ACOUSTIC EMISSION RESPONSE OF A36 STEEL
UNDER TENSILE LOADING

APPROVED:

DEDICATION

I would like to dedicate this work to my family. My family I dedicate this to for standing by me and giving support and encouragement during my most difficult year. The love and respect that I feel for my father, mother, brothers and sister cannot be expressed in words alone. So all I can say is that I am proud to be part of the Boehning team.

I also would like to give special thanks to my thesis advisor, Dr. Steve Stafford, for his personal and professional help in creating this thesis.

ACOUSTIC EMISSION RESPONSE OF A36 STEEL

UNDER TENSILE LOADING

by

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INTRODUCTION

Acoustic Emission can best be defined as bursts of elastic wave energy, or stress pulsation, generated within a solid material as the result of sudden stress relaxation. In practice all crystalline materials emit acoustic emission when deformed. 1/ The oldest analogy of this phenomenon is the earthquake. 2/ Internal stresses build within the earth's crust until a point is reached at which stresses are suddenly released by a permanent shift of the earth's surface. Emissions given off by this large scale deformation are recorded by a seismograph. Acoustic electronics perform a similar function in that this same emission behavior is a characteristic of the metals. Through the use of substitute equipment these metallic emissions can be detected, monitored, and measured. For this study of mechanical behavior during tensile loading, such emissions have been recorded, charted, and entered for inspection.

A metal under an increasing load exhibits certain acoustic emission responses. Primarily these responses are dependent on the metal's previous history - prior mechanical work and heat treatment. 3/ In this study the heat treatment of an A36 steel has been varied to observe the effect on

acoustic emission of a sample when tensionally stressed. The A36 steel was selected because of its importance as a structural metal and has not been previously tested in this manner.

EXPERIMENTAL PROCEDURE

The metal tested was an A36 steel originally in 0.25 inch by 1.50 inch bar stock. All specimens were machined according to the specifications given in Figure 1.

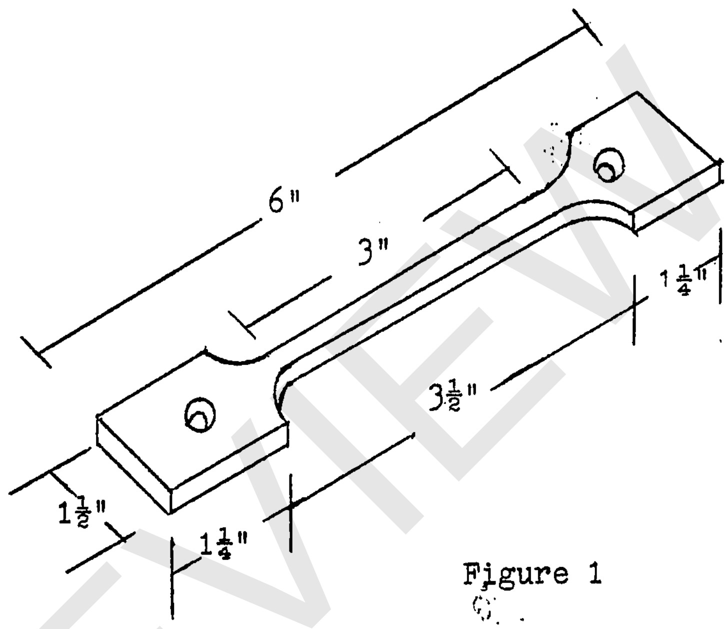

Figure 1

A36 is a low carbon steel with minimal alloy constituents. The ASTM specifications lists the chemical composition as 0.26 Carbon, 0.04 Phosphorus and 0.05 Sulfur in weight percent. The steel used in testing was analyzed by carbon analyzer to be 0.27 weight percent Carbon.

All specimens were prepared according to various commercial heat treatment procedures as listed in Table 1.

Table 1

SAMPLE VARIATIONS

NUMBER OF SAMPLES	HEAT TREATMENT
2	Annealed
2	Normalized
1	As quenched
1	Quenched and tempered for one hour at 250° C
2	Quenched and tempered for one hour at 450° C
2	Quenched and tempered for two hours at 450° C
1	Quenched and tempered for three hours at 450° C

After heat treatment each specimen was pulled in tension using an Instron tensile machine Model TT-C (10,000 lb. capacity). A crosshead speed of 0.02 in./min. was used for all tests. Throughout each test mechanical behavior was observed using a Dunegan/Endevco Series 3000 acoustic emission detection system (see Figure 2).

The acoustic emission equipment was set up to eliminate grip noise and allow only those events associated with mechanical deformation of the test specimen to be recorded. A schematic of the equipment sensor arrangement is illustrated in Figure 3.

