MDC-TR-68-59

AIR FORCE MISSILE DEVELOPMENT CENTER

TECHNICAL REPORT

TEST RESULTS OF RAIL TOP PLASTIC TRAYS AS A MEANS OF PROGRAMMED WATER BRAKING FOR MONORAIL ROCKET SLEDS

John E. Krauss

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June 1968

HOLLOMAN AIR FORCE BASE

NEW MEXICO

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AIR FORCE MISSILE DEVELOPMENT CENTER
DIRECTORATE OF TEST TRACK
AIR FORCE SYSTEMS COMMAND
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FOREWORD

The recovery of monorail rocket sleds traveling at high velocities on the Holloman Test Track is a continuing problem. Water has long been used as a braking medium to decelerate track vehicles. The use of water trays described in this report is one method being tested by AFMDC as a braking device for monorail vehicles. The continuing requirement for a safe, practical, and predictable means of recovery for these vehicles resulted in the tests described herein.

PUBLICATION REVIEW

This Technical Report has been reviewed and is approved.

Tyler A. Redfield

TYLER A. REDFIELD
Colonel, USAF
Director of Test Track

ABSTRACT

Tests were conducted on the Holloman Test Track to determine the feasibility and practicability of using water-filled frangible rail-top trays to brake monorail track vehicles.

This braking technique has been tested at entrance velocities of up to approximately fifteen hundred feet per second with predictable and effective results.

LIST OF ILLUSTRATIONS

Section 1

INTRODUCTION

Currently the Holloman Test Track is testing water filled frangible rail-top plastic trays as a means of braking monorail rocket sleds. This system is attractive for several reasons. First, the brake geometry and structure are suitable for many monorail sled configurations with negligible weight and/or aerodynamic drag penalties. Second, by varying the depth of water in the trays, programmed braking is possible. Third, the trays promise to eliminate some of the undesirable features of similar systems, such as clogging the slipper gap with plastic water bags or other debris attendant to other monorail water braking devices.

Section II

DISCUSSION OF METHOD

The operation of the water tray braking method may be described as follows. The trays (fully described in Section III) are placed end to end on the track in a line which is continuous for the length of the braking distance selected. The track station where the initial tray is located is selected based on desired sled velocity at onset of braking. With the trays on the track at the proper location, the necessary amount of water required for the selected braking profile is measured into each tray. The amount of water contained in the trays used for these tests varied from a minimum depth of 1/4 inch per tray to trays that were completely filled to a depth of 2-1/4 inches.

The rocket sled used in these tests is fitted with a concave vertical-wedge water-brake. (See Fig. 2.) The momentum exchange angle is the tangential angle measured from the longitudinal axis of the wedge to the aft extremity of the wedge. (See Fig. 1.) The vertical wedge concept is desirable because it produces no vertical braking force components, and all lateral braking components are self-reacting.

When the wedge of the moving vehicle impacts the tray it disintegrates the frangible plastic and exchanges momentum with the braking medium (water by imparting velocity to the water. This exchange of momentum can be predicted and its rate controlled by the quantity of water impacted.

The force imparted to the sled by the momentum exchange is adequately described by the equation:

$$F = \rho A V^2 (1-\cos\theta) \qquad \text{(Ref. 1)}$$

where

F - Braking Force - lbs

ρ - Density of braking medium - slugs/ft^3

A - Area of braking medium - ft^3

V - Velocity - ft/sec

- Deflection angle

(Ref. 1) ISTRACON Report No. 60-1, pages 4-2-4 thru 4-2-7.

Section III

TEST EQUIPMENT AND PROCEDURES

One vehicle was used in these tests. It was a monorail sled No. IMS 6632. A vertical concave water brake was fitted to the sled's front end. The momentum exchange angle of this water brake was 70°. This type of brake wedge was selected because it provides braking forces that are symmetrical about the vertical longitudinal plane of the vehicle and thus provide no vertical forces. Some physical characteristics of the vehicle including brake, were: loaded weight 115 pounds, empty weight 91 pounds, frontal area .32 ft^2. The vehicle is shown in Figure 2.

