CHEMICAL SYSTEMS LABORATORY

US Army Armament and Research Command
Aberdeen Proving Ground, Maryland 21010

ARCSL-SP-83007

# EXPERIMENTAL AERODYNAMIC FACILITIES OF THE AERODYNAMICS RESEARCH AND CONCEPTS ASSISTANCE SECTION

by

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Research Division

February 1983

U.S. ARMY ARRADCOM

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| 20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)<br>This report is intended to acquaint activities within the Department of Defense and approved Government contractors with the experimental aerodynamic facilities currently in use at Chemical Systems Laboratory. | | |

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## PREFACE

The work involved in preparing this report was authorized under Project 1L161102A71A, Research in Defense Systems, Chemical Deterrence.

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# EXPERIMENTAL AERODYNAMIC FACILITIES OF THE AERODYNAMICS RESEARCH AND CONCEPTS ASSISTANCE SECTION

## 1. INTRODUCTION

The Aerodynamics Research and Concepts Assistance Section (ARCAS) is one of several research activities within the Chemical Systems Laboratory (CSL) of the US Army Armament Research and Development Command (ARRADCOM), as shown in Figure 1. The ARCAS personnel and laboratory facilities are located at the Edgewood Area of the Aberdeen Proving Ground, Maryland 21010. The basic mission of the ARCAS includes two areas as summarized in Figure 2. The primary mission involves research and development support related to the aerodynamic and aeroballistic aspects of advanced chemical delivery vehicles. This includes the evaluation and optimization of advanced aerodynamic chemical munition configurations as well as the analysis of the effects of chemical type payloads on their flight performance. Secondly, because of the technical expertise of the ARCAS personnel and their special aerodynamic laboratory facilities, the mission also includes providing assistance to ARRADCOM and DOD in demonstrating the feasibility of advanced aerodynamic weapons concepts.

To support this mission, the ARCAS possesses an aerodynamic laboratory with a unique array of experimental aerodynamic facilities including four wind tunnels and a special projectile flight simulator. The wind tunnels cover the subsonic, transonic, and supersonic speed regimes and also include a special vertical wind tunnel facility. The flight simulator allows full sized artillery payloads to undergo the simultaneous spinning and coning motion of the projectile in flight.

These facilities are specifically intended for applied research and are adaptable to a variety of different instrumentation and data acquisition arrangements depending on the type of experimental information desired.

This report presents a brief description of each of the major experimental facilities including their basic performance and special capabilities. Additional information can be obtained through the following:


