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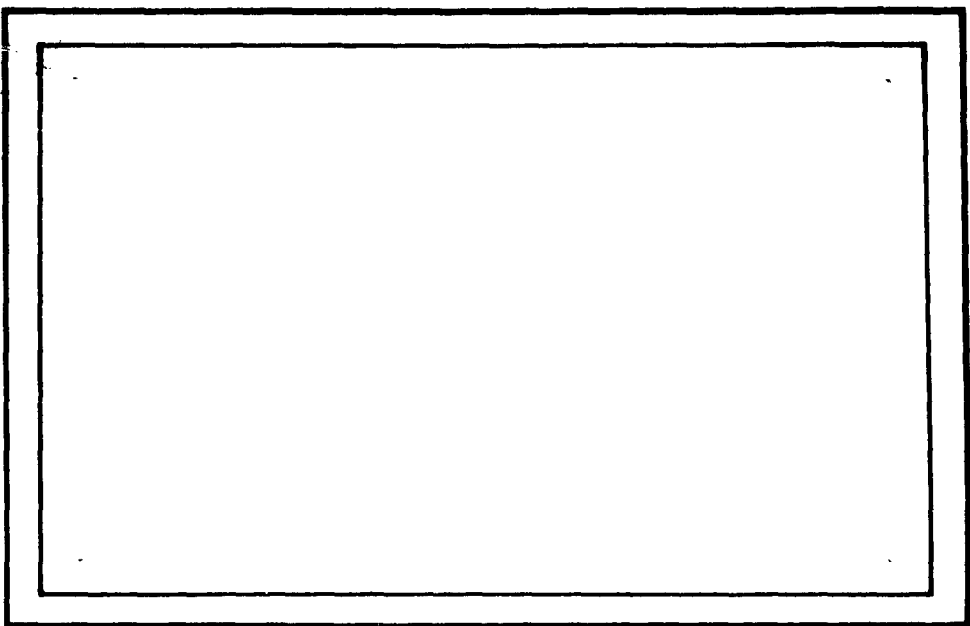
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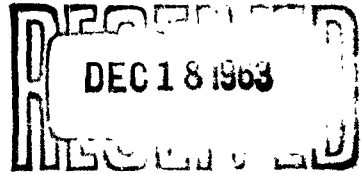


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ACOUSTIC WAVE - BURNING  
ZONE INTERACTION  
IN SOLID PROPELLANTS

(1)

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SUMMARY

Preliminary results of the study of the interaction of the flame zones of two composite solid propellants with transmitted sound waves are reported. The interpretation of the results is ambiguous because of excessive experimental scatter. The reduction of this scatter is discussed.

Experiments to determine the frequency spectrum of the combustion noise from burning composite propellants are described together with some preliminary results. Further work of this nature is discussed.

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## INTRODUCTION

The object of the acoustic wave-burning zone interaction investigation at AeroChem is to study the ability of the flame zone of a solid propellant to amplify or to attenuate sound waves which are passed through it. The general approach to this study has been presented in previous publications together with details of the progress which has been made to date.<sup>1</sup>

In brief, the approach which is being used is to couple a flat disk of solid propellant by an air acoustic transmission line to an acoustic driver. The transmission line is formed by a tube with the propellant fixed in one end and with the driver at the other. The end of the tube which holds the propellant is located within an anechoic chamber. Sound energy from the acoustic driver is partially transmitted through the propellant and radiated into the anechoic chamber. The sound signal is detected by a microphone which is located within the anechoic chamber, and the resulting electrical signal is sent to a wave analyzer. While sound of a given frequency is being transmitted through the propellant, the propellant is ignited and the change in the amplitude of the microphone output signal with the presence of combustion is studied to detect the attenuation or the amplification of the sound signal that is produced by the presence of the flame zone. The hot exhaust gases which leave the flame zone also have an acoustic effect, and this effect must either be eliminated or a proper correction must be applied if the action of the flame zone itself is not to be obscured. This system was described in somewhat greater detail in Ref. 1 and the system flow diagram of Fig. 1 of this report is taken from that reference.

