Operation of Channeltron® and Spiraltron* Electron Multipliers in The Pulse Saturated Mode with Output Caps

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OPERATION OF CHANNELTRON® AND SPIRALTRON* ELECTRON MULTIPLIERS IN THE PULSE SATURATED MODE WITH OUTPUT CAPS

Many experimenters operate capped Channeltron Electron Multipliers (CEM) in the pulse saturated mode for counting input events. An end-cap often is sealed to the CEM so that the detector and its high voltage connections can be potted without fear of contaminating the inner surface of the CEM. With this configuration the output signal terminal of the device is common with the high voltage terminal.

Experimentally, it is well known that each event multiplied by the capped CEM appears as a negative charge pulse at the common output terminal; this pulse is somewhat smaller than the equivalent pulse seen with an adequately biased free anode (typically 60 percent in the CEM 4010). In an effort to examine why the capped CEM exhibits this characteristic, a CEM 4010 was mounted with a free anode biased 225 volts positive with respect to the output electrode; and current waveforms were taken across a 91 ohm load impedance using a Tektronix Type 85A oscilloscope and a Type 82 preamplifier. The electrical connections were similar to those shown in Figure 8. The rise time of this setup is approximately 4×10^{-9} second. Figures 1, 2, and 3 show the results of this experiment when the CEM is operated in soft saturation (2050 volts), moderate saturation (2300 volts), and hard saturation (2650 volts), respectively. In each figure, trace a is the inverted current waveform at the output electrode, $-i_e$; trace b is the current waveform at the free anode, i_a; and trace c is the sum of these two currents, $i_a + i_e$, obtained externally in a summing resistor. The quantity $i_a + i_e$ is analogous to the current waveform seen at the cap of a capped CEM. Other Bendix experiments have confirmed that the pulses i_a and i_e essentially occur simultaneously.

Examination of traces a and b in each figure shows that the electrode pulse i_e appears to have been attenuated and its waveform somewhat distorted compared to the anode pulse, but that the pulse width has not been affected. The fact that the quantity $i_a + i_e$ does not equal zero results primarily from the attenuation of i_e. We may hypothesize that in the pulse saturation mode the anode collects the full output charge, but that the "mirror image" net positive charge left on the channel wall is located well inside the CEM and is thus seen attenuated at the channel output terminal.

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The corresponding waveforms of a Model 4213-X Spiraltron Electron Multiplier (SEM) with a 3 mm cone are shown in Figures 4, 5, 6, and 7. The waveforms shown in Figure 7 were obtained with the SEM operated in extremely hard saturation. Examination of Figures 4, 5, and 6 reveals that:

1. The SEM pulse width is very narrow compared to the CEM pulse width (15×10^{-9} second compared to 40×10^{-9} second); this is even more noteworthy when the nominal rise time of the oscilloscope (4×10^{-9} second) is taken into account. Since the SEM has an extremely small transit time spread one may infer that the transit time, pulse rise time, and pulse rise time jitter must also be smaller than for the CEM.

2. Except when operated in extremely hard saturation, (Figure 7), the SEM current waveforms i_a tend to have an isosceles triangular shape, instead of the steep-sided trapezoidal shape typical of the CEM. Although the true i_a pulse of the SEM is probably obscured by the oscilloscope response characteristics, it is plain that the extended flat-topped pulse typical of the saturated CEM only begins to occur when the SEM is operated in hard saturation.

3. The two SEM current pulses i_a and $-i_e$ are similar in shape and differ only slightly in amplitude (except when operated in hard saturation--Figure 7). This means that the sum of $i_a + i_e$ is very small compared to each component. Hence, one would expect that only small output pulses would be obtained from an SEM with a simple end-cap; actual experiments confirm that this indeed occurs, as well as that the pulse height distribution is (predictably) broadened.

One concludes therefore that SEM 4213-X type multipliers with a simple end-cap do not yield very satisfactory pulse signals; this has been confirmed experimentally. However, a number of end-cap configurations have been conceived to produce a satisfactory signal; the exact characteristics of each arrangement are being evaluated at this time. Because they are rather more complex than the simple cap, it is recommended that the experimenter select the configuration most suitable for his requirement and obtain the SEM already fabricated with that type of cap. Figure 8 shows an end-cap which is basically an electrically isolated free anode. This configuration requires a bias voltage for the anode; however, negative pulses are available at the anode and "mirror image" positive pulses are available at the output electrode.

Figure 9 shows a configuration which can take external connections similar to those for a simple CEM cap; however, the SEM is about 0.4 inch longer. Figure 10 depicts another design in which the SEM is only slightly lengthened; and the positive output pulses are taken off at the Spiraltron electrode. It is also possible to simply lengthen the SEM Spiraltron section about 0.6 inch to increase the L/D and permit simple capping.

To summarize:

1. Output pulses from simple end-capped CEM's and SEM's result from the addition of two charge pulses of opposite polarities.

2. A useful negative output pulse can be obtained from the CEM with a simple end-cap, because of the attenuation of the positive electrode pulse.

3. The similar amplitudes of the anode and electrode pulses of the SEM make special capping treatment necessary in order to obtain useful pulse amplitude and narrow amplitude distribution.