The water trays used for this test were fabricated of expanded polystyrene plastic beads. The material weighs approximately one and one-half pounds per cubic foot when expanded. Each tray is five and one-half feet long with molded ends forming water dams. Each tray can be filled to the required depth to provide the desired braking force. The water trays are designed to minimize ingesting of tray material between the rail and slipper of the vehicle. The maximum cross sectional water area available is approximately 10 in^2. The installation of the trays on the track is shown in Figure 3.

The velocity measurements were made by a breakwire system. Velocities are computed on a measured distance and elapsed time basis The time is measured continuously and the elapsed time between the severing of the wires by the vehicle recorded. The time elapsed between the breaking of any two wires is related to the distance between the wires to calculate the average velocity of the vehicle over that distance. The distances between the breakwires are measured to the nearest 1/10 ft. The breakwires were spaced at approximately fifty foot intervals in the braking area and approximately 100 foot intervals immediately prior to and after the braking area. Thus, the breakwire locations relative to each other are in the order of 4/10 of 1 percent accuracy over the shortest interval. The accuracy is also affected by other factors, such as wire tension from breakwire to breakwire, signal propagation and rise time which introduce further timing errors. What contributions are made to the overall inaccuracies of the system by such factors are not presently known.

Section IV

DISCUSSION AND RESULTS

A single run without braking was made to establish the velocity/distance characteristics for this vehicle. This profile is presented in Figure 4.

In the three braking test runs the entrance velocity relative to track position of the water trays was established from this figure.

Each of the braking runs was based on arbitrarily selected "g" levels and entrance velocities. After these parameters were established (selected) a braking profile was made to determine water quantities and exit velocities. In each case, the total water tray length was selected that was somewhat greater than that providing the selected force. This was done to further reduce the vehicle's velocity and results in actual braking force values that when averaged differ from the selected forces.

This discrepancy can be overlooked when the comparisons are made between the predicted exit velocities and the actual exit velocities and the correlation achieved.

The test results are compared to the predictions in Figures 5, 6, and 7. These same figures are representative of the effectivenss of the braking method. The comparison of the deceleration in the same velocity regimes, both with and without braking, is readily made.

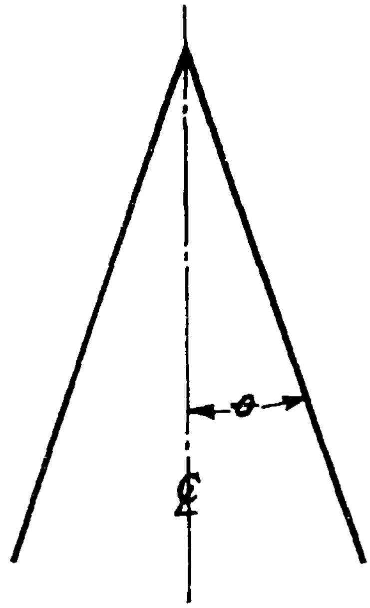
The variations between predicted and actual results might be attributed to the problem of measuring the depth of water in the trays. A variation of ± 1/16 incnes is not particularly meaningful in water depths of two inches or more, but can be very meaningful when measuring depths of a quarter of an inch where this tolerance results in water volume variations of 25 percent.

None of the three tests indicated any phenomenon other than that predicted.

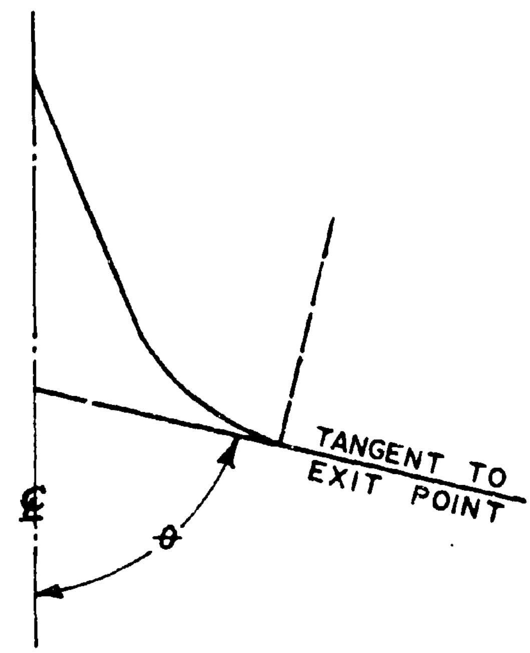
Section V

CONCLUSIONS

Utilizing programmed water braking as provided by the trays results in a predictable reduction in coast distances for a monorail vehicle.



