory for $\gamma = 1.6 \times 10^4$; however, for

$\gamma \leq 3 \times 10^4$; our results are systematically $(7 \pm 2)\%$ below the theoretical value. We suggest an explanation in terms of the finite detector thickness and a relativistic effect.

3. Design Considerations for a 70- to 140-MeV Gamma Ray Liquid Xe Shower Counter [Gruhn, E-10]. Present alternatives¹ in high-energy photon detection are limited in either efficiency or resolution. Resolutions of 1-MeV FWHM at 130 MeV with an acceptance of $\sim 10^{-4}$ and a conversion efficiency $\sim 2\%$ are achieved utilizing pair spectrometers. Resolutions of 6.2 MeV and 100% conversion efficiencies have been achieved with NaI at similar photon energies. The purpose of these design considerations is to determine the conditions where a liquid Xe shower counter can be used to achieve resolutions equal to or better than the pair spectrometer with a conversion efficiency similar to NaI.

Using the Monte Carlo cascade simulation tables of Messel and Crawford,² we are able to characterize the development of the shower in the liquid Xe.

Fig. 1. The energy deposit per radiation length as a function of depth for forward-going particles for an incident photon energy of 100 MeV.

Figure 1 shows the energy deposit per radiation length (2.31 cm for liquid Xe) as a function of Xe depth in radiation lengths for forward-going particles at an incident photon energy of 100 MeV. Figures 2 and 3 show the specific energy deposit of backward-going photons and electrons, respectively. Figure 4 shows the distribution of the mean number of electrons and photons in the shower.

The data³ shown in Fig. 4 were taken with a liquid Xe bubble chamber with incident photon energies of 80 ± 12 MeV. Since the cascade calculations were done for lead, these data are taken as confirmation of B. Rossi's approximation A. The integral of the radial distribution of the mean number of particles with respect to the cascade core is given in Fig. 5. Integrating from the tail of the shower in Fig. 1, we see that a mean energy of 1 MeV escapes beyond 24 radiation lengths. The initiation of the shower has a jitter in position of 1.87 rad-

iation lengths. This jitter is expected to have a correlated jitter in the tail that, because of energy escape, will limit the resolution of the detector. At 100-MeV photon energy we estimate this contribution to the resolution to be given by

$$\frac{\Delta E}{E} = e^{-.23X_D(r.l.)} \quad (1)$$

where X_D is the detector thickness in radiation length. A plot of Eq. (1) is shown in Fig. 6. This plot indicates that a major contribution to the NaI resolution is due to shower leakage.¹ The advantage of the liquid Xe then is that larger detector geometries can be achieved.

In Fig. 5 we can see that the incident direction of the photon can be established to about 10^{-2} rad by establishing a core axis orientation. This requires registering the core position at $t = 2$ and $t = 10$ radiation lengths.

Fig. 2. The specific energy deposit for backward-going photons.

Fig. 3. The specific energy deposit for backward-going electrons.

Fig. 4. The distribution of the mean number of electrons and photons in the shower.

Fig. 5. The integral of the radial distribution of the mean number of particles with respect to the cascade core.

Fig. 6. The contribution of energy escape fluctuations to the resolution as a function of detector thickness, X_D (r.l.)

a. Multielectrode Shower Counter Design. A conical volume (~ 190 L) of liquid Xe filled uniformly with electrodes as indicated in Fig. 7 is assumed. Let us also assume N_0 gaps per radiation length and a total detector thickness of X_d (radiation lengths). Following Radek⁴ and assuming a

Fig. 7. Electrode geometry for conical liquid Xe 70- to 140-MeV photo shower detector.

filter time constant that scales inversely with N_0 , we find for the equivalent noise charge ENC for liquid Xe

$$ENC = 1.00(n_0 C_D)^{1/2} \text{ rms electrons} \quad , \quad (2)$$

where C_D is the detector capacitance. For this conical design

$$C_D = \frac{C_0}{n_1} (n_0 X_D)^3 \quad , \quad (3)$$

where $C_0 = 0.381$ pF. We then are able to show

$$\Delta E (\text{MeV, FWHM}) = 2.89(n_0 X_D)^{3/2} \text{ keV} \quad , \quad (4)$$

for the conical detector.

If one then takes the square root of the sum of the squares of Eqs. (1) and (4), we find the net resolution as a function of detector thickness and electrode spacing. This is shown in Fig. 8.

The filter time constant is given by

$$\lambda = \frac{10}{n_0} \mu s \quad . \quad (5)$$

Because of the relatively long time required to process the signal, this detector is expected to be more sensitive to backgrounds.

b. Few-Electrode Shower Counter Design. In Fig. 9 a detector design with a net detector capacitance of less than 100 pF is shown. An electronic resolution of less than 1000 electrons (FWHM) can be achieved using standard charge-sensitive preamplifiers. The goal would be to filter the current signal to a fraction of the total drift time, thereby minimizing the fluctuations in leakage out of the sides of the detector. The resolution is then estimated to be approximately

$$\frac{\Delta E}{E} = \frac{22.6 \times 10^{-3}}{E(\text{MeV}) \Delta t / t_0} \quad , \quad (6)$$

Fig. 8. Energy resolution of 100-MeV photon shower detector as a function of detector thickness, $X_D(r.l.)$.

where $\Delta t/t_0$ is the fractional time when the current signal is integrated,

$$\frac{\Delta E}{E} = 5 \times 10^{-3} \quad , \quad (7)$$

for

$$\frac{\Delta t}{t_0} = \frac{1}{25} \text{ at } 100 \text{ MeV} \quad . \quad (8)$$

Fig. 9. Electrode geometry in the few-electrode shower counter design.

The integration time would be approximately $10 \mu s$. The length of the current signal would be used to locate the core of the shower. This design is simpler and offers the possibility of slightly better resolution over the multielectrode design. The resolution to first order is independent of small amounts of electron scavenging by oxygen.

4. Development and Use of a Liquid Ar Detector for Relativistic Heavy Ions [DeVries, P-7; Flynn, P-7; Gruhn, E-10, Hendrie, Van Bibber, LBL]. A proposal has been submitted and approved for time on the BEVALAC to test a new concept in liquid Ar charged-particle detectors. Some of the design and physical properties of this detector are discussed below. The basic design goal of this detector is to achieve energy measurements with a resolution (FWHM) of 2000^{-1} for particles with ranges between 1 and 15 cm in liquid Ar. In addition, some particle identification information is expected to be achieved by following the signal along the Bragg curve.

In Fig. 10 we show an artist's schematic of the heavy ion detector. The design will be consistent with ultrahigh vacuum techniques. The dewar and feedthroughs will be constructed of stainless steel,⁵ and metal seals will be used throughout. The thin windows will consist of 76- μm Kapton. The questions of charge collection from the region of the window remain to be addressed. The electrons from the ionization in the track drift across a 4-cm drift space through a double screening grid. The electrons then drift from the grid to a multiple anode, which is designed to sample the signal along the Bragg curve. A sapphire window, placed beyond the range of the particles, will be viewed by a photomultiplier tube. This photomultiplier will

Fig. 10. An artist's schematic of the heavy ion detector.

produce a signal from the scintillations and Cerenkov light along the track. The signal, expected to be prompt, will start a clock that will measure the drift time of the electrons to the grid. The drift time information will allow first-order corrections for those contributions to the resolution associated with geometry. These contributions are related to both electron scavenging effects and grid screening inefficiencies.

In Fig. 11 we show the fractional change in signal per centimeter of drift due to electron scavenging by oxygen in liquid Ar.⁶ From Fig. 11 we see that an oxygen relative concentration less than 1 ppb is required. In order to achieve this purity, we are designing the system to have an effective wall outgassing rate of less than 10^{-10} torr $\ell/\text{cm}^2\text{s}$.

The ionization density along the track of a heavy ion is relatively high and recombination of the electrons and ions is expected to dominate the response of the detector. In the next few paragraphs we discuss the effects of recombination on the signal.

The recombination rates for electrons and ions are expected to be described by the following equation

$$\frac{dn^+}{dt} = \frac{dn^-}{dt} = -\alpha n^+ n^- \quad (9)$$

where α is the recombination coefficient, n^+ is the density of positive ions, and n^- is the density of electrons.

Note Eq. (9) neglects the effects due to diffusion. We write

$$n^+ = n^- = N$$

where N is the plasma density and

$$\frac{dN}{dt} = -\alpha N^2 \quad (10)$$

The dependence of the probability for surviving recombination on the initial plasma density is found by solving Eq. (10).

$$P(N_0) = \frac{N(t)}{N_0} = \frac{1}{1 + \alpha t N_0} \quad (11)$$

Fig. 11. The fractional change in signal per centimeter of drift due to electron scavenging by oxygen in liquid Ar as a function of oxygen concentration.

where t is an effective time for crossing the plasma and to first-order accounts for the neglect of considering diffusion effects.

N_0 is the initial plasma density. The plasma density can be related to the stopping power of the ion by the expression

$$N_0 = \frac{1}{\epsilon} \frac{dE}{dx} \cdot \frac{1}{A}, \quad (12)$$

where A is an effective track area and ϵ is 22.6 eV/ion pair, then

$$P\left(\frac{dE}{dx}\right) = \frac{1}{1 + \frac{\alpha t}{\epsilon A} \cdot \frac{dE}{dx}}. \quad (13)$$

The signal per unit length of track is then given by

$$\frac{\Delta S}{\Delta x} = P(dE/dx) \cdot \frac{dE}{dx} \cdot \frac{1}{\epsilon}. \quad (14)$$

or

$$\frac{\Delta S}{\Delta x} = \frac{1}{\epsilon} \frac{dE}{dx} \cdot \frac{1}{1 + \frac{\alpha t}{A\epsilon} \cdot \frac{dE}{dx}}. \quad (15)$$

It is useful to inspect the case of extreme ionization density. In this case $P \rightarrow 0$ and

$$\frac{\Delta S}{\Delta x} \rightarrow \frac{A}{\alpha t}. \quad (16)$$

In this limit the signal becomes independent of ionization density or dE/dx .

This has the interesting result that the total signal,

$$S = \frac{A}{\alpha \cdot t} \cdot R(E), \quad (17)$$

where R is the range of the particle. This response is very similar to that found for scintillators.⁷

If we assume $A/\alpha \cdot t$ scales with the Z of the particle as it does in the case of scintillators and use the recombination data of Gruhn and Edmiston,⁸ we can then predict the response of this detector to various heavy ions.

In Fig. 12 we show the signal-per-unit path length in electrons/centimeter as a function of the stopping power of the heavy ion, dE/dx (MeV/cm).

Note the saturation of the signal for the highest values of dE/dx for each ion. Note also that the effects of recombination for a fixed dE/dx is least for the heaviest ions. This latter effect results from the assumption that $A/\alpha \cdot t$ scales with Z . A similar effect is observed in the case of the scintillators.⁷

In Fig. 13 we plot the total signal in electrons as a function of particle kinetic energy. The response is seen to be nonlinear near the end of the range of the particle. The charge loss due to recombination is greatest for the heaviest ions and is field dependent. The statistics of these charge losses are not expected to compromise the design goal of a resolution of 2000^{-1} .

5. Recombination of Alpha-Excited Carriers In Liquid Ar [Edmiston, Gruhn, E-10]. We are continuing our recombination studies⁸ by looking at the free-carrier yields in liquid Ar as a function

Fig. 12. The signal-per-unit path length as a function of the stopping power.

Fig. 13. The total signal as a function of particle kinetic energy.

of temperature from 86 K to 96 K. Our data show that recombination of carriers excited by ~ 5 -MeV α particles is independent of temperature over this 10° span. This result was unexpected; therefore, several precautions were taken to assure the data validity.

The free-carrier yield is measured in a parallel-plate ionization chamber of 1.9-cm-diam disks spaced 0.25 cm apart. The α source is ^{241}Am deposited on the cathode ($0.01 \mu\text{Ci}$, 4-mm diam). The liquid Ar is pure to within 1 part in 10^8 O impurity.⁵ The temperature is measured with two copper-constantan thermocouples and by monitoring the pressure. The two thermocouples, about 1 cm from the ionization cell, are on opposite sides. The thermocouple and pressure measurements present temperature agreement to within 1° . The thermocouple placement also allows us to rule out gradients. Data acquisition is computer controlled. The computer controls the electric field, the acquisition time at each field, a waiting period with zero field so the dielectric can relax,⁸ and peak centroid fitting. Therefore, these parameters do not change between 86 K and 96 K runs. The preamplifier and associated electronics are not "touched" between the 86 K and 96 K runs.

A set of data is shown in Fig. 14 for runs at 86 K and 96 K. The 2% difference at the higher fields is statistically insignificant. We estimate

our relative errors to be about 2% and our absolute errors to be about 5%. On a given day the 86 K and 96 K data always agree within 2%.

In our previous work⁸ we presented evidence that the recombination at 84 K follows the geminate recombination theory of Onsager. This theory predicts the free-carrier yield to be

$$G_\infty(E) = \phi_0 [\exp(-r_{kT}/r_0)] [1 + (e^3/2\epsilon_k T^2)E] \quad (18)$$

This equation should be valid for fields below 7 kV/cm and is explained further in our earlier paper.⁸ It is important to remember that this equation accounts for the neutralization of an isolated pair at $t = \infty$. Both conditions are not realized in this experiment. A more precise accounting of the neutralization in the Onsager model is found using the "method of prescribed diffusion" by Mozumder.⁹ A lack of temperature dependence is predicted in the latter model for a particular time after the initiation of the neutralization process. Such a prediction is not made in a columnar recombination model. The simple Onsager prediction is shown by curve A in Fig. 14.

Fig. 14. Observed charge vs electric field for α particles from ^{241}Am in liquid Ar at 86 K and 96 K. Line A is the low-field Onsager prediction at 86 K and line B is the prediction at 96 K.

6. Development of a High-Pressure Test Chamber for Liquid Ar Studies [Edmiston, Gruhn, E-10]. As our studies of liquid Ar as an ionization chamber medium^{5,10} continue, we would like to take data over a wide temperature range. In order to study liquid Ar over the entire liquid-state temperature range, we must work at pressures up to 50 atm¹¹ as shown in Fig. 15. Our present Ar dewar is safe to 20.7 N/cm² (30 psig) or about 30.8 N/cm² (3 atm) absolute.

We have designed and constructed a high-pressure Ar chamber to operate up to 50 atm. The design incorporates two chambers, one inside the other. The inner chamber is highly pressurized for containment of the liquid Ar. It contains a small parallel-plate ionization cell, two thermocouples, a capacitive level sensor, and electrical feedthroughs. It is 304-series stainless steel with an 11.4-cm conflat-flange lid. It has been tested by LASL Groups WX-1 and WX-5 up to 100 atm. The outer chamber, a commercial dewar safe to 3 atm absolute, contains a suitable refrigerant. We chose Freon-13 for the refrigerant because it is nontoxic, nonflammable, and has a low vapor pressure over the temperature range of interest. The Freon-13 is cooled by a flow of liquid N through a copper coil. Two thermocouples in the Freon-13 monitor the temperature. Figure 16 is a diagram of the system.

The operating sequence begins with condensing Freon-13 and cooling it to about 90 K. Then we condense the Ar. The Freon-13 dewar holds about 3 L.

Fig. 15. Vapor-pressure curve for liquid Ar.

Fig. 16. High-pressure liquid Ar ionization chamber.

This heat capacity, coupled with the dewar insulation, allows us to keep the Ar temperature fairly stable (within 1° for 5 to 10 min). This system does not employ a recirculating Ar purification technique, as is employed in our low-pressure system.⁵ Thus, it is not designed to keep the Ar pure for long periods of time.

We have not yet collected Ar data. However, we have collected data that show that the system will operate over the desired temperature range. The Ar will remain pure for about 1 day, the Freon lifetime is several weeks, and the dirty Ar can be replaced with clean Ar in about 2 h. Thus, the system is operable and we can take Ar data.

7. Splitting of the Si Free-Exciton Ground State [Hammond, E-10; Silver, T-11]. The lowest lying electronically excited state of pure crystalline Si is the free exciton (FE) state. This state consists of an electron and a hole bound together by their coulomb attraction into a H-like state. The electron and hole have a binding energy of ~14.1 MeV.¹² It was predicted¹³ in 1960 that this state was split into twofold degenerate states, Δ_6 and Δ_7 , due to the interaction of the hole at $K = 0$ with the anisotropic charge density of the electron in the conduction band. The first experimental evidence for this splitting was reported¹⁴ in 1975 and more recently¹⁵⁻¹⁷ has been measured to be 0.4 ± 0.1

MeV, 0.35 ± 0.05 MeV, and 0.29 ± 0.05 MeV by three different techniques. We have improved the first method to make an accurate measurement of this FE ground-state splitting in Si.

The strong FE recombination luminescence in Si consists of four lines, only two of which have been spectroscopically resolved. These lines are due to recombination from the Δ_6 and Δ_7 states with TO phonon assist and recombination from the Δ_6 and Δ_7 states with LO phonon assist. The two lines observed spectroscopically are the TO and LO phonon replicas. Each replica contains the Δ_6 and Δ_7 luminescence lines. The luminescence line shape for FE has intensity¹⁸

$$I(E) \propto (E - E_X)^{1/2} \exp[-(E - E_X)/KT] \quad (19)$$

where E_X is the exciton binding energy. Because the relative occupation of the Δ_6 and Δ_7 states varies in a Boltzmann distribution with temperature, and because the recombination rates $R_L^6, R_L^7, R_T^6, R_T^7$ are different, the relative strengths of the LO and TO phonon replicas vary with temperature. This temperature dependence reflects the ground-state splitting ΔE . Detailed line fits of the FE luminescence from 1.6 K to 10 K have yielded an accurate measure of the FE ground-state splitting in Si of 0.31 ± 0.03 MeV. These fits have also yielded values for the transition rates. Figure 17 shows

fig. 17. Line fits are shown to LO and TO phonon-assisted FE luminescence spectra in Si. The solid lines (histograms) are the data and the dotted lines are the calculation. The fits show excellent agreement with the model and indicate a ground-state splitting of 0.31 MeV.

line fits at two temperatures. A paper reporting this work has been submitted to Solid State Commun.

8. Electron-Hole Liquid Phase Diagram in Si [Hammond, E-10 and Silver, T-11]. In Si at temperatures 27 K, high densities of nonequilibrium electrons and holes can condense into metallic electron-hole droplets (EHD). This is a first-order phase transition and follows a gas-liquid phase diagram completely analogous to those used in the study of gases. When the "gas" of nonequilibrium electrons and holes reaches a threshold density, condensation occurs. The liquid appears in droplets with a much higher density. The droplet density side of the phase diagram for Si has been measured.^{19,20} We intend to measure the gas side of the Si phase diagram and at the same time test nucleation theories of EHD formation and measure the EHD surface tension.

To determine the shape of the gas phase side of the gas-liquid phase diagram we measure the laser pumping threshold for EHD formation. In this manner we cannot determine the absolute density of the gas, but the relative densities at threshold, and thus the shape of the phase diagram. It is expected from nucleation theory that the up-and-down threshold densities will be different. The comparison between these different thresholds will give a measure of the EHD droplet surface tension in Si.

Figure 18 is a measurement of the up-going laser pump threshold for EHD formation in Si at 10 K and 15 K. The ratio of intensities of the FE line at 1.13 μm and the EHD line at 1.147 μm is plotted vs pump power. This is done because the EHD line has a small background due to FE emission. Thus, as long as no EHDs are present, the ratio is a constant. The break in the curve occurs at the threshold pump power. The plots show that the threshold exciton density for EHD formation is 5.75 times higher at 15 K than at 10 K.

9. Thermopower Position Sensor [Hammond, Gruhn, E-10]. Group E-10 has developed a large-area position-sensing Si detector that is now being used for beam alignment at the L-1 eight-beam laser facility. This detector concept has much wider possible applications. Its operation depends only on the production of local heat by a particle or photon beam and the thermal voltages (Seebeck effect) thus produced in the detector material. Any material

Fig. 18. Laser power is plotted vs the ratio of EHD to FE luminescence intensity. The break point in the plot (where the ratio starts to rise above its initially constant value) corresponds to the threshold for nucleation of EHDs. Data at 10 K and 15 K are shown. The thresholds occur at 4 units and 23 units, respectively.

that displays a Seebeck effect and to which electrical contact can be made could be used as a position sensor. Silicon is an ideal material for this application because of its high thermopower, availability, and technology. Other materials, such as diamond, which has a much higher thermopower, could be used in this application also.

The properties of the thermopower sensor have been studied in detail in a two-electrode configuration on a 7.6-cm single-crystal Si wafer. The basic materials used for these detectors were 380- μ m thick, 16 Ω -cm, p-type, 7.6-cm Si wafers with one side polished and etched. Two circular Al alloyed contacts 4.5 cm apart and 0.5 cm in diameter were formed on the etched surface. The back surface was covered with a thin coating of broadband-absorbing black paint. The painted surface of the wafer was illuminated with an ~ 1 -W continuous-wave CO_2 laser through a conventional camera shutter and with the beam defocused by a spherical Cu mirror to ~ 1.27 -cm diam. The pulse energy was measured through a Ge beam splitter with a joule meter. The voltages at the two alloyed contacts were put through a differential amplifier. The amplified differential voltage signal was then put into an oscilloscope and recorded on film. Figure 19 shows the structure of the detector used to collect the data shown in Figs. 20, 21, and 22.

We achieve excellent agreement with our measurements if we assume that the Si detector is thermally isolated except for being weakly tied to the

room-temperature atmosphere. We also assume that the wafer has large radial extent (a good assumption when the contacts are not near the edges of the wafer). We assume that the gaussian laser beam strikes the wafer producing a gaussian thermal profile. The heat then propagates radially outward at a rate determined by the diffusion equation

$$\frac{\delta f}{\delta t} = \kappa \left(\frac{\delta^2 f}{\delta r^2} + \frac{1}{r} \frac{\delta f}{\delta r} \right) ; \quad (20)$$

with a gaussian incident beam, a gaussian is an exact solution to this equation

$$f(r, t) = \Delta T(r, t) = \frac{E}{4CdK\pi} \frac{e^{-r^2/4Kt}}{t} , \quad (21)$$

Fig. 19. Two possible voltage signals from this 2-contact Si detector are V_{x+} and V_{x-} . The ohmic contacts are alloyed Al. The wafer's side exposed to the laser is thinly coated with a broadband-absorbing black paint. The signal we measure is $V_{x+} - V_{x-}$.

Fig. 20. Time response of thermopower detector.

where E = energy deposited by the beam,
 C = specific heat of material,
 d = thickness of material, and
 K = thermal diffusivity of material.

Hence, the contact that is closer to the incident beam receives a higher temperature and thus a higher voltage than the further contact. The magnitude and time response of the signal may be written:

$$V = \frac{SE}{4\pi C d K} \left\{ \frac{e^{-x^2/4Kt}}{t} - \frac{e^{-(l-x)^2/4Kt}}{t} \right\}, \quad (22)$$

where S = thermopower of material and
 l = electrode spacing.

Fig. 21. For a 2.54-cm-diam beam, 100 μ s in duration, 100 mJ in energy, the peak voltage signal $V_{x+} - V_{x-}$ is plotted for different beam positions along the x-axis. The voltage signal is linear in position as expected.

Figures 20 through 22 show the excellent agreement of this model with the measured detector response. Using this model, it is simple to design a four-electrode position sensor that yields signals proportional to the x and y positions independent of beam energy and only weakly dependent on beam size. Computer simulations have demonstrated the feasibility of this approach.

Since the detector we have described requires only heat production and development of subsequent thermal voltages for its operation, any material that displays a Seebeck effect and to which electrical contact can be made may be used in a detector. Silicon is an obvious choice because of its extremely high thermopower and the high technology associated with this material. Single-crystal Si wafers, 12.7 cm in diameter, are readily available commercially. Silicon is also an obvious choice for high-energy laser applications because of its very

Fig. 22. Energy dependence of signal peak (1-ns pulse).

high laser damage threshold ($\geq 10^9$ w/cm² at 10.6 μ m). For high-power density applications, the black paint may be discarded and the Si doped to absorb the radiation itself. For even higher power density applications, the Si may be coated with a thin film of Cu or Ag. Although only $\sim 1\%$ of the energy would be absorbed, this could be more than sufficient to produce usable signals. It is also worthwhile noting that if the Si detector temperature can be lowered, thermopower increases as great as three orders of magnitude²¹ may be achieved. Great sensitivity can thus be achieved by cooling. Also, although we have used this device thus far in pulsed beam mode only, it could certainly be used in continuous-wave applications. In this application the signal would be dc. Finally, the detector sensitivity is inversely proportional to the square of the electrode spacing. Thus, for small detectors extremely high resolution could be achieved. Positioning laser beams with submicron resolution can easily be imagined.

10. Laser Scanner [Stollar, Maggiore, E-10]. A dual-wavelength scanning laser system has been developed to provide nondestructive mapping of optical interactions in semiconductor devices. A test sample is scanned with 6328 Å or 1.15- μ m wavelength light. Signals from the sample itself, reflected light, or transmitted light are used singly or in combination to provide sample information. The signals are displayed on an oscilloscope or on a television. The system is composed of three sections: optics, electronics, and display. The optics section has been aligned. The electronics section required that portions of the preamplifier be rewired and the addition of voltage regulators to the mixer power supplies to minimize 60-cycle noise. The TV display functions properly although it produces a small amount of 15-kHz noise. The microscope magnification varies from 7.5X to 250X. The scanning spot size varies from 133- μ m diam at 7.5X to 4- μ m diam at 250X for a 1-mm spot diameter at the exit pupil point of the microscope. Under optimum conditions, the spot diameter at the exit pupil point can be reduced to 0.6 mm. Then the spot size scanning the sample varies from 80 μ m at 7.5X to 2.4 μ m at 250X. The maximum diameter of the scan at 7.5X is 6 mm and 180 μ m at 250X. The resolution of the scanner is better than 2 μ m with 6328 Å and 4 μ m

with 1.15- μ m light. Scanning of large (3-cm-diam) samples without the microscope has not yet been fully developed. The operation and performance of this scanner will be compared to the National Bureau of Standards (NBS) scanner in June.

11. Pyroelectric Detectors [Stollar, E-10]. An effort to develop pyroelectric detectors for use at high power levels has been funded by Group L-9. A pyroelectric detector is a thermal sensor whose operation is shown in Fig. 23. The equivalent circuit is shown in Fig. 24. Note that a signal is proportional to a change in temperature, not the absolute value of the initial or final temperatures. The pyroelectric materials of primary interest for use at 10.6 μ m are strontium barium niobate (SBN) with a strontium-to-barium ratio of 1 (otherwise known as 50/50 SBN or $\text{Sr}_{0.5}\text{Ba}_{0.5}\text{Nb}_2\text{O}_6$), and lithium tantalate (LiTaO_3). Other materials include lanthanum-doped lead zirconate (PLZT) and polyvinyl fluoride films (PVF). Areas of interest in this program are on the following page.

(a) At temperature T_0 , the polarized pyroelectric material is in equilibrium with a finite internal electric field. There is no current flow.

(b) During a heat pulse that changes the temperature from T_0 to $T_0 + \Delta T$, the polarization changes due to the change in the lattice spacing. This change in polarization yields a displacement current observed by the ammeter.

Fig. 23. The pyroelectric detector.

Fig. 24. The equivalent circuit of a pyroelectric detector. I_p is the current generator, C_p is the detector chip capacitance, R_p is the detector resistance, R_L is the load resistance, and C_L is the load capacitance: $R_p \gg R_L$.

