COPY NO. 13 P/W. TUNN/138

LONG RANGE TANK JETTISON TESTS
SERIES I AND SERIES II
.07 SCALE
N.A.E. LOW SPEED WIND TUNNEL

DEC. 1957 G. K. DIMOCK

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AVRO

A. V. ROE CANADA LIMITED
MALTON - ONTARIO

TECHNICAL DEPARTMENT (Aircraft)

AIRCRAFT: ARROW

REPORT NO: P/WIND TUNNEL/138

UNCLASSIFIED / NON CLASSIFIÉ

FILE NO:

NO. OF SHEETS:

TITLE:

ARROW .07 SCALE LONG RANGE TANK JETTISON TESTS

SERIES I AND SERIES II

N.A.E. LOW SPEED WIND TUNNEL

August and November, 1956.

Classification ~~cancelled / changed to:~~ confirmed as UNCLASSSIFIED
By authority of: DRDA 7/DARFT 5-8/DAS Eng 6-4-5
Date: 5 Nov 1992
Signature: B. Aubrey
Unit / Rank / Appointment: DSIS 3, Secretary CRAD HQ DRP

PREPARED BY G. K. Dimock DATE Dec. 1957.

CHECKED BY G. K. Dimock DATE

SUPERVISED BY [signature] DATE

APPROVED BY [signature] DATE

ISSUE No.	REVISION No.	REVISED BY	APPROVED BY	DATE	REMARKS
					UNCLASSIFIED

FORM 1316A

SUMMARY

Low speed wind tunnel jettison tests using dynamic scale models have been completed for the long range fuel tank installation on the Arrow for level flight conditions. Several tank configurations were checked in two series of tests. The full scale Mach number range simulated was .2 to .85; the full scale altitudes simulated were sea level, 20,000 feet; and 40,000 feet.

Satisfactory jettison characteristics were obtained for a tank configuration with the "small" tail, -2° incidence to the fuselage datum, and a 5° release angle.

The jettison tests showed that the tanks can be jettisoned clear of the aircraft at all speeds and altitudes within the flight envelope of the tank for level flight conditions (with dive brakes closed). The initial pitching moment of the tanks resulted in the horizontal tail of the tanks (especially empty tanks) coming close to interfering with the fuselage, but there were no positive cases of contact. The full tanks generally fell straight down below the aircraft except at low altitudes when the aircraft was yawed, when they moved outboard. The empty tanks almost always moved outboard as they fell below the aircraft. A flight test programme for tank jettison tests was proposed on the basis of the test results.

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1.0 INTRODUCTION

This report presents the results of two series of jettison tests which were performed using .07 scale dynamic models of the long range fuel tank. The dynamic models were jettisoned from their position underneath the fuselage of the .07 scale Arrow model in the 6 x 10 ft. Low Speed Wind Tunnel at the National Aeronautical Establishment, Ottawa.

The investigation was made to evaluate the proposed jettison arrangements with respect to tank-aircraft interference, and to determine the trajectories of tanks jettisoned from the aircraft for various level flight conditions.

2.0 MODELS

2.1 MODEL DESIGN

The dynamic scale models used in these tests were designed and manufactured by Avro Aircraft Limited. The design data, based on dynamic similarity at three altitudes is given in the Appendix to this report.

The model configurations used in the two series of tests are listed in Table 1. The various models were designated by letters painted on the sides of the tanks.

The models were constructed to scale using various combinations of different woods, metals and plastics to obtain the desired dynamic properties. The full tank models were made of solid impregnated mahogany with blocks of lead for ballast, and had aluminum tail surfaces. The tank empty models were constructed using balsa and birch centre-sections, and formed acetate sheet fore- and after- bodies. The tail surfaces were made from birch or balsa, and pieces of lead or aluminum were used for ballasting.

The actual and required inertia properties are compard in Table 2.

2.2 DESCRIPTION OF MODELS

The dimensional characteristics of the tank models are sketched in Figure 1. One of the series II models is shown in Figure 2. The tank models were fitted to the bottom of the fuselage by means of slotted release pins on the two forward struts, and an undercut swivel pin on the aft pylon. A spring-loaded slide located in the fuselage fitted into the slots of the forward pins, and the undercut part of the swivel pin fitted to a hole in a plate on the bottom of the fuselage above the aft pylon.

The forward pin (guide pin) on the aft pylon determined the release angle at which the model was dropped. When the release slide was operated the front struts fell free and the model pivoted about the swivel pin. As the model pitched nose down, the guide pin moved out of its slot and allowed the swivel pin to come clear of the fuselage.

For the series 1 tests the models rotated thru $7\frac{1}{2}^{\circ}$ from the initial incidence before being fully released. In series II, the release angle was reduced to 5°.

The forward struts were cambered to contribute a nose down load after the tank was released.

3.0 DESCRIPTION OF TESTS

3.1 TUNNEL TEST ARRANGEMENT

The .07 scale model of the Arrow I aircraft was mounted in the 6x10 ft. test section by means of a tail strut and twin wing struts. The tank models were fitted underneath the fuselage of the aircraft model. The drawing in Figure 3 shows the position of the tank as tested on the model.

Two photographs of the aircraft model with a tank model installed are given in Figure 4. The B owden cable, which can be seen in these pictures, was connected to the release mechanism in the model fuselage and to a bicycle- type brake handle outside the test section. When the handle was pressed the release mechanism moved free of the slotted pins and the model pivoted until it fell free. The models come free as soon as the handle was pressed.

A catch-screen of chicken-wire was installed across the test section about 10 ft. behind the aircraft model. Cushions of rubberized packaging material were nailed to the tunnel floor in an attempt to protect the models from excessive damage.

Two Fastax high-speed cine-cameras were used to record each jettison test. One camera was placed on the tunnel floor at the entrance to the test section about 10 ft. from the aircraft model. The front camera was on the centre-line of the aircraft but was not lined up with the models when the aircraft model was yawed. In the series I tests the other camera was set up outside the test section on a line approximately 30° from the perpendicular to the longitudinal axis of the Arrow model, and slightly below the level of the tank models. For the series II tests the second camera was aligned along the perpendicular to the aircraft centre-line, but was inclined such that a three-quarter view of the bottom of the fuselage at the tank was obtained.

The film speed was set at about 750 frames per second for both test series. The Fastax timing unit operates from a 120 volt, 60 cycle a.c. supply which results in 120 timing marks on the film per second. The time between the beginning of one mark and the starting point of the next will be 0.00833 seconds.

At the beginning of a test run the cameras were started and allowed to run for about two seconds in order to reach the desired film speed before the photographic lighting system was switched on. The release handle was pressed just after the lights came on, and the cameras were stopped when the models hit the catch-screen.

The tank models were always checked for satisfactory wind off free fall before proceeding with a test run. Models that could not be made to fall satisfactorily, or that were too loose, were not used.

3.2 TUNNEL OPERATING CONDITIONS

The tunnel operating conditions are given in the Appendix. The basic parameter for tunnel operation is the indicated dynamic pressure.

$$q_{dial} = 1.069\ q_{true}$$

4.0 TEST PROGRAMME

4.1 SERIES I

In test series 1, the tanks were released after about $7\frac{1}{2}^{o}$ rotation from the initial position.

