aerospace engineering department

# TEXAS A&M UNIVERSITY

A Final Report

on

THE PULSED AIR GUST GENERATOR

Space Technology Division
NASA Grant No. NGR-44-001-036
Simulation of Atmospheric Processes



TEXAS ENGINEERING EXPERIMENT STATION

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# THE PULSED AIR GUST GENERATOR

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## Introduction

A method of producing controlled gusts on a uniform airstream would simplify the experimental investigation of gust effects. Gusts normal to the stream vector have been produced by mechanically oscillated airfoils, but the maximum frequency is limited by the problem of oscillating large surfaces.

A method of producing gusts by modulating air jets was proposed and tried by Thomas.[1] A feasibility study made in the Texas A&M University 2' x 3' wind tunnel led to the design and construction of a gust generator for the 7' x 10' wind tunnel. With a test section large enough for research above the troublesome Reynolds number effects, the facility would be a very useful research tool.

## Apparatus

The Texas A&M 7' x 10' wind tunnel is a closed return tunnel with a contraction ratio of 10 and the rather long centerline length of 420 ft., (Fig. 1). The jet pulsing apparatus is an array of 16 nozzles, four on each of four air supply pipes with rotary valves for flow control. This array is located at the downstream end of the test section with the nozzle discharge directed upstream. Figure 2 shows the nozzle array, while Fig. 3

shows the rotary valve drive system which is capable of frequencies from 3 to 60 hz.

Compressed air from a high pressure storage system is supplied at reduced pressure (up to 100 psi) to two header tanks, one on each side of the tunnel (Fig. 3). Air storage is sufficient for a 15 to 20 second run.

The control and recording equipment is shown in Fig. 4. A detail of the rotary valve geometry is shown in Fig. 5. The nozzle is designed for a discharge Mach number of 2 and has an exit diameter of 1.90 inches.

## Calibration Tests

A series of tests has been run to measure the operating characteristics and effectiveness of the apparatus for producing longitudinal gusts. The storage pressures, header tank pressure (both tanks), static pressure on the ceiling and floor of the test section 7.5 ft. upstream of the nozzles, and the streamwise velocity at a point 7.7 ft. upstream of the nozzles were recorded as functions of time.

It was determined immediately that the tunnel could be forced in its low frequency resonant modes. No data on the fundamental was taken on this series. The first harmonic at 5.5 hz corresponds to a wave length of one half tunnel circuit length about 210 ft. The tunnel responds well at 9 hz but not higher. Results at 5.5 hz for a tank pressure of 17 psig are shown in Fig. 6. The velocity response is slightly cylcoidal with a peak-to-peak amplitude of 14 fps on a mean velocity of 70 fps.

The response of the tunnel obtained by continuously increasing the pulsing frequency from 12 to 18 and 28 cps to 60 hz showed little indication of further standing waves. The region 18 to 28 cps was omitted because it was in the range of the first flapping mode of the fan blades. Continued testing was carried out at 38 and 54 hz as representative of the upper range.

Initial tests at 38 hz brought out the response shown in Fig. 7 from which was deduced that the jet flow modulation was far from sinusoidal. Tests to measure the total pressure at the nozzle verified this suspicion (Fig. 8). There was not time for redesign of the nozzles but it was thought that a small shift in the phases of the valves would help. Subsequent runs showed considerable improvement when the top and bottom rows of nozzles were shifted 30° ahead of the center rows. Note that a complete pulse occurs every 180° rotation of the valve shaft. All subsequent high frequency runs were made with this offset. Results at 38 hz with three tank pressures are shown in Fig. 9. The largest peak-to-peak oscillation is 10 fps with a mean speed of 42 fps. The peaks in the velocity trace are not due to jet mixing, although the mixing region is not far downstream. The results at 54 hz are similar.

Tests with the hot wire anemometer positioned directly upstream of a nozzle showed penetration of the jet to a point of 7.7 feet ahead of the nozzles for a tank pressure of 30 psig at 9 hz and at 60 psig at 38 hz. No penetration occurred at a point 12 ft. ahead of the nozzles up to 60 psig, though the mean tunnel velocity was reduced to 40 fps.

The gust results are summarized in Fig. 11-14. The peak-to-peak amplitude (Fig. 11) shows the values obtained for various tank pressures. The 5.5 and 9 hz points are at resonance. There is a considerable dependence of gust amplitude on frequency at a fixed tank pressure for the higher frequencies.

The testing was carried out at constant fan pitch and speed. The gust generator slows the tunnel down as shown in Fig. 13. The rate is nearly independent of initial airspeed setting.

The effect of initial airspeed on gust production was looked into briefly. Figure 12 shows the gust intensity for two airspeeds, and Fig. 14 the ratio of gust intensity to mean tunnel velocity. It is apparent that the mean speed has little influence, that the gusts are additive to it.

The spatial variations of gust intensity and phase have not been determined nor the normal component of gust velocity. These tests are planned in the next test period.

In summary, the generator appears very promising as a tool for unsteady flow research.

## Reference

1. Thomas, Richard E. and Moreland, Bruce T., Jr., "Gust Simulation in a Wind Tunnel," Space Technology Report 67-52, July 1967.