Each sample was mounted in the Instron (Figure 4) by use of one-half inch dowel pins at each grip. For monitoring of acoustic emission response, three transducers were used. A transducer (Dunegan/Endevco S140 B/HS) was

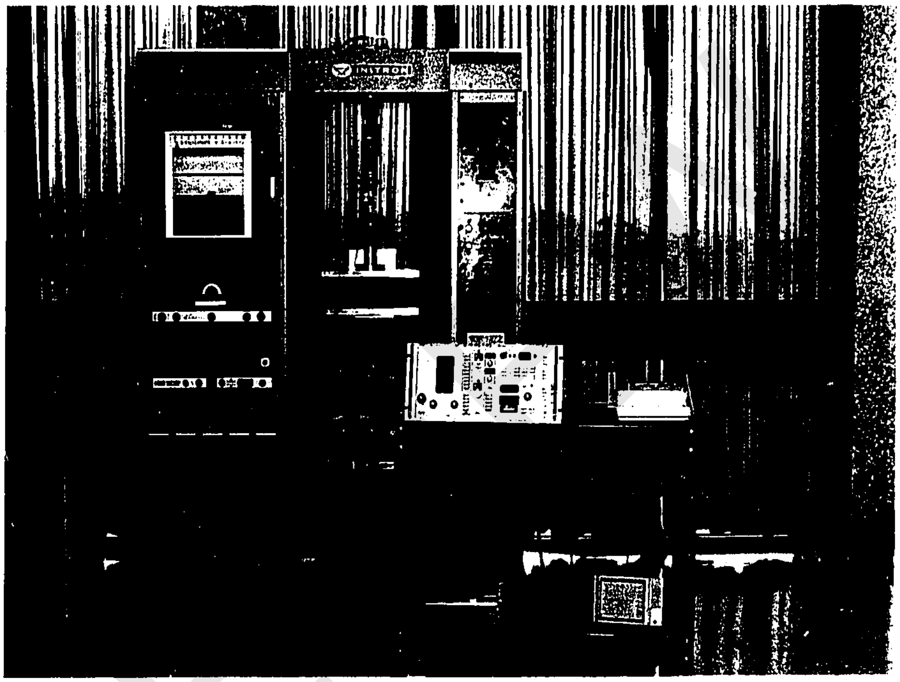

Figure 2

Dunegan/Endevco Series 3000

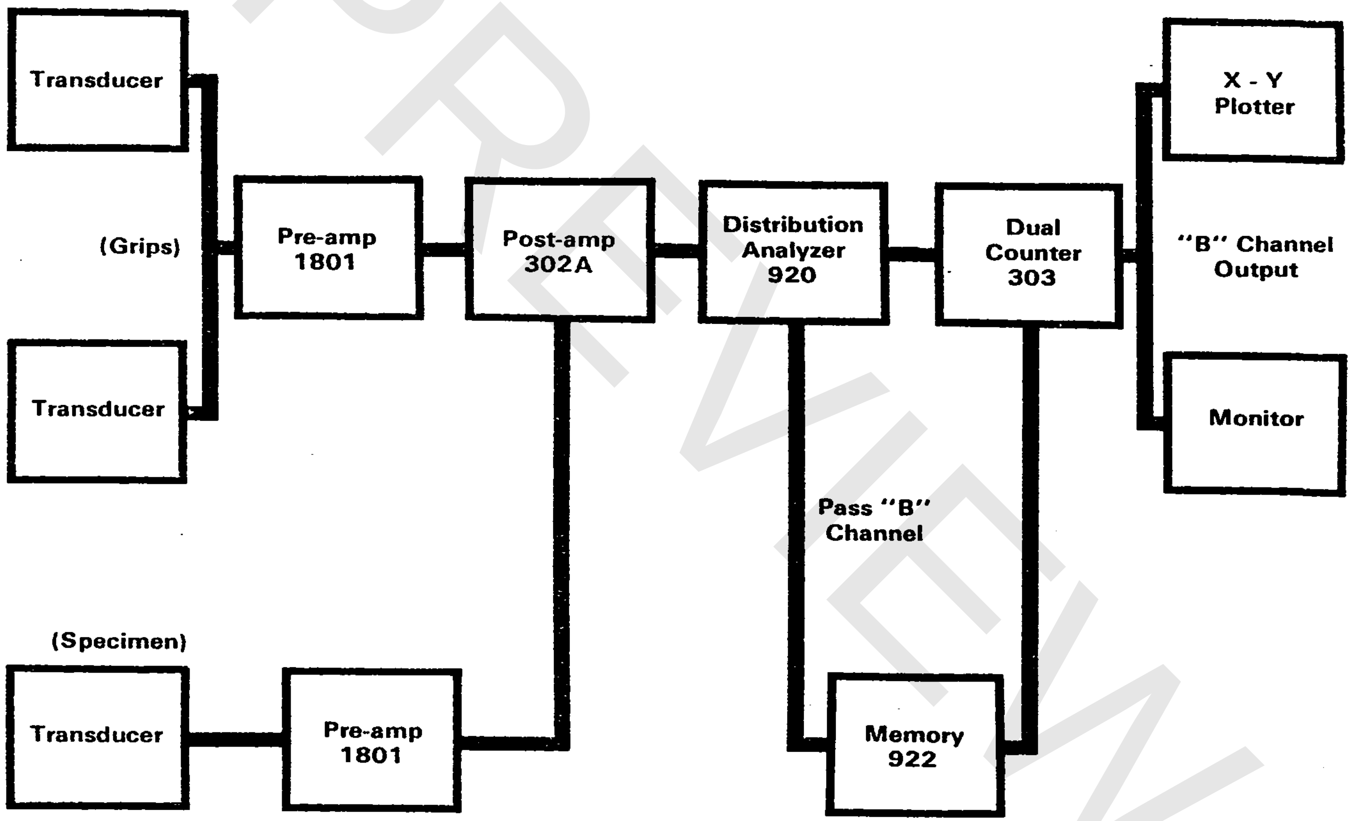

Figure 3

Schematic of the Equipment Sensor Arrangement

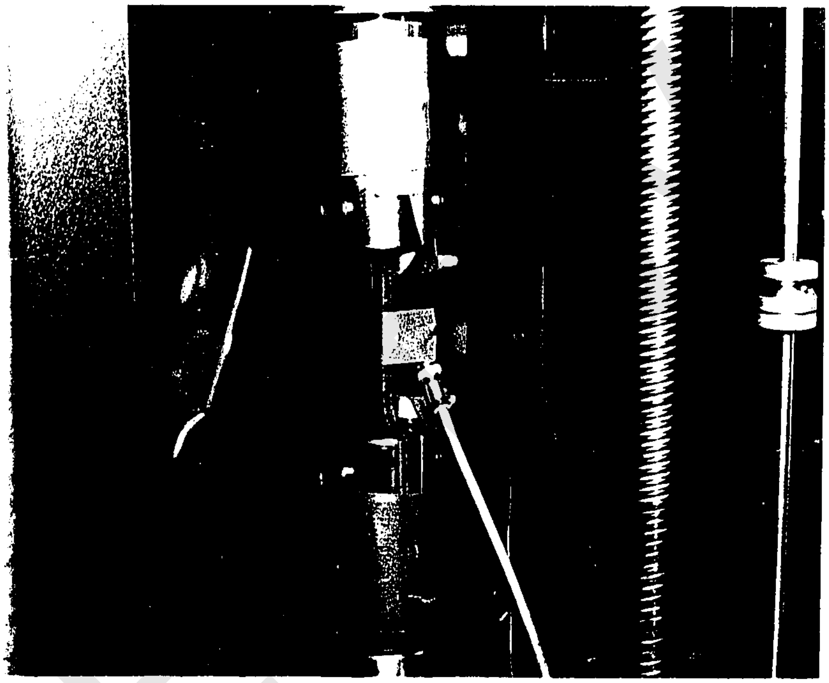

Figure 4

Transducer Arrangement

attached to each grip. The third transducer (Dunegan/ Endevco S140 B) was mounted at the center of the reduced section of the tensile specimen. Silicon grease was used as a couplant for all sensors.

The key to elimination of grip noise was the distribution analyzer operating in the locate mode. This gave it the ability to locate an event occurring between the guard transducers mounted at the grips and the transducer mounted to the specimen. Once an event occurred, the analyzer displayed a number between zero and one hundred. This represented a percentage of distance between the guard and specimen transducers approximating where the event occurred. Using the analyzer's capability of allowing a window to be set outside of which an event would not be processed, noises emitting from the grip areas were removed.

Results were obtained by opening the test window completely from zero to one hundred, allowing all events to be passed and displayed on the monitor. By tapping the dowel pins with a sharply pointed wire, a registration of the "grip" noise location was displayed on the monitor. All events processed from the grip areas were greater than fifty-five. To determine the location of events in the tensile specimen, the reduced section of the specimen also was tapped. This resulted in values less than fifty-three for an event occurring in the specimen. Therefore, the window for all the tensile tests were set at one through

