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CORRELATIONS OF NET AND PRIMARY BEAM CURRENTS IN DRY NITROGEN BACKGROUND GAS

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by

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CONTENTS

ILLUSTRATIONS

SECTION 1

INTRODUCTION

Fluence determinations constitute half the data needed to understand material response; the definition of loading conditions is only as good as the fluence prediction. In the case of medium to high dose experiments, graphite calorimetry loses its effectiveness because the graphite itself begins to respond to the energy deposition. Removal of graphite from the calorimeter because of blowoff or spall carries off energy, which is not communicated to the thermocouples. Consequently, active voltage and current diagnostics are employed to define the beam environment.

The accelerating voltage is well-known on each shot from the outputs of the voltage and $\dot{B}$ monitors. However, primary currents during sample irradiation cannot be measured, because the sample obscures the beam-guide exit. Therefore, empirical correlations between the net and primary currents are used to predict peak primary currents. The shape of the primary-current waveform appears to remain constant for fixed background-gas pressure. Thus, knowledge of the peak primary-current amplitude is sufficient to calculate total beam calories, H, according to

$$H = \int V(t)\, I_p(t)\, dt,$$

since "phasing" between V and I_p caused by beam-front erosion is known from measurements.

Once the total beam energy is known, uniform beam intensity achieved with guide cones makes it possible to determine fluence, by dividing the total beam energy by the uniform irradiation area.

This process is pivoted on the empirical net-primary correlation, which is statistical in nature -- the more measurements, the better the correlation. Performing these measurements during contrast pulsing reduces the number of data points per day. The alternative is to diagnose the several beam environments on the 738 Pulserad (say, three fluences at two or three energies) once for all.

Past attempts at net-primary current correlations suggested that dry nitrogen might make a better background gas than air. The day-to-day variations in the onset of gas conductivity (breakdown) were attributed to the presence of hydrogen, in the form of water vapor, which made net-primary current correlations virtually humidity-dependent.

In recent months, a dry-nitrogen background-gas system has been implemented on the 738 Pulserad. Double-purging on pump-down and filling the chamber with dry nitrogen after the shot guarantee that background-gas constituents do not vary from day to day. Since the effect of these changes could not be calculated, it was necessary to confirm or reestablish the net-primary current correlation.

To make this report complete, the results of two pulsing days on the 738 Pulserad, one of which was conducted under Project 33-126-02, are included. Project 33-126-02 consisted of 56 hours of physicist time, 16 hours of technician time, one day of pulsing on the Pulserad 738 machine, one hour of computer time, and one hour of data digitizing by Stanford Research Institute. The total cost of the program was $1708.00.

SECTION 2

EXPERIMENTAL PROCEDURE

All pulsing for this experiment was performed on the 738 Pulserad. The machine output was adjusted to give a mean electron energy of 250 to 300 keV. The pulse charge ranged from 3.5 to 4.0 MV. Data was taken using the two types of guide cone most often used at Physics International for impulse experiments (MFCRR and SADO). In both beam guides, Rogowski coils were situated as close to the cone exit as possible (less than 0.5 inch apart).

Background-gas (dry nitrogen) pressures were held at 450 microns for the straight, slotted guide cone (MFCRR) and at 250 microns for the curved, slotted guide (SADO). Total beam calories ranged from 80 to 110. Cone exit diameters were 5/8-inch and 3/8-inch for MFCRR and SADO, respectively.

The current detectors were the standard Faraday cup for the primary current and standard Rogowski coils for the net current. The net- and primary-current detectors were located as physically close as possible, to minimize beam-current losses between the detectors. Fourteen usable data points were obtained with the MFCRR cone, and seventeen usable points were obtained with the SADO cone.

