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Isbester

PAP 359

Memorandum
Chief, Water Conveyance Branch

Denver, Colorado
May 18, 1978

Chief, Hydraulics Branch DLK 5-26-78

T. J. Isbester

Cavitation Tests Performed on Controller 30RFAV-4, Flamingo Flow Control Station and Observations on Hitachi Pumps - Southern Nevada Water System

This memorandum contains results of hydraulic investigations during a field trip covering the period March 27-31, 1978, and supplements Hydraulics Branch Travel Report TR-78-7, dated April 18, 1978. Previous tests on controllers at Flamingo are covered in:

Hydraulics Branch Travel Report, dated June 30, 1975

Hydraulics Branch Paper Memorandum, dated August 27, 1975

Hydraulics Branch Travel Report with Appendix 1, dated September 15, 1977

These investigations have been made in an attempt to extend the useful head range of butterfly valves used to control flow.

TEST PREPARATIONS

Prior to the tests, five 3/16-inch (4.76-mm) air injection holes were drilled to intercept the air jacket in the anticavitation disk installed in controller 30RFAV-4. The holes were placed along the downstream side of the leading edge of the disk and as near the periphery as possible. The holes were spaced symmetrically at 7-1/2° beginning on centerline. Holes provided by the manufacturer in both the leading and trailing downstream surfaces of the disk were plugged because air injection through the holes did not flow into cavitation zones.

The air jacket within the disk is common to all holes drilled from the outer surface of the disk. For the first test, it was appropriate to have a limited number of holes installed and only on the leading edge side. These were the most difficult to drill, requiring Mr. Ed Zaputka of the project office to crawl through the venturi meter on the upstream side to get in a position to drill.

After completion of the first test, two additional 3/16-inch (4.76-mm) holes were drilled near the periphery of the downstream side of the trailing edge of the disk and a second test was performed. By proceeding in this manner, the question was answered as to whether air injected into the leading edge was more effective in controlling cavitation and related noise than a combination of holes both up and downstream.

TEST EQUIPMENT

The test equipment and placement was similar to that contained in the September 15, 1977 travel report. The equipment included an orifice chamber and series of orifice plates, thermometer, aneroid barometer, calibrated pressure gages, sound level meter, water U-tube manometer, air pressure regulator, air compressor and vibration transducer, and readout.

TEST I

Pressure at the air intake, sound levels, and vibration amplitudes were recorded prior to injecting air into the disk (figure 1). Stationing for sound level measurements corresponded to figure 8 of the September 15 report. The same readings were repeated for a series of air injection rates. These readings were recorded for 10 percent increments of disk rotation to fully open. The graphs of sound level versus air flow rate are shown in figures 2A through 2E. The graphs of vibration amplitude versus air flow rate are shown in figure 3. A sound power reduction factor is plotted against decibel reduction in figure 1 to provide insight in understanding the amount of improvement achieved.

CONTROLLER REMOVED FOR INSPECTION AND DRILLING

At the completion of the first series of tests, the controller was uncoupled from the line and raised so that two additional holes could be drilled in the downstream face of the trailing edge. During this time, the valve was inspected and photographed. The disk was noted to open upstream with the leading edge on the invert of the valve. With the unperforated disk and operating mechanism, the leading edge was on the crown side.

Several areas of cavitation erosion in the valve body were noted (figures 4 and 5). One was on both sides of the body downstream of the seal and slightly above the shaft. The other was on the invert upstream of the seal on both sides of the centerline. The erosion on the invert was in a Devcon filler placed to eliminate the offset on the upstream side of the seal retainer. Considering the relatively low resistance of the Devcon material to cavitation erosion, the damage is minimal. The erosion covers a total area of about 7 in^2 (4500 mm^2) on either side of centerline to a maximum depth of about 1/16 inch (1.6 mm). The Devcon filler was not as smoothly applied as it should have been, which may have contributed to the erosion. The eroded areas on either side of the body above the shaft extended about 3 inches (76 mm) vertically and 3/4 inch (19 mm) horizontally downstream from the seal.

TEST II

After the two additional holes were drilled into the trailing edge of the disk and the controller was reinstalled in the line, a second series of tests similar to test 1 were repeated. The results are shown in figures 1 and 2A through 2E. At larger gate openings, a vibration in the line was noted which was not apparent in the first series of tests. The vibration became severe and forced termination of testing at a 100 percent disk opening. The results of vibration amplitude versus airflow rate are included in figure 6.

DISCUSSION OF RESULTS

Positive pressure at the air intake to the disk air jacket eliminated the possibility of ambient air being drawn into the valve to mitigate cavitation and noise. The positive pressure was present for all disk openings and both series of tests.

Air supplied to the holes in the leading edge of the disk (test 1) was more effective in reducing cavitation-associated noise than when air was supplied to a combination of holes in the leading and trailing edges. Evidentally the major portion of cavitation occurs where accelerating flow separates from the surface around the leading edge of the disk. Air supplied to the separation zone through the leading edge holes probably moves along the donwstream face of the disk to shed into the downstream conduit. No measurements could be made to show whether or not the air spreads laterally to relieve cavitation associated with the shaft.

With air injection, significant sound level reductions were achieved for all disk openings in test 1 and for all openings except 100 percent in test 2. At small disk openings, lower rates of injection were more effective than larger rates in reducing sound level. For both tests 1 and 2, vibration amplitudes were also significantly reduced with air injection for all disk openings. These reductions were accompanied by a decrease in frequency of vibration. As with sound level, lower air injection rates at smaller disk openings were more effective than larger rates.