fifty-three resulting in all grip noise being eliminated from all test data.

The total gain of the preamplifier input to the distribution analyzer from the grip areas was about 91 db while the total gain from the specimen sensor was about 93 db. The difference in gain was to compensate for the parallel transducer placement. The distribution analyzer could then receive and process essentially two equal inputs and give a more accurate location reading for an event.

PRESENTATION OF DATA

The amplitude (energy) of an emission comes in either of two components. Low level continuous emission which consists of a generally continuous stream of low amplitude pulses, or high level bursts. These bursts are not as frequent and consist of high amplitude stress pulses.[2] To convert these pulses into a parameter of counts, the energy of these pulses were compared to an arbitrary trigger level. In this work, the trigger level of one volt was inherent to the equipment used. When a transducer picks up an acoustic emission event the transducer begins to oscillate to its own resonant frequency releasing a signal to the counter. This signal is compared to its trigger level and any pulse which exceeds this level is considered as one count (see Figure 5).

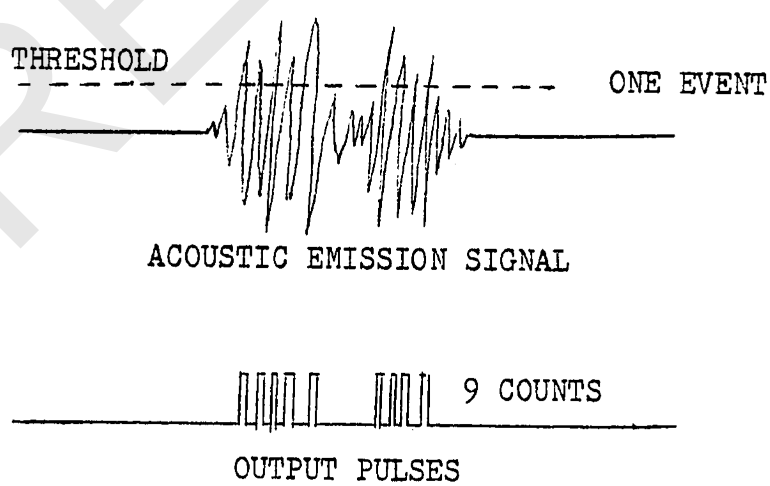

Figure 5

In this way, a large amplitude event will yield more counts than a smaller one due to the larger number of oscillations crossing the threshold triggering level. The net result is the conversion of pulses in a material into a parameter of counts which could be compared with other parameters such as strain or time. For comparison, stress vs. strain, the total cumulative counts vs. strain, and count rate vs. strain were plotted together. Appendix 1 contains the raw data or actual X-Y plotter generated test results.

