THE UNIVERSITY OF MICHIGAN

College of Engineering

Department of Nuclear Engineering

Laboratory for Fluid Flow and Heat Transport Phenomena

Technical Report No. 01077-1-T

CURRENT STATUS OF GAS GUN RAIN EROSION SIMULATOR

S. T. Hinckley
C. L. Kling
R. Cheesewright
F. G. Hammitt

Financial Support Provided by:

U. S. Naval Air Development Center

Contract No. N62269-67-C-0631

August, 1967

ABSTRACT

A review of the current status of work on a gas gun rain erosion simulator is presented, showing the various jet configurations and performance as a function of gun pressure which results. Unfortunately, with the present arrangement the data scatter is too great for the simulator to be used for ranking materials for erosion resistance. Modifications are discussed which it is hoped will reduce the scatter among the data to an acceptable level.

CONTENTS

	Page
Abstract	ii
Introduction	1
Present Results	2
Anticipated Technique Improvements	3
Technique Modifications Previously Examined	4
Detailed Jet Characteristics	5
Bibliography	7
Figures	8

INTRODUCTION

The current task in regard to the gas gun momentum exchange jet device is to standardize or systematize the techniques in which it can be used as a rain erosion simulation device. The previous work[1,2] has been of an exploratory nature to examine different techniques which might give appreciably higher velocity jets or configurations more closely resembling a rain drop. This report discusses some of the variations that have been tried as well as variations presently under consideration.

The emphasis of the present work is to determine that jet condition (form and size) which is most damaging. The most obvious damage criteria for single impact studies are pit depth and/or depth to diameter ratio. Therefore, samples of 1100-0 aluminum have been subjected to damaging impacts and attempts have been made to determine damage versus gun pressure in terms of these parameters as a function of nozzle size. However, the present results (Figures 1 and 2) show a great deal of scatter for tests involving nozzles of 1.0 and 1.8 mm diameter, respectively (nozzles 4 and 5). Hence, it appears necessary to improve the repeatability of the jet configuration. This can be evaluated more easily for the present in terms of jet and gun parameters rather than pit dimensions.

PRESENT RESULTS

These considerations have suggested the following possible presentations of the data:

Pellet Velocity vs. Gun Pressure

Pellet Momentum vs. Gun Pressure

Pellet Energy vs. Gun Pressure

Jet Velocity vs. Gun Pressure as a function of nozzle diameter

Jet Mass vs. Gun Pressure as a function of nozzle diameter

Jet Energy vs. Gun Pressure as a function of nozzle diameter

Jet Momentum vs. Gun Pressure as a function of nozzle diameter.

The mechanical strength of the nozzles limits the maximum usable pressure at present to about 500 lbf/in^2.

However, only the first three, which do not involve the momentum interchange between pellet and jet, show reasonable reproducibility and have not proved to be significant, presumably because of the large (up to 100%) variations in the jet characteristics under an apparently fixed set of conditions (Figures 3 through 9). Thus, reproducibility and consistency of the jet constitute the primary objectives in the development of this facility at the present time.

ANTICIPATED TECHNIQUE IMPROVEMENTS

The following techniques will be attempted to increase the reproducibility of jet and damage characteristics:

1. Back leakage in the nozzles has been greatly reduced by the replacement of the original neoprene seals by lead seals (Figure 10). However, the tight-fitting lead seals involve substantial friction losses in the impact phenomena. Such a seal, which must be forced in with a hammer, is clearly a source of poor reproducibility. It is anticipated that these will be replaced by close-fitting, machined, aluminum piston-discs. The fit between the piston and the nozzle chamber walls would then be substantially reproducible between shots, though some increase in back leakage may occur.
2. The nozzles will be filled under water to eliminate the possibility of air pockets in the nozzles, which may have been a source of poor reproducibility.
3. The nozzle mounting block will be more firmly attached to the gun mount to eliminate variation in the impact point.

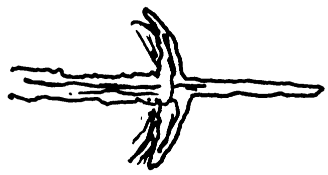
The above modifications should allow more systematic results to be obtained, e.g. as reported by the Naval Ordnance Laboratory[3] (Figure 11).

TECHNIQUE MODIFICATIONS PREVIOUSLY EXAMINED

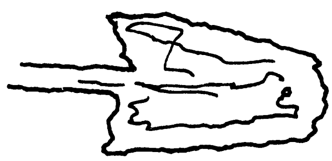
1. A layer of "Scotch Tape" was applied to the nozzle orifice to act as a "burst diaphragm" to see whether the resultant initial pressure build-up in the chamber would result in a cleaner, more repetitive jet. However, this modification did not have the desired effect.
2. A "Constant-Pressure" nozzle design, i.e. a nozzle with internal air chambers, the expansion of which should provide a more constant pressure on the water during its expulsion from the chamber, led to mechanical difficulties in that the gasket material flowed plastically into the air chambers. Also, no marked improvement in jet characteristics was noted.
3. The effect of varying the quantity of water in the nozzles was investigated. It was found that nozzles with less than the maximum possible quantity of water often led to somewhat higher jet velocities, but the repeatability in this condition was very poor.
4. In an attempt to get a spherical drop impacting the target rather than a jet, a spherical drop of about 1.8 mm was placed above the nozzle outlet and expelled by striking with a teflon piston driven by the gas gun pellet. This resulted in a jet with a spherical shell configuration of relatively large diameter (about 12.5 mm for a nozzle diameter of 1.8 mm) and travelled at a very low velocity of 150 m/s. The photographs show a curious, small particle travelling with the jet in each case, which appeared to be a piece detached from the teflon piston (Figure 12). Thus, this technique did not produce a high velocity spherical drop as had been hoped.

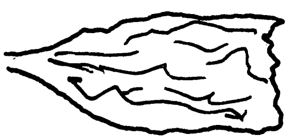
DETAILED JET CHARACTERISTICS

The pictures taken of each firing were classified according to the principal jet configuration. Four main jet shapes were observed. Each jet photographed was then identified as one of the given types or a combination of two. Previous researchers with similar equipment have indicated a strong dependence of jet shape on the nozzle loading technique, with the shape of the meniscus at the nozzle opening being a controlling factor.[4] The present results suggest that the jet shape is also dependent on the pressure with which the water is expelled from the nozzle. This is brought out by the correlation of jet shape with gun pressure. The four main jet configurations are illustrated below:

A. 

B. 

C. 

D. 

Typical photographs of these major types are illustrated in Figures 13 through 16. Figure 17, showing type B, also indicates on closer inspection that the large head is primarily spray with a solid liquid jet proceeding up to the base of the small Monroe jet.

The correlation of these arbitrary jet configurations with gun pressure is shown in Figure 18. With nozzles 4 (D=1.0 mm) and 5 (D=1.8 mm), the jet shape seemed to become more cylindrical, i.e. narrow with a strong central jet, as pressure increased. Nozzle 6 (D=3.1 mm) seemed to teach this condition at lower pressures and then the jet diverged as the pressure increased.

The relative damaging power of the different jet configurations has not yet been determined.

BIBLIOGRAPHY

1. Hammitt, F. G., "Laboratory Scale Devices for Rain Erosion Simulation," Report No. IP-775, Department of Nuclear Engineering, The University of Michigan, April 1967.

2. Pitek, M. T., "Preliminary Water-Jet Impact Studies Using a Gas Gun-Momentum Exchange Facility," Report No. 08153-2-T, Department of Nuclear Engineering, The University of Michigan, January 1967.

3. Scher, M. P., "Liquid Impact Simulator," Report NOLTR 65-181, U.S. Naval Ordnance Laboratory, White Oak, Maryland, June 1966.

4. Dowden, F. P., and J. H. Bronton, "The Deformation of Solids by Liquid Impact at Supersonic Speeds," Proceedings of the Royal Society, 263, 433-450 (1961).

