

NASA Technical Memorandum 81867

INITIAL DIRECT STRIKE LIGHTNING DATA

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(NASA-TM-81867) INITIAL DIRECT STRIKE
LIGHTNING DATA (NASA) 25 p HC A02/MF A01
CSCL 04B

N8J-32023

Unclass

G3/47 28741

AUGUST 1980



National Aeronautics and
Space Administration

Langley Research Center
Hampton Virginia 23665

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August 1980

Page 17, figure 11: Replace with revised figure.

Page 20, figure 14: Replace with revised figure.

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SUMMARY

This report presents the initial results obtained during direct strike lightning tests of the NASA Langley Research Center lightning-instrumented F-106B aircraft. The tests were conducted in the vicinity of the National Severe Storms Laboratory, Norman, Oklahoma. Three strikes are reported from two flights on June 17, 1980, in this report.

SYMBOLS

\dot{B}	rate of change of magnetic flux density, tesla per second
\dot{D}	rate of change of electric flux density, ampere per square meter
\dot{i}	rate of change of current, ampere per second
A/m ²	ampere per square meter
m	meter
T/s	tesla per second
A/s	ampere per second
P-P	peak-to-peak

INTRODUCTION

This report presents the initial direct strike lightning data obtained during lightning flight tests at the National Severe Storms Laboratory in Norman, Oklahoma, in June 1980. There were three strikes to the aircraft on

June 17, 1980. Strike one occurred during the first flight and strikes two and three occurred during the second flight of the day. The measurement parameters are rate of change of electric flux density over a range of 50 amperes per square meter, rate of change of magnetic flux density over a range of 20 000 tesla per second, and rate of change of strike current over a range of 100 kilo amperes per microsecond. The isolated and shielded instrumentation system employs high-sample-rate digital transient recorders with augmented memory capacity and a wideband analog recorder for data acquisition and recording. Reference 1 provides a description of the instrumentation system; references 2 and 3 provide detailed descriptions of the transient recorders and the electromagnetic sensors.

System Configuration

The sensor/data recorder configuration and characteristics were as shown in table I for the sensor locations shown in figure 1.

Sensor	Recorder	Sample Rate (Bandwidth)	P-F Full Scale	Threshold
D Forward	Transient	100 MHz (50* MHz)	49 A/m ²	+4.9 A/m ²
B Longitudinal	Transient	100 MHz (50* MHz)	17390 T/s	1739 T/s
D Right Wing	Wideband Analog	(6 MHz)	56 A/m ²	1 A/m ²
I	Wideband Analog	(6 MHz)	10 ¹¹ A/s	2 x 10 ⁹ A/s

*Four-pole linear phase low pass filter 3 dB point at 50 MHz.

TABLE I

The sign convention chosen for polarity resolution of the measured fields and currents is such that an increasing electric field vector into the aircraft is positive, and increasing current from aft to forward is positive and results in a positive magnetic field measurement.

Strike Scenarios

The strike scenarios were deduced from pilot comments and examination of the minor burn marks left by the lightning. Figures 2, 3, and 4 show the scenarios for the three strikes.

The initial strike to the aircraft occurred at 12:23 ^h CDT during penetration of a thunderstorm northwest of Oklahoma City, Oklahoma. The aircraft was penetrating an electrically active storm at an airspeed of 154 m/s (300 KIAS) and at an altitude of 4 800 m (16 000 ft), the approximate freezing level, experiencing light turbulence and precipitation. The pilot reported the flash originating ahead of the aircraft, moving from his right and curving toward the aircraft to strike the nose boom. Later examination of the aircraft revealed that the first attachment was to the angle-of-attack vane near the tip of the nose boom with subsequent swept attachments along the left side of the fuselage and the top of the left wing with exit points on the trailing edge of the left wing tip and the tip of the vertical tail. (See fig. 2.)

The second and third strikes to the aircraft occurred on the second flight of the same day (17:28:35 and 17:33:50 CDT) in very similar flight conditions; i.e., altitude of 4 800 m (16 000 ft) and airspeed of 154 m/s (300 KIAS). The attachment points of these strikes to the aircraft were determined through post-flight examination, aided by pilot's comments, and are diagramed in

figures 3 and 4. The second strike appeared to attach first to the angle of sideslip vane on the nose boom or on the nose boom itself and then split down both sides of the aircraft. The left branch apparently reattached along the top of the left wing, exiting the left wing tip and the trailing edge of the elevon. The right branch left two paths of marks on the right side of the fuselage with the lower path continuing beneath the wing to an exit point on the elevon trailing edge.

The third strike apparently struck the nose boom or sideslip vane, reattached to the pitot-static probe and UHF antenna under the forward fuselage and ceased.

Lightning Strike Data

The records of the strike data are presented in figures 5 through 17. Data from the \dot{D} forward sensor were recorded on the transient recorder during the first and third strikes. No magnetic field or boom current data were recorded during the strikes even though the instrumentation system was verified fully operational during both pre- and post-flight tests. The magnetic signals generated by these particular lightning strikes were below the thresholds established by the nominal system sensitivities shown in table I.

Figures 5 and 6 depict the chronology of the transient recorder memory records for the two strikes. The details of the recorded waveforms are shown in figures 7 through 17 with expanded time scales. Note that the data are the derivative of electric flux density and those portions of the waveforms indicating constant \dot{D} are constant rates of change within the 6-bit resolution of the transient recorder.

CONCLUDING REMARKS

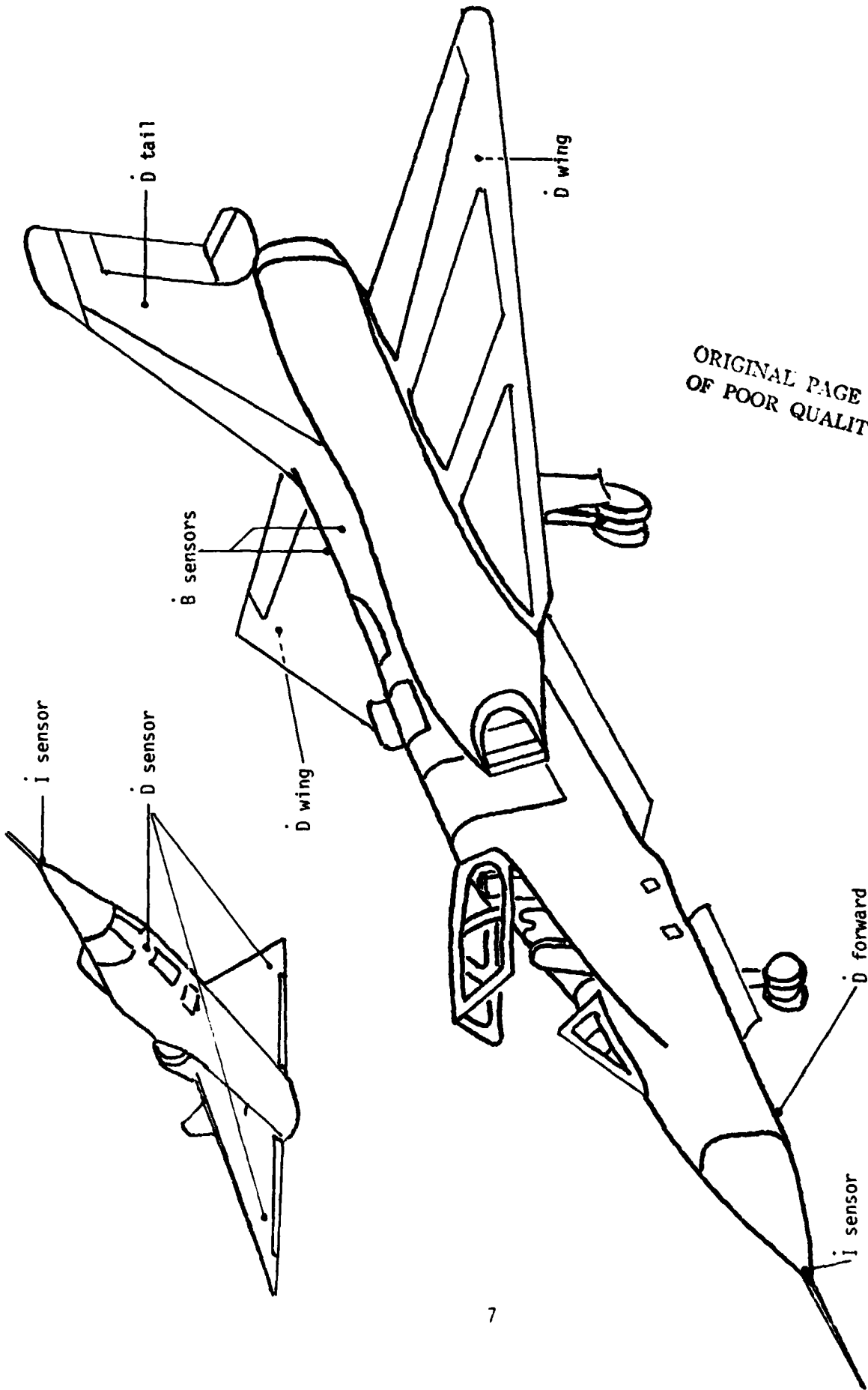
The strike data are noteworthy in that the electric characteristics (\dot{D}) reached about 40 percent and 60 percent of full scale whereas the magnetic characteristics (\dot{B} , \dot{I}) were below system threshold. An independent lightning experiment, onboard during these tests, also indicated that the currents associated with these strikes were relatively low amplitude. There are a number of cases in the recorded data wherein large signal excursions occurred during a time span of a few data samples as shown in figures 9, 13, and 15, for example. The data system operated at 10 nsec (one sample each 10×10^{-9} second) interval along with a 4-pole low pass presample filter with a cutoff frequency of 50 MHz. For this configuration, the amplitude error due to alias errors would not exceed about 35 percent (see ref. 4) of the measured level.