The count rate vs. strain plot was generated by measuring the number of counts recorded by the X-Y plotter at sixty second intervals. The count rate for each time interval was calculated by dividing the number of counts by the number of seconds at that point. This procedure was followed from point to point until fracture of the sample occurred. These calculations were necessary in that the Dunegan/Endevco Series 3000 equipment could not perform this same function because the entire system was set up to eliminate grip noise and plot total cumulative counts.

Two specimens were tested in the annealed and normalized condition; one specimen for each heat treatment was monitored without the grip noise being eliminated, while the other specimen was tested by the grip noise elimination procedure. This was done to compare the affect grip areas would have on the acoustic emission response during tensile

testing.

For all specimens, once they were pulled to fracture, a sample was sectioned out for metallography. Each sample was polished and then etched in nital and photographed at a magnification of 400X.

RESULTS

The two specimens tested and monitored without the grip noise being eliminated, in the annealed and normalized condition, are illustrated in the following pages by Figures 6 and 7, respectively. The acoustic emissions data was not used for evaluation due to the obvious contamination caused by noises originating from the grip areas.

Figure 8 is an illustration of the plots generated for the specimen in the annealed condition monitored with the grip noise elimination method. The count rate vs. strain plot rose quickly to a peak near the point of yielding for the material, then decayed in emission until fracture. The total cumulative counts vs. strain plot increased rapidly until the point of yielding was attained where it then began to slowly decrease in slope.

The plots generated in the testing of normalized specimens monitored with the grip noise eliminated are shown in Figure 9. The count rate vs. strain plot reached its maximum near the onset of yielding of the material then decayed in emission to a low value. The total cumulation of counts vs. strain plot rose quickly in the yield region then leveled off.

The remaining specimens were tested in the hardened condition. The martensitic structure of each specimen was varied by changing either the tempering

