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ACOUSTIC WAVE-BURNING ZONE INTERACTION IN SOLID PROPELLANTS

Quarterly Progress Report No. 3

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AeroChem Research Laboratories, Inc.

Princeton, New Jersey

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SUMMARY

During this period, the installation of guard rings of burning propellant around the burning propellant sample improved the reproducibility of the results in the flame zone amplification experiment. However, more effort is required to make this experiment still more reproducible.

Experiments were performed to determine the frequency spectrum of the combustion noise from burning strands of solid propellant. For all propellants tested, composite and double base alike, the sound intensity increased sharply from 1000 cps to a maximum at approximately 3000 cps and then decreased monotonically with frequency beyond 3000 cps. The sole effect of oxidizer particle size was to change the sound intensity level of the spectrum curve, but not its form.

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INTRODUCTION

The object of the acoustic wave-burning zone interaction investigation at AeroChem is to study the ability of the burning zone of a solid propellant to amplify or to attenuate sound waves which are passed through it. The presentation of the results of this program in terms of a "response function" is also contemplated. The response function itself may then be used to calculate the "acoustic admittance of the burning surface". The experimental approach to this problem has been presented in previous publications and it will not be reiterated here.[1,2]

PROGRESS DURING THE LAST QUARTER

During this quarter work was continued upon both the problem of measuring the amplification or attenuation of a sound wave which traverses the propellant flame zone and the problem of determining the spectral distribution of the combustion noise which is produced by a burning propellant. Some work was initiated to determine if "luminosity waves" caused by the passage of sound from the acoustically driven system through the propellant flame zone could be detected with photometric apparatus.

Sound Wave Amplification

During this period a guard ring of propellant was installed around the burning propellant sample. This was done in an effort to minimize the effect of the propellant exhaust gases upon the change in sound level which is recorded upon ignition of the sample (Fig. 1). The operation of the experiment was then as follows: As described in Ref. 2, a sound wave from the coupler tube was transmitted through the propellant, radiated into the anechoic chamber, and detected by a microphone which was located within the chamber. The microphone signal was fed to a wave analyzer and thence to a chart recorder. The propellant guard ring was then ignited by a hot wire and it established an annular jet of hot exhaust gases about the axis of the propellant sample. This jet of gases may or may not have caused a change in the signal which is received at the microphone — this is not of primary concern to the experiment; it does, however, require interpretation to understand the general behavior of the sound field within the chamber when influenced by the presence of a jet of hot gases. After 1 1/2 to 2 seconds, the circulation of hot gases into the core of the jet caused the ignition of the sample. The change of the signal received at the microphone upon the ignition of the sample was the interesting quantity.

This system was used with guard rings of an 80:20 mixture of ammonium perchlorate and P-13 resin, and with samples of a presumably unstable propellant which was supplied by the Rohm and Haas Company. Although the scatter of the data was less severe than was the case with the previous system, it was still unsatisfactory. The changes in signal which occurred upon ignition of the sample were too small to be determined accurately with the present recording system. This sensitivity problem will be solved during the ensuing period by using a recorder with zero suppression. This will permit the use of a more sensitive range of the recorder to measure the signal change than can be used if the entire signal level is recorded.

More important than the problem of sensitivity was the observation that on occasion the data indicated attenuation rather than amplification, which was usually obtained under supposedly identical conditions. This observation is difficult to understand and it will be the subject of further investigation. Possibly the method of securing the samples in the sample holders is at the root of this problem. Other methods of securing the samples are presently under investigation.

For the propellants tested, the results indicate that a transmitted sound wave is amplified by the burning zone and that this amplification decreases with increasing sound frequency. An amplification of approximately 1.5 db was found at 1000 cps and this decreased to approximately 0.3 db at 10,000 cps. Because of the problems mentioned above, these results are subject to revision.