## PROGRESS DURING THE LAST QUARTER

By the beginning of this quarter, the anechoic chamber had been completed and the experimental equipment had been gathered together and tested. At the beginning of this period, the system was put into initial operation.

### Flame Zone-Acoustic Wave Interaction

Initial experiments of the type described above were run on two modifications of one basic propellant. The propellants contained the following percentages of ammonium perchlorate, Rohm and Haas P-13 styrene base polyester resin, and aluminum, respectively: 75/25/0; 75/24/1. Sound frequencies of 6 cps bandwidth and ranging from 500

to 14,000 cps were used. The microphone was placed approximately 8 feet from the propellant with its axis intersecting the axis of the coupling tube (which is horizontal) at the propellant. The angle of intersection of the axes was  $90^{\circ}$ . Because the exhaust gases jet straight away from the face of the propellant, this placement of the microphone minimizes the hot gas path length through which the sound wave passes enroute to the microphone. This in turn minimizes the strong attenuation of the sound signal by the exhaust gases. The normal ray emission from the propellant is strongly attenuated by these gases.

The results of this work showed sufficient experimental scatter (both quantitatively and qualitatively) to render their interpretation ambiguous. However, the following general trends appeared to be present. From the lowest frequency tested (500 cps) to approximately 3000 cps, the flame zones of the two propellants tended to amplify the transmitted sound wave. Above approximately 3000 cps, they tended to attenuate a transmitted sound wave except in the frequency band around 3980 cps where there seemed to be an equal probability of amplification or attenuation. Above this frequency, attenuation appeared to be the rule.

The scatter was sufficiently serious to frequently show both amplification and attenuation for consecutive tests at a given set of conditions.

An effort was initiated to eliminate the causes of the experimental scatter and also to rectify certain other faults in the system.

The present system, which includes the modifications described below, is shown in Figs. 2 - 5. The following improvements were made in the system.

- 1) Common mode pickup had been bothersome on the microphone signal. The electronic system was rearranged with more effective shielding of all leads and with greater isolation of all input signal leads (i.e., the power amplifier input or output leads and the power amplifier output voltmeter leads) from the microphone output lead and from the analyzing and recording apparatus. The ignition circuitry was revised to eliminate 60 cycle pickup in the anechoic chamber. At the present time, common mode signal pickup is no longer a problem.
- 2) Sound of an undesirably high intensity level from the acoustic driving system was leaking into the anechoic chamber and finding its way to the microphone by a path other than through the propellant. Because this sound was tuned to exactly the frequency to which the wave analyzer was set, the

analyzer could not discriminate against it as it can in the case of sound of a random frequency, and the recording system recorded the sum of the amplitude of this sound and of that which passed through the microphone (with the effect of the relative phase angle included). This amounted to approximately one half of the sound amplitude which was received at the microphone.

The source of this sound was twofold;

- a) the transmission of sound through the walls of the coupling tube and into the anechoic chamber and
- b) the radiation of sound from the insulated box which held the acoustic drivers, and the transmission of this sound through the cinder block walls of the anechoic chamber into the chamber -- the acoustic driver system was located outside of the anechoic chamber and the coupling tube passed through the walls of the chamber.

In an attempt to solve item (a), a 2.875" O.D. x 2.315" I.D. red brass pipe shield was placed over the 1.660" O.D. x 1.272" I.D. red brass pipe coupler tube. The annulus between the coupler tube and the shield was packed with glass wool insulation and the outer surface of the shield was covered with similar insulation. This substantially reduced, but did not eliminate, the radiation of sound from the wall of the coupler tube. Because this sound is radiated most strongly in a direction normal to the tube axis, and because the propellant radiates sound most strongly parallel to the tube axis, the microphone (which is strongly directional) was relocated so that its axis intersected the coupler tube axis at an angle of  $45^{\circ}$  at the propellant surface. This eliminated the problem of extraneous sound reception from the tube walls at the expense of restricting the location of the microphone.