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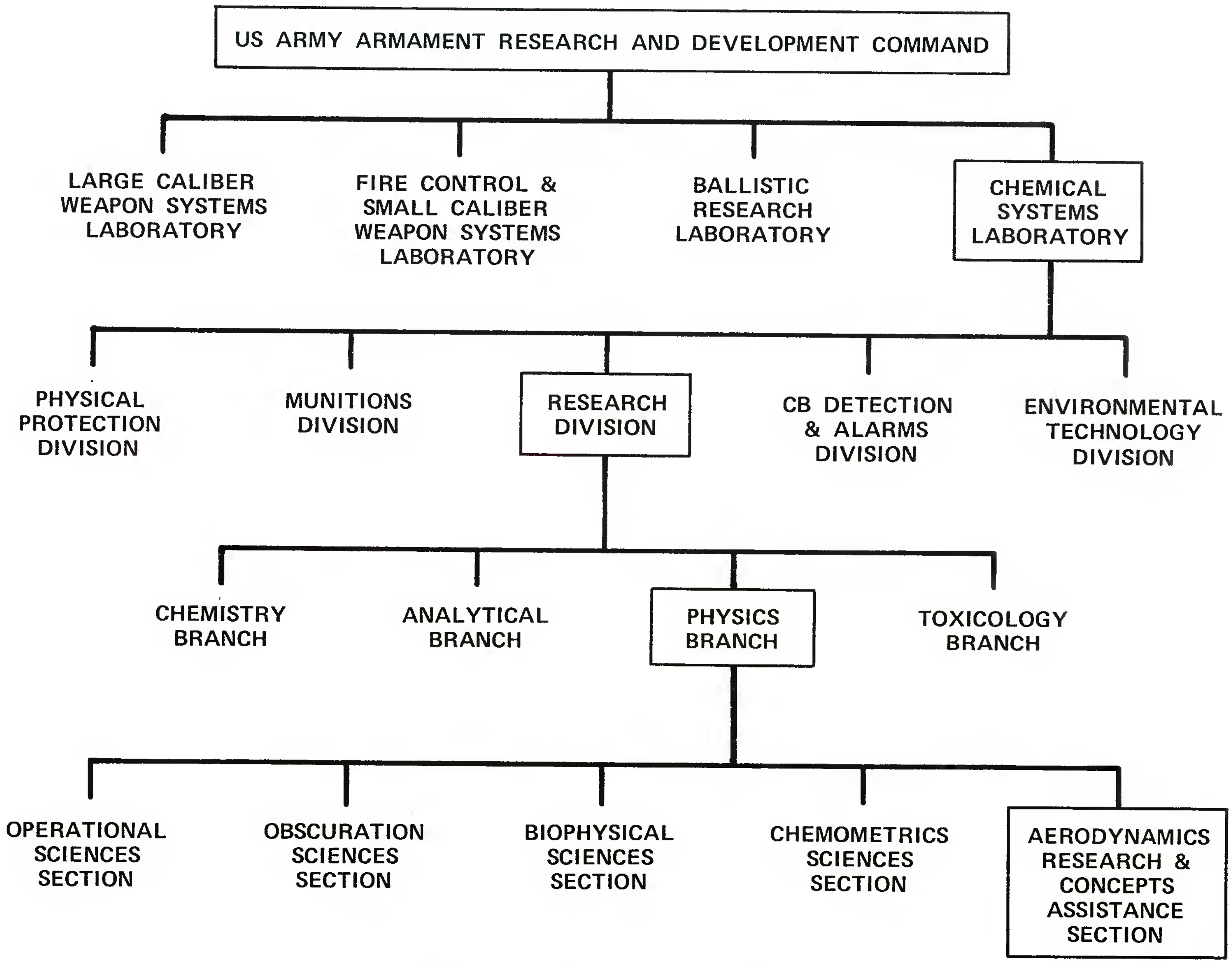

Figure 1. Organizational Chart

AERODYNAMICS RESEARCH AND CONCEPTS ASSISTANCE SECTION

CONDUCT AERODYNAMIC RESEARCH IN SUPPORT OF CSL PROGRAMS WITH EMPHASIS ON FLIGHT PERFORMANCE REQUIREMENTS AND PAYLOAD EFFECTS UNIQUE TO CHEMICAL MUNITION DELIVERY VEHICLES

PROVIDE ASSISTANCE TO ARRADCOM AND DOD IN THE FEASIBILITY DEMONSTRATION OF ADVANCED AERODYNAMIC WEAPONS CONCEPTS

Figure 2. Mission Statement

## 2. SUBSONIC WIND TUNNEL (40x28 INCHES)

This is an open circuit, continuous flow, subsonic wind tunnel having a rectangular test section 40 inches wide, 28 inches high, and 72 inches long. The tunnel is powered by a 125-horsepower electric motor which operates a constant-speed fan located downstream of the test section. Test section air velocity is controlled by means of variable opening louvers which regulate airflow through the fan. This permits a range of air velocity in the test section from 10 to 240 ft/sec. The downstream fan arrangement results in a low turbulence air flow condition. The 96-inch wide by 72-inch high settling chamber can also be used as a secondary test section, allowing larger items to be tested over a velocity range from 5 to 40 ft/sec. Both the test section and settling chamber include extensive window area for observation of the model during the test.

The tunnel is specifically designed for testing of ordnance items such as projectiles, bombs, submunitions, parachutes, and special aerodynamic devices. A variety of strut and sting supports can be adapted to specific models and instrumentation arrangements depending on the model configuration and the type of experimental data desired. Internal strain gage balances covering a range of sizes and load capabilities are available for static force and moment tests. Mounting fixtures to assess dynamic stability and evaluate the characteristics of spinning configurations can also be utilized. Special purpose tests to measure specific phenomena or the functioning of particular mechanical components can also be accomplished.