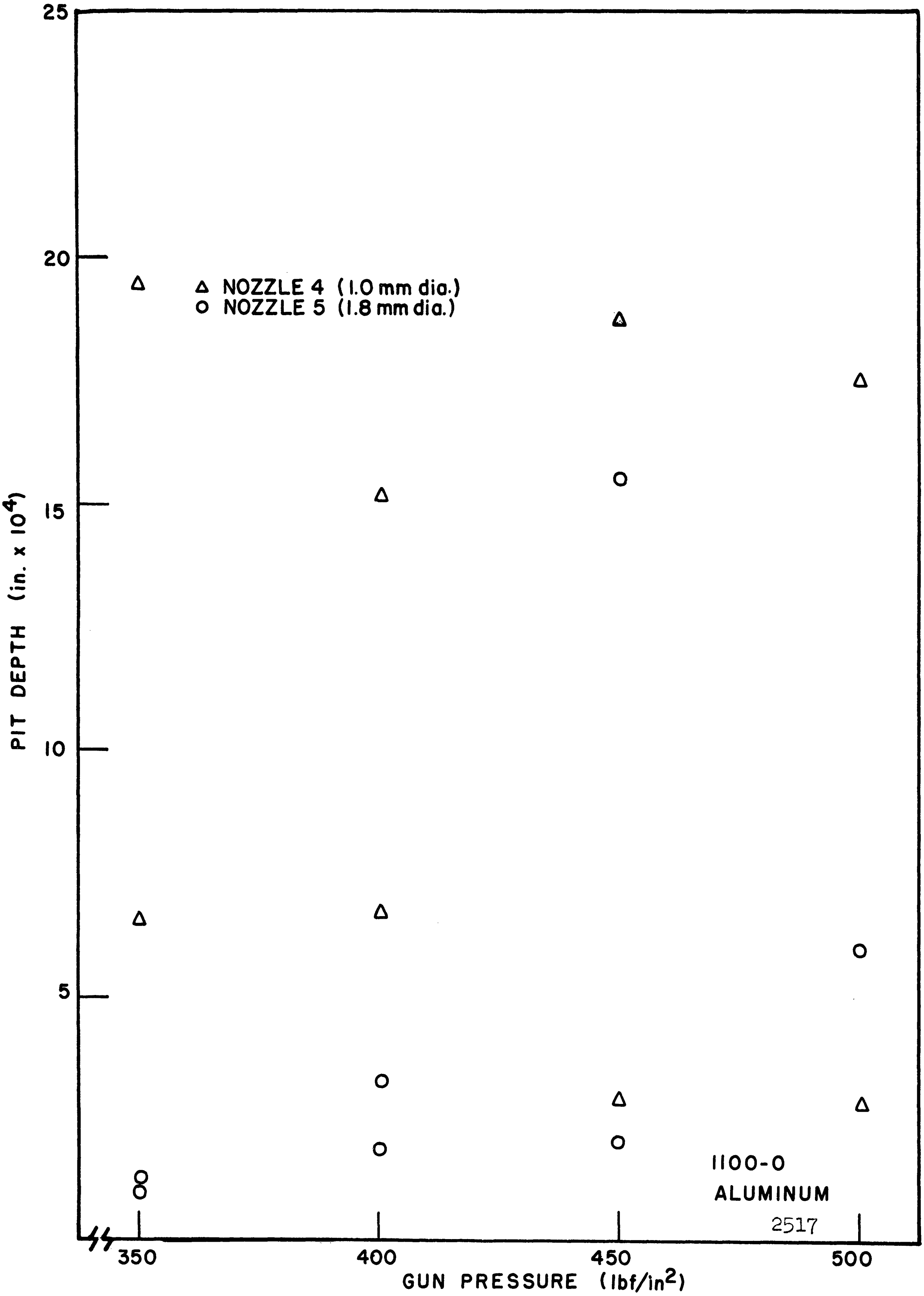


Fig. 1 - Pit depth vs. gun pressure for 1100-0 aluminum.

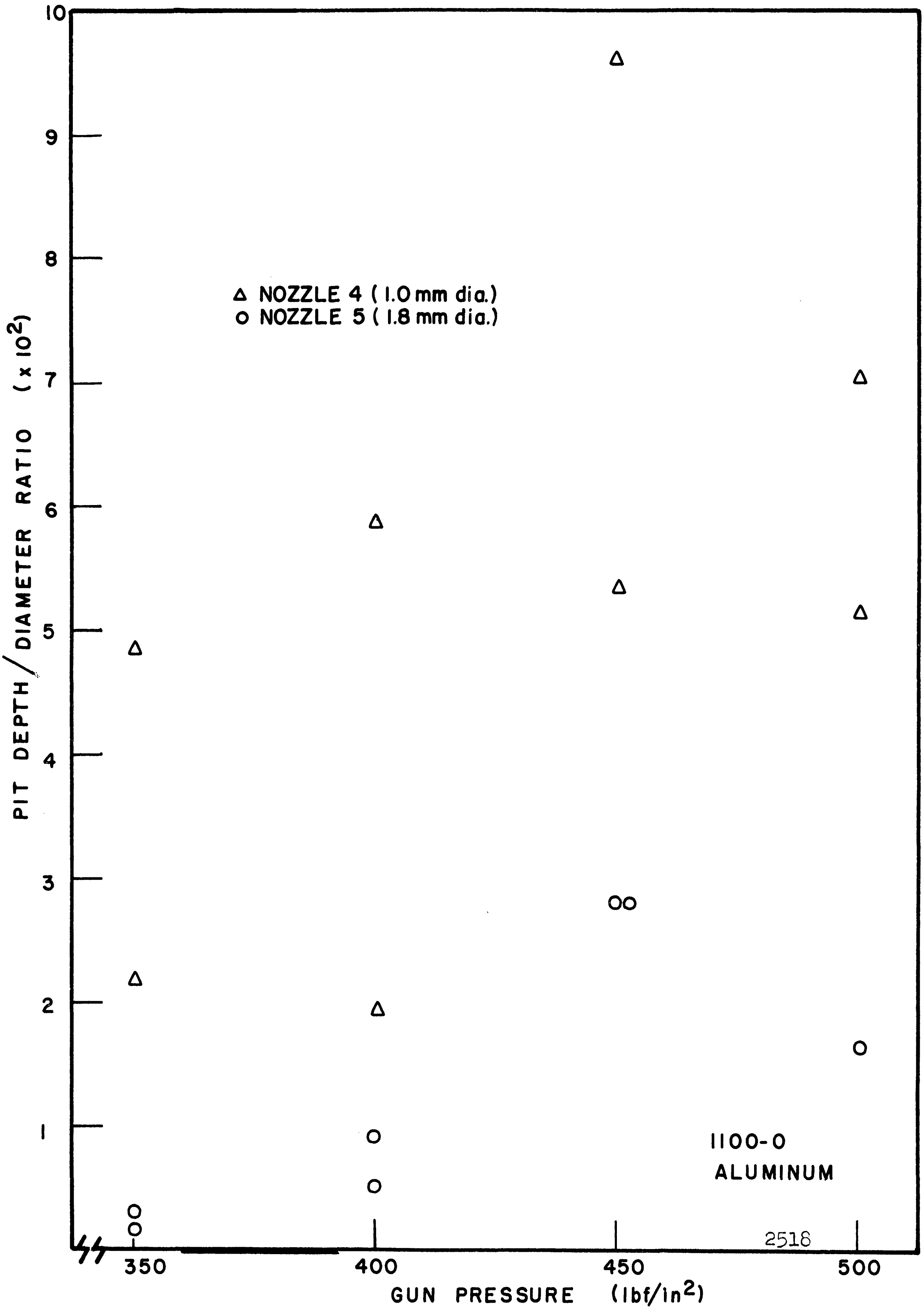


Fig. 2 - Pit depth/diameter vs. gun pressure for 1100-0 aluminum

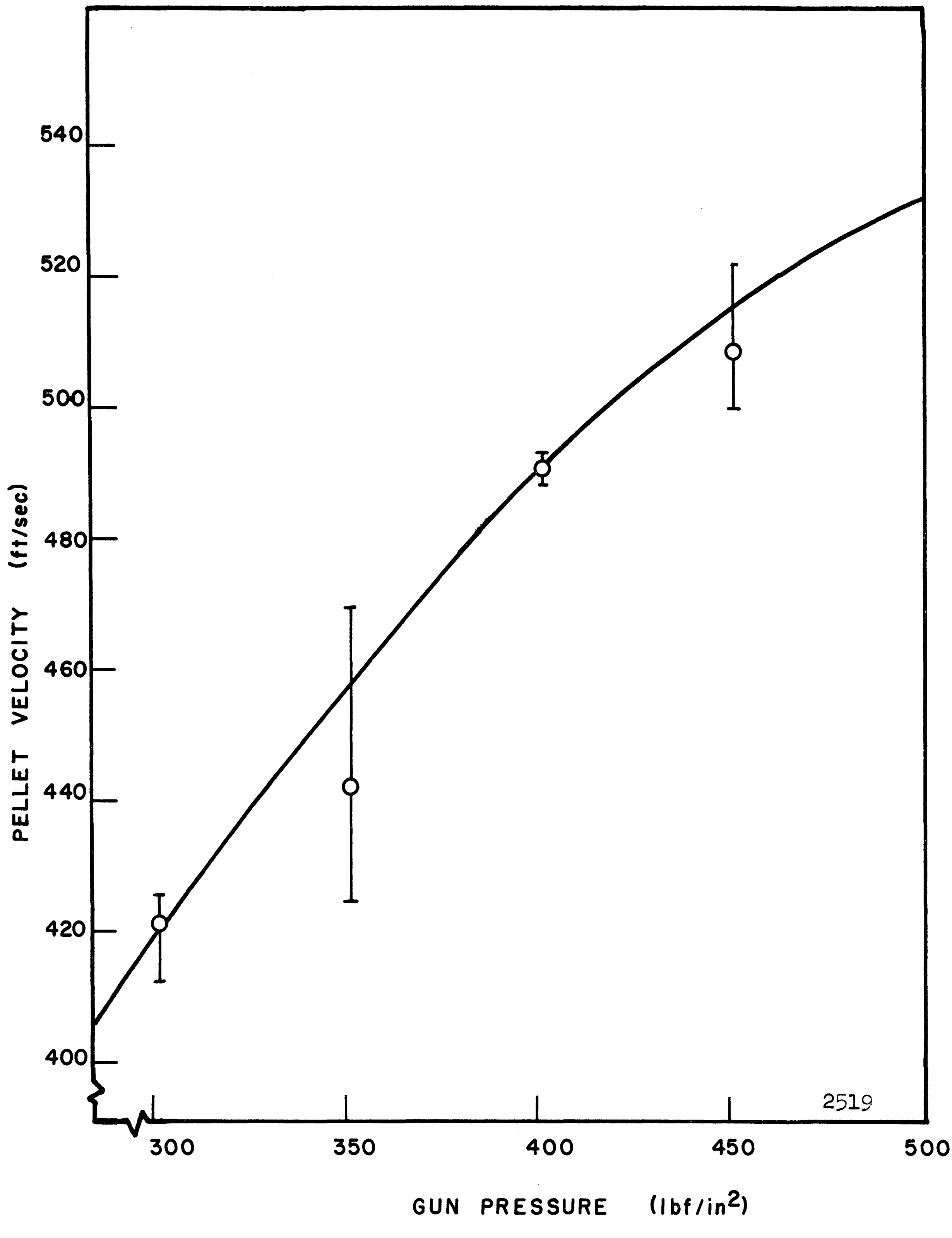


Fig. 3 - Pellet velocity vs. gun pressure.

