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REPORT NO. RD-TR-70-7

AN OIL FLOW STUDY OF A SONIC REACTION JET EJECTING FROM A BODY OF REVOLUTION INTO A FREE STREAM OF MACH NUMBER RANGE 1.75 TO 4.5

by

Troy A. Street

April 1970

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U.S. ARMY MISSILE COMMAND

Redstone Arsenal, Alabama 35809

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Advanced Systems Laboratory
Research and Engineering Directorate
U. S. Army Missile Command
Redstone Arsenal, Alabama 35809

Abstract

An oil flow test has been conducted to obtain flow patterns in the vicinity of a transverse sonic jet ejecting from a body of revolution into an oncoming supersonic flow of M_∞ = 1.75, 2.0, 3.0, 4.0, and 4.5. The angle of attack was ±10 degrees with jet total-to-free stream static pressure ratios up to 100. The jet was oriented to various angular positions at several longitudinal body locations.

Contents

Illustrations

Symbols

B_1	4-caliber tangent-ogive cylinder body
c	Fin chord (in.)
C_1	Circular (C), sonic (subscript 1) jet normal to the body surface
D	Missile body diameter (in.)
Hg	Mercury
M_∞	Free stream Mach number
P_{oj}	Jet total pressure (cm Hg)
P_∞	Tunnel static pressure (cm Hg)
r	Fin leading edge radius (in.)
s	Fin span (in.)
S_{1L}	Slot (S), sonic (subscript 1) jet longitudinally (subscript L) oriented with the model center line axis.
S_{1T}	Slot (S), sonic (subscript 1) jet oriented transversely (subscript T) to the model center line axis
t	Fin thickness (in.)
TiO_2	Titanium oxide
X_j	Jet longitudinal location (in.)
X_0	Jet location on the body 2.75 inches from the nose
X_1	Jet location on the body 4.125 inches from the nose
X_2	Jet location on the body 6.000 inches from the nose
X_3	Jet location on the body 7.875 inches from the nose
α	Angle of attack (deg)
φ_j	Jet orientation relative to the pitch plane (deg)

1. Introduction

The Advanced Systems Laboratory of the U.S. Army Missile Command has maintained an active interest in reaction jet control studies for several years. The literature [1, 2] to date largely reflects experimental studies by forces and moments or surface pressure measurements. The purpose of this oil flow test series was to obtain visual flow patterns in the vicinity of the jet and to record these patterns. This flow pattern will be used later for verification of the location and shape of the bow shock and its associated separation shock as predicted by the recently developed theoretical technique [3, 4]. The theoretical technique assumes that the jet can be replaced by a spherically capped cylinder as shown in Figure 1. A method of characteristics solution of the flow field around the cylinder yields local flow properties which are integrated between the capped cylinder and the bow shock to predict resultant forces and moments. The area of integration is vitally important to the resultant forces and moments and the area of integration is a function of the shape and location of the bow shock. These statements relative to the existing theoretical model are made only to show the stimulus for the conduction of this oil flow test series: the actual comparison of the experimental and theoretical bow shocks will be made later with only the experimental data presented herein.

The photographs contained herein are for Mach numbers 1.75 to 4.5, angles of attack between ±10 degrees, jet total-to-free stream static pressure ratios up to 100, various jet angular orientations, and longitudinal body positions. These photographs show unique details in the flow patterns and certainly reveals the complexity of the flow about a reaction jet.

An appendix contains the photographs and a table of conditions for each Mach number of the test series.

2. Apparatus

a. Test Facility

The Ballistic Research Laboratories at Aberdeen Proving Ground, Maryland, provided the wind tunnel test facilites for this two-test series. Tunnel No. 1 was used for the initial entry and Tunnel No. 3 for the second entry.

Tunnels No. 1 and No. 3 are essentially the same, as both operating ranges are approximately 1.5 to 5.0 with test sections 15 inches high by 13 inches wide and 13 inches high by 15 inches wide, respectively. Other tunnel characteristics may be found in the work by McMullen [5]. A distinct difference in the two tunnels is that Tunnel No. 3 has a glass window in the top of the tunnel in addition to the side wall window. Tunnel No. 1 has only a window in the side wall (Figure 2).

b. Test Conditions

The wind tunnel test conditions were Reynolds number per inch of 0.48×10^6 with other conditions as shown in Table I.

TABLE I. WIND TUNNEL TEST CONDITIONS

M_∞	Total Pressure (cm Hg)	Total Temperature (°F)
4.5	400	87
4.0	321	87
3.0	193	87
2.0	118	85
1.75	107	83

No difficulty was observed in maintaining these conditions throughout the tests.

c. Model

The model used in these tests was a 4-caliber tangent ogive nose on a 5-caliber cylindrical afterbody. A schematic of the model is shown in Figure 3 and the model is shown mounted in Tunnel No. 1 in Figure 2.

Four jet longitudinal body locations were used for this test. These locations and dimensions are given in Table II.

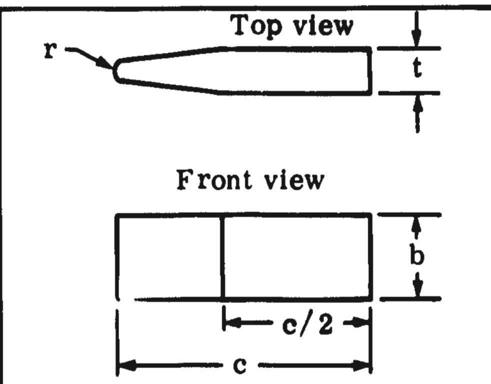
TABLE II. JET LONGITUDINAL LOCATION AND NOMENCLATURE

Position	X_j (in.)	X_j/D
X_0	2.750	2.00
X_1	4.125	3.00
X_2	6.000	4.36
X_3	7.875	5.73

The fins used in these tests were located at the base. The fins were either aligned with the jet or interdigitated 45 degrees from the jet angular location. The fin nomenclature and dimensions are shown in Table III.

TABLE III. FIN NOMENCLATURE AND DIMENSIONS

Fin No.	c (in.)	b (in.)	t (in.)	r (in.)	c/b
0.00	No Fins On the Body				
1.00	1.375	0.342	0.054	0.0135	0.250
1.45	1.375	0.342	0.054	0.0135	0.250
2.00	1.375	0.687	0.054	0.0135	0.500
2.45	1.375	0.687	0.054	0.0135	0.500
3.00	1.375	0.928	0.054	0.0135	0.675
3.45	1.375	0.928	0.054	0.0135	0.675



Notes: 1. The first digit in the fin number relates to the fin size.
2. The two digits after the decimal in the fin number indicate the fin orientation, in degrees, relative to the jet.

The jets used during the test were of the slot and circular type configuration. The circular jets were convergent nozzles with 0.11-inch diameters (Figure 4a). The slot jets were also convergent nozzles in the 0.275-inch length direction with straight sides in the 0.0345-inch width direction (Figure 4b). Both nozzle shapes have sharp corners at the exit. The slot jets were used with the slot aligned longitudinally with the flow and with the slot aligned transversely to the free stream flow.

The jet supply line (Figure 2) from an external source is located behind the strut and extends around the strut to a collar on the base of the sting mount. The jet supply to the model is furnished through the sting and dummy balance to the model pressure chamber. An identical installation was used when the model was mounted in Tunnel No. 3.

d. Test Procedure

The substance used to coat the model was a mixture of titanium dioxide (TiO_2) and 200 Dow Corning Silicone Oil as shown in Table IV. The mixture was applied with a brush from the grit band to the model base. The grit band was 0.25 inches wide and 1.0 inch from the nose with a 0.080-inch

TABLE IV. COATING MIXTURE

Mach No. Range	Titanium Dioxide (TiO_2)	200 Dow Company Silicone Oil
1.75→3.0	1cc	7cc of 350 centistokes
3.0→5.0	1cc	7cc of 500 centistokes

grit. The oil coating thickness was not measured, but the viscosity is the parameter that dictates the speed with which the coating is blown off. Thus the viscosity is the important parameter varied in the technique used for these photographs.

In the first oil flow entry a check was made to ascertain that no leakage occurred when the jet supply valve was closed. Neither visual observation nor a 1-hour lapse time with the tunnel pumped down revealed a leak in the jet supply valve. For the second entry an auxiliary jet supply valve was installed to insure positive shut-off in the closed position.

Another check was made to determine how many pressure ratios could be run prior to recoating the model. Pressure ratios of 0, 10, 20, 40, and 100 were run with only one coat (Figures E-9a, E-9c, E-9d, E-9e, and E-9g, respectively) and without bringing the tunnel or jet supply to zero. Although some mixture residue marks did remain from one pressure ratio to another it was felt that sufficient flow detail was obtained for an exploratory experiment, particularly since only pressure ratios of 0, 40, and 100 were planned.

Another check was made to determine if a hysteresis effect exists. A run was made by starting the tunnel and, after the test section steady state was reached by turning the jet on. Then the situation was reversed; the jet was activated, then the tunnel was started and a photograph taken at the steady state condition. The "apparent" bow shock was more forward by using the latter method as evidenced by comparing Figures E-9e and E-9i for $P_{oj}/P_\infty = 40$ and Figures E-9g and E-9j for $P_{oj}/P_\infty = 100$. The result is that some apparent hysteresis does exist. Throughout the test the former method was used.

The first entry in Tunnel No. 1 was an exploratory test with the photographs taken through the glass side door. For the second entry the same setup existed in Tunnel No. 3 except that a second camera was installed in the top of the tunnel. Simultaneous photographs were taken with cameras located in the pitch and yaw planes. The top view camera was located further from the model than the side view camera. This arrangement gave excellent photographic coverage.

3. Results

The photographs obtained from this oil flow test series are presented in the appendices in Mach number sequence as follows:

Appendix	Mach Number
A	1.75
B	2.00
C	3.00
D	4.00
E	4.50

The photographs in each appendix are preceded by a table showing the model orientation, tunnel conditions, and values of the test variables.

The photographs are arranged according to the information obtained. For the second entry where simultaneous photographs of the same conditions were made, these are presented on opposing pages. The photographs from the first entry are presented similarly, except, since only one camera was available, the opposing photographs are for the same conditions except the model is rolled 90 degrees. This is the case where both conditions were photographed.

Unfortunately, the jet supply valve did leak at Mach number 4.5 in the first entry with the valve closed. Although photographs were taken for this $P_{oj}/P_\infty \approx 0$ case, many are not shown in this presentation of the data. Some photographs of $P_{oj}/P_\infty \approx 0$ are presented to give an indication of the flow streamline patterns, particularly for the high angle-of-attack situations.

Since the two cameras were located at different distances from the model, the size of the model in the photographs differ. In order to obtain as much local flow detail in the vicinity of the jet as practically possible and, secondarily for documentation continuity, the photographs from both cameras are enlarged to give an approximately 2.0-inch diameter model image. Enlarging the model image to magnify the local flow details necessitates a sacrifice of the entire model view. However, to show the flow about the fins, the photographs for $M_\infty = 1.75$ were not enlarged as much as the photographs at other Mach numbers.

Schlierens and shadowgraphs that contribute shock information pertinent to the corresponding surface flow details are presented. For completeness, shadowgraphs from a similar test at conditions corresponding to those of the current test are occasionally included [6]. The schlierens and shadowgraphs are shown to add dimension to the surface photographs.

4. Concluding Remarks

The visual data collected as a result of this oil flow study are of sufficient quality to allow examination of the local flow details in the vicinity of the reaction jet on a body of revolution. The associated shock characteristics, such as the separation zone, the bow shock shape, and the reattachment zone are of sufficient detail to allow these data to be used for verification of existing techniques that predict shock formation about a reaction jet.

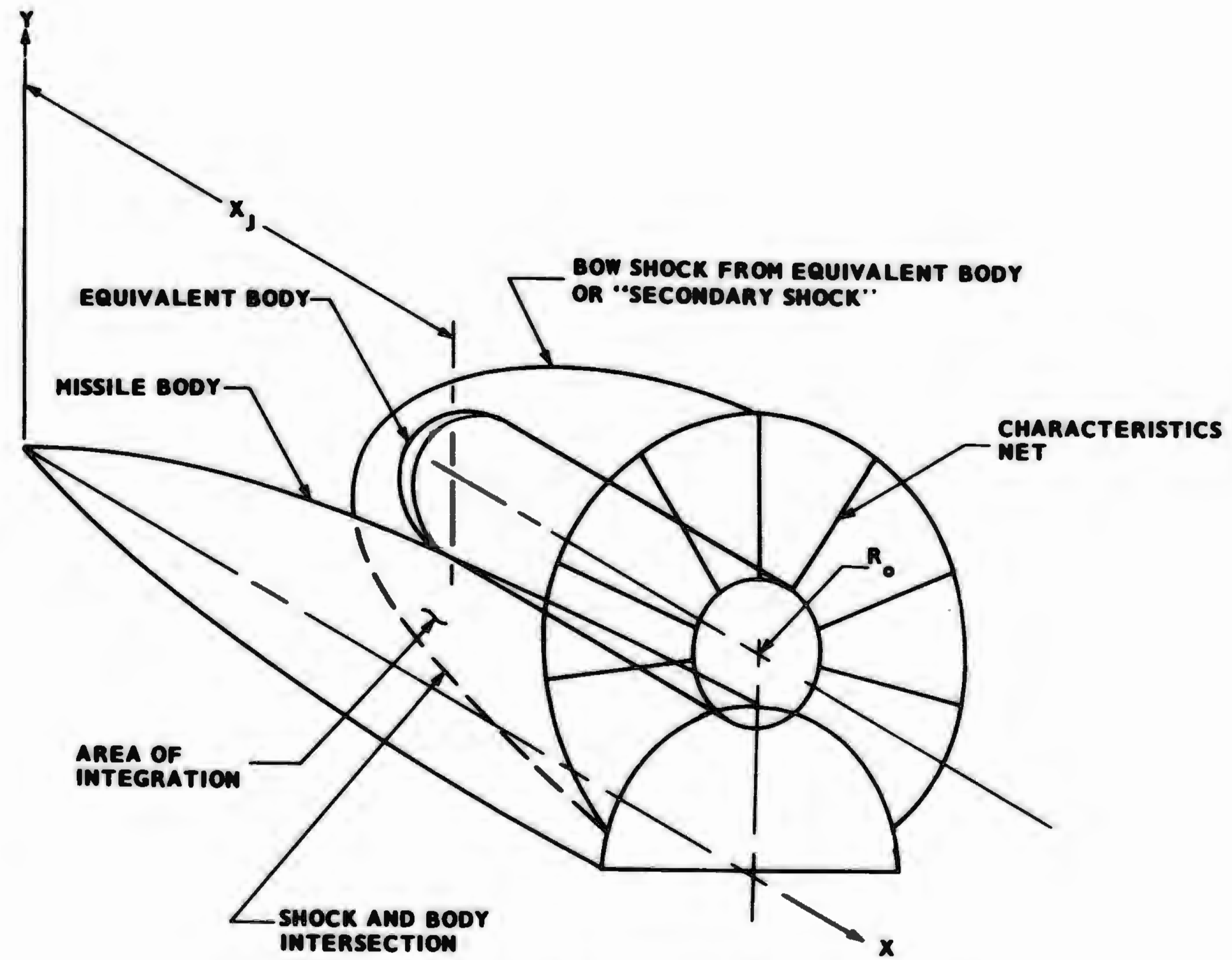


FIGURE 1. MODEL FOR EQUIVALENT BODY ANALOGY

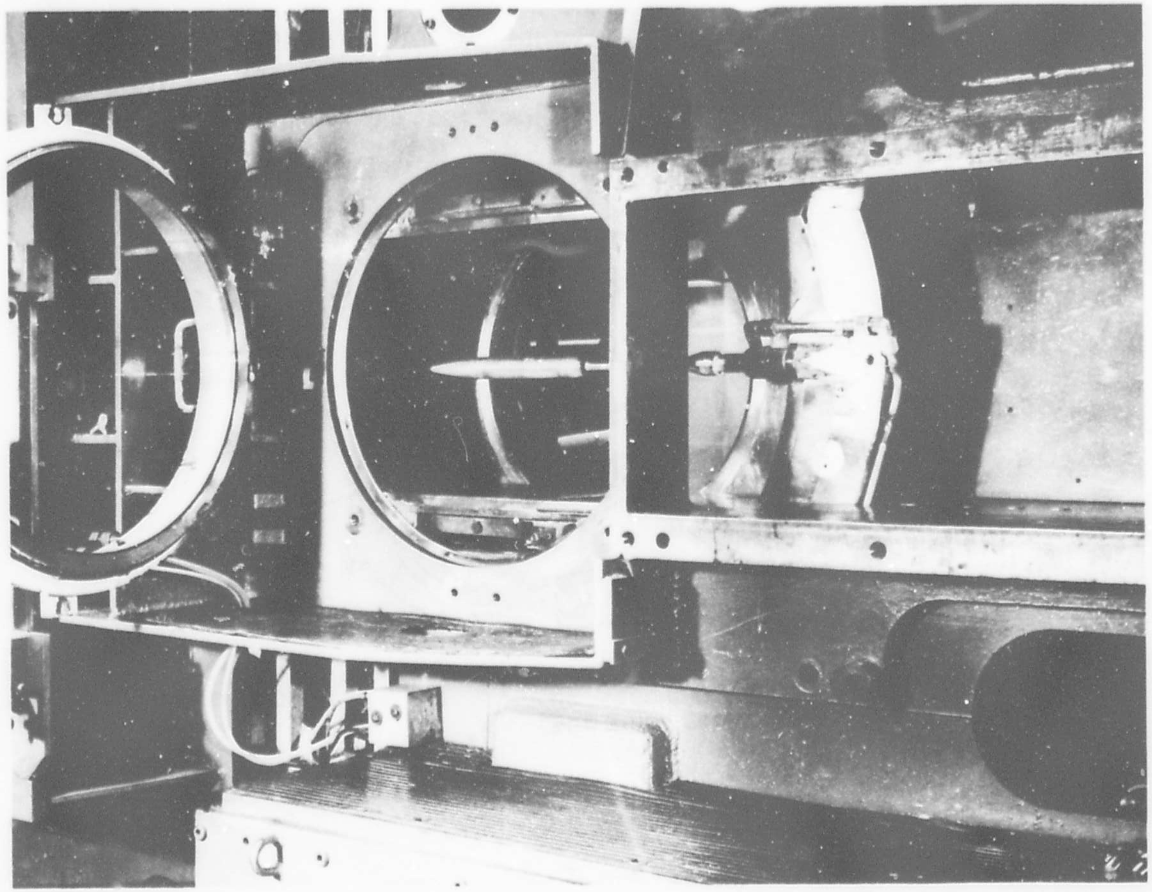
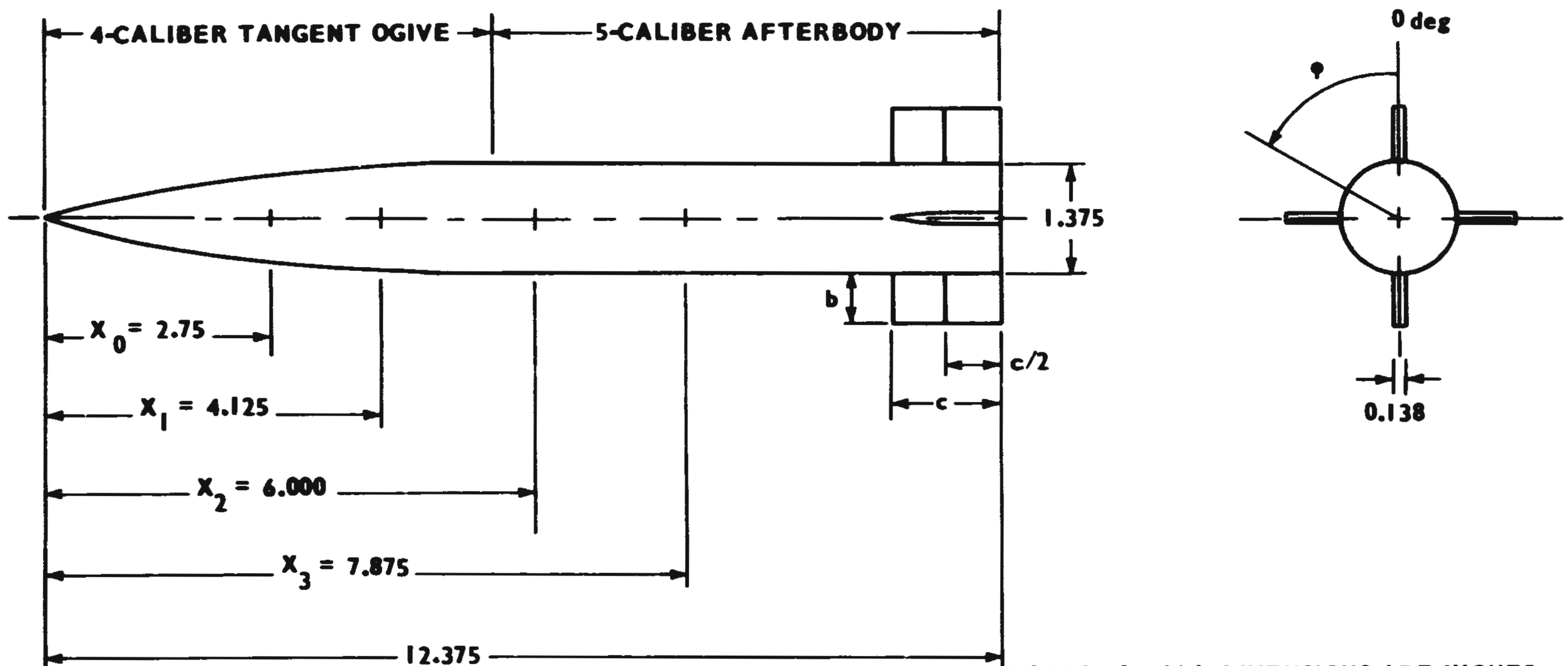


FIGURE 2. REACTION JET MODEL MOUNTING AND TEST FACILITY ARRANGEMENT IN TUNNEL NO. 1



NOTES:
1. ALL DIMENSIONS ARE INCHES, EXCEPT AS NOTED
2. SEE ELSEWHERE FOR VARIOUS FIN DIMENSION: b, c, c/2
3. ALL FOUR FINS IN A SET ARE IDENTICAL AND WERE ORIENTED AT VARIOUS ANGLES FROM φ = 0 deg

FIGURE 3. SCHEMATIC OF THE SUPPORTING RESEARCH REACTION JET TEST MODEL

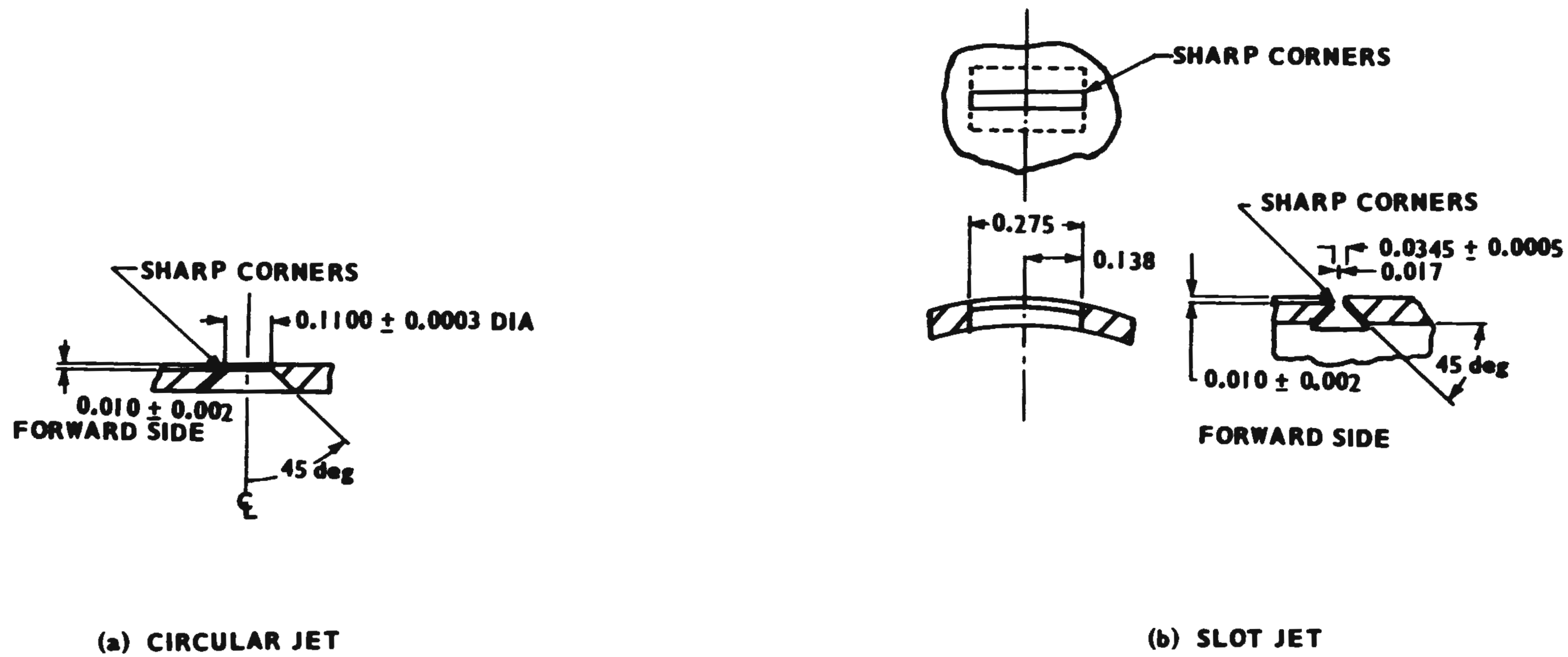


FIGURE 4. SCHEMATIC OF THE MODEL JETS

References

1. Spring, D. J., Street, T. A., and Amick, J. L., Transverse Jet Experiments and Theories — A Survey of the Literature, U. S. Army Missile Command, Redstone Arsenal, Alabama, Report No. RD-TR-67-4, June 1967.

2. Spring, D. J., Street, T. A., and Amick, J. L., Transverse Jet Experiments and Theories — A Survey of the Literature (U), U. S. Army Missile Command, Redstone Arsenal, Alabama, Report No. RD-TR-67-5, September 1967 (Secret).

3. Cassel, L. A., Davis, J. G., and Engh, D. P., Lateral Jet Control Effectiveness Prediction for Axisymometric Missile Configurations — Final Report, McDonnell Douglas Astronautics Company, Santa Monica, California, U. S. Army Missial Command, Redstone Arsenal, Alabama, Report No. RD-TR-68-5, June 1968.

4. Cassel, L. A., Durando, N. A., Bullard, C. W., and Kelso, J. M., Jet Interaction Control Effectiveness for Subsonic and Supersonic Flight — Final Report, McDonnell Douglas Astronautics Company, Santa Monica, California, U. S. Army Missile Command, Redstone Arsenal, Alabama, Report No. RD-TR-69-21, September 1969.

5. McMullen, J. C., Wind Tunnel Testing Facilities at the Ballistics Research Laboratories, Ballistics Research Laboratories, Aberdeen Proving Ground, Maryland, Report No. BRL-1292, July 1960.

6. Street, T. A., Experimental Investigation of Reaction Jets on a Body of Revolution with and without Fins in Supersonic Flow, U. S. Army Missile Command, Redstone Arsenal, Alabama, Report No. RD-TM-70-3.

Appendix A
M_∞ = 1.75 Flow Visualization Data

TABLE A-I. TEST VARIABLES AND VISUAL DATA COLLECTED FOR M_∞ = 1.75

Configuration	ϕ_j (deg)	Fin No.	α (deg)	P_{oj}/P_∞	Figure Showing Photographs	Figure Showing Schlierens	Figure Showing Shadowgraphs	Test Series
$B_1C_1X_2$	90	3.45	0	0	A-1a			April 1969
			0	40	A-1b			
			0	100	A-1c			
			5	0	A-2a			
			5	40	A-2b			
			5	100	A-2c			
			10	0	A-3a			
			10	40	A-3b			
$B_1C_1X_2$	90	3.45	10	100	A-3c			April 1969

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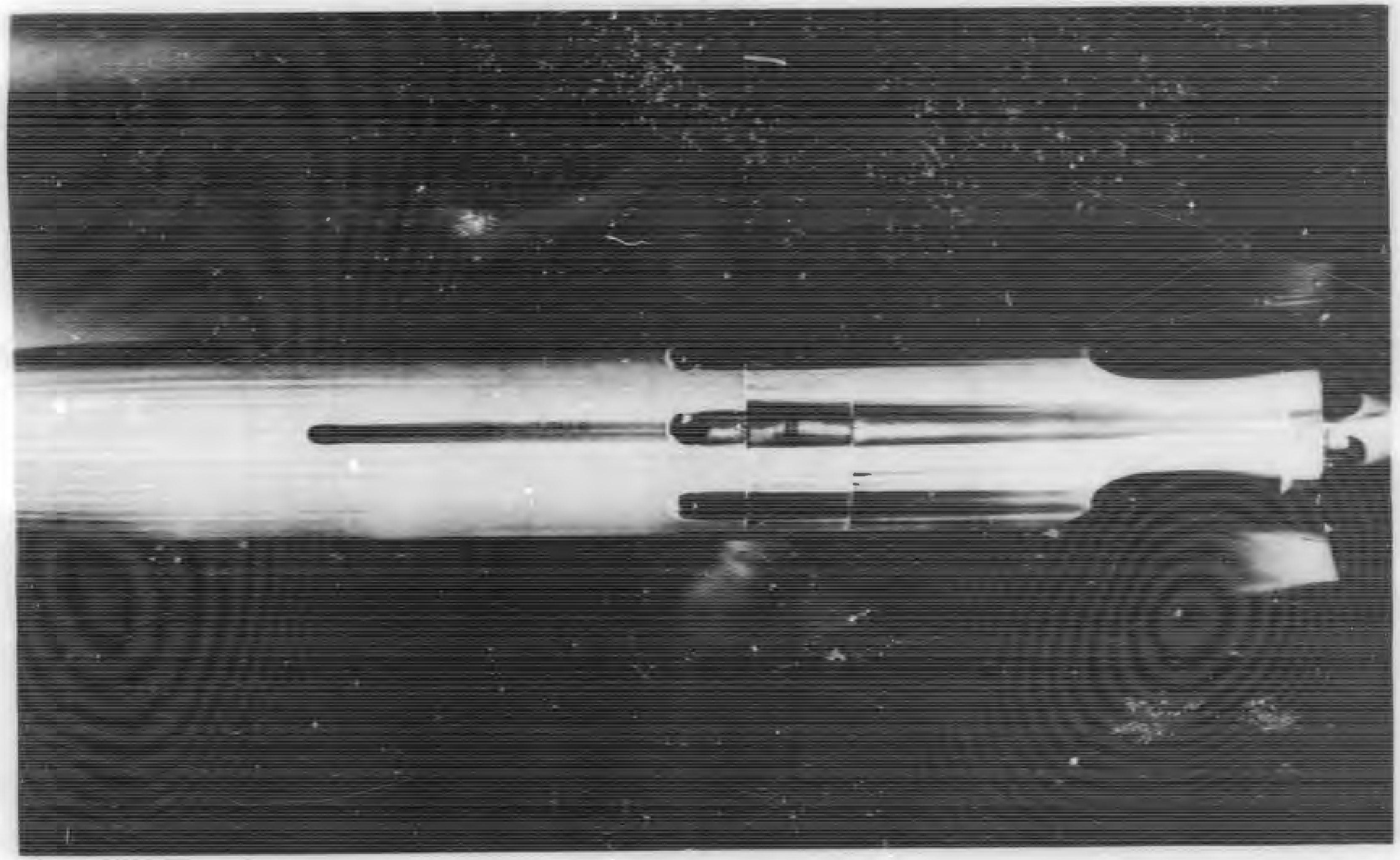

FIGURE A-1a. REACTION JET FOR $B_1C_1X_2$ WITH α = 0 DEGREES; P_{oj}/P_∞ = 0

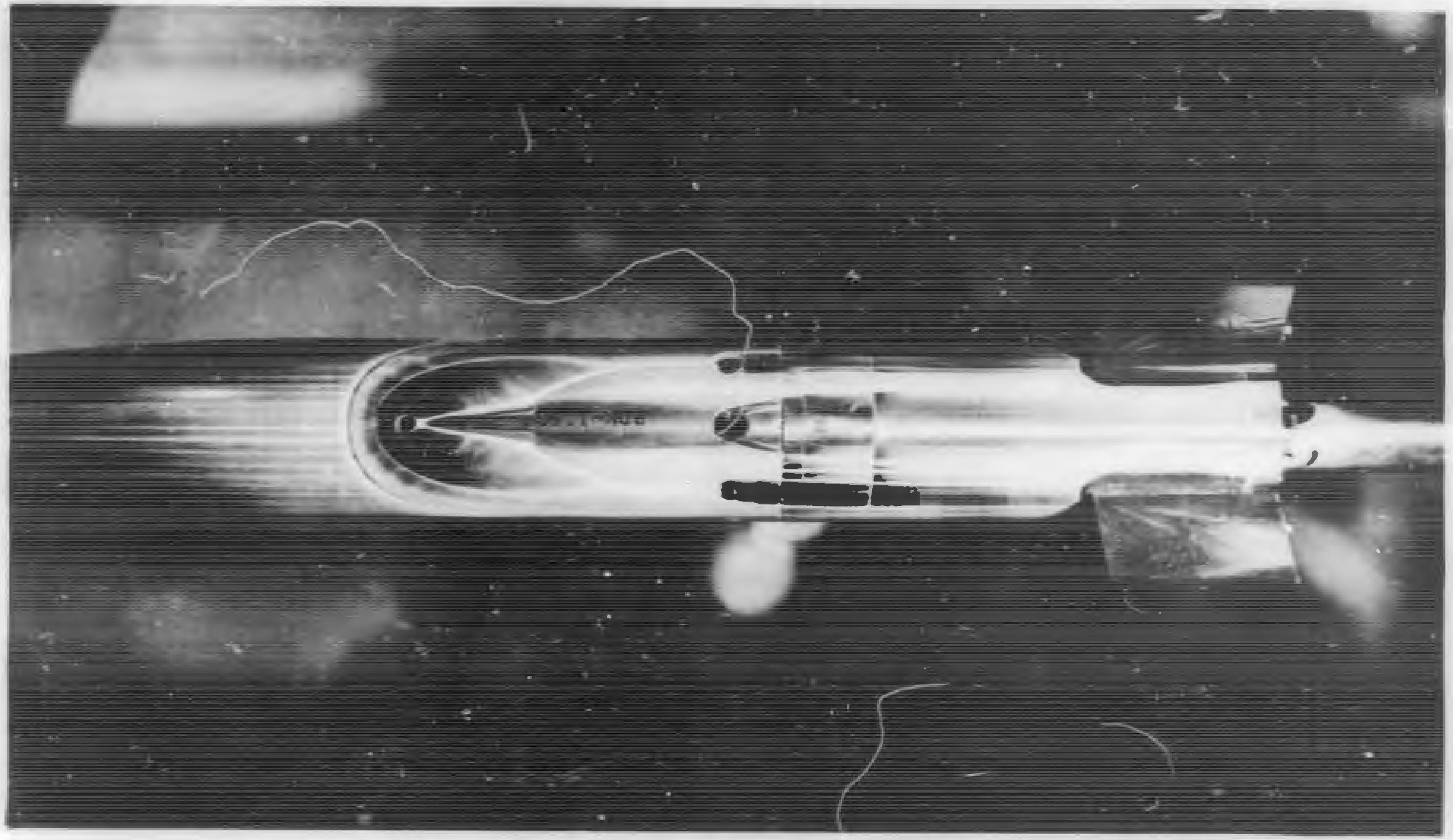

FIGURE A-1b. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 40$

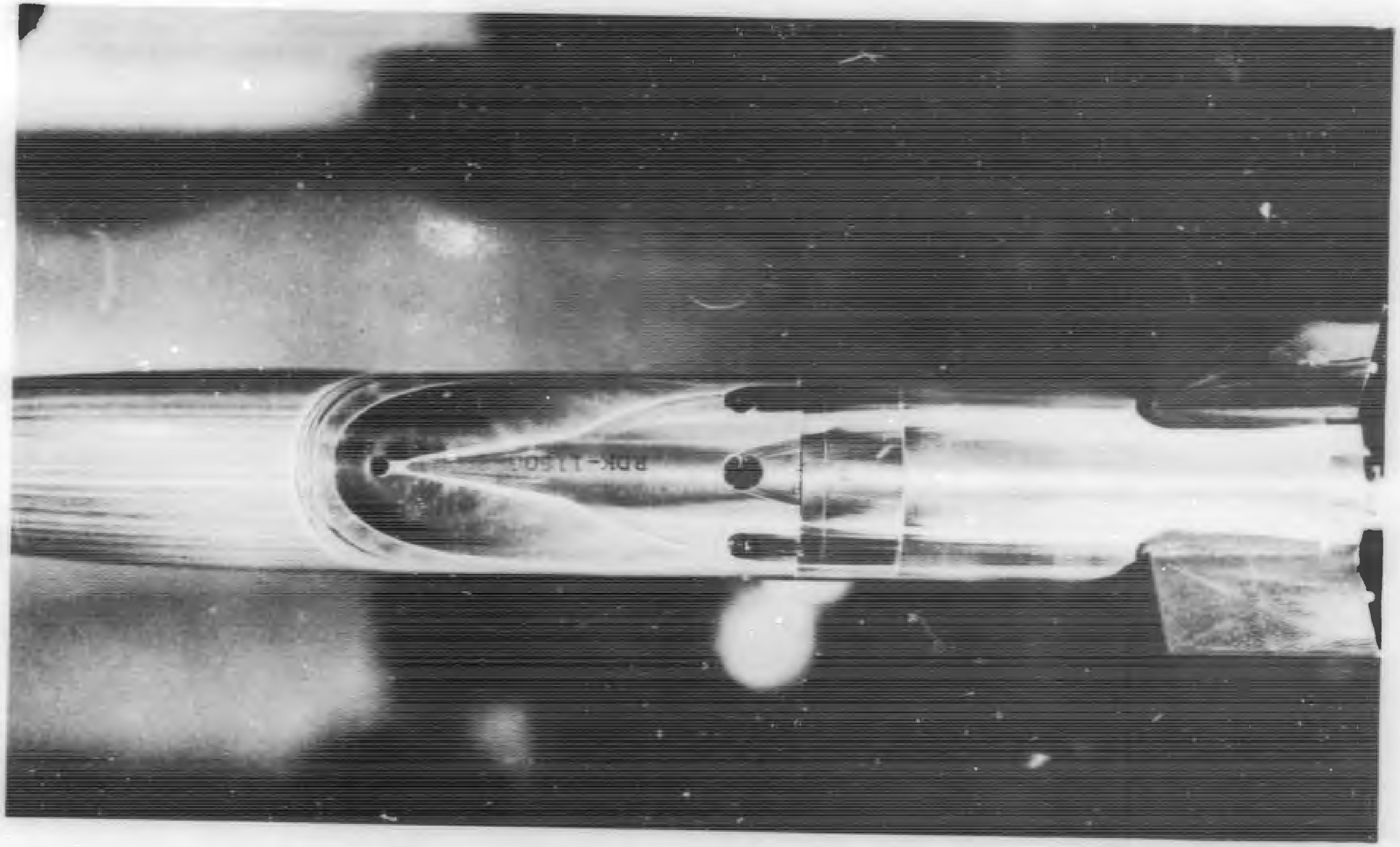

FIGURE A-1c. REACTION JET FOR $B_1C_1X_2$ WITH α = 0 DEGREES; P_{oj}/P_{∞} = 100

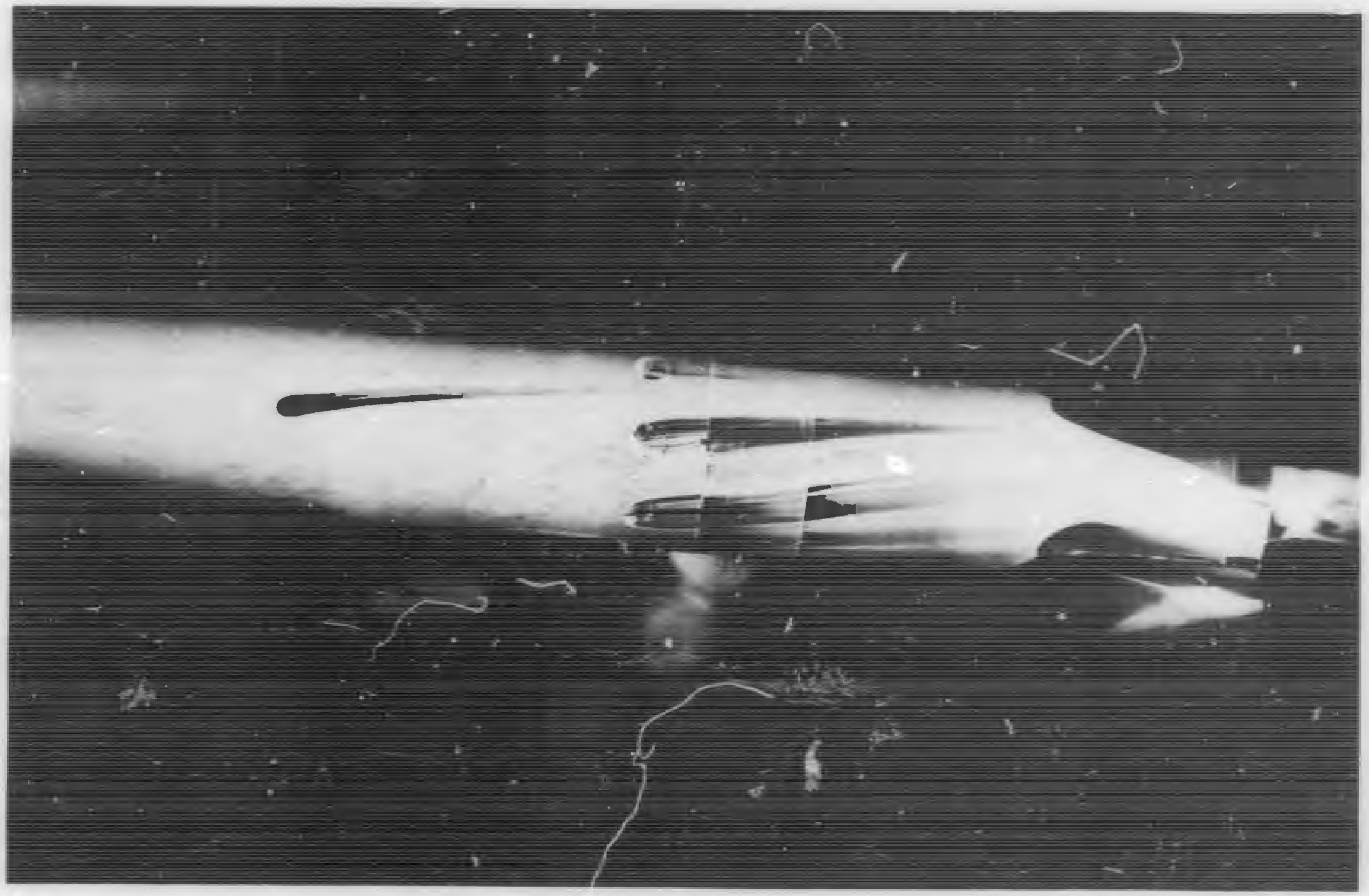

FIGURE A-2a. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_\infty = 0$

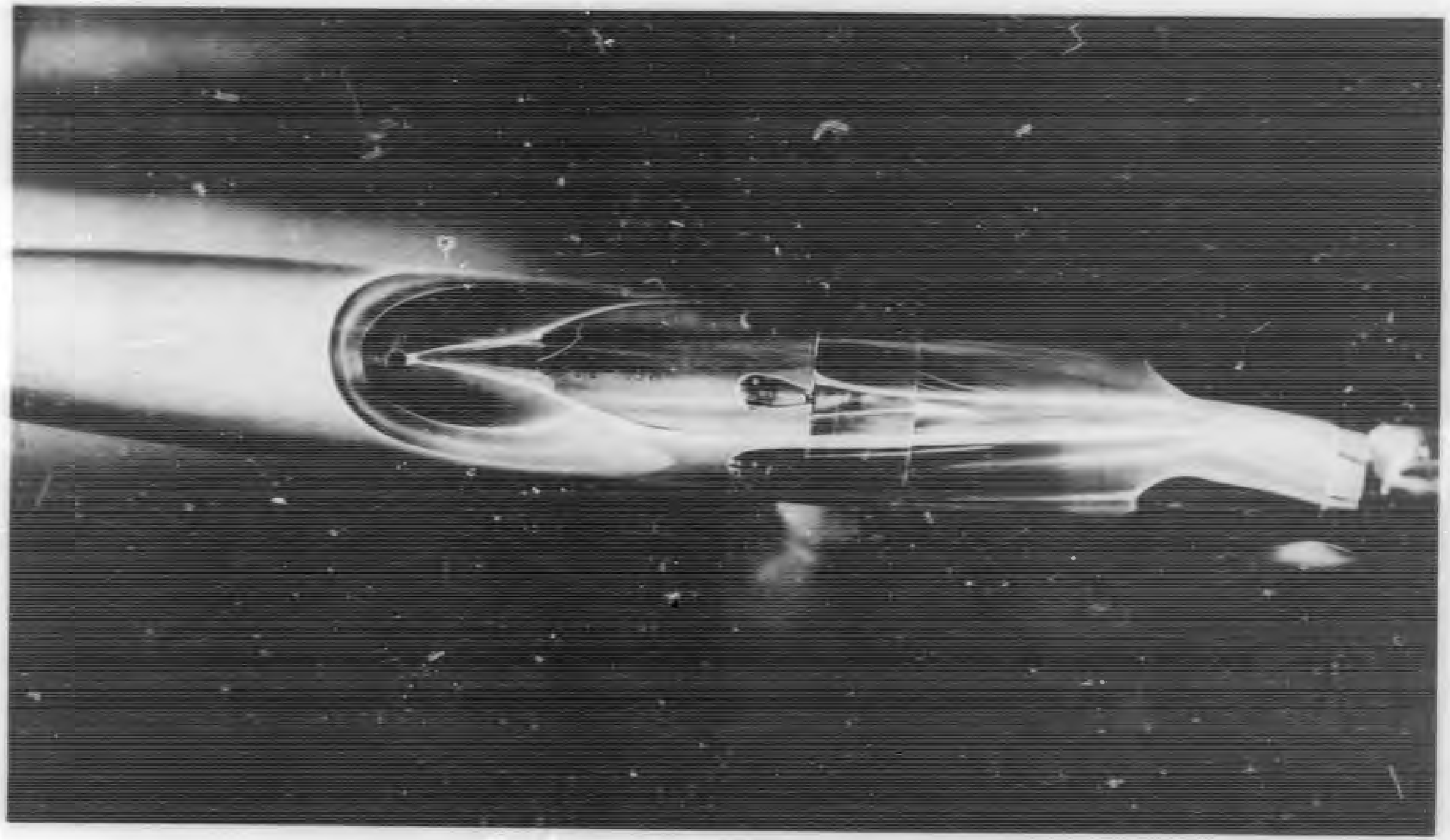

FIGURE A-2b. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_\infty = 40$

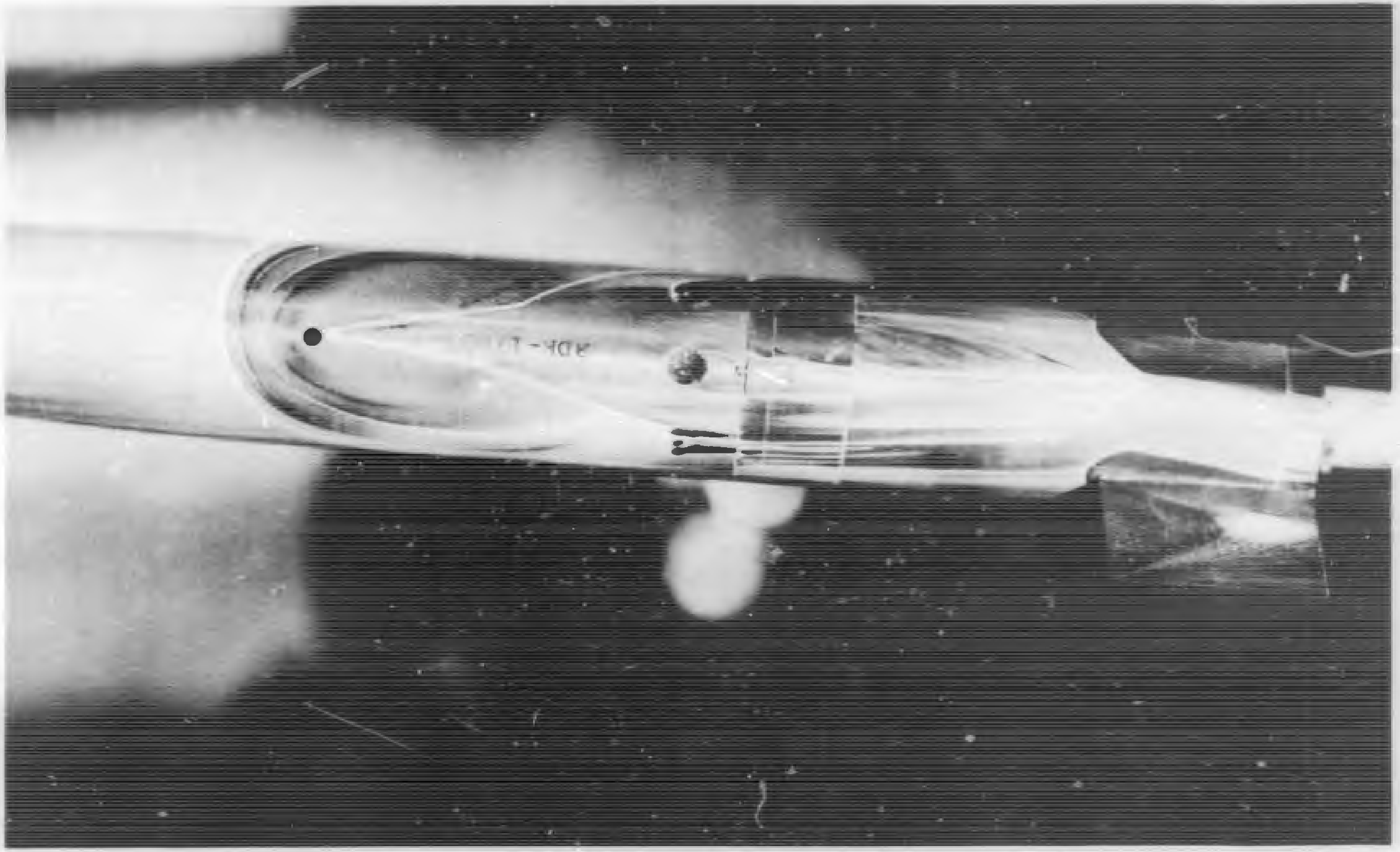

FIGURE A-2c. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_\infty = 100$

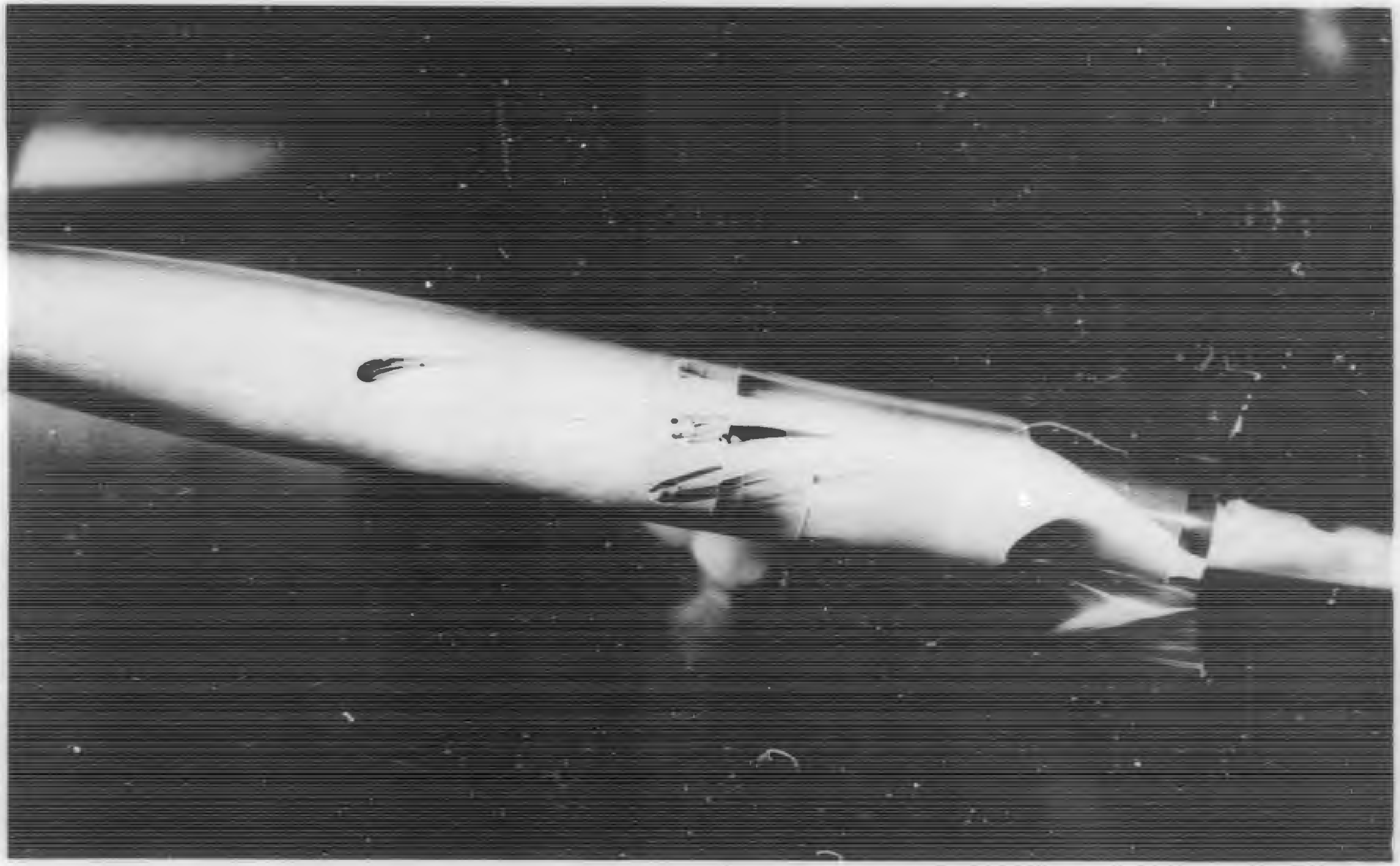

FIGURE A-3a. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_{\infty} = 0$

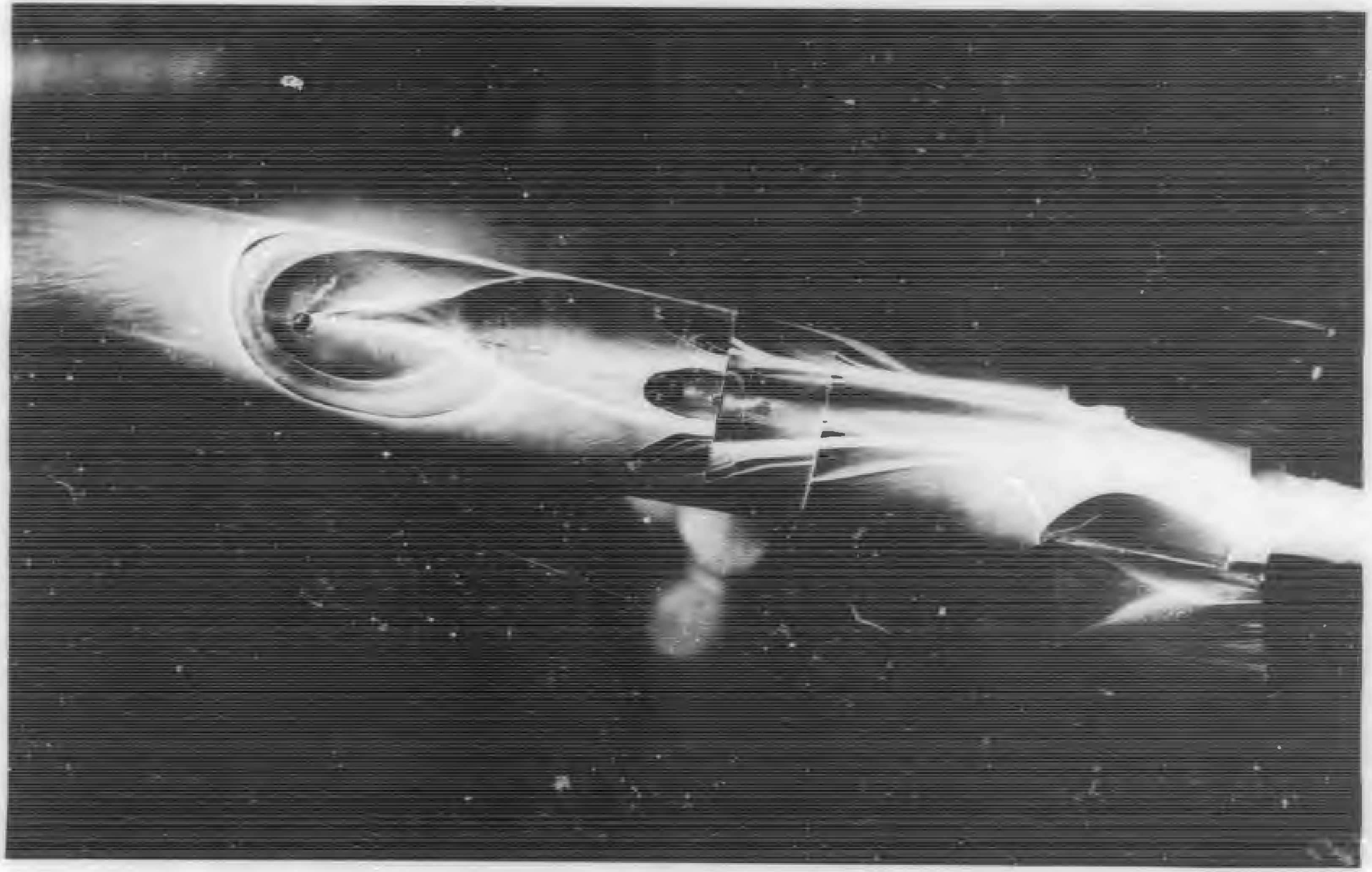

FIGURE A-3b. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_\infty = 40$

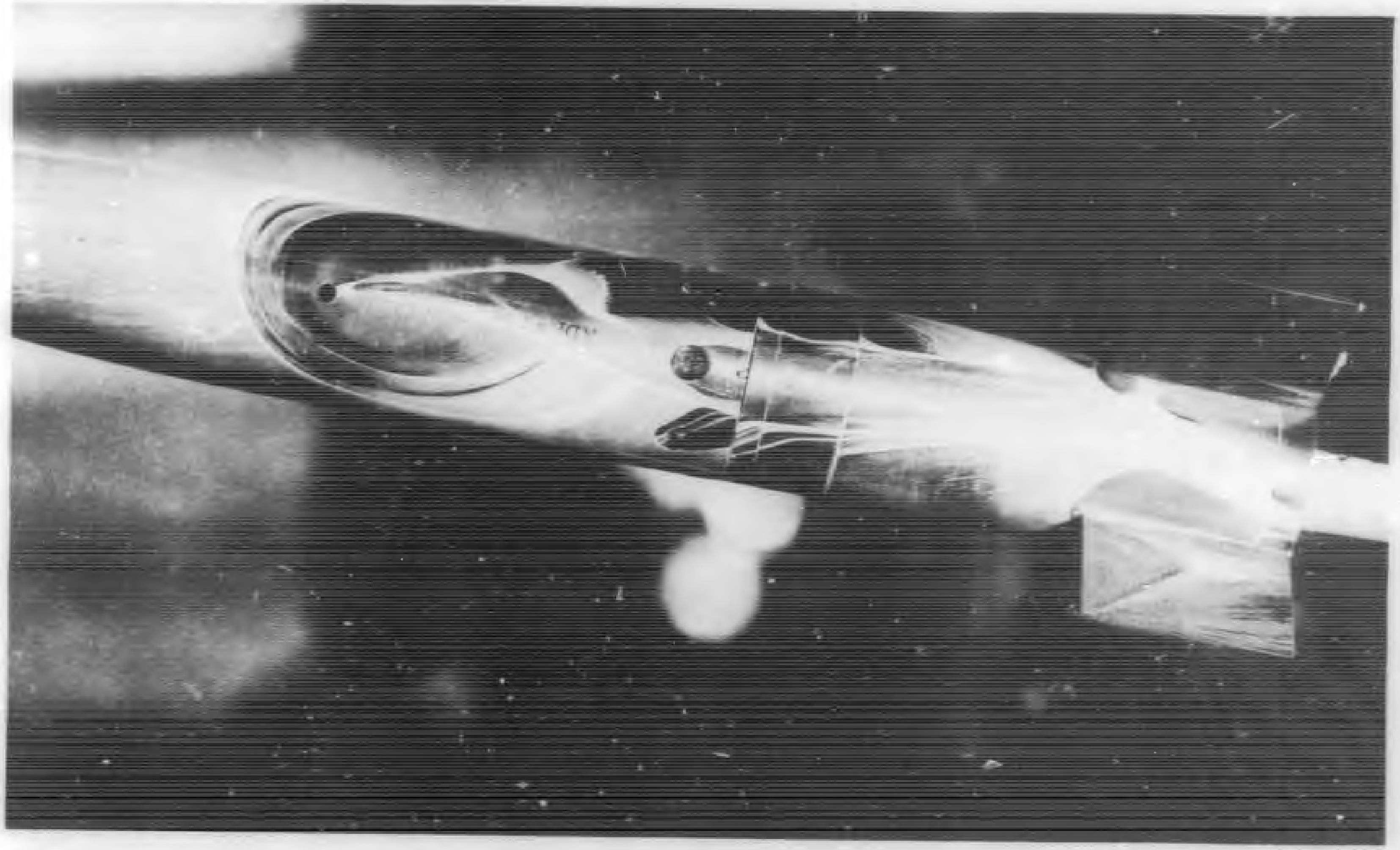

FIGURE A-3c. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_{\infty} = 100$

Appendix B
M_∞ = 2.0 Flow Visualization Data

TABLE B-I. TEST VARIABLE AND VISUAL DATA COLLECTED AT $M_\infty = 2.00$

Configuration	ϕ_j (deg)	Fin No.	α (deg)	P_{oj}/P_∞	Figure Showing Photographs	Figure Showing Schlierens	Figure Showing Shadowgraphs	Test Series
$B_1C_1X_2$	90	0.00	0	0	B-1a			April 1969
↓	0	↓	0	0	B-1b			↓
	90		0	40	B-1c			
	0		0	40	B-1d			
	90		0	100	B-1e			
	0		0	100	B-1f			
	0		5	0	B-2a			
	0		5	40	B-2b			
	0		5	100	B-2c			
	0		10	0	B-3a			
	0		10	40	B-3b			
	0		10	100	B-3c			
	0		10	0		B-3d		
	0		10	40		B-3e		
	0		10	100		B-3f		
	0		-5	0	B-4a			
	0		-5	40	B-4b			
	0		-5	100	B-4c			
	0		-5	0		B-4d		
	0		-5	40		B-4e		
$B_1C_1X_2$	0	0.00	-5	100		B-4f		April 1969

TABLE B-1. TEST VARIABLE AND VISUAL DATA COLLECTED AT $M_\infty = 2.00$ (Concluded)

Configuration	ϕ_j (deg)	Fin No.	α (deg)	P_{oj}/P_∞	Figure Showing Photographs	Figure Showing Schlierens	Figure Showing Shadowgraphs	Test Series
$B_1C_1X_2$	0	0.00	-10	0	B-5a			April 1969
↓	0	↓	-10	40	B-5b			↓
	0		-10	100	B-5c			
	0		-10	0		B-5d		
	0		-10	40		B-5e		
	0		-10	100		B-5f		
$B_1C_1X_1$	90		0	0	B-6a			
↓	90		0	40	B-6b			
$B_1C_1X_1$	90	0.00	0	100	B-6c			April 1969

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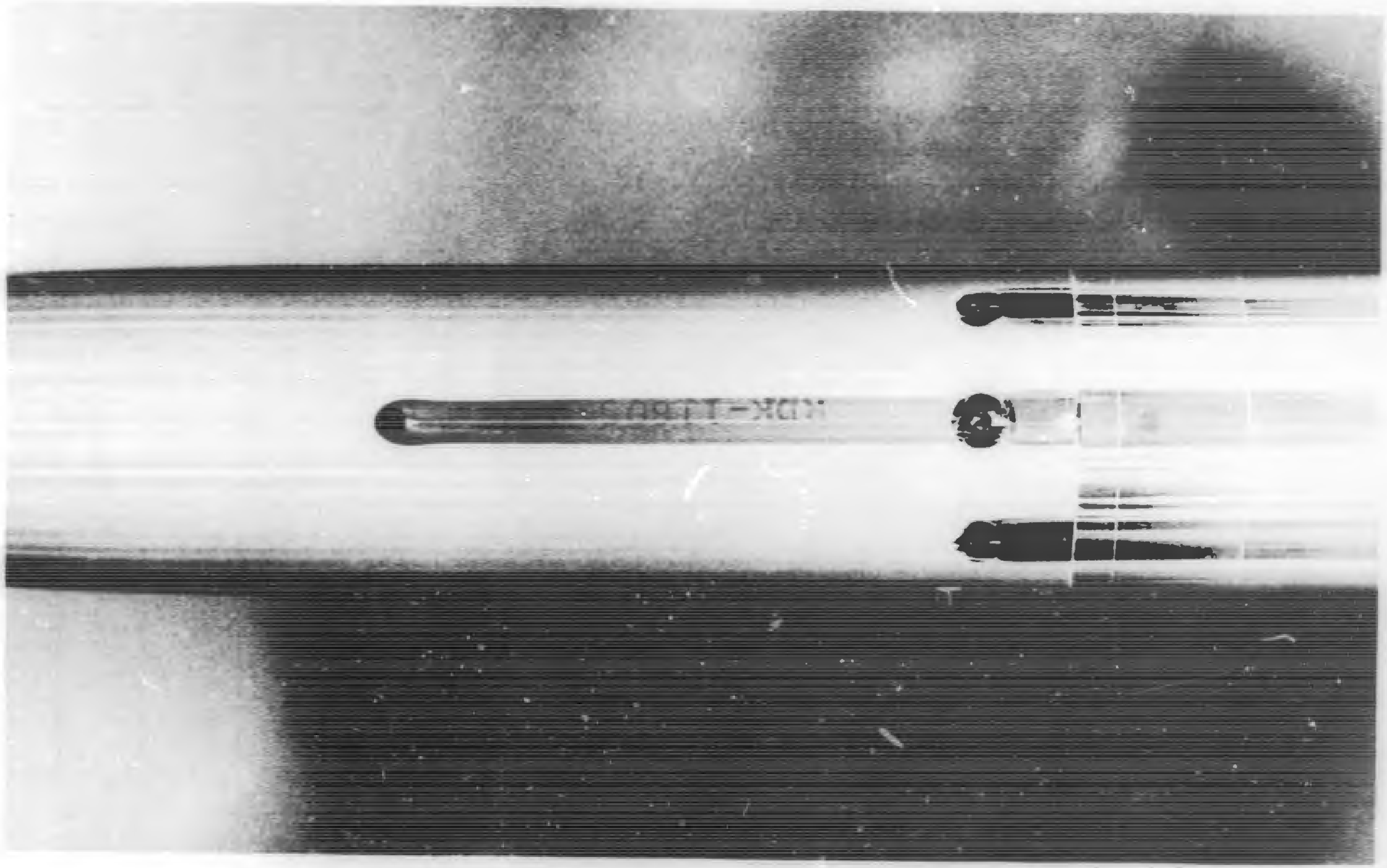

FIGURE B-1a. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 0$

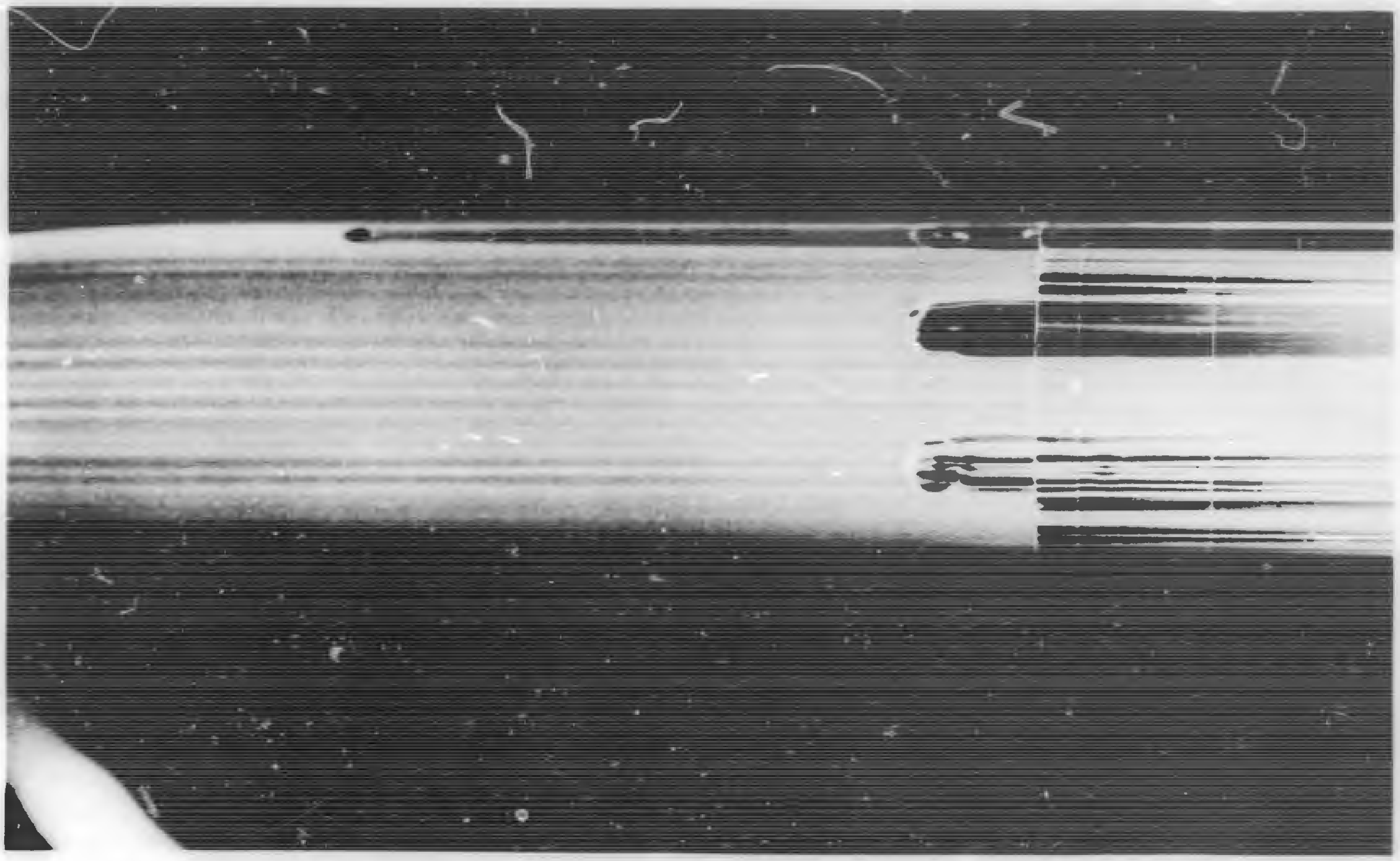

FIGURE B-1b. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_{\infty} = 0$

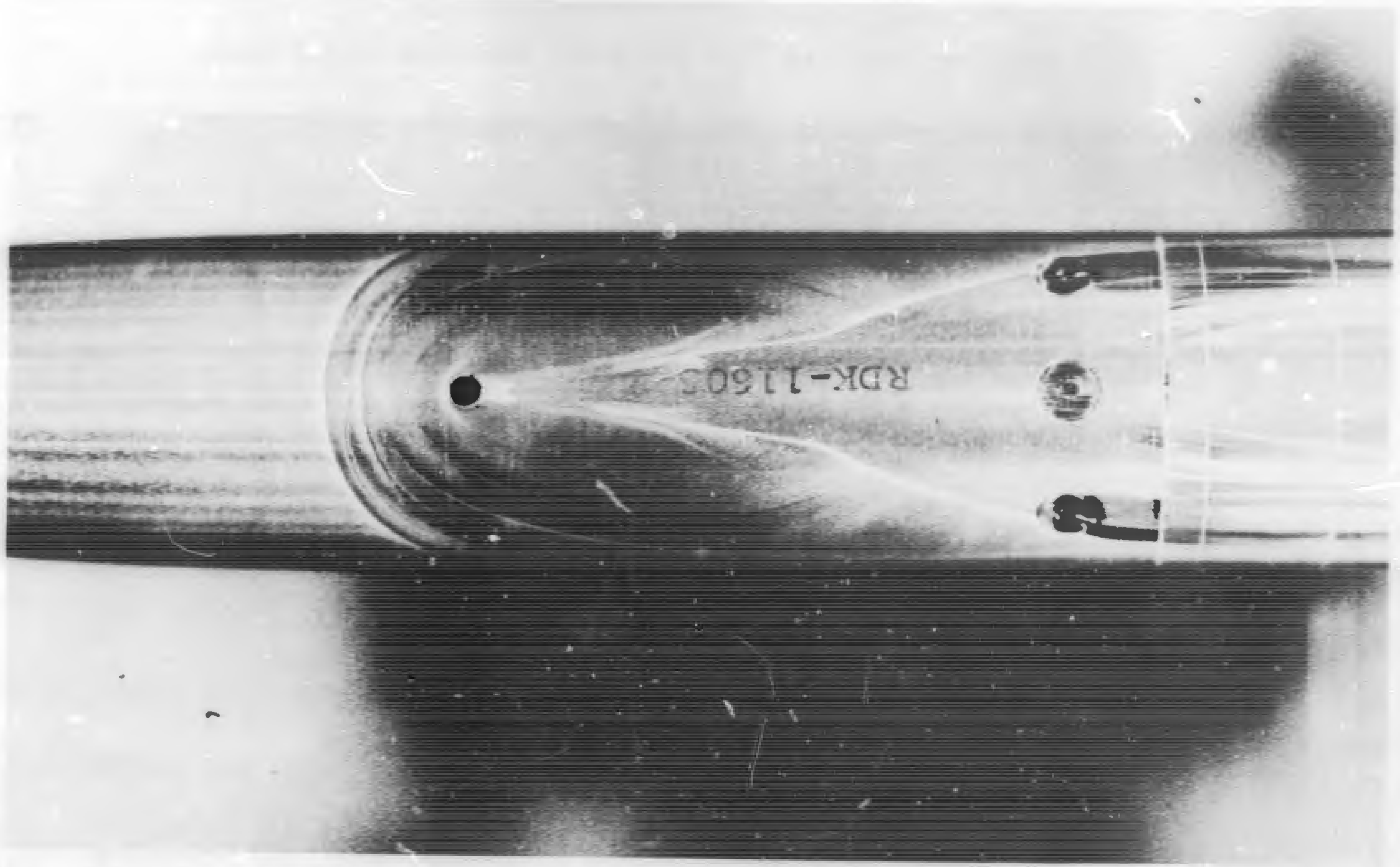

FIGURE B-1c. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 40$

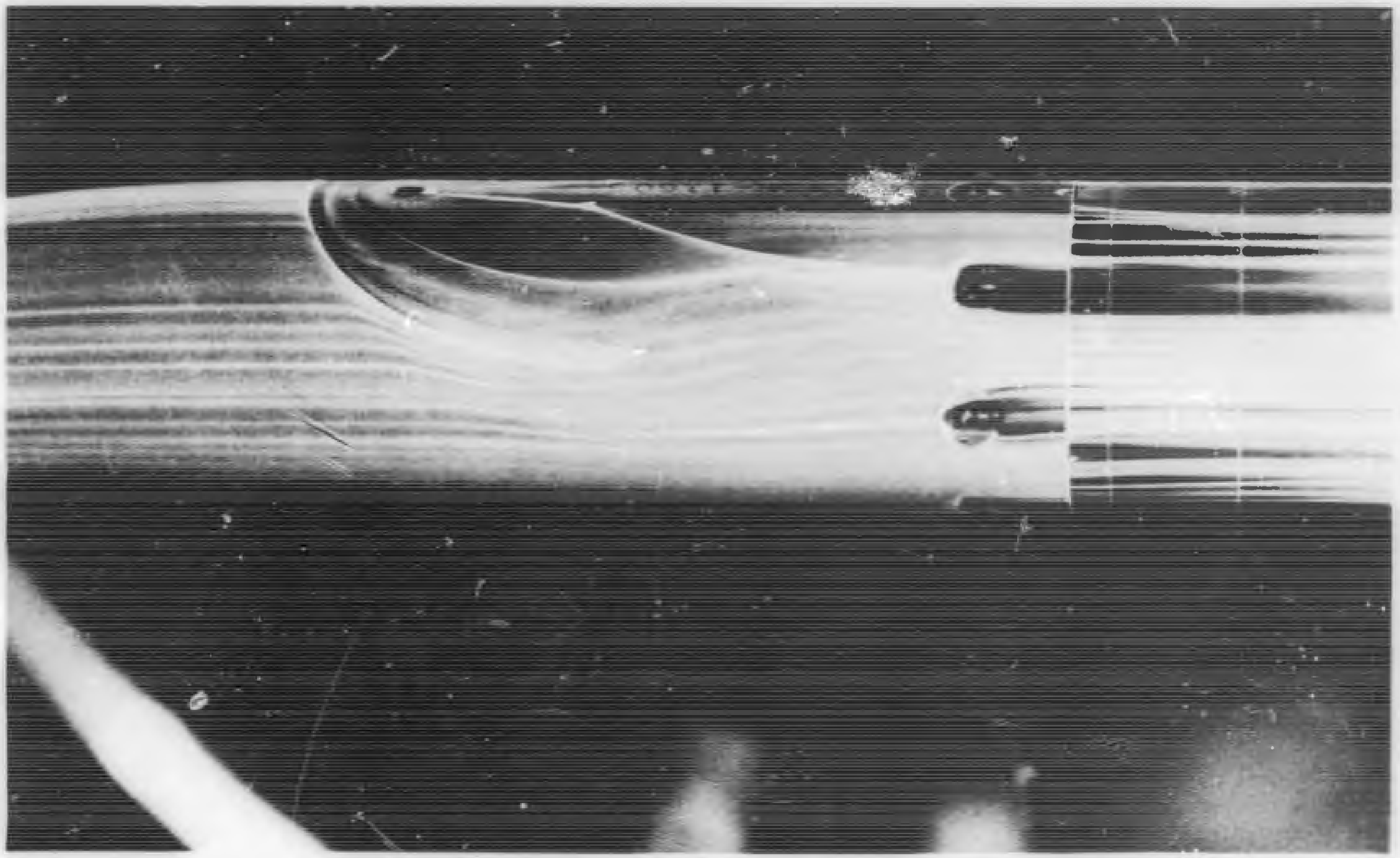

FIGURE B-1d. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_{\infty} = 40$

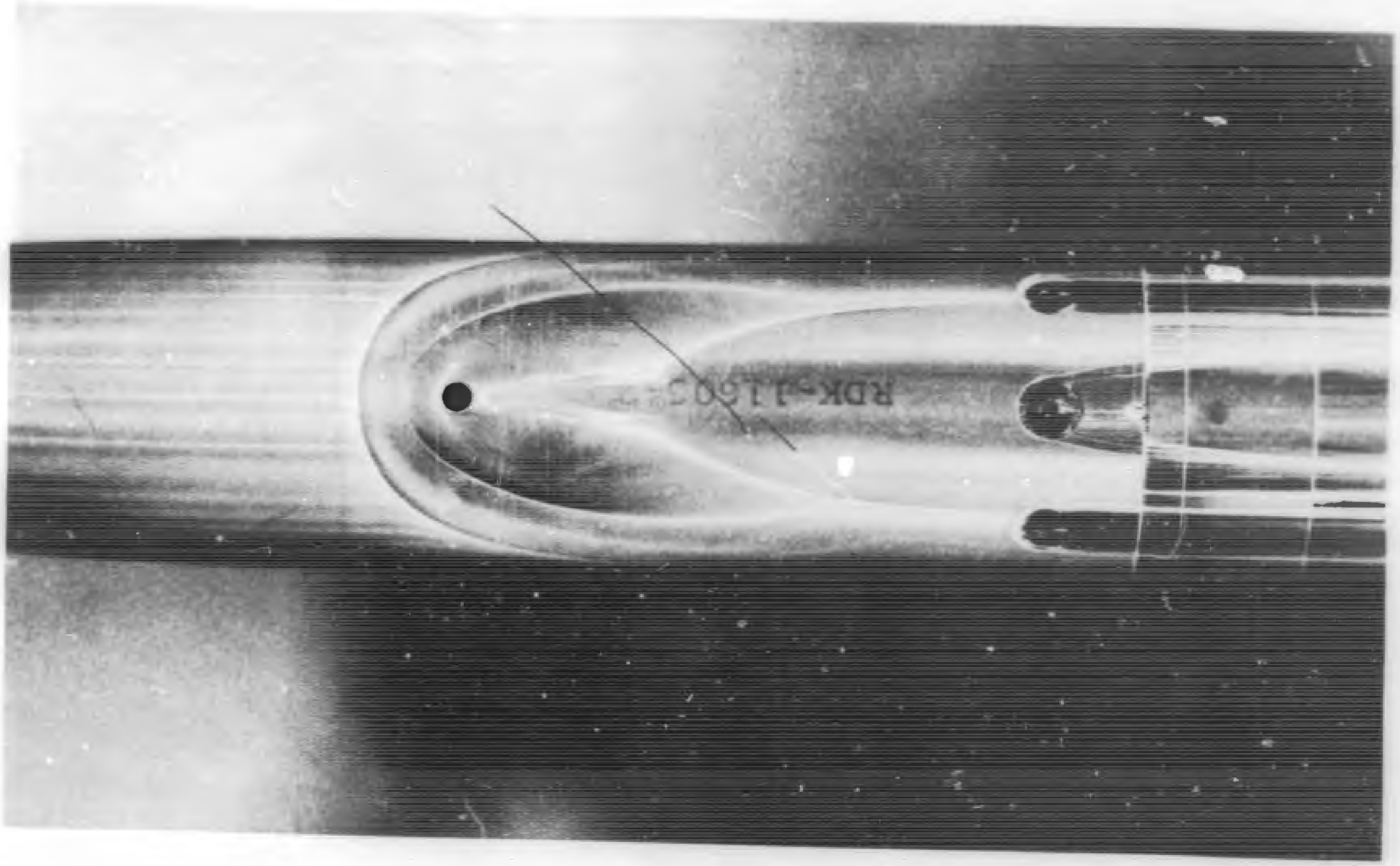

FIGURE B-1e. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_{\infty} = 100$

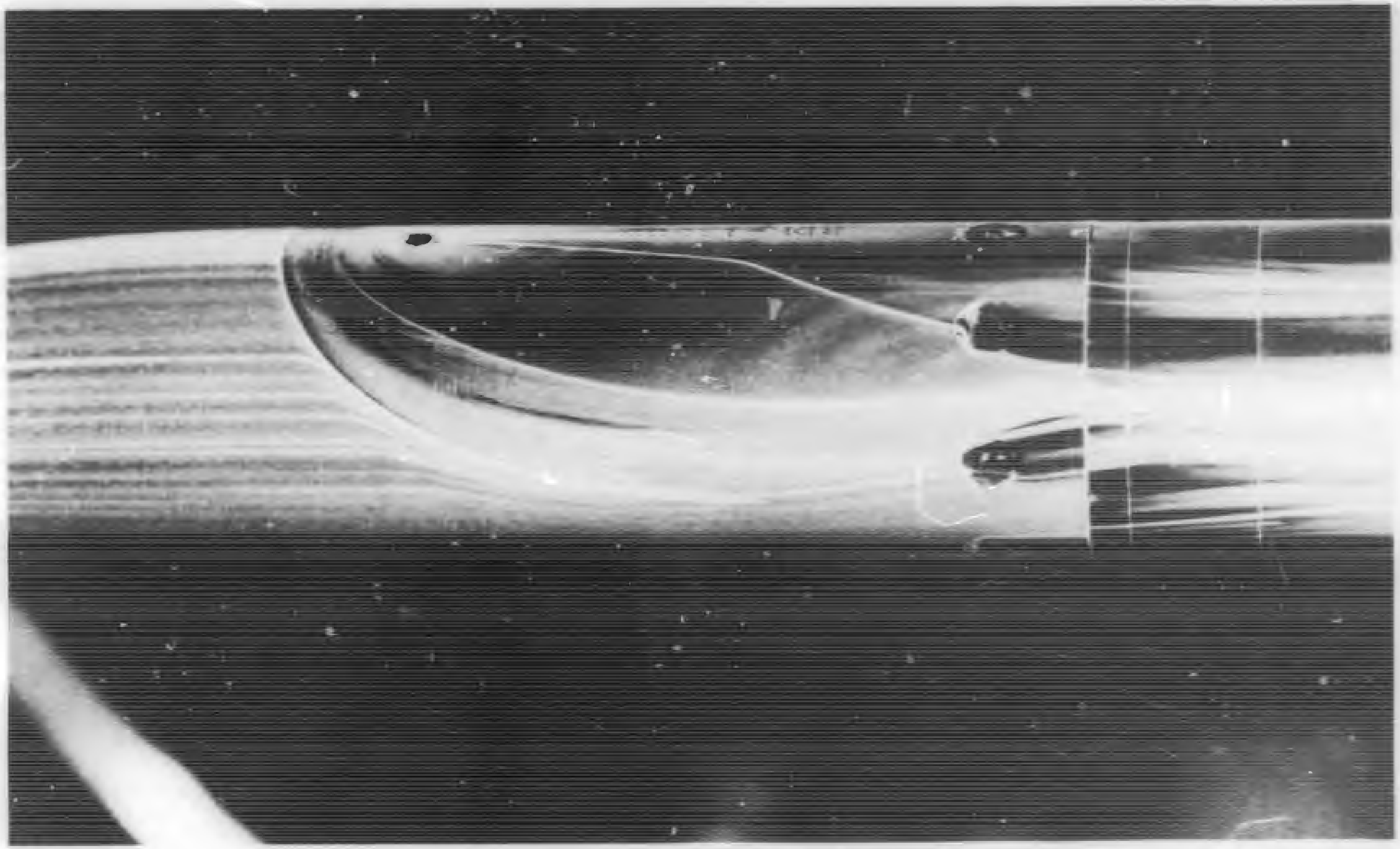

FIGURE B-1f. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_{\infty} = 100$

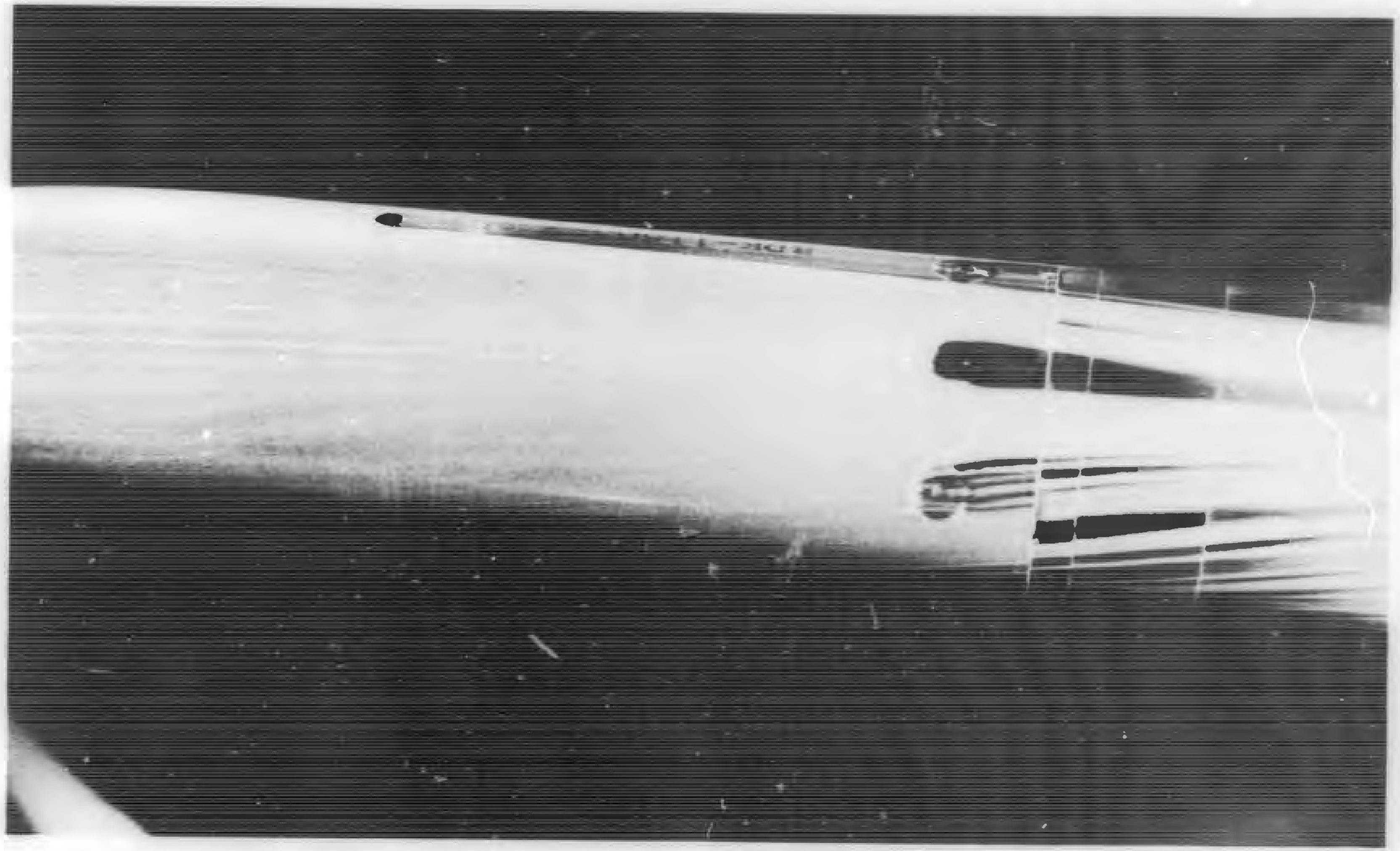

FIGURE B-2a. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_{\infty} = 0$

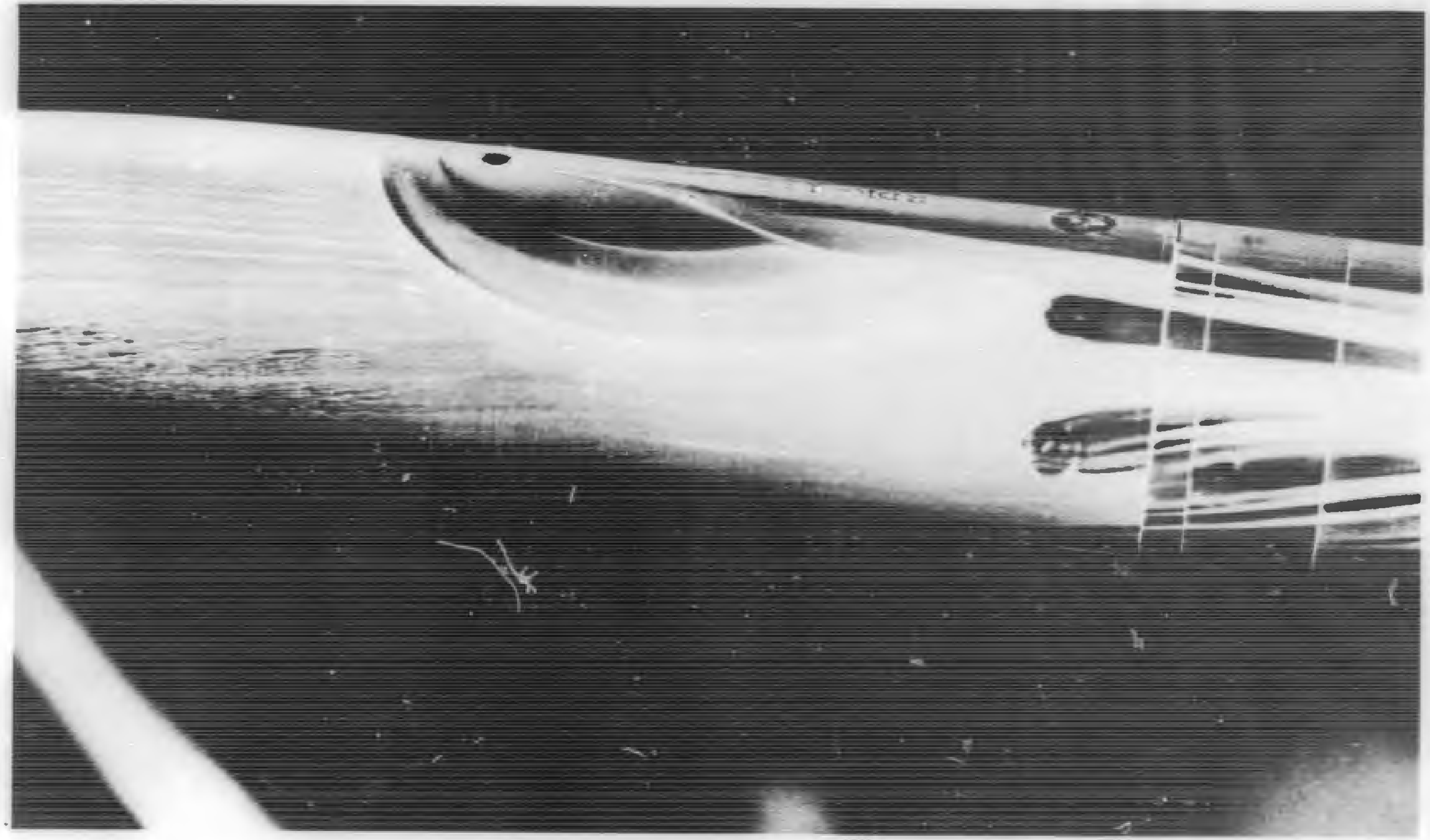

FIGURE B-2b. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_{\infty} = 40$

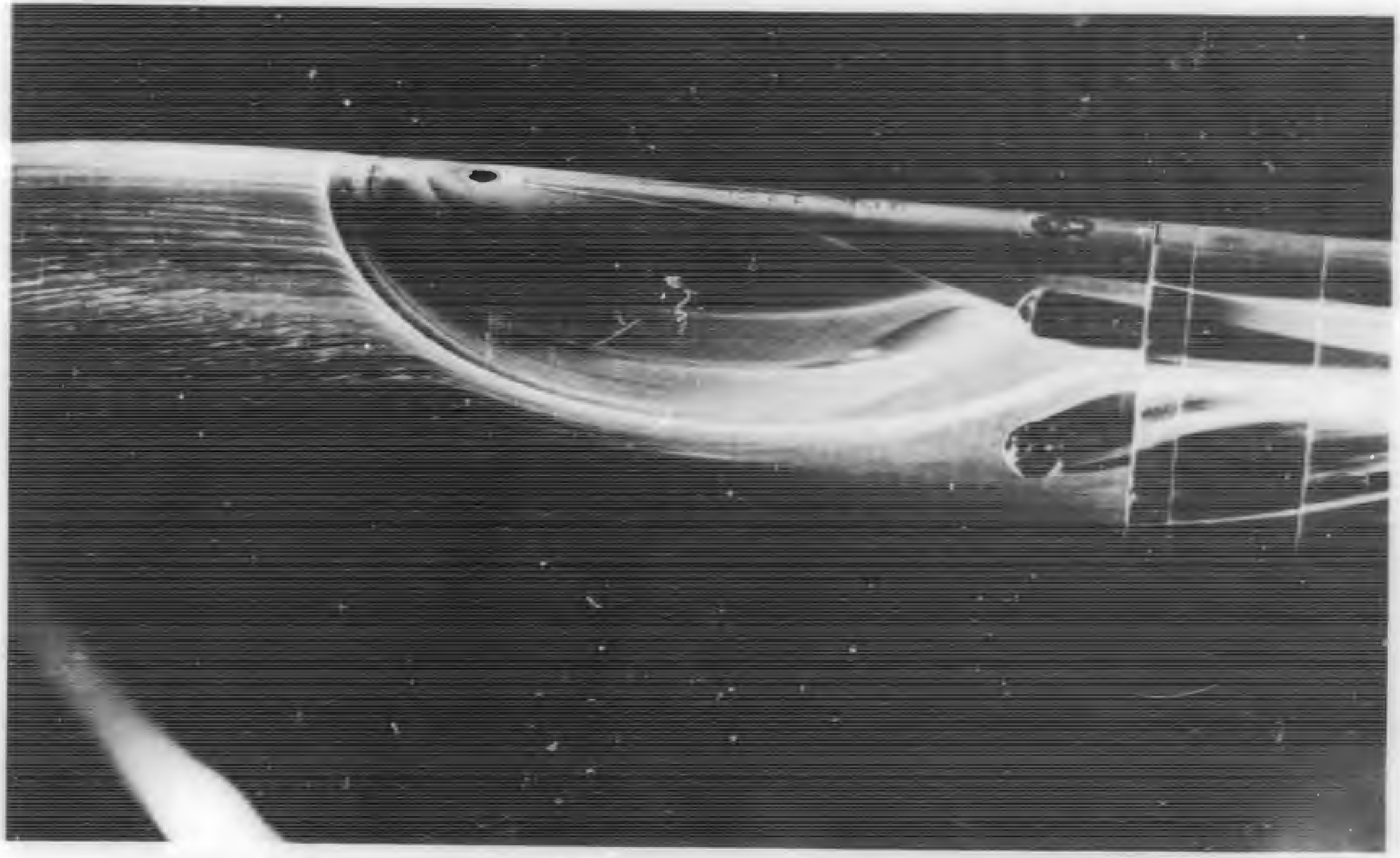

FIGURE B-2c. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_\infty = 100$

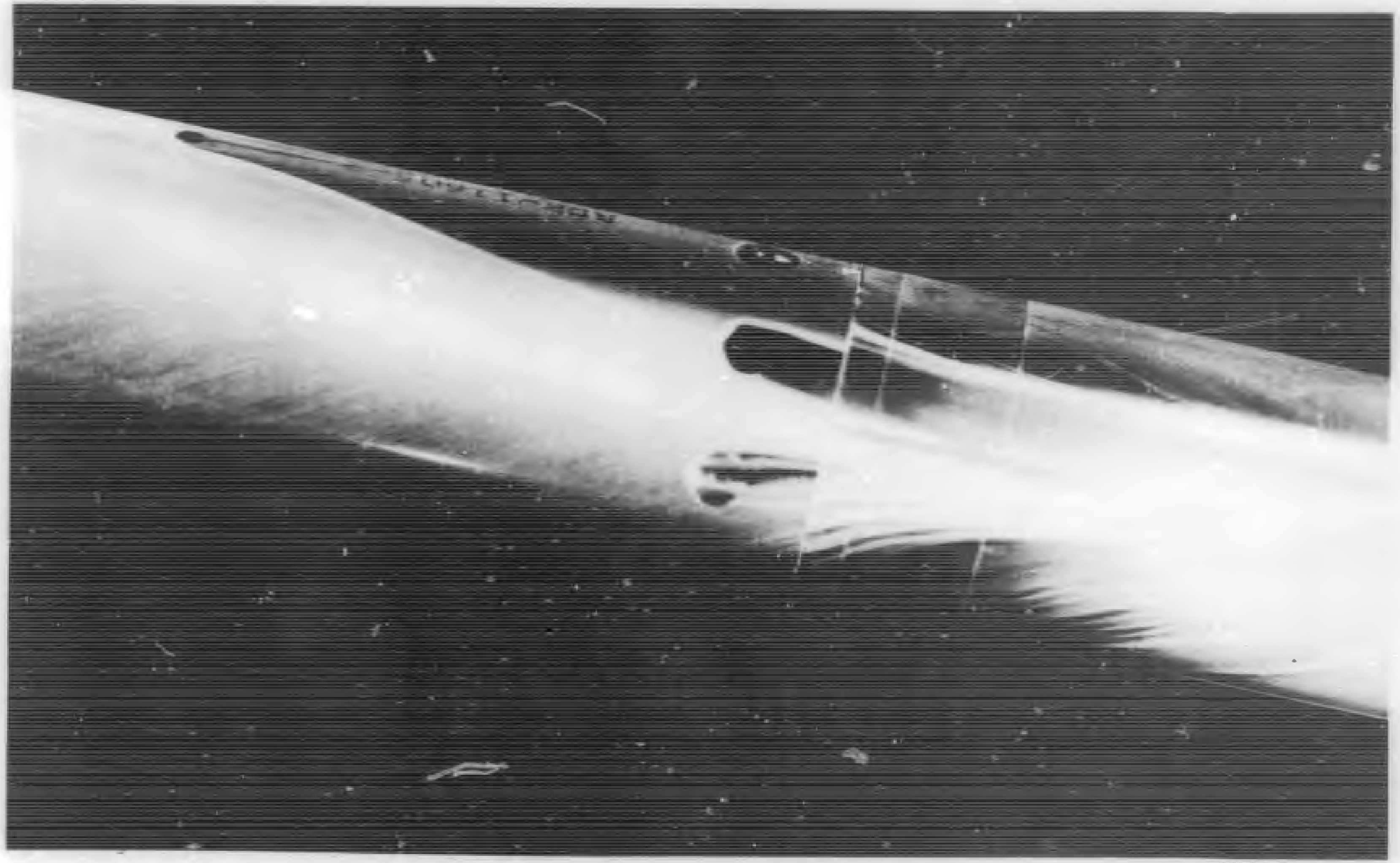

FIGURE B-3a. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_\infty = 0$

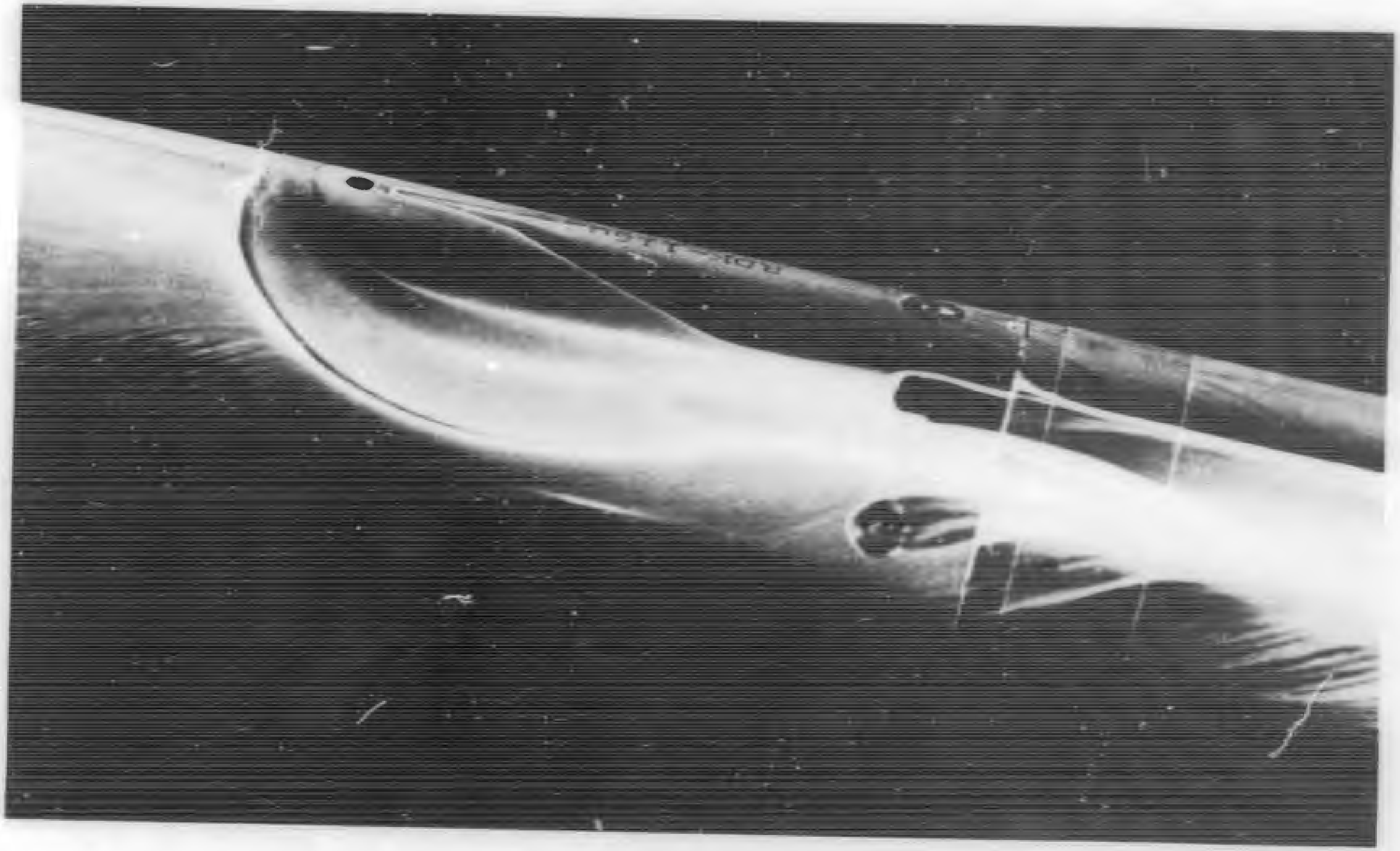

FIGURE B-3b. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_{\infty} = 40$

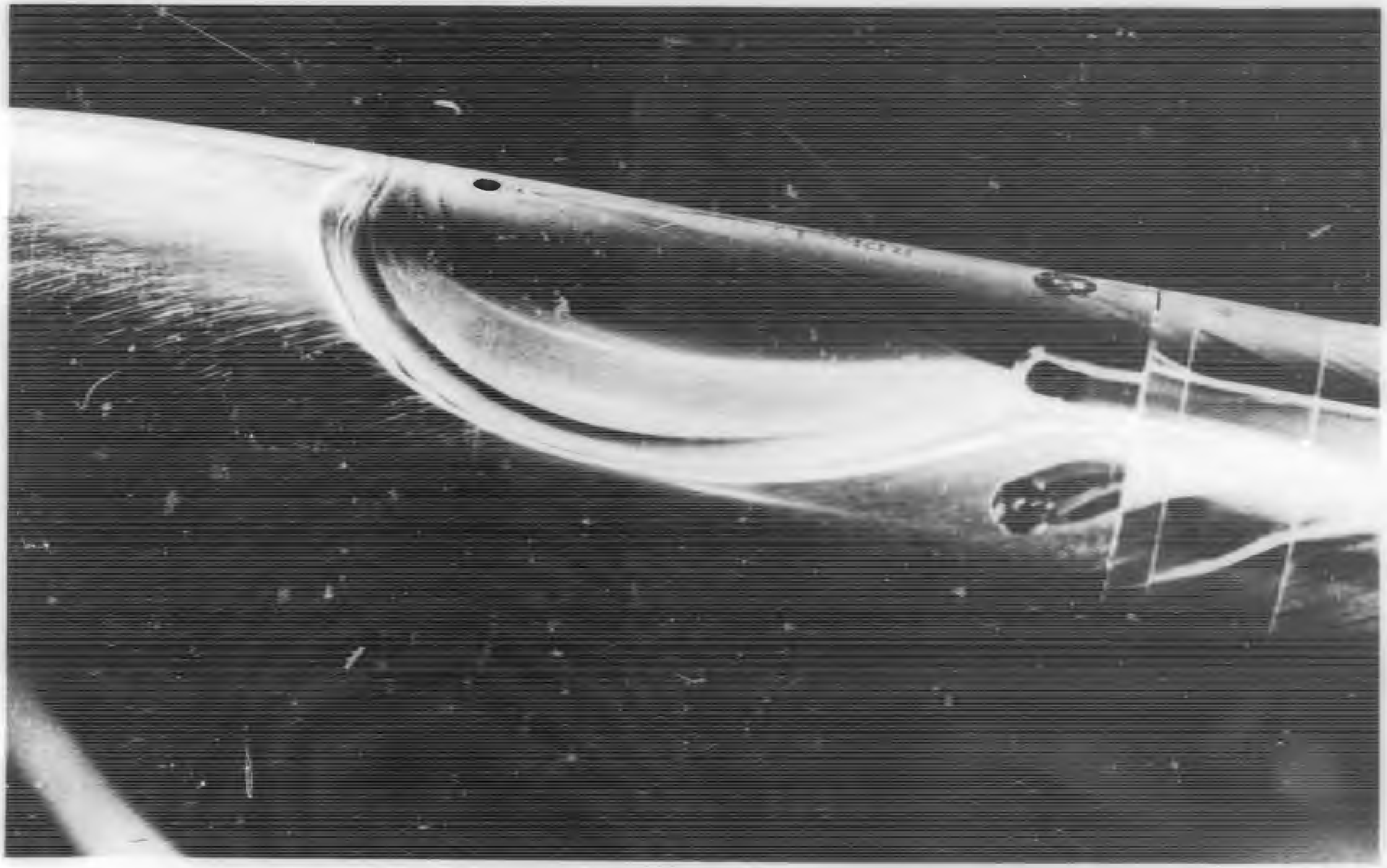

FIGURE B-3c. REACTION JET FOR $B_1C_1X_2$ WITH α = 10 DEGREES; P_{oj}/P_{∞} = 100

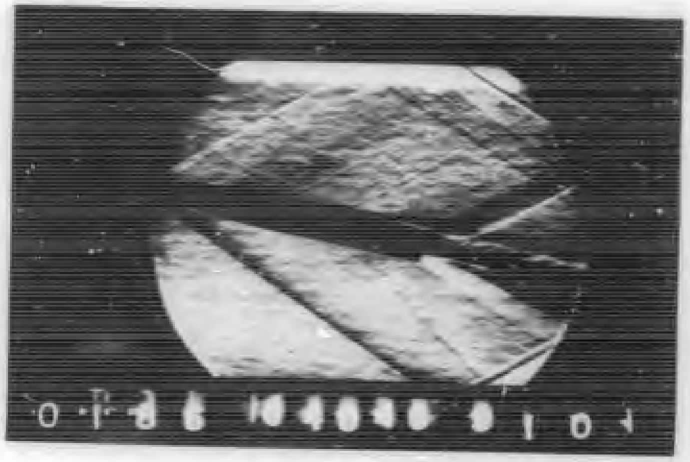

FIGURE B-3d. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_{\infty} = 0$

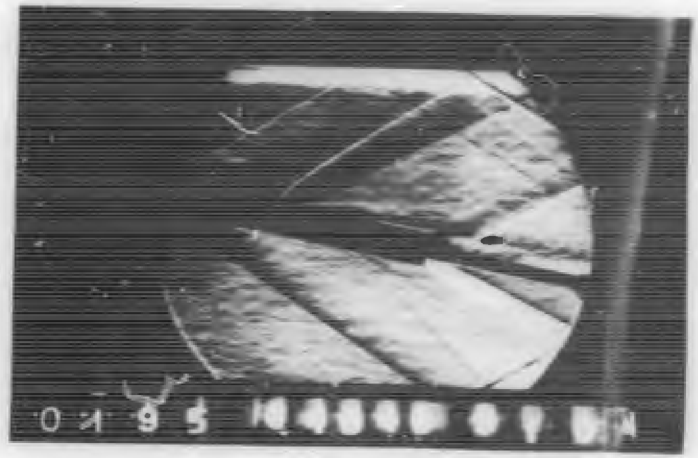

FIGURE B-3e. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_{\infty} = 40$

FIGURE B-3f. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_{\infty} = 100$

