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CALIBRATION OF THIN FILM EMP SENSORS BY AFWL COAXIAL CHAMBER

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ABSTRACT

Preliminary EMP calibration data on magnetic thin film current sensors has been obtained. The Air Force Weapon Lab's Coaxial Chamber was used as the EMP standard and a current pulse width of 40 ns was used. We found that the sensitivity of the sensors can be increased by controlling the width of the 90° wall strip and that the current scales for the sensors were linear. The results strongly suggest that we can vary the dimensions of our sensors to meet different measurement requirements.

2. INTRODUCTION

The magnetic thin film current sensors[1,2] are simple, passive device designed for EMP measurements. In the previous supported work by Defense Nuclear Agency and Air Force Weapons Laboratory (AFWL) at Kirtland Air Force Base, we field tested the thin film sensors at Kirtland Air Force Base. The conclusion[3] was that a more stringent calibration of the sensors was needed before the sensors can be applied for general use. One of the problems with calibration was that a standard for calibration was not available. It was difficult to establish a well defined electromagnetic pulse of a known magnitude.

In the present contract with AFWL, the main thrust of our effort is directed toward the calibration of the thin film sensors. The AFWL furnished us with a CCC-1A-Calibrated Coaxial Chamber whereby an adjustable and well defined electromagnetic pulse can be produced. The EMP created in the chamber will be used as standard to calibrate the thin film sensors. The present report summarized our preliminary calibration data.

3. DESCRIPTION OF THE AFWL'S COAXIAL CHAMBER

The AFWL's chamber, which serves as an EMP standard, is a 50 Ω transmission line section modified to accommodate our thin film sensors. A cross section view of the chamber is shown in Figure 1. Within the chamber (between R_1 and R_2), the $\overline{H}$ field created by a current pulse through the central conductor has circular symmetry and is related to radial distance r and current I by,

$$\overline{H} = \frac{I}{\partial \pi r} \quad . \tag{1}$$

For our convenience, we express the H in Oersteds, I in Amperes and r in millimeters. Equation (1) becomes

$$H(Oe) = \frac{I}{\partial \pi r \times 10^{-3} \times 80}$$

$$\approx 2 \times \frac{I(amp)}{r(mm)} \tag{2}$$

We can plot $\overline{H}$ vs r, with I as the variable parameter. Figure 2 shows the field strength (within the chamber) for different currents. The insertion of the thin film sensor inside the chamber produces neglegible disturbance to the field because the thickness of the film is only a few hundred angstroms.

4. CALIBRATION PROCEDURE

The calibration of a thin film current sensor included the following steps.

(1) Formation of a 90° wall by the "zapper."

(2) Observation and/or photorecording of the domain wall.

(3) Adjustment of the mercury switch pulser to obtain a predetermined current pulse.

(4) Observation and/or photorecording of the current pulse by OSC.

(5) Insertion of the thin film sensor into the chamber.

(6) Application of a single pulse to the sensor.

(7) Photorecording of the registered information on the thin film sensor.

The steps were repeated for each pulse. For the present work, a fixed pulse width of 40 nanoseconds was chosen (typical pulse shape is shown in Figure 3). The current was the only variable. The displacements of the domain wall for each of the current levels were determined from the photographs. We plot the current I vs. displacement r and obtained the calibration curve for the sensor.

5. RESULTS AND DISCUSSION

We used two sensors in this calibration experiment. The two sensors were chosen because the magnetic properties of the films were mostly uniform over the entire length of the films.

In experimenting over the location of the 90° wall relative to the edges of the film, we found that 90° walls made near to the edges of the film responded better to the short pulses. Figure 3 shows such a narrow strip 90° wall. Attachments were made on the "zapper" such that the 90° wall was made on the same location each time. We can adjust the attachments to obtain the desired width for the 90° wall strip. A calibration run was made for each width of the 90° wall strip. Table 1 shows the data for three calibration runs. The domain wall displacements were represented by S, displacement measured from the reference end of the sensor, and r, inferred distance from the center of the inner conductor. Figure 4 and 5 show the calibration curves for sensors green-x and blue-x respectively. We made two runs on green-x with different widths of the 90° wall strip to check qualitatively the effect of strip width. The magneto-optic readout photos for the three runs are shown in Figure 6, 7 and 8. We examined the domain wall displacements with the magnetic tape viewer also and can measure off the distances just as easily.

We will first discuss the linearity of the calibration scale. Figure 4 and 5 show that for a proper width of 90° wall strip one can obtain linear readout scale for the thin film current sensors. Theoretical analysis by AFWL suggested that the readout scale should be linear and we confirmed their finding by our own analysis. We made dc current calibration runs on both sensors and found the readout scales to be linear.

The effect of the 90° wall strip width was examined in the present experiment. When the width of the 90° wall strip was made too wide (more than a millimeter), the sensitivity of the sensor to short current pulses was markedly reduced. For 40 ns pulses, a current of 12-14 Amps would be needed to displace the wall enough for observation. With reference to Figure 2, 12-14 amps is equivalent to over 6 Oe at the reference end of the film. For the narrow strip 90° domain walls, as shown in Figure 4 and 5, only 2.5-3 Oe was requried for observable displacements.