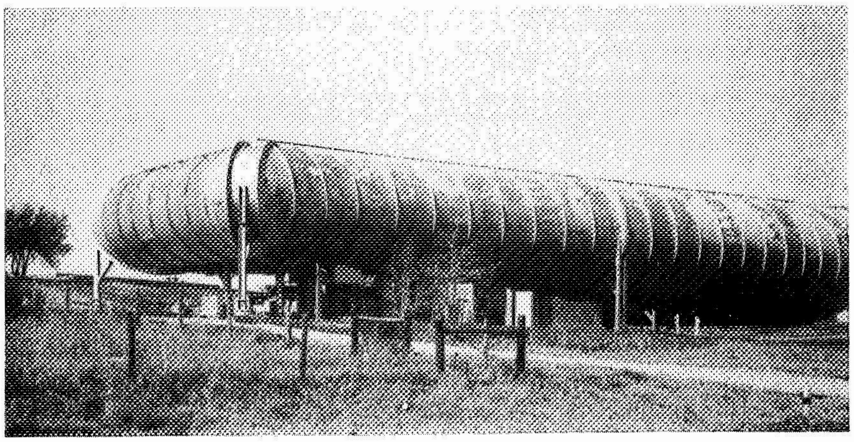

FIG. 1. General View of Tunnel

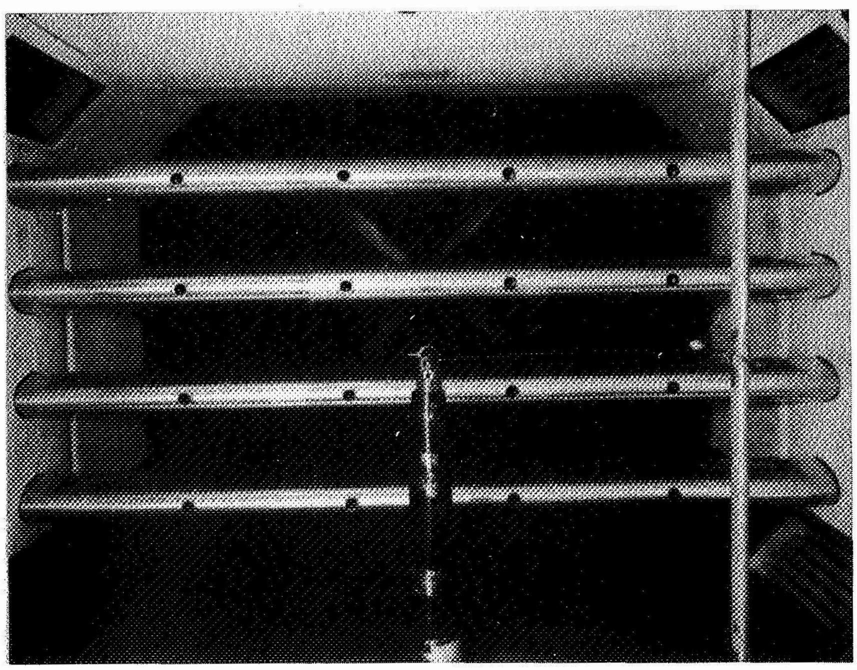

FIG. 2. Nozzle Installation in
Test Section

