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**CHEMICAL
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CENTER**

CRDEC-TR-309

**EXPERIMENTAL AERODYNAMIC FACILITIES
OF THE AERODYNAMICS RESEARCH AND
CONCEPTS ASSISTANCE BRANCH**

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RESEARCH DIRECTORATE**

February 1992

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**U.S. ARMY
ARMAMENT
MUNITIONS
CHEMICAL COMMAND**



Aberdeen Proving Ground, Maryland 21010-5423

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PREFACE

The work described in this report was authorized under Project No. 1O1611O2A71A, Research in CW/CB Defense, Chemical Deterrence. This work was started in January 1992 and completed in February 1992.

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EXPERIMENTAL AERODYNAMIC FACILITIES OF THE AERODYNAMICS RESEARCH AND CONCEPTS ASSISTANCE BRANCH

1. INTRODUCTION

The Aerodynamics Research and Concepts Assistance Branch (ARCA Br) is one of several research activities within the Chemical Research, Development and Engineering Center (CRDEC) of the U.S. Army Armament, Munitions and Chemical Command (AMCCOM), as shown in Figure 1. The ARCA Br personnel and laboratory facilities are located at the Edgewood Area of the Aberdeen Proving Ground, Maryland 21010-5423. The mission of the ARCA Br 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 munition 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 ARCA Br personnel and their special aerodynamic laboratory facilities, the mission also includes providing assistance to AMCCOM and DOD in demonstrating the feasibility of advanced aerodynamic weapons concepts.

To support this mission, the ARCA Br possesses an aerodynamic laboratory with a unique array of experimental aerodynamic facilities including four wind tunnels, a unique projectile flight simulator and several special purpose air guns. 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 motion of the projectile in flight. The airguns allow a wide range of projectile sizes, velocities and spin rates to be evaluated.

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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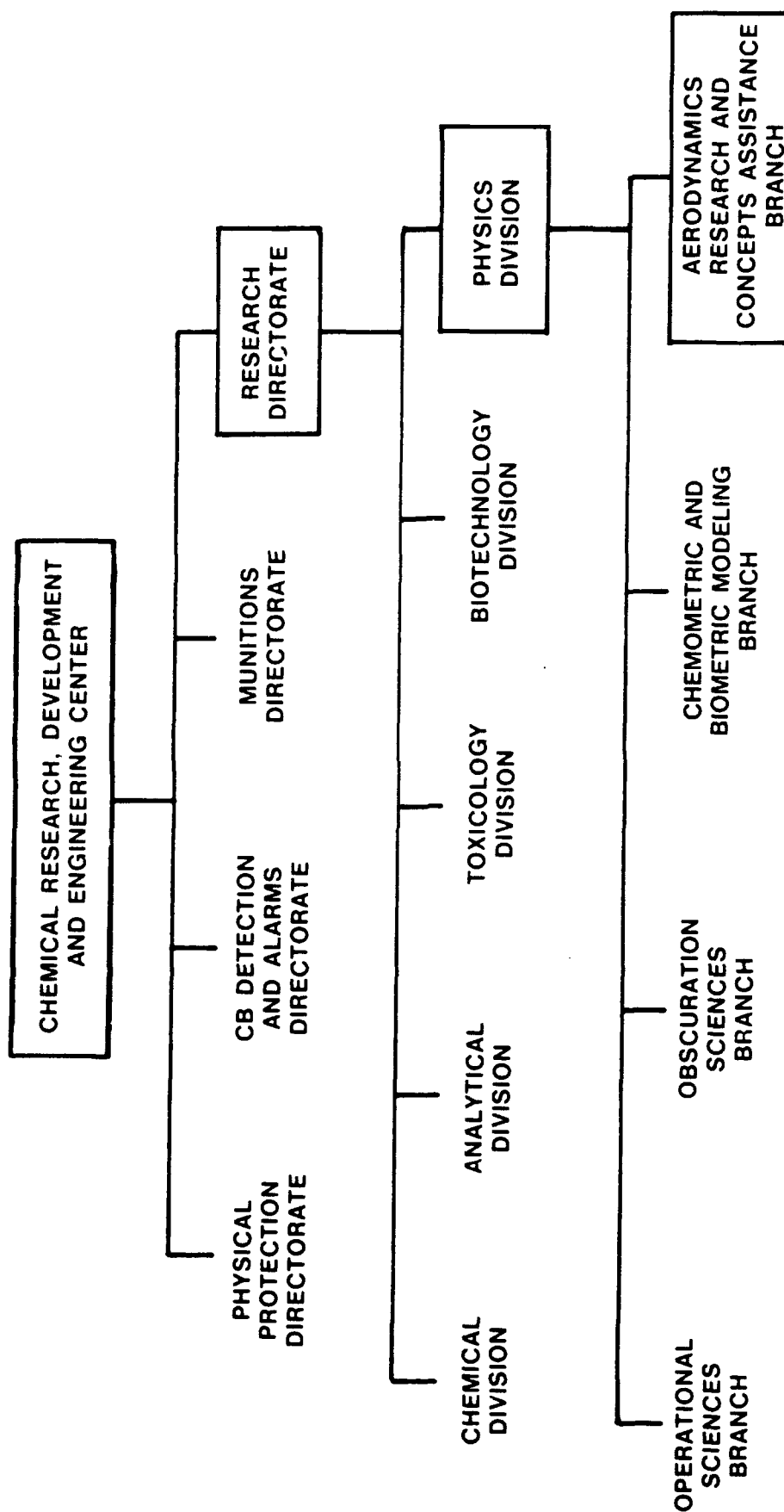