The present experiment offered the following facts and suggestions. First of all, the current scale for the thin film sensors is linear as predicted. Secondly, we learned that the sensitivity of the current sensors for short current pulse (tens of nanoseconds) can be influenced by the width of the 90° domain wall strip. Prior to the present experiment, the only other parameters that affect the sensitivity of the sensors were the material composition and film thickness of the sensor. Lastly, the experiment showed that our present sensor's dimension was not suited for short pulse detection. We made our 90° wall close to one edge in order to form a narrow 90° wall strip. In so doing, the sensor can detect only one direction of current flow. We need to make narrower width sensors to begin with so that the 90° wall made at the center of the film will form narrow 90° wall stirps on both sides of the wall. We may very well use the width of the film to control the sensitivity of the sensors for short pulses.

REFERENCES

1. UCID-16240, "A Simple Sensor and Recorder for Fast Current Pulses," March 1973.

2. UCID-16364, "A New Transient Surface - Current Sensor and Recorder," October 1973.

3. UCID-16945, "Final Report for EMP Instrumentation Project DNA 1ACRO 75-815 Magnetic Thin Film Sensors," October 1975.

LIST OF FIGURES

ACKNOWLEDGEMENT

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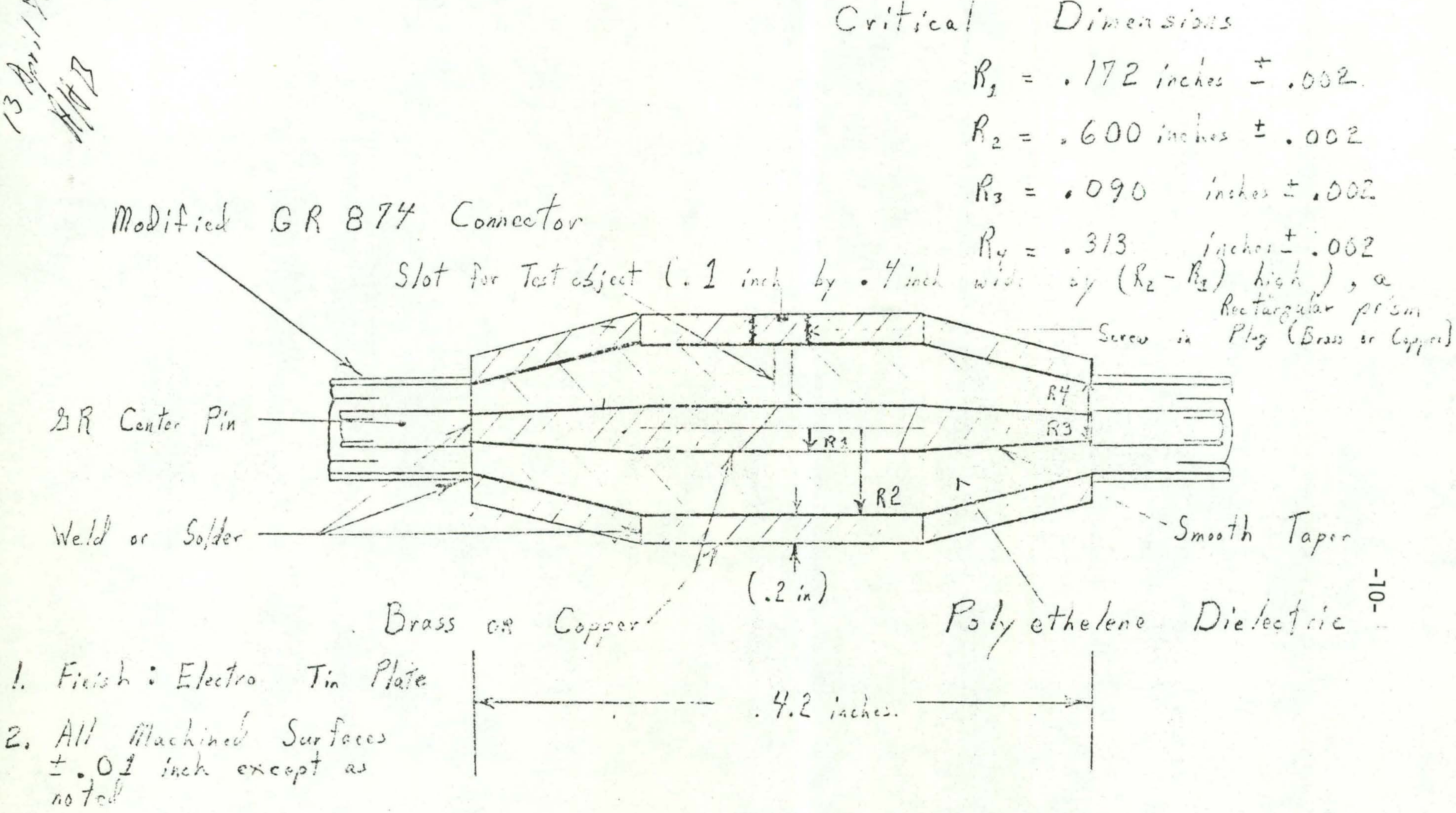