Ten level flight conditions with the aircraft at zero yaw were simulated including:

Sea Level at M= .85, .7, .5, .2,
20,000 ft.at M= .85, .7, .5,
40,000 ft.at M= .85, .7, .5.

The basic configurations tested were full and empty tanks with the small tail (see Figure 1), set at -2^{o} incidence to the aircraft datum. These configurations were tested at the ten flight conditions.

The empty tank configuration was also investigated for low speed sea level conditions using -3^{o} incidence and the small tail, and -2^{o} incidence with the large tail. The large tail was 1.2 times the size of the small tail.

4.2 SERIES II

As a result of the series 1 tests, the tank models were re-tested with the release occuring after rotation thru about 5^{o} from the initial position.

The full and empty tanks configurations with the small tail and -2^{o} incidence to the aircraft datum were used. Both configurations were tested at the ten flight conditions out lined above with the aircraft at zero yaw and 5^{o} yaw to the left.

5.0 TEST RESULTS - SERIES I

The jettison tests performed in this series are listed in the schedule of test films given in Table 3. The high speed test films were studied by projecting them at 16 frames per second and also by means of a frame by frame analysis using a film viewer giving about twenty times magnification. The results of this analysis are summarized in Table 4.

5.1 DISCUSSION

The film analysis indicated that there were a relatively large number of cases in which the model tail fin appeared to interfere with the aircraft fuselage.

The summary in Table 4 lists three instances for the -2° incidence, small tail full tank configuration where the tail appeared to come very close (Runs 8,9, and 6) and possibly hit the fuselage, and three cases in which the tail came close (Runs 10,4,1). These cases occured mainly at the two lower altitudes simulated. Empty tank tests with the same configuration produced two cases where the tail came close (Runs 11 and 20) at 40,000 ft.

There was one run (22) for the -3° incidence small tail empty tank configuration where the tail came very close, and there were two that only came close (Runs 23 and 25).

When the test films were projected the model tail in Runs 8,9 and 25 appeared to hit the fuselage, ie., the tail moved up towards the fuselage as the tank pitched nose down and appeared to bounce off the fuselage. Runs 10,6,1, and 22 were considered to have come very close to hitting the fuselage.

Although tests using the -3° incidence small tail configuration were only conducted for empty tank, sea level conditions, it can be seen that if the full tank, -2° incidence, small tail configuration interferes frequently with the fuselage, the full tank would also interfere using -3° incidence. Thus the use of -3° incidence for jettison purposes would be generally unsatisfactory.

The effect of increasing the tail size is indicated by comparing Runs 15 and 16 with Runs 21 and 24. Unfortunately only low speed conditions were checked but the increased tail size appears to have a slight beneficial effect, on the basis of these few tests. The pitching motion at very low speed remained the same, but at M=.5, was reduced from approximately 16° to 12°.

On the basis of the results of this test series it was concluded that the jettison of a full scale, -2° incidence, small tail tank configuration would be unsatisfactory, in that the tank would interfere with the fuselage. A recommendation was made that tests be conducted using the -2° incidence small tail configuration to investigate the effect of reducing the release angle to 5°.

6.0 TEST RESULTS - SERIES II

The jettison tests performed in Series II are listed in the schedule of test films given in Table 5. The high speed test films were studied in the same manner as the Series 1 test films. The results of the film analysis, with particular emphasis on roll and yaw angles at the release, are summarized in Table 6.

6.1 Discussion

The analysis data in Table 6 lists only three runs where the tail of the tank model came close to interfering with the aircraft fuselage (Runs 4, 13, 15). These cases are for empty tanks with the aircraft at zero yaw (Run 4, 20,000 feet), amd 5° yaw to the left (Run 13, sea level, and Run 15, 40,000 feet).

For this test series closeness to the fuselage was based on the percentage reduction in the initial tail-fuselage clearance estimated from the films. For the runs referred to above, the reduction in the initial clearance was 55% to 60%. When the films were projected, Run 4 was judged to have come close, and in Run 13, although the tail never actually hit the fuselage according to the frame - by - frame analysis, the tail appeared to bounce off the fuselage. In this latter case the model probably hesitated slightly as the swivel pin freed itself from the mounting plate in the aircraft model.

In contrast with the previous test series, all of the full tank models jettisoned at either 0° or 5° of yaw came free satisfactorily, with only a moderate amount of tail movement to-wards the aircraft (25% average). The reduction of the release angle reduced the nose down attitude of the full tanks after release by 2° to 10° with the aircraft at zero yaw. Thus the tail would not tend to move to-wards the fuselage as much in this test series. The empty tank pitching was not noticeably affected by the reduction in release angle, and these models tended to pitch tail-up to-wards the fuselage more consistently than the full tanks. When the aircraft model was yawed, the full tank tail-up pitching reduced; whereas, the tail-up motion of the empty tanks increased, even for the few cases tested.

This initial motion is contrasted in the Series II high-speed film strip reproductions given in Figures 5 and 6. In Figure 5, the tail did not move to-wards the fuselage, and in Figure 6, the initial tail clearance was reduced by about 55%.

On the basis of the dynamic model jettison tests conducted in this series, the 5° release angle and the -2° incidence small tail tank configurations were adopted by the Technical Design Department for the Arrow.

6.2 Roll and Yaw Angles at Release

The roll and yaw angles at the 5° release angle given in Table 6 were determined from the test films to provide limiting angles for the design of the aft swivel pin. The maximum angles originally issued were: roll $\pm 15^\circ$, yaw $\pm 10^\circ$. More recently , when the problem of the design of the fuel line coupling between the tank and the fuselage arose, the films were re-analized, and it was found that the maximum yaw limit was closer to $\pm 5^\circ$, as indicated in Table 6.

The roll and yaw angles of the tank as it pitches down can be assumed to vary linearly with pitch angle from zero values at the initial position to the maximum values at the 5° release angle. It should be remembered that these limiting values apply for level flight conditions.

The roll angles at release for the full tank (ψ =0 and -5°), and empty tank ($\psi = 0^\circ$), are moderate (0 to 5°); whereas for the empty tank at 5° of yaw the roll angle increases 10° to 15°. Similarily the yaw angles at release for the full and empty tanks ($\psi = 0$) are moderate (less than 3°) ; whereas for the full tank (sea level, $\psi = -5^\circ$), and empty tank ($\psi = -5^\circ$), the yaw angle increases to 5°.

The rolling and yawing motion of the tank models illustrating moderate conditions are shown in Figure 5, and the limit angles are shown in Figure 6.

6.3 Tank - Missile Clearance

The problem of Sparrow missile-long range tank interference when the missiles must either be fired or jettisoned while the tank is still in use was also investigated.

The time taken for the missile to reach its fully extended position after the missile doors start to open is $1\frac{1}{4}$ seconds. It was established from the aircraft- missile launcher geometry that the top of the tank forward pylons should be at least six feet below the fuselage before the missile doors started to open to ensure that the tank would be well away before the missiles were fully extended. Cases for which the time taken by the tank to drop the required six feet would be the least were analized and the results are listed in Table 7. These data were used to establish requirements for time delays between tank and missile jettison signals.

The tabulated values show that the tank would always be well clear of the aircraft before the missiles were fully extended. The values issued were .5 to .7 seconds for full tank, and .2 to .5 seconds for empty tank. The maximum values occured at low speed and high altitude, e.g., M= .5 at 40000 feet.