Figure 1. Organizational Chart

**AERODYNAMICS RESEARCH AND CONCEPTS
ASSISTANCE BRANCH**

**CONDUCT AERODYNAMIC RESEARCH IN SUPPORT OF CHEMICAL
RESEARCH AND DEVELOPMENT CENTER 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

This is an open circuit, continuous flow, subsonic wind tunnel having a rectangular test section 1.0 m wide, 0.7 m high, and 1.8 m long. The tunnel is powered by a 94 kilowatt 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 3 to 73 m/sec. The downstream fan arrangement results in a low turbulence air flow condition. The 2.4 m wide by 1.8 m high settling chamber can also be used as a secondary test section, allowing larger items to be tested over a velocity range from 1.5 to 12 m/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.

A computerized data acquisition system is utilized to automate the acquisition, reduction and plotting of the resultant test data.

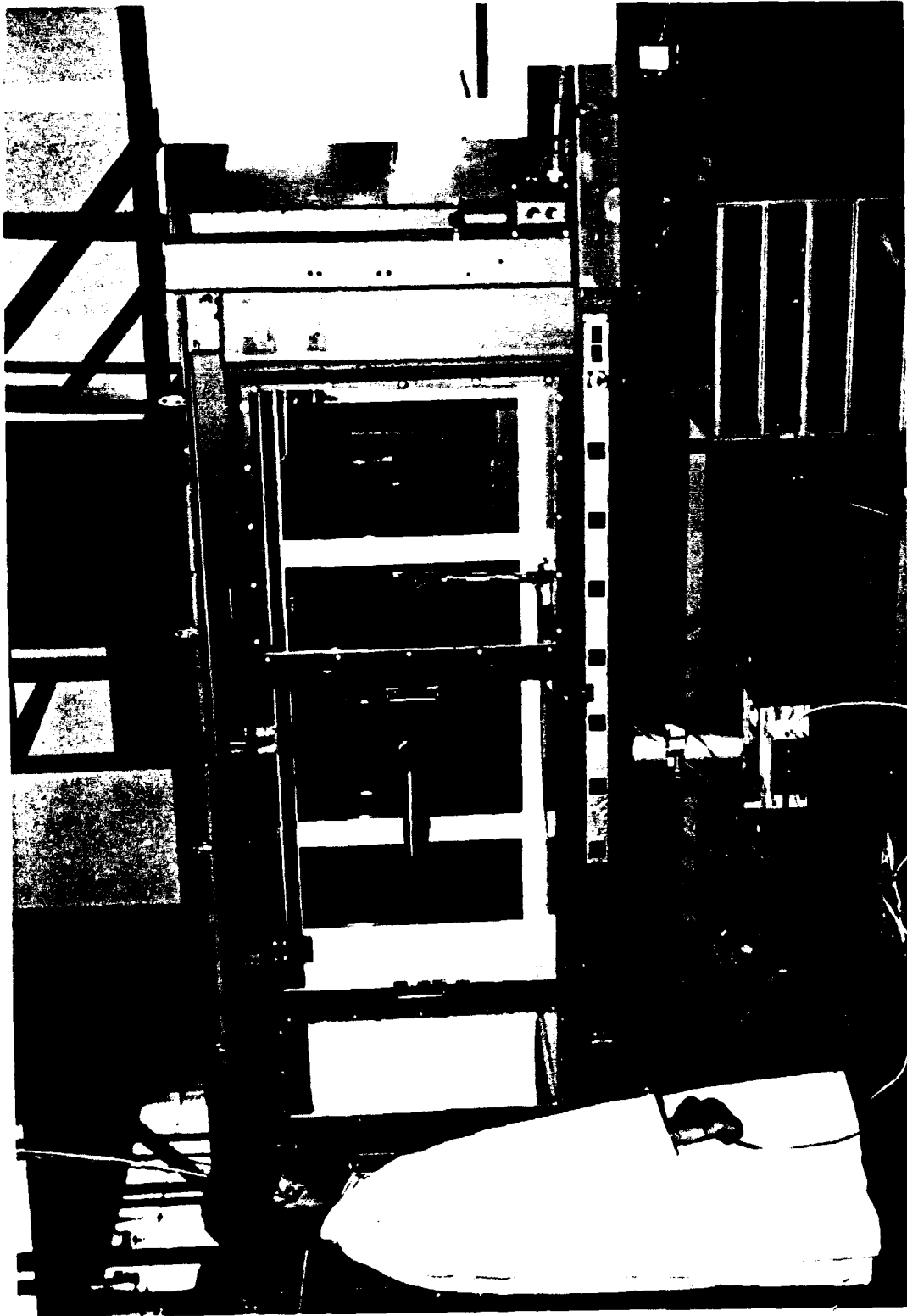


Figure 3. Subsonic Wind Tunnel (0.7 X 1.0 Meters)