Fabrication

- Hardware (impedance matching)
- Mounting (epoxies, substrates, etc.)
- Geometry (size and position of the chip)
- Material (SBN, LiTaO_3 , etc.)
- Chip preparation (cutting and polishing)

Performance

- Damage threshold and its relationship to chip preparation and mounting
- Stability and repeatability of a single device
- Interchangeability
- Speed of response (improve and control)
- Responsiveness (sensitivity)

Three prototypes have been fabricated from Crystal Technology 50/50 SBN with performance similar to Molelectron commercial P5-00 detectors. As the latter do not perform in accordance with Molelectron published figures (which are based on calculations using material parameters taken from the literature), the first step has been to measure the dielectric constant, Curie temperature, resistivity, and pyroelectric coefficient of the SBN material and use these values to calculate the performance. The subsequent expected performance agrees with the actual performance of the Molelectron detector within 2%. Comparison of the expected performance and the actual performances of the prototypes is in progress.

12. Ion Microprobe Facility [Maggiore, E-10; Keaton, E-D0; Nachamkin, E-DOR; Tesmer, P-9]. The major design work for the nuclear microprobe facility using the P-9 Van de Graaff accelerator has been completed; fabrication and assembly have begun. Detailed beam optics calculations²² for the trajec-

tories of charged particles in a superconducting solenoid have been made and a magnet has been specified and ordered. The magnet specified for the final lens has a room temperature bore 1 cm in diameter. The magnet length is 5 cm and it has a maximum field on axis of 81 271 gauss at its design current of 75 A. The characteristics of the 3-segment magnet are given in Table I. The chromatic aberration coefficient for 4-MeV protons is calculated to be 6.6 cm. The spherical aberration coefficient has been calculated to be 8.4 cm. The bid from Inter-magnetics General Corp. was accepted and delivery is expected in August.

The beam line up to the first microcollimator has been assembled and tested. A turbomolecular pump is used to maintain the vacuum in the beam line at $< 8 \times 10^{-7}$ when open to the accelerator. Total beam transmission of 86% has been obtained through the 203-cm energy analysis magnet and beam transport system. A quadrant detector in front of the differential pumping port located after the quadrupole triplet locates the beam at this point but is not able to indicate whether proper focus and alignment have been obtained. Alternative alignment procedures are being considered.

A 0.91- by 1.2- by 1.5-m concrete shielding block has been moved into location for mounting the experiment. It is isolated from the floor by a multiple wood, felt, and rubber pad. Vibration measurements made before installation of the beam pipe indicate that the isolation from the floor should be adequate.

The jaws for the microcollimators have been fabricated, but examination of the edges with an SEM indicated that there may be uniformity problems. The micromachining process appears to leave a rolled-over gold edge with a step 0.5- μm deep. This

TABLE I
CHARACTERISTICS OF THE 3-SEGMENT MAGNET

	Section I Innermost Section	Section II Center Section	Section III Outermost Section
Section width (cm)	5.0	5.0	5.0
Section i.d. (cm)	5.0	11.5	19.3
Section o.d. (cm)	11.5	19.3	31.6
Current density (A/cm^2)	1.01×10^4	1.43×10^4	2.46×10^4
Maximum field-on-winding (Oe)	87 212	72 796	56 119

deviation from the ideal wedge geometry may reduce the beam to halo ratio by a factor of 2.

The specimen chamber piezoelectric drivers for specimen motion and control circuits for the micro-collimators are expected to be delivered within the next 2 months.

B. Electronic Temperature Monitoring and Identification for Livestock (USDA/H-6) [Bobbett, E-4; Koelle, E-5; Landt, E-DOR; Salazar, E-2]

The US Department of Agriculture (USDA) and the Department of Energy (DOE) have been supporting an electronic identification and temperature-monitoring project at Los Alamos Scientific Laboratory (LASL) since early 1973. The development indicates that a subdermally implanted, electronic transponder with no batteries can be remotely activated and will transmit temperature and identification information to a receiver in a few tenths of a second. Development of this electronic identification and temperature-monitoring system into a commercially available product line will enable the cattle industry to carry out more extensive management control practices.

1. Background. In 1971 LASL began work for the Animal and Plant Health Inspection Services (APHIS) branch of the USDA. The inadequacy of animal identification systems at that time was a very important problem in disease control, and LASL scientists were asked to consider ways of improving identification. Many concepts were considered, such as magnetic-tape ear tags, battery-powered transmitters, color-coded ear tags, implanted capsules with stable or radioactive isotopes, laser branding, cryogenic branding, solar-powered electronic transmitters, and resonant antenna backscatter from a radar beam.

In the winter of 1972, LASL scientists were asked to consider the possibility of passively monitoring the temperatures of animals during ante mortem inspection at slaughterhouses. In considering this problem, a remote temperature-monitoring system was envisioned using encoded microwave backscatter from a fixed-frequency interrogator. It soon became apparent that identification numbers could also be encoded on the temperature signal. Thus, a combination of animal identification and temperature monitoring seemed possible, and work was started to determine the technical feasibility of

the concept. The first step was to demonstrate the feasibility of a passive remote transponder having both identification and temperature. No effort was made to optimize the circuitry or to include the full number of digits that might be required. This stage was accomplished in the fall of 1973, and the equipment was demonstrated at the US Animal Health Association (USAHA) meeting in St. Louis. The next step was to develop a temperature-only monitoring transponder, which would function under the skin without batteries. It was soon found that animal tissue presented significant problems in powering an implanted transponder and obtaining a valid return signal. Solving these problems required the development of new antennas and new circuits for extracting energy from the interrogating beam. A very important consideration was the necessity of powering the transponder with an interrogating beam whose intensity was within acceptable biological nonionizing radiation standards. A demonstration of the subdermally implanted, temperature-only indicating transponder was accomplished in September 1975. A second unit implanted in November 1975 was still functioning in May 1977. In July 1977 the transponder of the second unit ceased returning temperature data. The unit is still implanted in order to determine long-term biological effects.

In December 1975 a system for passively monitoring the temperature of six cows was installed at the National Animal Disease Laboratory at Ames, Iowa, under the supervision of Dr. Gary Seawright (currently with H-6). This experiment suggested that an animal's subdermal temperature changes with even minor stresses. These animals are periodically subjected to interrogation and observed. There is no evidence of degradation or biological incompatibility.

An informal report, LA-6725-MS, on the Model 75 temperature-only system was published in February 1977 and a progress report, LA-6812-PR, on the Model 76 temperature and identification system was published in July 1977.

Two implants have been rejected within 5 months of implantation in one animal. The rejections are apparently not due to any immunological causes but rather appear to be due to a pressure necrosis phenomenon. Another animal has rejected one of the longer (13-cm) transponders also. To lessen the

pressure necrosis problem, we are investigating a different transponder shape.

Transponder antenna performance was improved by connecting the antenna to the transponder electronics via a one-quarter wavelength of 100- Ω coaxial cable. The interrogation range was doubled to 3.5 m for a given power level. This achievement was demonstrated to USDA/APHIS representatives in November during a program review of this project.

2. Current Activities. The plans for this fiscal year called for the preparation and execution of a large-scale field test to measure the performance of commercial equipment in a real environment (for example, dairy, feed lot, research environment). This approach would aid technology transfer while simultaneously encouraging the development of a system that would satisfy the needs of a national livestock electronic identification system.

Considerable effort has been expended preparing for the field tests. The first order of business was to locate potentially interested manufacturers and then determine if they were qualified to develop a national system. A "research and development sources sought" advertisement was placed in the January 13, 1978, issue of the Commerce Business Daily to locate potential manufacturers. Approximately 6 of the more than 18 respondees have the required potential. We developed a set of operational (functional) and technical specifications for review by the National Livestock Electronic Identification Board (NLEIB) patterned after our system. These specifications will also be reviewed by prospective manufacturers in order that they may input technological, production, and economic tradeoffs as appropriate.

An improved digital encoding scheme has been developed by A. Koelle, E-5. This should lessen the complexity of the receiver decoding logic, and thus lower the manufacturing costs. He will breadboard this concept to demonstrate the feasibility. A simplification in the rf section of the interrogator-receiver, demonstrated by J. Landt, will also result in a cost savings.

The Office of Telecommunications Policy (OTP), the Spectrum Planning Subcommittee (SPS), and the Federal Communications Commission (FCC) have been approached with a request through Group E-1 for the appropriate rf licensing so that we can operate the

identification system outside Los Alamos. We hope to obtain a frequency that will also apply to future commercial systems. As part of the license petitioning process, we will have to conduct interference tests near installations that use frequencies near the proposed identification system. This effort has required the purchase of some capital equipment.

3. Future Efforts. We will continue working with the NLEIB, FCC, manufacturers, users, and Congress to develop commercial equipment for national systems. We will purchase two sets of best available equipment to start field testing and we will construct a second small interrogator-receiver in the 915-MHz range.

4. Public Relations. In order to demonstrate to the cattle industry and prospective manufacturers that a small identification system is feasible, we designed and constructed a 2-kg, 7.5- by 15- by 24-cm hand-held minisystem that will radiate 4 W of power. A system that will radiate 50 W of power will require an auxiliary package that will be approximately the same size and weight of the hand-held interrogator-receiver.

We submitted an entry to the annual Industrial Research 100 Awards for Innovation competition in February.

5. Science Hall Exhibit. As a result of the technical achievements of the "Electronic Temperature Monitoring and Identification for Livestock" project, Robert Brashear, Group PUB-2, has requested a working system for Science Hall exhibition. The "Model 76" backpack unit has been modified and delivered to PUB-2. This unit will provide reliable operation at 915 MHz and requires no special licensing for use in the Science Hall. To support the Model 76 backpack interrogator, several room-temperature transponders and specialized transponder antennas have been built. An additional remote display unit was also constructed. Several models, purchased to house the transponders, illustrate the potential of electronic identification for a variety of applications. Brashear is proceeding with construction of a display case and E Division will continue to support this effort as the components are assembled into a working electronic identification demonstration.

6. Patents. Patent No. 4 075 632 was awarded to Howard A. Baldwin, Steven W. Depp, Alfred R. Koelle, and Robert W. Freyman for an interrogation and detection system.

C. Active Telemetry Transmitters for Animal Temperature Monitoring (H-6) [Koelle, E-5]

Group H-6 has been involved in monitoring cattle temperature, using "active" (battery-powered) sensor-transmitter devices that monitor the animal's temperature by means of a thermistor probe inserted into the ear canal. Such measurements offer a convenient and nonintrusive means of monitoring the animal's physiological state. Expansion of LASL's capability for making such measurements is needed in conjunction with the upcoming field tests of the Passive Electronic Identification and Temperature-Monitoring System, to be performed under USDA sponsorship and funding.

The active temperature probes have a low-power RC oscillator in which the thermistor is the timing resistor. The frequency is set for a period of about 1 s at the nominal temperature and, because the thermistor has a rapid variation of resistance with temperature, the period decreases at about 5%/°C with increasing temperature. The oscillator triggers a crystal-controlled rf transmitter to produce a short pulse once every period. The pulses, in the frequency band from 148 to 152 MHz, are sent to a receiver with frequency synthesizer-controlled tuning and the period is measured and printed out with a microprocessor-controlled frequency counter system.

Group H-6 has used two kinds of active temperature probes. One, using a CMOS oscillator and a receiver, was purchased from Sensory Systems about 5 yr ago. These units work well after a LASL modification, but they are bulky and have only a few channels in a system. Another probe made by a different vendor uses a discrete miniaturized bipolar transistor oscillator and a crystal-controlled rf pulse transmitter. It is mounted on the animal's ear using a modified ear-tag attachment. This probe has been used with several different modified "scanner" receivers and contains many more channels per system. These units have been used by the USDA at the Veterinary Services Laboratory (VSL) of APHIS at Ames, Iowa, in conjunction with vaccine tests for communicable cattle diseases.

Many problems with these commercial transmitter units had developed and little success had been achieved in solving these problems, which were primarily erratic shifts in calibration during use. Alfred Koelle was asked to study the design of these units and suggest a solution for the problems. Since experiments and tests were already scheduled, the goal was to retrofit the units at LASL and at VSL-Ames. Another task was evaluating the design of these units to determine if they would be suitable for the upcoming electronic ID field tests and, if not, to design a unit that could be produced either at LASL or by a commercial vendor under contract.

A schematic of the commercial design was obtained from the vendor, was breadboarded in the laboratory, and was examined in detail. The unit's performance was adequate, and there was no indication of the erratic behavior reported by the users. The circuitry was discussed in a telephone conversation with the designer. One of the problem units was obtained from R. Payne, H-6, and was connected to a variable voltage supply. Various test connections were made to the circuitry so its behavior could be studied. It was found that the timing oscillator calibration shifted when the rf transmitter was allowed to function; the amount of the shift was a function of the rf activity level. The conclusion was that rf from the unit's own transmitter was getting into the timing circuit and the jumps in calibration were probably caused by jumps in the rf activity, which in turn could be caused by loading changes on the output antenna, mode shifts in the crystal oscillator, or other functions. A solution in the form of rf decoupling at the timing circuit input was tested, and this seemed to reduce the dependence of the timing period on the strength of the rf activity. This information was given to the vendor, who had a number of the VSL-Ames transmitters in his shop for rework at the time. He made the suggested modifications before returning the units to VSL-Ames. A number of the LASL units were modified by Payne. At last report from VSL-Ames, several of the units had totally failed due to other problems such as broken connections or thermistor probe failure, but the erratic behavior problem seemed to have been solved, and the vaccine tests were in progress.

The second part of the task, to design a unit that will be suitable for future use on a larger scale, is in progress. An examination of the circuitry used in the current commercial unit showed that if performance could be improved, a complete redesign using a hybrid package CMOS oscillator would have significant advantages over the present units. A discussion with the vendor indicated that he was aware of the problems and the possibilities for improvement, but that he was not in a position to take the commercial risk and did not have the facilities for making such a major design change. The present plan is to do the development work on an improved temperature transmitter at LASL and then produce them either at LASL or under contract to our design, depending upon whether a favorable bid is received at the time. The present vendor would be on the list of prospective bidders.

It was decided that the new design should be applicable to both an externally mounted (ear-tag) configuration or for use as an implant. The aims, therefore, are small size and that all materials, including the power source, be biologically acceptable. The size requirement calls for the lowest power drain possible to allow use of the smallest battery available. Because all electrochemical batteries have some drop in voltage with life, it is desirable that the timing oscillator have as little change in period as possible over the output voltage range of the battery. For the externally mounted applications it is also necessary that the period not change too much with ambient temperature.

Work has begun on the timing oscillator and in locating commercial sources for a suitable battery and a very small transmitter oscillator crystal. It is expected that a device can be built that will be less than one-half the volume and weight of the units in use and with considerably better performance in terms of insensitivity to supply voltage and temperature changes.

The power source will be one or two Panasonic BR425 lithium cells with a solid electrolyte that does not leak or outgas. These are nominally 2.8-V, 40-mA-h "pin" cells. An operating life of 3 months is expected for externally mounted units with two cells and a 1/s 5-ms transmitter pulse.

The CMOS timing oscillator operates at about 100 Hz and is divided down in a CMOS counter. The

transmitter drive pulse is obtained by tapping off the appropriate stage of the counter and differentiating the counter output. By using a relatively high-frequency oscillator it will be possible to use a physically small and stable ceramic timing capacitor, thereby bypassing the problem of having to compromise on either the size or the quality of the timing capacitor, as has been true in previous designs where a period of about 1 s has been used directly in the timing oscillator. The CMOS frequency divider takes negligibly more operating current than the oscillator itself. The oscillator and frequency divider will be fabricated as a hybrid circuit using commercially available CMOS chips, ceramic-chip capacitors, and thick-film resistors.

The basic oscillator to be used is somewhat different from the commonly used two-inverter configuration described by RCA. As shown in Fig. 25, this circuit uses three inverters. The additional inverter provides more loop gain and allows the oscillator to work down to a lower supply voltage before deviating too much in period. This circuit will work at 2.3 V with RCA CD4069 inverter sections, whereas the two-inverter configuration is usable to only 2.9 V. This change, therefore, makes operation possible at the voltage of a single 2.8-V lithium cell.

Another change is the use of straight inverter sections from a CD4069 hex inverter chip rather than the use of two-input NOR gates. Straight inverters have a more symmetrical threshold characteristic than gates and the result is better supply voltage and temperature insensitivity, plus the ability to function at lower supply voltages.

Another change is a high-value resistor across the timing capacitor. The reason for this is to

Fig. 25. Basic CMOS oscillator for active temperature probe.

avoid having an indeterminate voltage at the input to the first inverter when the timing resistor is disconnected. In the externally mounted units the thermistor probe will be removable, using a connector such as a Microdot. If no other dc path is provided to set the input inverter voltage, it may "float" near the switching threshold, with the result that a relatively large current may flow in the CMOS circuits and rapidly discharge the battery. With the added resistor the circuit will "lock up" in one or the other logic state and draw negligible current. The units can then be stored with the batteries in place and the thermistor probe disconnected with negligible current drain on the battery.

The next stages of this work will include design of the rf transmitter and packaging for the ear-tag configuration.

D. Superconducting Josephson Junction Switching Devices [Wang, E-DOR; Narud, E-DO]

1. Introduction. Recent technological advancements in the fabrication of integrated superconducting circuits offer the possibility of ultra-high speed (picosecond switching time) digital instruments.²³ The advantages of the superconductive electronics are high speed and low dissipation (approximately $\mu\text{W/gate}$), together with lossless, dispersionless, properly terminated transmission lines.

A program has been initiated to develop a set of Josephson logic elements for instrumentation tailored to specific LASL needs such as nuclear instrumentation, laser fusion, and weapon diagnostics.

2. Evaluation of Existing Available Facilities for Junction Fabrication. The first approach studied is thin-film deposition by rf sputtering. Two metals have been studied.

Niobium is a refractory metal with the highest superconductive transition temperature $T_c = 9.2\text{ K}$ for any element. After numerous depositions of Nb thin films under various conditions, the best films have $T_c = 8.8\text{ K}$. However, the variations of T_c range from 7.7 to 8.8 K for a given rf power, predeposition pressure, Ar partial pressure, substrate, and thickness (1200-2000 Å). For thinner films of about 300 Å, T_c may vary by a factor of 2 (3.5-7 K) with a very broad temperature transition ($\Delta T_c \approx 1.5\text{--}2\text{ K}$). Since a 10% spread of T_c can give

rise to more than 10% variation in the supercurrent, these films are of marginal use.

For proximity bridges, Ta film with a bulk $T_c = 4.3\text{ K}$ is a convenient material since rf-sputtered Ta film of 1100 Å remains normal down to at least 1 K with or without Ti substrate.

The second approach is thin-film deposition by ion beam coating. With the cooperation of an ion beam coater manufacturer, a 2000 Å Nb film coated at 450°C and 66.7 MPa (5×10^5 torr) superconducting at 5 K.

Shaping of electrodes and junctions by photolithography or Nb shadow mask results in degradation of the film ($T_c = 3\text{ K}$) due to contamination. Glass shadow mask is used for structures of about 1 mm with limited success.

Tunnel barriers of Nb oxide, Zr oxide, Si, Si oxide, and Al oxide were prepared by either rf sputter etching technique or thermal oxidation. The lack of control of rf power level ($\pm 50\%$) and oxygen partial pressure ($\pm 50\%$) results in poor reproducibility. This problem is compounded by the damage to the tunnel barrier produced by the high-momentum transfer in the sputter deposition of Nb counter electrodes.

3. Conclusion. The existing rf sputter system is not suitable for fabricating Nb/oxide/Nb tunnel junctions. This conclusion can also be inferred from the fact that there is no published report of successful fabrication of such junctions by this technique. Consequently, a high-vacuum system has been ordered with the intent of adding an electron-beam deposition system later for fabrication of refractory tunnel junctions.

Recent improvement in the stability upon thermal cycling of Josephson tunnel(ing) junctions based on Pb alloys makes this approach an attractive alternative.²⁴

E. Adaptive Control Applied to Heating, Ventilating, and Air-Conditioning (HVAC) Systems [Farris, E-4]

1. Background and Introduction. The objective of this project is to investigate the use of adaptive and optimal control techniques to minimize auxiliary energy consumption while maintaining a comfortable environment in solar heated and cooled buildings. Previous work has led to simulations of heating system operation in which an adaptive optimal controller demonstrated a substantial savings

(28.8%) in auxiliary energy consumption when compared with operation by a conventional controller.

2. Technical Accomplishments. The insight gained from our study and suggestions made at various presentations of our work have led us to define several model modifications that will give additional credence to our work and provide an acceptable, defensible model from which we can draw firm conclusions. The primary modifications are to

- a. Make the model a two-zone model; that is, include a perimeter zone as well as an interior zone to be controlled.
- b. Include the internal building mass to provide the appropriate thermal capacitance.
- c. Utilize a simplified solar collector model.
- d. Include parasitic (pump and fan) energy requirements in the energy consumption evaluation.
- e. Simulate various structures for introducing the auxiliary energy into the building.

These modifications have been examined and many of the changes required for their implementation are fairly well defined.

Simulation of the cooling system operation by the adaptive optimal controller has been accomplished and compared with operation by a conventional controller. An auxiliary energy savings on the order of 20% has been demonstrated by the adaptive optimal controller. These results are preliminary, but quite encouraging.

Following a consulting visit in August 1977, James L. Melsa, University of Notre Dame, directed the work of one of his students in the development of an on-line system identification technique for use by the adaptive optimal controller. Their report has been received but the technique has not been fully tested. We are encouraged by the preliminary results of its operation, which were demonstrated last August, and by the results presented in the report.

3. Technology Transfer. Presentation of our adaptive control concepts and results continues to be an important part of our effort. In December 1977 we visited three manufacturers of controls for HVAC systems and/or solar domestic hot water systems and discussed our mutual interests in some depth. The results of our work were presented at the DOE Contractors' Meeting for Solar Controls Projects

held February 28 - March 1, 1978, in Washington. Further results and concepts were presented in two papers at the Workshop on the Control of Solar Energy Systems for Heating and Cooling held May 23-25, 1978, in Hyannis, Massachusetts. In addition, seminars have been presented at the University of New Mexico and at Drexel University in Philadelphia.

We sense a growing interest in the concept of adaptive optimal control. It is recognized as being in the development stages, but its benefits are being acknowledged as are its sophistication and consequently complex implementation requirements. The future for the concepts being investigated seems very bright.

4. Plans. The model modifications described in the Technical Accomplishments section will be implemented and further simulation results obtained. When the simulations are complete, simplifications in the adaptive optimal control technique will be made, where possible, and implementation will be investigated. Use of adaptive optimal control concepts will also be studied for application in domestic hot water systems and residential HVAC systems.

A study will be performed at Notre Dame under Melsa's direction to establish an upper bound on achievable performance with an optimal controller. The resulting control will not be feasible because it will be an open-loop control, but its performance will establish a criterion for comparison.

A high level of activity in the area of technology transfer will continue.

F. Physics of Reentrant Superconductivity [Wang, E-DOR; Huang, Q-10; Smith, CMB-5]

1. Introduction. Recently the compound ErRh_4B_4 was found to be superconducting at $T_c = 8.7$, followed by a return to the normal state at $T_m = 0.9$ K due to the onset of long-range magnetic ordering of Er ions.²⁵ The compound ErRh_4B_4 is a member of a system of ternary compounds MRh_4B_4 , which exhibit superconductivity for $M = \text{Th}, \text{Y}$, or one of nine rare earth (RE) elements, and magnetic ordering for $M = \text{Gd}, \text{Tb}, \text{Dy}$, and Ho .^{26,27} In particular, GdRh_4B_4 undergoes ferromagnetic transition at 5.6 K. The fact that Gd^{3+} ion is in S state makes the interpretation of experimental results easier than other RE ions with finite orbital movements. The large spin state and the well-defined localized movements

of Gd ions render themselves to be a very effective probe for studying factors responsible for the re-entrant superconductivity in ErRh_4B_4 . We recently measured and reported the variations of the superconducting critical temperature T_c , the magnetic ordering temperature T_m , and the upper critical field H_{c2} of a series of pseudoternary $\text{Gd}_x\text{Er}_{1-x}\text{Rh}_4\text{B}_4$ compounds, for $x = 0$ to 1.²⁸ A departure of the T_c vs x curve from the Abrikosov-Gor'Kov (AG) theory was observed for $x \geq 0.1$ (Fig. 26).

2. Analysis and Conclusion. On the basis of the theories by Fulde and Maki,²⁹ and by Werthamer, Helfand, and Hohenberg,³⁰ we calculated the dependencies of H_{c2} on the temperature and Gd concentrations. Over the entire measured range, the spin polarization effect can adequately account for our measured reentrant upper critical field in the $\text{Gd}_x\text{Er}_{1-x}\text{Rh}_4\text{B}_4$ system for $x = 0$ to the critical concentration $x_c \approx 0.28$ over the entire superconducting regime (Fig. 27). The upward departure of the superconducting transition temperature vs Gd concentrations from the AG curve is consistent with the strong spin-orbit scattering present in such a system.

Fig. 26. Phase diagram of the $\text{Gd}_x\text{Er}_{1-x}\text{Rh}_4\text{B}_4$ system. Closed symbols stand for inductive superconducting (T_c) and magnetic (T_m) transition temperatures; open symbols for resistive T_c . Solid line corresponds to AG curve with $x_c = 0.28$, and $T_{C0} = 8.655$ K. The dashed line indicates the calculated Curie-Weiss temperature based on mean-field theory.

Fig. 27. Upper critical field H_{c2} vs temperature for seven $\text{Gd}_x\text{Er}_{1-x}\text{Rh}_4\text{B}_4$ samples with x ranging from 0 to 0.24. Calculated values of H_{c2} are given by the solid and broken curves using the theory of Fulde and Maki.

From the device point of view, since one can magnetically switch the phase of this material from the paramagnetic (normal) state to the diamagnetic (superconducting) state and then to the ferromagnetic state with decreasing temperature, this class of compound is potentially useful for device applications.

II. ENGINEERING SUPPORT, R. A. GORE, ALTERNATE DIVISION LEADER

A. Development Projects

1. Introduction. The activities reported in this section include both LASL-funded projects and projects funded by outside agencies. These projects are usually aimed at obtaining an understanding of a problem, the development of a solution to a given problem, or the development of a new capability or resource required in support of basic research.

2. Microcomputer Development [Ethridge, Criscuolo, E-5].

a. Intel ASM-48. As reported in our previous semiannual report, E-5 has developed a comprehensive support capability for single-component microcomputer applications. This capability will expand as LASL's needs grow and commercial units change. Complete ASM-48 hardware/software design aids now available in E-5 include

MDS Microprocessor Development System

ASM-48 Macro Assembler

PROMPT-48 EPROM Programmer/Debugger

ICE-48 In-Circuit Emulator for 8048/8748/8035.

A Printronix 150 line/min printer has recently been added to this system and will be operational in July 1978. It is further planned to add the RMX 80 real-time multitasking executive to this system early next fiscal year. This hardware/software allows support for all eight of the announced ASM-48 microcomputers that includes the initial 8048/8748/8035, the universal peripheral interface (UPI-48) versions 8041/8741, the internal memory expanded version 8039/8049, and the extremely low end version 8021. The ninth version of this family, the 8022, has not yet been announced by Intel, but is strongly expected to include 8021 functions, as well as an internal 8-bit analog-to-digital converter (ADC).

Over the last year, approximately 11 different hardware/software designs by E-5 group members have used this support equipment to varying degrees. The following is a list of these projects that are in various stages of design or are complete:

Group Q-2 shelf monitor for real-time inventory

Group Q-2 time monitor for real-time inventory

Group Q-2 Feynman variance calculator unit

Group Q-2 reduced variance calculator unit

Group Q-1 sewer monitor system for TA-55

Group Q-1 industrial waste monitor system for TA-55

Group H-5 stack particulate matter sampler for EPA

E-Division universal peripheral calculating system

Group H-1 neutron radiation monitor

Groups M-3/M-6 device interface module

Group CMB-1 spectrophotometer unit

b. Universal Peripheral Calculating System.