REFERENCES

1. Pitts, Felix L., et al.: Inflight Lightning Characteristics Measurement System. Report No. FAA-RD-79-6. Federal Aviation Administration - Florida Institute of Technology Workshop on Grounding Technology, Melbourne, Fla., March 6-8, 1979, pp. 105-111.
2. Thomas, Robert M., Jr.: Expanded Interleaved Solid-State Memory for a Wide Bandwidth Transient Waveform Recorder. NASA CP-2128, FAA-RD-8-30. Lightning Technology, NASA Langley Research Center, April 22-24, 1980, p. 119.
3. Trost, Thomas F.; and Zaepfel, Klaus P.: Broadband Electromagnetic Sensors for Aircraft Lightning Research. op. cit., p. 131.
4. Stiltz, Harry L., ed.: Aerospace Telemetry. Prentice Hall, Englewood Cliffs, NJ, 1961, p. 90

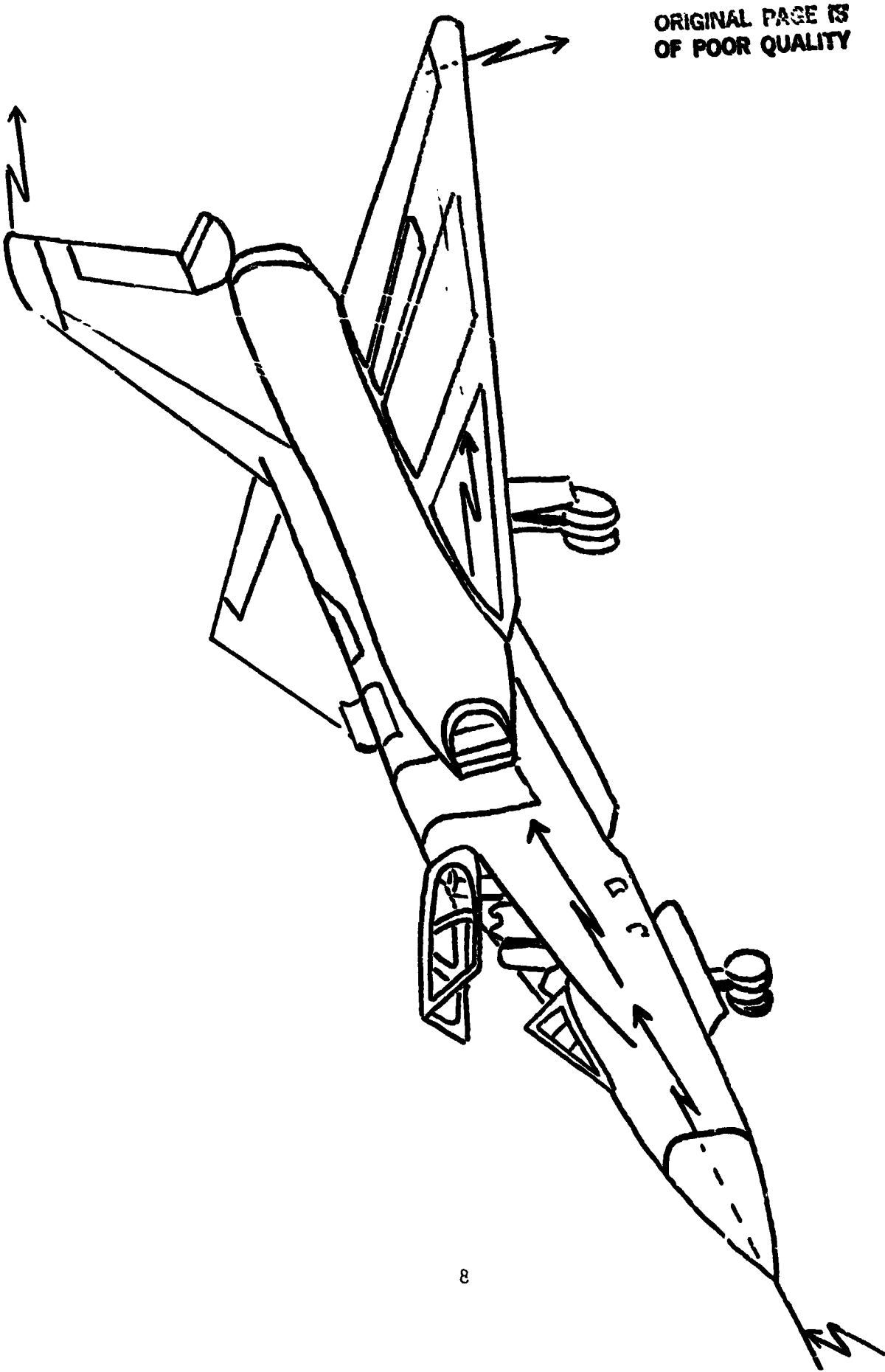
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Figure 1. - Sensor Locations



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Figure 2. - Strike 1 Attachment Path

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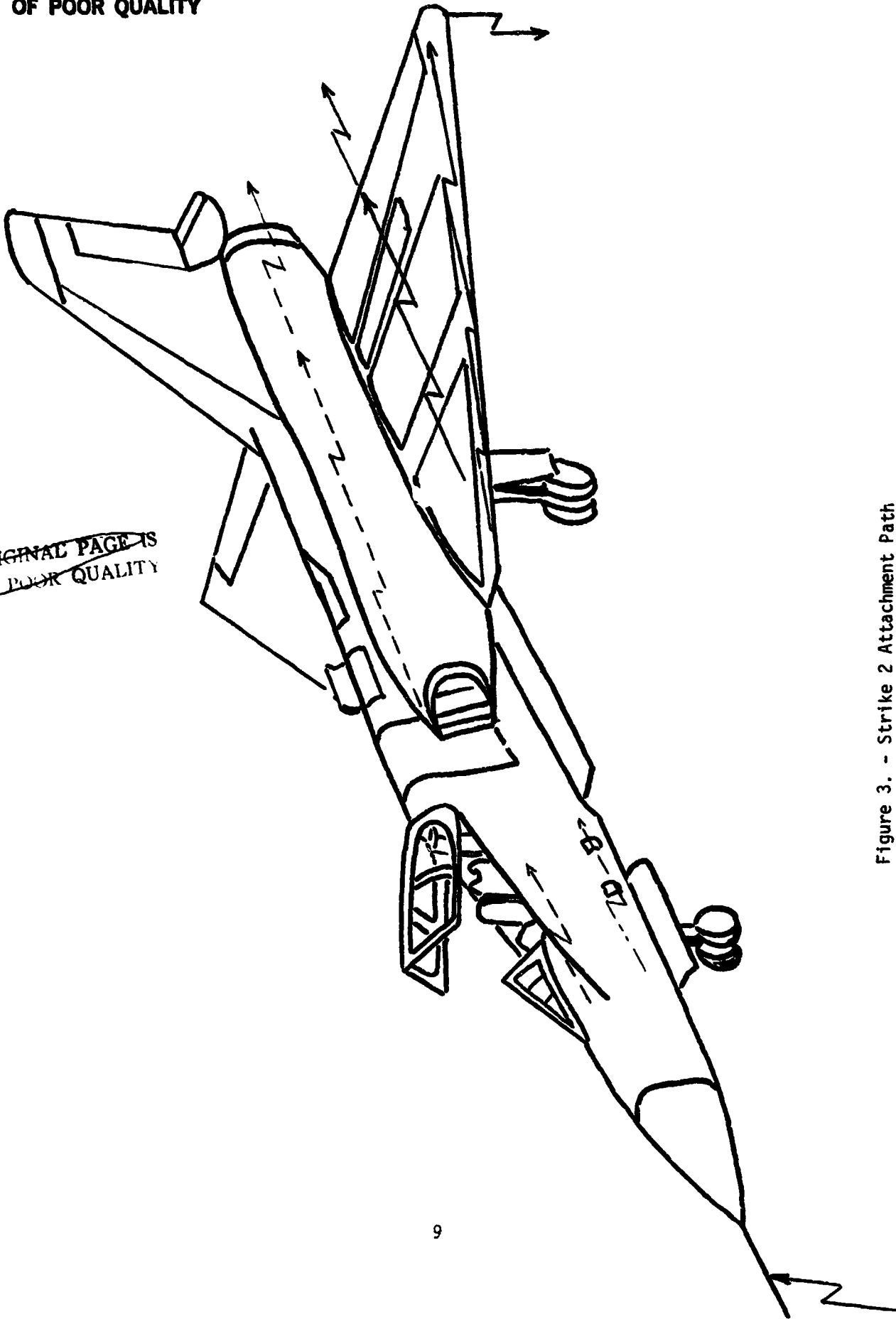