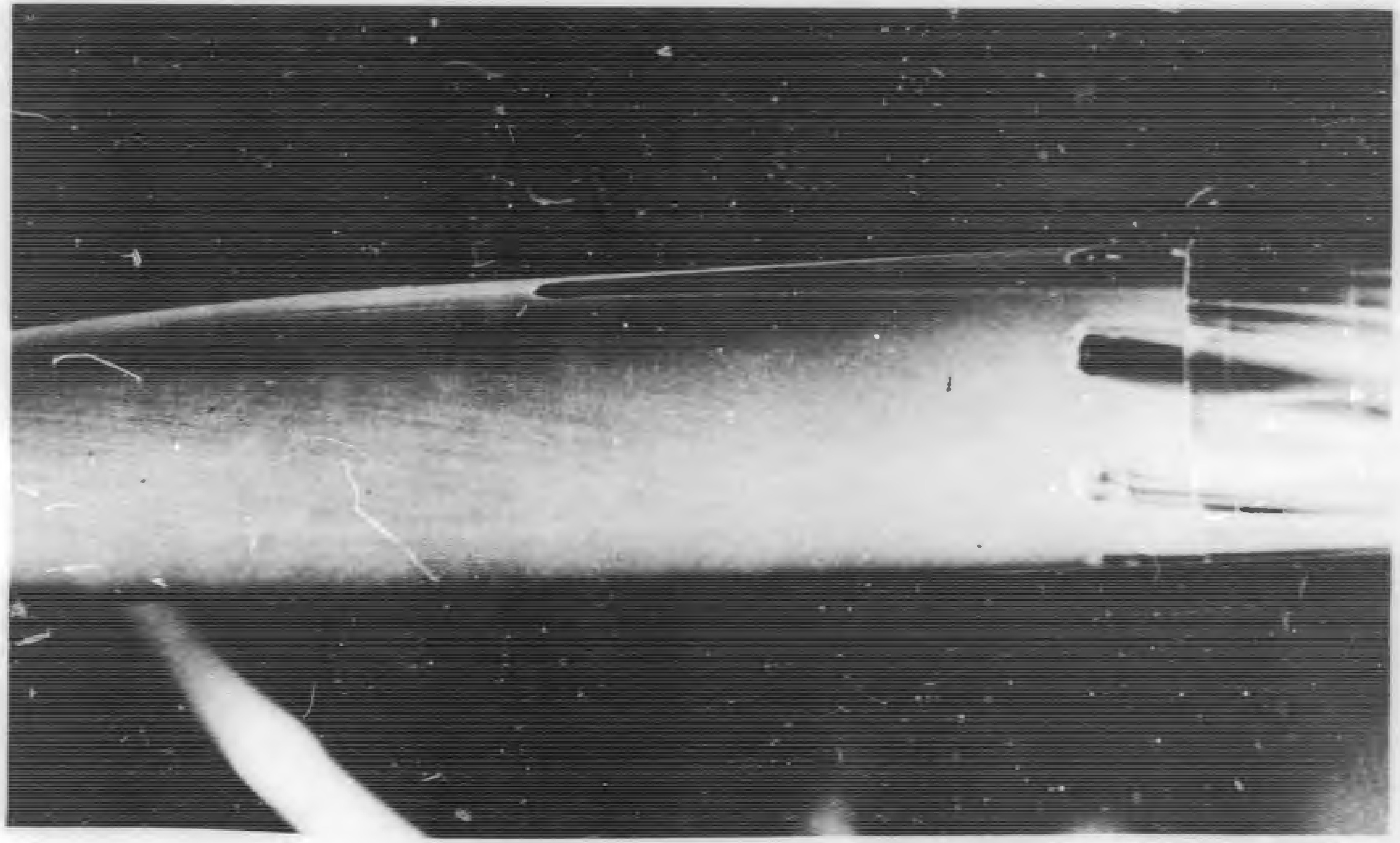

FIGURE B-4a. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_\infty = 0$

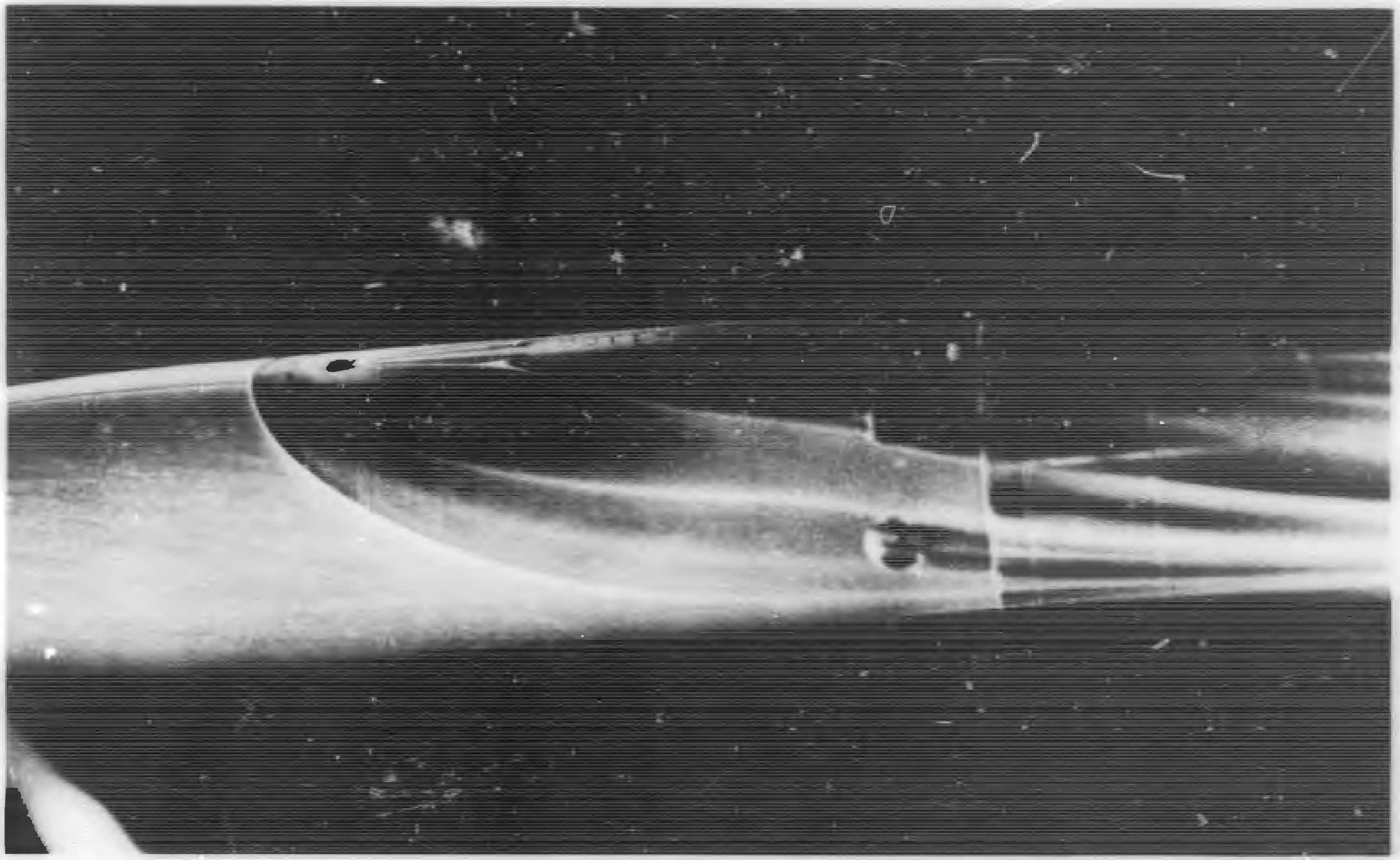

FIGURE B-4b. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_\infty = 40$

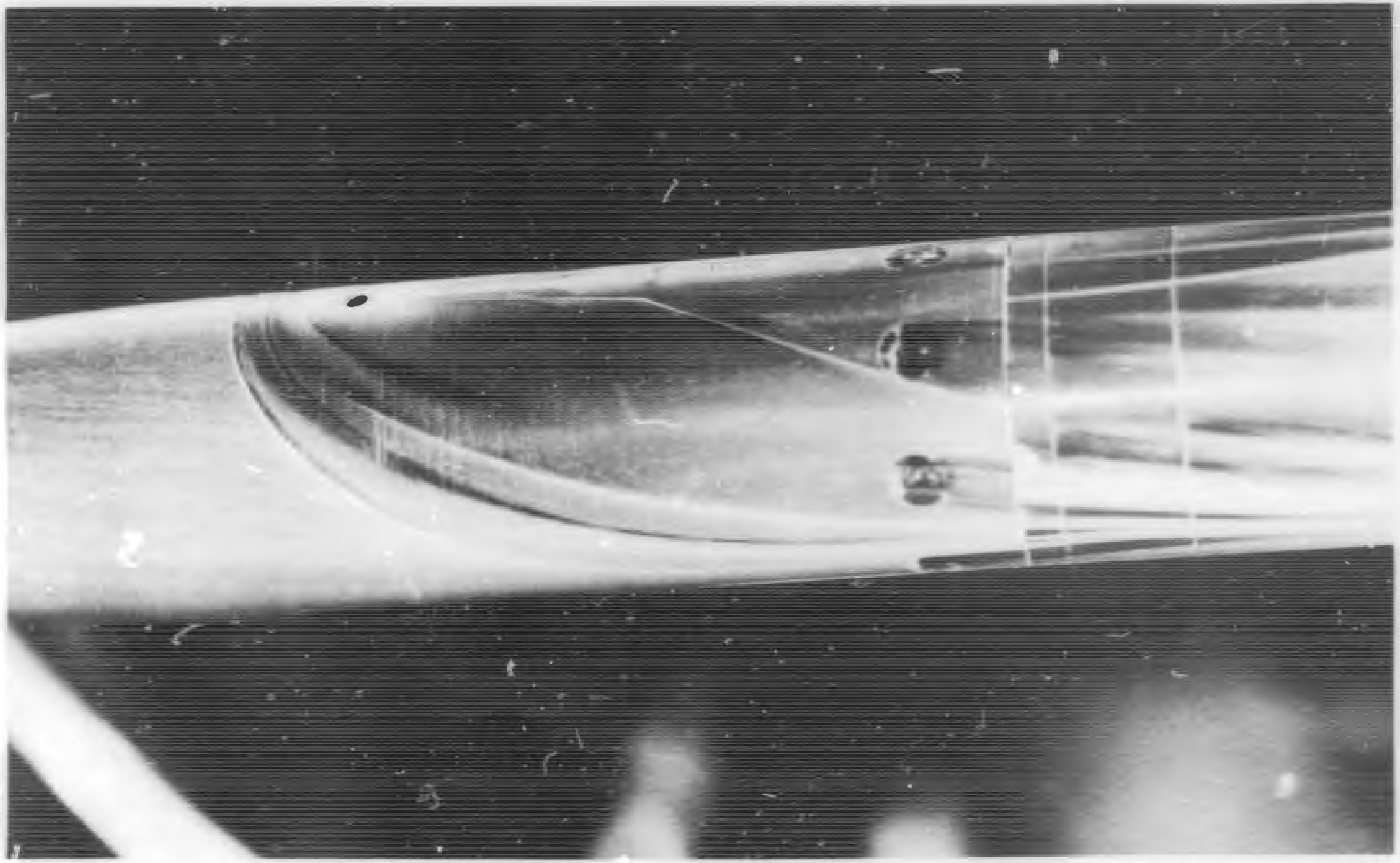

FIGURE B-4c. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_\infty = 100$

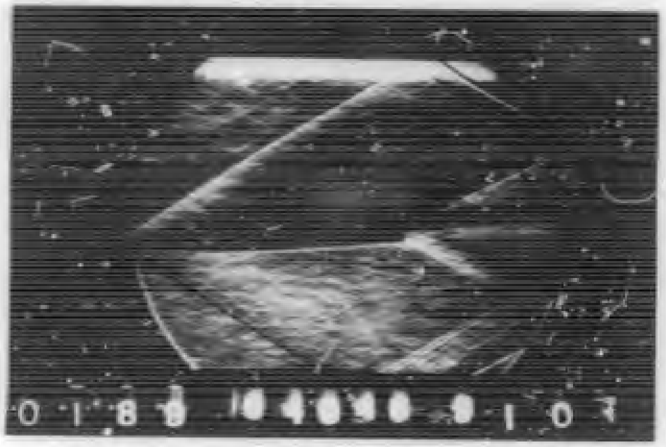

FIGURE B–4d. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_\infty = 0$

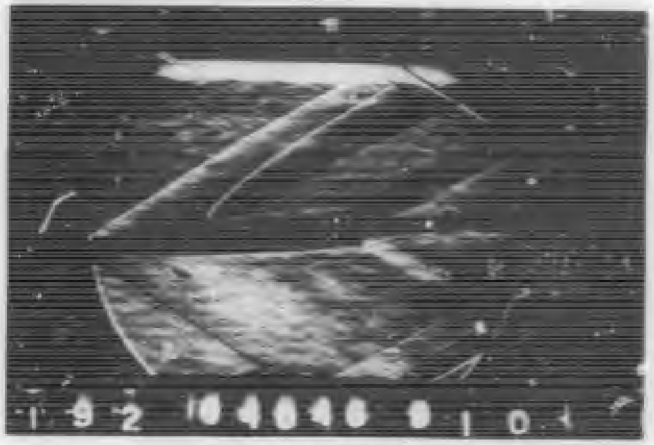

FIGURE B–4e. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_\infty = 40$

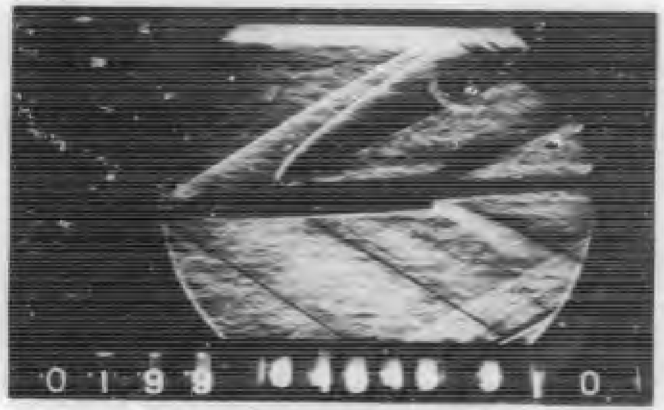

FIGURE B–4f. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_\infty = 100$

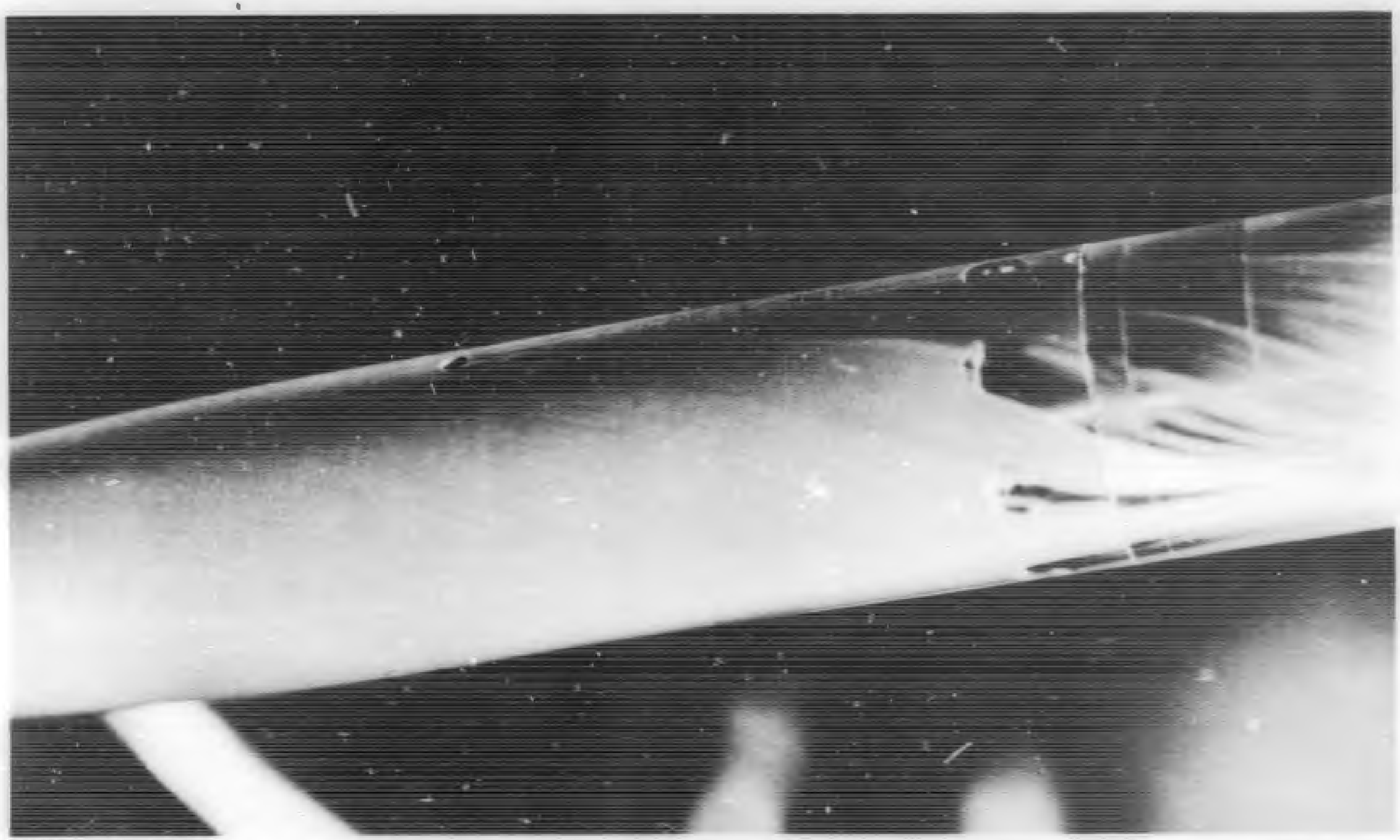

FIGURE B-5a. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_\infty = 0$

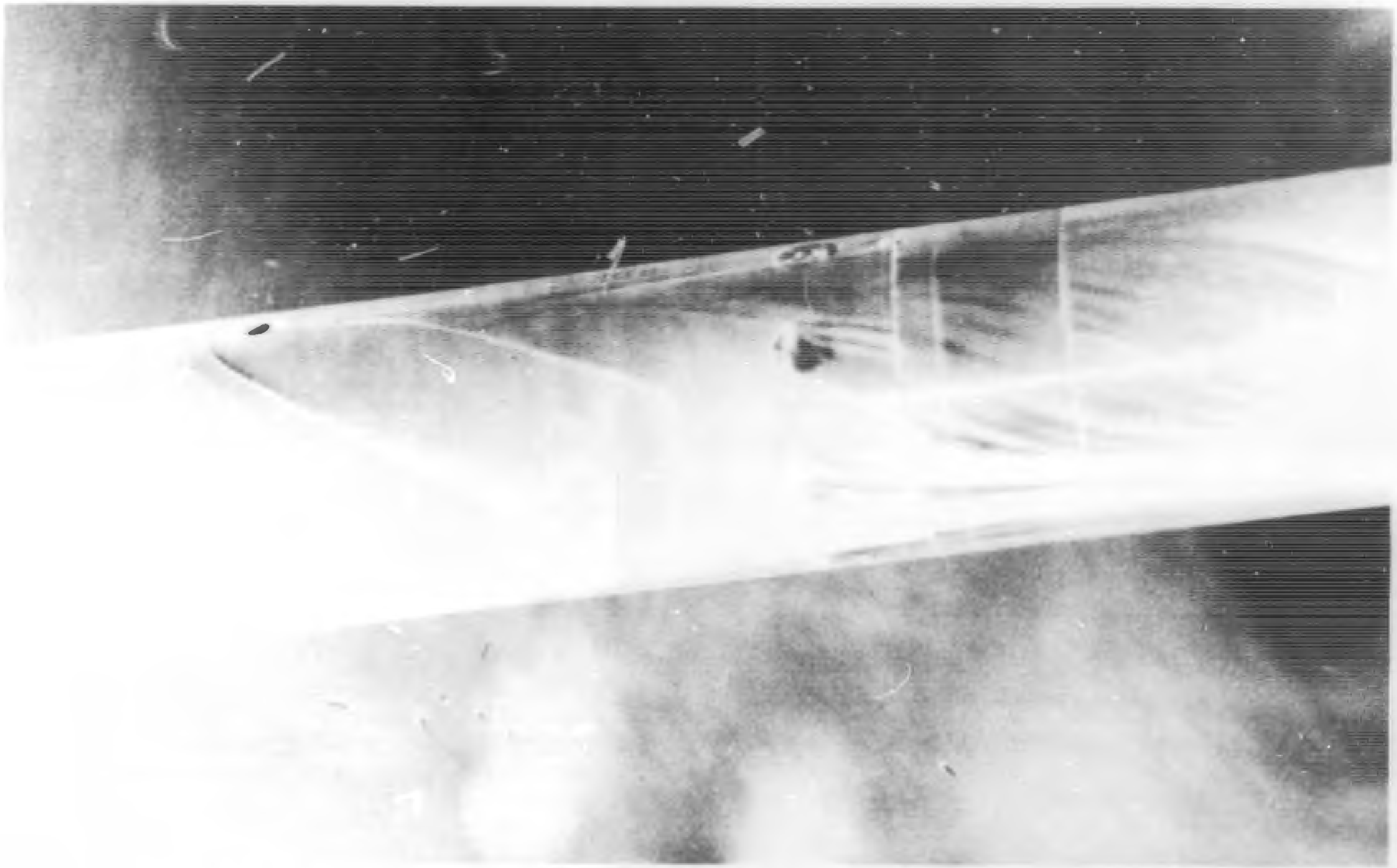

FIGURE B-5b. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_{\infty} = 40$

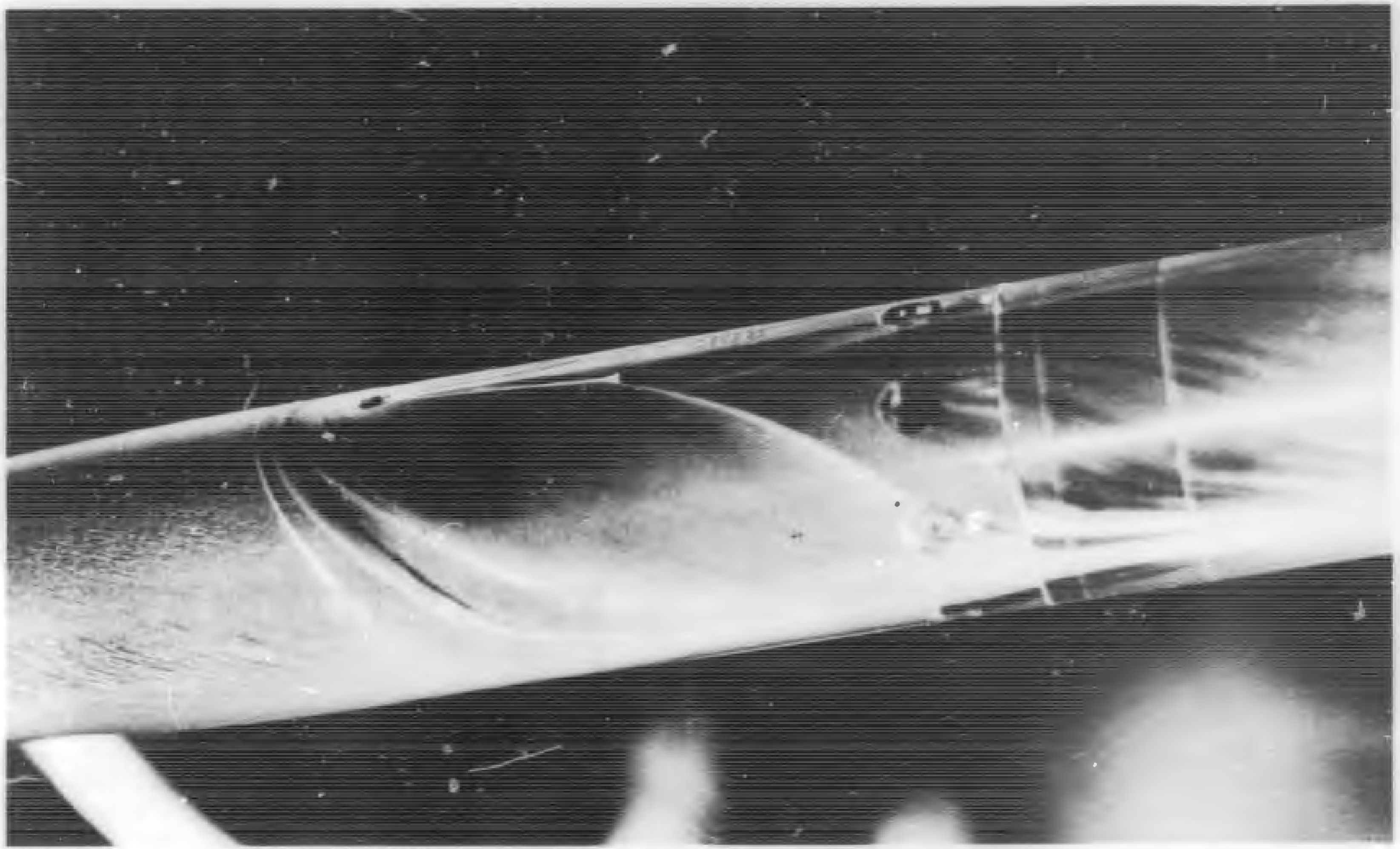

FIGURE B-5c. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_\infty = 100$

FIGURE B-5d. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_{\infty} = 0$

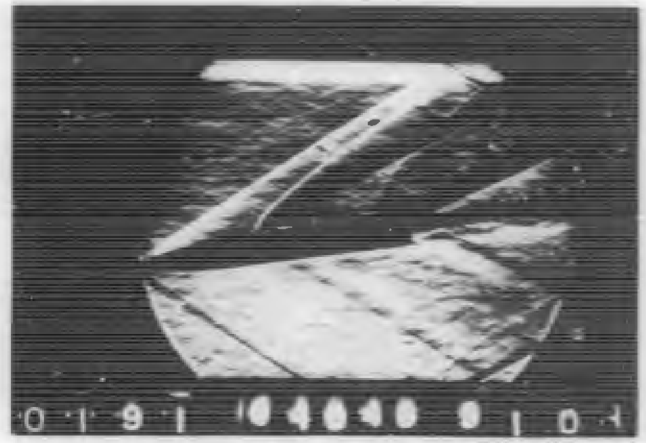

FIGURE B-5e. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_{\infty} = 40$

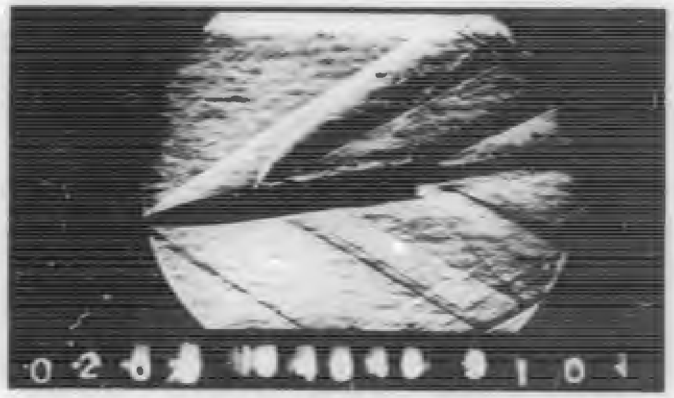

FIGURE B-5f. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_{\infty} = 100$

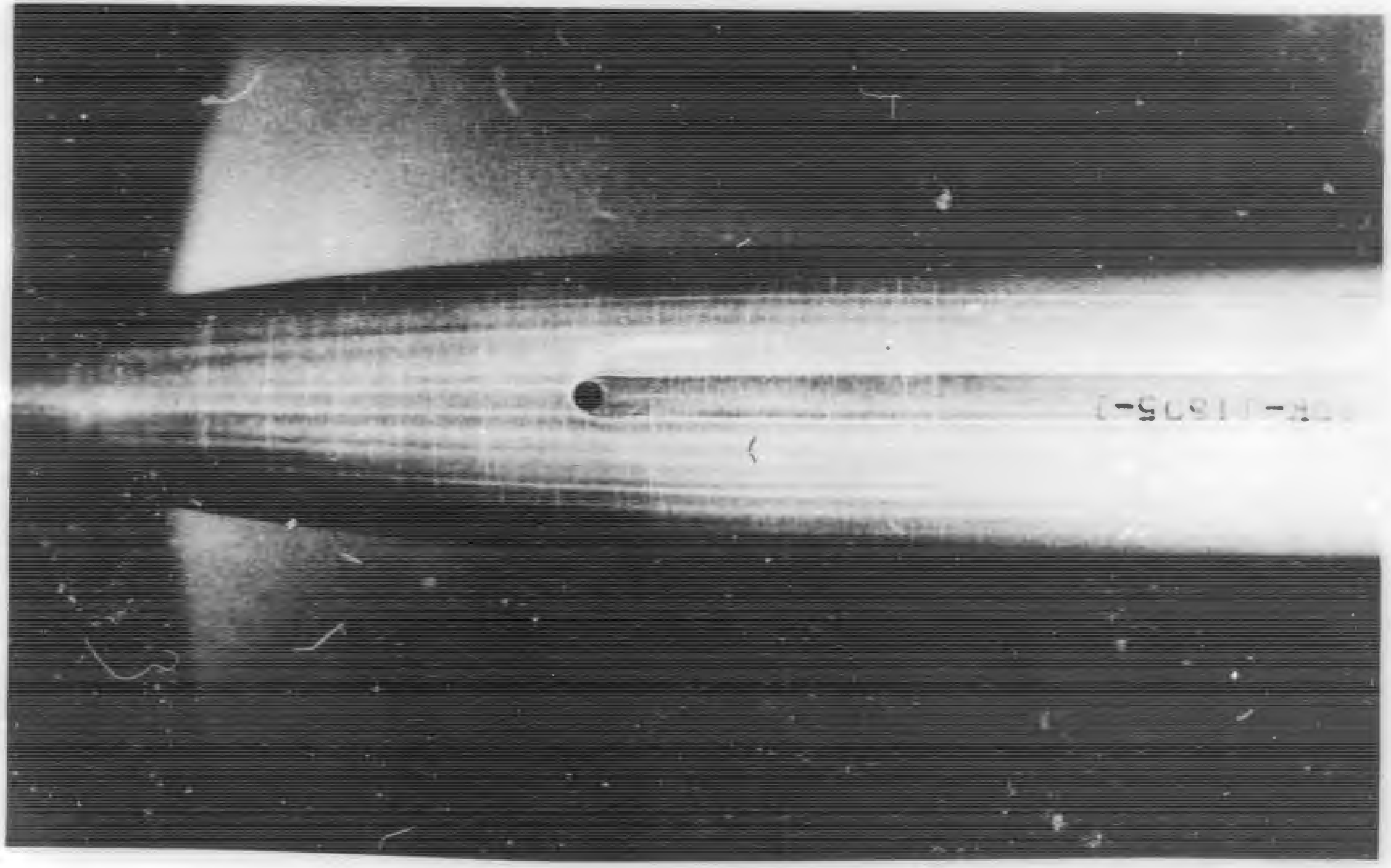

FIGURE B-6a. REACTION JET FOR $B_1C_1X_1$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 0$

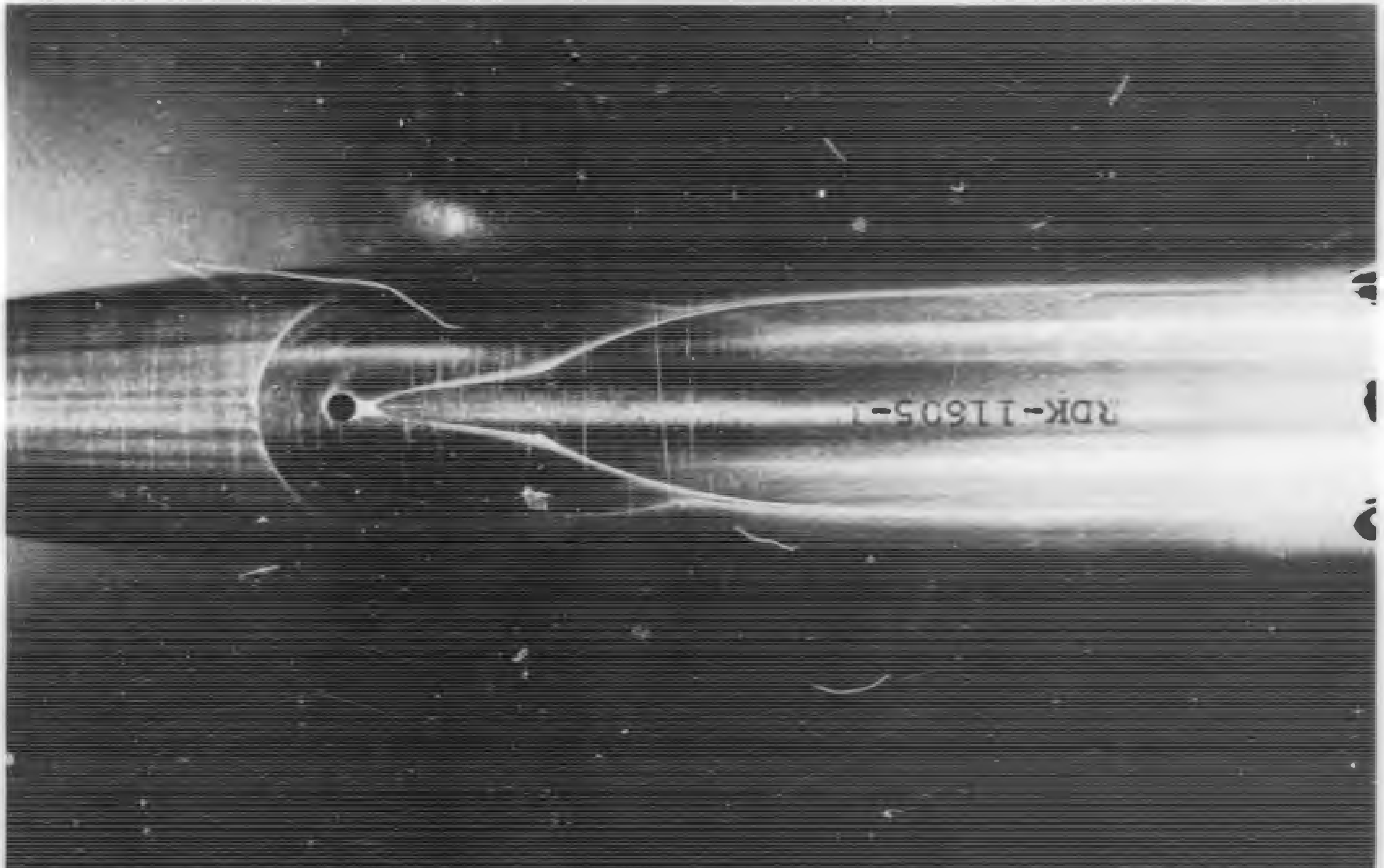

FIGURE B–6b. REACTION JET FOR $B_1C_1X_1$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 40$

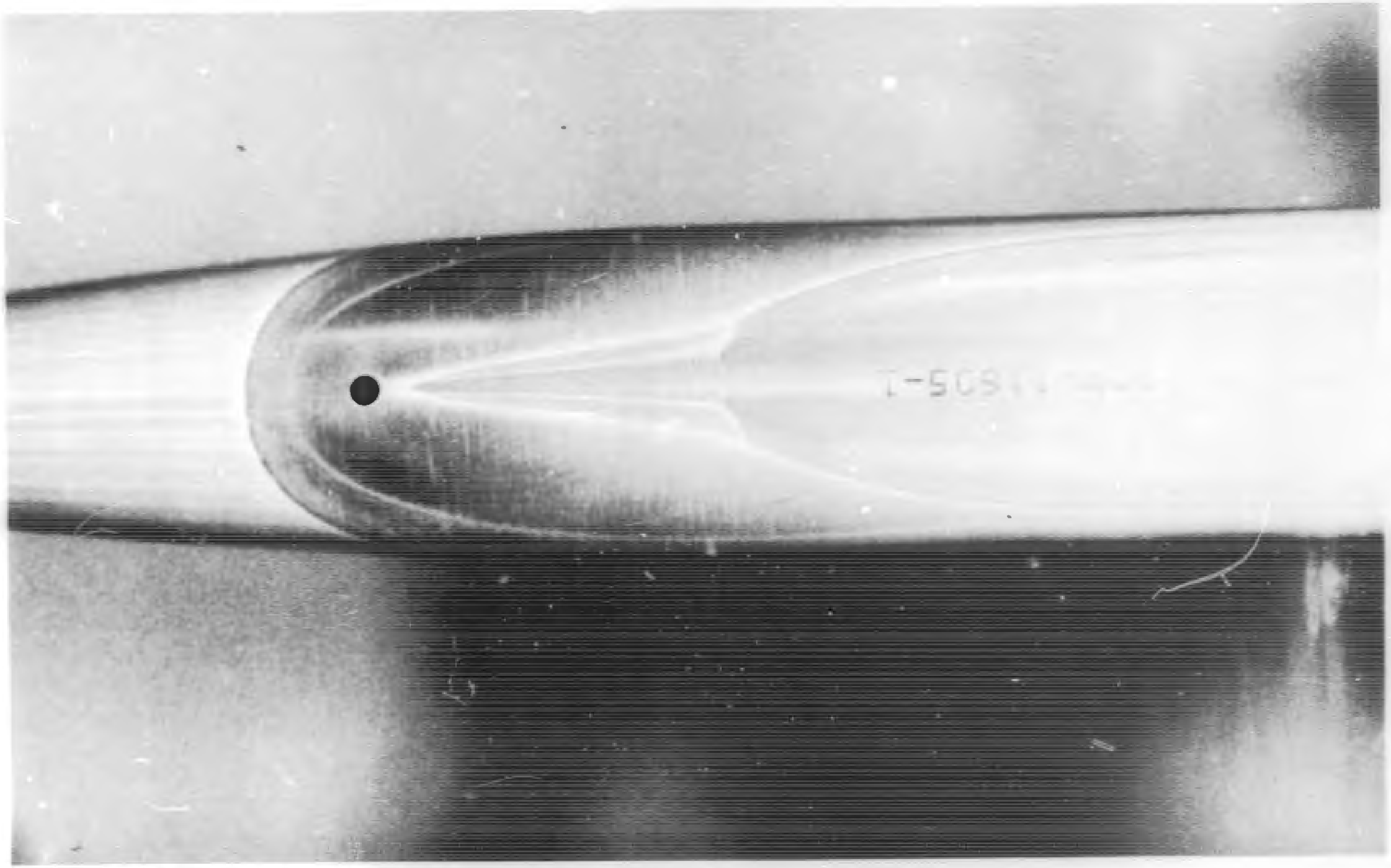

FIGURE B-6c. REACTION JET FOR $B_1C_1X_1$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 100$

Appendix C
M_∞ = 3.0 Flow Visualization Data

TABLE C-I. TEST VARIABLES AND VISUAL DATA COLLECTED FOR $M_\infty = 3.0$

Configuration	ϕ_j (deg)	Fin No.	α (deg)	P_{oj}/P_∞	Figure Showing Photographs	Figure Showing Schlierens	Figure Showing Shadowgraphs	Test Series
$B_1C_1X_3$	0	0.00	0	0	C-1a			September 1969
			0	0	C-1b			
			0	10	C-1c			
			0	10	C-1d			
			0	40	C-1e			
			0	100	C-1f			
			0	100	C-1g			
			5	0	C-2a			
			5	0	C-2b			
			5	10	C-2c			
			5	10	C-2d			
			5	40	C-2e			
			5	40	C-2f			
			5	100	C-2g			
			5	100	C-2h			
			10	0	C-3a			
			10	0	C-3b			
			10	10	C-3c			
			10	10	C-3d			
			10	40	C-3e			
			10	40	C-3f			
$B_1C_1X_3$	0	0.00	10	100	C-3g			September 1969

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TABLE C-I. TEST VARIABLES AND VISUAL DATA COLLECTED FOR $M_{\infty} = 3.0$ (Continued)

Configuration	ϕ_j (deg)	Fin No.	α (deg)	P_{oj}/P_{∞}	Figure Showing Photographs	Figure Showing Schlierens	Figure Showing Shadowgraphs	Test Series
$B_1C_1X_3$	0	0.00	10	100	C-3h			September 1969
			10	100			C-3i	
			-5	0	C-4a			
			-5	0	C-4b			
			-5	10	C-4c			
			-5	10	C-4d			
			-5	40	C-4e			
			-5	40	C-4f			
			-5	100	C-4g			
			-5	100	C-4h			
			-5	100			C-4i	
			-10	0	C-5a			
			-10	0	C-5b			
			-10	10	C-5c			
			-10	10	C-5d			
			-10	40	C-5e			
			-10	40	C-5f			
			-10	100	C-5g			
			-10	100	C-5h			
	0		-10	100			C-5i	
	45		0	0	C-6a			
			0	0	C-6b			
			0	10	C-6c			
			0	10	C-6d			
$B_1C_1X_3$	45	0.00	0	40	C-6e			September 1969

TABLE C-I. TEST VARIABLES AND VISUAL DATA COLLECTED FOR $M_\infty = 3.0$ (Continued)

Configuration	ϕ_j (deg)	Fin No.	α (deg)	P_{oj}/P_∞	Figure Showing Photographs	Figure Showing Schlierens	Figure Showing Shadowgraphs	Test Series
$B_1C_1X_3$	45	0.00	0	40	C-6f			September 1969
			0	100	C-6g			
			0	100	C-6h			
			5	0	C-7a			
			5	0	C-7b			
			5	10	C-7c			
			5	10	C-7d			
			5	40	C-7e			
			5	40	C-7f			
			5	100	C-7g			
			5	100	C-7h			
			10	0	C-8a			
			10	0	C-8b			
			10	10	C-8c			
			10	10	C-8d			
			10	40	C-8e			
			10	40	C-8f			
			10	100	C-8g			
			10	100	C-8h			
			-5	0	C-9a			
			-5	0	C-9b			
			-5	10	C-9c			
			-5	40	C-9d			
$B_1C_1X_3$	45	0.00	-5	40	C-9e			September 1969

TABLE C-I. TEST VARIABLES AND VISUAL DATA COLLECTED FOR $M_\infty = 3.0$ (Concluded)

Configuration	ϕ_j (deg)	Fin No.	α (deg)	P_{oj}/P_∞	Figure Showing Photographs	Figure Showing Schlierens	Figure Showing Shadowgraphs	Test Series
$B_1C_1X_3$	45	0.00	-5	100	C-9f			September 1969
			-5	100	C-9g			
			-10	0	C-10a			
			-10	0	C-10b			
			-10	10	C-10c			
			-10	10	C-10d			
			-10	40	C-10e			
			-10	40	C-10f			
			-10	100	C-10g			
$B_1C_1X_3$	45	0.00	-10	100	C-10h			September 1969
$B_1C_1X_2$	0	2.45	0	10			C-11a	February-March 1969
			0	20			C-11b	
			0	40			C-11c	
$B_1C_1X_2$	0	2.45	0	100			C-11d	February-March 1969

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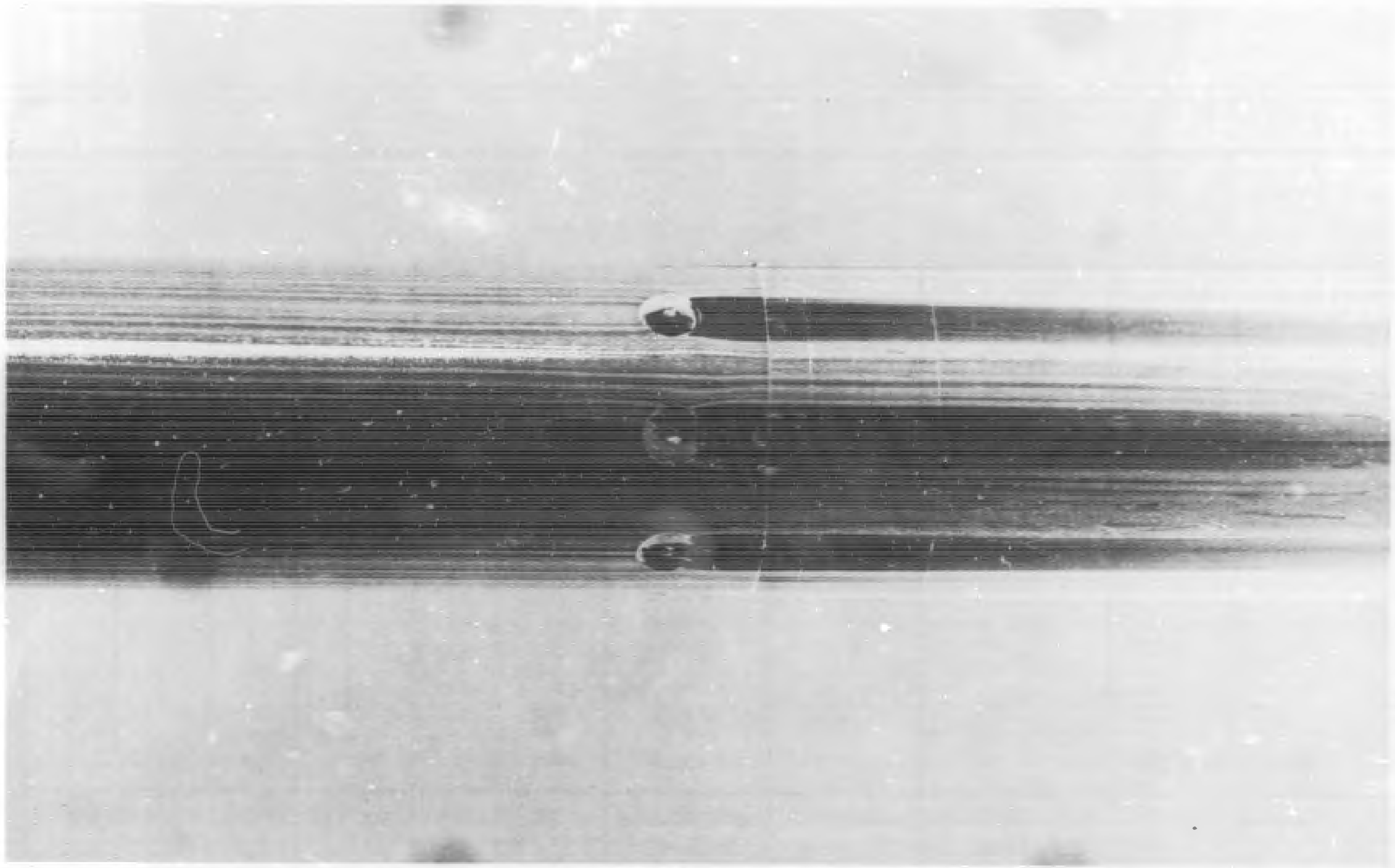

FIGURE C-1a. REACTION JET FOR BC_1X_3 WITH $\alpha = 0$ DEGREES; $P_{oj}/P_{\infty} = 0$

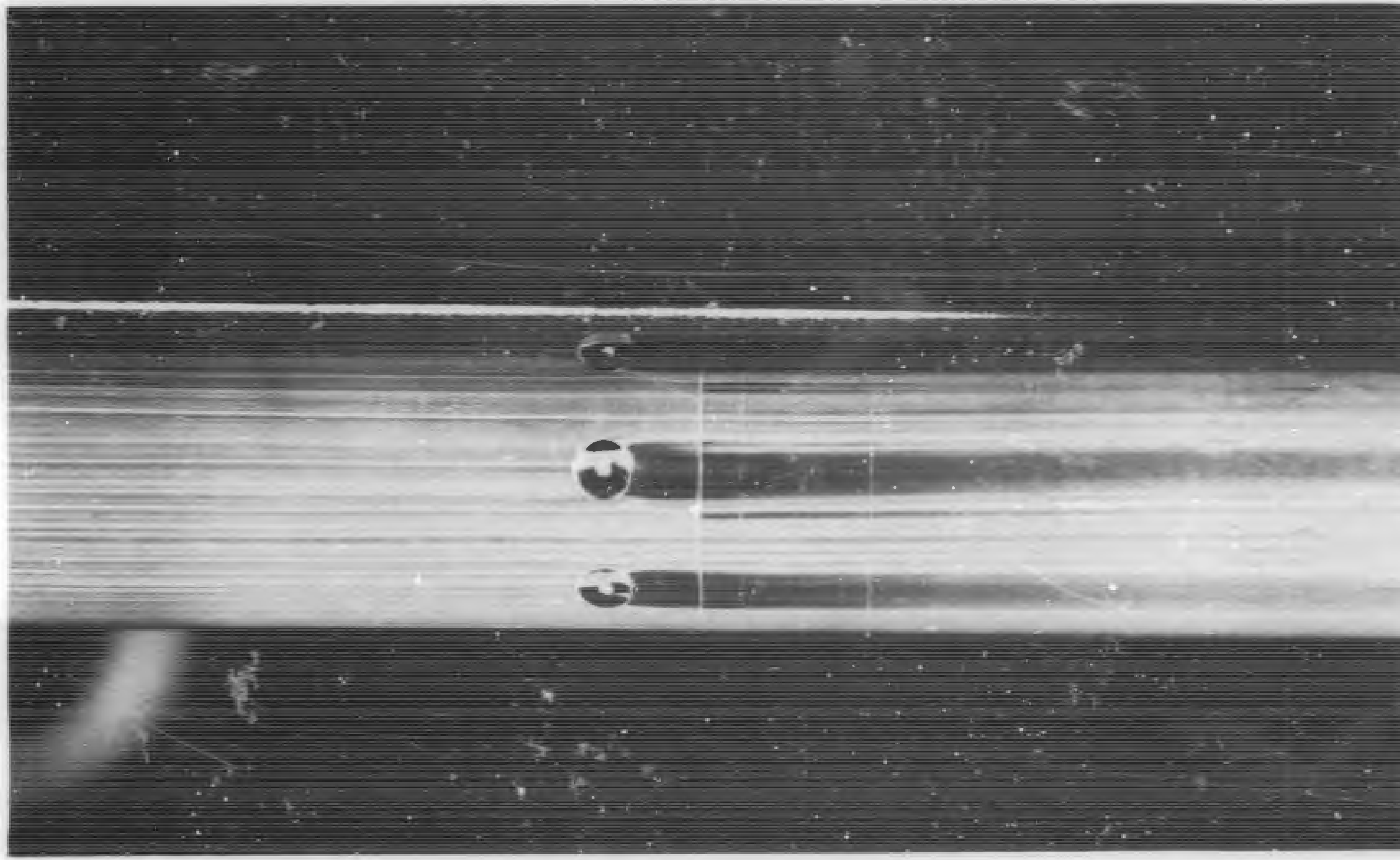

FIGURE C-1b. REACTION JET FOR BC_1X_3 WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 0$

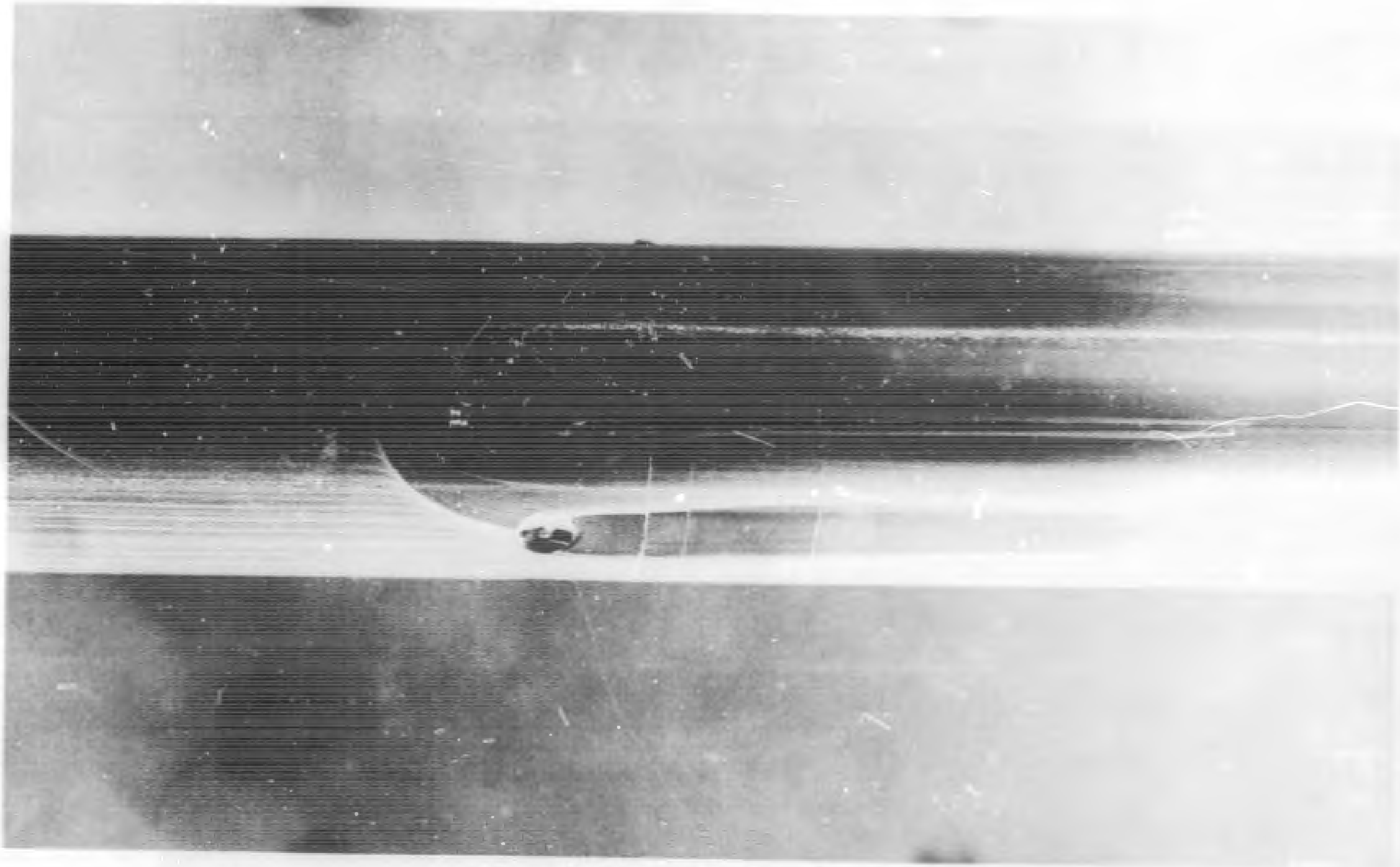

FIGURE C-1c. REACTION JET FOR BC_1X_3 WITH $\alpha = 0$ DEGREES; $P_{oj}/P_{\infty} = 10$

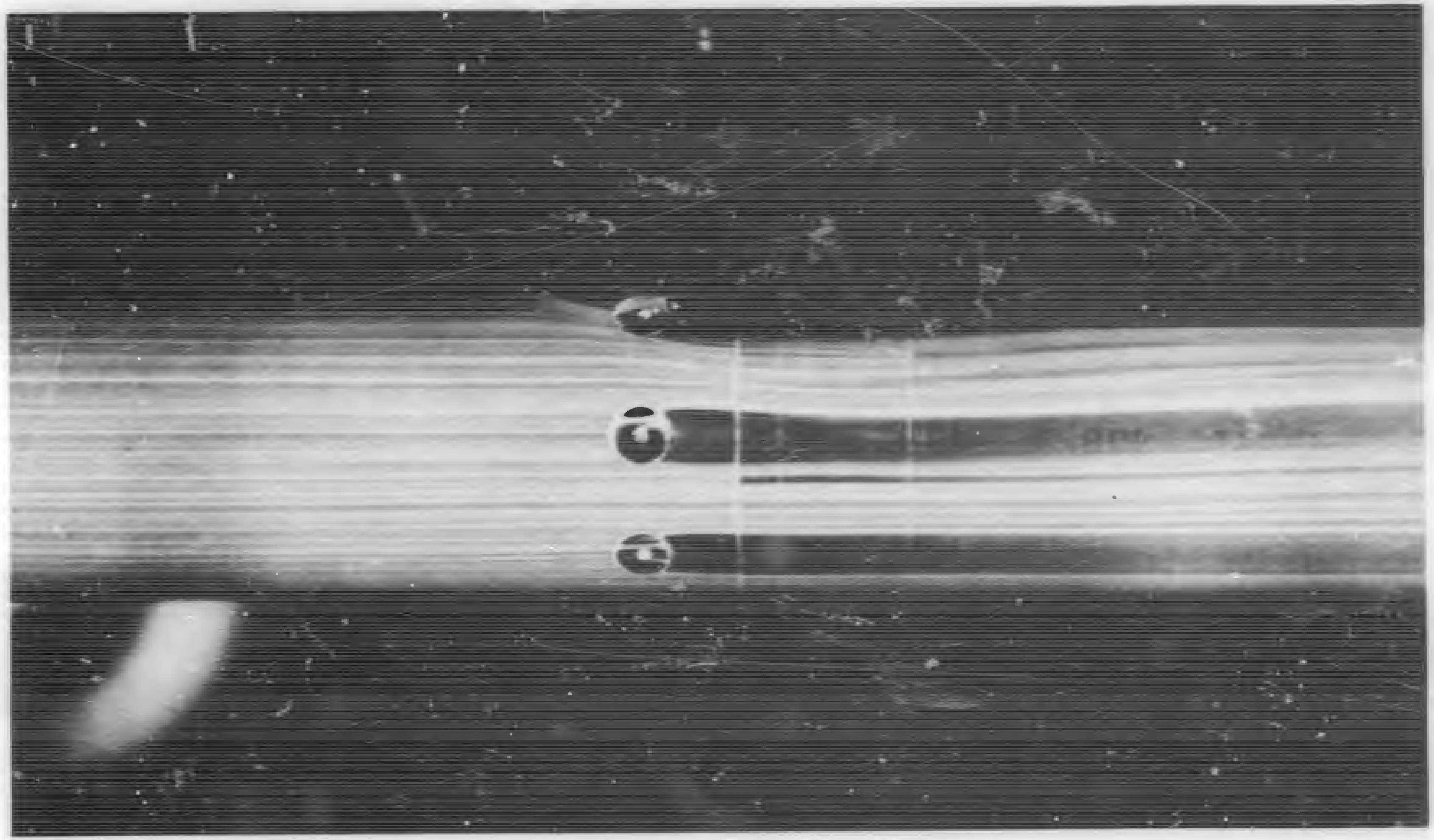

FIGURE C-1d. REACTION JET FOR BC_1X_3 WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 10$

PHOTOGRAPH SHOWING REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 40$, NOT AVAILABLE

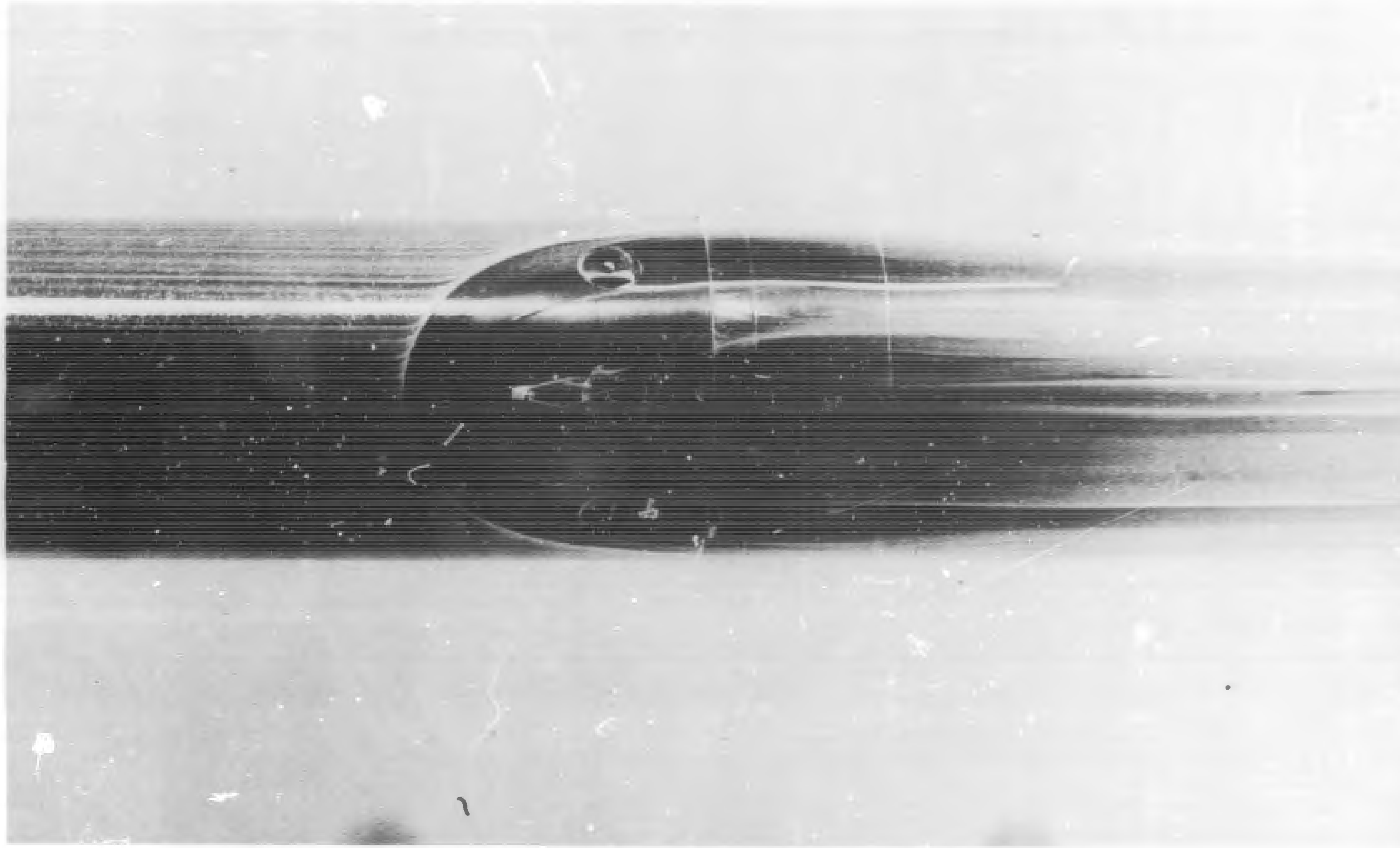

FIGURE C-1e. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 40$

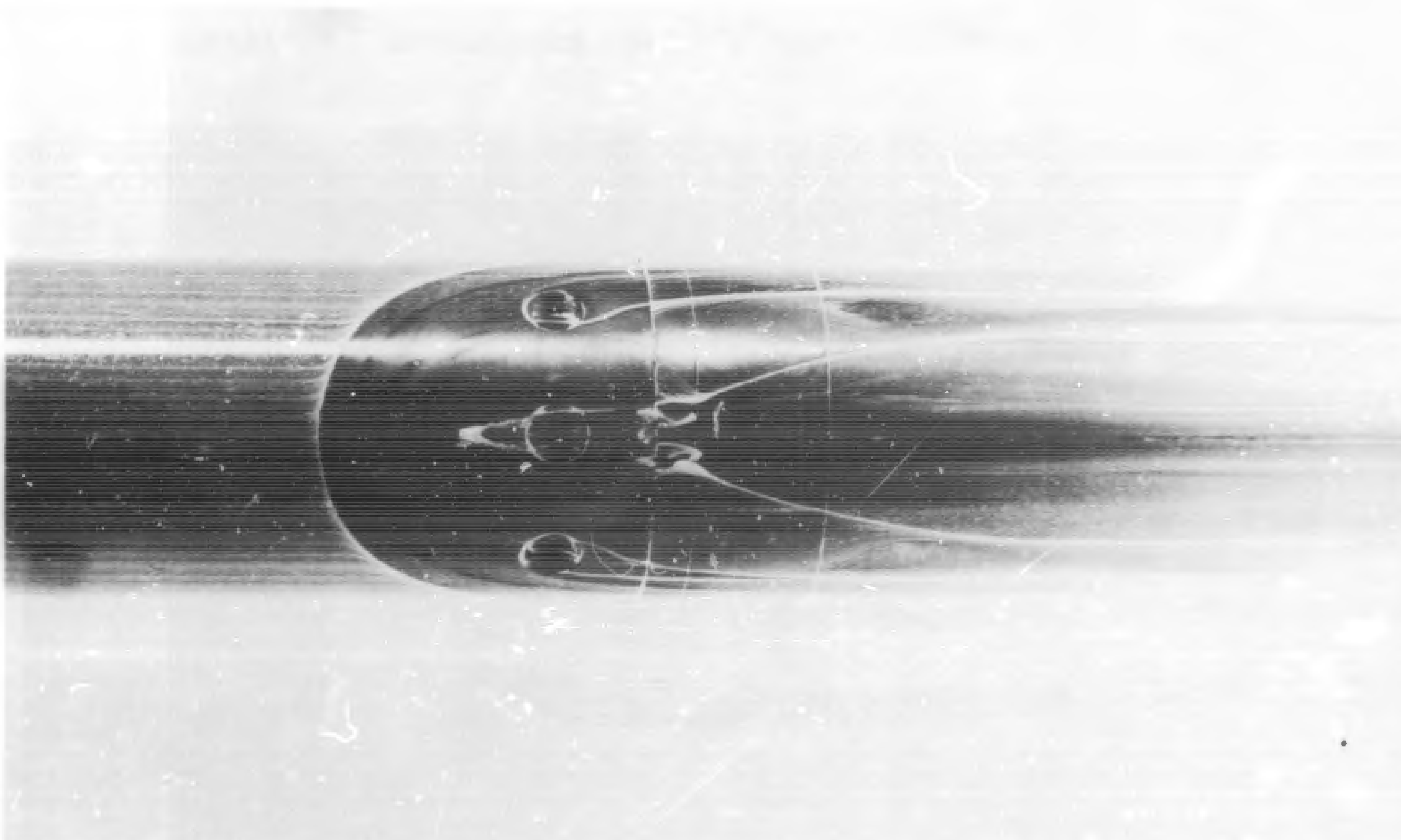

FIGURE C-1f. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 100$

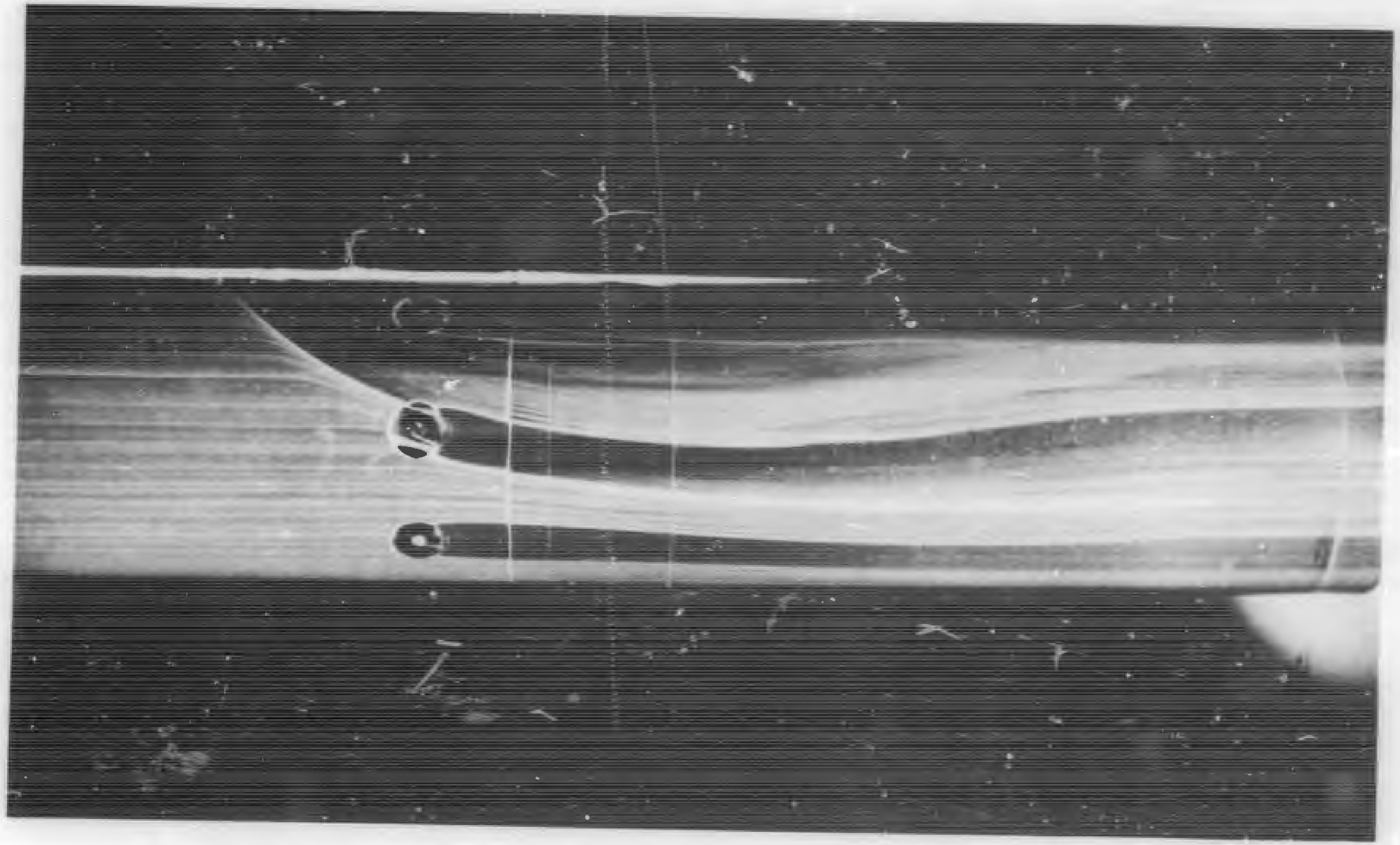

FIGURE C-1g. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_{\infty} = 100$