Fig. 1. AFWL CCC-1A-Calibrated Coaxial Chamber

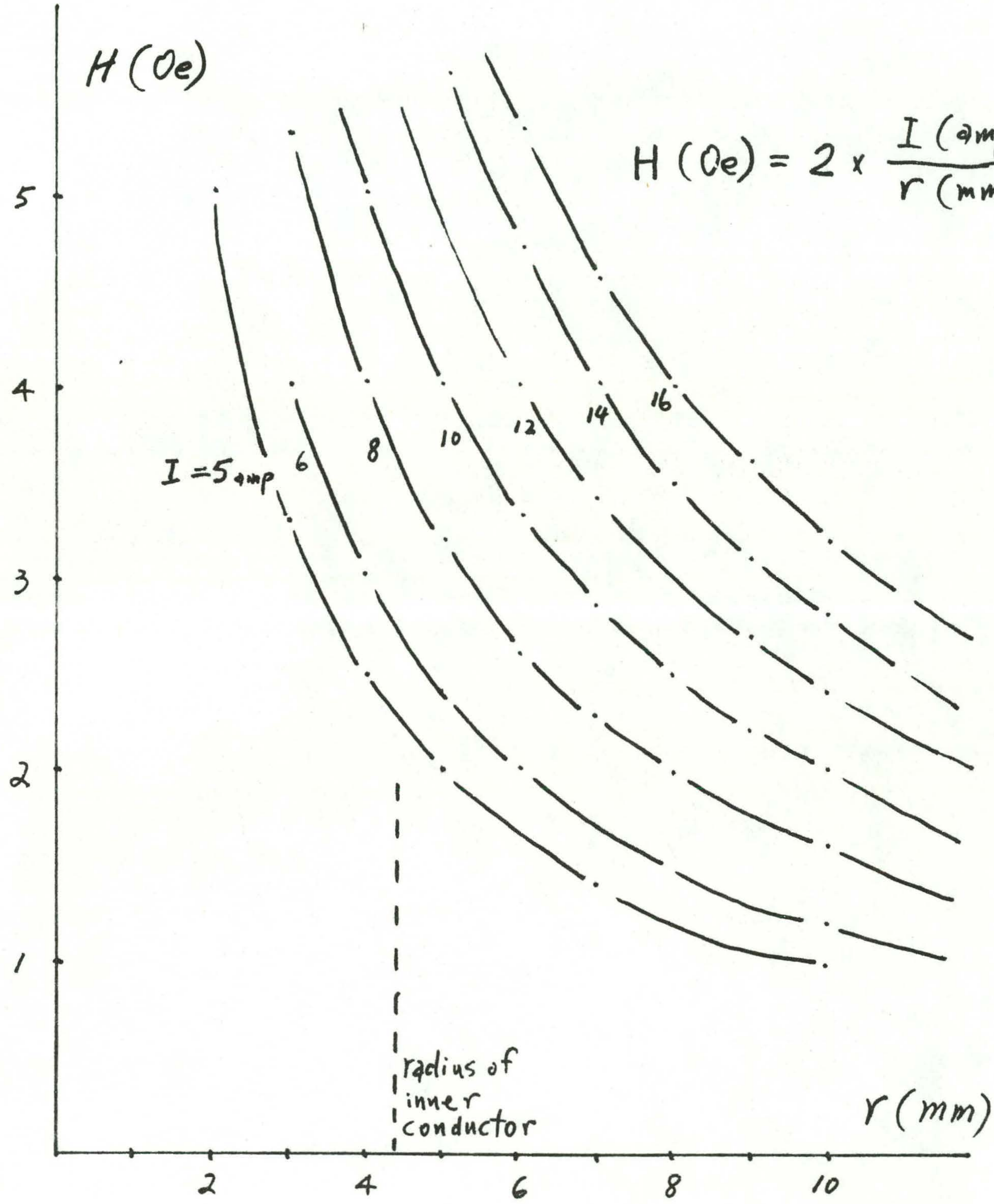
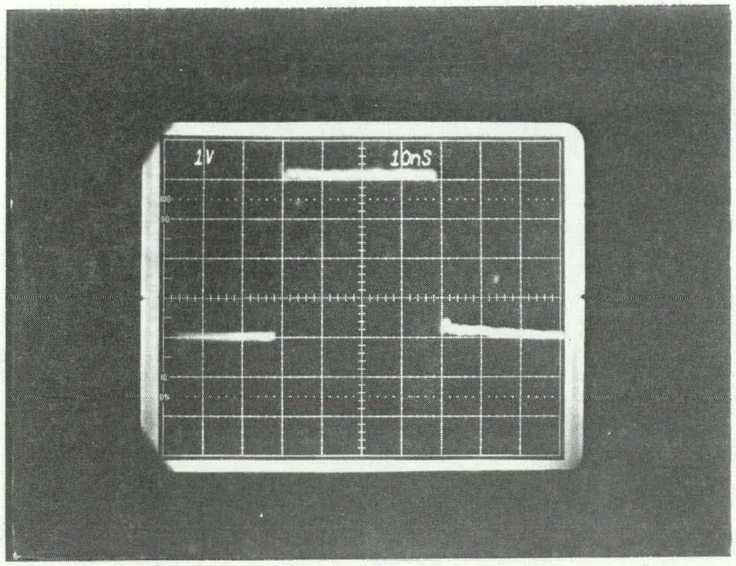