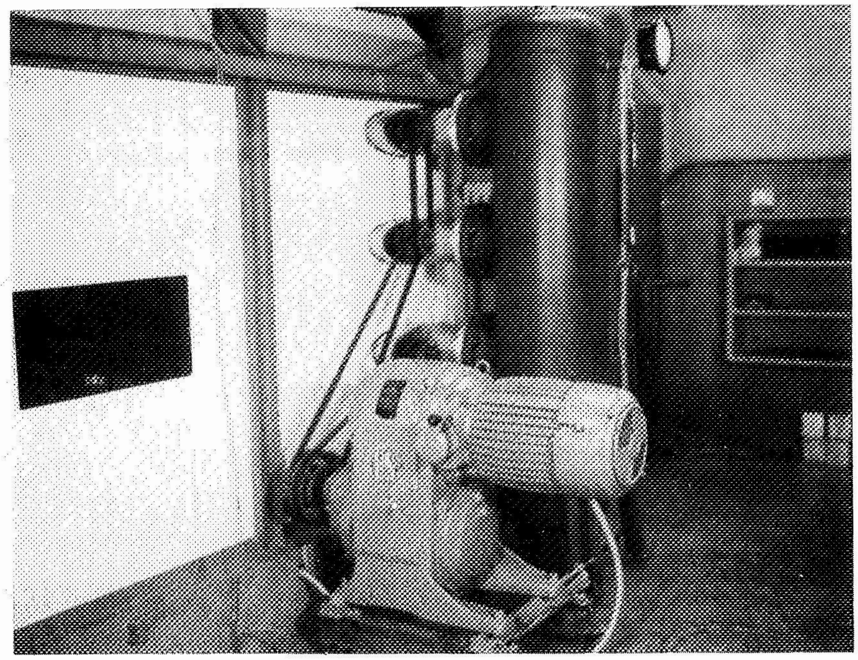

FIG. 3. Rotary Valve Drive System

FIG. 4. Control Panel and Recorder

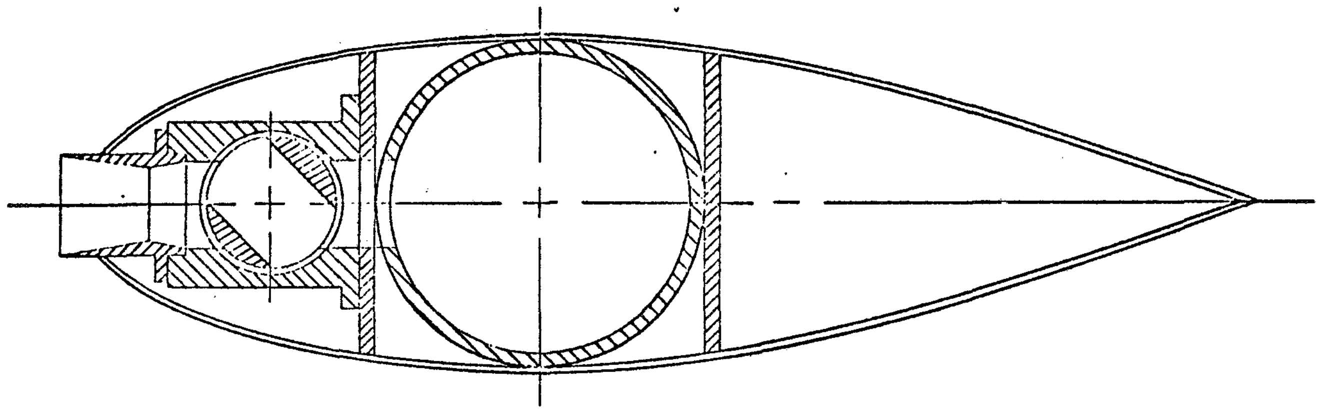