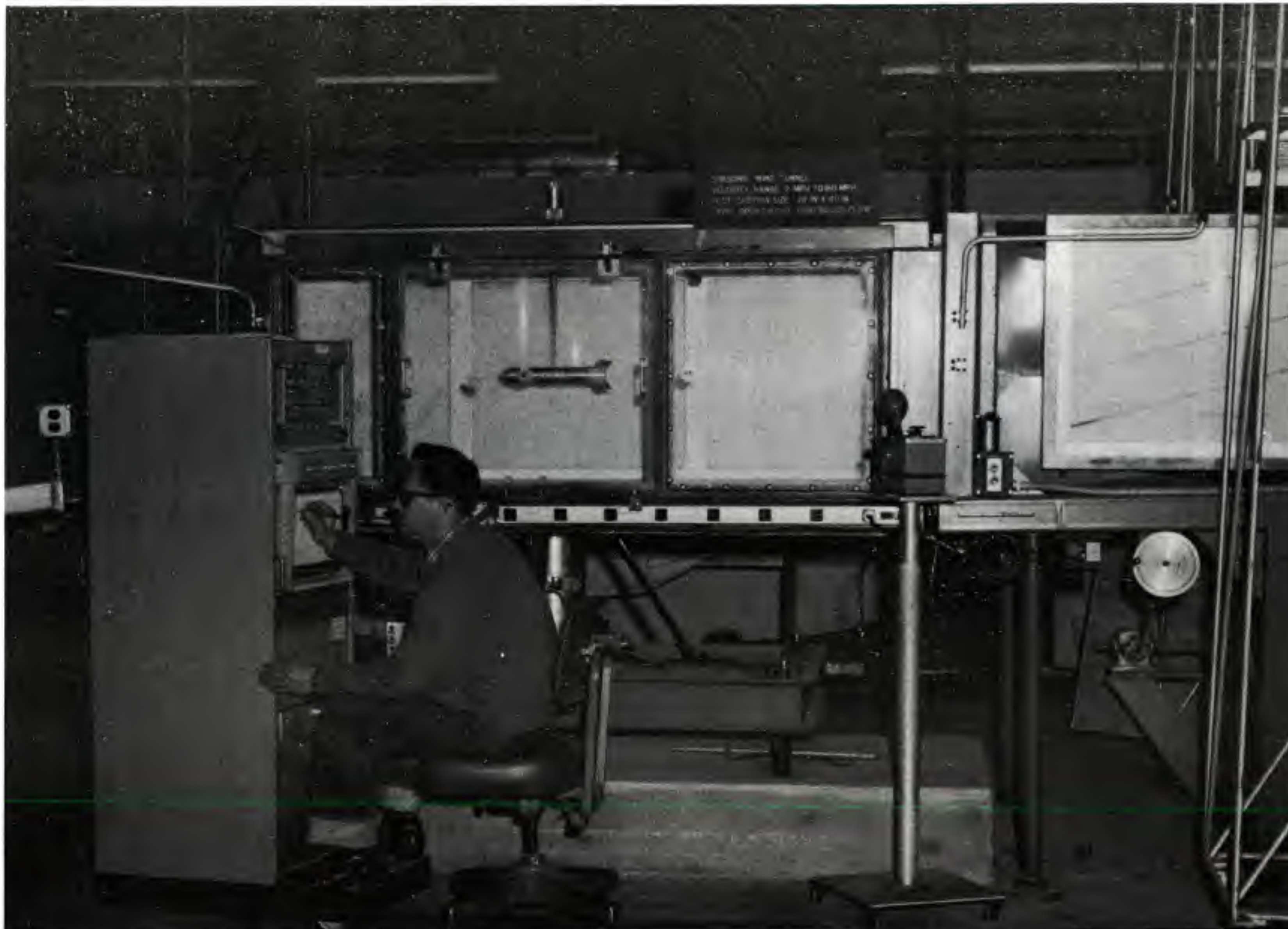

Figure 3. Subsonic Wind Tunnel (40 x 28 Inches)

Figure 4. Typical Model Installation in 40x28 Inch Subsonic Wind Tunnel

## 3. TRANSONIC WIND TUNNEL (20x20 INCH)

This is an open circuit, blow down transonic wind tunnel which exhausts to the atmosphere. The square perforated test section measures 20 by 20 inches and has a length of 72 inches. The tunnel has a fixed sonic nozzle with the test section Mach number controlled by a combination of stagnation pressure setting, adjustment of plenum chamber flow flaps, and use of diffuser chokes. The tunnel can be operated at any Mach number between .45 and 1.2, including Mach 1.0. An air supply tank volume of 6,000 $ft^3$ at 140 psi is available allowing test runs of up to 14 seconds duration. Pump up time required to replenish the air supply between runs is about 30 minutes. Side windows are available which allow observation of the model during the test.

