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September 1981

EXPERIMENTS WITH TRACK VENTILATION FOR AMPHIBIOUS TRACKED VEHICLES AND WITH TRACK COVERS AND RETRACTION

by
P. Ward Brown and W. E. Klosinski

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Gentlemen:

The enclosed report is submitted in accordance with the subject contract, and a further 18 reports have been distributed in accordance with CRDL A002.

This submission completes the work due under Delivery Order 1, Item 3 and Delivery Order 5, Item 1 of the subject contract.

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DAVIDSON LABORATORY

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An experimental model investigation of the effects of local pressurized captive air bubbles in the track wells of an amphibious vehicle is reported. In addition, the effects of track retraction and of track covers are documented. The track ventilation does not reduce the calm water drag, however, track retraction and the use of track covers can reduce the total drag by 40% at typical operating speeds.

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September 1981

EXPERIMENTS WITH TRACK VENTILATION FOR AMPHIBIOUS TRACKED VEHICLES AND WITH TRACK COVERS AND RETRACTION

by

P. Ward Brown and W. E. Klosinski

Prepared for

David W. Taylor
Naval Ship Research and Development Center
Code 112

Under

Contract N00014-80-D-0890
(Davidson Laboratory Project 4904/105)

Approved: ____________________
Daniel Savitsky
Deputy Director

INTRODUCTION

A series of investigations into the hydrodynamic characteristics of tracked amphibious vehicles is being carried out by Davidson Laboratory in support of the Marine Corps Surface Mobility Exploratory Development Plan. These investigations have been initiated under the direction of the David W. Taylor Naval Ship Research and Development Center (NSRDC), Code 112, which manages the Mobility Program.

One of the previous studies has shown[1] that by covering the tracks of an LVT on the sides and bottom, the drag can be halved at a speed of 8 mph. The mechanical complexities and added weight of the track covers could raise serious objections to the use of such devices. Because of the potential for achieving an impressive drag reduction an alternate means of "fairing" the tracks has been considered. This consists of local pressurized captive air bubbles in the track wells which would effectively "unwet" the tracks during water-borne operations.

This report deals with an experimental investigation of the effects of track ventilation and the results obtained. In addition the effects of track retraction and of track covers were confirmed.

MODEL

The model used for these tests was based on an existing LVTP-7 model, however extensive modifications to the hull were carried out and it is referred to herein as an LVT model. The model length was 38 inches. Hereafter all dimensions will refer to a full-size 26 ton (52,000 lb) vehicle. General particulars are given in Table 1, together with conversion factors for a 14 ton vehicle. Photographs of the model under test and in various configurations are shown on Figures 1 to 6.

Five model configurations were tested:

Configuration A: Tracks fully retracted, with front and rear "seals" and side covers. Used in track blowing tests.

Configuration B: Same as A but without rear seals.

Configuration C: Tracks down, no side covers. The basic LVT configuration.

Configuration D: Same as C with side covers.

Configuration E: Same as C with tracks fully retracted and covered.

Configuration A

The model is shown on Figure 2. The tracks are fully retracted flush with the central hardstructure and side plates are fitted also flush with the bottom. In the lower view the method used to seal the tracks at front and rear, so as to retain the air bubble, can be seen. Each track well can be supplied with air from a pair of axial fans mounted in series. The fans can deliver the equivalent of up to 500 cubic feet of air per second to each track. In order to bring the track flush with the bottom, it was necessary to make and fit small diameter road wheels, as shown at the top of Figure 3. For comparison the regular wheels are shown in the lower photograph together with a detail of the track, showing the road shoes mounted on a steel belt. When fully retracted the tracks blocked the air exit from the fans so four road shoes were removed, as shown, and a hole cut in the flexible steel belt.

In order to permit testing up to 16 mph, a full width bow flap at an angle of 16° extending 59 inches forward was fitted since it is known[2] that otherwise the LVT will dive at speeds in excess of 8 mph. A bow view of the model with this flap is included at the top of Figure 4. The plates sealing off the rear of the track wells are shown at the bottom of this figure.

Configuration A was ballasted to float at 1° bow up, at a displacement of 26 tons. This resulted in an LCG 2.7% of the length aft of midship.

Configuration B

This was similar to Configuration A, with an alteration to the rear seal. The two wedge-shaped foam inserts taped over the aft ends of the tracks (shown at the bottom of Figure 2) were removed, and the rear sealing plates (shown at the bottom of Figure 4) were modified so that the lower edge was level with the axle of the last wheel. This created a large opening at the rear of the track cavity for the air to flow out of. The trim of this model was slightly increased so that when vented the air would exhaust uniformly around the model. The LCG was at -3.6%.

Configuration C

This was the basic LVT configuration as shown at the bottom of Figure 5 and was tested with the fans off.

Configuration D

This is the basic LVT with side plates as shown at the top of Figure 5.

Configuration E

This configuration shown on Figure 6 represents the basic LVT with tracks fully retracted and with side and bottom track covers. This was tested in two conditions: with the track wells flooded and with the track wells dry and buoyant, i.e., at reduced draft.

APPARATUS AND INSTRUMENTATION

The calm water tests were carried out in Davidson Laboratory Tank 3. The model was generally free to trim and heave but fixed in yaw and roll. Heave masts which translated vertically through teflon roller bearings, were coupled to the model through a drag balance, a moment balance and a locking pitch pivot box whose axis was located 14.2 ft aft of the bow and 2.65 ft above the hull bottom. An electronic inclinometer measured trim, while a linear transducer measured vertical displacement of the pitch pivot axis.

The fan pressure was measured on the starboard side at a point midway between the fan and the top of the track well. A static pressure tap was inserted at this point and connected to a pressure gage on the carriage. It should be noted that due to the obstruction of the fan duct exit by the track and road wheels, the pressure in the track well will be somewhat less than that in the fan duct. This circumstance also prevents the calculation of fan power from the pressure measurements as was originally intended, however it will develop that the nature of the results is such that a knowledge of the fan power is immaterial.

For the fixed-trim track blowing tests the locking pivot box allowed the model to be set at a precise trim. The pitch moment was then measured by a balance whose focus was located at the pitch pivot axis.