4. With special capping, an SEM can provide either a positive or a negative output pulse, or both.

5. When capped SEM's are desired, the device should be ordered from the manufacturer in the most suitable capped configuration.

6. SEM output current pulses are very narrow; their shapes suggest that the rise time, transit time, and jitter of the SEM are very small, even compared to respective values for the CEM.

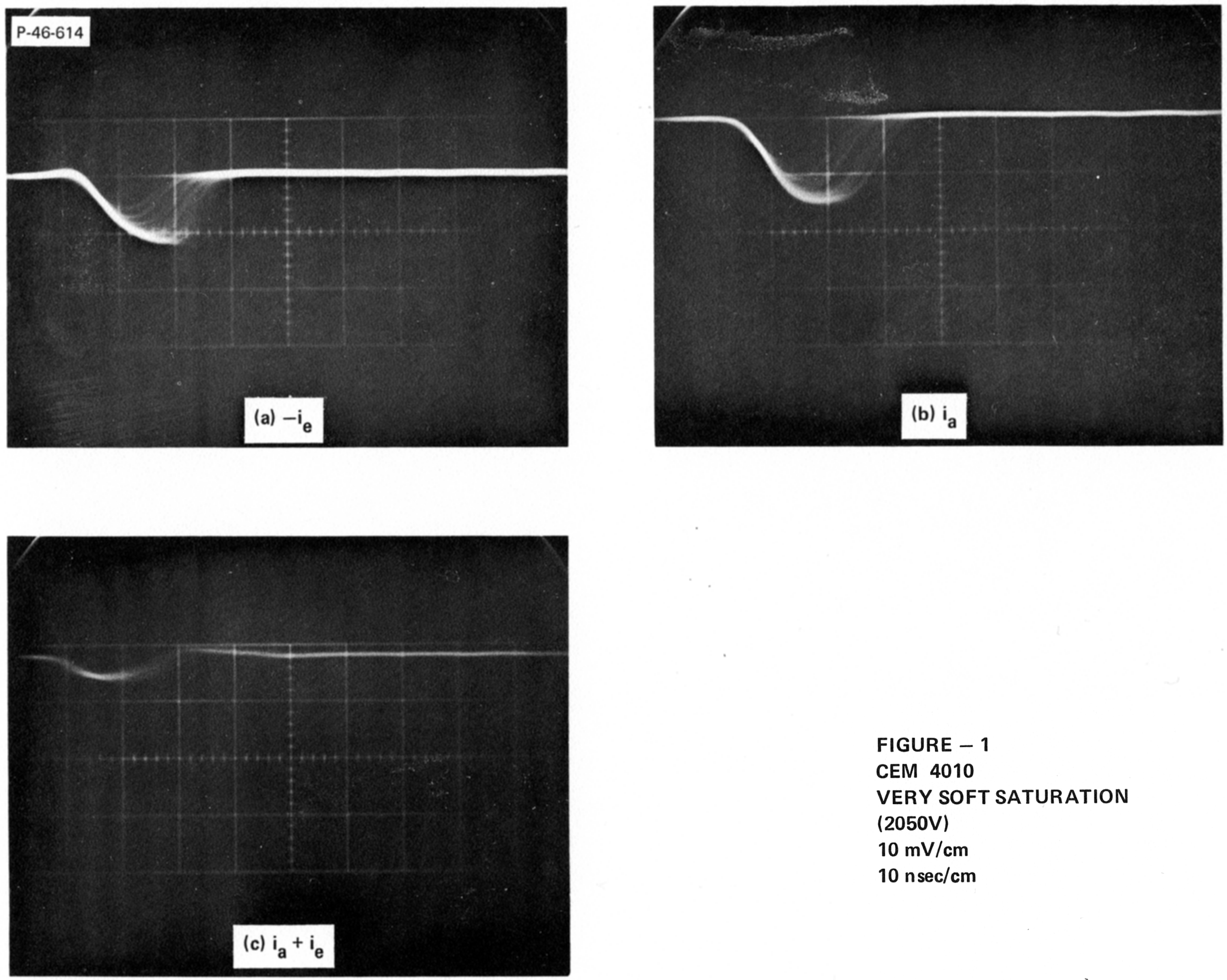


FIGURE – 1
CEM 4010
VERY SOFT SATURATION
(2050V)
10 mV/cm
10 nsec/cm

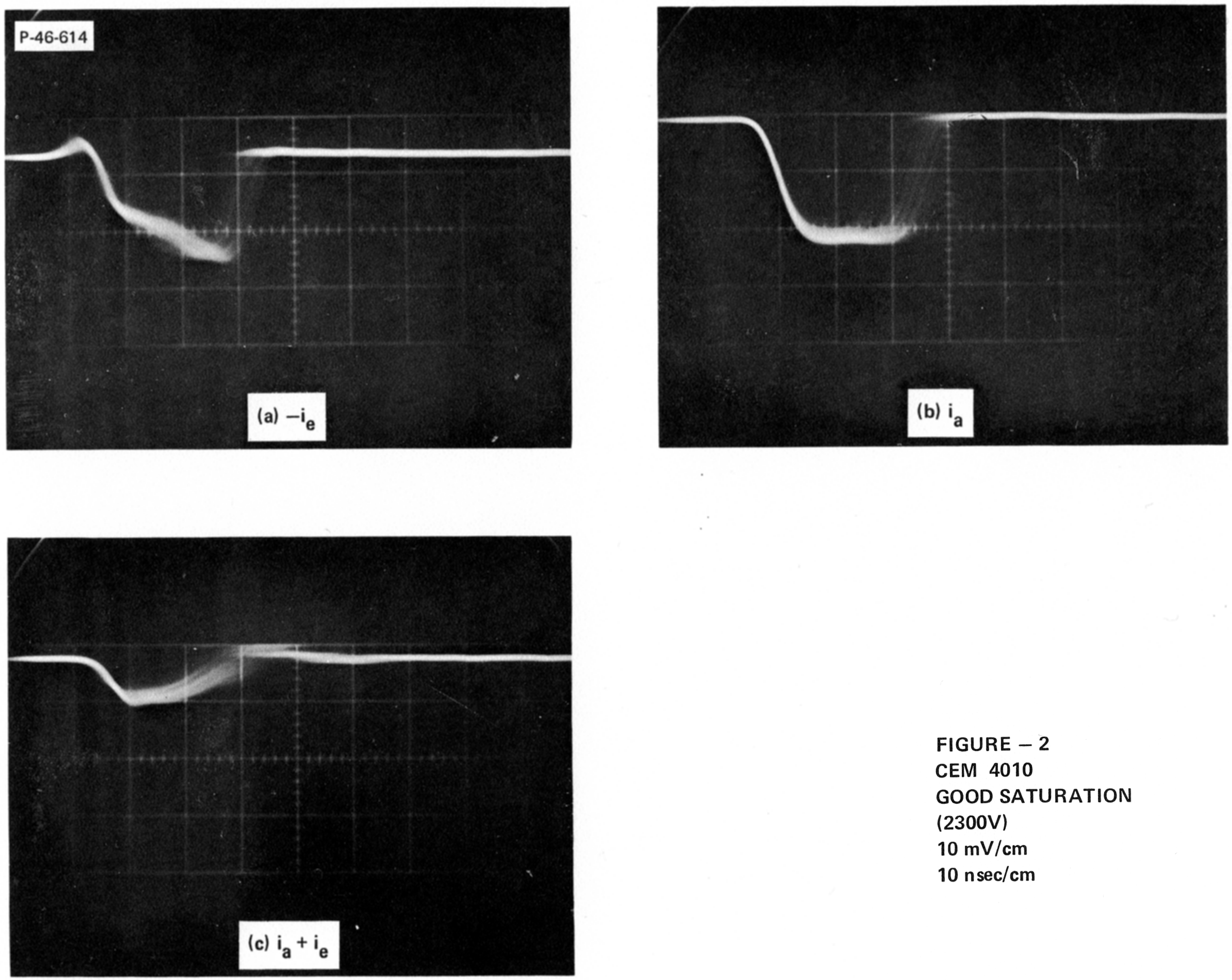


FIGURE – 2