Air injected into the disk is not expected to eliminate cavitation in all areas of the valve body; although, if air moves laterally from the injection holes, some benefit may occur to the area above and downstream from the shaft. Undoubtedly, a reduction in cost of injecting pressurized air could be achieved with proper placement of injection holes, both in the body and disk of the valve. Use of small offsets into the flow at selected stations may provide sufficient contraction and pressure reductión to draw in ambient air to critical areas, eliminating the need for compressed air entirely.

Also, a redesign of the basic configuration of the butterfly valve may be appropriate. The need for a tight seal, required in conventional butterfly valves, may be unnecessary for a valve used for control. A small disk closing against an orifice placed within a large conduit may provide sufficient circulation to the discharging flow to prevent cavitation erosion similar to that experienced at Flamingo.

The tests were very successful in demonstrating the benefit of introducing a compressible medium to a cavitation zone. Cavitation cannot occur until vapor pressure is reached in the fluid. Thus, small quantities of air injected in zones of cavitation can expand greatly, raising the pressure in the zone above the vapor pressure level and eliminating the detrimental erosion. Some systems may be adversely affected by accumulations of air downstream from the injection point.

HITACHI PUMPS 1A7 AND 2A1

The pumps were disassembled and being readied for protective coating at the time of my visit. The general condition of the pumps appears to be poor and concern for pump longevity warranted. There is a high degree of corrosion as well as cavitation erosion, which if not stopped, will definitely shorten the pump life. The heaviest damage has been to critical areas in the cast housings such as casing ring support material, material adjacent to the stuffing boxes, and to the suction baffle (figure 7). Several areas of cavitation damage within the pumps appeared to be due to local irregularities in the flow surfaces, particularly on the suction baffle. Also, several eroded areas on the bottom portion of the housing near the part line were observed. These point to the possibility that an offset exists in the flow passage between the two halves, causing cavitation to occur (figure 7). A method was suggested to evaluate alinement. This would require the use of a cardboard template placed between the two halves of the pump and compressed so as to leave an imprint. An indicating fluid such as a red lead could be applied to the corners of the flow passages in the upper and lower halves to improve the definition of the imprint. Flow passage imprints should remain on either side of the template, allowing a determination of the accuracy of alinement. The necessity for smooth continuous flow passages within the pumps is increased by the marginal suction head available at the facility.