The Electronics Division development of a universal peripheral calculating system incorporating an Intel universal peripheral interface 8741 (ASM-48 microcomputer version) and a National number cruncher microprocessor 57109 has begun. The development objective is to design a microprocessor bus peripheral unit with scientific calculation capability at hand-held calculator speeds. One important feature of this design not included in similar commercial systems is the basic mode of accepting program segments downloaded from a host microprocessor (8048, 8080, 8085, or 6800) for calculation as opposed to a single key stroke command (one key stroke at a time).

The development will terminate with completion of an operational wire-wrap breadboard and complete schematic, with software documentation, on LASL drawings. The system hardware is so small that, theoretically, the hardware would be integrated into a user system design. Therefore, no E-Division packaging development is planned at this time.

3. Computer-Aided Design and Manufacturing [Johnson, E-4].

The automatic drafting system hardware was shipped to Design Aids, Inc., for system check-out. Acceptance tests were run at Design Aids and the complete system arrived at LASL in late April. The system is operational and several demonstrations have been given.

The wire-wrap activity has been very busy during this reporting period. Approximately 30 new jobs and 10 updates of previous jobs were completed.

The automatic placement codes that were written last year have been converted to run under NOS using the FTN compiler. This conversion was necessary to permit an uncleared consultant to work on the programs.

Additions to the codes include

- a. Easy error recovery for manual startup.
- b. Keep a running count of dedicated and non-dedicated sockets to ensure enough undedicated sockets are available to place the remaining number of undedicated chips.
- c. The dimensions were increased to permit running a larger problem.
- d. Some "bugs" were uncovered and fixed.

The design automation project at Lawrence Livermore Laboratory (LLL) has resulted in development of an automatic foil router for printed circuit (PC) cards. A copy of this software system has been brought to LASL and is now operational in the Central Computing Facility (CCF). More experience with the code will be required before production can begin.

4. NSRSC System Performance Studies [Murray, E-4]. Performance studies on the National Security and Resources Study Center (NSRSC) solar energy system have been completed for the 1977-78 heating season. The installed instrumentation provided re-

liable measurements, giving energy balances accurate to within 3%. The PDP-11/34 computer has performed reliably with negligible down time. The computer software successfully provided the required calculations, with the system operating essentially unattended except when specific experiments were being run, or when software development was proceeding.

The heating season energy summary for the system is given in Table II. The overall solar heating fraction for the building was 79%.

In preparation for the solar cooling season, a number of modifications and additions were made to the system. Four unused watt transducers were moved to measure the electrical power consumption of the cooling tower fan, the pumps for the two water chillers, and the recently added domestic hot water tank. The interrupt lines to the computer were rewired to obtain a more positive system mode change indication.

Software additions include several improvements in energy summary table formats, including the ability to provide any one of five different sets of

TABLE II
NATIONAL SECURITY AND RESOURCES STUDY CENTER
HEATING RESULTS FOR 77/78

Solar Data											
Mon	Sun Horz	Sun 35	Coll Out	HTex In	Tank Out	Dom HW	Aux Steam	Total Heat	Pump 1+2	TSM _{max} C	TSM _{min} C
11	250398	391575	137263	157752	117561	2829	15966	136356	5619	56	42
12	228969	377450	126154	132912	109306	3004	39903	152213	5766	57	44
1	234305	354603	117158	120910	97528	3322	60037	160887	5665	55	41
2	274293	364729	114197	115328	95823	3016	43392	142231	5566	59	43
3	293798	453173	150007	149517	119142	3314	19575	142031	6562	67	46
4	<u>520504</u>	<u>527493</u>	<u>148655</u>	<u>144725</u>	<u>126073</u>	<u>2877</u>	<u>794</u>	<u>129744</u>	<u>6736</u>	<u>78</u>	<u>57</u>
TOT	1902265	2469024	793434	821145	665434	18362	179667	863462	35913	62	45

Building Data											
Mon	Hot Water	Tot Elec	Tot Light	Fans S+R	Pump 3+4	Tot Heat	HTRC Unit	Fresh Air	TAM _{max} C	TAM _{min} C	DD C*D
11	121427	222300	130068	39111	2610	293216	50026	178502	9	-1	357
12	148202	236960	141249	44367	3629	337447	55386	197627	7	-2	484
1	157331	237126	139383	42501	3251	342465	54320	181256	4	-5	574
2	139878	221739	130802	38131	2904	311716	49610	140681	5	-4	498
3	144254	250188	150718	44099	2990	342061	56225	235397	12	0	386
4	<u>130559</u>	<u>244582</u>	<u>137011</u>	<u>42967</u>	<u>2436</u>	<u>312973</u>	<u>39624</u>	<u>230742</u>	<u>15</u>	<u>4</u>	<u>265</u>
TOT	841650	1412895	829230	251177	17821	1939878	305191	1164205	9	-1	2565

UNITS: MJ/Mon

units. Also, system summaries are automatically printed in a one-line format at a short interval (1 or 2 min) during a chiller run, and time plots of key system measurements are now available on the VT-55 oscilloscope. An example of these plots is shown in Fig. 28.

5. Computerized Tomography [Lundy, E-5; Rose, Waechter, E-2]. Exploration of industrial computerized tomographic imaging applications continued under a LASL New Research Initiative Proposal (NRIP) grant with R. Morris, Group M-1, and M. Cannon and R. Kruger, Group M-8. The primary activity during this period has been the design and fabrication of a system to permit making x-ray tomographs of various objects. The system will initially use only a single source and detector but is designed so that various sources ranging from low-energy x-ray machines, to radioactive isotope sources, to a 24-MeV Betatron can be used. The system will also allow experimentation with various detectors. The system consists of a mechanical assembly that positions the object being imaged relative to a fixed x-ray source and detector. An interface to an existing PDP-11/40 computer was designed and built to allow tomographic scanning of the object and data collection. Scan velocity is crystal-controlled to 0.01% accuracy and can be varied under software control over a 100 to 1 range up to 1-1/2 cm/s. On the rotational axis, upward step movements from 0.02° can be programmed. During continuous transverse scanning, x-ray transmission measurements could be programmed as close together as 0.0005 cm, although collimation limits would appear to make this resolution unfeasible. The first tomographic images from this system should be made in July.

Some discussions were held on possible applications of tomography to problems of other organizations, Sandia Laboratories, Albuquerque (SLA) and the National Bureau of Standards (NBS). The M-Division personnel involved in this work have undertaken a neutron tomography computer simulation study for NBS.

6. Eastern Gas Shales Project [Springer, E-4]. Gas production simulation from Devonian shale involves modifying the existing shale matrix by methods including hydraulic or explosive fracturing. We have been concerned with the latter, designing shape charges for jet penetration of Devonian shale

Fig. 28. NSRSC daily performance plots.

and measuring dynamic rock properties of the shale. In conjunction with the explosive stimulation program we have been studying diffusion of gas through naturally fractured shale with the intent of developing techniques for determining the expected improvement in gas production after applying a particular stimulation technique.

Economical shale gas production today occurs only in naturally fractured regions. If one could characterize the fracture structure, the distribution function of cracks, sizes, lengths, directions and intersections as well as properties of the gas shale diffusion constants, porosity, permeability, rock solubility, stratigraphy, and the like, then one could estimate the improvement in gas production following a known change in the region around the wellbore after stimulation.

We are in the process of collecting production data from a large number of wells in the Cottageville area in West Virginia, a high producing, naturally high fractured shale gas area. With computer codes we have been developing, we are determining what assumptions about the fracture structure will or will not reproduce the observed distribution in the observed production data. We will use the measured properties of the shale that are available. Both the digital computer and the hybrid computer

models of gas diffusion can be used. The interconnections on the hybrid model, developed last year, can be used to represent interconnecting fractures with gas diffusing into the fracture walls. The physical source of gas in the fractures is believed to diffuse from the first 10 to 20 cm of shale surrounding the walls.

We will infer different probabilistic models for the fracture structure and will compare computer simulations of well-production distributions with the real observed production rates and pressures at initial and later times.

7. Fast Solid-State Camera [Lundy, Criscuolo, Parker, E-5; Martin, Echave, E-2].

a. Introduction. With few exceptions, high-speed photography has been accomplished by the use of photographic film cameras. Though highly perfected, these techniques suffer two severe limitations for diagnostics recording of transient events. First, the total number of pictures of an event is limited inversely by camera speed. Second, the camera cannot be started or stopped instantly but has to be brought up to speed and stopped rather slowly. Therefore, use of a photographic film camera for transient event studies requires prior knowledge or control of the event timing. Television cameras would provide essentially instant start and stop characteristics, but their standard frame rate is 30 frames/s, and it has not been possible to operate TV cameras at rates above 500 frames/s; the TV camera sensitivity varies inversely with the frame rate.

The fast solid-state camera (FSSC) provides instantaneous starting and stopping, frame rates as high as 100 000 frames/s, any arbitrary transfer function between light intensity and stored information, frame storage limited only by the size of memory, dynamic range exceeding that of film, and a sensitivity that is essentially independent of the frame rate. Conceptually, an FSSC functions as follows: An optical image is formed continuously on an array of photosensors. Each photosensor element generates an electrical signal proportional to the light intensity at that image point. At predetermined time intervals, the electrical signal amplitudes of all photosensors are sampled in parallel, digitized, and stored in a first-in first-out (FIFO) memory. When the memory is filled, the old-

est stored picture is dumped to provide storage for the next frame. The sequence continues until a stop signal is given. At that time, the memory will contain all the preceding frames (pictures) minus those that have been forced to spill over.

E Division proposed development of the FSSC as the solution to certain diagnostics problems the US Air Force had with studying large detonations. A contract was received early in this quarter and development is now under way.

A block diagram of the FSSC being developed is shown in Fig. 29. The front end is a conventional 35-mm single-lens reflex camera. At the focal plane, the film has been replaced by a 10 by 10 array of photosensors. Though a 10 by 10 array provides a very coarse spatial resolution, it is deemed adequate for the prototype under development. The output current of each photosensor is proportional to the instantaneous intensity of the light falling on it. The signal buffers change the analog current signals to voltages that are then converted to digital signals for storage in the memory. The timing and control enhances the camera's versatility as shown in the following list of features and performance requirements.

b. Features.

- The absence of any moving parts, other than the optics, eliminates one of the inherent limitations of film-based, high-speed, motion picture cameras, and reduces maintenance costs.

- Synchronization of the FSSC with a random event to be recorded is considerably simplified over that of a film camera. The FSSC can be left running until a signal indicating the event is over has been received. The previous 256 images then remain in the semiconductor memory.

- The FSSC will record more images than film-based cameras of comparable frame rate. The FSSC being built will record 256 images; this could be increased to 4000 images for about a 20% increase in cost.

- The gray scale for the FSSC is arbitrary.

- It may be linear, logarithmic, etc. It may be desirable to select from more than one gray scale before conducting a test.

- The dynamic sensor range is such that the maximum framing rate can be maintained with sunlit

Fig. 29. FSSC Test Site interface.

scenes as well as with detonation scenes. This is not the case for film cameras.

• The digital output of the camera system is in accordance with Electronic Industries Association (EIA) Standard 232C. This allows the system to be easily connected to standard computer I/O equipment, to data-acquisition computers, or to a modem for telephone line transmission to a remote computer.

c. Performance Specifications

Optics

Field of view: 0.5 x 0.5 m to 0.2 x 0.2 m at a distance of 30.5 m

Resolution: 5.1 to 20.3 cm at a distance of 30.5 m.

Sensor Array

Spectral sensitivity: Must "see" 6000 K light from sunlit scene to detonation light, which may be over 1000 times brighter.

Size: 100 elements in a 10 by 10 matrix.

Dynamic range (light intensity): 2000 to 1.

Control Electronics

Frame rate: Can be adjusted from 5000 to 100 000 frames/s with a constant exposure time per frame of ~ 10 μ s.

Recording time: 2.5 ms at 100 000 frames /s, 50 ms at 5000 frames/s.

Gray scale: Eight levels of gray will be converted to a 3-bit binary code.

Digital output: The picture data will be transmitted by the camera to a display device or computer via EIA RS 232C standard protocol.

Timing: All timing signals for operating the FSSC will be generated within the camera.

Synchronization: A master clock input for synchronizing multiple cameras will be provided.

Power back-up: The ac power supply for the memory will be backed up automatically by a battery pack in the event of a power-line failure.

Postevent trigger input: An input will be provided that will cause the camera to stop taking pictures.

d. Project Status.

Optics. The viewing distance ranges from 30.5 to 182.9 m. The required fields of view can be covered with a standard 80- to 300-mm zoom lens equipped with a 3K extender when the viewing distance is 30.5 m. At the larger distances, astronomical telescopes equipped with Barlow lenses may be required. In all cases, the effective aperture must be at least F12 to be able to see a sunlit scene. Development work is being carried out with a variety of surplus camera lenses, the longest having a focal length of 1000 mm and an aperture of f6.3. The final lens complement has not been determined.

Camera. A Nikon F-2 with eye-level finder and an extra back has been ordered. This camera is judged as the most versatile and most likely to be available later, should duplication be required.

Sensor Selection. Initially, the controllable sensitivity of the photo-FET was found very attractive, but this product has excessive variations in sensitivity. Also, the requirement for three leads per sensor made the array too complicated; therefore, a simple photodiode, the SD-041, was selected.

Sensor Array. A number of sensor array fabrication methods were investigated. The version employed uses SD-041 chips, which are fastened by a conductive epoxy to a PC board substrate. The active area of the array is 20% of a 1.8- by 1.8-cm image plane area. Two arrays made to LASL specifications have been delivered by the Silicon Detector Corp. They will be evaluated and installed in the extra back of the Wilson F-2 in early June.

Signal Buffers. The signal buffers will be located in the camera to drive the 0.3-m cable

connecting the camera to the signal processor and controller box. The equipment may be used in a high EMI environment. Therefore, to keep the signals out of the millivolt range, this section now supplies two outputs for each channel. One, for voltages from 20 V down to about 1 V, comes directly from the input transimpedance amplifier. The second, for voltages from 0.4 V down to 10 mV, comes from a 50X buffer stage. The circuit development is complete and PC boards for all 200 channels are now in fabrication and should be completed in early June.

Analog-to-Digital Converters (ADC). The ADCs are composed of 800 comparators, 8 adjustable reference supplies that determine the 8 shades of gray, and 100 priority encoders. They will be located in the signal processor-controller box. The circuit development is complete and it is being incorporated into the PC layout for the camera control system.

Controller Status. The controller of the FSSC is well into the design phase. Analysis of the FSSC interaction with the test site, Fig. 29, and identification of the controller subassemblies and their interfaces, Fig. 30, have been accomplished.

A wire-wrap prototype of a single A/D-memory channel has been built and satisfactorily tested. Layout of a 4-channel A/D-memory PC card has been completed.

The A/D-memory controller has been designed and a wire-wrap card is being fabricated. The software design has been initiated. All parts have been identified and ordered with no delivery problems anticipated.

Check-out of the software, card cage bus, and A/D-memory card is expected to begin the first of July. This will be followed by integration of the operator's console and the camera.

e. Scattered Light Test. A parallel study has indicated that it will be very difficult to achieve a light ratio, in the image of a single scene, of 2000:1. This is particularly true for neighboring picture units (pixels). To determine the validity of this indication and also to get a direct measure of the expected scene brightness, a 2-channel camera has been assembled. This will be field tested in conjunction with a propellant detonation to be prepared by M-3. The camera will be aligned so that an image of the detonation falls on one diode.

Fig. 30. Block diagram of the FSSC controller.

Simultaneous measurements of the outputs of this diode and its neighbor are expected to provide a measurement of the image light ratio that can be expected. This test will be conducted in late May or early June.

8. Fiber Optics [Longmire, E-5]. A number of digital fiber optic communication links have been constructed for various groups within LASL. These links usually consist of low-speed, moderate to short distance systems for communication between computers or between computers and peripheral devices.

Three bidirectional links were constructed for AP Division for communication between central computers and satellite computers in a high EMI laser environment. Group AP-1 has requested an investigation into the possibility of using fiber optics with a hand-operated control box for communicating

with a computer in a high-noise environment. The concept would incorporate the added advantage of not requiring a power source at the hand-held control box. A number of fiber optic links have been constructed for Group M-6. Currently under construction is a low-jitter, fast-pulse trigger system for them.

Also under consideration is an expendable, low-cost, widebandwidth analog link that could be built in large numbers. Other in-house fiber optics are being delivered to L Division. E Division has provided growth for further characterization and updating of our present digital fiber optic system. The US Air Force Weapons Laboratory at Kirtland Air Force Base has expressed considerable interest in LASL fiber optics developments and capabilities. A 100-m link was delivered to them for use in computer communications. To date, at least one major fiber

optic developmental link is under construction and several proposals are being offered for widebandwidth systems. The most recent system is a low-jitter, fast-pulse link for triggering Marx generators. The design goal will be under 1-ns jitter and a fiber length of 50 m.

Other interest has been expressed in the areas of widebandwidth analog systems and other moderate-distance digital systems.

B. Program Support

1. Introduction. This section of the report describes E Division's role in those LASL programs where there is a long-term dedicated effort. The discussions include the general nature of the overall program, as well as the technical nature of our support.

2. Support for Associate Director, Administration.

a. LASL Automated Security Access Control System (SECA) [Rivera, E-5]. During 1977 it became apparent that the desired efficiency level of Protective Force operations would be reduced due to new DOE regulations that could not be effectively satisfied by employing manual procedures. Adding to the Protective Force staff was not a solution from both an economic and practical standpoint. What was needed was a system that would provide the inspectors with methods and means by which their effectiveness and responsiveness could be markedly improved in order to more completely satisfy their regulatory mission. To this end, it was decided in late 1977 that a Laboratory-wide SECA was the solution to this critical and timely problem.

The primary purpose of the SECA is to control physical access to secure areas, buildings, sensitive areas within buildings, and vaults. This will be accomplished through the use of magnetic stripe badges encoded with unique identification numbers. Only the bearer of a valid and properly encoded badge will be able to gain entrance through an entry point secured by the SECA. For added protection at some entry points, each badge holder will be required to enter a memorized code via a keyboard to complete the establishment of identity and to gain admittance.

When a badge is inserted into one of the SECA badge reading units, the SECA will, as a minimum, check that the badge is current and valid, the bear-

er is privileged for entry at that location, and that the bearer is not already recorded as being within the access area. If any condition that will cause access to be denied is defective, the guards are notified immediately by visual indicators and audio alarms. All events caused by alarm or abnormal conditions will be logged and become permanent records.

The first step in the SECA implementation is to issue new badges to all badge holders. This task will be accomplished by the end of summer. The new badges will be credit card size. The front of the badge will contain a color photograph of the bearer along with printed identification information. The magnetic stripe is located on the back of the badge. Badge fabrication and encoding are in accordance with ANSI and ABA standards.

In parallel with the rebadging effort is the task of acquiring a stand-alone SECA for the CMR building. Initially, the CMR building SECA will control four entry points: the front door entrance, the back gate entrance, the loading dock entrance, and one of the vaults. The CMR building SECA is expected to be fully operational by October 1977. Shortly after installation of the unit, eight additional badge reading units will be added to the system. Six of these units will be used for vault access and the other two for access to buildings SM-35 and SM-66.

Operation of the CMR building SECA will provide valuable experience to LASL in the area of automated access control. This experience will be directly applied to the design and implementation of the long-range Laboratory-wide SECA. It is expected that the Laboratory-wide SECA will control somewhere between 250 and 400 badge reading units. The procurement specification for this unit is expected to be completed by December 1978.

In the interim period between installation of the CMR building and Laboratory-wide SECAs, requirements will exist for providing SECA capability for various sites throughout the Laboratory. This problem is being studied to determine a practical and cost-effective method by which interim SECA capability can be achieved.

b. LASL Long-Range Upgraded Alarm Systems (LORAX) Project [Hartway, E-5]. The background and history of the LORAX project is well documented in

a LASL report.³¹ The purpose of the LORAX is to upgrade the LASL Security intrusion detection system (IDS), the fire alarm system (FAS), the plant monitor system (PMS), and the personnel authorization and supervision system (PASS) by utilizing modern computer and data communications technology. The project includes:

- Construction of a new building to serve as the LASL-operated central alarm station (CAS).
- Addition of display-keyboard terminals to the existing DOE Protective Force alarm center (DOE station 100) and five DOE fire stations.
- Addition of computer equipment for computer-aided dispatching (CAD) system capability, including computer-compatible vhf radio equipment.
- Addition of new personnel badge readers and support equipment necessary to utilize the new LASL magnetically encoded badges.
- Upgrading of the telecommunications system toward a LASL-wide, government-owned, wide-band data communications system.

Because of the large scale of this project in both time and monetary resources, the project is broken down into separate program phases and will be funded by a combination of construction funds, indirect funds, and GPP funds for FY-77 through FY-80.

(1) Long-Range Upgraded Alarm Systems and Interim Projects. The budgets for this first 4-yr stage of the project have been determined and successfully submitted to DOE. A brief summary of the major program phases follows.

FY-77 Interim IDS. Because the LORAX implementation start-up time is 2 yr and the security requirement for improved alarm systems cannot be held in abeyance, a short-term or interim alarm upgrade program was initiated with FY-77 safeguards funds. This system is described below.

FY-77 Interim FAS. In a similar manner to the short-term or interim IDS, an interim FAS program has been initiated. The interim FAS system consists of the addition of a SESCOA brand digital telephone dialing system and an Image Systems brand microfilm retrieval projector for use in the station 100 alarm center. The SESCOA unit allows economical data acquisition for fire alarm signals from sites where

inadequate telephone lines are available to utilize the existing FAS, and where the site is of sufficient importance to be protected during the interim period until the sites can be multiplexed into LORAX. The Image Systems microfilm projector system will provide for semiautomated access to maps, site and building plans, and fire response preplans in a manner similar to that which will be automated under the LORAX program.

FY-77 Interim Data Communications System. The long-range data communications capabilities required to support the LORAX project are not scheduled for major funding until FY-80 or later. An interim program consists of adding an rf cable TV link between the NSRSC remote-controlled personnel access Mardix booth and the DOE station 100 alarm center. A related effort calls for the addition of TV cable between SM-28 and TA-46. These efforts are in effect a pilot study to determine the feasibility of utilizing TV cable techniques to satisfy the LORAX wideband data requirements.

FY-77 Interim PASS. The personnel access and supervision system encompasses all related uses of the new LASL magnetically encoded badges, as well as other methods of personnel surveillance and supervision such as remote access-control booths and surveillance closed circuit TV (CCTV). These access control measures are in lieu of, or supplemental to, keys and guards at various locations. Another application is authorization for stock issue at the LASL warehouse and, in general, augmenting the security access and authorization system, which is now manually performed by the DOE Protective Force. An interim security access control system is being installed in the CMR building as a model site-security badge-reading access control subsystem for the LORAX PASS. This system is described elsewhere in this report.

Another major element of the PASS system is the use of CCTV for exterior site-perimeter surveillance, in context with the Safeguards IDS early warning perimeter alarm systems, and internal site surveillance in context with the DOE "buddy system" access requirements for special nuclear materials (SNM). In preparation for the FY-79-80 implementation of these systems, an engineer has been assigned the responsibility of acquiring the necessary skills in CCTV, cable TV, and data communications technologies.

An interim PASS project now under way consists of the utilization of a remote CCTV and control system at the north rear fence gate of SM-29, for the purpose of allowing the guard in the front of the building to control access to this gate remotely from his guard post. This project allows realignment of the Protective Force requirements in order to more effectively utilize their deployment at the more critical SNM sites.

FY-78 LORAX IDS, FAS, PMS, PASS, and CAD. The first implementation of the LORAX program will use FY-78 funds and will consist of construction of the new CAS, complete with computer equipment and peripherals, data communications gear, operator consoles for IDS and FAS, emergency power generator, and uninterruptable power supply (UPS) system. The CAS (SM-440) is a 560-m² facility to be located just south of the CMR building; it is expected to house the LORAX system. The CAS design includes an electronics support area and an office area sufficient for 24-h support capability for the LORAX. The CAS Title II engineering design is now in progress. The CAS is scheduled for completion in mid-June 1979.

The FY-78 LORAX IDS provides for a new IDS operator console in the CAS and DOE station 100, and the IDS sensor upgrading and multiplexing at TA-21, SM-66, SM-35, and TA-55.

The FY-78 LORAX FAS includes new FAS operator consoles in the CAS, in DOE station 100, and in each of the five DOE fire stations, multiplexing of the fire alarms at 23 buildings, and computer interfaces to allow the existing and interim FAS to be incorporated into the LORAX.

The FY-78 PASS provides for basic compatibility between the LORAX-IDS and the SECA only, and the total PASS capabilities will be funded in future years from other sources. The PASS-SECA compatibility is required to coordinate the security access authorization data obtained from SECA badge readers with the access-secure controls of the entrance and interior IDS alarm systems.

The FY-78 LORAX CAD provides the basic computer-aided dispatching capabilities for the LORAX security and fire alarm operator positions. Typical CAD features are vhf radio transponders in key IDS and FAS vehicles that provide real-time feedback to the dispatchers on the status of their response forces, data bases for alarm response preplans that

include alternate or back-up plans, and vehicular printers and displays in critical response units.

The LORAX FY-78 procurement schedule is the first-stage LORAX procurement and requires the acquisition of the above capabilities from a single turnkey vendor. The budget for this contract consists of \$975k from safeguards funds and up to \$1000k from fire protection funds. The procurement is to be accomplished by a Request for Proposal (RFP) to be based on functional requirements (end use requirements) rather than a component specifications package. These functional requirements are now being written and will be completed by mid-July 1978. The schedule calls for release of the RFP in mid-August 1978. The earliest delivery anticipated for the CAS LORAX equipment is August 1979. This LORAX program and procurement schedule is outlined in the LORAX procurement plan.

FY-79-80 LORAX IDS, FAS, PMS, PASS, and CAD. The LORAX program projections for FY-79-80 include continued expansion of the basic LORAX system initiated in FY-78.

The FY-79-80 LORAX IDS includes continued site sensor upgrading and multiplexing in all of the remaining LASL sites, which allows for the removal of the existing and interim IDS systems. A significant aspect of the FY-79-80 IDS is the early warning perimeter alarm upgrading at LASL SNM handling sites, namely TA-21, SM-29, SM-66, SM-35, TA-55, TA-41, TA-16, and TA-18. The early warning system requires site-perimeter alarming and CCTV surveillance as a measure of protection against outside aggression activities. Many of these techniques are state-of-the-art technologies and will require E Division to obtain expertise in these areas sufficiently in advance of the construction schedules to allow preliminary design specifications to be developed. It is therefore anticipated that by early calendar year 1979, E Division will have additional personnel on the LORAX program dedicated to these technologies and engaged in analysis and design activities, and data communications systems.

The FY-79-80 LORAX FAS, PMS, PASS, and CAD systems provide for continued expansion and growth of the capabilities in upwards compatible fashion with the initial FY-78 LORAX systems, sufficient to eliminate the requirements for continued operation and maintenance of the corresponding existing and interim systems, where appropriate.

(2) Interim Alarm System [Trump, E-5]. The interim alarm system, a portion of LORAX, is a stand-alone IDS for CMR building (SM-39) and W-Site (TA-41). The system monitors the status of various door switches, motion detectors, and access-secure switches (key actuated), located at the two protected sites, and provides status and alarm information for all points to a security officer at station 100. Additionally, it generates a chronological log of all alarm activity and operator response.