EXCHANGE ANGLE FOR WEDGE



EXCHANGE ANGLE FOR CONCAVE WEDGE

FIGURE 1

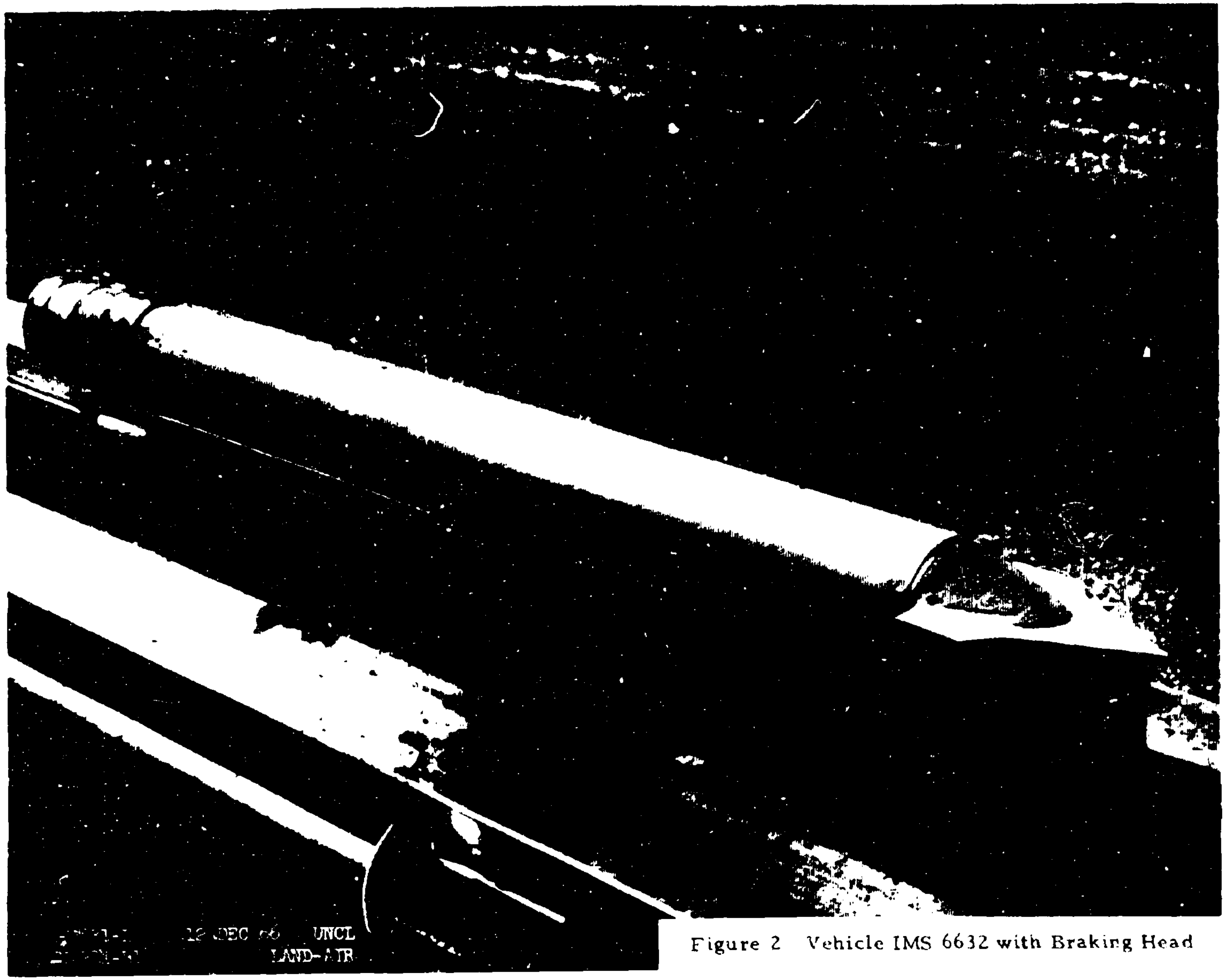


Figure 2 Vehicle IMS 6632 with Braking Head