T. J. Isbester

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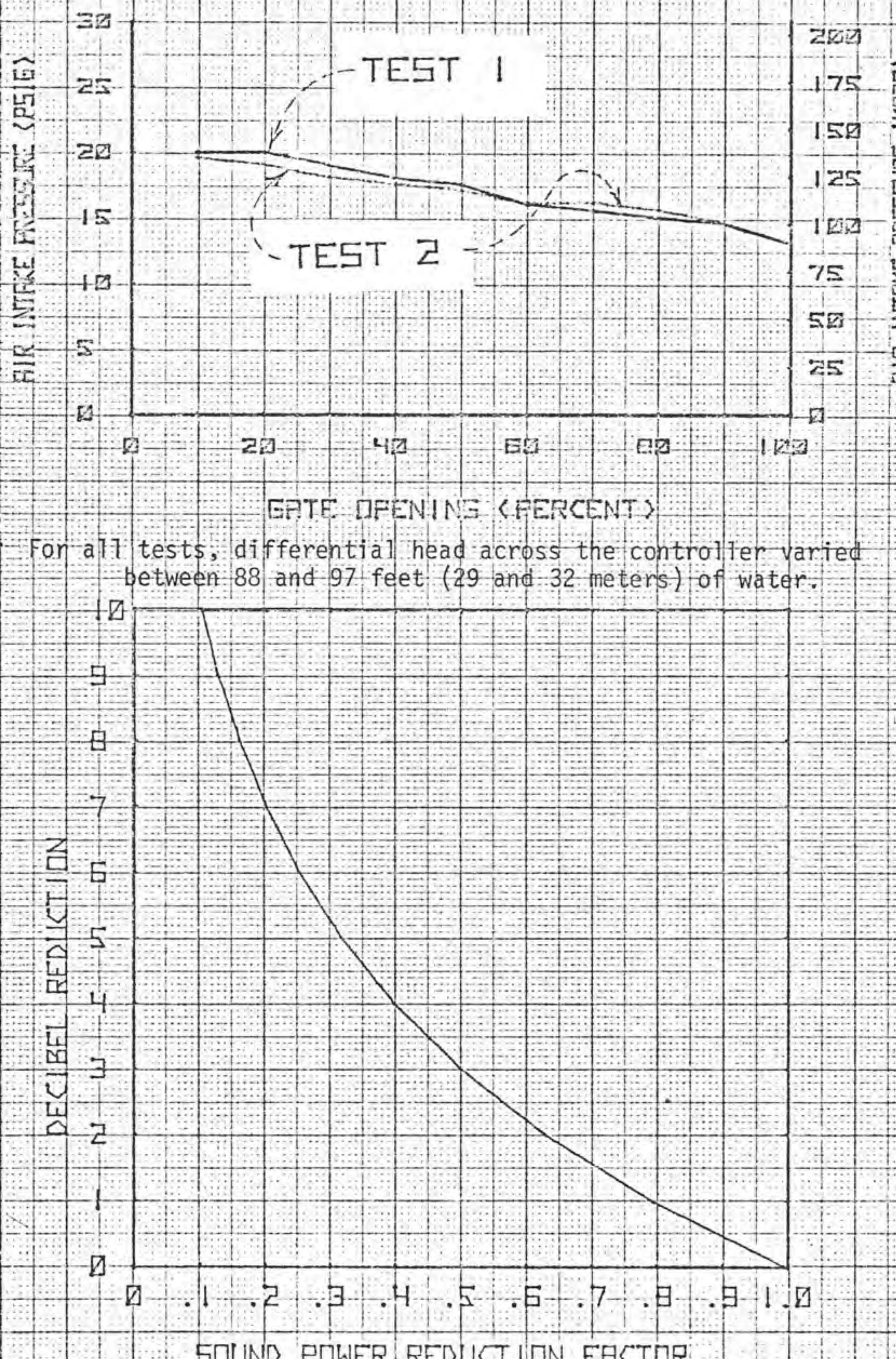
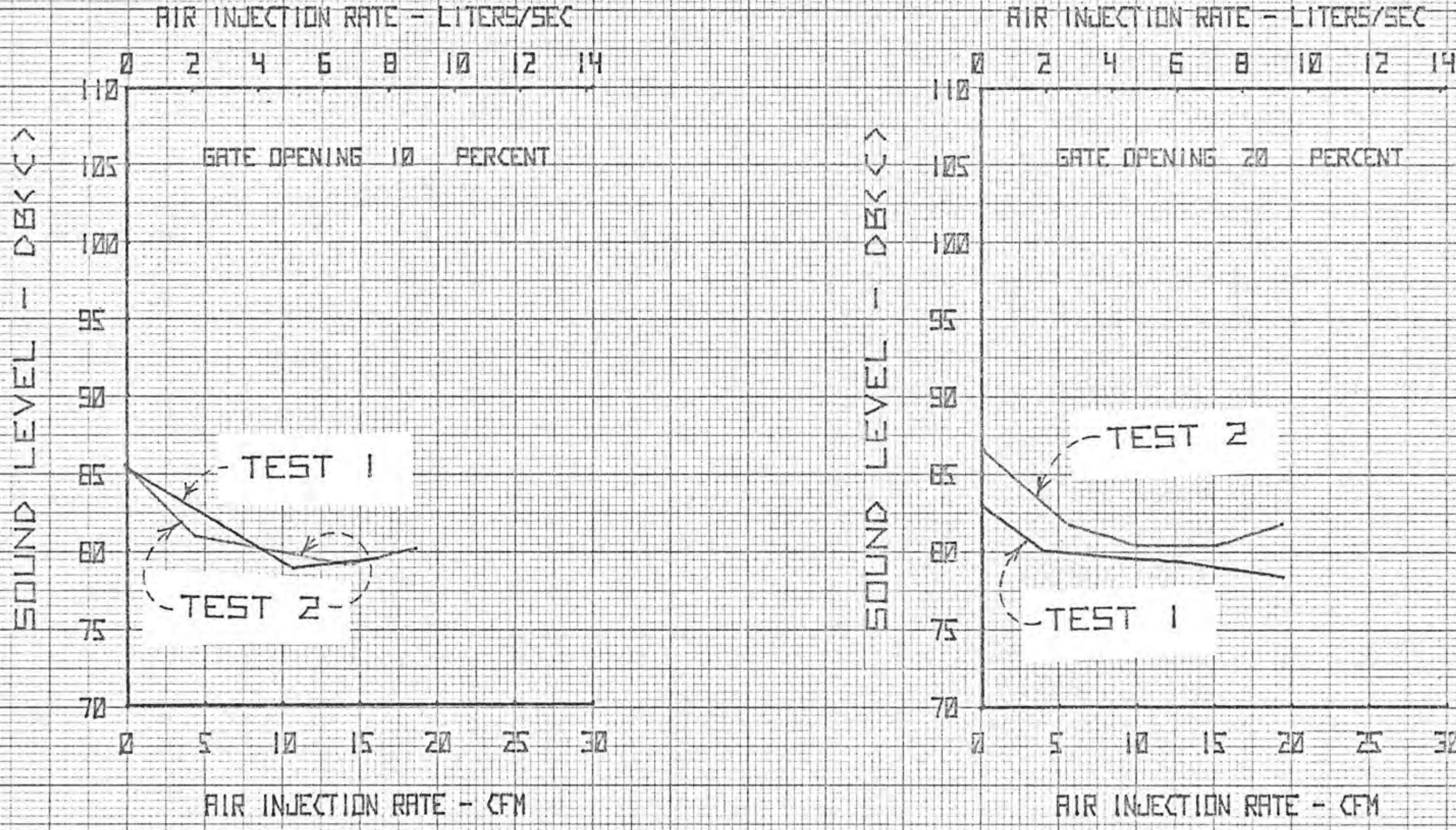
FIGURE 1