The system consists of a PDP-11/34 minicomputer running RSX-11/M, now supporting three disks, a system terminal, line printer, programmer terminal, operator terminal, and a 16-line communications interface connected to remote multiplexers located at the protected sites. The multiplexer supplier, CSI Division of LFE Corp., has also supplied the MODSCAN software that permits communication between the remote multiplexers, alarm data base, and the operator display terminal. E Division has designed a multiplexer input (status) card and an output card. The status card permits the multiplexer to monitor the state of six input points (door switches, etc.) in a line supervisory mode, initiating an alarm signal for any departure from the normal condition (line open, shorted, or loaded). The output card is used to drive remote indicators, usually associated with access-secure switches, to provide a visual indication of change of state.

A fabrication order has been placed with Missouri Research Laboratories (MRL), Albuquerque, to supply a sufficient quantity of status and output cards for the CMR building. Parts are being accumulated for a second fabrication order for cards to complete the W-Site installation.

The Zia Company crafts have completed the trunk wiring, multiplexer box, and junction box installation at the CMR building and are currently installing similar items at W-Site. This installation is scheduled for completion by May 31, 1978. Group E-1 personnel are completing the sensor wiring and trunk cable check-out at CMR in preparation for the multiplexer installation scheduled for early June 1978. As soon as this installation is complete, Group E-1 will begin the W-Site installation work, which is scheduled for completion in July 1978.

Modifications to station 100, located at the DOE building, have been coordinated by ENG-4 and are

nearly complete. The modifications include remodeling the room to provide space for the computer, adding UPS with battery and diesel generator back-up, and improvements to the air-conditioning system to handle the increased heat load from the computer system.

The interim system is scheduled to go on-line in the CMR building during the latter part of July 1978 and at W-Site the following month. As experience is gained with the system during July and August, a decision will be made whether or not the interim system should be expanded to include additional sites.

(3) MODSCAN Software [Wilkins, Whitfill, E-5].

Interim Computer. The PDP-11/34 computer has temporarily been installed at E-5, TA-0, and is being used to develop all MODSCAN software. The machine is under a 90-day warranty. The RK05f disk drive has an intermittent error of "dropping ready," which is being addressed.

RSX-11M with LFE Modifications. The LFE RSX-11M has been installed on the interim system. Modifications allow MODSCAN to bypass the RSX FILES 11 processor for more efficient disk accessing.

Standard MODSCAN. A standard MODSCAN system is now operational on the interim system. The standard version does not include report-by-exception. A single RTU is connected to the system and MODSCAN has successfully scanned the status points on the RTU. To use the standard MODSCAN, a data base had to be generated that exactly reflected the configuration of points on the single RTU. The following items will be tested next.

- Scanning analog points
- Setting relays
- Associated relay processing
- Access-secure processing
- Checking all communication channels on the DZ-11 interfaces

Operator Displays. The operator console displays are being evolved from a primitive version design by LFE personnel. The first step in the evolution is to design a set of displays with an excess of operator options that facilitate testing the items mentioned above. The final set of displays will be a subset of the intermediate set, refined for ease of use by the real operators.

Data Base Editor. A data base editor, DEMOD, has been written to permit access to all attributes of the data base while MODSCAN is running. This tool can be used during development of the system to stop-start scanning, enable-disable alarms, cause alarms, etc. When MODSCAN becomes operational, DEMOD will be used to maintain the data base; that is, to activate new points as they are added to the RTUs.

3. AP-Division Support.

a. JUMPer Project (AP-1) [Winston, E-5; Springer, E-4; Whittemore, E-2]. This support consists mostly of working with C. Tallman, AP-1, designing and fabricating electronics equipment for the JUMPer Project. The following items were addressed in the past period.

The final two "minipulsers," mentioned in the previous report, were completed. These units provide outputs of variable repetition rate and variable-width pulses to drive solenoids that control gas flow in lasers.

Two rather elaborate pressure controllers were completed with the help of A. Whittemore, E-2. Much of the preliminary design work was done by C. Tallman, AP-1, and T. Springer, E-4. The controllers work with servo valves to smoothly ramp gas pressure up to a preset value and hold it there for a preset time of up to 10 s. Pressure must come up as rapidly as possible and not oscillate. One of these units is functioning satisfactorily.

A band reject active filter was designed and fabricated. The center frequency of the reject band is adjustable from 1.2 to 11 kHz, the Q is adjustable from 1 to 20 kHz, and the gain is variable from about 1 to 10.

b. AP-Division Support [Deal, Kozubal, Milich, Robinson, E-5]. This team performs various hardware and software tasks for Group AP-4 experiments. Currently, more than 50% of our effort consists of general support of ongoing and new experiments. These experiments are PRL-II, CFRL, a laser-induced fluorescence (LIF) experiment, CO₂/CF₄ laser development, an experiment at DP-West, and the laser experiment at Oak Ridge Gaseous Diffusion Plant.

Transient Digitizers. Sixteen LeCroy Model 2256S transient digitizers were purchased and checked out. Several required on-site or factory

repair. A FORTRAN-callable driver for the 2256S was developed and added to our run-time utility library.

Improved Normalize Routine. A new normalize (average to center of trace) routine was developed for use with Tektronix 7912 transient digitizers. This routine produces greater accuracy at the sacrifice of execution speed. The greatest improvement is evident on sharp transitions of a waveform, where there are typically four or more vertical points for each horizontal address.

Interprocessor Communications. A package of routines has been developed to handle down-line loading and file transfer between the host and satellite CPUs. Elements of this package are being tested. The package will handle NOVA and microNOVA processors and can be configured for various communications paths, including dial-up and fiber optic links. An error checking and recovery protocol is built into the down-line load modules, and error checking and recovery for the file transfer modules are performed by an optional, higher level protocol.

When implemented, the user program at any satellite will be able to perform the file functions: open, close, create, delete, read, and write. Read and write will be by block, record, sequential binary, and line modes. All functions will be accessible at the FORTRAN-IV level.

The kernel communications routine for the satellites, AOSCOM, links the user terminal to an AOS port and handles down-line loading of user programs. A PROM version of AOSCOM is being developed for use on microNOVA processors.

Automatic Program Generator. Because of the large number and variety of experiments being performed in AP-4, an "automatic" program generator is being developed. This program will use a definition of an experiment to produce a run-time module tailored to that experiment. The proposed procedure, detailed in Fig. 31, is used as follows. An experiment is defined by the user entering or editing a source file in the experiment definition language (1). He then executes a macrolanguage processor (2), which converts the source into structured FORTRAN-like code to ANSI FORTRAN-IV. The resultant code is compiled (4) and bound along with run-time library routines into an executable program (5). The user must then either down-line load the program or transfer it to a diskette.

Fig. 31. Automatic program generator functions.

Our current tasks include defining the experiment definition language and writing the primitives to handle 7912s and most of the CAMAC I/O modules used by AP-4. Primitives are also being defined to do data tabulation, plots, and store-recall of data on disk files.

New Equipment Design. Examples of new equipment design are an industrial-type motor control circuit for the aerodynamic lab, temperature control circuit, interlock circuit to detect computer fail-

ure, high-voltage air gap firing circuit, and a digital interface between an optical multichannel analyzer and a computer via CAMAC.

4. CMB-Division Support.

a. **TSTA (CMB-3)** [Grundmann, McDonald, Springer, E-4; Damran E-5].

Analysis. The Tritium System Test Assembly (TSTA) is a LASL facility being constructed for the purpose of developing, demonstrating, and interfacing technologies required in the deuterium-tritium fuel cycle of future fusion reactor systems. An artistic version of this facility is shown in Fig. 32. The facility is basically a physical simulation of a fusion reactor tritium system including the vacuum system, fuel injection, fuel cleanup, isotope separation, control, and emergency systems. Flexibility is being designed into the system to allow testing of new components under actual deuterium-tritium conditions. The overall objective of the project is to demonstrate the long-term reliability and safety of deuterium-tritium handling facilities. The estimated cost of the project is \$12M and is presently scheduled for completion in the 1980-81 time frame.

E-Division support involves assisting in the design and installation of the instrumentation and computer control system in the facility. Early this fiscal year the project manager requested that we also review facility simulation requirements so that this support would be available, if needed. A short study was undertaken to review the various TSTA subsystems from the point of view of the modeling process and interactions between subsystems. From this study an initial flow diagram of the primary process system was made and some initial equations and methods of modeling the various subsystems were

Fig. 32. Tritium systems test assembly.

formulated. It was recommended that the simulation be carried out with a modular structure so that modifications to the various subsystems could be simulated quickly and easily as the facility design evolves. It was also determined that a general-purpose simulation code, LASAN, is available at LASL that appears to be well suited for the simulation. A recommendation was made for 1-1/2 staff member average effort to be spread over the construction and implementation period of the project in order to effect an adequate level of modeling support.

As a result of this study it has been decided to support the simulation effort at a level of one full-time staff member beginning last January.

Master Data-Acquisition and Control System (MDAC) for TSTA.

The E-5 responsibility for this project includes the design, procurement, fabrication, installation, check-out, and operation of the data-acquisition and control subsystems that will interface with the computer subsystem being designed by R. Stutz, ENG-8. Group E-5 is also responsible for the design and implementation of a man-machine interface subsystem, an uninterruptable power supply for the MDAC, and an emergency generator set (EGS) for the TSTA.

System Functions. The primary compound purpose of the MDAC is to accurately measure performance parameters and provide control of components, subassemblies, and the TSTA as a whole; to assure adequate safeguarding and records accountability of the large tritium inventory; to provide alarms for out-of-limit processes and conditions; and to record the resulting information as a permanent data base.

System Description. The MDAC hardware configuration consists of a data-acquisition subsystem (DAS), a process control subsystem (PCS), a man-machine interface subsystem (MMI), a computer subsystem (CSS), and software subsystem (SSS).

Data-Acquisition Subsystem. The DAS contains a collection of transducers and other signal sources, interconnecting cabling between these sources, and major DAS equipment components used for conditioning, formatting, and interfacing TSTA parameters to the CSS.

The computer-to-CAMAC interface has been designed during this reporting period. The basic in-

terface is contained in a single CAMAC crate (known as a system crate) containing 25 stations. Control is exercised by a computer-independent master crate controller mounted in two stations at the right-hand end of the crate. All other stations can be used for user and interface modules as determined by system requirements.

The system can be extended by inserting branch couplers into the system crate. Up to seven couplers can be used, each coupler linking the system crate to a maximum of seven additional crates via a standard CAMAC branch highway. Thus, a complete system may contain up to 50 crates (that is, the system crate plus 49 branch crates). Each branch crate may be controlled by a standard type A-1 or A-2 crate controller.

Control is brought into the system crate via computer-dependent modules that act as the source of command in the CAMAC system. Up to 10 independent computers (not necessarily of the same type) can be connected to the system via the system crate and will be used in a time-sharing arrangement. For maximum reliability and redundancy, all four of the MDAC computers will be interfaced to the DAS and PCS subsystems via this method.

This basic system crate is duplicated in the system as depicted in Fig. 33. This configuration allows one to extend the system redundancy down to the individual crates that contain the DAS and PCS modules. It is anticipated that the individual crates would be duplicated also when a tritium fuel

Fig. 33. MDAC-CAMAC subsystem for TSTA.

processing facility is actually interfaced to a fusion power reactor. This interface is shown in Fig. 34.

The following specifications were written and released for procurement.

- CAMAC - Powered crate assembly
- CAMAC - Master crate controller
- CAMAC - Computer interface (control)
- CAMAC - Computer interface (data)
- CAMAC - I/O bus termination module
- AC line voltage regulator

The following two specifications were also written and released during this reporting period.

Measurement and control parameter identification

Workmanship standards -- electrical and electronic assemblies

Purchase orders for other equipment such as electrical cable, instrumentation amplifiers, and equipment racks have also been released.

Process Control Subsystem. The PCS and the DAS are integrated subsystems. All process-oriented functions of the TSTA shall be under computer control. The detailed design of the PCS has been started. Specifications and drawings are being prepared for major components of the subsystem.

Man-Machine Interface Subsystem. The MMI serves as an interface between system operators and the MDAC. We have not yet begun detailed design of this equipment.

Computer Subsystem. The CSS is designed as a modular redundant system wherein the control and data-acquisition functions of the four CPUs and disks can be shared for continued safe operation, in case of malfunction of any one or more units.

Uninterruptible Power Supply. A UPS will be provided that will supply the total power requirements of the MDAC at the specified frequency,

voltage, and phase. A specification for this equipment has been drafted; however, procurement has been delayed until FY-79.

Emergency Generator Set. An EGS to supply power to the TSTA in the event of a power line failure will be provided. The procurement of this item is scheduled for FY-80; therefore, little design effort is scheduled until FY-79.

Software Subsystem. The software for the TSTA computer subsystem consists of the computer operating system, TSTA control-data collection, training, data reduction, simulation, and the software controller. The software task is being outlined and the specification controlling its structure is being prepared.

b. Plutonium Facility (CMB-11) [DesJardin, Reitzel, Hart, Owens, Dorin, Cummings, Martinez, E-5; Thomas, Spears, E-2].

Since late 1974, E Division has been responsible to CMB-11 for the design, procurement, fabrication, installation and check-out of the Plutonium Facility data systems and process line instrumentation. During this reporting period the following significant activities have taken place.

(1) Welders.

200 Area. The complete system including the Hobart welder, limited-volume chilled water system, and instrumentation has been installed in the plant. Final check-out is awaiting completion of intercable connection and tie-in to plant services.

300 Area.

● GTAW - Cyclomatic. Factory acceptance tests were completed during the first week of December 1977. Integration of cyclomatic hardware with instrumentation equipment was accomplished in the 1A-55 machine shop area. Check-out and performance testing were concluded in late January. All equipment has been installed in the plant. Final check-out is awaiting completion of equipment intercable connection and tie into plant services.

● EB - Leybold-Heraeus. Factory acceptance tests were completed at Leybold-Heraeus during the first week of March 1978. Equipment is awaiting final positioning and interconnection before in-plant performance tests can be conducted. The definition of and proposal for a computerized data-acquisition system still remains to be accomplished.

Fig. 34. CAMAC system redundancy for TSTA interface.

(2) Building Control Multiplex System.

Plant equipment and systems check-out have been completed for heating, ventilating, switchgear, fire, CAMS, and many of the miscellaneous but necessary data channels. Building fail-over tests under computer control were initiated and completed.

During check-out and fail-over tests, numerous but minor problems with wiring and multiplexer operation were encountered. For a majority of the problems, the solution was obvious and repair or correction was effected immediately. Other problems such as intermittent CCU failures and computer interface malfunctions required on-site investigation and correction by IC Engineering factory personnel.

(3) Process-Line Instrumentation. All control panel racks (CPR) have been completed, checked, and delivered to the plant, except the autoclave, which is complete but awaiting final instrument check-out. All local panels and instruments have been completed, checked, and delivered either to the plant or to the warehouse as spares. Many instruments of various sizes and complexity have been designed, fabricated, checked, and delivered upon request. These items are too numerous to mention in great detail; however, a fairly accurate list is available upon request. During this report period, we have moved from a 334.4-m² room to approximately 37.1 m² while at the same time maintaining full support for the facility.

c. Computer Specification (CMB-3) [Criscuolo, E-5]. The scope and specifications of this program were presented in detail in LA-7149-PR and will not be repeated here. The present status is that the specification has cleared Supply and Property, the CADP office, and DOE. Bids were received in mid-May and it is expected that an order will be placed in the first part of July 1978.

5. H-Division Support.

a. Group H-1 [Backsen, Seamons, E-5; Carrier, E-2].

RATS. Formal documentation of the remote area telemetry system (RATS) continues and will be completed during this reporting period. Fabrication of a second RATS, to verify the documentation, is presently under way.

Alpha System. Software during this reporting period included modification of the alpha operation system to make it compatible with the H-1 mouse

house PDP-11/40 system. Appropriate documentation was also provided.

Wahl Interface. Design and development of a microcomputer-based interface between the TARAS PDP-11/20 system and the Wahl digital display were begun during this reporting period. The interface utilizes an Intel 8748 microcomputer. Design is 90% complete. Fabrication and software development are under way.

VORP. Fabrication of 25 voltage output radiation probes (VORP), under REECO purchase order 1416-W-01-8, was completed during this reporting period.

NTS Support. About 2 man-months (eight trips) were spent in support of H-1 at the Nevada Test Site (NTS) during this reporting period.

b. Group H-7 Support [Reitzel, Barnett, Green, E-5]. Since late 1977, E Division has been providing engineering support to H-7 for the design, specification, procurement, installation, and check-out of instrumentation data systems.

During this reporting period, two significant areas of support have been pursued.

TDF (Incinerator). The formal procurement cycle for a stand-alone 250-channel data logger system has been initiated. The equipment should be delivered in July 1978. After installation, the data system will be used for measurement and logging of process parameters associated with incinerator operation.

Radioactive Liquid Waste Management. A proposal for E-5 support of a computer-based monitor and control system was submitted to H-7 for review and approval in early May 1978. The proposal encompasses all phases of activity from system design and specification through installation and check-out.

c. Instrumentation for Automated Cancer-Cell Sorting and Analysis (H-10) [Hiebert, Greenwood, Jacques, Nickell, E-5; Van Lyssel, Hanson, Sandler, E-2]. Our support of the National Cancer Institute (NCI) through Group H-10 continues at a high level. Most of this support consists of special instruments designed for analytical measurements on individual biological cells in flow systems. Mechanical and optical properties of cells are measured at high rates, the data are processed through computer control, and cell sorting decisions are made. The various versions of these high-speed systems are

powerful tools in cell biology research. Significant progress has been made on a fast multiparameter data-acquisition system, on the sorting electronics for multiangle light scatter systems, on the dual laser system for visible as well as near-uv excitation of several new fluorochromes, and on several special-purpose instruments.

The prototype LACEL data system, a general-purpose fast unit for data-acquisition of measurements from many cell parameters, is nearing completion. As many as eight input parameters can be processed. Input timing decisions are made with 8-fold logic, and two sorting directions are established on the basis of time and pulse amplitude decisions made on four parameters for each direction. The system is arranged to allow two simultaneous experiments to be operated through the interface to a single computer. The system is designed in modular form to be adaptable to a wide assortment of experimental needs.

The dual-analog data-in module, which receives two parameters and digitizes their values for transmission to the computer, has been designed and checked out. The data coincidence module for making input timing decisions has been designed and checked out. The computer-controlled scaler module for counting events at various system input and output ports has been designed and checked out. The prototype bin and power supply assembly has been fabricated. A computer word-out simulator has been built to assist check-out. The sorting module has been designed and is being assembled; it is the last major module required for the system. It is also the most complex electronic circuitry. Software is being developed by several experimenters in Group H-10.

The highly successful multiangle light scatter system using Recognition System's wedge-and-ring photodetector arrays is being expanded to allow cell sorting. Up to now the system has been used only for cancer cell identification with no means of reacting to the analyzed data. The sorting system developed during this period uses a commercial gated amplifier and single-channel analyzer to determine which cell is to trigger the sort sequence circuitry. The sorting circuits include a clocked delay to synchronize the sort command signal with the oscillator driving the droplet generator, and a

charging pulse generator to charge a selected droplet containing a cell that is subsequently sorted by electrostatic deflection. Work has started on the next generation of multiangle light scatter systems. Two unique photodiode arrays have been designed, and fabrication was completed in the E-2 Hybrid Facility. These arrays are made of PIN photodiode detectors in optochip form. One array contains 60 photodiodes in a circular array to be used for 360 light scatter experiments. The other array has 41 photodiodes in a "cross" layout. Each array is mounted on a mother board along with transimpedance preamplifiers on each channel. These circuits were also fabricated in the Hybrid Facility.

New electronics to handle as many as 32 channels of parallel photodiode information are being designed. Each preamplifier will be followed by a simple gain stage that will feed a sample-and-hold (S-H) circuit. The S-H is controlled by a master pulse signal processing network that senses when the crest of the input pulse has occurred. At that moment, the master control sends out a hold signal to all S-H, thus giving an effective peak sense-and-hold action to all incoming signals. The held levels are fed to two 16-channel analog multiplexers, which in turn feed two logarithmic pulse amplifiers and two fast 8-bit ADCs. Each ADC output forms one byte to the computer interface and two photodiode channels generate a word. We hope to be able to assimilate the data from 32 channels carrying the individual cell scatter pattern signature in less than 200 μ s. If all goes well, one such system will be built for Memorial Sloan-Kettering Cancer Center in New York and one will be used at LASL.

Several accessory circuits have been designed for the dual laser system that is used for looking at two-color fluorescence and light scatter of cells excited by two wavelengths. The Model 8166 amplifier-integrator was designed to amplify pulses from photomultiplier sensors and integrate the pulse under controlled gated conditions. This technique of signal processing smooths out some of the systematic variations of signals that result as the cells traverse the laser beam. The Model 8168 region-of-interest signal processor was designed to control the display of a two-parameter multichannel pulse-height analyzer in synchronism with the pulse bounds setting of the Model 417 signal processor.

Several instruments have been developed for determining cell diameter by measuring the cell time of flight as it traverses a laser beam that is narrower than the cell diameter. The Model 8157 slow time-to-amplitude converter (TAC) senses when the cell edge meets the laser beam for the TAC "start" signal, and senses the moment of cell exit from the laser beam for the "stop" signal. Thus, the TAC output becomes a measure of cell (or nucleus) diameter. An interesting variation of this scheme has been implemented by researchers at Penn State. They have developed a circuit that generates TAC signals from constant-fraction discrimination techniques. This yields diameter data that are less dependent on pulse height and more nearly proportional to pulse form. One such circuit has been built for H-10 experimenters to evaluate.

Work continues in support of measurements of short fluorescent decay times of stained cells excited by a pulse designed to give controlled triggering of a pulsed nitrogen laser, in synchronism with the arrival of a cell in the region illuminated by the laser.

6. L-Division Support.

a. Laser Fusion Support (L-1) [Sutton, Day, Hanna, Remington, Sanders, Tucker, Wells, E-5; Hansen, Spencer, Waechter, E-2; Cummings, Teasdale, WX-4; Feind, Karpen, MRL]. E Division is supporting the L-Division development of two carbon-dioxide pulse lasers to be used for fusion research, the eight-beam laser system at building 86, now known as Helias, and the Antares laser. The Helias laser is discussed here.

Several areas of the L-1 Helias laser system have been supported by E Division for the past few years. These areas include control system design, fabrication and installation, computer-control programming, optical alignment, mechanical design and fabrication, and technical support for electrical and mechanical assembly of the Helias laser. The E-Division support has involved virtually all groups at one time or another. The present level of support is seven full-time staff members from E-4, E-5, and E-10, eight full-time graded series from E-4 and E-2, and many part-time or occasional personnel from E-2.

The L-1 goal of extracting full energy from the Helias laser was met on April 12, 1978. In the past

6 months all effort has been focused on reaching that goal and the E-Division team has contributed substantially in attaining it. The control system was used in full support of reaching this goal.

A paper entitled, "Minicomputer/CAMAC Control System for an Eight-Beam CO₂ Laser Facility," submitted to the 1978 IEEE/OSA Topical Meeting on Inertial Confinement Fusion, was accepted and presented in February. The authors were E. Jolly, D. Remington, L. Sanders, J. Sutton, M. Thomason, and F. Wells. This paper briefly describes the Helias control system.

On May 3 and 4, 1978, a planning retreat for all Helias staff personnel was held at Taos, New Mexico. Schedules were developed for work to be accomplished during the next 6 to 9 months.

A summary of specific E-Division activities and their present status follows.

(1) Control Programming. The control program, EBS, has been evolving for the past 2 yr. Several versions of the program will be written in developing one that will support the target experiments expected to begin in the summer of 1978.

The EBS program has two basic parts: machine controls and data acquisition. Machine controls include operation of the E-beam Marx generators, pulse-forming network (PFN) pulsers, supporting spark gap gas systems, E-beam chamber vacuum system, laser gas control system, and other minor supporting subsystems. Data acquisition includes testing and reading the high-speed digitizers, displaying acquired data, storing digitized data and other shot parameters on disk and magnetic tape, retrieving lost data from magnetic tape, updating parameters, and logging operations.

The EBS control program has evolved into a three-task multiple overlay (three overlay areas) using almost 28 k of core storage on the Data General Eclipse S/200 control computer. The control program was recently converted to use FORTRAN V, which increased the speed of execution (by about 10 times) and decreased the amount of core storage needed (by about 10%) to operate the program. All supporting subroutines and library routines as well as supporting stand-alone programs have been converted to FORTRAN V or to be FORTRAN V compatible. Other recent additions to the control program have been laser gas pressure top-off at the beginning of

the charge cycle, fast plotting, and PFN charge voltage modification.

The laser gas top-off uses some of the laser gas filling routines to adjust the laser gas pressure before charging. This gives better control on the gas pressure at shot time. It will also provide a means of compensation for amplifier-to-amplifier gain nonuniformities.

To improve the operation of the program, the plotting speed of the shot electrical data has been increased dramatically. Plots that had taken 18 s to display on the Tektronix 4014 terminal can now be displayed in about 4 s. Several different methods for increasing plotting speed were investigated before the optimum method was found. Displays are now obtained by reading a disk file that contains the graphical information for the plot background and outputting this information using a new assembly language plotting subroutine. This subroutine is also used to display the plotted electrical data. In addition to data plotting the method is used to display capacitor bank charge voltage during the charge sequence.

The PFN charge voltage modification will allow charging the PFNs to different charge voltages. This modification requires a major change in the charge routine of the main operating program and is now being tested.

In addition to the main operating program, other supporting stand-alone programs have been written or modified.

- An alignment monitor program was written. This program interfaces with the beam alignment segment sequencer and uses the color display to inform the operator of alignment status. The first version of the program is in use now, but it is expected that this version will evolve in the near future.

- An interface between the new asynchronous line multiplexer (ALM) and with a remote microprocessor for beam diagnostics has been studied. Some subroutines to support the ALM have been written and tested.

- The laser gas program has been modified so that now an operator can shut the system down in the middle of an operation if there is any problem. The program will shut off the vacuum pumps and close all the valves in an orderly fashion. The orderly shutdown can be obtained by pushing one button on the control console.

- Two other support programs, called CRASHSV and TAPESV, for EBS are being updated. The purpose of CRASHSV is to allow data to be retrieved from the digitizers in the event of a system crash at shot time. The other support program, TAPESV, allows data to be retrieved from the on-line tape in case data are lost from the disk. These programs are being converted to FORTRAN V, and CRASHSV will be used to update the operations log file.

A computer link to the CCF has been established in building 86. This allows front-end optics codes to be run. The optics code that has been written by Shappert and Montgomery has been put on our Data General Eclipse S/200 and comparisons of execution time and accuracy between the CDC-6600 and our computer are being made. This will determine if it would save time to run the Schappert and Montgomery code on our computer instead of the CDC-6600.

Some development of a nonlinear least squares curve fitting code, to be used to fit some pulse data from the front-end room at a later date, has been done. The least squares code uses the algorithm of Marquardt, which is a combination of the gradient method and the Taylor series method.

We are now working on a program to monitor the position of all the target chamber mirrors. This program will be written in Intel 8085 assembly language. Multiple precision multiplication and division routines need to be written. The assembly language is converted to machine language by means of a cross assembler that produces output for an EPROM programmer. A paper on the project by D. Wells and D. Remington has been submitted to the CUBE Symposium to be held at LASL in October.

(2) Beam Positioner Equipment. During the reporting period all mirror mounts, stepping motor controllers, and beam alignment system cables from the oscillator-preamplifier area through the final spacial filters in the power amplifiers were installed. This hardware enables the alignment team to steer the eight beams to the target chamber input ports.