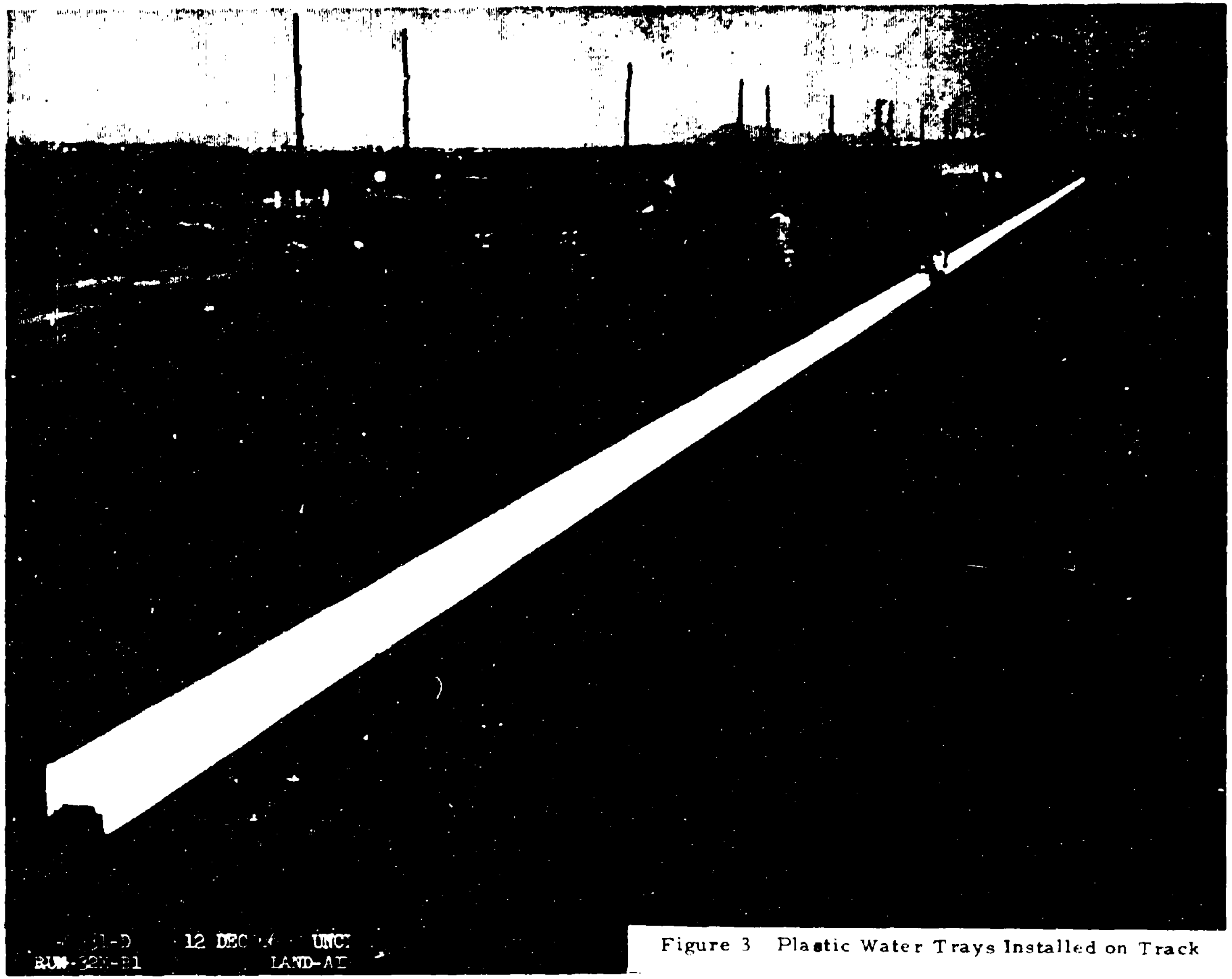


Figure 3 Plastic Water Trays Installed on Track

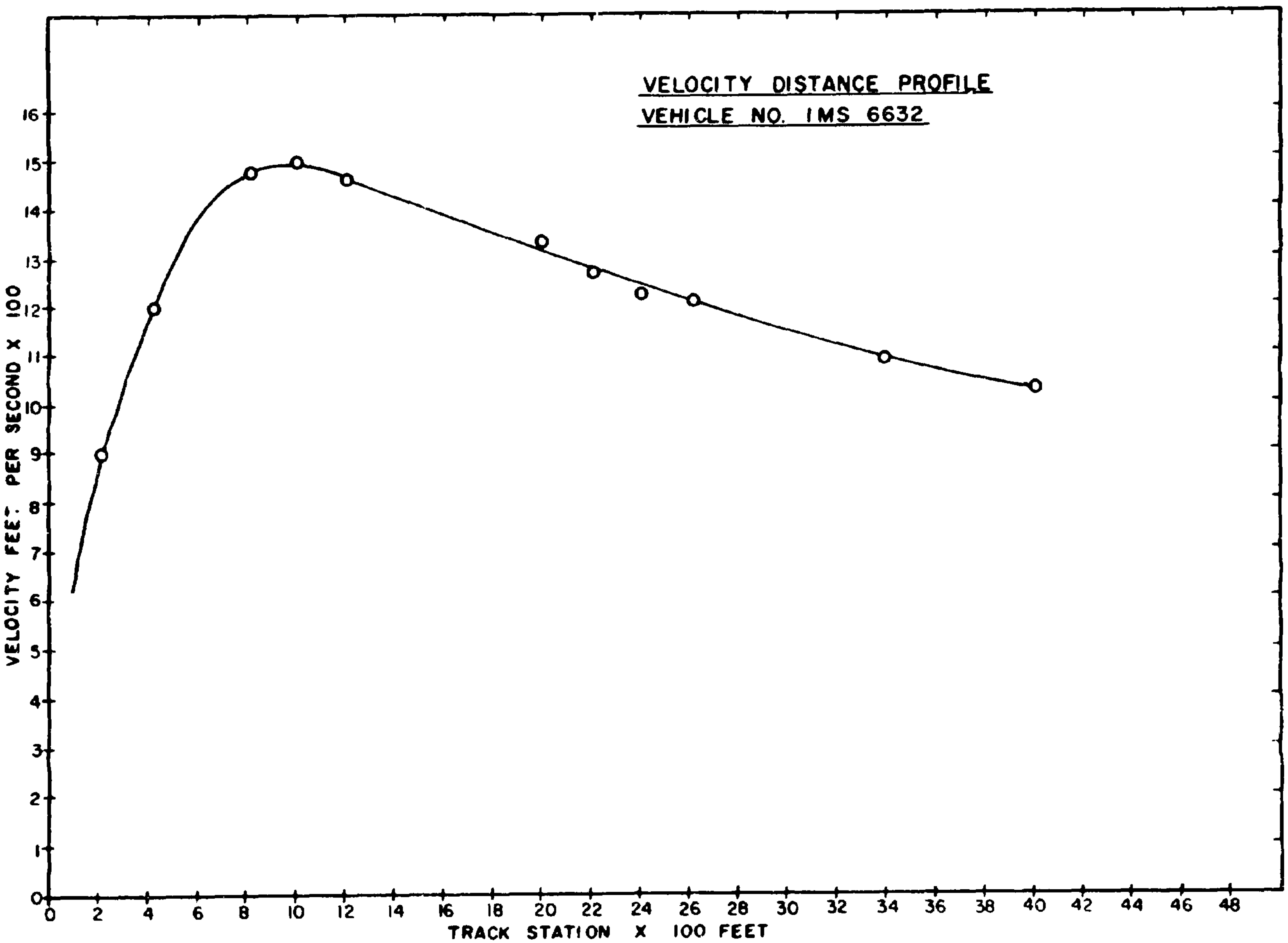

VELOCITY DISTANCE PROFILE
VEHICLE NO. IMS 6632
VELOCITY FEET PER SECOND X 100
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
TRACK STATION X 100 FEET