FIGURE 5. JET NOZZLE AND ROTARY VALVE ASSEMBLY

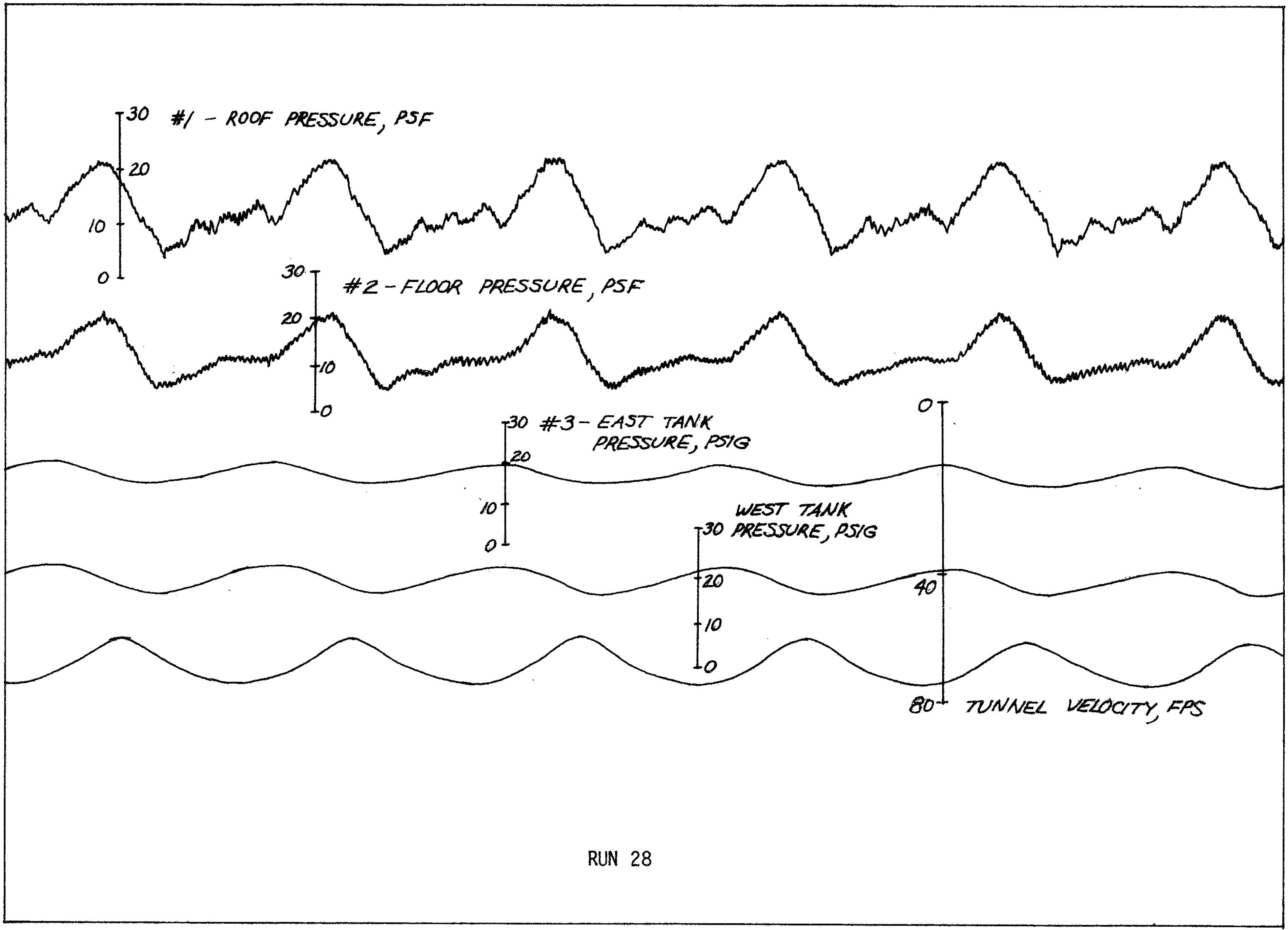


FIG. 6. GUSTS AT 5.5 HZ VALVES IN PHASE

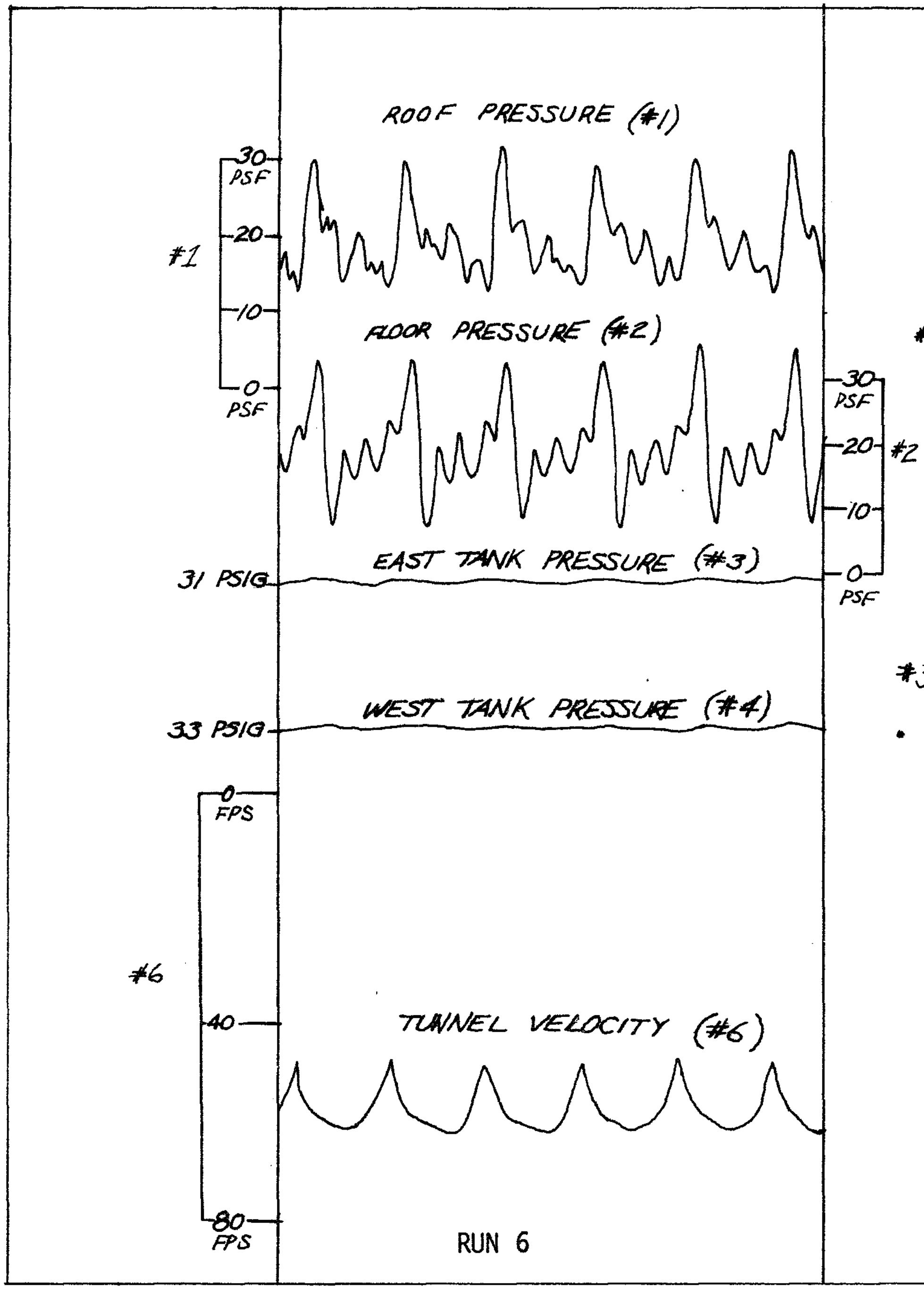