After this equipment was installed and checked out, effort was directed to improving portable beam positioner and motor address decoder reliability. Principally, this has included securing integrated circuit (IC) packages in their sockets with clamps and replacing flat ribbon cables with another type

of cable that stays more securely in place. Also, with a minor change in circuit configuration, two CMOS inverters have been eliminated in each motor address decoder.

The majority of problems encountered in maintaining this equipment have centered on cable connector malfunctions, such as short circuits in MS3126A series connectors, cold solder joints in D-type connectors, and intermittent opens in flat cable connectors. These problems and occasional electronic component malfunctions have been corrected as they were observed.

Within the next 6 months the D-type connectors will be replaced by MS-type bulkhead feedthrough connectors and MS crimp-type cable terminations. All flat cables will be replaced with more reliable cable types. Individual cables will be repaired or replaced as necessary to improve reliability.

Delta Mirror Mount Controllers. There are 16 mirror mounts, 8 flat turning mirrors, and 8 parabolic focusing mirrors in the Helios target chamber. These mirrors will be positioned to direct and focus the eight laser beams onto the target. Each mirror mount contains a three-point drive mechanism having three stepping motors located at the corners of an equilateral triangle. To provide manual positioning of these motors in an ordered fashion, a delta mirror mount controller has been designed.

All stepping motor driver equipment for the target chamber mirror mounts has been installed and checked out. This includes a rack-mounted delta mirror mount controller for the control room, a portable controller for use in the target chamber, a motor controller interface box, 16 bulkhead feedthroughs, and 32 cables. Previously, a prototype portable controller and six motor address decoders had been installed near the target chamber.

With this equipment, the 16 mirrors in the target chamber can be steered to direct and focus the 8 beams onto the target. A switch is provided on the control room unit to select beam steering either from this controller or from the portable unit at the target chamber.

After this hardware was checked out, the original portable delta mirror mount controller was transferred to building TSL-85 where it is used for moving two mirror mounts installed there. Later in the summer this unit will be updated with circuit

modifications necessary to make it identical to the new portable controller. It will then be available as a spare unit for TSL-86.

Mirror Position Display System. Now in the design and fabrication stage is the mirror position display equipment. The functions of this hardware are

- To monitor the revolutions of the 48 stepping motors that drive the 16 mirror mounts in the target chamber and to store their absolute positions in nonvolatile memory.

- To display the position of any selected mirror mount in either absolute motor steps or in FOCUS, TILT, and ROTATE positions. The latter display can be either in motor steps or microns.

- To record the motor positions on the Eclipse computer disk storage unit.

Motion of the 48 motors in the target chamber will be sensed by 48 incremental optical encoders coupled to the motor drive shafts. Outputs from the encoder tracks will be multiplexed to the circuits located near the target chamber. These circuits will address the mirror mount being moved and transmit step information to the display chassis located in the control room. Data transmission will be via a fiber optic cable data link. For these circuits it is planned to use a type 8748 microprocessor and a type 8351 UART.

Encoder data processing and display data will be accomplished by the mirror-position display chassis in the control room. This unit will contain an 8085 microprocessor board along with type 2716 EPROM program memory and 5105 RAM data storage memory. A battery standby power supply will maintain the motor position data should primary power fail. Type 8251 UARTs will communicate with the target chamber circuits and the Eclipse computer.

Early in this reporting period the 8085 microprocessor board was operated with a TI-735 terminal. A data storage memory circuit with standby battery power was assembled and tested with the microprocessor. Using this equipment, considerable experience was gained in programming the 8085. Also, tests indicate that the battery pack can maintain the memory contents for several weeks following primary power interruption.

The display chassis is now being constructed. All address decoder, data memory, and display

circuits have been designed and all circuit board wire wrapping has been completed. A circuit board containing a level shifter for the encoders has been designed and 60 boards have been fabricated. Sixty incremental optical encoders have been supplied by the vendor and a like number of encoder housing ports have been received. Finally, the fiber optic circuit boards and cable are on order from E-5.

The following tasks remain to be completed.

- The design and fabrication of electronic circuits required for deriving the motor stepping data from the encoders. An encoder is now being tested and its outputs, when driven by a stepping motor, are being studied. This work should suggest an appropriate design for the multiplexer and processor to derive the stepping data.

- Complete the fabrication of the mirror position display chassis. This should be accomplished within the next month. Check-out will begin immediately thereafter.

- Assemble the 48 encoder units and cables for the 16 mirror mounts and install them in the target chamber. This will be accomplished by two or three technicians later in the summer.

- Write and debug the programs necessary for operating the system. Recently, D. Remington, E-4, has been assigned to this project. He will work principally on writing these programs, and he should provide substantial help in completing the project.

- Install the display chassis in the control room and the processing circuits at the target chamber, along with the fiber optic data links. Check out the system.

It is anticipated that the system will be in operation by August 15, 1978.

Recently, an abstract was written for a paper to be presented at the CUBE Symposium in October 1978. It was entitled "Mirror Position Display Equipment for the Target Chamber Mirror Mounts of the Eight-Beam Laser Fusion Research Facility," by David A. Remington and Frank D. Wells.

(3) Target Chamber Vacuum System Controller. The target chamber vacuum system controller will provide electrical controls to operate all vacuum equipment associated with the target chamber. The control system will provide the necessary active and passive interlocks as specified by L-10. The control system, operable from any of three

locations, will present data to all three locations simultaneously. These locations are the target chamber area, the control room, and the control computer.

Two cryogenic pump controllers have been constructed and are operable. These controllers provide interlocked operation of the Cryogenic Technology, Inc., (CTI) cryogenic pumps used in the target chamber vacuum system. Each controller is capable of automatically regenerating its pump in addition to controlling its cryopump and compressor unit. Operation of these controllers revealed that a few modifications would be desirable. The changes include allowing the cryopump and compressor to operate independently of each other and incorporating latching relays with compressor interlock status indicators. Water-flow interlocks also had to be changed to be compatible with new water-flow switches installed in each helium compressor. All of these modifications have been completed.

A comparator chassis has been constructed and is now being checked out. This chassis makes comparison between pressures indicated by Varian 810 thermocouple vacuum gauge controllers and setpoints to satisfy interlock conditions for the main controller. The comparator chassis also contains instrumentation amplifiers to amplify the thermocouple vacuum gauge outputs to 0 to 10-V signals for remote readout of pressures in the vacuum system by the main controller.

The main controller has been fabricated and is being checked out. It will provide all necessary interlocks for safe mechanical operation of the target chamber vacuum system. The main controller will indicate status of all valves and pumps in addition to displaying pressures throughout the vacuum system. The main controller will communicate with a remote controller located in the target chamber area. The remote controller will appear to be identical to the main controller from the front panel, but it will have priority over the main controller and the control computer. The control computer will be able to check the status of the target chamber vacuum system at any time, but it will operate the system only if enabled through two key interlocks. The main controller is operable to the extent that it is able to control all valves and pumps in the system. However, the interlocks have been

temporarily bypassed until the comparator chassis can be completed and the analog section of the main controller can be checked out. A partial link between the main controller and the remote controller has also been established, which allows the remote controller to operate the system and indicate status of the system excluding pressure readout.

(4) Target Insertion Device Controller.

The target insertion device controller will provide electrical controls to transport a target from an airlock outside the target chamber into the center of the target chamber. The controller will also control valves and pumps associated with the target. The controller consists of a manual control panel that will allow manipulation of the target insertion device components, a target carrier tracker that will track target insertion and removal and provide interlock information, and an automatic sequencer that will insert or remove a target upon command.

The manual control panel has been completed. This panel provides interlocked operation of the target insertion device. The design of the target carrier tracker and the automatic sequencer has been postponed.

(5) Three-Axis Manipulator and Burn-Paper Controller. The 3-axis manipulator and burn-paper controller will be composed of two systems. The first system will provide remote control of a 3-axis microposition that holds a target in the center of the target chamber. The second system will provide remote control of the burn-paper holder that can be carried by the target carrier. A prototype controller has been constructed to allow immediate operation and will be evaluated soon. Once evaluation has been completed and all requirements have been determined, fabrication of the actual controller will begin.

(6) Building Safety and Warning Light System. The Helias warning light has been a manual system to date. For safety reasons, this system must be automatic. The design for the safety interlock and door warning lights has been completed and fabrication and installation are nearly complete. This system will allow selection of room safety conditions by automatically detecting low- and high-level hazards and displaying the appropriate warning at the entrance to each room. A master

panel in the control room will show the status of all rooms.

(7) Optical Isolation for the Shielded Rooms.

An investigation is under way into optical isolation to eliminate ground loop problems with signals coming into the computer screen room from the control room.

(8) Saturable Absorber Gas Control System. Due to instability problems in the laser power amplifiers, a saturable absorber was designed for the Helias laser. The controls for this system have been designed, fabricated, and installed. This system is now fully operational and is being used routinely.

(9) Room-Temperature Target Insertion Mechanism (TIM). The TIM is a device that will inject a laser fusion target through an airlock, into a 13-mPa (10^{-6} torr) vacuum, and locate it to within $\pm 2.5 \mu\text{m}$ of a predetermined point in space. The point in space is defined by the center of a sphere that is used to align the laser. The current status of the TIM and its associated hardware is discussed in the following paragraphs.

The entire TIM has been installed and tested for reliability. Some minor problems were encountered during this testing; however, they have been corrected.

The TIM is currently removed from the target chamber to accommodate additional hardware that will provide high-voltage isolation from the target chamber. The hardware is being fabricated now.

Five target holders and one alignment sphere holder have been fabricated and assembled. A fixture that will enable one to align the target center to the sphere center in the laboratory, before the targets are inserted into the target chamber, has also been fabricated and tested. The results of the test show that the fixture is suitable for aligning the targets to the $\pm 2.5\text{-}\mu\text{m}$ tolerance.

A new method for mounting the alignment spheres is being designed. Currently, the spheres are glued onto their stalks and occasionally they become detached. The new method consists of electrical discharge machining (EDM), grinding a hole into the ball, and then fitting a portion of the stalk into the hole. This attachment method should be much more reliable than the gluing method.

A 3-axis manipulator that enables one to remotely translate the target in the X, Y, and Z axes has been designed and fabricated by T. Tucker. The requirements for the mechanism are as follows.

- It must have a range of ± 1 mm.
- It must have a resolution of $2.5 \mu\text{m}$.
- All hardware must fit into a 57° cone about the horizontal axis whose vertex is at the target.
- Existing hardware must be used as often as possible.

Preliminary evaluations indicate that the mechanism will perform very satisfactorily; however, testing in the working environment must be performed to determine the acceptability of the design. The manipulator controls, designed by L. Sanders, are performing very satisfactorily. A target alignment fixture that will accommodate the type of target holder necessary for the manipulator has been designed and fabrication is nearly complete. A carrying case, designed by R. Teasdale, will transport five target holders at once and is suitable for carrying classified targets. A burn-paper holder that will index to be perpendicular to each laser beam (one at a time) and mounts onto the TIM, has been fabricated and assembled.

Five collets that hold the target stalks have been coated with 1.5-mm -thick lithium fluoride to determine if the coating will reduce the contribution of the collets to the self-oscillation problems of the triple-pass amplifiers. It is desired to measure the absorption of the coating on the collets before installation, and then determine the effect in the working environment. The collets are currently being shipped to LASL.

A vibration survey of the Helias has been conducted. Most of the data are presently being reduced; however, time displacements associated with the TIM have been determined. A summary of the TIM data is listed in Table III. These results indicate

that the resonant vibration of the TIM in the working environment is much less than the $\pm 2.5\text{-}\mu\text{m}$ positional tolerance. A procedure for determining the repeatability and stability of the TIM is currently being devised.

Two autocollimators that mount inside the target chamber have been designed and fabricated. The autocollimators are used to determine if the target is located at the proper position inside the target chamber. A testing procedure is being devised to determine the stability of these devices.

A fixture, designed by W. Teasdale, WX-4, for determining some of the requirements for a cryogenic target insertion mechanism, is being fabricated.

b. Antares Laser Project (L-10) [Gutscher, Seifert, E-5]. A structured analysis of the control system requirements has been completed and it has been determined that a tree-structured computer-based system is needed to meet all of the requirements. Hewlett-Packard's HP-1000 computers will be used for all the major system nodes. Their DS-1000 computer network software will provide communications protocol, task-to-task interactions, file transfer capabilities, and resource sharing. Digital Equipment LSI-11 microprocessors will provide the interfaces between the HP-1000s and the Antares laser system. The LSI-11s were chosen because they can provide all of the interfaces required between the laser hardware and the computer network. Some instrumentation requirements can be met by using CAMAC devices with LSI-11 crate controllers. Others require only LSI-11 type I/O cards. An optimum design will be developed based on capabilities and costs. Initial procurement is under way for LSI-11 components and development hardware and software for building prototypes for the front end and laser hall. The first prototype is scheduled to be used in the prototype front-end system and should be ready for evaluation by November 15, 1978. A complete control system for one beam line of the front end should be ready by October 1, 1979.

Development of the necessary communication protocol for connecting the LSI-11s to the HP-1000s is in the preliminary stages, with several designs being considered. The purchase of two PDP-11/03s should allow for reasonable experimentation of this approval, and will also provide for control support of the prototype front end scheduled to start up in September.

TABLE III
RESULTS OF TIM VIBRATION TESTING

Apparent Resonance Frequency	Associated Displacements in Each Axis (Micrometers)		
	X	Y	Z
120 Hz	0.018	0.150	0.150

7. M-Division Support.

a. PHERMEX Enhancement Program (M-2) [Johnson, E-5]. All major PHERMEX detection chamber enhancement projects are complete except the microNOVA data retrieval back-up system software and documentation. A system study is presently under way on the PHERMEX machine for the control and monitoring system.

b. Detonation and Shock Wave Physics Support (M-3, M-6, M-DO) [Lundy, Love, Parker, E-5; Martin, Waechter, E-2]. Work on the microprocessor-based firing-site control system continues. The firing site control system is now installed at Ancho Canyon for Group M-6. Final system tests are being conducted before changeover. The interface to the rotating mirror camera is operating. System modifications have been proposed for Group M-3. Final system modification will be determined before this installation. Completion of the first system is now scheduled for July 1978.

Support work for the short-exposure (10 ns) microchannel plate image intensifier cameras used for detonation studies at Group M-3 included making two more high-voltage donuts for supplying proper voltages to image intensifier tubes and designing and constructing an image intensifier tube test system. This test system will permit rapid evaluation of new image intensifier tubes and of the effect of changing tube voltage parameters on image quality. It should be in use by mid-summer.

Some further instrumentation was built and delivered to the Hercules Power Co. Rocket Propellant Hazards Test Facility near Salt Lake City under a US Navy contract with M Division. This included a 3-channel digital time delay, a 12-channel pulse fan-out, a 5-channel pulse-boost amplifier, and two pocket pulser.

A proposal was submitted in conjunction with M Division to the US Air Force Rocket Propulsion Laboratory at Edwards Air Force Base to provide detonation instrumentation for an MX missile stage hazards test in January 1979. Indications are that this will be funded and will include operating some 20 channels of explosive pin switch timing circuits and the fast solid-state camera being built for the US Air Force Space and Missile Systems Organization.

In conjunction with Group M-3, a proposal was prepared for Pantex to permit them to use the short exposure image intensifier camera techniques devel-

oped by Group M-3. This includes avalanche pulsing circuits and timing circuitry.

8. P-Division Support.

Electron LINAC Experiment (P-1) [Winston, E-5]. Most of this work consists of electronic support for the construction of a small electron accelerator. Accelerator characteristics include a beam current of a few hundred milliamps, energy of 4 or 5 MeV, pulse widths from 0.3 to 3 μ s, pulse repetition rates of up to 50/s, and an rf accelerating field frequency of 1300 MHz frequency. Most of the rf system work on the machine was performed by W. Stein, P-1, and E-Division personnel did most of the other electronics work. The machine has been used for some experiments and others are planned soon. Some types of work for which it will be useful are

- A study of low-energy x rays produced by collision of the electron beam with a pulsed laser beam. Equipment is now being designed and built for this experiment.

- Feasibility studies of radiographic techniques in connection with the reactor safety program. This includes a study of using an accelerator as a source of x rays for taking radiographic movies of a reactor core assembly in use and as it is destroyed by an accident. These studies are nearly complete and the technique seems to be technically feasible.

- Feasibility studies of using the electron beam to pump a laser. Group AP-2 personnel are doing the laser work for this study, since the LINAC can be operated at fairly high repetition rates. These experiments have not been very successful yet, but it is believed that the problem lies in building the lasers.

Considerable time has been spent in the maintenance of the machine and routine work connected with it. The following electronic equipment was also worked on in the past period.

- A triple constant-current power supply for beam focusing magnets is nearly complete. This consists of three power supplies, each capable of 3-A output into loads of up to 7 Ω . Regulation capability will probably be to a few hundredths of a percent.

- A system for monitoring the position of the electron beam after it has been bent is complete but has not been operationally checked. The device uses

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- A system for monitoring the position of the electron beam after it has been bent is complete but has not been operationally checked. The device uses

an 11-wire harp in the beam line for the input and the output is a graph-like presentation from an oscilloscope. The beam pulses may be from 0.3 to 3- μ s wide and the time resolution of the monitor is a few nanoseconds, so an energy spectrum may be obtained at any time during the pulse. Much of the construction of this unit was done by A. Whittemore, E-2, and D. Hoover, P-1.

- A chassis used with the beam-position monitor to control the energy of the LINAC has been constructed but not checked out in use. This chassis uses signals from the beam position monitor to control the electron energy so that the beam remains in a fixed position for collision with the laser beam.

- Design of a magnet power supply that will bend the electron beam down into a dump target after it has collided with the laser beam has been started. This supply will have optional current and field or position control, so other chassis will have to be provided to go with it. The beam position here must be controlled fairly closely to prevent its striking the tube walls and making background x rays. The field must change as the energy changes to keep the beam centered.

9. Q-Division Support.

a. Real-Time Inventory System (Q-2) [Ethridge, Kuckertz, E-5]. Group Q-2 is engaged in a research and development program to investigate ways to continuously inventory and safeguard special nuclear material (SNM) while in storage vaults.

The real-time inventory system physical layout is shown in Fig. 35. The basic concepts of this system are to continuously monitor all SNM in the storage vault; to measure the physical and nuclear parameters of all SNM entering and leaving the vault; and to monitor all personnel entering and leaving the vault. A minicomputer (Data General NOVA-3 in the prototype system) will be used on-line to do the monitoring and transaction processing. A typical transaction would take place as follows. A person wishing to place SNM into the storage vault would enter a request for this transaction at the transaction terminal. The computer would ask certain questions to authenticate the requester's identity and authority. The material destined for the storage vault would be placed in the vault via door 1 of the material verification station (MVS). Next,

Fig. 35. Real-time inventory system physical layout.

the material would be weighed and a gamma spectra and neutron spectra taken. This information would be retained by the computer until the material is removed from the vault. The requester then enters an anteroom of the vault via the gamma portal monitor. The requester is not permitted to carry SNM or any metal objects through the gamma portal monitor. The SNM is removed from MVS via door 2 and placed on a previously designated shelf monitor in the vault. The requester then leaves the vault and anteroom without any SNM or other metal objects. The SNM is monitored continuously for evidence of unauthorized tampering or removal.

Other types of transactions are completed in a similar manner with the basic proviso that all SNM enters and leaves the vault via the MVS while all people enter and leave the vault via the gamma portal.

With the exception of the shelf monitor and some special-purpose interfaces, all of the system hardware is being purchased from commercial sources. The main thrust of the system development is divided into two main areas, the design and development of the shelf monitors and the design and development of computer software to operate the system.

(1) Shelf Monitors. The shelf monitor has been redesigned primarily to reduce cost. Electronics material costs have been reduced from approximately \$70 to \$30 in the 10 000 quantity range. This cost reduction was realized by replacing the

hardware logic components with an Intel 8040 microcomputer. The IC package count of 40 has been reduced to 7. Approximately 20% of the microcomputer on-board program memory is needed to achieve present shelf-monitor requirements. The addition of intelligence to the shelf monitors will undoubtedly lead to an increase in the design requirements as the system development continues. The Intel 8048 contains 1 k of ROM program memory. For the first 16 shelf monitors, the Intel 8748, which contains 1 k of UV EPROM program memory, will be used. The use of 8748 with erasable programmable memory allows for systems changes with no hardware cost involved.

As a result of this program, Group E-5 has developed complete 8048-8748-8035 microcomputer system design capability. The microcomputer software, the hardware breadboard, and the programming of the first 8748 are complete.

The microcomputer shelf monitor design has been completed. The 20- by 20-cm printed wiring board has been reduced to a 10- by 10-cm design, a size reduction of 75%. Sixteen units are being fabricated for the Q-2 system. Two hundred units will be fabricated for the TA-55 demonstration system this fall.³²

(2) Time Monitor. An additional microcomputer unit to be placed on the shelf monitor bus to report the data-acquisition internal time to the minicomputer has been designed. The hardware-software design is primarily a subset of that of the shelf monitor.

(3) NOVA-3 Computer System. The computer system that will monitor SNM in a vault is shown in its entirety in Fig. 36. The system consists of a Data General peripheral device. All instrumentation controlled by this computer system is interfaced to the NOVA-3 I/O bus by one of two standard interfacing schemes: (1) EIA RS232 or (2) CAMAC Dataway. The RS232 interface is a standard device supplied by Data General Corp., while the crate controller, which allows communication with the CAMAC crate, is a commercial product obtained from BiRa Systems Corp. All instrumentation, with the exception of the shelf monitors, is connected to the NOVA 3 via a CAMAC crate. This CAMAC subsystem is shown in Fig. 37.

Software has been written to simulate a 16-shelf-monitor system plus a time monitor. At pres-

ent this software exercises each of the shelf monitors and keeps appropriate statistical data pertaining to their operation in a disk storage file. This system has been run for long periods of time (7 days) with results that show the scale in the shelf monitor appears to be stable to within ± 2 counts/s out of a total of 1400 counts/s.

b. DYMAC System Software (Q-3) [Ford, Wooten, Elkins, Dorin, E-5; Hagen, Q-3; Cordova, AADP]. The DYMAC program became operational on January 19 when the Nuclear Material Office (NMO) received the first shipment of SNM at the new facility. During the reporting period, the DYMAC system ran 45 processing days and handled 2178 transactions. No SNM differences occurred during comparison of the physical inventory with the DYMAC general ledger or with the laboratory-wide LASL accountability system (LAS) for nuclear materials. One difference did occur in the isotopic content, a maximum of 2 g, but this is due to normal rounding errors. Although there were no SNM differences between the two accountability systems, DYMAC and LAS did show differences in other fields of the inventory records. They did not always concur on the creation date of the item, its location, shelf, item description, measurement code, bulk amount, or bulk units. This lack of agreement is because LAS waits to modify the inventory until the end of the month, then it does not always execute the transactions in chronological order. In all cases of disagreement, the DYMAC inventory was correct.

(1) Back-up Computer. Experience indicates that the initial plan to use the NOVA 840 computer from Phase I is no longer viable. Its limited memory and inability to run INFOS, the data base manager, make it useless for back-up and training purposes. Originally, we had thought we could use the data base manager, written for DYMAC Phase I, at TA-55, but now that we have more clearly defined the resource needs for back-up and training, we find that INFOS is indispensable. We have begun procedures to purchase another Eclipse C330 that will include the following equipment.

- Eclipse C330 with 80-k words of memory, memory allocation and protect (MAP), and expansion chassis
- 20-Mbyte top loader disk system
- Magnetic tape unit

Fig. 36. Real-time inventory system schematic diagram.

Fig. 37. Real-time inventory system CAMAC subsystem.

- Two system CRTs
- Real-time clock
- Line printer, 125 char/s
- Communication chassis with asynchronous line multiplexer with ALM-16 and four 4-line, 20-mA interfaces

(2) General Software Modifications. The changes to DYMAC software are an ongoing function as the system grows to accommodate the facility's processing and accountability needs. Among the changes made during the reporting period were an expanded measurement control program, additional off-line reports, and improved user functions.

The measurement control program now includes a table of all the weight and count standards required for maintenance of the NDA instruments. Another program update includes TNC maintenance.

The DYMAC system generates two new off-line reports. One report sorts and sums the inventory by location and by shelf to aid in taking physical inventory. The other sorts and sums the inventory by special designator.

Ongoing improvements to user functions clarify messages, shorten system response time, and make data entry easier. For example, the user can now delete a character from his entry data by hitting the delete key; formerly when he hit the delete key an underscore appeared on the screen following the character string he wished to change. The user can now delete an entire line of entry data by hitting the backslash key. Another improvement is response time-outs that release the system from a terminal request if the user lets 5 min elapse before responding, and from an instrument readout if the response takes more than 1 min. This makes the system more available to other users.

(3) Advanced Carbide Fuels: Transaction Refinement. The transaction sequence for the advanced carbide fuels process in the ^{239}Pu R&D wing (mentioned in LA-7211-PR) has been altered. The two changes to the list, shown in Fig. 38, were the addition of option 12, REDUCE BRIQUETTES, which adjusts the bulk value of a briquette lot to account for a 19% loss in the reduction furnace, and the reordering of transactions 8 through 16 to more closely resemble the order of physical processing.

(4) Metallography Transactions. DYMAC programmers defined a transaction sequence, shown in

```

<<< SELECT OPTION >>>
1...RECEIVE FROM MANAGEMENT ROOM
2...TAKE SAMPLE
3...RETURN FEED STOCK TO MANAGEMENT ROOM
4...SEND SAMPLE OR SCRAP
5...PREPARE NEW BATCH
6...ADD CARBON AND UO2 to PUO2 BATCH
7...TRANSFER IN GLOVE BOX LINE (WITH MEASUREMENT)
8...REDESCRIBE BATCH
9...WEIGH SCRAP
10...SEND BRIQUETTES TO REDUCTION FURNACE
11...RECEIVE AND VERIFY BRIQUETTES
12...REDUCE BRIQUETTES
13...BLEND LOT
14...SEND SINTERED PELLETS TO GRINDING
15...RECEIVE SINTERED PELLETS
16...WEIGH AND SEND FINISHED PELLETS
?_____

```

Fig. 38. Updated transaction sequence for the advanced carbide fuels process.

Fig. 39, for the metallography process, which occupies the rest of the ^{239}Pu R&D wing. The transactions will be ready when metallography processing begins. Most input to the metallography process is pellet samples from the advanced carbide fuels process. Metallography technicians cut each pellet in half; they save one half as a reserve sample and process the other half. Scrap generated includes sweepings, grit, paper, cloths and wipes, etching solution, and mounting materials.

The material value for each pellet fragment is less than a gram, the minimum accountable unit for plutonium. Normally, each fragment would not appear on the book inventory. To keep a close record of the metallography process, however, DYMAC will account for the plutonium to the milligram.

(5) Metal Fabrication Transactions. DYMAC programmers defined and wrote the transactions for the metal fabrication process, which occupies the entire 300 wing. There are three option lists, corresponding to the material management room, fabrication process, and supervisory capabilities.

```

<<< SELECT OPTION >>>
1...RECEIVE SAMPLE PELLET
2...APPORTION PELLET TO PIECES, SCRAP POTS
3...COLLECT PELLET PIECES TO BE SCRAPPED
4...MEASURE SCRAP
5...SEND SCRAP TO RECOVERY
6...WEIGH UNPROCESSED PELLETS TO DETERMINE MIP
?_____

```

Fig. 39. Transaction sequence for metallography process.

```

<<< SELECT OPTION >>>
1...RECEIVE FROM OUTSIDE 300 WING
2...SEND TO PROCESSING
3...RECEIVE FROM PROCESSING
4...SEND OUTSIDE 300 WING
5...SHELF TRANSFER
?_____

```

Fig. 40a. Option list for the 300 wing material management room.