The tunnel is specifically designed to evaluate the aerodynamic performance and structural characteristics of ordnance items. The high Reynolds number flow situation duplicates actual dynamic pressures present at sea level flight conditions. Intentional release of components or structural failure of test elements can occur without damage to the wind tunnel. Both sting and side wall model mounts are available which can be adapted to a variety of internal strain gage balance systems for force and moment tests. These mounts include an automatic pitch/pause mechanism to allow rapid angle-of-attack surveys during the limited tunnel operation times. Other special instrumentation and data acquisition arrangements can be installed depending on the test requirements.

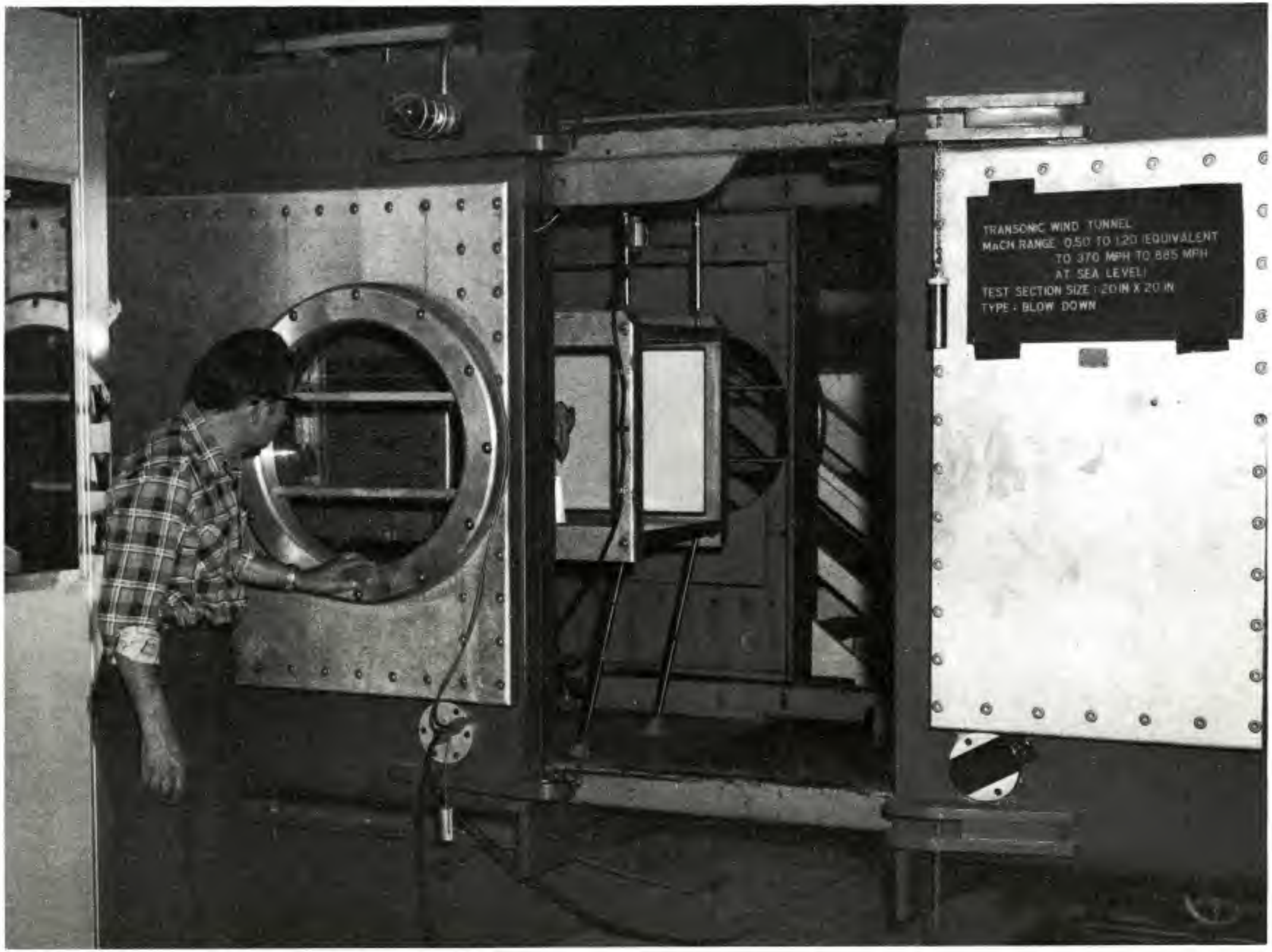


Figure 5. Transonic Wind Tunnel (20 x 20 Inch)