The problem of extraneous sound radiated from the acoustic drivers and passing through the walls of the chamber (item b) was eliminated by enclosing the driver unit in a much more soundproof box outside the anechoic chamber than the one used previously. This was effective in reducing this source of sound to a tolerable level.

Some additional shielding may be required in the future to further improve the system; however, at the present time extraneous sources of sound no longer seem to exceed tolerable limits.

The repositioning of the microphone has aggravated the problem of the attenuation of the sound signal by the jet of exhaust gases from the propellant. This attenuation increases with the signal frequency, as should be expected,<sup>2</sup> and it will probably also increase with the temperature of the exhaust gases.<sup>2</sup> Furthermore, this attenuation will undoubtedly be affected by the composition of the exhaust gases. It is planned to circumvent this problem by surrounding the sample of test propellant with a guard ring of propellant of the same composition. The testing sequence will then be as follows. The guard ring will be ignited and it will produce a jet of exhaust gases similar to that which is produced by the test sample. The sound signal from the propellant will be monitored by the microphone and the test sample will then be ignited. The change in signal amplitude upon ignition will be the quantity of interest. The presence of a jet of hot gases both prior to and after ignition of the test sample should tend to eliminate their effect upon the change of signal caused by the presence of the propellant flame zone.

#### Frequency Spectrum of Combustion Noise from a Burning Composite Solid Propellant

During this period experiments were initiated to determine the frequency spectrum of the combustion noise which is emitted by a burning solid propellant.

In this work, a strand of solid propellant was burned in the anechoic chamber and the microphone was placed in a position to receive the resulting acoustic noise signal. The signal from the microphone was sent to the wave analyzer. During the period of burning of the propellant, the tuning of the wave analyzer was swept over the desired range of frequencies. The wave analyzer meter signal was recorded on a chart recorder as amplitude versus time. The frequency sweep rate was known together with the limits of the frequency range swept, and this, together with the chart record, provided an amplitude versus frequency record.

This experiment was performed with one propellant -- the propellant formulation contained the following percentages of ammonium perchlorate, Rohm and Haas P-13 styrene base polyester resin, and carbon black, respectively; 76.5/21.6/1.9. The sound spectrum, which is reproducible, is shown in Fig. 6.

The amplitude clearly is at a maximum in the range from 2500 to 4500 cps. Above 6000 cps it has decreased substantially.

Because the noise at any given frequency fluctuates randomly with time (see Fig. 7), instantaneous amplitudes such as those obtained by the scanning technique described above are less meaningful than are time averaged values. Plans to obtain such time averaged values will be discussed in a later section of this report.

#### FUTURE WORK

During the ensuing quarter, work will continue on both the flame zone-acoustic wave interaction and the combustion noise spectrum.

##### Flame Zone-Acoustic Wave Interaction

A propellant guard ring will be installed about the propellant sample and this method of negating the influence of the jet of hot exhaust gases will be evaluated. Further shielding for the coupler tube may also be installed. When the effects of the hot exhaust gas jet have been overcome, if the experimental scatter has thereby become tolerable, the flame zone-acoustic wave interaction of the above propellants will be investigated over a range of frequencies.

Activity has been initiated to obtain samples of propellants some of which have and some of which have not exhibited instability in rocket motors. When the experimental method has been perfected to the degree that it yields reliable results, these propellants will be tested.

##### Combustion Noise Experiments

A preamplifier will be installed between the microphone and the wave analyzer. This will permit moving the microphone further from the propellant (the present distance is 8 inches) and this in turn will lessen the change in angle between the microphone axis and the line joining the microphone and the burning surface during the burning period. Thus the small influence of the angular sensitivity of the microphone will be removed from the results.

Further, an electrical integrator will be connected to the wave analyzer recorder output to determine the average value of the combustion noise output at any pre-selected frequency. The operation of the experiment will then be as follows. The wave analyzer will be set to record the amplitude of one given frequency (the bandwidth will be 6 cps) and the propellant will be mounted in the anechoic chamber with the microphone

facing it at a distance of approximately 10 feet. When the propellant is ignited, the preamplified microphone signal will be sent to the wave analyzer and the wave analyzer recorder output signal will be integrated for approximately 1 minute. Thus, from the integrated signal, a quantity proportional to the time averaged sound power may be calculated. This will be plotted directly (or some standard frequency will be chosen and the quantity will be plotted in d.b.), versus frequency. When sufficient runs have been made, a graph of the acoustic frequency spectrum of the combustion noise will be available.