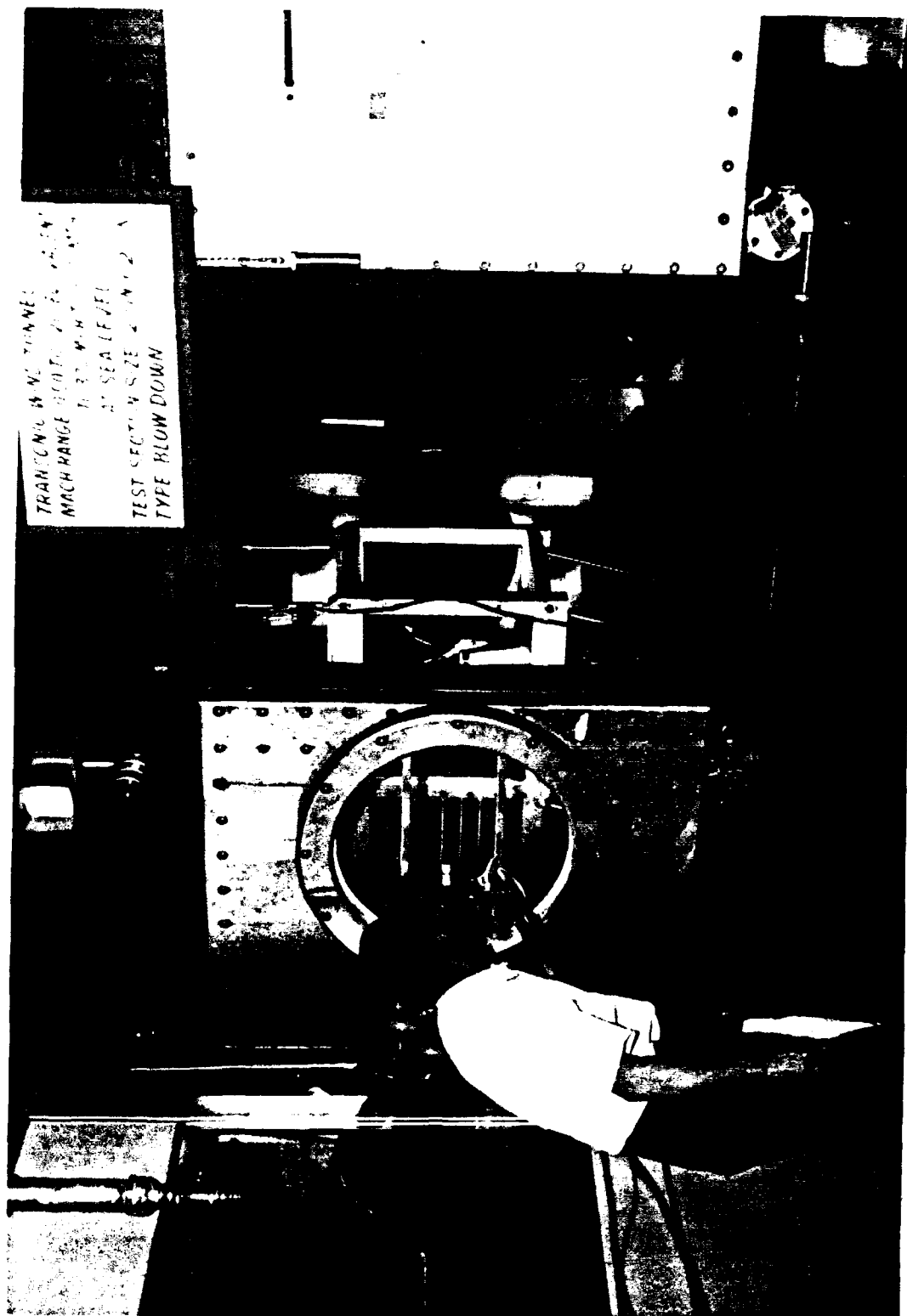


Figure 4. Typical Model Installation in 0.7 X 1.0 Meter Subsonic Wind Tunnel

3. TRANSONIC WIND TUNNEL

This is an open circuit, blow down, transonic wind tunnel which exhausts to the atmosphere. The square perforated test section measures 0.5 m by 0.5 m and has a length of 1.6 m. 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 0.45 and 1.2, including Mach 1.0. Test section stagnation pressures can be varied from 0.034 through 138 kPa. An air supply tank volume of 170 m³ at 1.0 MPa 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 static force and moment tests as well as pitch and roll damping rigs to evaluate dynamic stability. 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.