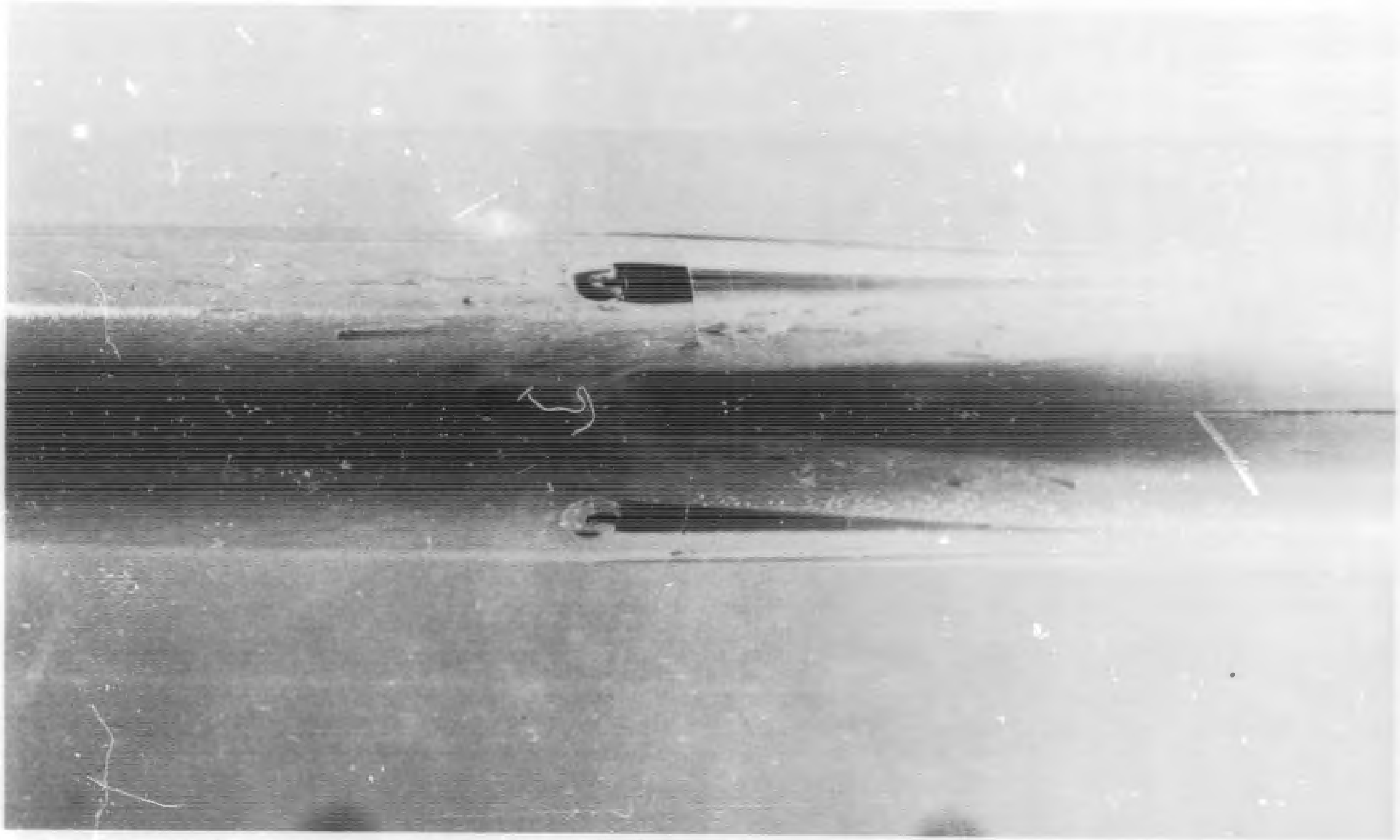

FIGURE C-2a. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_{\infty} = 0$

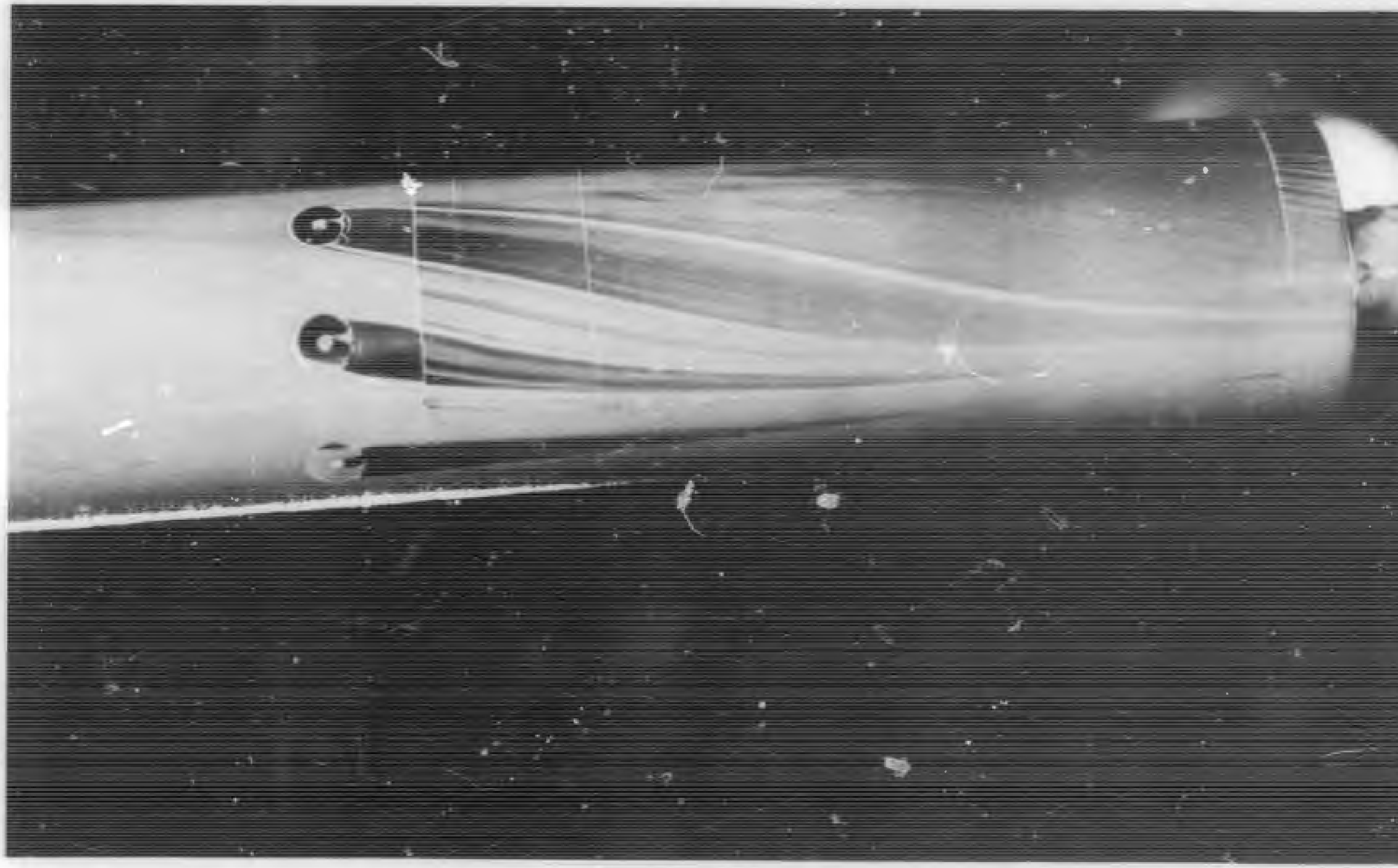

FIGURE C-2b. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_{\infty} = 0$

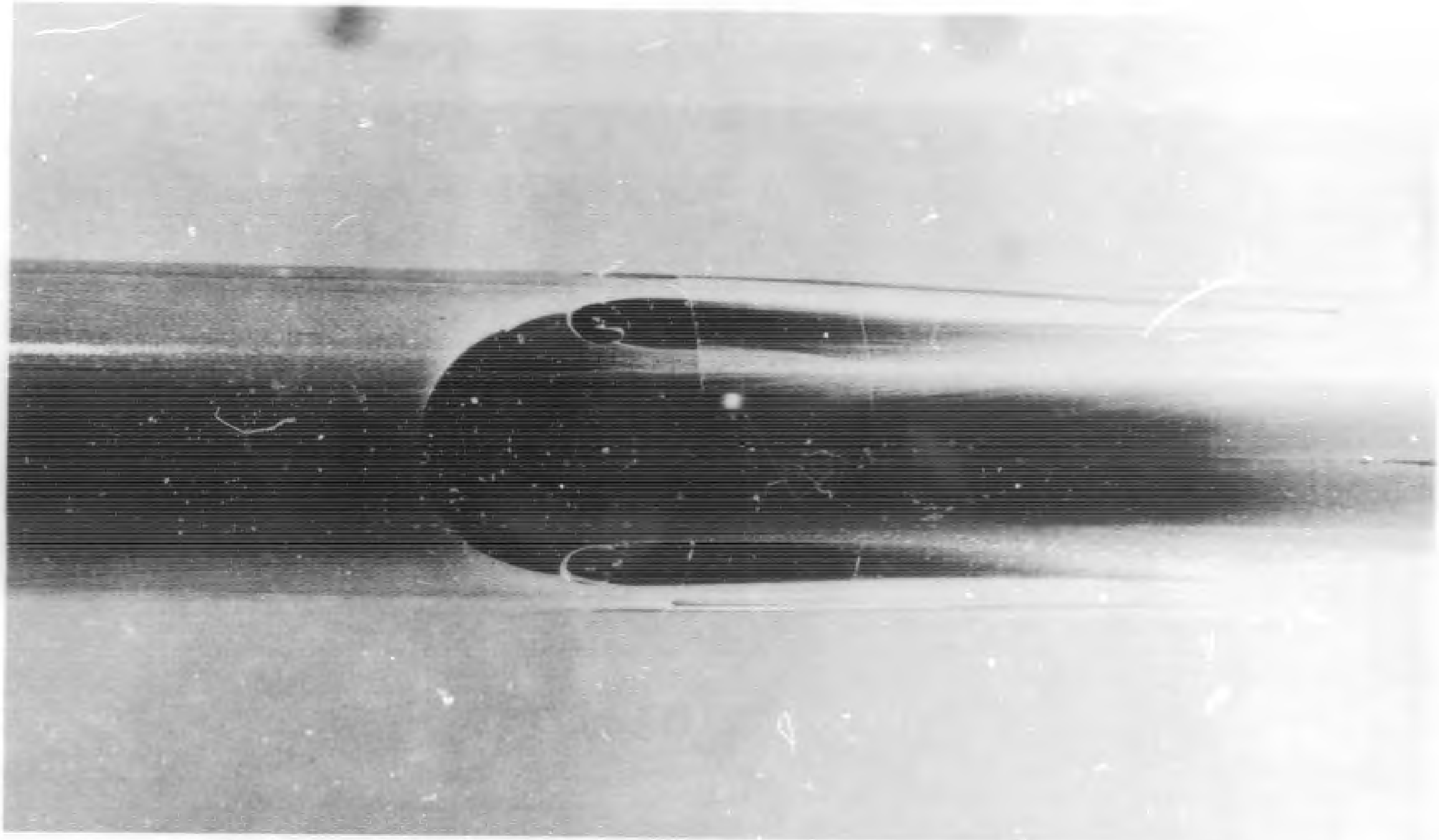

FIGURE C-2c. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_{\infty} = 10$

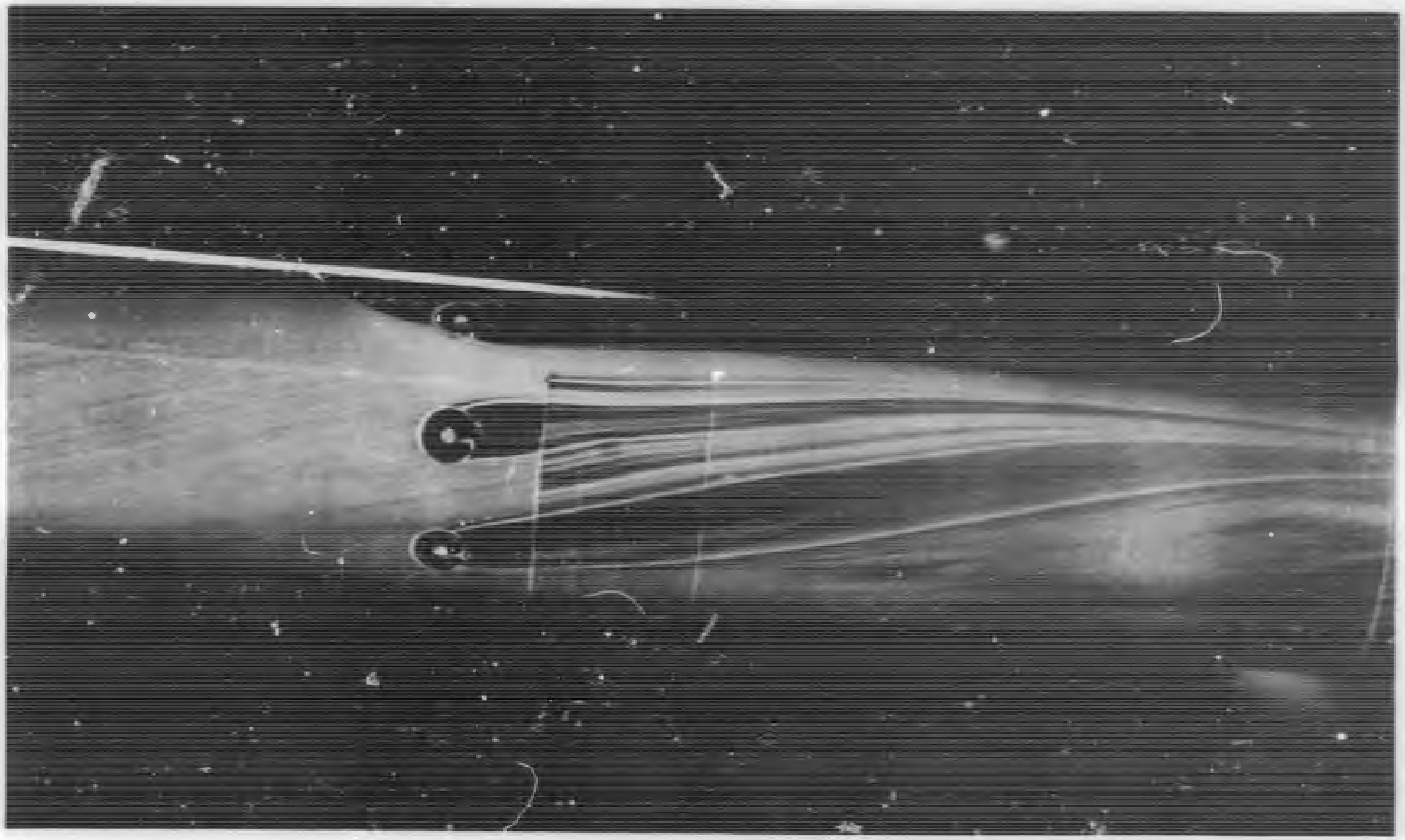

FIGURE C-2d. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_\infty = 10$

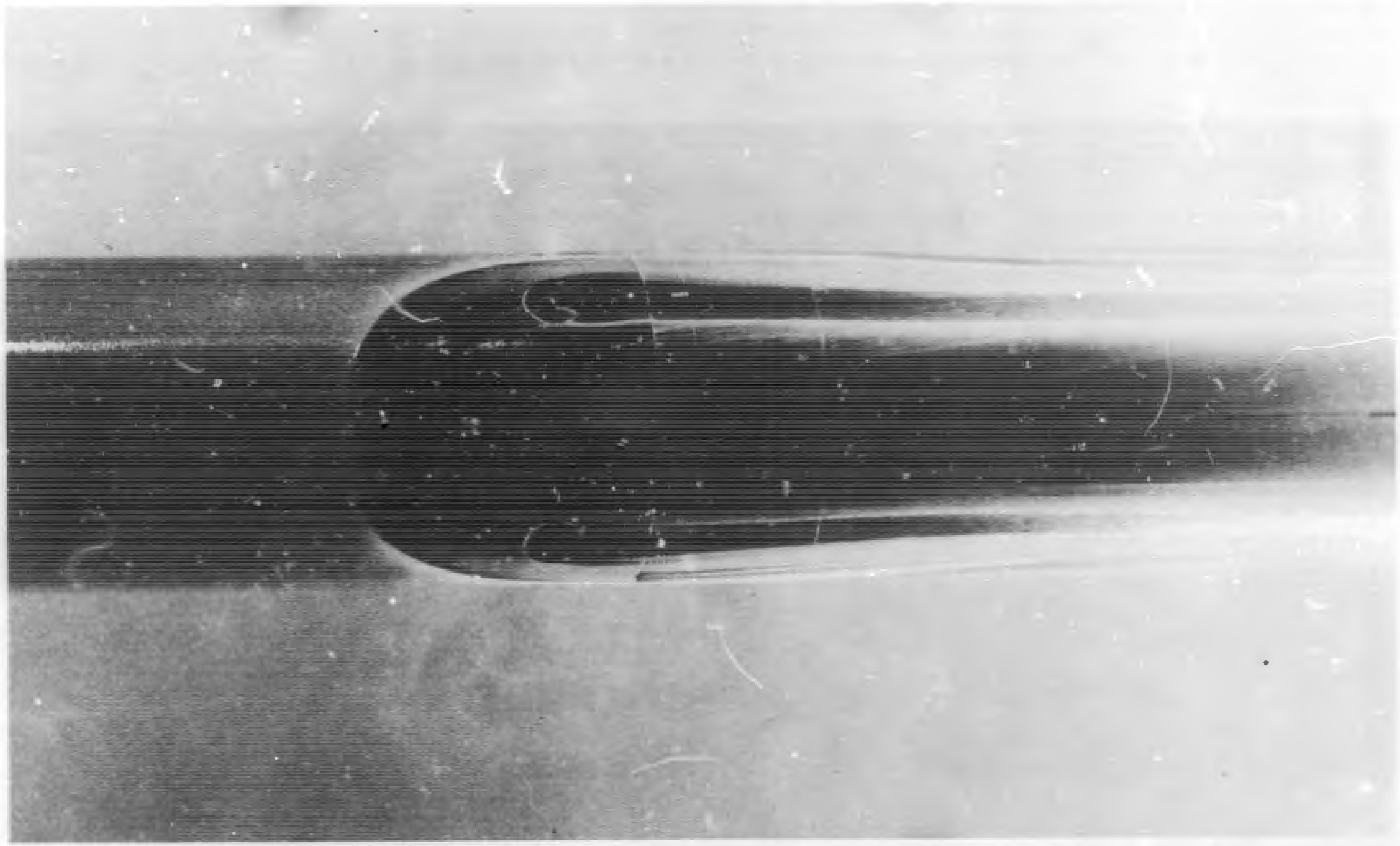

FIGURE C-2e. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_\infty = 40$

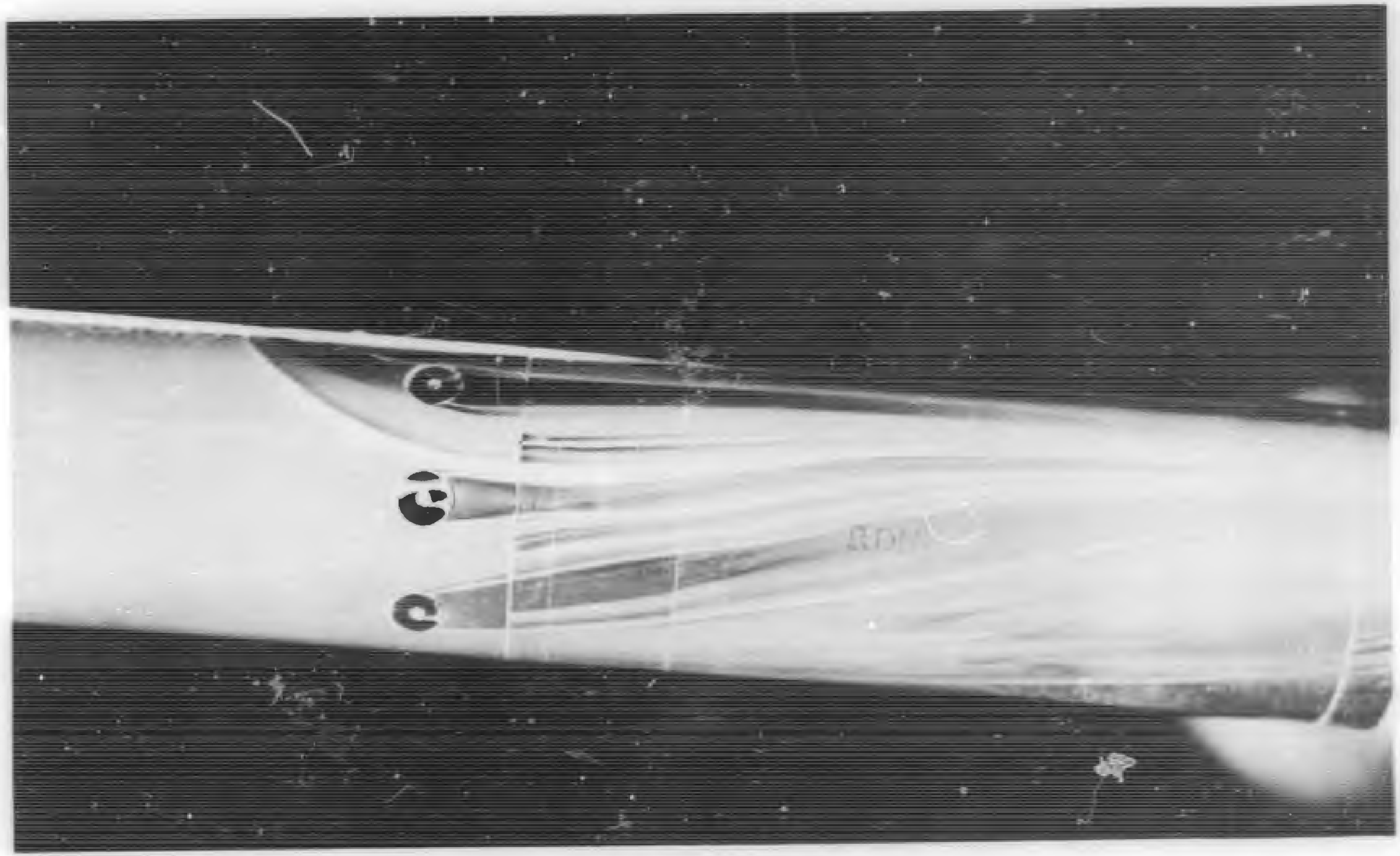

FIGURE C-2f. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_{\infty} = 40$

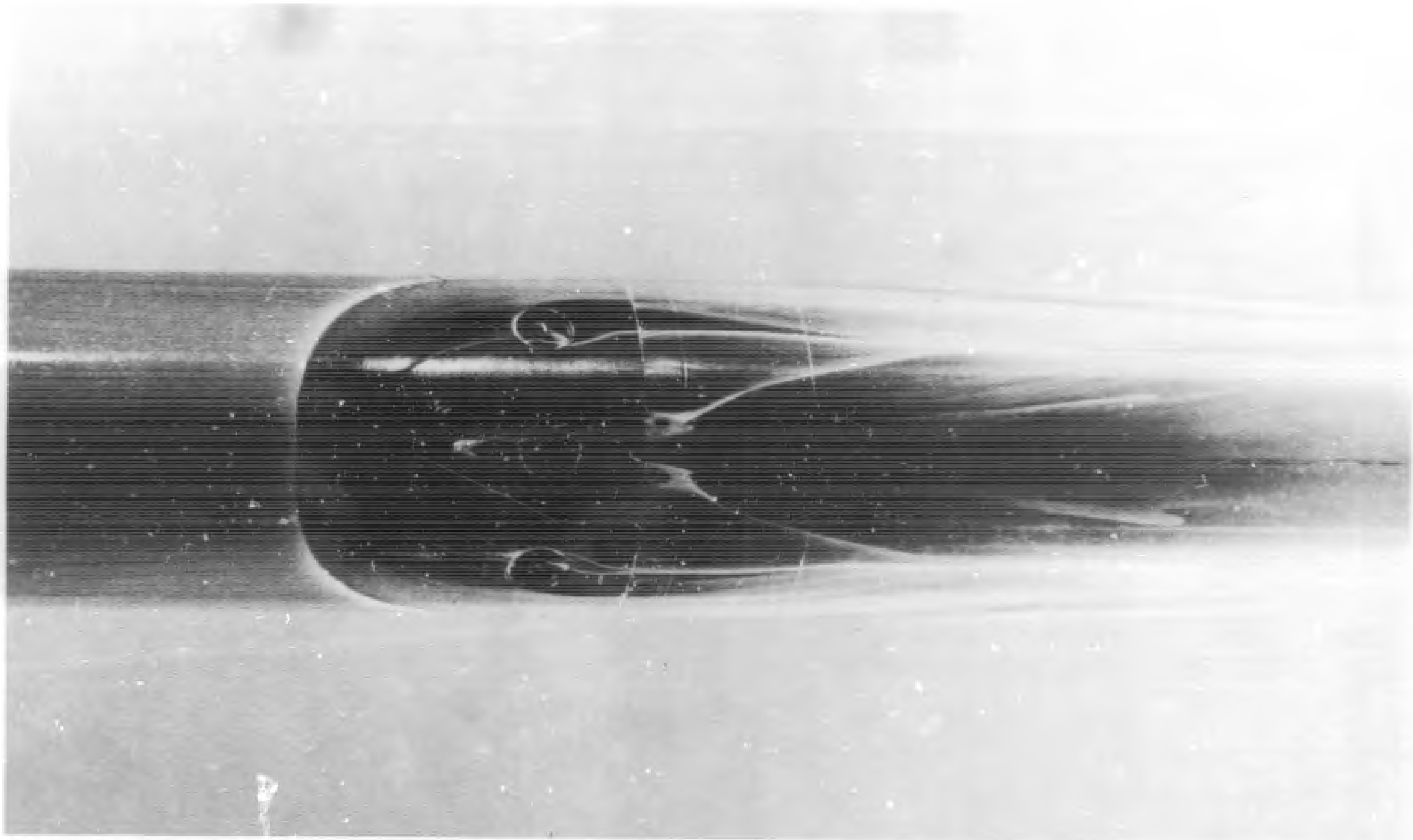

FIGURE C-2g. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_\infty = 100$

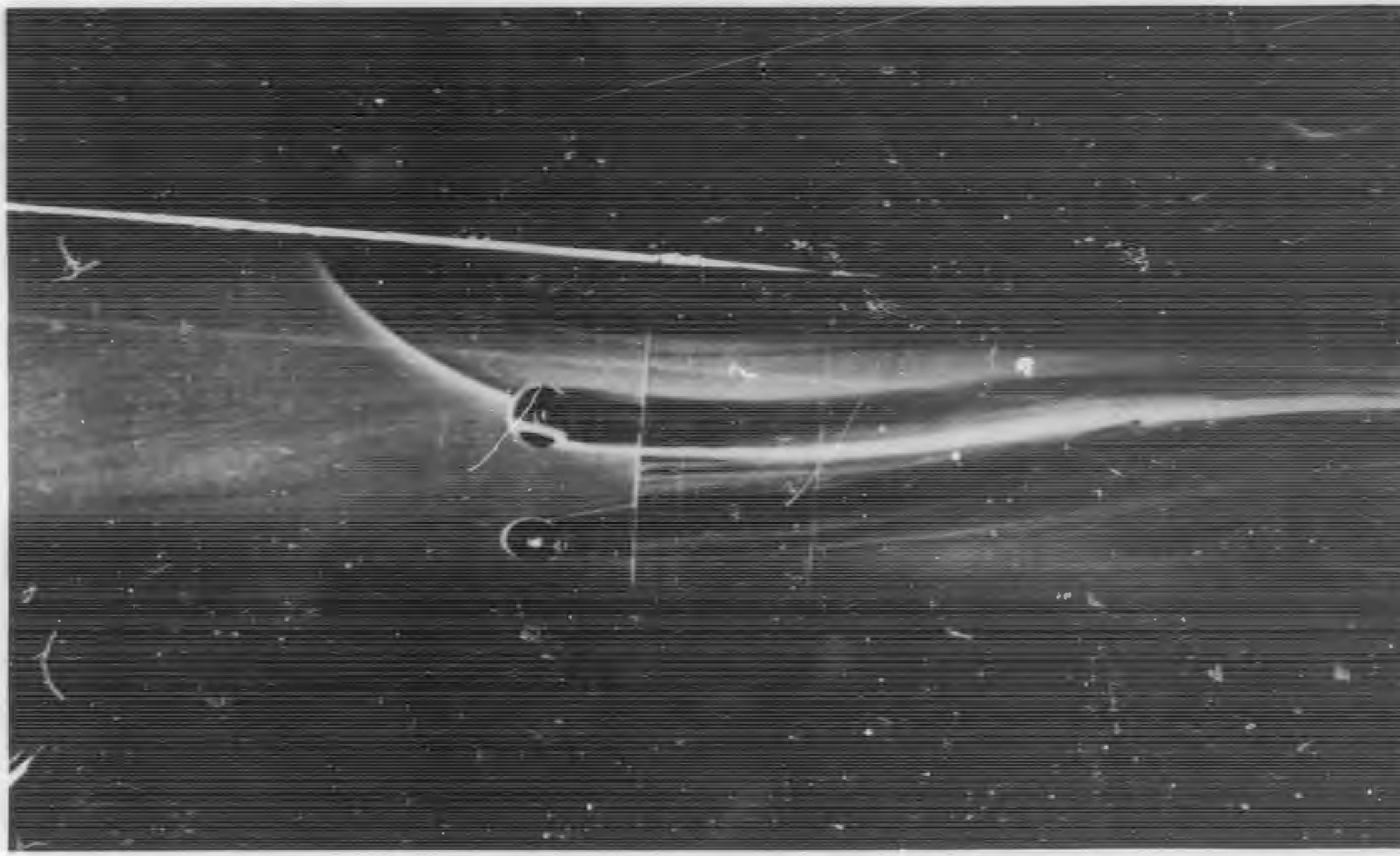

FIGURE C-2h. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_\infty = 100$

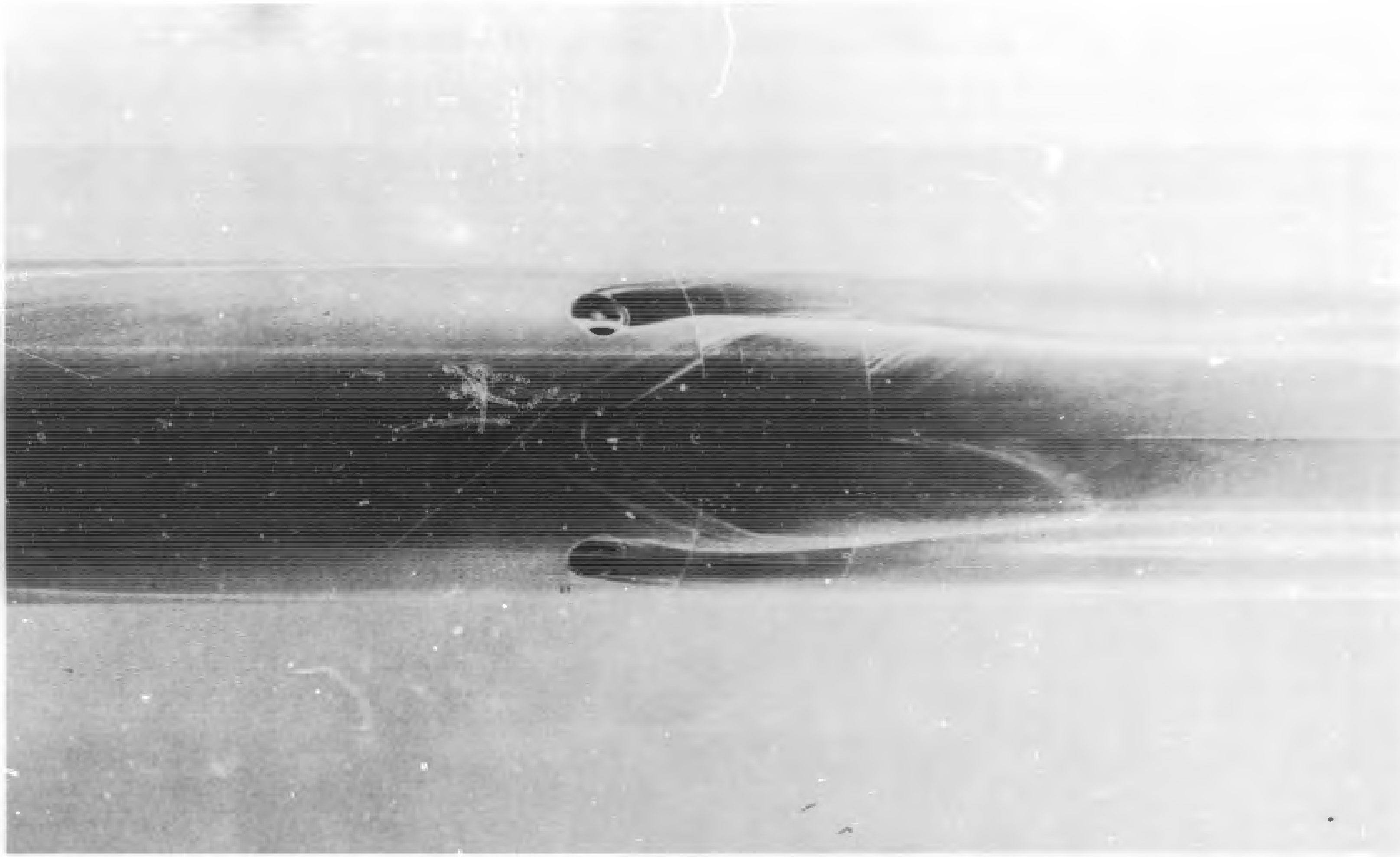

FIGURE C-3a. REACTION JET FOR $B_1C_1X_3$ WITH α = 10 DEGREES; $P_{oj}/P_\infty = 0$

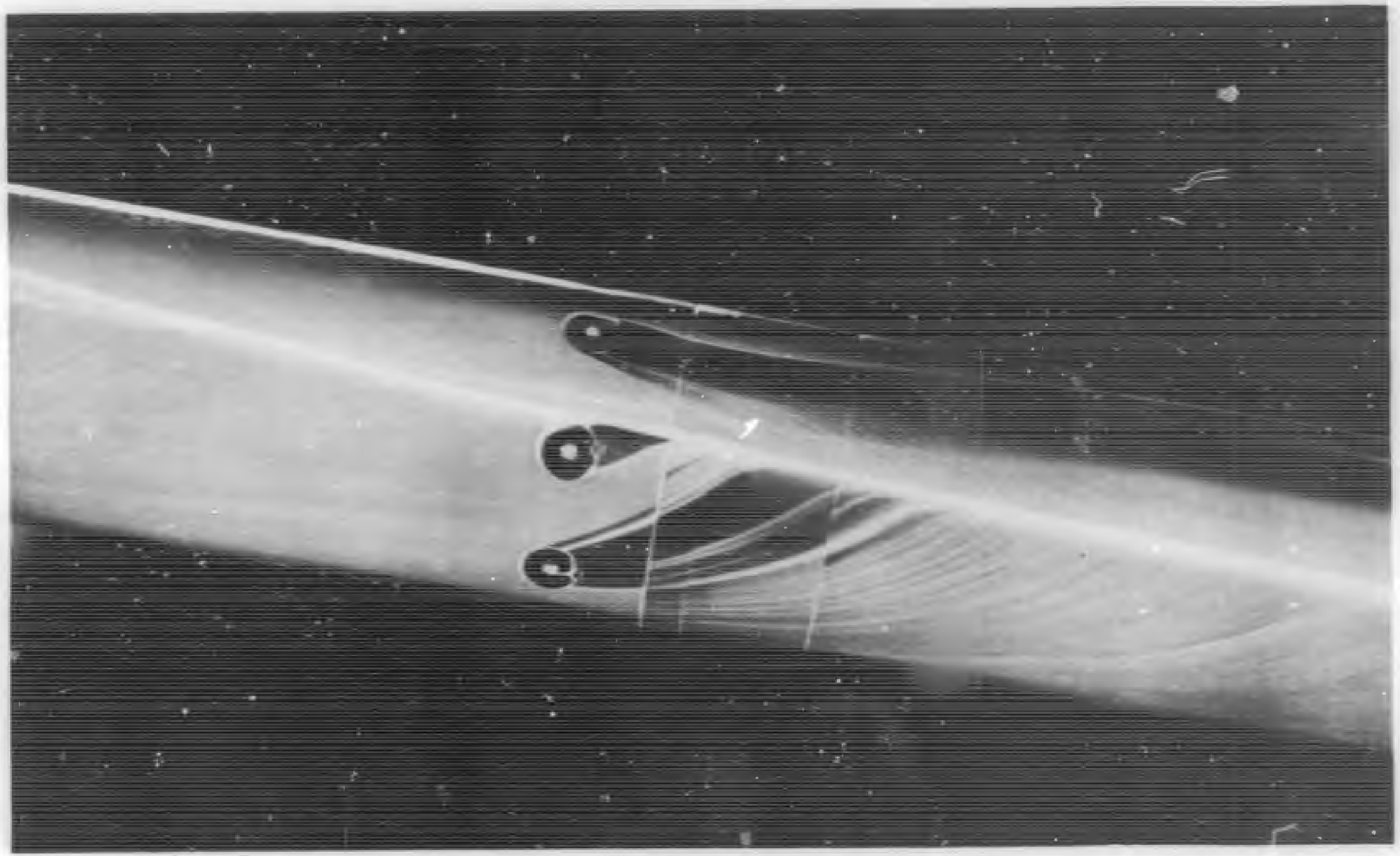

FIGURE C-3b. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_\infty = 0$

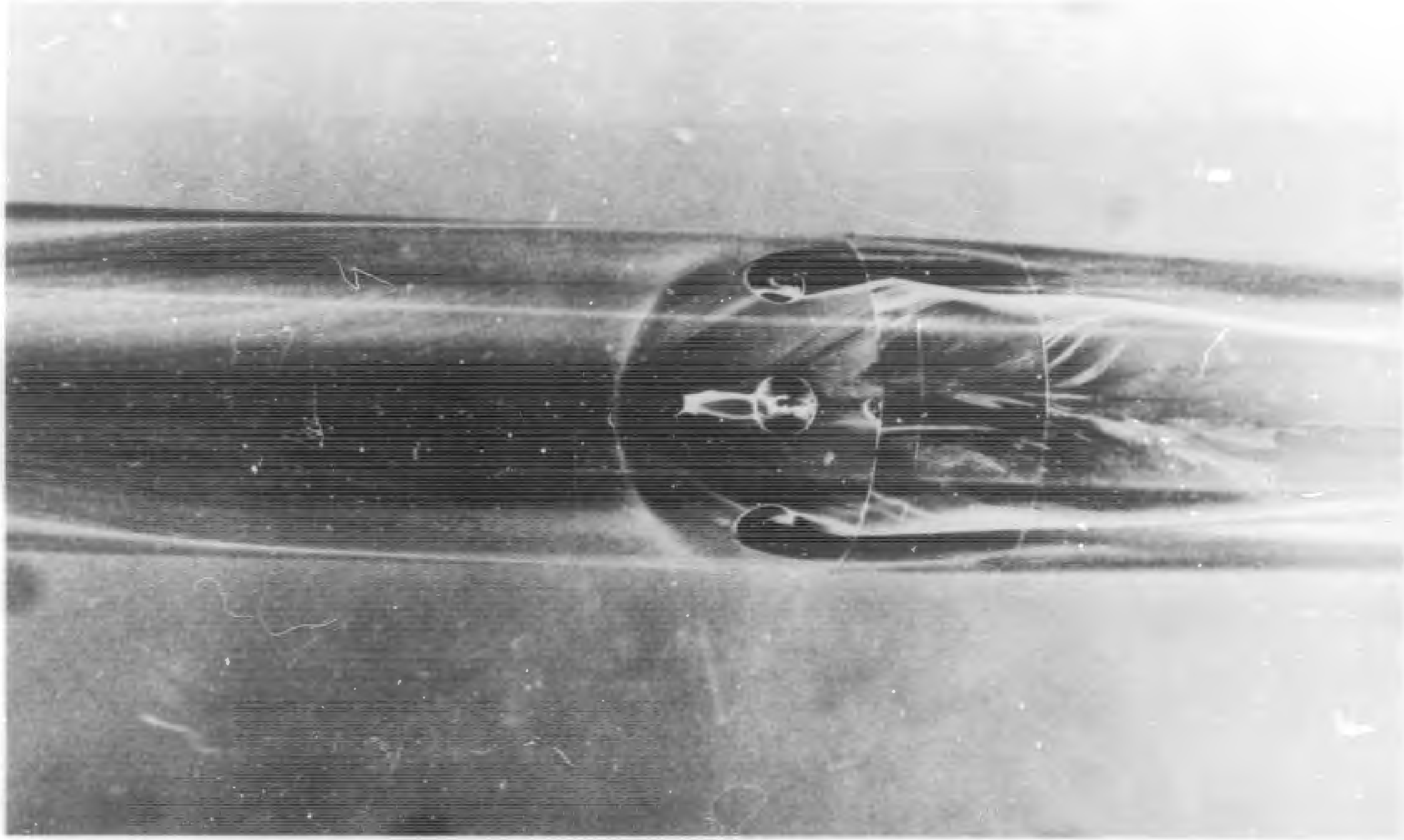

FIGURE C-3c. REACTION JET FOR $B_1 C_1 X_3$ WITH α = 10 DEGREES; P_{oj}/P_{∞} = 10

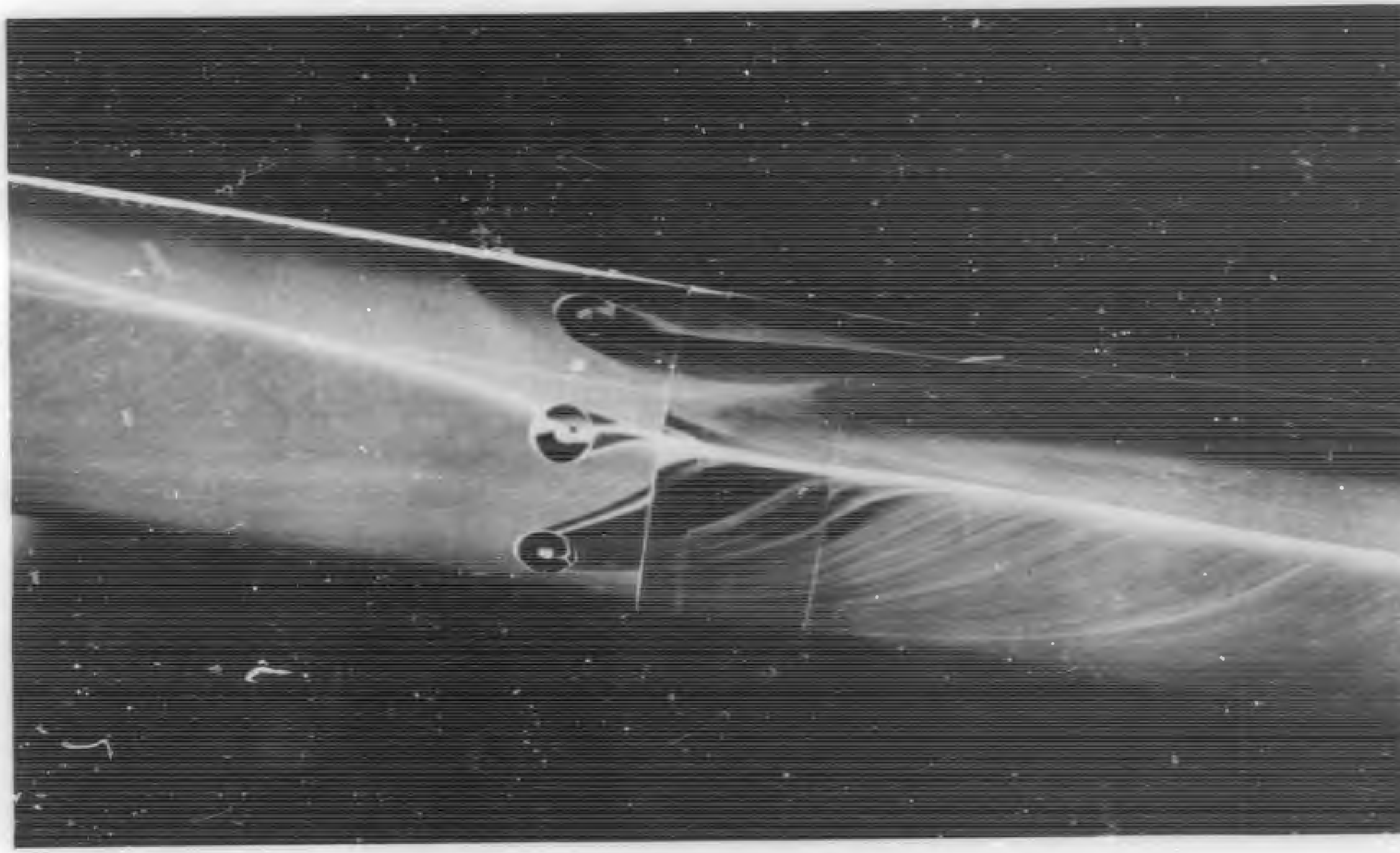

FIGURE C-3d. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_{\infty} = 10$

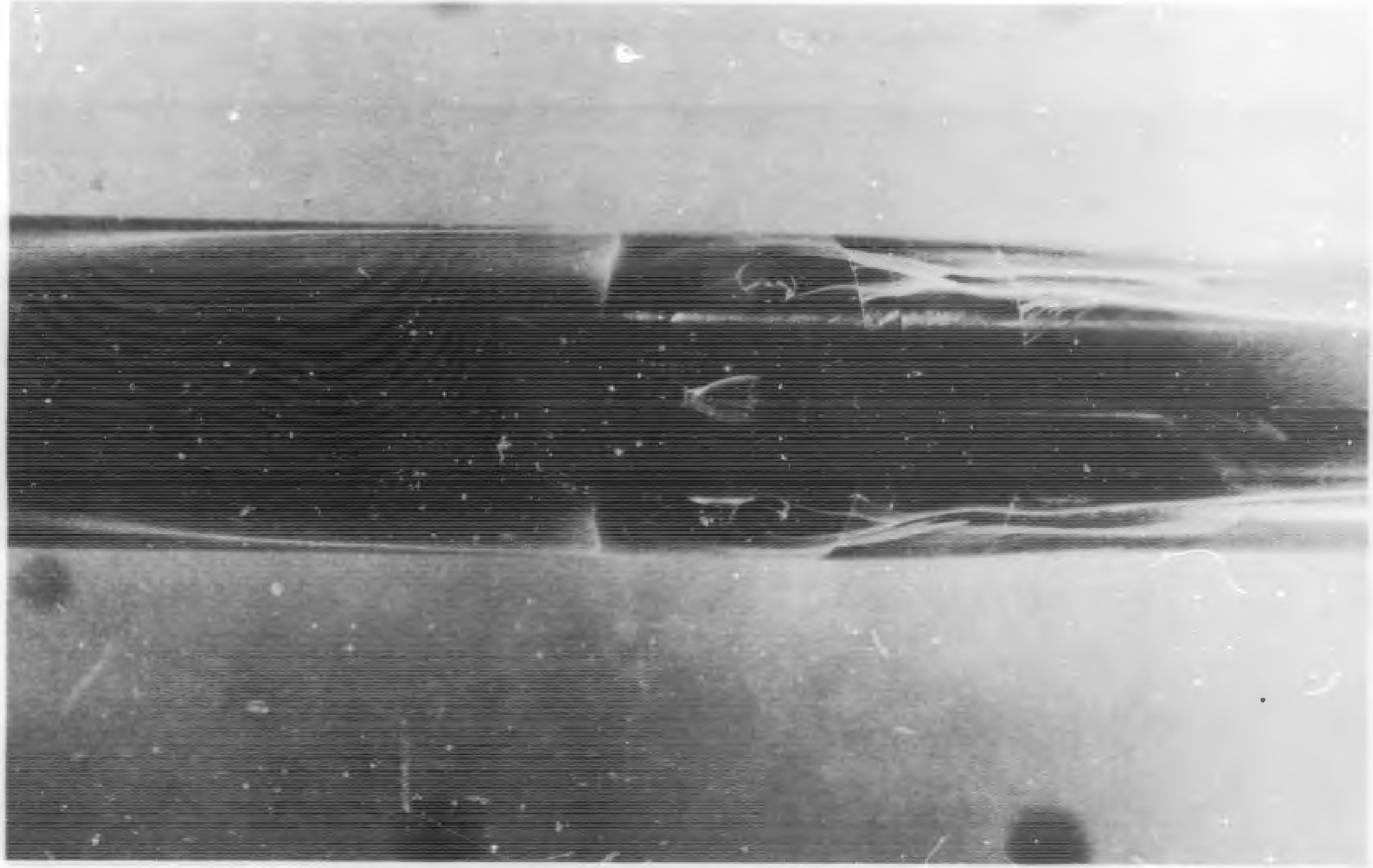

FIGURE C-3e. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_{\infty} = 40$

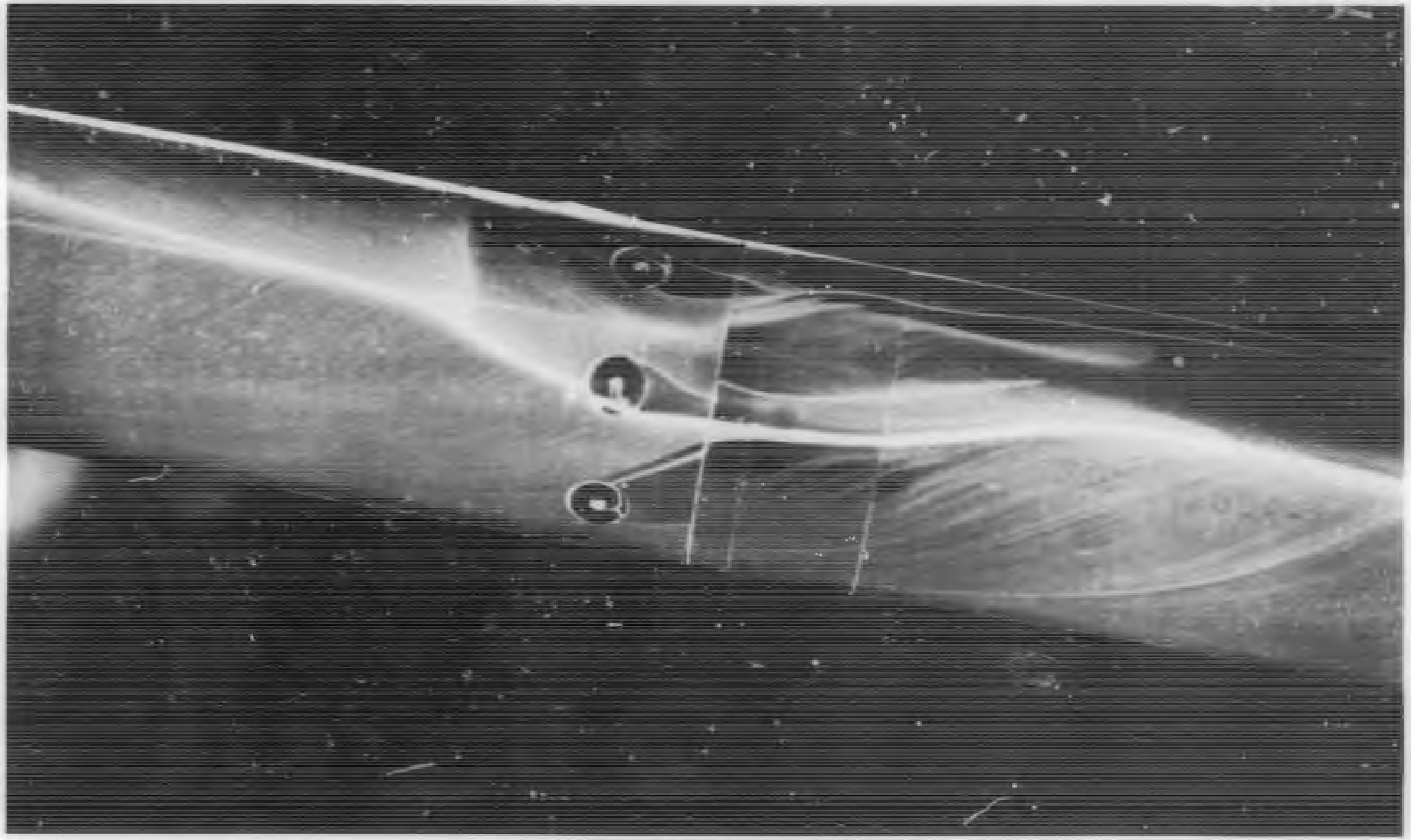

FIGURE C-3f. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_\infty = 40$

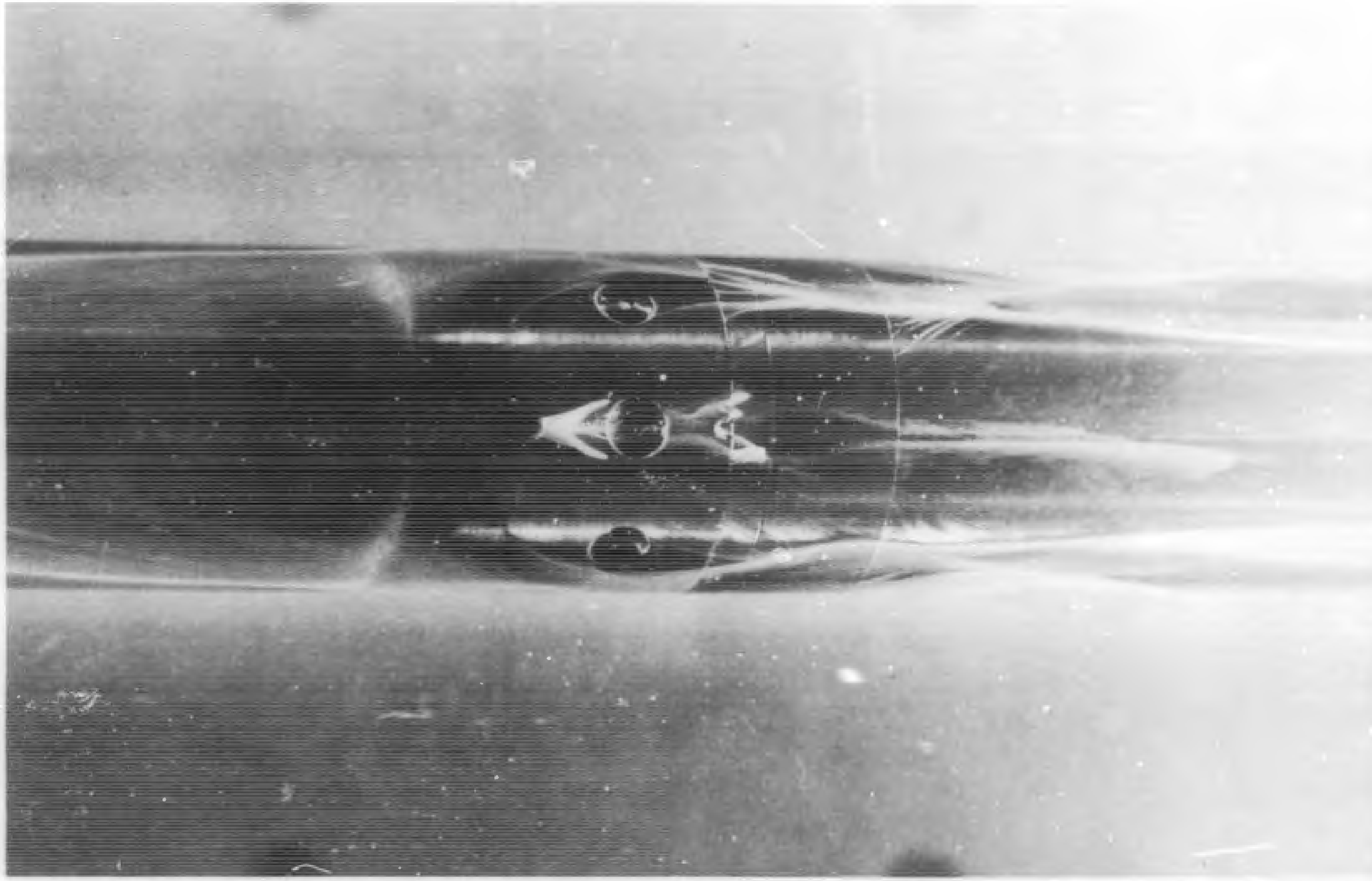

FIGURE C-3g. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_\infty = 100$

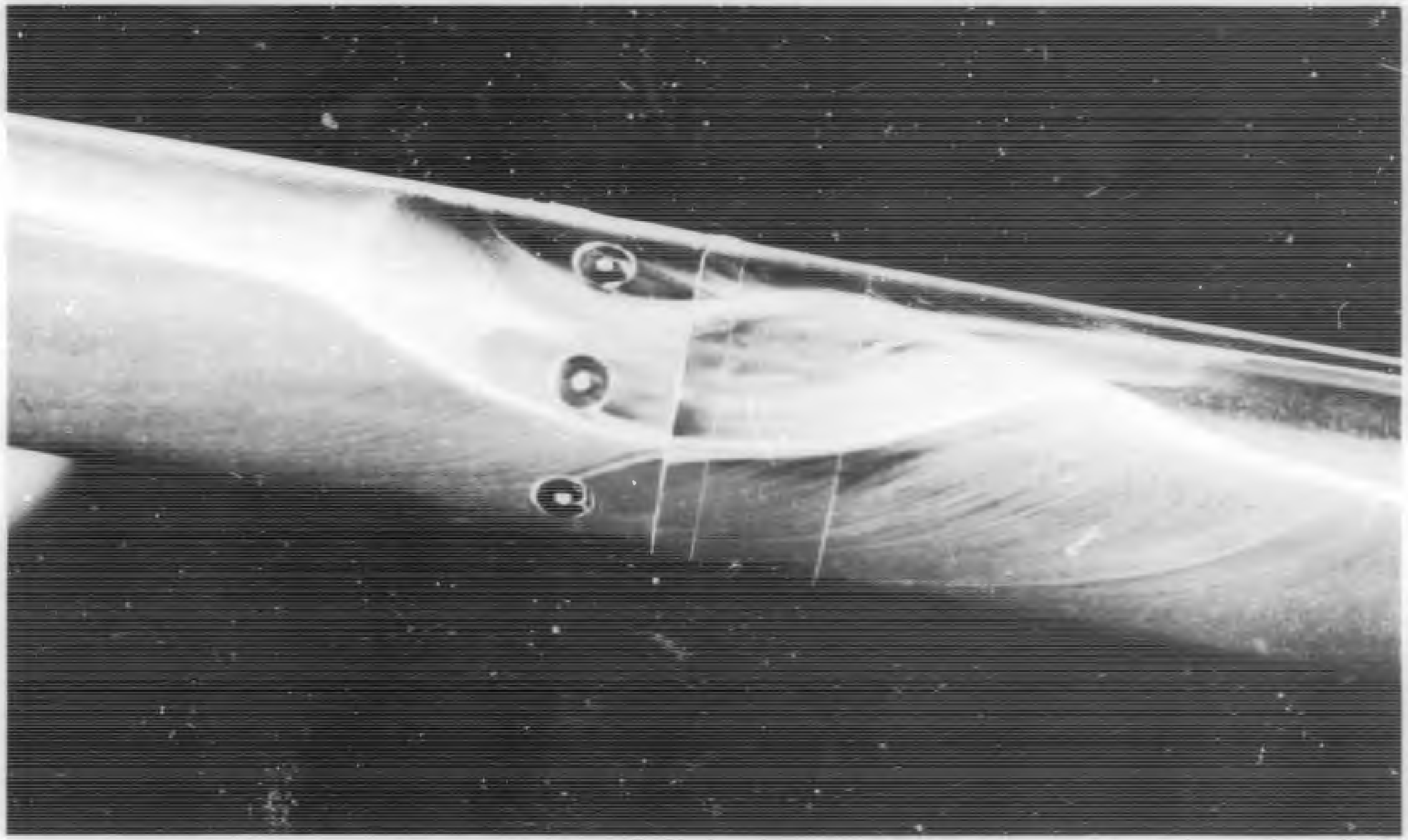

FIGURE C-3h. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_{\infty} = 100$

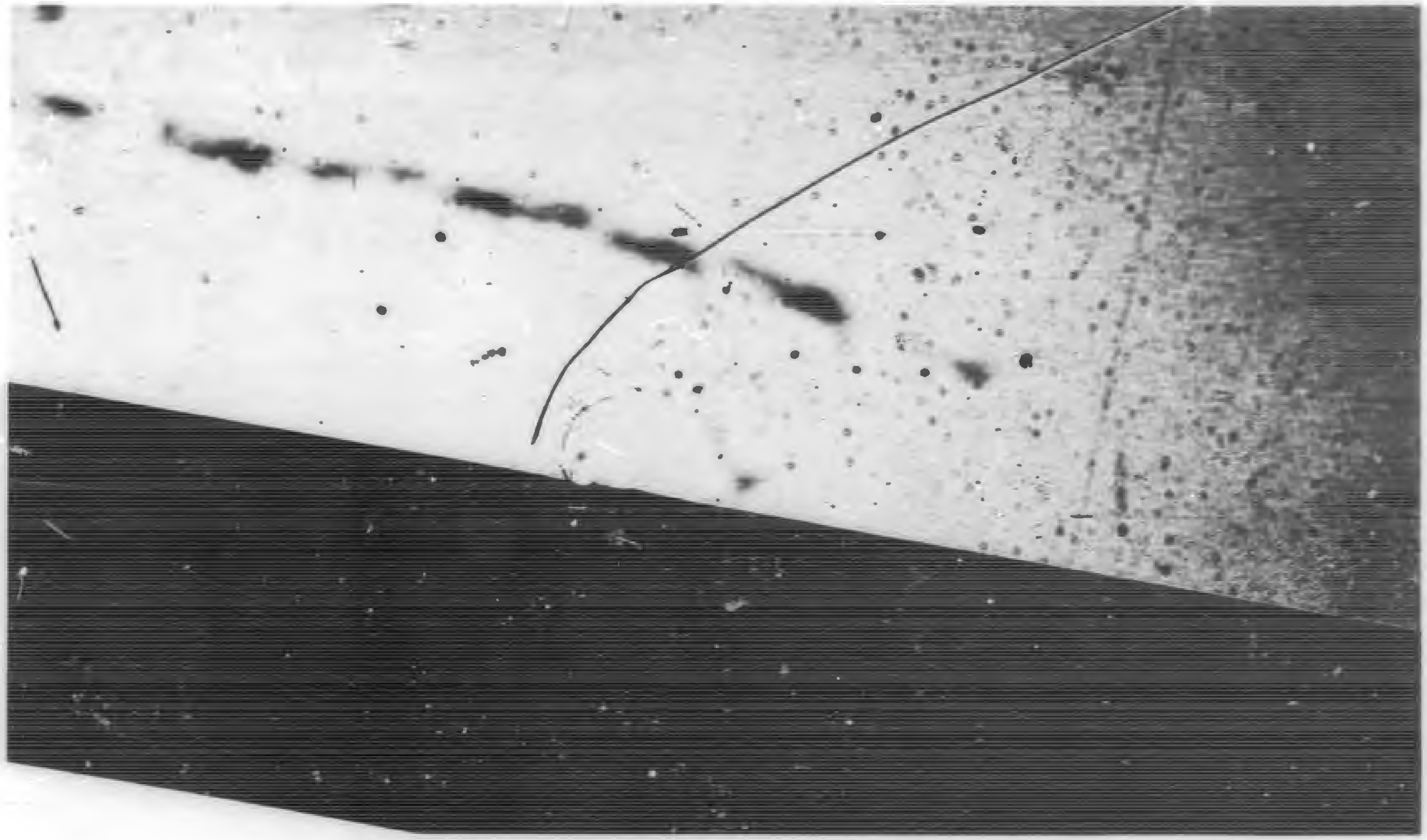

FIGURE C-3i. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_\infty = 100$

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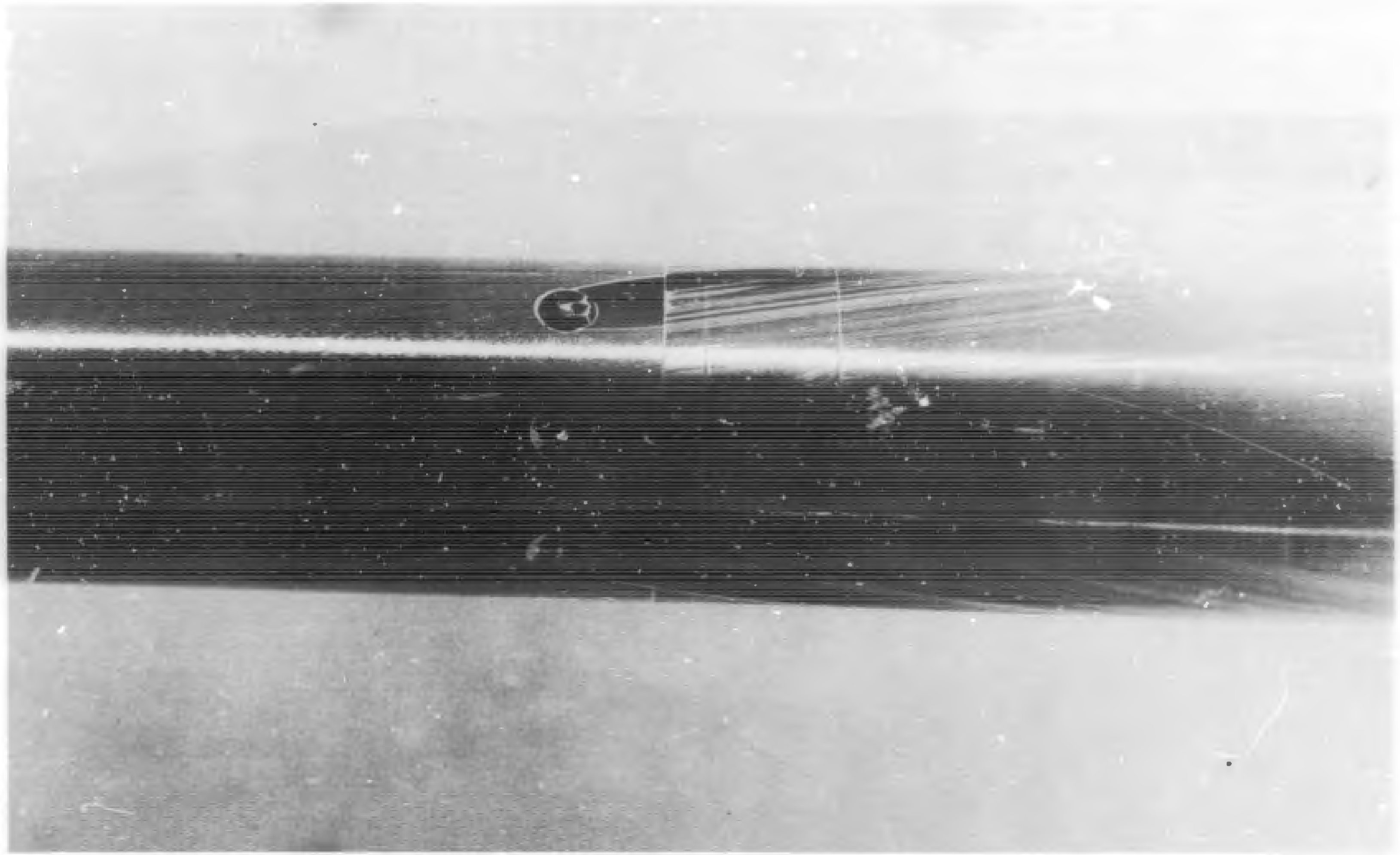

FIGURE C-4a. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_{\infty} = 0$

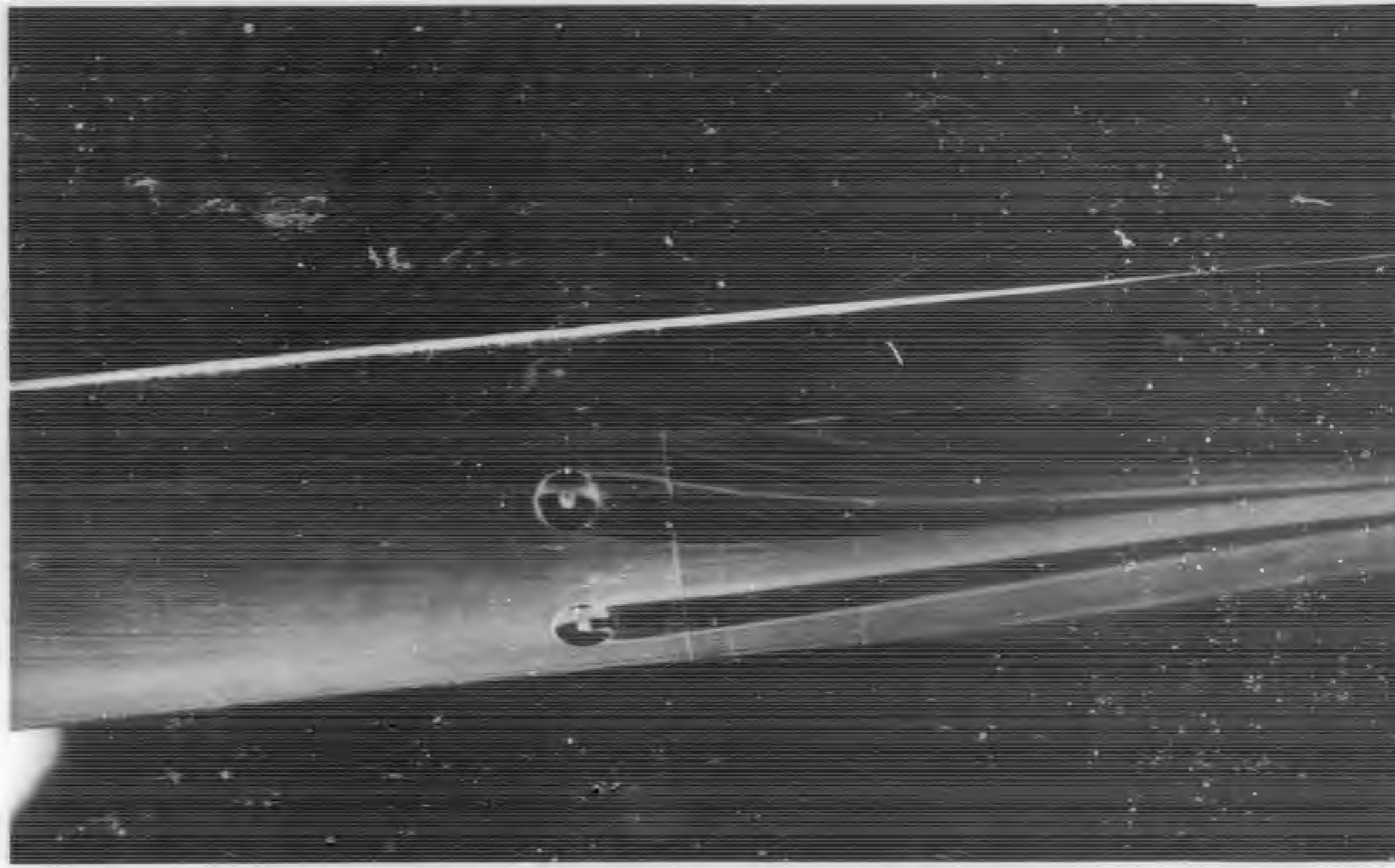

FIGURE C-4b. REACTION JET FOR $B_1C_1X_3$ WITH α = -5 DEGREES; P_{oj}/P_∞ = 0

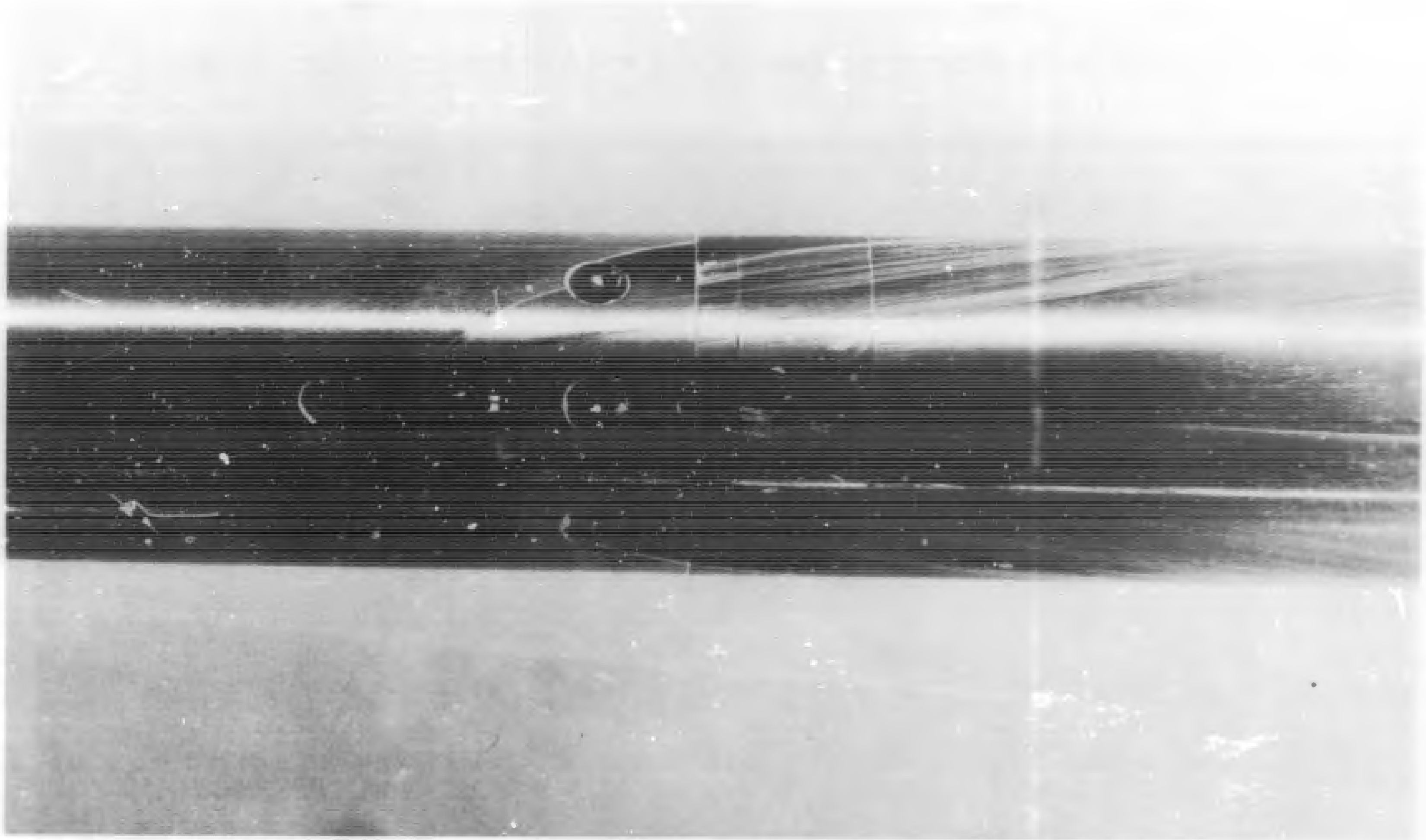

FIGURE C-4c. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_\infty = 10$

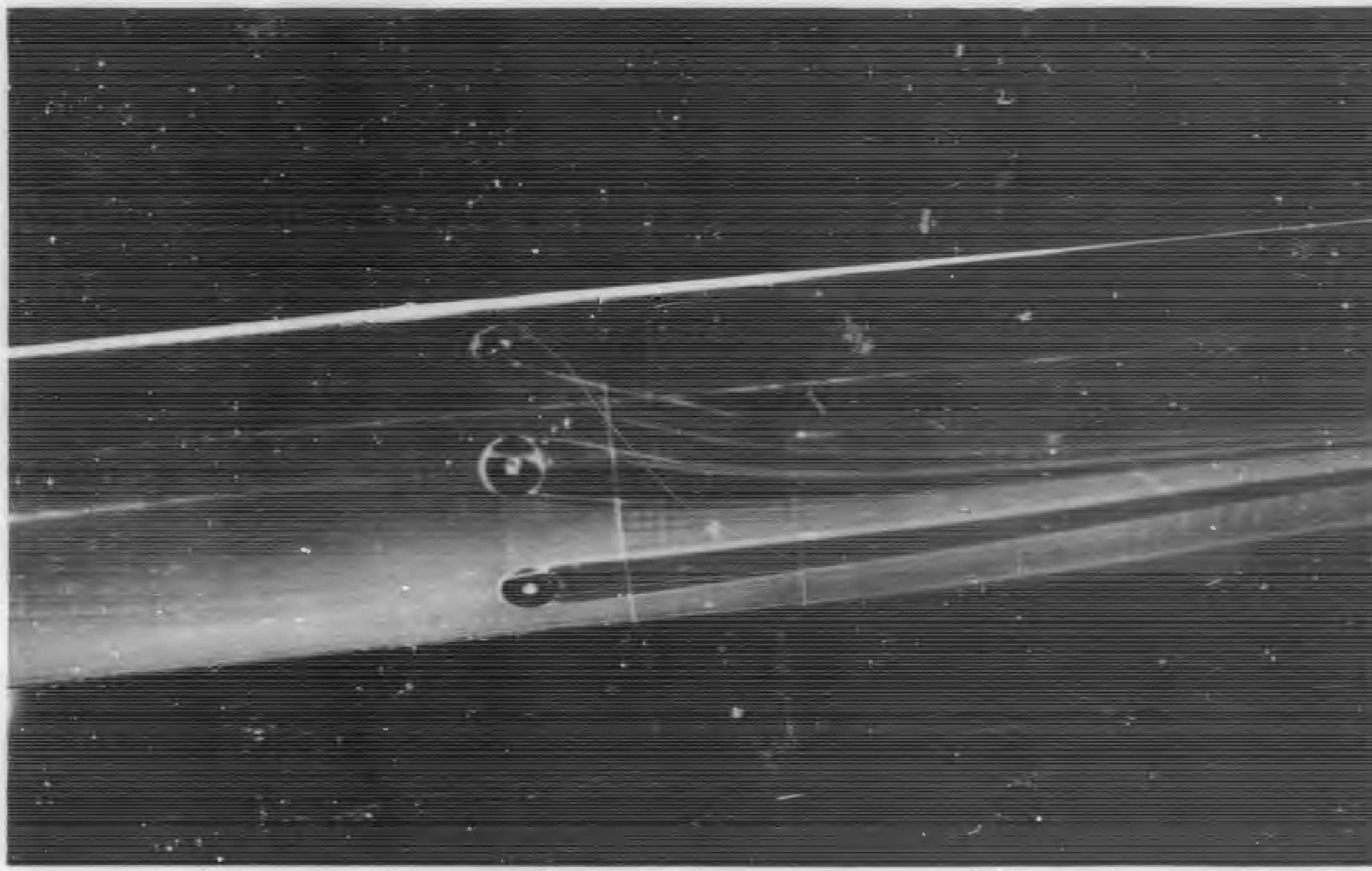

FIGURE C-4d. REACTION JET FOR $B_1C_1X_3$ WITH α = -5 DEGREES; P_{oj}/P_∞ = 10

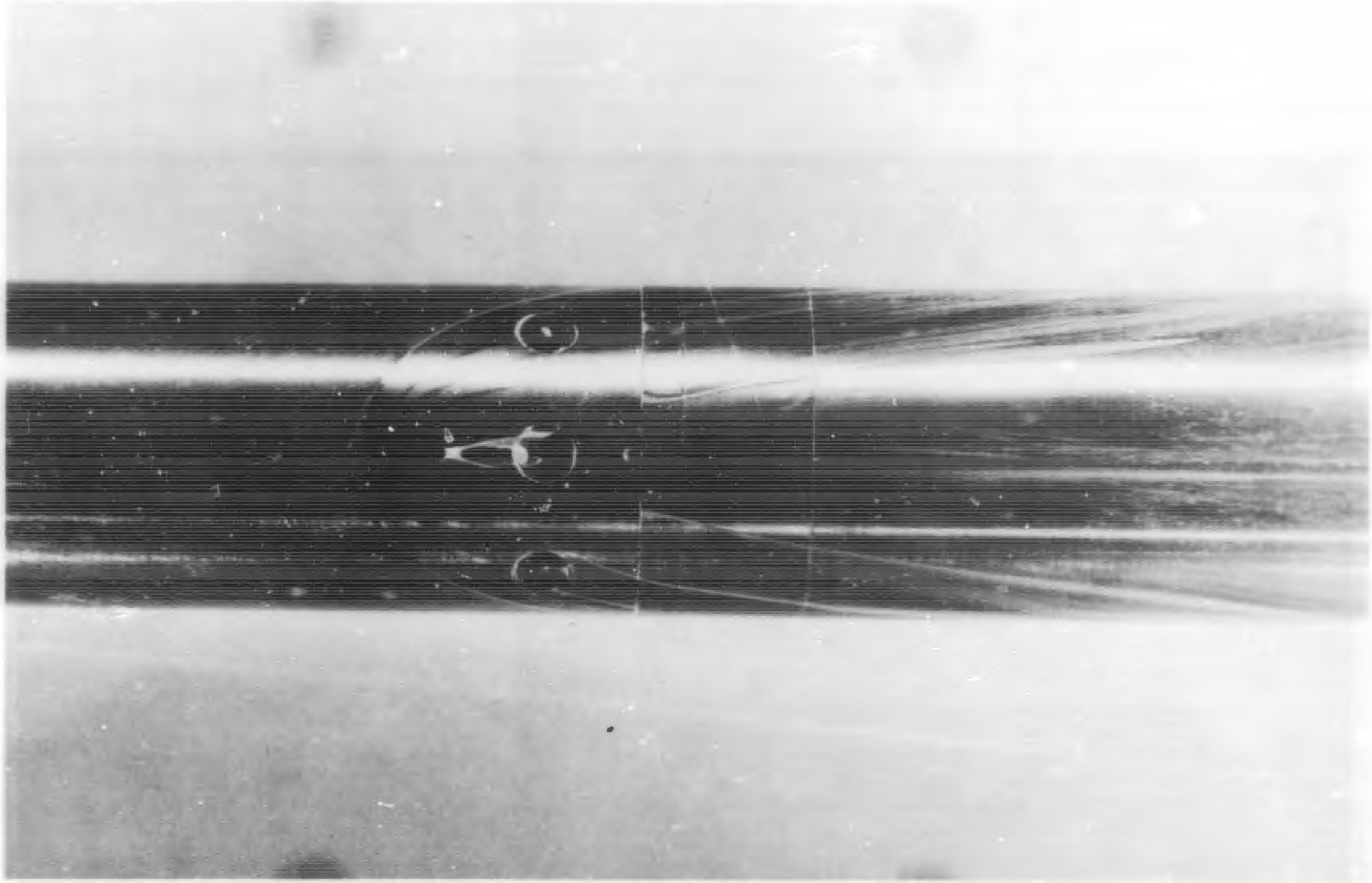

FIGURE C-4e. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_{\infty} = 40$

FIGURE C-4f. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_\infty = 40$

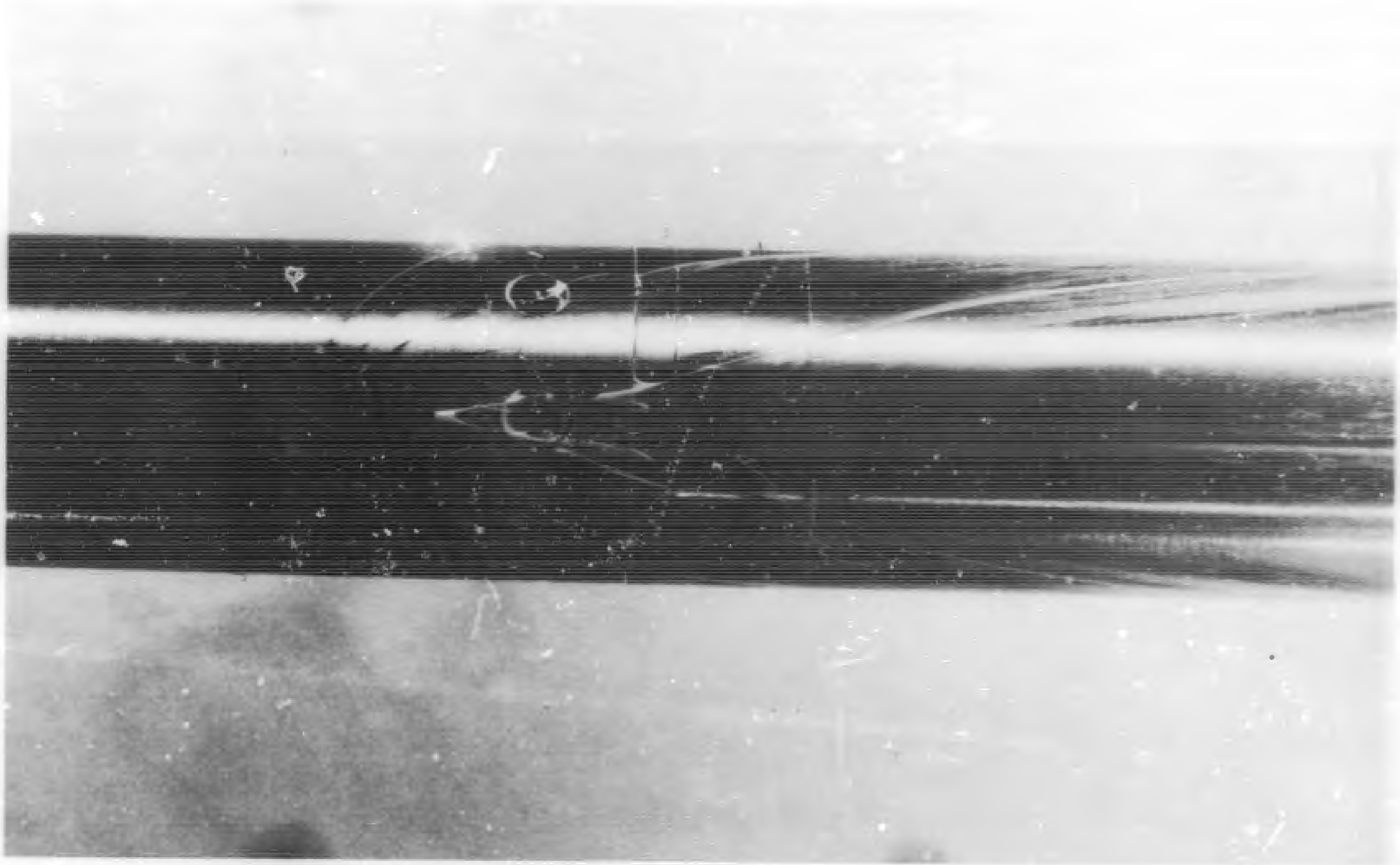

FIGURE C-4g. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_\infty = 100$

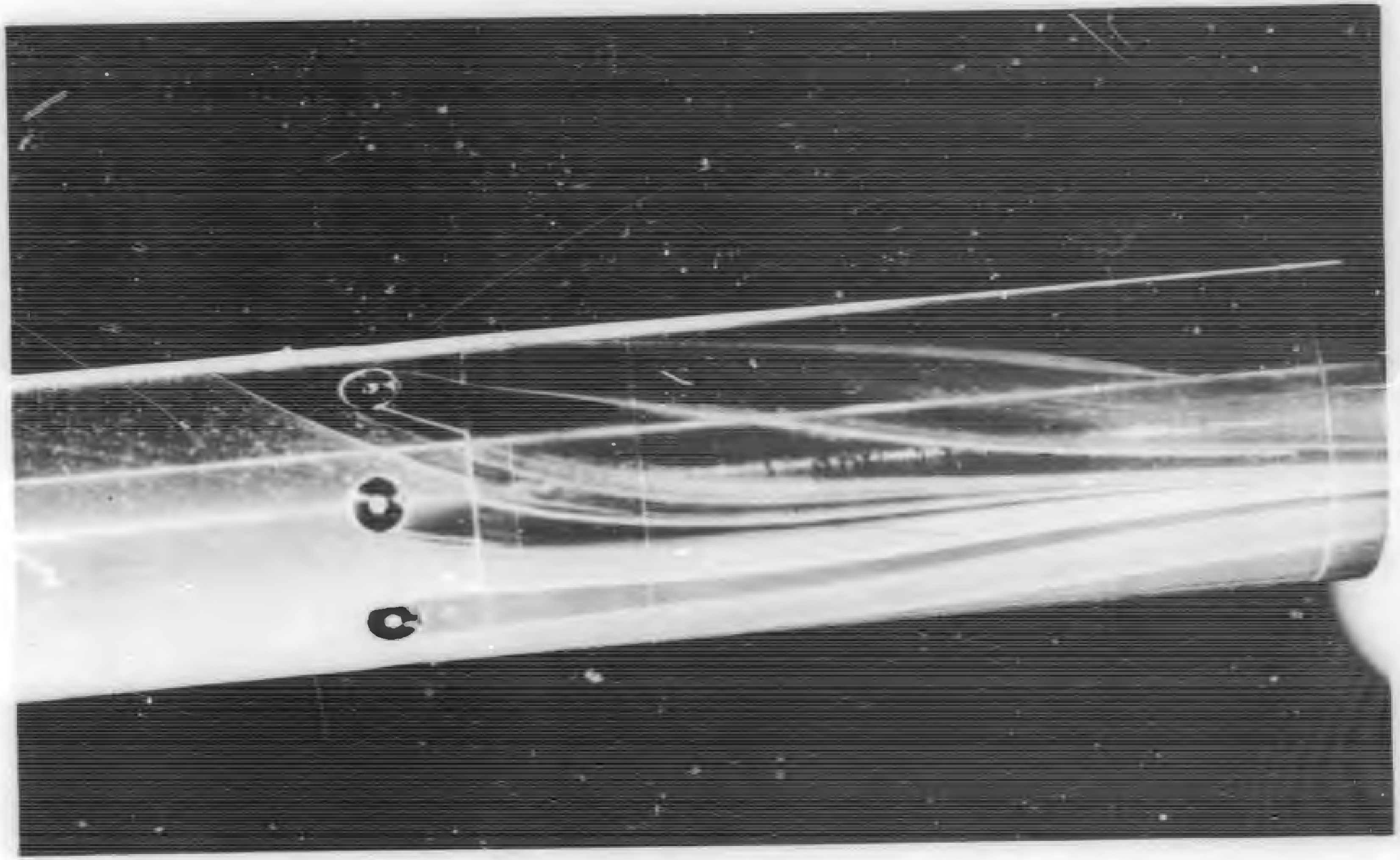

FIGURE C-4h. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_{\infty} = 100$

FIGURE C–4i. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_\infty = 100$

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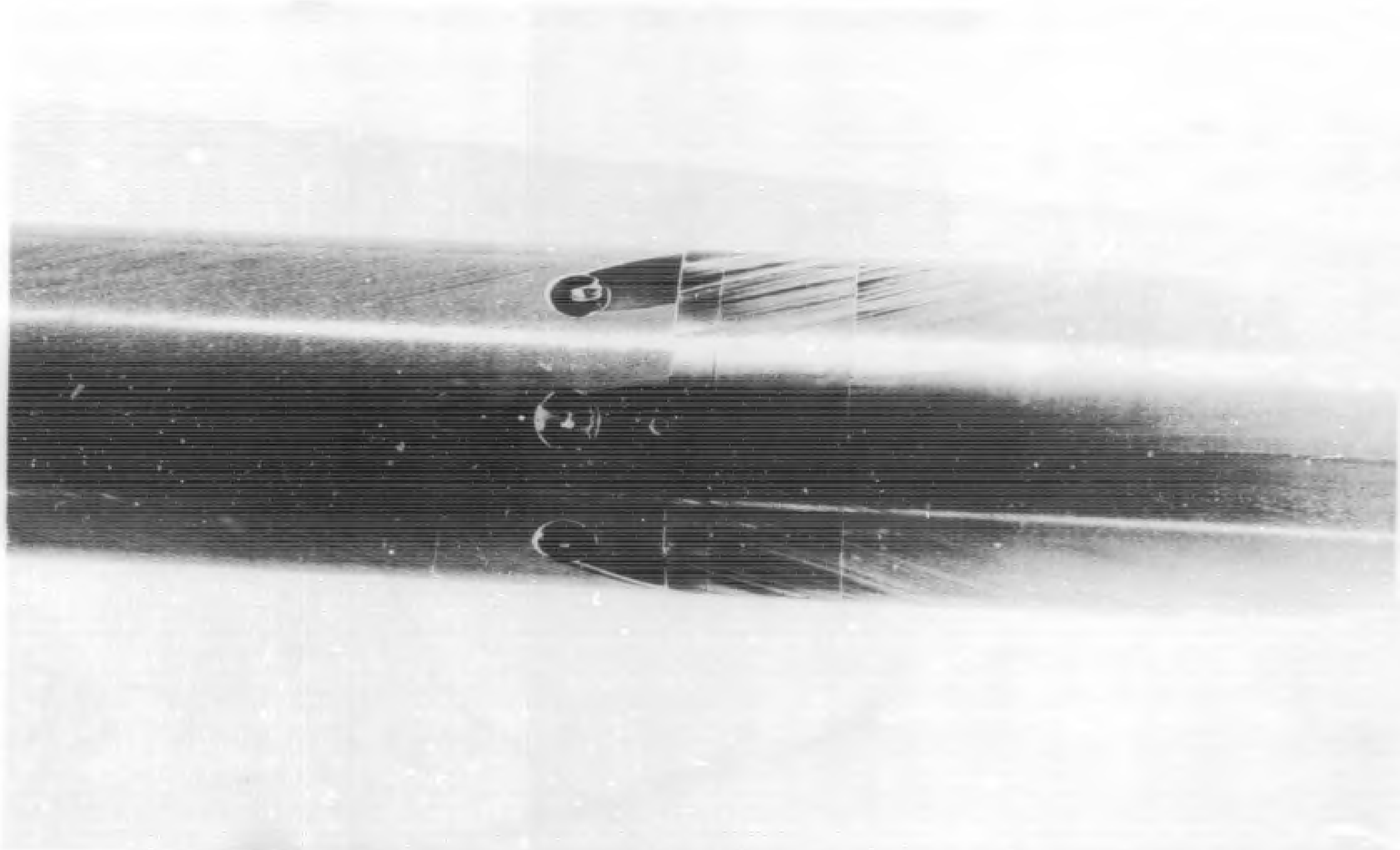

FIGURE C-5a. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_\infty = 0$

FIGURE C-5b. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_\infty = 0$

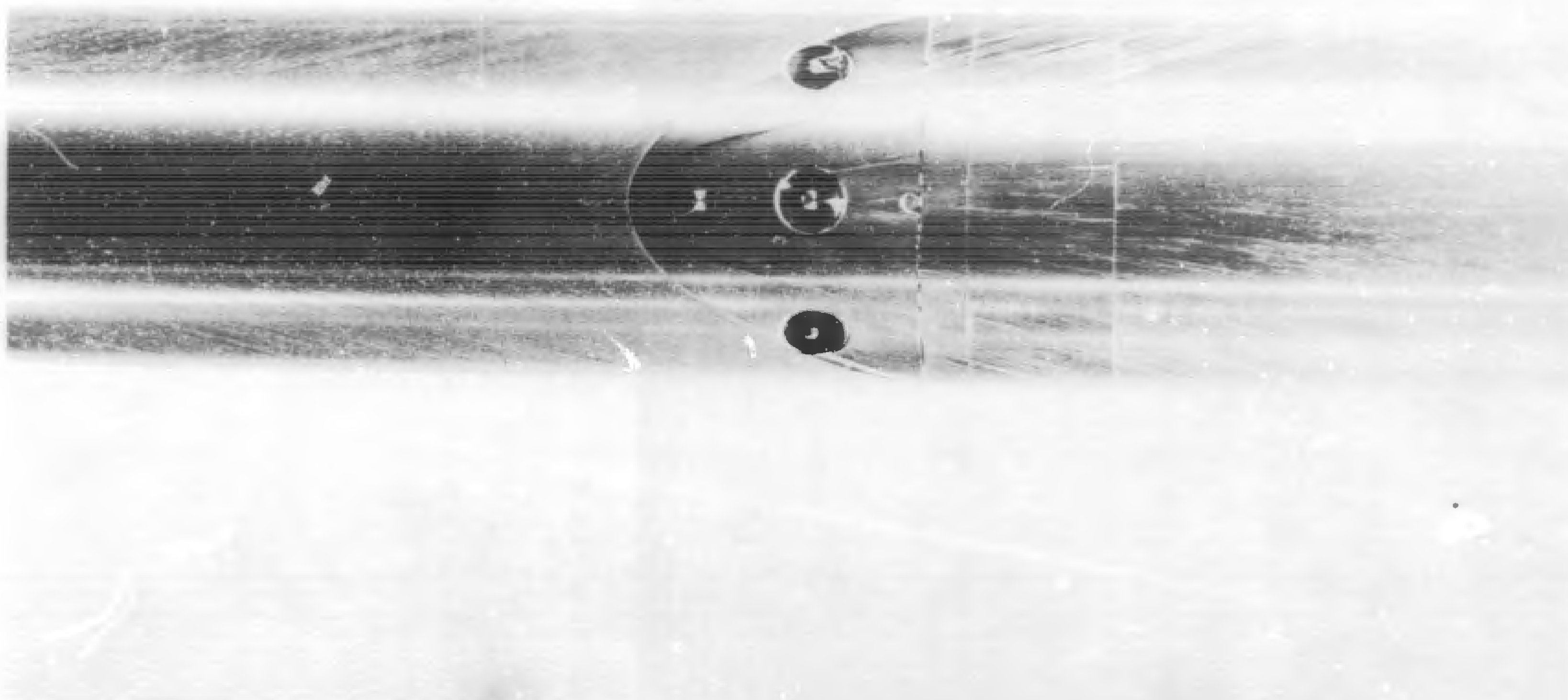

FIGURE C-5c. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_\infty = 10$

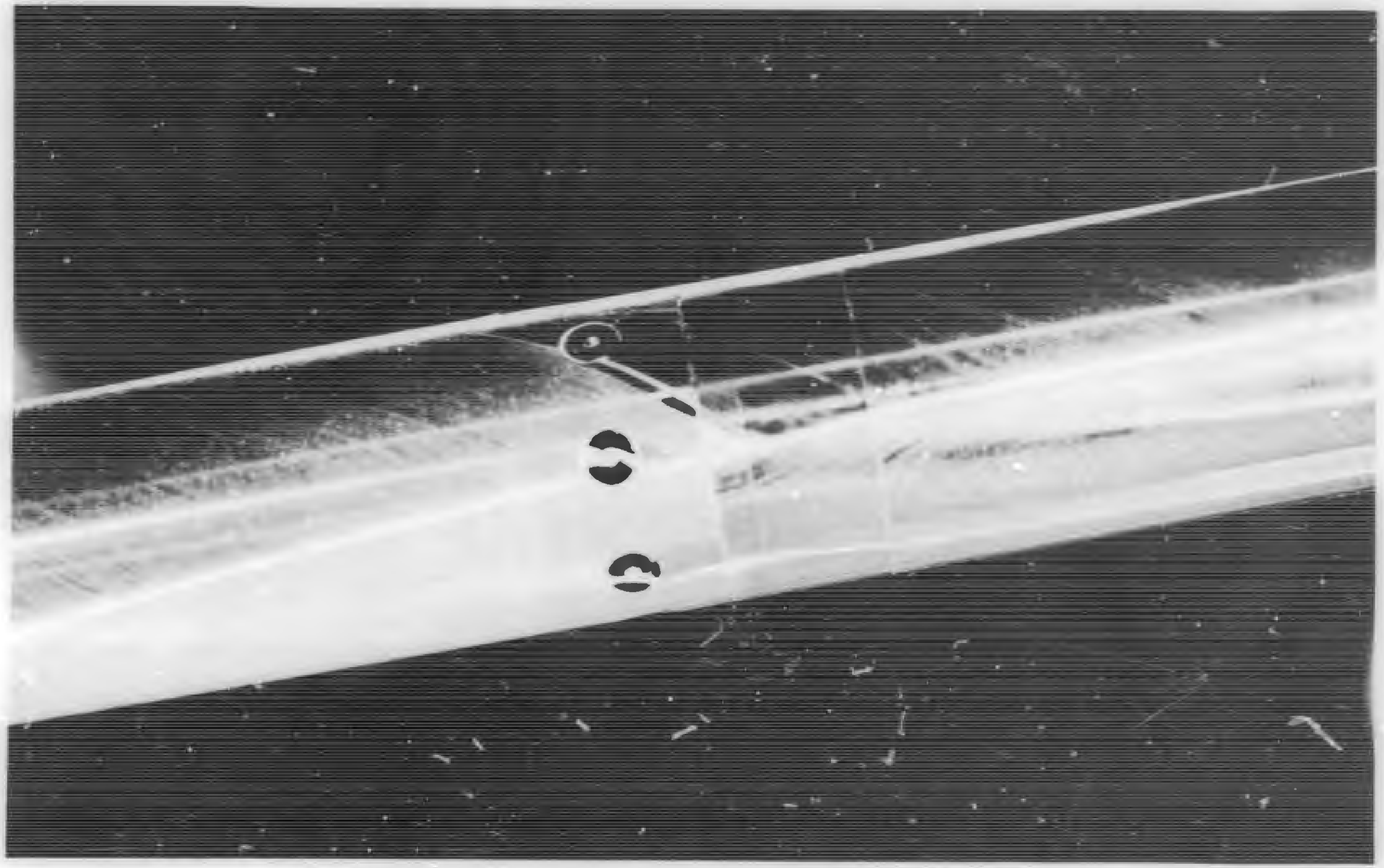

FIGURE C-5d. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_{\infty} = 10$

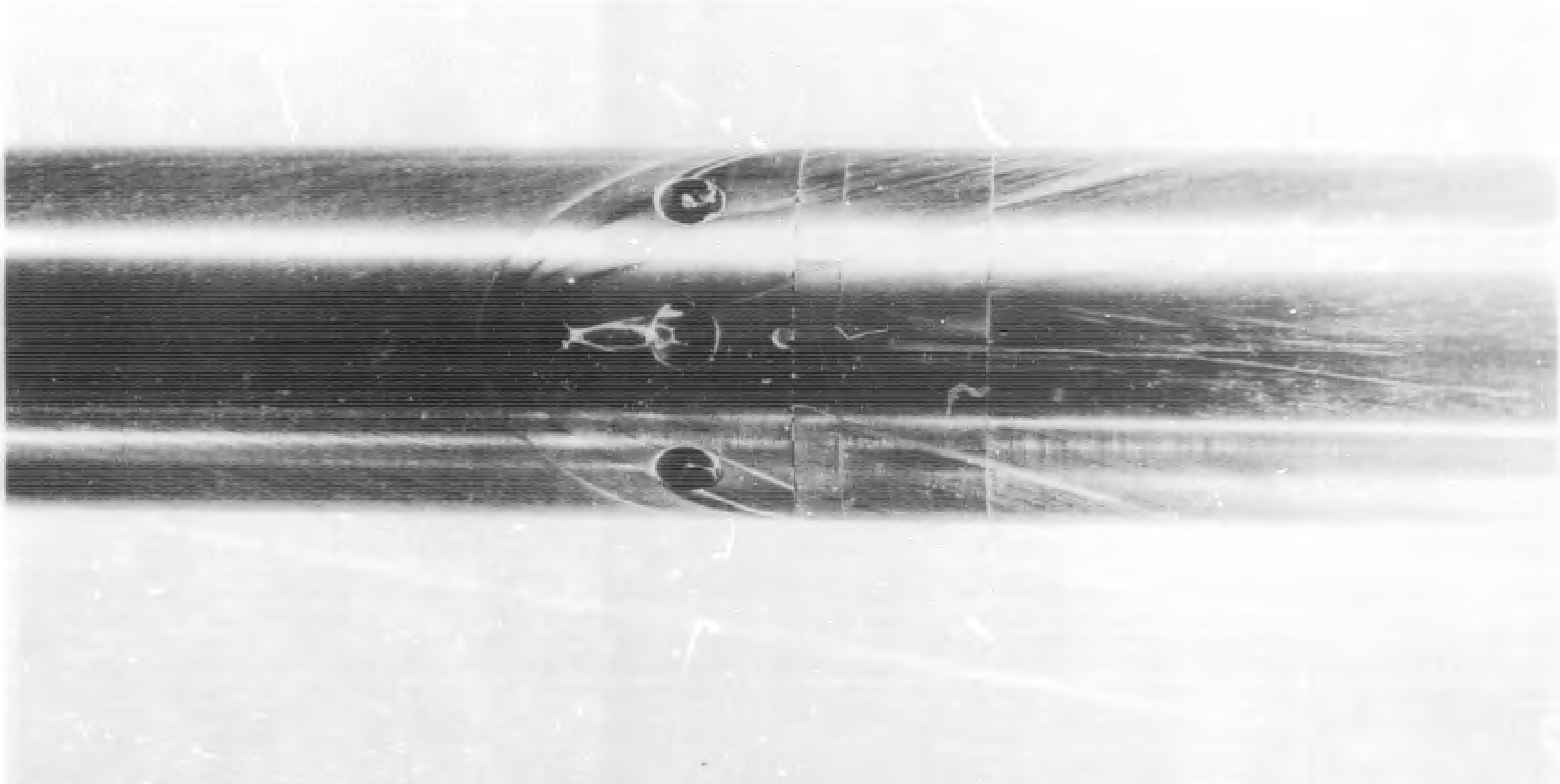

FIGURE C-5e. REACTION JET FOR $B_1C_1X_3$ WITH α = -10 DEGREES; P_{oj}/P_{∞} = 40

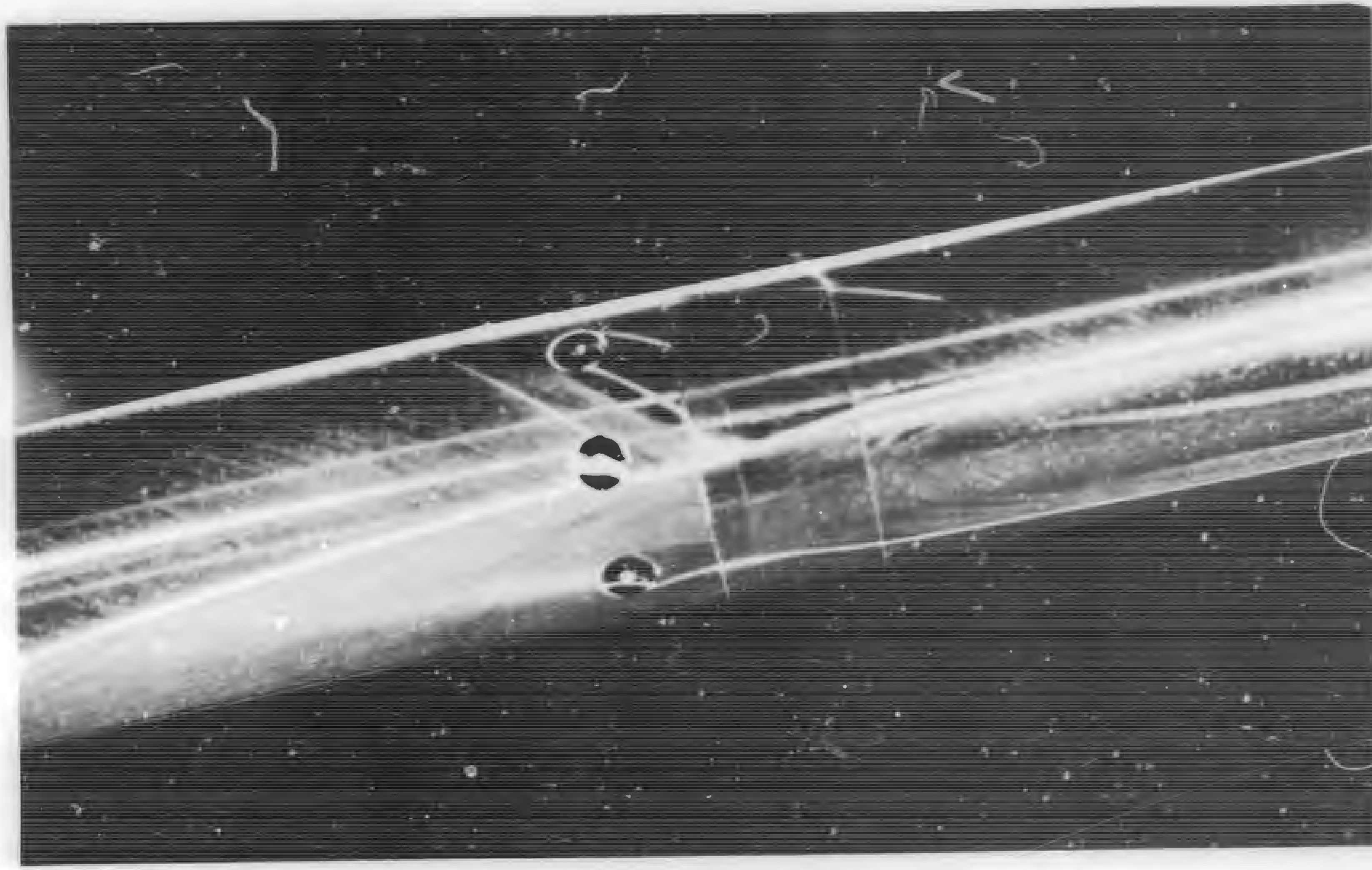

FIGURE C-5f. REACTION JET FOR $B_1C_1X_3$ WITH α = -10 DEGREES; P_{oj}/P_∞ = 40

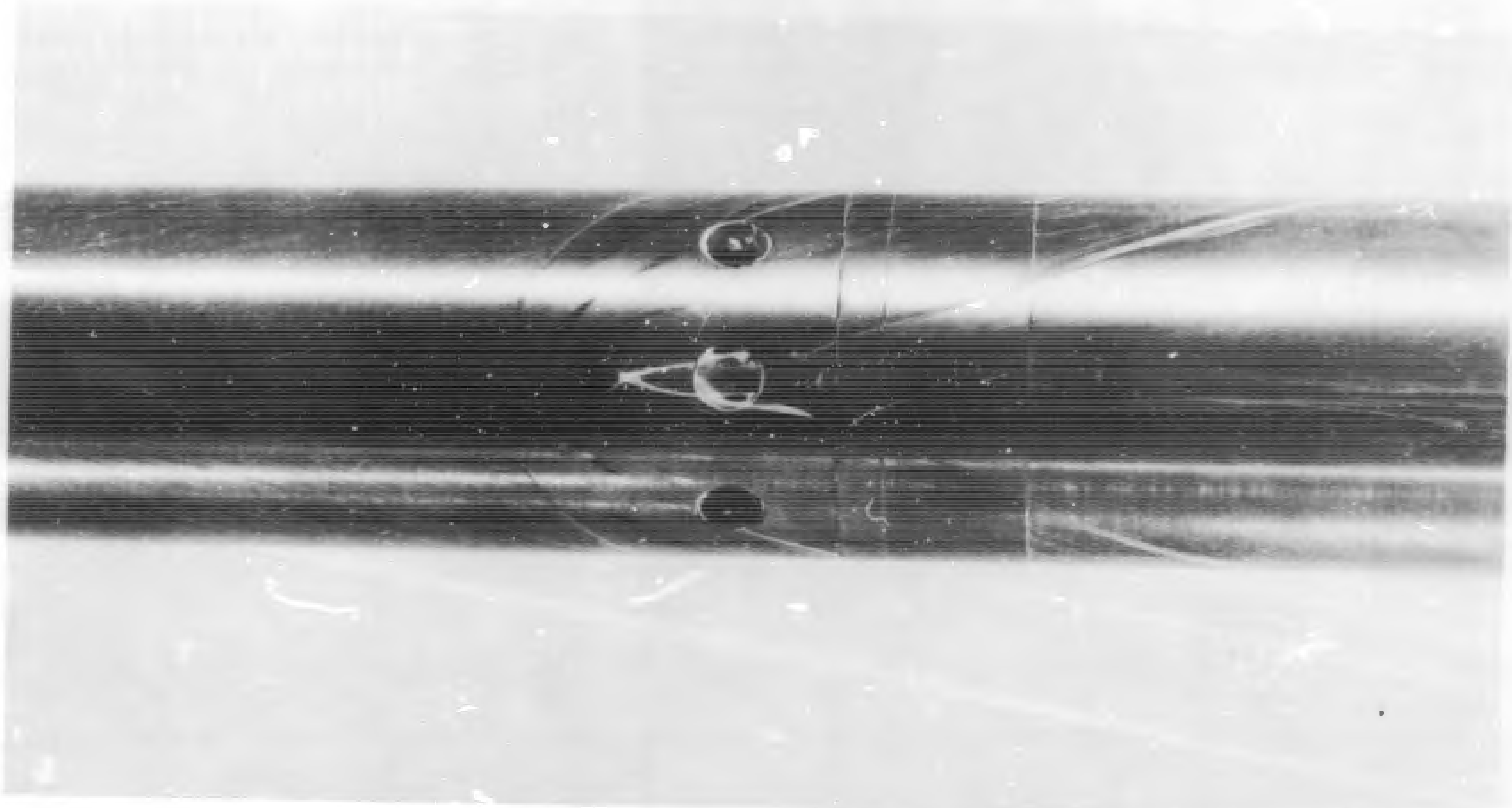

FIGURE C-5g. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_\infty = 100$

FIGURE C-5h. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_{\infty} = 100$

FIGURE C-5i. REACTICN JET FOR $B_1C_1X_3$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_\infty = 100$

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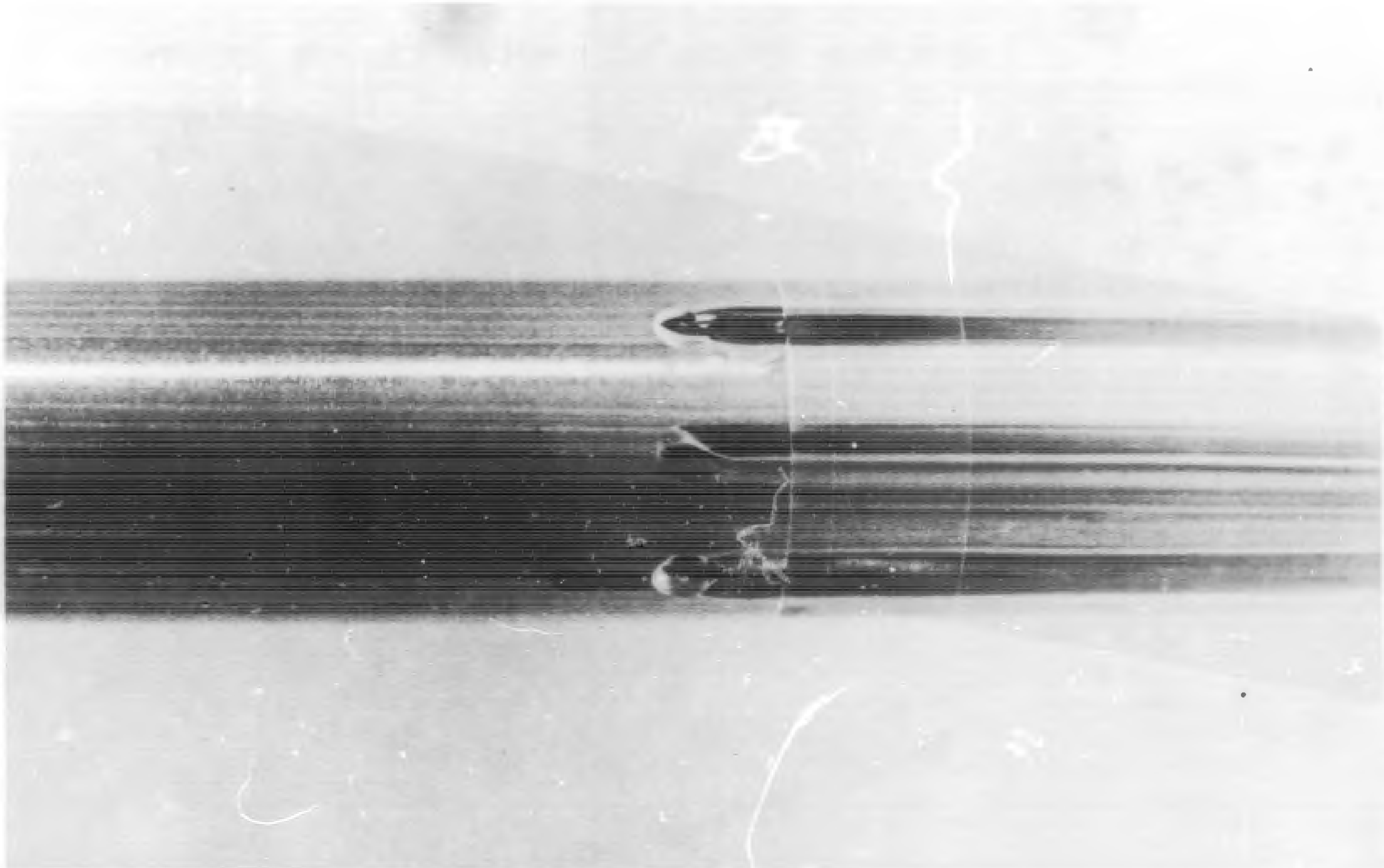