Combustion Noise Spectrum

Tests were run to determine the spectral distribution of the combustion noise from burning strands of solid propellant. The tests were run as follows: A strand of propellant (3/8" square in most cases) was mounted vertically on the end of a 1/2 inch diameter vertical rod in the anechoic chamber. The position of the strand holder was approximately 1 1/2 ft from one wall and midway between two corners of the room. The strand was approximately 7 ft above the floor of the anechoic chamber. The highly directional microphone was similarly located with respect to the opposite wall and it was pointed at the burning strand. The microphone signal was sent to a preamplifier and thence to the wave analyzer. A dc signal, proportional to the wave analyzer meter reading, was sent to an electrical integrating circuit which integrated the signal over a period of 51.8 sec.

To run a test, the wave analyzer was set to a given frequency (6 cps bandwidth), and the strand was ignited by a hot wire. The average level of the microphone signal at this frequency over the integrating period could then be determined from the wave analyzer range settings together with the integrated voltage from the wave analyzer. At any frequency the microphone signal amplitude varied with time as shown in Ref. 2.

The results of these tests were reported as db relative to a standard signal level. The results from the tests of three propellants which differed only in their ammonium perchlorate particle size distribution are shown in Fig. 2. Table I presents the results for all of the propellants tested and Table II gives the composition of these propellants.

The intensity versus frequency curves were of similar form for all of the propellants tested. The curves have maxima at approximately 3000 cps and the intensity decreases monotonically as the frequency increases. There is some evidence that the intensity may increase at frequencies below 1000 cps. The sole influence of oxidizer particle size appears to be to lower the sound intensity but not to change its spectral distribution.

The similarity of the sound spectra from widely varying types of propellant might suggest that an acoustic property of the chamber may be the controlling influence on the data. Several tests have been run to check this possibility (i.e., changing the positions of the strand and of the microphone within the chamber and replacing the strand with an electro-mechanical sound source), and thus far the results appear to validly reflect a property of the combustion noise of the propellants.

This work will be extended during the ensuing period.

Acoustically Induced Luminosity Waves

Towards the end of this reporting period, work was initiated to determine if the passage of a sound wave through the propellant flame zone and exhaust gases caused a modulation of the luminosity of the exhaust gases. A slit system was used to define a beam of light which passed in front of a sample disc of propellant which was mounted on the acoustic coupler tube. The light beam impinged upon a photomultiplier tube and the resulting electrical signal was sent to the wave analyzer. As sound was transmitted through the burning propellant, the amplitude of the photomultiplier signal at the sound frequency was determined with the wave analyzer. This was compared with the signal which was obtained at the same frequency when another sample was burned without being acoustically driven. Preliminary results indicate that luminosity waves are detectable under these conditions. These results have not yet been checked and they should be regarded as tentative. This work will continue during the next reporting period.

FUTURE WORK

The following work will be pursued during the ensuing period:

1) Tests will be run to determine if the acoustic signal which drives the propellant discs in the amplification tests, remains constant when the propellant sample is ignited. It has been assumed that the acoustic influence of the burning zone is not reflected back through the propellant and into the coupler and driver system. Although this seems a fairly safe assumption, it will presently be tested.

2) It will be attempted to measure the change in phase of the sound signal which is received at the microphone when the propellant sample is ignited.

3) Combustion noise spectra will be taken for additional propellants. Further tests will also be made of the validity of this work.

4) The investigation of acoustically induced luminosity waves in the propellant combustion gases will be continued.

5) Preliminary experiments will be made to determine the effect of propellant composition upon the acoustic damping properties of the combustion gases.

REFERENCES

[1] Blair, D. W.: "Acoustic Wave-Burning Zone Interaction in Solid Propellants", Quarterly Progress Report No. 1, AeroChem TN-38, 1 May 1961 - 30 September 1961

[2] Blair, D. W.: "Acoustic Wave-Burning Zone Interaction in Solid Propellants", Quarterly Progress Report No. 2, AeroChem TN-40, 1 October 1961 - 31 December 1961