FIG. 7. NOZZLES IN PHASE

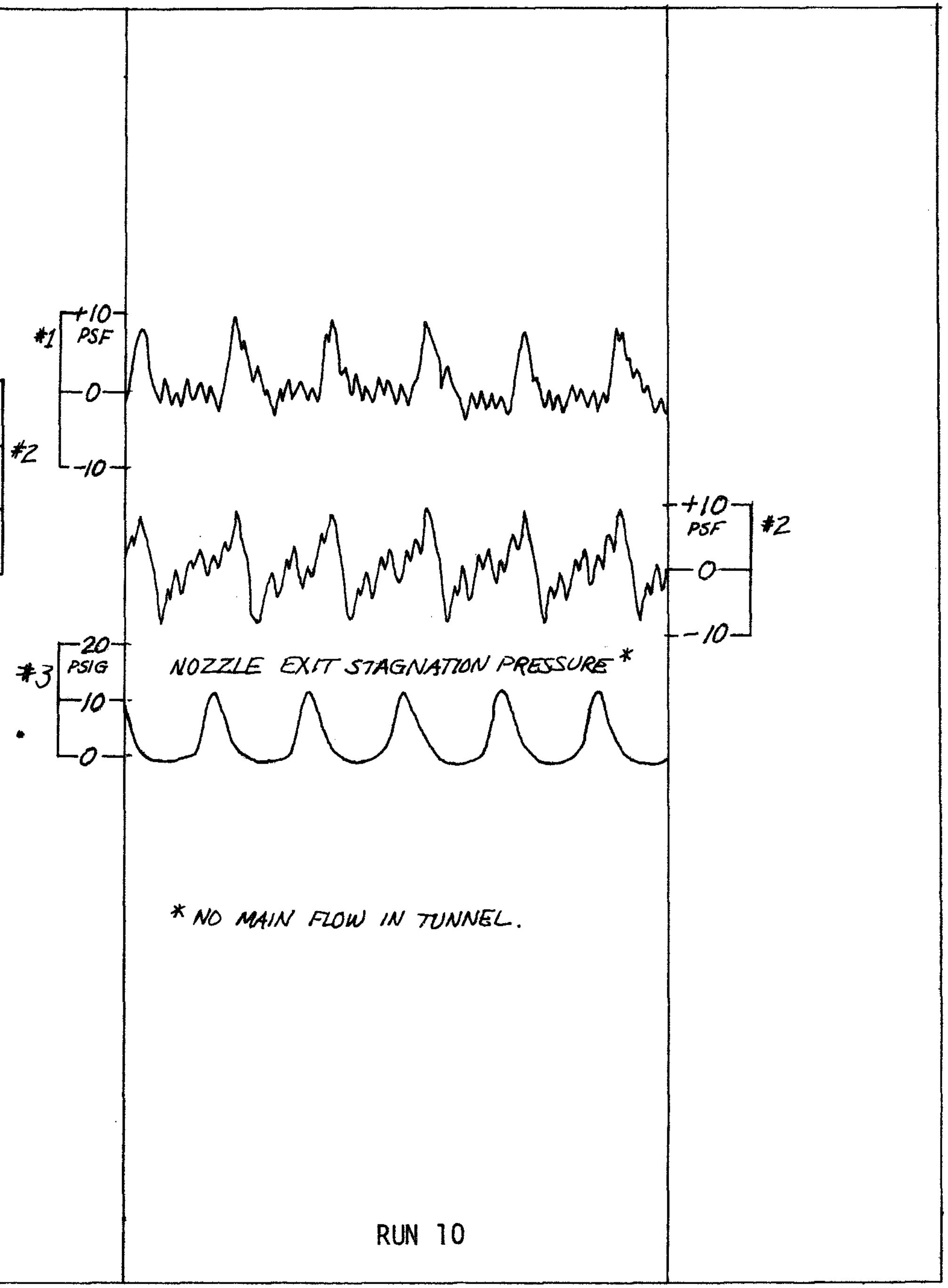


FIG. 8. TOTAL PRESSURE AT NOZZLE DISCHARGE

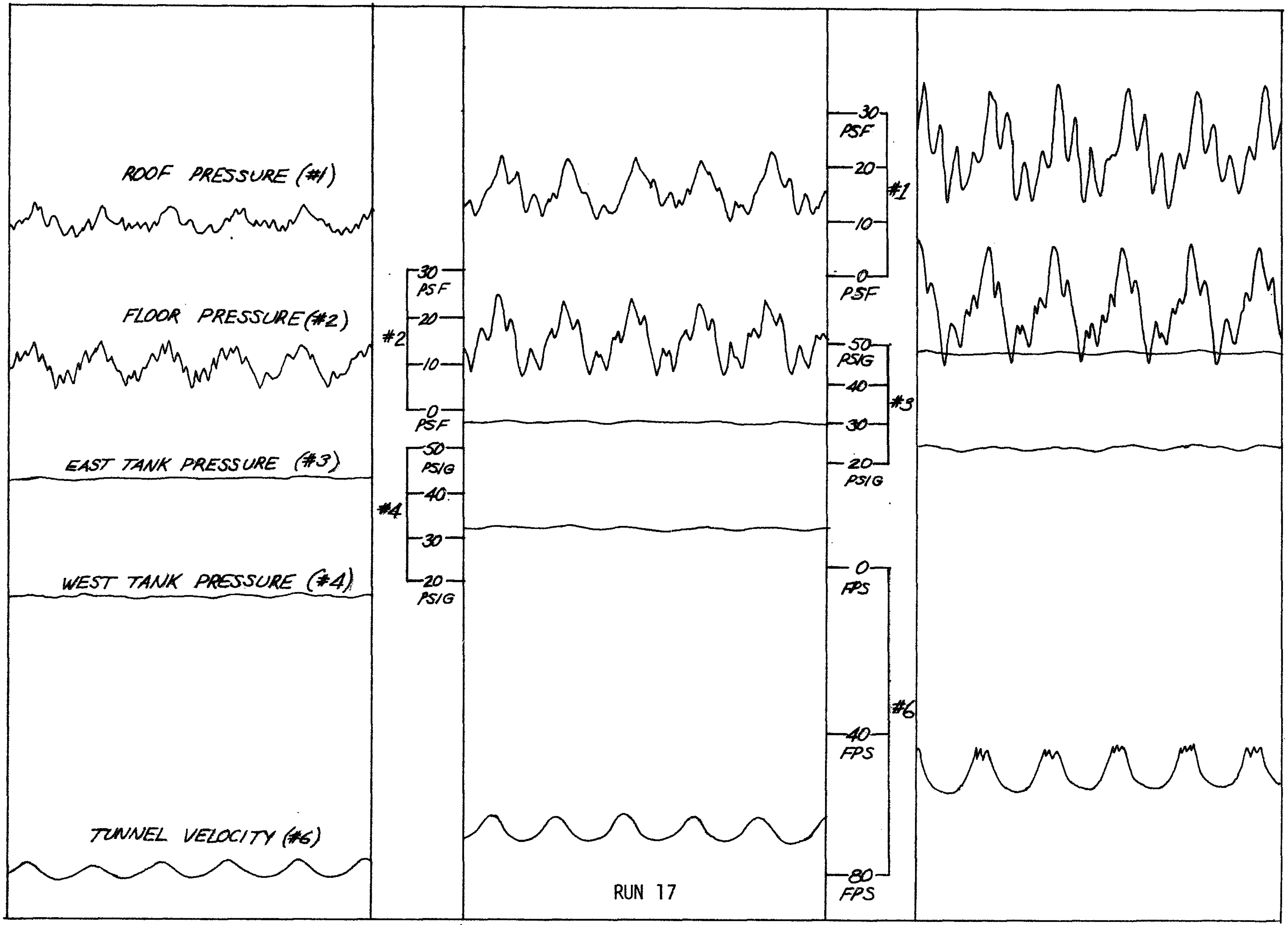