The 300 wing material management room is a unit process whose option list is shown in Fig. 40a. Options 2 and 3 follow material sent to and received from the fabrication unit process. Options 1 and 4 follow material sent to and received from other processes in the facility, such as the vault, counting room, or recovery wing. Option 5 follows material as it moves with the material management room.

The option list for the fabrication process, shown in Fig. 40b, is for the process operator to choose from as he performs the various process steps. The transactions call for a measurement or they write an MIP transaction where required.

The supervisory option list, shown in Fig. 40c, requires a password for access. Options 1 and 2 allow a supervisor to send and receive material without going through the material management room. Such material will not go through the conveyor system because of its size or because it is sealed and cannot be entered into the glove box line through one of the many hoods in the processing area. Options 3 and 4 are transactions whose sensitivity requires a supervisor to perform them.

```

<<< SELECT OPTION >>>
1...RECEIVE FROM MANAGEMENT ROOM
2...RECEIVE FROM WITHIN FABRICATION PROCESS
3...SEND ENTIRE LOT WITHIN FABRICATION PROCESS
  (MEASURE AND AUTOMATICALLY MIP THE DIFFERENCE)
4...SEND ENTIRE LOT WITHIN FABRICATION PROCESS
  (NO MEASUREMENT OR CHANGE OF SPECIAL DESIGNATOR)
5...COMBINE OR DIVIDE LOTS
6...SEND ENTIRE LOT TO ISO PRESS ROOM (NO MEASUREMENT)
7...RECEIVE ENTIRE LOT FROM ISO PRESS ROOM
8...MEASURE IN TNC
9...CHANGE SHELF
10...CHANGE ITEM DESCRIPTION
11...CHANGE BULK
12...RECEIVE AT ISO PRESS ROOM
13...SEND ENTIRE LOT FROM ISO PRESS ROOM (NO
  MEASUREMENT)
14...BULK WEIGHT VERIFICATION
?_____

```

Fig. 40b. Fabrication process option list.

```

<<< SELECT OPTION >>>
1...SEND FROM PROCESS (NOT VIA MANAGEMENT ROOM)
2...RECEIVE INTO PROCESS (NOT VIA MANAGEMENT ROOM)
3...CLEAR LOT TO MIP
4...WEIGH AND APPLY FACTOR
?_____

```

Fig. 41c. Supervisory option list.

(6) Streamlining the NMO Transactions. The NMO has two shipping-receiving accounts, one in the count room and the other in the vault. The option lists associated with each are identical and are shown in Fig. 41. We modified option 1 to make it repetitive. Now the NMO and his staff can receive a series of items consecutively without having to return to the start-up menu. This eliminates entering user number, password, receiving account, process, and option selection for each item. At the end of each RECEIVE transaction, the system asks whether the user plans to receive another item. If he answers yes, he can begin entering specific information about the next item. Option 6 has also been modified for repetitive SEND within the facility. As with option 1, this transaction allows the operator to send a series of items without having to return each time to the start-up menu.

Option 8 has been added to enable the NMO to make corrections. He selects it when he detects an entry error made while receiving an item from an external account. It is not unusual for data entry errors to occur when an item is first entered into the data base, because there is so great a quantity of information to enter for it. He makes the correction through account 7ER, which has been set up exclusively for error corrections.

In the vault transaction sequence, shown in Fig. 42, the repetitive transactions have been added to options 1 and 2. Transactions 3 and 4 have

```

<<< SELECT OPTION >>>
1...RECEIVE EXTERNAL SHIPMENT INTO TA-55
2...SEND EXTERNAL SHIPMENT FROM TA-55
3...ITEMIZE A SHIPMENT
4...COMBINE ITEMS TO FORM A SHIPMENT
5...CLEAR NONPHYSICAL ITEM TO ACCOUNT 777
6...SEND ITEM WITHIN TA-55
7...RECEIVE ITEM FROM WITHIN TA-55
8...EXTERNAL TRANSACTION CORRECTION
?_____

```

Fig. 41. Shipping-receiving accounts option list.

```

<<< SELECT OPTION >>>
  ...RECEIVE INTERNAL ITEM
  ...SEND INTERNAL ITEM
  3...GENERAL EDIT OF NONNAME ATTRIBUTES
  4...TRANSFER TO ACCOUNT 777 (NO PHYSICAL MOVE)
?_____

```

Fig. 42. Value transaction sequence.

been added. In the transaction sequence for account 777, shown in Fig. 43, the NMO clearing account, options 8 and 9 were added. The GENERAL CORRECTIVE TRANSACTION allows the NMO to correct input mistakes. The WRITE IN FROM ACCOUNT 991 transaction allows the NMO to adjust the station balance without moving material; this will be used to change such fields as material type or SNM value because of chemical analysis results.

c. Nambé Pueblo Solar Heating System (Q-11) [Murray, E-4]. The effort to collect solar heating system performance data on the Nambé building continued. Continuing difficulty with VIDAR magnetic tape data-acquisition system lead to its replacement with an HP-9830 system, which became available after the NSRSC computer became operational.

Essentially 2 months' data were obtained using the HP system, although several power failures resulted in loss of data for a few days. A power fail/auto-restart modification was added to the HP-9830 late in March and this solved the problem of power outages.

The data are collected on cassettes that are transmitted to machine "O" at the CCF over a 300-baud line via the HP-9830 at Q-11. The software to process the data is implemented on the NOS system and provides energy consumption summaries and plots of the data. The energy summaries obtained so far

```

<<< SELECT OPTION >>>
  1...CHANGE ENRICHMENT
  2...DECAY
  3...NORMAL OPERATING LOSS
  4...WRITE-OFF TO MUF
  5...DEGRADATION
  6...WRITE-OFF SHIPPER-RECEIVER DIFFERENCE
  7...TRANSFER MATERIAL BACK TO PROCESS CUSTODIAN
  8...GENERAL CORRECTIVE TRANSACTION
  9...WRITE IN FROM ACCOUNT 991
?_____

```

Fig. 43. Transaction sequence, account 777.

TABLE IV
NAMBÉ MEAN DAILY ENERGY SUMMARIES

	March	April
Collector incident	18.9 (1669)	17.7 (1561)
Rock bin input	6.29 (554)	4.84 (426)
Rock bin output	1.42 (125)	1.00 (88)
Furnace heat	3.63 (320)	0.47 (41)
Building heat	5.01 (441)	1.33 (117)

Units: MJ/m² collector (Btu/day ft²)

are given in Table IV. The energies are mean daily values in Btu/ft² of collector area per day.

Numerous data plots have been obtained for study of the system performance. Some typical examples are shown in Figs. 44, 45, and 46.

The system has now been switched to the summer operating mode to study temperature coast-down in the rock bin storage system, and to prepare for summer evaporative cold storage experiments.

d. Passive Solar Heating Data Processing (Q-11) [Murray, E-4]. A study to determine the feasibility of processing ASCII coded data cassettes on the NSRSC PDP-11/54 was performed. These cassettes are being recorded on 10 Accurex-Autodata/9 data-acquisition systems located at various passive solar heating experiments in this area. The data are transmitted over a 300-baud line to the CCF, a process that has proved to be extremely cumbersome.

Fig. 44. Nambé collector output and incident energy.

Fig. 45. Nambé rack bin input and output.

It was proposed to Group Q-11 that the tapes could be read on the PDP-11/34 at 2400 baud, then transmitted to the CCF over a 4800-baud dial-up line using a DEC communications terminal emulator software package. Another PDP-11/34 with the DEC software package is being used successfully at LASL for a similar application, and it was demonstrated that the tapes could be read on the NSRSC machine at the 2400-baud rate.

It was decided to use the proposed method, and the required hardware and software has been ordered.

e. Data-Acquisition and Control System for the Gas-Cooled Fission Reactor (GCFR) Disruptive Core Test Program (Q-13) [Damran, E-5; Miller, E-2]. This task involves E Division acting as design consultants for the duration of the GCFR disruptive

core program. Explicit responsibility has been given to E Division for the design and implementation of the instrumentation and control system to gather diagnostic data and to control the independent variables of each experiment.

During this reporting period, we completed the design and installation of 50 channels of instrumentation to test cell 1 and 10 channels of instrumentation to test cell 2. We have completed the installation of 32 instrumentation channels on the first 37-rod GCFR fixture. These include 24 Chromel Alumel temperature measurements, 3 voltage measurements, 1 current measurement, 1 pressure measurement, 1 vacuum measurement, 1 gas flow measurement, and 1 water flow measurement. We have installed the controls and have completed the dummy load test to demonstrate the operation of the 2.5-MW generator set. We have completed the vacuum bakeout test of the 37-rod GCFR fixture using the HP-3052A data-acquisition system to acquire data and control the 2.5-MW generator set.

During the next reporting period, we will continue to assist with the planned GCFR tests, which include tests at high vacuum, ambient pressure, and high pressure.

We will also be working on the design and installation of 200 more instrumentation channels to test cell 1 and 40 more instrumentation channels to test cell 2. The 250 instrumentation channels in test cell 1 will be used for the 400-rod GCFR fixture, while the 50 channels of instrumentation in test cell 2 will be used for intermediate tests of smaller test fixtures or subassemblies of the 400-rod GCFR fixture.

C. Instrumentation Support

1. Introduction. This section contains reports on a wide variety of small instrumentation projects that support LASL research on a continuing basis. Additional information on the items described here can be obtained from the people identified in the headings.

2. Gamma Scanner (CMB-1) [Greenwood, Kuckertz, E-5; Hanson, Whittemore, E-2]. Barry Barnes purchased a Nuclear Data ND6600 computer-based pulse-height analyzer system to replace the Canberra 50/50 system in use at DP-W Site. Control circuitry for the fuel-rod transport system will be provided by E-5.

Fig. 46. Nambé rack bin temperature profile.

The requirements include the following.

- a. Computer (ND6600) control of five stepping motors and their associated position encoder data readouts, gating control for a Nuclear Data 4-input multichannel scaler unit, and six scalers with 2^{20} or greater maximum count capacity. The control for these scalers will include inhibit/allow gating for each input channel, a start pulse to initiate the multiscaling pass, and a time-base output.
- b. A manual controller and display unit for each of the five stepping motor/encoder units with the following features:
 - Display of encoder position data, both directly from the encoders and through the computer.
 - Single-step and adjustable count rate with front panel controls.
 - A preset count capability to allow an operator to program a motor to step either cw or ccw any number of steps up to a maximum of 10^5 , then stop automatically.
 - An over-limit detector to allow any of three sets of over-limit switches on the x, y, and z mechanisms to disable the motors, as well as to display the disable condition. An override switch will also be provided.
- c. Modification of the existing cable hookups for the Canberra 50/50 for compatibility with the new system and to allow the Canberra 50/50 to be available on a standby basis, if needed.

An "intelligent" CAMAC crate controller will be used to provide the basic interface to the ND6600 through a 9600-baud RS-232 serial transmission link. Standard commercially available CAMAC modules will be used for the stepping motor drivers, input and output registers, and scaler channels.

Design of the multichannel scaler control unit for the ND6600 has been completed and the prototype unit fabricated. Design of the five manual controller chassis, which will provide computer-independent individual control and position monitoring as well as preset limit control and indication for the transport mechanism, has been completed and fabrication is in progress.

3. Mass Spectrometer Modification (CMB-1)

[Buchen, E-5]. A CEC Model 620 gas mass spectrometer was modified to accept an automatic ranging circuit that was designed by M. Trump, E-4, for analog recording of peak intensities. The 30-Hz modulated vacuum tube circuitry for peak detection was replaced with a solid-state parametric amplifier electrometer. Its output is fed to the automatic ranging circuit that permits recording peak heights whose amplitudes vary by four orders of magnitude. Both the magnitude and range are recorded to provide peak ratio measurement with better than $\pm 1\%$ accuracy.

4. Graphite Thread Coating Instrumentation and Control System (CMB-3) [Buchen, E-5, Southard, E-1; Gallegos, E-2]. An instrumentation and control system was designed and fabricated to provide an indication by electronic instrumentation of the mass flow of 10 separate gases, pressure of 2 gases, and the temperature of an oven to heat the environmental atmosphere for continuous CVD coating of graphite thread. Controls were also provided for the temperature of the environmental oven and for a mechanical vacuum pumping system.

5. Tritium Line Instrumentation (CMB-3) [Buchen, E-5; Umphres, Gallegos, E-2]. Group CMB-3 requested that existing vibrating reed electrometers be replaced with more stable and reliable solid-state units for indication and recording of tritium level at three separate locations in a tritium processing line. It was further requested that separately adjustable control points be provided for pump actuation and other process controls on each of the channels. A separately adjustable alarm set point was also to be provided for above-tolerance indication of tritium level. A 4-channel level indication and control system was designed, fabricated, and installed at DP-East. It provides front-panel meter indication of tritium level at each location, a recorder output for each, and separate control and alarm set points for each of the four channels. The fourth channel was included for future system expansion.

6. Intelligent Data-Acquisition and Control System (CMB-3) [Damran, E-5]. The intelligent data-acquisition and control system (IDACS) is a transportable unit available to many users. The system will accept a wide range of signal levels that are

passed through signal conditioners and filters before they are converted to a 12-bit binary value recorded on a TI-733 ASR tape cassette. Various operating modes are available by operator interaction through the keyboard. A program-selectable number of TTL input and output signals will also be available. The system has been completed and delivered. The software portion of the project is approximately 50% complete.

7. Miscellaneous CMB Projects [Buchen, E-5; Gallegos, Umphres, E-2]. Several short-term projects were completed for CMB groups and are listed by group and title. They included the following:

a. CMB-5. A pressure temperature control and recording system for a neutron experiment at LAMPF. It will provide 0 to 10-Vdc signals to their data-acquisition system for 690 MPa (0 to 100-k psia) and 0 to 1000°C.

A projectile velocity measurement system for the isotope fuels impact tester gas gun. It will replace the pin system for velocity measurement for certain projectile shapes. It contains a 2-channel interrupted light-beam velocity detector. The light beam will be interrupted by fins spaced at 0.64-cm intervals on the projectile face. The time between pulses derived from the fins will be a measure of the projectile velocity.

b. CMB-6 [Buchen, E-5]. A preliminary test was made for the velocity measurement system of the ram of a Dynapak machine. A 30.5-cm stroke velocity transducer was purchased from Trans-Tek for this application and its output was fed to the E-5 Biomation transient digitizer. This scheme appears to be a practical solution for this problem. However, further mechanical design and fabrication will be required for the transducer mount before additional tests can be conducted.

A furnace was required for brazing individual stems to laser target microspheres. With the cooperation of D. Court, CMB-7, a simple solution was provided by a microfurnace design that is nothing more than a lamp bulb whose glass envelope has been removed and its filament replaced with a tungsten helix of appropriate inside diameter to accommodate the microsphere. It results in a simple, expendable furnace.

8. Multichannel Scaler Display Driver (MCSDD) (CNC-2) [Brown, Nickell, E-5]. The MCSDD will be a

2-wide CAMAC module that will provide x-, y-, and z-axis signals to an x-y display oscilloscope. The data displayed will come from the Model 3016 multi-channel scaler (MCS) now being developed. The data in the MCS memory are transferred to the MCSDD when the memory is accessed. This means that the contents of the memory will be displayed only when the MCS is active (that is, in the RUN or READ mode). When the MCS is not active, a signal will be provided to blank the display (to prevent burning the CRT phosphor). The x-axis will correspond to the channel address and the y-axis will correspond to the number of counts in each channel.

The features of the MCSDD are described below:

1. Data clock LED

The data clock light-emitting diode (LED) emits a light pulse ~ 30-ms duration each time data (that is, channel address and data count in that channel) are transferred to the MCSDD from the MCS.

2. Counts full-scale switch

This 6-position rotary switch determines the number of counts needed to produce full-scale amplitude of the y-axis signal from 2^{10} to 2^{20} . The adjustment steps are in factors of 4.

3. Overrange indication

A flip-flop is set when the channel count transferred to the MCSDD exceeds the setting of the counts full-scale switch. This condition is indicated by the orange LED. Pushing the orange clear pushbutton clears this flip-flop.

4. Wraparound

When observing a small peak in the presence of a large peak, it is possible that the large peak will have some channels where the counts full-scale switch setting will be exceeded. The normal MCS display will show a "wraparound" display where the peak will start building up again at the bottom. With the wraparound toggle switch in the on position, the normal wraparound display will be presented. With the wraparound toggle switch in the off position, the display will show full scale for those channels where the count exceeds the counts full-scale switch setting.

5. Memory size LEDs

Three LEDs are used to indicate memory size selected at the MCS. The full scale x-axis signal will be adjusted automatically to be the same for each of the three memory sizes (128, 256, 512).

6. Outputs

The x, y, and z signals will be available from LEMO connectors on front and rear panels. The maximum x, y, and z outputs will be adjustable from a front-panel screw-driver adjust. The maximum output for the x and y signals will be 2.5 V and the maximum z signal will be 5 V.

The design is essentially complete and is in E-2 Fabrication.

The multichannel scaler to work with this driver has been designed and fabrication has begun. This wire-wrap CAMAC module has been pin listed by Group E-2 in preparation for wire wrapping. The first computer run has been received and checked. The unit is scheduled to be wire wrapped and mechanical assembly should be completed by the end of the May.

This unit is intended to work with the MCS display driver that is being engineered by D. Brown, E-5. Pin listing on the display driver was started in mid-May.

9. 10-A Laser Pulser (E-10) [Brown, E-5; Marquez, Staley, E-2]. R. Hammond is investigating exciton luminescence in silicon after it has received a pulse of light from a gallium arsenide laser. It was required that the laser be driven by a large first pulse of current followed by a smaller second pulse. The transition from the first pulse amplitude to the amplitude of the second pulse was to be monotonic.

A pulser was built in a 3-wide NIM module. The pulser characteristics are shown in Table V.

TABLE V
PULSER CHARACTERISTICS

	<u>First Pulse</u>	<u>Second Pulse</u>
Amplitude (adjustable)	0-10 A	0-10 A
Duration (adjustable)	0.2-2 μ s	2-100 μ s
Risetime	$\approx$ 0.2 μ s	N/A
Fall time	$\approx$ 0.2 μ s	0.2 μ s

The laser represented a nonlinear load and the drop was $\approx$ 2 V at 10 A. To supply the current, a 3-stage Darlington was used as the output driver. The output transistor was a 2N5038. To limit the current to the load, a 1.66- Ω resistor was used at the output of the driver in series with the load.

Outputs, BNC, from each side of the 1.66- Ω resistor were incorporated for oscilloscope adjusting and monitoring of the current pulse to the laser. The unit has been delivered and is performing satisfactorily.

10. Borehole Optical Survey System (G-4) [Handy, Parker, Brown, E-5]. The difficulties that would be encountered in mounting a TV camera down-hole for fracture viewing were studied. This would involve operation at a temperature of 260°C and a pressure of 69 MPa (10 000 psi). The camera temperature would not exceed 85°C. The video (composite) would be transmitted over a single coax cable 4.6 km long without intervening amplification. The field of view would be at 90° at a distance in clear water of 7.6 to 20.4 cm from the optical axis of the camera. A horizontal resolution capable of resolving a 0.5-mm-wide crack in granitic rock was required. The vertical resolution was for a 1-mm-wide crack and viewing should be possible while the camera descends at 15 cm/s (30 ft/min).

The camera operating temperature required the use of a silicon-diode-array vidicon. The cracks to be observed are in granitic rock, therefore of low contrast. For this reason, 10 TV lines were dedicated to crack resolution. The resolution limit, which for standard raster closed-circuit television (CCTV) is 550 horizontal elements by 350 vertical elements, sets the maximum field of view at 27.5 mm horizontal by 35 mm vertical. To reduce confusion of adjacent TV "fields" (two fields per picture frame in TV) during camera motion, it was recommended that the TV raster (scanning system) be rotated 90°. This also helps adapt to the desired camera field of view.

The camera field of view and the picture area on the face of the vidicon set the greatest object-to-image ratio at 2.8. A macrozoom lens covering a focal range of 36 to 80 mm is recommended to retain the desired object-to-image ratio at all object distances. A proctoscope or one of its many variants was recommended for the optical relay between the lens focal plane and the vidicon faceplate.

The study concluded that it would be difficult to propagate standard CCTV over 4.6 km of coax without the use of several equalization amplifiers in the line or recourse to a large-diameter rigid coax. An alternative that was recommended was the use of a balanced 124- Ω transmission line with a pre-emphasis amplifier at the camera end and a post-equalization amplifier at the monitor end.

For televising a fast-moving field of view, it was recommended that the illumination on the vidicon be as high as possible to decrease the vidicon decay time to appreciably less than a frame time. A face-plate illumination exceeding 6 lm/m² was recommended. For an effective lens aperture of f3.5, 50% transmission in the water and 10% reflection from borehole wall, a scene illumination of 52 000 lm/m² is required.

11. Seismic Recorder (G-2) [P. Rose, E-5]. The algorithms for the data-acquisition portion have been worked out. There should be a meeting with G-2 to see if they meet their specifications before coding. The software that M. Seamons is developing for the 1802 MADAS system for Sandia will be used as a basis for the G-2 system, interrupt handler, string processor, and cassette-terminal driver. (This may mean that the sample rate of 0.1 μ s may have to be slowed down.)

Currently, there are some problems with the RCA-supplied development software (COSMOS). The program should be working by the beginning of June and should be installed by the end of June.

12. Calculating Display System for H-5 Prototype Exhaust Stack Sampler (H-5) [Ethridge, E-5; Littlefield, Elder, H-5]. The exhaust stack sampler, incorporating a calculating display system that was the ASM-48 microcomputer and 57109 number cruncher microprocessor, will be recommended to the EPA in conclusion to a contract "Evaluate and Improve the Present Method-5 Emission Control Standards." Group E-5 estimates and a proposal to H-5 detailed an estimate of \$16k to develop and design the system, software, and hardware prototype for the calculating display system. At present, H-5 has funded only \$6k for system and software design. Additional funds may become available to allow E-5 to participate in the hardware fabrication and system debug phase of the project. Approximately 1000 units exist at present without a calculating display

system. A potential replacement of 200 units with the design under development is possible.

A majority of the electronic parts have been selected and procured for the prototype. Sufficient system design effort has been completed to allow generation of the schematic diagram. Software design has begun and some of the peripheral driver routines are being written.

The major LSI devices incorporated in the design include

1. ASM-48 8035 microcomputer
2. National MM 57109 number cruncher
3. Intel 8279 keyboard-display controller
4. Intel 8155 expansion 256-word RAM and I/O unit
5. Intel 8755 expansion 2-K word EPROM and I/O unit
6. National ADC-0816 single-component 16-channel, 8-bit ADC
7. Litronix DF-111 quad LCD driver and latch.

All of the LSI devices are packaged in a 40-pin, dual-in-line package except the number cruncher, which is packaged in a 28-pin DIP package.

13. 16-Channel Counter/Clock System (H-5) [Greenwood, Hiebert, E-5; Hanson, Whittemore, E-2]. A 16-channel, 6-decode counter system to provide counter data storage, LED readouts, and multiplexed outputs with an interface to a TI-733 terminal with cassette tape option for data recording was requested by H. Ide, H-5. Manual control for two blocks of counter channels, both from switch-selectable inhibit-allow buses or two independent programmable 1-min to 24-h timers, was specified. Group H-8 has requested a 4-channel system with all other features identical to the H-5 system. Design, fabrication, and bench check-out have been completed on both systems.

14. Model 1277 Respirator Test Signal Processor (H-5) [Hiebert, E-5; Sandler, Van Lyssel, E-2]. Testing the fit and efficiency of respiratory protective devices requires a unique test arrangement. The human subject with respirator face piece in place is positioned in a closed chamber. The chamber is filled with a physiologically acceptable aerosol as a challenge agent for the respirator. A scattered-light photometer is used to measure concentration of aerosol in the chamber and concentration that penetrates the respirator, thus giving a

measure of respirator efficiency. The subject is required to perform a series of physical exercises as these measurements are made to determine if any peculiar contortions affect the respirator action. Photometer response is recorded on a strip-chart recorder and interpreted manually.

The respirator test signal processor is a design to digest the photometer data and give an automatic readout of the information of interest. The desired data give the average of the crest values of aerosol penetration resulting from a set sequence of test exercises. Figure 47 is a block diagram of the instrument. Input signals from the photometer pass through a 1-Hz low-pass filter, feed a peak sense and hold, and are differentiated. The differentiated signals cross zero at the crest of the input excursions; the zero-crossing rate discriminator triggers at this time and enables the readout of the crest-amplitude measurement of the peak-sensed level. The information is stored in a register. At the same time, the crest count register is incremented. In this way, the crest value of as many as 64 excursions can be stored. The ratio between the accumulated crest amplitude information and the number of crests gives the average crest per cent penetration.

The simple instrument works well, but it is limited by the quality of signals from the photometer. The system may have to be linked to a computer for more sophisticated data treatment.

15. Film Reader (M-3) [Criscuolo, E-5]. The present M-3 film reader designed and built about 15

Fig. 48. Film reader block diagram.

yr ago, has become more difficult to maintain. The system has been enhanced by replacing the teletype, the paper-tape punch reader, and the encoder and serializer readouts. This will improve the data-editing process, provide a data medium that is compatible with CCF NOS input; and preserve the "quick look" data-reduction capability.

Figure 48 is a block diagram of the system. A microcontroller is the major unit of this system. When activated by the foot switch, it will record data from the X encoder or the XY encoders on the diskette and display the data on the console. In

Fig. 47. Respirator test signal processor block diagram.

addition, the microcontroller will maintain the encoder and serializer displays and handle the data editing on the console. When data recording is completed, the microcontroller will, on command, transfer the data on diskette to the Wang 720 for quick-look processing.

The system was delivered and made operational the first week of April. Group M-3 personnel have been familiarized with the system and normal data-acquisition activity has resumed using the enhanced system.

16. Drift Chamber Electronics (MP-10) [Brown, E-5; Van Lyssel, E-2]. Both the energetic pion channel and spectrometer (EPICS) and the high-resolution spectrometer (HRS) facilities at LAMPF use several multiwire drift chambers (MWDC) to obtain high-resolution position information of particles. C. Morris, MP-10, would like to improve the performance of these MWDCs. Deciding whether to add or subtract the drift distance from the anode wire location requires the use of two closely spaced offset MWDCs at each position-sensing plane. There would be several advantages if this left-right decision could be made independently by each MWDC:

- The efficiency would be increased because a valid event would only have to produce a signal in one anode plane instead of both anode planes.
- The down time would be reduced because data could be obtained with only one MWDC operating.
- The analyzing time would be reduced if each MWDC provided a binary left-right signal. This could lead to ~25% increase in throughput.

Recent work by Fisher³³ indicates that in a MWDC, the avalanche does not always surround the anode wire and the positive signals on the adjacent cathode field wires are not identical. The signals on the cathode wire nearest the avalanche is about 10% larger than on the opposite cathode wire. For the chambers at EPICS and HRS, typical signals on the cathodes are about 1 mV and the difference in amplitude is about 100 μ V. The first request was for a low-noise preamplifier with a risetime of about 10 ns so that the difference signal could be studied in detail.

A preamplifier was built using the triple differential line receiver MC 10116 IC. The three ECL line receivers were connected in cascade and biased at the middle of their logic swing. For the 100- μ V signals, they acted as a linear differential amplifier with an overall gain of ~500 and a risetime of ~10 ns.

