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PERFORMANCE OF THE AMF 36- AND
48-INCH BLAST CLOSURE DEVICES

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by:

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ABSTRACT

The 36- and 48-inch AMF blast closure devices were tested to determine their air flow characteristics, closure times, blast resistance and weatherability. At an air flow of 10,000 cfm, the 36-inch valve had an intake pressure drop of 0.55 inches of water and an exhaust pressure drop of 0.39 inches of water; the 48-inch valve at an air flow of 13,000 cfm had an intake drop of 0.53 inches of water and an exhaust drop of 0.36 inches. The closure time of each valve was about 170 msecs. Sensor reaction time averaged about 50 msecs. The 36-inch valve was not damaged by tests in the NCEL Atomic Blast Simulator at pressures up to 192 psi; however, the 48-inch valve's reopening and latching mechansim was moderately damaged when subjected to a blast pressure of 204 psi. The effects of three years of weathering indicates that a severe corrosion problem exists unless the valves receive proper maintenance.

INTRODUCTION

Vitiation of air in underground military shelters is minimized by the use of mechanical ventilation systems. Outside air is drawn in, mixed with shelter air, and then discharged to the outside. This air passes through intake and exhaust ducts which open at the earth's surface. In blast-protected shelters, these openings must be fitted with a closure device to prevent the entrance of the overpressure from a nuclear explosion.

There are two basic types of blast exclusion devices, usually called blast closure valves; one is actuated by the flash and the other by the blast wave of a nuclear explosion. The Bureau of Yards and Docks (BUDOCKS) and the Defense Atomic Support Agency (DASA) have sponsored the test and evaluation of various blast valves at NCEL to determine their air-flow characteristics, closure times, blast resistance and weatherability. This report covers the results of tests on the 36- and 48-inch diameter flash-actuated valves developed for BUDOCKS by the American Machine and Foundry Company (AMF).

BLAST VALVE DESCRIPTION

The two AMF blast valves are of the poppet type and are almost identical in design except for their size. An exterior view of the 48-inch model is shown in Figure 1. The cast-aluminum torispherically-shaped head has radial reinforcing ribs and is supported by a machined-steel, hollow 7-3/4-inch O.D. shaft which slides in a tube. Inside this shaft is a spiral compression spring to hold the head open and a small shaft inside the spring connecting the head to a piston in the operating air cylinder. The head is closed against the resistance of the spring when high-pressure air enters the operating air cylinder. The head is kept closed by four pins spaced 90 degrees apart near the rims of the head which engage mating spring-loaded latches on the valve body. The latches are released by air applied to a low-pressure air cylinder located at the end of the above mentioned tube. Figure 2 shows the latches, cables and pulleys associated with the closing and opening of the valve.

Air from a 25-cubic inch high-pressure air bottle is piped through an explosive valve and a four-way manual control valve on its way to the operating air cylinder. It is also piped to the re-opening air cylinder. The bottle has been sized to hold enough pressurized air for one closing and one opening of the valve. This air bottle, the electronics equipment for amplifying the signal from the sensing element, and the valves and fittings are all located in

a control box as shown in Figure 3. By use of the four-way valve, the explosive valve can be by-passed for manual operation of the blast closure valve.

The blast valve is operated when the squib in the explosive valve is fired by an electrical impulse from a sensing element. The high pressure air in the air bottle is thus released.

The sensing element detects only the characteristic double flash of a nuclear explosion and is omni-directional. In actual use it could be located aboveground on a pedestal or it could be located belowground with a mirror system reflecting the flash to the sensor.

TEST FACILITY AND INSTRUMENTATION

The air flow and blast resistance tests were conducted on existing laboratory facilities.

Air Flow and Pressure Loss

The air flow characteristics were determined in the air-flow-measurement test duct. The test facility consists of a heavy duty centrifugal blower, a 15-hp varidrive motor, a variable inlet vane-type air controller, a short inlet duct, and the discharge duct where the air flow measurements are made. The air flow duct, which is 28 inches in diameter by 24 feet long and has an "egg-crate" type air straightener, was designed to AMCA* standards. A maximum air flow of about 15,000 cfm can be obtained; however, this depends on the resistance to air flow of the device being tested. Air flow was actually measured with a Taylor pitot-venturi tube which previously had been calibrated with a standard pitot tube.

Pressure drop of the valve at various air flows was determined by measuring the difference in static pressure between the upstream and downstream side with a Merium micro-manometer. The head of the AMF valve is always at atmospheric pressure, therefore the measured pressure drop also includes a duct entrance or exit pressure loss. A piezometer ring was installed on the transition ducts connecting the valve to the test facility. This averages the static pressure at that point.