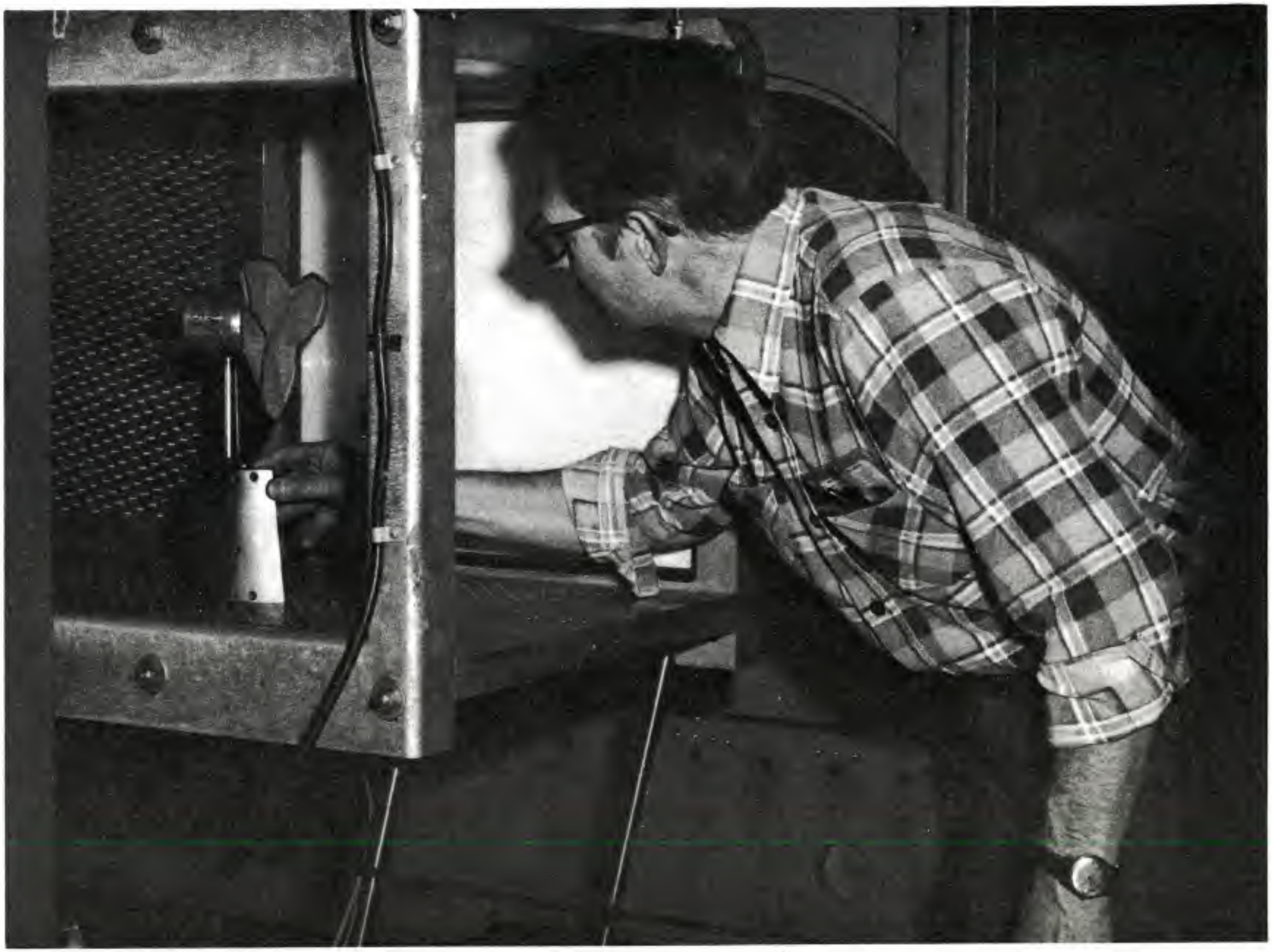

Figure 6. Typical Model Installation in 20x20 Inch Transonic Wind Tunnel

## 4. SUPERSONIC WIND TUNNEL (6x6 INCH)

This is an open circuit, blow down, supersonic wind tunnel which exhausts to the atmosphere. The square test section measures 6 inches by 6 inches. The tunnel can be operated at any fixed Mach number between 1.5 and 3.8. In addition, the Mach number can be selectively varied during the run. This feature provides a means of rapidly evaluating the aerodynamic characteristics of a configuration as a function of Mach number during a single run. Run times of up to 20 seconds are possible with the 6,000 $ft^3$, 175 psi air supply available. About 10 minutes are required to pump-up the air supply tanks between runs.

The tunnel was designed for testing scale models of ordnance items. However, full scale models of small projectiles can also be evaluated. The open diffuser arrangement permits release of model components or liquids in the test section. A selection of internal and external strain gage balances and associated mounting fixtures are available for both static and dynamic testing. In addition, a color schlieren system allows visualization of the flow field.