FIGURE C-6a. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 0$

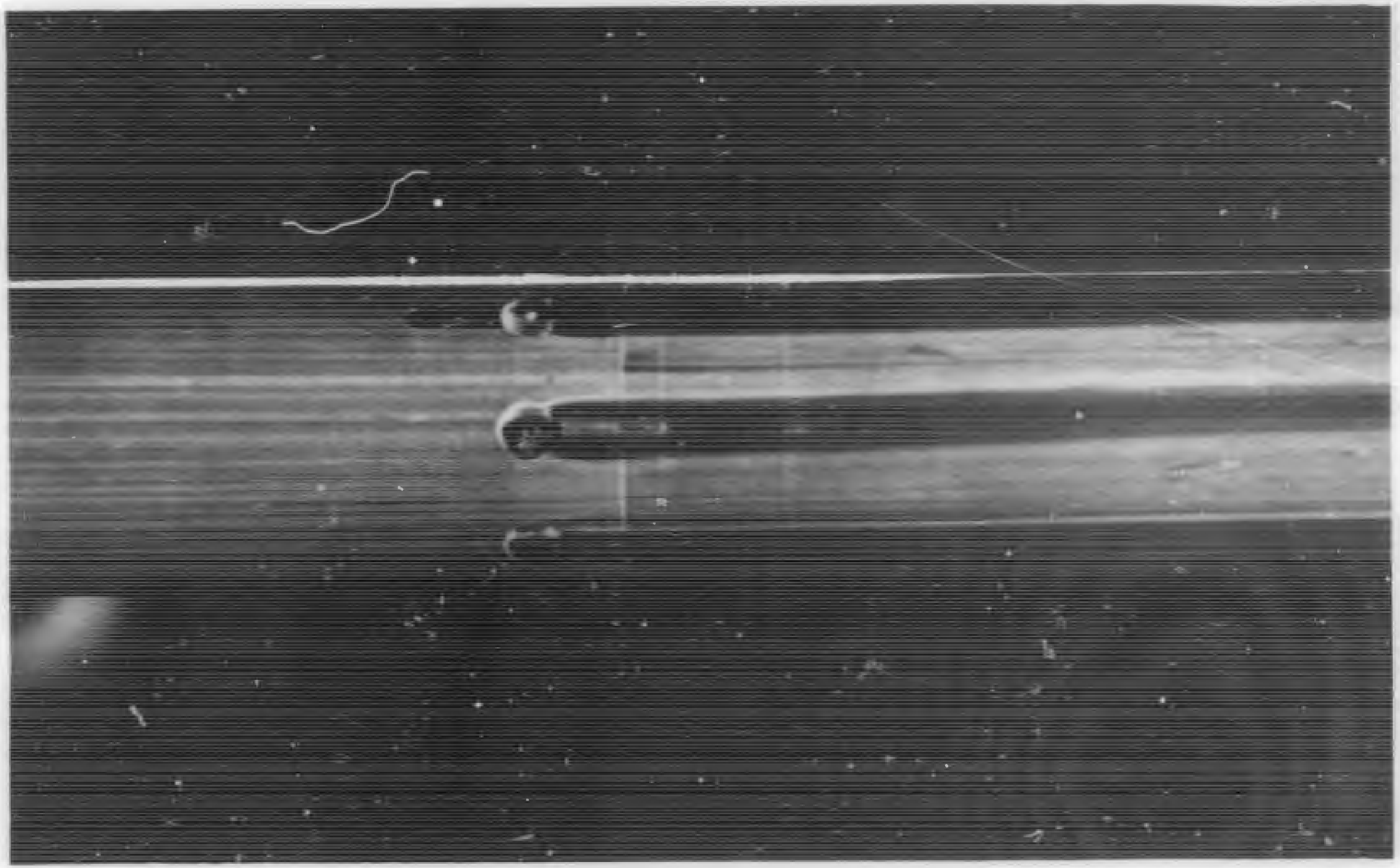

FIGURE C-6b. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 0$

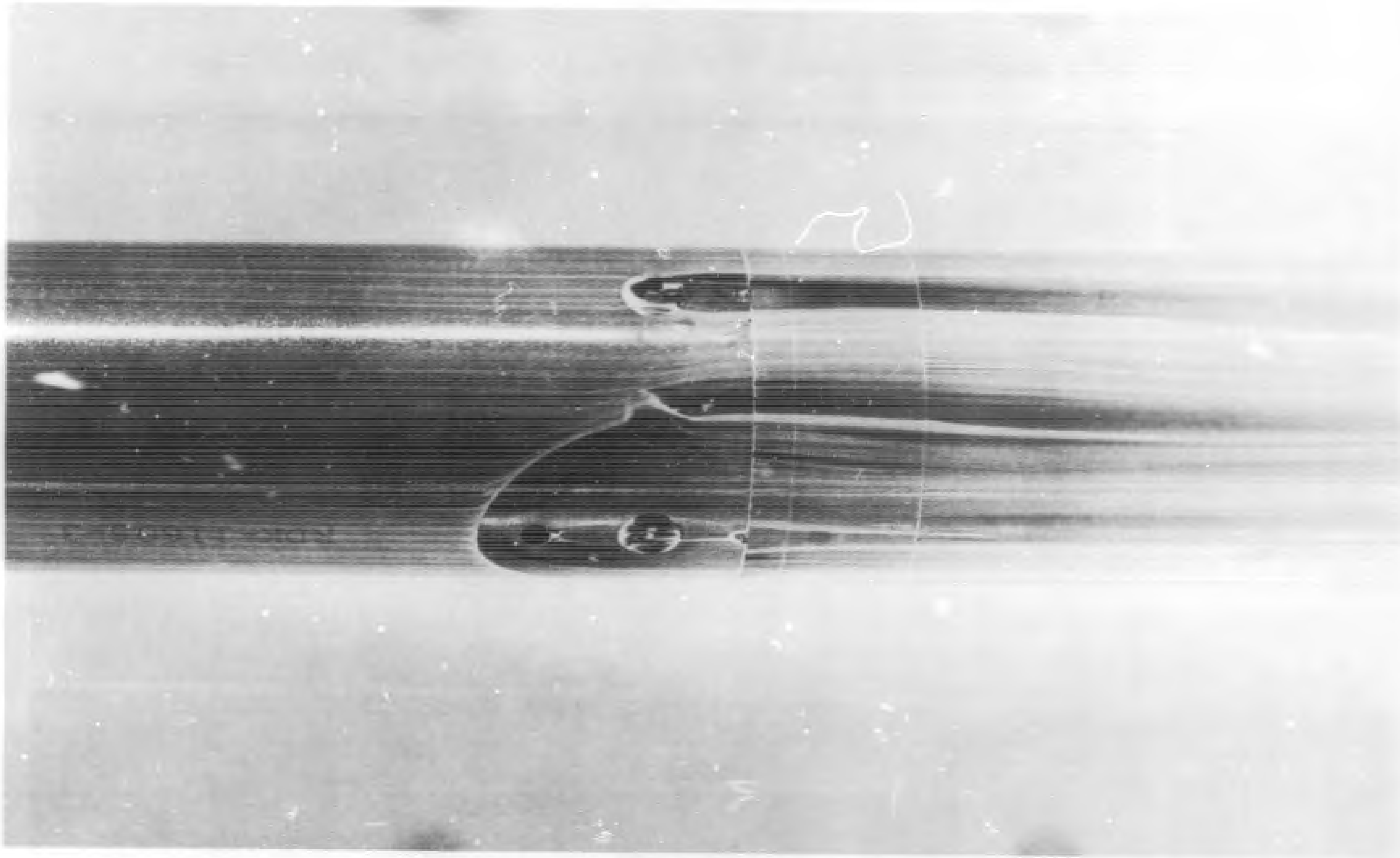

FIGURE C-6c. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_{\infty} = 10$

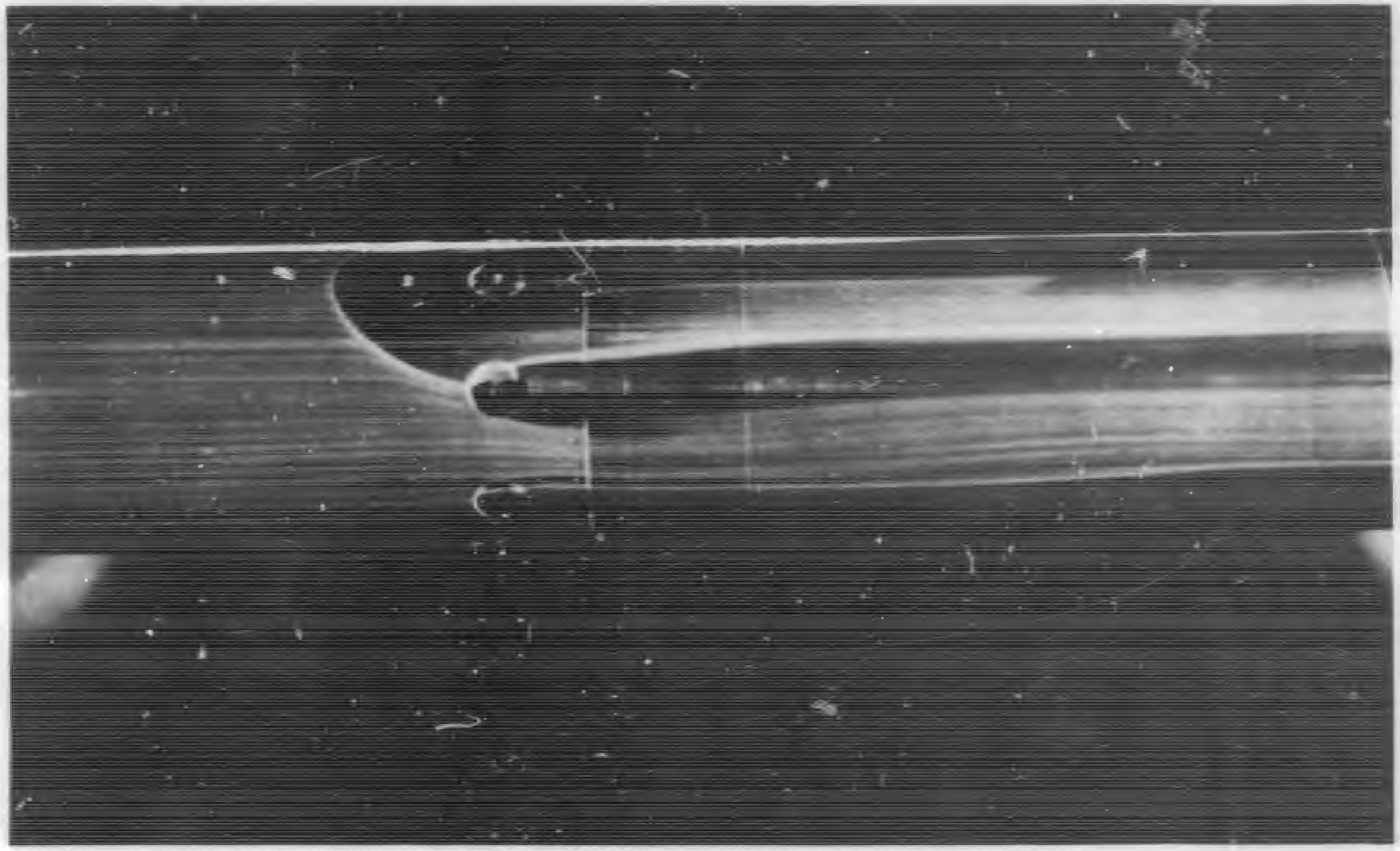

FIGURE C-6d. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 10$

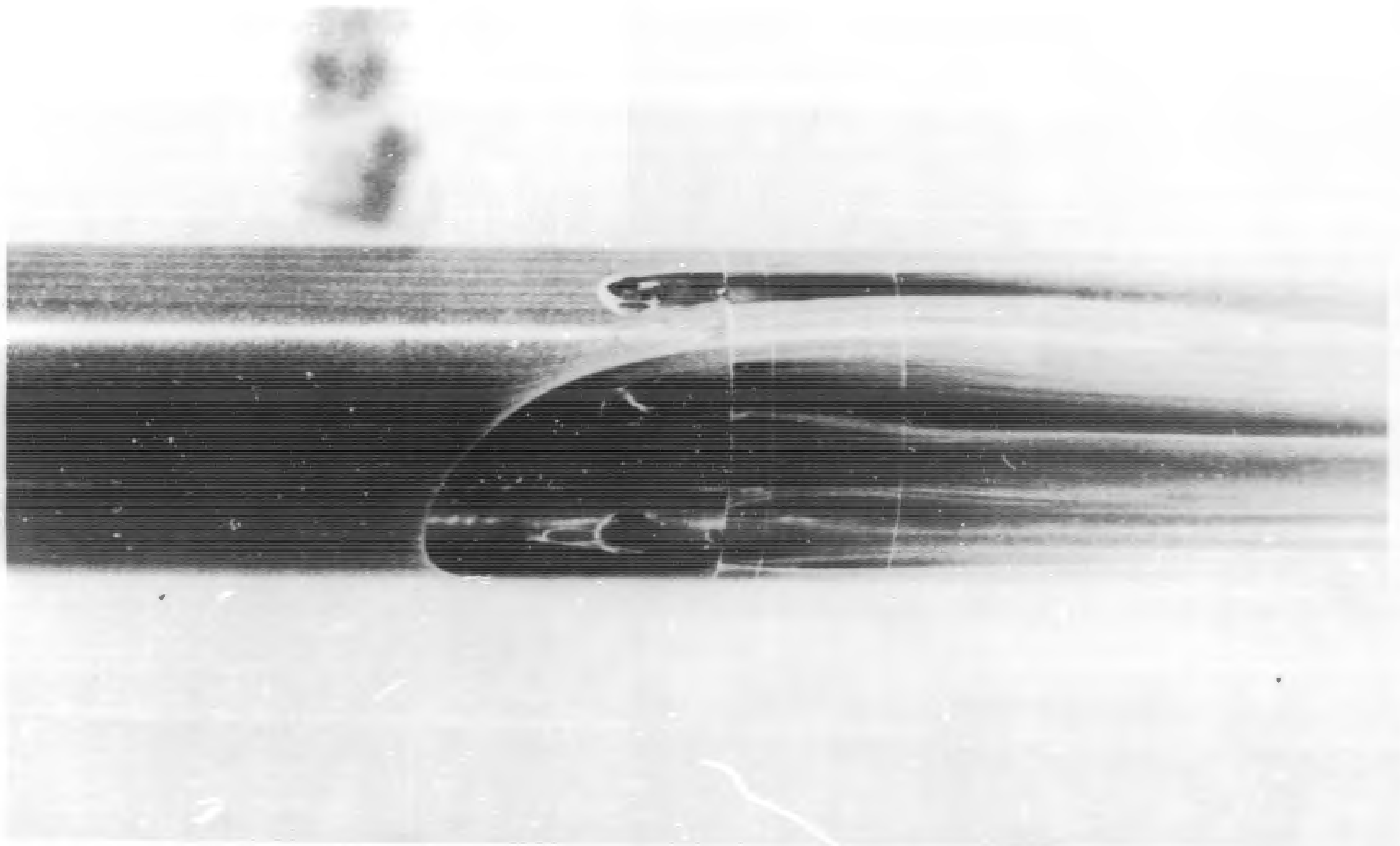

FIGURE C-6e. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 40$

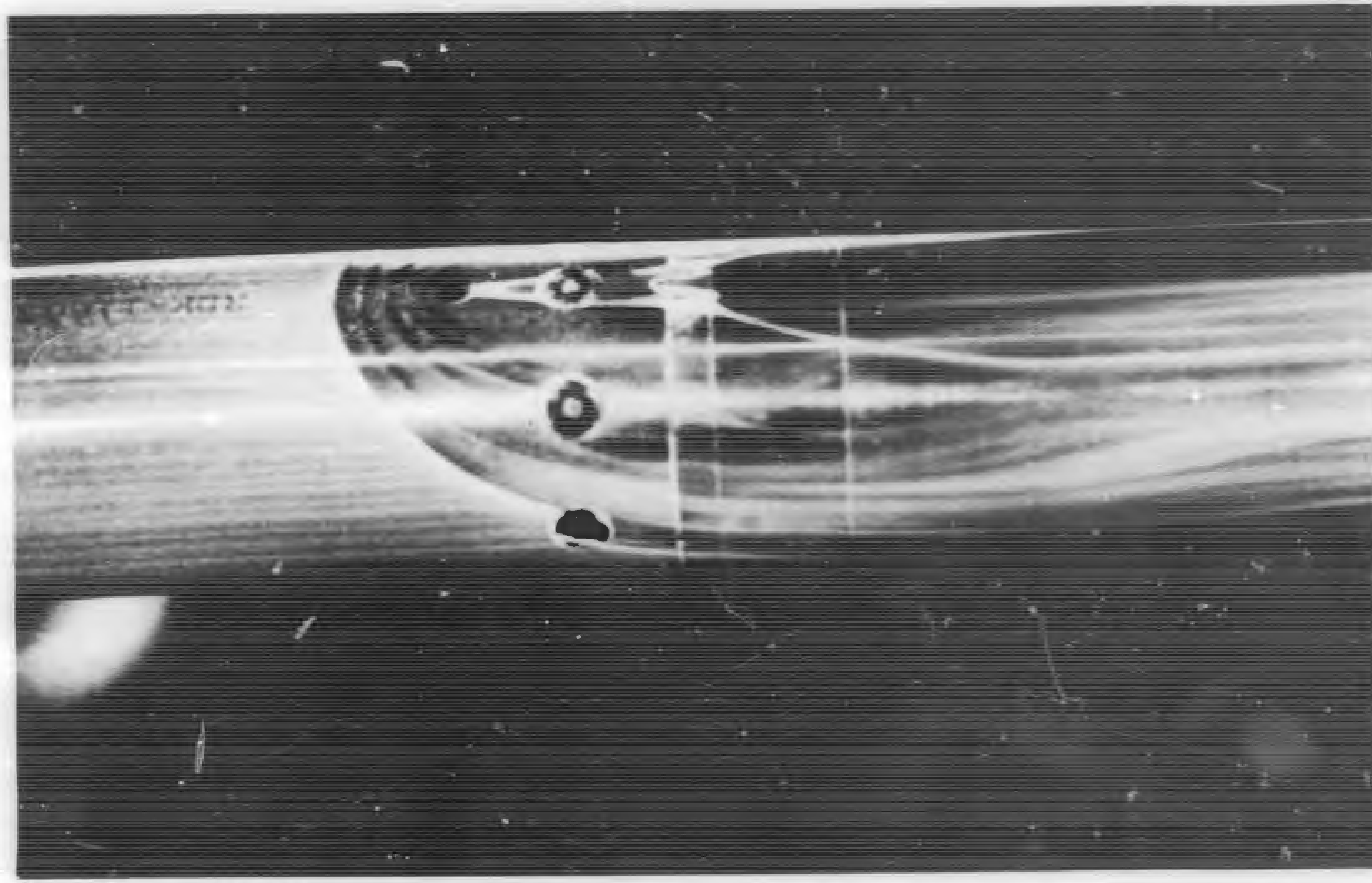

FIGURE C-6f. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 40$

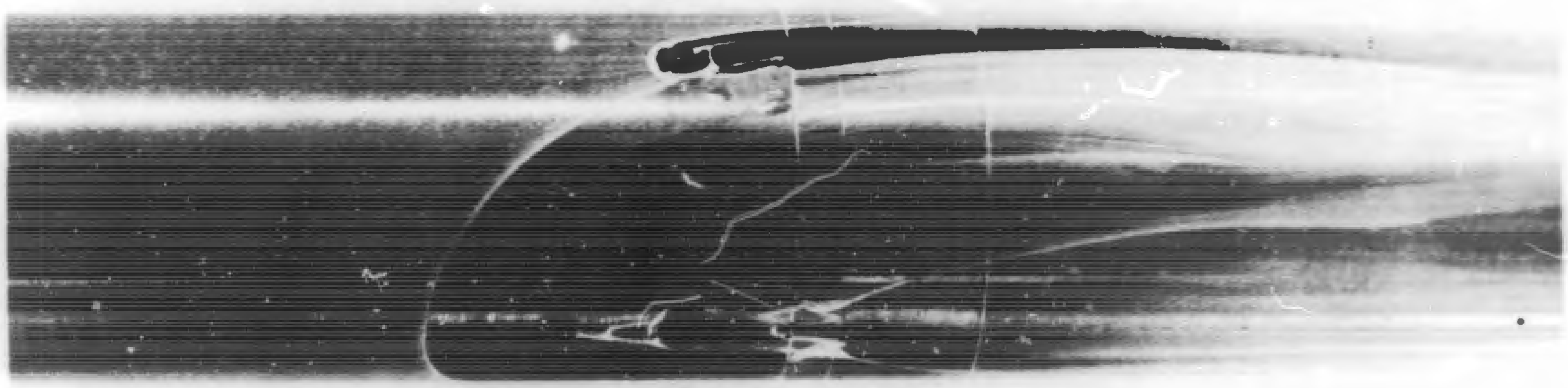

FIGURE C-6g. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 100$

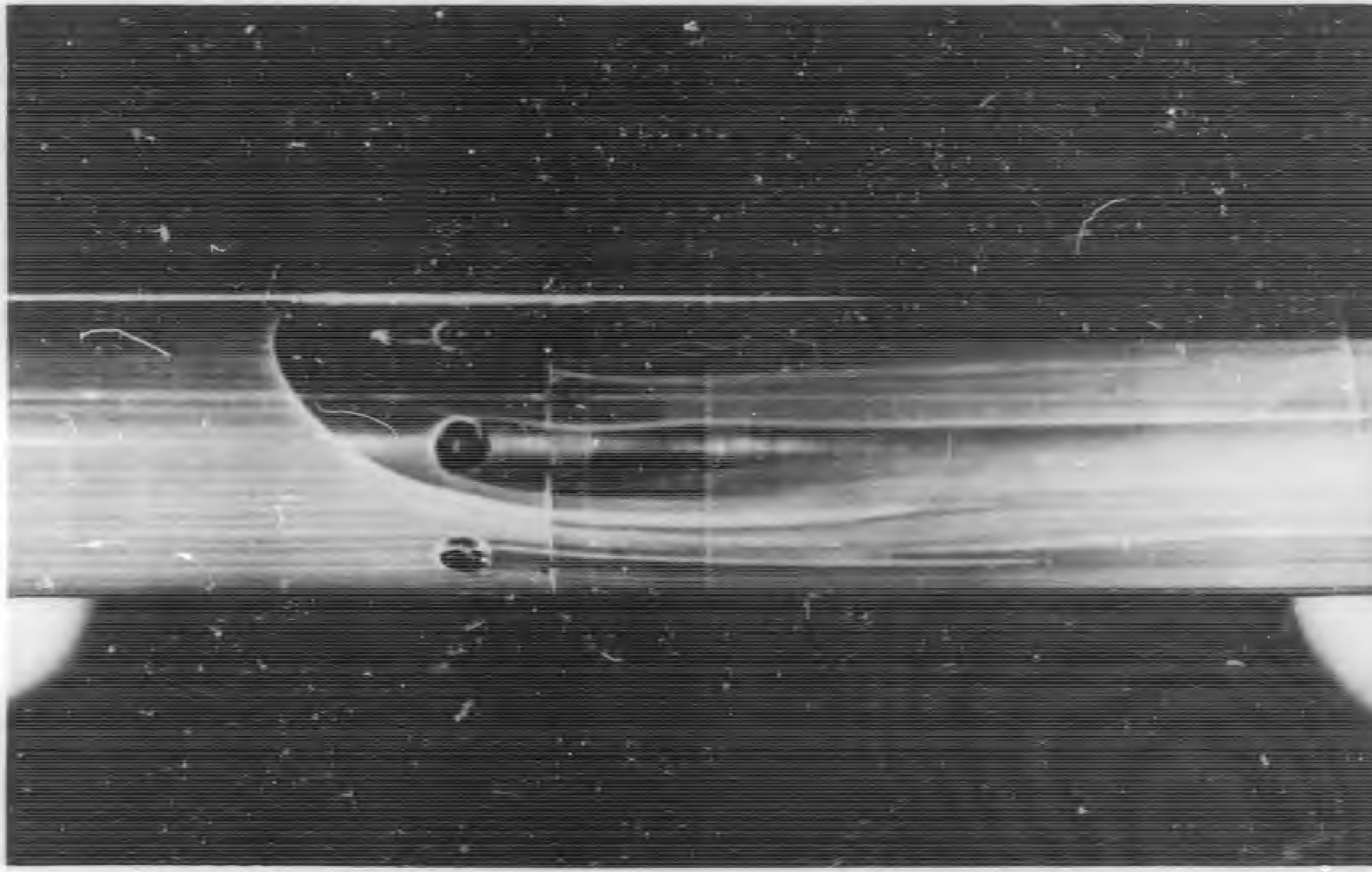

FIGURE C-6h. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_{\infty} = 100$

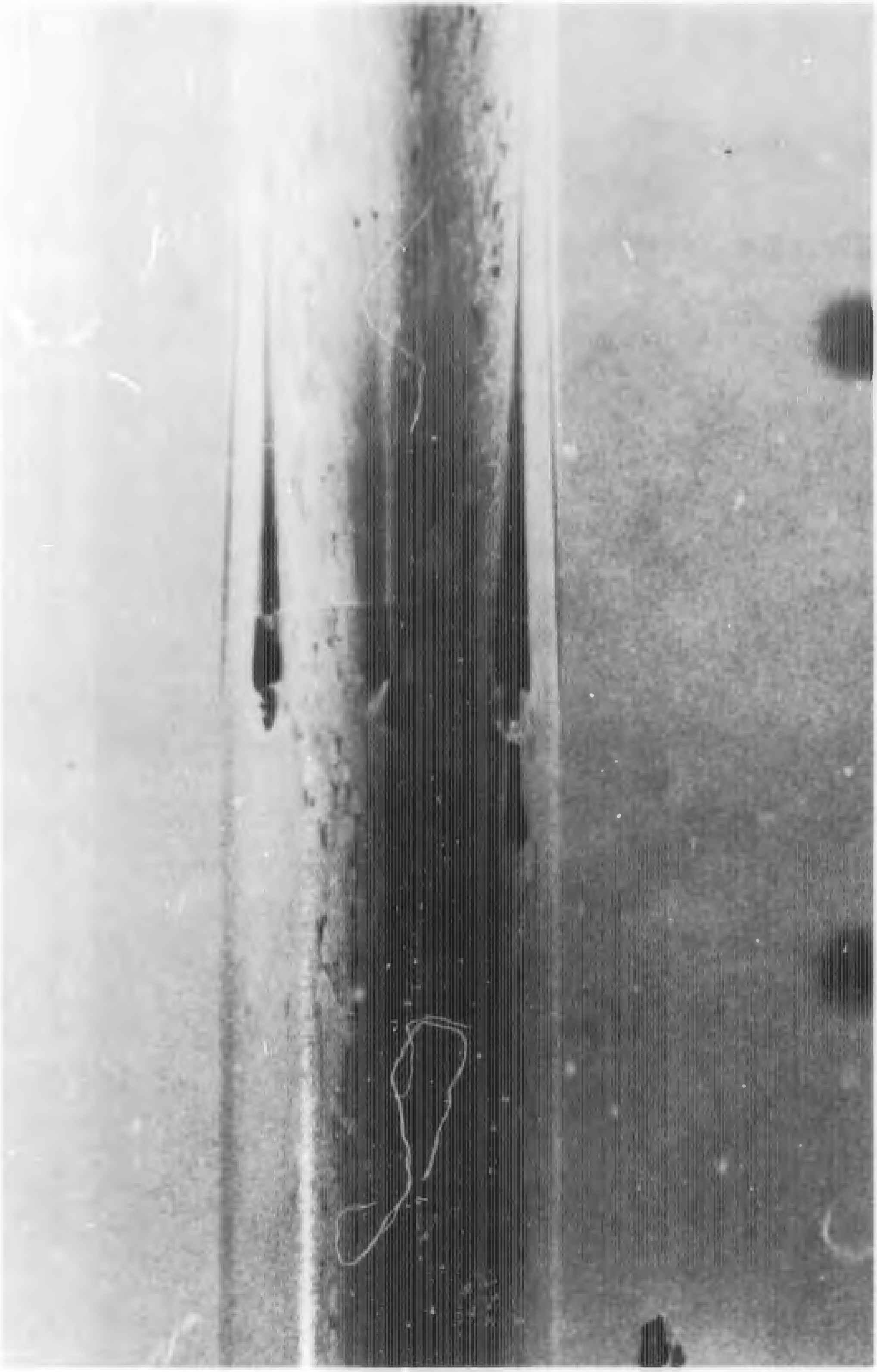

FIGURE C-7a. REACTION JET FOR $B_1C_1X_3$ WITH α = 5 DEGREES; P_{oj}/P_∞ = 0

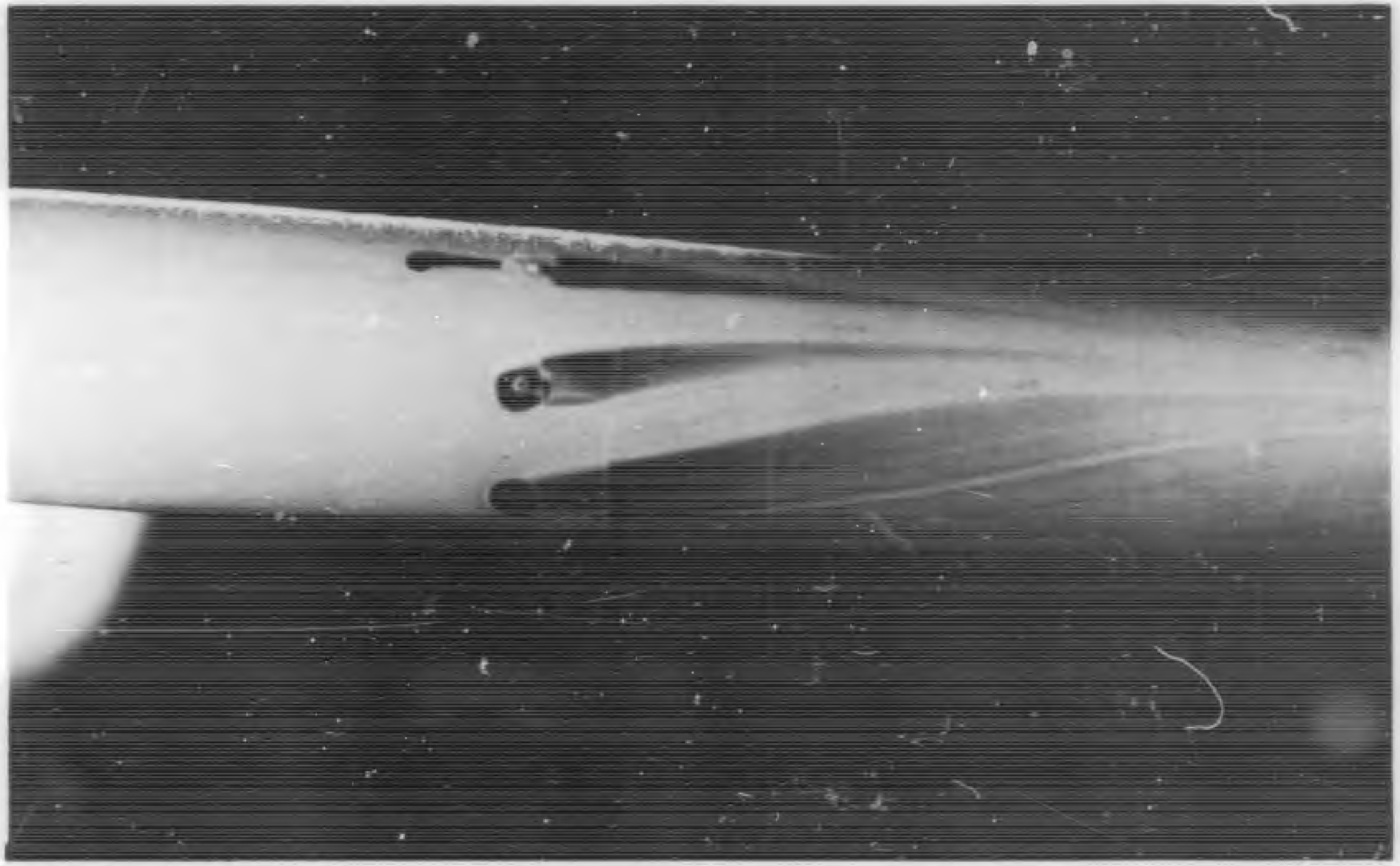

FIGURE C-7b. REACTION JET FOR $B_1C_1X_3$ WITH α = 5 DEGREES; $P_{oj}/P_{\infty} = 0$

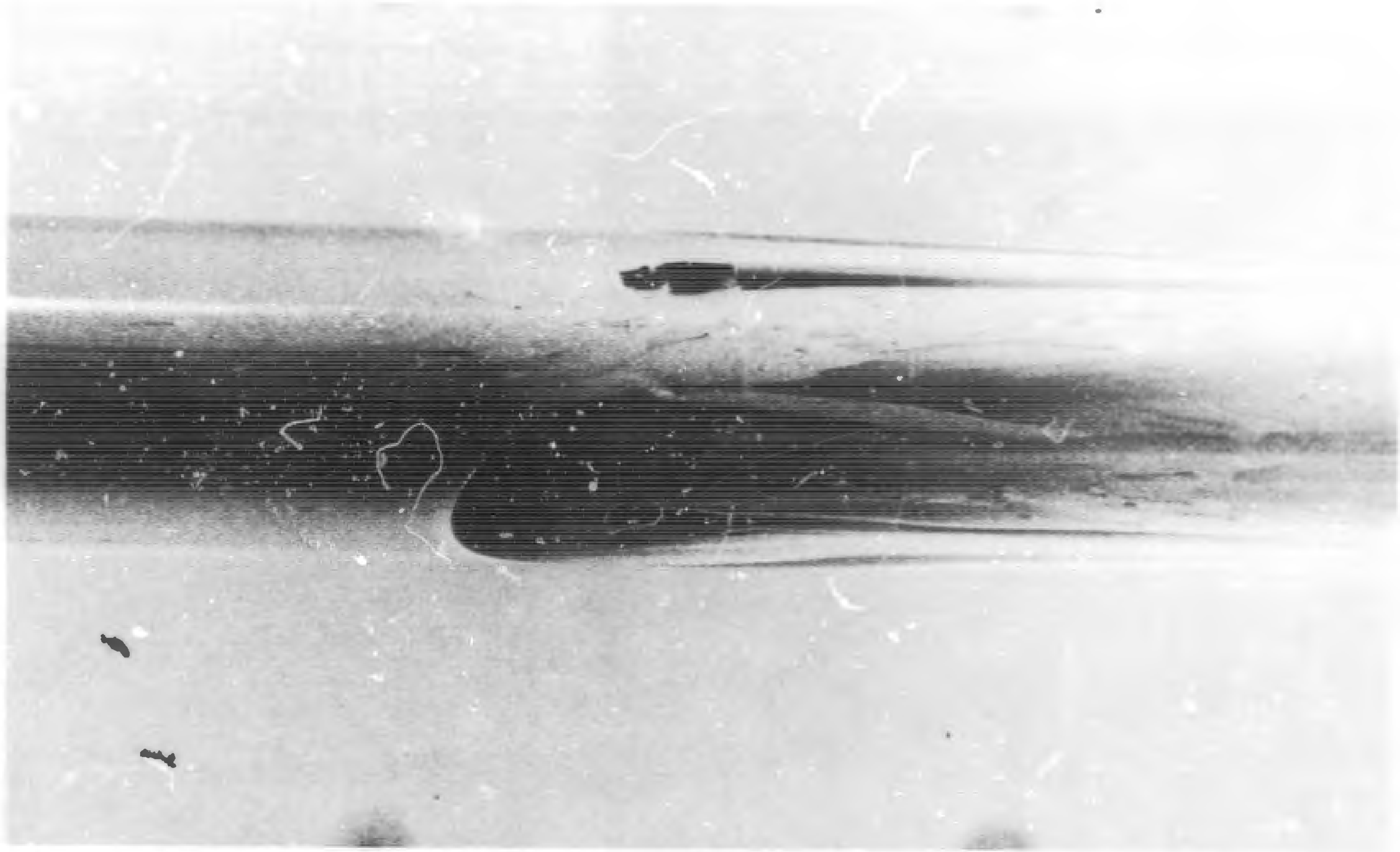

FIGURE C-7c.   REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_{\infty} = 10$

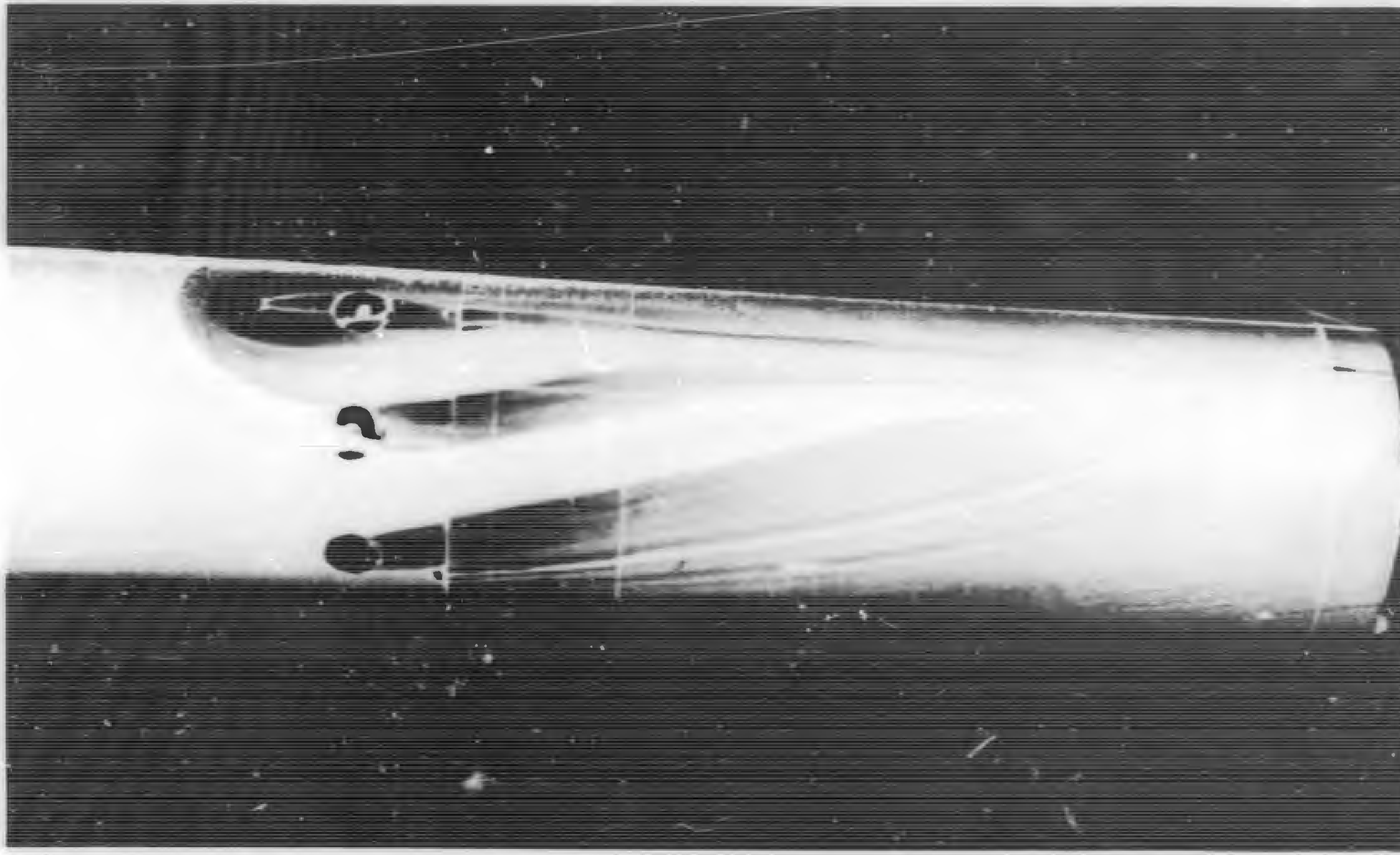

FIGURE C-7d. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_{\infty} = 10$

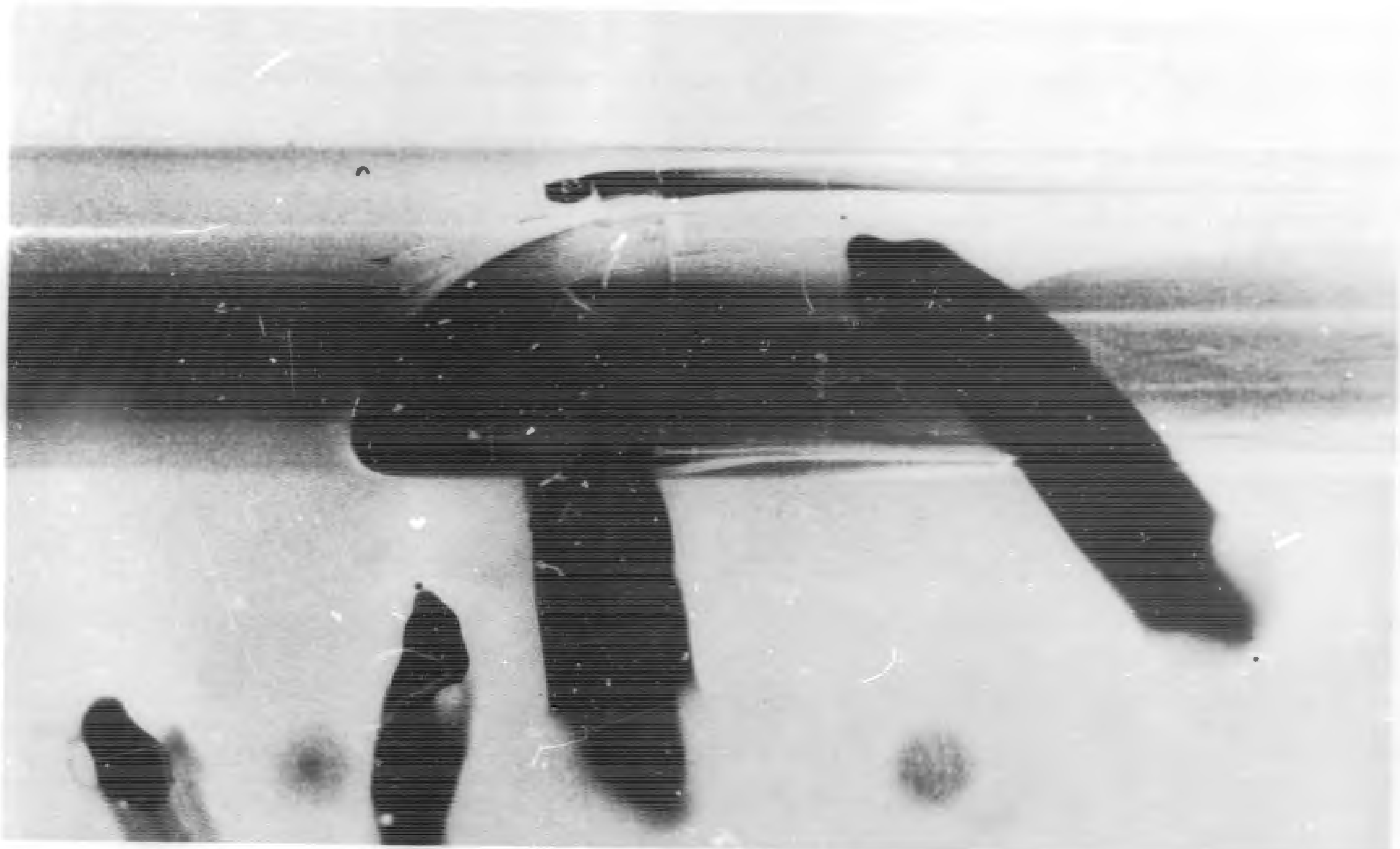

FIGURE C-7e. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_{\infty} = 40$

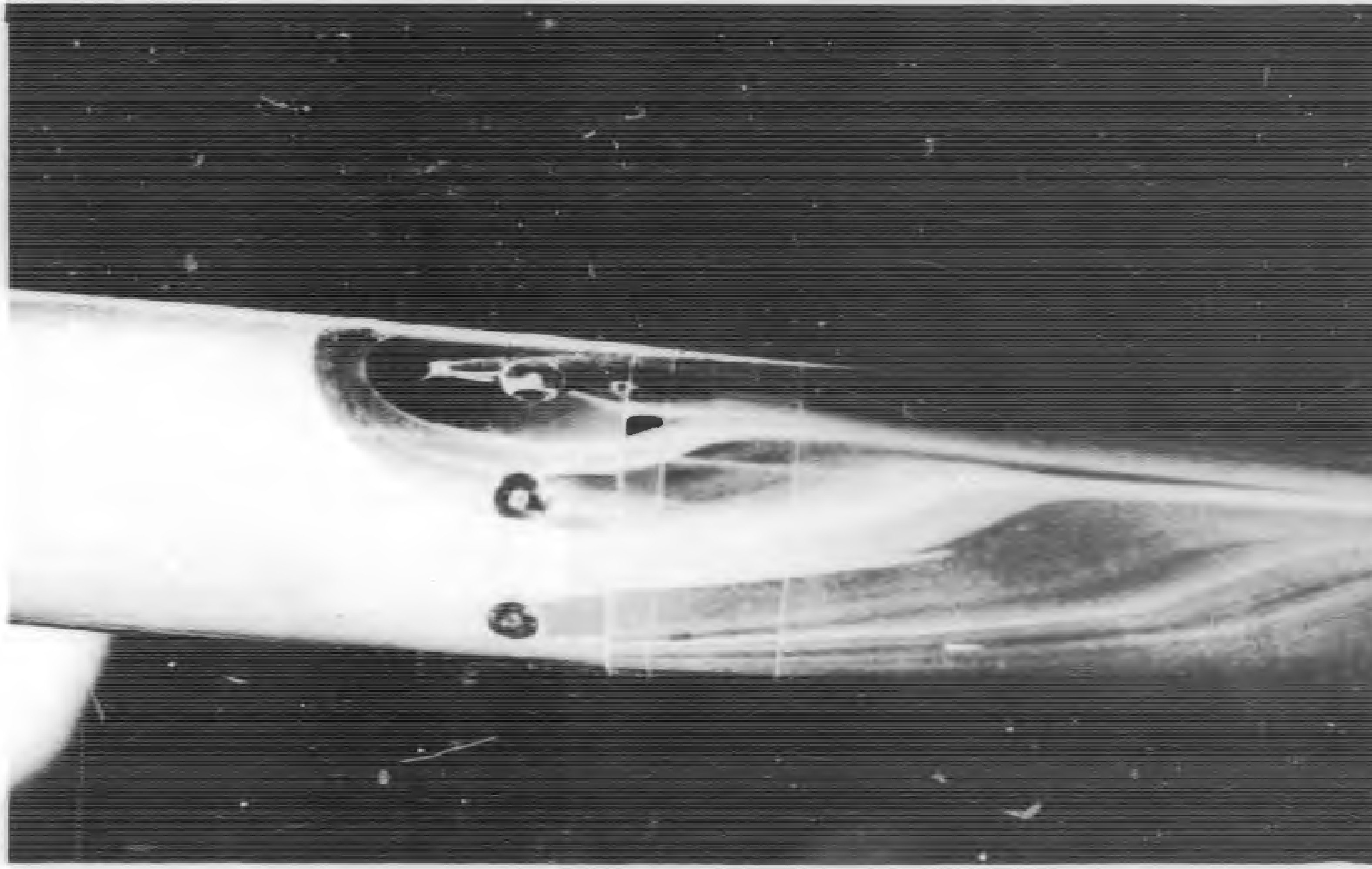

FIGURE C-7f. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_\infty = 40$

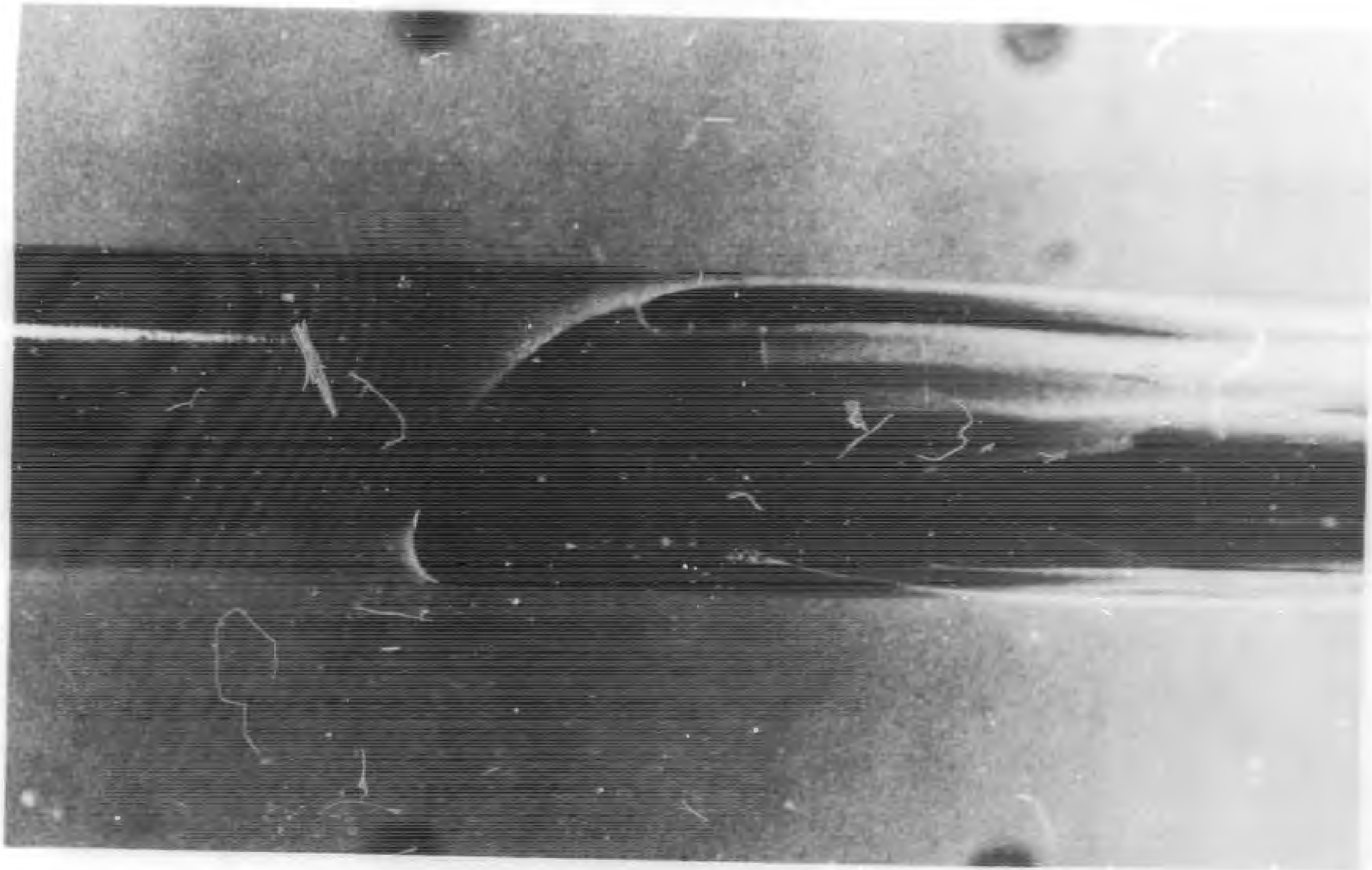

FIGURE C-7g. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 5$ DEGREES; $P_{oi}/P_{\infty} = 100$

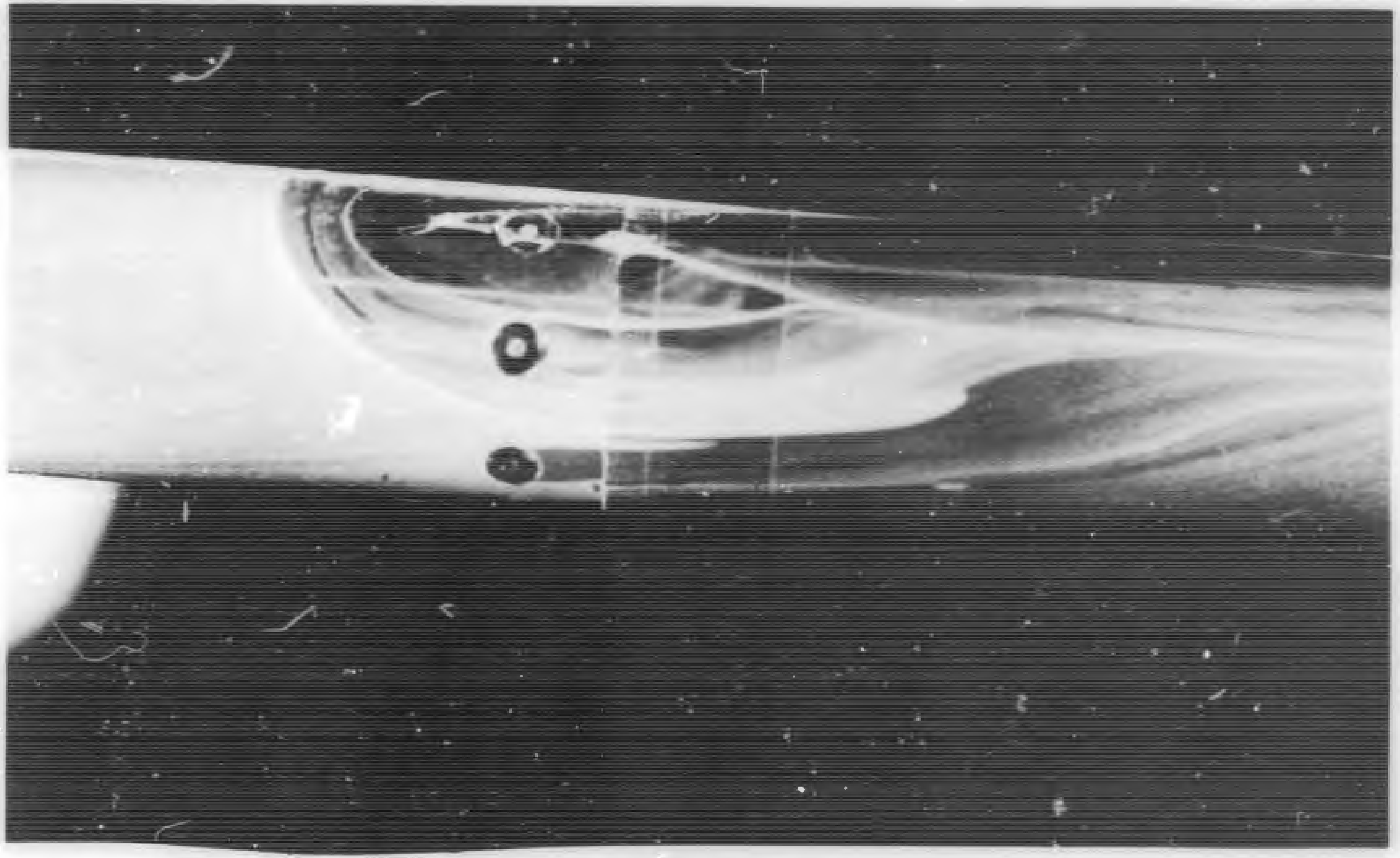

FIGURE C-7h. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_\infty = 100$

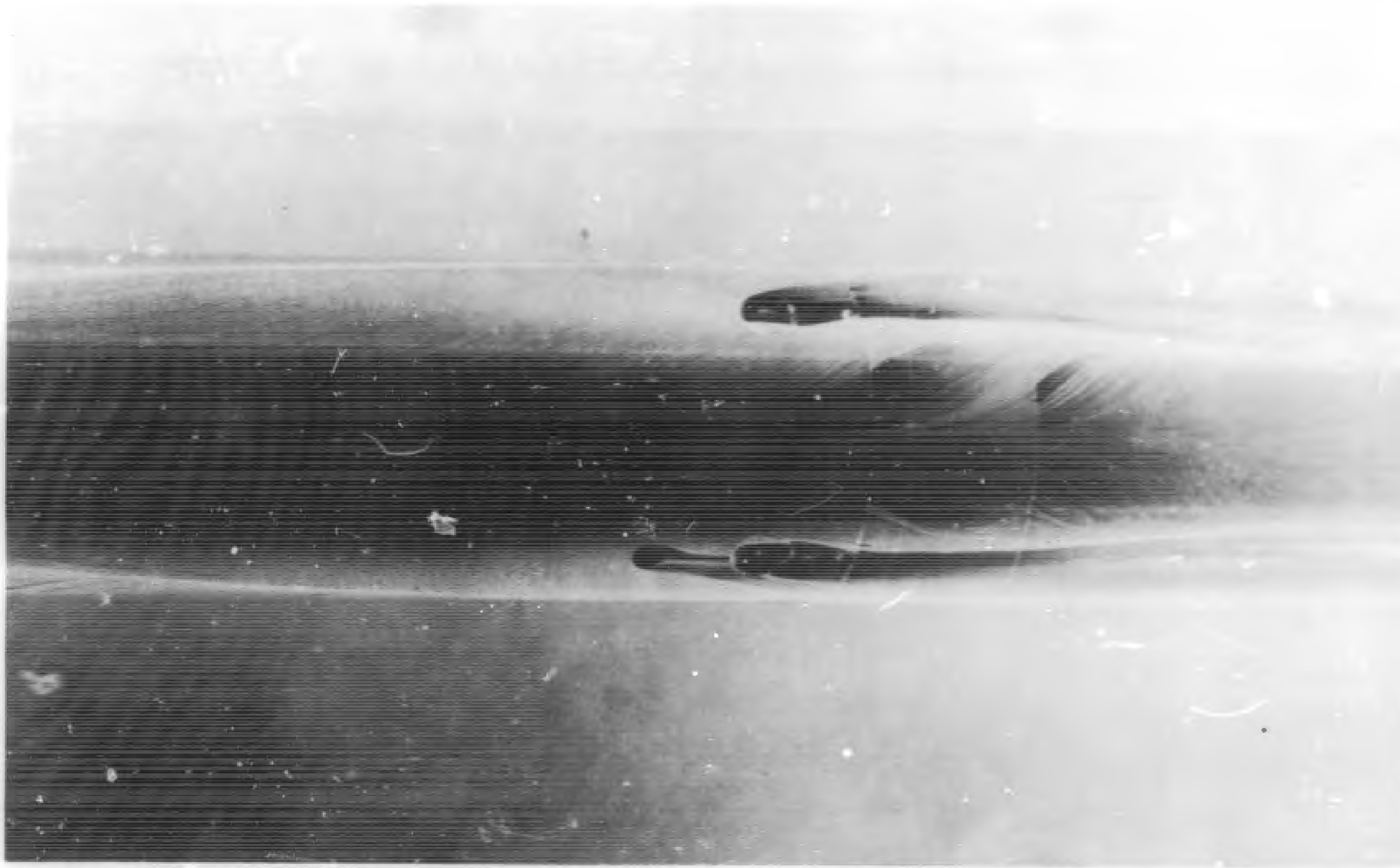

FIGURE C-8a.   REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_{\infty} = 0$

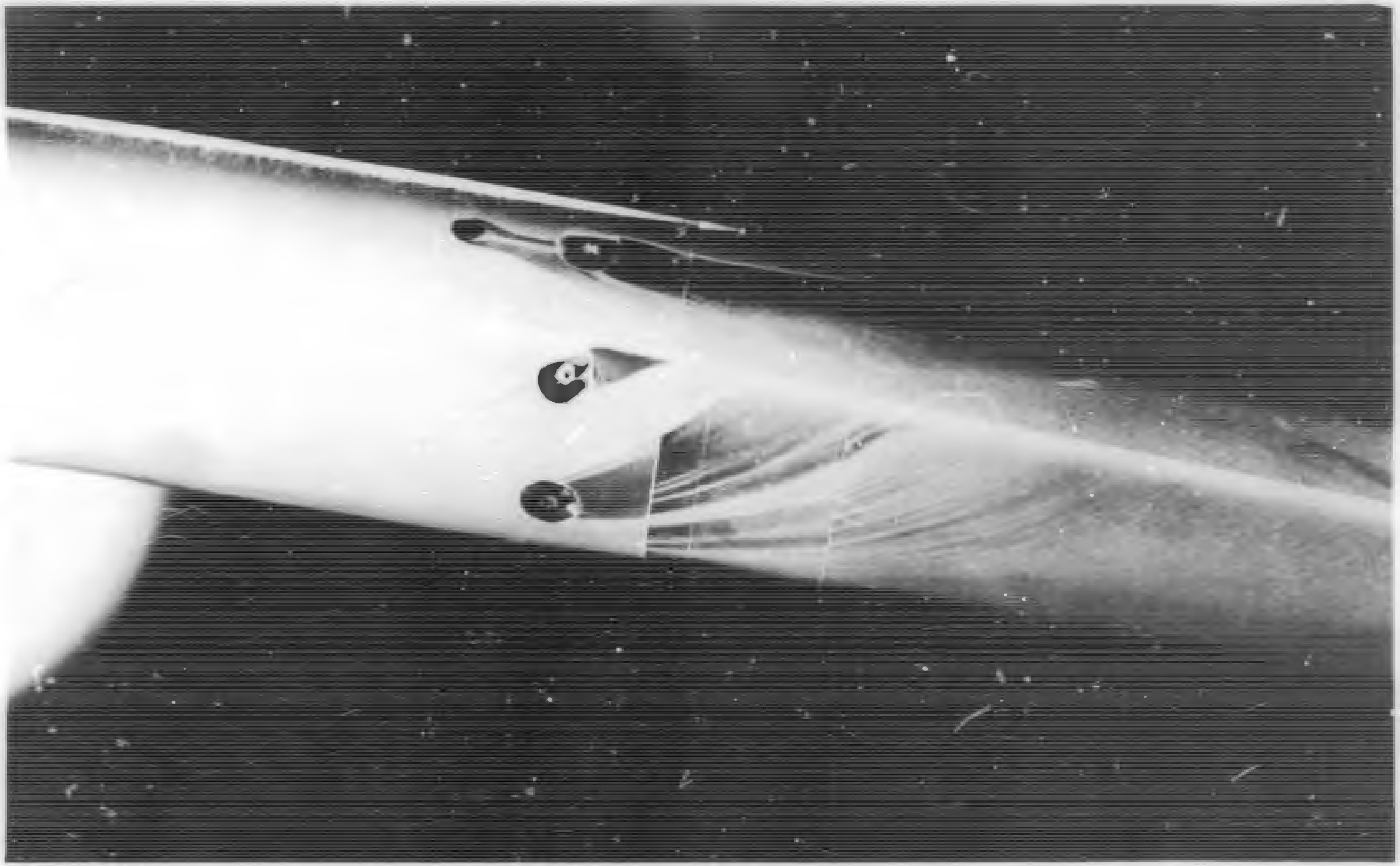

FIGURE C-8b. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_{\infty} = 0$

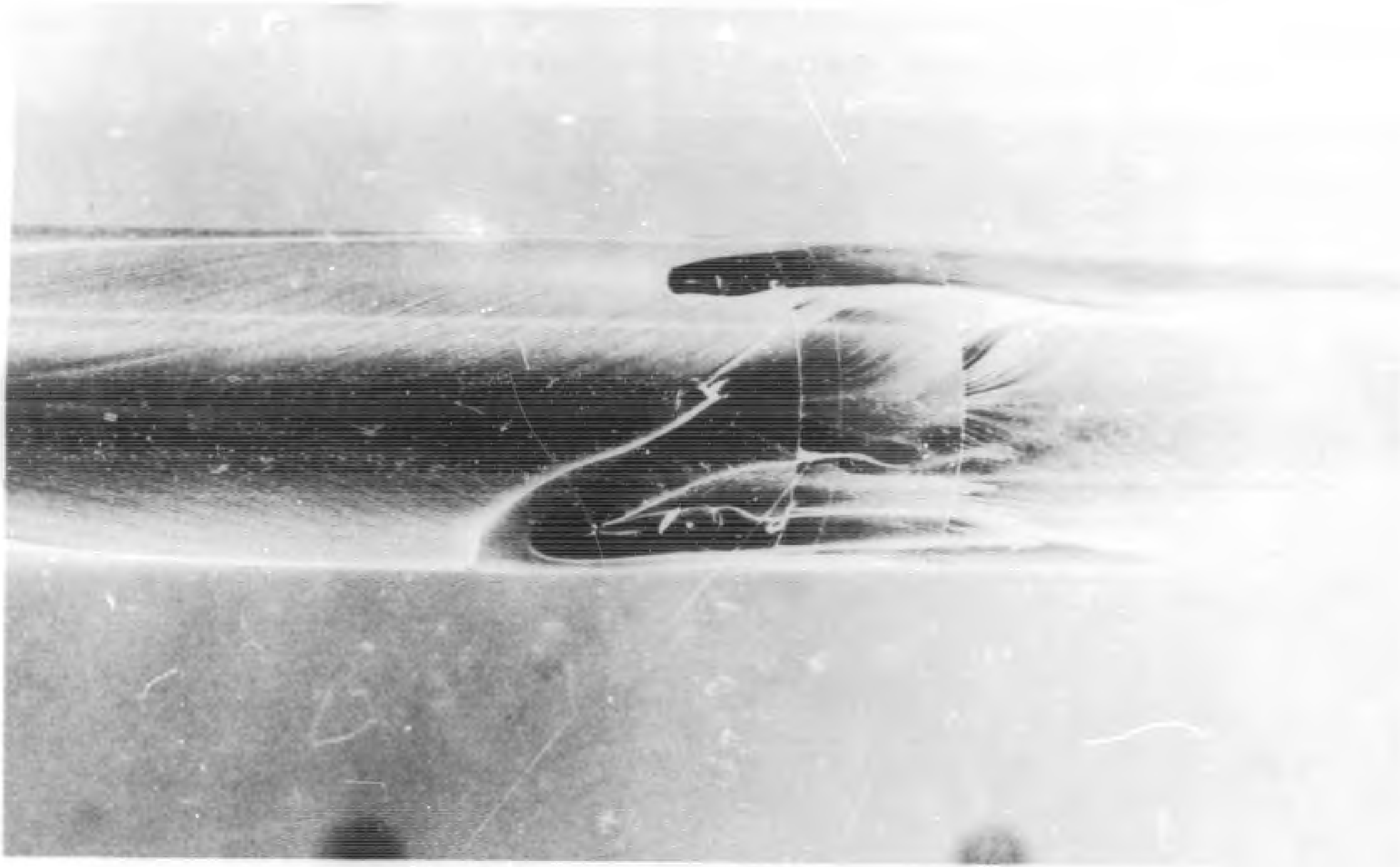

FIGURE C-8c. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_{\infty} = 10$

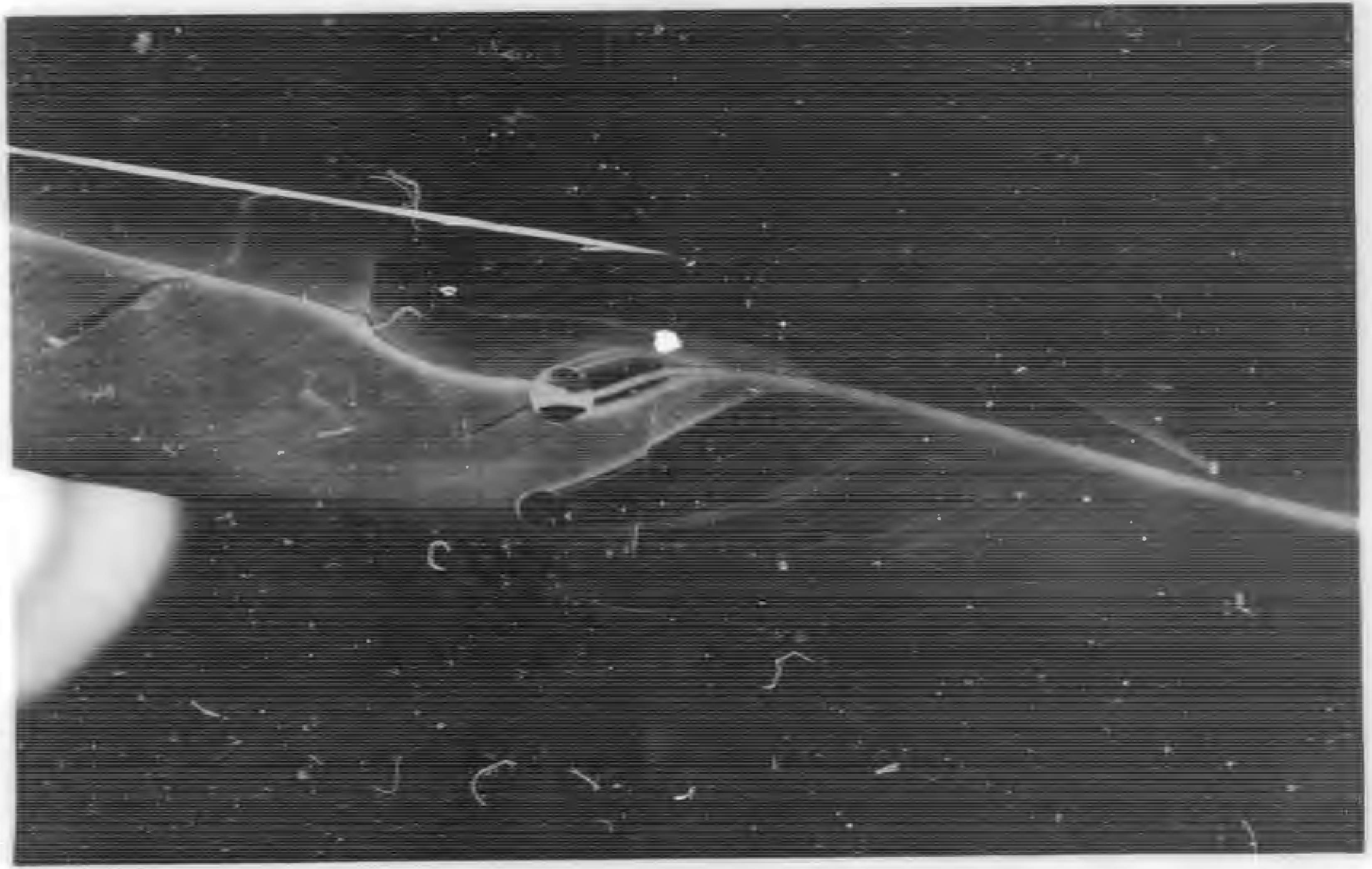

FIGURE C-8d. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 10$ DEGREES: $P_{oj}/P_\infty = 10$

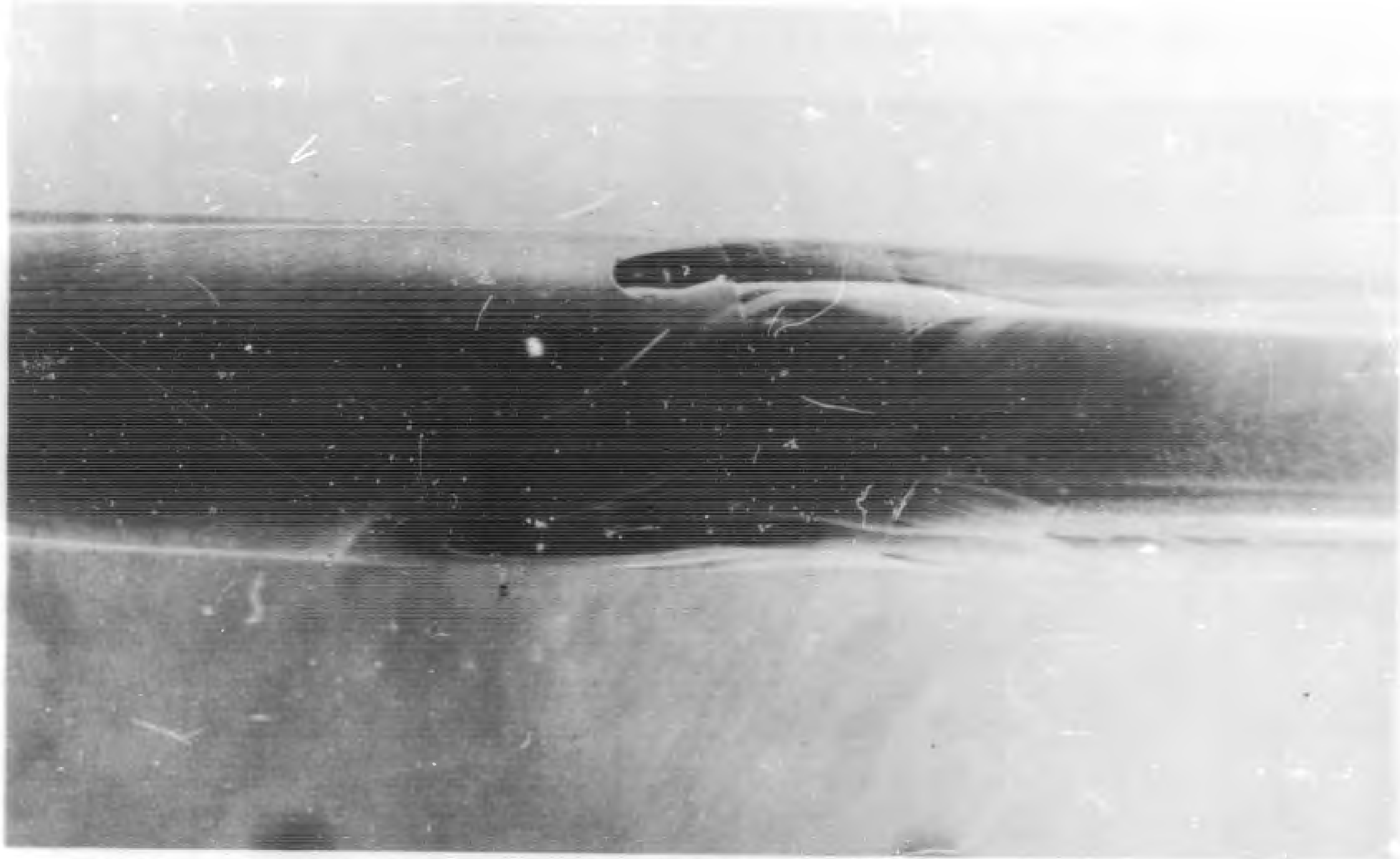

FIGURE C-8e. REACTION JET FOR $B_1C_1X_3$ WITH α = 10 DEGREES; P_{oj}/P_{∞} = 40

FIGURE C-8f. REACTION JET FOR $B_1C_1X_3$ WITH α = 10 DEGREES; P_{oj}/P_{∞} = 40

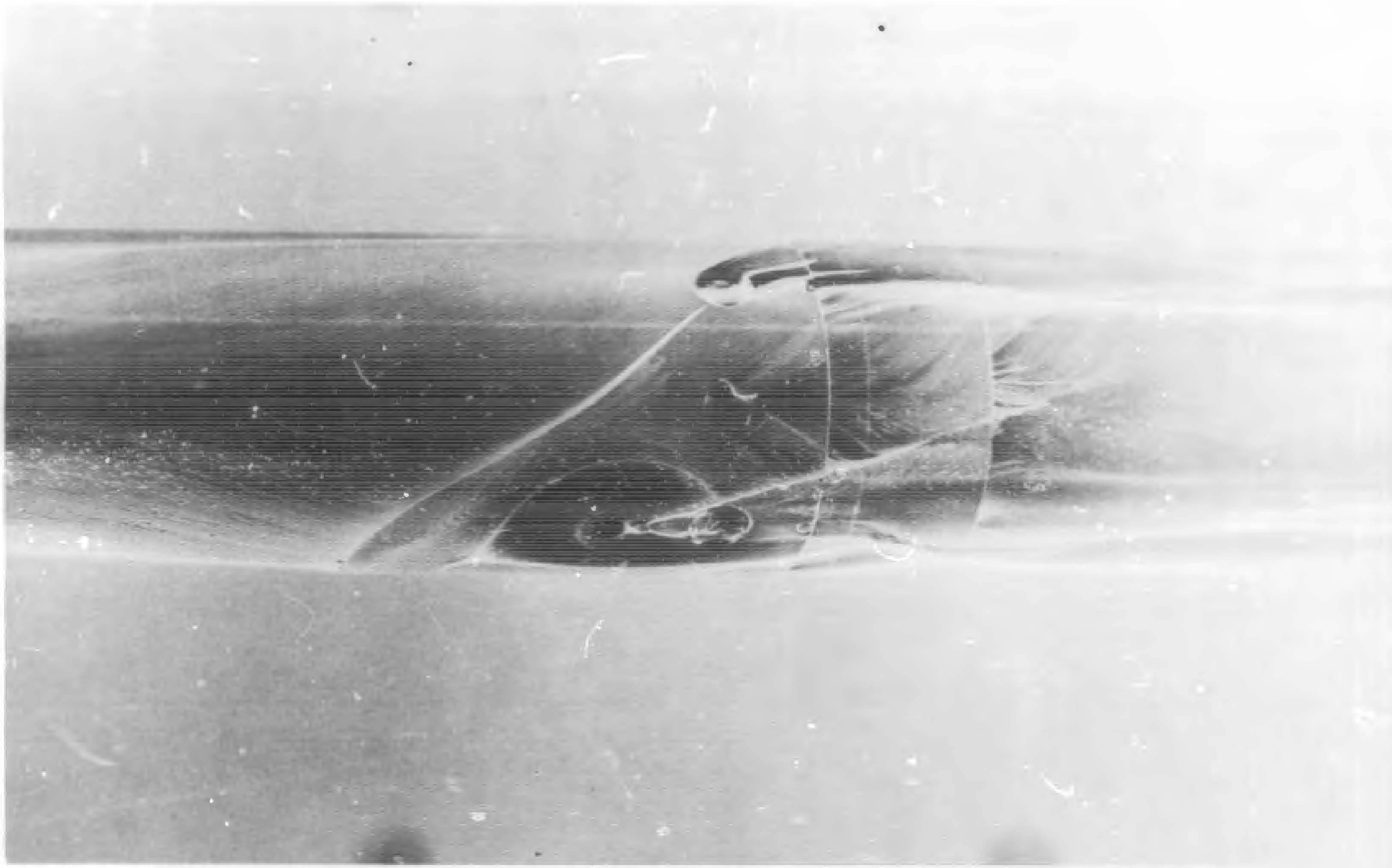

FIGURE C-8g. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_\infty = 100$

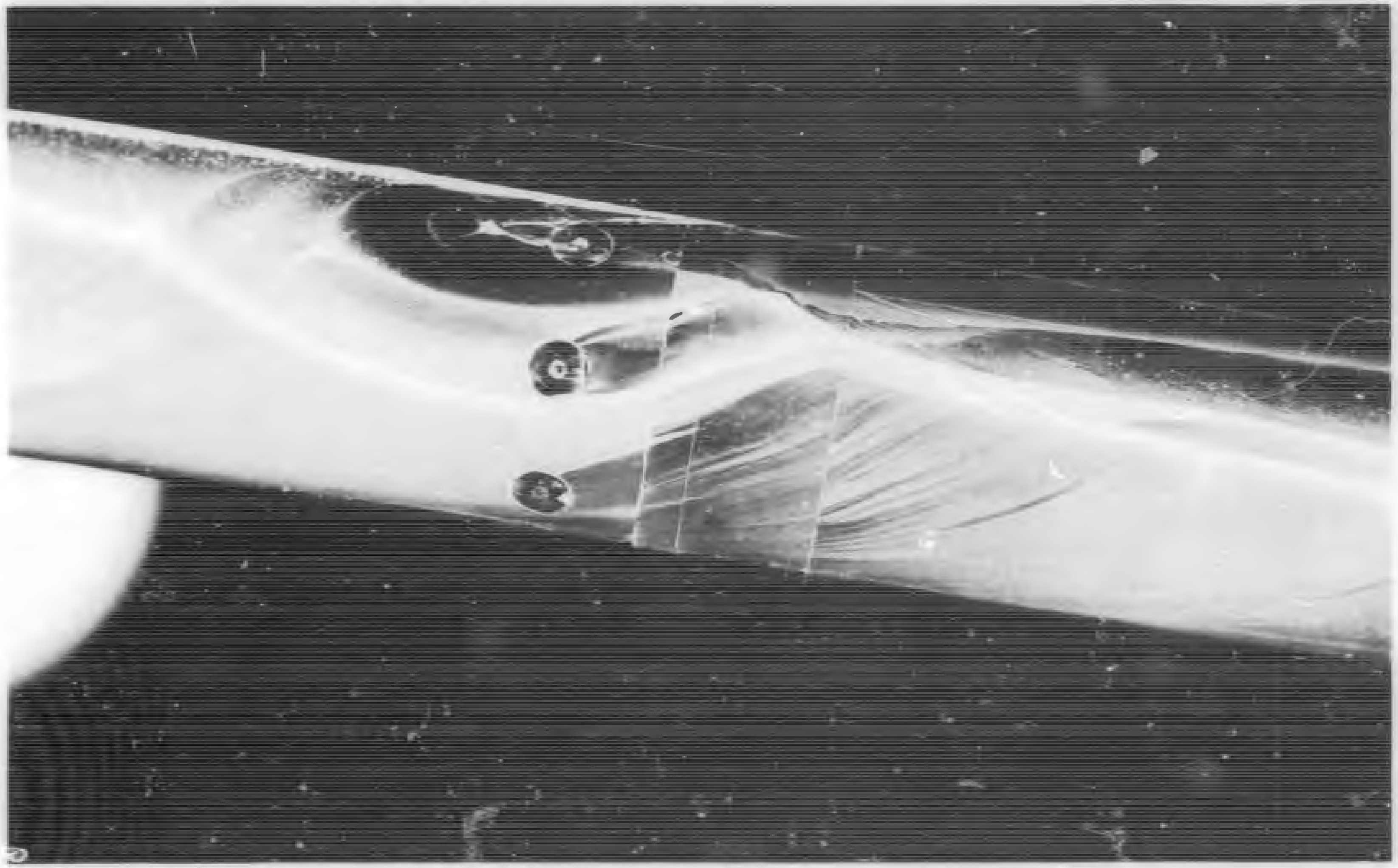

FIGURE C-8h. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_\infty = 100$

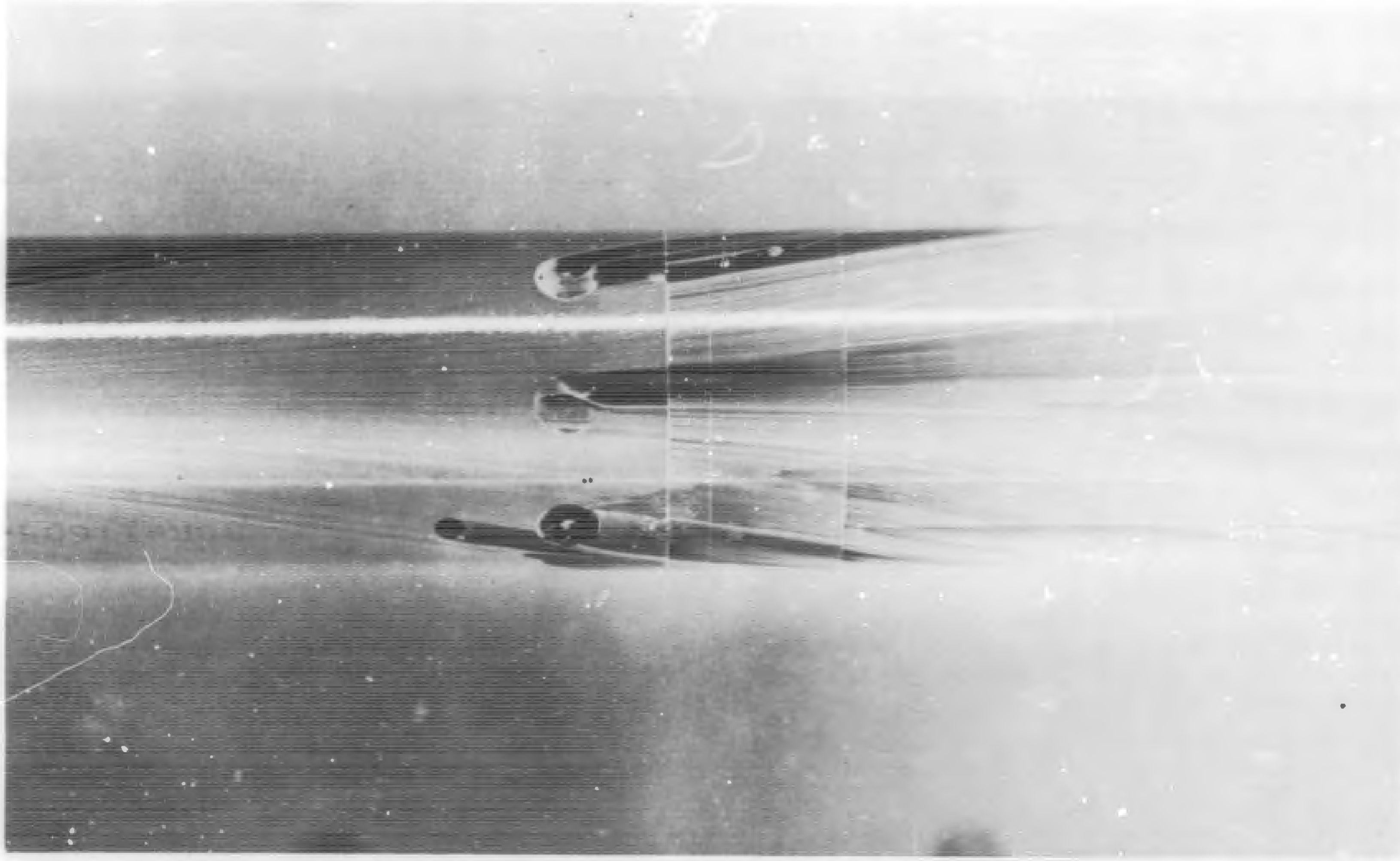

FIGURE C-9a. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_{\infty} = 0$

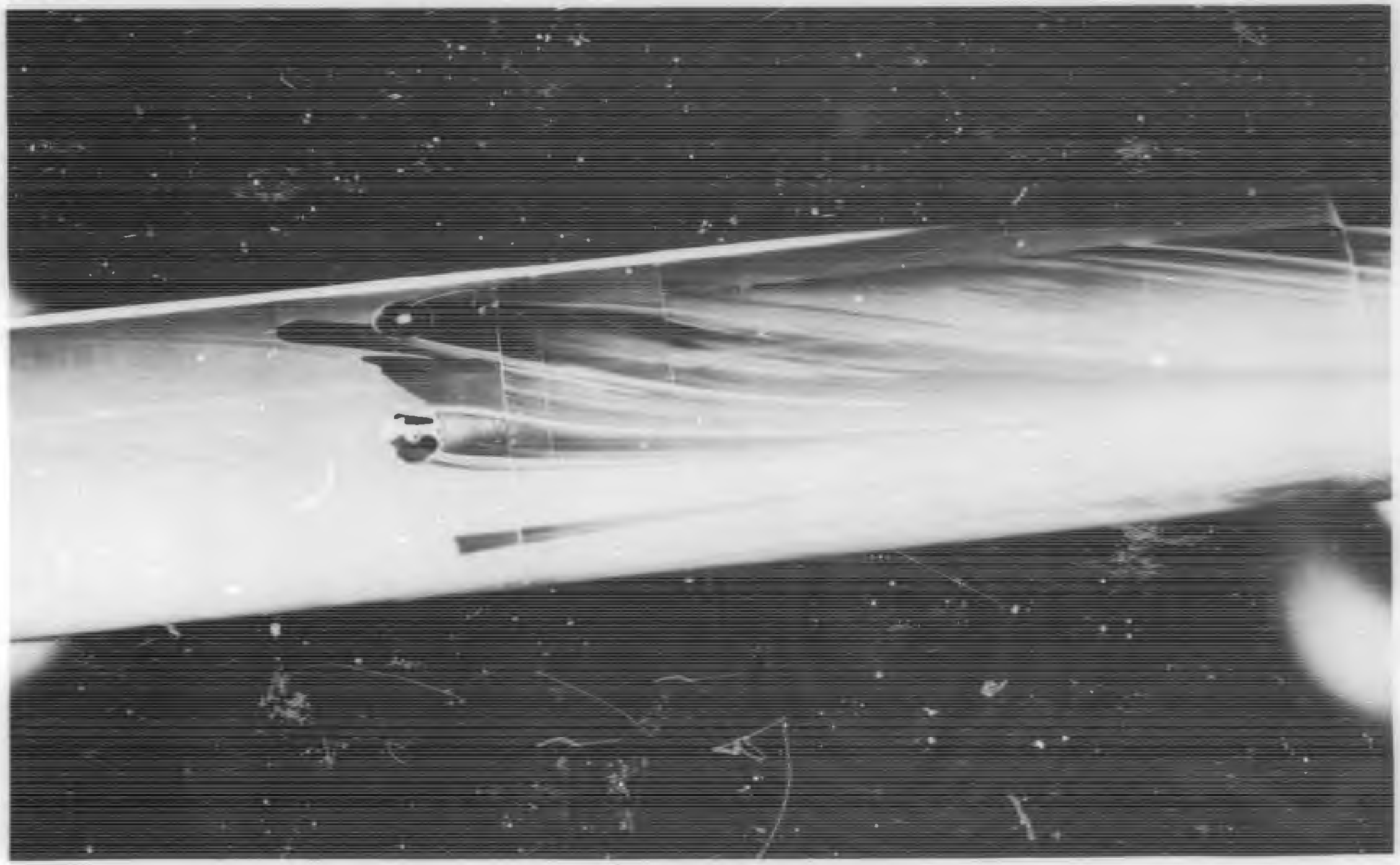

FIGURE C-9b. REACTION JET FOR $B_1C_1X_3$ WITH α = -5 DEGREES; $P_{oj}/P_\infty = 0$

PHOTOGRAPH SHOWING REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_\infty = 10$, NOT AVAILABLE

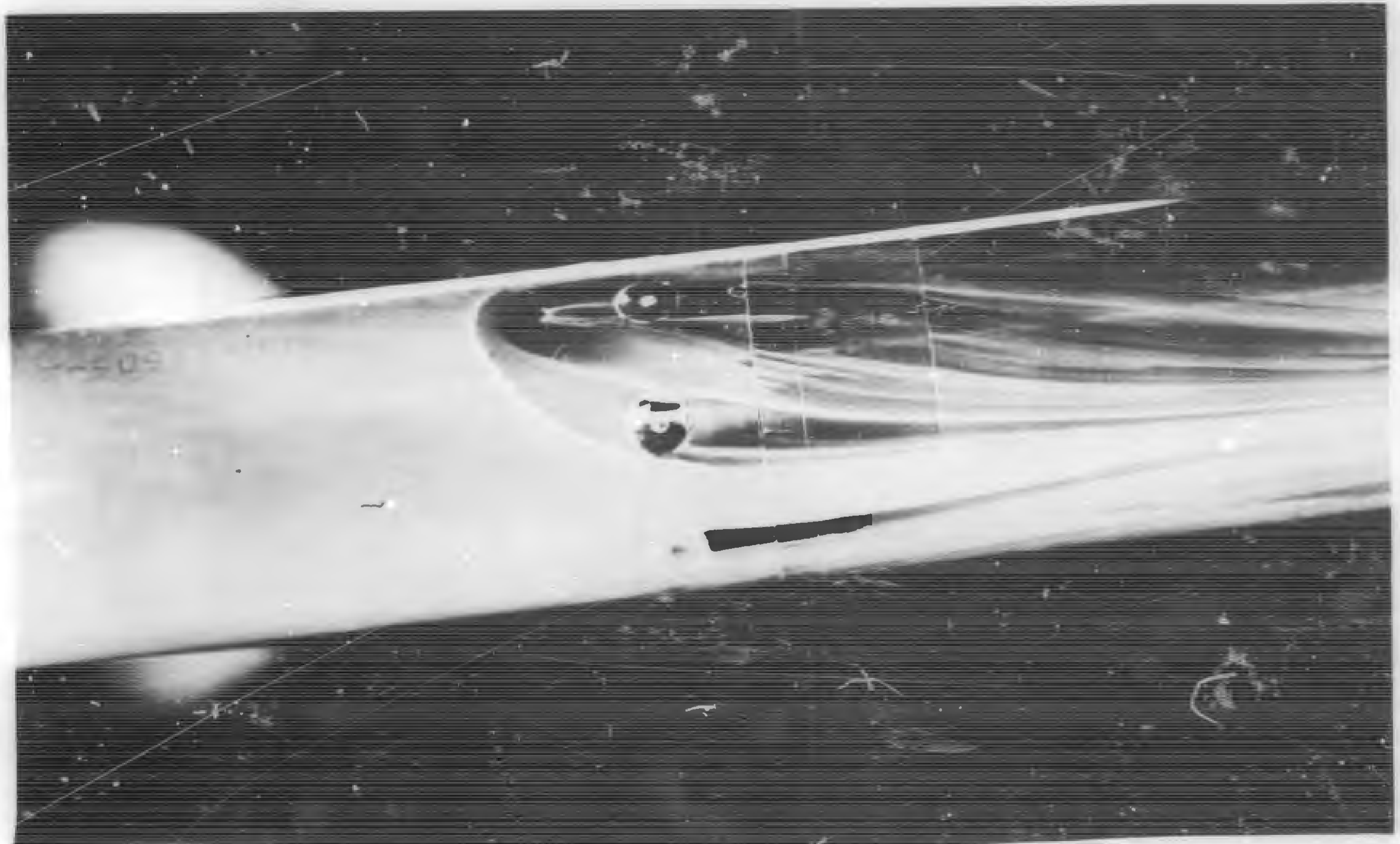

FIGURE C-9c. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_{\infty} = 10$

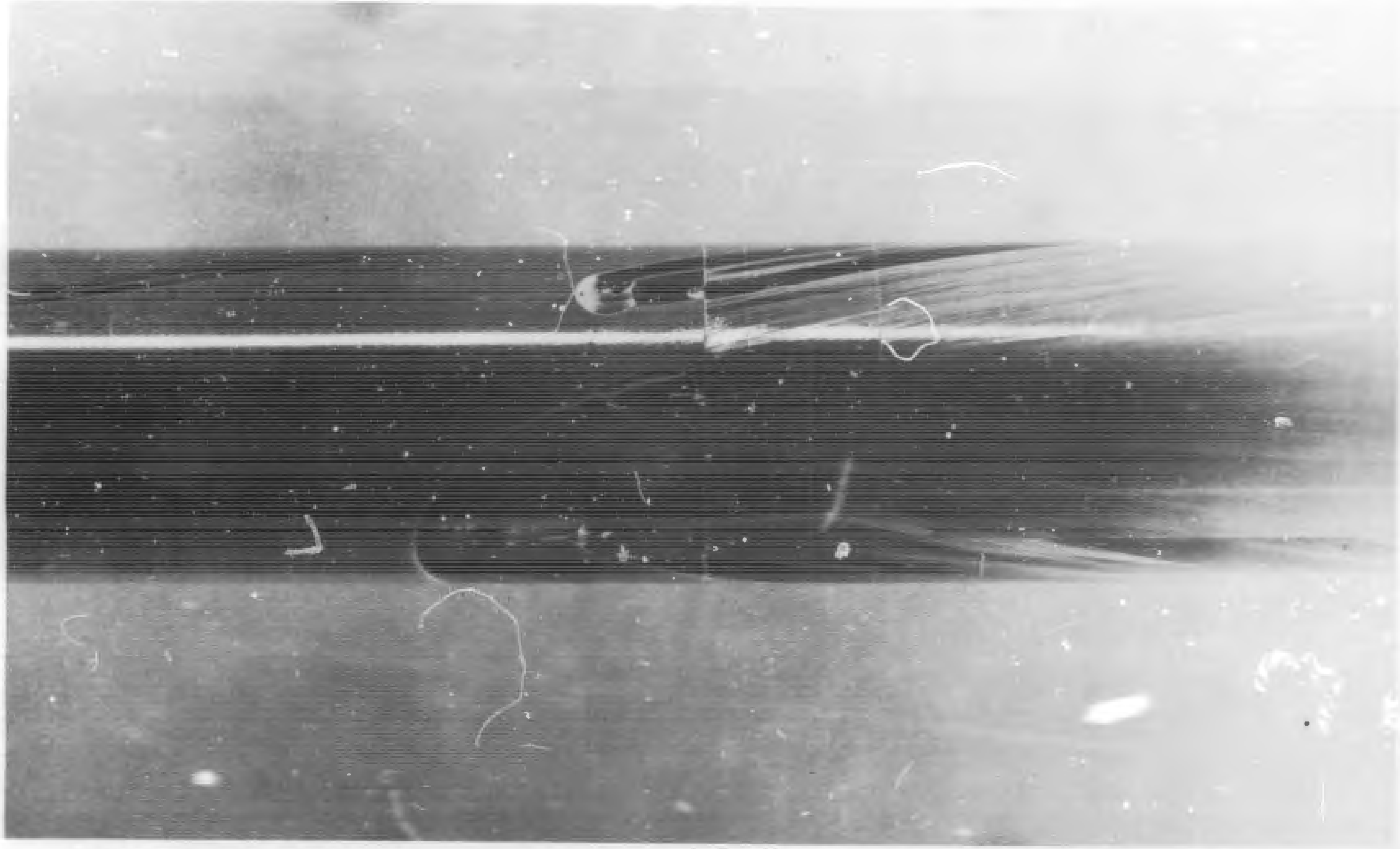

FIGURE C-9d. REACTION JET FOR $B_1C_1X_3$ WITH α = -5 DEGREES; P_{oj}/P_∞ = 40

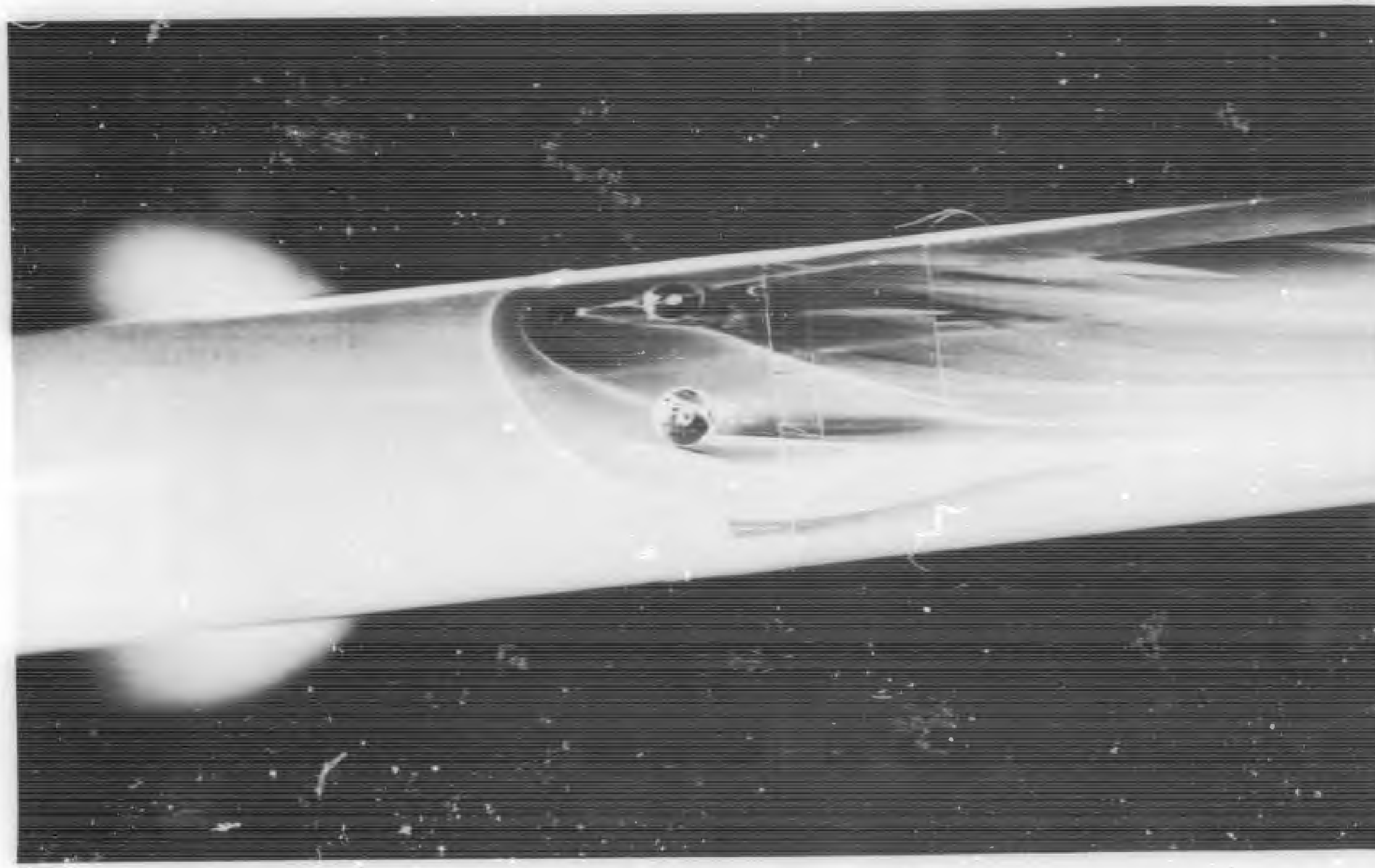

FIGURE C-9e. REACTION JET FOR $B_1C_1X_3$ WITH α = -5 DEGREES; P_{oj}/P_∞ = 40

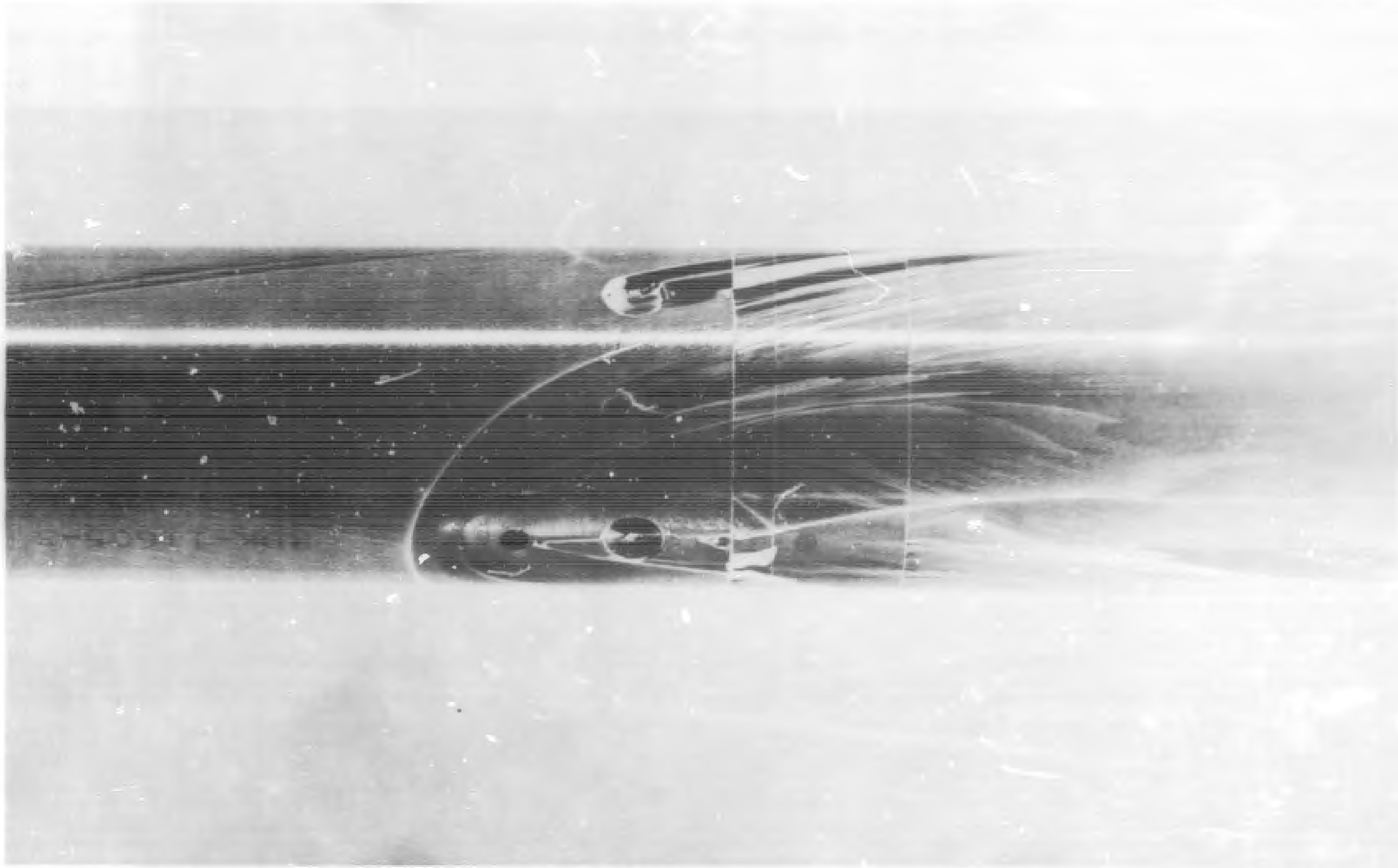

FIGURE C-9f. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_\infty = 100$

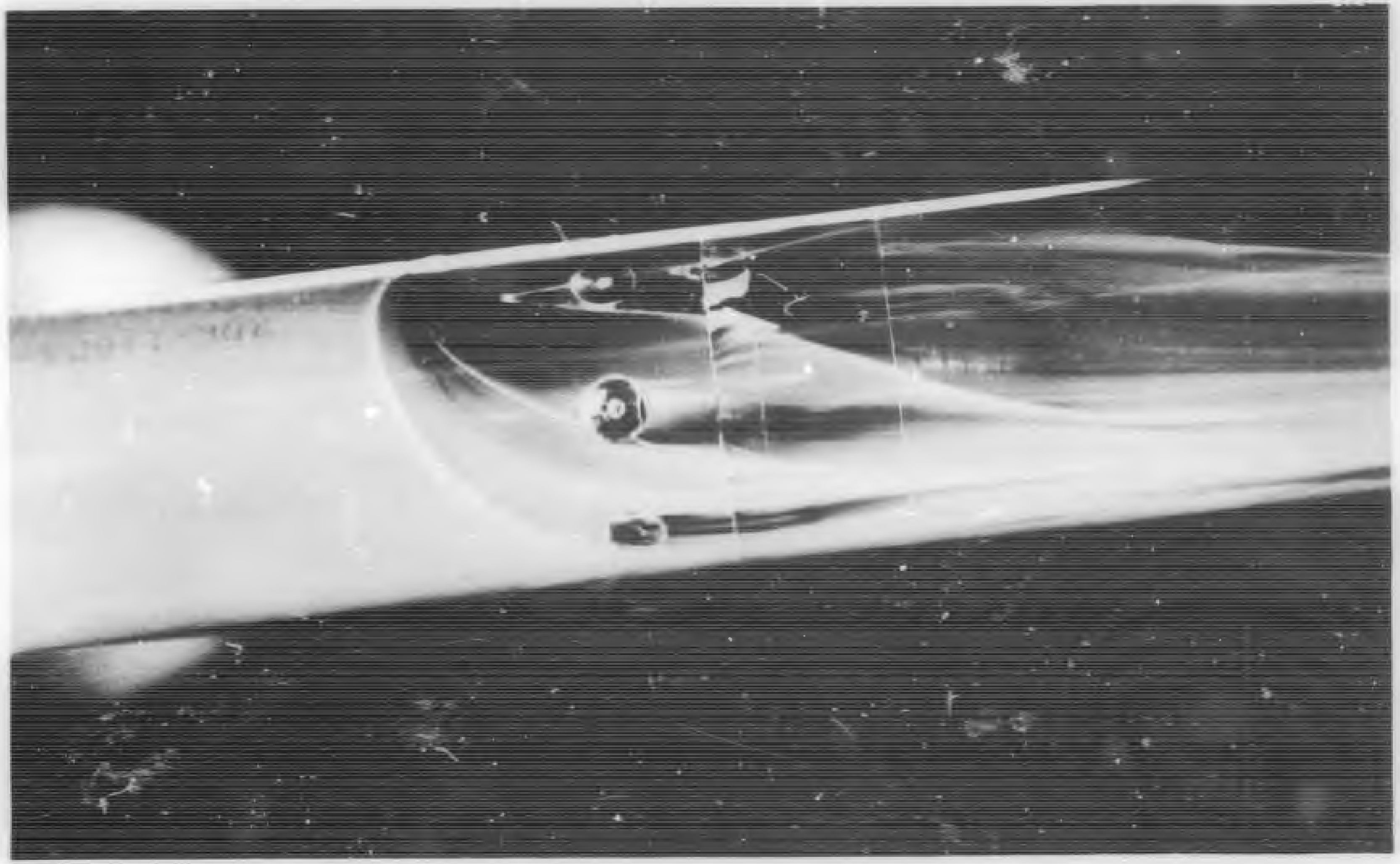

FIGURE C-9g. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_\infty = 100$

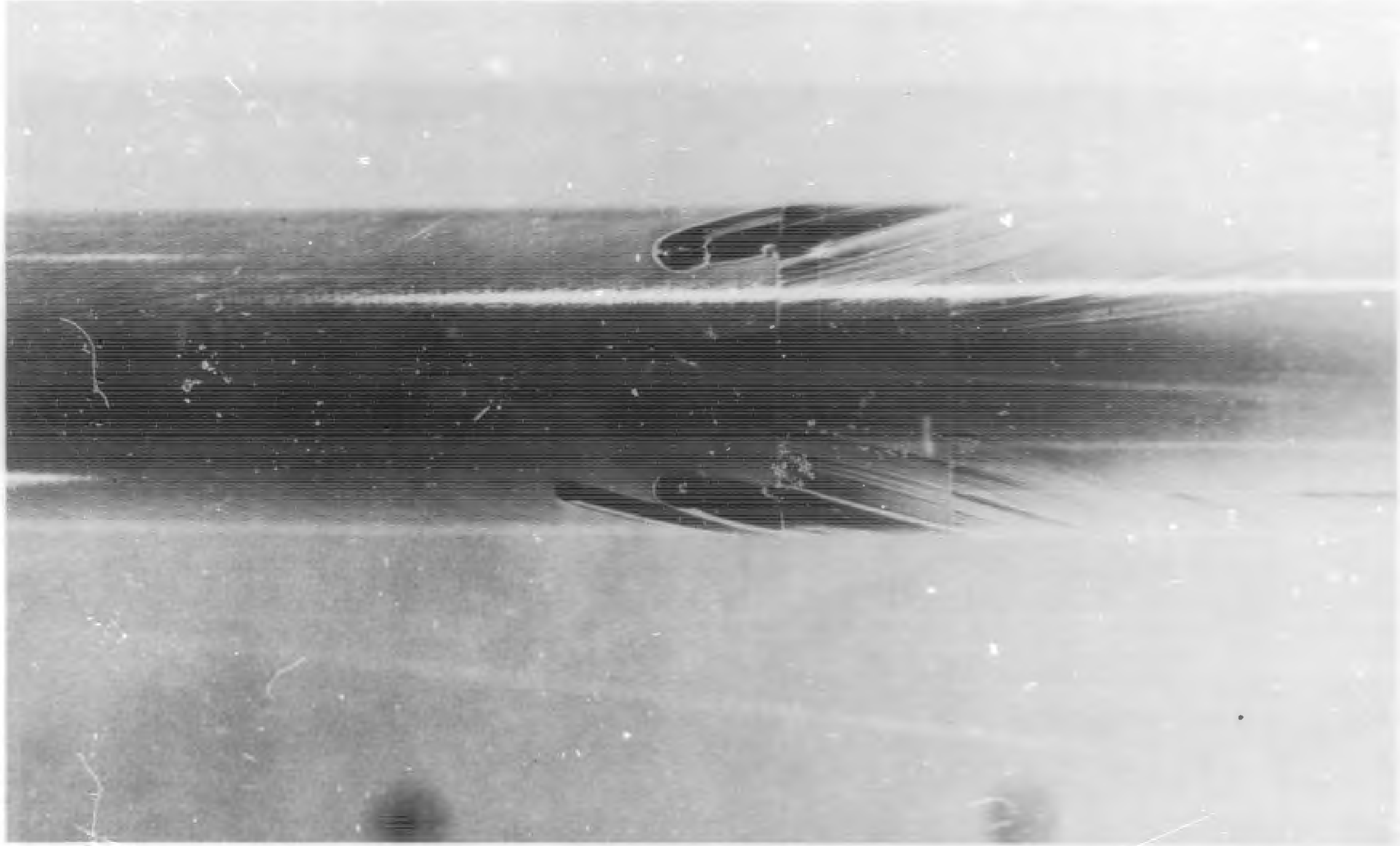

FIGURE C-10a. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_\infty = 0$

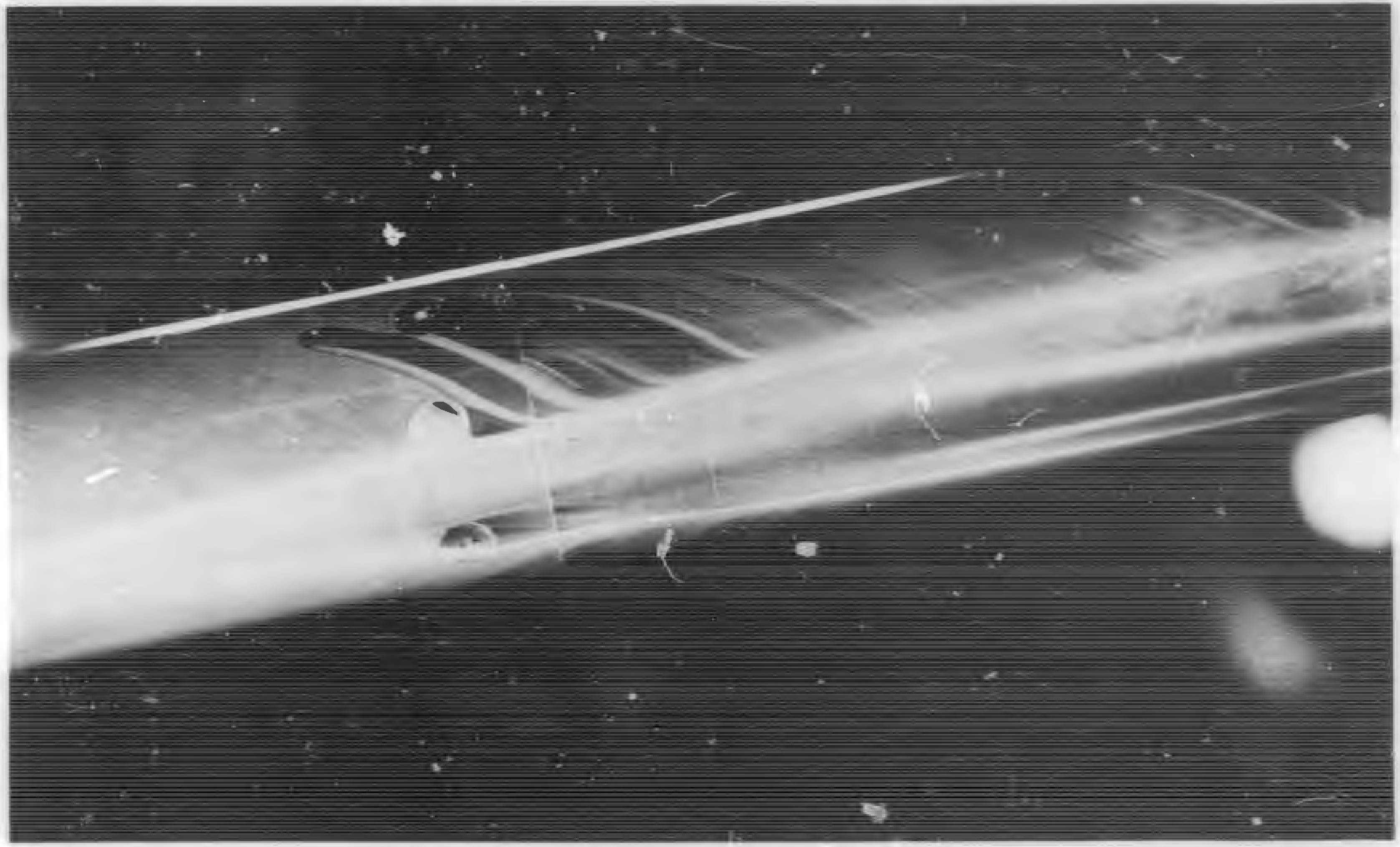

FIGURE C-10b. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_\infty = 0$

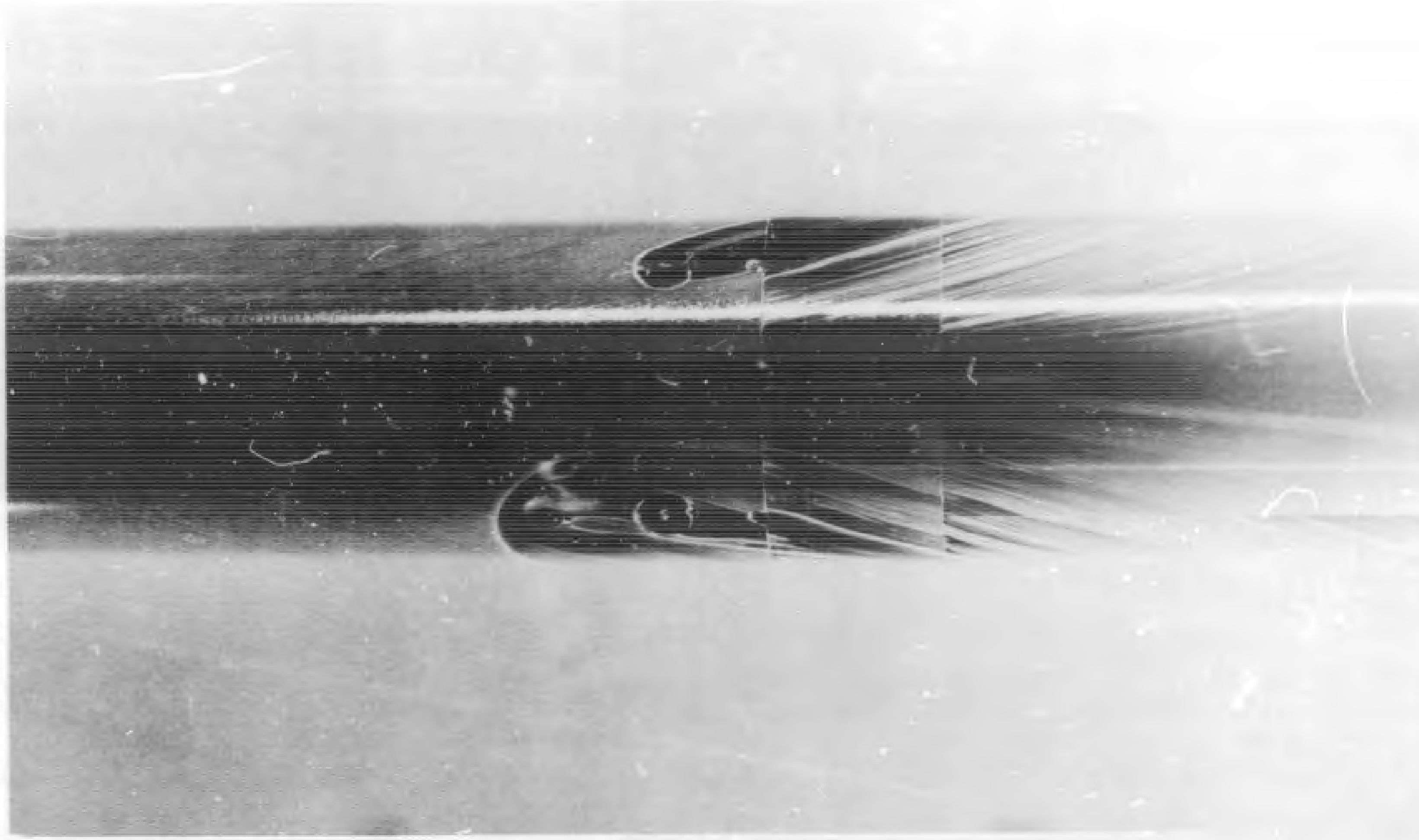

FIGURE C-10c. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_{\infty} = 10$