CEM 4010
GOOD SATURATION
(2300V)
10 mV/cm
10 nsec/cm

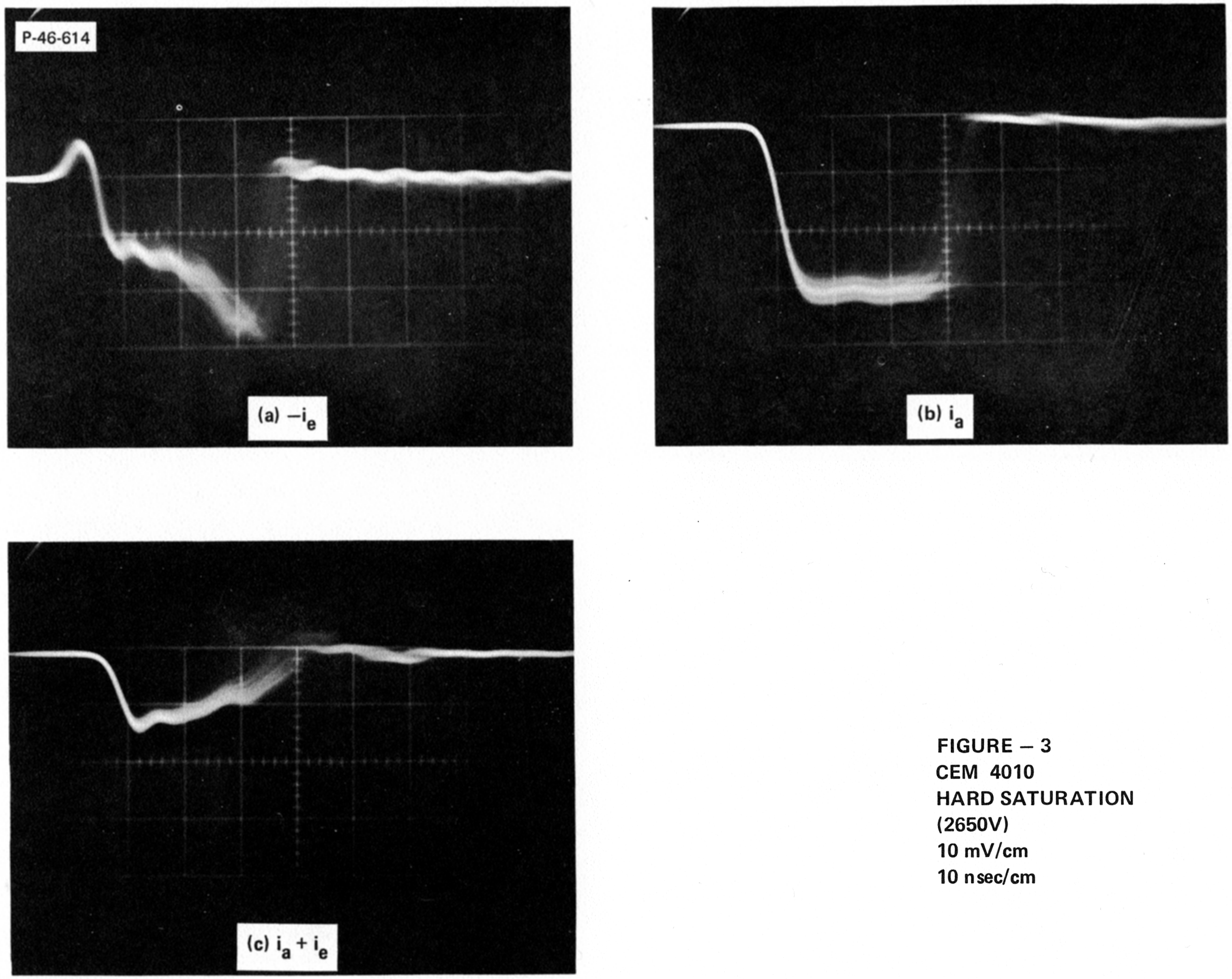
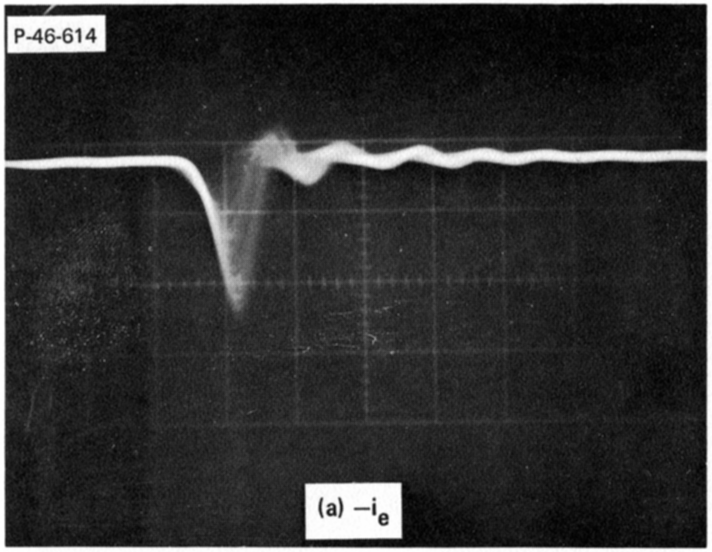
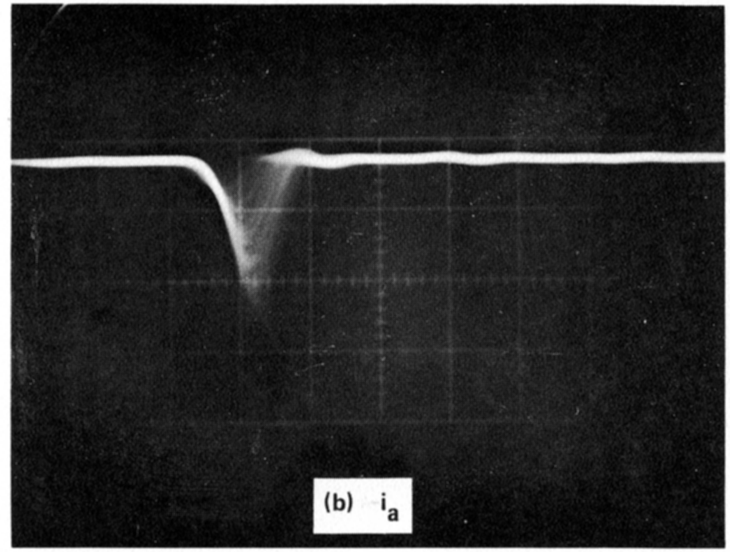


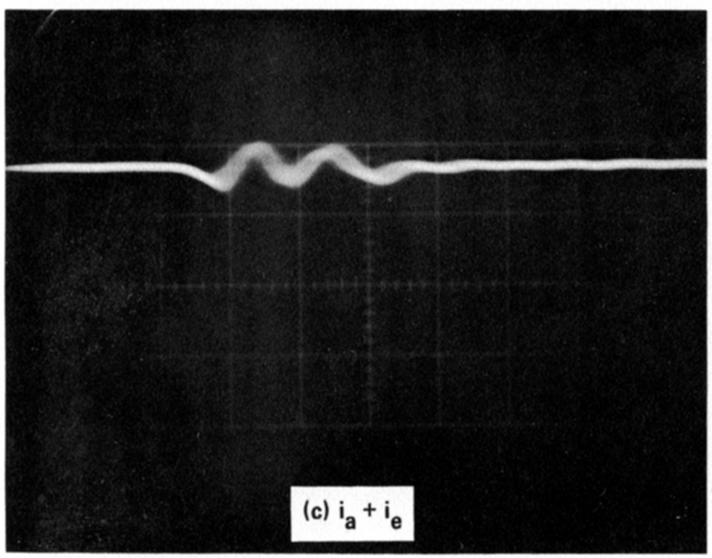
FIGURE – 3
CEM 4010
HARD SATURATION
(2650V)
10 mV/cm
10 nsec/cm