*Air Moving and Conditioning Association, formerly National Association of Fan Manufacturers.

Closure Times

The closure time of each valve was determined by triggering the valve from a simulated flash of a nuclear explosion. The activation and closure events were recorded on an oscillograph.

The simulated flash aimed at the sensing element, was produced by using a stroboscopic light for the first sharp pulse and a 250-watt infra-red bulb for the long-rise second pulse. A micro-switch was affixed to the valve to indicate closure of the valve's head. The oscillograph was connected to the stroboscopic light, the explosive valve, and the micro-switch. The chart paper from the oscillograph, moving at a known speed, indicated a "blip" when the strobe light was flashed, a second "blip" when the explosive valve was fired, and a third "blip" when the valve head was closed. Sensor reaction time and valve closure time was obtained from this graph.

Blast Resistance

The tests to determine the blast resistance characteristics of each valve were conducted in the Atomic Blast Simulator. This simulator, originally built for testing structural components, is capable of generating blast pressures up to about 200 psi with decay times similar to those from a nuclear weapon burst. Figure 4 shows the 48-inch valve in place, ready for test.

The pressure exerted on the head of the valve was measured by two Statham pressure-measuring cells. The strains at various locations on the valve judged to be points of maximum strain were determined by SR-4 strain gages. The information from these instruments was recorded on a Consolidated Electronics Company oscillograph.

METHOD OF TEST

The evaluation of each valve consisted of tests to determine its pressure drop over a range of air flows, closure times, blast resistance and weatherability.

Air Flow and Pressure Loss

The air flow characteristics of the valve were determined first with the air entering the valve and then with air leaving the valve. These two positions respectively simulate actual use of the valves on the intake and exhaust air ports of a protective shelter. Pressure loss data was recorded at intervals over a wide range of air flows, generally up to the maximum capacity of the blower.

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Closure Times

The closure time tests were conducted on the 48-inch valve with the valve in both the vertical and horizontal positions and with air bottle pressures varying from the recommended 1200 psi down to 800 psi. The 36-inch valve was tested in the vertical position only at an air bottle pressure of 1200 psi. The closure times are reported as the interval between the instant that the explosive valve received the signal from the sensing element and actual closure of the head. Reaction time of the sensing element was also recorded.

Blast Resistance

Blast resistance of the valves was determined in a series of blast simulator tests that were conducted at pressures starting at about 25 psi and increasing in varying increments to approximately 200 psi. Strain gage readings were analyzed after each test to determine if the metal at the point under observation was nearing failure. The head of the valve was held in a closed position during the blast tests by the latching mechanism.

Weatherability

The weatherability of the valves was determined by placing them outside for exposure to the elements in test area approximately one-half mile from the Pacific Ocean. During the exposure period the valves remained in a vertical position. They received no maintenance nor special treatment, such as a preservative coating or lubrication of moving parts, prior to or during the tests.

RESULTS OF THE TESTS

The results of the tests to determine pressure drop at various air flow rates are given in Table I for the 36-inch valve and Table II for the 48-inch valve. This data is shown graphically by the curves in Figure 5. It can be seen that each valve has a higher pressure loss when in the intake position than for the exhaust position; the exhaust loss being about 68 percent of the intake loss. The pressure loss data includes a duct entrance or exit loss as appropriate.

The results of the closure time tests of the 48-inch valve in both the horizontal and vertical position are given in Table III. The horizontal-vertical average closure time was 171 msecs at the manufacturer recommended air bottle pressure of 1200 psi. The tests conducted at 1100 and 1000 psi indicate that closure time was

not adversely affected in either position by these lower pressures, except that for the horizontal position these times were slightly improved for reasons that are not known. The tests conducted on the 48-inch valve at a pressure of 900 psi and 800 psi in the horizontal and vertical position respectively, indicates that closure time was increasing as air bottle pressures were decreasing. The one closure time test conducted on the 36-inch valve with the air bottle pressure at 1200 psi showed that it closed in 170 msecs. The reaction time of the sensing element averaged about 50 msecs for all tests.

During the closure time tests it was observed that the residual pressure in the air bottle after closure of the head ranged from 400 to 600 psi. This was sufficient pressure to operate the reopening mechanism. An additional observation showed that during these tests the explosive valves never failed to fire.

