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ABSTRACT

This report summarizes the current status and capabilities of sonic boom simulators which might be used in future studies of the effects of sonic booms on people, animals, or structures. The list of candidate simulators is based on a literature search which was confined to the United States and Canada. Some of the simulators are fully operational, others could be made operational with a modest investment, and still others would require a major investment. For the sake of completeness, some simulators which were the subject of a previous review (ref. 1), but which no longer exist, are also included herein.

INTRODUCTION

The majority of studies evaluating effects of sonic boom on people, animals, and structures were conducted during the 1960's. During this period a number of different types of simulators were developed to fulfill specific research requirements. A review of the characteristics of the facilities and techniques of simulating sonic boom is given in reference 1.

After the cancellation of the United States supersonic transport and until very recently, there has been little interest in the United States in the study of sonic boom effects. As a consequence, the simulator facilities have, in general, been little used and it was suspected that many of the facilities were no longer operational even if they still existed.

The United States Air Force has recently initiated a program of study of sonic boom effects to better define the overall impact of supersonic flight in limited operational areas. As one step in the preliminary definition and planning phase of the Noise and Sonic Boom Impact Technology (NSBIT) program, it was necessary to determine the operational readiness of simulators which would possibly be used in investigations of effects on people, animals, and structures. This report summarizes the current status and characteristics of those simulators which were discussed in the previous review article (ref. 1) or could be found in more recent reports.

The list of candidate simulators is based on a literature search which was primarily confined to the United States and Canada. Some of the simulators are fully operational, others could be made operational with a modest investment, and still others would require a major investment. For the sake of completeness, some simulators which were the subject of a previous review (ref. 1), but which no longer exist, are also included herein.

Simulators which might be used to study sonic boom effects on people, animals, or structures may be divided into five categories: loudspeaker systems, piston driven systems, shock tube driven systems, air modulator valve systems, and explosive charge systems. In the following section each of these simulator categories will be briefly described and the status of simulators reviewed.

LOUDSPEAKER SYSTEMS

Small chambers equipped with loudspeakers have been used extensively in studies of human response to impulsive noises, including sonic booms. With appropriate frequency and phase compensation, those devices are capable of producing a wide range of overpressures, rise times, and stimuli durations. Larger chambers equipped with loudspeakers might be used to study some aspects of human response to sonic booms. Such facilities have limited capability in terms of overpressure and low frequency characterisics but might be useful for studies of perception thresholds or reactions to sonic booms generated by aircraft at large distances from an observer. It probably requires that the noise stimuli be computer generated to compensate for the frequency response and phase characteristics of the sound reproduction system.

(i) Test Chamber at the Bioacoustics Laboratory, Lockheed (Rye Canyon) (ref. 2).
Status: No longer exists.

(ii) Test Chamber at Bolt, Beranek, and Newman, Cambridge (ref. 3).
Status: No longer exists.

(iii) Test Chamber at UTIAS, University of Toronto (ref. 4).
Status: No longer exists.

(iv) Anechoic Listening Facility, NASA Langley Research Center (ref. 5)
Status: Operational.
Specifications: Frequency response — 30 Hz - 10K Hz
Max. SPL — 90-95 dB
Volume — 20m^3
Computer-generated noise capability.

PISTON-DRIVEN SYSTEMS

Several piston systems have been used in studies of response of people and structures. Their testing volumes cover a wide range, from accommodating a single human to a small building. These systems typically have excellent low frequency capabilities, but somewhat limited high frequency and rise time capabilities. They are thus most appropriate for studies of structural response and response of people to sonic booms as heard indoors.

(v) Low Frequency Noise Facility, NASA Langley Research Center (ref. 6).
Status: No longer exists.

(vi) Dynamic Pressure Chamber, Wright Patterson AFB
Status: Operational.
Mode 1 (animal) Specification: Frequency Response — 1/2 Hz - 10 Hz
Max. SPL — 170 dB.
Volume — 1.2m^3
Mode 2 (human) Specification: Frequency Response — 1/2 - 10 Hz
Max. SPL — 130 dB.
Volume — 1.2m^3

(vii) Sleep Facility, Stanford Research Institute (ref. 7).
Status: No longer exists.