FIGURE C-10d. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_\infty = 10$

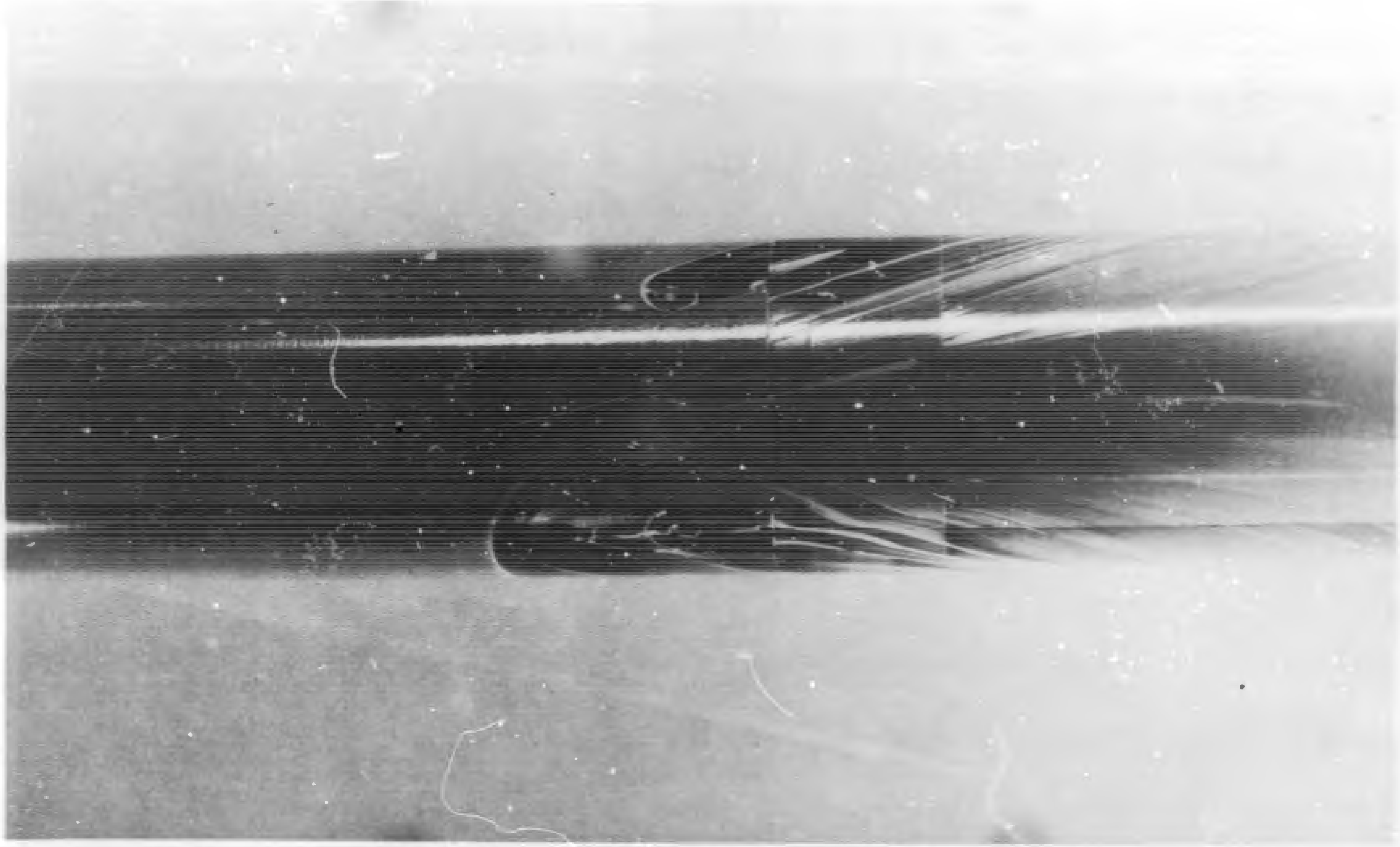

FIGURE C-10e. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_\infty = 40$

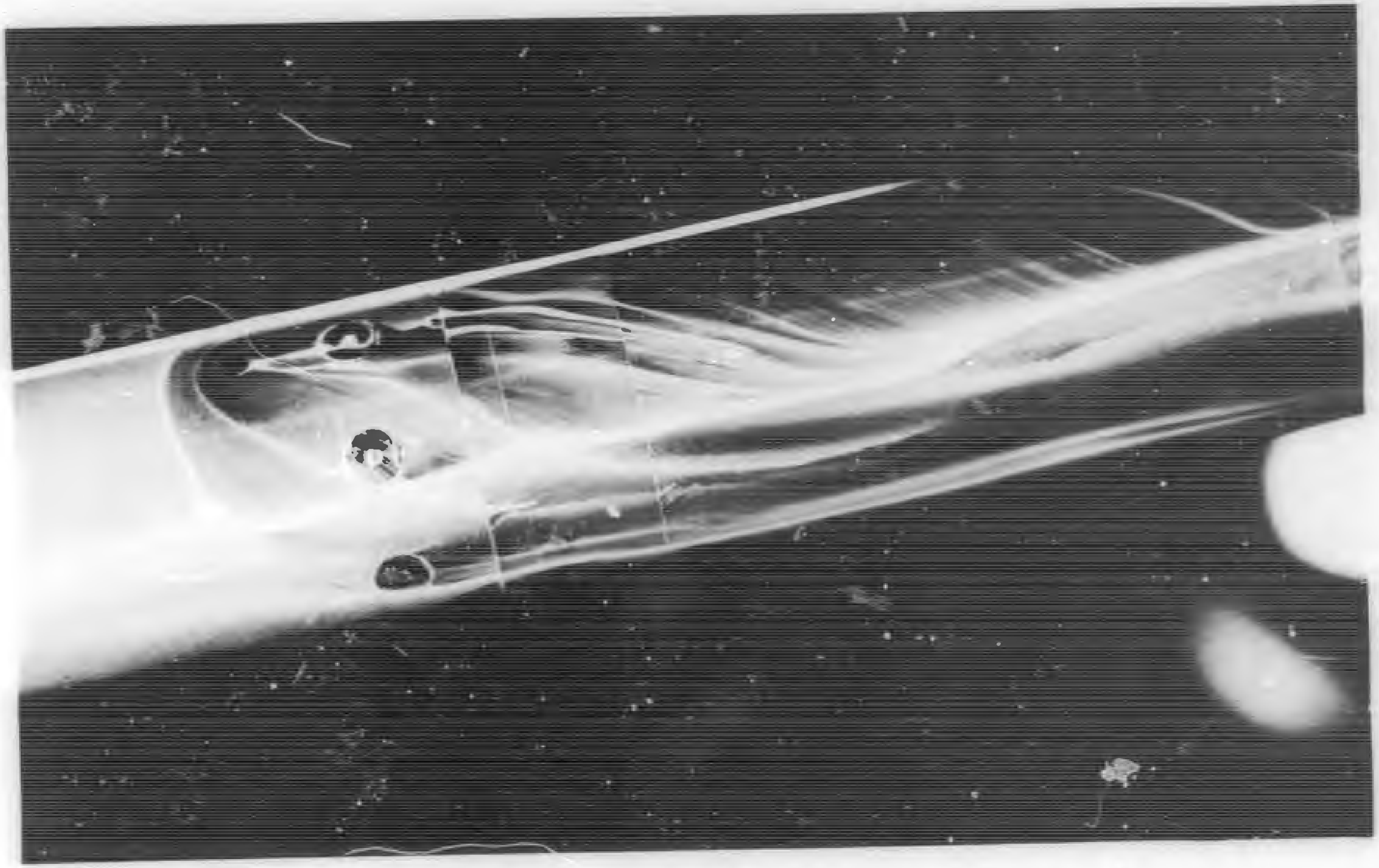

FIGURE C-10f. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_\infty = 40$

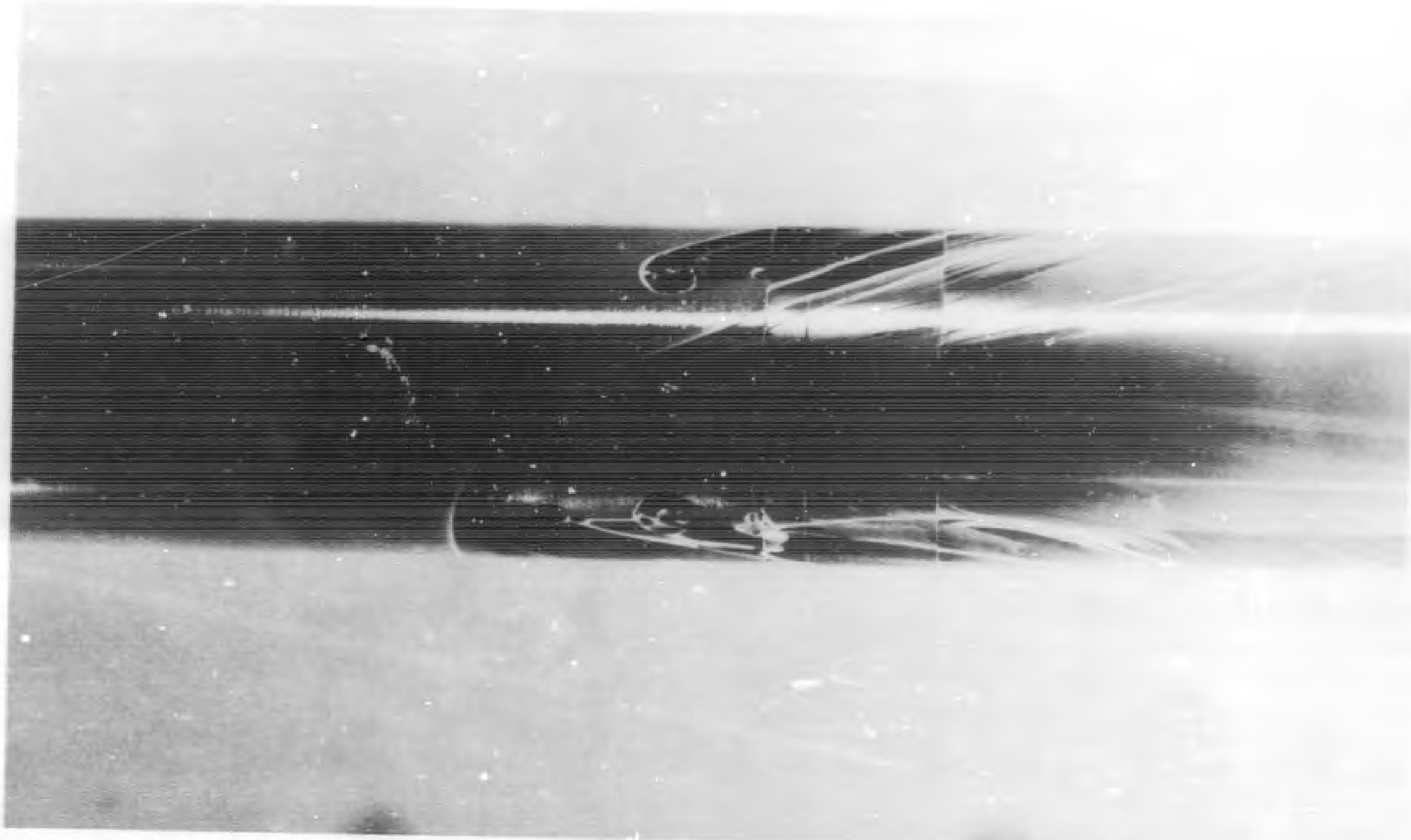

FIGURE C-10g. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_{\infty} = 100$

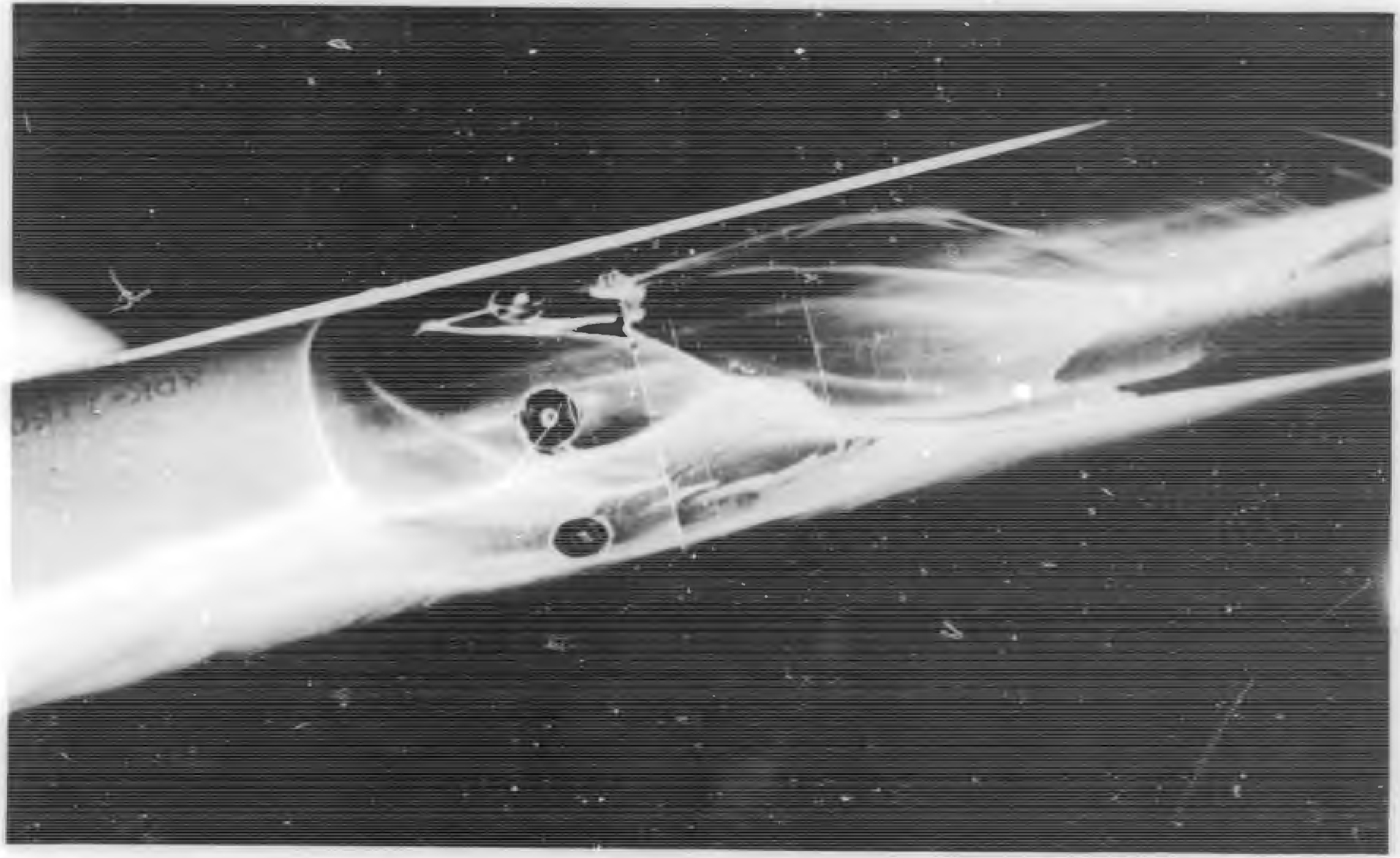

FIGURE C-10h. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_\infty = 100$

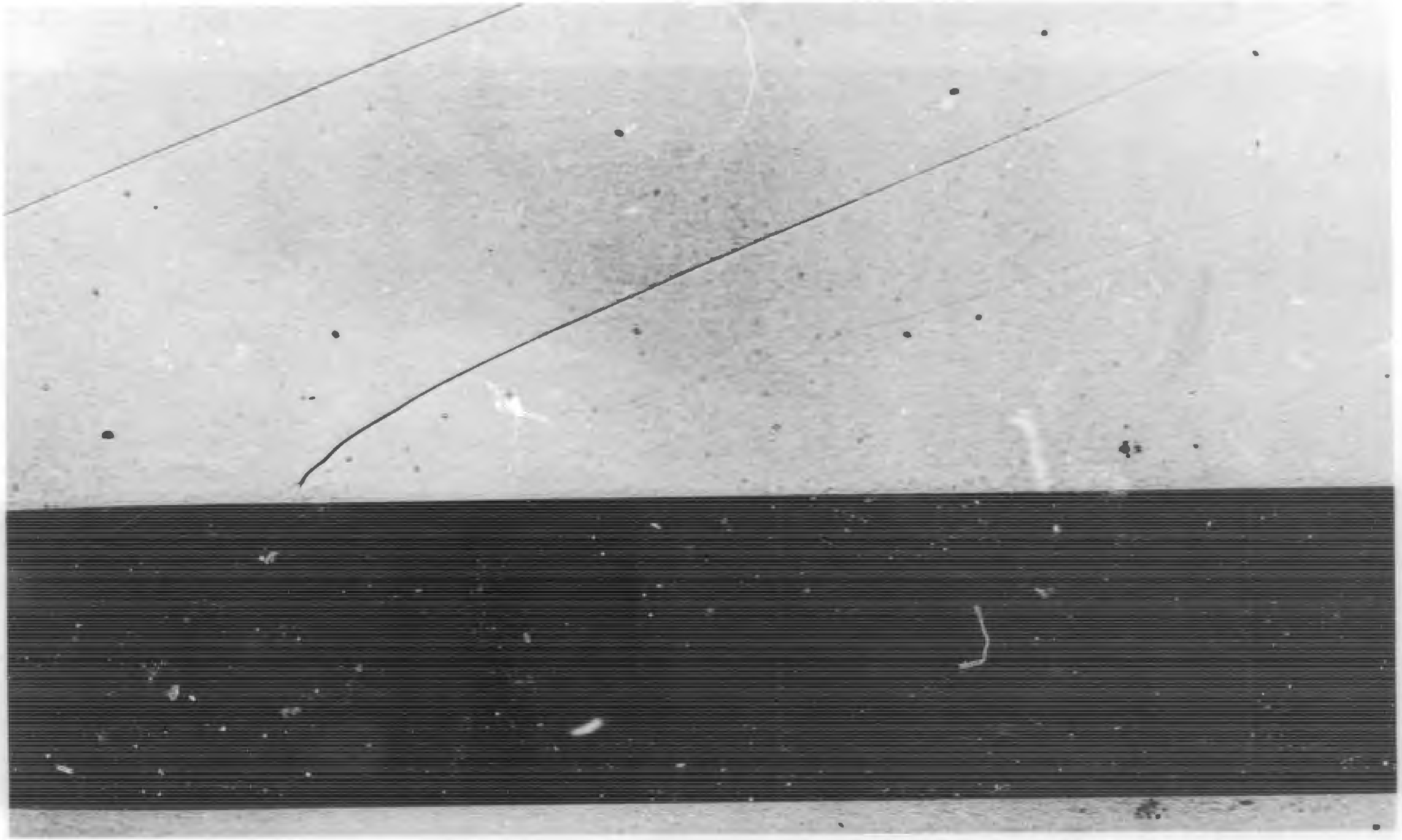

FIGURE C-11a. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_{\infty} = 10$

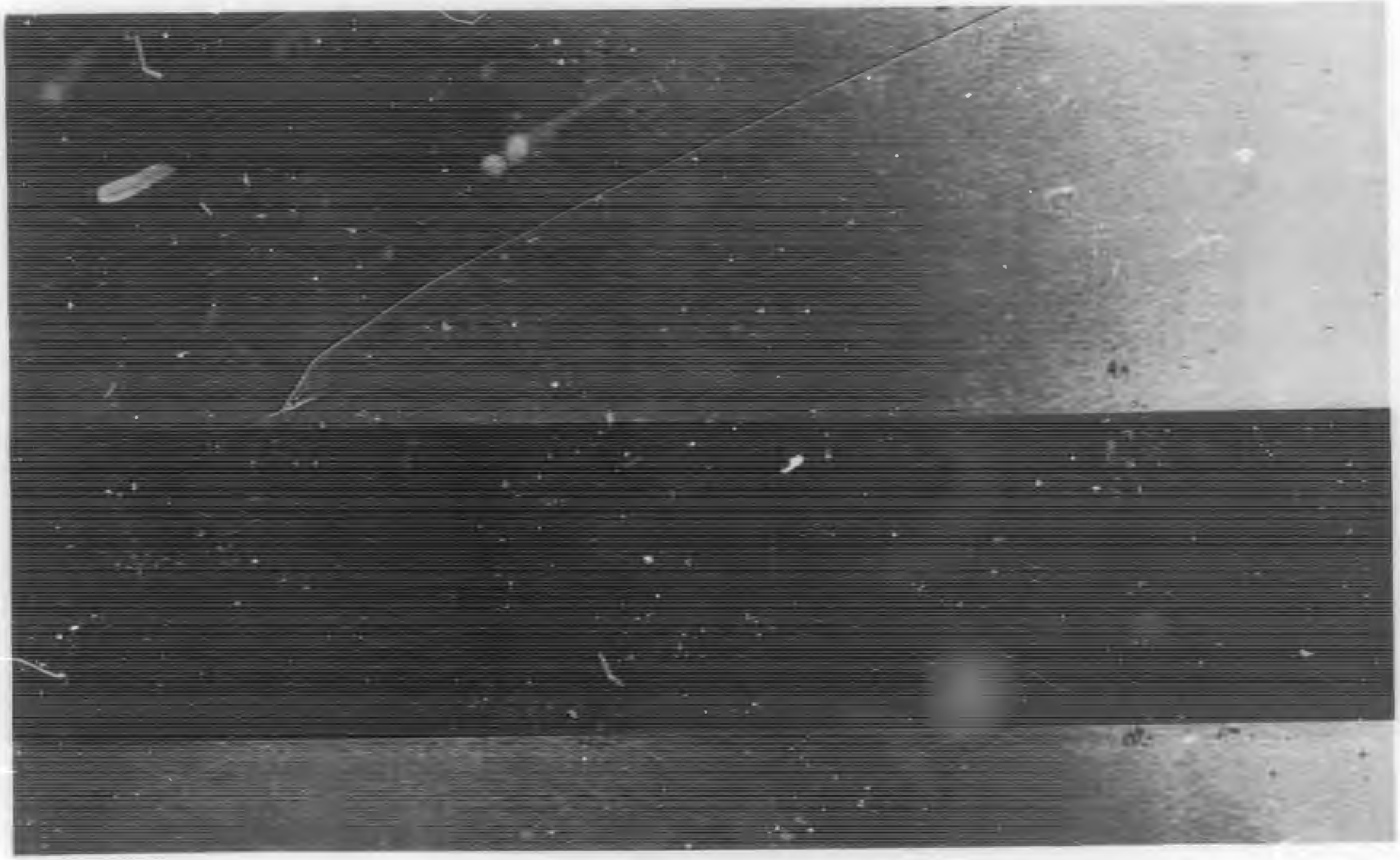

FIGURE C-11b. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_{\infty} = 20$

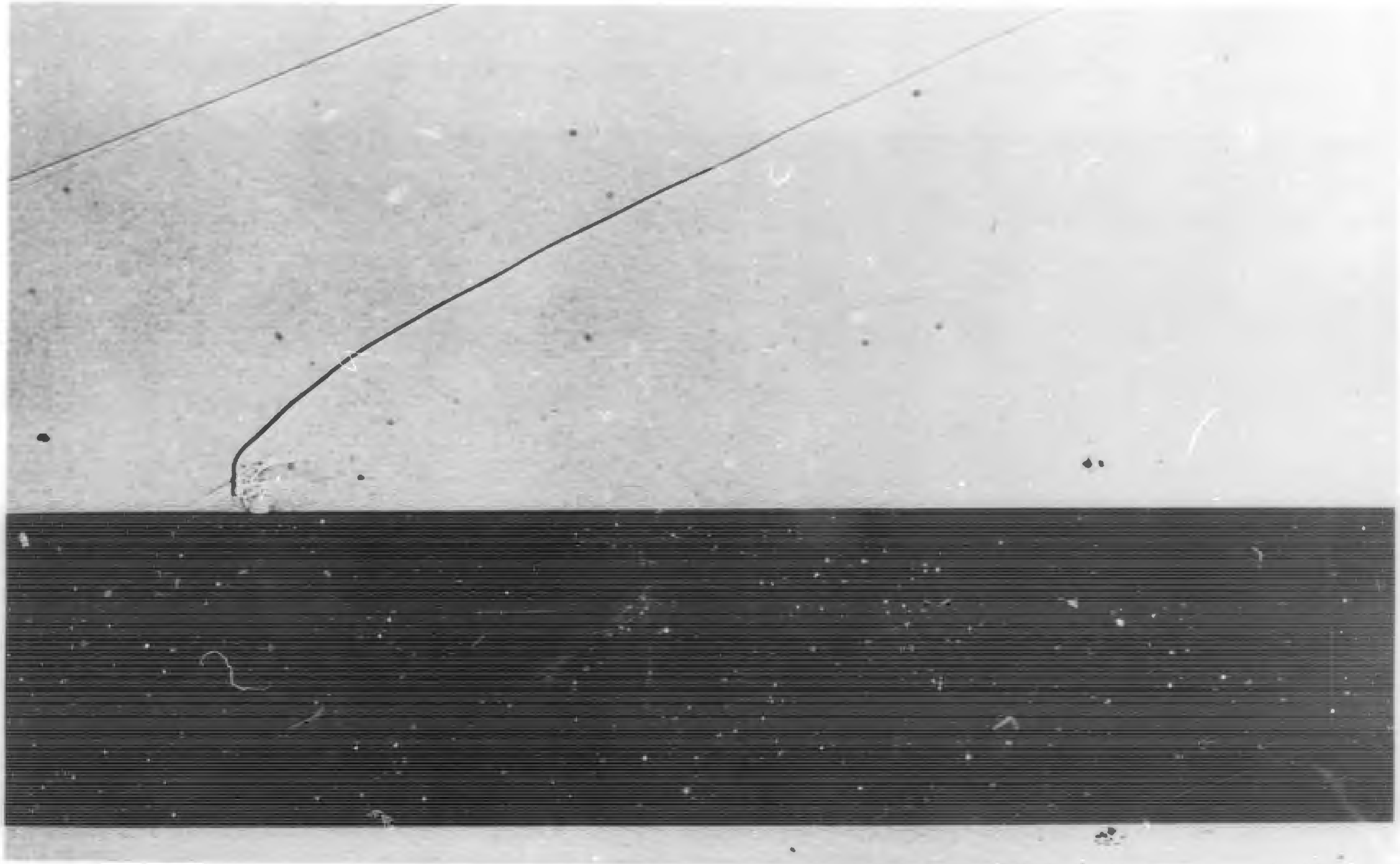

FIGURE C-11c. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 40$

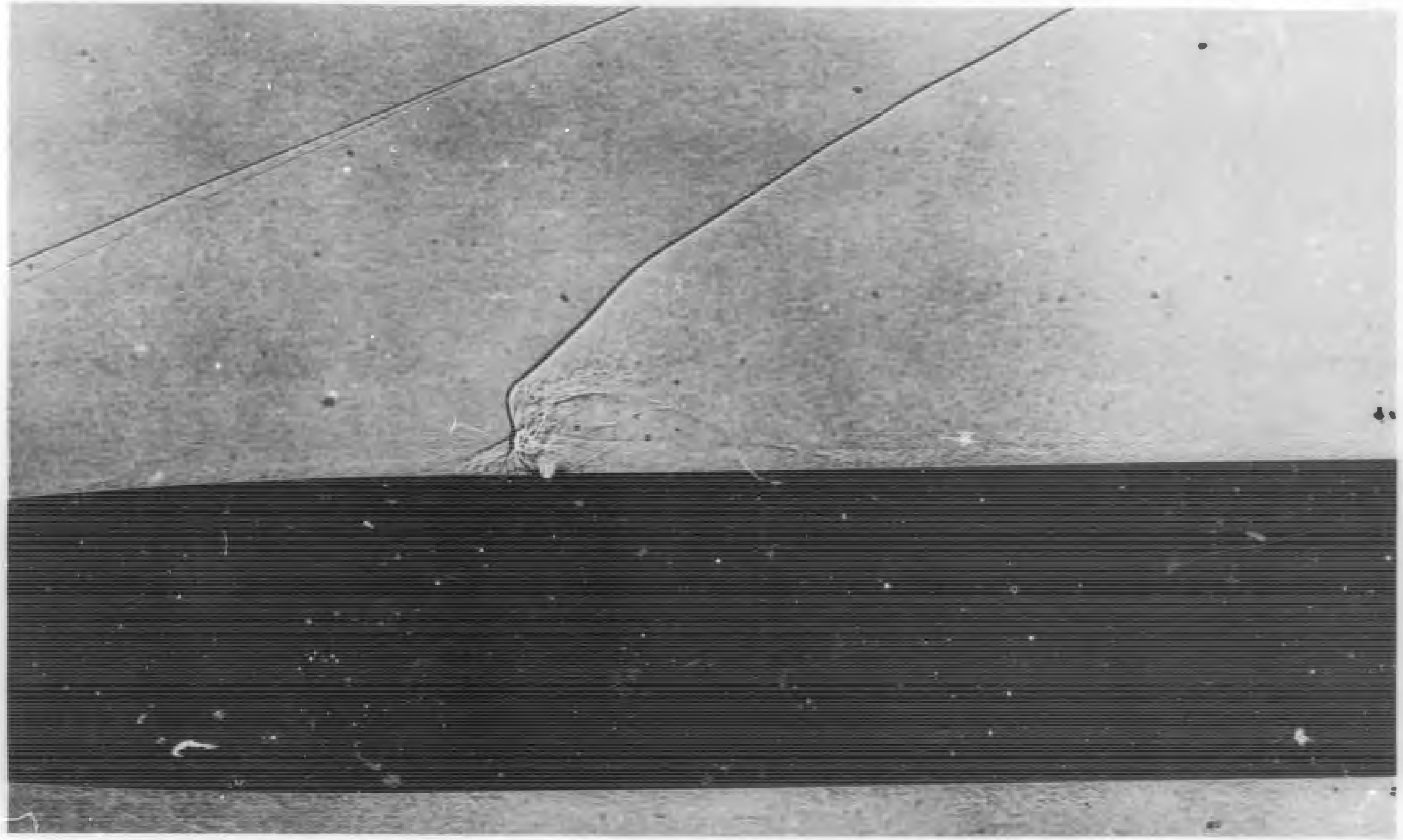

FIGURE C-11d. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 100$

Appendix D
M_∞ = 4.0 Flow Visualization Data

TABLE D-1. TEST VARIABLES AND VISUAL DATA COLLECTED FOR $M_\infty = 4.0$

Configuration	ϕ_j (deg)	Fin No.	α (deg)	P_{oj}/P_∞	Figure Showing Photographs	Figure Showing Schlierens	Figure Showing Shadowgraphs	Test Series
$B_1C_1X_3$	0	0.00	0	0	D-1a			September 1969
			0	0	D-1b			
			0	10	D-1c			
			0	10	D-1d			
			0	40	D-1e			
			0	40	D-1f			
			0	100	D-1g			
			0	100	D-1h			
			0	10			D-1i	
			0	40			D-1j	
			0	100			D-1k	
			5	0	D-2a			
			5	0	D-2b			
			5	10	D-2c			
			5	10	D-2d			
			5	40	D-2e			
			5	40	D-2f			
			5	100	D-2g			
			5	100	D-2h			
			10	0	D-3a			
			10	0	D-3b			
$B_1C_1X_3$	0	0.00	10	10	D-3c			September 1969

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TABLE D-I. TEST VARIABLES AND VISUAL DATA COLLECTED FOR $M_\infty = 4.0$ (Continued)

Configuration	ϕ_j (deg)	Fin No.	α (deg)	P_{oj}/P_∞	Figure Showing Photographs	Figure Showing Schlierens	Figure Showing Shadowgraphs	Test Series
$B_1C_1X_3$	0	0.00	10	10	D-3d			September 1969
			10	40	D-3e			
			10	40	D-3f			
			10	100	D-3g			
			10	100	D-3h			
			-5	0	D-4a			
			-5	0	D-4b			
			-5	10	D-4c			
			-5	10	D-4d			
			-5	40	D-4e			
			-5	40	D-4f			
			-5	100	D-4g			
			-5	100	D-4h			
			-10	0	D-5a			
			-10	0	D-5b			
			-10	10	D-5c			
			-10	10	D-5d			
			-10	40	D-5e			
			-10	40	D-5f			
			-10	100	D-5g			
	0		-10	100	D-5h			
	45		0	0	D-6a			
			0	10	D-6b			
			0	10	D-6c			
$B_1C_1X_3$	45	0.00	0	40	D-6d			September 1969

TABLE D-I. TEST VARIABLES AND VISUAL DATA COLLECTED FOR $M_\infty = 4.0$ (Continued)

Configuration	ϕ_j (deg)	Fin No.	α (deg)	P_{oj}/P_∞	Figure Showing Photographs	Figure Showing Schlierens	Figure Showing Shadowgraphs	Test Series
$B_1C_1X_3$	45	0.00	0	40	D-6e			September 1969
			0	100	D-6f			
			0	100	D-6g			
			5	0	D-7a			
			5	0	D-7b			
			5	10	D-7c			
			5	10	D-7d			
			5	40	D-7e			
			5	40	D-7f			
			5	100	D-7g			
			5	100	D-7h			
			10	0	D-8a			
			10	0	D-8b			
			10	10	D-8c			
			10	10	D-8d			
			10	40	D-8e			
			10	40	D-8f			
			10	100	D-8g			
			10	100	D-8h			
			-5	0	D-9a			
			-5	0	D-9b			
			-5	10	D-9c			
			-5	10	D-9d			
$B_1C_1X_3$	45	0.00	-5	40	D-9e			September 1969

TABLE D-I. TEST VARIABLES AND VISUAL DATA COLLECTED FOR $M_\infty = 4.0$ (Concluded)

Configuration	ϕ_j (deg)	Fin No.	α (deg)	P_{oj}/P_∞	Figure Showing Photographs	Figure Showing Schlierens	Figure Showing Shadowgraphs	Test Series
$B_1C_1X_3$	45	0.00	-5	40	D-9f			September 1969
			-5	100	D-9g			
			-5	100	D-9h			
			-10	0	D-10a			
			-10	0	D-10b			
			-10	10	D-10c			
			-10	10	D-10d			
			-10	40	D-10e			
			-10	40	D-10f			
			-10	100	D-10g			
$B_1C_1X_3$	45	0.00	-10	100	D-10h			September 1969

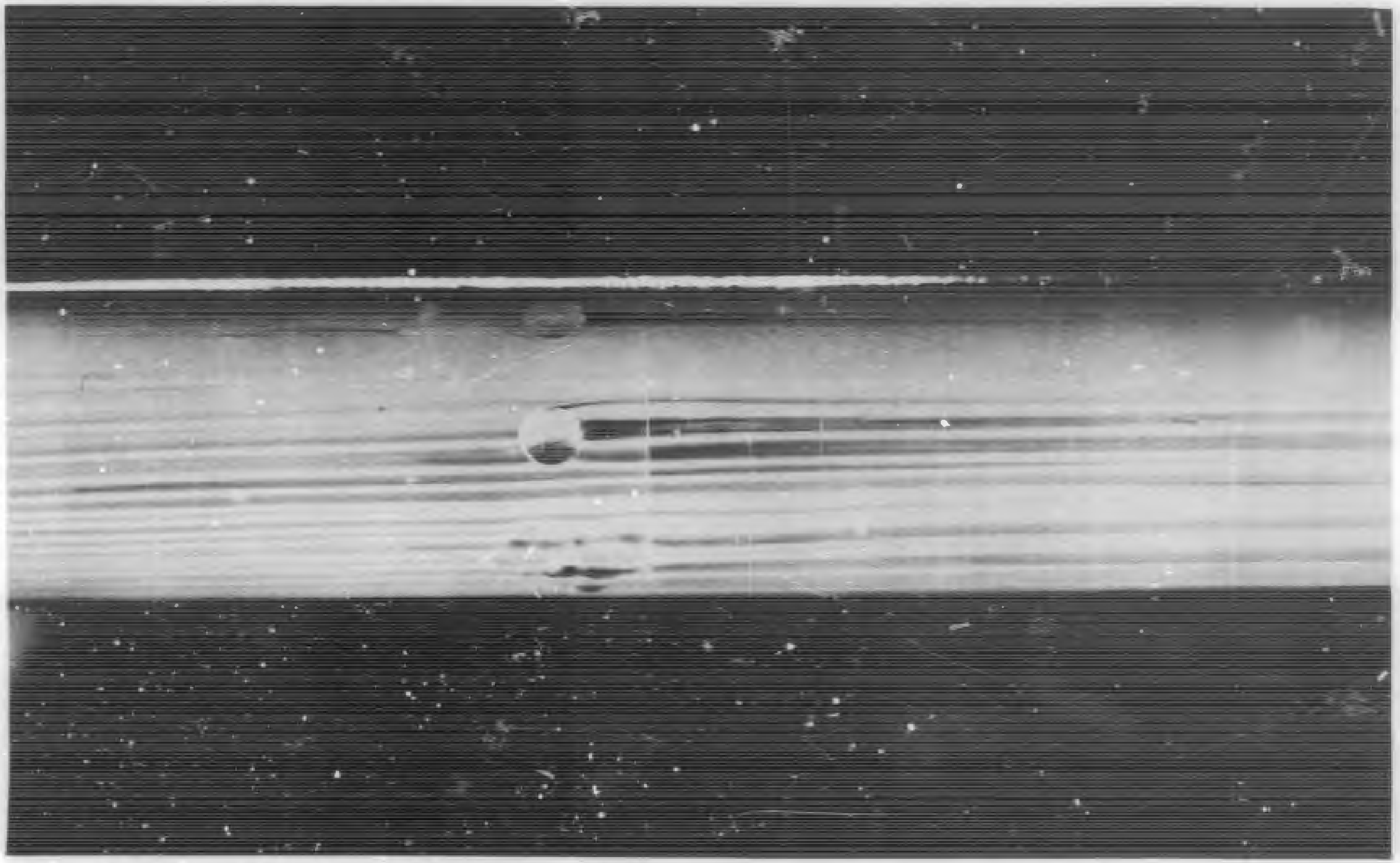

FIGURE D-1b. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_{\infty} = 0$

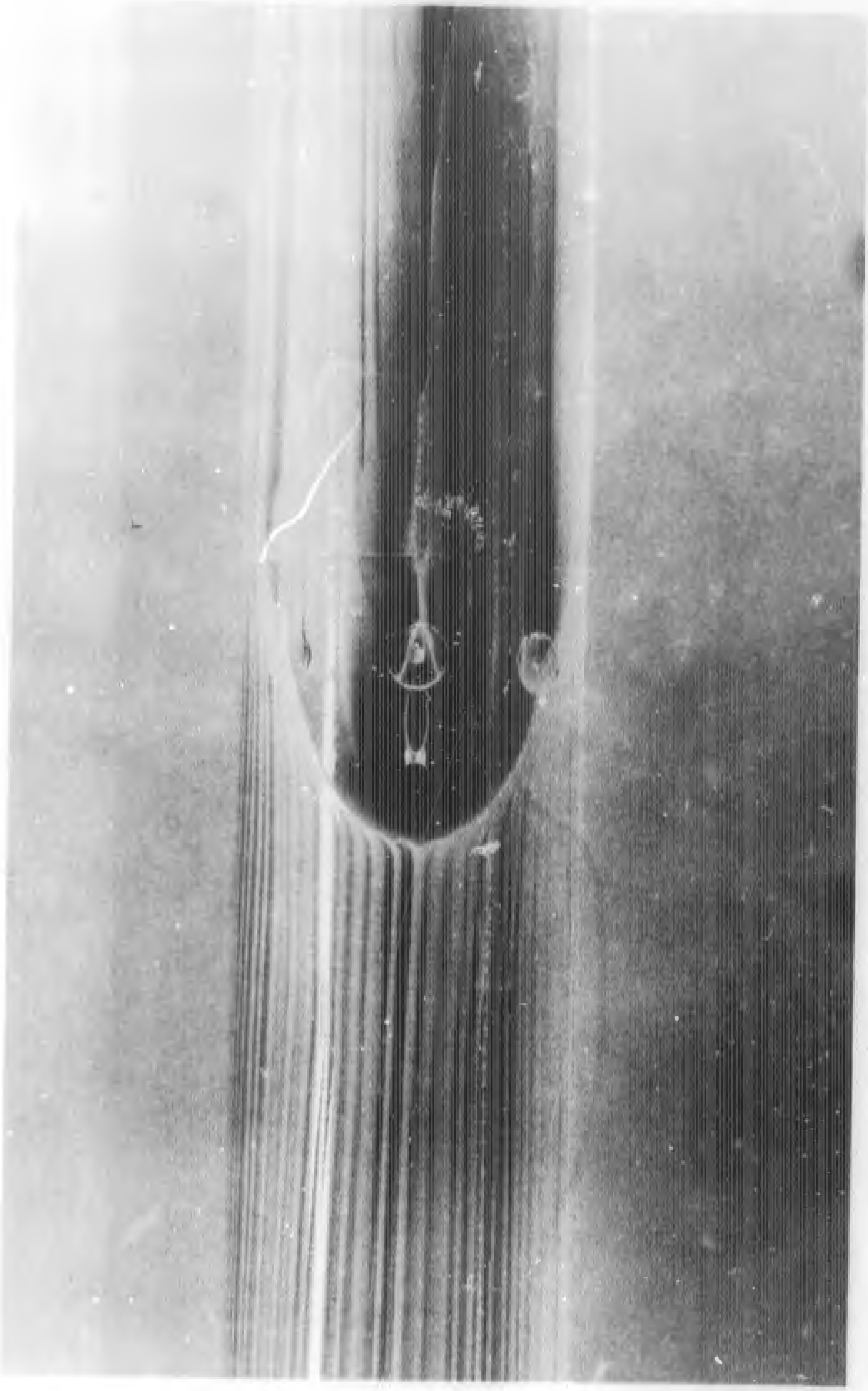

FIGURE D-1c. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_{\infty} = 10$

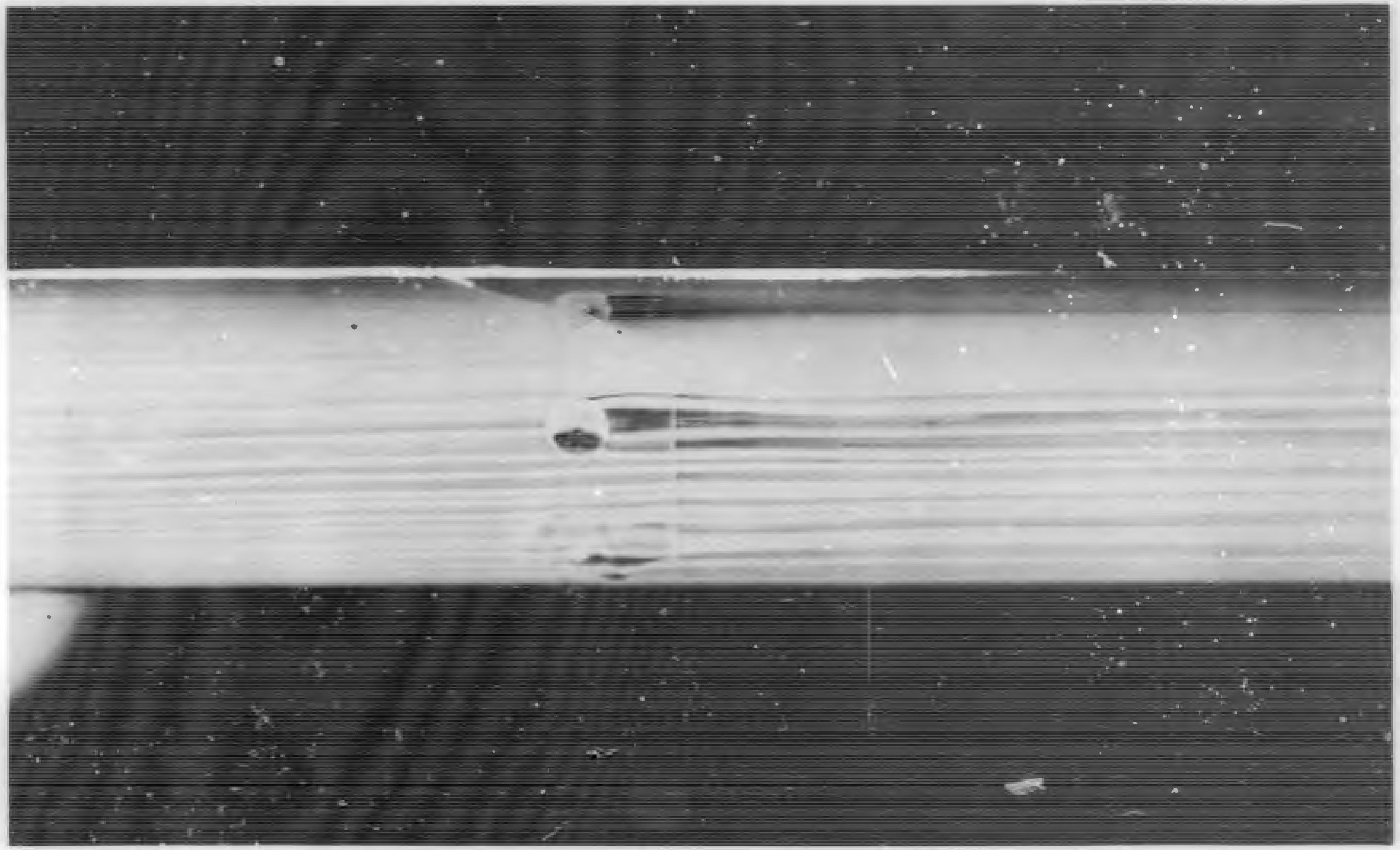

FIGURE D-1d. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 10$

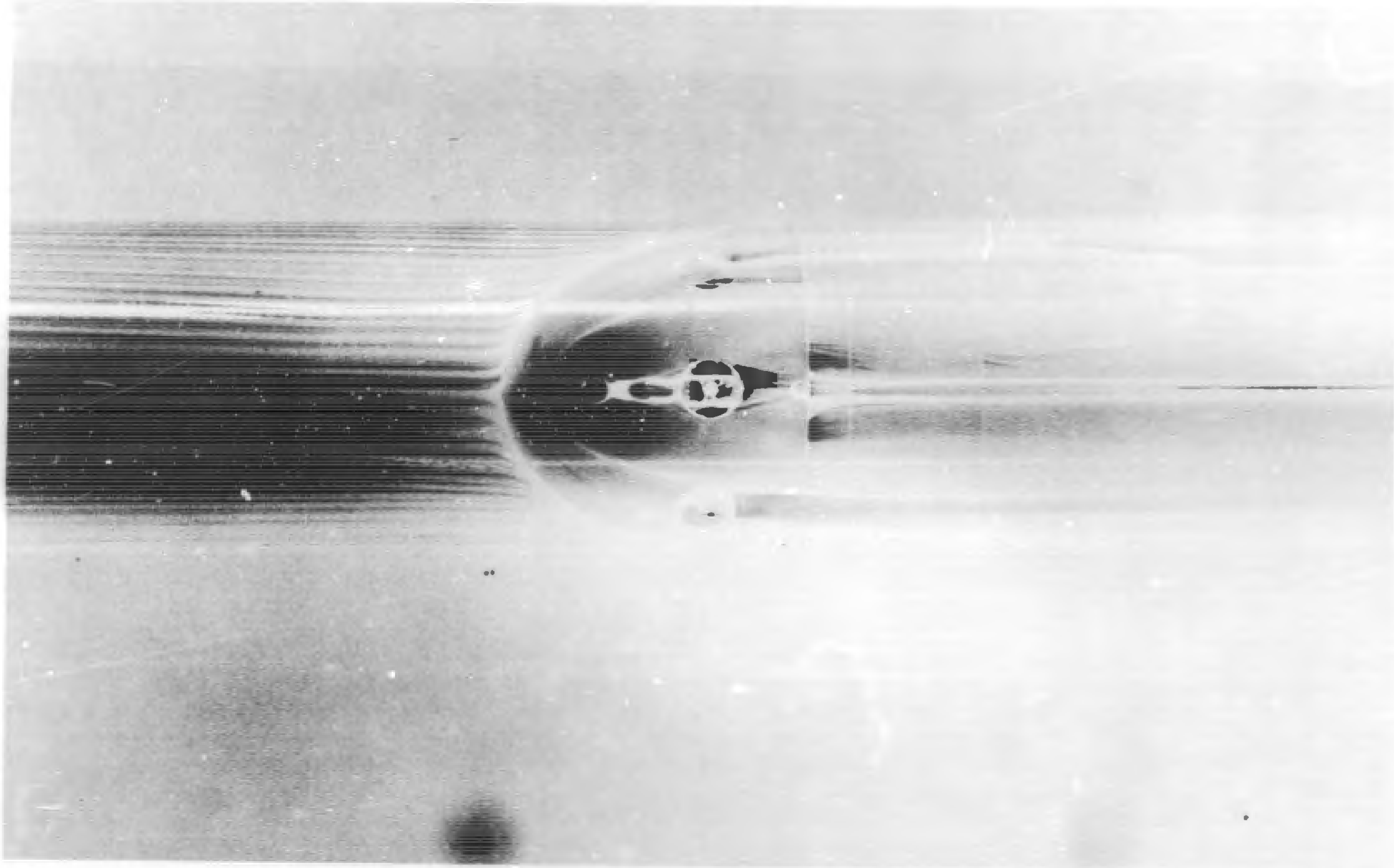

FIGURE D-1e. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 40$

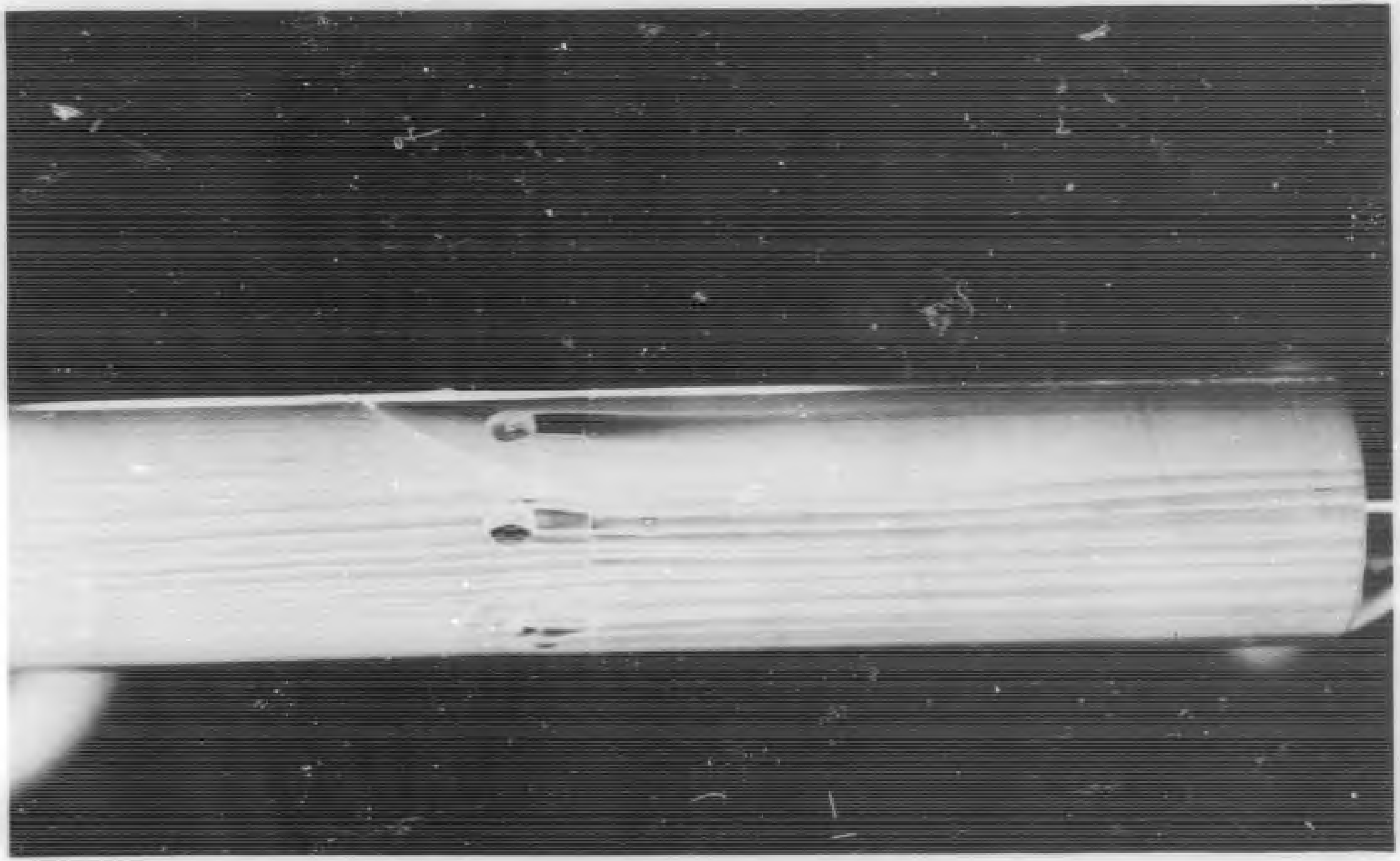

FIGURE D-1f. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 40$

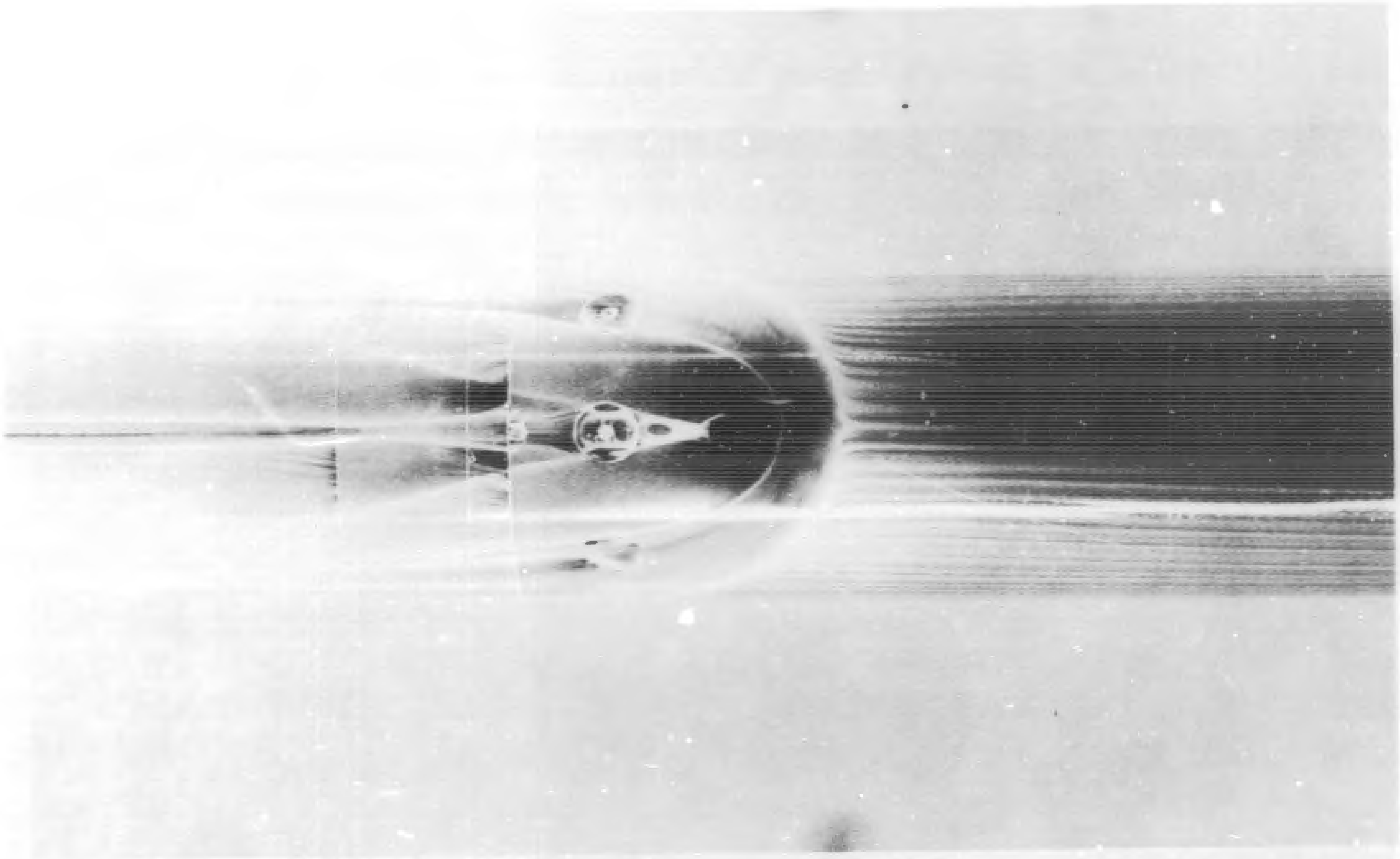

FIGURE D-1g. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 100$

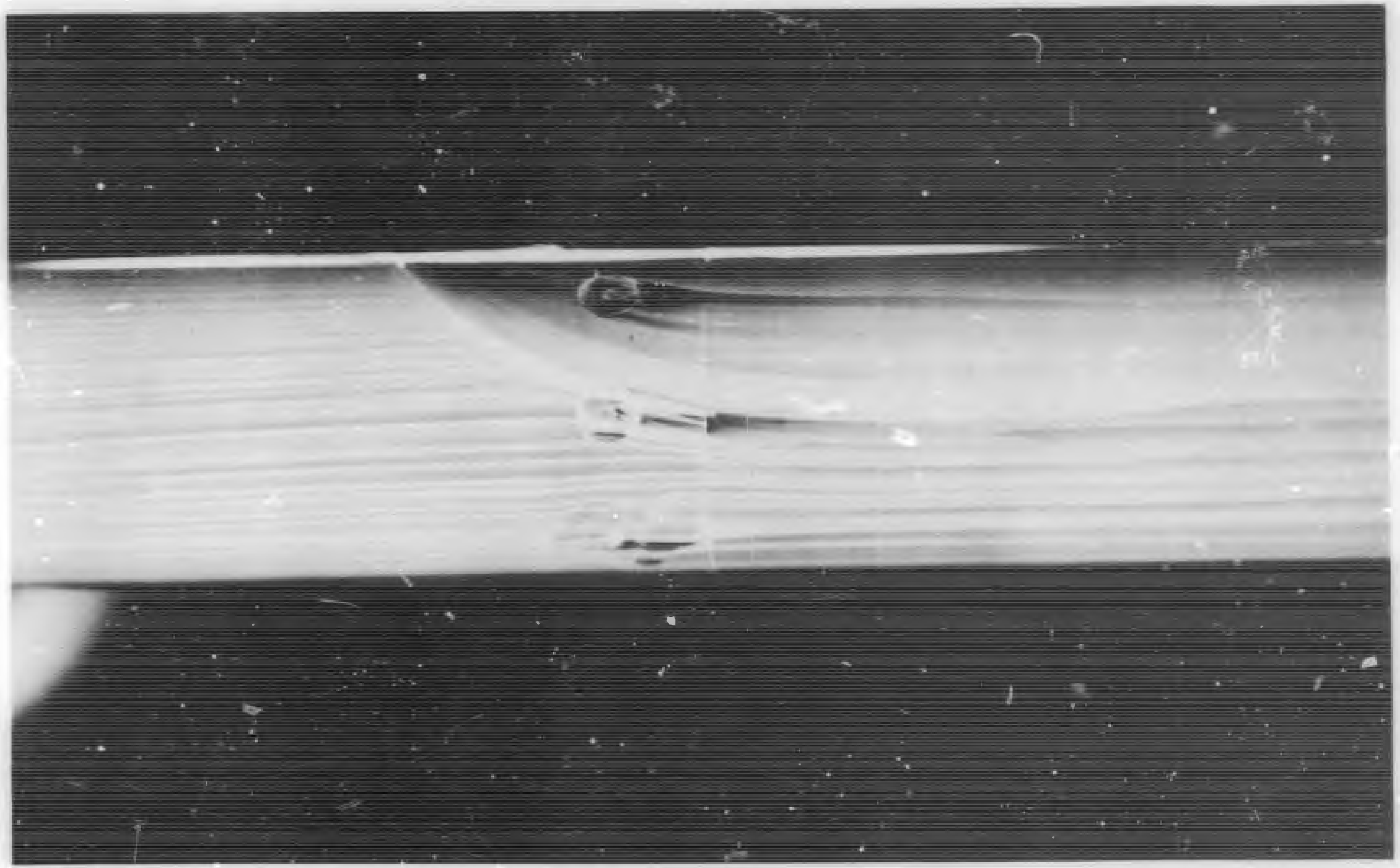

FIGURE D-1h. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 100$

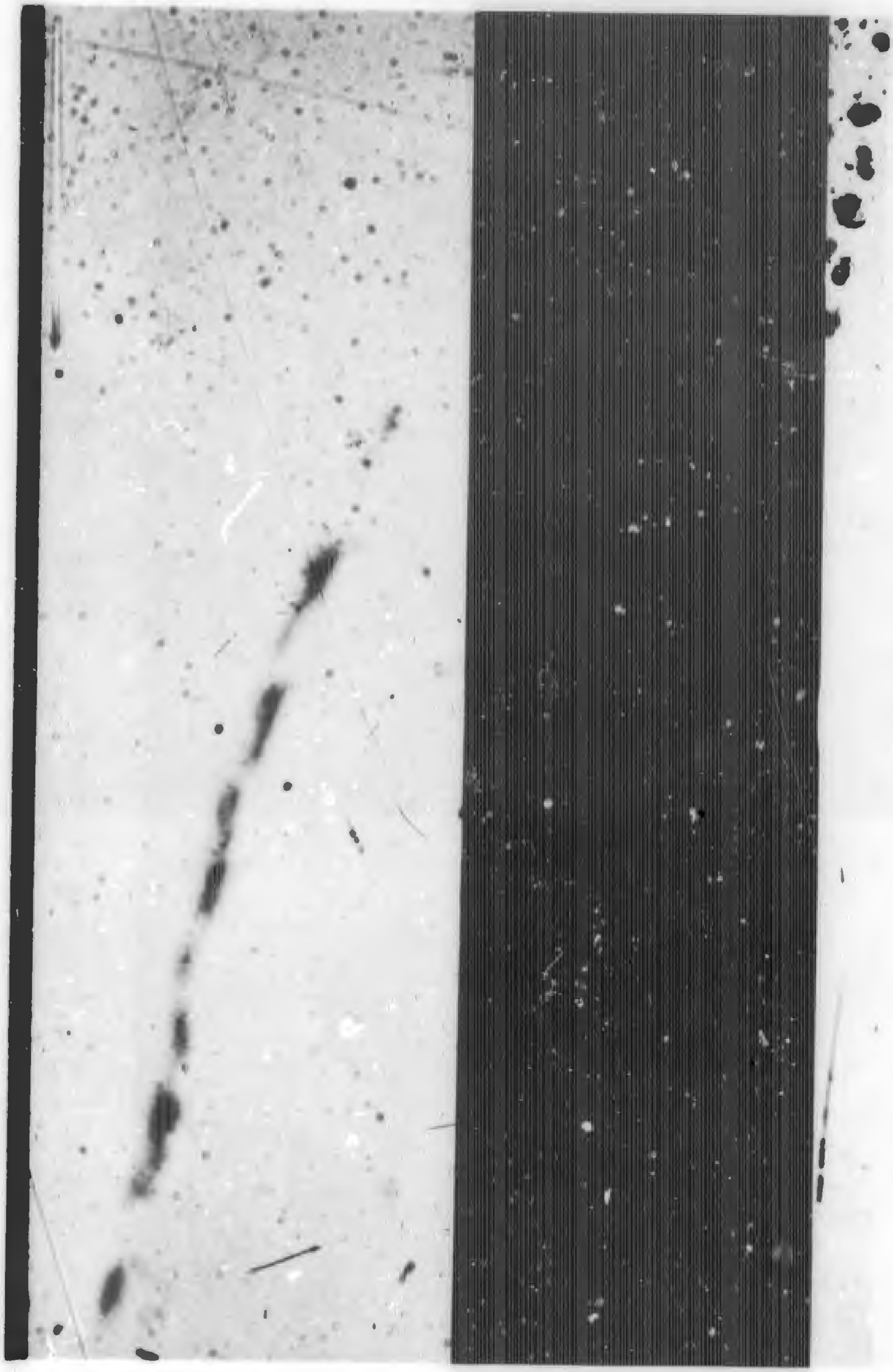

FIGURE D-1i. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 10$

FIGURE D-1j. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_{\infty} = 40$

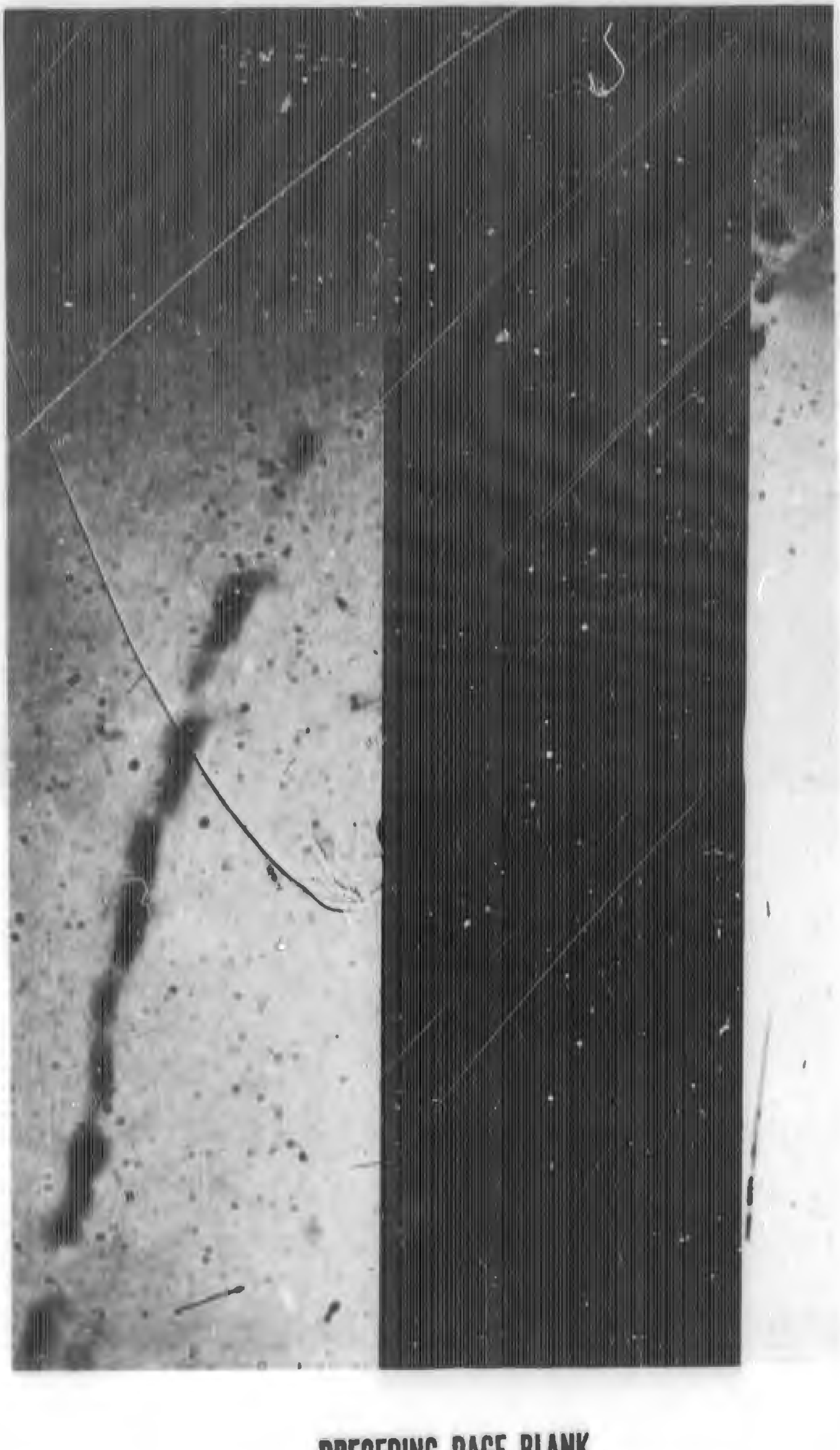

FIGURE D-1k. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 100$

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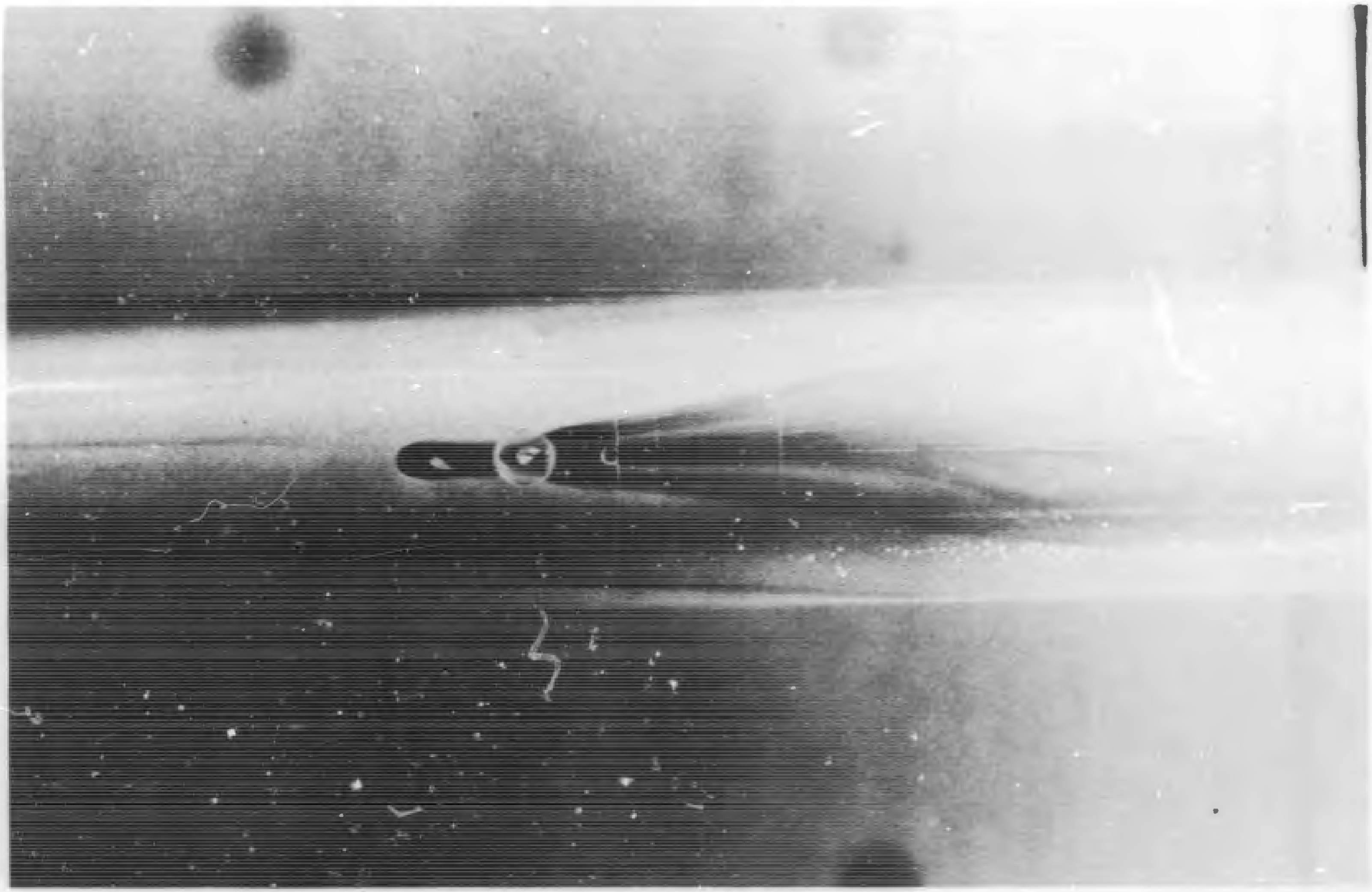

FIGURE D-2a. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_{\infty} = 0$

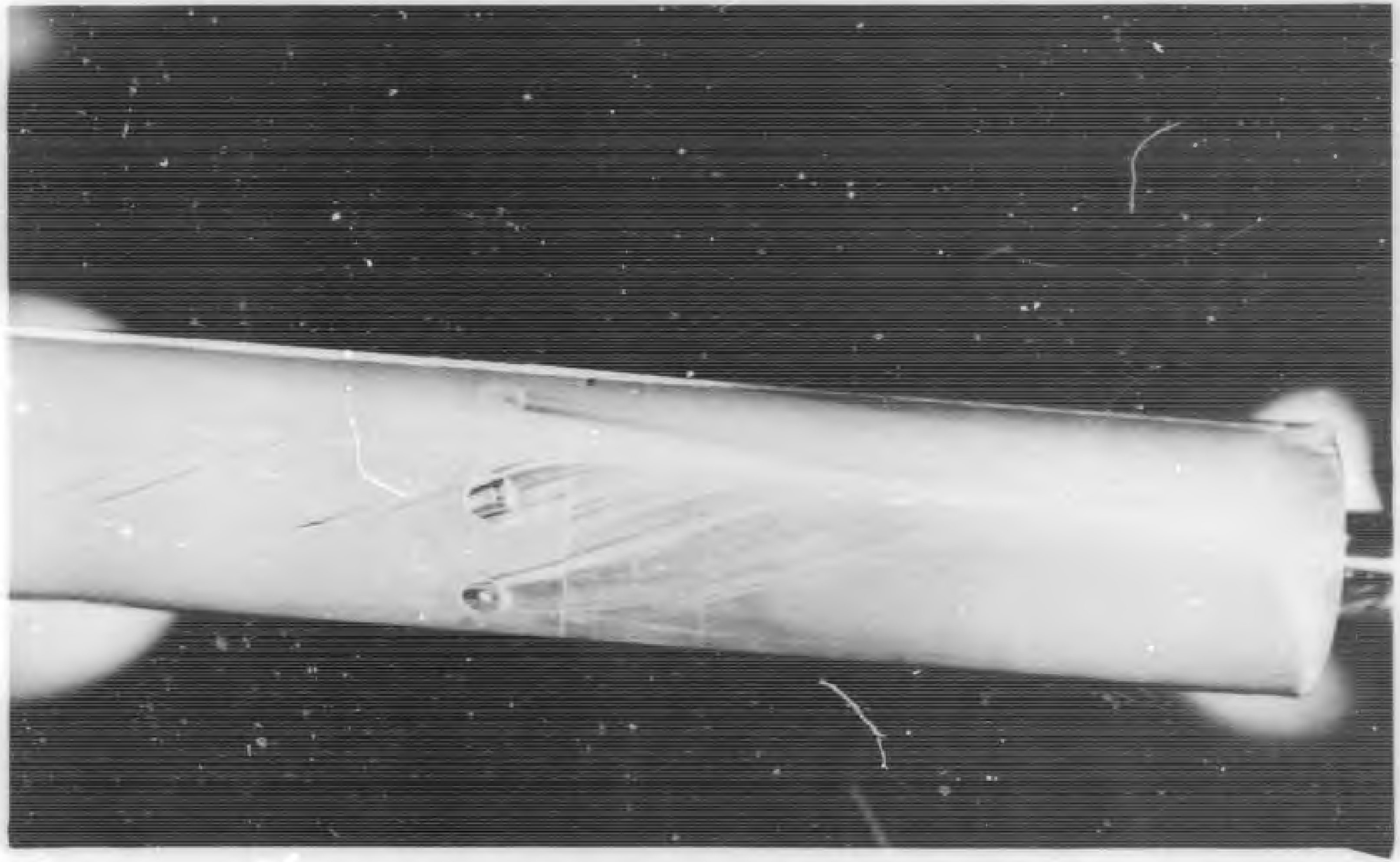

FIGURE D-2b. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_\infty = 0$

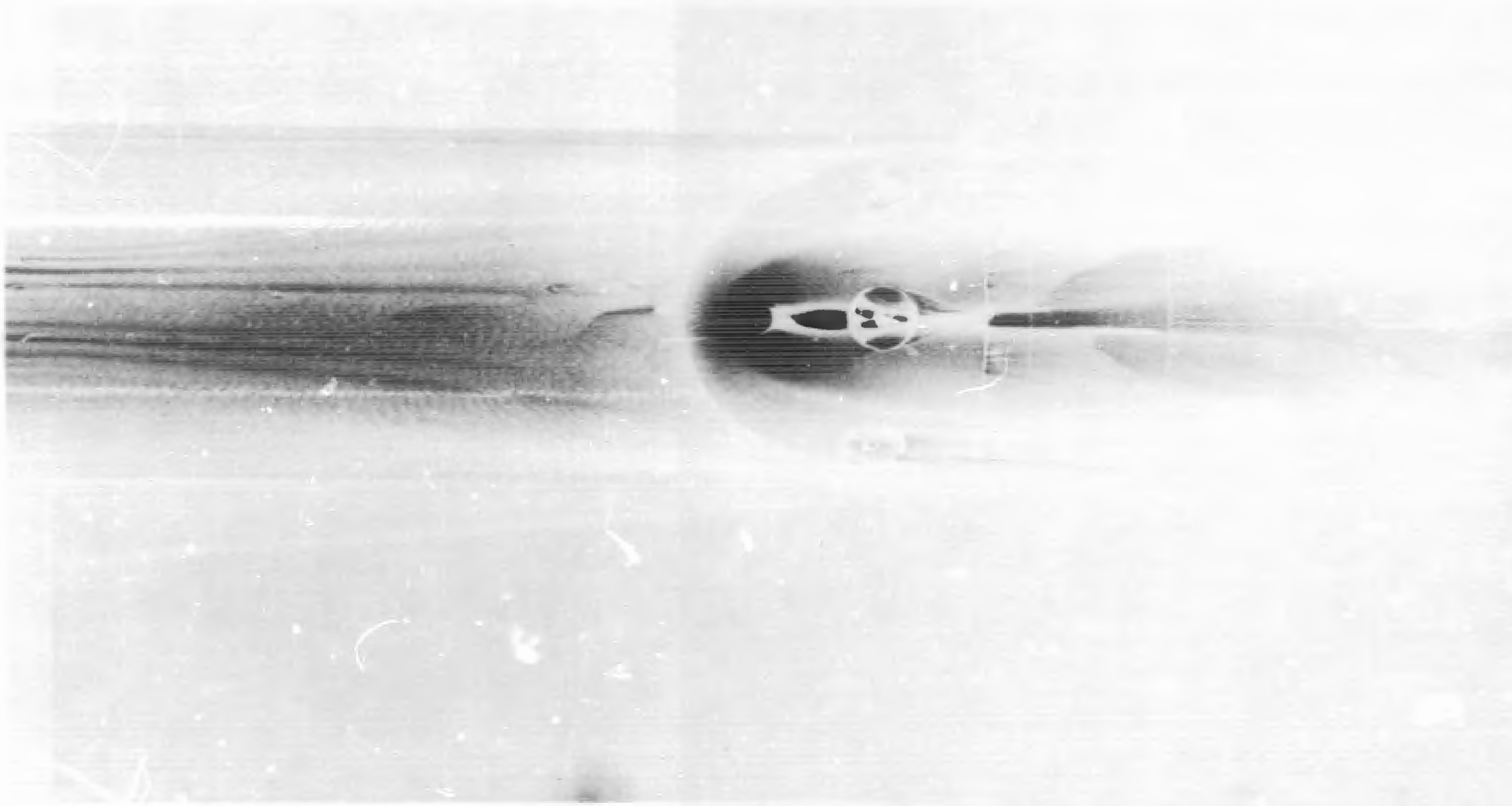

FIGURE D-2c. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_{\infty} = 10$

FIGURE D-2d. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_\infty = 10$

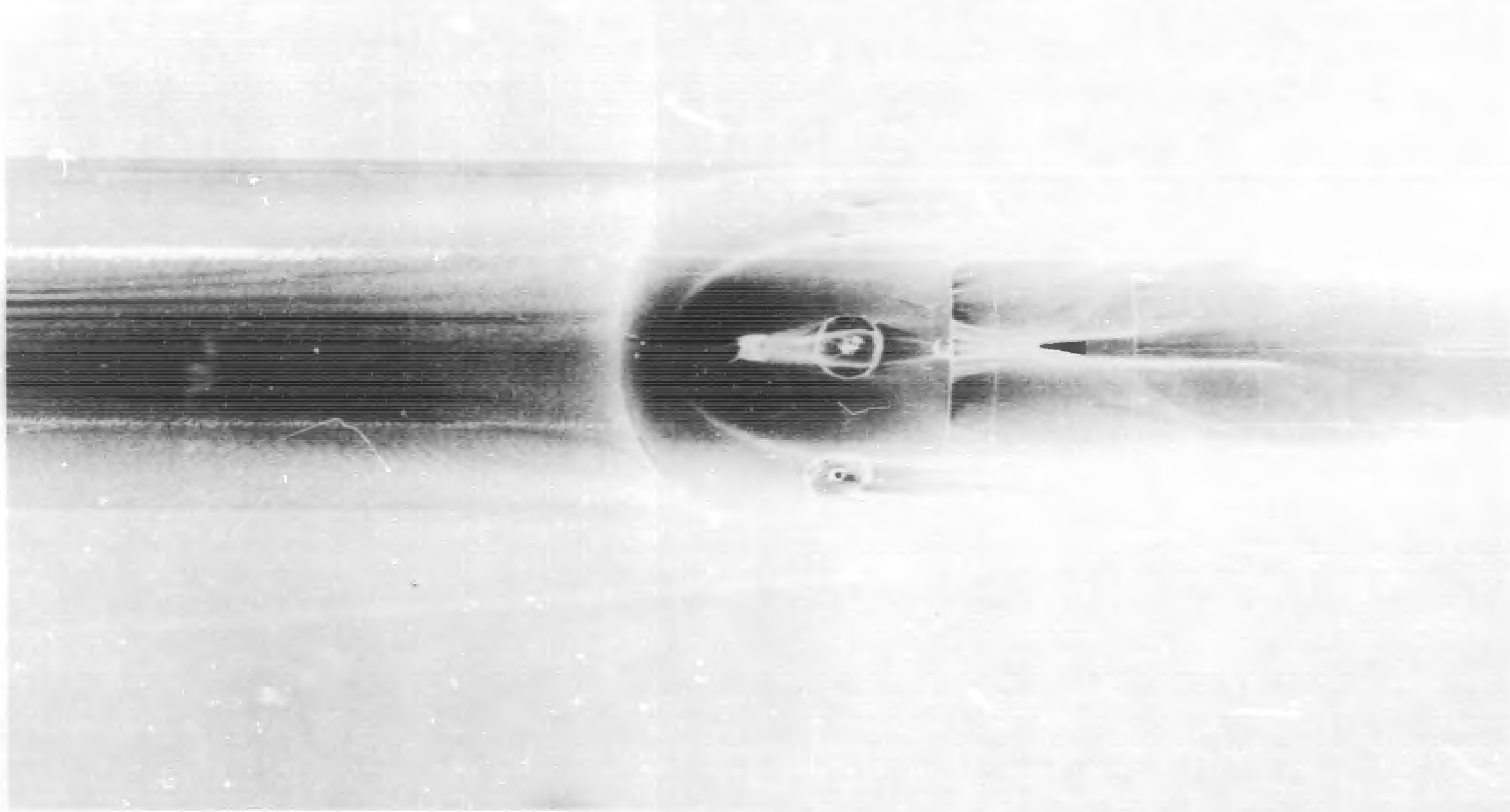

FIGURE D-2e. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_{\infty} = 40$

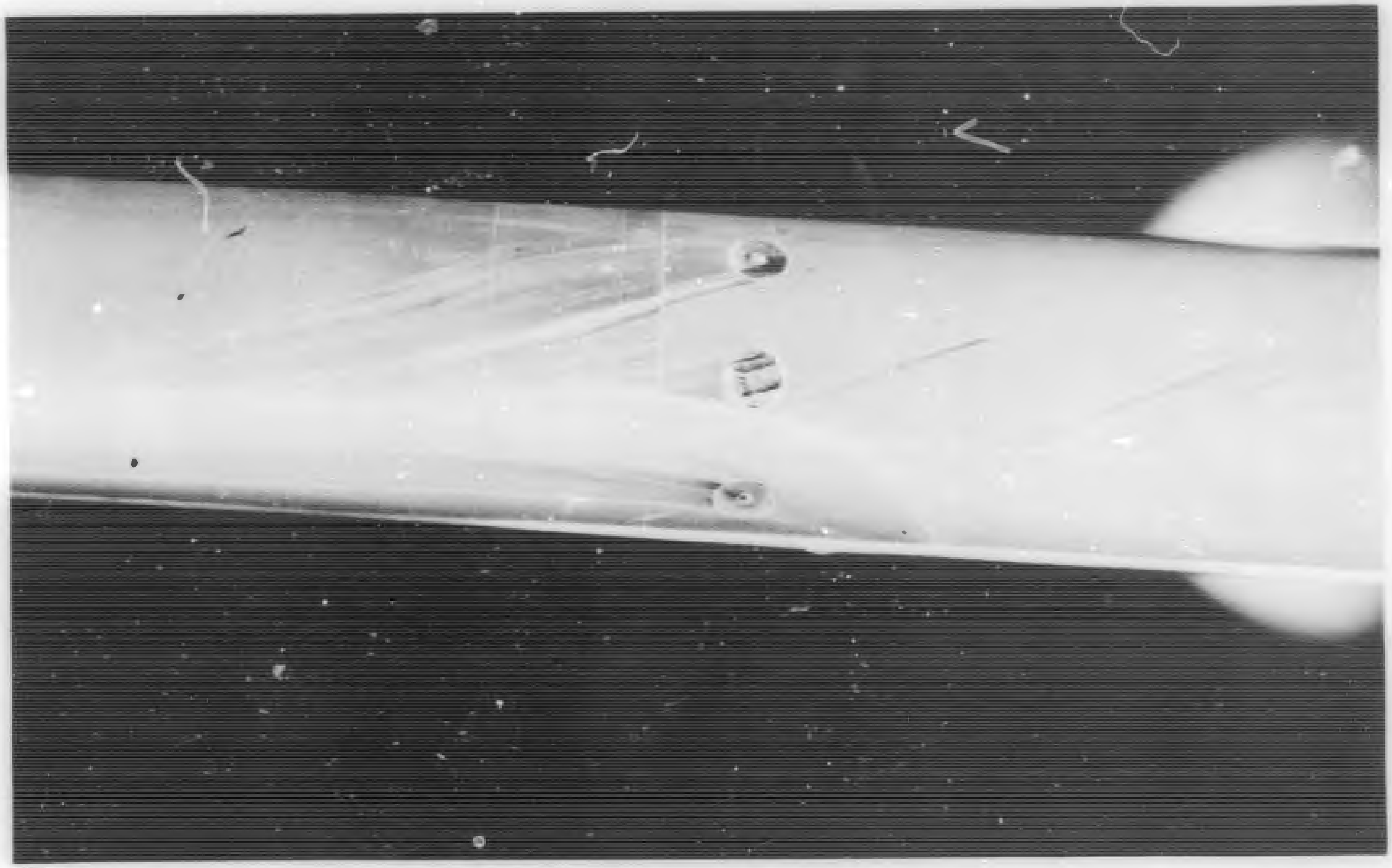

FIGURE D-2f. REACTION JET FOR $B_1C_1X_3$ WITH α = 5 DEGREES; P_{oj}/P_{∞} = 40

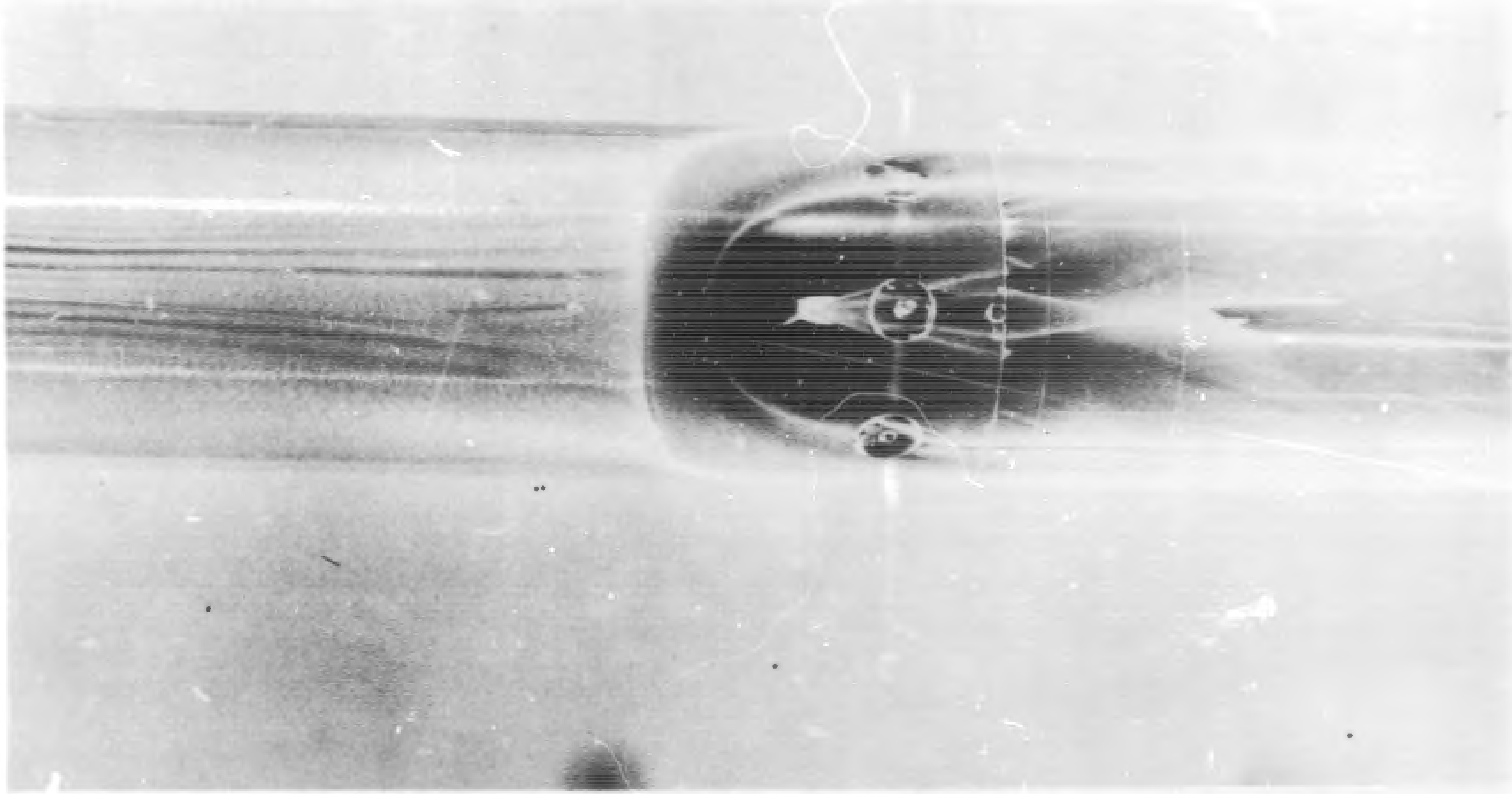

FIGURE D-2g. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_\infty = 100$

FIGURE D-2h. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 5$ DEGREES: $P_{oj}/P_\infty = 100$