6.4 Model Trajectories

At zero yaw, the full tank models fell straight down below the aircraft with little aft or lateral motion. The empty tanks tended to move outboard more than the full tanks. With 5°of yaw the full tank models moved well outboard of the airplane as they fell, except for the 40,000 feet models which tended to remain below the aircraft as they dropped away. All altitude models of the empty tank moved well outboard when the airplane model was yawed.

Typical trajectories are illustrated in Figures 5 and 6. In Figure 5, the model fell straight down below the airplane, and in Figure 6, the outboard motion with the airplane yawed is evident. In the front views, the models disappear from view at a distance about .2b to .25b below the aircraft model.

7.0 PROPOSED FLIGHT JETTISON TEST PROGRAMME

The following basic programme was proposed for jettison tests of the long range fuel tank from the Arrow at 1 (approximately) flight conditions:

	ALTITUDE	MACH NO.	SIDESLIP ANGLE	JETTISON CASE
(A)	Full Tank			
	Sea level	.3	0^o	After take-off, at 200 kts.
	20,000	.7	0^o	Full or nearly full tank jettisoned half-way along climb to limiting altitude for the tank.
	20,000	.7	5^o	
(B)	Empty Tank			
	Sea level	.3	0^o	At the end of subsonic flight, on approach.
	40,000	.7	0^o	At the end of subsonic climb to limiting altitude.
	40,000	.7	5^o	

The above conditions were based on the Series II test results. At 20,000 feet, M=.7 simulated level flight conditions, the full tanks tended to pitch tail-up to-wards the fuselage, and there was a moderate amount of roll before the swivel pin cleared the fuselage. The empty tanks showed the same effects at 20,000 feet and 40,000 feet for the Mach number range .5 to .85, except that the effects were slightly worse. That is, the initial rolling angles of the empty tanks were about 10^o, or more (especially with $\Psi = \pm 5^o$), and the tail appeared to come very close to the fuselage in a few cases.

8.0 CONCLUSIONS

Based on the dynamic tests of .07 scale models, the following conclusions for jettison characteristics of the long range fuel tank from the full scale Arrow can be made:

1. Satisfactory jettison characteristics were obtained for a tank configuration with the small tail (see Figure 1), -2^{o} to the fuselage datum and a 5^{o} release angle.

2. In some isolated cases, the tests indicated that the horizontal tail of the tank may come close to the fuselage, although there were no positive instances of contact. Tail-up motion will be more severe for jettisoned empty tanks than for full tanks. Reductions in initial tail clearance up to the order of 60% were observed in the tests.

3. Jettisoned full tanks will generally fall straight down below the aircraft, except at low altitudes with sideslip angles of the order of $\pm 5^{o}$, when the tanks will also move outboard as they fall. Jettisoned empty tanks will generally move outboard as they fall below the aircraft. The direction of outboard motion at zero yaw would depend on the conditions existing when the tank is released.

4. The tanks will jettison clear of the aircraft at all speeds and altitudes within the tank flight envelope 1 g conditions (dive brakes closed).

5. The speed brake fully open configuration was not investigated during these jettison tests. A study of the tank-extended dive brake geometry showed that interference between jettisoned tanks and the speed brakes was probable, considering the motion of the tanks after release. Unless further jettison tests with the extended speed brake configuration are performed, it must be assumed that for all flight conditions within the flight envelope of the tank, interference between jettisoned tanks and fully extended speed brakes is possible. Therefore the speed brakes must be closed before the long range tank is jettisoned.

6. The outflows underneath the fuselage will create rolling and yawing motions of the tanks as they pitch down to the release angle. The maximum roll and yaw angles at the 5^{o} release angle will be of the order of $\pm 15^{o}$ of roll and $\pm 5^{o}$ of yaw for level flight conditions. The maximum angles occured for empty tanks jettisoned with the aircraft yawed 5^{o}.

7. Assuming that the mechanical release mechanism on the models reasonably simulated the full scale design, the jettison tests showed that the initial tank motions will not cause the tank to jam in the release mechanism and fail to release.

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APPENDIX

DESIGN AND TEST DATA FOR TANK
JETTISON TESTS

FORM 1319A

DESIGN AND TEST DATA FOR MODEL JETTISONING TESTS

Model Scale: $\ell_m = .07 \ell_{fs}$

Design and Test Data

EQUIVALENT ALTITUDE ft.	EQUIVALENT MACH NUMBER	FULL SCALE T.A.S. m.p.h.	TUNNEL T.A.S. f.p.s.	TUNNEL DYNAMIC PRESSURE q_{dial} p.s.f.	AIRPLANE ANGLE OF ATTACK degrees	TANK MODEL WEIGHT		SEAT MODEL WEIGHT lbs.	PILOT MODEL WEIGHT lbs.
						Empty lbs.	Full lbs.		
S.L.	.2	152	59	4.4	12.8	.106	1.451	.021	.080
	.5	380	147.5	27.6	2.3				
	.7	533	207	54.4	1.3				
	.85	647	251	80.0	.9				
20,000	.5	353.5	137.2	23.9	5.4	.200	2.726	.039	.150
	.7	494	192	46.8	2.6				
	.85	600	233	68.9	1.8				
40,000	.5	331	128.6	21.0	13.7	.435	5.930	.084	.327
	.7	464	180	41.1	6.7				
	.85	563	218	60.4	4.4				

AVRO AIRCRAFT LIMITED
TECHNICAL DEPARTMENT (Aircraft)

AIRCRAFT: C-105

N.A.E. LOW SPEED WIND TUNNEL TESTS

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REPORT NO P/Models/44

SHEET NO 34

PREPARED BY G.K. Dimock DATE June 1956.

CHECKED BY DATE

Design and Test Data: (Continued)

Model radii of gyration = .07 full scale values.
Model C.G. to be in the same position as for the full scale body.
Models to be geometrically similar to full scale bodies except for small details.
Model time intervals along a trajectory will be = $\sqrt{.07}$ full scale values.
Seat model ejection velocity = 21.2 f.p.s. at all altitudes.

NOTE:

(1) Model weights were based on the following full scale weights:

Tank - empty	:	310 lbs.
Tank - full	:	4235
Ejection Seat	:	60
Pilot	:	233

(2) Seat model ejection velocity based on full scale ejection velocity of 80 f.p.s.

(3) Airplane angle of attack taken as angle to trim at T.A.S. (level flight with C.G. at .31 $\bar{c}$).

(4) $q_{true} = .936\ q_{dial}$

TABLES.

AVRO AIRCRAFT LIMITED
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TECHNICAL DEPARTMENT

REPORT NO. P/Wind Tunnel/138
SHEET NO.

AIRCRAFT: CF-105

PREPARED BY: G.K. Dimock | DATE: Dec. 1957.
CHECKED BY: | DATE:

TABLE 1

TANK MODEL CONFIGURATIONS AND DESIGNATIONS

EMPTY	FULL	INITIAL INCIDENCE w.r.t. AIRCRAFT DATUM	TAIL SIZE
A,B,C,	D,E,F,	-2°	Small
G		-3°	Small
H		-2°	Large

EMPTY	FULL	SIMULATED ALTITUDE
A,G,H,	D	Sea Level
B	E	20,000
C	F	40,000

Large tail size = 1.2x small tail size

TEST SERIES I

Configurations used: A to H inclusive

Release after rotation through $7\frac{1}{2}^{\circ}$ from initial attitude.