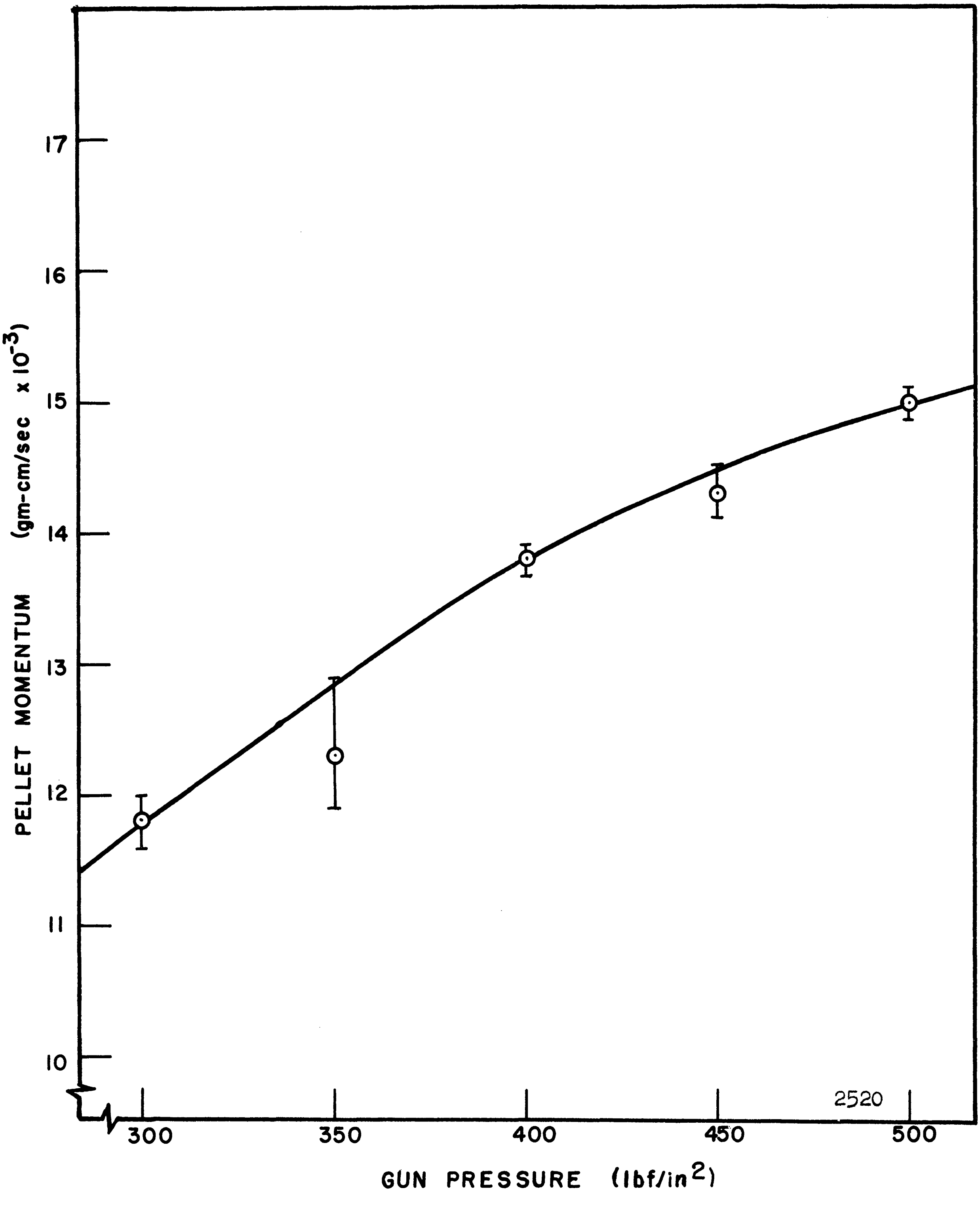


Fig. 4 - Pellet momentum vs. gun pressure.

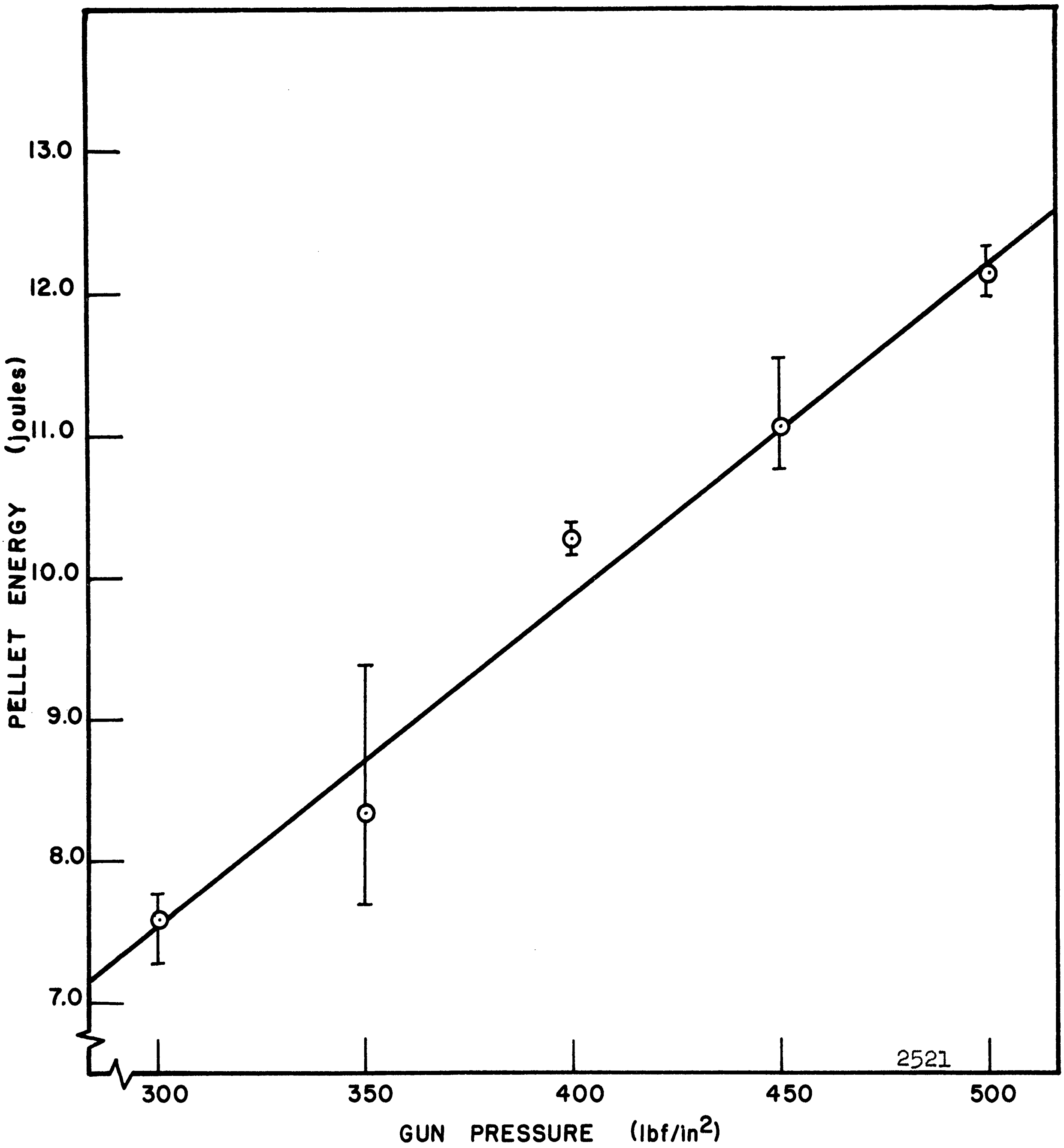


Fig. 5 - Pellet energy vs. gun pressure.