SECTION 3
ANALYSIS

Stanford Research Institute converted the original data, on Polaroid film, to digital form, on computer cards, for use in computer data-reduction codes. The Digital Data Processing code has been applied to these data, yielding the mean energy, total calories, and mean angle of incidence of each shot. Accurate measurements of beam erosion, obtained by careful timing of the voltage monitor, $\dot{B}$, and Faraday cup oscilloscopes during the experiment, were used, for the first time, in processing the data.

Net and primary currents have been correlated using the empirical formula

$$I_{pri}^{max} = I_1 + kI_2$$

where I_1 is defined as the value of the net current at the onset of neutralization; I_2 is the difference between I_1 and the maximum value of the net current; and k is an experimentally determined constant. PIP-711 discusses this correlation scheme further.

The Rogowski coil has an L/R time constant that causes its output to decrease exponentially with a constant input current. Depending on the pulse length and the Rogowski-coil time constant, this effect will cause errors of 10 to 20 percent in the determination of the maximum net current. A first-order correction for this difficulty has been made by approximating the net-current trace as a step function. By making measurements at several different times on the standard calibration trace, a time-dependent calibration of the Rogowski coil was obtained and a plot of calibration versus time drawn.

To determine the effective calibration of the Rogowski coil at the net current maximum, one examines the net-current record and measures the time from the indicated maximum to a point on the leading edge of the net-current trace at which the net current has about half its maximum value. The effective calibration is then obtained by referring to the previously prepared calibration-versus-time plot. The time-dependent correction is also applied to the determination of I_1, using the Rogowski-coil calibration corresponding to half the risetime of the leading edge of the net-current trace. The greatly magnified computer-output plot of the net current has proved particularly useful in making all these measurements.

A value of k was calculated for each shot. The arithmetic average of these k's was then calculated for each of the two beam conditions tested, and these average values were inserted in the correlation formula. The predicted value of the primary-current maximum was compared with the measured value. The results of this comparison appear in Figures 1 and 2. A perfect correlation would be represented by a 45 degree line.