Fig. 2. H vs r Plot for different I



pulse width ~ 40ns

Fig. 3A Typical Input Current Pulse

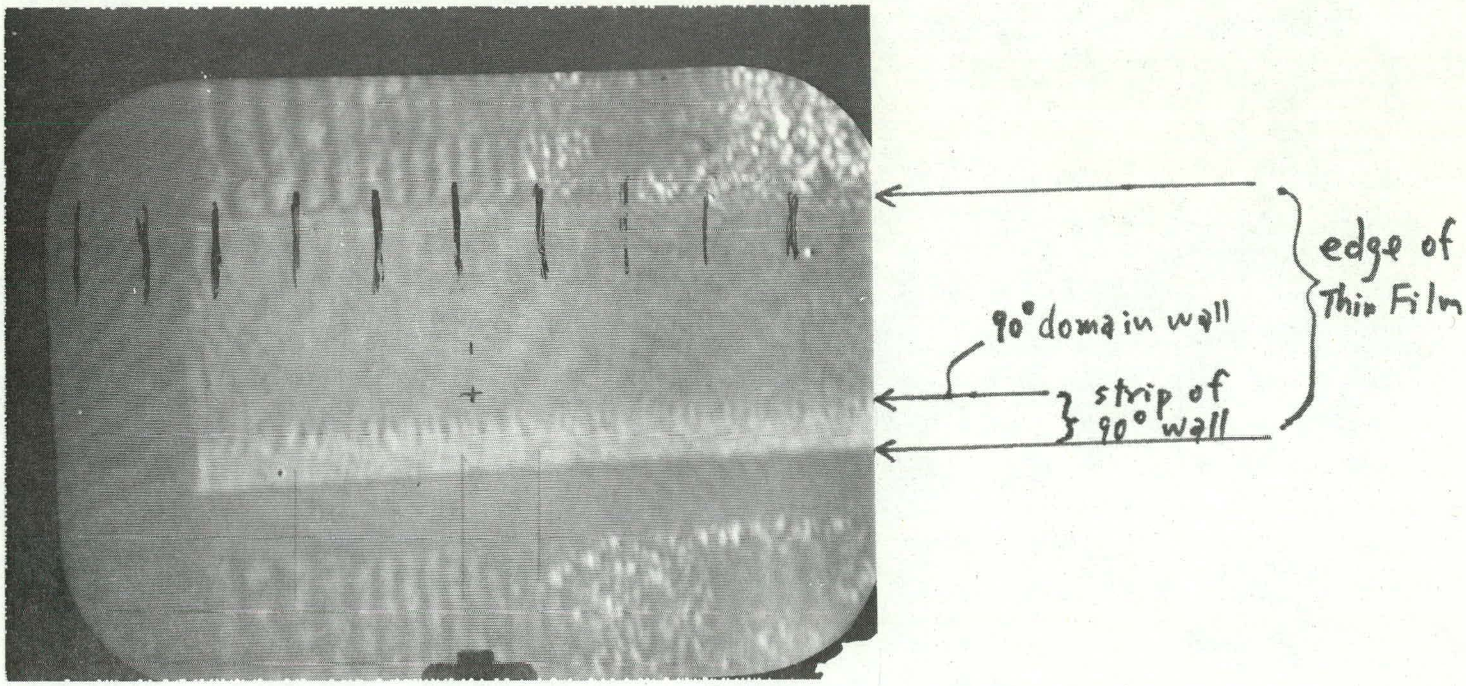


Fig. 3B Magneto-Optic Photograph of A Narrow Strip of 90° Domain Wall

Table I. Calibration Data For Two Sensors

Current (40 ns pulse)	Sensor Green-X				Sensor Blue-X	
	Narrow strip		Medium strip		Medium strip	
	s (mm)	* r (mm)	s	r	s	r
6 Amp	0.25 – 0.5	4.65 – 4.9	Not observable		Not observable	
8	1.25 – 1.5	5.65 – 5.9	[illegible].1 – [illegible].35	4.5 – 4.75	0.75 – 1	5.15 – 5.4
10	2.5 – 3	6.9 – 7.4	1.35 – 1.65	5.75 – 6.25	1.75 – 2	6.15 – 6.4
12	3.5 – 4	7.9 – 8.4	2.5 – 2.65	6.9 – 7.15	3 – 3.25	7.[illegible] – 7.65
14	4.5 – 5	8.9 – 9.4	3.1 – 3.5	7.5 – 7.9	4 – 4.25	8.4 – 8.65
16	5 – 6	9.4 – 10.4	3.9 – 4.	8.3 – 8.4	5 – 5.25	9.4 – 9.65