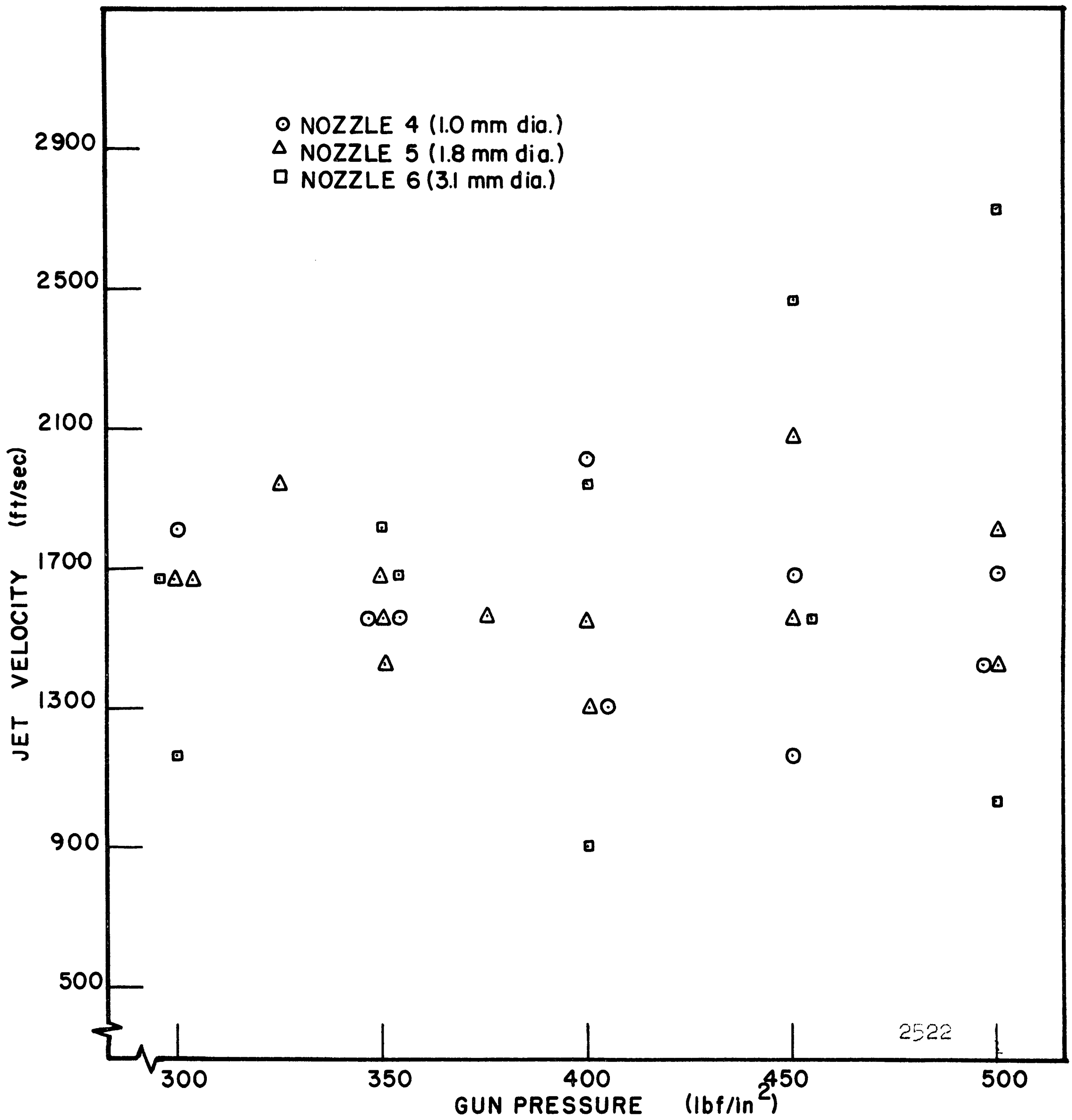


Fig. 6 - Jet velocity vs. gun pressure.

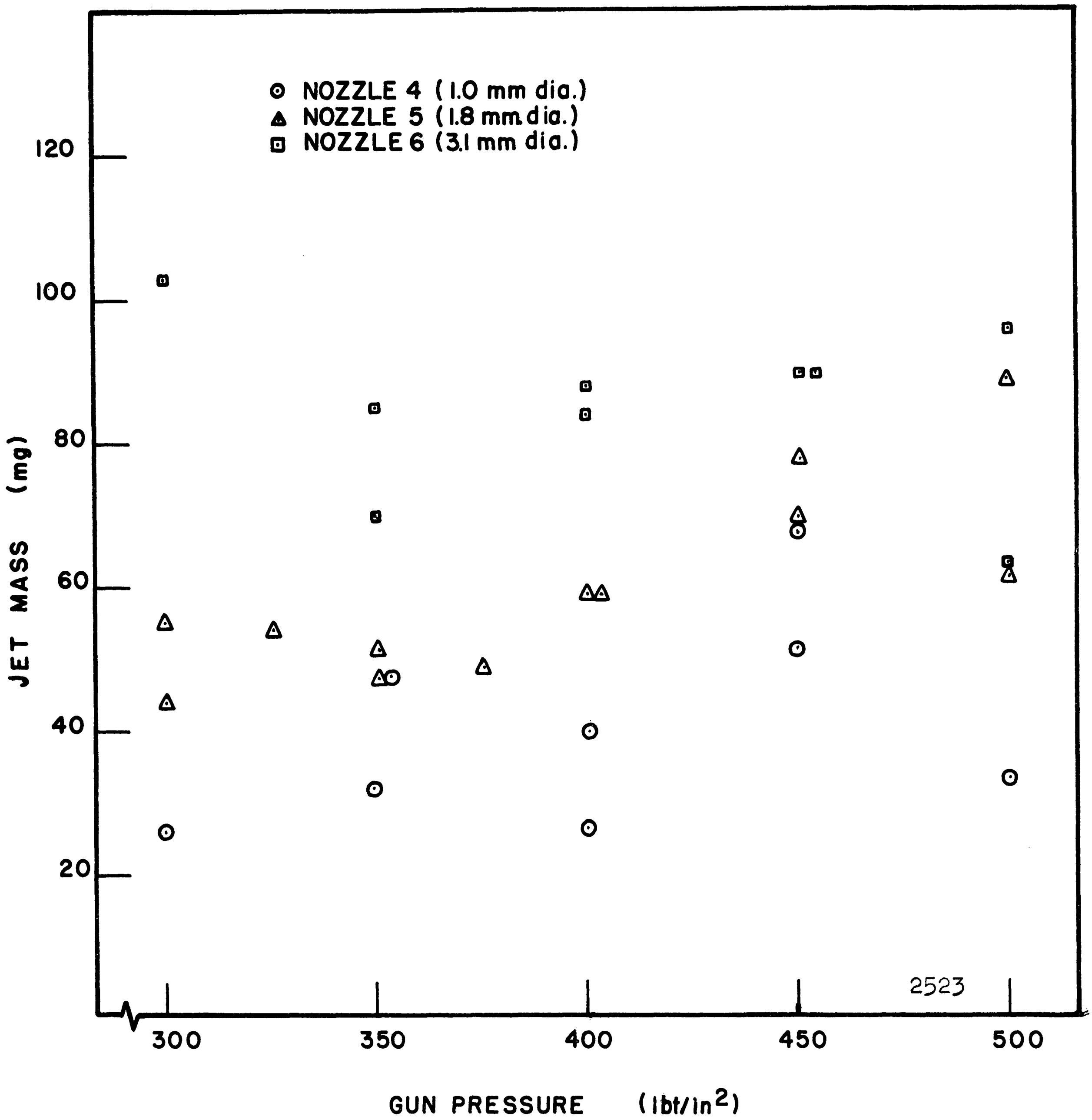


Fig. 7 - Jet mass vs. gun pressure.

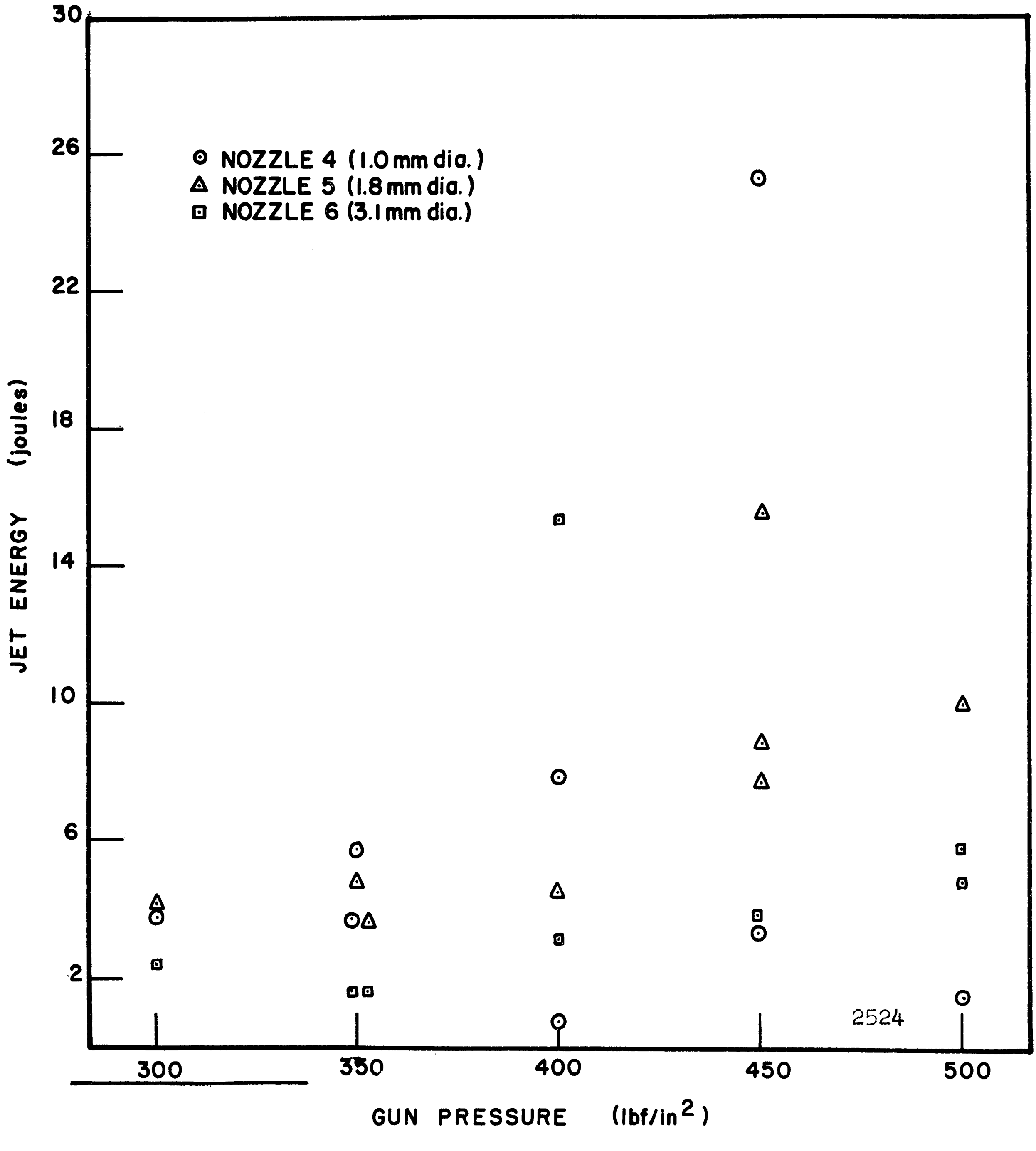


Fig. 8 - Jet energy vs. gun pressure.