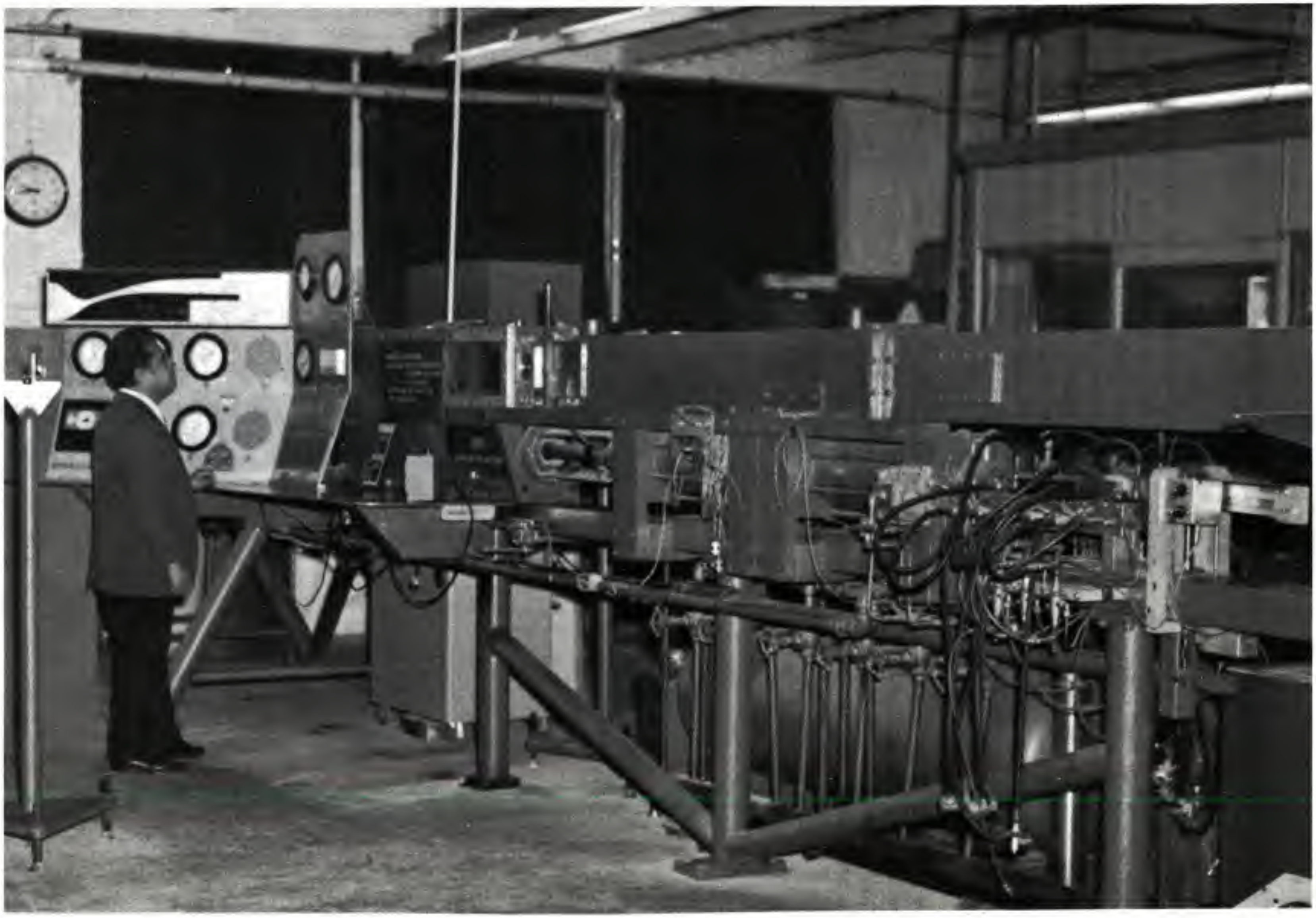

Figure 7. Supersonic Wind Tunnel (6 x 6 Inch)


Figure 8. Typical Model Installation in 6x6 Inch Supersonic Wind Tunnel

## 5. VERTICAL WIND TUNNEL

This is an open circuit, continuous flow, subsonic wind tunnel oriented to have the air flow in a vertically upward direction. The tunnel includes two octagonal test sections mounted in tandum. The lower test section measures 30 inches across its flat surfaces and has a length of 96 inches. The upper test section measures 20 inches across the flat surface and is 48 inches long. The constant speed fan located on the lower level, upstream of the test sections, is powered by a 150-horsepower, electric motor. Air speed control in both test sections is provided by variable opening louvers which regulate the air flow to the fan. Maximum air flow velocity in the larger test section is 140 ft/sec and in the smaller test section is 400 ft/sec.

The main purpose of a vertical type tunnel is to evaluate the dynamic motion of free flying configurations. The test section velocity can be adjusted so that the upward directed aerodynamic drag exerted on the model is equal to its downward acting weight. The model will then be freely suspended in the test section without the motion constraints and flow interference effects of rigid mounts or struts. Although the model is prevented from translating, it is free to assume its natural motion for all three degrees-of-rotational-freedom: pitch, yaw, and roll. This is particularly valuable for testing free fall munitions such as submunitions and special devices where flight stability and minimal rotational motion is of prime importance. The facility has also been used to investigate flow phenomena associated with liquid droplets and other aerodynamic bodies which are sensitive to support interference and motion cross coupling effects. Rapid and