(viii) Sleep Facility, Civil Aeromedical Institute, FAA, Oklahoma City (ref. 7).
Status: Operational, with modest investment.
Specification: This facility is identical to the SRI facility (vii, above) and consists of a room with a piston driven pressure chamber attached to one wall.
Max. Overpressure — 96 Pa (2 psf.)
Minimum Rise Time — 5-10 msecs.
Volume — $26m^3$

(ix) Sleep Facility, North Carolina State University (ref. 8)
Status: Operational.
Specification: This facility is similar to (vii) and (viii) above.
Max. Overpressure — 120 Pa (2.5 psf.)
Minimum Rise Time — 5 msecs.
Stimulus Duration — 80-320 msecs.

(x) Construction Engineering Research Laboratory, U. S. Army Corps of Engineers.
Status: Operational
Specification: This facility, which has been used to simulate blast noise effects on structures and people, consists of a large shaker table mounted in a baffle. Adjacent to the shaker is a structure which represents part of a house having standard contruction and which is furnished.
Frequency Response — 0-200 Hz.
Max. SPL — 125 dB.
Duration — 10-40 msecs.

SHOCK-TUBE-DRIVEN SYSTEMS

Shock-tube-driven systems involve puncturing a diaphragm which results in the quick release of pressurized air to generate shock waves which then propagate down a tube (or horn) to a test specimen which may be located either inside the tube or adjacent to the exit of the tube. Such devices can generate N-wave signatures with very short rise times and very high overpressures. The largest of these devices can accommodate structural elements such as windows. The smaller ones have been used for studies of hearing damage using small animals such as chinchillas.

(xi) LTV Shock-Tube (ref. 9).
Status: Acoustic Horn (4 m) is at NASA Goddard, all other components no longer exist.

(xii) Twin-barrelled Shock Tube, Callier Center for Communcation Disorders, University of Texas at Dallas (as of 1/1/86 will be located at State University of New York, Plattsburg). This facility is primarily used for studies of hearing damage using small animals.
Tube exit size — 1.2 m x 1.2 m
Frequency Response — 60 Hz - 1K Hz
Max. SPL — 170 dB.
Minimum Rise Time — 8 msecs.

AIR MODULATOR VALVE SYSTEMS

These systems are the same as shock-tubes (previous section) except that the diaphragm is replaced by a high speed flow valve. This typically results in longer rise times, longer signal durations, and shorter duty cycles. Such systems have generally been used for testing of structural elements such as windows and walls.

(xiii) Wyle Laboratories Air Modulator System, Huntsville
Status: Operational with $50-100K investment.
Specification: Test Specimens — 1.8 m x 2.4 m
Frequency Response — Low

(xiv) General Applied Science Laboratory, New York (ref.10).
Status: Concrete horn section (24 m) exists, all other components no longer exist.

(xv) UTIAS Simulator, University of Toronto (ref. 11).
Status: All components exist except a 2.4 msection of duct and the reservoir ($30K)
Specification: Concrete horn 25m long, 3m x 3m base.
Max. Overpressure — 4800 Pa (100 psf.)
Minimum Rise Time — 6 msecs.
Stimilus Duration — up to 1 sec.

(xvi) Air Modulator Valve System, Callier Center for Communication Disorders, University of Texas at Dallas (as of 1/1/86, State University of New York, Plattsburg). This facility is used for studies of hearing damage using small animals.
Status: Operational.
Specifications: Frequency Response — 100 Hz - 1K Hz
Max. SPL — 200 dB.
Duration — 3 msecs.

EXPLOSIVE CHARGE SYSTEMS

Simulation techniques using explosive charges are particularly suited to large-scale outdoor testing. Multiple explosive line charges (ref. 12, 13) can be arranged to produce N-wave pressure signatures, where the length of the line determines the duration of the signal and the charge strength and distance to the observer determine the peak overpressure. A wide range of pressure profiles can be produced by varying the distribution of explosive along the charge. At a distance of 100-200 m from the source, peak overpressure of 96-144 Pa (2-3 psf) and durations of 100-200 msecs. may be achieved with modest amounts (2 Kg) of explosive.