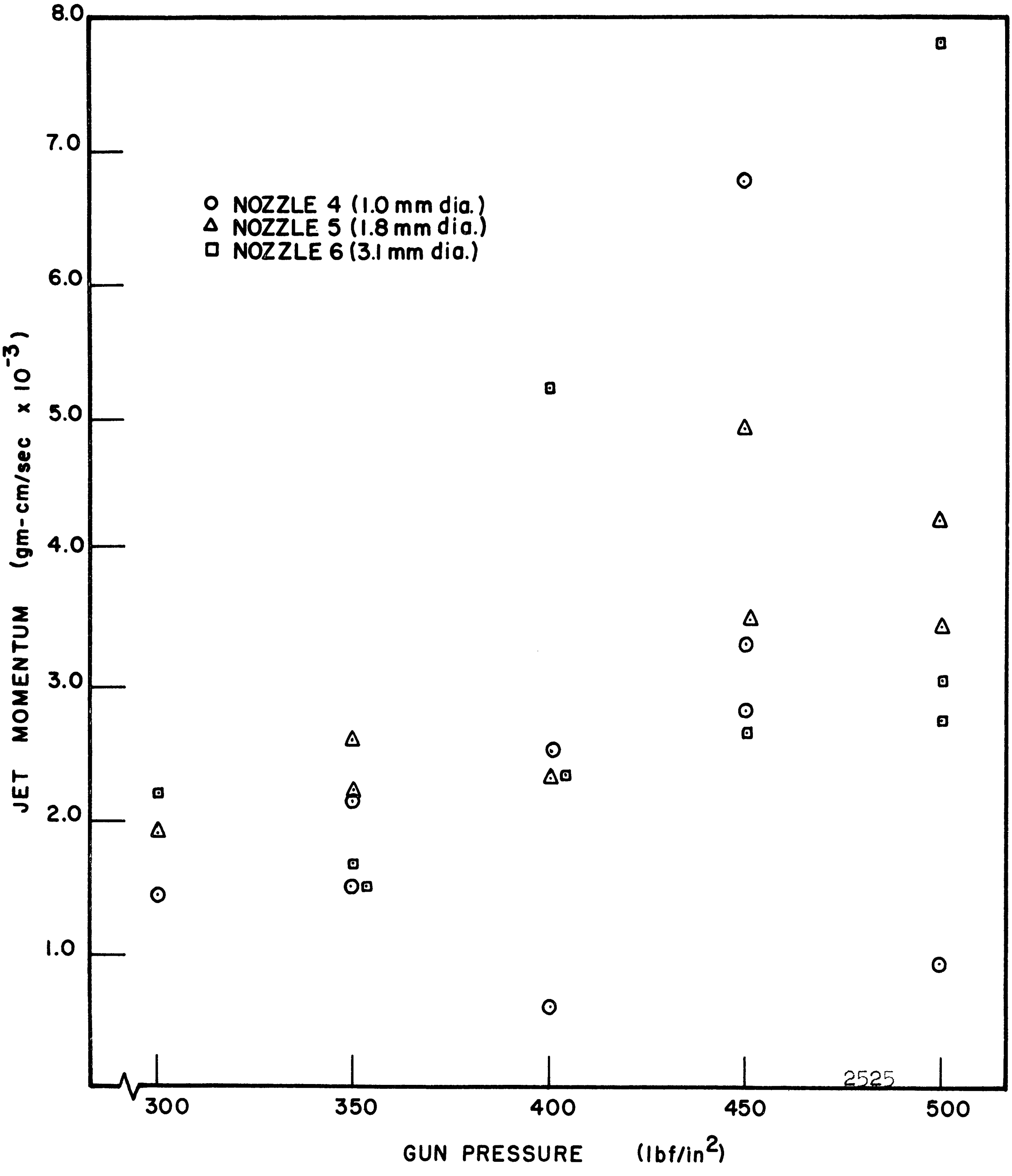


Fig. 9 - Jet momentum vs. gun pressure

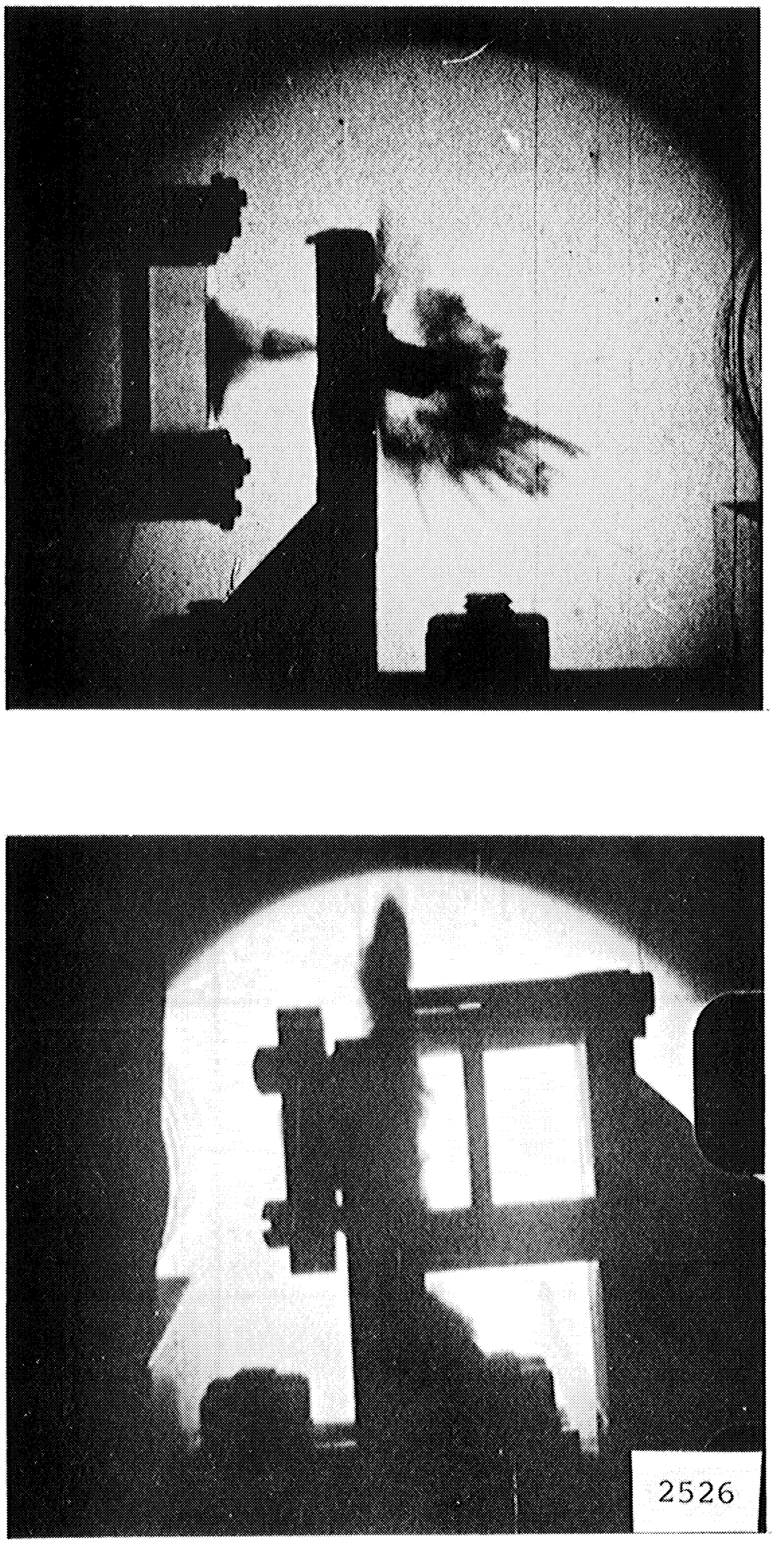


Fig. 10 - Comparison of back leakage (above) in earlier runs with later tests (below) in which lead gaskets were used.