FIGURE D-3a. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_\infty = 0$

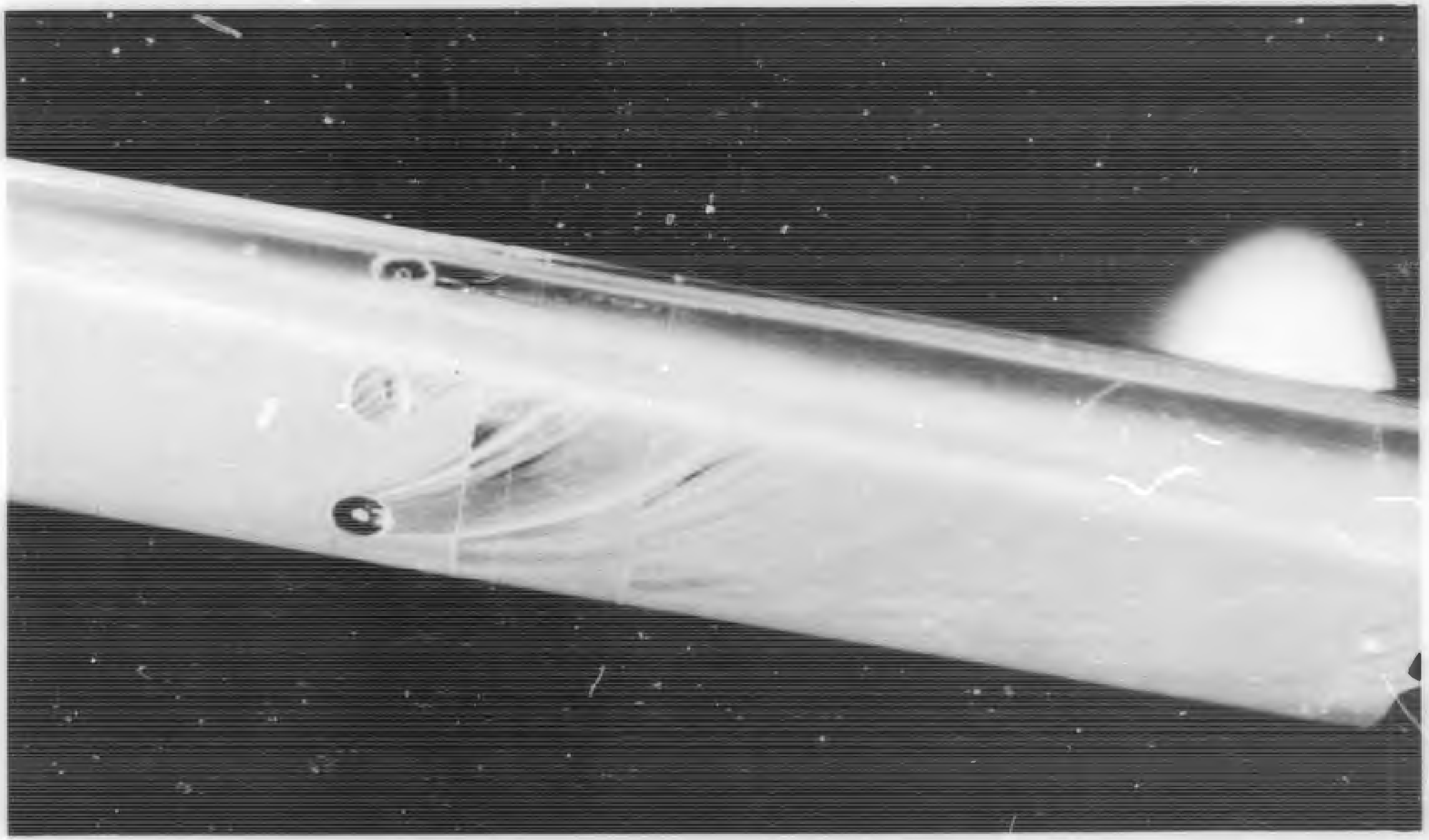

FIGURE D-3b. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_\infty = 0$

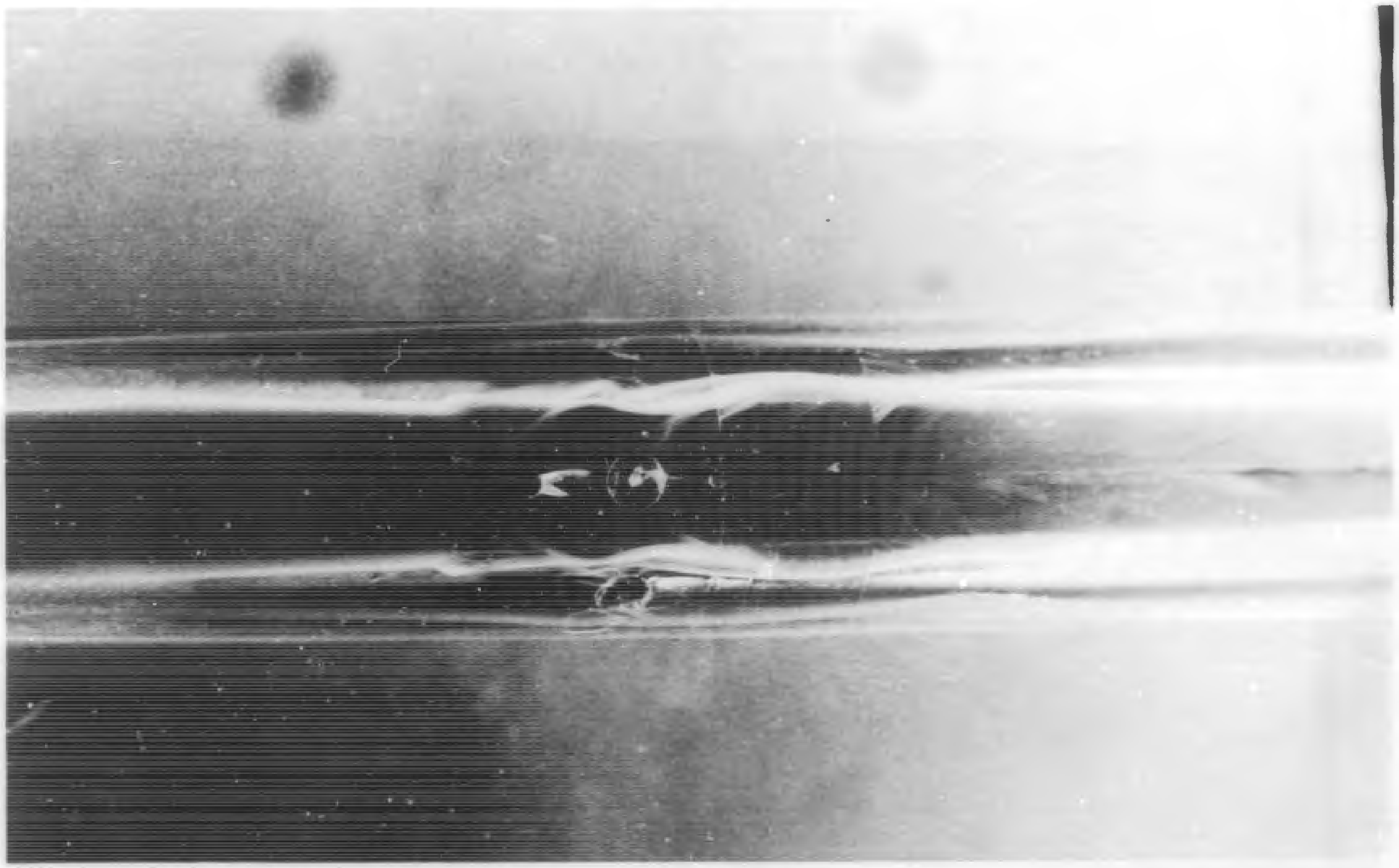

FIGURE D-3c. REACTION JET FOR $B_1C_1X_3$ WITH α = 10 DEGREES; P_{oj}/P_{∞} = 10

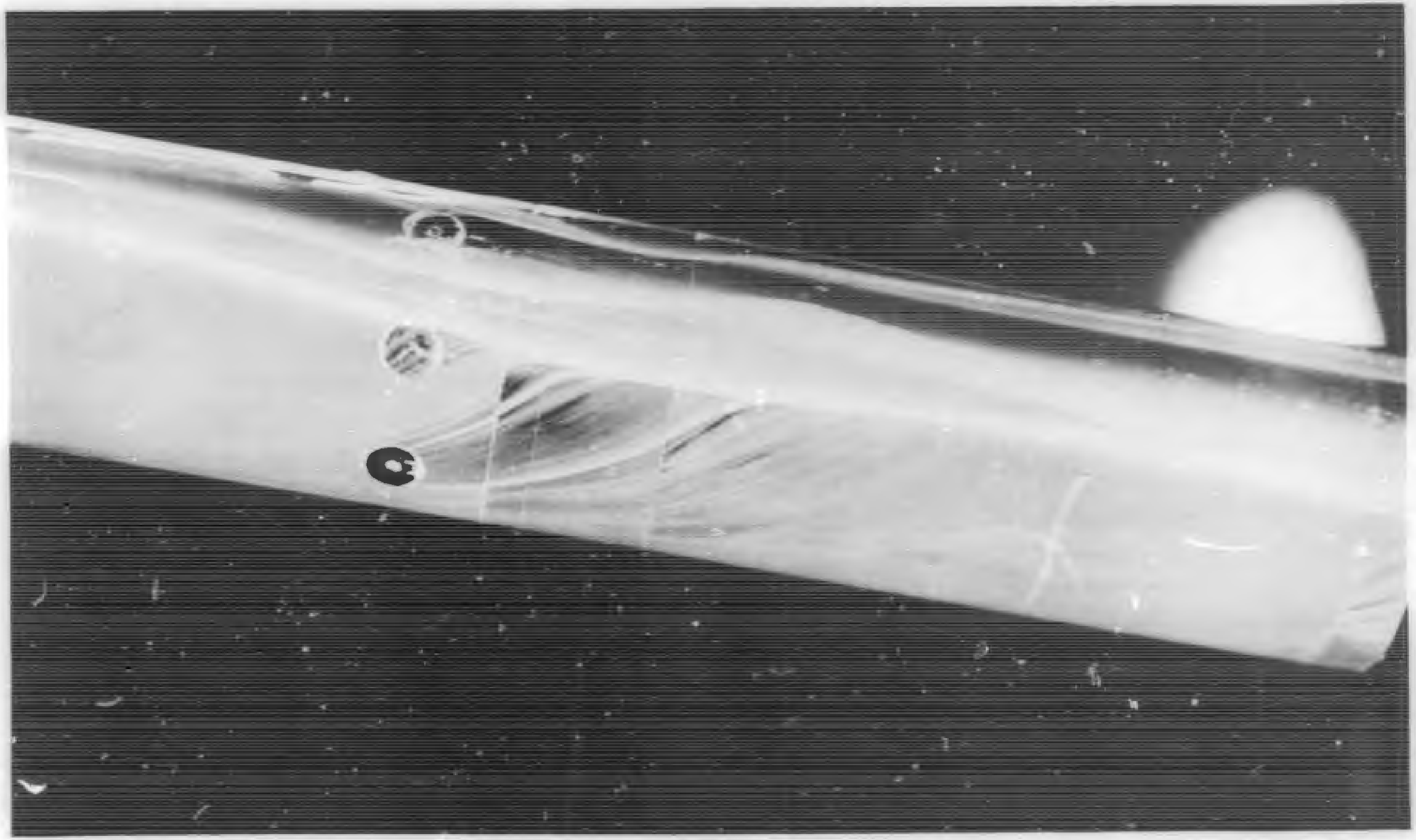

FIGURE D-3d. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_\infty = 10$

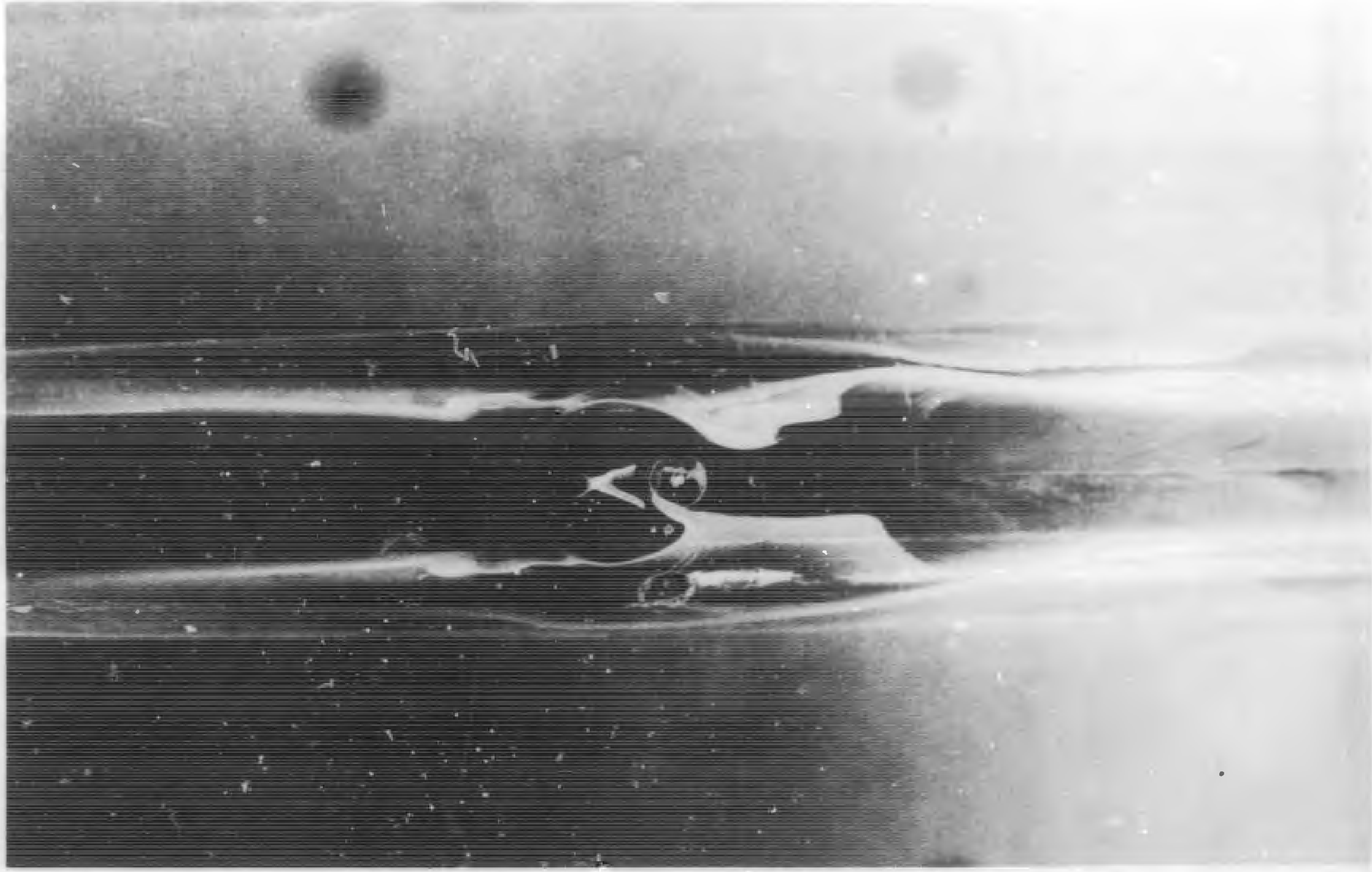

FIGURE D-3e. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_\infty = 40$

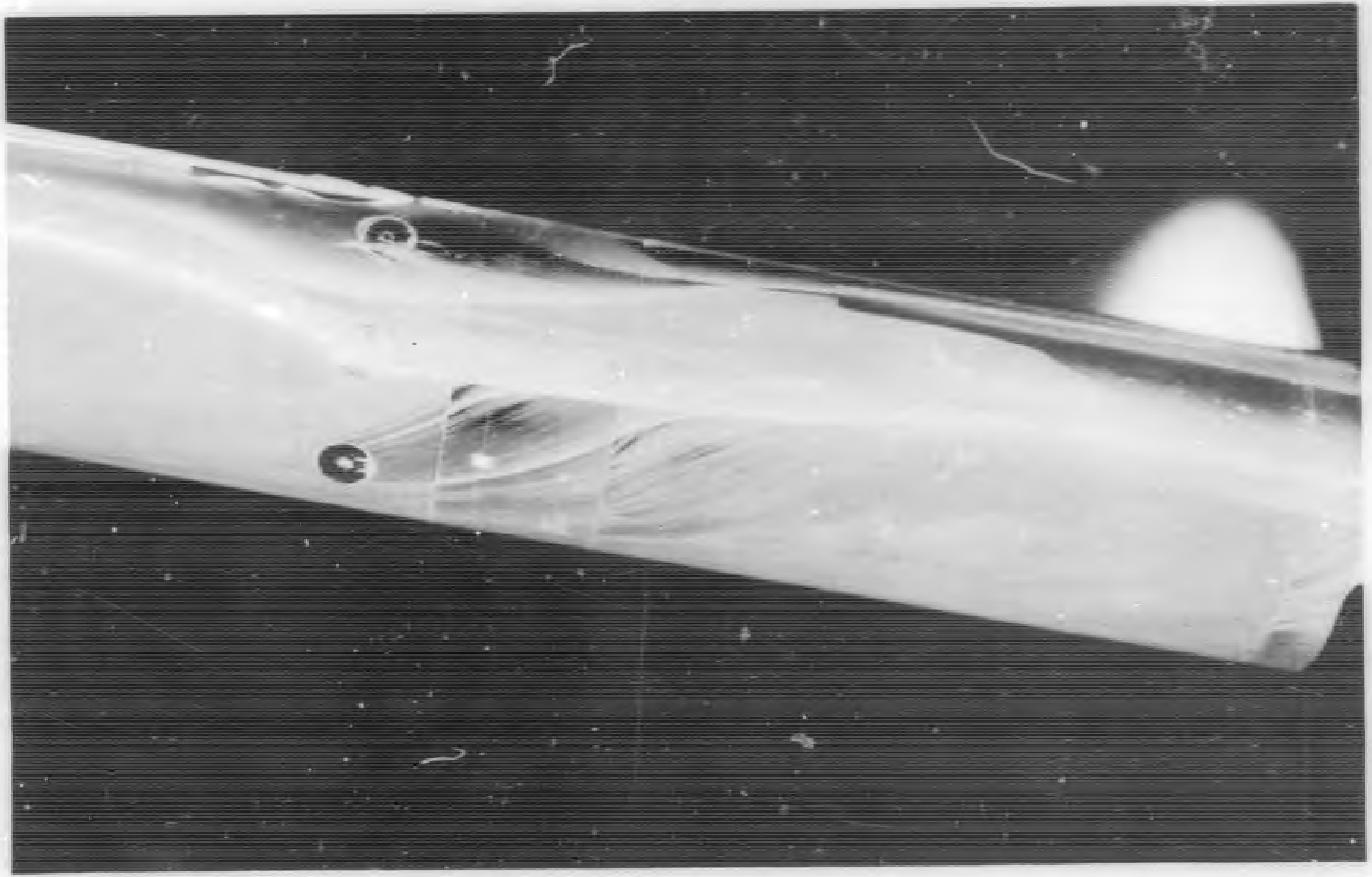

FIGURE D-3f. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_{\infty} = 40$

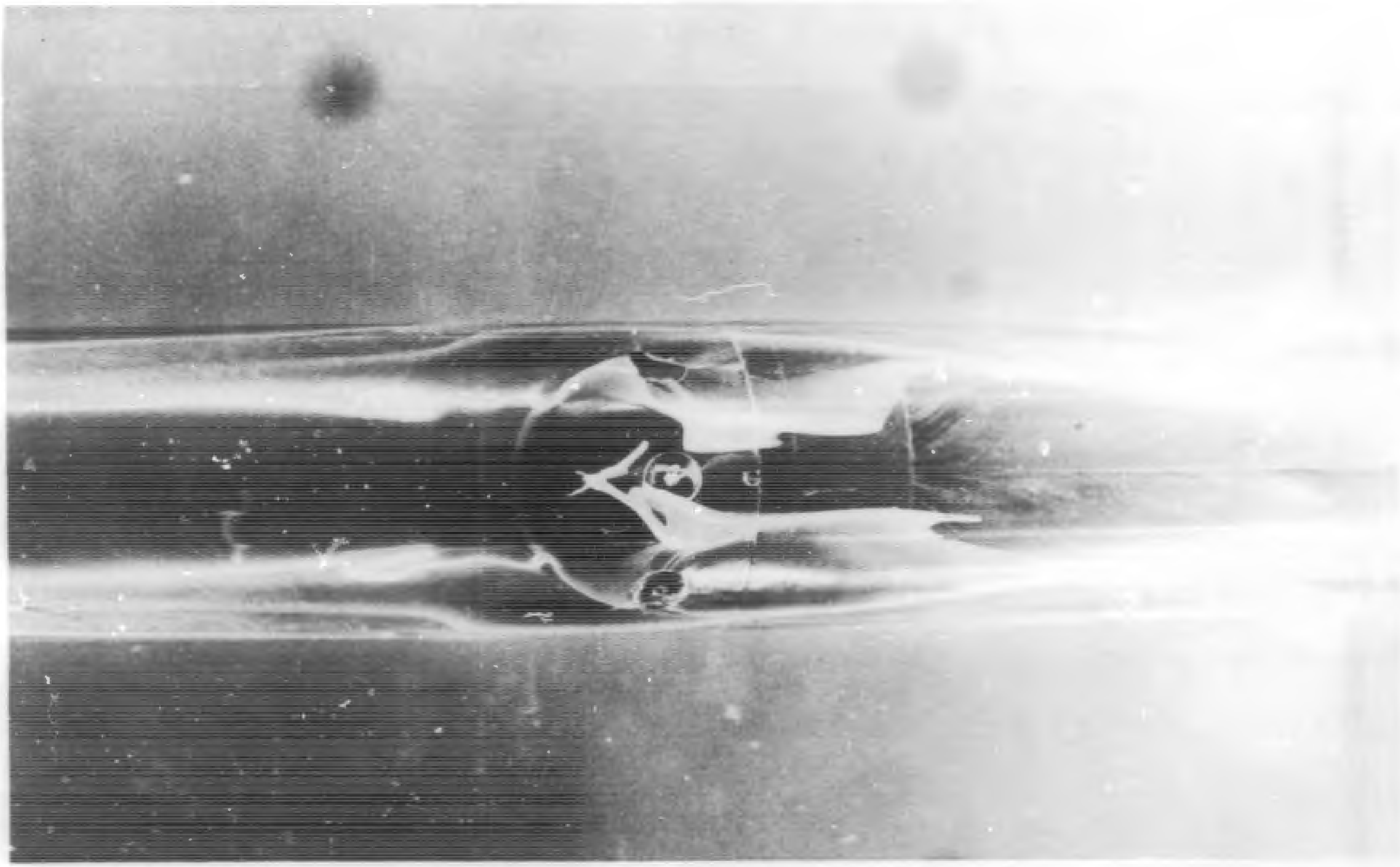

FIGURE D-3g. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_{\infty} = 100$

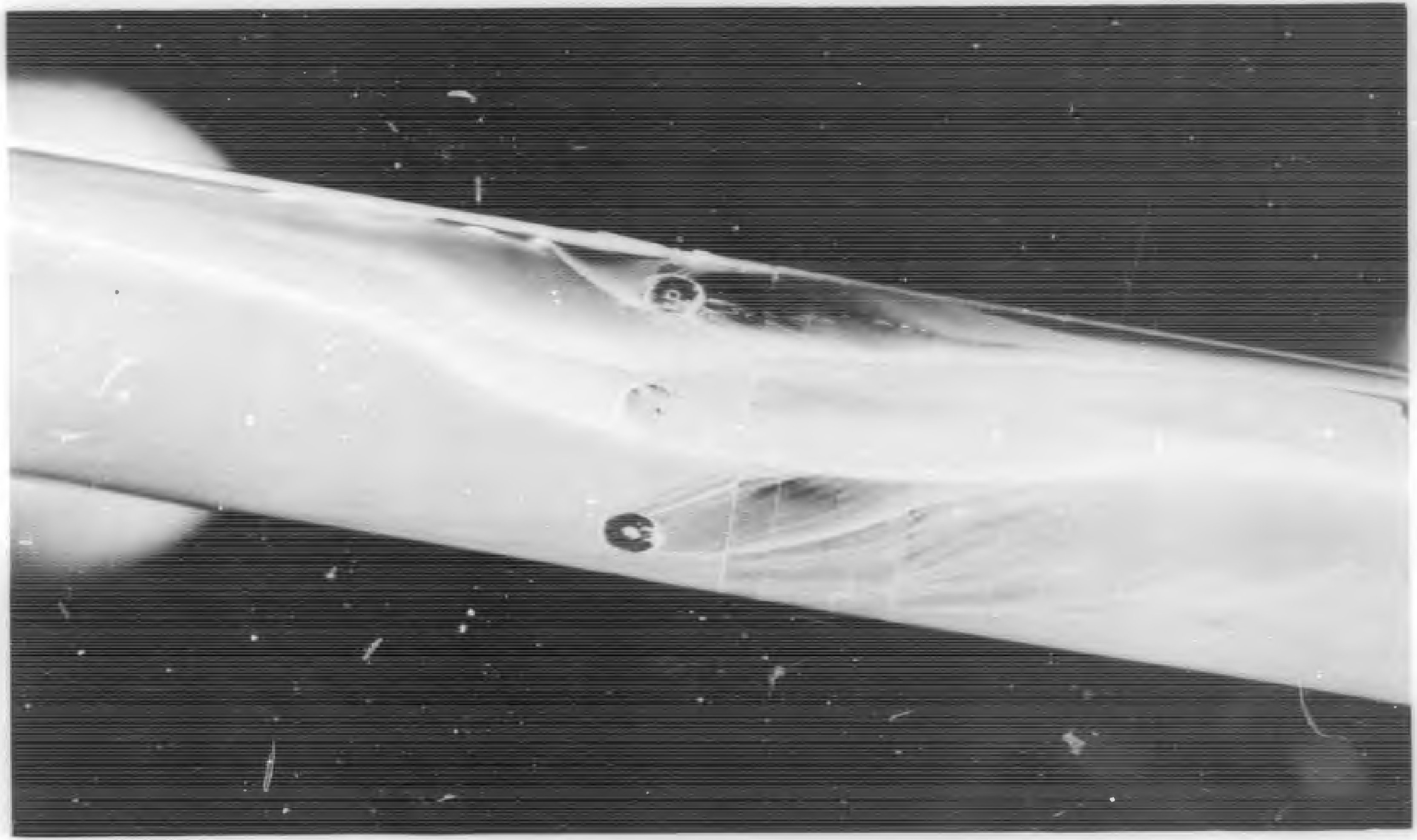

FIGURE D-3h. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_\infty = 100$

FIGURE D-4a. REACTION JET FOR $B_1C_1X_3$ WITH α = -5 DEGREES; P_{oj}/P_{∞} = 0

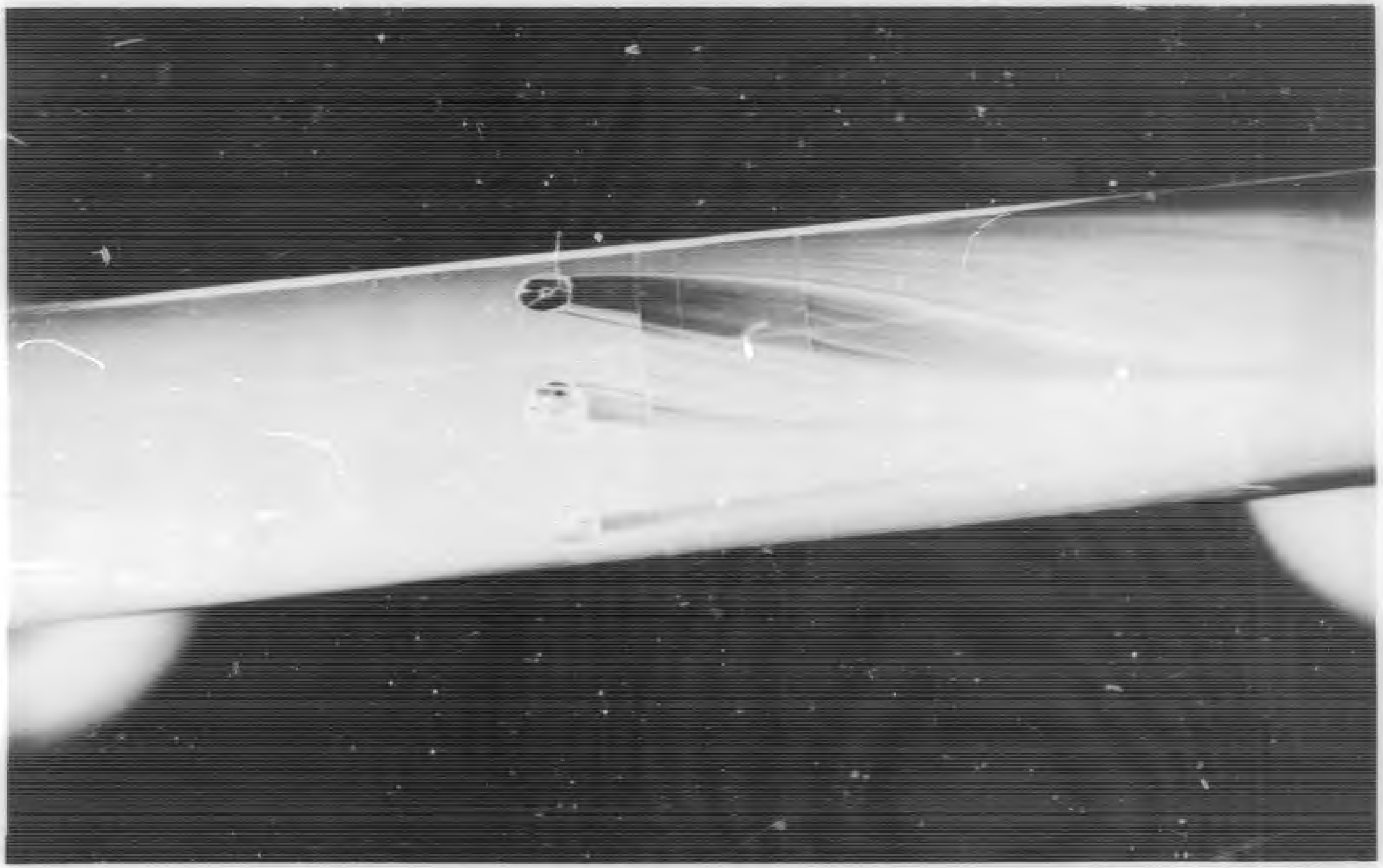

FIGURE D–4b. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_{\infty} = 0$

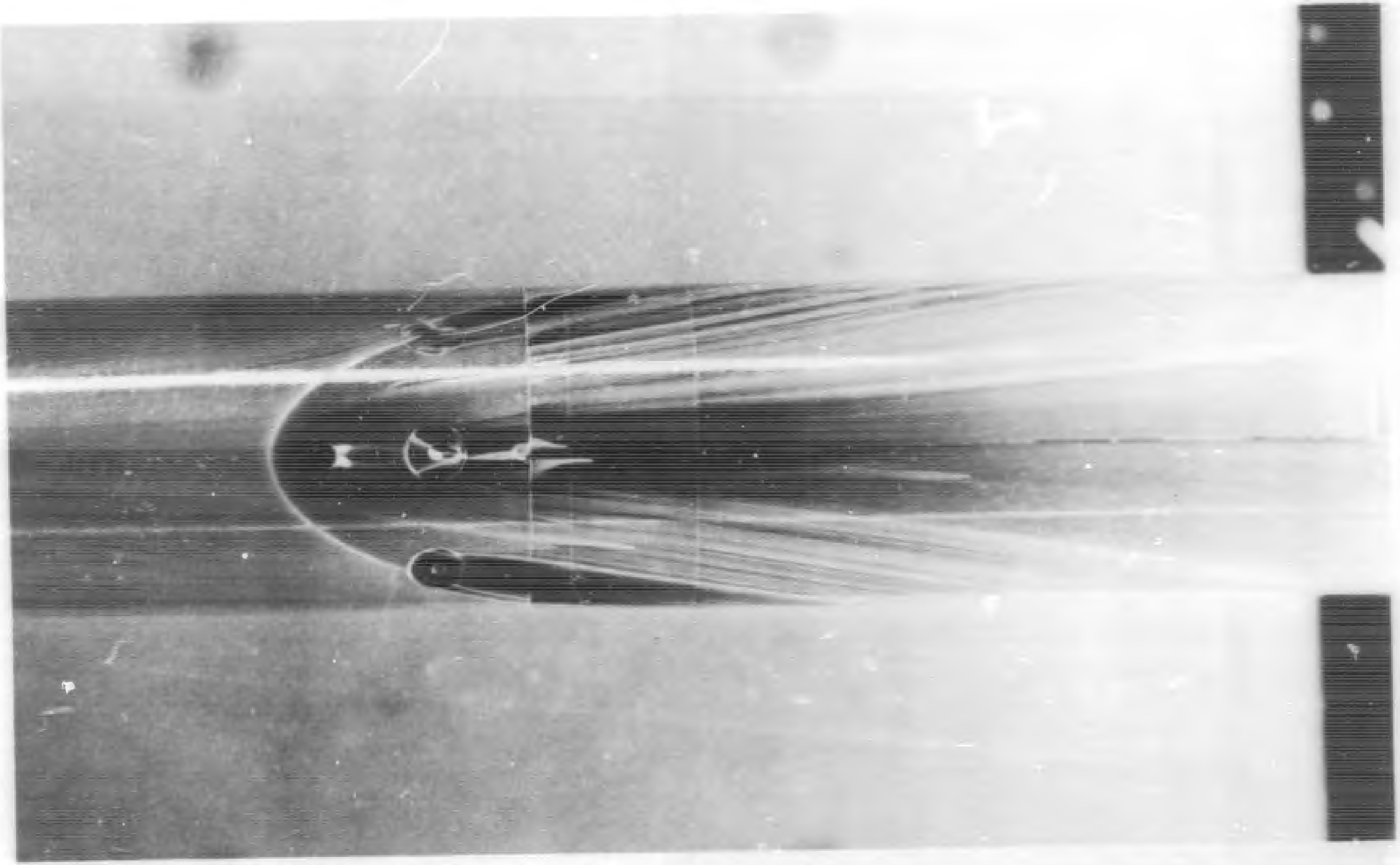

FIGURE D-4c. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_\infty = 10$

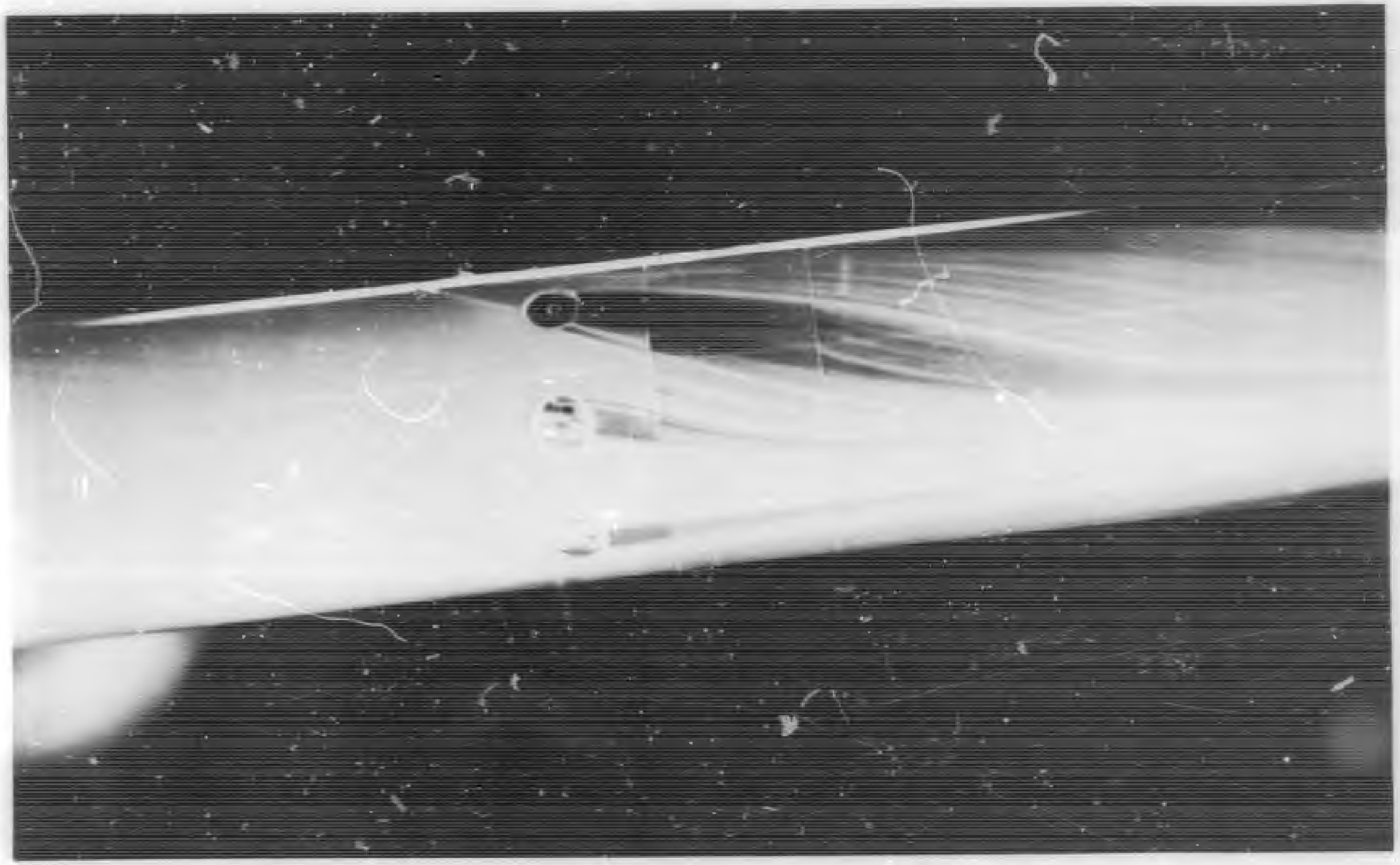

FIGURE D-4d. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_\infty = 10$

FIGURE D-4e. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_{\infty} = 40$

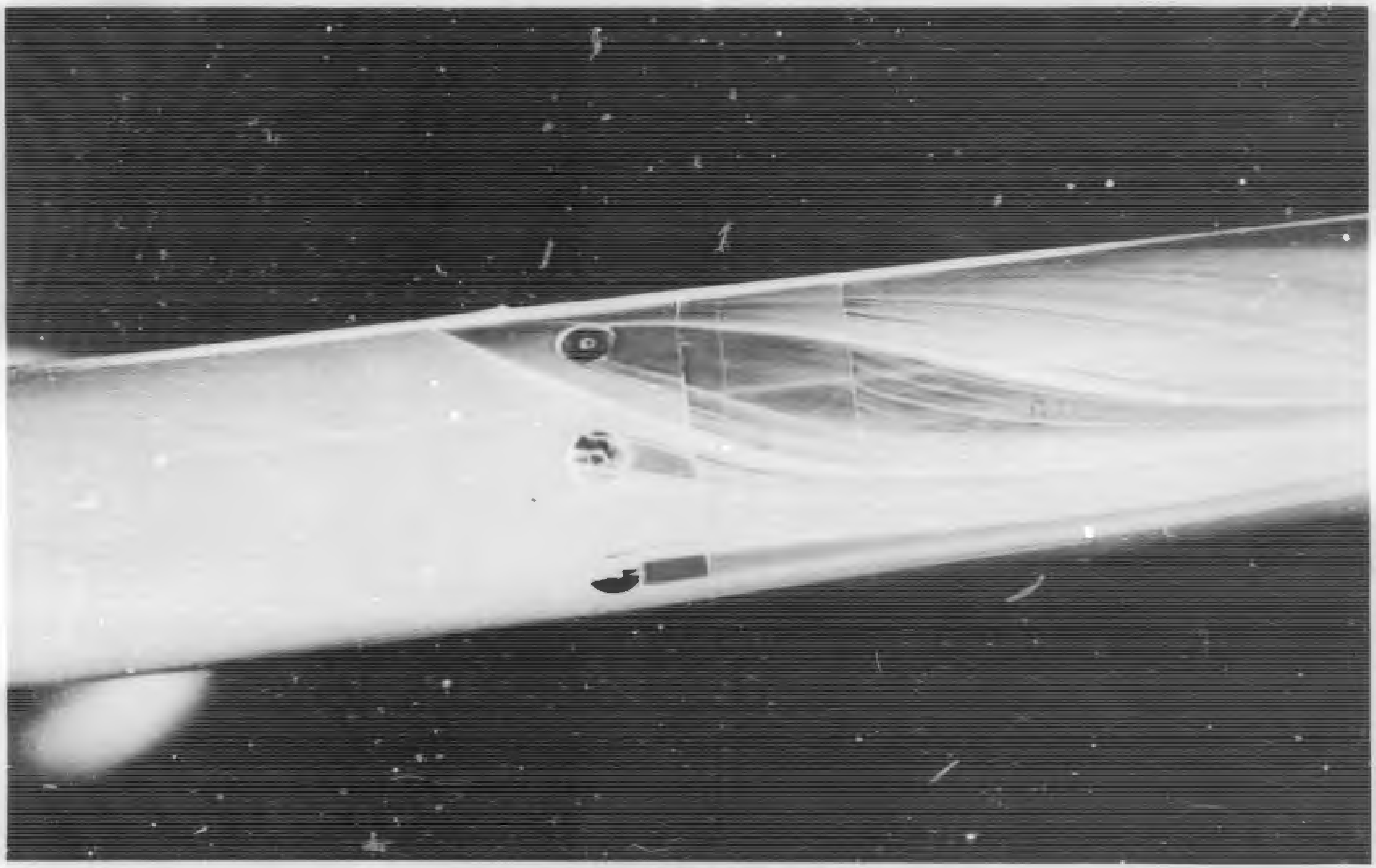

FIGURE D-4f. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_\infty = 40$

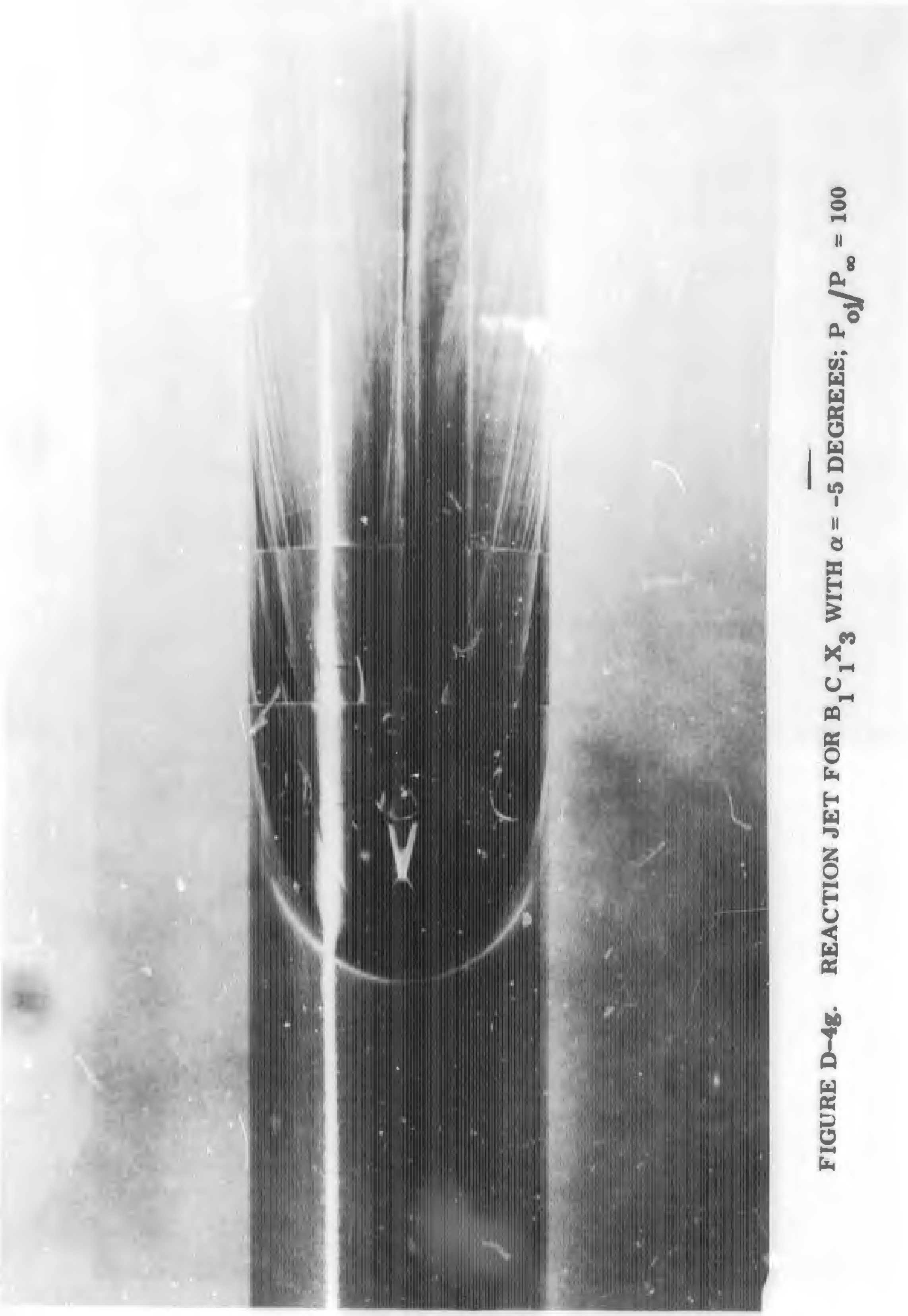

FIGURE D–4g. REACTION JET FOR $B_1C_1X_3$ WITH $\overline{\alpha} = -5$ DEGREES; $P_{oj}/P_{\infty} = 100$

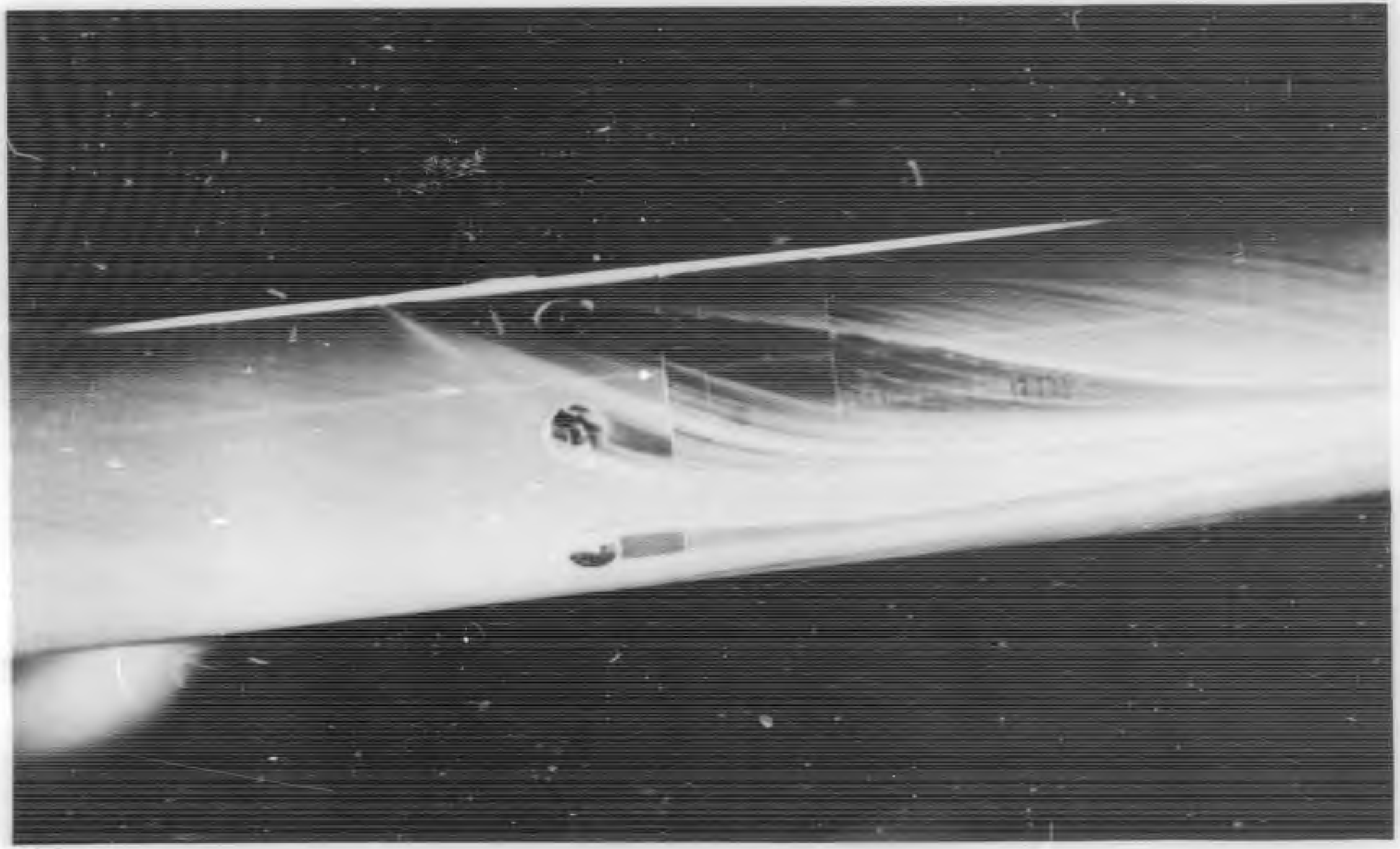

FIGURE D-4h. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_{\infty} = 100$

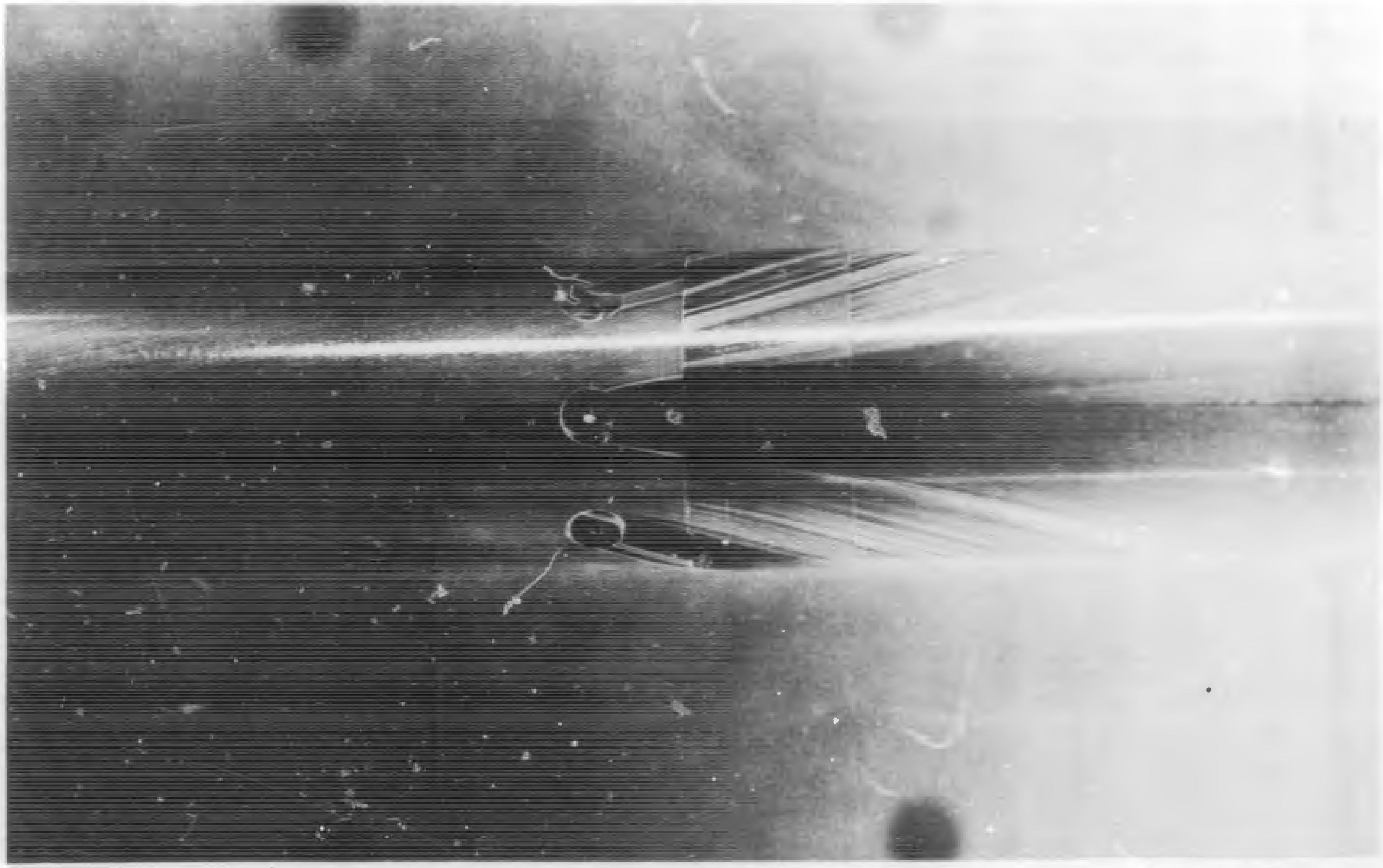

FIGURE D-5a. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_{\infty} = 0$

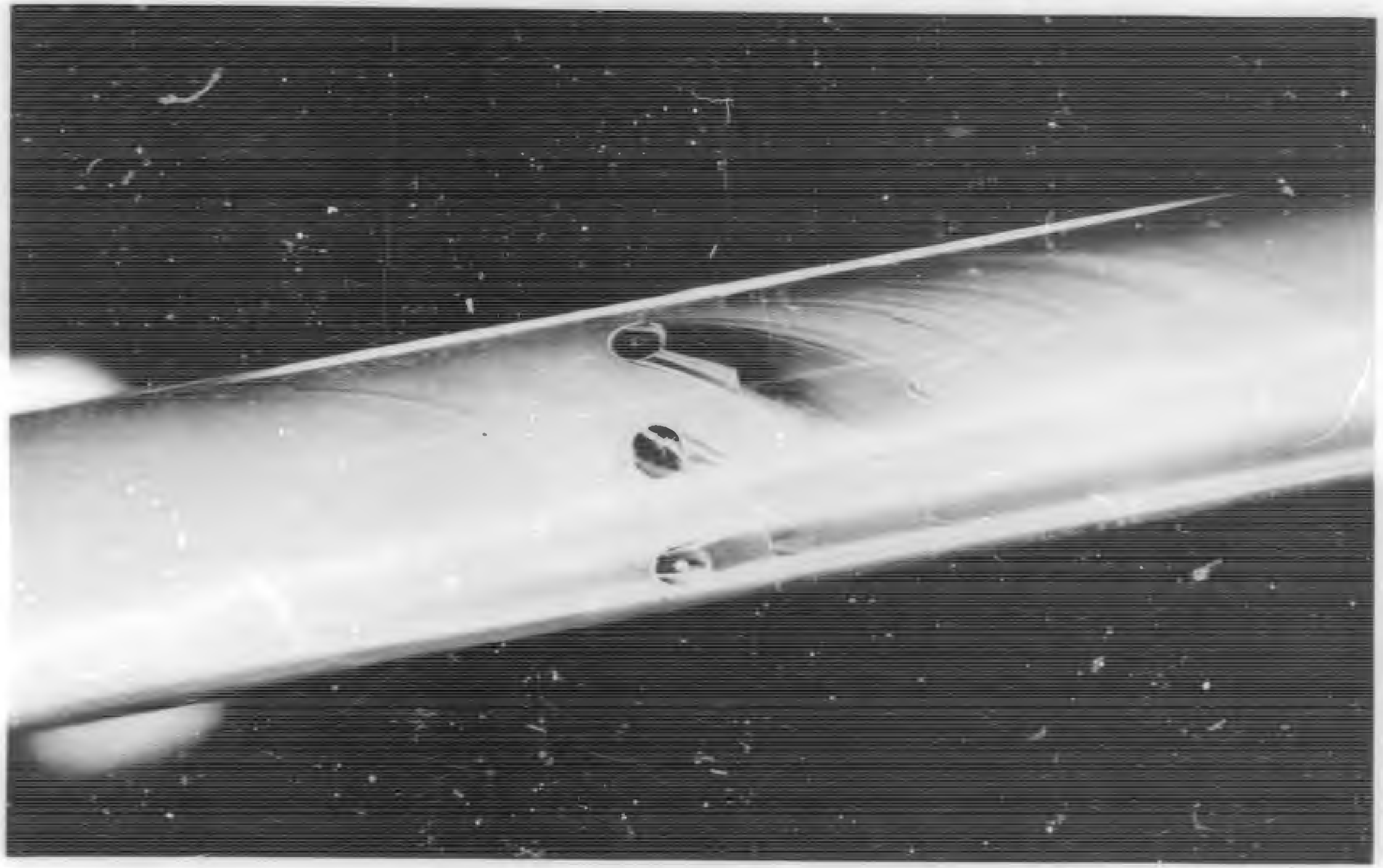

FIGURE D-5b. REACTION JET FOR $B_1C_1X_3$ WITH α = -10 DEGREES; $P_{oj}/P_{\infty} = 0$

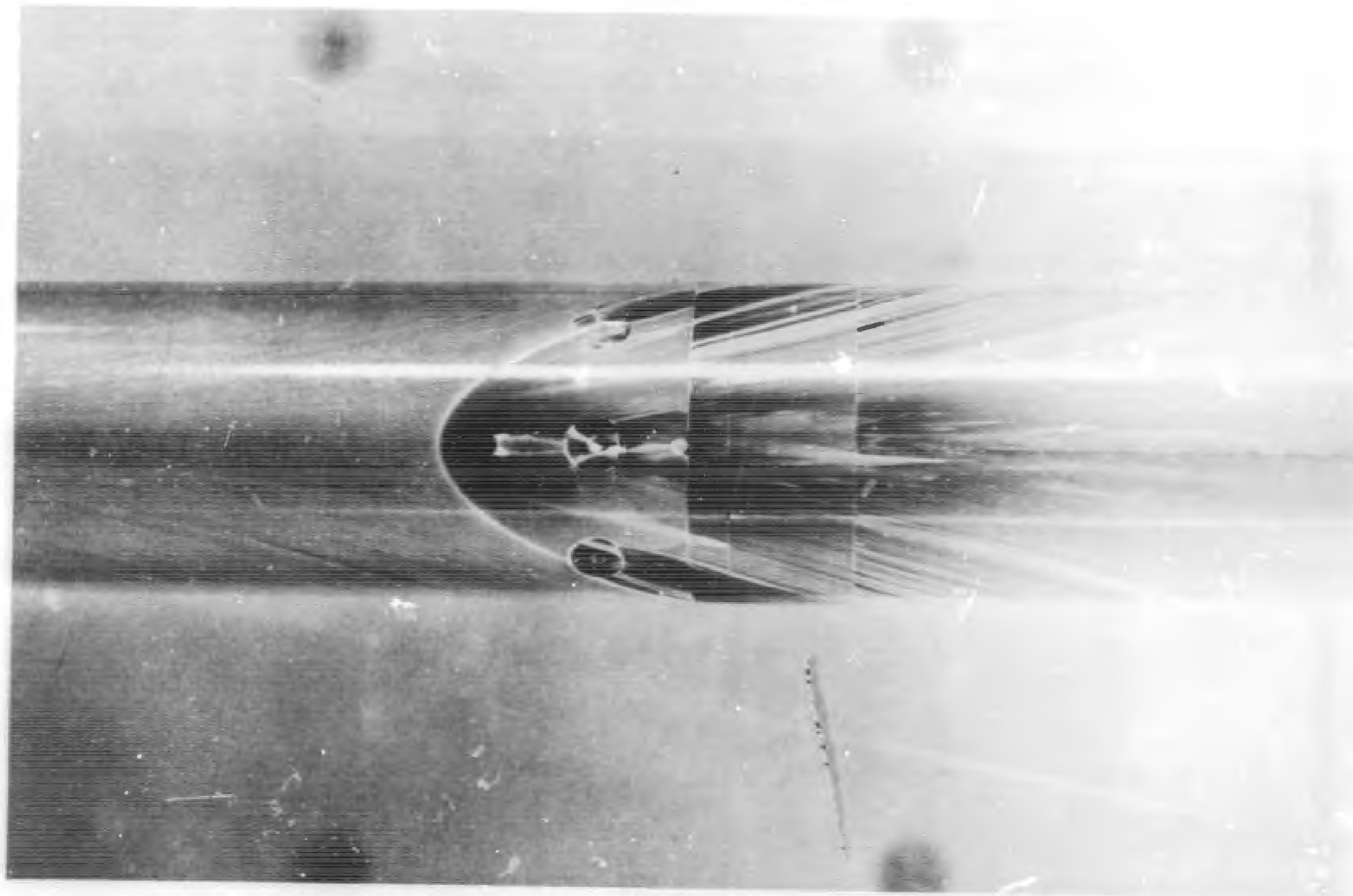

FIGURE D-5c. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_\infty = 10$

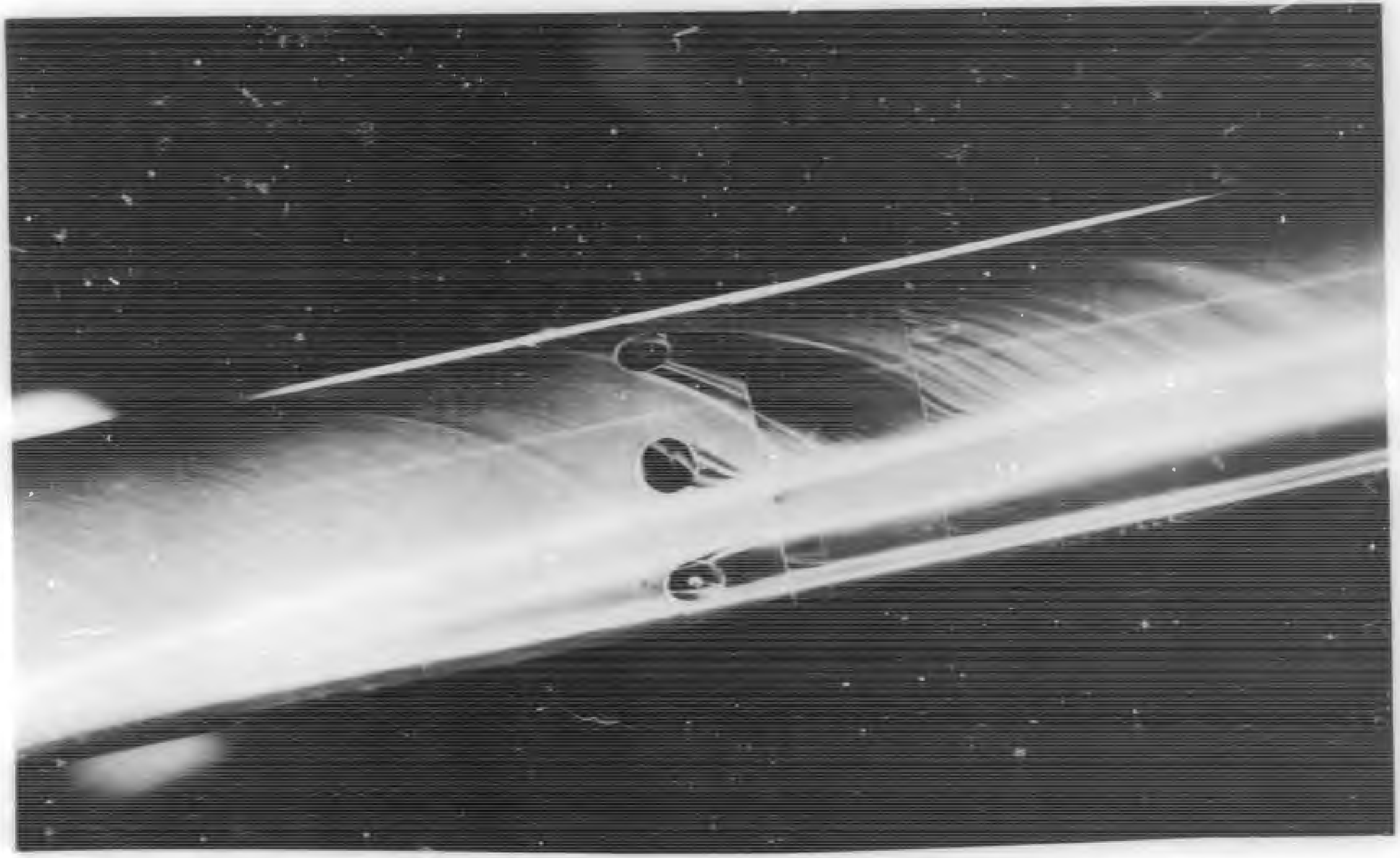

FIGURE D-5d. REACTION JET FOR $B_1C_1A_3$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_{\infty} = 10$

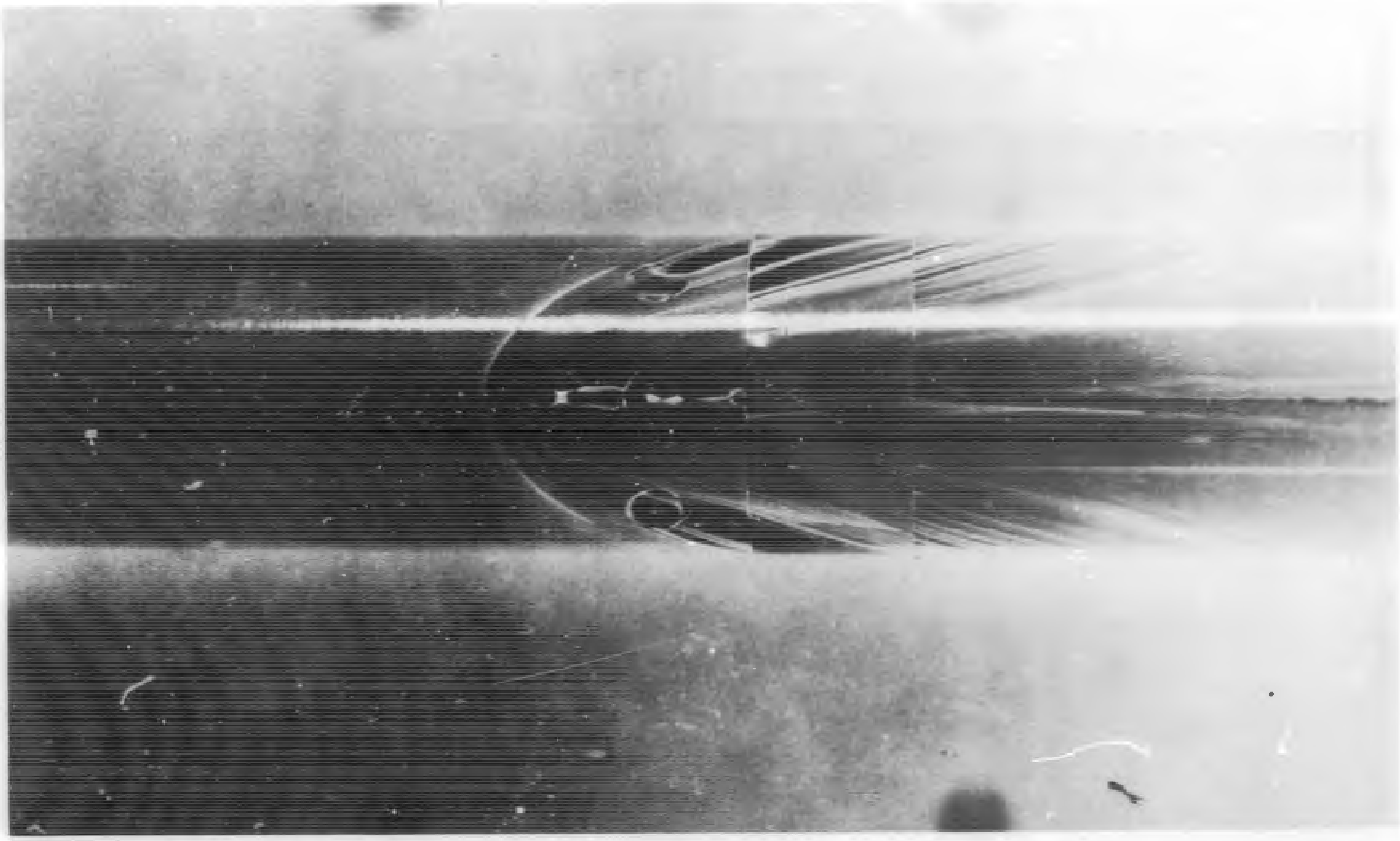

FIGURE D-5e. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_{\infty} = 40$

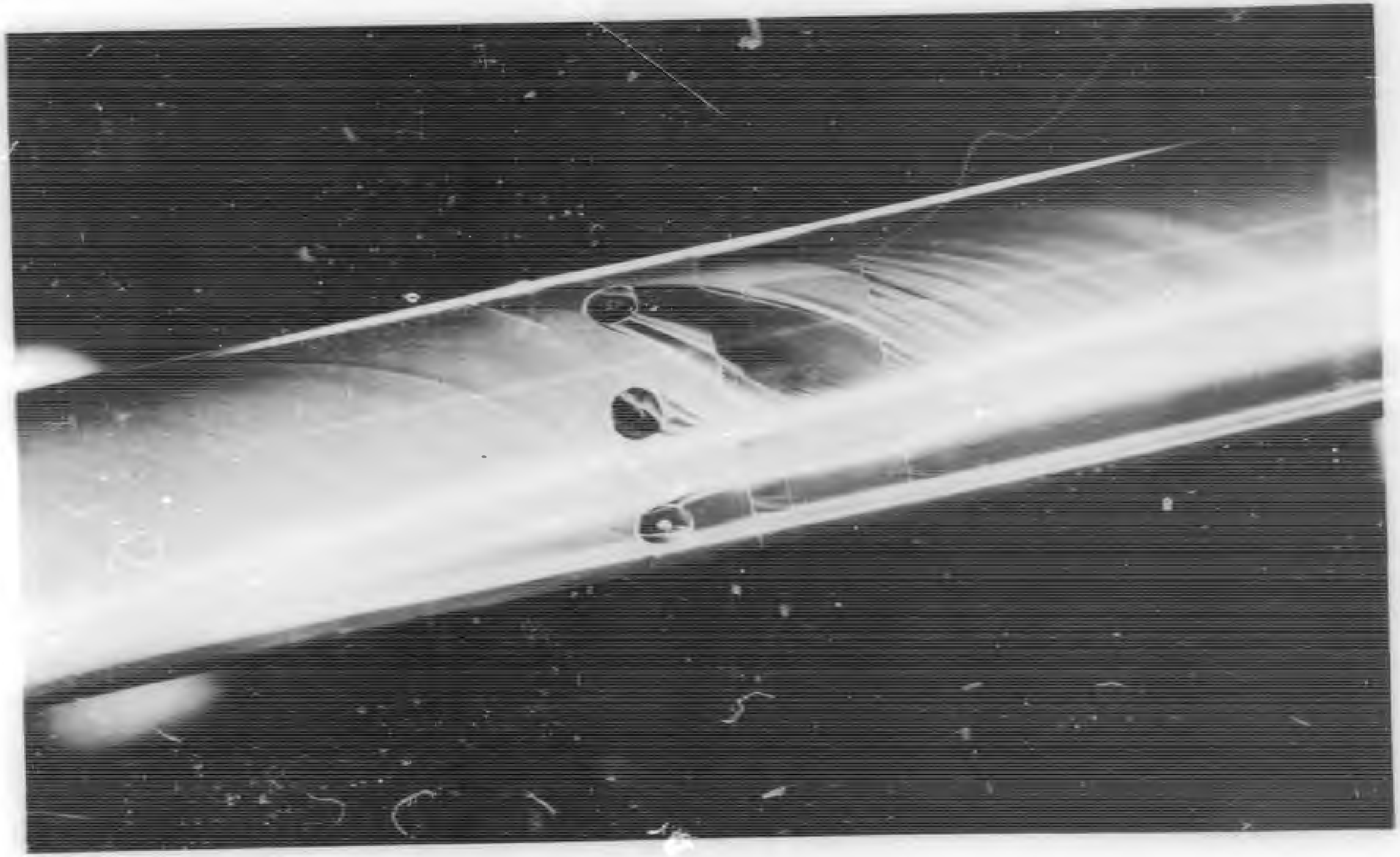

FIGURE D-5f. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_\infty = 40$

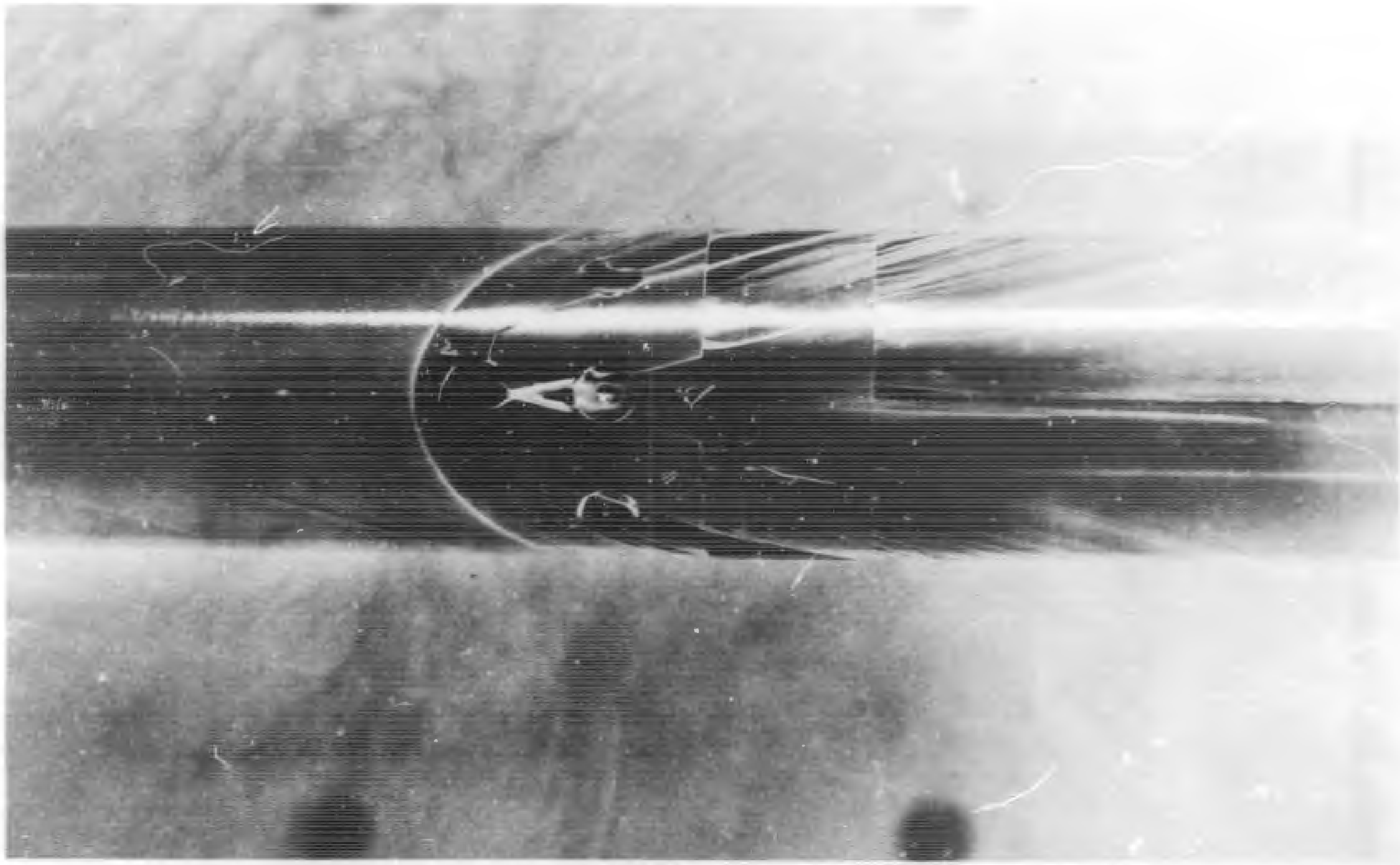

FIGURE D-5g. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_{\infty} = 100$

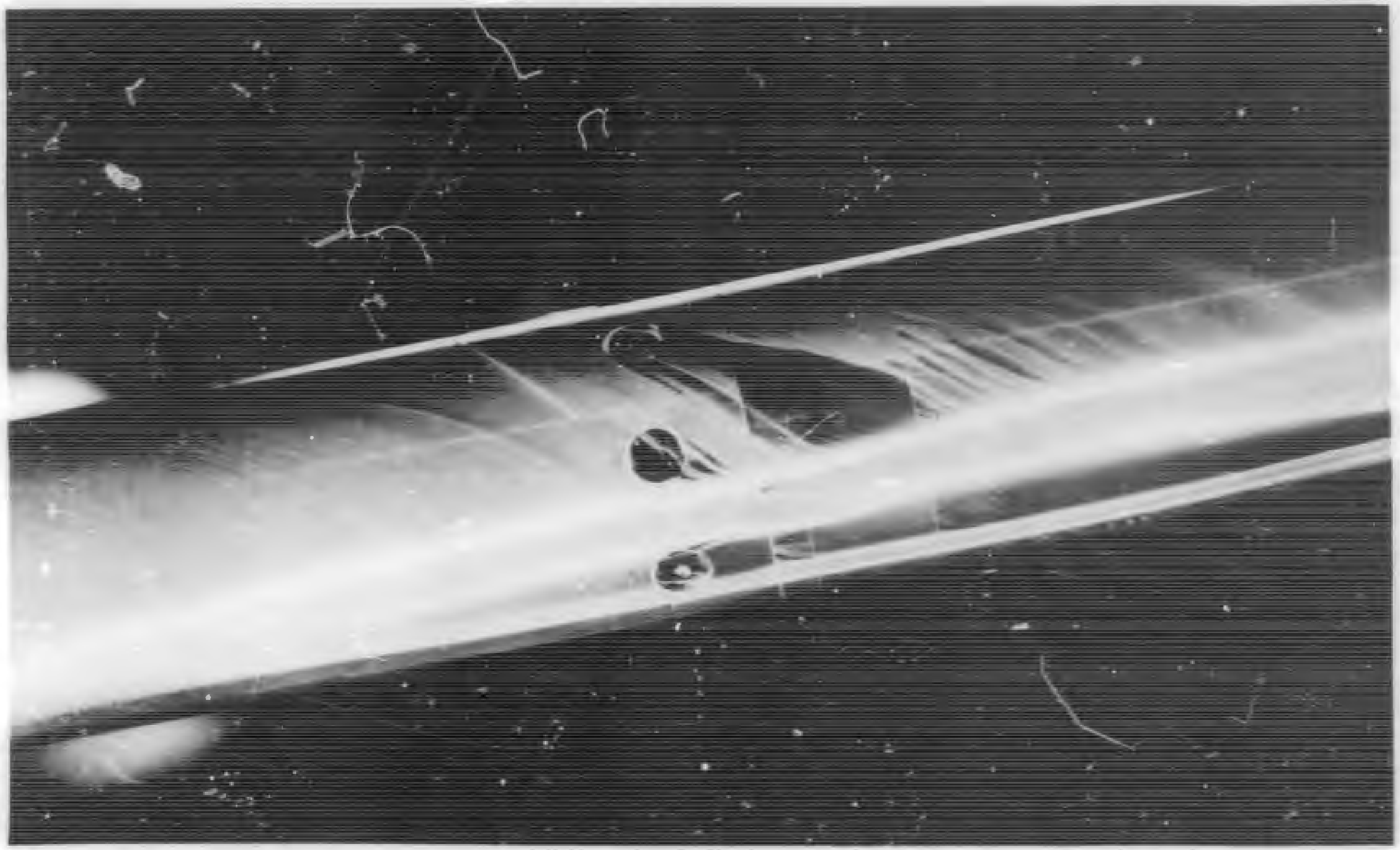

FIGURE D-5h. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_\infty = 100$

PHOTOGRAPH SHOWING REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_{\infty} = 0$, NOT AVAILABLE

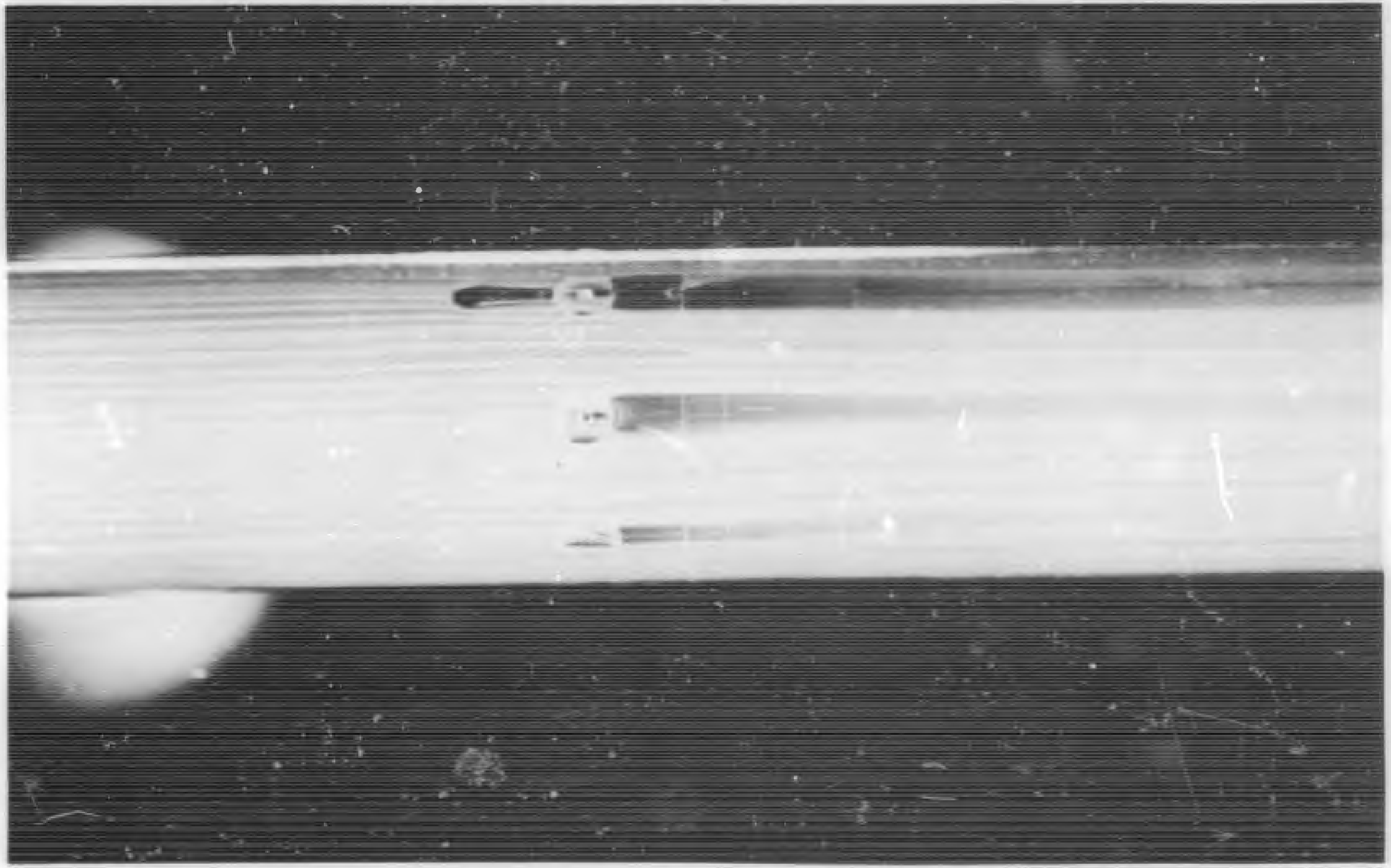

FIGURE D–6a. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_{\infty} = 0$

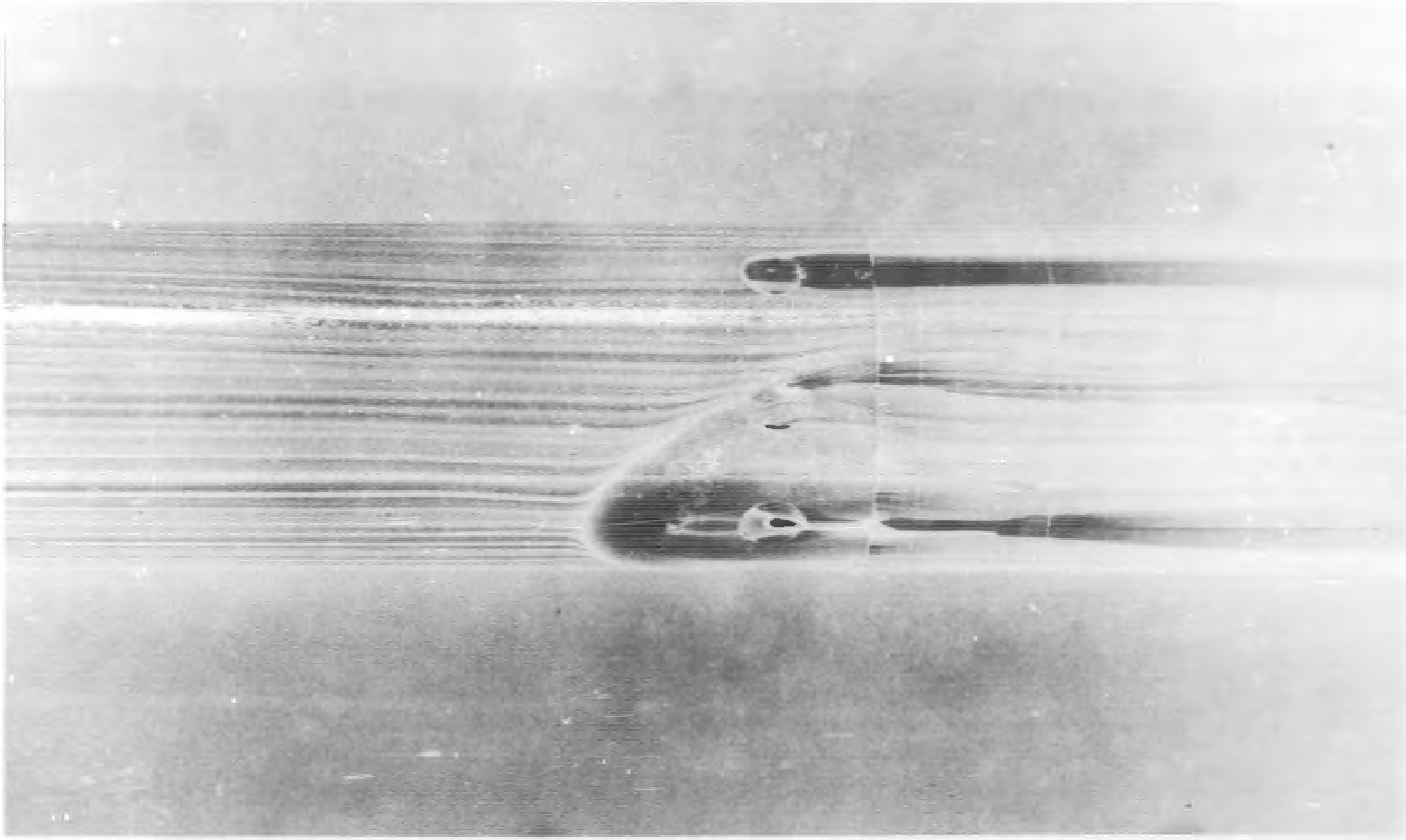

FIGURE D-6b. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 10$

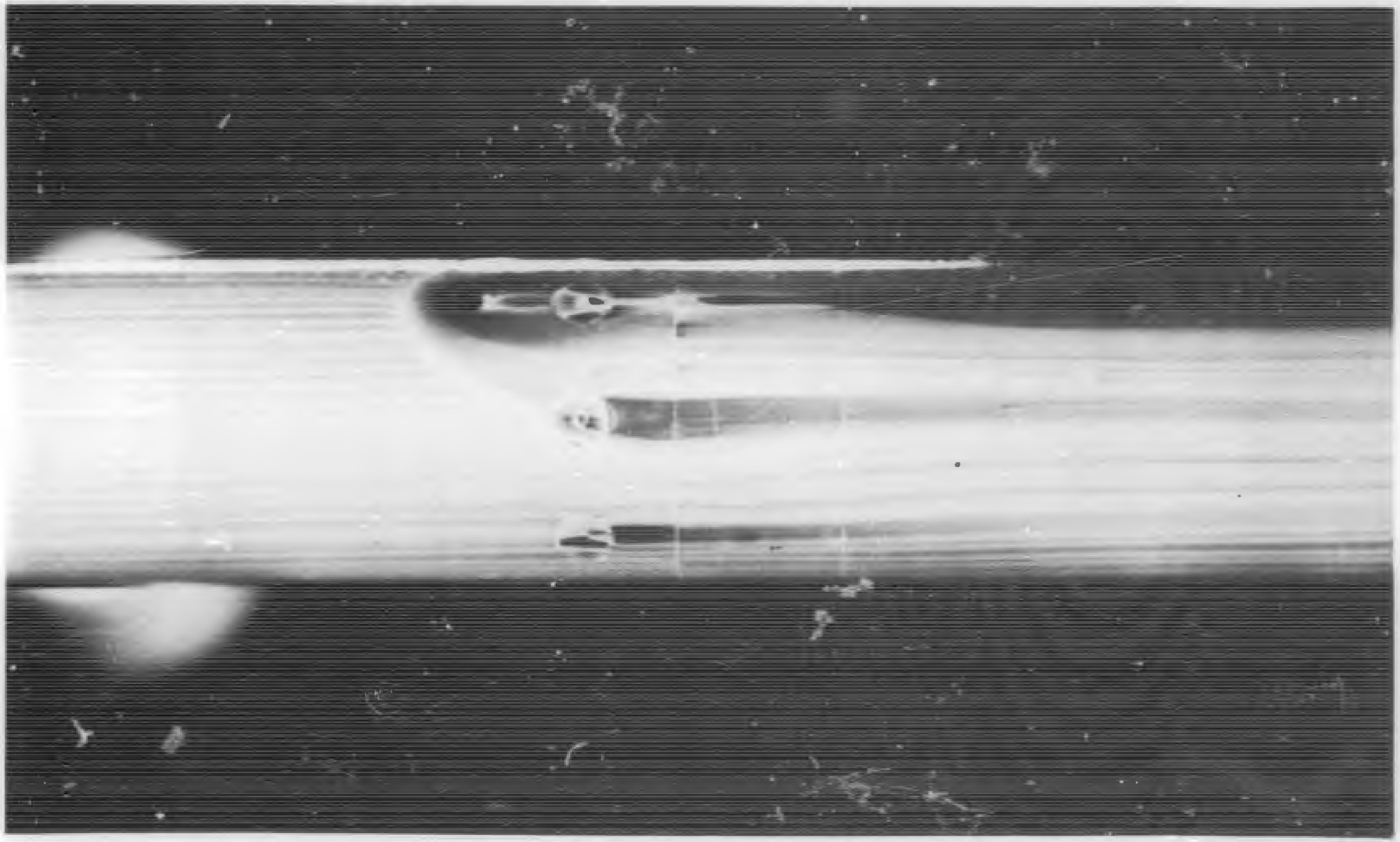

FIGURE D-6c. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 10$

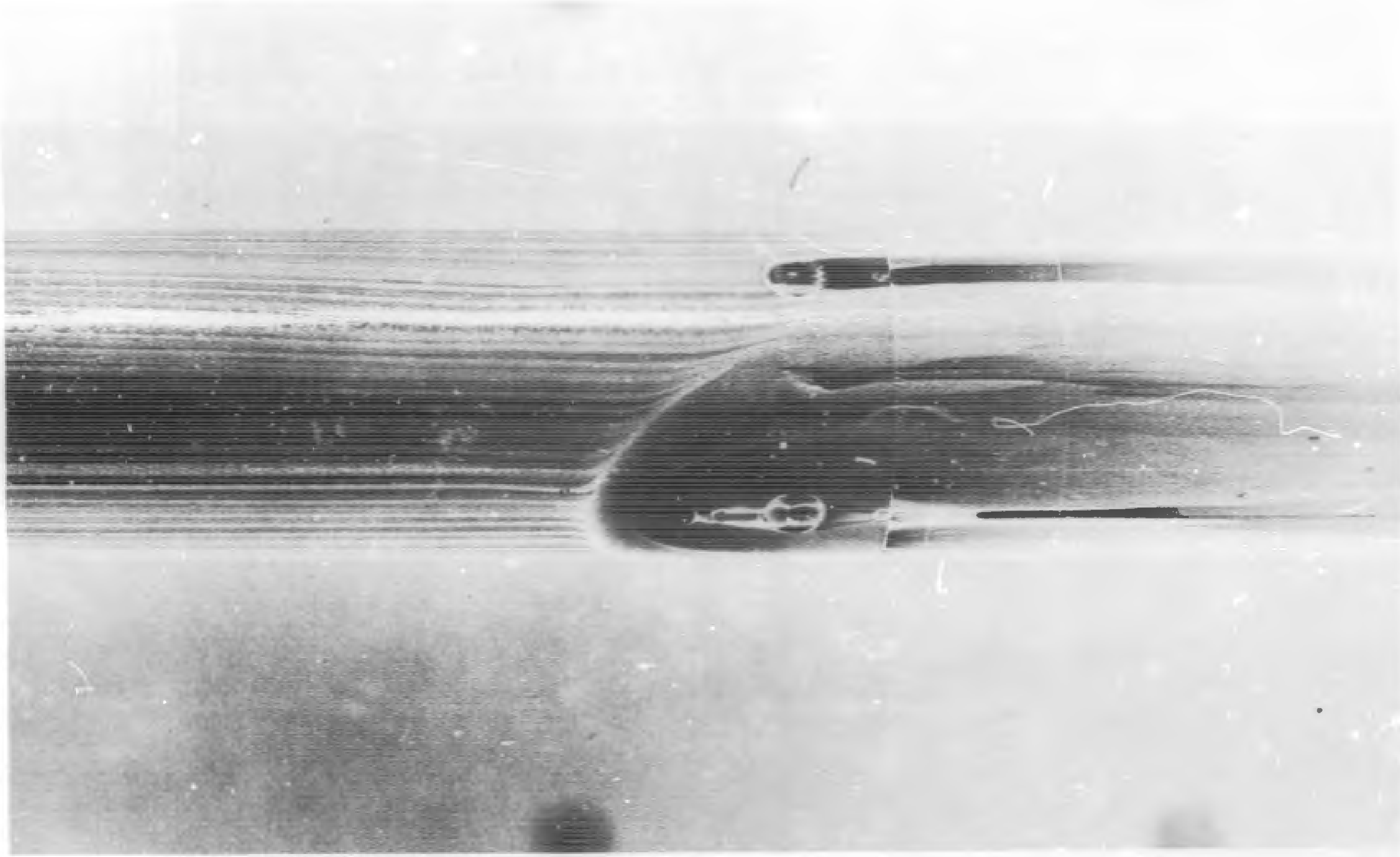

FIGURE D-6d. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 40$

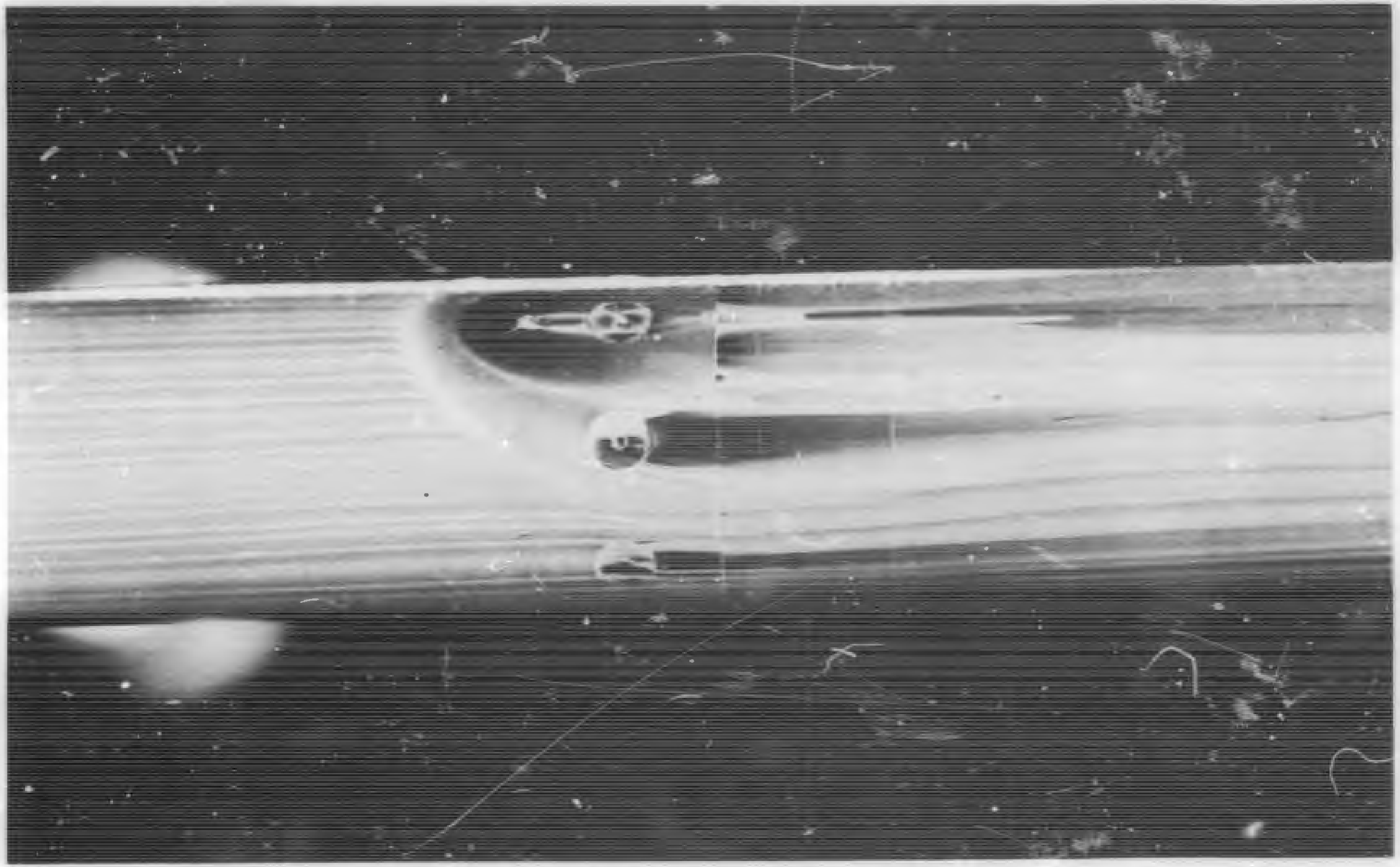

FIGURE D-6e. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_{\infty} = 40$

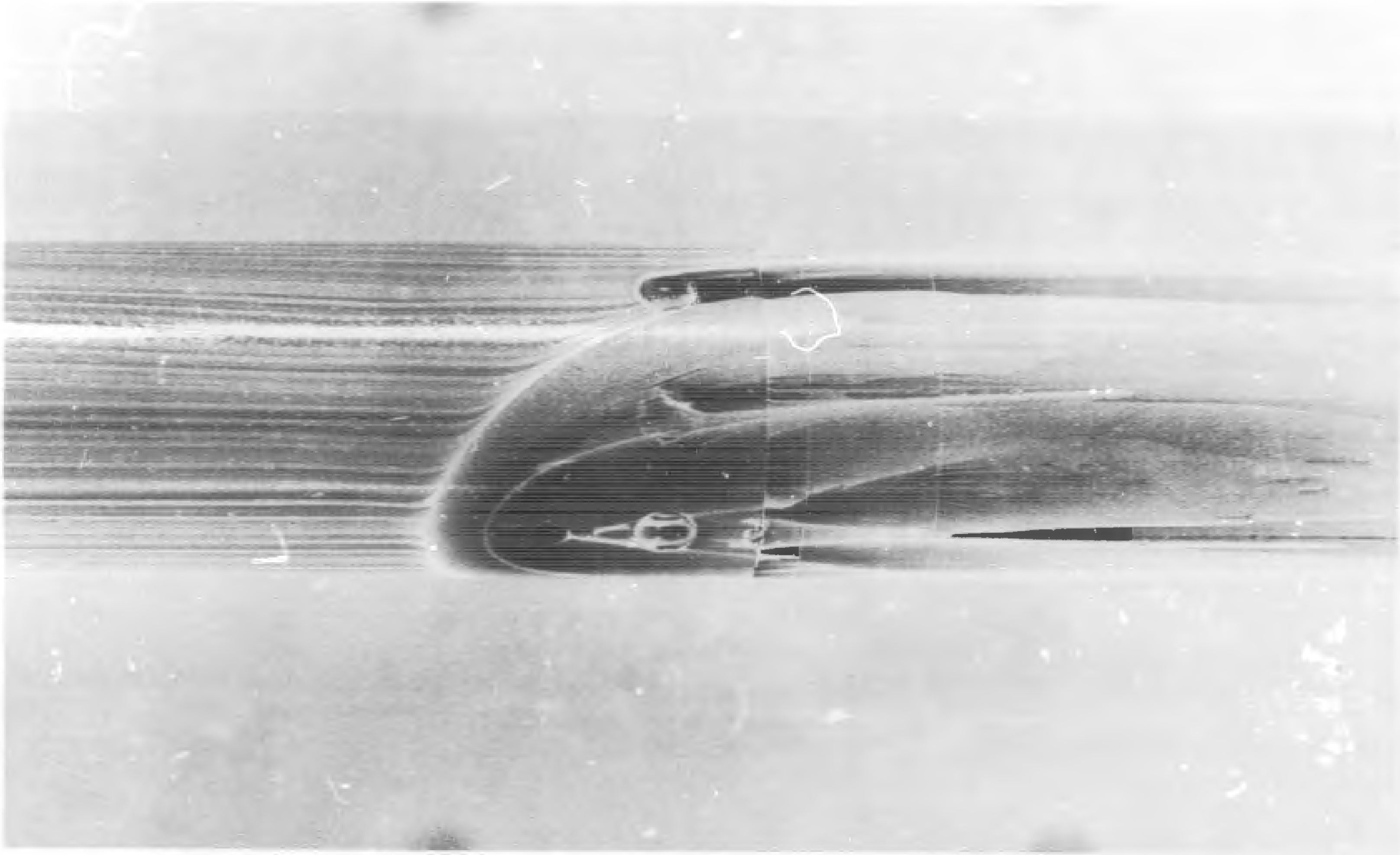

FIGURE D-6f. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_{\infty} = 100$