TEST SERIES II

Configurations used: A to F inclusive

Release after rotation through 5° from initial attitude.

FORM 1319A

TABLE 2

DYNAMIC PROPERTIES OF MODELS

1.0 Tank Full Models

SIMULATED ALTITUDE	PROPERTY	REQUIRED VALUE	ACTUAL VALUE	% ERROR
Sea Level	Weight W	1.451 lb.	1.451 lb.	
	Roll Inertia Ixx	.7614 lb.in.^{2}	.7775 lb.in.^{2}	2.1
	Pitch Inertia Iyy	25.141	25.358	
	Yaw Inertia Izz	25.141	25.347	
20,000	W	2.726	2.726	
	Ixx	1.428	1.267	-11.3
	Iyy	47.170	47.992	
	Izz	47.170	47.981	
40,000	W	5.930	5.930	
	Ixx	3.114	3.348	7.5
	Iyy	102.83	105.84	2.9
	Izz	102.83	105.85	2.9

2.0 Tank Empty Models

SIMULATED ALTITUDE	PROPERTY	REQUIRED VALUE	ACTUAL VALUE	% ERROR
Sea Level	W	.106	.106	
	Ixx	.0989	.1096	10.8
	Iyy	2.546	2.559	
	Izz	2.546	2.550	
20,000	W	.200	.200	
	Ixx	.1856	.1394	-24.9
	Iyy	4.777	4.791	
	Izz	4.777	4.790	
40,000	W	.435	.435	
	Ixx	.4046	.1785	- 5.6
	Iyy	10.413	10.301	
	Izz	10.413	10.340	

TABLE 3

.07 SCALE TANK JETTISON TESTS - SERIES I

SCHEDULE OF TEST FILMS

In the complete film of these tests, the test films will appear in the same order as the film numbers given below. The Avro reference number for the Arrow tank jettison film, Series I is 8-77

1.0 TANK FULL

1.1 Configuration: -2° Incidence, Small Tail

Film No.	Simulated Altitude	Full Scale Mach No.
7	Sea Level	.20
8		.50
9		.70
10		.85
6	20,000	.50
5		.70
4		.85
3	40,000	.50
2		.70
1		.85

2.0 TANK EMPTY

2.1 Configuration: -2° Incidence, Small Tail

Film No.	Simulated Altitude	Full Scale Mach No.
15	Sea Level	.20
16		.50
17		.70
18		.85
13	20,000	.50
14		.70
19		.85
11	40,000	.50
12		.70
20		.85

TABLE 4 (a) - SUMMARY OF FILM ANALYSIS - SERIES I

TEST CONDITIONS: Tank Full. - 2° incidence, small tail - Aircraft at zero yaw

RUN NO.	ALT	M	$\alpha°$	INITIAL ROLL	INITIAL YAW	INTERFERENCE WITH AIRCRAFT	REMARKS
8	S.L.	.5	2.3	R slightly (<5°)	R	Tail appeared to come very close to fuselage	Tank pitched thru approx. 23° nose down (from initial position) at release, tank fell straight down below the A/C.
9	↓	.7	1.3	R slightly	R, 45°	Tail came very close	Pitched nose down 21°, fell straight down below the A/C.
10	↓	.85	.9	R slightly	R, 45°	Tail came close	Pitched nose down 20°, fell below A/C, moved to right slightly.
6	20000	.5	5.4	R very slightly	R, very slightly	Tail came very close	Pitched nose down 22°, fell straight down below A/C.
5	↓	.7	2.6	R slightly	R slightly	None	Little pitching just below A/C, nose eventually pitched down 15°, tank fell straight down below A/C.
4	↓	.85	1.8	R	None	Tail came close	Pitched nose down 22°, fell straight down below A/C.
3	40000	.5	13.7	None	None	None	Model pitched to horizontal, then nosed down 10°, fell straight down below A/C.
2	↓	.7	6.7	R	R slightly	None	Pitched nose down 17°, fell straight down below A/C.
1	↓	.85	4.4	R	R slightly	Tail came close	Pitched nose down 20°, fell straight down below A/C.

R = to the right
L = to the left

NOTE: The initial roll and yaw angles were estimated for the period in which the models fell a tank body diameter below the aircraft fuselage. These angles are approximate and only serve to indicate rates of angular rotation.

The trajectory descriptions given in the remarks cover the model motion within .25b of the fuselage.

TABLE 4 (b) - SUMMARY OF FILM ANALYSIS - SERIES I

TEST CONDITIONS: Tank Empty. - 2° incidence, small tail - Aircraft at zero yaw

RUN NO.	ALT	M	α°	INITIAL ROLL	INITIAL YAW	INTERFERENCE WITH AIRCRAFT	REMARKS
15	S.L.	.2	12.8	L slightly	R, 45°	None, tail moved towards A/C.	Model pitched to horizontal, moved outboard to the right as it fell.
16		.5	2.3	L initially, then motion stabilized	R, 45°	None,	Pitched nose down 16°, moved outboard (R) as it fell below A/C.
17		.7	1.3	L very slightly, then reversed to R	R	None, tail moved towards A/C.	Pitched nose down 18°, moved outboard (R) as it fell below A/C.
18		.85	.9	R slightly		None, tail moved towards A/C.	Pitched nose down 15° moved outboard (R) past wing strut position (.2b from centre line) as it fell.
13	20000	.5	5.4	R slightly		None, tail moved towards A/C.	Pitched nose down 14°, moved outboard (R) past wing strut position.
14		.7	2.6	R slightly		None	Pitched nose down 13° moved outboard (R to .2b) as it fell below A/C.
19		.85	1.8	R		None, tail moved towards A/C.	Pitched nose down 14° moved outboard (R to .2b) as it fell below A/C.
11	40000	.5	13.7	L initially then reversed to R		Tail came close	Pitched to horizontal, moved outboard (R to .2b).
12		.7	6.7	R	R	None, tail moved towards A/C.	Pitched nose down 17°, moved outboard (R to .2b)
20		.85	4.4	L very rapidly, 45°	L, 45°	Came close, model rolled and fin came close to fuselage	Pitched nose down 12°, eventually rolled thru 180° as it fell straight down below A/C.

R = to the right
L = to the left

b = wing span.

TABLE 4 (c) - SUMMARY OF FILM ANALYSIS - SERIES I

TEST CONDITIONS: Tank Empty, - 3° incidence, small tail - Aircraft at zero yaw

RUN NO.	ALT	M	α°	INITIAL ROLL	INITIAL YAW	INTERFERENCE WITH AIRCRAFT	REMARKS
22	S.L.	.2	12.8	L, 45°	R	Tail came very close to fuselage	Pitched to horizontal, nose swung outboard (R) as it fell below A/C.
23	↓	.5	2.3	L slightly	R slightly	Tail came close	Pitched nose down 12°, fell straight down below A/C.
25	↓	.7	1.3	R	L slightly initially, then R	Tail came close as model rolled up towards A/C.	Pitched nose down 16°, fell with nose pitched down and yawed to R, but model did not move outboard very much.