The test data for the blast response tests are shown in Tables IV and V. An analysis of the strain-gage data for the 36-inch valve indicates that it was not near failure at any of the points investigated. The strain-gage data for the 48-inch valve shows that the strain on the radial rib increased severely as the pressure was increased; however, strain at the four highest test pressures was not obtained because of instrument malfunction. A visual inspection of the 36-inch valve showed that it received no damage whatsoever by being subjected to a 192 psi blast overpressure. The head of the 48-inch valve was not visibly damaged by a blast overpressure of 204 psi; however, during this test the closure plate at the lower end of the shaft tube failed, as shown in Figure 6. This failure also caused several of the cables connecting the air cylinder to the latching mechanism to snap.

A static pressure test of the pneumatic system of the control box when charged to 1500 psi showed that there was no significant drop in pressure over a six week period. A test on the 48-inch valve to determine the minimum pressure in the small air cylinder for re-opening the valve indicates that 200 psi is required to operate the release on the latches. Because of the similarity of the two valves, no such tests were made on the 36-inch valve.

The weatherability of the valves was observed over a three year period of outside storage. The weather during this time ranged from hot and dry to cold and rainy, with temperatures varying from about 35 F in the winter to about 82 F in the summer. The relative humidity was generally fairly high, the yearly mean averaging about 60 percent. The prevailing wind was off the ocean, averaging about 10 mph and carrying with it moisture laden air or a fine salty mist at higher velocities.

An inspection of the valves at the conclusion of the weather-
ability tests revealed that many parts were badly corroded,
particularly the chromium-plated head support shaft and key on the
48-inch valve. The support shaft on the 36-inch valve, which was
not chrome-plated, was not corroded; however, the key had deter-
iorated to the extent that the shaft supporting the head would not
slide properly. In particularly bad shape were the latching mech-
anisms on both valves including the pins, locks, cables and pulleys.
but it was judged that they would still function. No corrosion
occurred to head and body of either valve. No attempt was made to
operate the valves in their corroded condition.

DISCUSSION

The 48-inch valve was the first size produced by AMF and tested
at NCEL. It is obvious by comparing it with the 36-inch valve that
in the normal course of development some improvements had been made
in the design. For example, the one-squib, explosive valve furnished
with the 48-inch valve was replaced by a two-squib explosive valve
in the 36-inch valve to insure reliability -- either one or both
will fire when a proper signal has been received. The bolt ring was
made larger for easier installation and higher strength.

The evidence of extensive corrosion indicates that a routine
maintenance (lubrication) and periodic manual operation schedule
would be required to insure operational reliability for these valves.
In addition, a small, screened, shed-type shelter built over the
device possibly would give added protection by reducing the amount
of corrosion caused from direct contact with the elements and would
also prevent the entrance of bugs, rodents, etc., into the air ducts.

The explosive valves used on these closure valves can be used
only once and since they cost about $100 each can be disconnected
prior to a closure test to cut expenses. A meter can be attached
to the disconnected wires to measure the current generated by the
sensing device. If the rest of the system is in good working order,
it can be assumed that the current would have fired the squibs on
the explosive valve and that closure of the valve would have occurred.
The explosive valves require careful handling to prevent accidental
firing.

It should be pointed out that this valve may operate remotely
only once if the sensing element is located outside on a pedestal.
In addition, if two nuclear events occurred within minutes of each
other there may not have been time to replace the explosive valve
fired by the first event.

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The failure of the end plate on the 48-inch valve during the blast test at 204 psi caused damage to the latching mechanism which prevented re-opening of the valve pneumatically. It was judged that under actual conditions the only way the head could have been released would be by manually applying force to the locking mechanism. This could be accomplished only by having ready access to the inside of the valve. The information on this failure was passed to AMF personnel at the time of the tests and it is understood that the screws holding the end plate have been strengthened.

FINDINGS

1. The 36-inch valve at an air flow of 10,000 cfm has an intake pressure drop of 0.55 inches of water and an exhaust pressure drop of 0.39 inches of water.

2. The 48-inch valve at an air flow of 13,000 cfm has an intake pressure drop of 0.53 inches of water and an exhaust pressure drop of 0.36 inches of water.

3. The closure time of the valves with the air bottle at its design operating pressure of 1200 psi averaged about 170 msecs, excluding the reaction time of the sensing element.

4. The reaction time of the sensing element averaged about 50 msecs.

5. The 36-inch valve suffered no damage as a result of being subjected to a simulated atomic blast pressure of 192 psi.

6. The 48-inch valve received moderate damage to the re-opening and latching mechanism when subjected to a blast pressure of 204 psi, but was otherwise undamaged.