The apparatus included an unloader arm for adjusting the vertical load on the water. A remotely controlled pickup mechanism was mounted on the carriage, which allowed the model to be raised or lowered onto the water surface.

The signals from the transducers were relayed by overhead cables to the data station on shore where they were filtered (40 Hz low pass) and processed by an on-line PDP-8e computer, which includes an analog-to-digital converter. All data channels were monitored on an oscillograph.

An underwater mirror and camera setup enabled photographs of the model's underside to be taken. Color video recordings were made of each run by video camera mounted on the carriage off the port bow.

TEST PROGRAM

The object of the test program was to determine the effect of venting the tracks and to optimize the configuration to achieve the maximum beneficial effect. Therefore the course of the tests was determined by the results obtained and a considerable amount of exploratory work was done before a pattern emerged. The test conditions are summarized as a point of reference, and suggest a somewhat more orderly course of development than occured during the tests.

Configuration A was ballasted to $+1^{\circ}$ trim and run in calm water up to a speed of 16 mph to obtain a baseline. These free-to-trim tests were repeated with one fan per track turned on and with two fans per track. Since the fans were mounted in series doubling the number of fans doubles the pressure for the same flow rate. Turning on the fans caused a reduction in trim so fixed trim tests were run at speeds of 6, 8 and 10 mph. In addition a few runs were made at 8 mph with the model fixed in heave.

Configuration B, with an open rear seal, was run free-to-trim at speeds up to 12 mph.

Free-to-trim tests at speeds up to 14 mph were run for all the configurations without fans.

AIR TARES

During the test with the fans energised some question arose about the momentum drag due to the fans. Tests were run with the model out of the water at zero trim with a clearance corresponding to 6 inches above the water, at speeds up to 20 mph. The air tare was small, less than 5 lb/ton, and within ±10% is given by:

$$\text{Air Tare} = (V/10)^2 \text{ lb/ton}$$

where: V = speed, mph

These tests were run with the fans off, with one fan/track and with two fans/track. Turning the fans on had no effect on the air tare. It may be concluded that the momentum drag is negligible as far as the results reported herein are concerned.

RESULTS

The results of the test are presented in Tables 2 to 6 for a 26 ton vehicle. Conversion factors for a 14 ton vehicle are given in Table 1, whence the tabulated speeds should be multiplied by 0.9 to obtain the speeds corresponding to a 14 ton vehicle.

Referring to Table 3 for example, the tabulated quantities include the speed, the trim of the hardstructure, the draft of the hardstructure at midship, the longitudinal position of the CG as a percent of the hull length fore and aft of amidship, the pressure in the fan duct relative to atmospheric in feet of sea water, and the non-dimensional hydrodynamic drag in lb/short ton of displacement.

The video tape of the test runs has been delivered to NSRDC, Code 112.

DISCUSSION

The variation of water drag with speed for Configuration A is shown on Figure 7 for fan pressure of 0, 3 and 4.5 ft of water, and it is evident that track ventilation of the configuration has no effect on the hydrodynamic drag.

Turning on the fans has the effect of reducing the trim, as shown on Figure 8, by 2.5 degrees at 8 mph. It was thought that this bow down trim caused by the fans might be increasing the hydrodynamic drag and thereby cancelling the beneficial effect of the fans. Therefore fixed trim tests were run.

The variation of drag with trim at 8 mph is shown on Figure 9 to an expanded scale for zero, one and two fans per track. It can be seen that the effect of trim on drag is practically negligible as far as Figure 8 is concerned, since a decrease in trim would actually result in a small decrease in drag, but only by 4 lb/ton for each degree of trim. At the same time it may be noted that a considerable shift in LCG is needed to change the trim by 1 degree, of the order of 1% of the length at 8 mph.

With two fans on there is sufficient pressure generated to "unwet" the tracks, at least statically, as a study of the special underwater video record will show. However when the craft is underway the bottom of this "bubble" must deform and since the track wells are filled with tracks and wheels, the water must impinge on the tracks. Evidently the deformation of the captive air bubble is so severe that there is no reduction in hydrodynamic drag.

It is therefore concluded that track ventilation of the configuration considered is of no benefit and, since power is required to generate the bubble, would be a definite handicap.

The reduction in drag due to retracting the tracks and fitting covers, without ventilation, is shown on Figure 10. At 10 mph, for example, the percentage reduction in drag due to successively fitting side covers, retracting the tracks, fitting bottom covers and finally running with track wells dry is summarized in the following table:

Configuration	Drag lb/ton	Drag Reduction percent
Basic LVT	312	-
+ Side Covers	288	7.7
+ Track Retraction	237	16.3
+ Bottom Covers	213	7.7
+ Watertight Covers	184	9.3
	TOTAL	41.0

The results confirm those of the previous investigation[1] both qualitatively and quantitatively. The higher the speed the bigger the drag reduction due to retracting and covering the tracks, however, to run at high speed it is necessary to deploy a bow flap of the type used here and developed in Reference 2.

CONCLUDING REMARKS

Calm water tests of a model of a typical LVT amphibious tracked vehic e equipped with fans to produce a localized captive air bubble in the track wells have shown that there is no effect on the vehicle drag due to track ventilation.

The results of successively retracting and covering the tracks, without ventilation, show that the drag can be reduced by as much as 40% at 8 to 10 mph. The results are presented in tabular and graphical form so that they can be used in trade-off studies of the benefits and costs of track covers and retraction.

REFERENCES

1. Brown, P.W. and Klosinski, W.E., "The Contribution of Tracks to the Drag of an Amphibious Vehicle (LVTP-7)", Davidson Laboratory Report 2109, December 1979.

2. Brown, P.W. and Klosinski, W.E., "Modification for the LVTP-7 Bow Form to Improve Calm Water and Seakeeping Performance", Davidson Laboratory Technical Report 2074, December 1979.