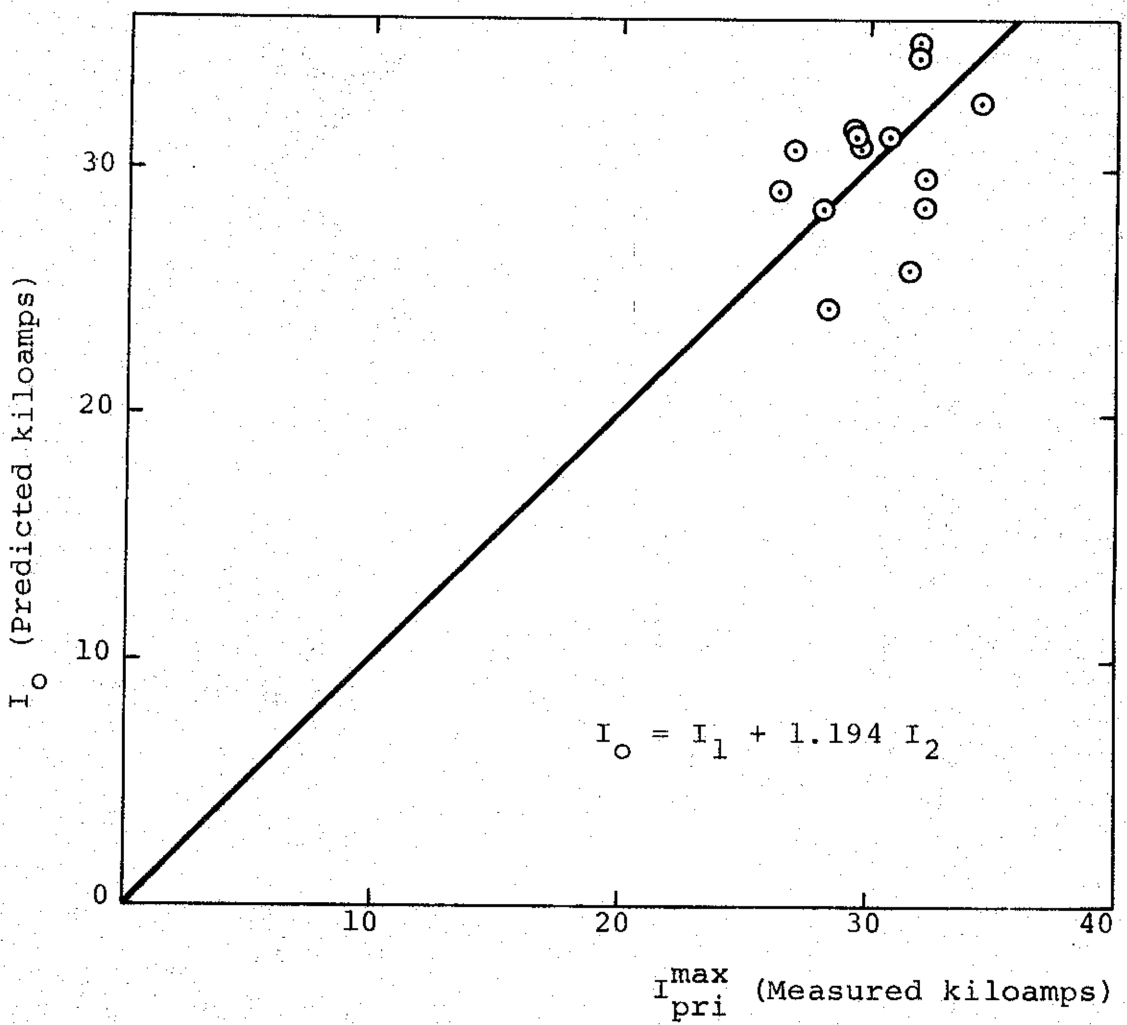

Figure 1 Measured versus predicted peak primary current in MFCRR cone.