7. The weatherability tests indicate that a severe corrosion problem exists unless the valves receive proper maintenance.

Table I. Air Flow Characteristics of the 36-inch AMF Valve

Air flow (cfm)	Pressure drop (inches of water)	
	Intake position	Exhaust position
4000	0.10	0.07
6000	0.20	0.14
8000	0.35	0.23
9000	0.45	0.30
10,000	0.55	0.39
11,000	0.66	0.46
12,000	0.78	0.55
13,000	0.91	0.62

Table II. Air Flow Characteristics of the 48-inch AMF Valve

Air flow (cfm)	Pressure drop (inches of water)	
	Intake position	Exhaust position
4000	0.05	0.03
6000	0.11	0.07
8000	0.19	0.13
10,000	0.31	0.21
11,000	0.38	0.26
12,000	0.46	0.31
13,000	0.53	0.36

Table III. Closure Time of the 48-inch Valve

Air Bottle pressure (psi)	Closure Time of Valve Head (msecs)	
	Horizontal position	Vertical position
1200	166	176
1100	144	177
1000	152	173
900	184	---
800	---	187

Table IV. Summary of Data for Blast Response
Tests on the 36-inch AMF Valve

Test No.	Load (psi)		Strain (μin./in.)		
	PC #2	PC #4	SG #1	SG #2	SG #3
10	46	80	47	55	95
11	75	106	73	132	127
12	121	164	85	---	145
13	140	173	250	112	132
14	149	192	201	32	167

Locations of measuring devices:

Pressure Cell (PC) #2: Test fixture, opposite center of valve.
Pressure Cell (PC) #4: Test fixture, near lower edge of valve.
Strain Gage (SG) #1: Bottom of radial rib in heel.
Strain Gage (SG) #2: Bottom of I-shaped radial support web.
Strain Gage (SG) #3: Inside of body opposite bolt ring.

Table V. Summary of Data for Blast Response Tests
on 48-inch AMF Valve

| Test No. | Load (psi) | | Strain (μ in./in.) |
	PC #2	PC #1	SG #1
1	24	28	372
2	54	58	310
3	70	85	1799
4	99	112	2026
5	120	136	**
6	143	159	**
7*	100	122	**
8	150	204	**

*Demonstration Test.

**No readable trace on oscillogram.

Locations of measuring devices:

Pressure Cell (PC) #2: Test fixture, opposite center of valve.
Pressure Cell (PC) #1: Test fixture, near lower edge of valve.
Strain Gage (SG) #1: Bottom of radial rib in head.