TABLE 1

PARTICULARS OF 26 TON VEHICLE AND
CONVERSION FACTORS FOR 14 TON VEHICLE

	26 Ton LVT	To Convert to 14 Ton LVT Multiply by
Displacement, lb	52,000	0.538
Length of Hull, in	308	0.814
Beam of Hull, in	127	0.814
Depth of Hull Hardstructure, in	81	0.814
Bow Flap:		
Length, in	59	0.814
Width, in	127	0.814
Angle, degrees	16.6	1
Nominal LCG:		
Distance Aft of Bow, in	162.4	0.814
Forward of Midship, percent of length	-2.7	1
Drag, lb/short ton	-	1
Speed, mph	-	0.9
Trim, degrees	-	1
Draft, ft	-	0.814

TABLE 2

CONFIGURATION A RESULTS

Tracks Retracted - No Fans

RUN	SPEED mph	TRIM deg	DRAFT ft	LCG %	PRESSURE ft. sea water	DRAG lb/s ton
			FREE TO TRIM TESTS			
1	0.0	1.0	4.4	-2.7	0	0
8	0.0	1.0	4.4	-2.7	0	0
21	0.0	1.1	4.3	-2.7	0	0
47	0.0	1.2	4.4	-2.7	0	0
2	2.0	1.2	4.4	-2.7	0	7
3	4.0	1.4	4.5	-2.7	0	27
4	6.0	2.0	4.6	-2.7	0	62
5	8.0	3.8	4.8	-2.7	0	140
6	10.0	5.7	4.9	-2.7	0	237
7	12.0	9.4	5.0	-2.7	0	489
9	14.0	11.7	5.2	-2.7	0	925
11	16.0	16.0	4.8	-2.7	0	1,238
			FIXED TRIM TESTS			
22	6.0	3.0	4.6	-3.6	0	66
35	8.0	0.0	4.6	1.8	0	132
23	8.0	3.0	4.7	-1.6	0	138
24	8.0	3.0	4.7	-1.6	0	137
32	8.0	5.9	4.8	-5.3	0	153
25	10.0	3.0	4.8	0.8	0	215
17	10.0	6.2	4.8	-3.8	0	240
			FIXED TRIM AND HEAVE TESTS			
39	0.0	3.0	4.1	-	0	0
40	8.0	2.9	4.1	-	0	128
43	0.0	3.1	5.3	-	0	0
44	8.0	3.1	5.3	-	0	157

TABLE 3

CONFIGURATION A-1 RESULTS

Tracks Retracted - One Fan/Track

RUN	SPEED mph	TRIM deg	DRAFT ft	LCG %	PRESSURE ft. sea water	DRAG lb/s. ton
			Free to Trim Tests			
49	4.0	-1.5	3.7	-2.7	3.2	24
50	6.0	-0.7	3.9	-2.7	3.2	57
51	8.0	1.4	4.2	-2.7	3.0	135
52	10.0	4.4	4.4	-2.7	2.8	241
53	12.0	8.8	4.6	-2.7	2.7	493
20	12.0	9.4	4.6	-2.7	2.7	482
54	14.0	14.3	4.6	-2.7	2.7	937
			Fixed Trim Tests			
12	4.0	5.9	4.0	-7.0	3.1	32
26	6.0	2.9	4.0	-5.6	3.1	64
13	6.0	5.9	4.1	-7.4	3.0	73
14	6.0	6.2	4.1	-8.0	3.0	71
36	8.0	-0.2	4.0	-0.7	3.1	129
27	8.0	2.9	4.2	-3.6	3.0	137
33	8.0	5.9	4.4	-6.1	3.0	151
28	10.0	2.9	4.3	-0.8	2.8	222
16	10.0	6.2	4.4	-4.3	2.8	244
18	12.0	9.4	4.6	-2.1	2.7	482
			Fixed Trim and Heave Tests			
41	8.0	2.8	4.1	-	3.0	140
45	8.0	3.1	5.3	-	3.3	157

TABLE 4

CONFIGURATION A-2 RESULTS

Tracks Retracted - Two Fans/Track

RUN	SPEED mph	TRIM deg	DRAFT ft	LCG %	PRESSURE ft. sea water	DRAG lb/s. ton
FREE TO TRIM TESTS						
55	4.0	-1.2	3.4	-2.7	4.6	39
56	6.0	-0.7	3.6	-2.7	4.6	78
57	8.0	1.2	3.9	-2.7	4.3	156
58	10.0	3.8	4.1	-2.7	4.0	251
59	12.0	8.2	4.3	-2.7	3.7	488
60	14.0	14.3	4.4	-2.7	3.7	916
FIXED TRIM TESTS						
29	6.0	2.8	3.6	-6.0	4.6	84
37	8.0	-0.2	3.7	-1.4	4.4	141
38	8.0	0.0	3.7	-1.5	4.4	143
30	8.0	2.9	3.9	-4.3	4.4	160
34	8.0	5.9	4.0	-6.5	4.3	172
31	10.0	3.0	4.0	-1.8	4.0	240
FIXED TRIM AND HEAVE TESTS						
42	8.0	2.8	4.1	-	4.5	169
46	8.0	3.1	5.3	-	5.7	182

CONFIGURATION B-2 RESULTS

Tracks Retracted - Two Fans/Track - Modified "Rear Seal"

FREE TO TRIM TESTS

RUN	SPEED mph	TRIM deg	DRAFT ft	LCG %	PRESSURE ft. sea water	DRAG lb/s. ton
77	0.0	-0.8	3.5	-3.6	3.9	0
78	4.0	-0.5	4.0	-3.6	3.0	26
79	6.0	0.4	4.1	-3.6	3.0	58
80	8.0	2.3	4.3	-3.6	2.9	129
81	10.0	6.0	4.7	-3.6	2.4	237
82	12.0	10.0	4.8	-3.6	2.0	480

TABLE 5

CONFIGURATION C RESULTS

Basic LVT, Tracks Down,
Free-to-Trim, No Fans

RUN	SPEED mph	TRIM deg	DRAFT ft	DRAG lb/s. ton
91	0.0	1.0	4.6	0
92	2.0	1.2	4.5	9
93	4.0	1.6	4.5	36
94	6.0	2.3	4.6	81
95	8.0	4.1	4.8	161
96	10.0	6.5	5.0	312
97	12.0	10.6	5.0	647
98	14.0	12.5	5.0	1,010

CONFIGURATION D RESULTS

Basic LVT, Tracks Down, with Side Covers

RUN	SPEED mph	TRIM deg	DRAFT ft	DRAG lb/s. ton
83	0.0	1.0	4.4	0
84	2.0	1.2	4.4	8
85	4.0	1.7	4.5	31
86	6.0	2.6	4.6	74
87	8.0	4.5	4.9	148
88	10.0	6.9	5.0	288
89	12.0	10.3	5.1	554
90	14.0	14.9	5.2	1,031