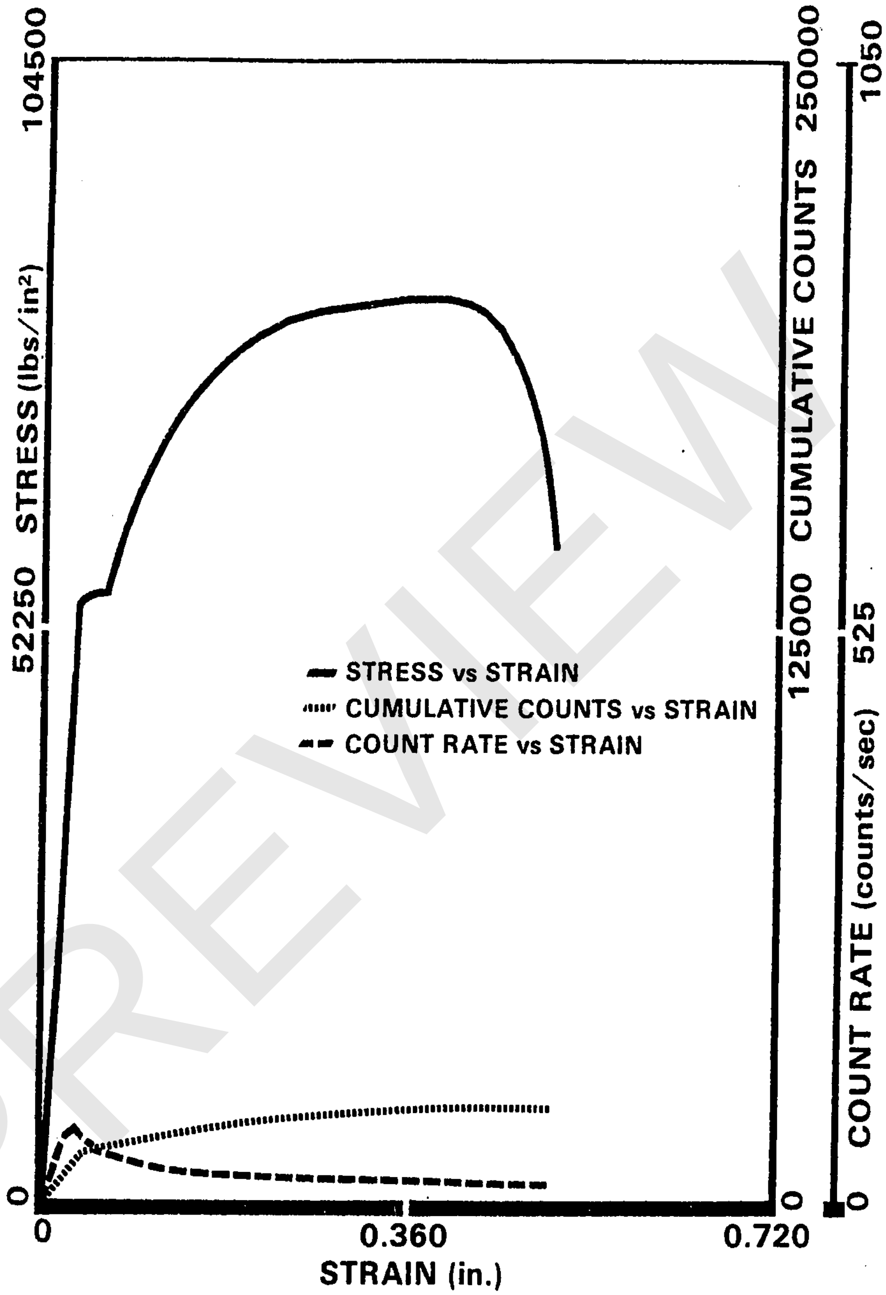

Figure 6

Annealed (Without Grip Noise Eliminated)

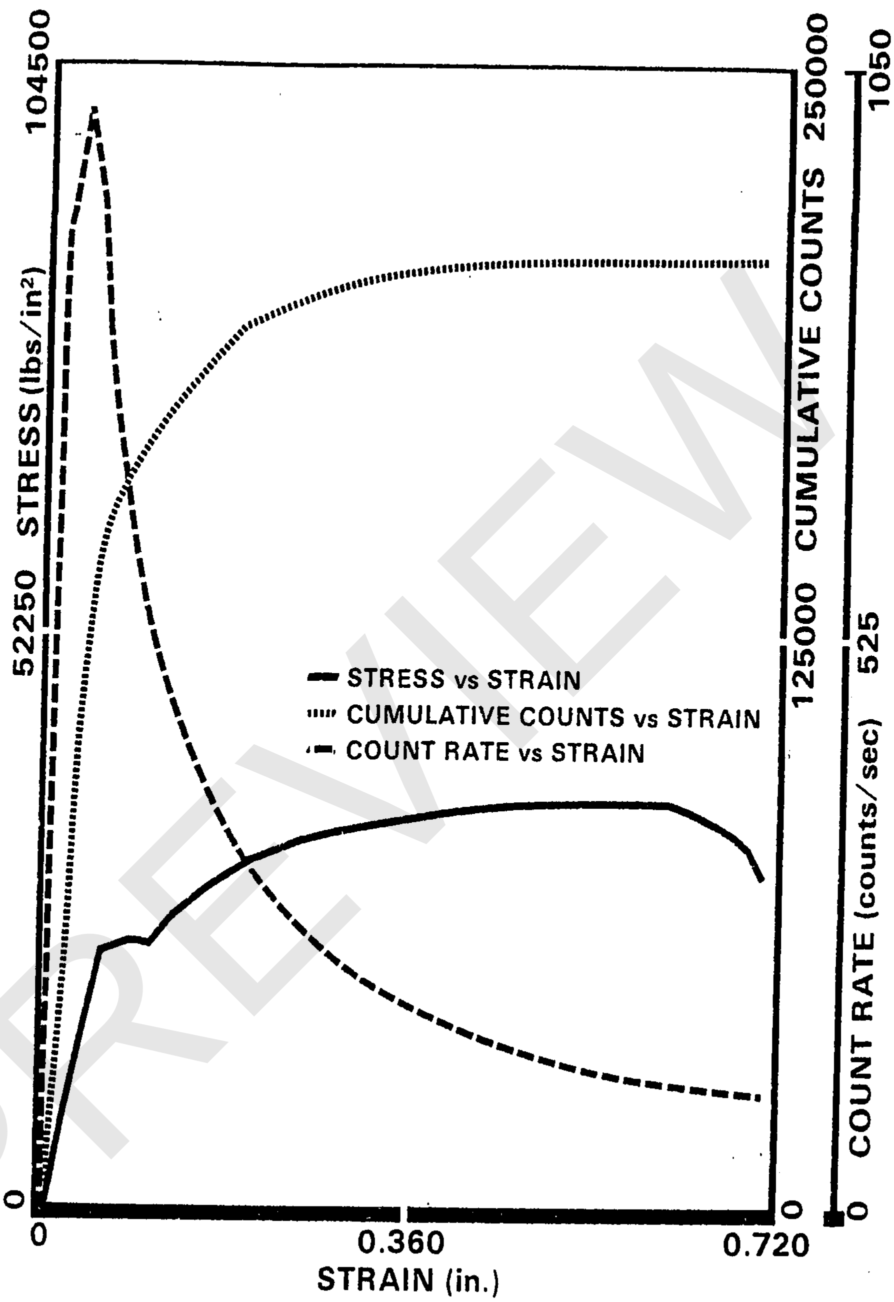

Figure 7

Normalized (Without Grip Noise Eliminated)