Figure 1. The 48-inch AMF Blast Closure Valve.
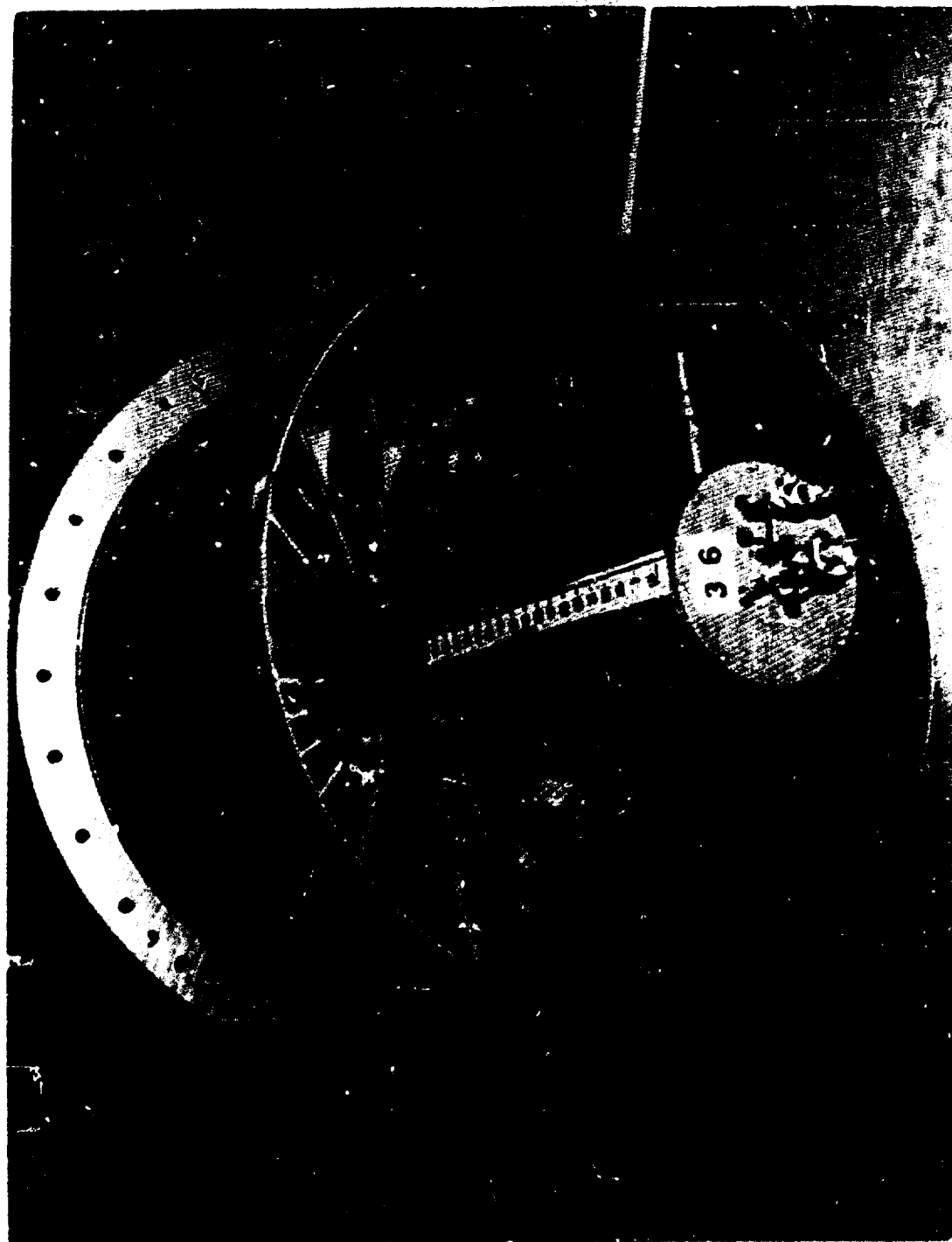
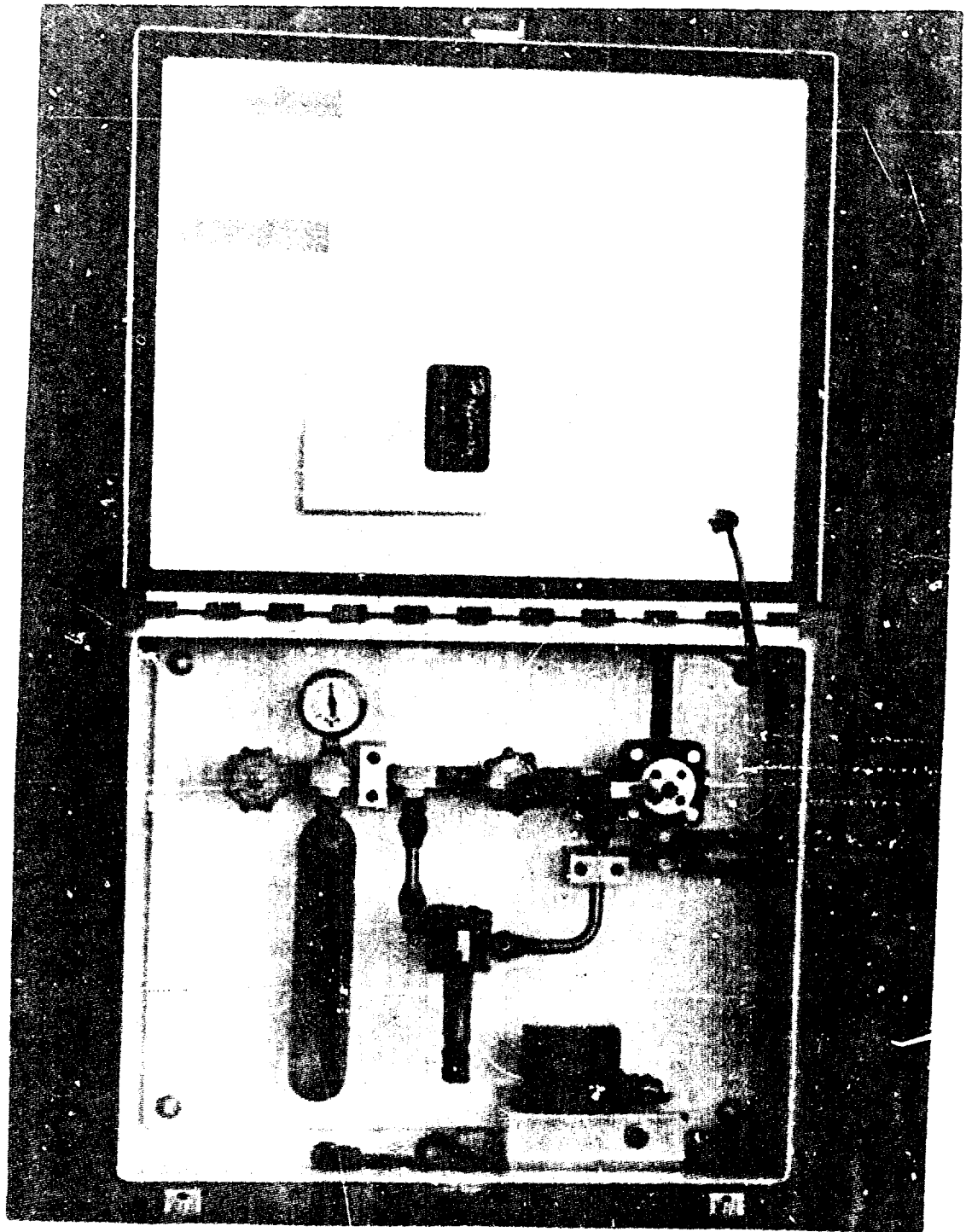Figure 2. Interior view of the 36-inch Air Valve.