TABLE 4 (d)

TEST CONDITIONS: Tank Empty, -2° incidence, large tail Aircraft at zero yaw

RUN NO.	ALT	M	α°	INITIAL ROLL	INITIAL YAW	INTERFERENCE WITH AIRCRAFT	REMARKS
21	S.L.	.2	12.8	L	R	None, tail moved towards A/C slightly	Pitched to horizontal, moved outboard (R) as it fell.
24	↓	.5	2.3	None	R	None	Pitched nose down 12°, moved outboard (R to .2b)

R = to the right
L = to the left

b = wing span

P/Wind Tunnel/138
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TABLE 6 (a) - SUMMARY OF FILM ANALYSIS - SERIES II

TEST CONDITIONS: Tank Full, Aircraft at zero yaw

RUN NO.	ALT	M	α^o	INITIAL[a] ROLL	INITIAL[a] YAW	WITHIN .2b OF FUSELAGE ROLL	WITHIN .2b OF FUSELAGE YAW	INTERFERENCE WITH AIRCRAFT	REMARKS
30	S.L.	.2	12.8	0	0	None	R slightly	None, tail moved away from fuselage	Model pitched to horizontal, fell straight down below A/C.
7	↓	.5	2.3	0	<1.2	None	R slightly	None, tail moved towards A/C (32%)[b]	Model pitched thru approx. 22° nose down (from initial position) at release. Fell straight down below A/C. in yawed, 20° nose down attitude.
26	↓	.7	1.3	0	<1.2	R, 45°	R, 45°	None (14%)	Pitched nose down 18°, moved slightly outboard (R) as it fell.
8	↓	.85	.9	0	1.5	R 90°	R > 45°	None (43%)	Pitched nose down 18°, moved slightly outboard (R) as it fell.
9	20000	.5	5.4	0	<1.2	R slightly	R slightly	None (20%)	Pitched nose down 13°, fell straight down below A/C.
27	↓	.7	2.6	4	1.3	L initially then R	R	None (32%)	Pitched nose down 16°, slight outboard motion.
10	↓	.85	1.8	0	<1.2	R slightly	R slightly	None (38%)	Pitched nose down 15°, fell straight down below A/C.
11	40000	.5	13.7	0	<1.2	L slightly	None	None, tail moved down	Pitched to horizontal, fell straight down below A/C.
28	↓	.7	6.7	<1.5	<1.2	R slightly	R slightly	↓	Pitched nose down 14°, fell straight down below A/C.
12	↓	.85	4.4	1.5	1.2	L slightly	R slightly	↓	Pitched nose down 12°, fell straight down below A/C.

R = to the right
L = to the left

b = wing span

[a] Initial roll and yaw angles were measured to within ± 1° at the point where the aft swivel pin just cleared the fuselage, ie., at 5° release angle.

b % figure gives approximate reduction in initial tail- fuselage clearance.

Note: The roll and yaw angles given for the distance covered by the film (within .2b to .25b below fuselage) are approximate and only serve to indicate rates of angular rotation. The trajectory descriptions given in the remarks cover the model motions within .25b of the fuselage.

TABLE 6 (b) - SUMMARY OF FILM ANALYSIS - SERIES II

TEST CONDITIONS: Tank Full, Aircraft yawed 5° left

RUN NO.	ALT	M	α°	INITIAL ROLL	INITIAL YAW	WITHIN .2b OF FUSELAGE ROLL	WITHIN .2b OF FUSELAGE YAW	INTERFERENCE WITH AIRCRAFT	REMARKS
17	S.L.	.5	2.3	5.5	5	L, 45°	$L > 45^{\circ}$	None, tail moved towards A/C. (9%)	Pitched nose down thru 12° approx., moved outboard (L) to wing strut position (.2b from centre line) as it fell.
23		.7	1.3	6.5	2.8	$L > 90^{\circ}$	$L > 45^{\circ}$	None, tail moved away from fuselage	Pitched nose down 15°, moved outboard (L to .2b) as it fell below A/C.
18		.85	.9	4.5	1.7	$L > 90^{\circ}$	$L > 45^{\circ}$		Pitched nose down 12°, moved outboard (L to .2b) as it fell.
19	20000	.5	5.4	2.5	1.7	$L < 90^{\circ}$	$L < 45^{\circ}$		Pitched nose down 14°, moved outboard (L) as it fell.
24		.7	2.6	3.5	1.9	L, 45°	L, 45°	None (20%)	Pitched nose down 12°, moved outboard (L) as it fell.
22		.85	1.8	1.5	2.0	L, 90°	$L > 45^{\circ}$	None (9%)	Pitched nose down 12°, moved outboard (L to .2b) as it fell.
20	40000	.5	13.7	<1.5	<1.2	L slightly	L slightly	None, tail moved away from fuselage	Model fell as it pitched to horizontal, fell almost straight down below A/C.
25		.7	6.7	0	<1.2	L slightly	$L < 45^{\circ}$		Model fell as it pitched nose down 13°, fell almost straight down below A/C.
21		.85	4.4	0	<1.2	L, 45°	L, 45°		Model fell below A/C. before it pitched nose down 9°.

R = to the right
L = to the left

P/Wind Tunnel/138
Series II

TABLE 6 (c) - SUMMARY OF FILM ANALYSIST- SERIES II

TEST CONDITIONS: Tank Empty, Aircraft at zero yaw

RUN NO.	ALT	M	α°	INITIAL ROLL	INITIAL YAW	WITHIN .2b OF FUSELAGE ROLL	WITHIN .2b OF FUSELAGE YAW	INTERFERENCE WITH AIRCRAFT	REMARKS
1	S.L.	.5	2.3	6.5	2.2	L slightly	R slightly	None, tail moved towards A/C. (32%)	Pitched nose down thru 12° approx., moved outboard (R) as it fell.
2		.85	.9	1.5	3.0	R slightly	R>45°	None (32%)	Pitched nose down 15°, nose swung outboard (R to .2b) as it fell.
3	20000	.5	5.4	5.5	1.7	L initially then R slightly	R>45°	None (20%)	Pitched nose down 15°, nose swung outboard (R to .2b) as it fell.
4		.85	1.8	3.5	1.2		R<45°	Tail came close to fuselage (60%)	Pitched nose down 18°, fell almost straight down below A/C.
5	40000	.5	13.7	5	1.7		R>45°	None (43%)	Pitched to horizontal, moved outboard (R to .2b) as it fell.
29		.7	6.7	2	1.2	R slightly	R,45°	None	Model fell straight down below A/C. as it pitched nose down 16°.
6		.85	4.4	3	1.7	R,45°	R>45°	None (43%)	Pitched nose down 16°, nose swung outboard (R to .2b) as it fell.
TABLE 6 (d)									
TEST CONDITIONS: Tank Empty . Aircraft yawed 5° left									
13	S.L.	.5	2.3	14.5	4.2	R initially then to L	L>45°	Tail came close to fuselage (55%)	Pitched nose down 17°, model nose hit L wing strut.
14	20000	.5	5.4	8	4.5			None (32%)	Pitched nose down 12°, model nose moved past L wing strut before hitting it.
15	40000	.5	13.7	8	4.2	R initially then L 45°		Tail came close (60%)	Pitched nose down 16°, model nose moved past L wing strut before hitting it.
16		.85	4.4	14	4.2	R initially then L rapidly		None (43%)	Pitched nose down 14° model nose moved past L wing strut before hitting it.