(a) $-i_e$



(b) i_a



(c) $i_a + i_e$

FIGURE– 4
SEM 4213-X
3 mm CONE
VERY SOFT SATURATION
2500V (1700 + 800)
50 mV/cm
10 nsec/cm

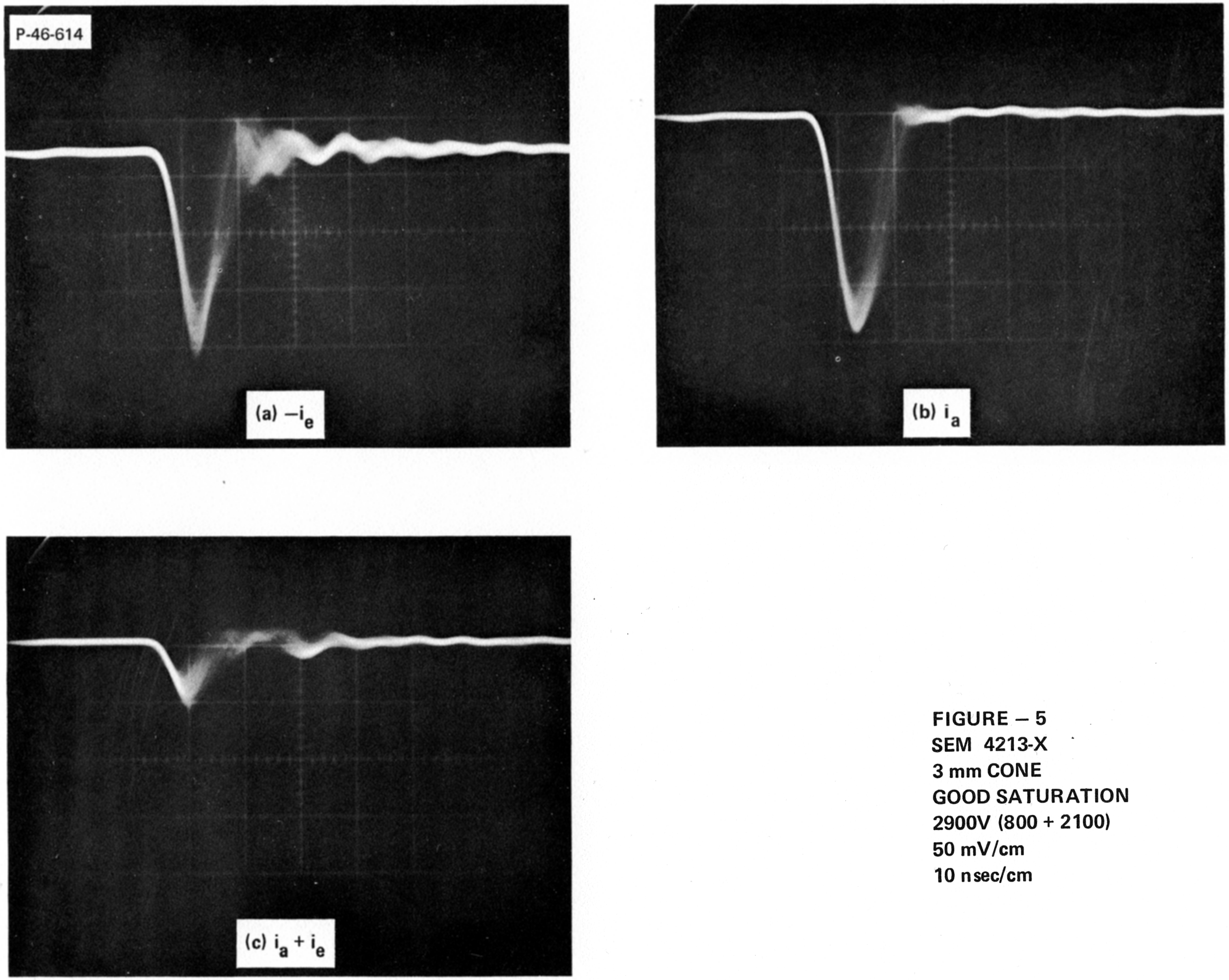


FIGURE – 5
SEM 4213-X
3 mm CONE
GOOD SATURATION
2900V (800 + 2100)
50 mV/cm
10 nsec/cm