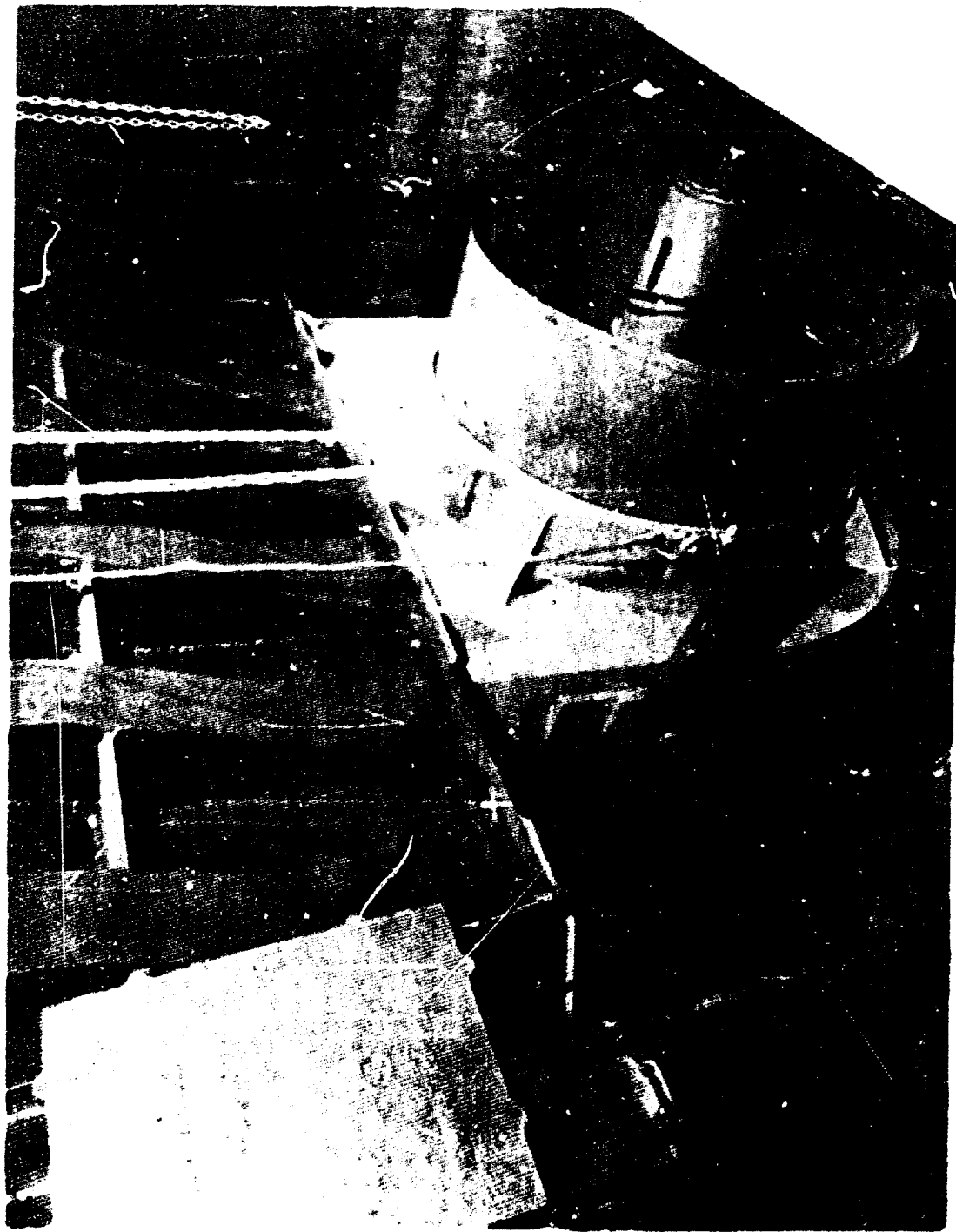Figure 3. Control box furnished with the A/F Valves.