Another explosive technique (ref. 14) uses a sausage-shaped balloon containing oxygen and methane with a line charge through the center of the balloon. Detonation of the line charge controls the ignition rate of the gas. At a distance of 250 m from a 18 m balloon the resulting N-wave has an overpressure of approximately 490 Pa (5 psf) and a duration of 75 msecs.

SUMMARY

It is evident from the above list that many sonic boom simulators no longer exist. The current status and possible applications of operational simulators is summarized as follows.

There are two facilities (viii, ix above) which have been used extensively for studies of human sleep disturbance and startle effects of indoor sonic booms, and which might also be used for studies of animals under laboratory conditions. These facilities are located at North Carolina State University and at the FAA, Oklahoma City. Other facilities which can be used for human response studies are the Dynamic Pressure Chamber at Wright Patterson AFB and the Anechoic Listening Facility at NASA Langley Research Center. There are two facilities (xii, xvi) which are used extensively for studies of hearing damage to small animals such as a chinchillas. Somewhat larger animals could be used in these facilities.

There are no currently operational shock tubes for testing structural elements. Two devices (xv, xvi) could be made operational. They are the Wyle Laboratories simulator and the UTIAS simulator at the University of Toronto. Both of these simulators are suitable for testing panels such as panes of glass. One other facility, at the Construction Engineering Research Laboratory, U. S. Army, is in essence a very large loudspeaker and can be used for structural or human response tests.

All of the above simulators are laboratory-based; none are amenable to use in field tests. Explosive charge techniques, outlined in a previous section, would be suitable for field test applications.

REFERENCES

1. Edge, Philip M., and Hubbard, Harvey H.: Review of Sonic-Boom Simulation Devices and Techniques. Journal of Acoustical Society of America, 51, pp. 722-728, 1972.

2. Shepherd, L. J., and Sutherland, W. W.: Relative Annoyance and Loudness Judgments of Various Simulated Sonic Boom Wave Forms, NASA CR 1192, 1968.

3. Pearsons, K. S., and Kryter, K. D.: Laboratory Tests of Subjective Reactions to Sonic Boom, NASA CR 187, 1967.

4. Niedzwiecki, A.: On the Loudness of Sonic Booms and Other Impulsive Sounds - Auditory Perception. UTIAS Report #236, University of Toronto, 1978.

5. Hubbard, H. H., and Powell, C. A.: Acoustic Facilities for Human Factors Research at NASA Langley Research Center - Description and Operational Capabilities. NASA TM 81975, 1981.

6. Edge, P. M., and Mayes, W. H.: Description of Langley Low Frequency Noise Facility and Study of Human Response to Noise Frequencies Below 50 CPS. NASA TN-D 3204, 1966.

7. Lucas, J. S., and Kryter, K. D.: A Preliminary Study of the Awakening and Startle Effects of Simulated Sonic Booms. NASA CR 1193, 1968.

8. Rash, L. C., Barrett, R. F., and Hart, F. D.: Development and Evaluation of a Device to Simulate a Sonic Boom. NASA CR 112117, 1972.

9. Dahlke, H. E., Kantarges, G. T., Siddon, T. E., and Van Houten, J. J.: The Shock Expansion Tube and its Application as a Sonic Boom Simulator. NASA CR 1055, 1968.

10. Tomboulian, R., and Peschke, W.: Description and Capabilities of a Travelling Wave Sonic Boom Simulator. NASA CR 1696, 1970.

11. Gottlieb, J. J.: Simulation of a Travelling Sonic Boom in a Pyramidal Horn. UTIAS Report 196, University of Toronto, 1974.

12. Hawkins, S. J., Hicks, J. A.: Sonic Bang Simulation by a New Explosives Technique. Nature 211, 1244, 1966.

13. Harper, M. J., Hawkins, S. J., Hicks, J. A.: Explosively Generated Air Pressure Waves for Structural Forcing. Journal Sound Vibration, 11(2), pp. 217-224, 1970.

14. Strugielski, R. T., Fugelso, L. E., Holmes, L. B., Byrne W. J.: The Development of a Sonic Boom Simulator with Detonable Gases. NASA CR-1844, 1971.

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16. Abstract

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