Figure 3. - Strike 2 Attachment Path

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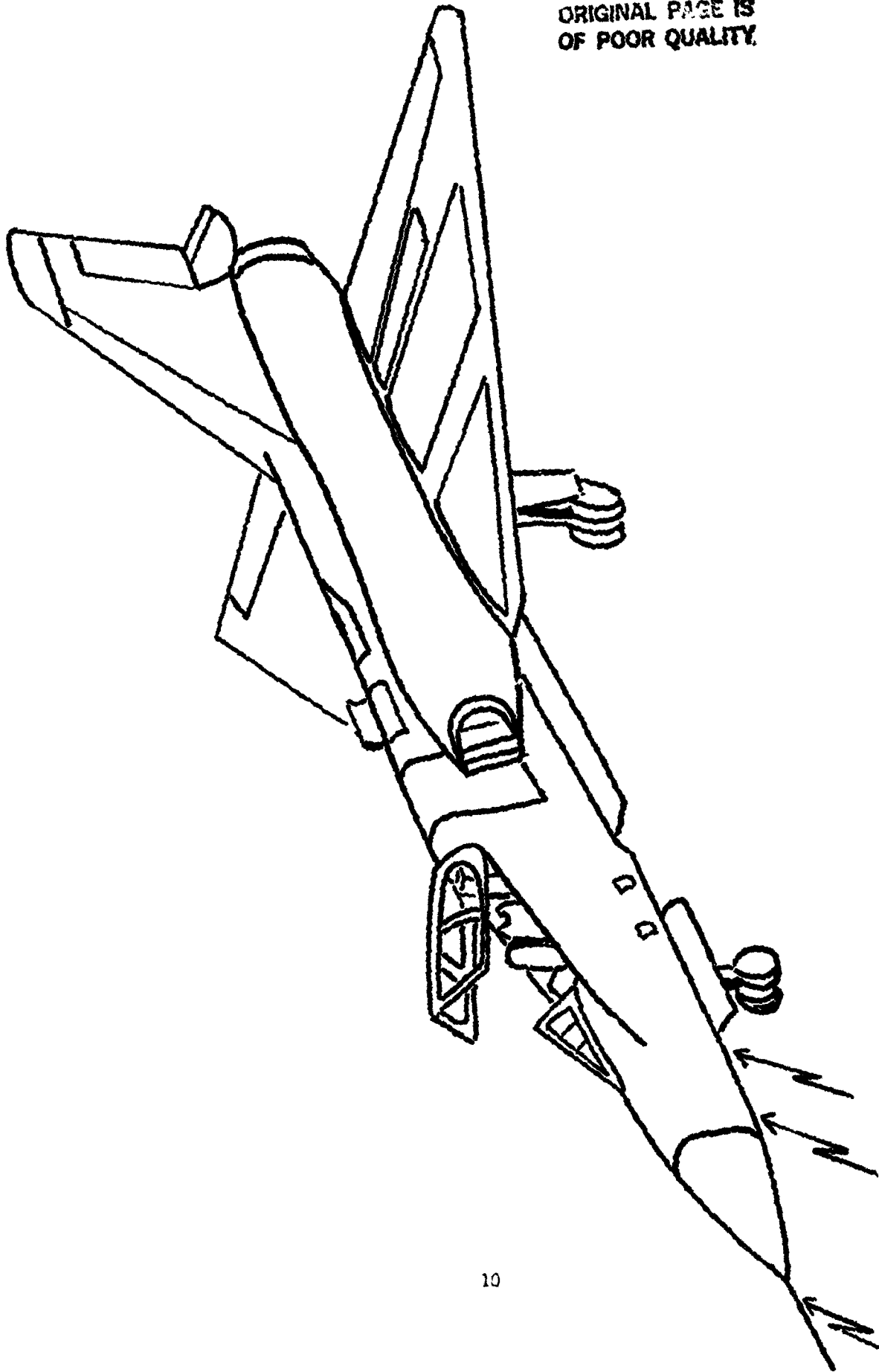


Figure 4. - Strike 3 Attachment Path

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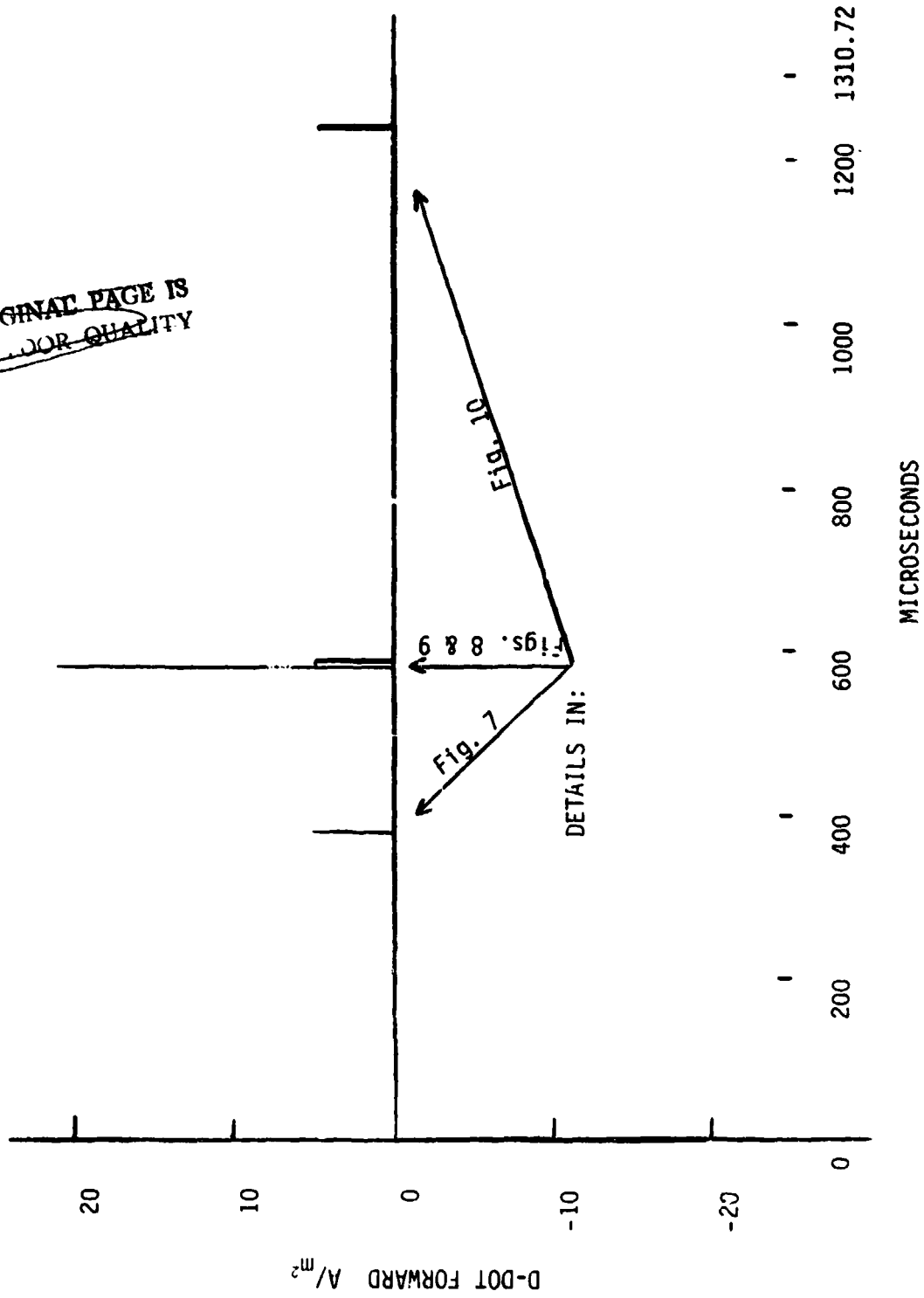