FIGURE 4

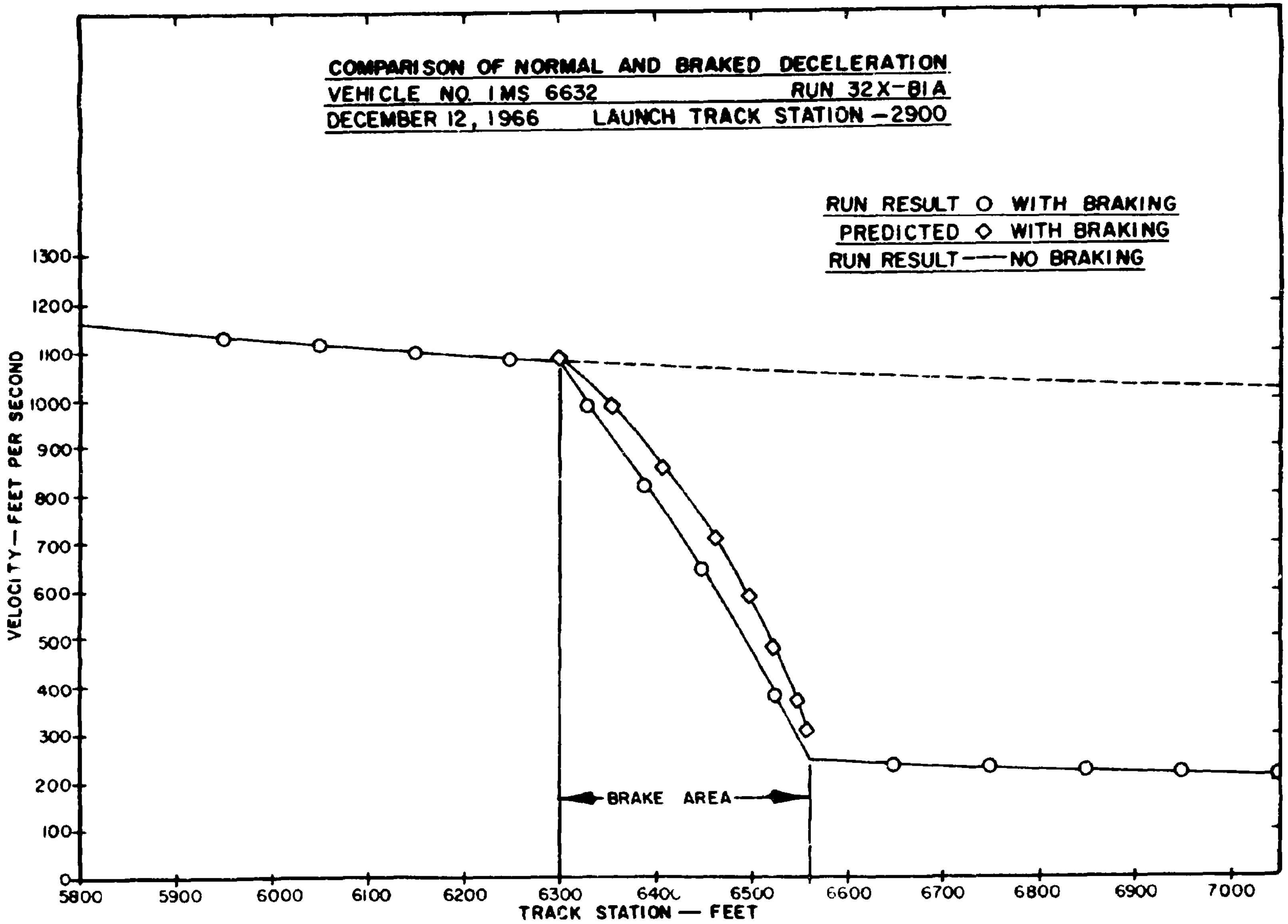

COMPARISON OF NORMAL AND BRAKED DECELERATION
VEHICLE NO. IMS 6632
RUN 32X-BIA
DECEMBER 12, 1966
LAUNCH TRACK STATION -2900
RUN RESULT ○ WITH BRAKING
PREDICTED ◇ WITH BRAKING
RUN RESULT --- NO BRAKING
VELOCITY — FEET PER SECOND
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
5800
5900
6000
6100
6200
6300
6400
6500
6600
6700
6800
6900
7000
TRACK STATION — FEET
BRAKE AREA