TABLE 6

CONFIGURATION E RESULTS

Basic LVT with Full Track Covers

E1-Flooded Covers

RUN	SPEED mph	TRIM deg	DRAFT ft	DRAG lb/s. ton
107	0.0	1.0	4.4	0
108	2.0	1.2	4.4	6
109	4.0	1.4	4.5	21
110	6.0	2.0	4.6	48
111	8.0	3.7	4.8	114
112	10.0	5.9	4.9	213
113	12.0	9.9	5.1	469
114	14.0	14.0	5.1	911

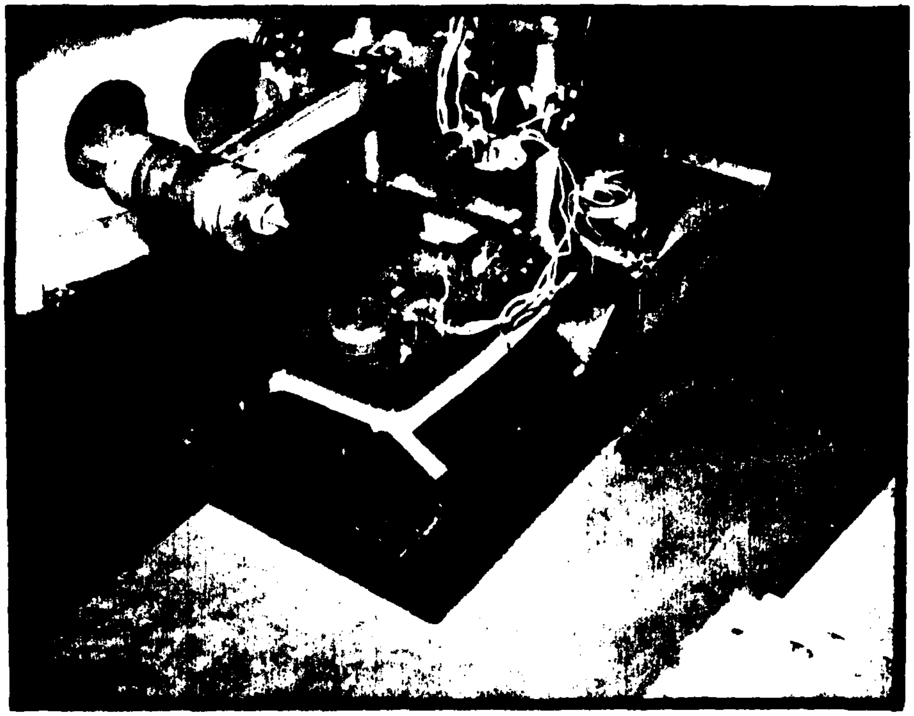
E2-Water Tight Covers

RUN	SPEED mph	TRIM deg	DRAFT ft	DRAG lb/s. ton
99	0.0	1.0	3.6	0
100	2.0	1.1	3.6	4
101	4.0	1.1	3.7	17
102	6.0	1.4	3.8	40
103	8.0	2.4	4.0	92
104	10.0	4.9	4.2	184
105	12.0	9.0	4.3	402
106	14.0	14.1	4.3	786

TABLE 7

VIDEO SCENARIO

RUNS	CONFIGURATION	FOOTAGE
1-11	A, Free-to-trim	16-73
13-48	A, A1 and A2, Fixed trim tests	73-191
49-54	A1, Free-to-trim	191-211
55-60	A2, Free-to-trim	211-236
61-75	Air tares	236-260
	General Over and Under Water Views of Configuration B2 at Rest with Fans on	260-284
78-82	B2, Free-to-trim	284-293
84-90	D, Free-to-trim	293-313
92-98	C, Free-to-trim	313-329
100-106	E2, Free-to-trim	329-348
107-114	E1, Free-to-trim	348-367



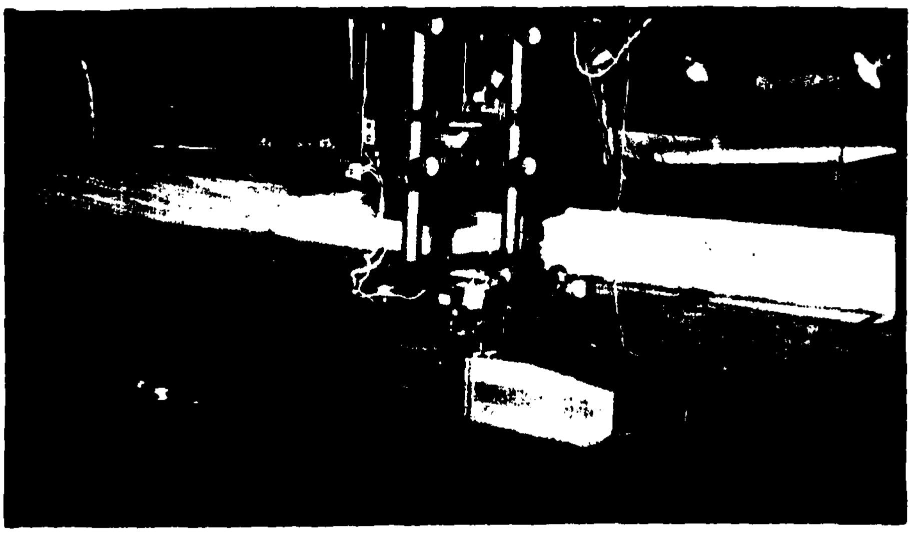
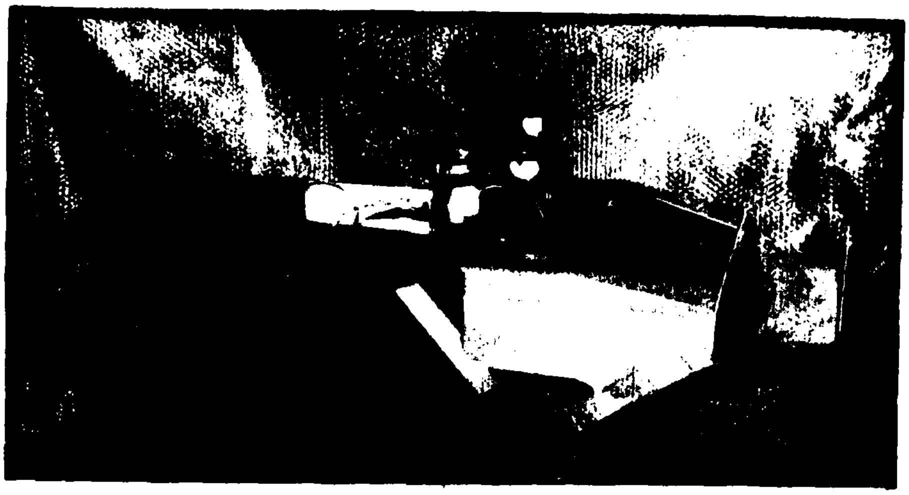
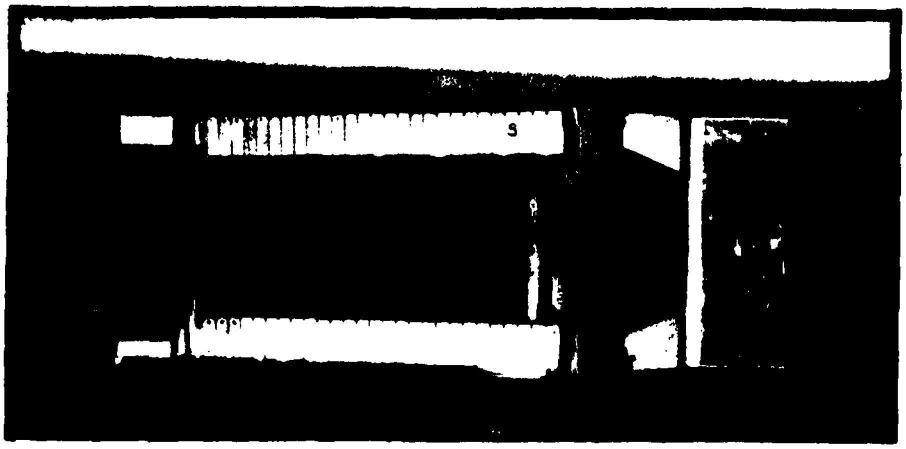