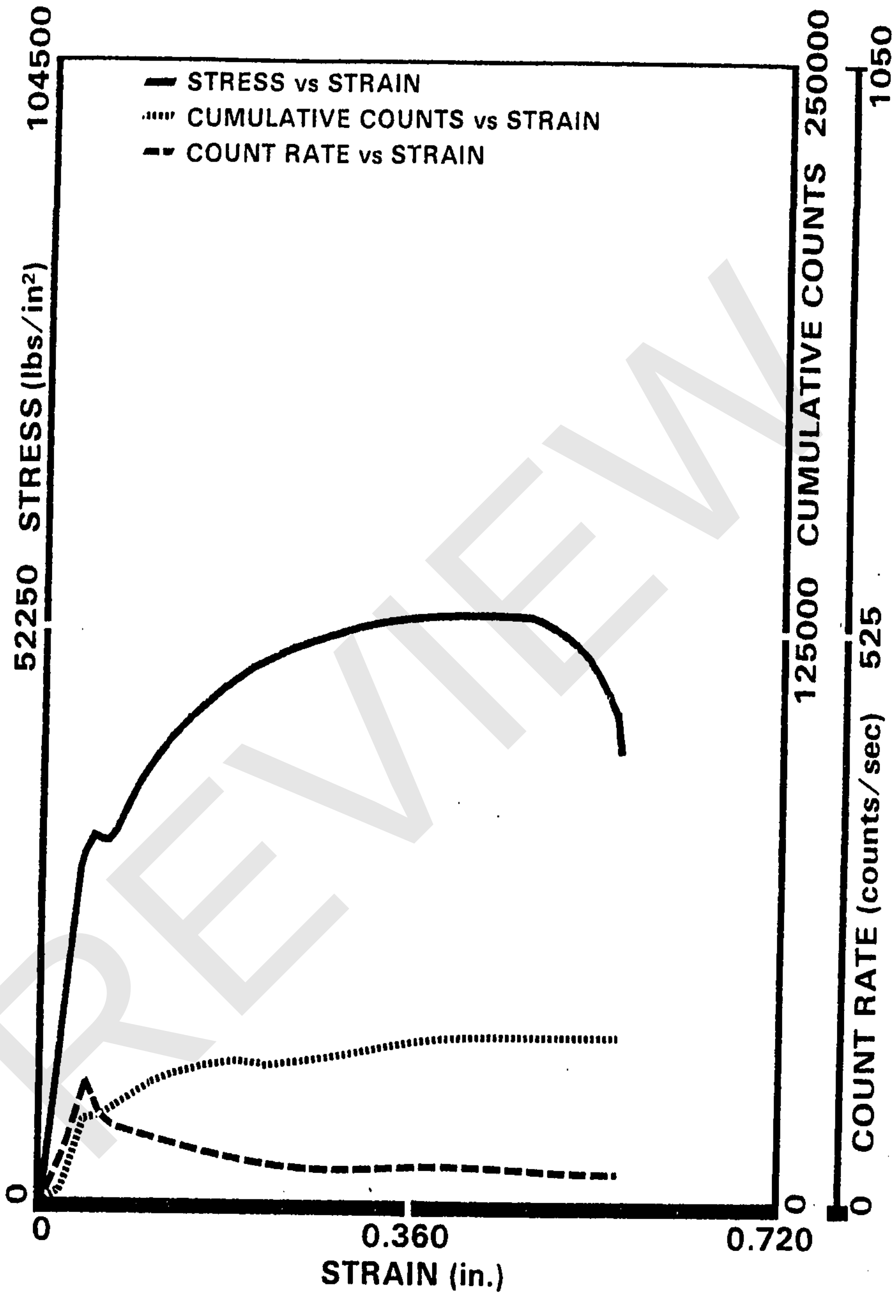

Figure 8

Annealed (Grip Noise Eliminated)