TABLE I

COMBUSTION NOISE SPECTRA FROM BURNING STRANDS

OF SOLID PROPELLANT

Frequency	Microphone Signal - db referred to 1 mv								
	Propellant Number								
cps	J21-11	J21-12	J21-13	J21-18	J21-16	J21-7	J21-19	J21-20	A
500	-19.4	-	-	-7.23	-	-	-	-14.6	-22.6
500	-	-	-	-6.54	-	-	-	-	-33.2
1000	-22.8	-25.9	-18.4	-7.75	-19.2	-	-14.0	-14.0	-31.4
1000	-	-	-14.9	-	-	-	-	-	-
1500	-16.2	-21.4	-	-6.54	-	-	-	-10.4	-28.0
1500	-	-23.6	-	-	-	-	-	-	-
2000	-11.6	-14.4	- 5.80	-4.36	- 7.53	-8.19	- 5.85	- 6.56	-22.9
2000	-	-	-	+1.44	-	-	-	-	-
2250	-	-	-	-	-	-	- 5.37	-	-
2500	- 7.73	-10.0	- 1.62	-1.51	- 2.62	-	0.00	- 0.04	-16.2
2500	- 6.31	-	-	-	-	-	- 5.37	-	-
2700	- 4.58	-	-	-	-	-	-	-	-
2900	- 2.61	-	-	-	-	-	-	-	-
3000	- 1.31	- 9.31	- 2.49	-0.73	- 1.51	-0.82	- 2.04	+ 0.76	-15.3
3000	- 2.61	-	-	+6.79	-	-	- 0.82	-	-
3000	- 4.47	-	-	-	-	-	-	-	-
3000	- 2.01	-	-	-	-	-	-	-	-
3100	- 2.27	-	-	-	-	-	-	-	-
3300	- 2.04	-	-	-	-	-	-	-	-
3500	- 3.60	-	- 6.93	-2.84	- 4.30	-	- 4.30	- 1.94	-17.2
3750	-	-	-	-6.72	-	-	-	-	-
4000	- 6.92	-	-10.9	-8.89	- 6.55	-14.0	- 8.89	- 8.19	-27.0
4000	-	-	-	-8.19	-	-	-	- 6.02	-
4000	-	-	-	-0.91	-	-	-	-	-
4500	- 7.75	-17.7	-	-	-	-	-	- 6.75	-
4500	-	-18.2	-	-	-	-	-	-	-
5000	- 8.41	-27.8	-	-7.12	- 8.19	-	- 8.89	- 8.89	-23.5
5000	-	-18.4	-	-	-	-	-	- 7.03	-
5000	-	-18.4	-	-	-	-	-	- 9.90	-
5000	-	-	-	-	-	-	-	-10.8	-
6000	-12.1	-	-	-	-	-	-	-13.6	-24.4
6000	-	-	-	-	-	-	-	- 6.92	-
7000	-16.6	-25.0	-	-12.0	-17.8	-	-15.2	-16.0	-28.8
8000	-	-	-	-	-	-	-	-21.0	-
9000	-27.6	-	-	-	-	-	-	-30.4	-
11000	-32.4	-	-	-	-	-	-	-	-
13000	-48.0	-	-	-	-	-	-	-	-

TABLE II

PROPELLANT TYPES USED FOR COMBUSTION NOISE EXPERIMENTS

Propellant No.	Percent NH_4ClO_4	Percent P-13 Resin	Percent Aluminum	Percent of NH_4ClO_4 Ground (10μ)	Percent of NH_4ClO_4 Unground (200μ)	Strand Cross-section inches
J21-7	80	20	0	30	70	9/16 dia.
J21-11	75	25	0	30	70	3/8 x 3/8
J21-12	75	25	0	100	0	3/8 x 3/8
J21-13	75	22.5	2.5	30	70	3/8 x 3/8
J21-16	80	20	0	30	70	3/8 x 3/8
J21-18	75	20	5	30	70	3/8 x 3/8
J21-19	80	18	2	30	70	3/8 x 3/8
J21-20	75	25	0	0	100	3/8 x 3/8
A	Double Base Propellant					1/4 dia.