R = to the right
L = to the left

b = wing span

P/Wind Tunnel/138
Series II

AVRO AIRCRAFT LIMITED
MALTON - ONTARIO
TECHNICAL DEPARTMENT

AIRCRAFT: ARROW

UNCLASSIFIED / NON CLASSIFIÉ

CONFIDENTIAL UNCLASSIFIED / NON CLASSIFIÉ

REPORT NO. P/Wind Tunnel/138
SHEET NO.

PREPARED BY	DATE
G.K. Dimock	Dec. 1957.
CHECKED BY	DATE

TABLE 7

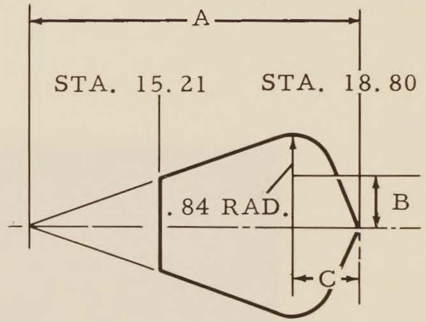
TIME TO DROP DATA

RUN NO.	ALT.	M	α°		FILM SPEED FRAMES/SEC.	SEC./FRAME FULL SCALE	FRAMES TO DROP	TIME TO DROP SEC. FULL SCALE
	TANK FULL							
30	S.L.	.2	12.8	0	720	.00525	109	.57
9	20000	.5	5.4	0	780	.00485	111	.54
11	40000	.5	13.7	0	720	.00525	124	.65
20	40000	.5	13.7	-5°	780	.00425	118	.57
	TANK EMPTY							
13	S.L.	.5	2.3	-5°	750	.00504	42	.21
3	20000	.5	5.4	0	720	.00525	67	.35
5	40000	.5	13.7	0	760	.0050	106	.53

Time to drop = Time for top of tank forward pylons to drop 6 ft. below the aircraft fuselage.

FORM 1319 A

	FIN GEOMETRY		AFT PYLON			GUIDE PIN HEIGHT
	SMALL	LARGE	TANK INCIDENCE			5° DROP ANGLE .051
				-2°	-3°	
A	5.50	4.82				
B	.88	1.21	A	.638	.493	$7\frac{1}{2}$° DROP ANGLE .065
C	1.28	1.40	B	.617	.504	