TRANSONIC WIND TUNNEL
MACH RANGE 0.4 TO 0.8
10-20 M.W. X 10-20 M.H.
2" SEA LEVEL
TEST SECTION SIZE 2' IN X 2' IN
TYPE BLOW DOWN

Figure 5. Transonic Wind Tunnel (0.5 X 0.5 Meters)



Figure 6. Typical Model Installation in 0.5 X 0.5 Meter Transonic Wind Tunnel

4. SUPERSONIC WIND TUNNEL

This is an open circuit, blow down, supersonic wind tunnel which exhausts to the atmosphere. The square test section measures 0.15 m by 0.15 m. 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 170 m³, 1.2 MPa 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 (0.15 X 0.15 Meters)

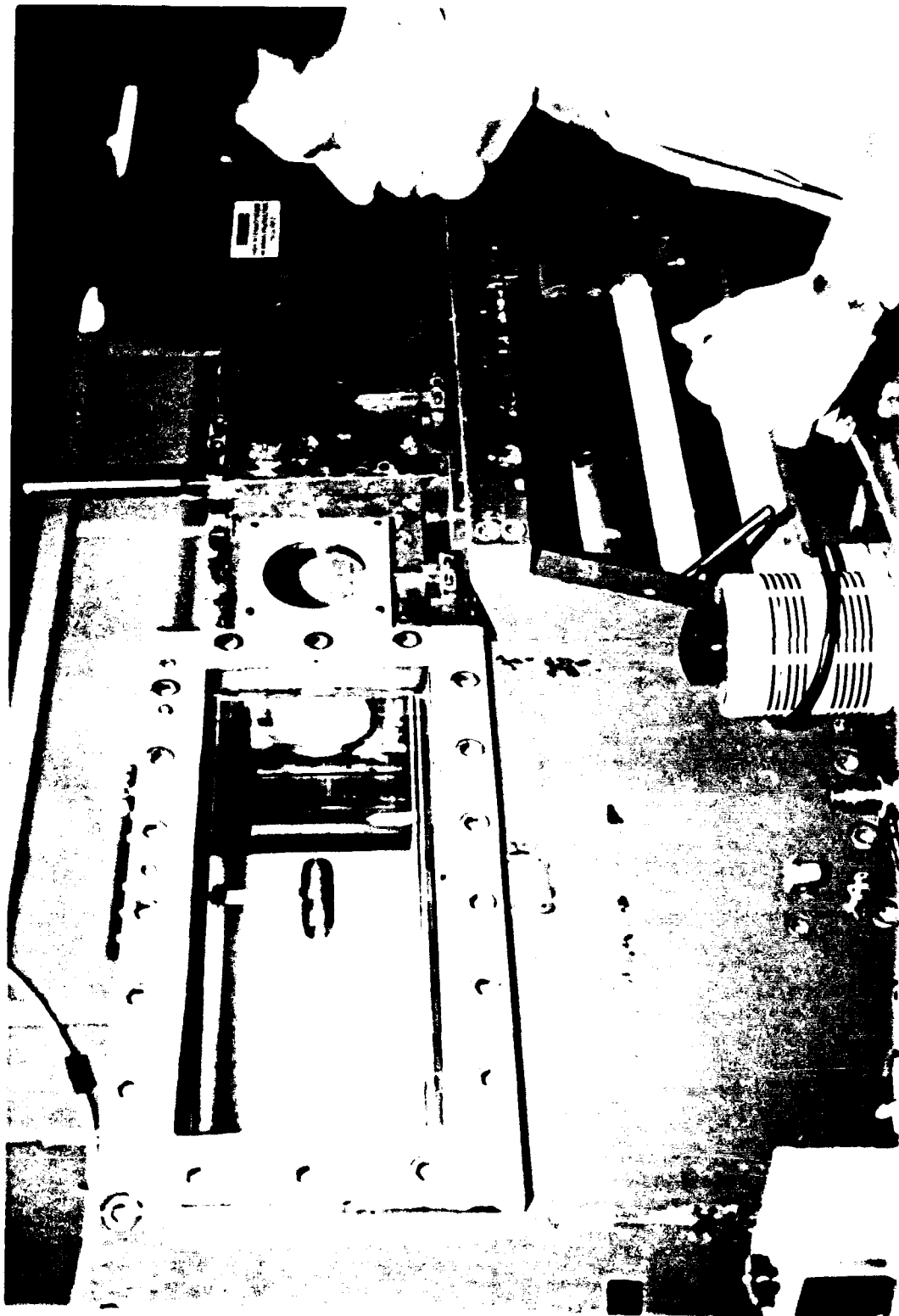


Figure 8. Typical Model Installation in 0.15 X 0.15 Meter Supersonic Wind Tunnel

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 tandem. The lower test section measure 0.76 m across its flat surfaces and has a length of 2.9 m. The upper test section measures 0.46 m across the flat surface and is 1.2 m long. The constant speed fan located on the lower level, upstream of the test sections, is powered by a 92 kilowatt 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 43 m/s and in the smaller test section is 122 m/s.