FIG. 9. GUSTS AT 38 HZ VALVES 30° OUT OF PHASE

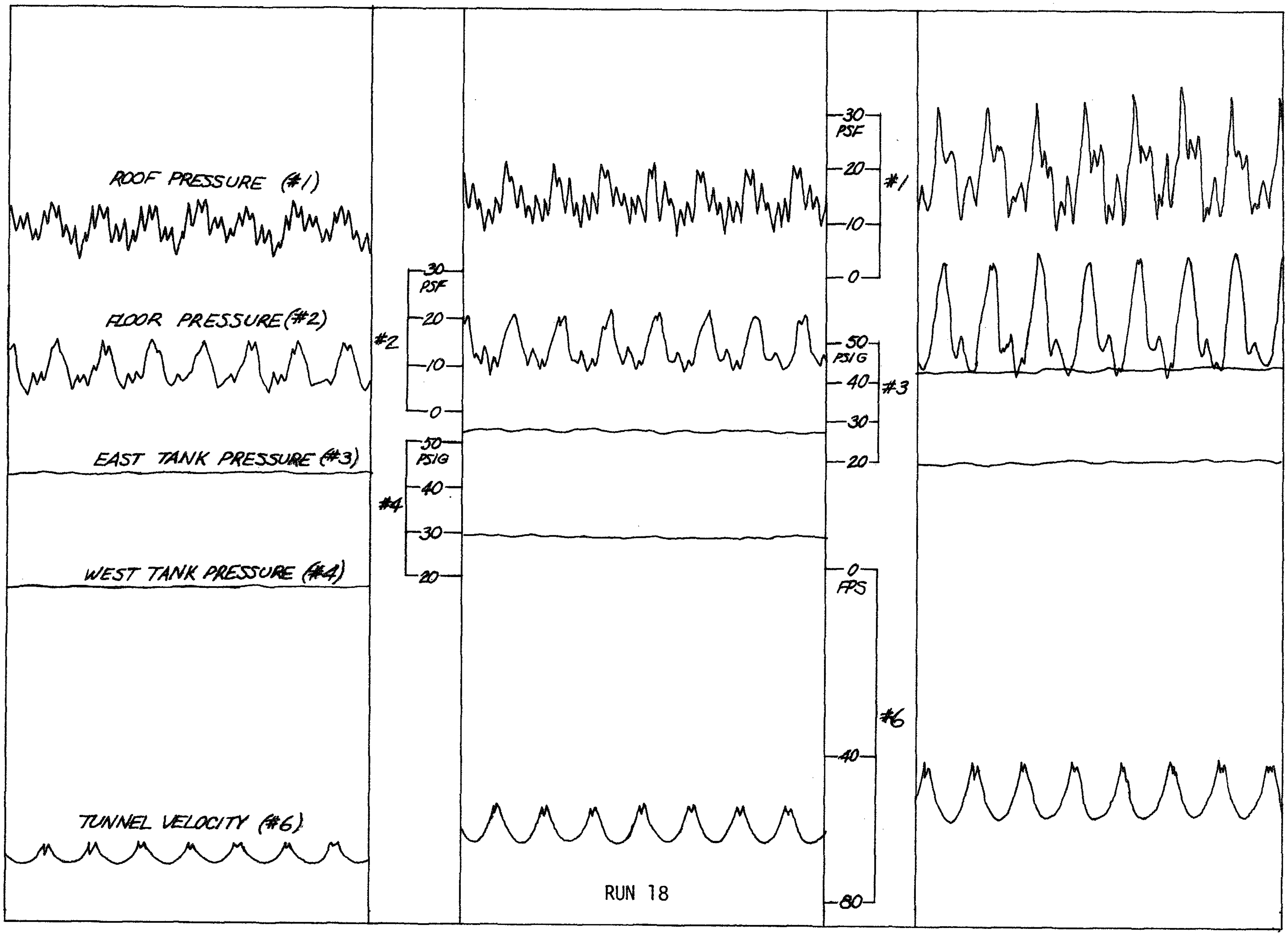


FIG. 10. GUSTS AT 54 HZ VALVES 30° OUT OF PHASE

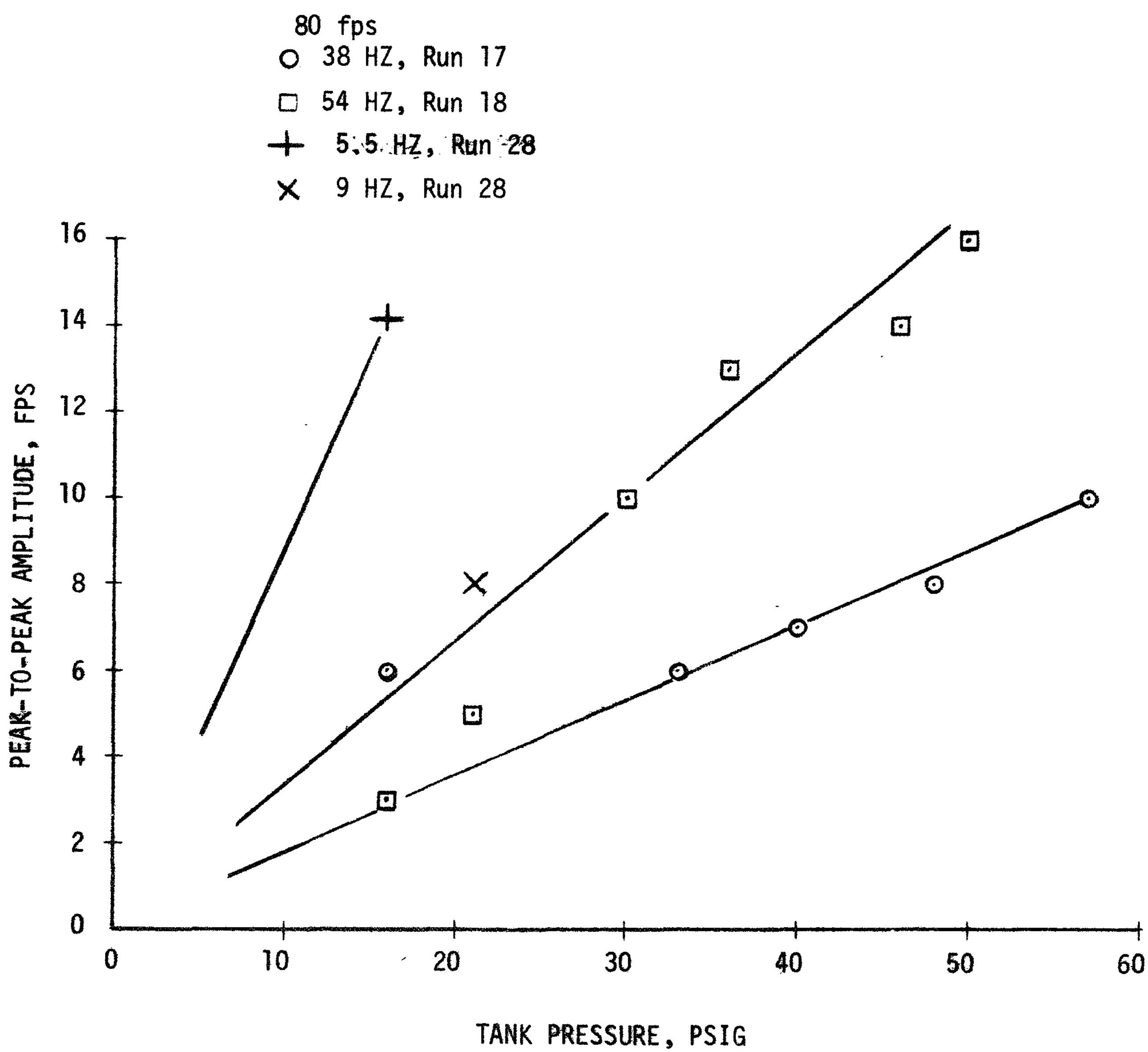