FIGURE 1 CONFIGURATION A UNDER TEST

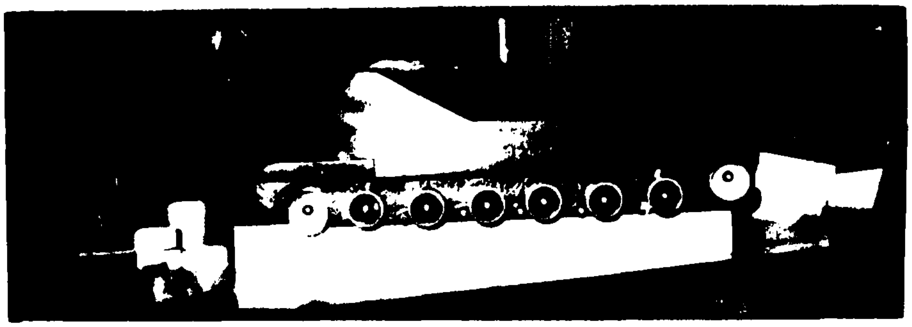


SIDE VIEW SHOWING BOW FLAP
AND TWO FANS PER SIDE

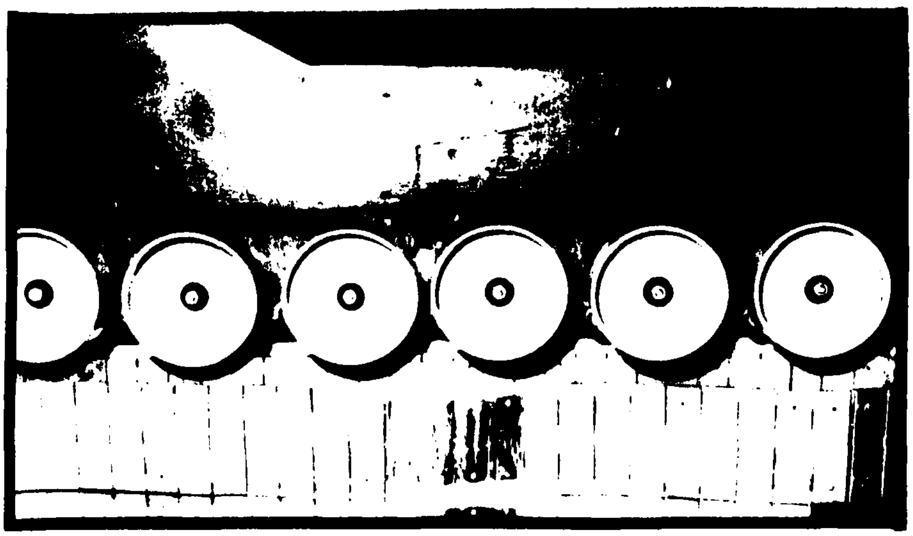


BOTTOM VIEW SHOWING FRONT AND REAR SEALS

FIGURE 2 VIEWS OF CONFIGURATION A