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.

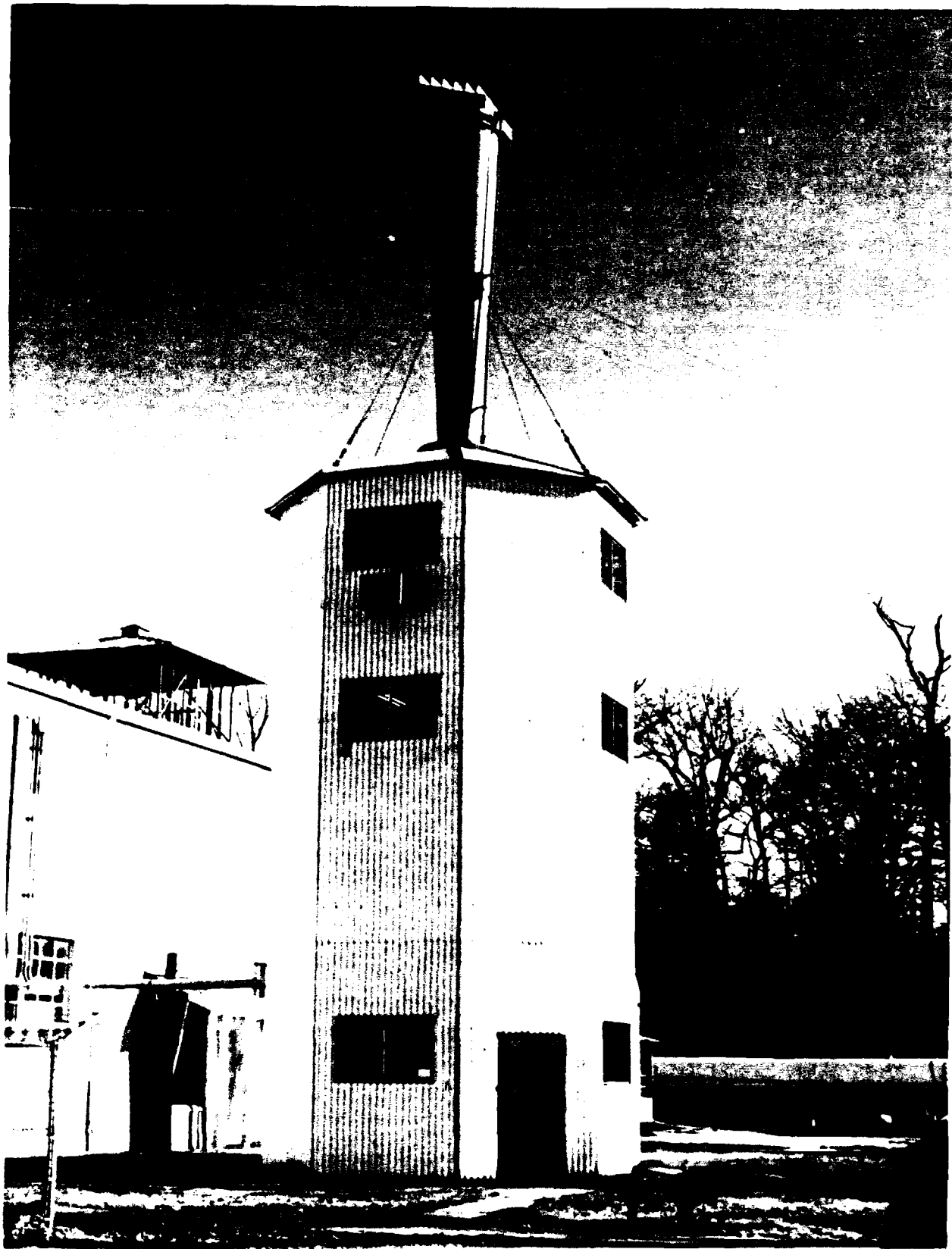


Figure 9. Vertical Wind Tunnel

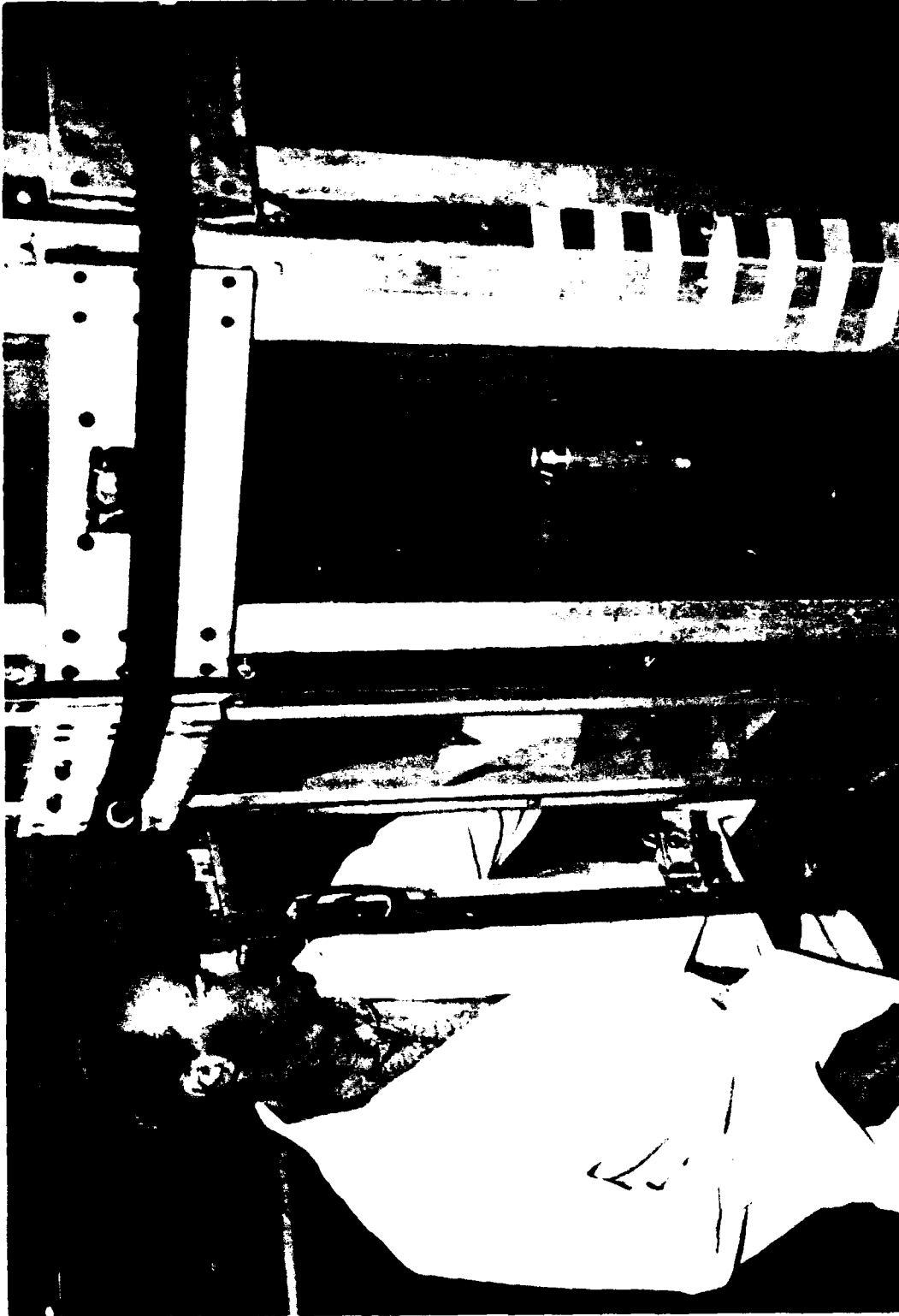


Figure 10. Typical Model Installation in 0.46 X 0.46 Meter Test Section of the Vertical Wind Tunnel



Figure 11. Typical Model Installation of 0.76 X 0.76 Meter Test Section of the Vertical Wind Tunnel

6. LABORATORY TEST FIXTURE FOR NON-RIGID PAYLOADS

This special laboratory fixture causes a full scale canister and inclosed payload from an artillery projectile to undergo 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 45 kg. Canister spin rates up to 200 Hz and coning rates of 17 Hz can be achieved. The canister can be set for fixed angle coning from 0 to 20° degrees in 5° 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 importance 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 fixture can also be used in experimental investigations of the detailed behavior of liquid fills with regard to both flight instabilities and mixing characteristics.