accurate screening of a large number of configurational parameters are possible. Extensive transparent windows around the test sections permit direct observation or filming for documentation and analysis. Selection of model scale and weight allow evaluation of Reynolds number variation as well as the determination of terminal velocity values. Special force and moment balances and associated mounting arrangements can also be installed in the test section as required.

Figure 9. Vertical Wind Tunnel

Figure 10. Typical Model Installation in 18 x 18 Inch Test Section of Vertical Wind Tunnel

## 6. PROJECTILE FLIGHT SIMULATOR FOR NON-RIGID PAYLOADS

This special laboratory flight simulator causes a full scale canister and inclosed payload from an artillery projectile to ungergo the combined spin and coning motion of the actual projectile in flight. The payload thus experiences the basic inertial environment it would have in flight and can respond in the same dynamic sense. The canister is attached to the simulator frame by bearings, allowing it to spin freely about its longitudinal axis, while the frame is forced to spin about a vertical axis. This results in the canister assuming the desired simultaneous spinning and coning motion similar to that of the projectile in flight. The simulator can accept a large variety of different canister geometries and sizes encompassing a broad range of artillery projectile calibers. The mass of the fully loaded canister can be as large as 100 lbs. Canister spin rates up to 15,000 rev/min and coning rates of 1,200 rev/min can be achieved. The canister can be set for fixed angle coning from 0 to 20 degrees in 5-degree increments. Tests could be conducted over a range of constant coning rates at each fixed coning angle, thus encompassing spin and precession motion corresponding to various firing zones and projectile flight yaw angles.