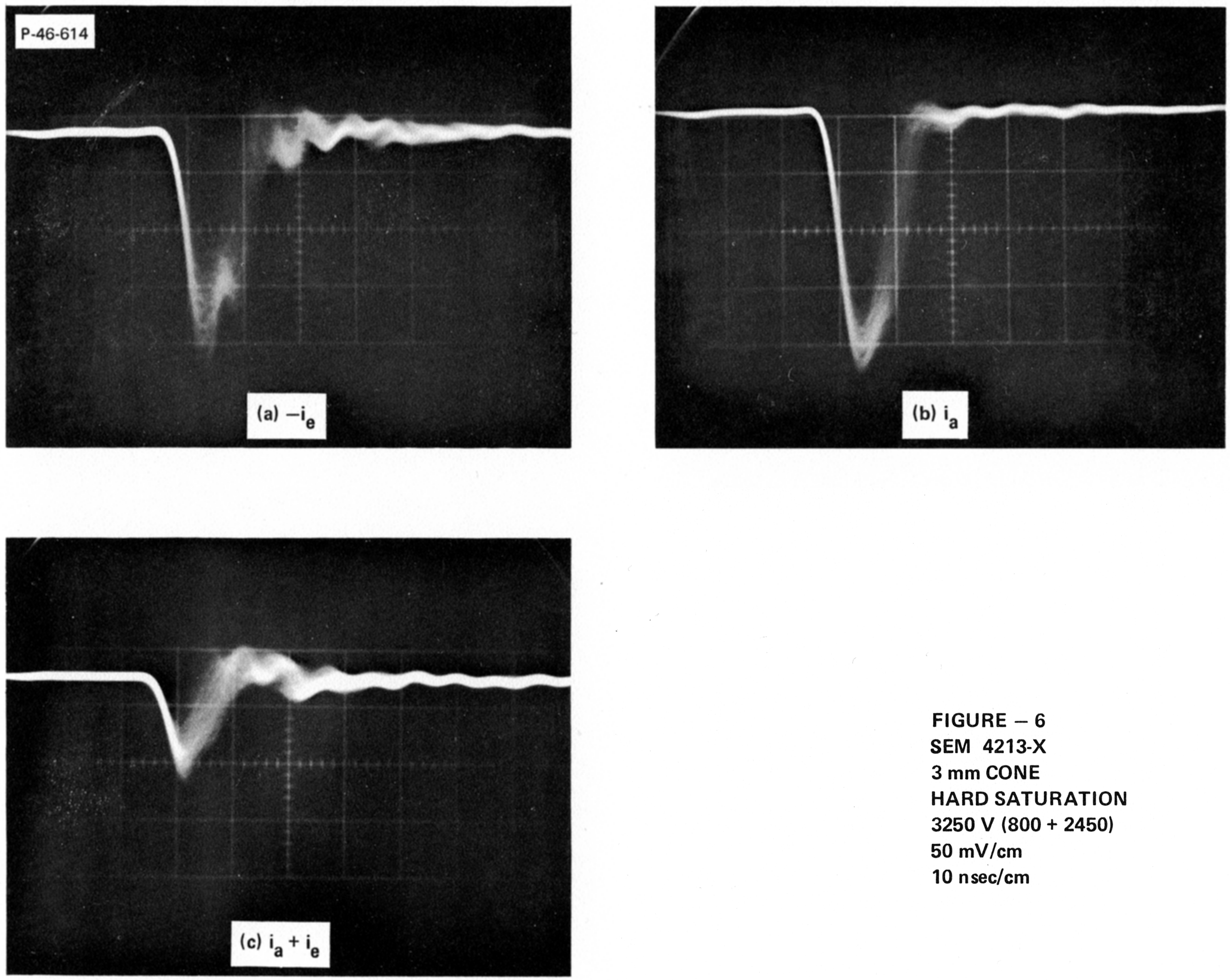


FIGURE – 6
SEM 4213-X
3 mm CONE
HARD SATURATION
3250 V (800 + 2450)
50 mV/cm
10 nsec/cm