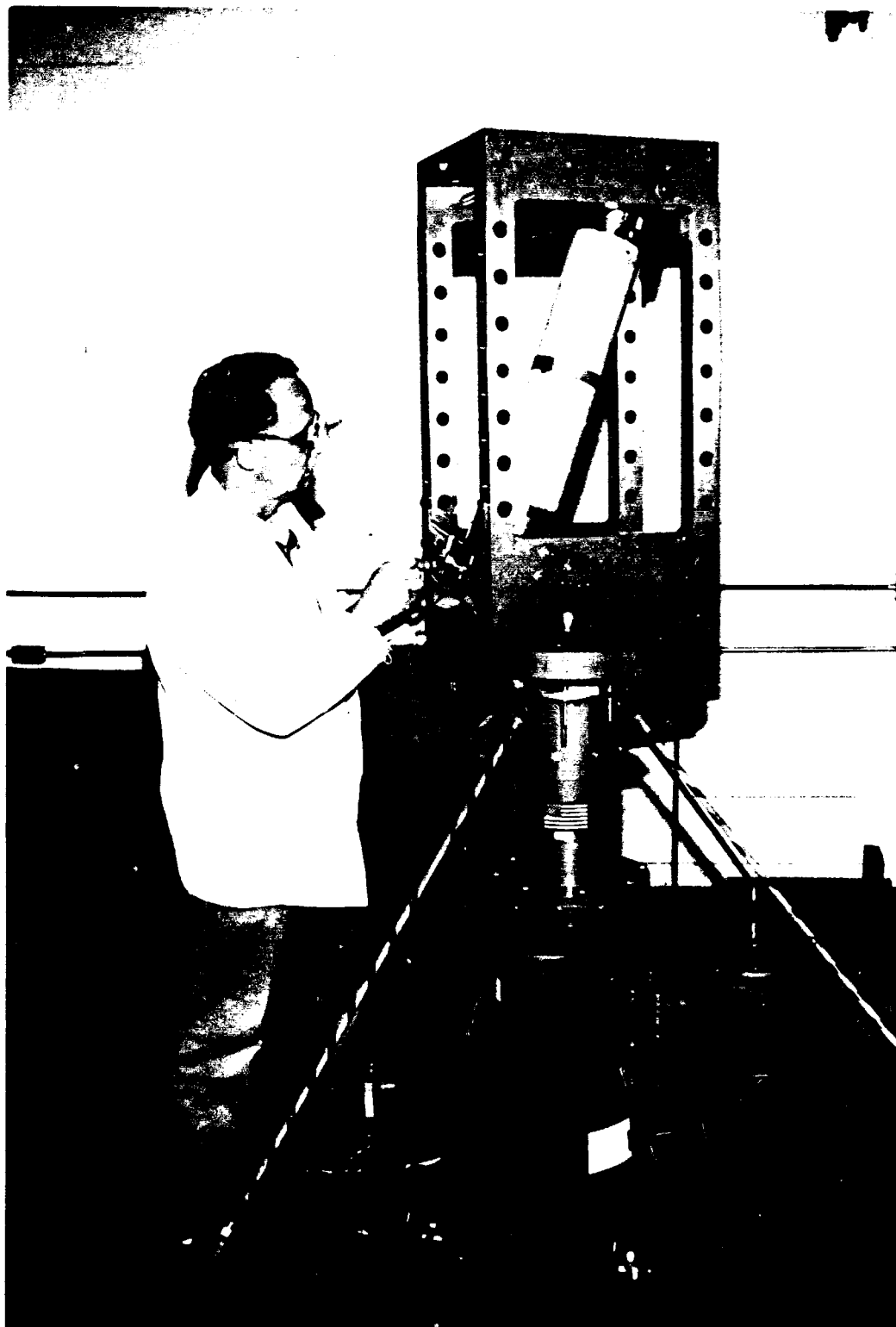


Figure 12. Laboratory Test Fixture for Non-Rigid Payloads

7. 155mm, SPINNING BARREL AIR GUN

The 155mm, Spinning Barrel Air Gun allows a variety of projectile configurations, weights and sizes to be launched over a large range of preselected velocities and spin rates. The gun barrel has an inside diameter of 155mm and an inside length of 2.4 m. Propulsive energy is provided by gaseous nitrogen contained in a 0.1 m³ rechargeable supply tank. The current maximum operating pressure for the gun is 6.9 MPa which can be increased in the future to 20.7 MPa. A reusable, quick-opening valve releases the high pressure nitrogen from the tank to the barrel in 3 milliseconds. Barrel spin is achieved by means of a nozzle/turbine arrangement using compressed air.

The gun and all ancillary components are mounted on a mobile trailer. Another special trailer contains standard compressed nitrogen bottles for recharging the gun. The gun and bottle trailers are shown in Figure 13. Compressed air for the barrel spin is acquired from a mobile, trailer mounted compressor. At a nominal pressure, the gun can launch a 4.5 kg projectile at 305 m/s. Heavier or lighter weight projectile can be fired at correspondingly lower or higher velocities. Various projectile shapes and sizes can be fired by utilizing proper sabot designs. The barrel can be spun at spin rates from 0 to 150 Hz independent of the desired launch velocity.

Ejection and dissemination of full scale payloads from 155mm artillery projectiles can be simulated with the gun producing the same velocity and spin rate conditions experienced in flight. The air gun will also allow the flight behavior of new chemical munitions to be evaluated without the instrumentation problems, complexity and costs associated with the use of standard gun or rocket systems. Ballistic screens and doppler radar instrumentation are available to measure muzzle and flight velocities. Details of inflight performance of test projectiles can be obtained from high speed movies or stop action still photographs.