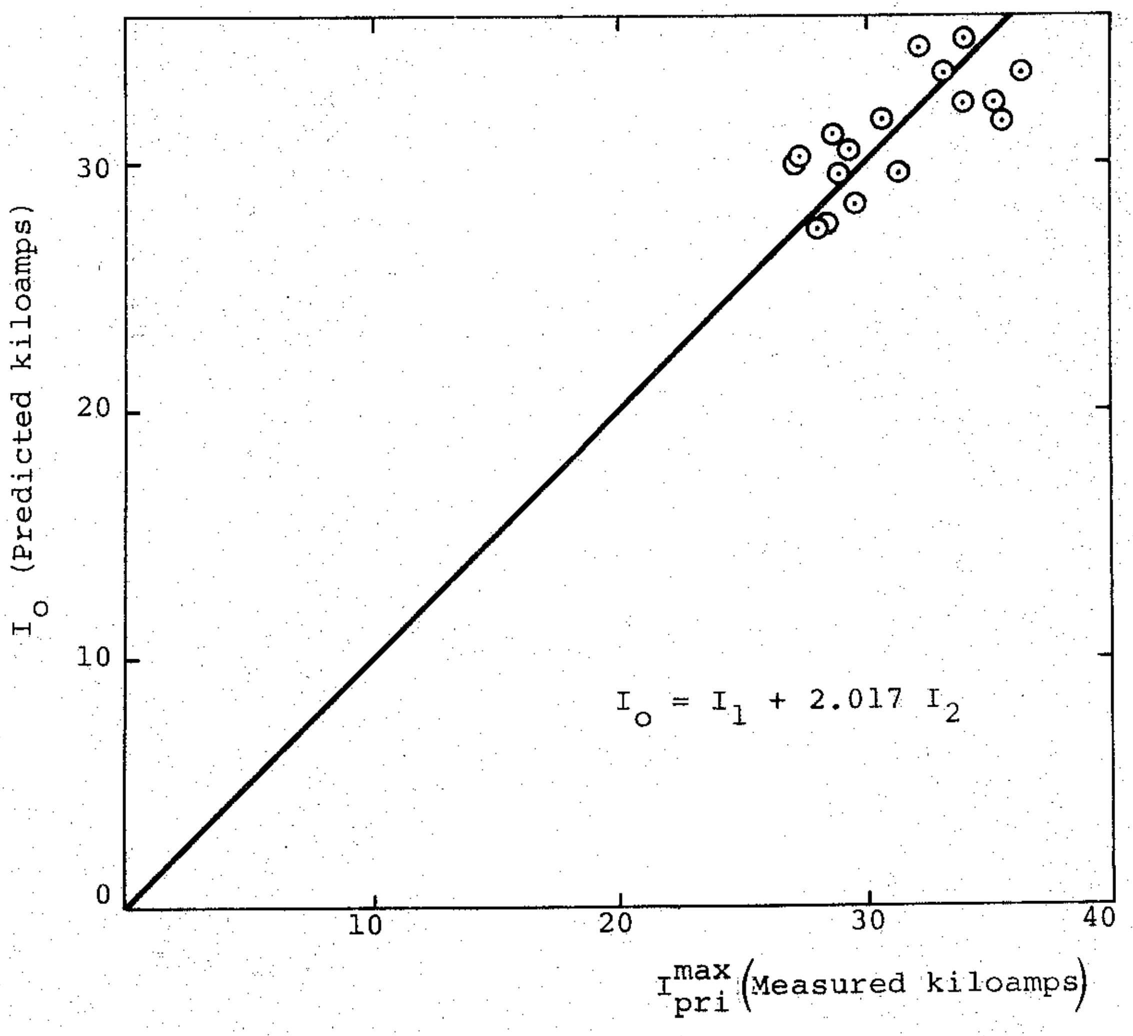

Figure 2 Measured versus predicted peak primary current in SADD cone.

SECTION 4
CONCLUSION

Beam-current correlation for the MFCRR (Figure 1) is less than ideal, the worst case of deviation being about 18 percent from perfect. This is attributed in part to spurious noise in the form of ringing at the beginning of the Rogowski coil trace. The source of this noise, which appears in a number of the traces, has not yet been discovered but appears to be related to the grounding scheme employed for the Rogowski coil. At the beginning of some of the traces, there is also a spike, which seems to be caused by poor injection of the beam into the cone. Both of these problems make the determination of I_1 very difficult.

The correlation achieved with SADO is reasonable with all but one point, (at 12 percent), falling within plus or minus 10 percent of perfect correlation (Figure 2). The average value of $k = 2.017$ agrees well with previous experiments. The net-current traces in this case were clean, and I_1 was well defined. It is evident that clean net-current traces are necessary to adequately correlate primary and net currents. An attempt should be made to discover and correct the sources of spurious output in the Rogowski coil.

Included for reference in Figures 3 and 4 are plots of the peak net current versus the peak primary current for MFCRR and SADO. The straight line drawn on each plot is the best linear fit through the origin to the data. The correlation thus ob-