AIR INTAKE PRESSURE AND SOUND POWER REDUCTION FACTOR

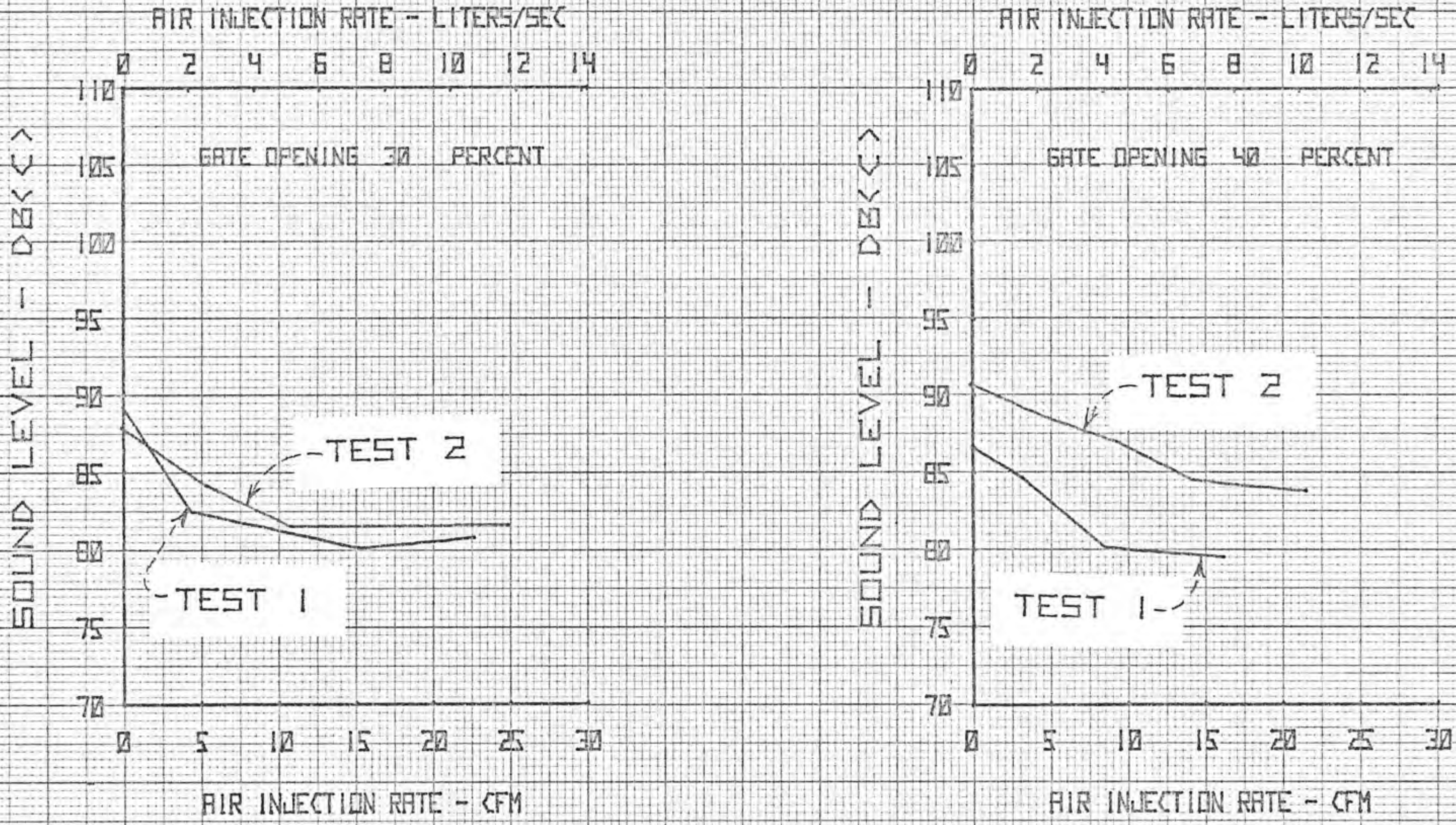
CONTROLLER 30 REAV - 4

FLAMINGO FLOW CONTROL STATION



FREE AIR INJECTION VS. SOUND LEVEL
CONTROLLER 30 RFAV - 4