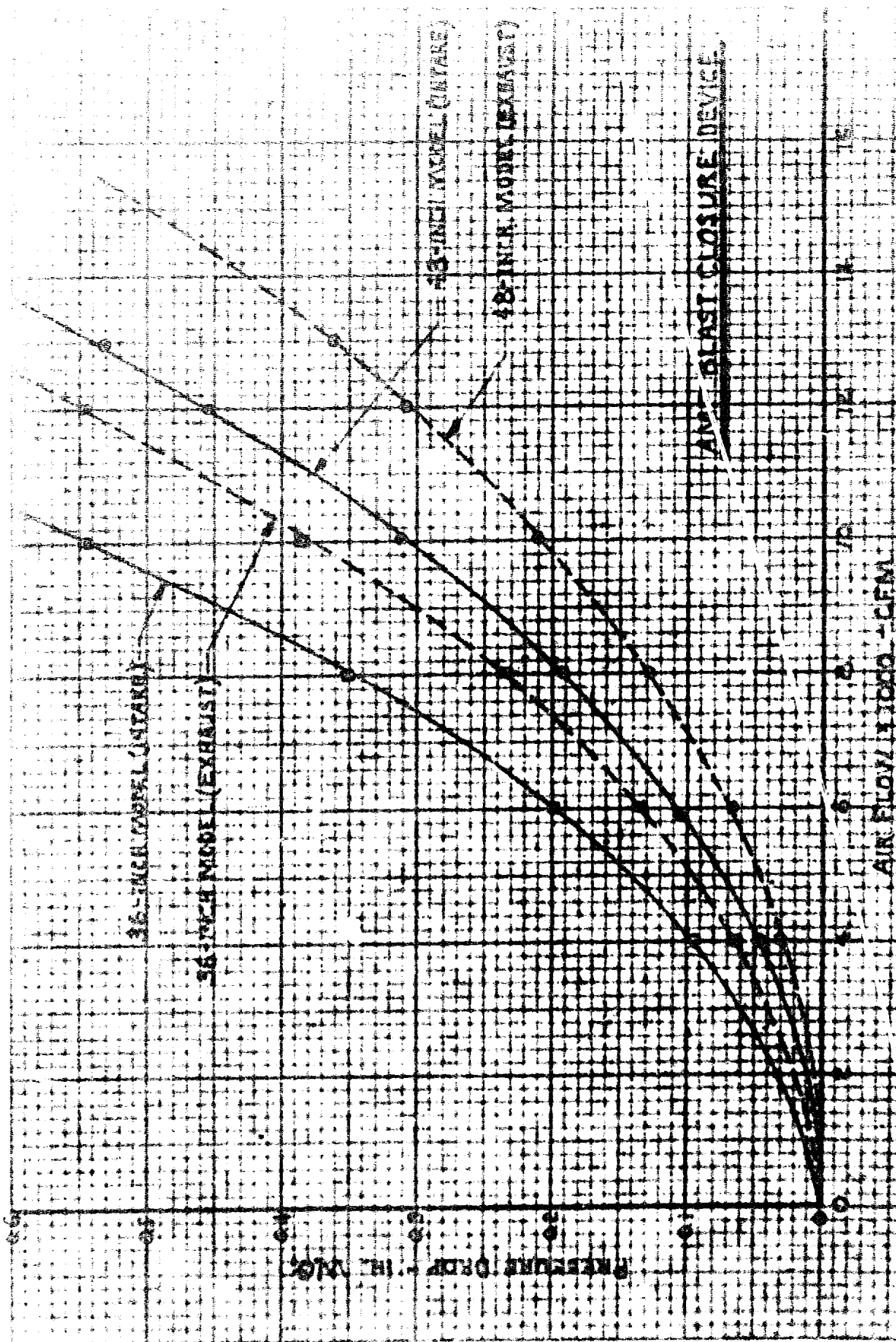The 19-inch AWP Valve mounted in the test fixture attached to the NCEL Blast Simulator.