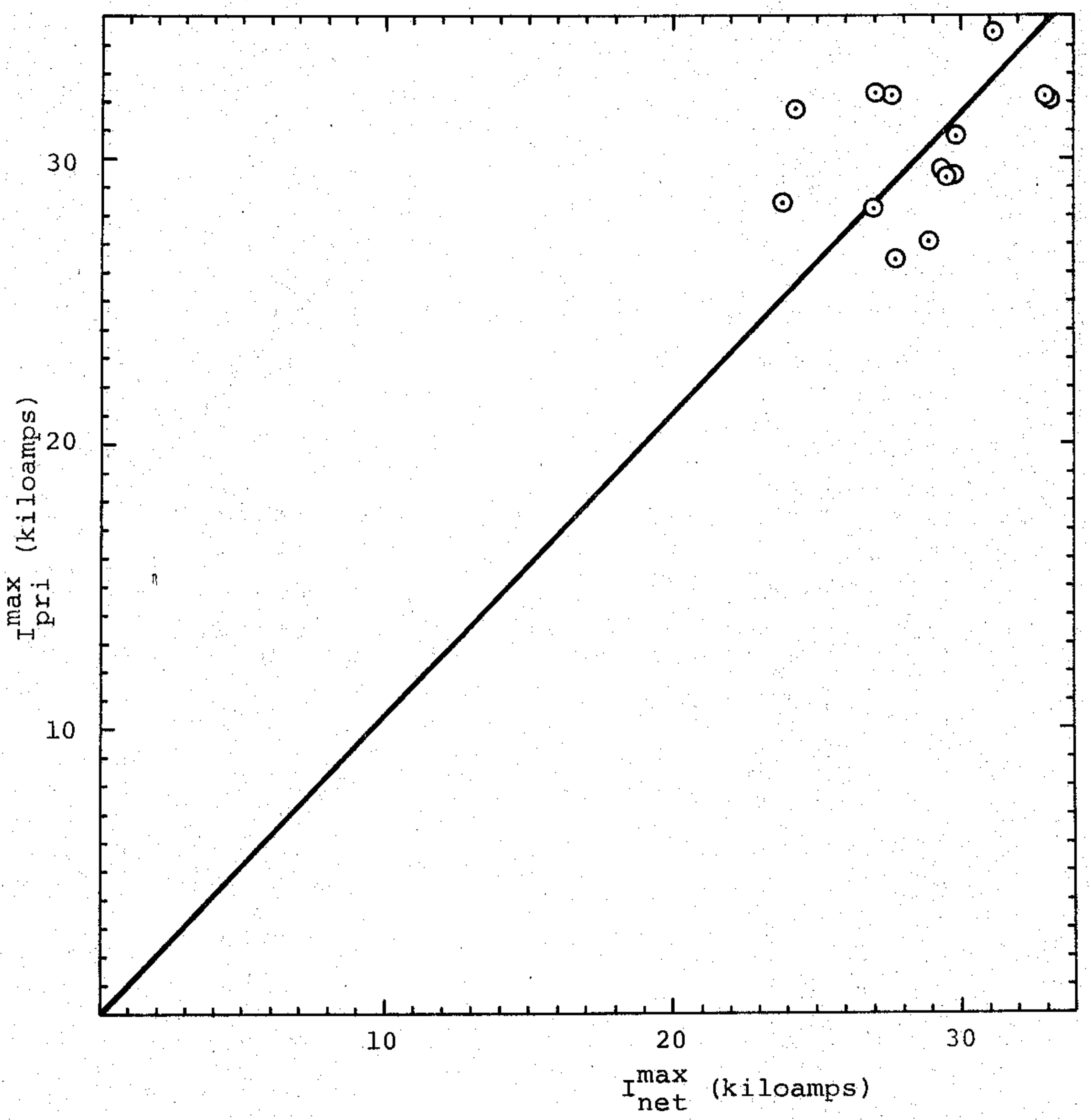

Figure 3 Peak primary current versus peak net current in MFCRR.