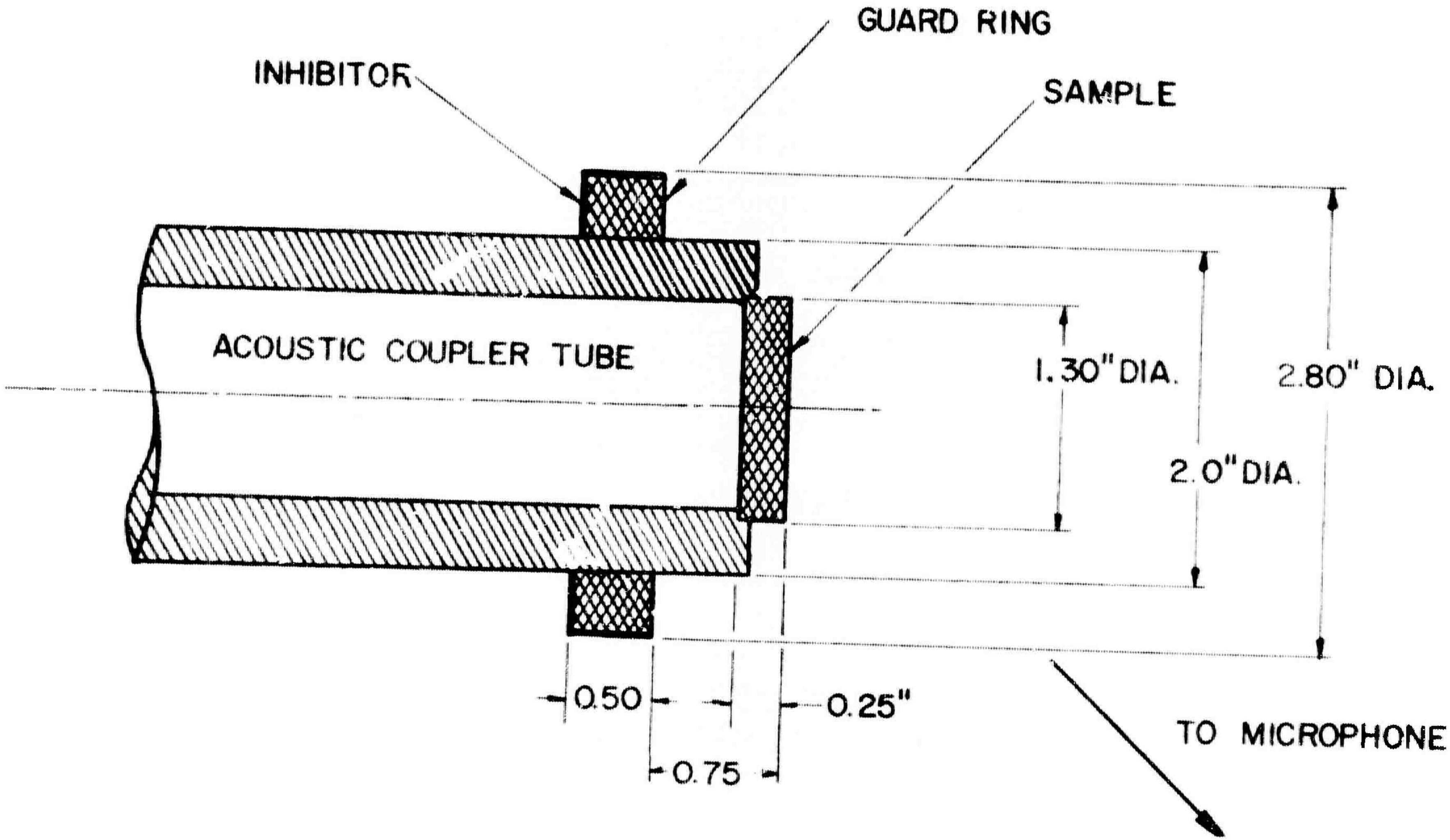

FIG. 1 SECTION VIEW OF ACOUSTIC COUPLER SAMPLE HOLDER WITH PROPELLANT SAMPLE AND GUARD RING IN PLACE