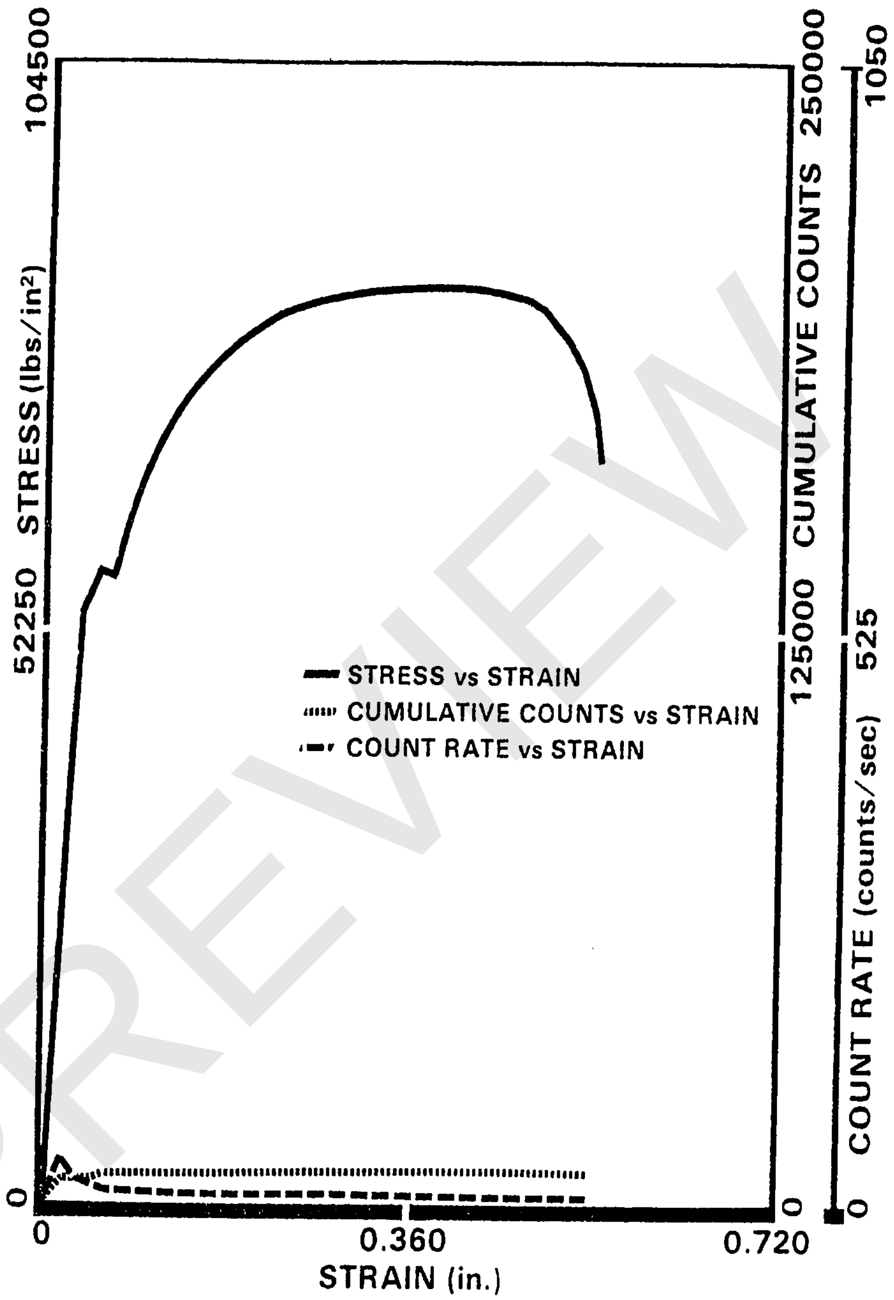

Figure 9

Normalized (Grip Noise Eliminated)

temperature or time. The tensile specimens were tested "as quenched", or tempered at either 250° C or 450° C. The effects of tempering time were studied in the 450° C temper by holding the specimens at this temperature for either one, two or three hours. The plots of these curves are shown starting with the "as-quenched" condition in Figure 10 and ending with the plot of the tempered for three hours at 450° C in Figure 16.