Figure 5. - Overview of Lightning Strike 1 Waveforms

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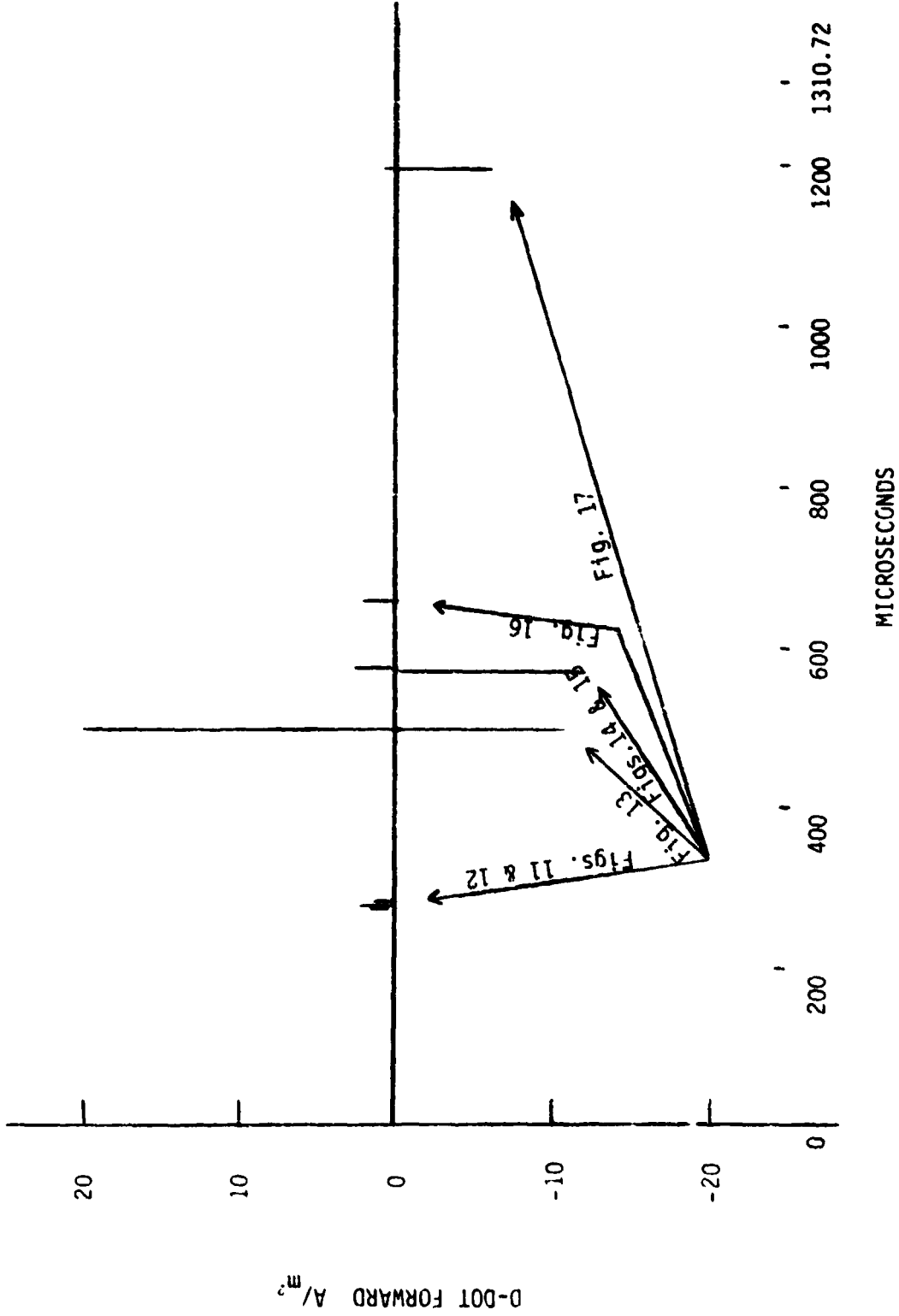
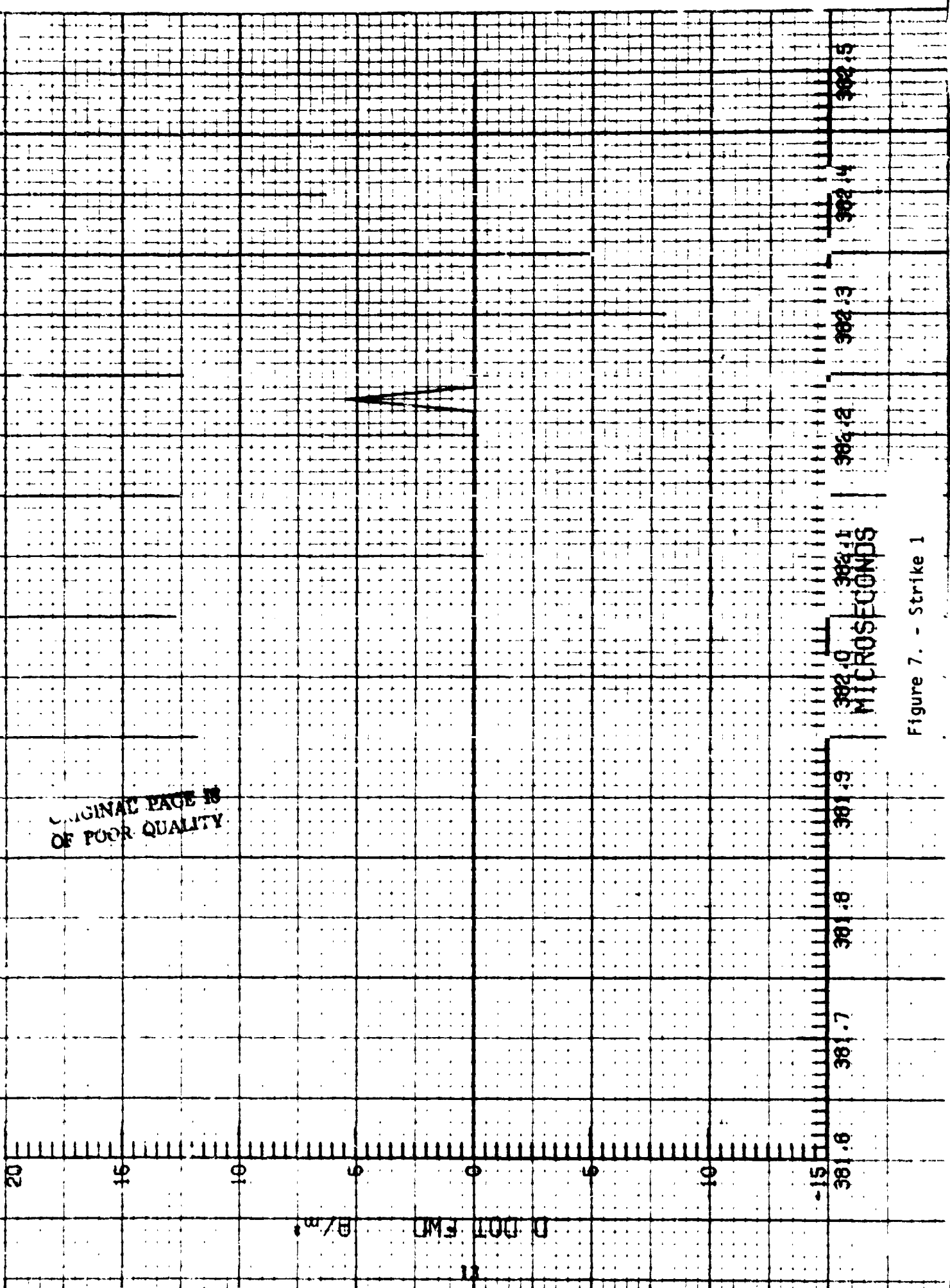
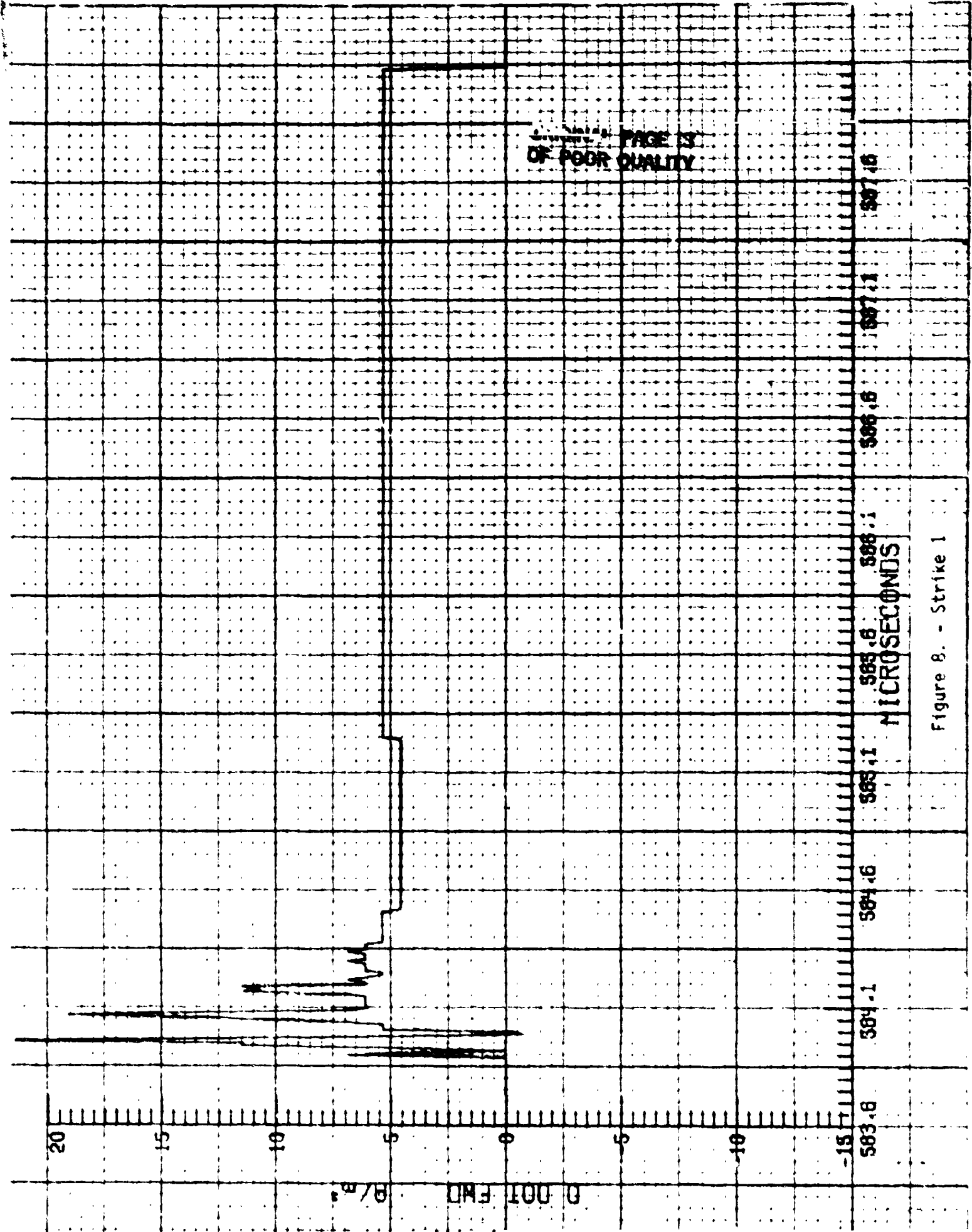