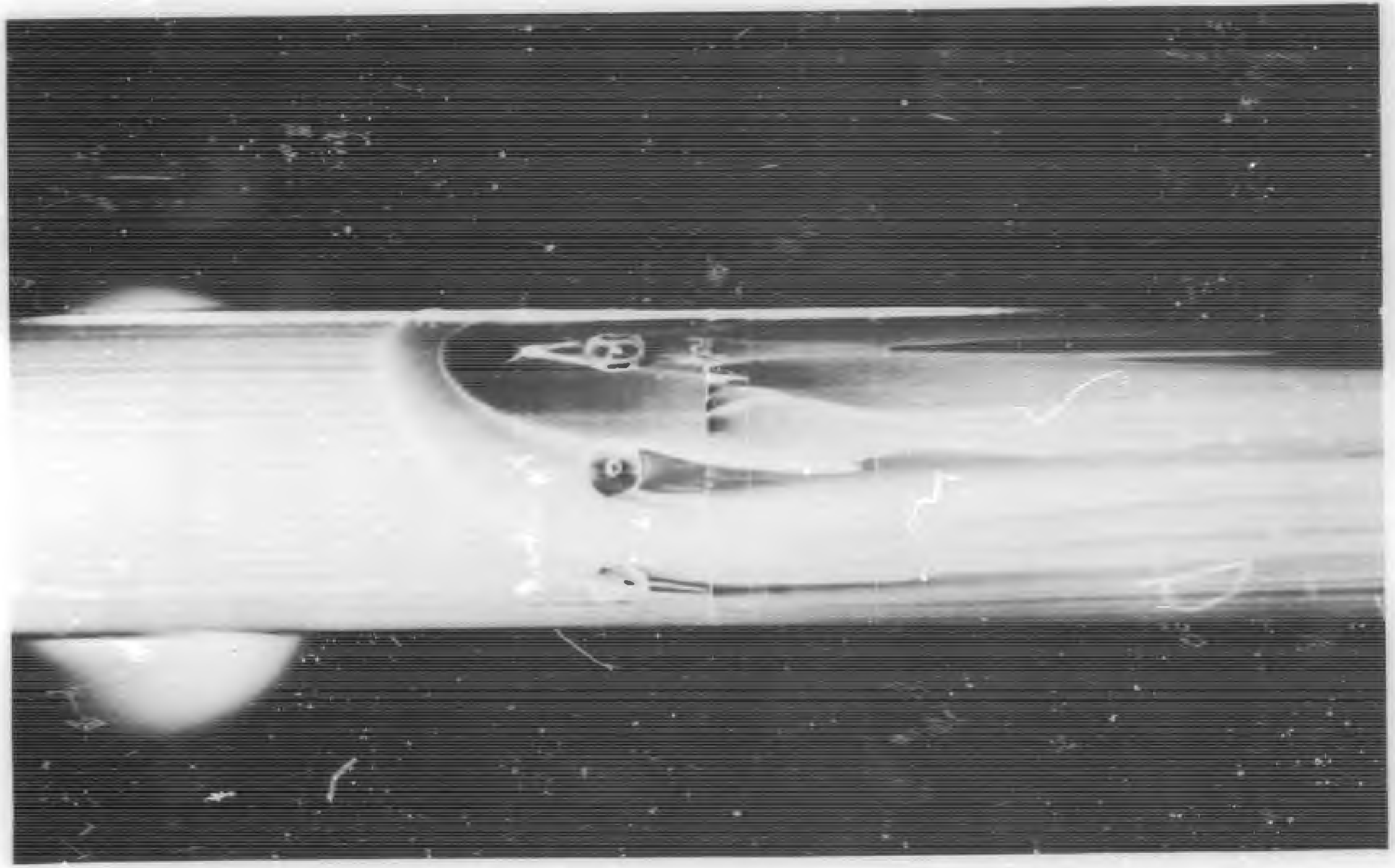

FIGURE D–6g. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 100$

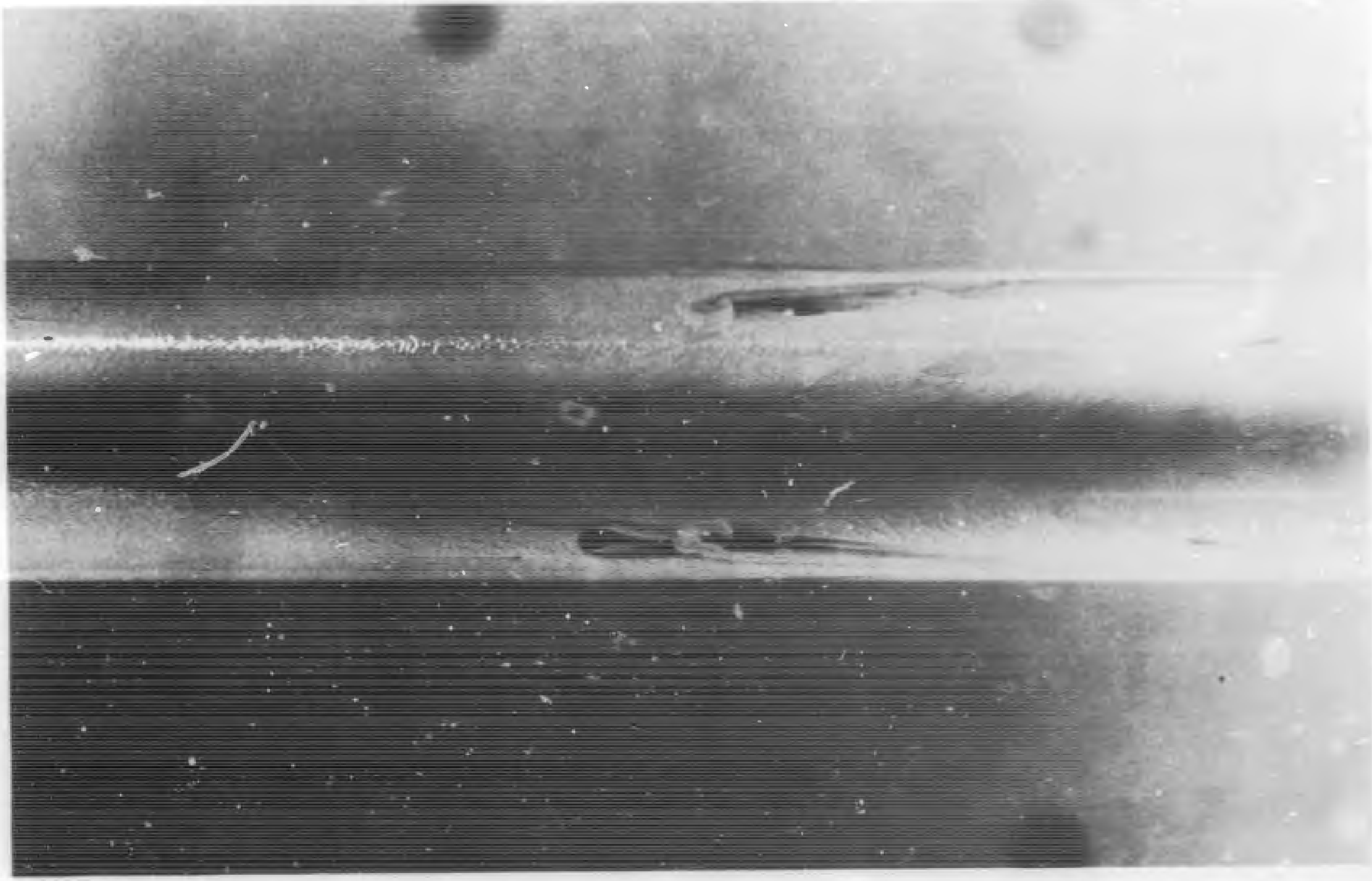

FIGURE D-7a. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_{\infty} = 0$

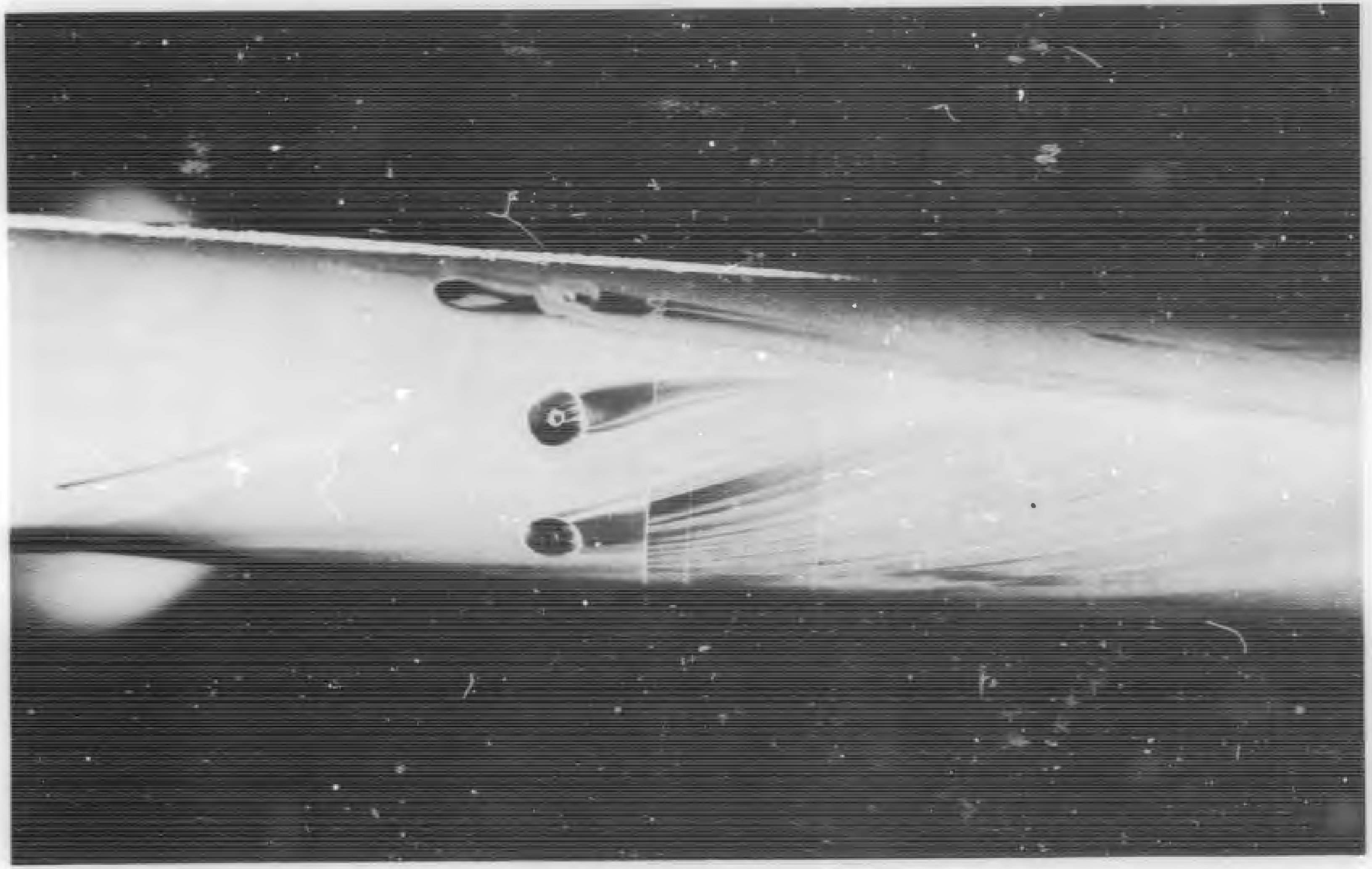

FIGURE D-7b. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_\infty = 0$

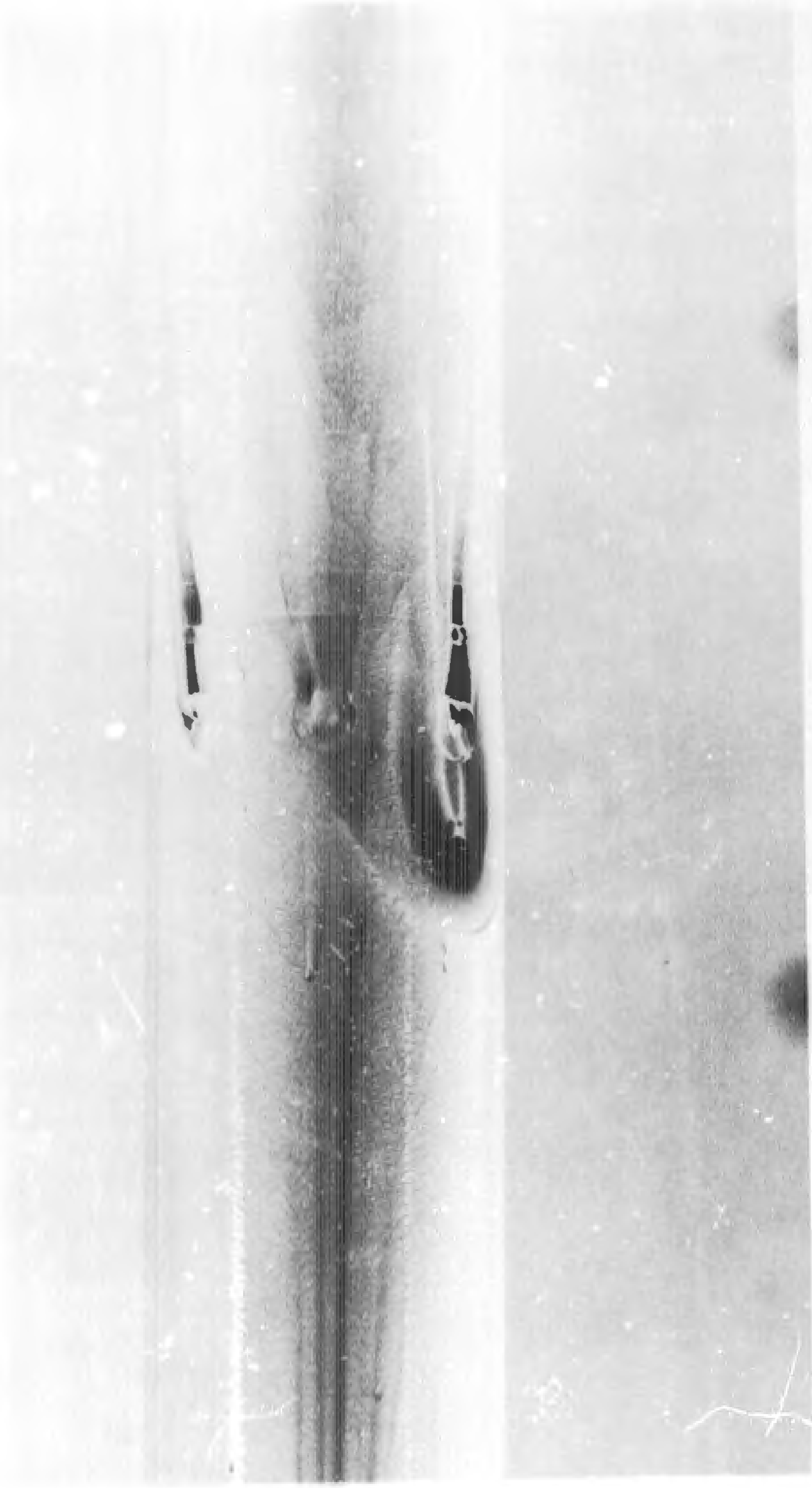

FIGURE D-7c. REACTION JET FOR $B_1C_1X_3$ WITH α = 5 DEGREES; P_{oj}/P_{∞} = 10

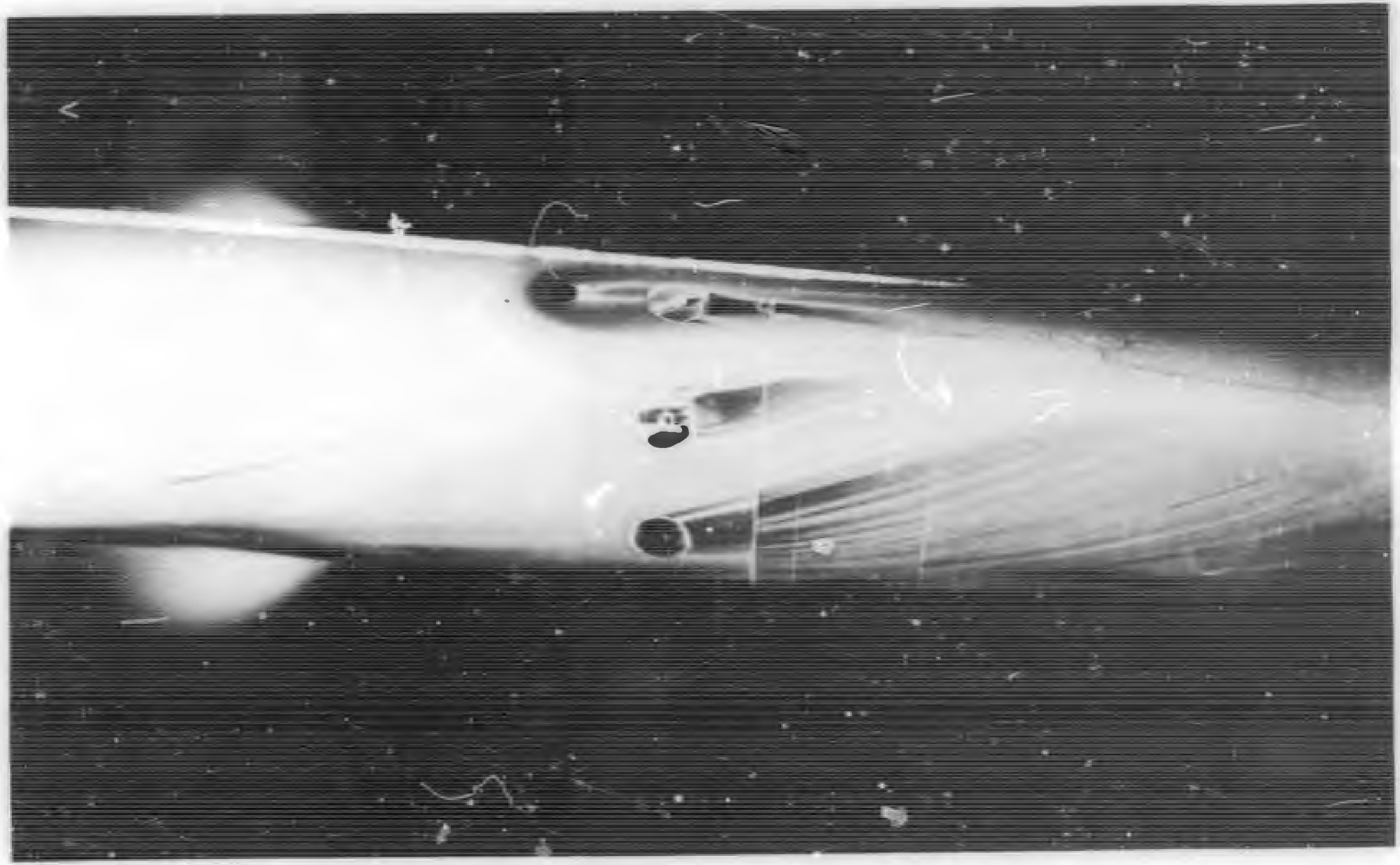

FIGURE D–7d. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_\infty = 10$

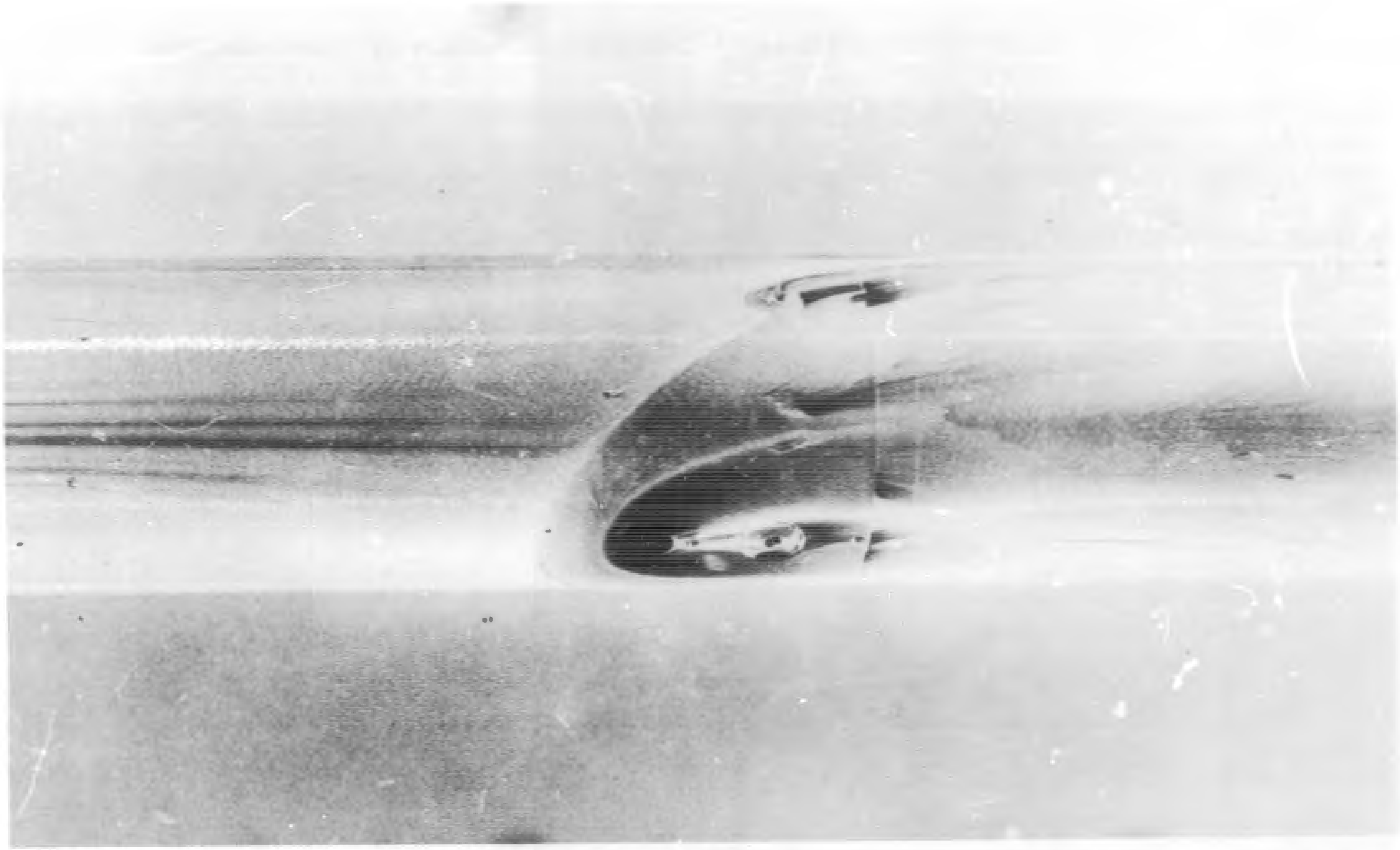

FIGURE D-7e. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_\infty = 40$

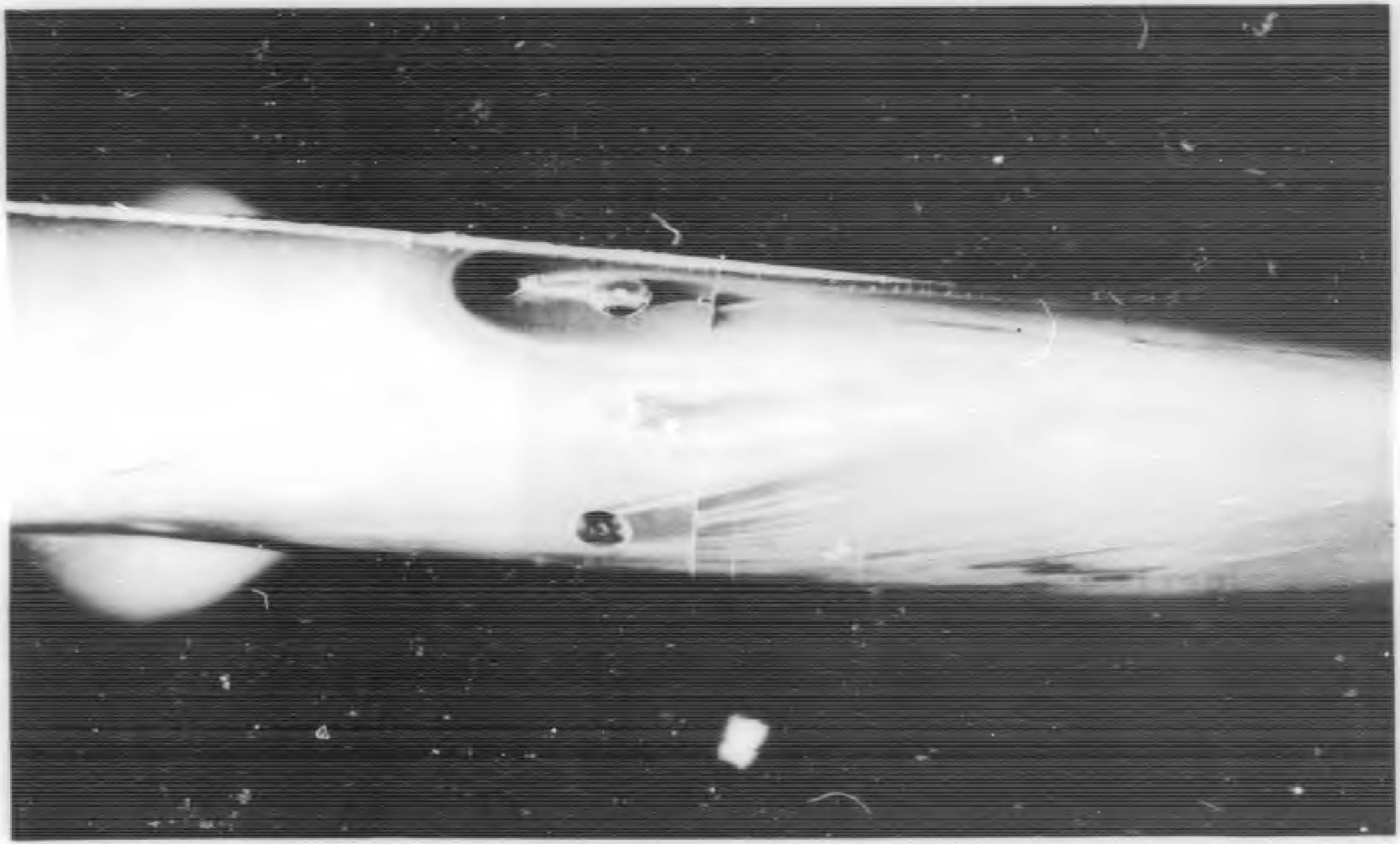

FIGURE D-7f. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_\infty = 40$

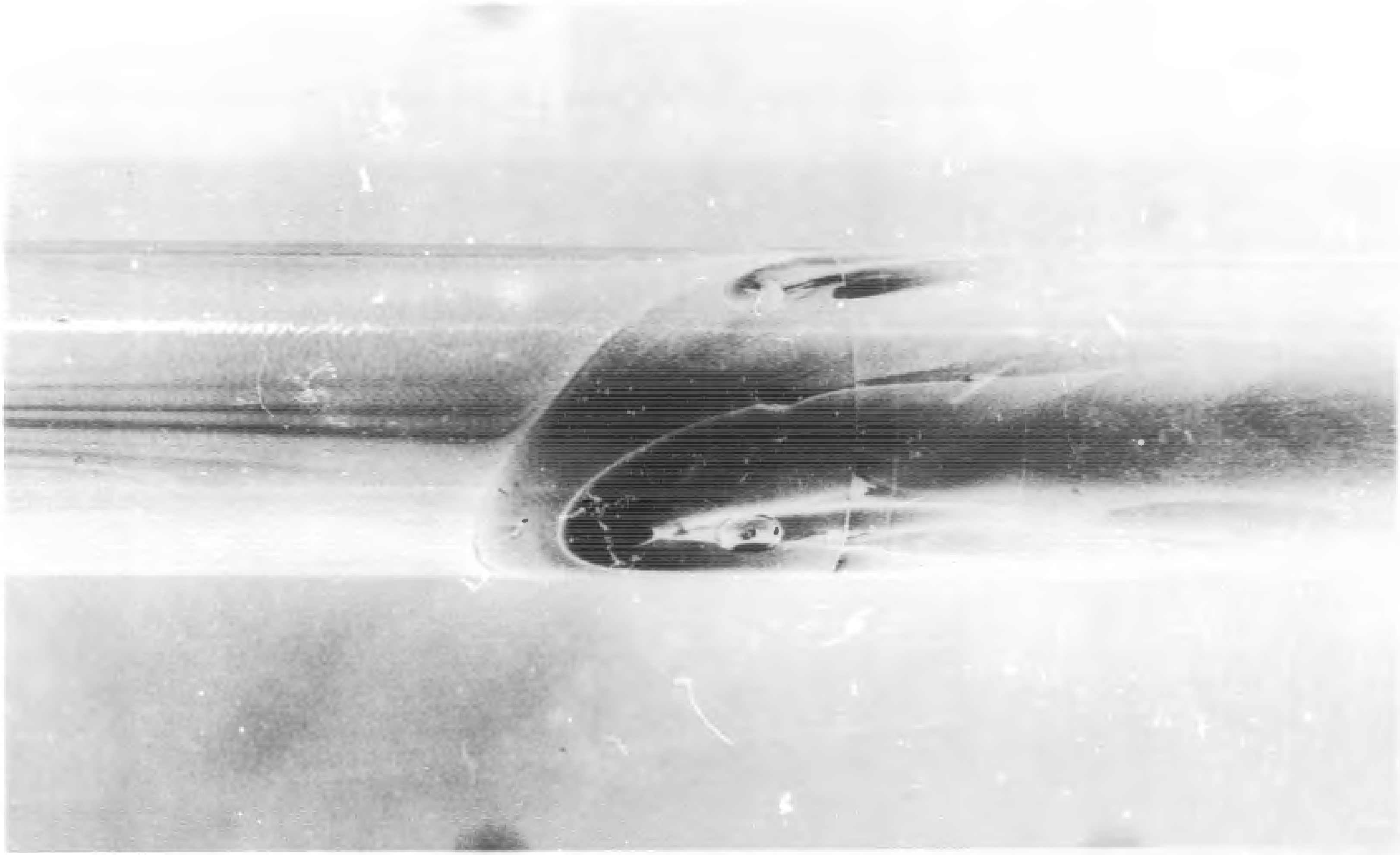

FIGURE D-7g. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_{\infty} = 100$

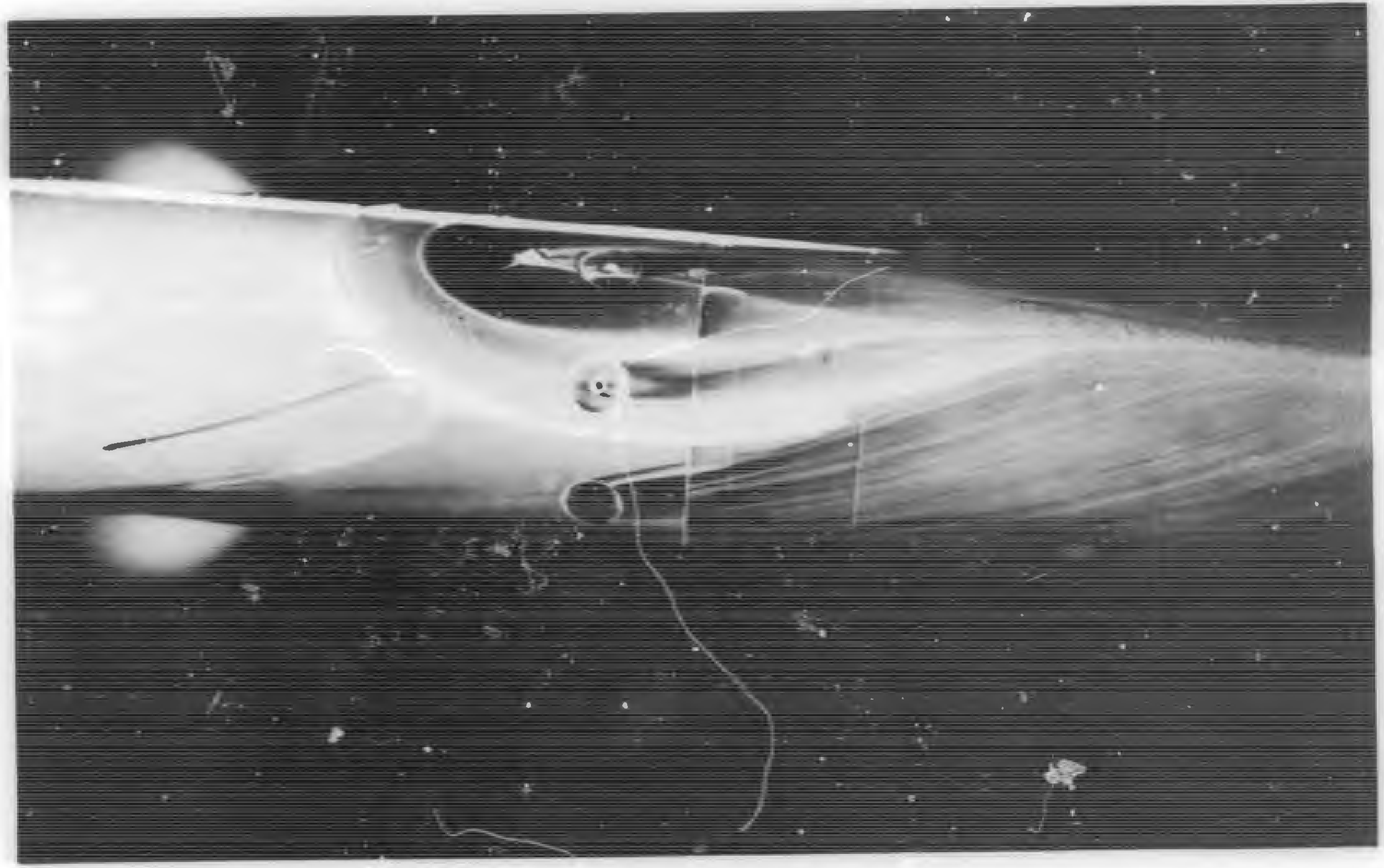

FIGURE D–7h. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_\infty = 100$

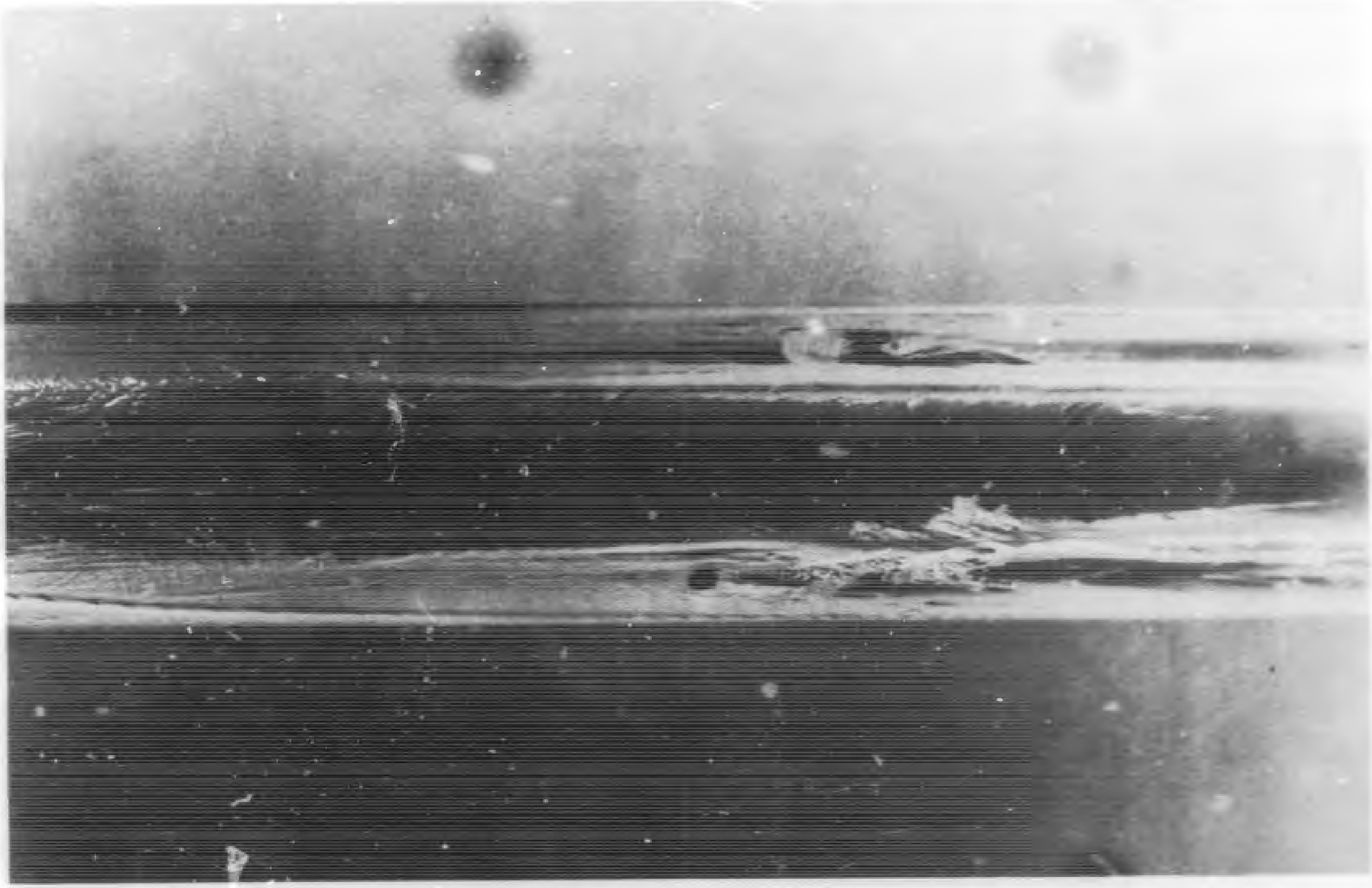

FIGURE D–8a. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_\infty = 0$.

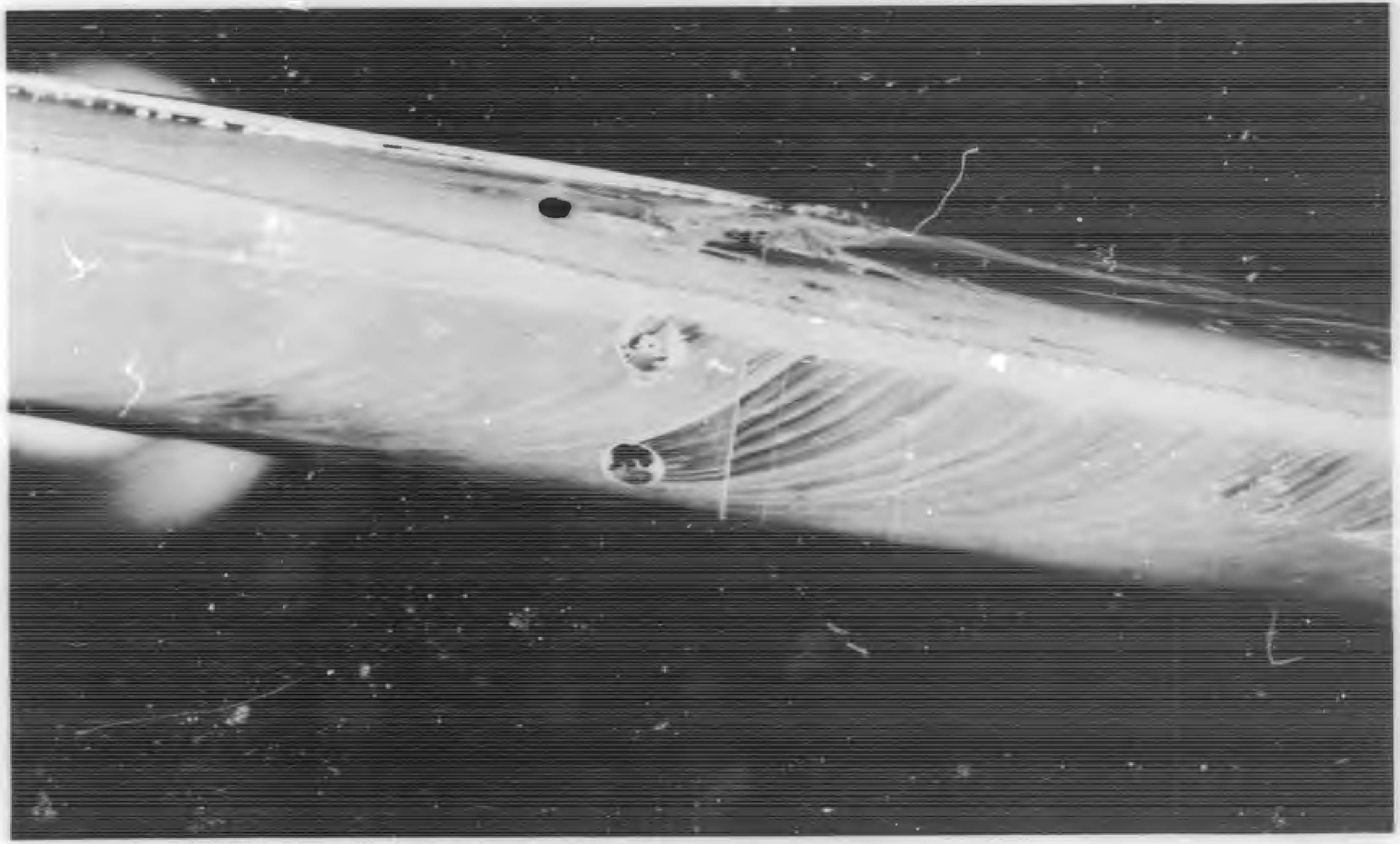

FIGURE D-8b. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_{\infty} = 0$

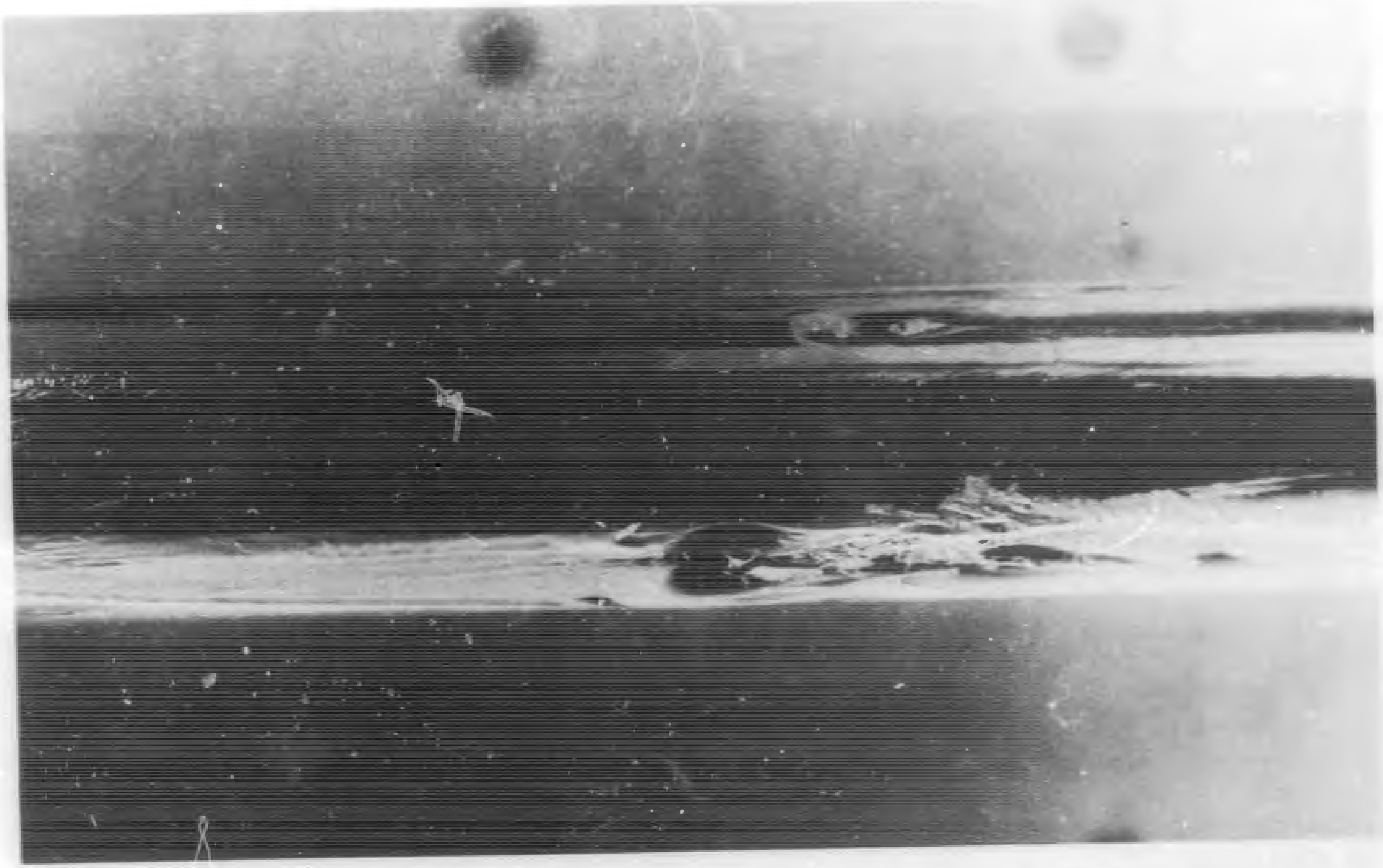

FIGURE D–8c. REACTION JET FOR $B_1C_1X_3$ WITH α = 10 DEGREES; P_{oj}/P_∞ = 10

FIGURE D-8d. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_{\infty} = 10$

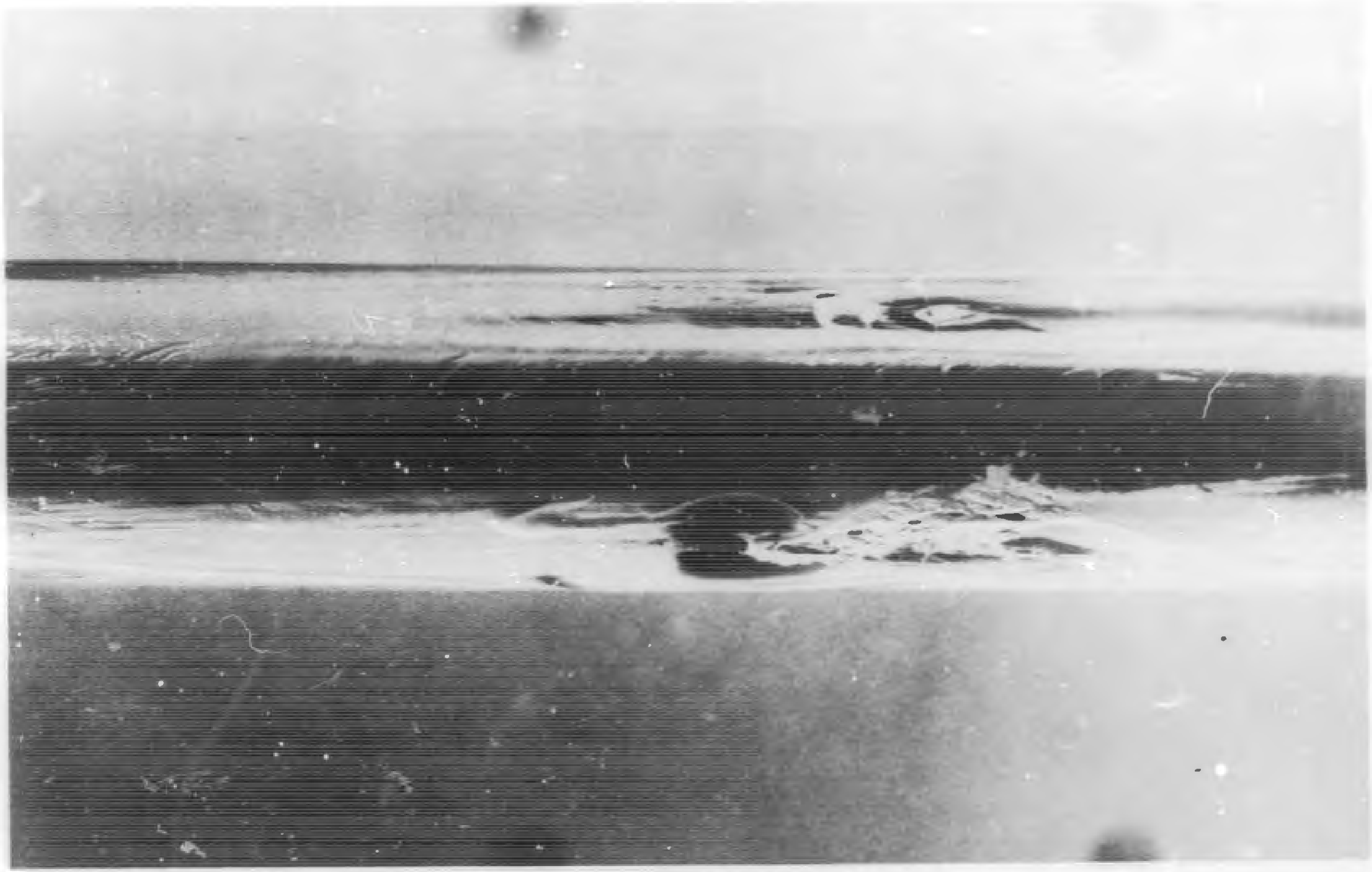

FIGURE D-8e. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_{\infty} = 40$

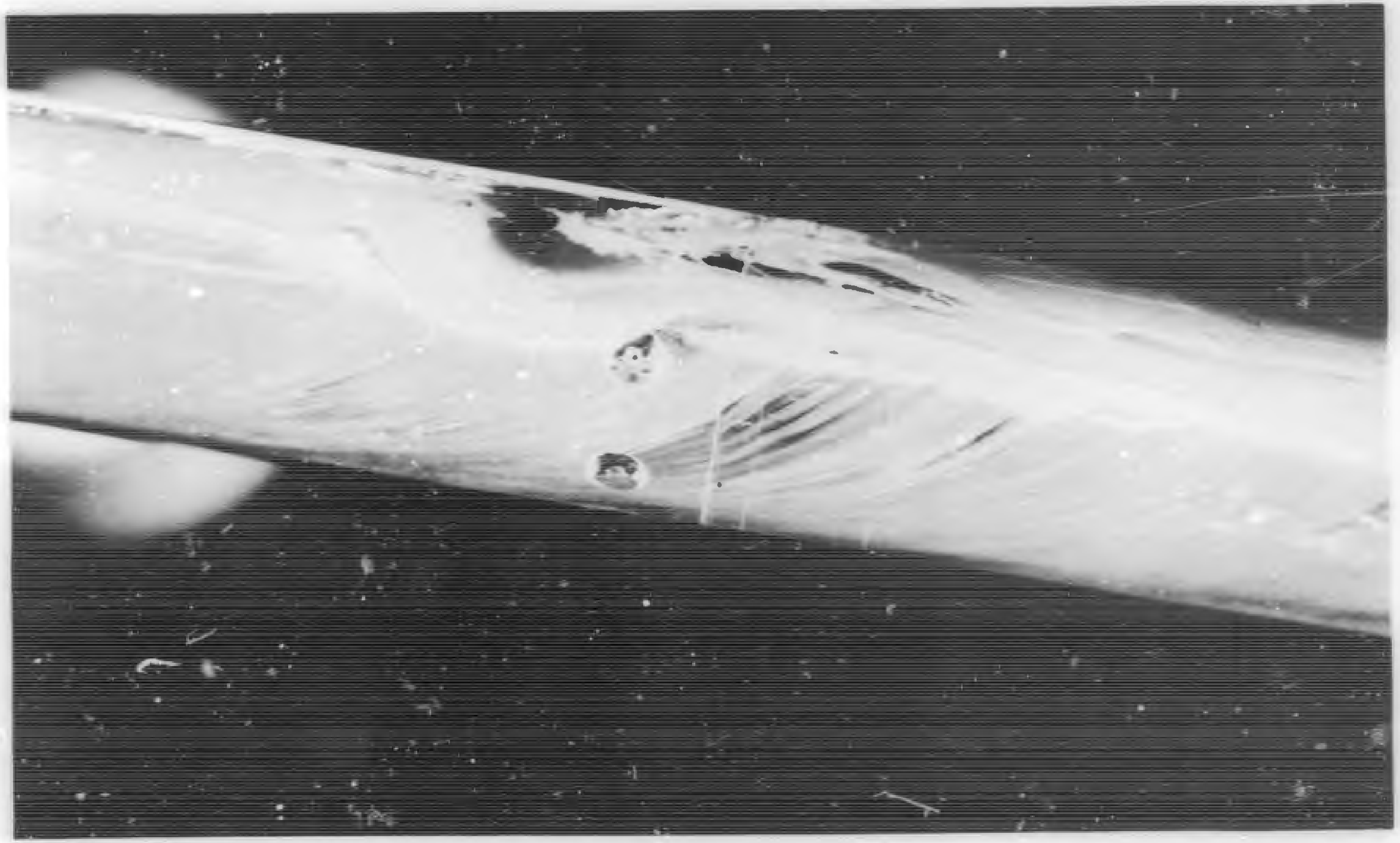

FIGURE D-8f. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_{\infty} = 40$

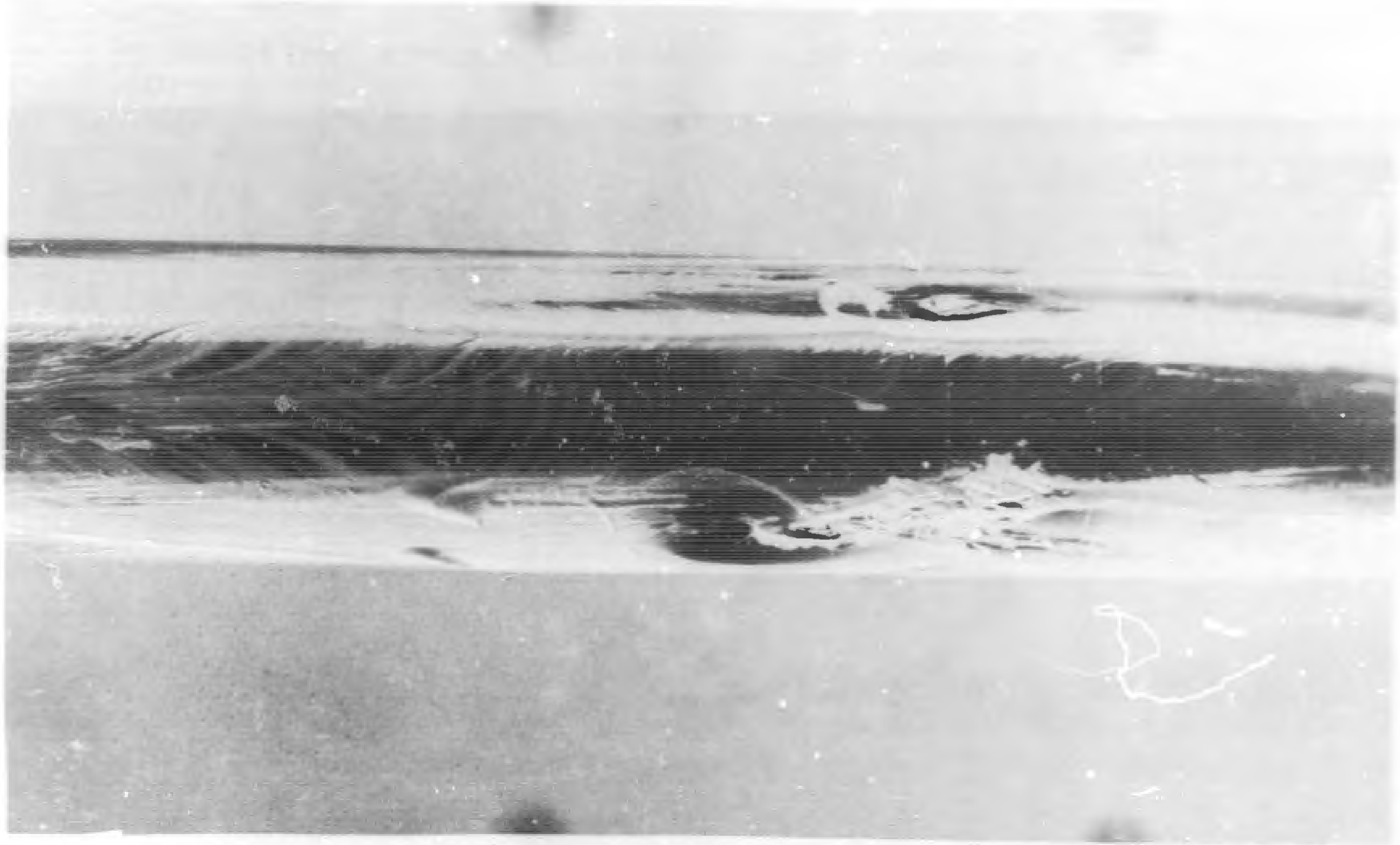

FIGURE D-8g. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_\infty = 100$

FIGURE D-8h. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_\infty = 100$

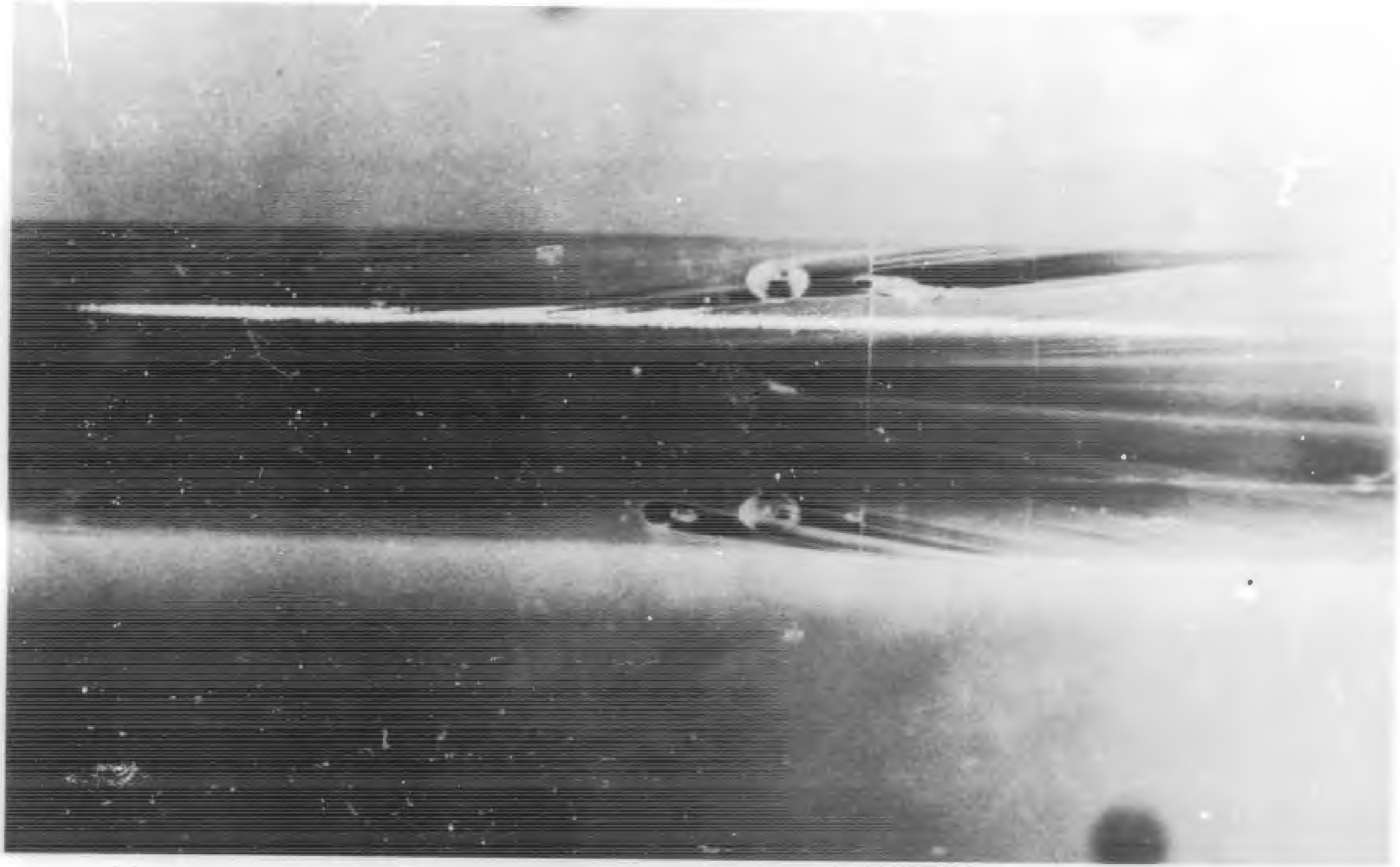

FIGURE D-9a. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_{\infty} = 0$

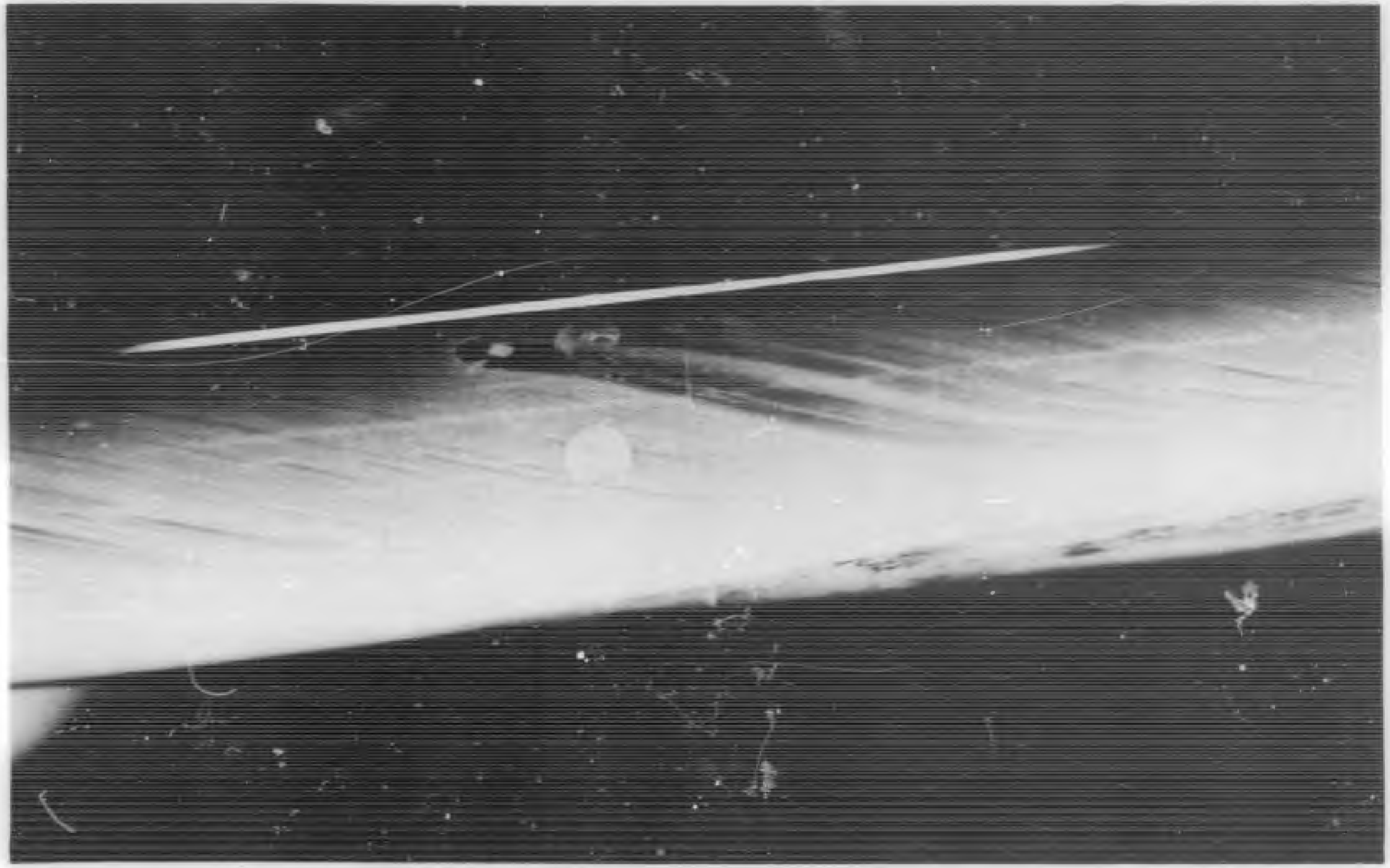

FIGURE D-9b. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_{\infty} = 0$

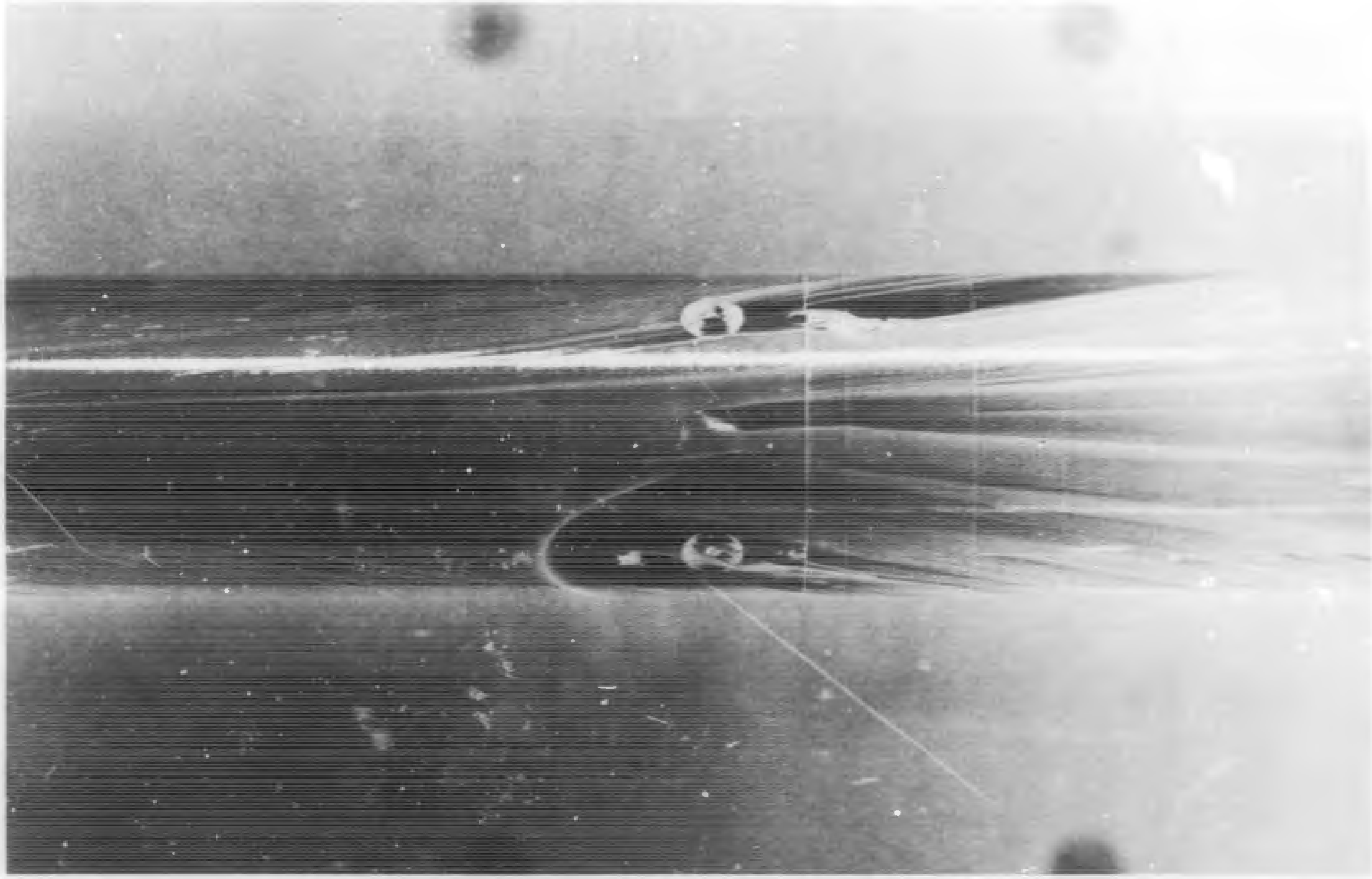

FIGURE D–9c. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_{\infty} = 10$

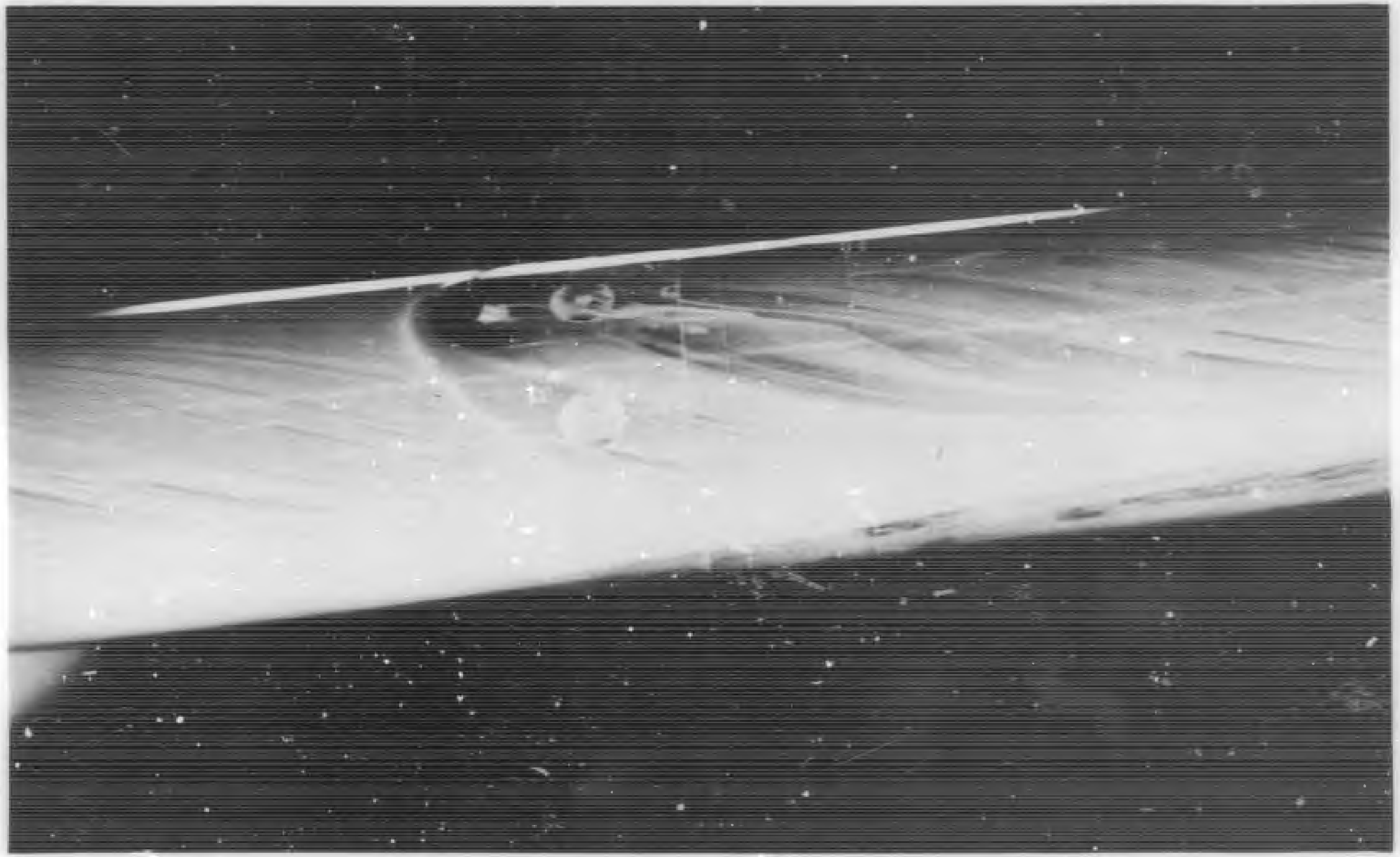

FIGURE D-9d. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_\infty = 10$

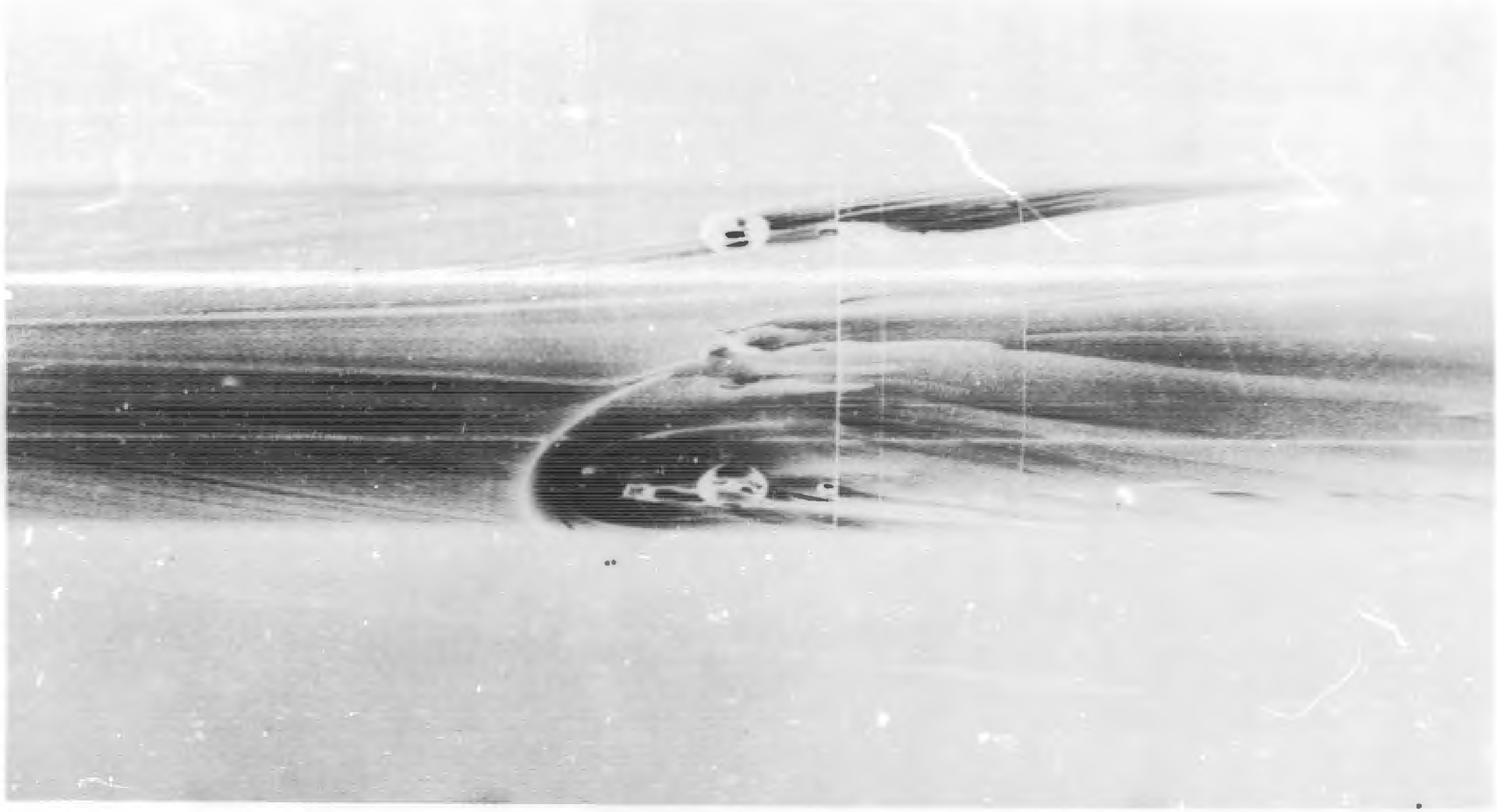

FIGURE D-9e. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_\infty = 40$

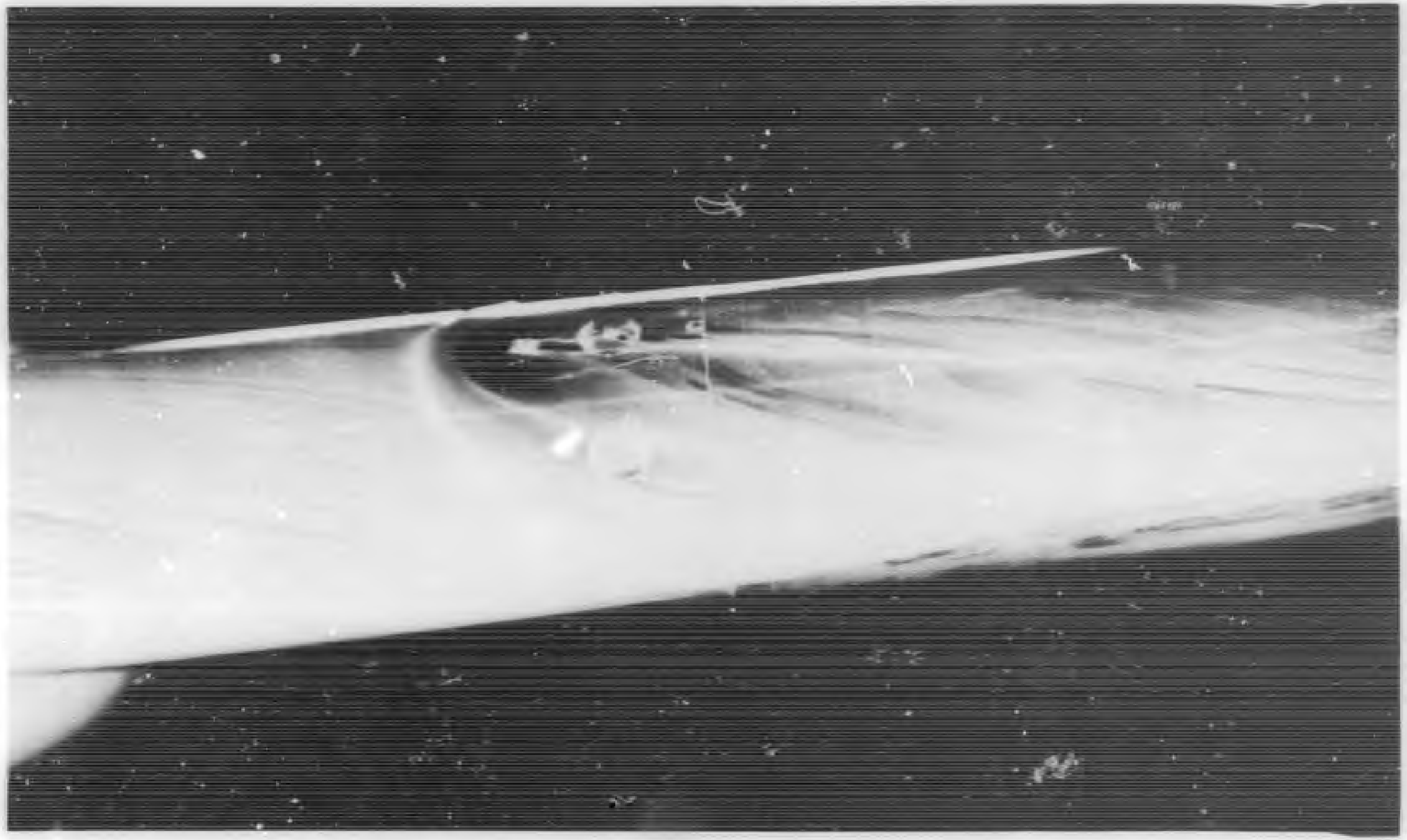

FIGURE D-9f. REACTION JET FOR $B_1C_1X_3$ WITH α = -5 DEGREES; P_{oj}/P_∞ = 40

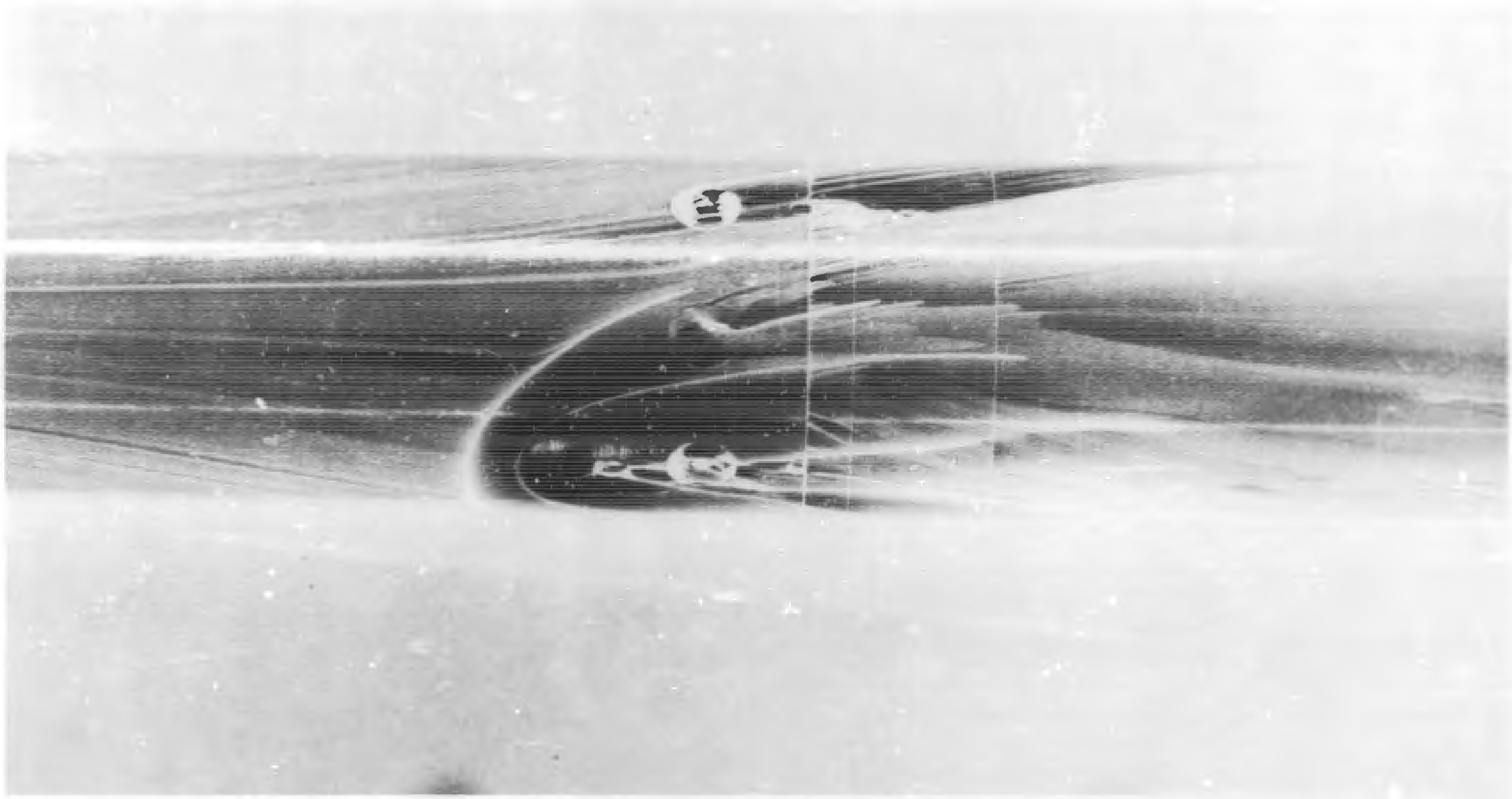

FIGURE D-9g. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_\infty = 100$

FIGURE D-9h. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_\infty = 100$

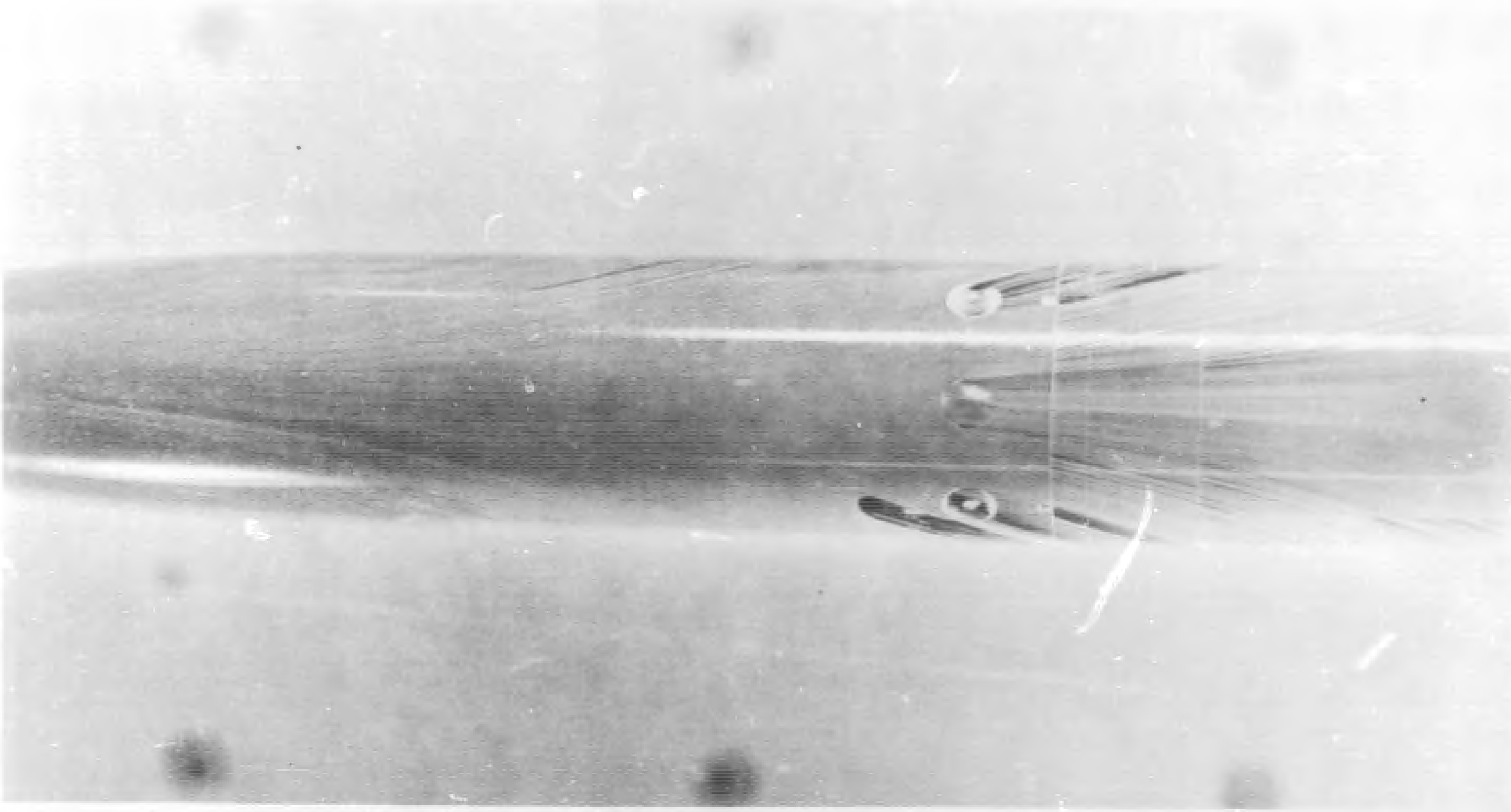

FIGURE D-10a. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_\infty = 0$

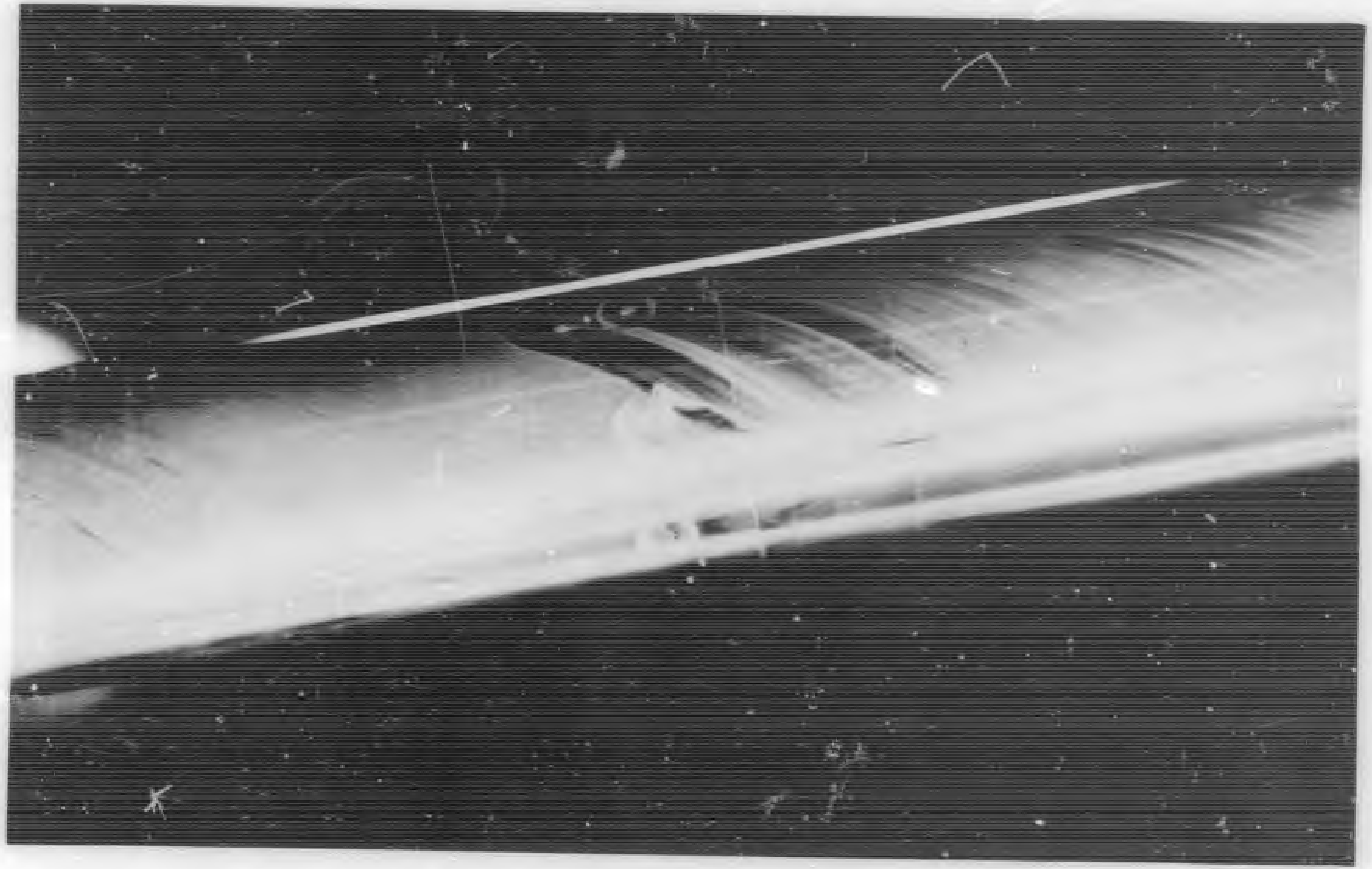

FIGURE D-10b. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_\infty = 0$

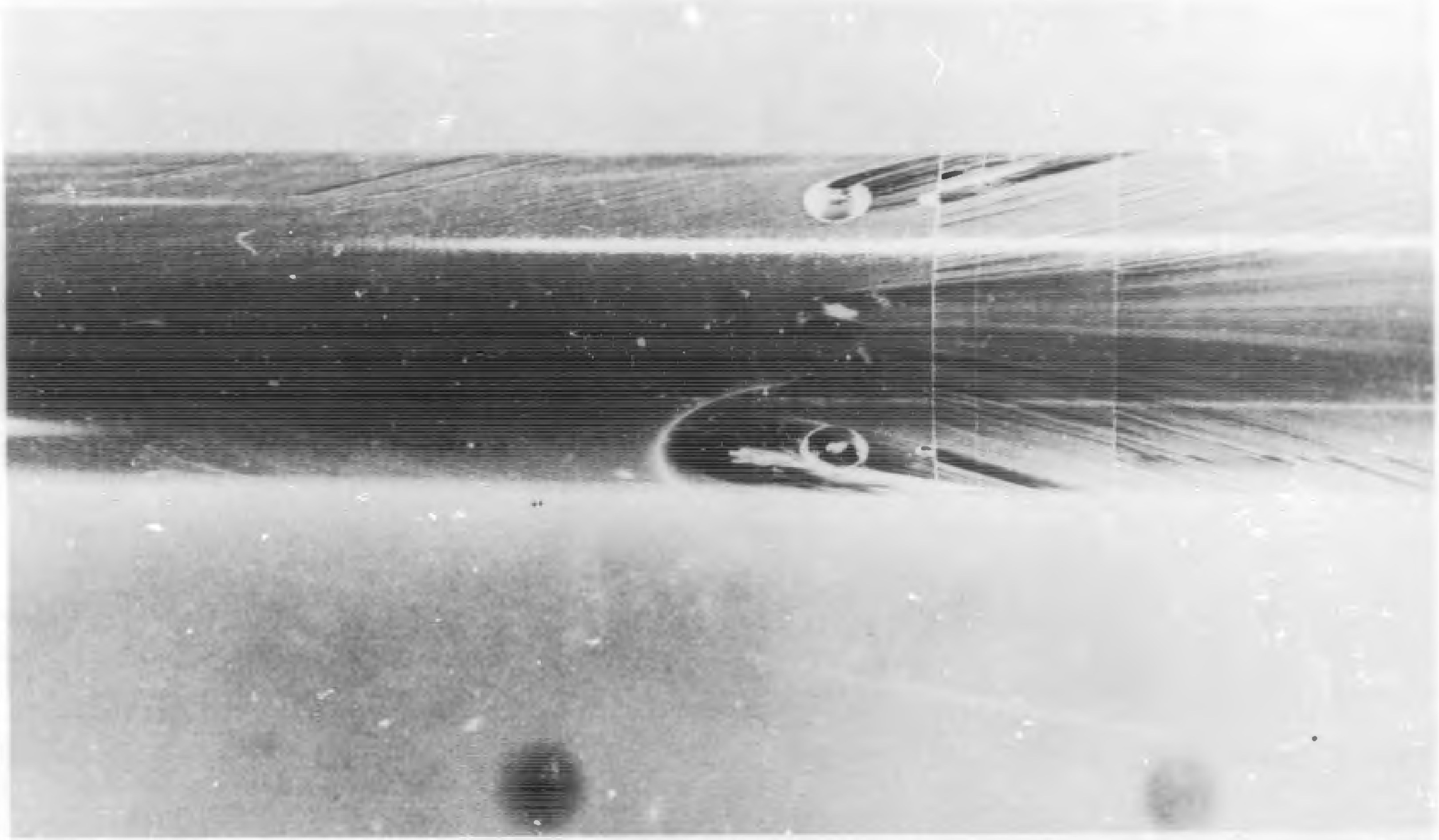

FIGURE D–10c. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_{\infty} = 10$

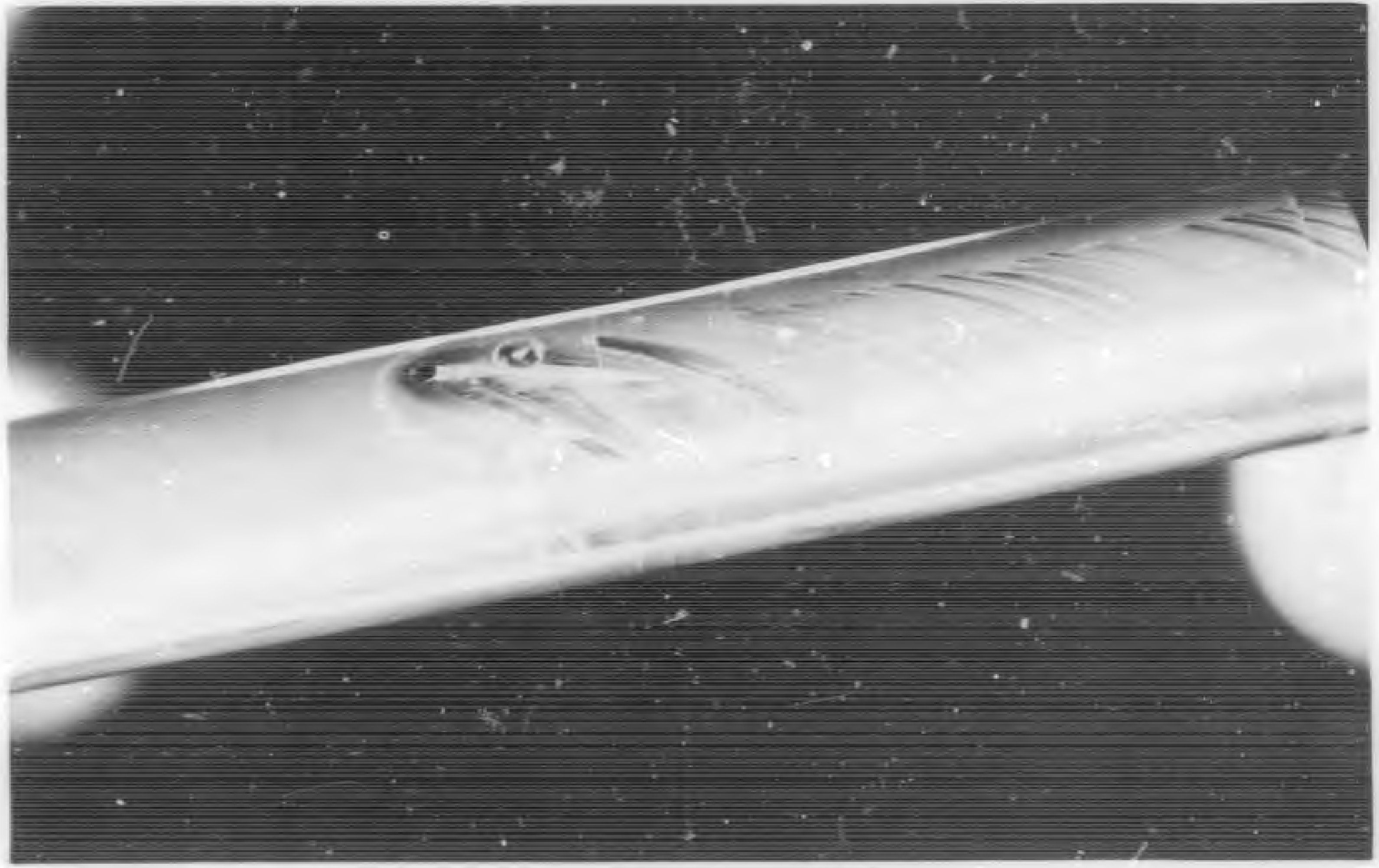

FIGURE D-10d. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_\infty = 10$

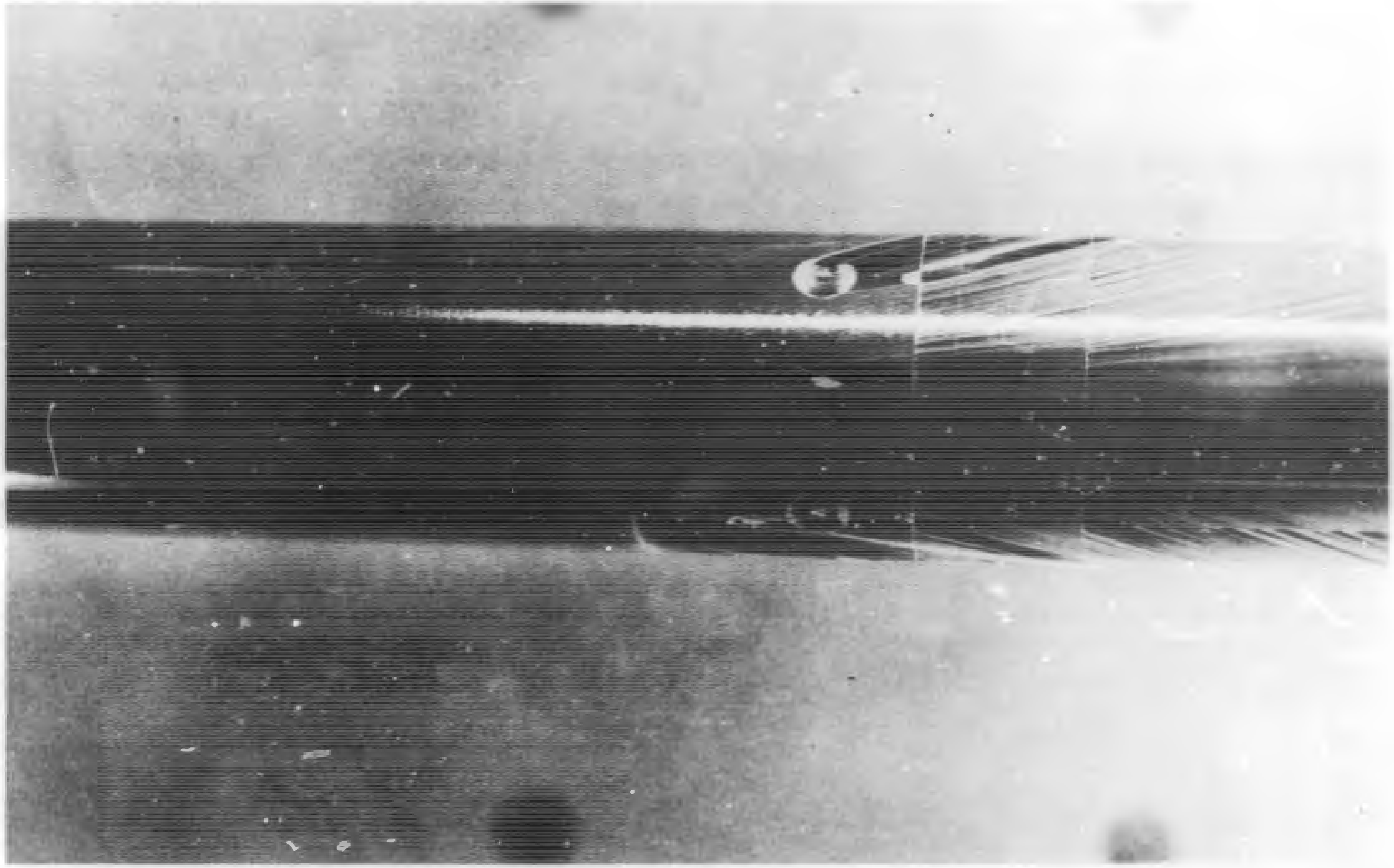

FIGURE D-10e. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_\infty = 40$

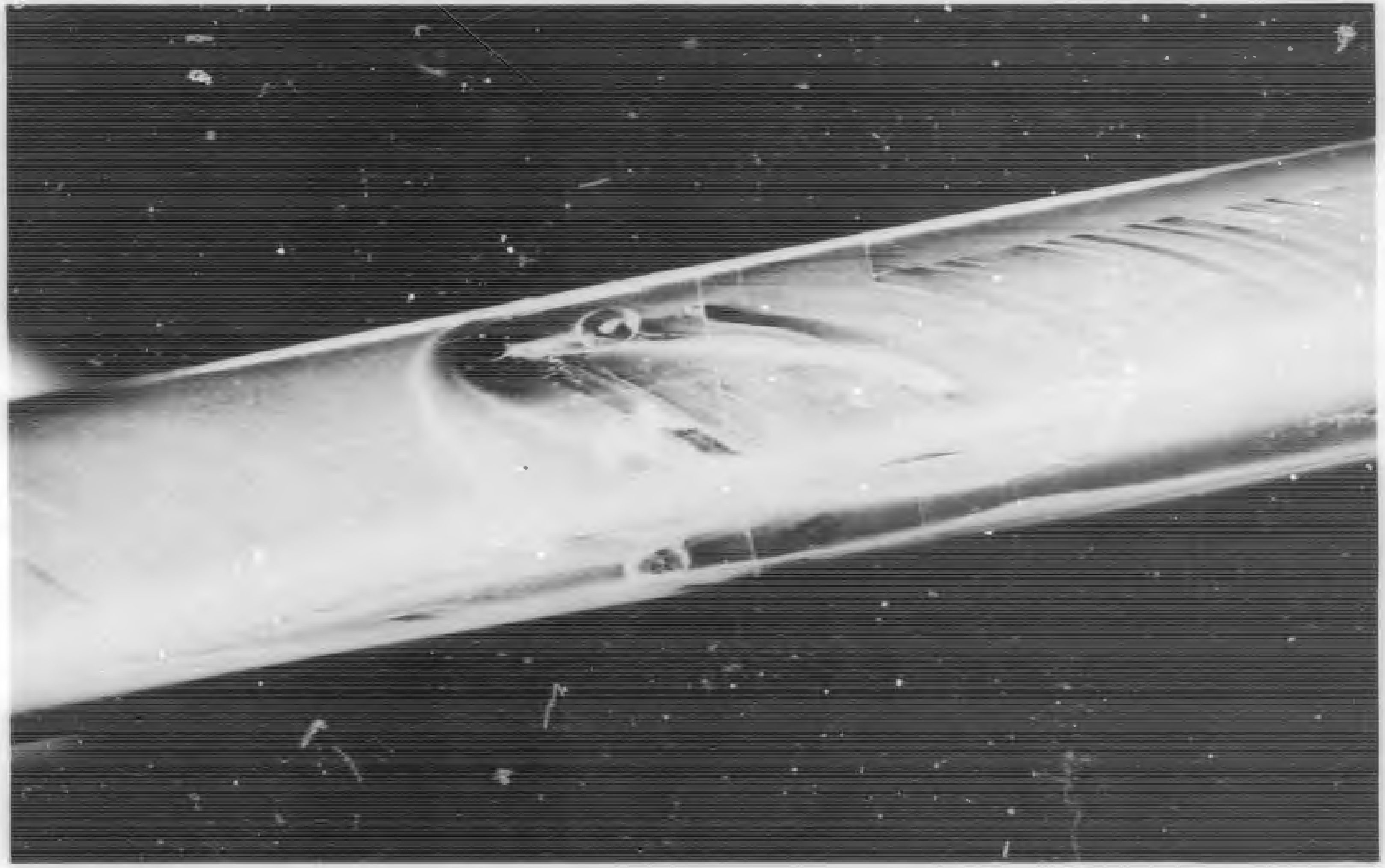

FIGURE D-10f. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_\infty = 40$

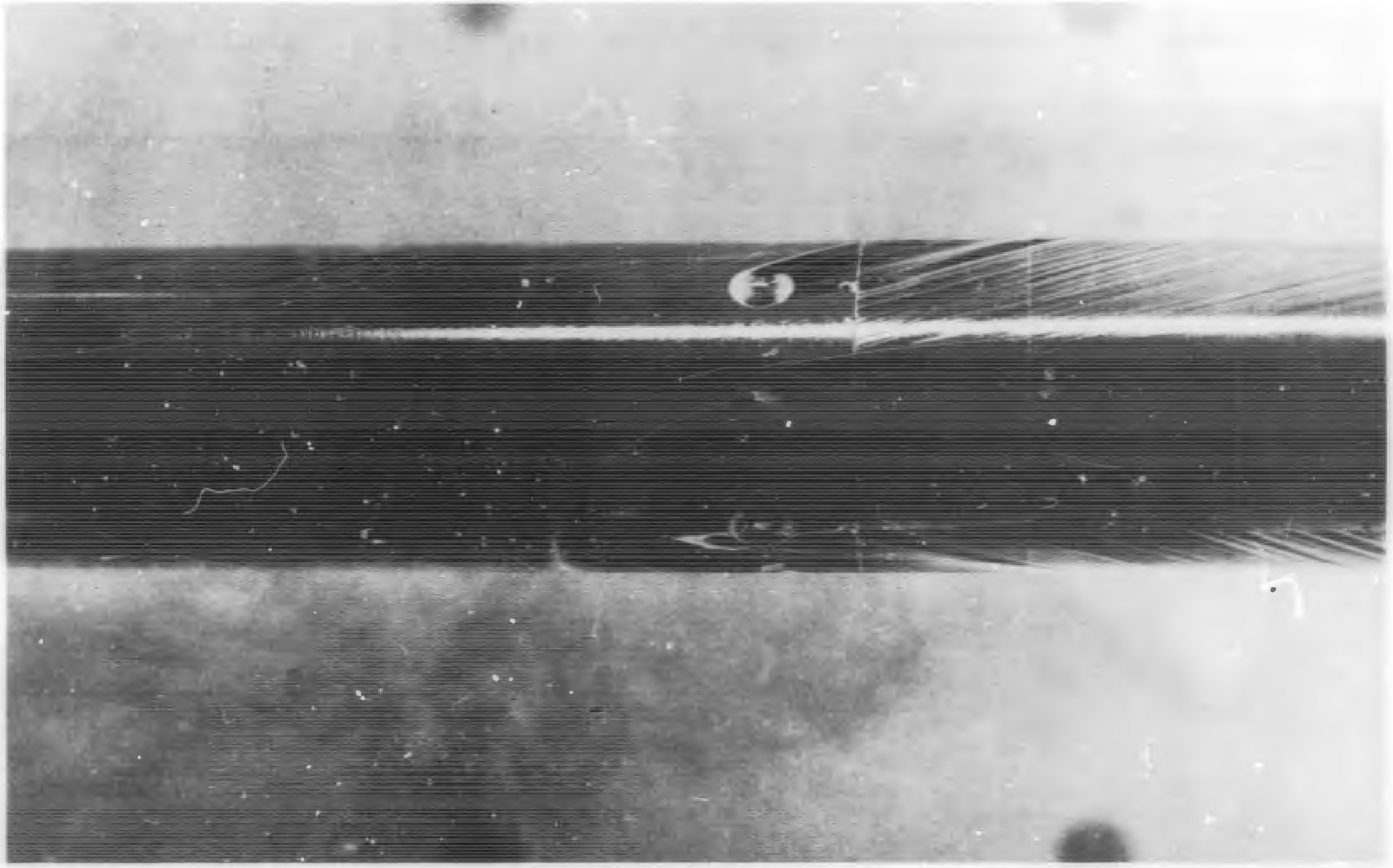

FIGURE D-10g. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_{\infty} = 100$