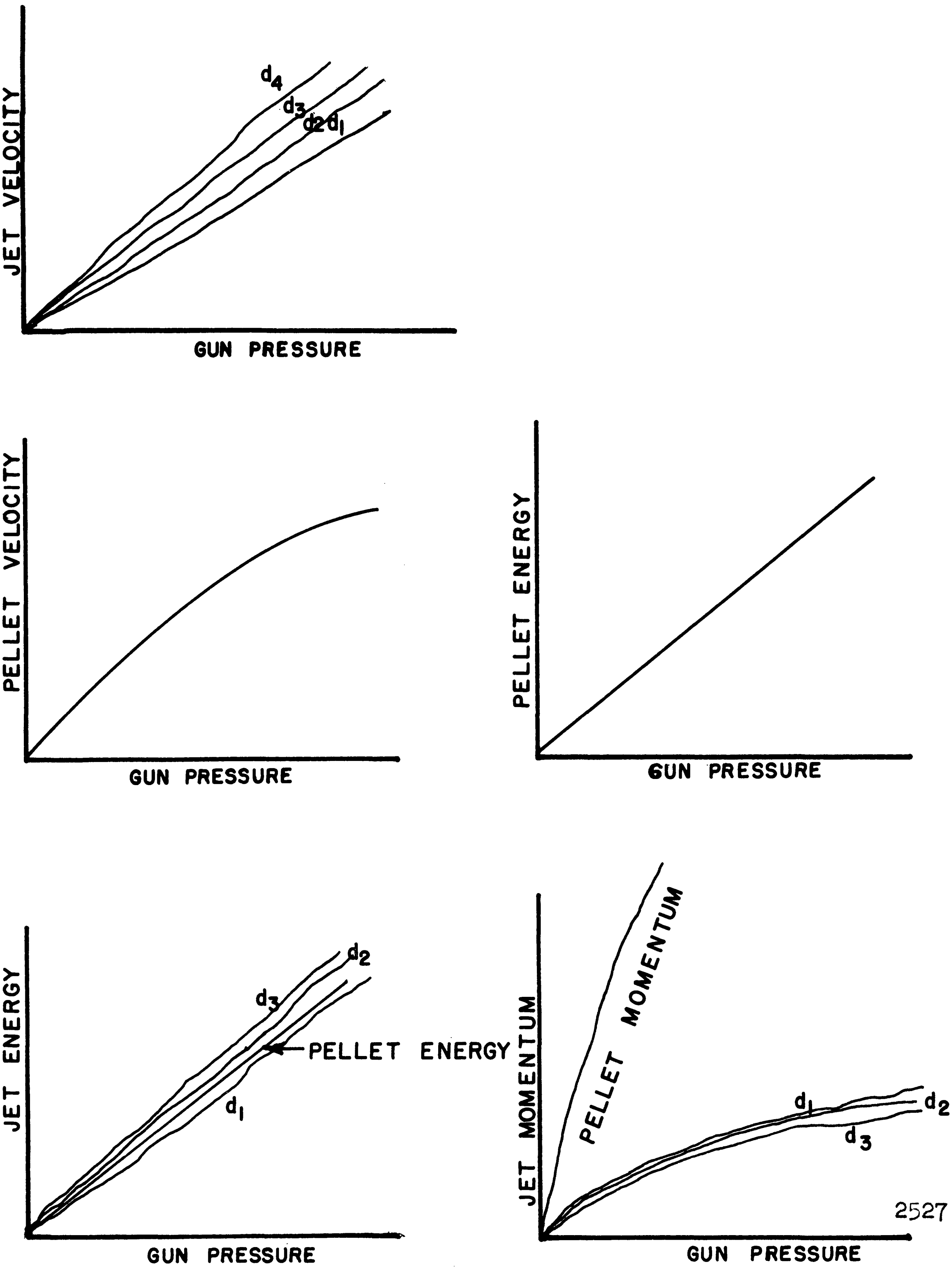


Fig. 11 - Expected dynamic properties of pellets and jets. (Ref. 3)

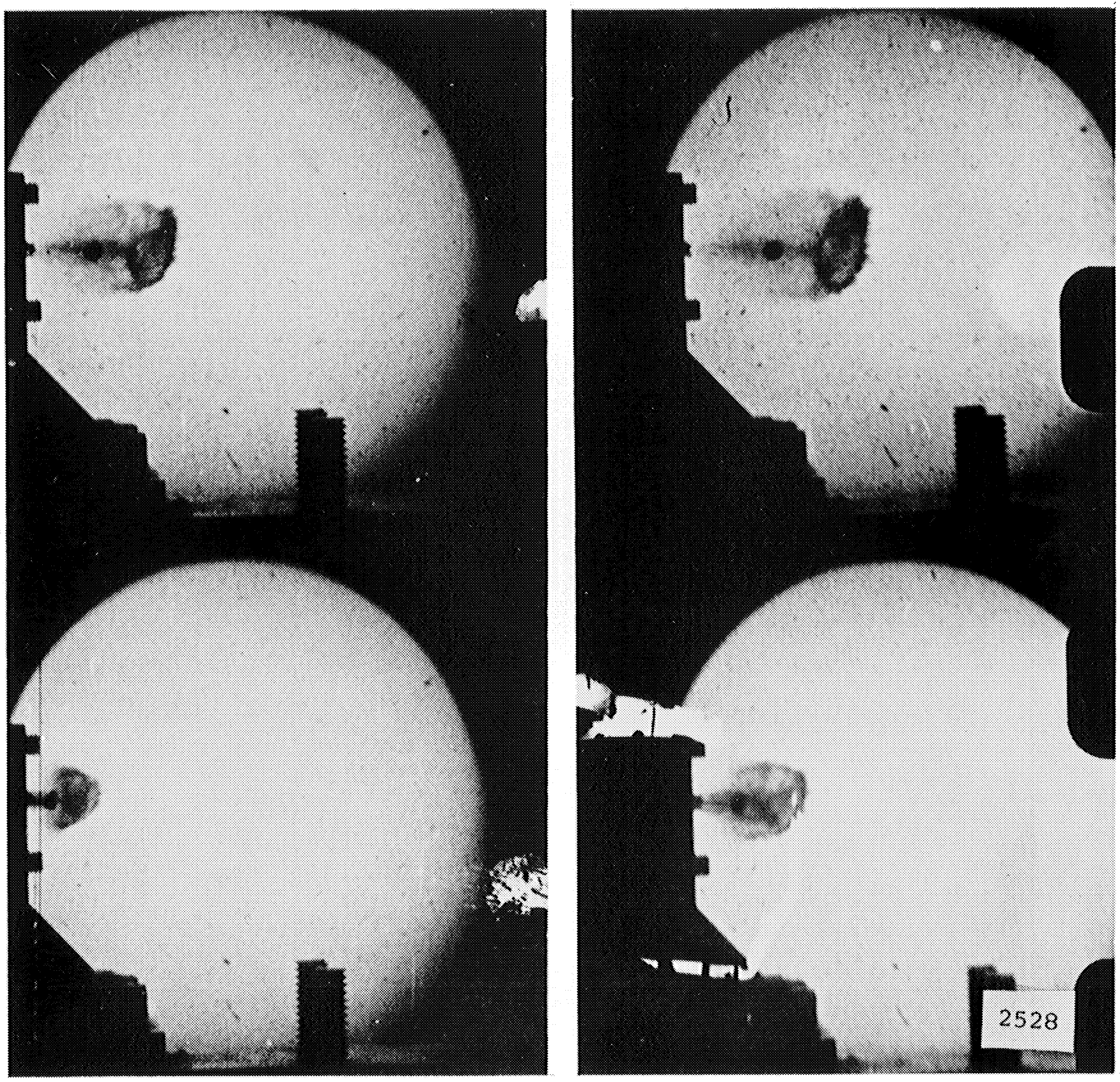


Fig. 12 - Photograph of spherical shell type jet traveling at 575 ft/sec.

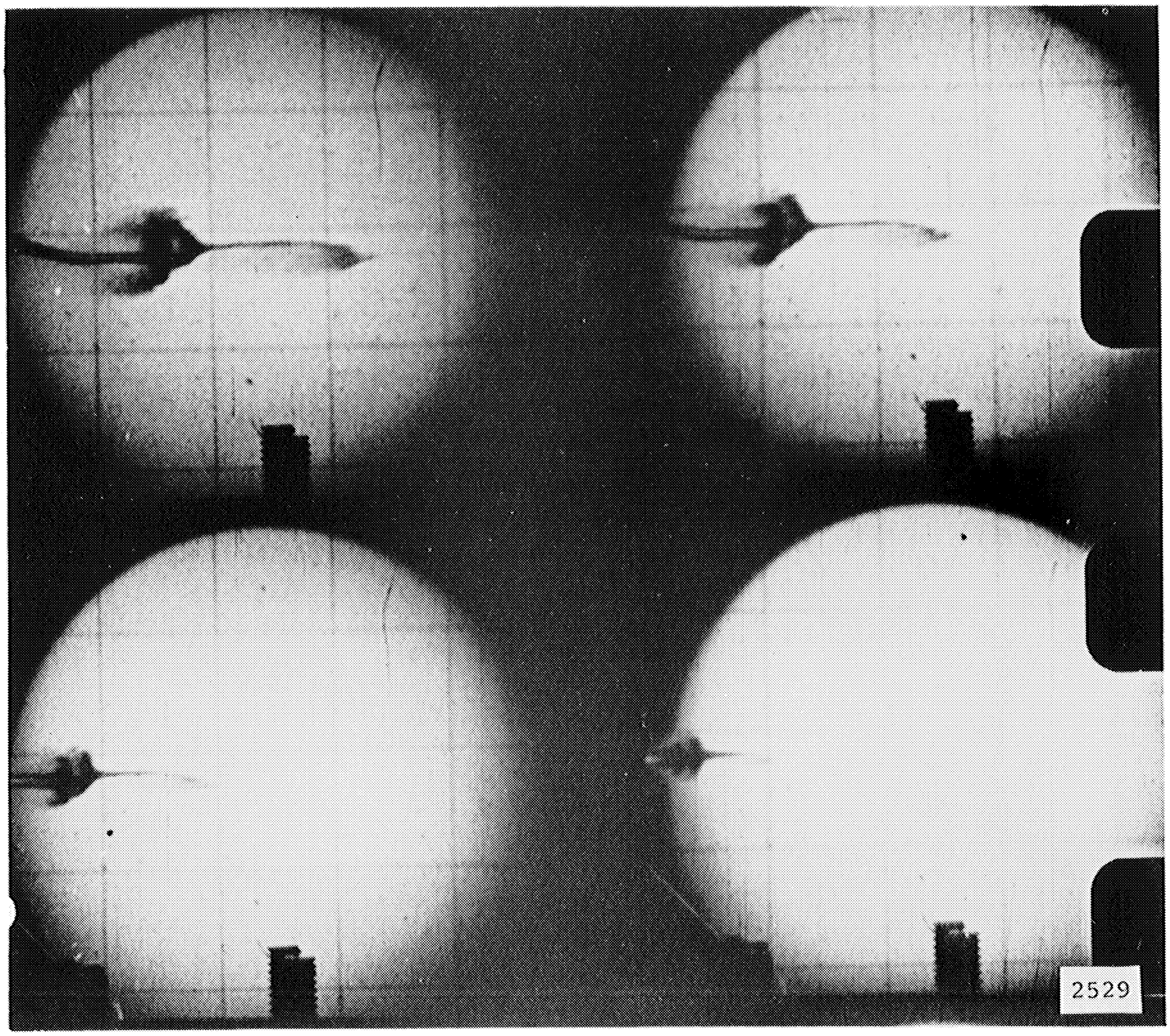


Fig. 13 - Photograph of type A jet configuration.
Jet is traveling at 1820 ft/sec.