Figure 6. - Overview of Lightning Strike 3 Waveforms



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Figure 7. - Strike 1



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Figure 8. - Strike 1

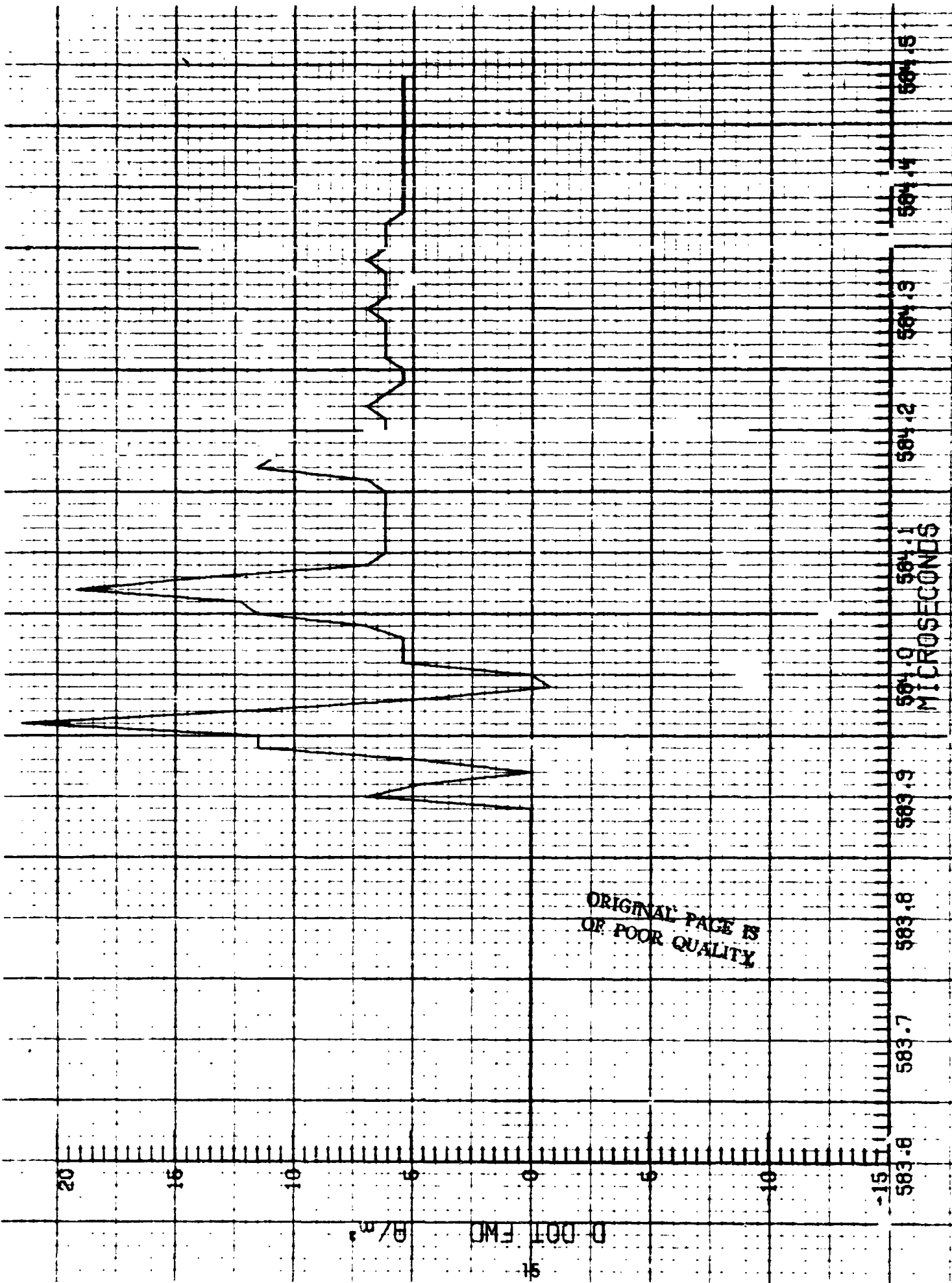
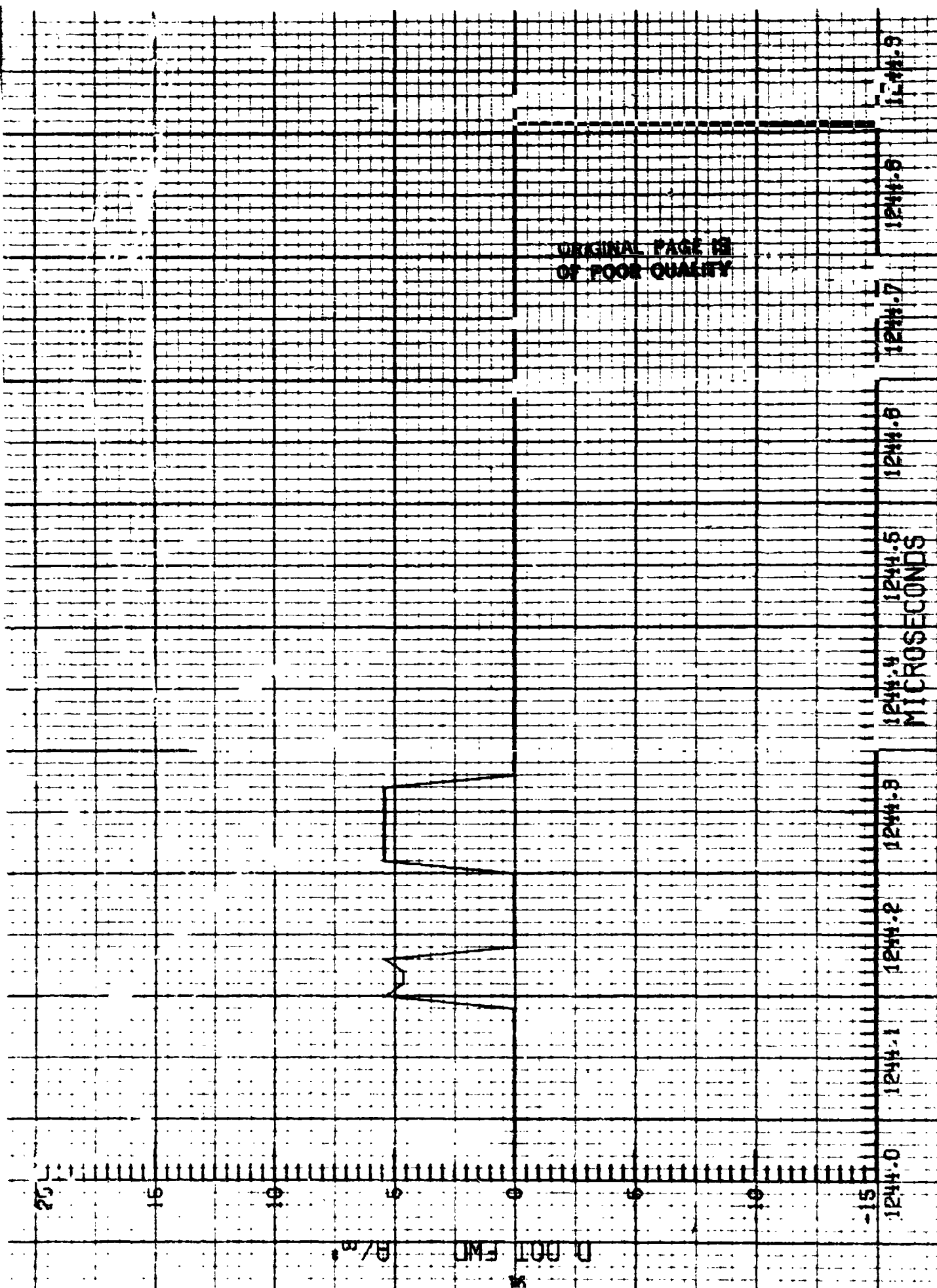