FIG. 11. GUST AMPLITUDE vs. TANK PRESSURE

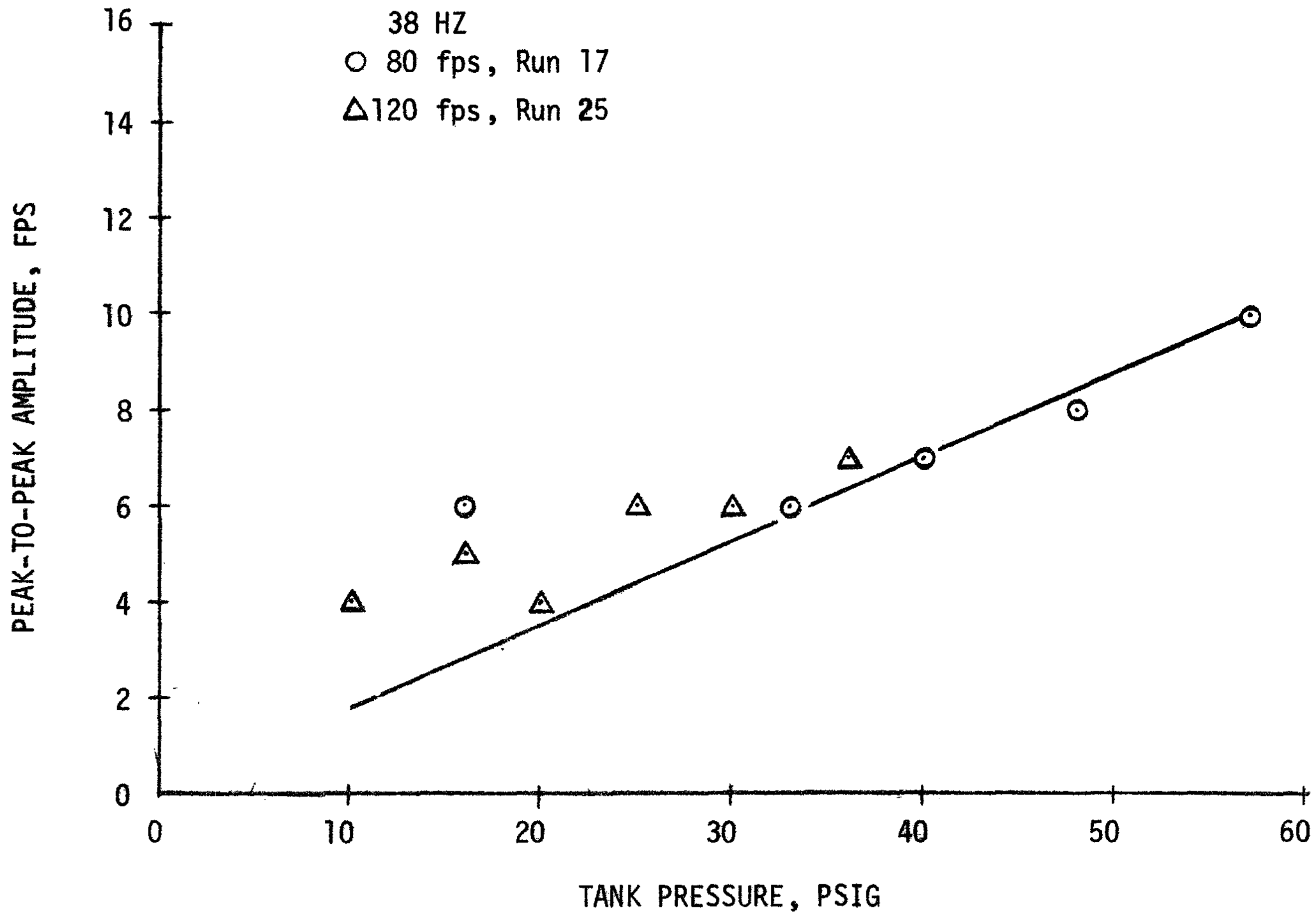


FIG. 12. GUST AMPLITUDE vs. SET AIRSPEED

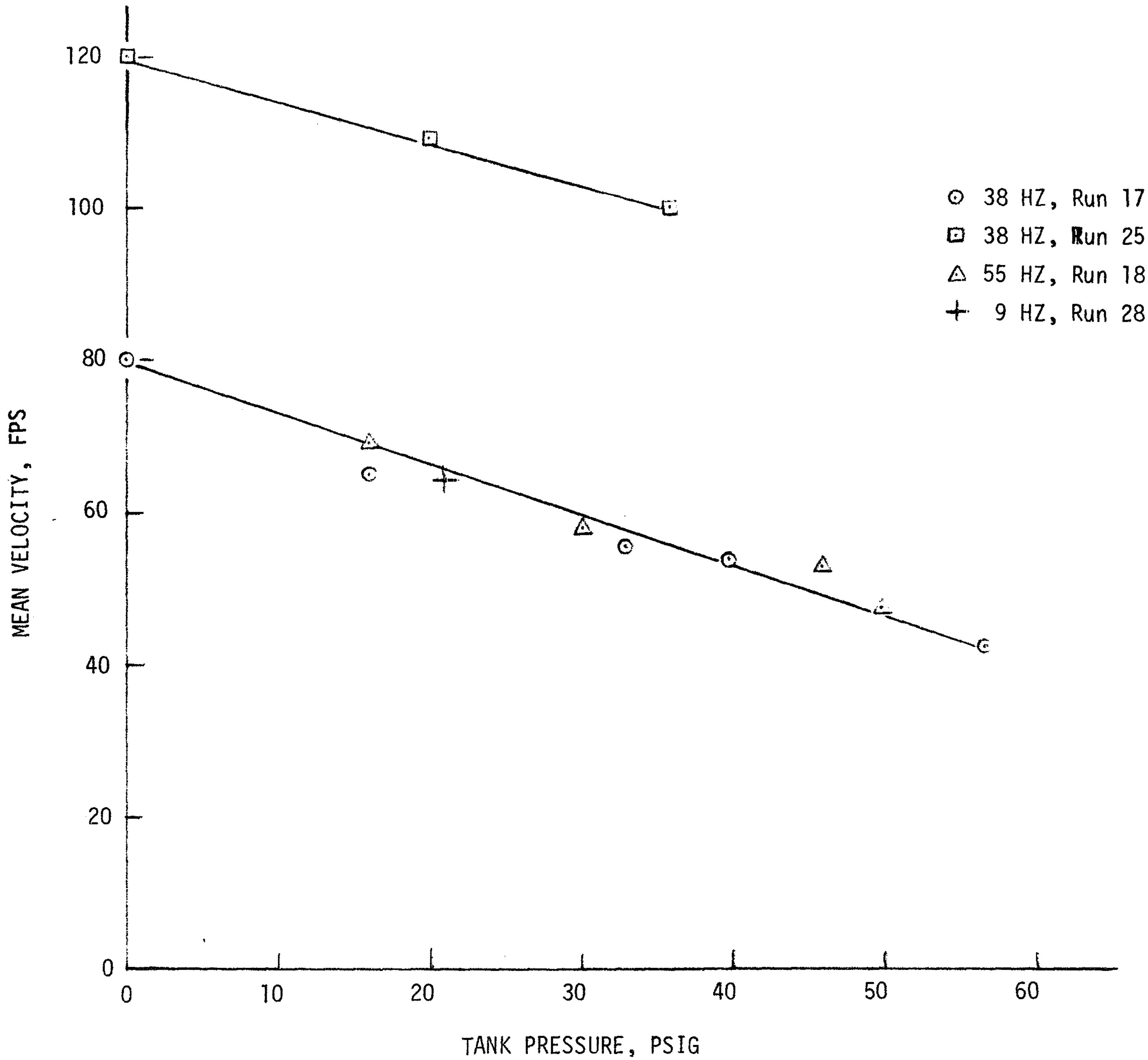