* $r = s + 4.4$

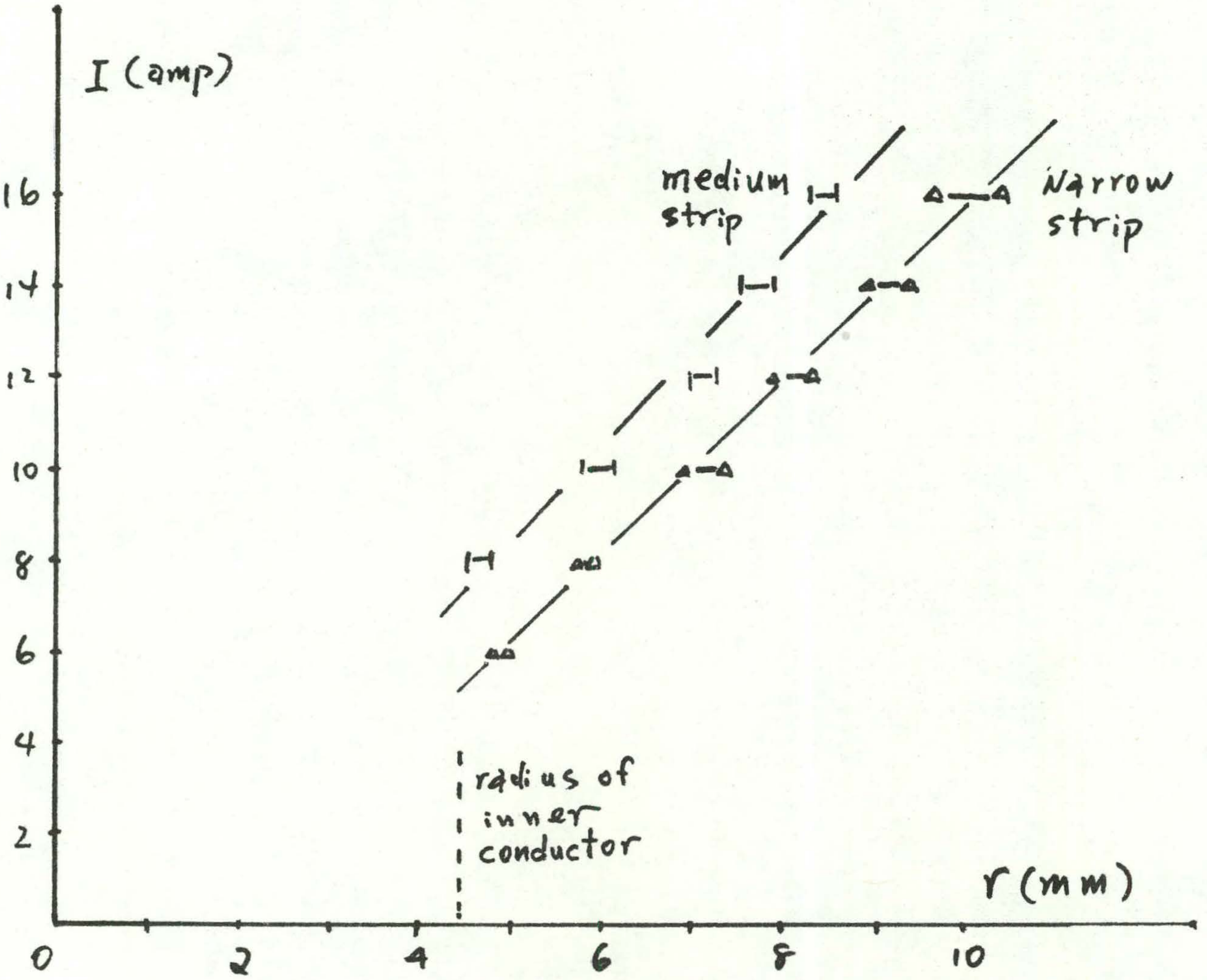


Fig. 4. Calibration Curve For Sensor Green-X

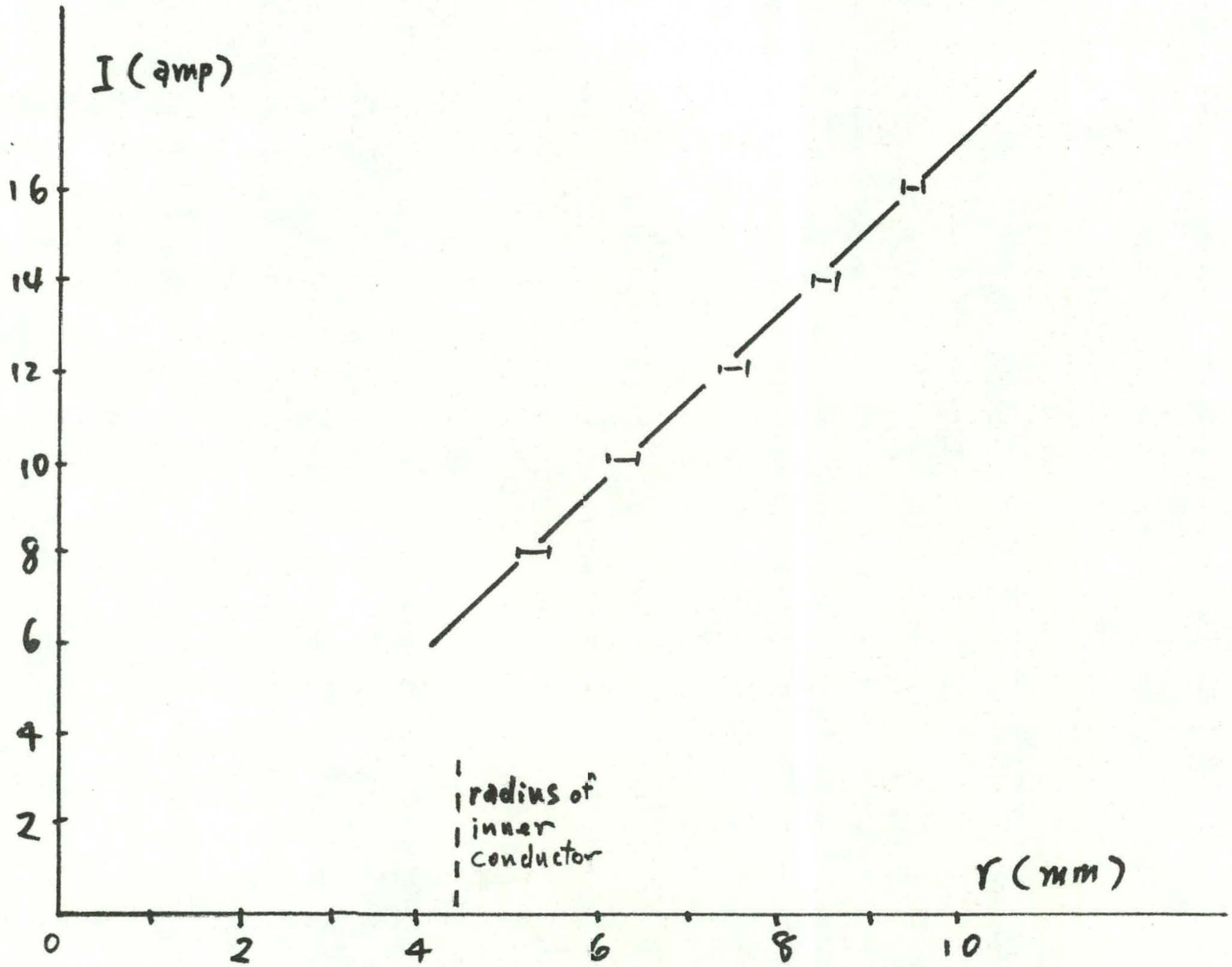