Figure 9. - Strike 1



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Figure 10. - Strike 1

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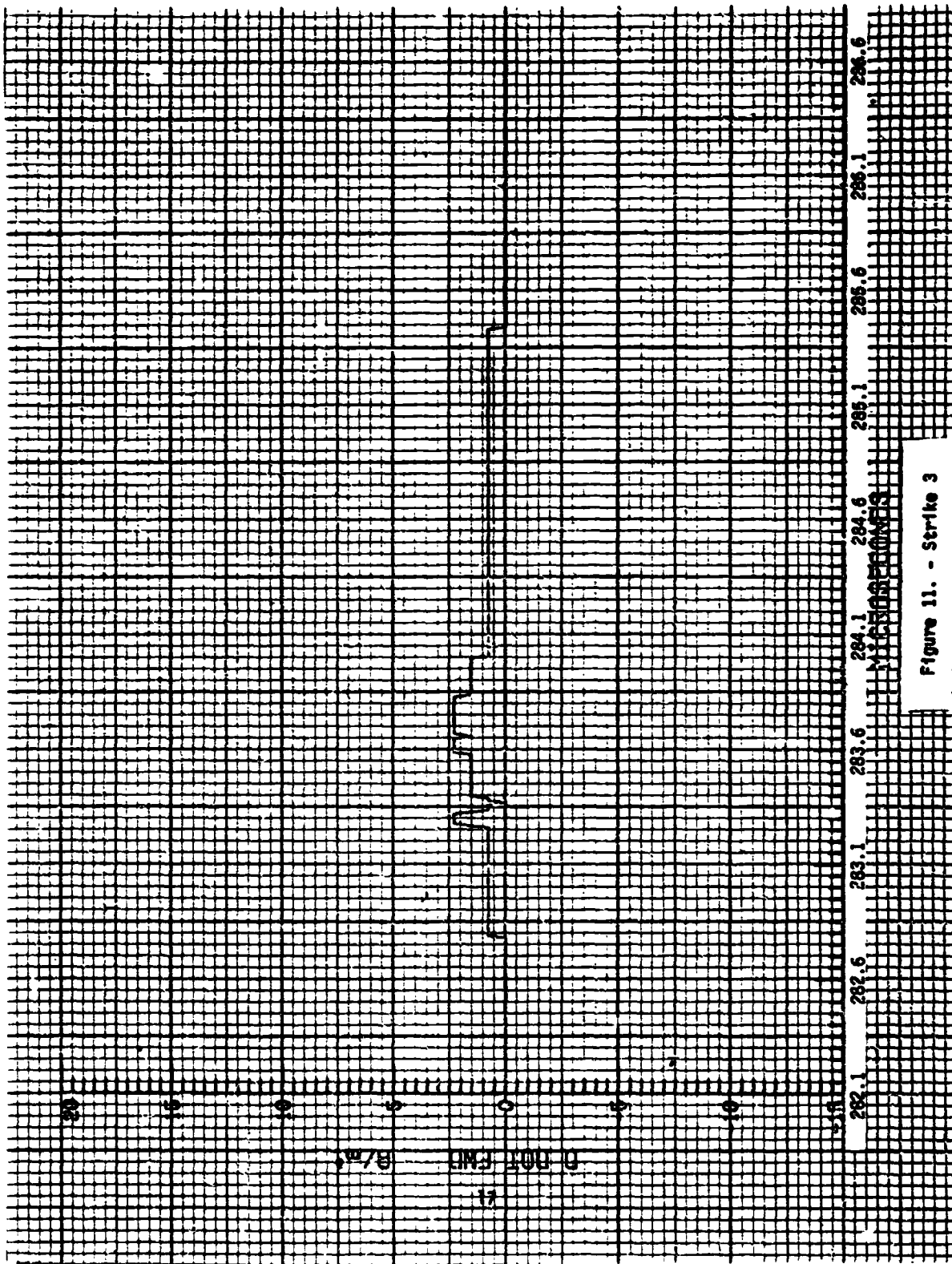