FIG. 13. EFFECT OF GENERATOR ON MEAN TUNNEL VELOCITY

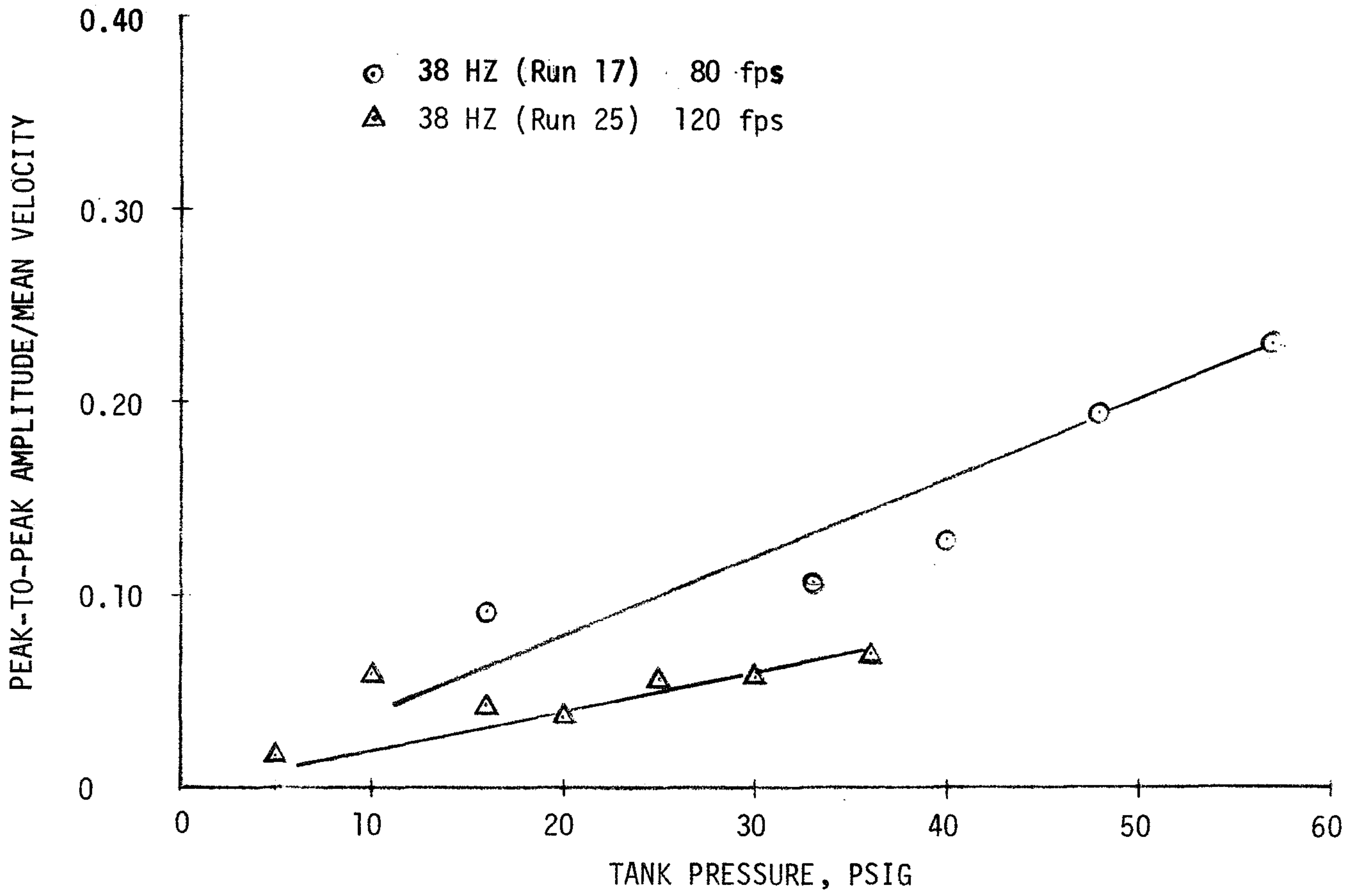


FIG. 14. GUST AMPLITUDE RATIO vs. TANK PRESSURE