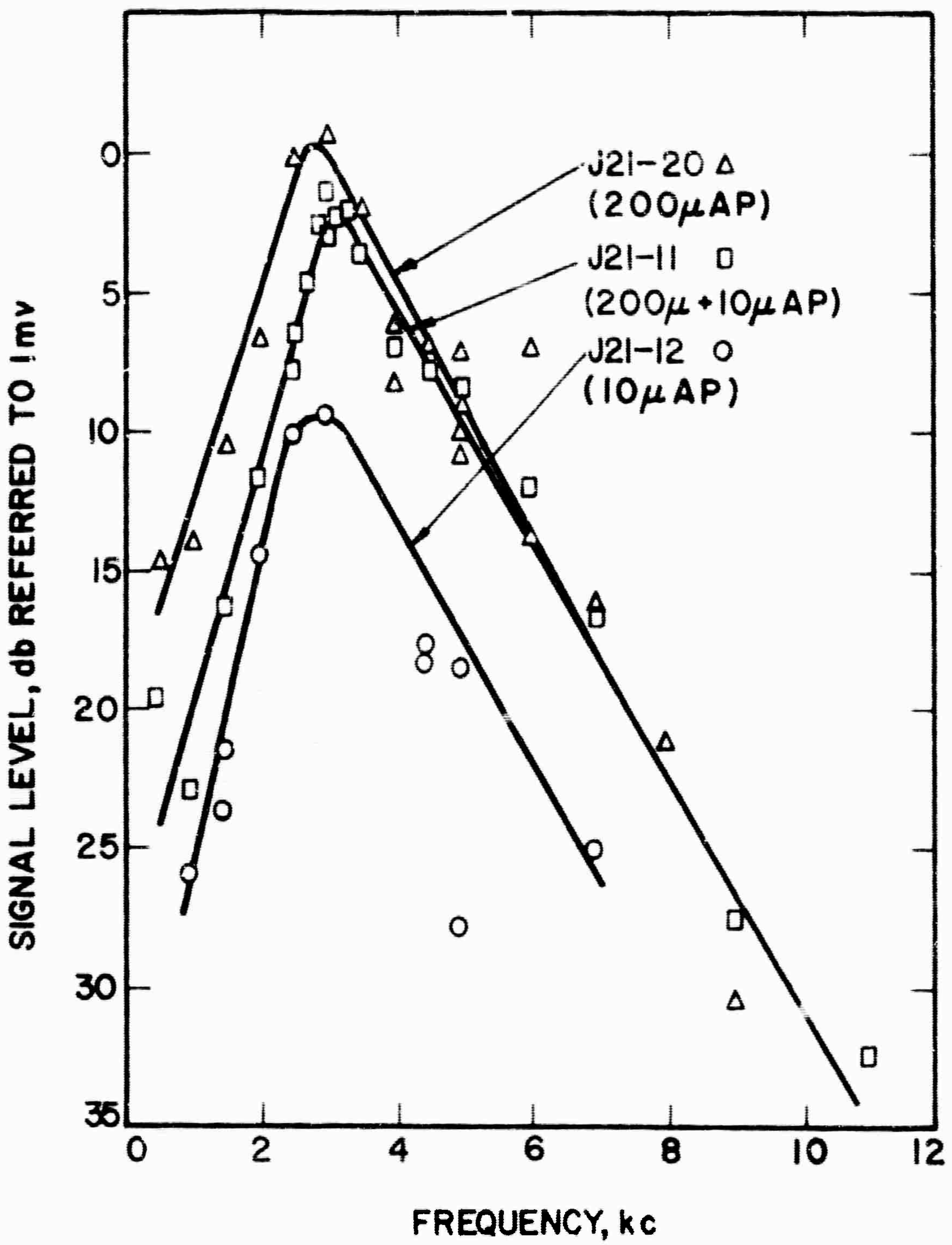

FIG. 2 COMBUSTION NOISE SPECTRA FROM THREE AMMONIUM PERCHLORATE (75%) P-13 (25%) SOLID PROPELLANTS