Figure 11. - Strike 3

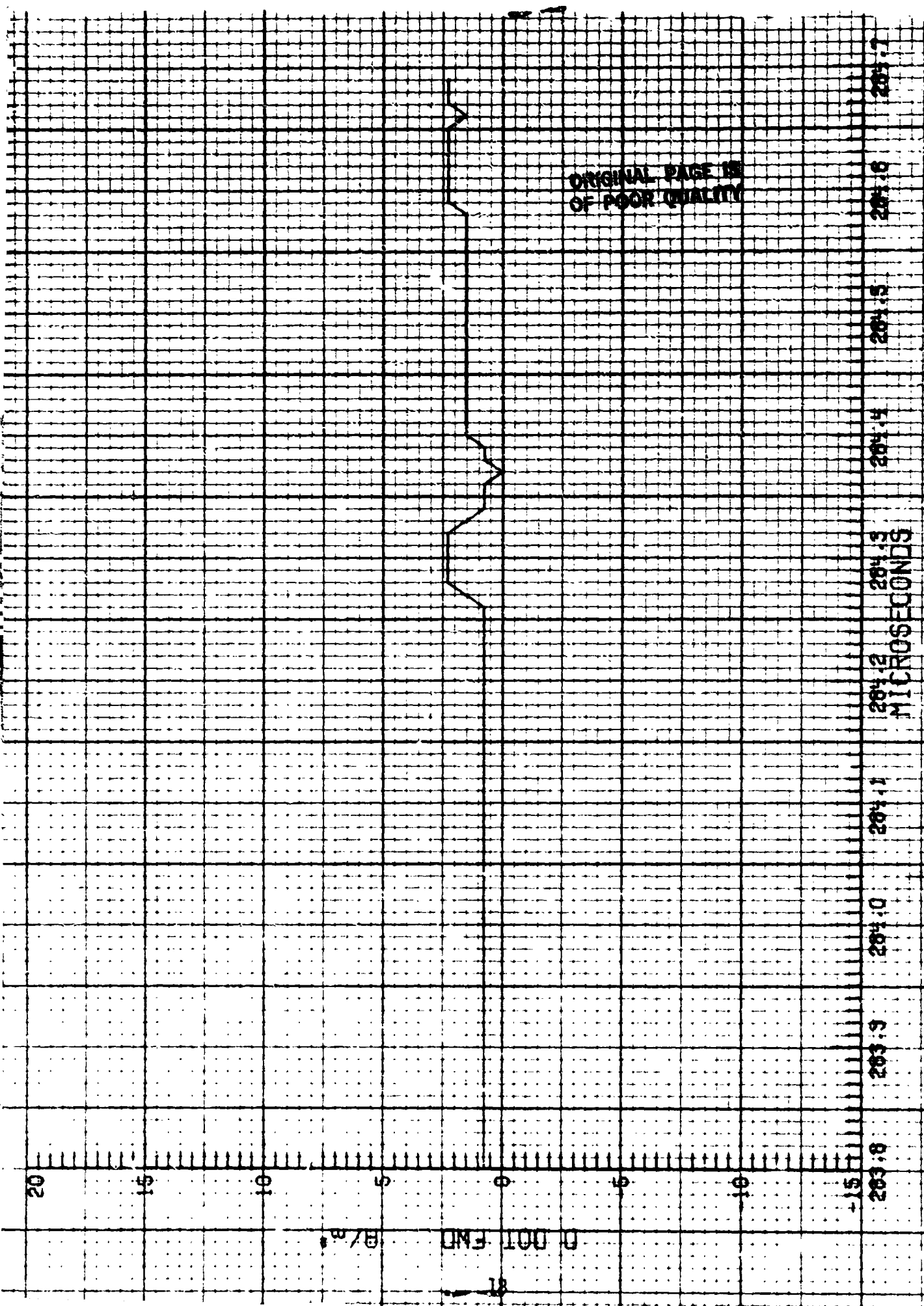


Figure 12. - Strike 3

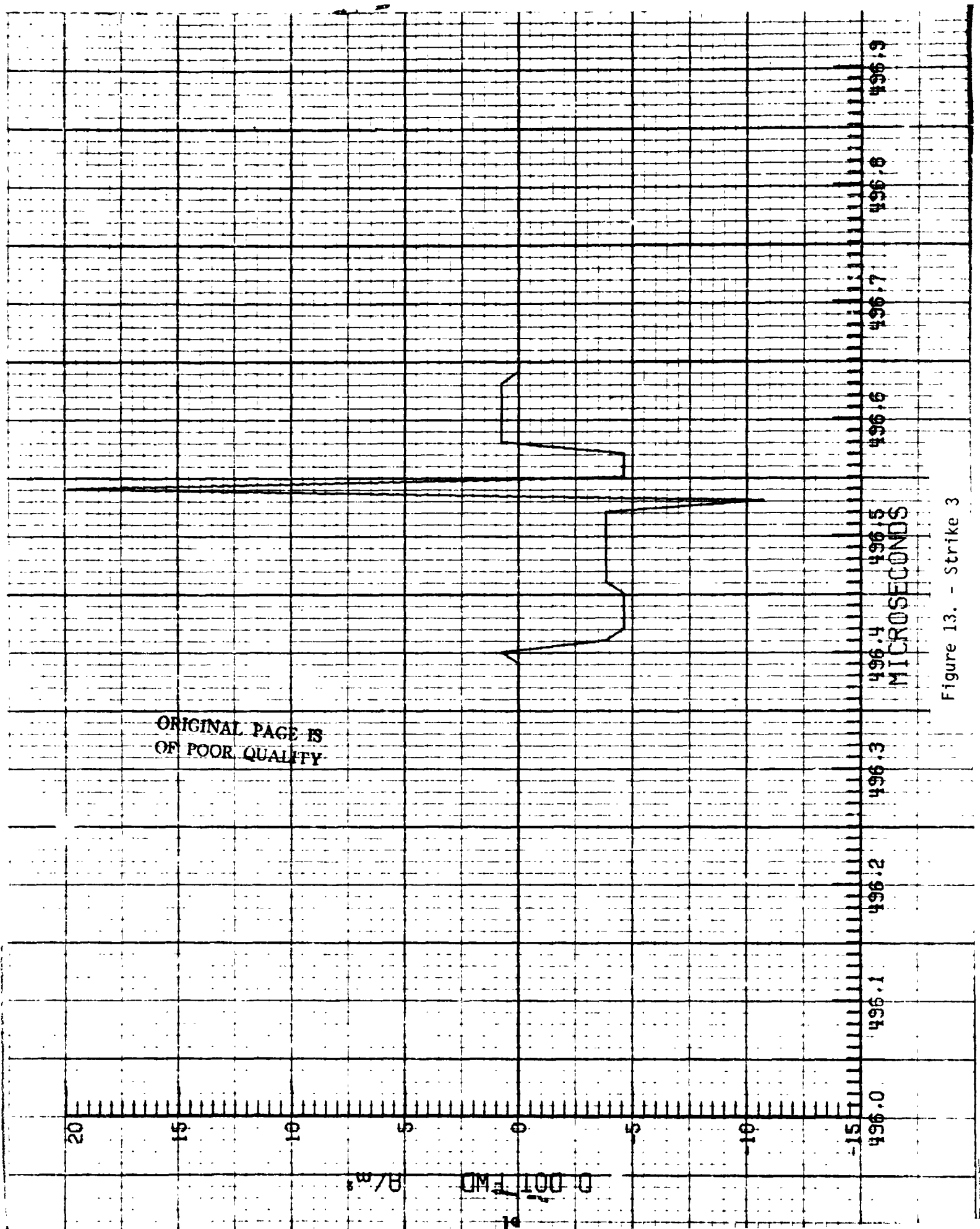


Figure 13. - Strike 3

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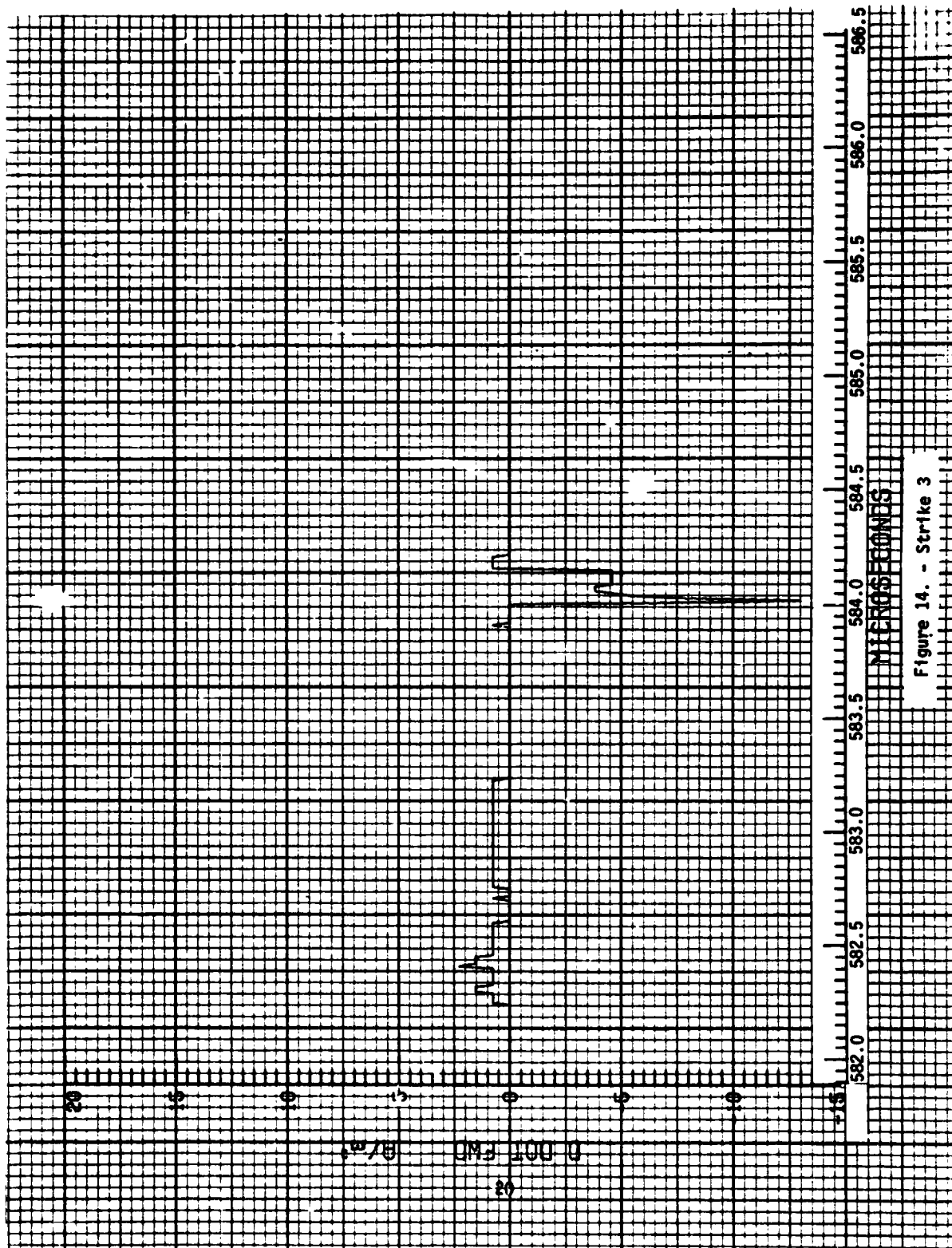