TAIL FIN

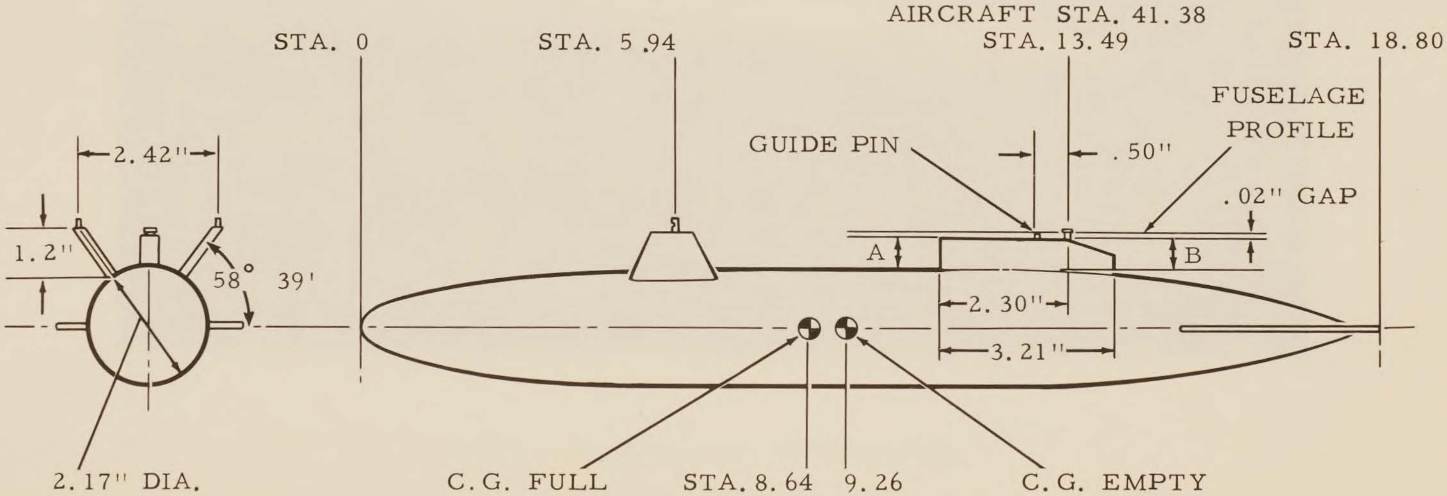


FIG. 1 .07 SCALE LONG RANGE TANK GEOMETRY

3010-105-1

P/WIND TUNNEL/138

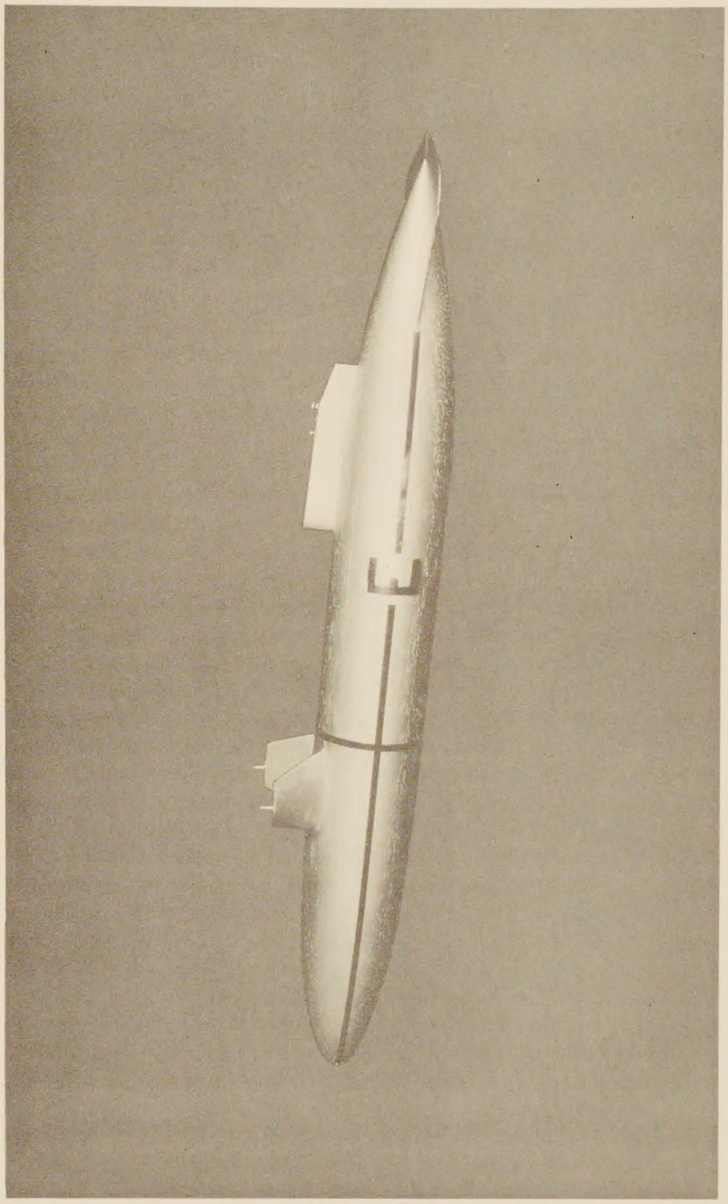


FIG. 2 LONG RANGE TANK MODEL

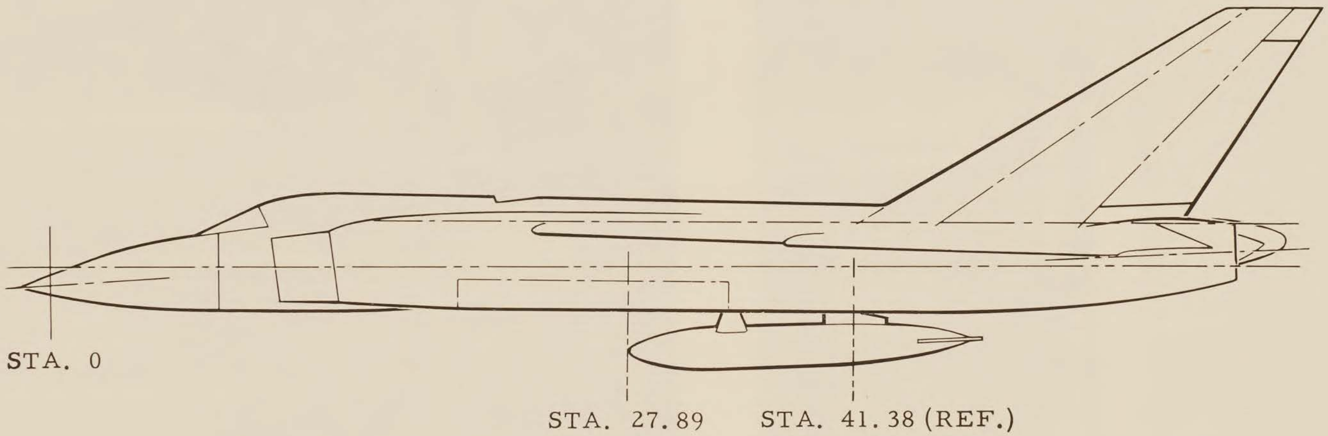


FIG. 3 ARROW .07 SCALE LONG RANGE TANK INSTALLATION

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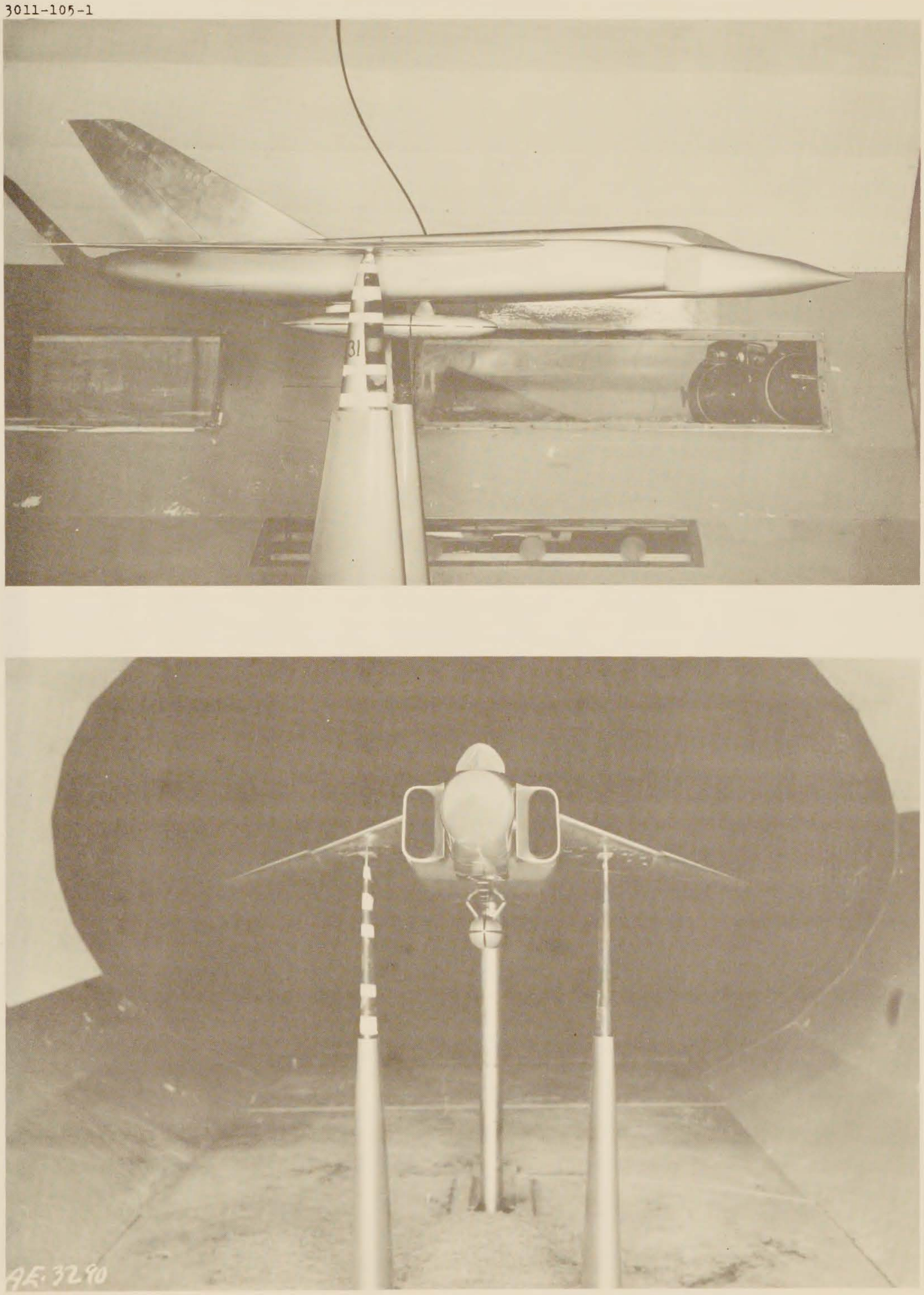