Various types of instrumentation can be incorporated in the simulator to measure different phenomena of interest. Of particular inportance is the despin moment created by the movement of certain non-rigid payloads associated with chemical munitions in response to the flight motion of the projectile. The magnitude of this despin moment can be easily and accurately measured on the simulator and is used to assess the potential of the payload to create a projectile flight instability. The simulator can also be used in experimental investigations of the detailed behavior of liquid fills with regard to both flight instabilities and mixing characteristics.

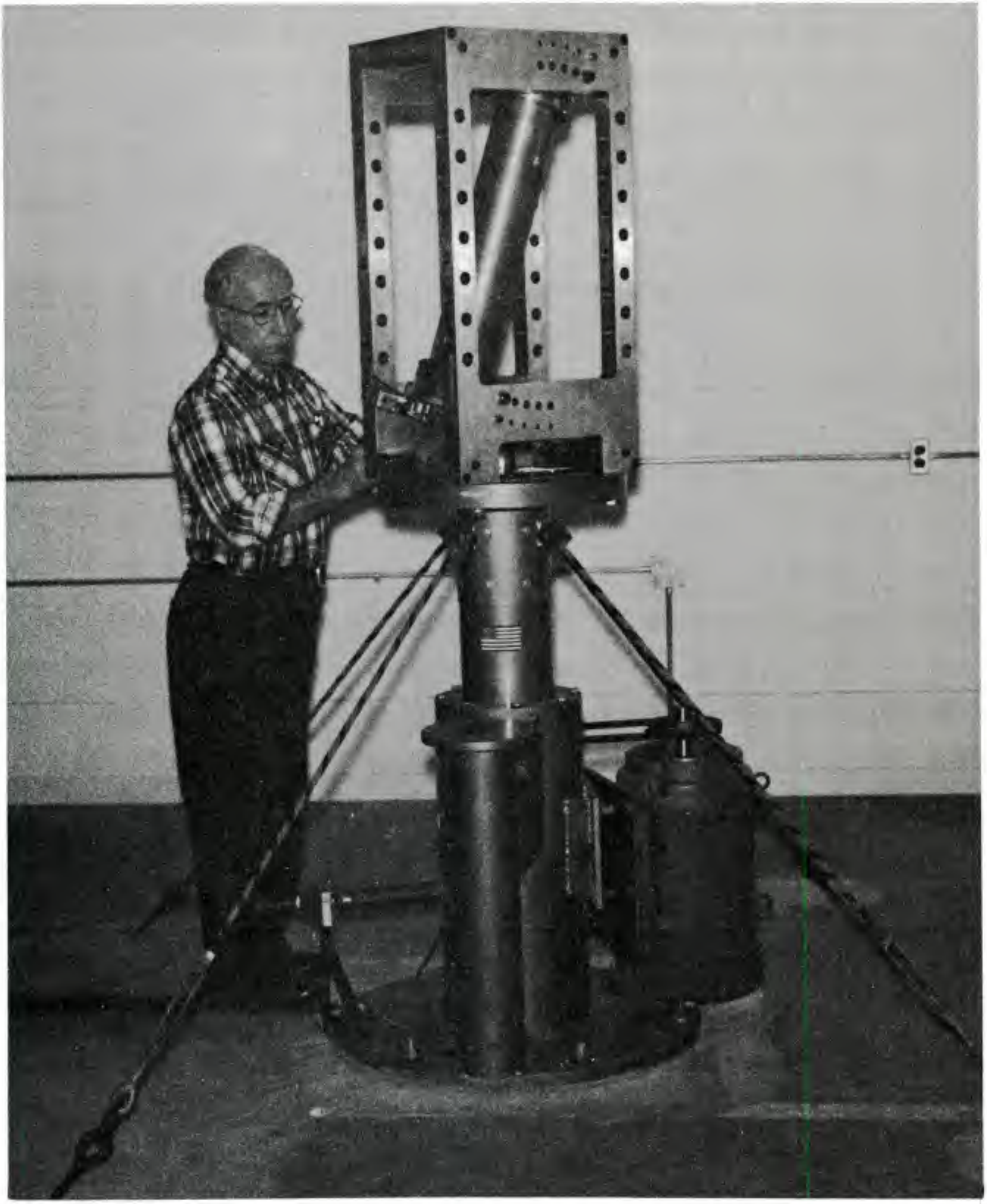

Figure 11. Flight Simulator for Non-Rigid Payloads

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