FLAMINGO FLOW CONTROL STATION

FIGURE 2A

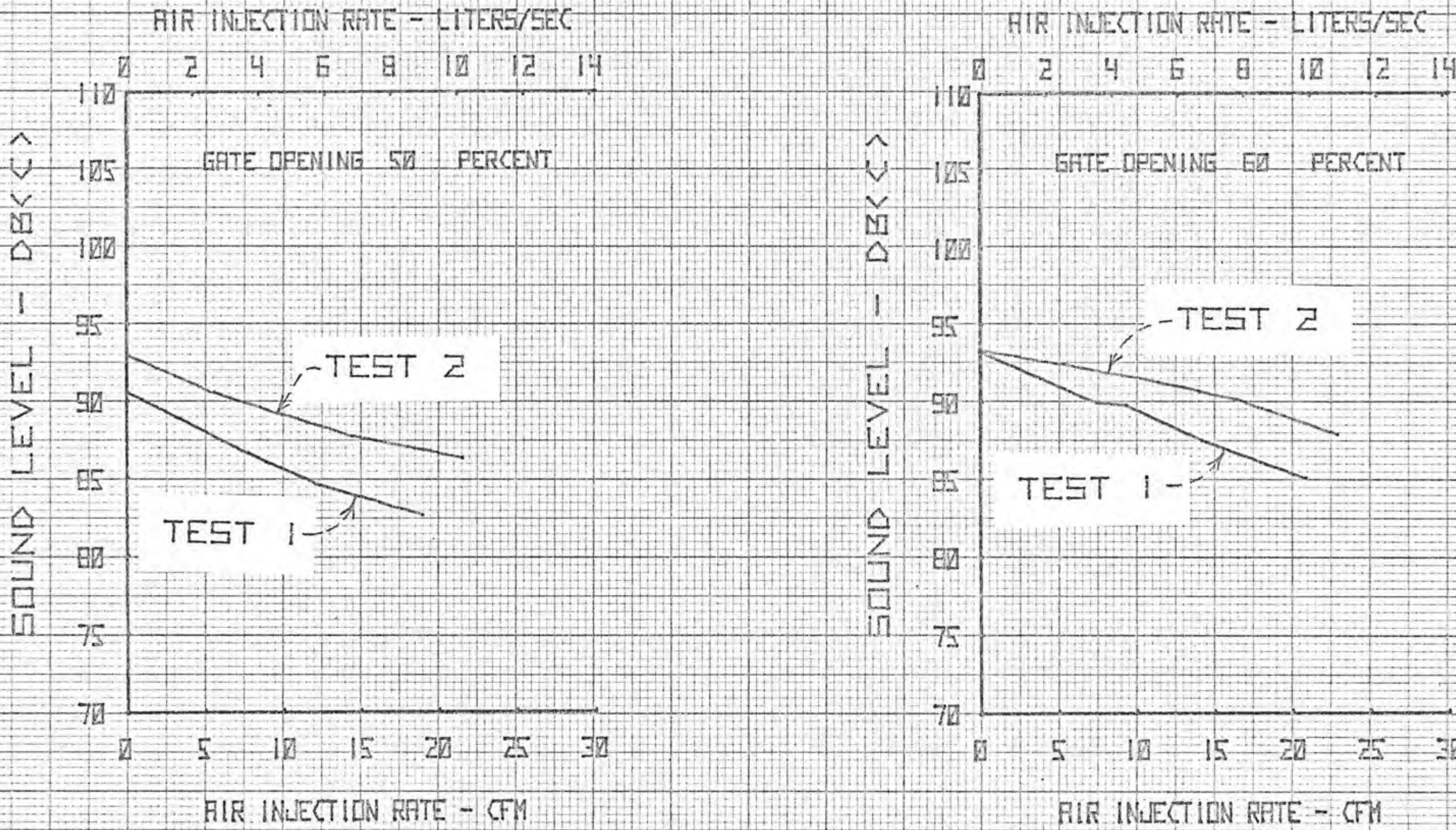


FREE AIR INJECTION VS. SOUND LEVEL

CONTROLLER 30 AFAV - 4

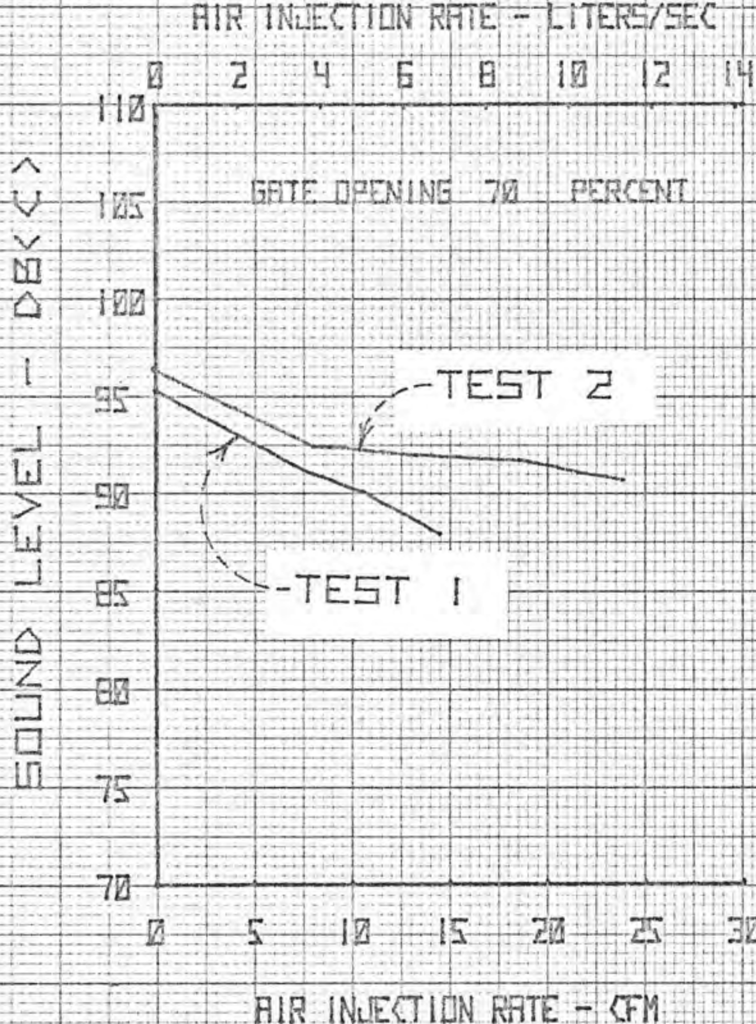
FLAMINGO FLOW CONTROL STATION