The possible significance of the noise spectrum will depend upon its variation from propellant to propellant and upon its correlation with certain definite properties of propellants. Whether or not such significance exists will be the subject of investigation during this period, together with an attempt to determine the particular source of this sound.

#### REFERENCES

- <sup>1</sup> Blair, D. W.: "Acoustic Wave-Burning Zone Interaction in Solid Propellants" Quarterly Progress Report No. 1, AeroChem TN-38, Contract Nonr 3477(00), ARPA Order No. 23-61, AeroChem Research Laboratories, Inc., Princeton, New Jersey, 1 May 1961 - 30 September 1961
- <sup>2</sup> Beranek, L. L.: Acoustic Measurements (New York: Wiley, 1949) pp. 64-72

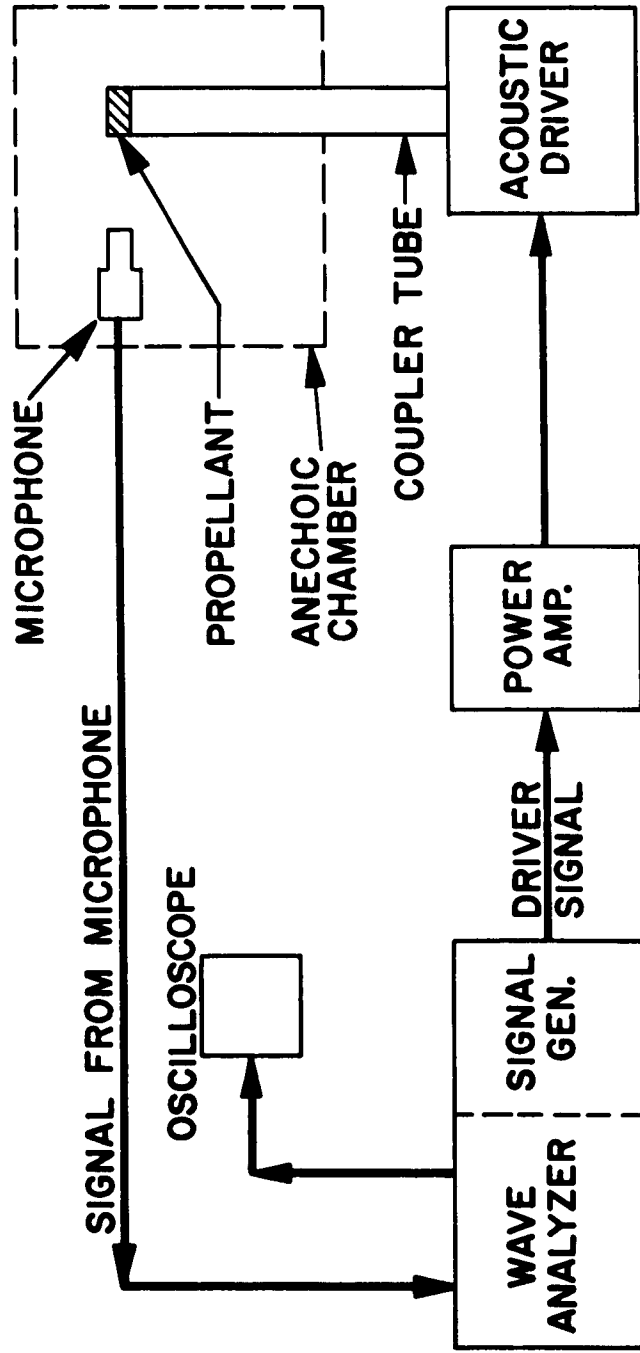