FIG. 4 JETTISON TEST ARRANGEMENT IN
THE 6' X 10' LOW SPEED WIND TUNNEL

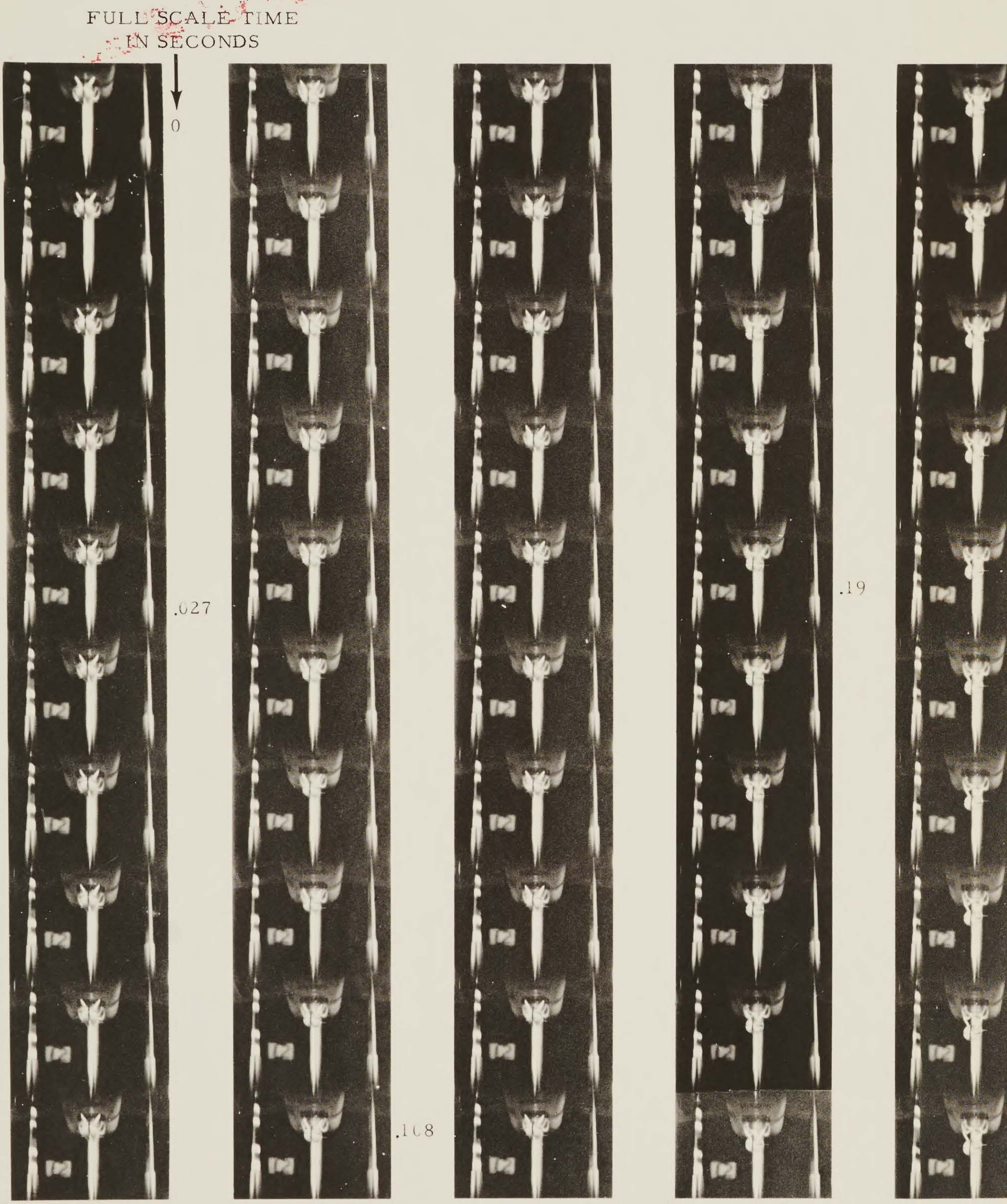

FIG. 5 (a) FRONT VIEW RUN NO. 12 - 40,000 FT., M = .85, α = 4.4°
TANK FULL, ψ = 0
FILM SPEED 700 FRAMES PER SECOND.

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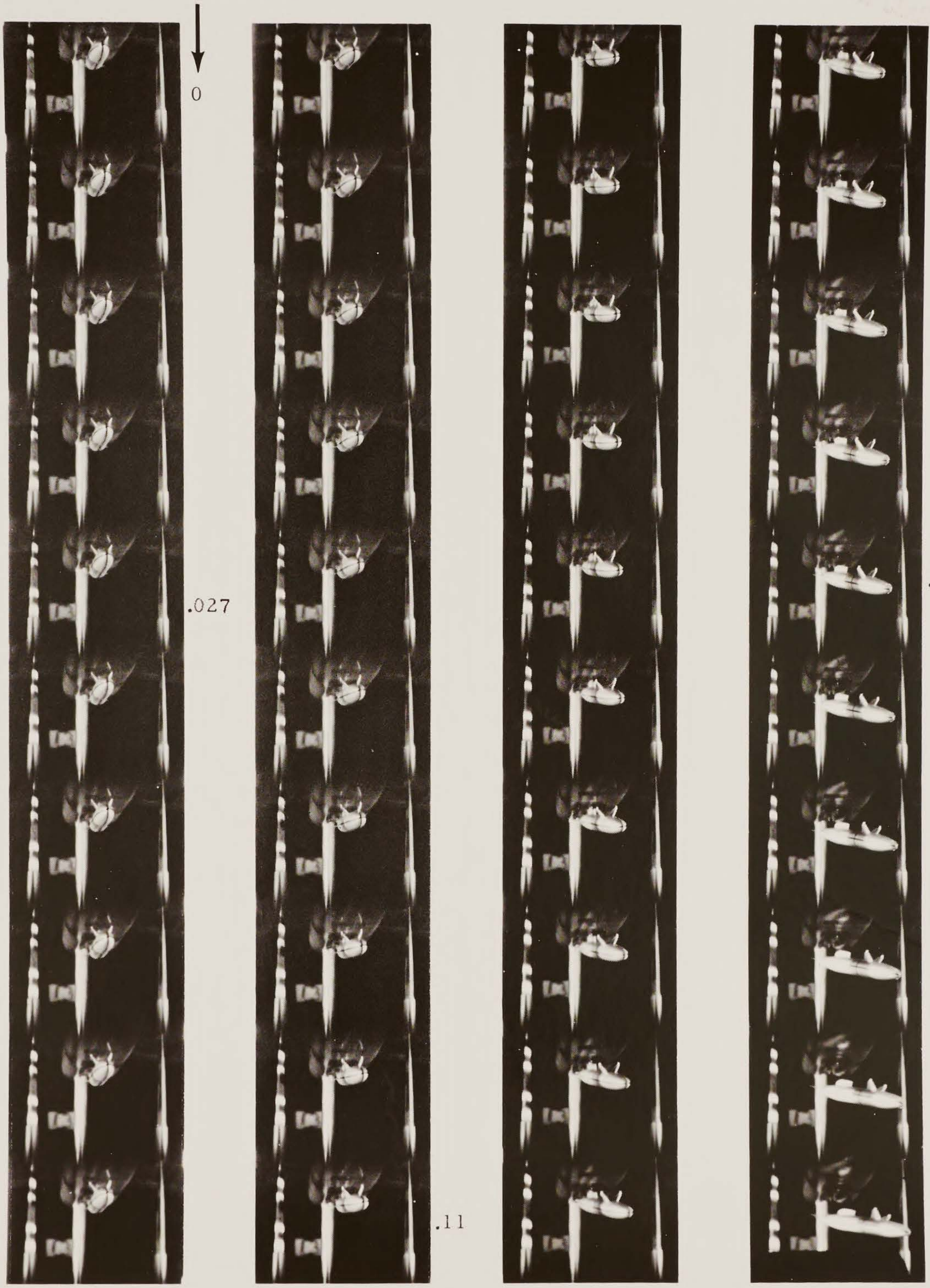

FIG. 6 (a) FRONT VIEW RUN NO. 13 - SEA LEVEL, M = .50, α = 2.3°
TANK EMPTY, ψ = -5°
FILM SPEED 690 FRAMES PER SECOND.

FULL SCALE TIME
IN SECONDS

FIG. 6 (b) SIDE VIEW RUN NO. 13 - SEA LEVEL, M =
TANK EMPTY, $\psi = -5^{o}$
FILM SPEED 750 FRAMES PER SECOND.