FIGURE 28



FREE AIR INJECTION VS. SOUND LEVEL
CONTROLLER 30 RFAV - 4
FLAMINGO FLOW CONTROL STATION

FIGURE 2C



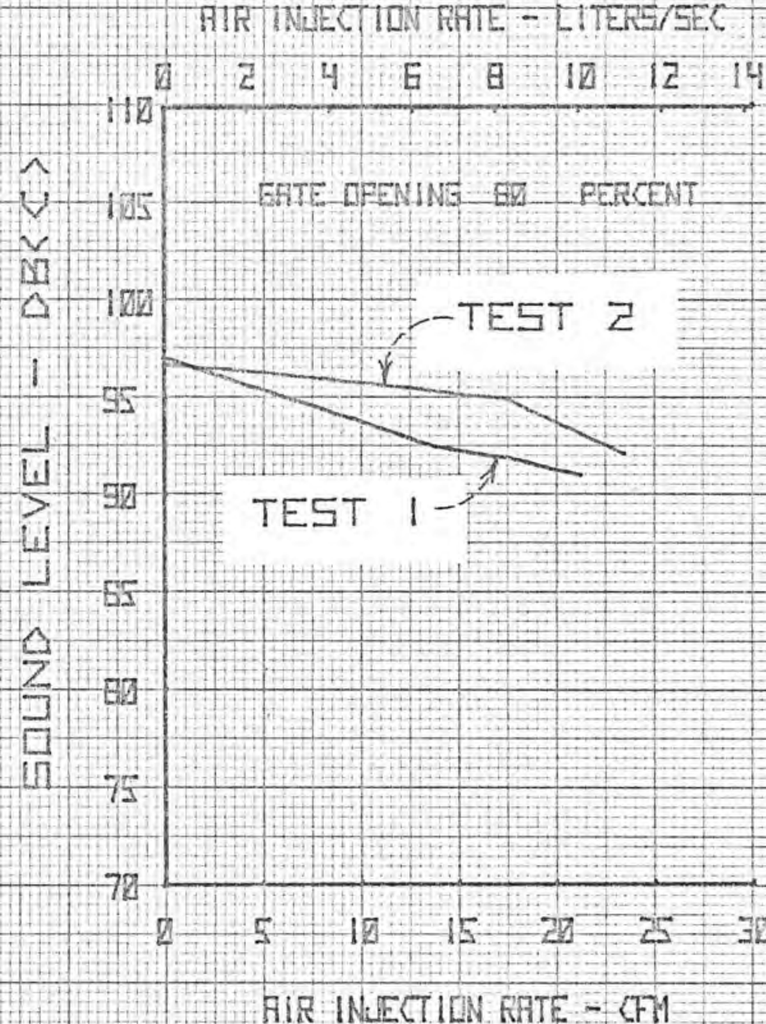
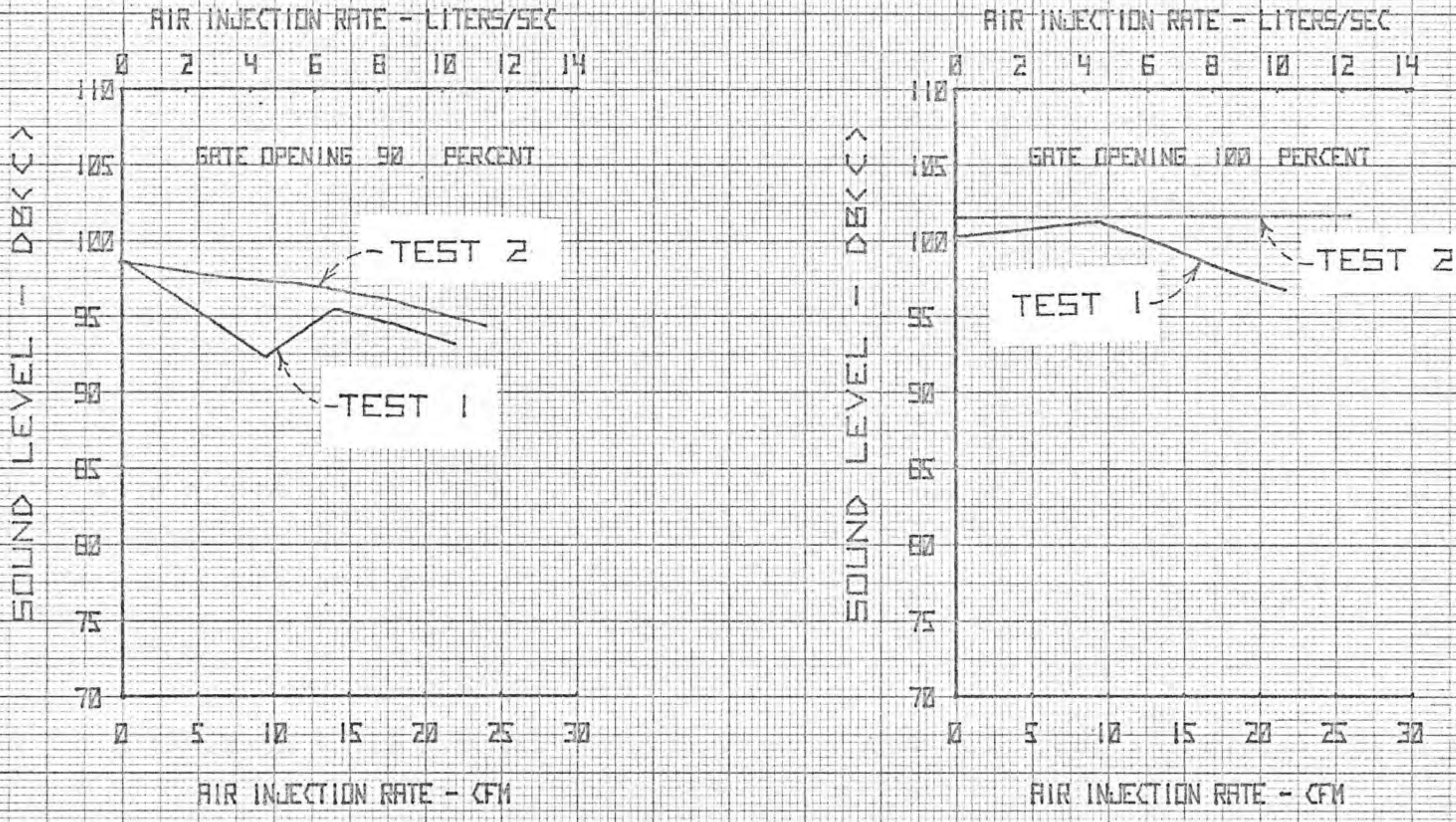