FIG. 1 - FLOW DIAGRAM FOR SOLID PROPELLANT ACOUSTIC INTERACTION EXPERIMENT

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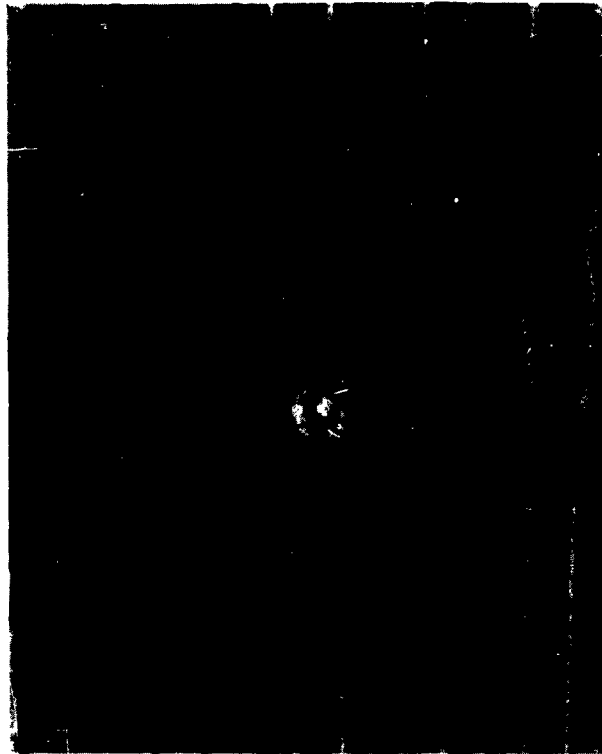


FIG. 2 - COUPLER TUBE IN ANECHOIC CHAMBER WITH PROPELLANT DISK IN PLACE  
AND READY TO BE FIRED  
The Wires are Ignition Leads and Ignition Wire.

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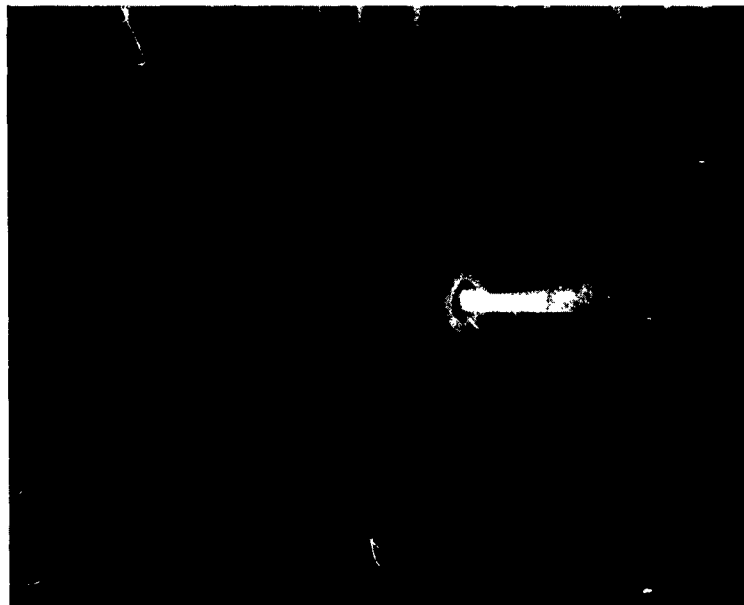


FIG. 3 - COUPLER TUBE AND BURNING PROPELLANT DURING A TEST





FIG. 4 - COUPLER TUBE WITH PROPELLANT BURNED OUT



FIG. 5 - VIEW OF ANECHOIC CHAMBER FROM THE OUTSIDE

The Soundproof Box Which Contains the Acoustic Drivers is Shown to the Right. Below the Box is a Closet Which Houses the Power Amplifier and the Ignition Circuitry.