This preamplifier was tested on a prototype chamber and the results were encouraging. The size of the difference signal increased with drift time and only for the events near the anode wire was the signal too small to make a left-right decision. These events were only about 4% of the total and the drift-time correction is not essential since the position of the anode wires is known. A preliminary measurement of the preamplifier noise indicated that it was about 1.6 times greater than that of a Tennelec low-noise charge amplifier. For the next step, we will develop a preamplifier with discriminators having three NIM outputs, a prompt signal from the sum of the two cathode signals, and a left or a right signal from the difference of the two cathode signals.

17. Amplifier System for Multichannel Fission Chamber (P-3) [Koelle, Hiebert, E-5]. Group P-3 is planning to build several multiplate fission chambers for use in a nuclear physics experimental system. Each chamber has 48 sections. The chamber signals, which are current pulses with a total charge proportional to the energy of the detected fission particle, need to be amplified and passed on to a constant fraction discriminator that acts as a threshold detector and also produces a timing-signal output whose timing is independent of the amplitude of the fission pulse. A timing jitter less than a few nanoseconds is desired.

There are several aspects of this system that make the amplifier system design difficult. It was decided that, because of the large number of sections in the fission chamber, four sections would be paralleled into one amplifier channel in order to reduce the number of signal channels from 48 to 12. Identification of the signal source would be made in subsequent computer processing. As a consequence of this, the source capacitance seen by the amplifier is increased from 60 to 240 pF and this, in turn, tends to increase the risetime and noise of the amplifier. Another source of difficulty is

that each amplifier input has to cope with an α background of $10^8/s$ because of the heavy loading of fissionable material on the chamber plates. The amplifier system must be resistant to baseline wandering caused by statistical pileups of the α pulses. If the baseline were to vary too much, it would be impossible to distinguish between pileups and the lower energy fission events; the timing pulses from the fission pulses would also be shifted about in time.

The amplifier system requirements included:

- A sufficiently short risetime and low noise despite the 240-pF source capacitance.
- Baseline control to cope with the α background.
- System could not overload.
- Sufficient overall gain to amplify the fission pulses to the level required by the constant fraction discriminator.
- Low cost.

A first attempt using a hybridized transimpedance amplifier resulted in failure due to excessive ringing. The hybrid amplifier was chosen because a small package would allow placement around the chamber without additional cables between the chamber and the amplifier input. Previous experience showed that any additional cable length would increase the input capacitance and increase the tendency for ringing.

An Ortec 142B charge-sensitive amplifier was tested with a 20-ns pulse from a pulser through a 1-k Ω resistor to make a pseudocurrent source and 220 pF was added at the amplifier input to simulate the chamber capacitance. It was found that the amplifier risetime under these conditions stretched to about 10 ns, the pulse was reasonably free from ringing, and the noise was still sufficiently low. While the risetime was not as short as desired, it was considered acceptable because the constant fraction discriminator could still obtain good timing from such a signal.

The next step was to obtain a genuine current signal from a photomultiplier mounted in a LAMPF assembly and coupled to a fast plastic scintillator looking at a high rate Co^{60} gamma source. A 30-cm cable was used between the PM assembly and the amplifier. A capacitor of 220 pF was added at the output of the PM assembly to simulate the chamber

capacitance. The amplifier was modified by shunting a 5-M Ω resistor across the feedback capacitor to reduce the time constant to about 10 μ s, which was necessary to reduce the pileup effects. A differentiating circuit with a built-in 10- μ s pole-zero compensation and loaded with 50 Ω was added at the output of the amplifier. It was found that the PM pulses could be recovered with reasonable fidelity with such a combination. The pole-zero cancellation time constant could be adjusted to keep the baseline quite flat. It was also found that if the 30-cm cable were made of 10- Ω line rather than 50- Ω line, the pulses could be recovered without undershoot. The 10- Ω line apparently provided a better match to the amplifier input.

Initial tests looked favorable when we tried the system with a test fission chamber supplied by R. Extermann and J. Moses, P-3. Next, the additional amplification needed to build up the signal to the level required by the constant fraction discriminator was added. This required two stages of $\times 10$ amplification and an inversion. Inversion was accomplished by inserting an inverting transformer made by winding 22 turns of bifilar wire on a high-permeability 1-cm ferrite toroid between the output of the 142B amplifier and the differentiating network. The transformer worked superbly with no visible deterioration of the pulse shape. The transformer time constant was long enough to have negligible effect on the baseline shift. Two stages of $\times 10$ amplification were added using a LeCroy VV100A and an Ortec $\times 10$ voltage preamplifier.

Final testing was done using different differentiating time constants and trying various modifications on the system. It was found that while the use of the 10- Ω input cable resulted in a fission pulse with less ringing than was the case with a 50- Ω cable, the risetime was noticeably lengthened due to the extra cable capacitance. On balance it seems that the pulse shape with the 50- Ω cable is preferable despite the noticeable undershoot at the tail of the pulse. The undershoot, while undesirable, is of short duration and will not result in objectionable baseline shifts. An RC network was added between the 142B amplifier output and the inverting pulse transformer to increase the dc resistance in the output path and reduce the dc load on the amplifier due to the several tenths of a volt

dc offset at the amplifier output. A compensating RL network was added at the output of the pulse transformer to form a 50- Ω constant impedance network with the differentiating circuit.

A block diagram of the amplifier system is shown in Fig. 49, with the modification details to the Ortec 142B amplifier and the inverting and differentiating components.

Figure 50 is an oscilloscope photo showing the signals at the output of the first x10 amplifier from the test fission chamber. The differentiating time constant is about 20 ns. The oscilloscope trigger is from the signal and has been set low so that the baseline noise can be seen. The baseline noise is from a combination of amplifier noise and α background. The structure in the baseline noise at the beginning of the sweep is due to the fact that the oscilloscope is internally triggered and is triggering on noise peaks for the baseline traces. The fine structure on the baseline trace is due to a persistent 100-MHz interfering signal present at the TA-46 location (KRSN-FM), which broadens all the traces. Note the good separation between the fission pulses and the baseline noise. If one looks carefully, the double-humped structure of the fission amplitude spectrum can be seen.

A final test was made with the amplifier output into one channel of an Ortec 934 quad constant fraction discriminator, using a pulser-generated signal to simulate the fission pulses and the background from the chamber. The total timing jitter for the smallest fission pulses was found to be of the order of 4 ns.

The result of this work is that it has been shown that under the specified conditions the fission pulses can be distinguished from the α and amplifier-noise background with plenty of margin and

Fig. 49. Amplifier system for fission chamber.

Fig. 50. Output signals from test fission chamber.

with risetime sufficient to allow adequate timing out of the constant fraction discriminator. This proves feasibility, provided the cost of the Ortec 142B amplifiers is acceptable. An inquiry has been made with Ortec as to the possibility of their producing a hybridized version of this amplifier. Ortec is considering this. Availability of a hybridized amplifier would allow construction of a more compact system and eliminate the 30-cm cable required with the standard 142B. The direction of further work will depend upon the availability of such a hybrid amplifier from Ortec. Consideration is also being given to the design of a similar amplifier in hybrid form at LASL.

18. Sample Changer (P-3) [Greenwood, Love, E-5]. This job consists of a CAMAC-based stepper motor control system and manual interface that is used for WNR target positioning. Each system is composed of a CAMAC stepper motor controller and a manual control chassis containing the motor power supply. One CAMAC module is used to input data from the absolute position encoder in each system. The control chassis features a single switch to both single step and ramp to a preset speed. The first system is scheduled for completion by the end of June.

19. Model 558 Supercube Controller System (P-7) [Greenwood, E-5; Whittemore, E-2]. The data-acquisition and control computer, an XDS930 located at the tandem Van de Graaff accelerator is being replaced with a MODCOMP IV utilizing a CAMAC interface. This changeover, which is expected to be completed this calendar year, necessitates either a

redesign of the existing experiment support instrumentation or design of very complex coupler interfaces. In the case of the existing supercube controller,³⁴ the coupler interface was judged to be so expensive to design and fabricate that we decided to redesign and fabricate the control circuitry with CAMAC-based hardware, while using as much of the existing equipment as possible. The new control system will retain the four optical encoders for reading absolute position of the detector arms, the multiplexer system for addressing and reading the encoders, the stepping motor power supply chassis, and the stepping motors. Two manual controller chassis will be provided, one to be located with the supercube in the experimental area, and one to be located in the tandem control room. Single-step and rate-operating modes will be provided at each location. Commercial CAMAC modules will be used for data input and stepping motor drive. Position display will be via a CAMAC alphanumeric TV monitor driver. Provision will also be made for addition of an LED display at each location for computer-independent control. Cube positioning around the accelerator beam will be done manually with CAMAC control to be provided at a later date. Logic and circuit design have been completed on the two manual controller chassis and fabrication is in progress.

2C. Model 398 Stable Delay (P-7) [Greenwood, E-5; Hanson, Whittemore, E-2]. E. Flynn, P-7, requested a digital delay unit with the following specifications.

- Delay range selectable with front panel switches from 0.5 μ s to 2.0 μ s in 10-ns steps.
- Input and output compatible with "NIM fast" signals (-0.8 V into 50 Ω).
- Two-pulse resolution of 1- μ s minimum.
- A 24-h temperature stability to allow a maximum delay variation of 0.1% of full delay range.

The circuit was designed using digital delay modules and temperature-regulated IC sockets. The packaging was arranged so two delay channels could be incorporated into a standard rack chassis with a 13.3-cm panel. The prototype unit has been designed, fabricated, checked out, and delivered to the customer.

21. Model 528 Calorimeter Control (P-9) [Hiebert, E-5; Van Lyssel, E-2]. G. Ohlsen and R. Brown desire to make precision measurements of accelerator particle beam intensities. Conventional integration of beam currents from charged particle beams is frequently not adequate. Researchers at the University of Zurich have developed a compensated calorimeter technique of determining precisely the heat produced by stopping particles in the Faraday cup. The instrument measures absolute beam intensity of neutrals as well as charged particles.

We have made a LASL version of the University of Zurich instrument. Bench tests of the control circuit have been good, but final adjustments must be made with the actual in situ characteristics of the calorimeter. The instrument is now being installed at the Van de Graaff accelerator.

22. Effluent Monitor (Q-1) [Ethridge, E-5]. As reported in previous semiannual reports, E-5 assumed the task of fabricating two microcomputer effluent monitors for Q-1. One system monitors the sewer line leaving the TA-55 Plutonium Facility. The second and more complex system monitors the industrial waste line also leaving this facility.

Both systems have been installed and are functionally reporting to the building computer. However, significant Q-1 effort is in progress to modify the calibration aspect of the design. Recent snowfall resulted in flooding in the sewer pit where the monitor-solenoid control electronics are located. Group Q-1 effort is continuing in the area of providing adequate environmental protection.

E Division has completed the initial task of fabrication and documentation of the two units. The industrial waste monitor has not been completely exercised to date pending Q-1 modification of detector source calibration hardware and procedure. Remaining E-Division effort includes maintenance.

A proposal to improve the design related to maintenance is being prepared, although Q-1 verbal approval has been expressed. This proposal is to replace the 150 to 200 logic device hardware-software development system effluent monitor microcomputer design with a more flexible 15-20 LSI device hardware-software microcomputer system utilizing the ASM-48 microcomputer family of devices. This design will produce a far simpler microcomputer hardware design for much easier repair and reduction of

monitor downtime. The present complex, heavily hard-wired design must be repaired in place with loss of monitor function during that period.

23. Reduced Variance Calculator (Q-2) [Ethridge, E-5]. Development of the Feynman variance calculator was detailed in our previous semiannual report. The reduced variance calculator is an improved design incorporating the high-speed data accumulation and scientific calculating system (8748 microcomputer and 57109 number cruncher) into one physical package for field deployment. The primary task of this unit is performing the data acquisition, analysis, and calculations in the determination of basic fission physics parameters, specifically the identification of fissionable material. The original unit software-hardware design has been upgraded to allow input of additional variables, definition of parameters for calibration, and equation selection as applicable to a specific environment.

The E-5 task has been design integration of new requirements and hardware-software into the new unit. Groups E-2 and E-4 are now packaging and wire wrapping the new hardware. Group Q-2 will debug the power supply lines and data-acquisition electronics. Group E-5 will then debug the total system, including the scientific calculation system, utilizing the newly acquired ICE-48 in-circuit emulator for the ASM-48 microcomputer. Upon final check-out, the unit will be installed in one of the nuclear emergency search team's (NEST) vans for field deployment.³⁵ Two additional units will be manufactured for Group Q-3.

24. Computer Interfaces (Q-2) [Longmire, E-5]. A number of interfaces between a Data General micro-NOVA computer and various types of nuclear instrumentation have been constructed for J. Pratt.

- a. A LeCroy pulse-height analyzer interface provides control functions and transfers the contents of its buffer memory to the computer.

- b. A timer-controller interface provides clock information to other interface cards and it allows the operator to program the system timer through front-panel thumbwheel switches. The programmable timer provides periodic interrupts for real-time data processing.
- c. An analog interface card inputs gain and offset information from a thumbwheel switch on the operator console. The computer software processes the contents of the switches and scales the data while continuously outputting it to the recorders.
- d. A number of counter scaler interfaces have been designed and are being constructed.

25. Model 8167 Void Fraction Meter (Q-8) [Hiebert, E-5; Van Lyssele, E-2]. Measurements of the concentration of liquids in a flowing gas or bubbles in a flowing liquid frequently require hot-film anemometer techniques. A thin platinum film is mounted in the stream. The film is connected to a bridge circuit configured to keep the film at an elevated temperature. The pulsed thermal effect of the passing droplet or bubble unbalances the bridge and a signal is produced.

The void fraction meter was designed and built to use the anemometer signals to produce a readout, which is a measure of the void fraction (VF) in the stream. The instrument computes

$$VF = 1 - \left(\frac{\bar{P}}{P_{\max}} \right)^m, \quad (23)$$

where $\bar{P}$ is a signal proportional to the average time that droplets or bubbles are in contact with the film, $P_{\max}$ is a signal value corresponding to a nonvoid (all liquid or all gas flow) situation, and m is an integer determined by the users.

III. TECHNICAL SERVICES, H. S. OLAFSON, ASSISTANT DIVISION LEADER

A. General Group Activities (E-1)

We are improving our services to the Laboratory, although we are experiencing some labor resource limitations. We have noted that delivery time on spare parts has increased.

For the purpose of this report, we will not detail the activities of each E-1 section but will include a general discussion of group directions.

The activities reported in this section include Groups E-1 and E-2 and the Minicomputer Maintenance Section of Group E-5. In addition, the services provided by the E-DO Information and Training Office are reported.

The Telecommunications Section continues to be heavily involved with DOE, the LASL Engineering Department, and the Zia Company in developing additional LASL telephone capabilities. We have held a series of meetings with Mountain Bell to attack problems stemming from long intervals on order completion, records, and assignments. Many telephone installations were completed during this report period and others initiated, but they will not be detailed here.

A program to replace the standard carbon lighting protection at the main distribution frame in SM-28 has been undertaken by the Protected Wireline Section. A new gas tube protective replacement device will be used to eliminate problems encountered on special circuits as a result of the lighting system. Many specifications and layouts have been prepared for building modifications for several groups. Many jackfield and protected wireline (PWL) installations have been completed and others initiated.

The Radio Section issued 55 new pagers and portable radios and installed 18 mobile radios in vehicles for various groups during this period. Thirty MX-350 portable radios and Converta-Cam consoles were installed in Protective Force vehicles. The MOTRAC radios that were removed from these vehicles have been placed in the radio pool for reissue. A Modat base logic unit and data display were installed at Protective Force headquarters. They will be used in conjunction with the MX-350 radios to provide station and duress alarm identification.

The IDS and Audio Section has provided various support functions to the Protective Force, CCF, and several LASL groups. This support included installations, circuit modifications, and evaluations. Work has also been done on a small radiation alert device that will replace a much larger unit.

Manufacturer's training on new kinds of terminals has been accomplished by the Terminal Section. This is particularly important since many new terminals are being purchased within the Laboratory and this will be an important capability.

The thrust of activity in the General Instruments, Radiation Instruments, and Physics Instrumentation Sections continues to be hiring and training new personnel. Work also continues on establishing data bases to record repair-related information on instruments. The workload in these sections continues at a very high level and new directions and support capabilities are being explored.

B. Recharge Programs (E-2)

1. Production Control Section. During this period we initiated 1462 work orders representing more than 800 jobs and supporting approximately 70 groups throughout LASL. In addition, approximately 4000 fabrication hours were awarded to Missouri Research Laboratories (MRL) for various electronic manufacturing jobs. Some of the larger jobs undertaken were: Model 9144-H time-interval meters for M-3; various controller chassis for CTR-9; DYMAC 4-channel amplifiers for Q-1 and Q-3; Model 50-B log amps for J-16; and target-chamber chassis for L-1. We have improved scheduling and schedule control and will soon have more efficient methods of cost tracking and control. Efforts are continuing to establish an effective materials control.

2. Photographic Section. We have ordered new products that have been introduced recently by Kodak, Inc. These products should increase the overall efficiency of this section and improve flexibility. In an effort to upgrade our services, we are becoming more involved with other E-2 sections involved in photographic work.

3. Silkscreen and Paint Section. An in-house silkscreen facility has been set up and is in operation at TA-6. A new screen-wash machine has been received and is being installed. Preparations are under way for the installation of a new paint booth and oven. New paint guns, sanding equipment, and

an oil and water extractor have been added and are in operation.

4. Electronic Fabrication Section. As noted in our last report, new equipment was being installed at the cable facility for the manufacture of cables used at NTS; this installation has been completed. We plan to develop manufacturing expertise for fiber optic cables and we are gathering literature on techniques, applications, and tooling. In addition, we plan to visit a manufacturer in this area of technology. We have constructed an 8141 digital delay generator test bed to be used primarily for pretesting production sub- and final assemblies and are looking into a similar instrument for reducing check-out time on the Model 9144 time-interval meter.

5. Electronic Support Model Shop. Since our last report, we have improved our quality control index from 10.6% to 7.8%, while meeting the production schedule. We transferred the power break to the Shops Department and have acquired a Stripet semiautomatic punch from the Zia Company. Work continues on remodeling and modernizing the shop.

6. Printed Circuit (PC) Facility. The E-2 PC facility has been very busy. A plan has been implemented to track and control rework time. We have obtained more working space to set up an NC drill and mill for our fabrication process. Our schedule effectiveness has remained at a very high level as does our quality control index. In the next few months, we will stress improvement in turnaround while maintaining the same degree of quality; our ultimate goal is to give a 3-day turnaround on 80% to 90% of our orders.

7. Hybrid Microelectronics Section. During this report period, we have processed 28 orders for hybrid microcircuits, precision resistors, and other items that did not require new development work. Numerous requests for hybrid circuits were received that were repeats of earlier work. These included orders for voltage output radiation probes, 100-MHz divide-by-10 circuits, SCR pulsers, metalized D-ring spacers, tri-digit transponders, and screen printed test patterns. Approximately 170 precision thin-film resistors were prepared for various groups in the Laboratory.

8. Design and Packaging Section. For the past 6 months, we have recruited design and packaging

personnel to support Laboratory projects and fill new vacancies in the Drafting Section. We are in the process of implementing a 3-day turnaround for PC board design, and this should become a reality within the next 6 months. The computer-aided drafting system has been delivered to E-4, and we are now training drafting personnel to operate the system.

We have developed computer terminal programs that will enable us to ascertain dimensions for hybrid photo masks with tolerances of ± 0.00020 at full-scale. This will greatly reduce the computational man hours necessary for producing these masks.

9. Technician Services Section. We are placing strong emphasis on training. Keeping our technicians abreast of technology advances is a very important aspect of our job. Many customers are requesting technicians with digital and instrumentation backgrounds. Therefore, emphasis has been placed on these two areas when courses and seminars were selected.

Group E-2 technicians are supporting many LASL programs and experiments; however, of special interest this report period is our successful support of the Geothermal Hot Rock Flow Loop Experiment. Twelve technicians were involved in 24-h/day operation. These technicians were required to work long hours under hostile weather conditions. All personnel received a "well done" from the G-4 Group Leader, Bert Dennis. The experiment is now in a scheduled shutdown, with our technicians working only 8 h/day; however, it is anticipated that 24-h operation will be resumed early in July.

10. Quality Control Section. We have continued inspection efforts in support of the photographic, paint, electronic fabrication, model shop, and PC sections. This has involved performing approximately 9000 inspections. Procurement of mechanical inspection equipment (surface plate and electronic gauge) to increase accuracy and speed has been proposed. A 35.5-cm optical comparator was acquired from salvage and reconditioned; investigations will be made of the utility of this device for E-2 inspections.

We have slowly increased our ability to test with fabricated instruments such as high-voltage power supplies, Model R141, Model 9144, and PDP-11 debugging tools. Several fixtures have been built

and tests have been performed for cables and hybrid microelectronics. A test bed for the Model 8141 was constructed; this allowed the major subassemblies of the instrument to be verified before final assembly. Early results have been successful.

One QC technician has continued working with the J-8 design team on a beam positioner for the L-Division EBS. The contact for this program has resulted in some E-2 fabrication tasks and we expect that the knowledge gained will be applicable to future involvement with laser electronics.

11. Detector Services. Over this period, Detector Services has grown in capability as well as adding one new member to the section. As the capabilities of the Detector Section have increased, we have taken over administration of the E-Division clean room facility and a facility for fabrication and repair of Ge(Li) spectrometers is now complete. This facility is fully housed within the detector labs in SM-40 and has alleviated the need for lab space at LAMPF. A solid-state testing setup has been assembled around our new Northern Scientific TN1710 analyzer. Measurements that can be made are leakage current, capacitance as a function of applied bias voltage, 4-point probing, and resolution. We have also established an ultrasonic grinding capability for solid-state detector fabrication. Because of the large number of Ortec low-energy spectrometers in use at LASL, we have established a repair capability that will allow replacement of Ge(Li) detectors with the new HP(Ge) type without returning the spectrometer to the factory. Medium-sized ($\approx 10\%$) closed coaxial Ge(Li) detectors are being drifted; these detectors should be available for replacement in Ge(Li) spectrometers in cases where the customer's detector cannot be repaired.

New projects being supported this period are pyroelectric detectors in E-10, Josephson junction work in E-DOR, and thin-silicon filters for L-4.

12. Special Projects. The Special Projects Section is currently fabricating 18 Model 1776 MCP oscilloscopes for L Division. These oscilloscopes should be completed by December 1978. We expect that J-14 will want 100 more of these oscilloscopes built during FY-1979 and 1980, if they can arrange the necessary funding.

C. Research and Development Programs (E-2)

Hybrid Microelectronics. The Hybrid Microelectronics Section has continued to serve many

Laboratory programs through the design and fabrication of hybrid microcircuits and engineering support in electronic materials technology.

During this period, we concluded a major circuit development program for Group P-4. Twelve different circuits were prepared through the prototype stage and are now fully documented and ready to be prepared in quantity for use in space electronics.

A highly complex hybrid microcircuit design was completed for Group Q-2. The circuit contained 21 CMOS integrated circuits, 3 transistors, 6 capacitors, and 28 resistors on a substrate that measured 2.86 by 3.87 cm. Multilayer thick-film techniques were used to attain the necessary circuit density.

A major effort has been the development and fabrication of hybrid microcircuits for a new beam position monitoring system at LAMPF. The hybrid circuits are 100-kHz precision rectifiers and 350 of the units will be prepared.

We have participated with Group E-5 in the development of photosensor arrays for Group H-10 light-scattering studies of blood cells. Two photosensor arrays have been prepared. One, a circular array having 60 photodiodes, is shown in Fig. 51. The second array was a cross design that contained 41 photodiodes. Each photodiode was accompanied by a preamplifier and a hybrid circuit.

Blood cell models are being prepared for Group H-10 for their studies of laser light scattering from cells of different sizes and shapes. The

Fig. 51. This photosensor array contains 60 photodiodes in a circular arrangement.

models are being prepared by photolithography of sputtered molybdenum on glass substrates.

We have completed the first portion of our development program to fabricate thin-film hybrid microcircuits. Commercially obtained thin-film substrates were processed in the E-Division clean room facility to yield a thin-film conductor pattern. This process may be used to fabricate conductor geometries that are too complex for thick-film screen printing techniques.

High-temperature resistors have been prepared for evaluation by Group E-4 in their high-temperature electronics program. Commercial thick-film materials are being processed by special techniques to prepare resistors that will operate at 500°C.

We are participating in a joint WX-7, CMB-6, and E-2 effort to develop detonator assemblies. It is expected that our thick-film processing expertise will be used in this program.

Group P-4 has requested our assistance in the development of resistors for use in a satellite-borne 100-kV power supply. Two resistor values, $2 \times 10^{11} \Omega$ and $2 \times 10^6 \Omega$, are required. Thick-film resistors are being prepared on substrates measuring 7.62 by 3.15 by 0.06 cm.

We have begun the development of a probe wire adapter system for use by Group CTR-2. Their magnetic probes for plasma diagnostics are terminated in 25- μ m-diam wires. An adapter is being fabricated that will allow the transition of these wires to coaxial cable. Thick-film conductor patterns will be screen printed on glass-ceramic substrates. Microsoldering techniques will be used to attach the 1-mil-diam wires and the cable to the adapter.

Group M-4 has requested that a digitizer counter hybrid microcircuit be developed. The circuit will consist of the hybrid integration of 6 TTL integrated circuits into a single 24-pin package. They anticipate that several hundred of these circuits will be required to meet their specifications.

The development of a hybrid circuit for a new film-badge-size radiation detector has been requested by Group H-1. The circuit design for this device was done by Group E-1.

Hybrid circuit techniques were used to develop 3 dB bridged tee attenuators for use on the 5-GHz oscilloscope project. These devices were unique, since they contained circuitry on both sides of the

substrate. A resistive network was fabricated on one side and a screen-printed thick-film capacitor was made on the opposite side of the substrate. Sixty of these attenuators are now being prepared for the E-2 manufacturing operation.

D. Minicomputer Maintenance (E-5) [Spector, Buchser, Bujnosek, Carlson, Cummings, Grall, Horn, Leibe, Santana, Springfield, Torrez, Ward]. During this report period, the E-5 Minicomputer Maintenance Section responded to approximately 1900 service calls on approximately 90 computers. These calls included service to 17 LASL divisions that receive maintenance support from E-5. We provide service primarily on DEC processors and other peripheral equipment built by 22 vendors. New devices for which in-house maintenance is now available include the Printronix 300 impact printer and the DEC RK06 disk drive. We plan to initiate in-house Data General maintenance around the beginning of FY-1979.

Monthly revenues for the group are distributed as follows:

Maintenance contract income	\$46 000
Maintenance Recharge	2 500
Form B	5 000
Data General Contract	<u>15 000</u>
Total	\$68 500

Levels of commitment are as follows:

MP Division	5 technicians
CMB Division (TA-55)	2 technicians
Remainder of LASL	<u>3 technicians</u>
	10 technicians

The Maintenance Section experienced some attrition in the last period with David Garcia transferring to another group, James Lucero returning to CDC, and Walter Schmidt transferring to the E-5 Design Section. Ray Eberley, an experienced new hire, will be on board in early June and will be assigned to MP Division. We have advertised in various journals for another Tech III and anticipate that the person will be hired by August 1, 1978. The entire computer maintenance industry is experiencing a shortage of well-trained, highly expert computer maintenance personnel. Our recent hiring efforts reflect this problem.

Training for the Maintenance Section has continued with completion of schooling in the DEC PDP-11/70, I/C multiplexer, Aydin display system, Tektronix 4010, and BiRa MBD.