FIGURE 2D

FREE AIR INJECTION VS. SOUND LEVEL

CONTROLLER 30 RFAV - 4

FLAMINGO FLOW CONTROL STATION

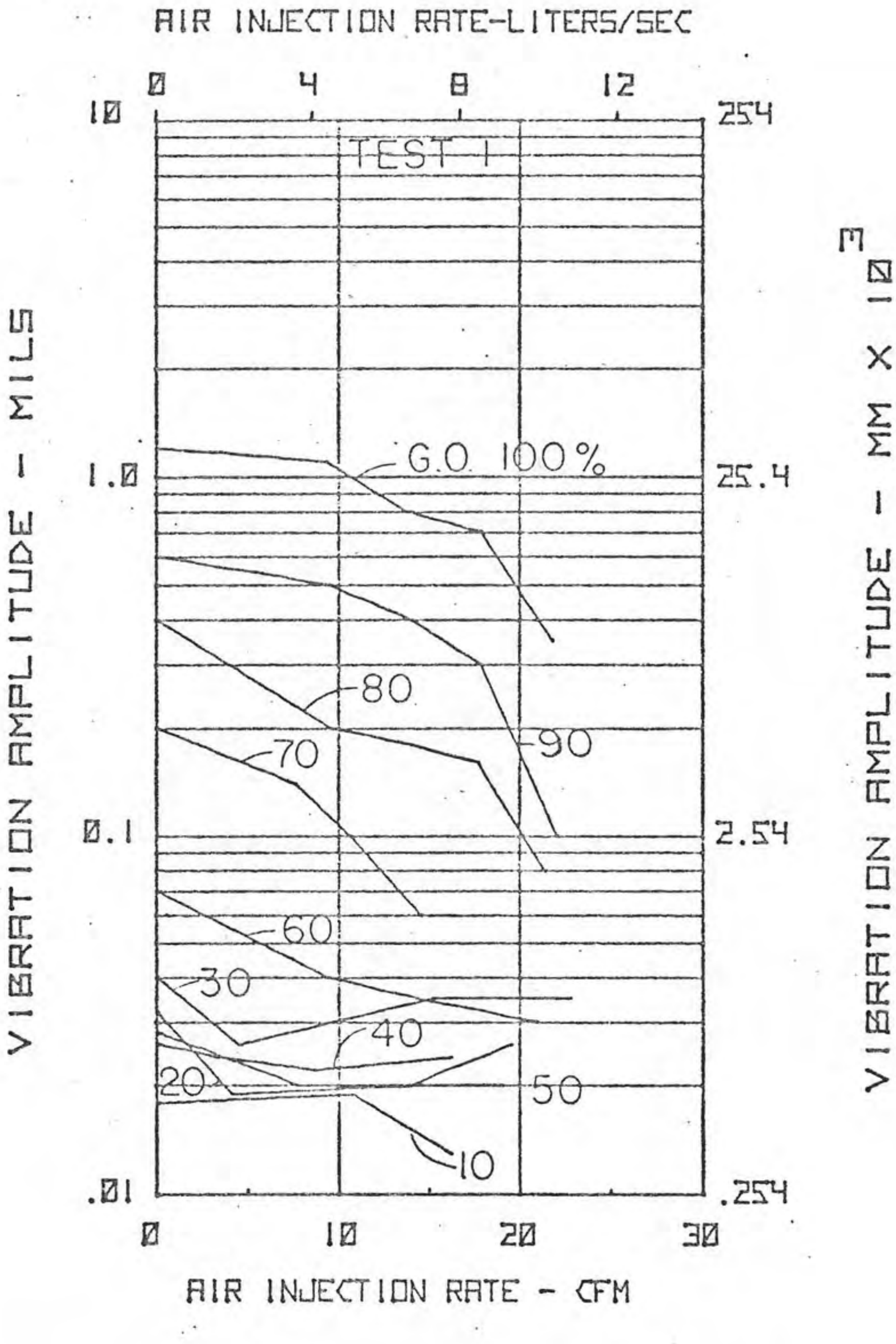


FREE AIR INJECTION VS. SOUND LEVEL

CONTROLLER 30 RFAV - 4

FLAMINGO FLOW CONTROL STATION

FIGURE 2E



FREE AIR INJECTION RATE VS. VIBRATION AMPLITUDE

CONTROLLER 30 RFAV - 4

FLAMINGO FLOW CONTROL STATION

FIGURE 4

LEFT RIGHT

CAVITATION EROSION TO BODY ABOVE SHAFT - FROM DOWNSTREAM

VIEW OF CONTROLLER FROM DOWNSTREAM END SHOWING 2 ADDITIONAL HOLES ON TRAILING EDGE, AND LOCATION OF EROSION ABOVE SHAFT