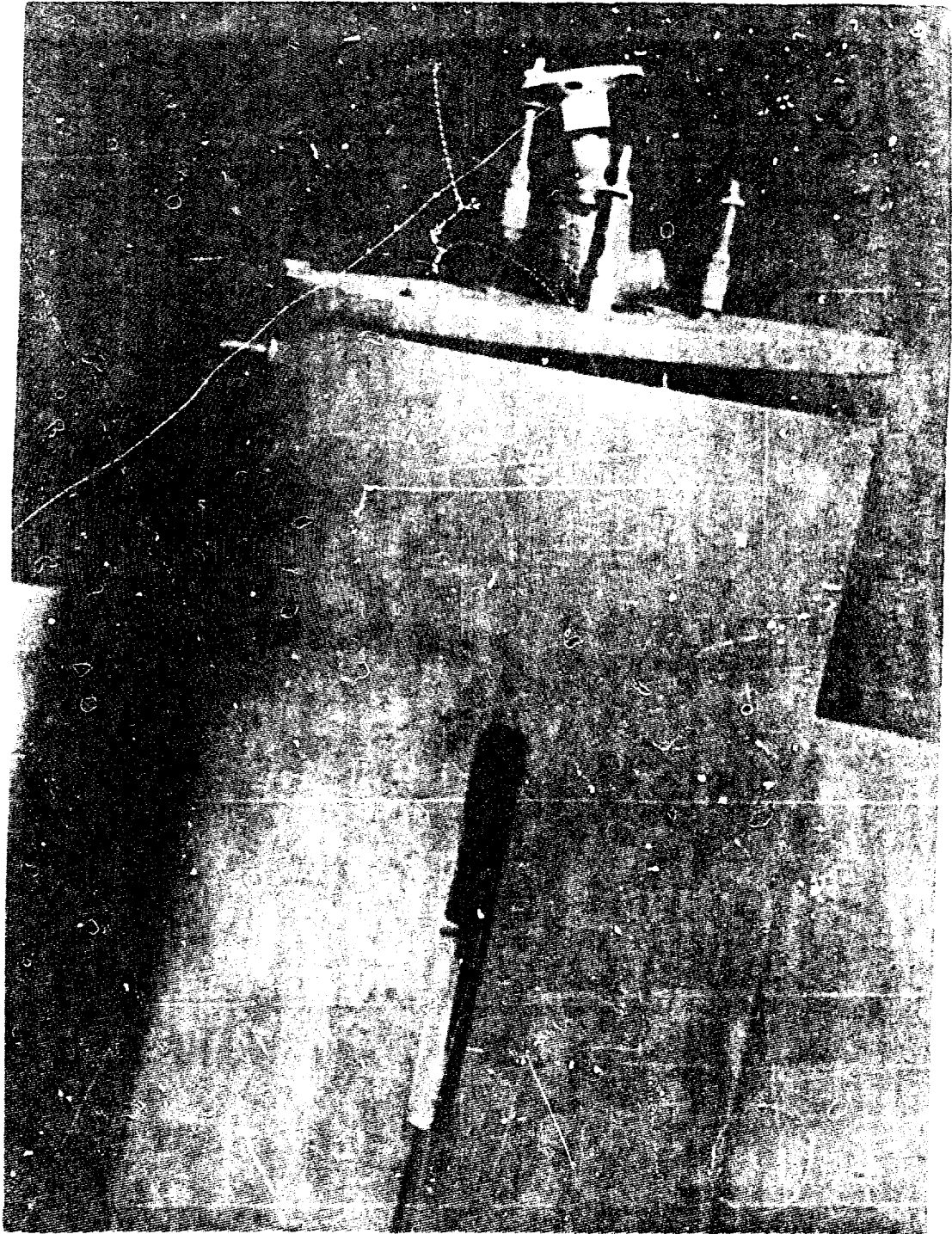
FIGURE 3. AIR FLOW CHARACTERISTICS.

Figure 4.   Failure of Tube Closure Plate on 3/4-inch AWP Valve.