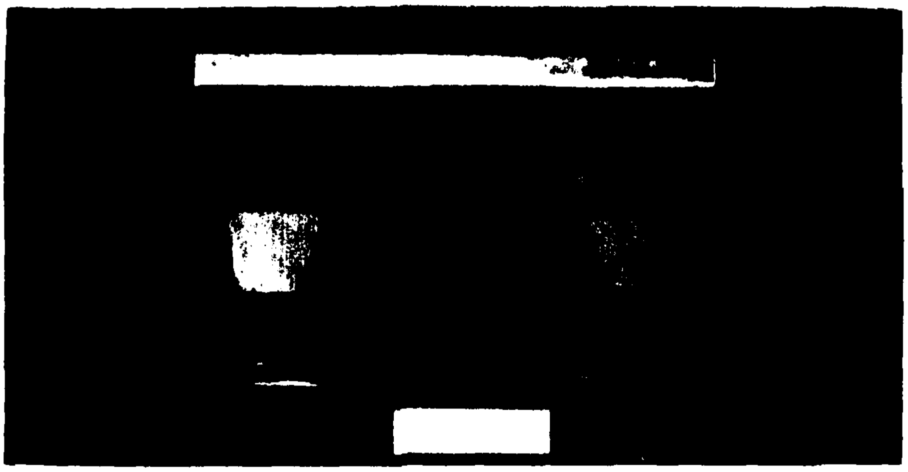


SMALL WHEELS FOR CONFIGURATION A



REGULAR WHEELS AND TRACK DETAIL

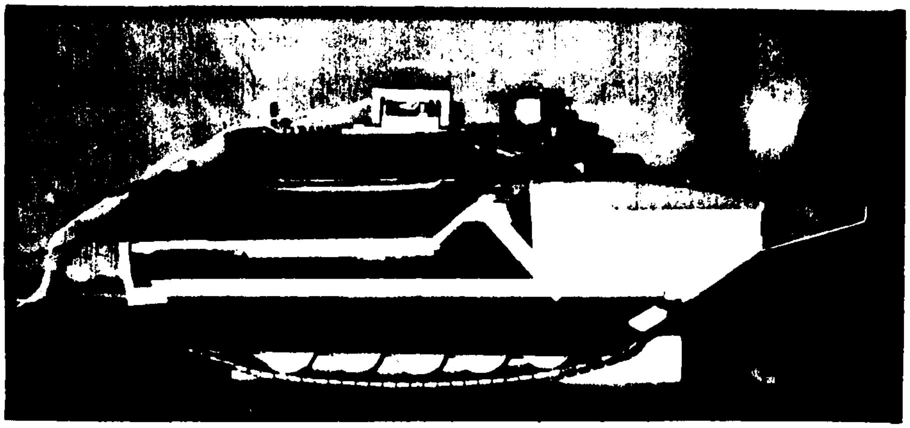
FIGURE 3 COMPARISON OF ROAD WHEELS



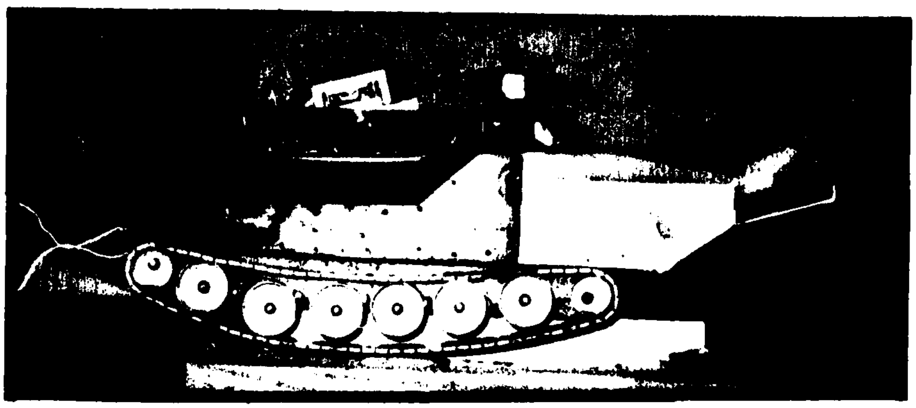
BOW VIEW

STERN VIEW

FIGURE 4 VIEWS OF CONFIGURATION A