The MP maintenance effort has been extremely busy with considerable expense and effort directed toward updating all the MBDs. John Buchser and a Group E-2 technician, Ida Jackson, have been assigned to this project. The 20 MBDs at LAMPF should be fully updated and identical in ECO level in July. The updated MBDs are extremely reliable so we expect that our labor will result in far less downtime for the MBD, a particularly troublesome device before the ECO update.

Because of a significant deviation in actual stock levels from those predicted by the Accounting Department, we have initiated tighter controls. This deviation was due to practically open access to the stockroom during the storesman's absence when he was on a stock run or similar errand for the group. We have since moved the stockroom and the entire Maintenance Section to a separate building at TA-46, instituted tighter controls, and reduced access to the stockroom to the storesman or his back-up. We expect significantly better results in the next stock audit.

E. Information and Training (I&T)

1. Summary [Lindberg]. Two new persons have been added to our staff during the report period, John Fox and Vickie Simon. John will work primarily with technicians as technician trainer. Vickie, a training specialist, will coordinate electronic training courses and assist in course development activities.

Information Service activities have been broadened to provide more support for E-5 personnel at TA-46. A major effort there was initiated by Alfred Koelle, who was assisted by Maureen O'Mara. The use of our visual search microfilm file (VSMF) service continues at the usual rate. We have been unable to locate any promising alternatives to VSMF, although Information Handling Services has a terminal-accessible system under development. Gus Ekeroth, E-2, is assisting in our ongoing program to reorganize and update the hard copy catalog file.

Five courses were conducted during the period involving 61 students for a total of 1460 contact hours. The new "Practical Microprocessors" course is being developed in E-1 for possible LASL-wide use in the future. The Career Assessment Workshop evaluation has been completed and the report is being finalized by Vickie Simon from information supplied

by Martha Brown. Video-assisted self-study increased substantially when the new DEC series, "Introduction to Minicomputers," was advertised for viewing. The initial technician training effort of John Fox has concentrated on obtaining a firm definition of skills and knowledge needed to perform various assembly tasks. The first course for assembly technicians based on this analysis will begin in June. We are continuing our close coordination with PER-5. Additional space PER-5 hopes to acquire may be made available for a technician training lab. The Personnel Department has also proposed that the Video Learning Center (VLC) be moved to space they plan to acquire later this summer.

Our personnel have received training in the use of MAPPER, a computer graphics system that we will use to generate training aids. Fox, Lindberg, and Simon will begin the Mager course on criterion referenced instruction as soon as all of the materials are received.

2. VSMF [O'Mara]. In the 6-month period from December 1977 to May 1978, a total of 224 VSMF searches was conducted. Of this number, 127 searches were made by E-Division personnel and the remainder were made by personnel from AP, AT, CTR, H, M, and P Divisions. Table VI summarizes the VSMF search activity.

3. Training Services [Lindberg].

a. Courses Conducted. Five courses were sponsored by E-Division Training Services during the past 5 months. These courses were attended by 61 persons and accounted for 1460 student contact hours. Two sessions each of the Certified Soldering and Soldering Recertification Course were conducted. The fifth course, "Practical Microprocessors," is now in progress and is being taught by Michael Wolf, E-1. This course is under development and is being offered only to E-1 employees. Course outlines follow.

- **Certified Soldering:** This course develops advanced soldering skills and self-evaluation techniques for improving manufacturing quality and reliability.
- **Soldering Recertification:** This course follows the Certified Soldering course by approximately 1 yr and is intended to reestablish and reevaluate techniques and skills that may have deteriorated.

TABLE VI
VSMF USAGE

Time Period	Total Usage			Non-E-Division Usage			
	Period Total	Running Total	Projected For Year	Period Total	Running Total	Projected for Year	% Non-E Usage
12/4/77-1/1/78	22	189	324	11	59	101	50
1/8/78-1/29/78	28	217	326	14	73	110	50
2/5/78-2/27/78	56	273	364	30	103	137	54
3/6/78-3/26/78	51	324	389	19	122	146	37
4/2/78-4/23/78	41	365	398	20	142	155	49
4/30/78-5/7/78	15	380	---	2	144	---	13

- Practical Microprocessors: Designed as an introductory course for technicians and staff members, "Practical Microprocessors" require some digital logic background as a prerequisite. Course topics focus on the needs of Level II and III technicians who service such equipment. The course is being presented as a developmental course and "scratch" videotapes are being made. These tapes will be evaluated and the presentation modified as necessary for the final version. The complete course will contain a thorough set of criterion referenced objectives, pre- and posttests, and some practical experiments. Coordinated into an integrated learning package, these experiments will be designed for completion on the Heath ET3400 microprocessor trainer. The target date for a Laboratory-wide presentation of the course is spring 1979. At that time the final set of course videotapes will be made. Subsequently, the tapes and experiments, Heath experimenters

and tests will be made available to Laboratory personnel through I&T Services.

Table VII summarizes the course information.

b. New Materials and Equipment. The DEC program, "Introduction to Minicomputers," has been obtained during this period. The self-study course is very popular. We have received 47 requests for the supporting textual material thus far. One organization, C-1, is using the material at the VLC in the proctored videotape mode with David Schultz as instructor.

- The Heath Company's self-study microprocessor course and trainer has been obtained and five of the units are being used in the "Practical Microprocessors" course.

4. Employee Development [Brown, Simon]. Analysis and evaluation of the second Career Assessment Workshop, a program developed by E Division, PER, and ERO has been completed. Evaluations included a study of participants' evaluations of the workshop and a study of behavioral changes in participants during the workshop. Demographics were completed

TABLE VII
CONTINUING EDUCATION COURSE SUMMARY

	Contact Hours	E-Division Registration	Non-E-Div. Registration	Non-E Per Cent
Certified Soldering (1)	40	10	0	0
Soldering Recert. (1)	12	9	1	10
Soldering Recert. (2)	12	1	9	90
Certified Soldering (2)	40	5	5	50
Pract. Microprocessors	20	21	0	0
Totals	124	46	15	25

on the original 200 applicants, showing the following breakdown:

Administrative	12.6%	Male	60%
Laboratory support	33.5%	Female	40%
Staff members	16.5%		
Technical support	37.4%		

In addition, an instrument has been designed as a suggested supervisor follow-up to record observations of the employee since participation in the Career Assessment Workshop. Participants were asked to evaluate the workshop in terms of activities conducted and then to comment on various aspects of the program. Activities receiving the highest ratings were System for Identifying Motivated Abilities (SIMA), Strong-Campbell Interest Inventory and Career Action Plan. The weakest activities indicated by the evaluation were Life Line, Values, and Fantasy Job.

The following conclusions are drawn from the participants' comments:

- Most respondents found the workshop to be personally rewarding.
- Some LASL employees are interested in obtaining a deeper understanding of themselves.
- Some persons have inadequate knowledge about career options within LASL.
- The SIMA activity received high "marks" and no negative comments. It could, therefore, be the nucleus of the whole workshop.
- A preworkshop interview is needed to clarify the purpose of the workshop and to determine its appropriateness for each individual.
- An environment for more intimate sharing of ideas and feelings would be beneficial.
- The workshop should be restructured for a shorter time period and possibly should be tailored for specific employee groups such as staff members, technicians, secretaries, etc.
- We might consider adding some form of "middle-aged adult" aptitude test.

Behavioral changes in participants were assessed by the Career Inventory, designed to measure changes in seven scales corresponding to the following behavioral objectives of the workshop:

- The participants will indicate greater job satisfaction and personal fulfillment on the job.

- The participants will use their interests, skills, and motivated abilities in their jobs.
- The participants will express increased self-awareness.
The participants will take responsibility for their own lives.
- The participants will set realistic goals for their careers, planning steps to reach goals.
- The participants will perceive an increase in their productivity and creativity on the job.
- The participants will seek more open communication with management and employees.

The Career Inventory was used in a pre-posttest situation and changes in scores were evaluated. Significant positive changes occurred in Scales #1 - Using Abilities and Interests on the Job; #5 - Realistic Goals and Career Plans; #4 - Self-responsibility, and #3 - Self-awareness. Some improvement was shown for Scales #6 - Communication on the Job, and #7 - Productivity and Creativity.

A more detailed report of the Career Assessment Workshop is being prepared for distribution.

5. Video-Assisted Self-Study [O'Mara]. Video viewing activity slowly increased over the past 5 months and increased substantially in April, the last complete month of record. The increase was due to the availability of the popular "Introduction to Minicomputers" from DEC. Video viewing activity is summarized in Fig. 52. During this period, we began recovering costs for expendable training materials by recharge to using organizations.

6. Technician Training [Fox]. After careful consideration of many course development techniques, we selected the criterion-referenced instructional (CRI) method as a mode for courses offered in E Division. New courses being developed in the technician training area are following the CRI methodology. We will attempt to restructure courses that are currently in progress.

Technician-Level Course Planning. "Introduction to Electronics and Fabrication". This course, currently in the planning stage is to be presented in June 1978. Basic skills and concepts in parts identification, soldering and wiring practices, schematic reading, and simple series-parallel circuits will be explored. Experiments will be designed around a volt-ohm-milliammeter (VOM) to be

Fig. 52. Video-viewing usage for 5-month period.

constructed by each participant. The CRI model is being applied to this course. Upon completion of the course, each student will have a functioning, calibrated VOM roughly equivalent to the Triplet 310 model.

Selection of students for the course will be based on two factors. First, and most important, the student should have little or no formal course work in electronics. The course is designed for beginning level technicians. The second factor is availability. Will the prospective students' workload be such that they can be released to attend the class sessions and complete the work? Students for this course will be selected primarily from E-2.

Task Analysis: One of the major tasks facing the Information and Training Office is that of teaching fabrication electronics technicians in E-2. A preliminary step in the development of an educational program to teach these technicians is a task analysis. Each section in E-2 is represented on the OJT Committee. Therefore, this committee was presented a slide-audiotape explanation of the CRI model. This presentation was followed by a discus-

sion of the various aspects of course development using a flow chart. The various sections of E-2 were asked to present a flow chart describing their specific jobs and activities. These flow charts are serving as the foundation for our task analysis of E-2 fabrication technician skills.

In subsequent meetings with the OJT Committee, each flow chart is dissected and each task analyzed. The skills, concepts, and abilities required by each task are identified. From this list, CRT objectives will be written that will provide a basis for course selection designed to solve specific E-2 needs. This model in course development will then be applied to other E-Division groups expressing a need for training. Ultimately, the method described may be adopted by other LASL divisions and departments to satisfy their educational needs.

7. Coordination with PER-5 [Lindberg]. Plans are being made to set up a Technician Training Laboratory in space that PER-5 will be acquiring in the Tri-Square complex. Although the lab will be available for many types of technician training, we will use and equip the space specifically for electronic technician training. Equipment and supplies are now being ordered for this purpose.

The Personnel Department has proposed that the prototype VLC be moved to the Tri-Square complex. The move would put the VLC in an open area and would provide additional space for the control area. The proposal is being studied and it appears that such a move would occur this summer, with the intention of having the VLC operating for fail classes.

8. Internal Training [Fox, Lindberg]. We have been engaged in internal continuing education during this period. John Fox and Vickie Simon have taken the MAPPER computer graphics course. MAPPER offers an efficient technique for computerized production of professional quality 35-mm color slides. We need a method of producing slides for classroom presentation and other teaching aids.

John Fox, Howard Lindberg, and Vickie Simon will soon begin a CRI course designed by Robert F. Mager. This course represents a scientifically sound structuring methodology for use in instructional design. The need for education and training to be able to prove accountability led to the development of CRI. When objectives are properly stated, the criteria for evaluation will clearly

state a level of competence. These factors define for teacher and learner exactly what it is that needs to be accomplished. Evaluation of the teaching-learning activity is competency-based rather than norm referenced. When the learner has mastered the concept or skill, he may progress to the next level. The CRI system eliminates nonessential content from a course. Results indicate higher student achievement and motivation when CRI is properly applied in course development. If our experiments with CRI are successful, we will consider offering courses through PER-5 for interested LASL instructors. At Sandia, all instructors are required to take such a course.

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APPENDIX A

DIVISION PAPERS, REPORTS, TALKS, AND MEETINGS

Papers Submitted for Meetings

Lawrence E. Bryant, Jr., B. G. Craig, A. S. Lundy, and W. Morton, "High-Energy Cine Radiographic Experiment," 13th Int. Congress on High-Speed Photography and Photonics, Tokyo, Japan, August 21-25, 1978.

T. M. Cannon, R. P. Kruger, A. S. Lundy, and R. M. Morris, "Simulated and Preliminary Performance Characteristics of a Computer Tomography Device for Industrial Applications," SPIE's 22nd Int. Symposium and Instrument Display, San Diego, California, August 28-31, 1978.

T. M. Cannon, R. P. Kruger, A. S. Lundy, and R. M. Morris, "The Design and Performance of an Industrial Computed Tomography System," Symposium on Real-Time Radiologic Imaging: Medical and Industrial Applications, Gaithersburg, Maryland, May 8-10, 1978.

C. Dwayne Ethridge, "A Single-Component Microcomputer-Controlled Diagnostic Bus for Consideration in the NIM Fast System Design," NIM Fast System Design Group Workshop, Boulder, Colorado, July 9-21, 1978.

C. D. Ethridge and W. M. Seifert, "Microprocessor Data-Input-Control Unit for Mark Century Numerical Contouring Control," IECEC '78 Conf. and Exhibit on

Industrial Applications of Microprocessors, Philadelphia, Pennsylvania, March 20-22, 1978.

C. D. Ethridge, T. H. Kuckertz, and N. Nicholson, "Single-Component Microcomputer Network Provides Data-Acquisition Shelf-Monitor System for Special Nuclear Material Real-Time Inventory," 1978 Nucl. Sci. Symposium, Washington, DC, October 18-20, 1978.

D. J. Erickson, W. B. Garn, R. S. Caird, B. L. Freeman, C. M. Fowler, R. E. Partridge, J. Landt, T. L. Berger, and L. H. Leussen, "Electromagnetic Radiation from a Pulse-Powered Broad-Band Antenna," IEEE Nuclear EMP Meeting, at the Air Force Weapons Laboratory, Kirtland AFB, Albuquerque, New Mexico, June 9, 1978.

Donald R. Farris, "Adaptive Optimal Control for Energy Conservation in Solar Heated and Cooled Buildings," Colloquium talk at UNM for EECS Department, Albuquerque, New Mexico, March 2, 1978, and Contractors Meeting for Solar Controls Projects, Washington, DC, February 28, 1978.

Donald R. Farris, "Energy Conservation through Optimal Control for a Solar Heated and Cooled Building," Abstract of talk for the Electrical Engineering Department, Drexel University, Philadelphia, Pennsylvania, May 22, 1978.

R. F. Ford, "Dymac Computer Hardware and Software," Data General Users Annual Group Meeting, San Francisco, California, October 26-28, 1977.

P. B. Lyons, L. D. Looney, J. Golob, R. Robichaud, R. Seno, J. Madrid, L. Hocker, and M. Nelson, "Neutron- and Gamma-Induced Transient Absorption of Optical Fibers," Conf. on Physics of Fiber Optics, University of Rhode Island, Kingston, Rhode Island, June 22-23, 1978.

H. S. Murray and J. C. Hedstrom, "On-Line Performance Calculations for the Los Alamos National Security and Resources Study Center," Conf. on Performance Monitoring Techniques for Evaluation of Solar Heating and Cooling Systems, Washington, DC, April 3-4, 1978.

H. S. Murray, J. C. Hedstrom, and J. D. Balcomb, "Solar Heating and Cooling Performance of the Los Alamos National Security and Resources Study Center," Int. Solar Energy Conf. on Performance of Solar Heating and Cooling Systems, Dusseldorf, Germany, April 19-20, 1978.

M. A. Trump, "Data-Acquisition and Monitoring System for Los Alamos National Security and Resources Study Center," Conf. on Performance Monitoring Techniques for Evaluation of Solar Heating and Cooling Systems, Washington, DC, April 3-4, 1978.

M. A. Wolf, C. J. Umbarger, and G. Entine, "Use of a Cadmium Telluride Detector in a New Tiny Pocket Radiation Chirper," IEEE Nucl. Sci. Symposium, Washington, DC, October 18-20, 1978.

Papers Submitted for Publication

David Brown, "An Improved Programmable Delay Line," submitted for publication in Nucl. Instrum. Methods.

R. H. Augustson, N. Baron, W. Ford, J. Hagen, T. K. Li, R. S. Marshall, V. S. Reams, W. R. Severe, D. Shirk, and R. F. Ford, "A Development and Demonstration Program for Dynamic Nuclear Materials Control," submitted for publication in Proc. of Int. Atomic Energy Agency Int. Symposium on Nuclear Material Safeguards, Vienna, Austria, October 2-6, 1978.

W. Ogle, P. Goldstone, C. Gruhn, and C. Maggiore, "Evidence for Finite Thickness Effects in Ionization Loss of Relativistic Electrons in Thin Silicone Detectors," submitted for publication in Phys. Rev. Lett.

M. A. Wolf and C. J. Umbarger, "A New Portable Alpha Survey Instrument," submitted for publication as a note in Health Phys.

Papers Accepted for Publication

David Brown and Ulrich Neumann, "An Improved Programmable Delay Line," accepted for publication in Nucl. Instrum. Methods.

C. Dwayne Ethridge and William M. Seifert, "Microprocessor Data-Input-Control Unit for Mark Century Numerical Contouring Control," accepted for publication in Proc. of IECI '78 Conf. on Exhibit of Industrial Applications of Microprocessors," Philadelphia, Pennsylvania, March 20-22, 1978.

D. R. Farris, T. E. McDonald, and J. L. Meisa, "A Brief Comparison of Inherent Controller Capabilities," accepted for publication in Proc. of Workshop on the Control of Solar Energy Systems for Heating and Cooling, Hyannis, Massachusetts, May 23-25, 1978.

D. R. Farris, T. E. McDonald, and J. L. Meisa, "Energy Conservation Through Adaptive Optimal Control for a Solar Heated and Cooled Building," accepted for publication in Proc. of Workshop on The Control of Solar Energy Systems for Heating and Cooling, Hyannis, Massachusetts, May 23-25, 1978.

J. C. Hedstrom, H. S. Murray, and J. D. Balcomb, "Initial Operation and Performance of a Rankine Chiller and an Absorption Chiller in the National Security and Resources Study Center," accepted for publication in Proc. of 3rd Workshop on the Use of Solar Energy for the Cooling of Buildings, San Francisco, California, February 15-17, 1978.

J. A. Landt, "Characterization of the Transient Far-Field Response of Thin-Wire Antennas," accepted for publication in Proc. of URSI Meeting, College Park, Maryland, May 15-19, 1978.

Richard F. Smale and Michael H. J. Backsen, "VORP, An Improved Detector System for Remote Measurements," accepted for publication in Proc. of Health Phys. Society 11th Midyear Topical Symposium on Radiation Instrumentation, San Diego, California, January 17-19, 1978.

H. S. Murray and J. C. Hedstrom, "On-Line Performance Calculations for the Los Alamos National Security and Resources Study Center," accepted for publication in Proc. of Conf. on Performance Monitoring Techniques for Evaluation of Solar Heating and Cooling Systems, Washington, DC, April 3-4, 1978.

P. B. Lyons, J. E. Golob, L. D. Looney, M. A. Nelson, and T. J. Davies, "A Fiber-Optic Time Domain Reflectometer," accepted for publication in Proc. of SPIE Technical Symposium East on Guided Wave Optical Systems and Devices, Washington, DC, March 28-29, 1978 and submitted to Opt. Eng.

M. E. Thuot, "Fiber Optics and Microprocessors: A Control System Solution for the Laser Fusion Environment," invited paper accepted for publication in Proc. of NEPCON/WEST, Anaheim, California, February 28-March 2, 1978 and in Proc. of NEPCON '78 EAST Conf., May 9-11, 1978.

C. John Umbarger and Michael A. Wolf, "Two New Portable Survey Instruments: The Field Phoswich Detector and the Wee Pee Wee," Health Phys. Society 11th Midyear Topical Symposium on Radiation Instrumentation, San Diego, California, January 17-19, 1978.

R. H. Wang, C. Y. Huang, and J. L. Smith, "Critical Field Effects of the Gd in $Gd_xEr_{1-x}Rh_4B_4$," accepted for publication in Proc. of 15th Int. Conf. on Low-Temperature Physics, Grenoble Cedex, France, August 23-29, 1978.

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APPENDIX B
ABSTRACTS OF PUBLISHED PAPERS
JANUARY THROUGH JUNE 1978

M. Bartholdi, G. C. Salzman, R. D. Hiebert, and G. Seger, "Single-Particle Light-Scattering Measurements with a Photodiode Array," *Opt. Lett.* 1, p. 223 (December 1977).

A monolithic 128-element photodiode array is used to detect the light scattered between 7.5 and 21.5° with 0.1° resolution from single particles in a flow stream. The scan of the linear array is synchronized with the light-scattering event by a precursor signal. Monodispersed samples of polystyrene latex microspheres with diameters of 12.5, 15.7, and 19.8 μm were examined.

M. D. Edmiston and C. R. Gruhn, "Energy Resolution Considerations in Liquid Ionization Chambers," *IEEE Trans. on Nucl. Sci.* NS-25, No. 1 (February 1978).

The calculated Fano factors limit the energy resolution of liquid argon and liquid xenon ionization chambers to 4 keV FWHM and 2 keV FWHM, respectively, at 1 MeV. This paper discusses the problems encountered when trying to achieve these limits. First experimental results of our liquid argon detector are presented.

C. R. Gruhn and M. D. Edmiston, "Geminate Recombination of α -Particle-Excited Carriers in Liquid Argon," *Phys. Rev. Lett.* 40, No. 6 (February 1978).

We report experimental evidence showing that the electric-field-dependent yield of carriers excited in the track of an α particle stopping in liquid argon is dominated by geminate (initial) recombination of electron-ion pairs. This is the first confirmation of geminate carrier recombination in a noble-gas liquid. The thermalization length of the hot electrons is determined to be about 28 nm.

A. R. Koelle, S. W. Depp, J. A. Landt, and R. E. Bobbett, "Short-Range Passive Telemetry by Modulated Backscatter of Incident CW RF Carrier Beam," *Bio-telemetry, III* (Academic Press, Inc., 1976).

Modulated backscatter telemetry was developed as a means for reporting the temperature of cattle,

along with an identification code for each animal. Objectives included low cost and passive (no battery) operation of the implanted transponders. This novel telemetry method should be useful in other applications. The paper describes the principle of operation and solutions to some of the problems encountered during the development.

A. Lundy, J. R. Parker, J. S. Lunsford, and A. D. Martin, "Avalanche Transistor Pulser for Fast-Gated Operation of Microchannel Plate Image-Intensifiers," *IEEE Trans. on Nucl. Sci.* NS-25, No. 1 (February 1978).

Transistors operated in the avalanche mode are employed to generate a 1000-V 10- to 30-ns-wide pulse with < 4-ns rise and fall times. This pulse is resistively attenuated to ≈ 270 V and drives the image intensifier tube which is a load of ≈ 200 pF. To reduce stray inductance and capacitance, transistor chips were assembled on a thick-film hybrid substrate. Circuit parameters, operating conditions, and coupling to the microchannel plate image-intensifier (MCPI²) tube are described.

To provide dc operating voltages and control of transient voltages on the MCPI² tube, a resistance-capacitance network has been developed which (a) places the MCPI² output phosphor at ground, (b) provides programmable gains in "f-stop" steps, and (c) minimizes voltage transients on the MCPI² tube.

B. G. Strait and M. E. Thuot, "A Microprocessor Stepping-Motor Controller," *Microcomputer Design and Applications*, (Academic Press, Inc., 1977).

A new concept for digital computer control of multiple stepping motors which operate in a severe electromagnetic pulse environment is presented. The motors position mirrors in the beam-alignment system of a 100-kJ CO₂ laser. An asynchronous communications channel of a computer is used to send coded messages, containing the motor address and stepping-command information, to the stepping-motor controller in a bit serial format over a fiber-optics

communications link. The addressed controller responds by transmitting to the computer its address and other motor information, thus confirming the received message.

Each controller is capable of controlling three stepping motors. The controller contains the fiber-optics interface, a microprocessor, and the stepping-motor driver circuits. The microprocessor program, which resides in an EPROM, decodes the received messages, transmits responses, performs the stepping-motor sequence logic, maintains motor-position information, and monitors the motor's reference switch. For multiple stepping-motor application, the controllers are connected in a daisy chain providing control of many motors from one asynchronous communications channel of the computer.

B. G. Strait, M. E. Thuot, and J. P. Hong, "A Distributed Microcomputer Control System for a High-Energy Gas-Laser Facility," Computer, Reader Service No. 10 (September 1977).

Laser research facilities, with their typically severe EMI environment and attendant need for minimum length data links, represent an ideal application for a distributed microcomputer-based control system. This paper presents the conceptual design of a distributed control system for the High-Energy Gas-Laser Facility (Fig. 1). Third in a series of experimental CO₂ laser fusion systems at Los Alamos Scientific Laboratory in New Mexico, the HEGLF is aimed at exploring the use of lasers in thermonuclear research for power generation. As presently conceived, the system will contain multiple microcomputers, each under supervision of a central minicomputer. It will monitor six power amplifiers, the high-voltage pulse-power system, the laser preamplifiers, and the target systems, as well as automatically align the laser beams onto the target. System components, which will be distributed throughout the facility, will be interconnected via fiber-optics cables so as to combat the electromagnetic noise environment when the laser is fired.

R. H. Wang, R. J. Laskowski, C. Y. Huang, J. L. Smith, and C. W. Chu, "Magnetic and Superconducting Transitions in Gd_xEr_{1-x}Rh₄B₄ and Gd_xY_{1-x}Rh₄B₄," J. Appl. Phys. **49**(3) (March 1978).

The magnetic and superconducting transition temperatures and upper critical fields have been measured for Gd_xEr_{1-x}Rh₄B₄ and Gd_xY_{1-x}Rh₄B₄. The pressure dependence of T_C for the Er system for $x \leq 0.05$ is 0.5×10^{-2} K/kbar. Both systems exhibit reentrant behavior, that is a superconducting transition followed by a magnetic transition at a lower temperature that destroys the superconductivity. For the Er system, the initial additions of Gd actually raise the superconducting critical field followed by the expected decrease for greater additions.

M. Zaider, J. F. Dicello, and R. D. Hiebert, "A Pulsed System for Obtaining Microdosimetric Data with High Intensity Beams," IEEE Trans. Nucl. Sci., Vol. NS-25, No. 1, (February 1978).

The use of heavy particle accelerators for radiation therapy requires high intensity beams in order to produce useful dose rates. Conventional microdosimetric techniques are not applicable under these conditions because exceedingly high count rates result in detector damage, gas breakdown, and saturation effects in the electronics. We describe a new microdosimetric system developed at the Pion Biomedical Channel of LAMPF. The accelerator provides a variable low intensity pulse once every ten high intensity macropulses. The voltage on the detector is pulsed in coincidence with the low intensity pulse so that we were able to operate the detector under optimum data-taking conditions. A low noise two-stage preamplifier was built in connection with the pulsed mode operation. A comparison is made between data obtained in pulsed (high intensity beam) and unpulsed (low intensity beam) modes. The spectra obtained by the two methods agree within the experimental uncertainties.

US Patent Issued

Howard A. Baldwin, Steven W. Depp, Alfred R. Koelle, and Robert W. Freyman, "Interrogation and Detection System," US Patent 4 075 632, February 21, 1978.

The specification relates to a telemetering apparatus comprising a generator which generates at least a single frequency rf signal, a transponder for receiving that signal and for amplitude modulating it in accordance with information selected for

transmission, an antenna on the transponder for reflecting the amplitude modulated signal, and a receiver which is preferably located at the generator.

The receiver processes the signal to determine the information carried thereby.