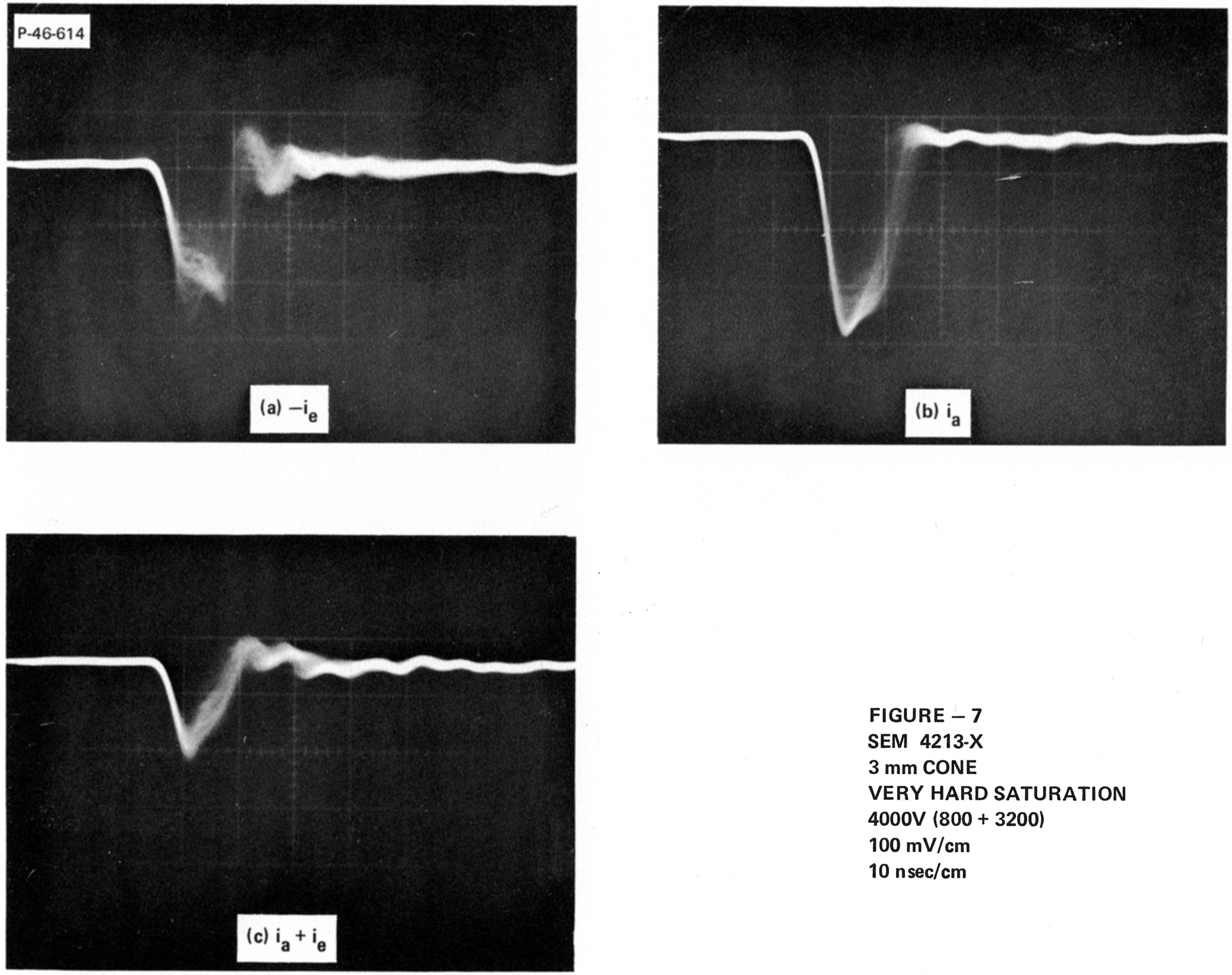


FIGURE – 7
SEM 4213-X
3 mm CONE
VERY HARD SATURATION
4000V (800 + 3200)
100 mV/cm
10 nsec/cm

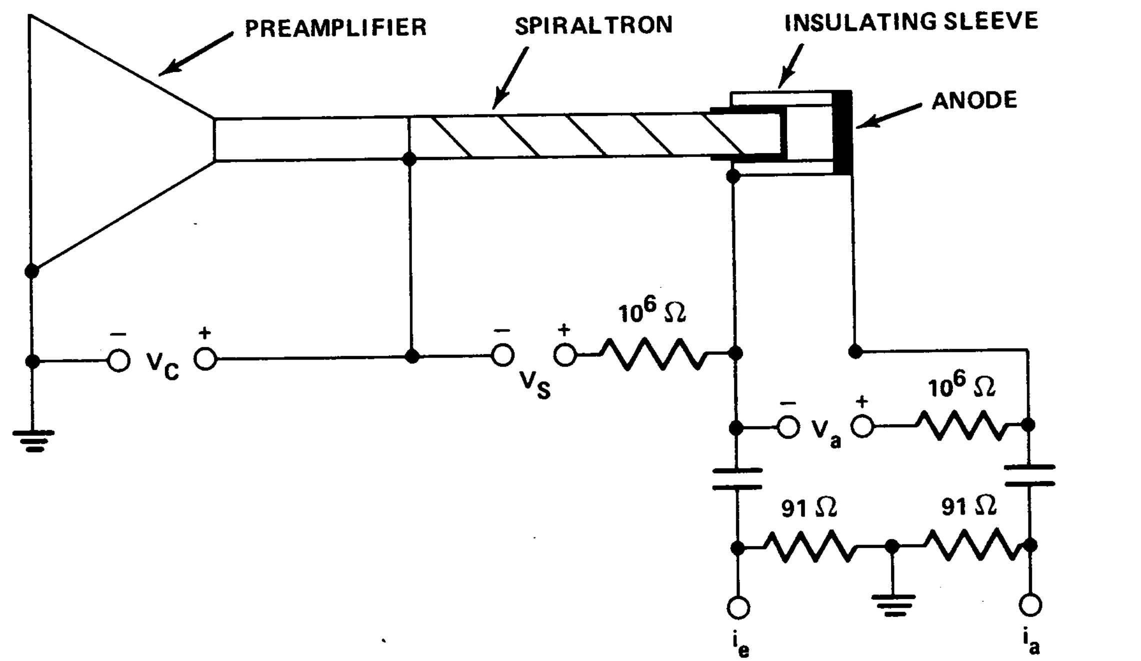


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FIGURE – 8 SEM 4213-X WITH FREE-ANODE CAP