FIGURE 5

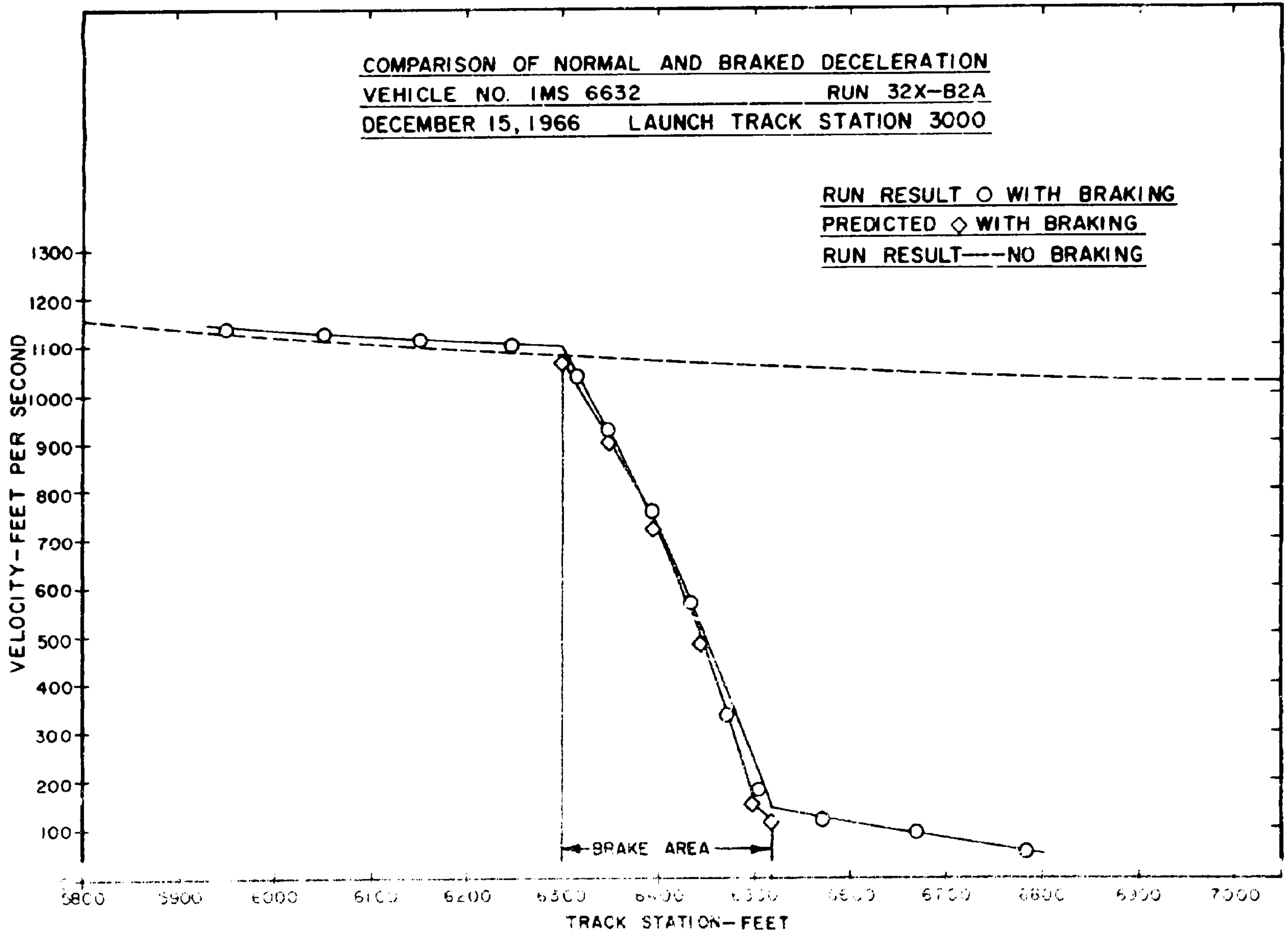

COMPARISON OF NORMAL AND BRAKED DECELERATION
VEHICLE NO. IMS 6632
RUN 32X-B2A
DECEMBER 15, 1966
LAUNCH TRACK STATION 3000
RUN RESULT ○ WITH BRAKING
PREDICTED ◇ WITH BRAKING
RUN RESULT ---- NO BRAKING
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
VELOCITY-FEET PER SECOND
BRAKE AREA
5800
5900
6000
6100
6200
6300
6400
6500
6600
6700
6800
6900
7000
TRACK STATION-FEET

