Marshall

~~NASA CR-102838~~

~~X70-74997~~

NASA GRANT NGL 11-002-085

N71-14213
NASA CR-112959

BEHAVIOR OF NOZZLES AND ACOUSTIC LINERS IN THREE-DIMENSIONAL ACOUSTIC FIELDS

Quarterly Report for Period 1 June 1970 to 31 August 1970

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PROGRESS DURING THE REPORT PERIOD

A. Summary of Progress

The computer program that uses experimental data to determine the nozzle admittances has been updated in order to (1) eliminate a double-root solution and (2) to statistically curve-fit the resultant admittance data. Prior to actual nozzle testing preliminary tests were conducted in order to determine (1) the effectiveness of the installed muffler; (2) the best mode of chamber frequency excitation; (3) the chamber acoustics under flow and no-flow conditions; and (4) the quality of the data measured by various transducers located at different locations along the chamber. Due to the failure of its predecessor, a different tape recorder is presently being added to the system, and actual nozzle testing will take place shortly.

B. Theoretical Studies

A considerable amount of work has been devoted to final modifications of the computer program that calculates the desired nozzle admittances from experimental sound pressure level and phase measurements. Studies conducted during this period showed that for a given set of input data the computer program may calculate two solutions for the nozzle admittance function. In order to eliminate this difficulty an additional subroutine, capable of selecting the proper solution, has been added to the computer program. In its present form the developed computer program can use available experimental data to compute the desired nozzle admittance function.

In addition to the aforementioned computer update, a parallel effort to statistically curve-fit the admittance data has been conducted. During the test, five axial pressure transducers are employed to sample the acoustic wave within the chamber. During data analysis, three pressure measurements are required to determine the nozzle admittance at that particular frequency. By using the five pressure measurements in combinations of three, ten values of the admittance are generated at each frequency. In the event that the five pressure measurements are perfect, all ten nozzle admittance values will be equal. As a result of experimental inaccuracies the computed admittances, at each frequency, will differ from one another. In order to treat the data-scatter, the computer program will apply various statistical methods at each frequency and then curve-fit the admittance data over the frequency range.

Additional efforts associated with the analytical investigation of three-dimensional standing wave behavior in chambers with lined walls as well as the prediction of the admittance values of nozzles with rapidly-converging walls have continued during this report period; the studies have, however, not progressed to the point where significant results can yet be presented.

C. Experimental Investigations

The installation of the muffler together with system modifications required to accommodate the muffler have been completed. Preliminary results of the tests conducted to determine the amount of chamber noise reduction due to the insertion of the muffler into the system indicate approximately 20 db reduction in the chamber flow noise. Based on this "quick-look" data, additional testing of the muffler to generate more specific information was deemed unnecessary, and the muffler will be retained as an integral part of the flow system.

The acoustic liner has been fabricated, and it will be tested once the exhaust nozzles have completed their test cycles.

The experimental efforts conducted during this report period were directed at the determination of the admittance values of the manufactured convergent-divergent nozzles, whereas the previous report period efforts were directed at understanding the control and operating characteristics of the simulated rocket cold-flow system. As a prelude to the current effort, the following questions had to be answered:

(1) Could the desired experimental data be obtained by using a continuous frequency sweep? In this case the frequency of the excited three-dimensional waves will be changed in a continuous pre-assigned rate. An alternative to this method of operation would be to run separate tests at various discrete frequencies that are of interest to rocket designers.

(2) Is there a significant difference between the acoustic properties of the cold-flow rocket simulator under flow and no-flow conditions?

(3) Is there a significant difference in the characteristics and quality of the data obtained from pressure transducers located at different locations along the tube (e.g., transducers located at the mid-section of the chamber and near the nozzle entrance)?

A total of seven complete tests were conducted during this report period, and the data was analyzed in order to answer the aforementioned questions. The use of an automated frequency sweep during the test is the preferred mode of operation because it provides data at many more frequencies from which admittances can be determined. This mode of operation also conserves on the limited supply of air available for the blowdown tests. The sweep cannot, however, be used if the sweep-rate exceeds the maximum sweep-rate that is acceptable to the data processing equipment (e.g., the tracking filter). The filter employed for data processing has a 1.5 Hz bandwidth when the signal level is 3 db down from its maximum level and 6.0 Hz bandwidth when the signal is 60 db below its maximum value. By recording the test data at a tape recorder speed of 30 ips (i.e., inches per second) and reducing the data at a tape speed of 1-7/8 ips, the tracking filter senses a sweep rate of 0.009 Hz/sec that is sufficiently slow to satisfy filter requirements.

Some considerations were given to investigating the acoustics of the system under no-flow conditions and then using this information as a guide during actual flow experiments. To check the feasibility of this approach the acoustic properties of the system under flow and no-flow conditions had to be compared. Comparisons of acoustic data obtained during flow and no-flow tests revealed that the introduction of flow into the system results in a significant modification of the acoustic properties of the system. When no air is flowing in the system, neither the injector holes nor the nozzle throat are choked. Under these conditions, the portions of the system located upstream of the injector plate and downstream of the nozzle throat can affect the acoustic properties of the chamber. When flow is introduced into the system, the influence of that portion of the system that is located upstream of the injector plate is changed whereas the influence of the system downstream of the nozzle throat is eliminated. As a result the acoustic properties of the system under no-flow conditions are entirely different from the acoustic properties of the system during actual testing. Another difference between flow and no-flow testing is associated with changes in the speed of sound. The electropneumatic acoustic drivers used in the experimental setup require relatively little air flow. Consequently, during no-flow testing the rate of discharge from the air supply tanks is small while the rate of decrease in air temperature, due to the expansion of the compressed air, is negligible. This is not the case during flow testing when the air flows through the main chamber and the temperature changes between 60°F at the start of the test and -30°F at the end of the test. This wide temperature excursion results in a rapid change in the speed of sound (that in turn results in a change in wavelength) during the test; a change that greatly affects the acoustic properties of the system. In view of the above-described observations, the previously-mentioned possibility of using no-flow data to determine the acoustic properties of the system should be discarded.

Comparisons of data recorded by various transducers located at different locations along the chamber indicated qualitative similarity in the observed frequency spectrum as well as the sound pressure level. The recorded signals were also qualitatively similar to data obtained in related sound-flow interaction experiments.

Based on the above findings it was decided that the investigation of the system as well as the actual nozzle testing should be conducted under flow conditions. The frequency of the excited waves will be changed in a continuous manner over a predetermined frequency range, and any of the transducer locations can be used with the same degree of confidence. It was expected that the actual testing would have been completed at this date; a massive failure of the system's tape recorder unfortunately resulted in a temporary postponement of the scheduled testing. Another tape recorder is presently being incorporated into the system, and acquisition of the desired data is expected to begin shortly.

D. Expected Progress During Next Report Period

The computer program will be finalized. The new tape recorder will be inserted into the system, and nozzle admittance tests will be conducted. Testing of the acoustic liner will be initiated, and work on the other analytical investigations will continue.