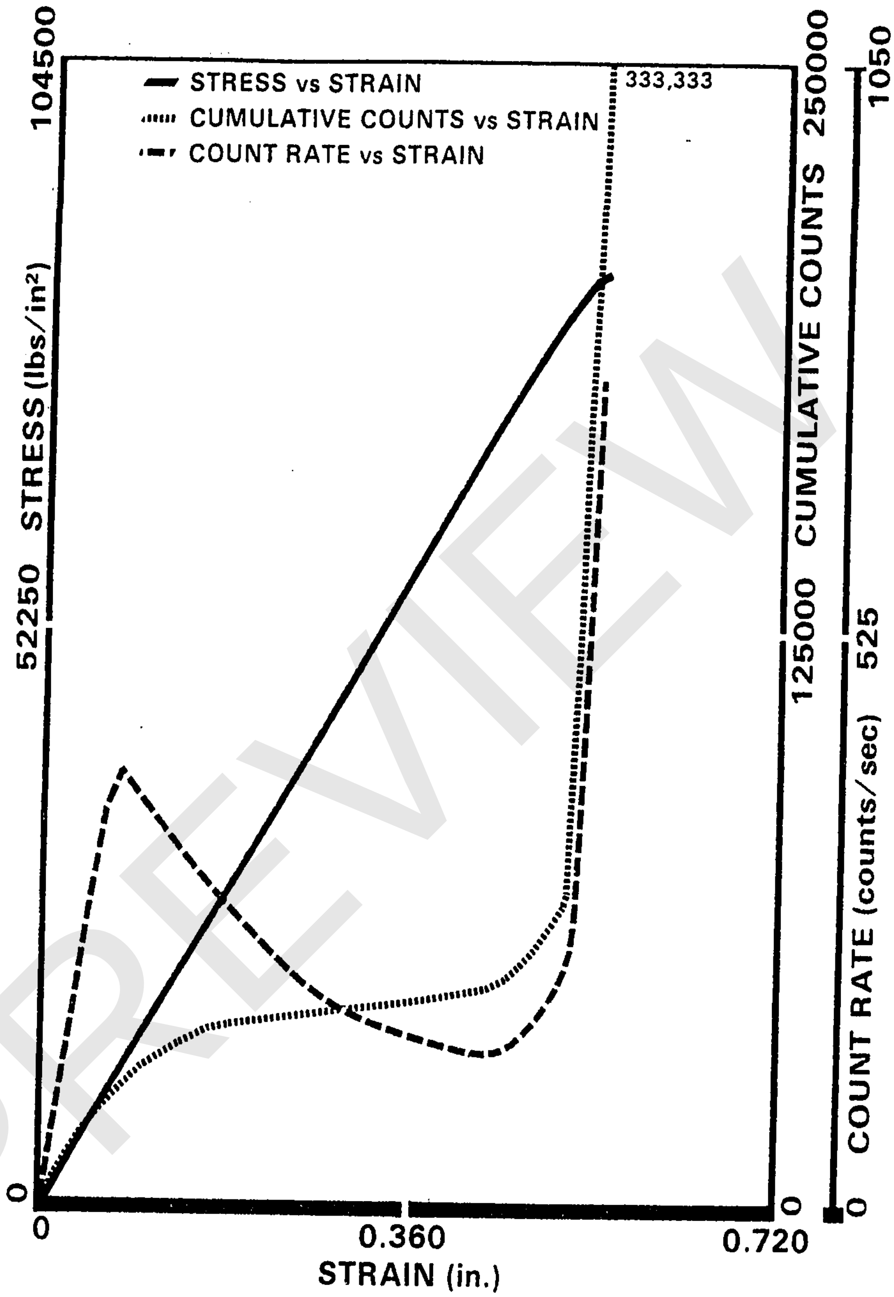

Figure 10

As-Quenched (Grip Noise Eliminated)

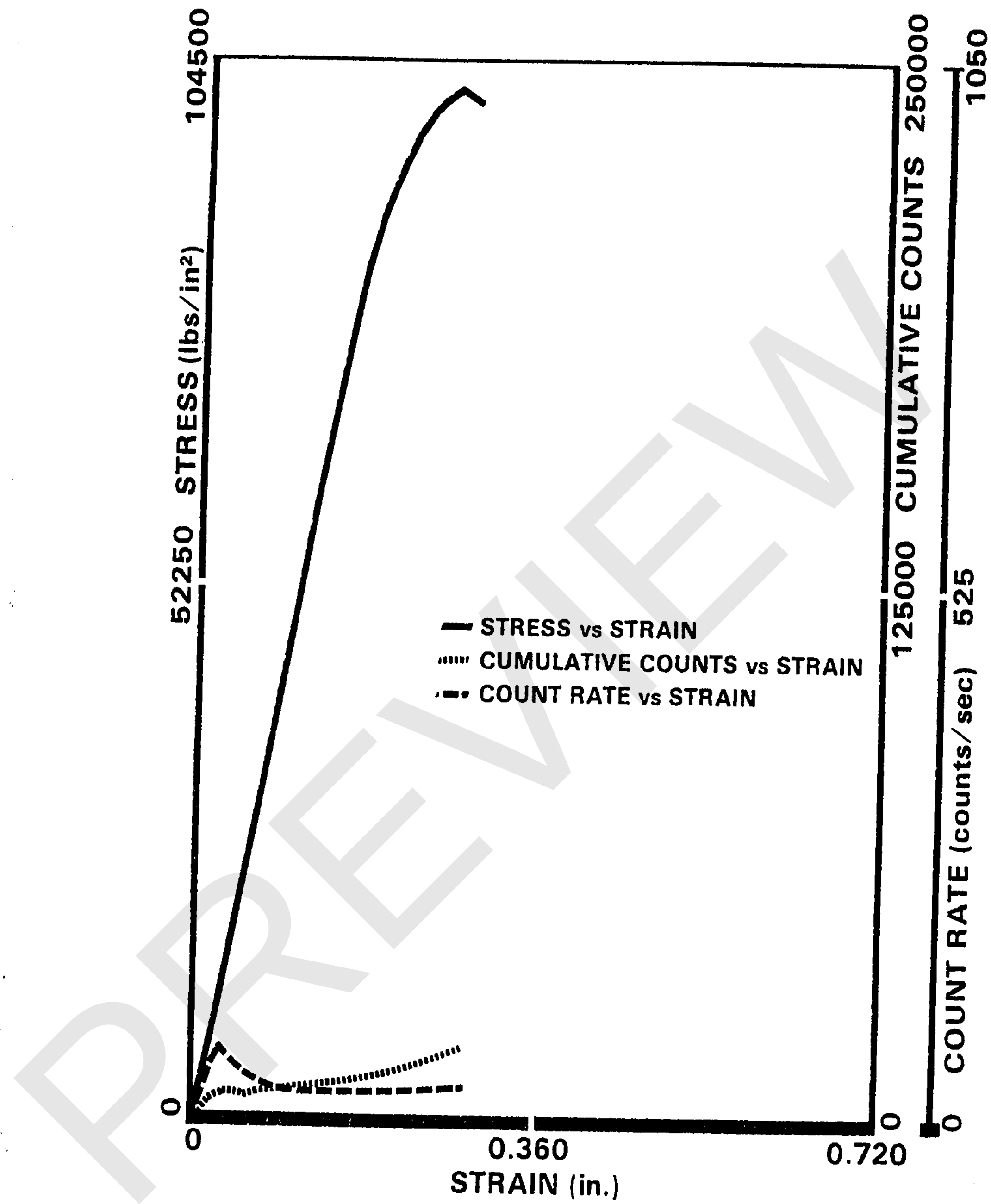

Figure 11

250° C Temper for One Hour