FIGURE 6

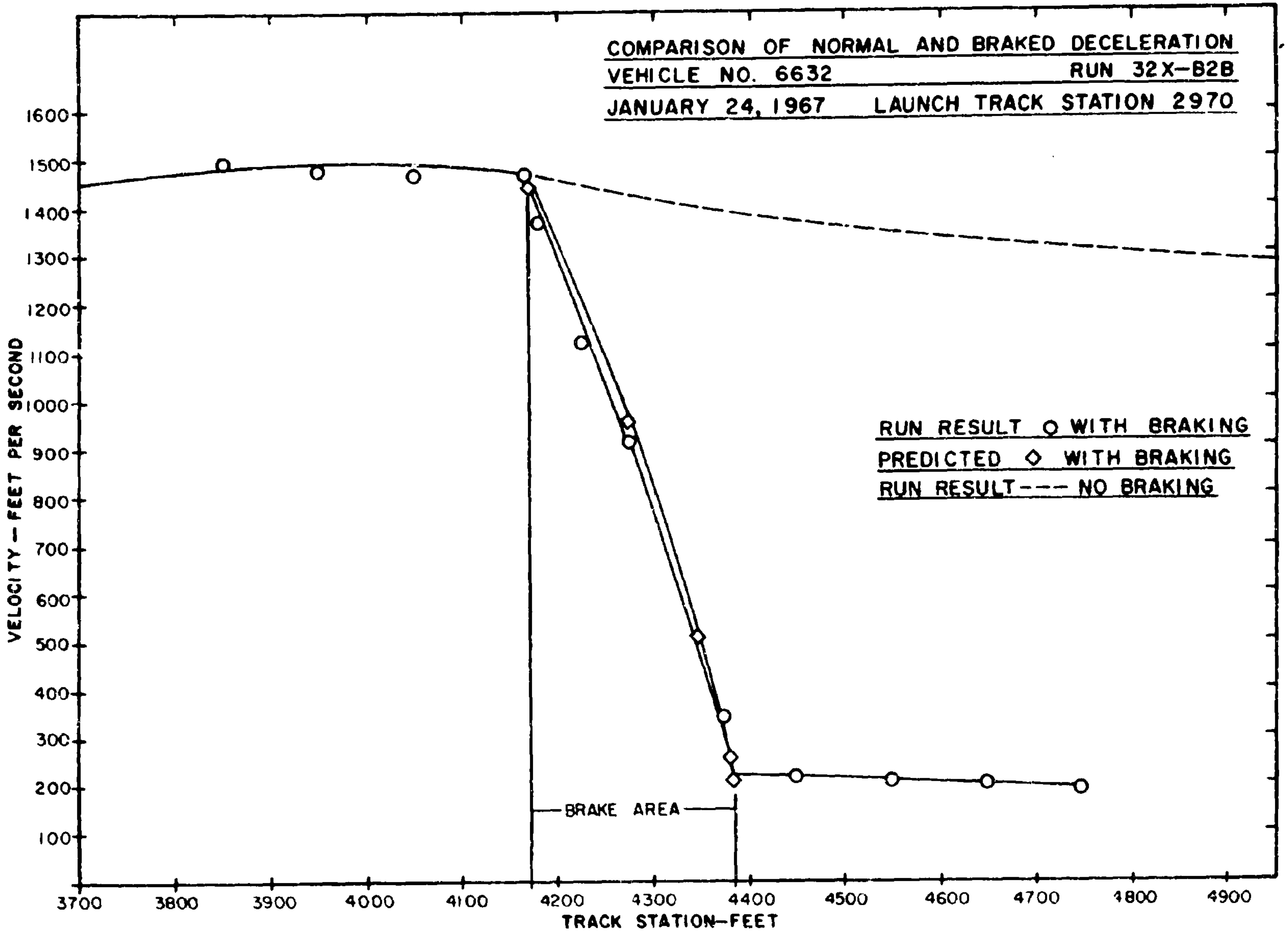

COMPARISON OF NORMAL AND BRAKED DECELERATION
VEHICLE NO. 6632
RUN 32X-B2B
JANUARY 24, 1967
LAUNCH TRACK STATION 2970
RUN RESULT O WITH BRAKING
PREDICTED ◇ WITH BRAKING
RUN RESULT--- NO BRAKING
BRAKE AREA
VELOCITY — FEET PER SECOND
TRACK STATION—FEET
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
3700
3800
3900
4000
4100
4200
4300
4400
4500
4600
4700
4800
4900

FIGURE 7

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frangible rail-top trays						

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