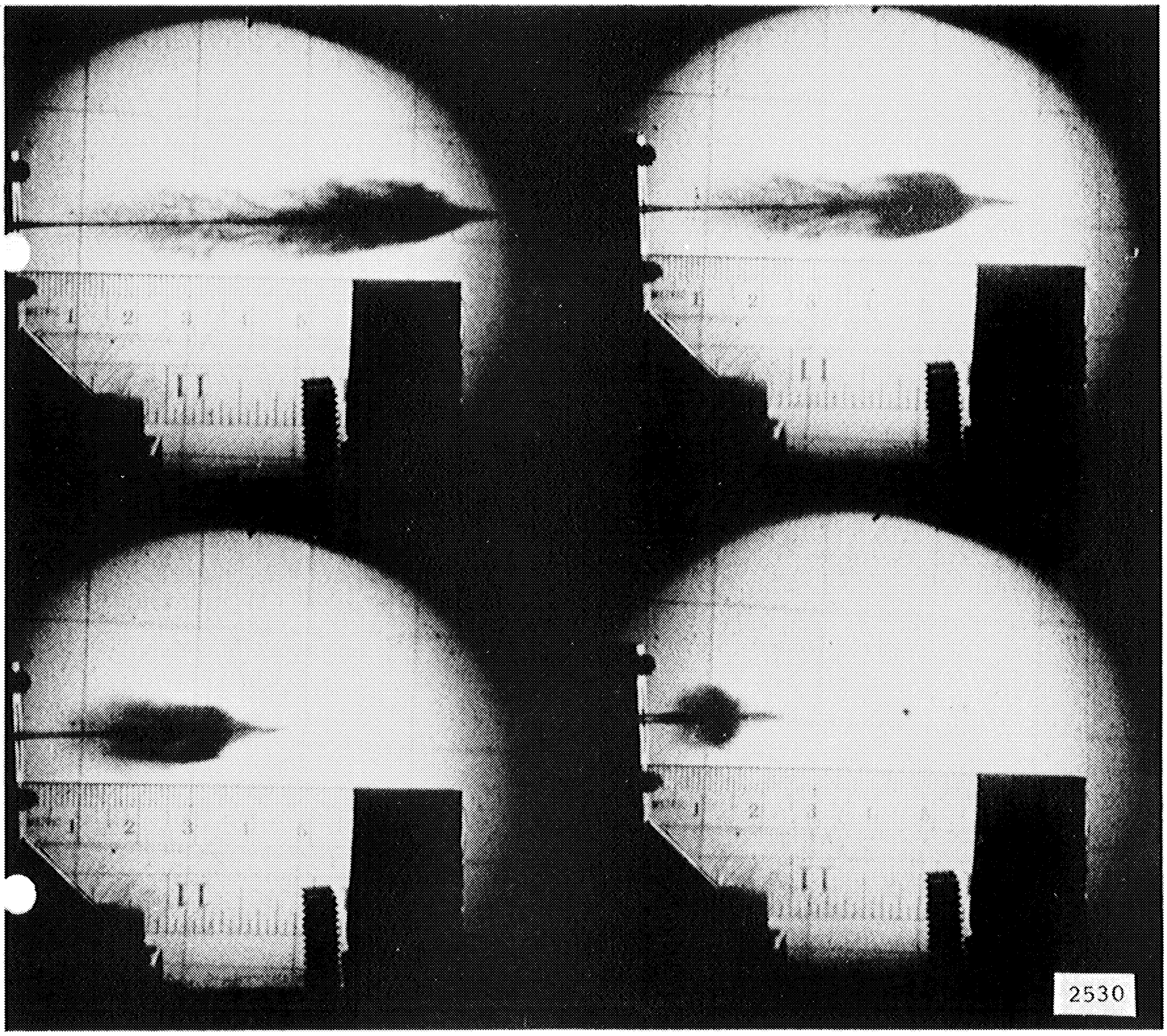


Fig. 14 - Photograph of type B jet configuration. Jet is traveling at 1560 ft/sec.

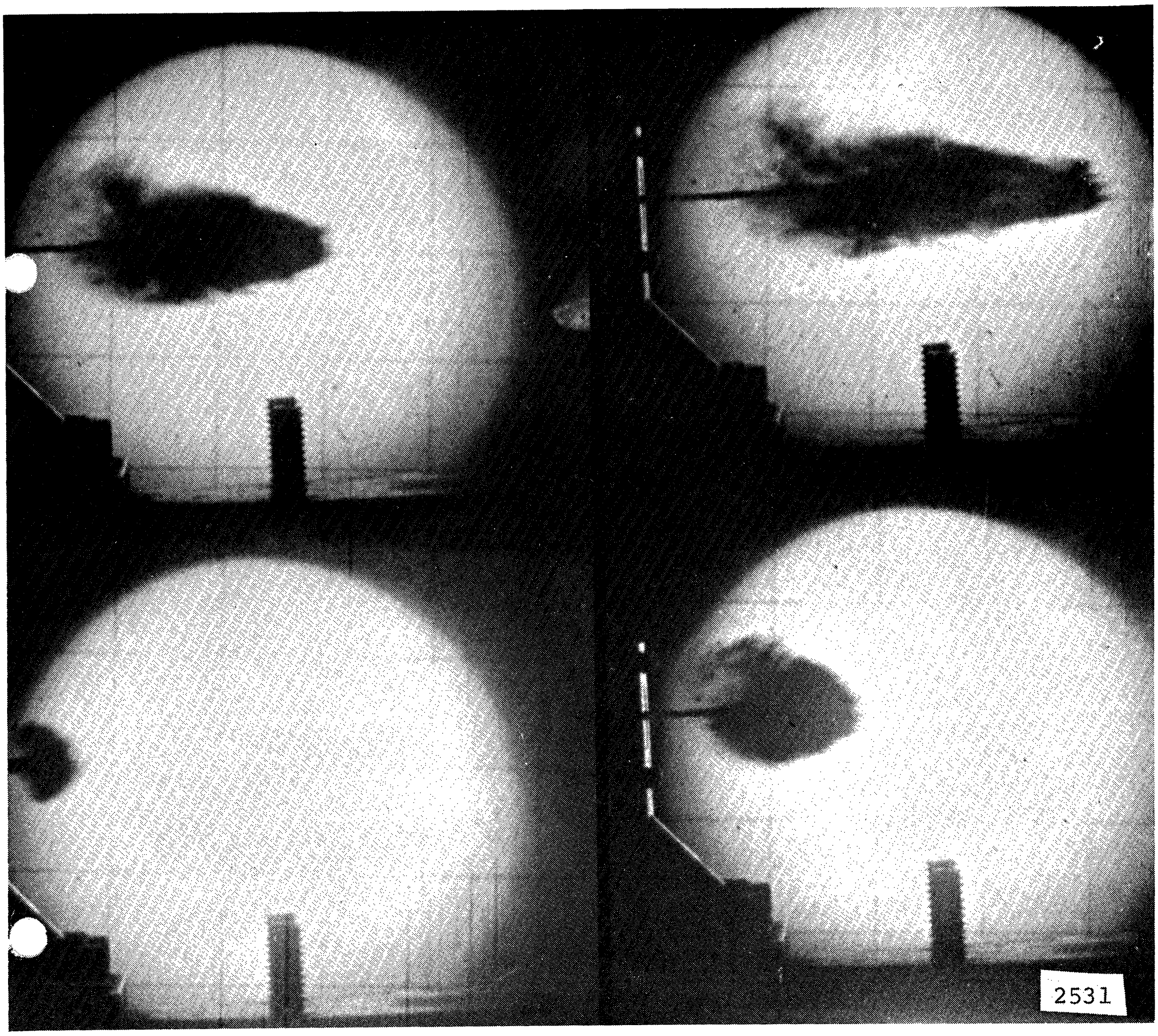


Fig. 15 - Photograph of type C jet configuration. Jet is traveling at 1560 ft/sec.