CONFIGURATION D



CONFIGURATION C, BASIC LVT

FIGURE 5 CONFIGURATIONS C AND D

TRACKS RETRACTED WITH SIDE AND
BOTTOM TRACK COVERS

FIGURE 6 CONFIGURATION E

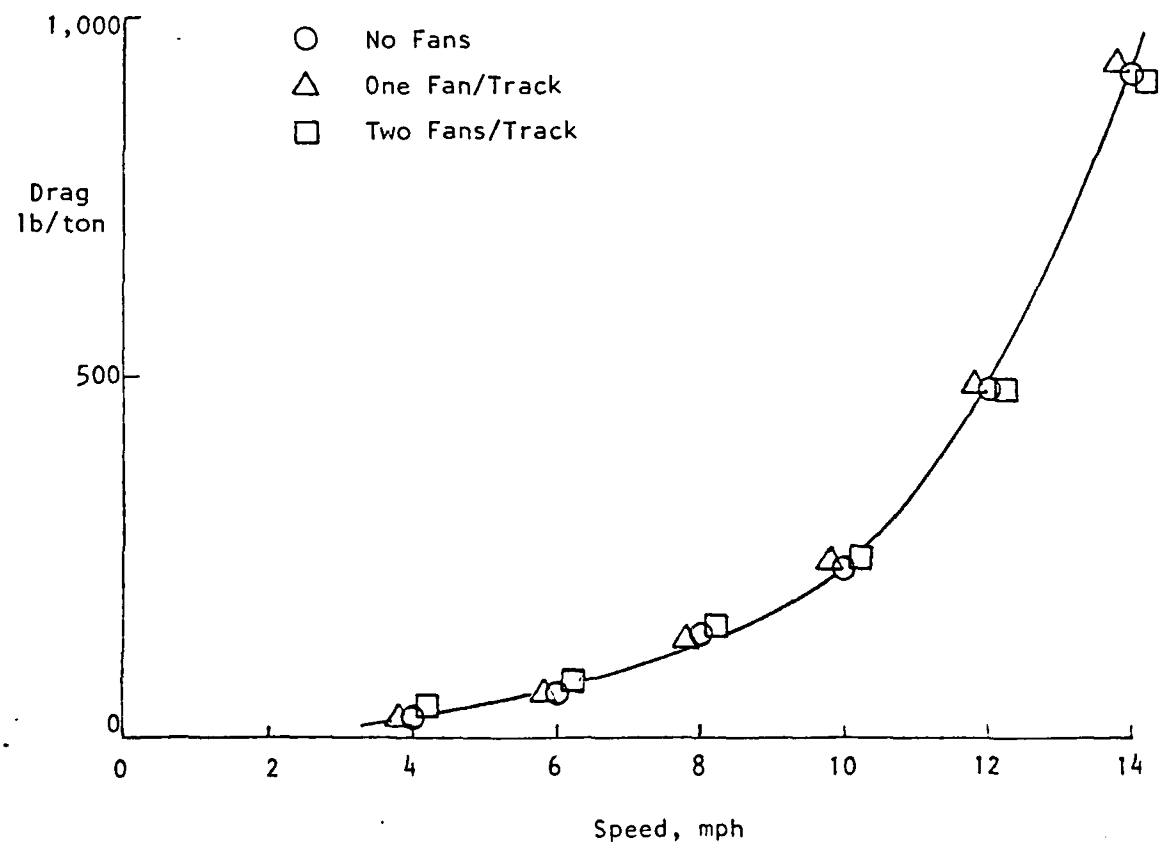


FIGURE 7 EFFECT OF TRACK BLOWING ON WATER DRAG