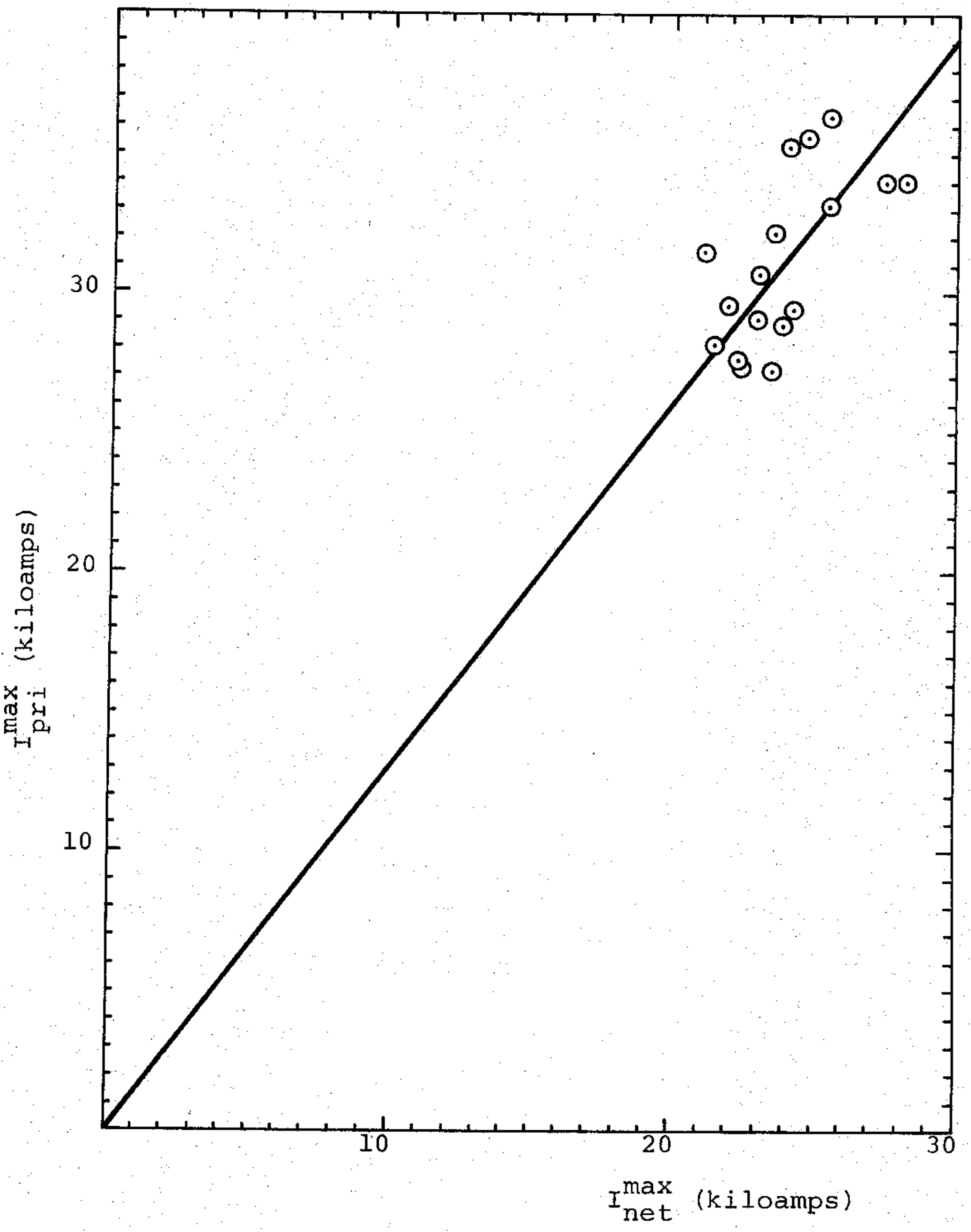

Figure 4 Peak primary current versus peak net current in SADO.

tained is somewhat poorer in both cases than in the scheme outlined above. The MFCRR deviates 24 percent from perfect in the worst case, while four of the seventeen SADO data points deviate by more than 10 percent from perfect. Nevertheless, this simple correlation method may still be useful, particularly in cases where I_1 is poorly defined on the net-current trace.

Steps have been taken to commit much of the laborious and time-consuming work involved in establishing the primary-net current correlation to computerization. Several preliminary codes have already been written for this task, but additional work is needed to make them operational. An attempt should be made to develop a computer program which will reconstruct the entire primary-current shape from information contained in the net current. If successful, such a scheme would reproduce variations in the primary-current pulse shape and duration. This, in turn, would lead to more accurate fluence determinations for material-response experiments.