Fig 5. Calibration Curve For Sensor Blue-X

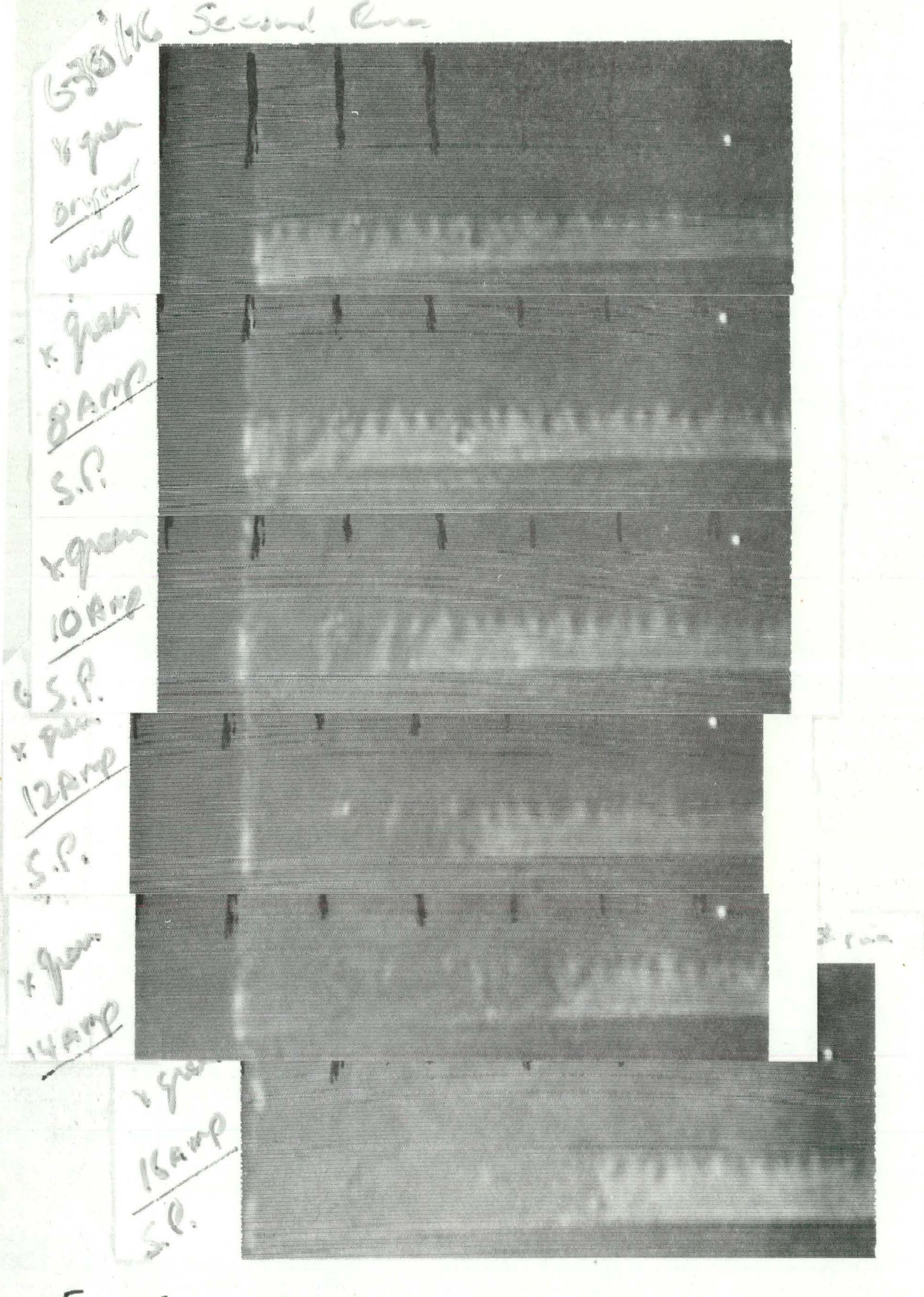


Fig. 6 Calibration Photos For Sensor Green-X with medium-width strip of 90° wall