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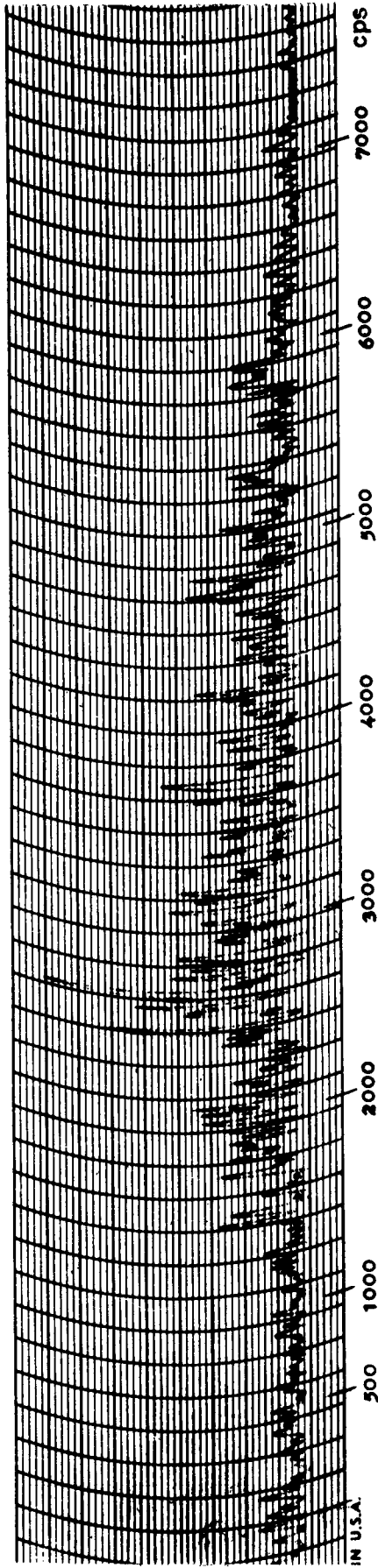


FIG. 6 - COMBUSTION NOISE SPECTRUM FROM A 3/8" SQUARE STRAND OF COMPOSITE SOLID PROPELLANT BURNING IN AN ANECHOIC CHAMBER

Scanning Rate was 170 cps/sec. The Amplitude Scale is Arbitrary.

61-14

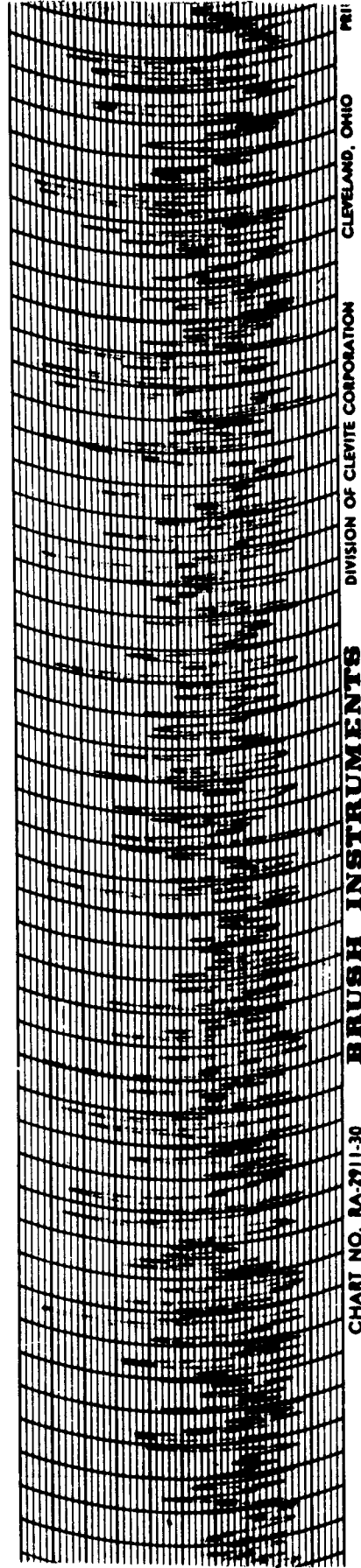


FIG. 7 - AMPLITUDE VARIATION (ARBITRARY SCALE) OF THE 2800 ± 3 CPS COMBUSTION NOISE FROM A COMPOSITE SOLID PROPELLANT BURNING IN AN ANECHOIC CHAMBER

Abcissa is 1 Sec/Major Division.