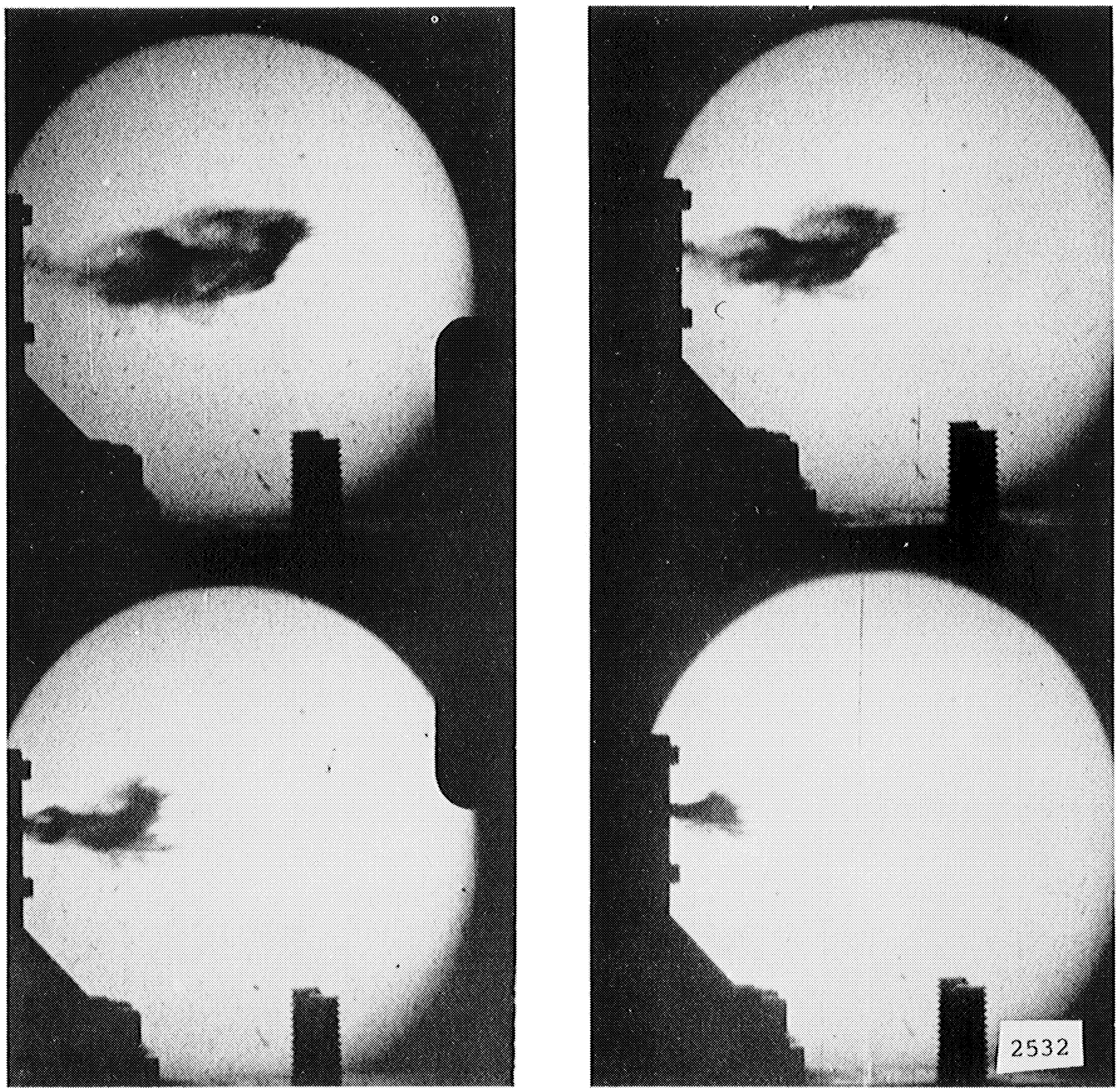


Fig. 16 - Photograph of type D jet configuration.
Jet is traveling at 1560 ft/sec.

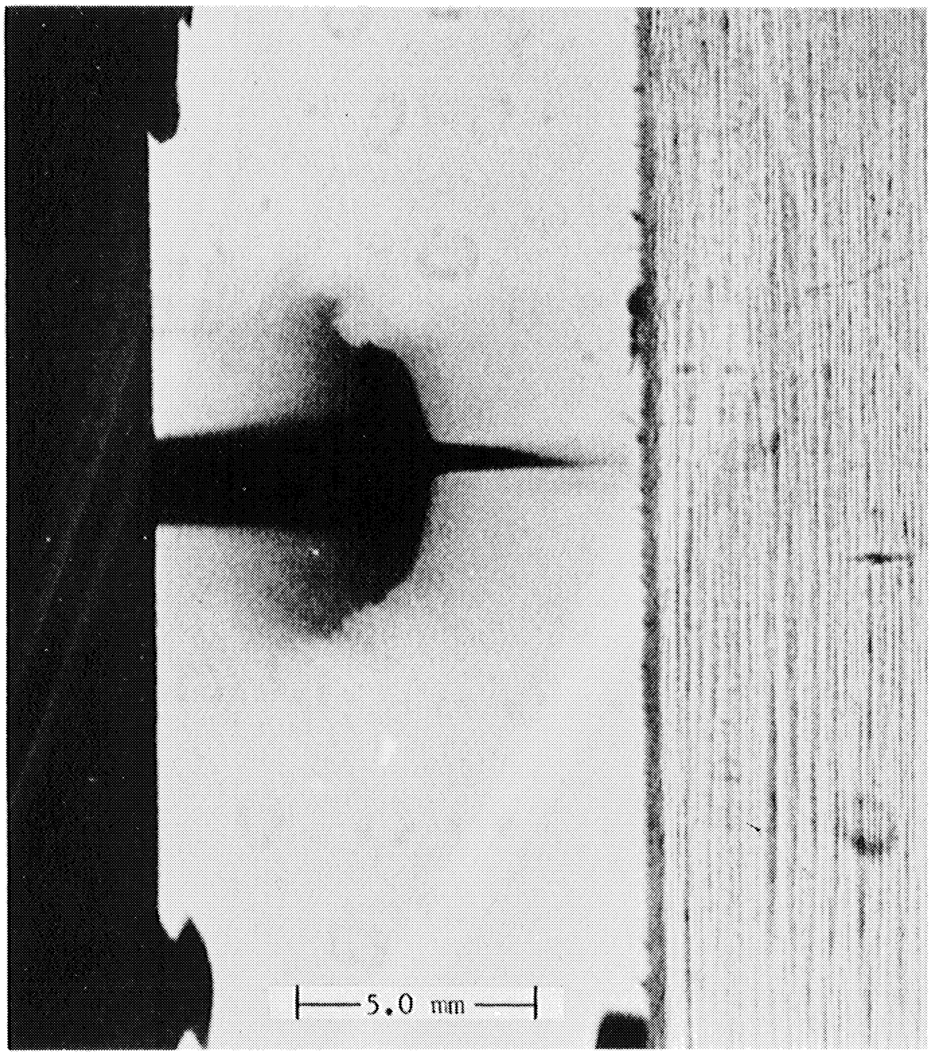


Fig. 17 - High Speed Photograph
of Type B Jet from Nozzle 5 (1.8 mm).

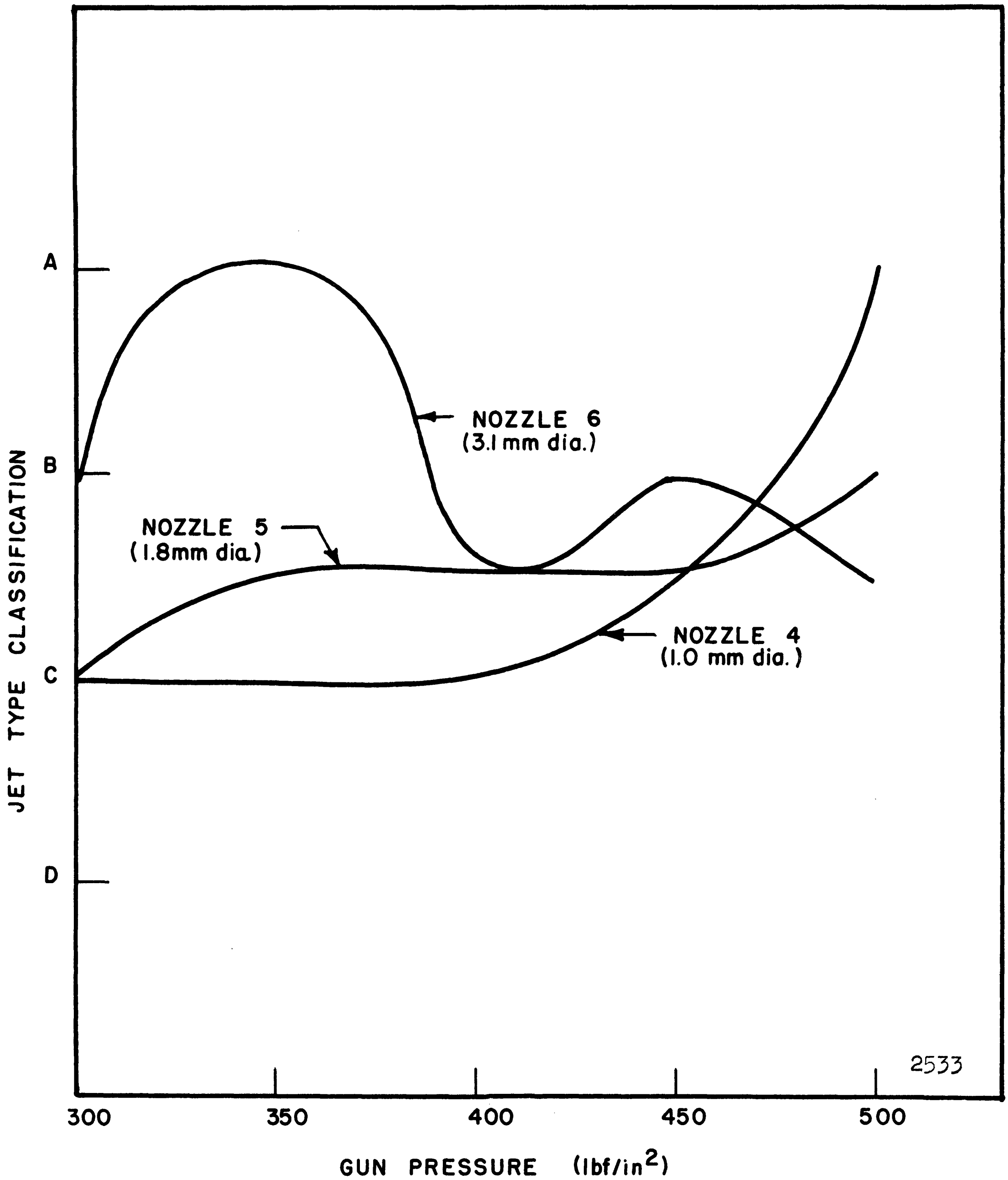


Fig. 18 - Approximate jet configuration vs. gun pressure.