Figure 14. - Strike 3

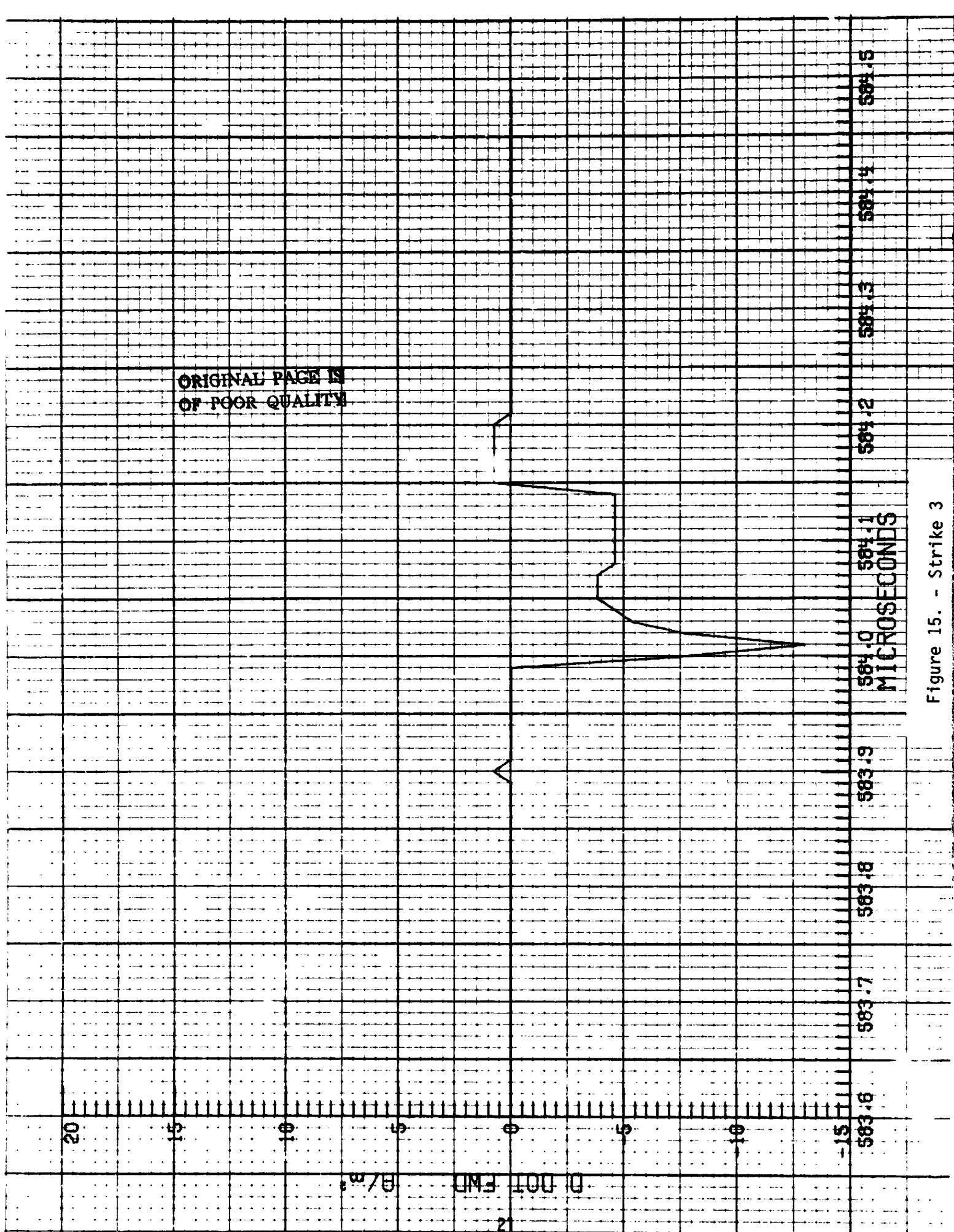


Figure 15. - Strike 3

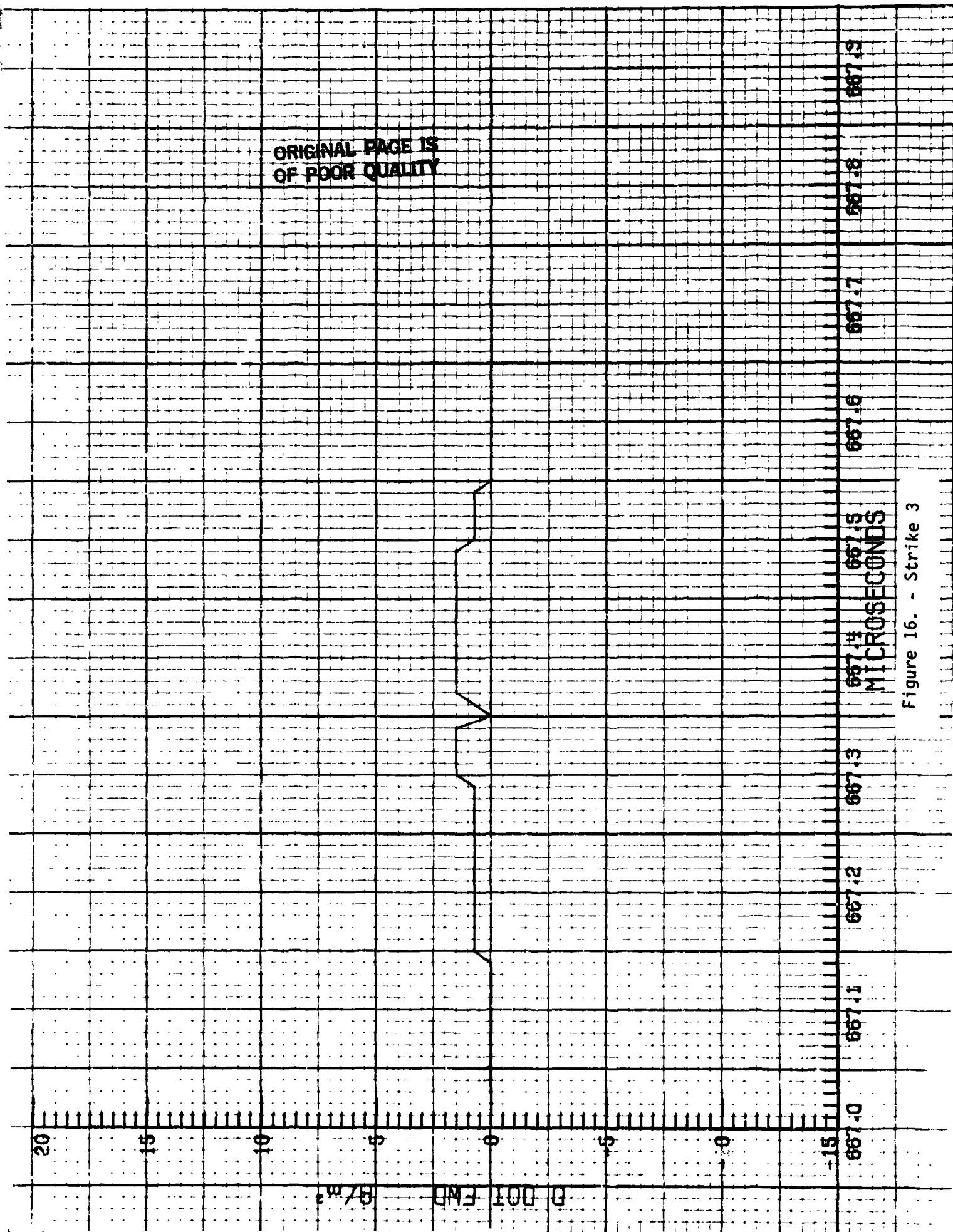


Figure 16. - Strike 3

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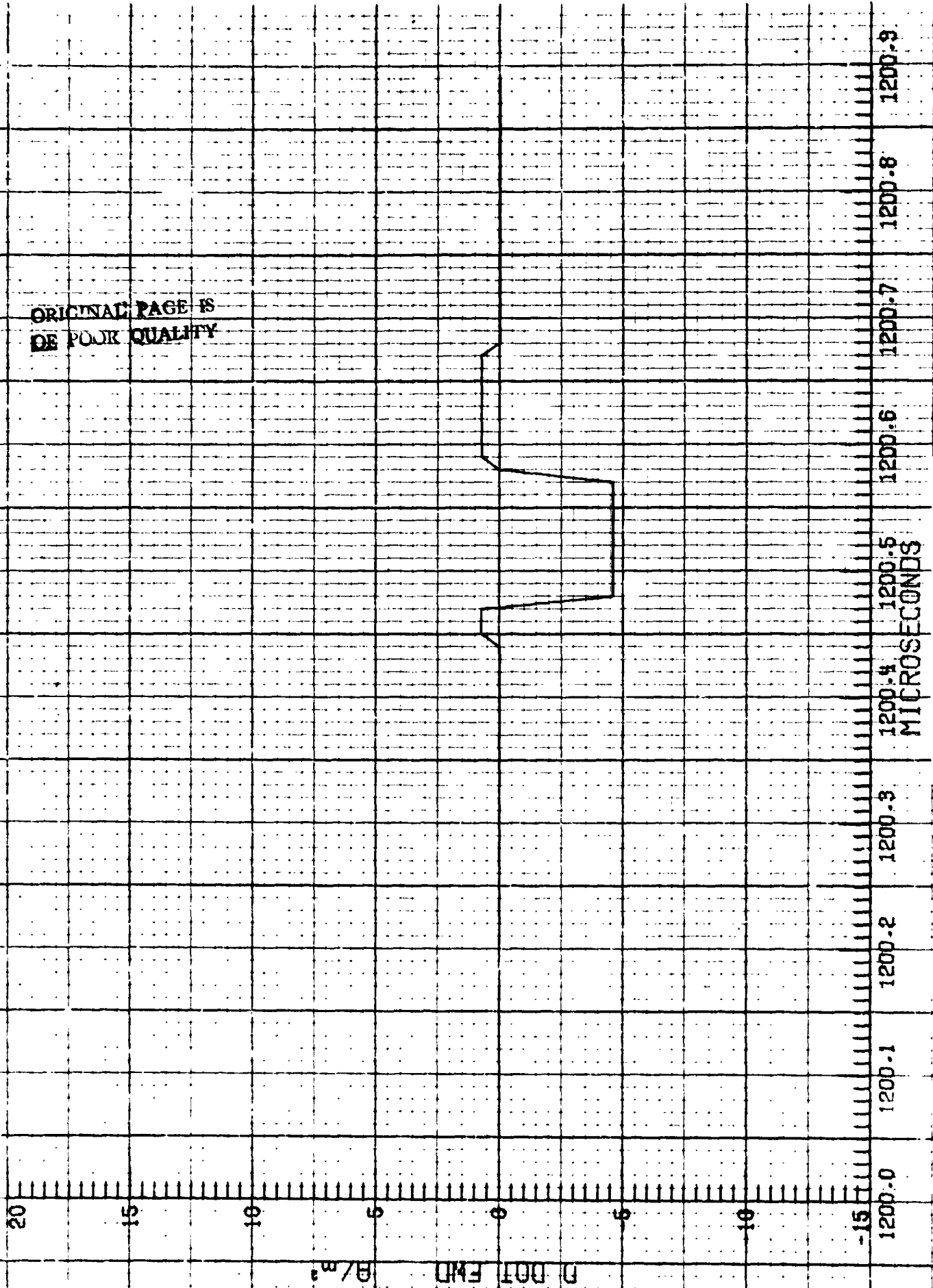


Figure 17. - Strike 3