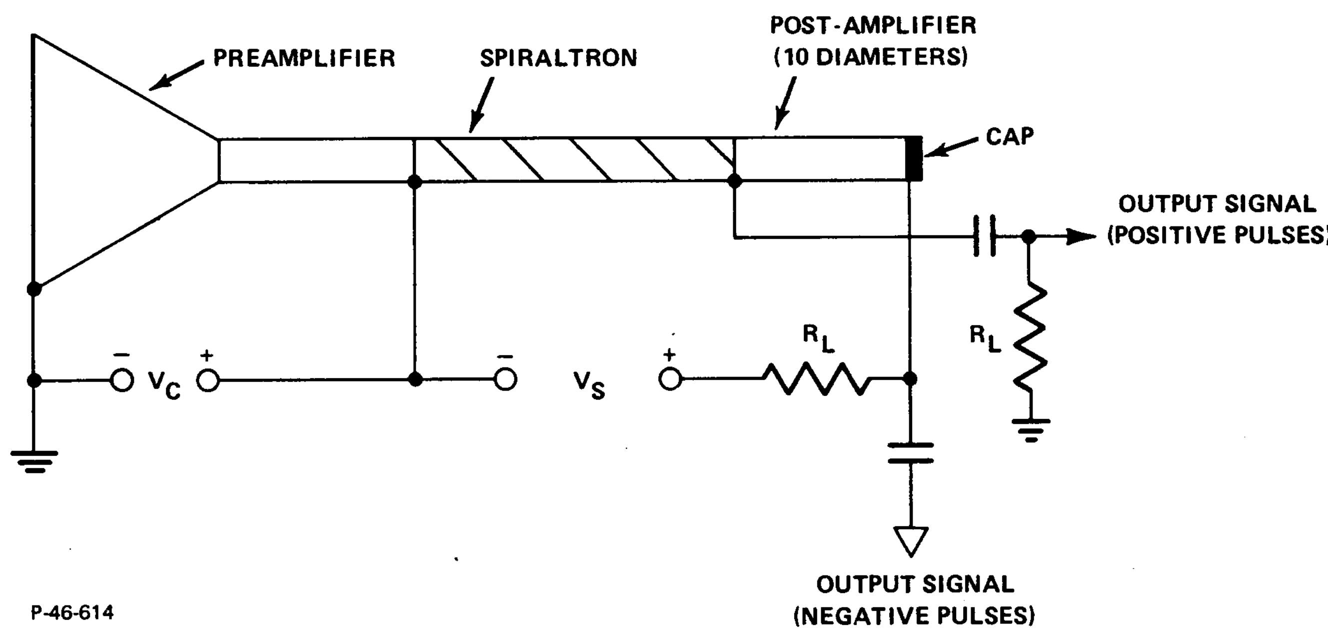

FIGURE – 9 SEM 4213-X WITH CAPPED POST-AMPLIFIER

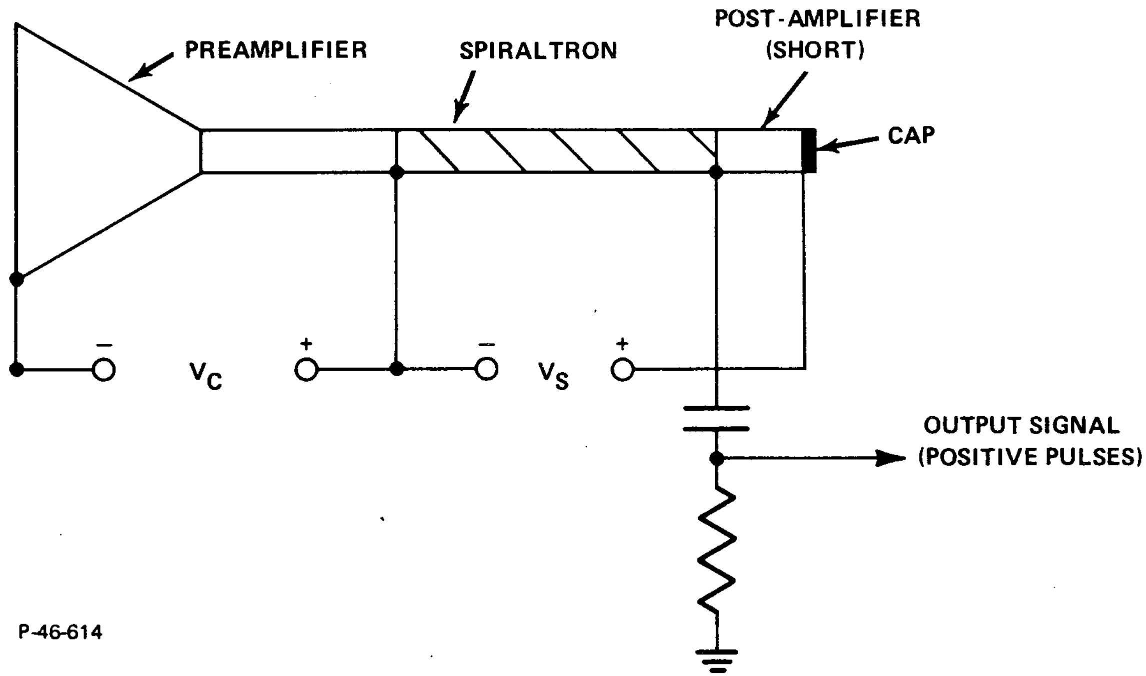

FIGURE – 10 SEM 4213-X WITH SHORT CAPPED POST-AMPLIFIER

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