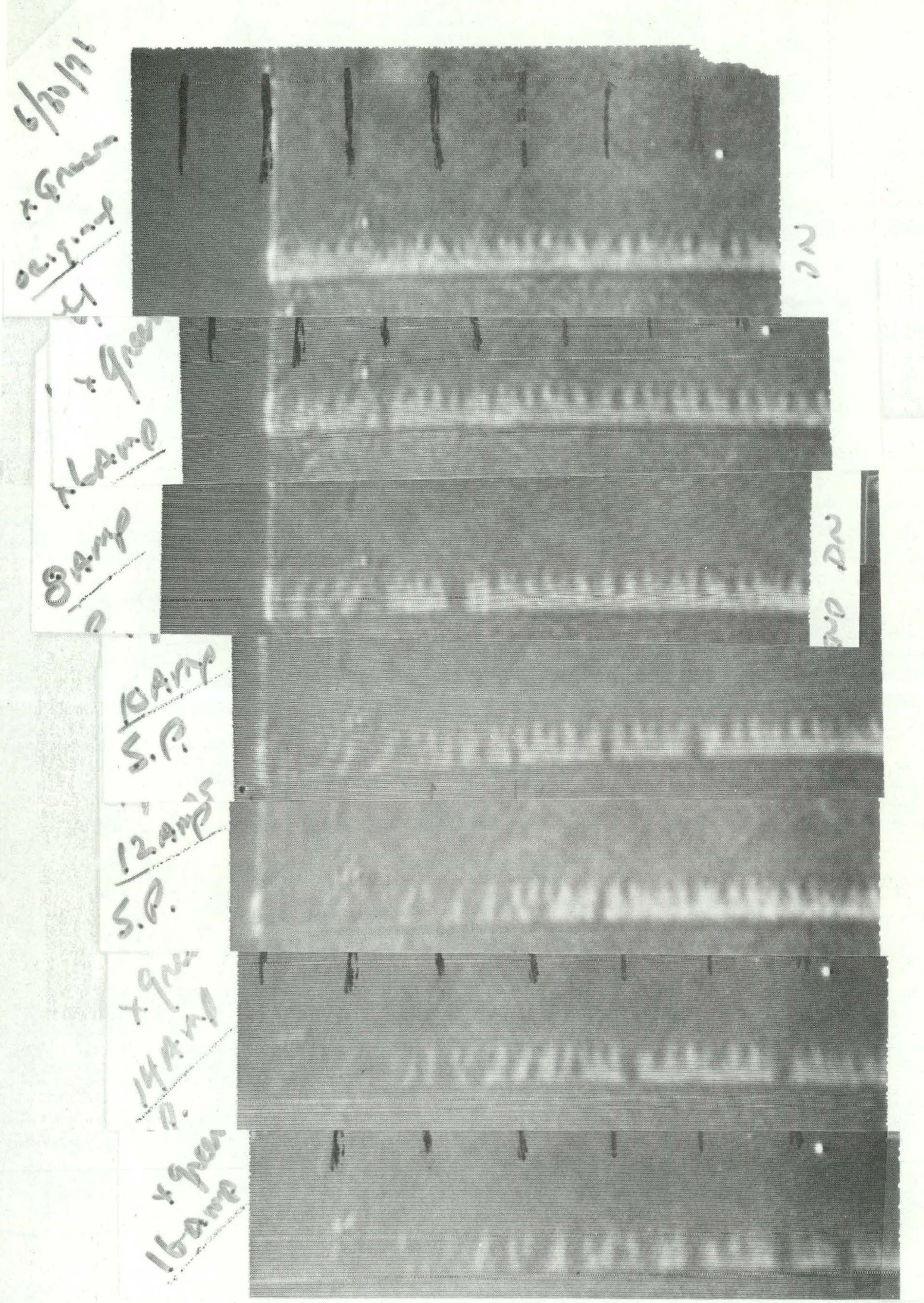


Fig. 7 Calibration Photos For Sensor Green-X With Narrow-width Strip of 90° Wall

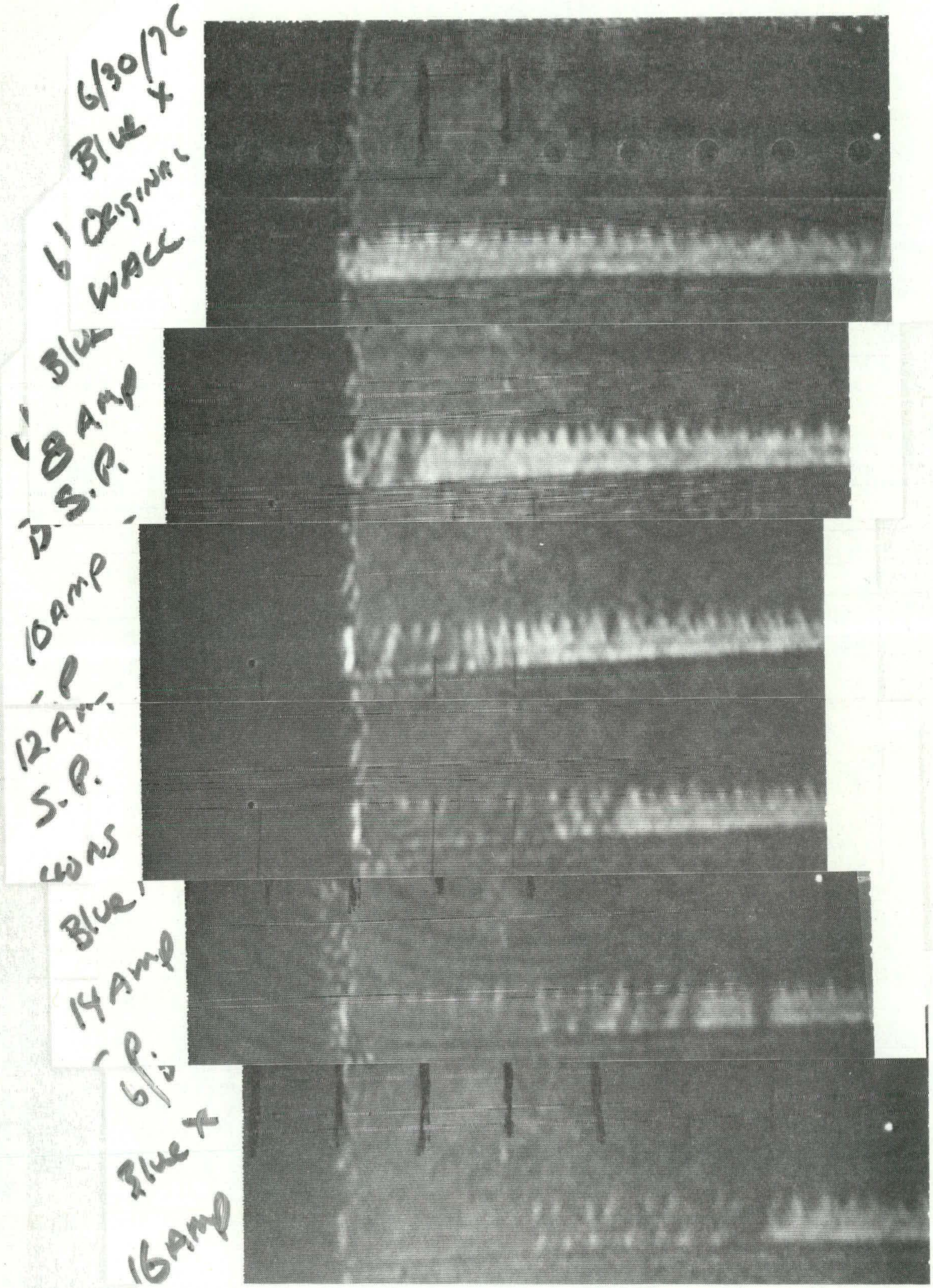


Fig. 8 Calibration Photos For Sensor Blue-X with Medium-width strip of 90° Wall

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