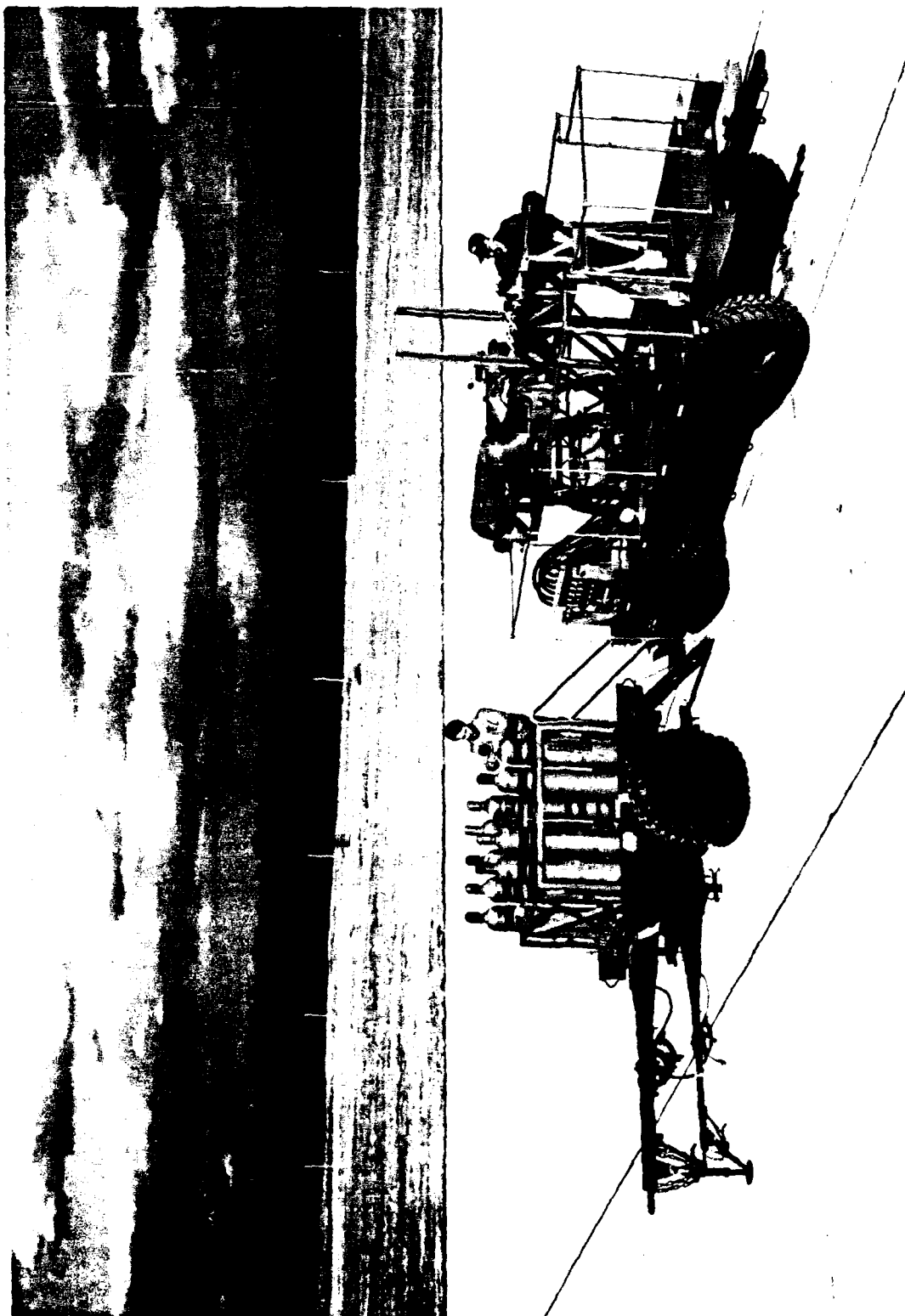


Figure 13. 155mm Spinning Barrel Air Gun

8. COMPUTER AIDED DESIGN SYSTEM

The branch includes a Computer Aided Design (CAD) system which allows models, mounts and associated components to be designed and associated engineering drawings prepared. A typical workstation for the COMPUVISION CAD system is illustrated in Figure 14. Both planar, individual and assembly drawings as well as wire-frame and solid, three-dimensional formats can be created. These workstations are tied directly into the main CRDEC CAD computer network which uses identical hardware and software elements. This makes possible the utilization of automatic computer aided equipment during fabrication in the CRDEC shop facilities which are located adjacent to the ARCA Br laboratory area. This arrangement permits the rapid design and fabrication of hardware required for experimental operations.



Figure 14. Computer Aided Design (CAD) System