CONTROLLER 30 RFAV-4

FLAMINGO FLOW CONTROL STATION

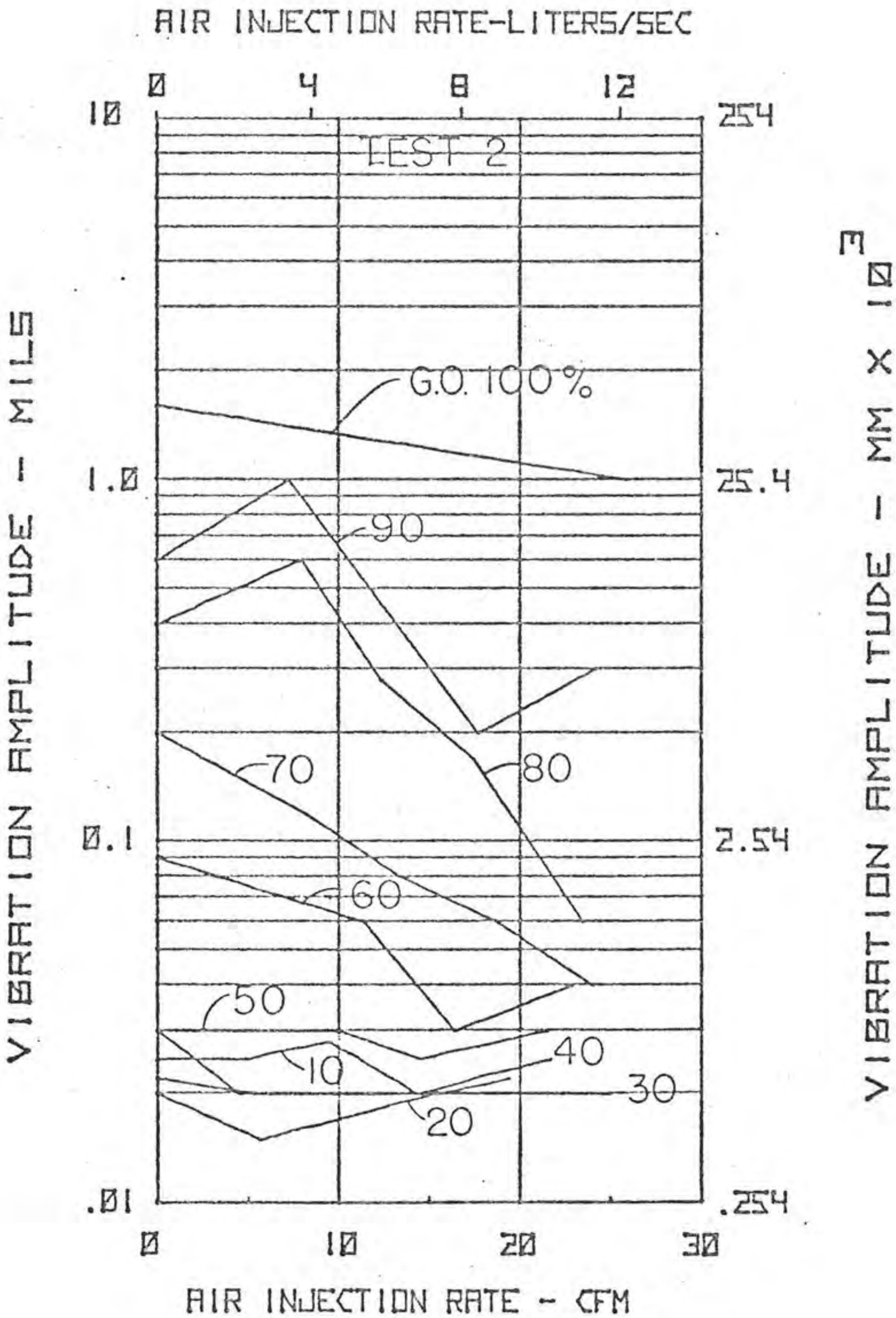
FIGURE 5

CAVITATION EROSION ON INVERT - FROM UPSTREAM SIDE OF CONTROLLER

CONTROLLER 30 RFAV-4

FLAMINGO FLOW CONTROL STATION

FIGURE 6



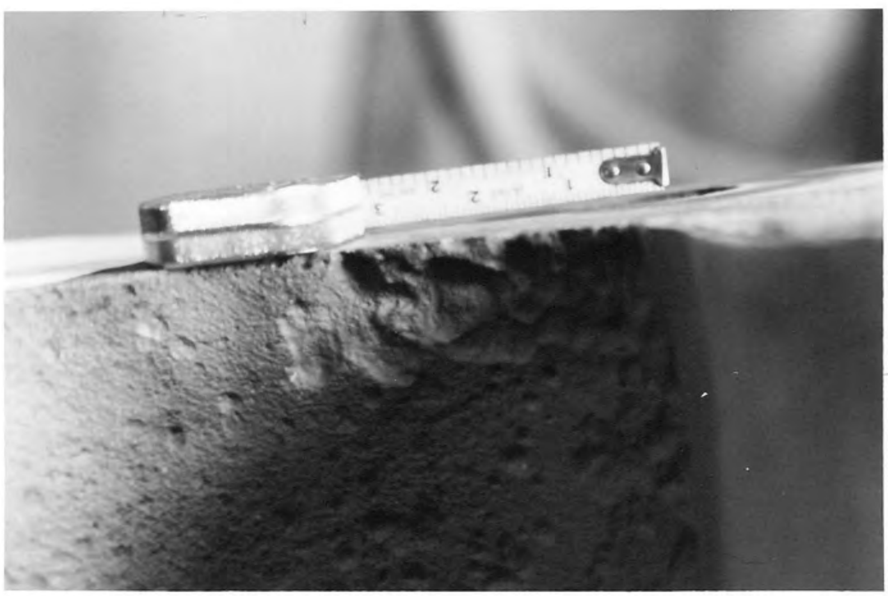
FREE AIR INJECTION RATE VS. VIBRATION AMPLITUDE

CONTROLLER 30 RFAV - 4

FLAMINGO FLOW CONTROL STATION

FIGURE 7

CAVITATION EROSION TO SUCTION BAFFLE



AREA OF EROSION IN BOTTOM HALF OF PUMP
HOUSING JUST DOWNSTREAM OF PART LINE

HITACHI PUMPS

SOUTHERN NEVADA WATER PROJECT