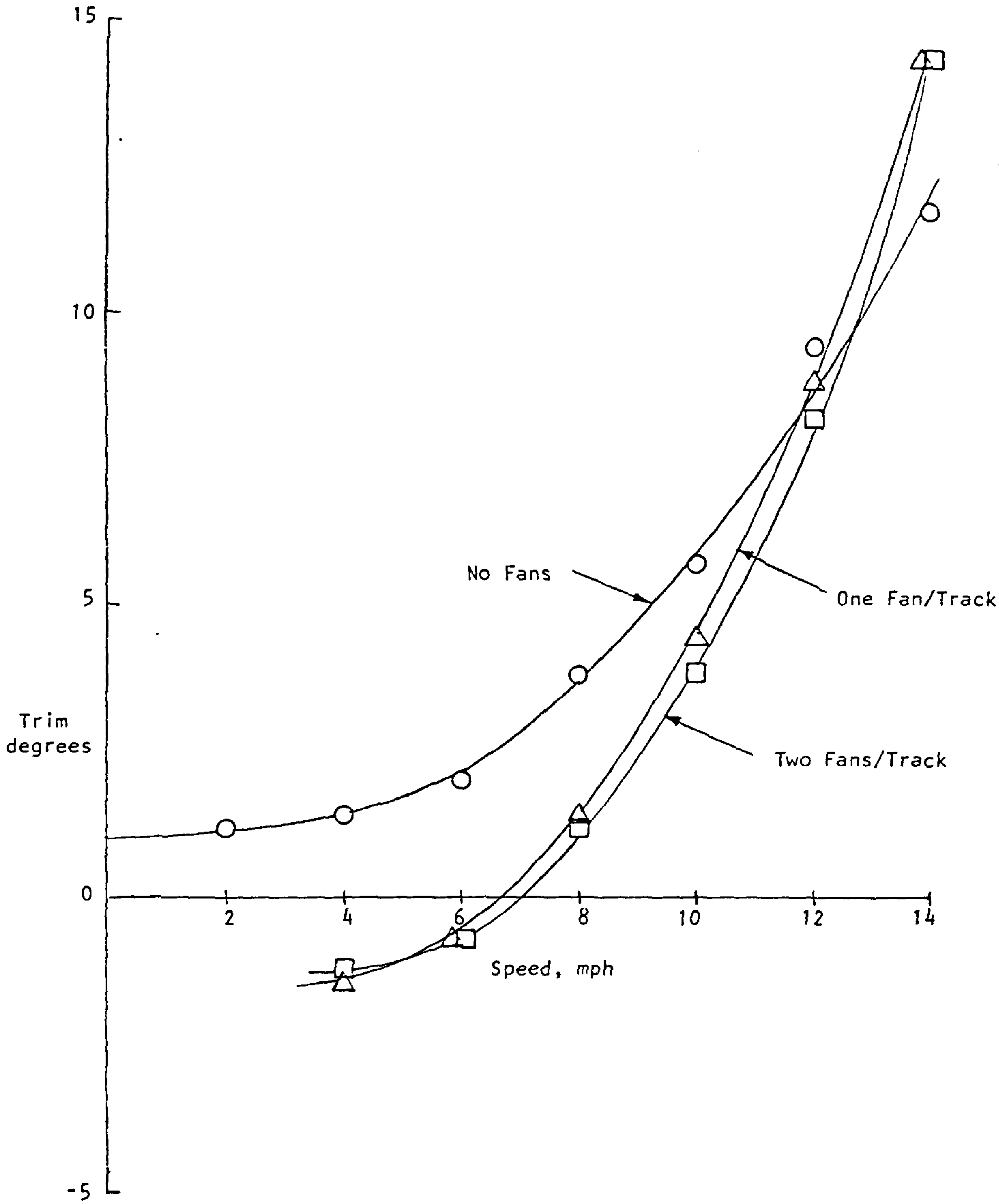


FIGURE 8 EFFECT OF TRACK BLOWING ON TRIM

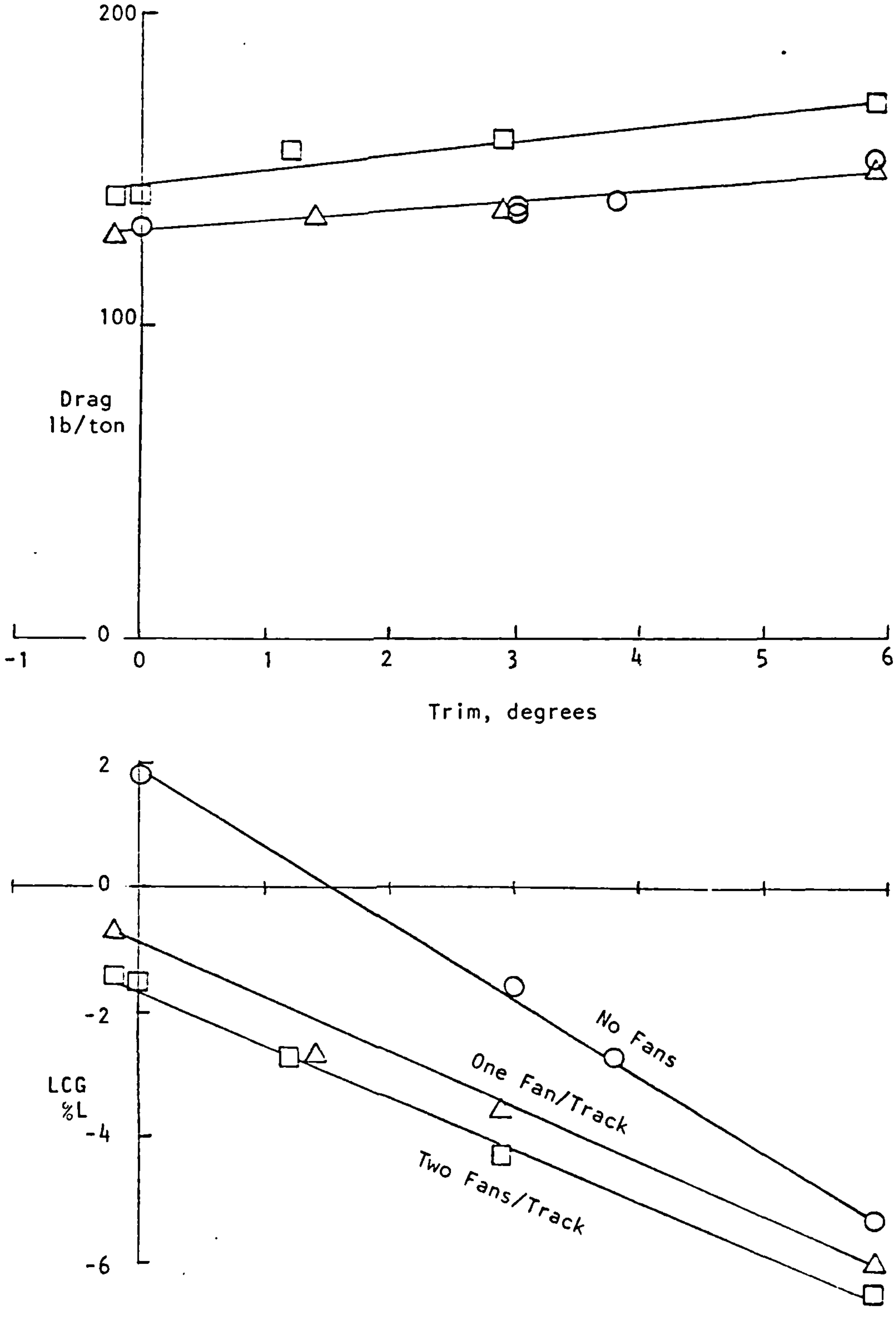


FIGURE 9 VARIATION OF DRAG WITH TRIM AT 8 MPH

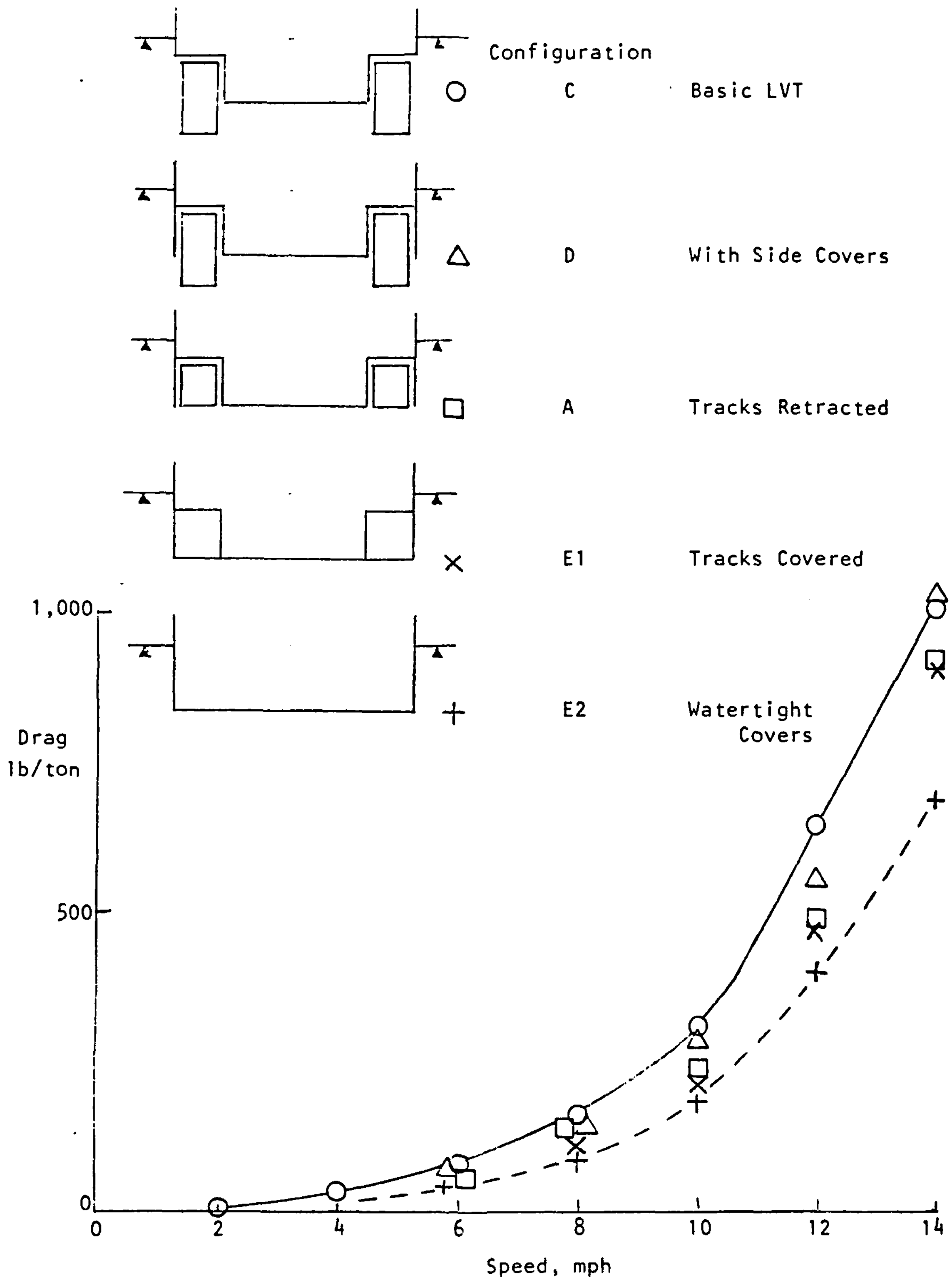


FIGURE 10 EFFECT OF TRACK CONFIGURATION ON WATER DRAG