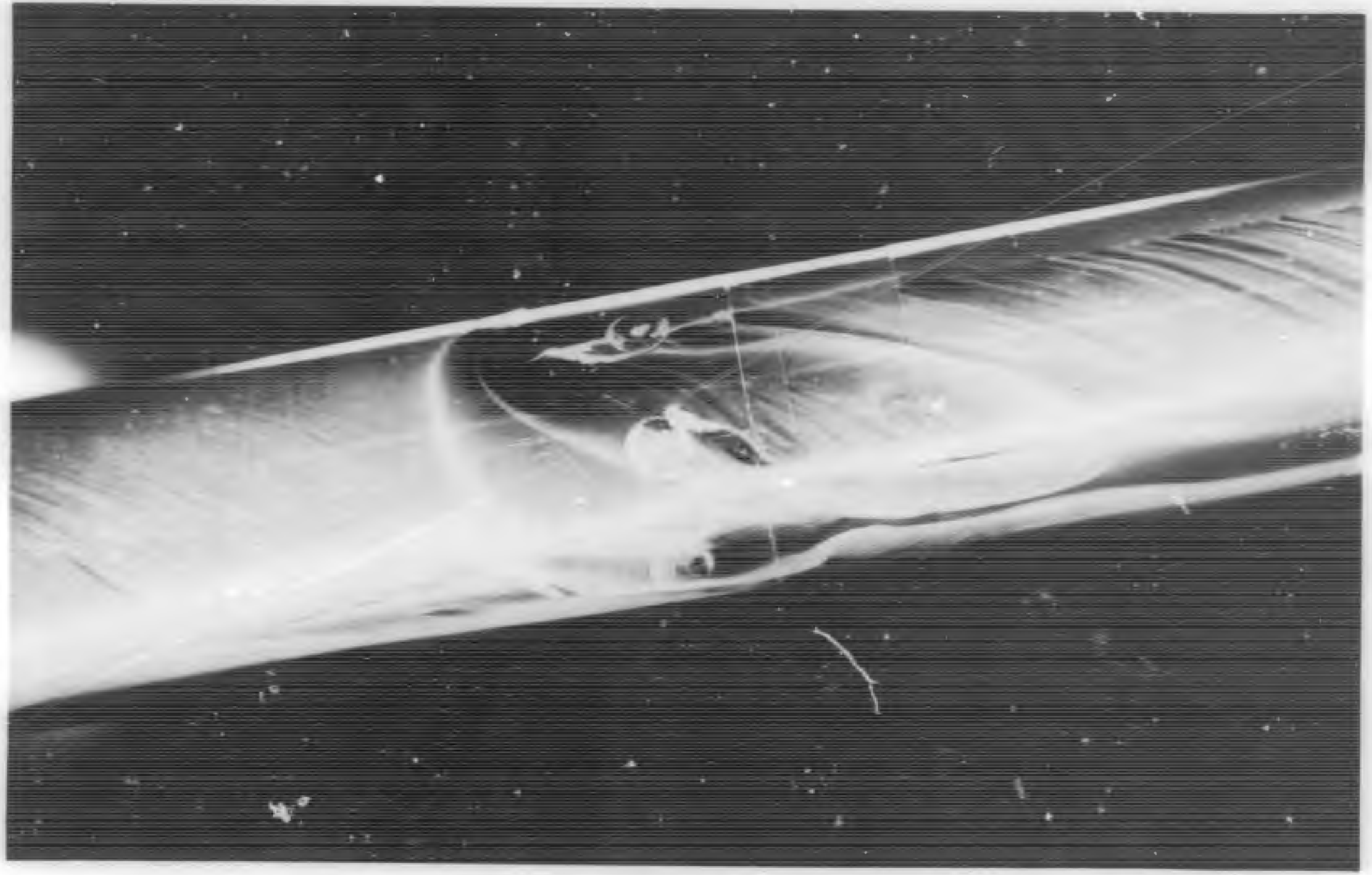

FIGURE D–10h. REACTION JET FOR $B_1C_1X_3$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_\infty = 100$

Appendix E
M_∞ = 4.5 Flow Visualization Data

TABLE E-I. TEST VARIABLES AND VISUAL DATA COLLECTED FOR $M_\infty = 4.5$

Configuration	ϕ_j (deg)	Fin No.	α (deg)	P_{oj}/P_∞	Figure Showing Photographs	Figure Showing Schlierens	Figure Showing Shadowgraphs	Test Series
$B_1C_1X_0$	90	0.00	0	0	E-1a			April 1969
	0		0	0	E-1b			
	90		0	40	E-1c			
	0		0	40	E-1d			
	90		0	100	E-1e			
	0		0	100	E-1f			
	0		0	~550	E-1g			
	0		0	0		E-1h		
	0		0	40		E-1i		
	0		0	100		E-1j		
	0		0	~550		E-1k		
	90		10	0	E-2a			
	0		10	0	E-2b			
	90		10	100	E-2c			
	0		10	100	E-2d			
	0		-10	0	E-3a			
	0		-10	40	E-3b			
	0		-10	100	E-3c			
	0		-10	0		E-3d		
	0		-10	40		E-3e		
$B_1C_1X_0$	0	0.00	-10	100		E-3f		April 1969

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TABLE E-I. TEST VARIABLES AND VISUAL DATA COLLECTED FOR $M_\infty = 4.5$ (Continued)

Configuration	ϕ_j (deg)	Fin No.	α (deg)	P_{oj}/P_∞	Figure Showing Photographs	Figure Showing Schlierens	Figure Showing Shadowgraphs	Test Series
$B_1C_1X_1$	90	0.00	0	0	E-4a			April 1969
↓	0	↓	0	0	E-4b			↓
	90		0	40	E-4c			
	0		0	40	E-4d			
	90		0	100	E-4e			
	0		0	100	E-4f			
	0		0	0		E-4g		
	0		0	40		E-4h		
	0		0	100		E-4i		
	90		5	40	E-5a			
	0		5	100	E-5b			
	90		5	40	E-5c			
	0		5	100	E-5d			
	0		5	40		E-5e		
	0		5	100		E-5f		
	90		10	40	E-6a			
	0		10	100	E-6b			
	90		10	40	E-6c			
	0		10	100	E-6d			
	0		10	40		E-6e		
	0		10	100		E-6f		
	0		-5	40	E-7a			
↓	0	↓	-5	100	E-7b			↓
$B_1C_1X_1$	0	0.00	-5	40		E-7c		April 1969

TABLE E-I. TEST VARIABLES AND VISUAL DATA COLLECTED FOR $M_\infty = 4.5$ (Continued)

Configuration	ϕ_j (deg)	Fin No.	α (deg)	P_{oj}/P_∞	Figure Showing Photographs	Figure Showing Schlierens	Figure Showing Shadowgraphs	Test Series
$B_1C_1X_1$	0	0.00	-5	100		E-7d		April 1969
↓	0	↓	-10	40	E-8a			↓
	0		-10	100	E-8b			
	0		-10	40		E-8c		
$B_1C_1X_1$	0		-10	100		E-8d		
$B_1C_1X_2$	90		0	0	E-9a			
↓	0		0	0	E-9b			
	90		0	10	E-9c			
	90		0	20	E-9d			
	90		0	40	E-9e			
	0		0	40	E-9f			
	90		0	100	E-9g			
	0		0	100	E-9h			
	90		0	40	E-9i			
	90		0	100	E-9j			
	0		0	0		E-9k		
	0		0	40		E-9l		
	0		0	100		E-9m		
	0		5	40	E-10a			
	0		5	100	E-10b			
	0		5	40		E-10c		
	0		5	100		E-10d		
	0		10	40	E-11a			
	0	0.00	10	100	E-11b			April 1969

TABLE E-I. TEST VARIABLES AND VISUAL DATA COLLECTED FOR $M_\infty = 4.5$ (Continued)

Configuration	ϕ_j (deg)	Fin No.	α (deg)	P_{oj}/P_∞	Figure Showing Photographs	Figure Showing Schlierens	Figure Showing Shadowgraphs	Test Series
$B_1C_1X_2$	0	0.00	10	40		E-11c		April 1969
	0		10	100		E-11d		
	0		-5	40	E-12a			
	0		-5	100	E-12b			
	0		-5	40		E-12c		
	0		-5	100		E-12d		
	0		-10	40	E-13a			
	0		-10	100	E-13b			
	0		-10	40		E-13c		
$B_1C_1X_2$	0		-10	100		E-13d		April 1969
$B_1C_1X_2$	0		0	40			E-14a	February-March 1969
	0		0	100			E-14b	February-March 1969
$B_1S_{1L}X_2$	90		0	0	E-15a			April 1969
	0		0	0	E-15b			
	90		0	40	E-15c			
	0		0	40	E-15d			
	90		0	100	E-15e			
	0		0	100	E-15f			
	0		0	0		E-15g		
	0		0	40		E-15h		
	0		0	100		E-15i		
	90		5	40	E-16a			
	0		5	40	E-16b			
$B_1S_{1L}X_2$	90	0.00	5	100	E-16c			April 1969

TABLE E-I. TEST VARIABLES AND VISUAL DATA COLLECTED FOR $M_\infty = 4.5$ (Concluded)

Configuration	ϕ_j (deg)	Fin No.	α (deg)	P_{oj}/P_∞	Figure Showing Photographs	Figure Showing Schlierens	Figure Showing Shadowgraphs	Test Series
$B_1S_{1L}X_2$	0	0.00	5	100	E-16d			April 1969
	90		10	40	E-17a			
	0		10	40	E-17b			
	90		10	100	E-17c			
	0		10	100	E-17d			
	0		10	40		E-17e		
	0		10	100		E-17f		
	0		-5	40	E-18a			
	0		-5	100	E-18b			
	0		-10	40	E-19a			
$B_1S_{1L}X_2$	0		-10	100	E-19b			
$B_1S_{1T}X_2$	90		0	0	E-20a			
	0		0	0	E-20b			
	90		0	40	E-20c			
	0		0	40	E-20d			
	90		0	100	E-20e			
	0		0	100	E-20f			
	90		5	40	E-21a			
	90		5	100	E-21b			
	90		10	40	E-22a			
$B_1S_{1T}X_2$	90	0.00	10	100	E-22b			April 1969

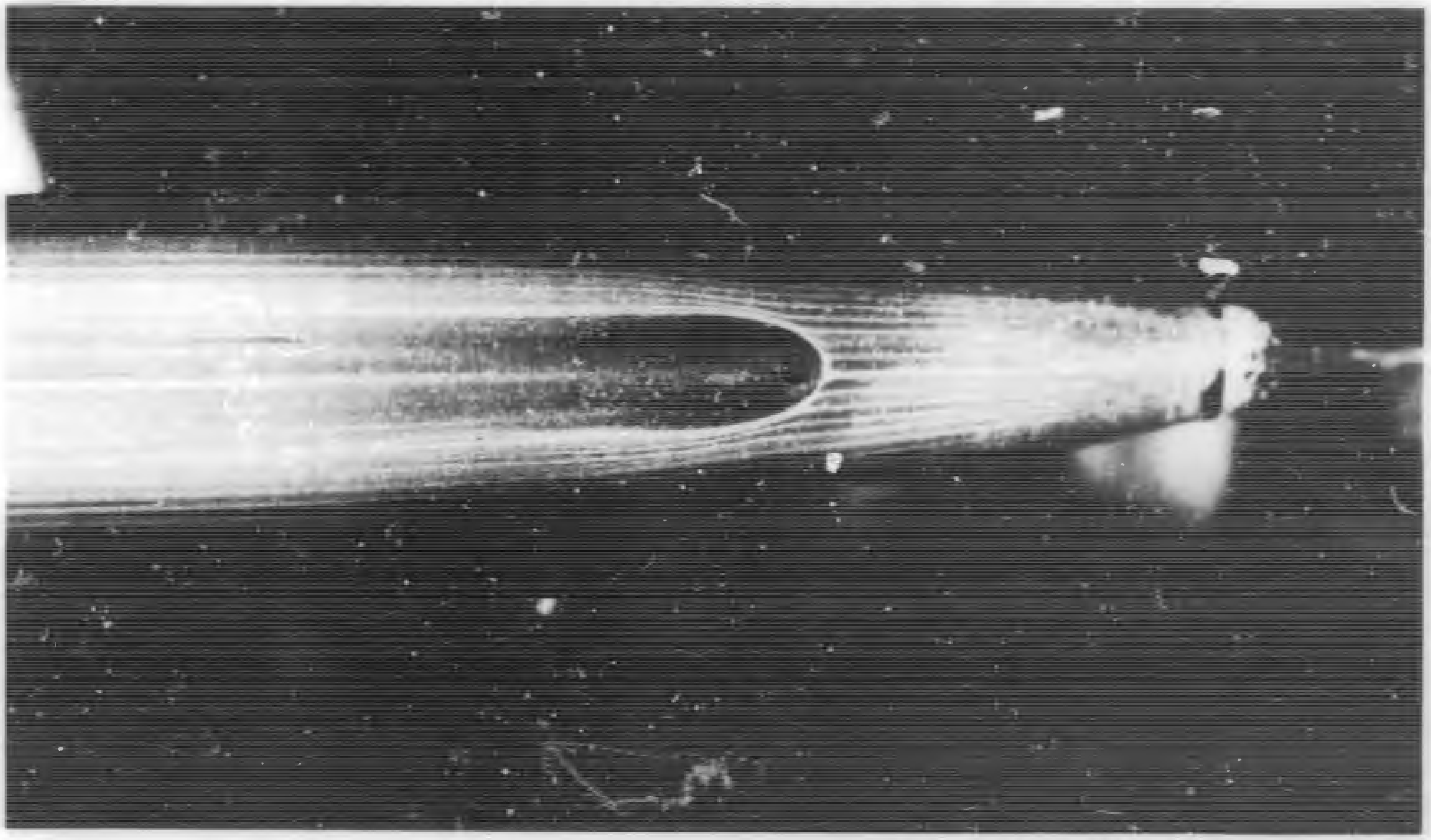

FIGURE E-1a. REACTION JET FOR $B_1C_1X_0$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_{\infty} = 0$

FIGURE E-1b. REACTION JET FOR $B_1C_1X_0$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_{\infty} = 0$

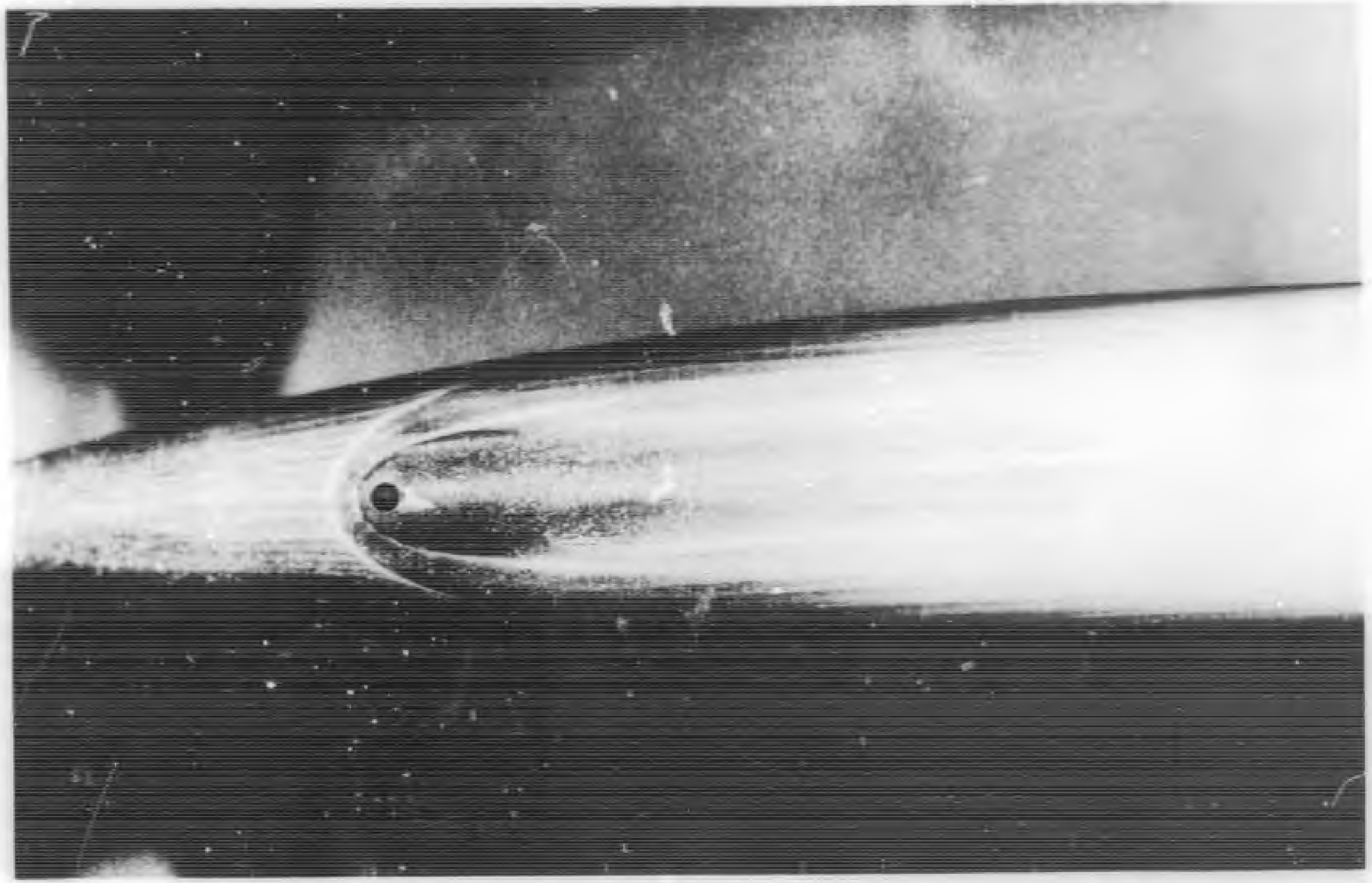

FIGURE E-1c. REACTION JET FOR $B_1C_1X_0$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_{\infty} = 40$

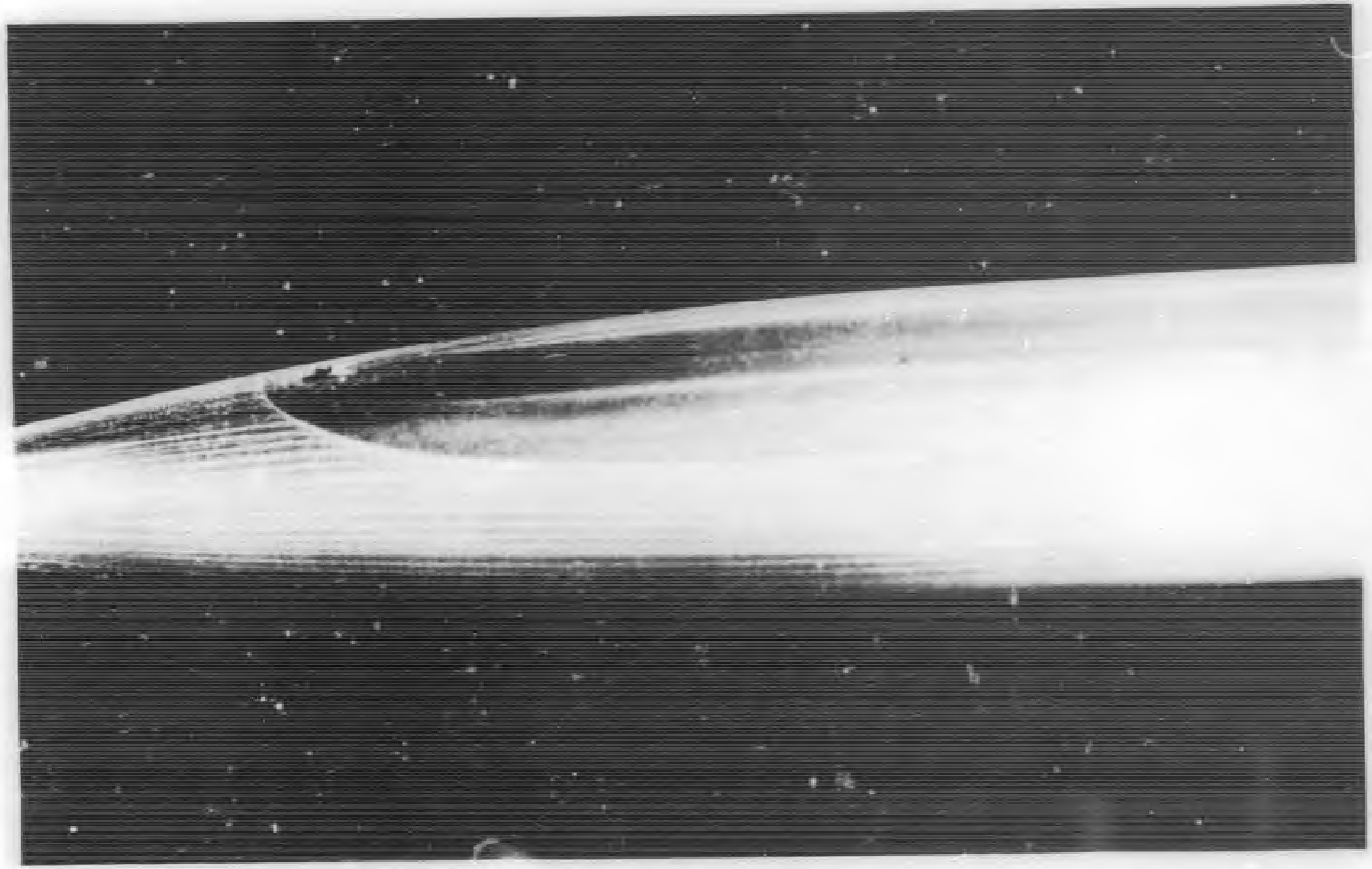

FIGURE E-1d. REACTION JET FOR $B_1C_1X_0$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 40$

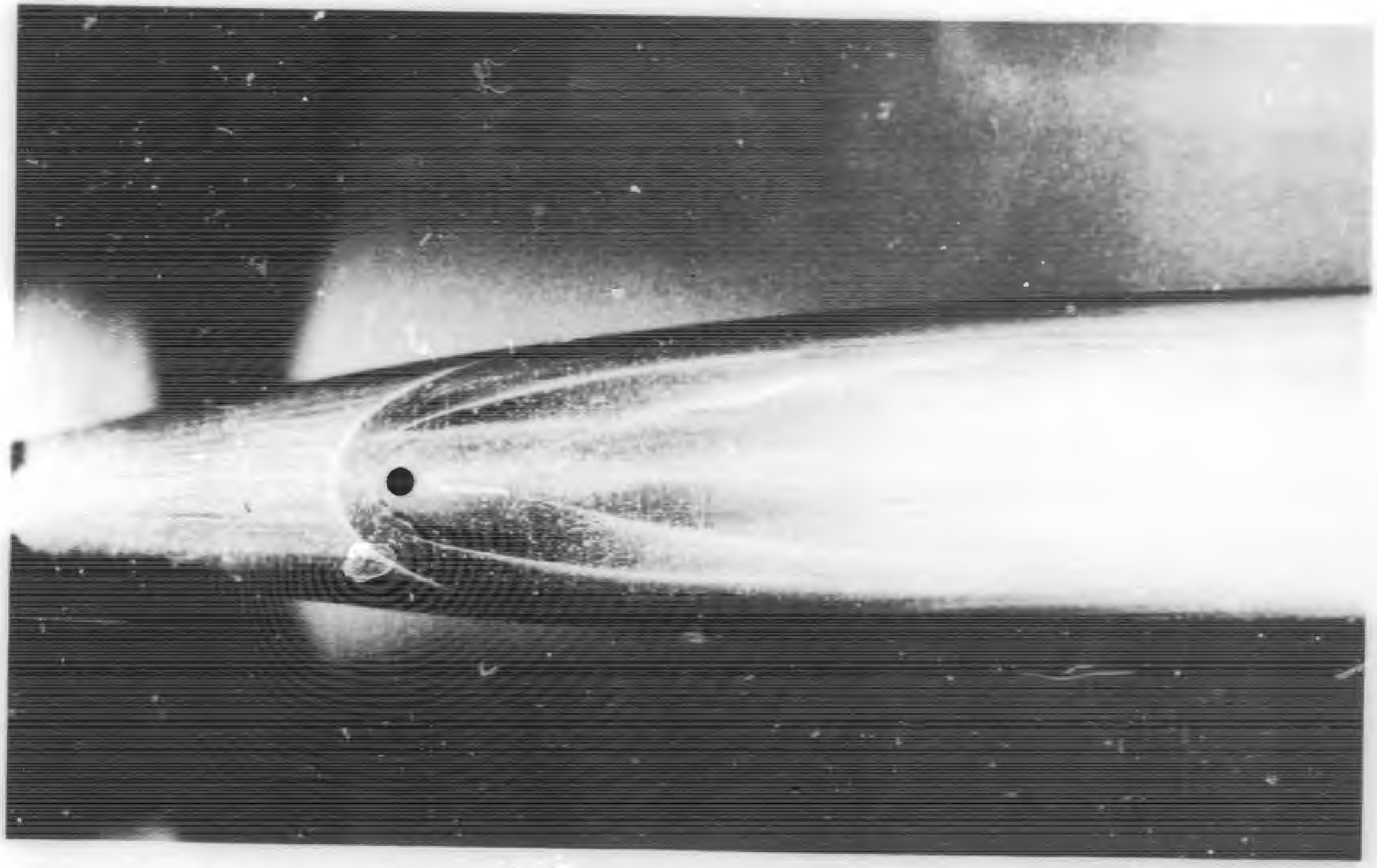

FIGURE E-1e. REACTION JET FOR $B_1C_1X_0$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_{\infty} = 100$

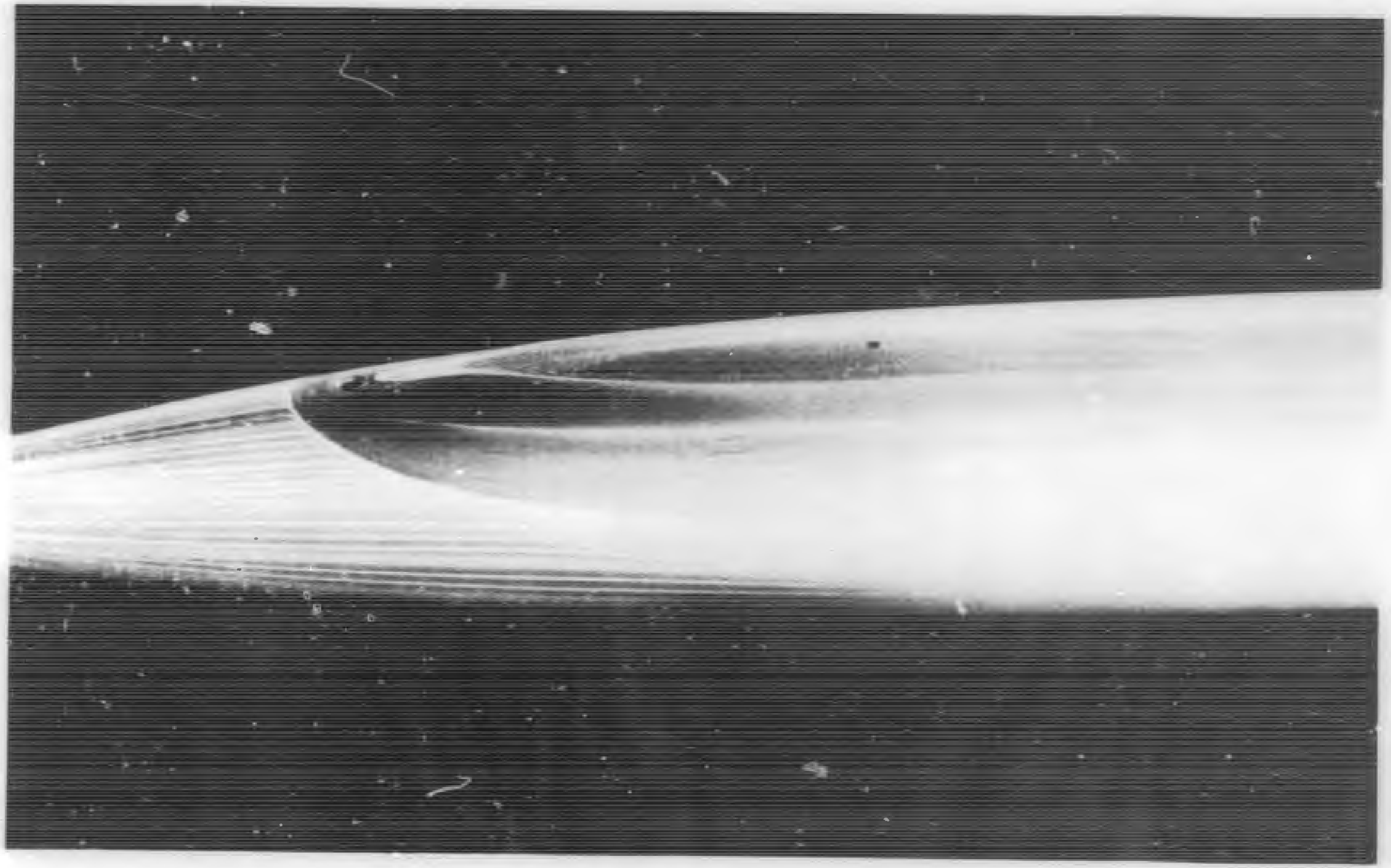

FIGURE E-1f. REACTION JET FOR $B_1C_1X_0$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_{\infty} = 100$

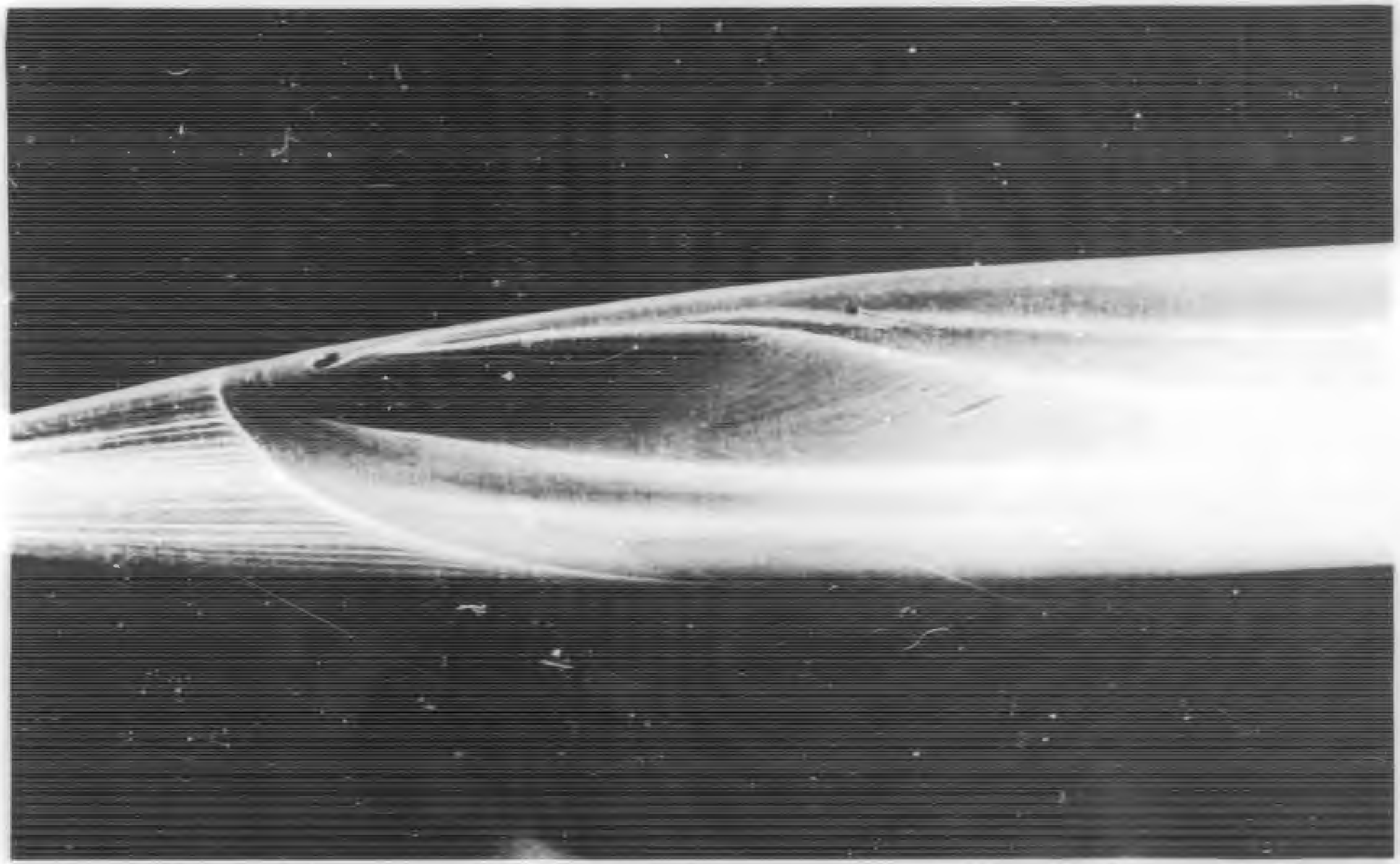

FIGURE E-1g. REACTION JET FOR $B_1C_1X_0$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = \sim 550$

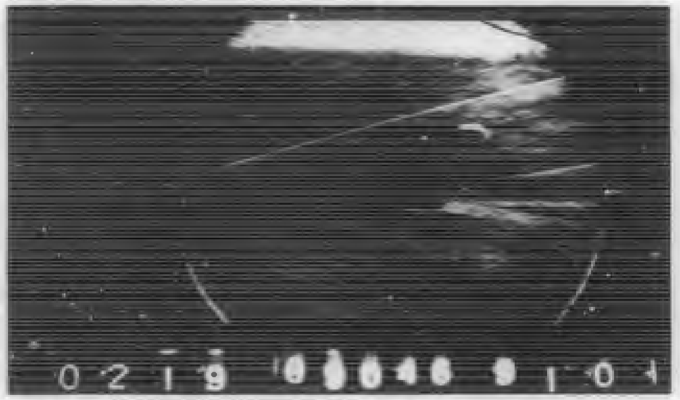

FIGURE E-1h. REACTION JET FOR $B_1C_1X_0$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 0$

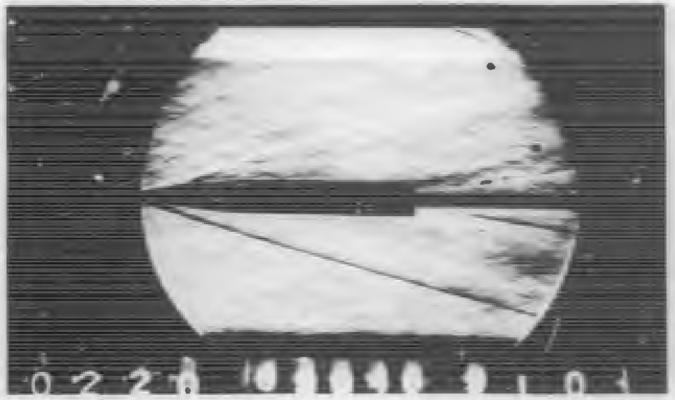

FIGURE E-1i. REACTION JET FOR $B_1C_1X_0$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 40$

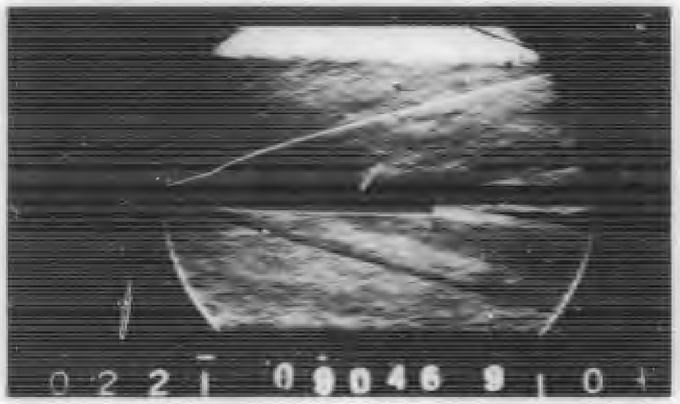

FIGURE E-1j. REACTION JET FOR $B_1C_1X_0$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 100$

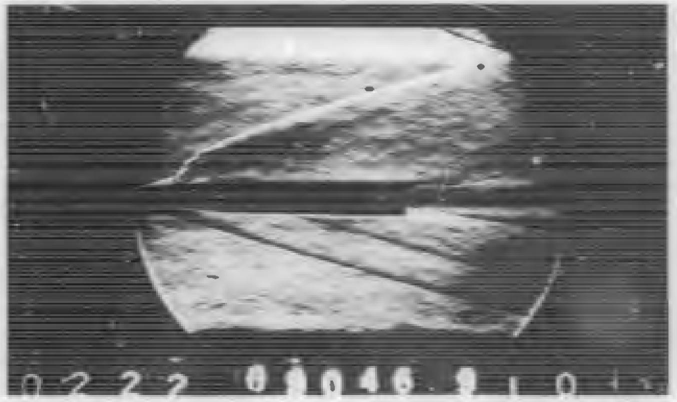

FIGURE E-1k. REACTION JET FOR $B_1C_1X_0$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = \sim 500$

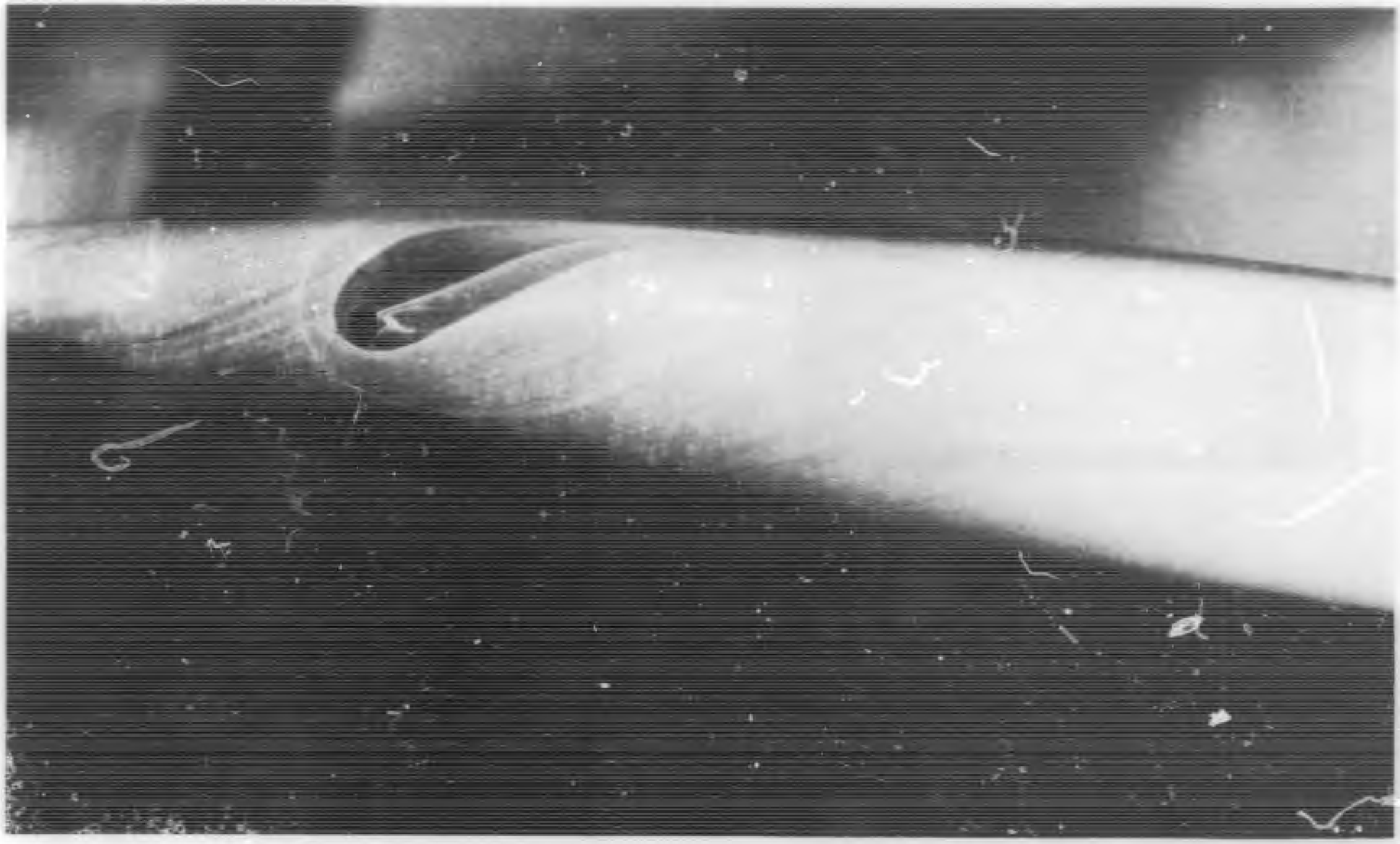

FIGURE E-2a. REACTION JET FOR $B_1C_1X_0$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_\infty = 0$

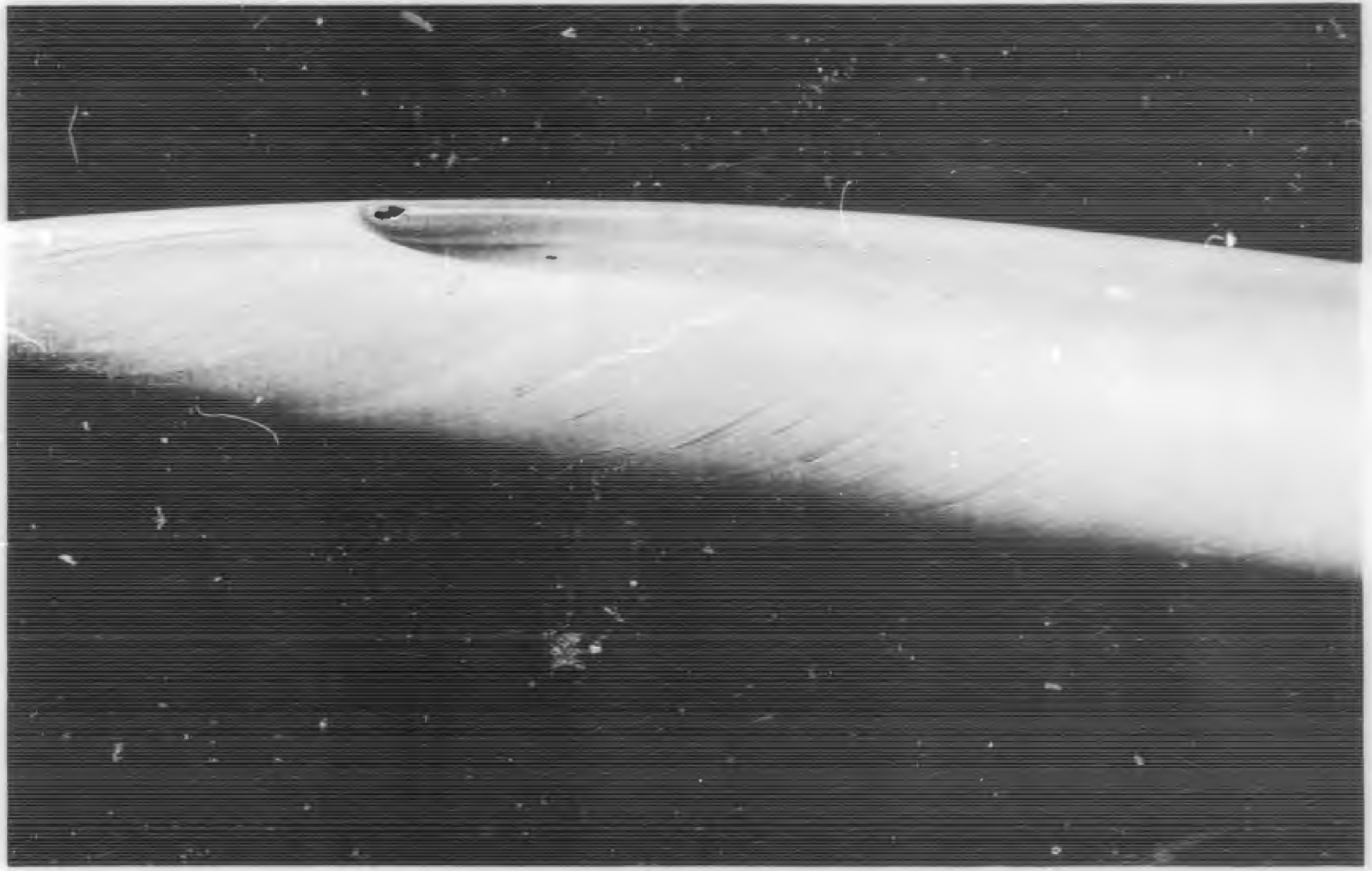

FIGURE E-2b. REACTION JET FOR $B_1C_1X_0$ WITH α = 10 DEGREES; $P_{oj}/P_\infty = 0$

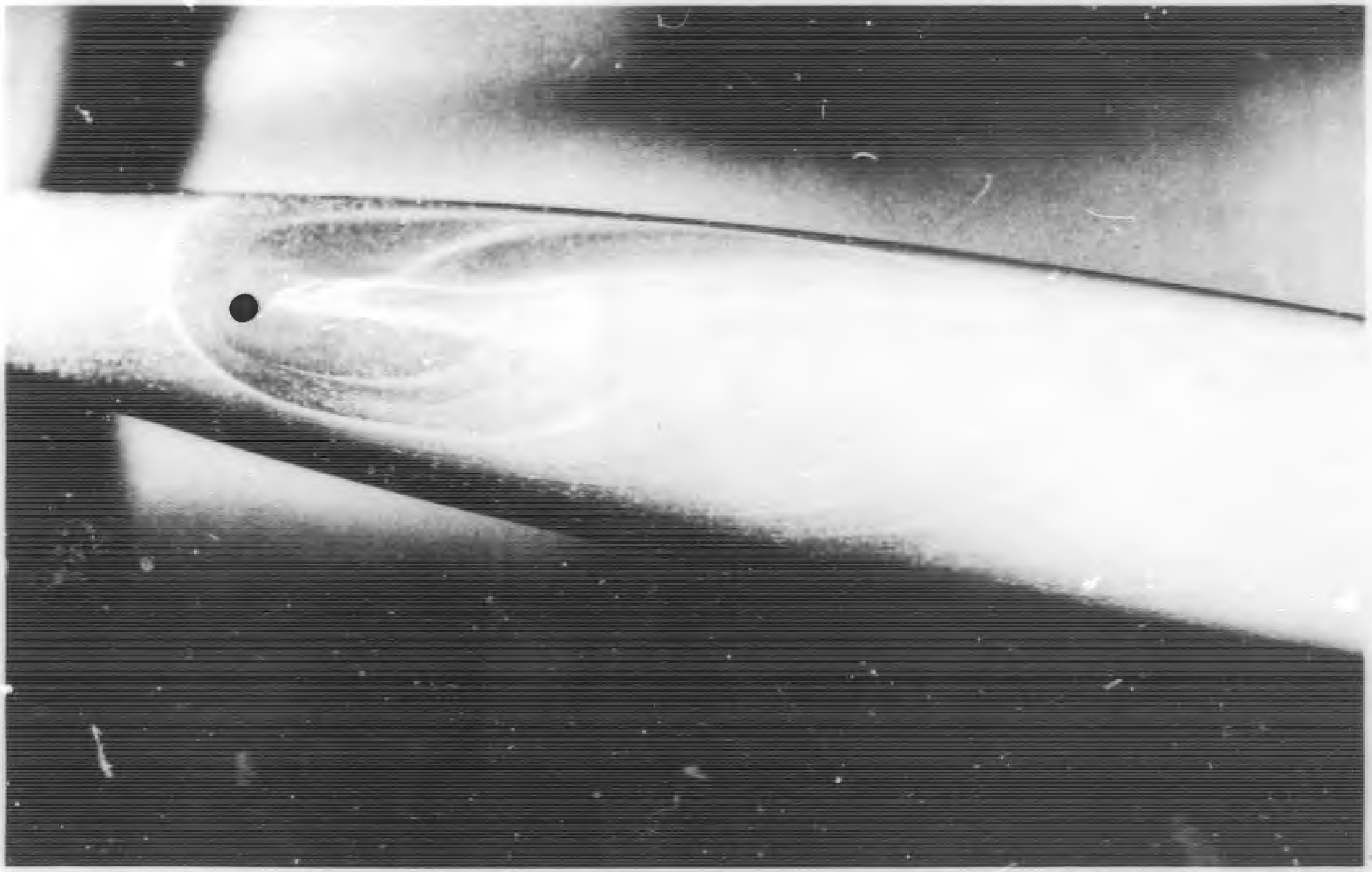

FIGURE E-2c. REACTION JET FOR $B_1C_1X_0$ WITH α = 10 DEGREES; P_{oj}/P_{∞} = 100

FIGURE E-2d.   REACTION JET FOR $B_1C_1X_0$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_\infty = 100$

FIGURE E-3a. REACTION JET FOR $B_1C_1X_0$ WITH α = -10 DEGREES; P_{oj}/P_{∞} = 0

FIGURE E-3b. REACTION JET FOR $B_1C_1X_0$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_{\infty} = 40$

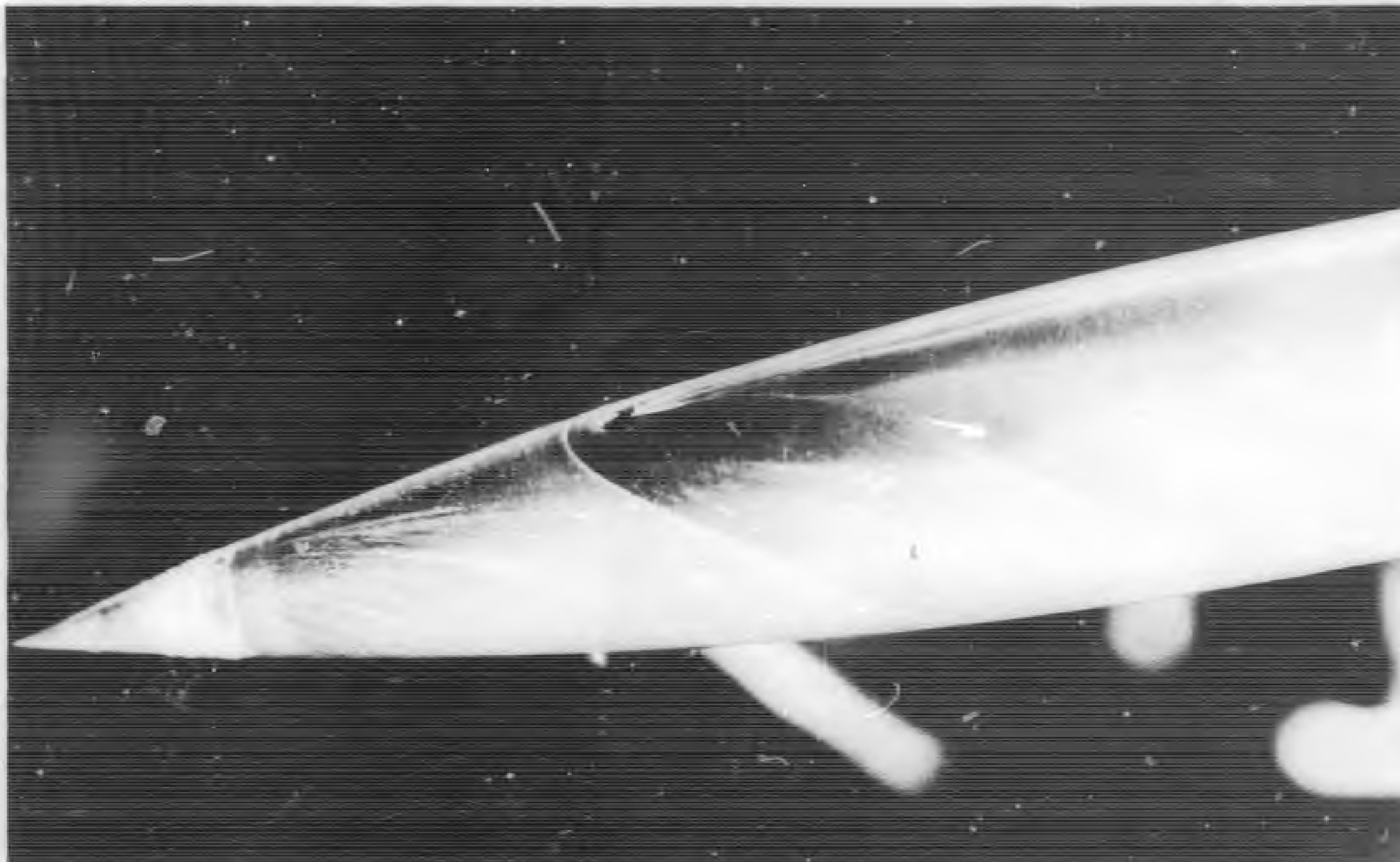

FIGURE E-3c. REACTION JET FOR $B_1C_1X_0$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_\infty = 100$

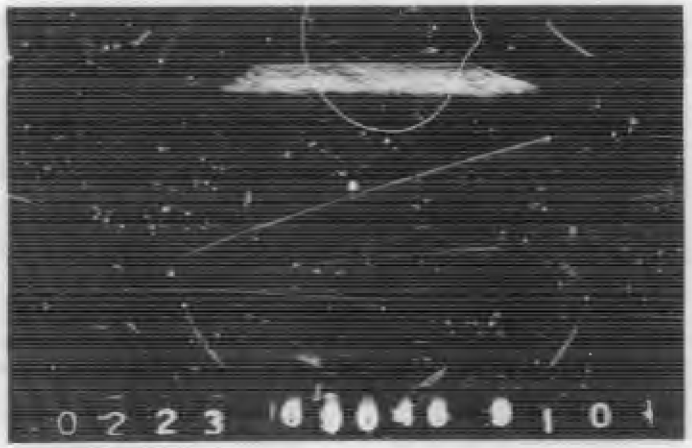

FIGURE E-3d. REACTION JET FOR $B_1C_1X_0$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_\infty = 0$

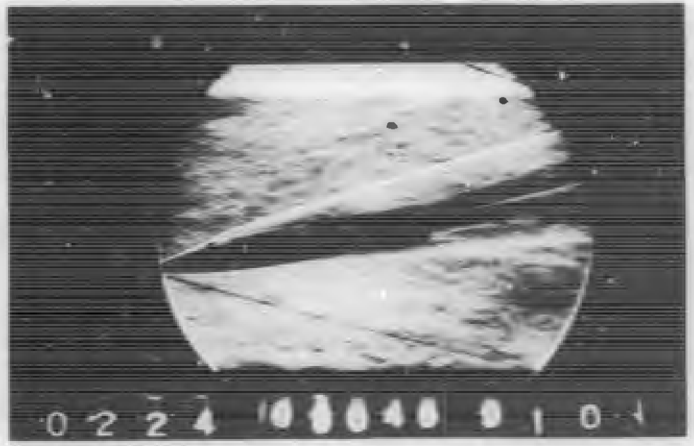

FIGURE E-3e. REACTION JET FOR $B_1C_1X_0$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_\infty = 40$

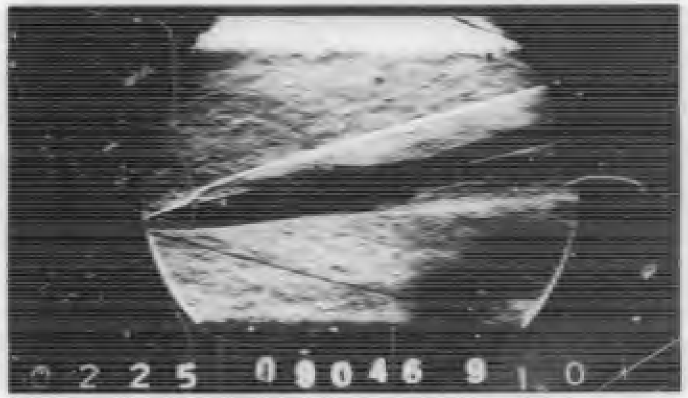

FIGURE E-3f. REACTION JET FOR $B_1C_1X_0$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_\infty = 100$

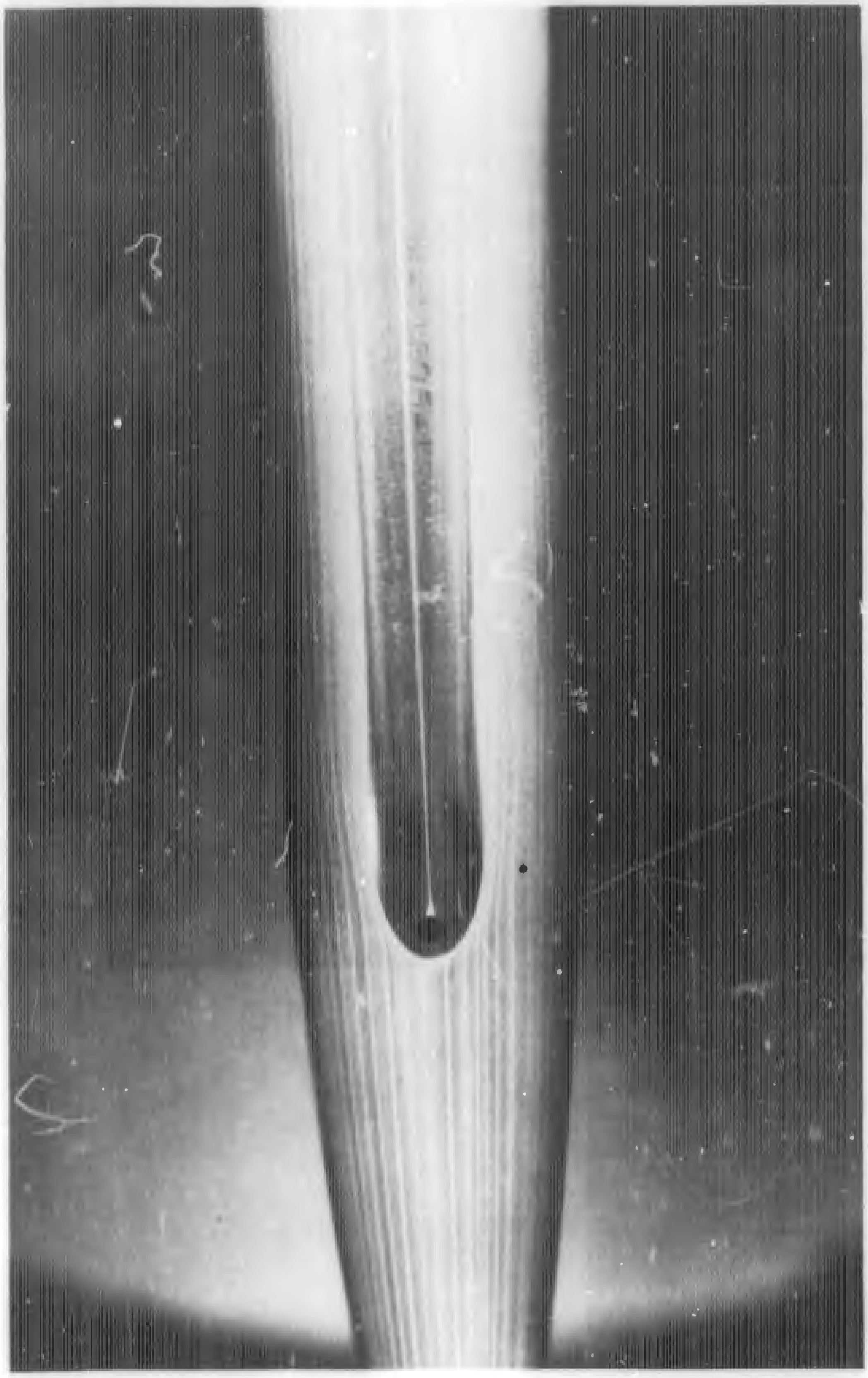

FIGURE E-4a.   REACTION JET FOR $B_1C_1X_1$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 0$

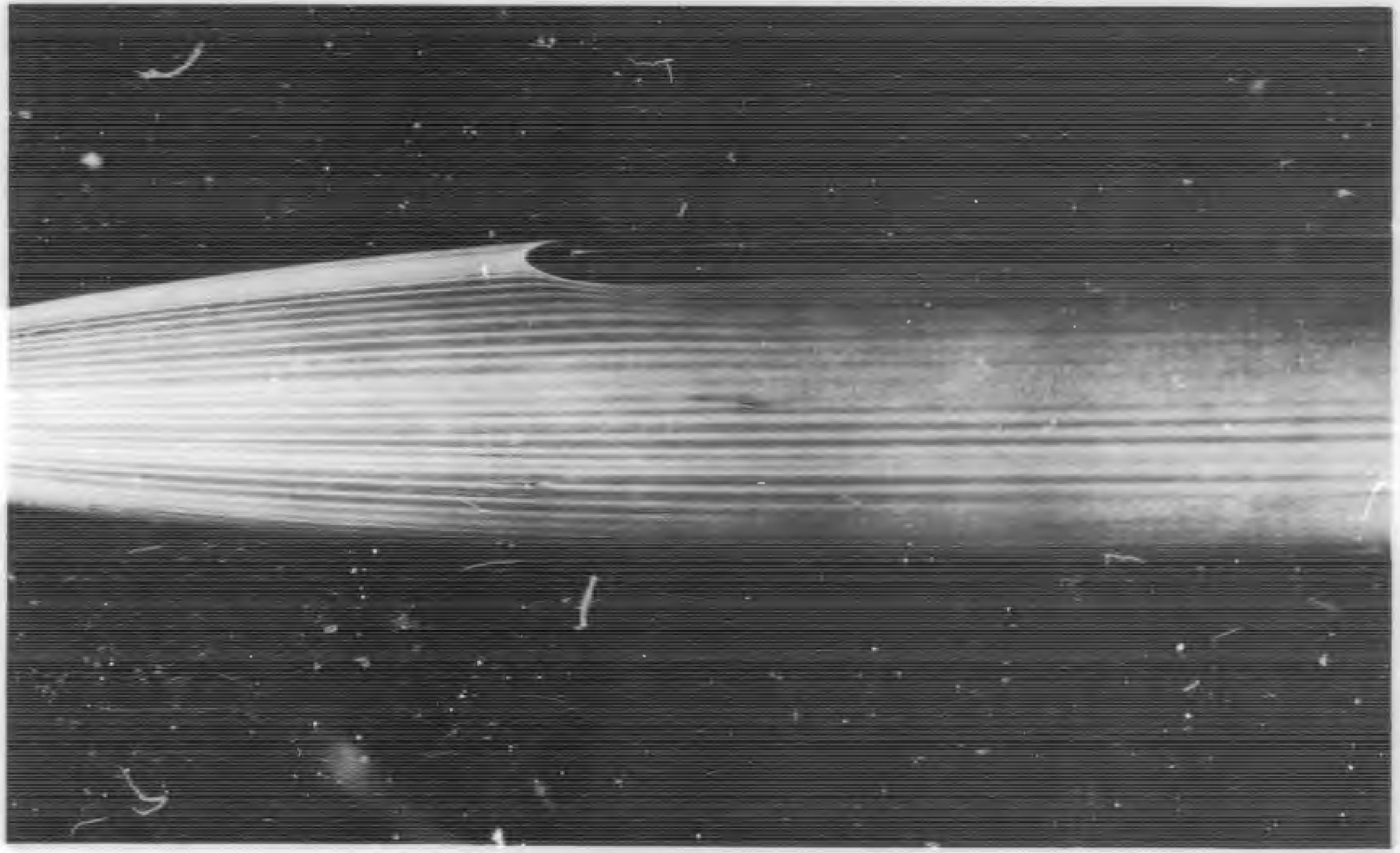

FIGURE E-4b. REACTION JET FOR $B_1C_1X_1$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 0$

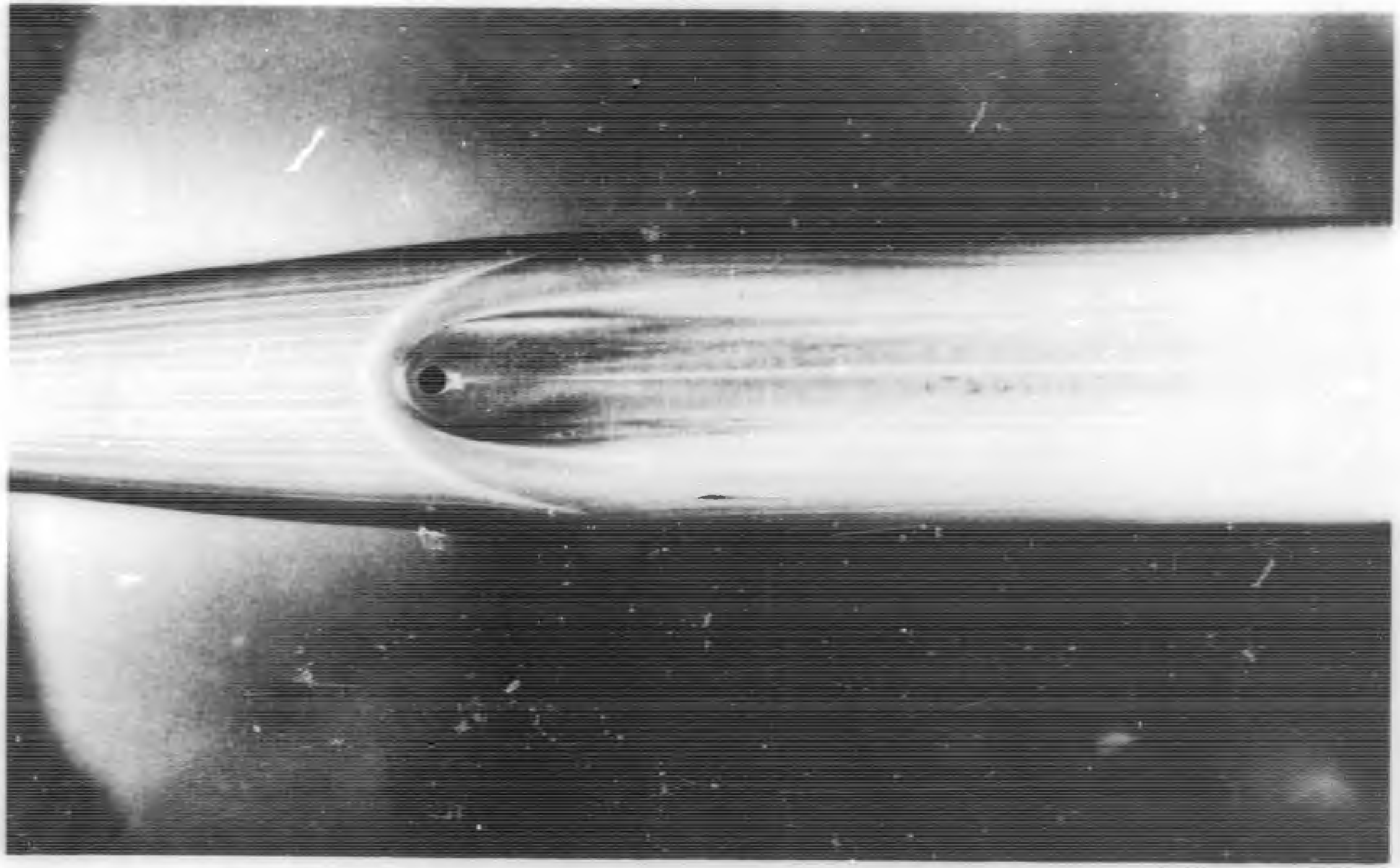

FIGURE E-4c. REACTION JET FOR $B_1C_1X_1$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 40$

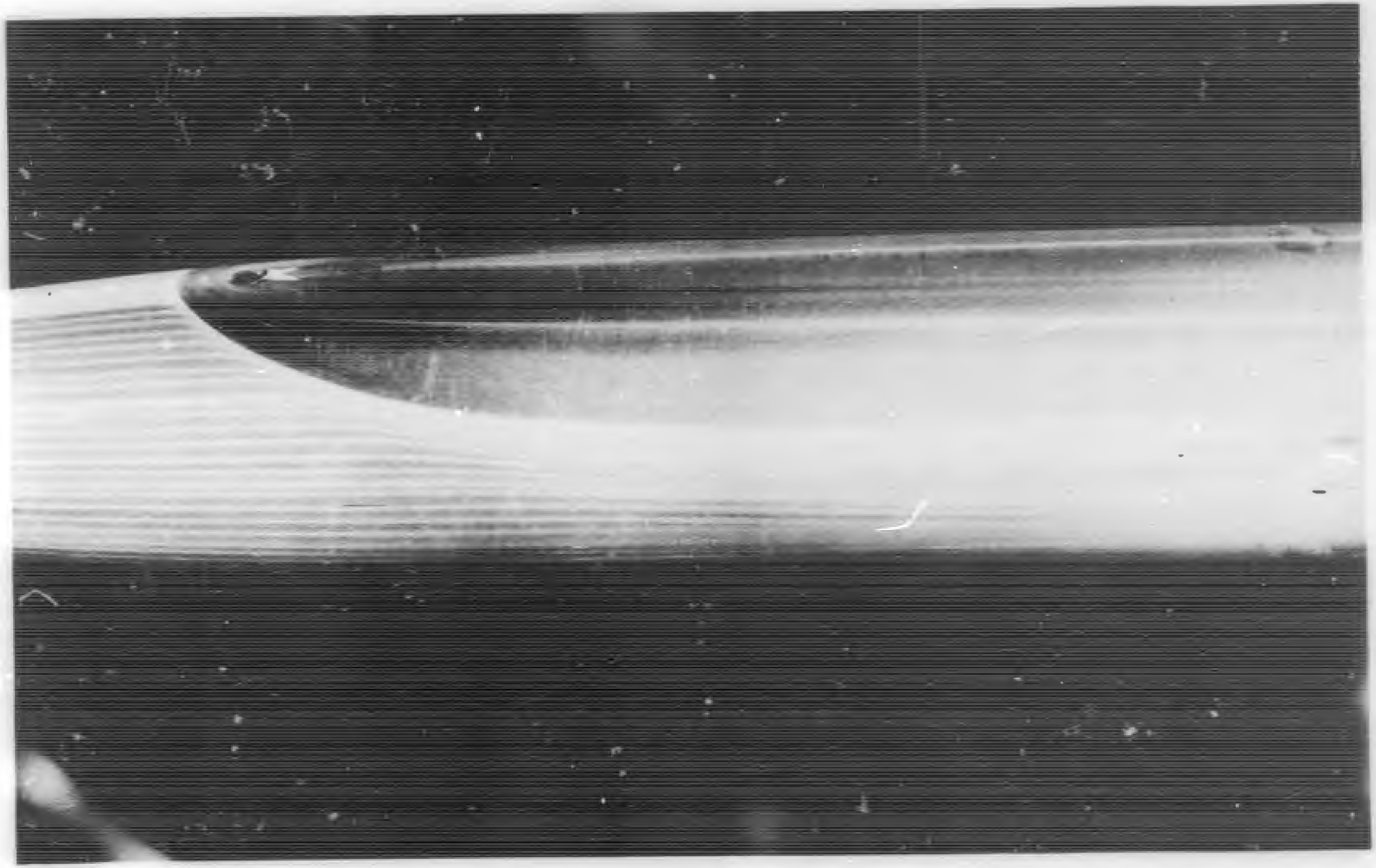

FIGURE E-4d. REACTION JET FOR $B_1C_1X_1$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_{\infty} = 40$

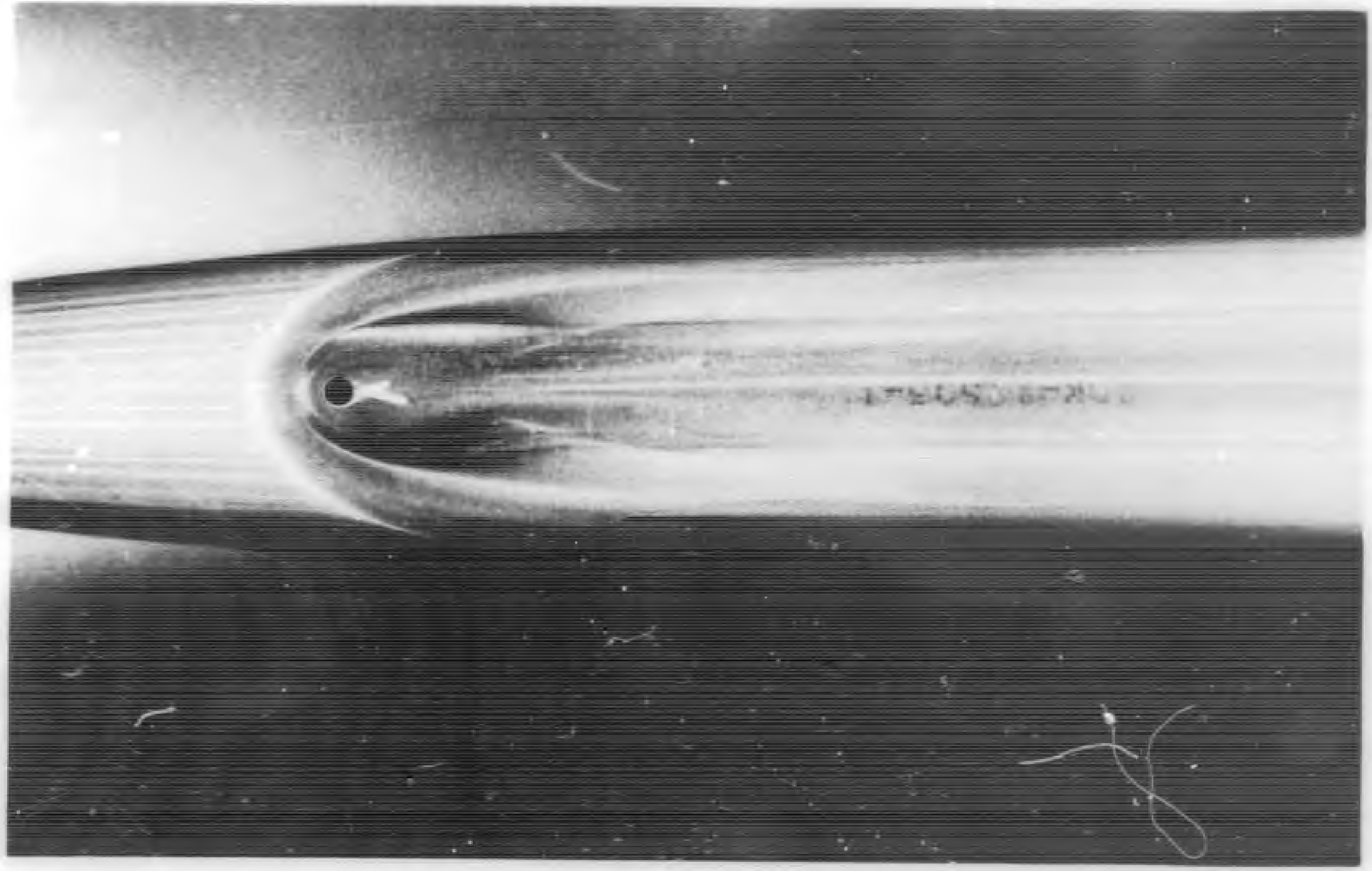

FIGURE E-4e. REACTION JET FOR $B_1C_1X_1$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 100$

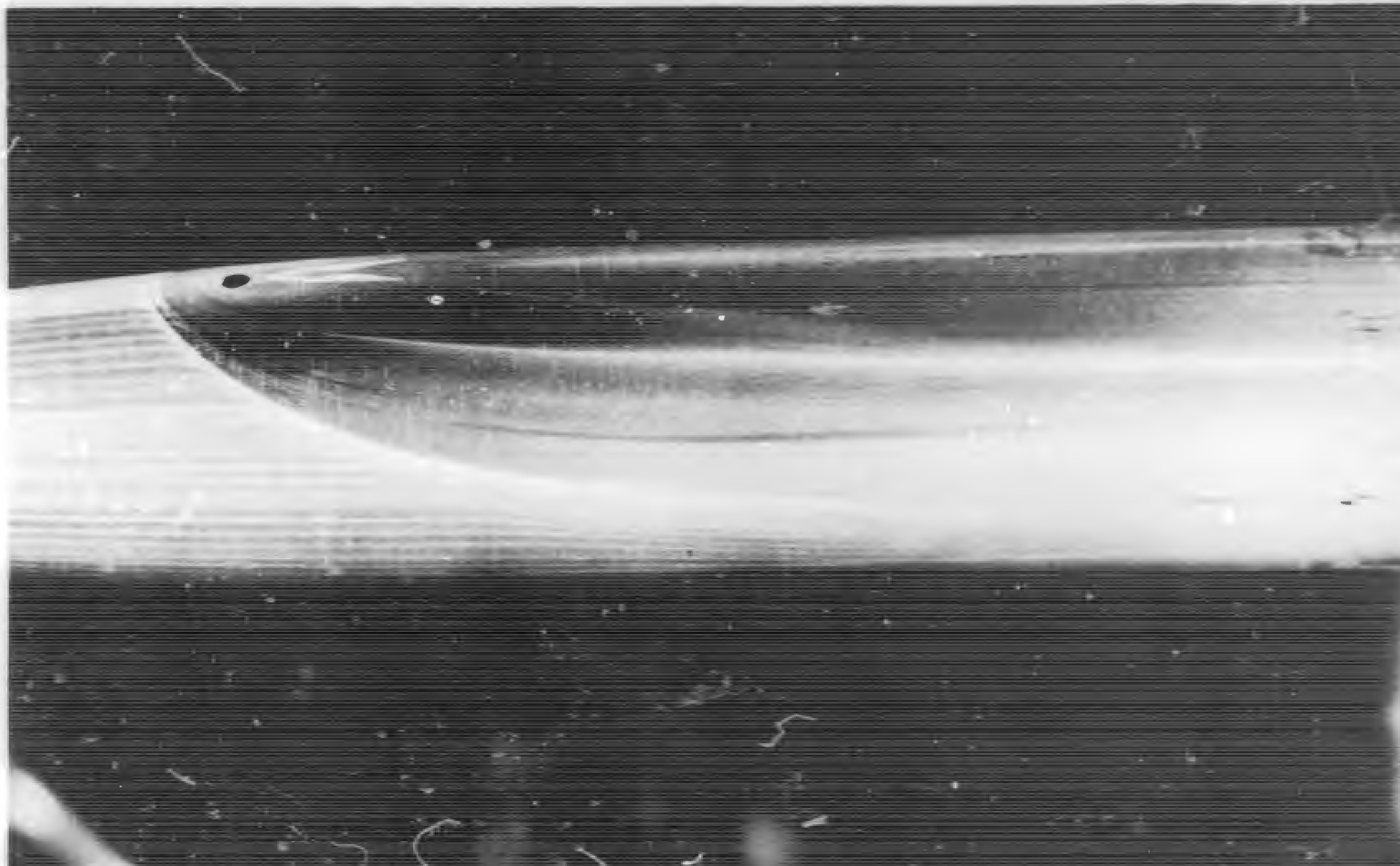

FIGURE E-4f. REACTION JET FOR $B_1C_1X_1$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 100$

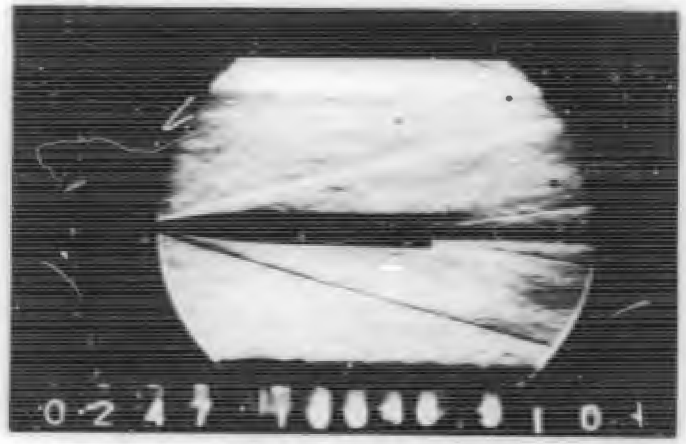

FIGURE E-4g. REACTION JET FOR $B_1C_1X_1$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 0$

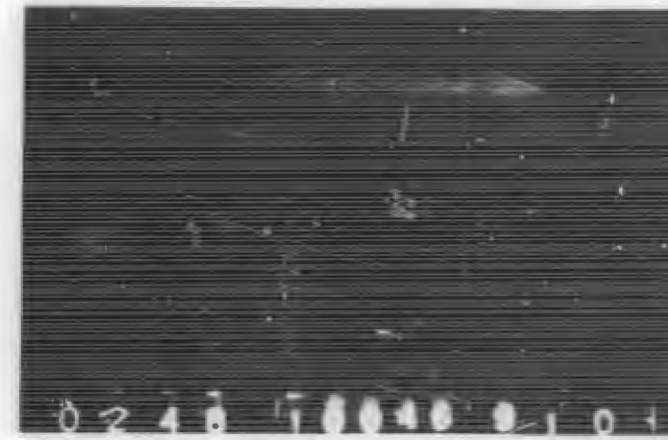

FIGURE E-4h. REACTION JET FOR $B_1C_1X_1$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 40$

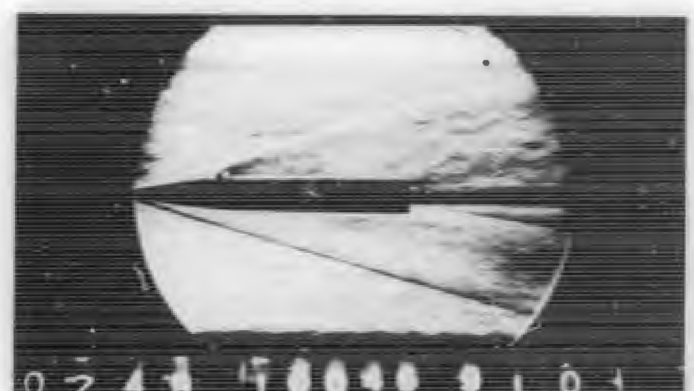

FIGURE E-4i. REACTION JET FOR $B_1C_1X_1$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 100$

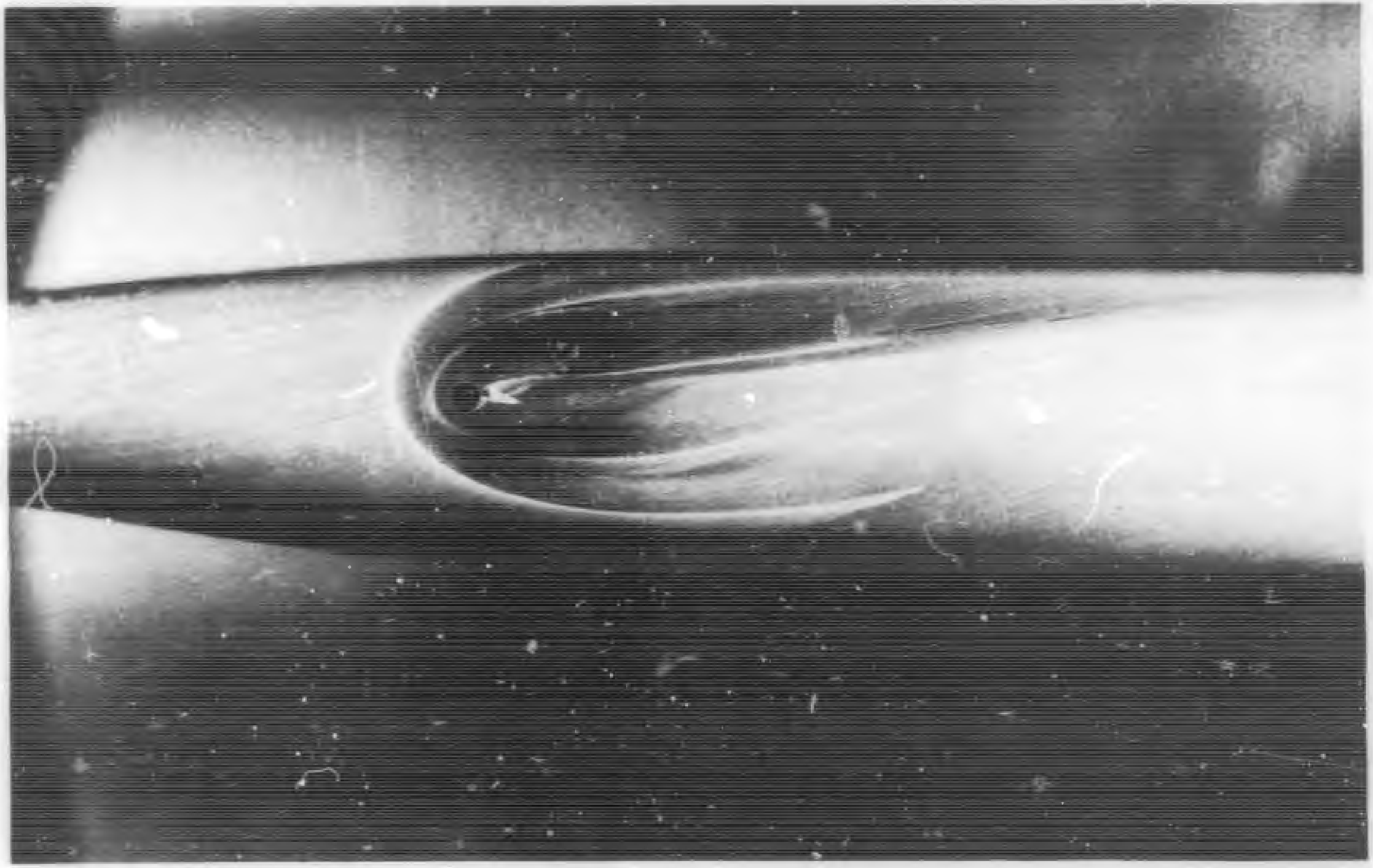

FIGURE E-5a. REACTION JET FOR $B_1C_1X_1$ WITH α = 5 DEGREES; P_{oj}/P_∞ = 40

FIGURE E-5b. REACTION JET FOR $B_1C_1X_1$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_\infty = 100$

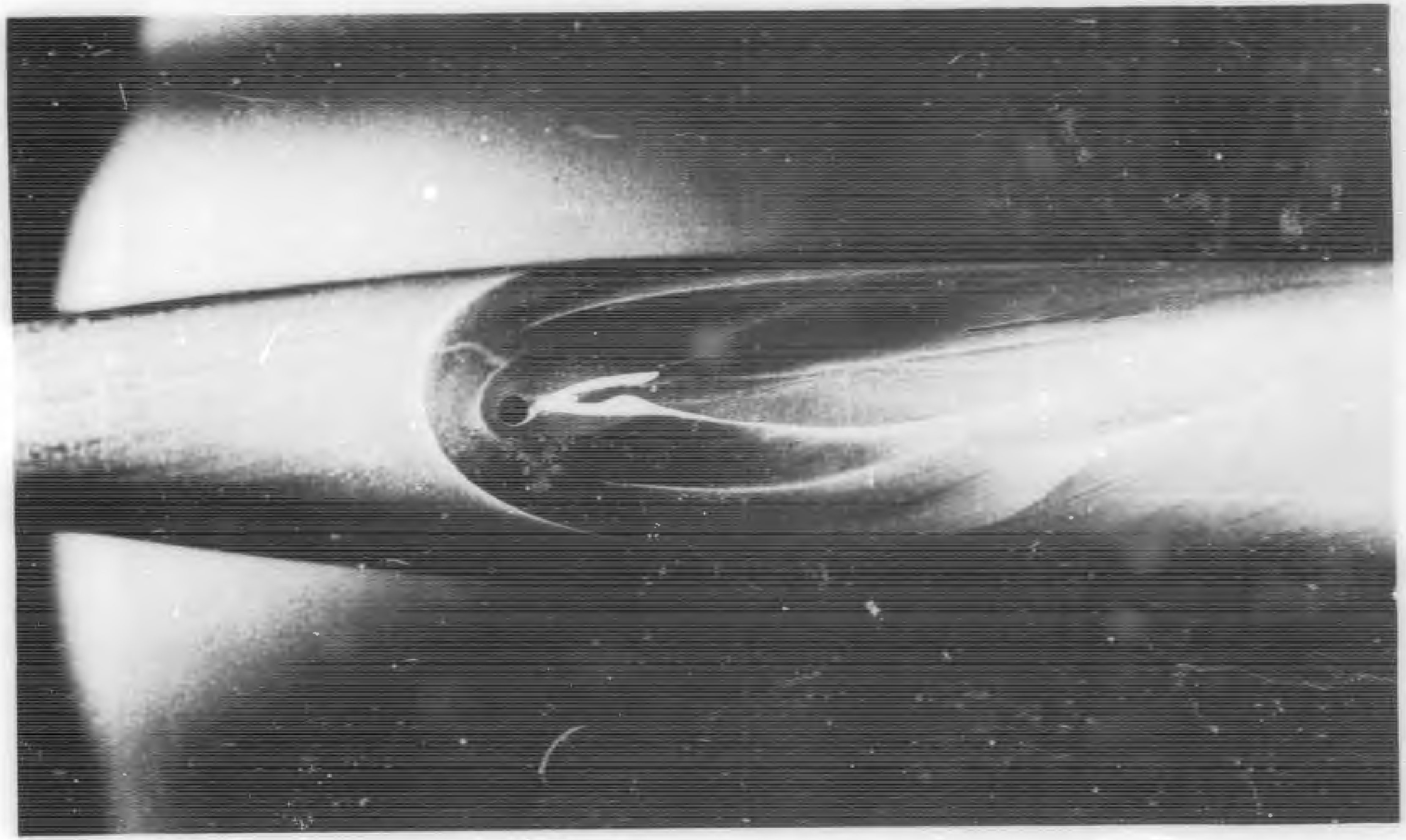

FIGURE E-5c. REACTION JET FOR $B_1C_1X_1$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_\infty = 40$

FIGURE E-5d. REACTION JET FOR $B_1C_1X_1$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_\infty = 100$

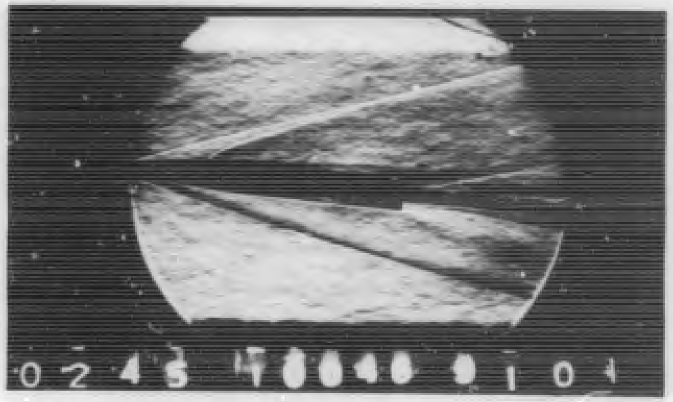

FIGURE E-5e. REACTION JET FOR $B_1C_1X_1$ WITH α = 5 DEGREES; P_{oj}/P_∞ = 40

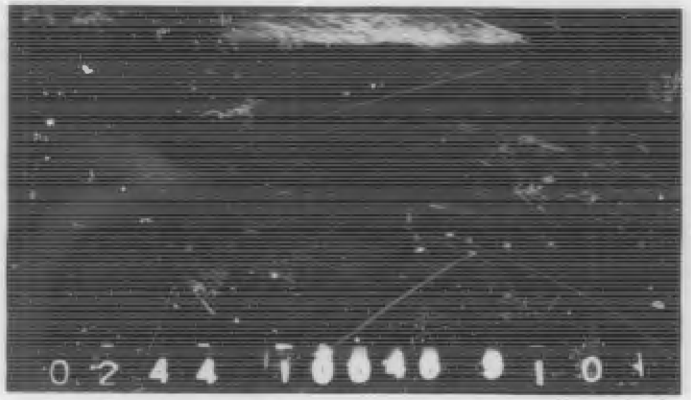

FIGURE E-5f. REACTION JET FOR $B_1C_1X_1$ WITH α = 5 DEGREES; P_{oj}/P_∞ = 100

FIGURE E-6a. REACTION JET FOR $B_1C_1X_1$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_{\infty} = 40$

FIGURE E-6b. REACTION JET FOR $B_1C_1X_1$ WITH α = 10 DEGREES; P_{oj}/P_∞ = 100

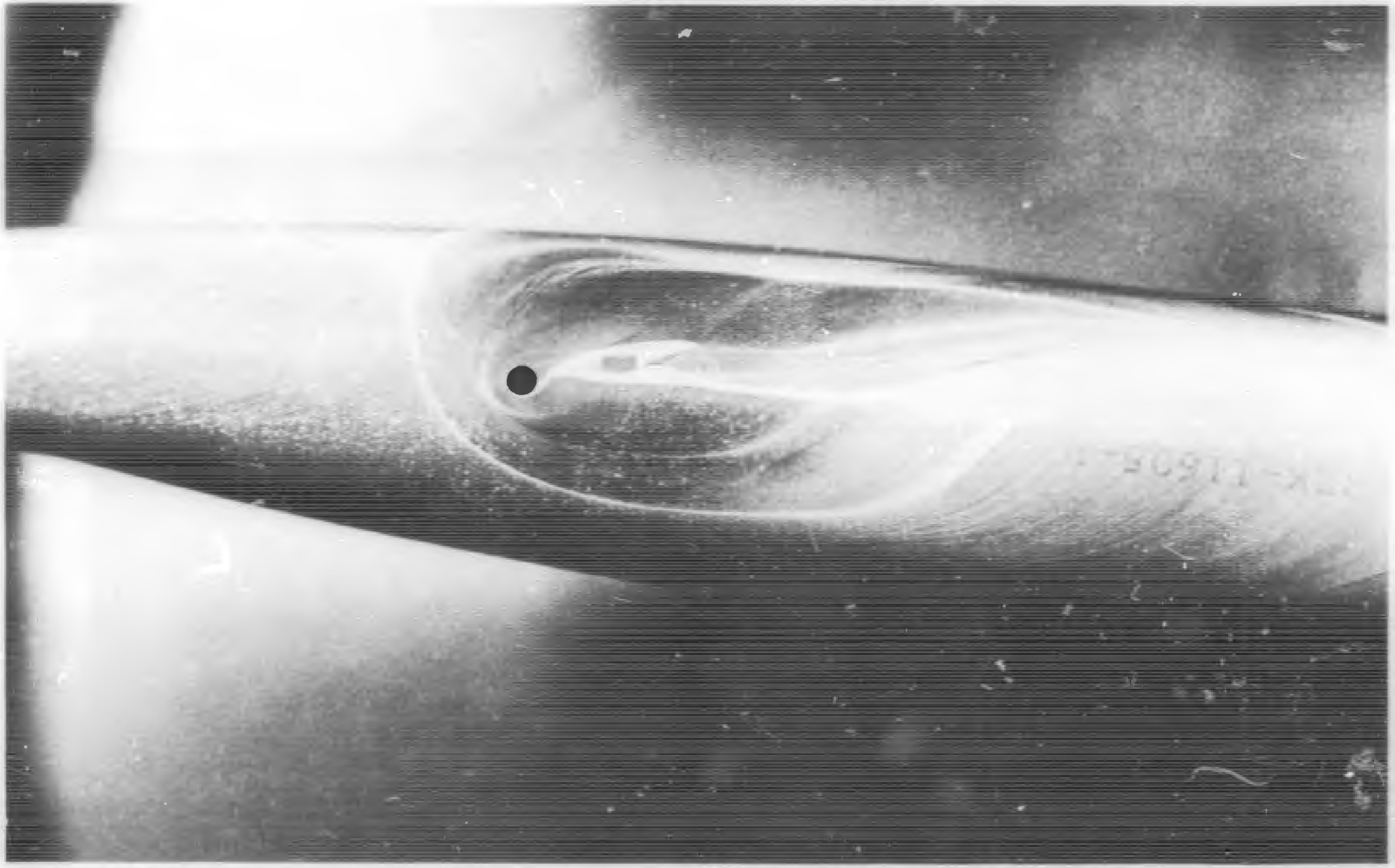

FIGURE E-6c. REACTION JET FOR $B_1C_1X_1$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_{\infty} = 40$

FIGURE E-6d. REACTION JET FOR $B_1C_1X_1$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_{\infty} = 100$

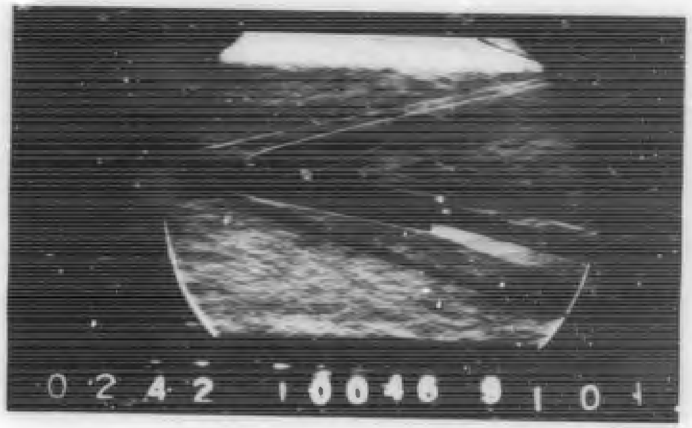

FIGURE E-6e. REACTION JET FOR $B_1C_1X_1$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_\infty = 40$

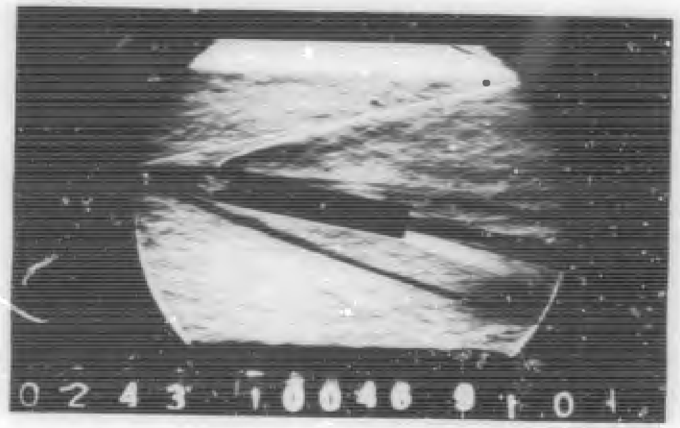

FIGURE E-6f. REACTION JET FOR $B_1C_1X_1$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_\infty = 100$

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FIGURE E-7a. REACTION JET FOR $B_1C_1X_1$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_\infty = 40$

FIGURE E-7b. REACTION JET FOR $B_1C_1X_1$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_\infty = 100$

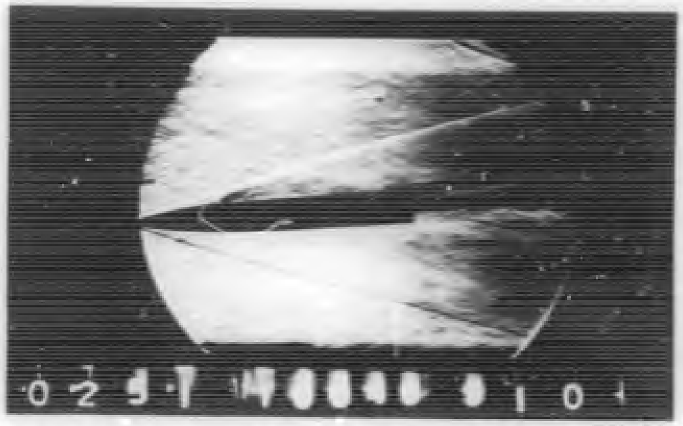

FIGURE E-7c. REACTION JET FOR $B_1C_1X_1$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_\infty = 40$

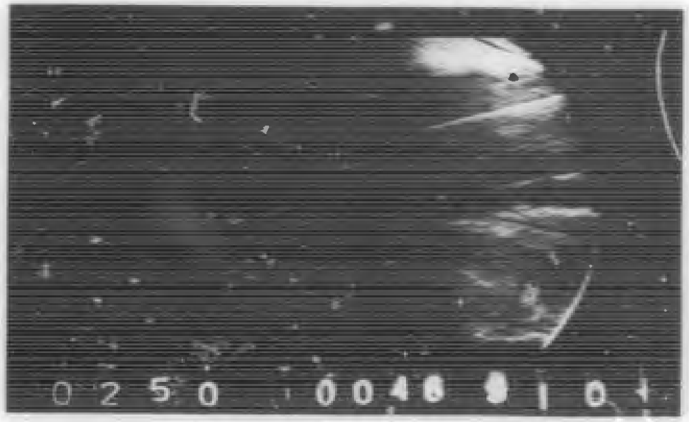

FIGURE E-7d. REACTION JET FOR $B_1C_1X_1$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_\infty = 100$

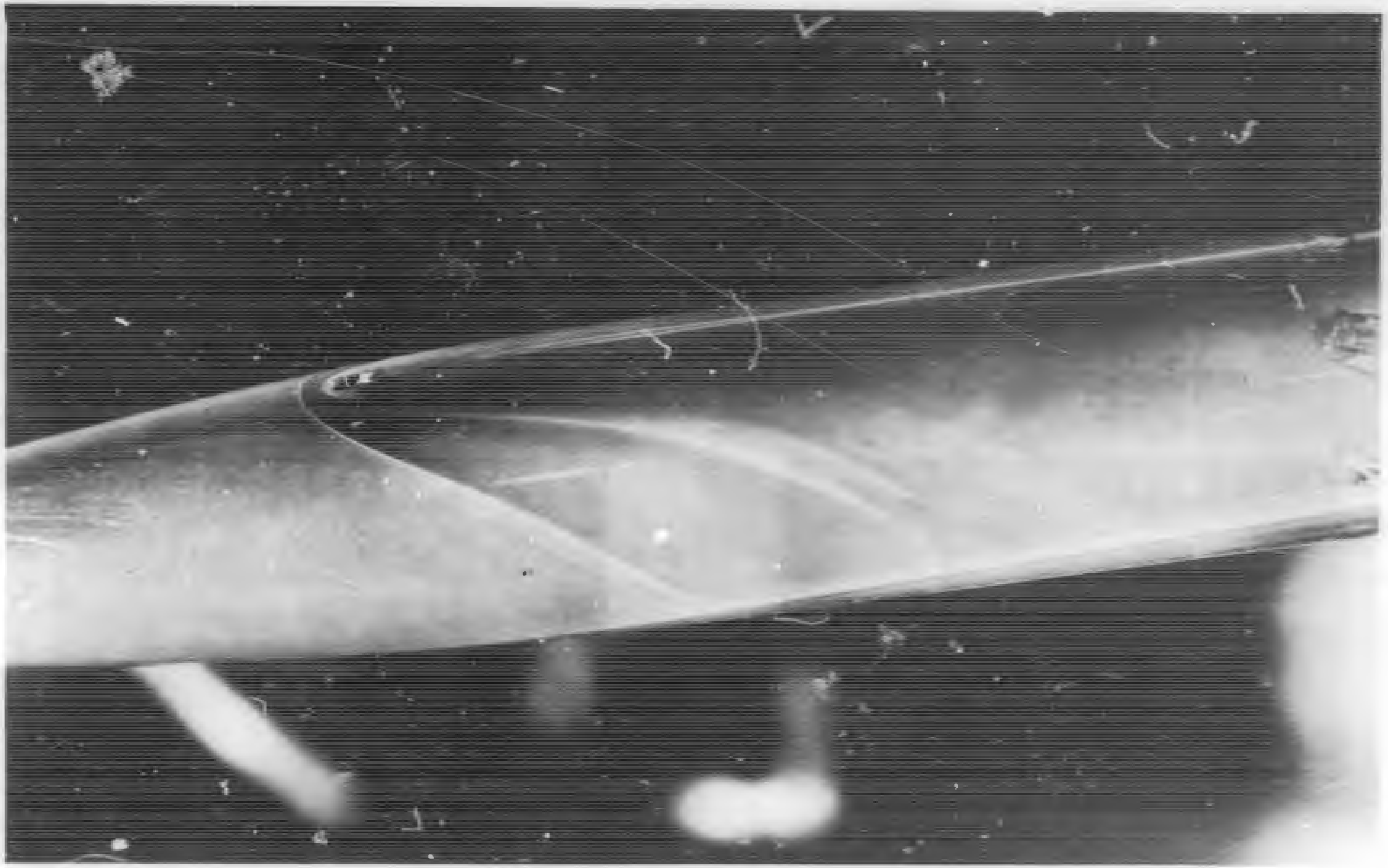

FIGURE E-8a. REACTION JET FOR $B_1C_1X_1$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_{\infty} = 40$

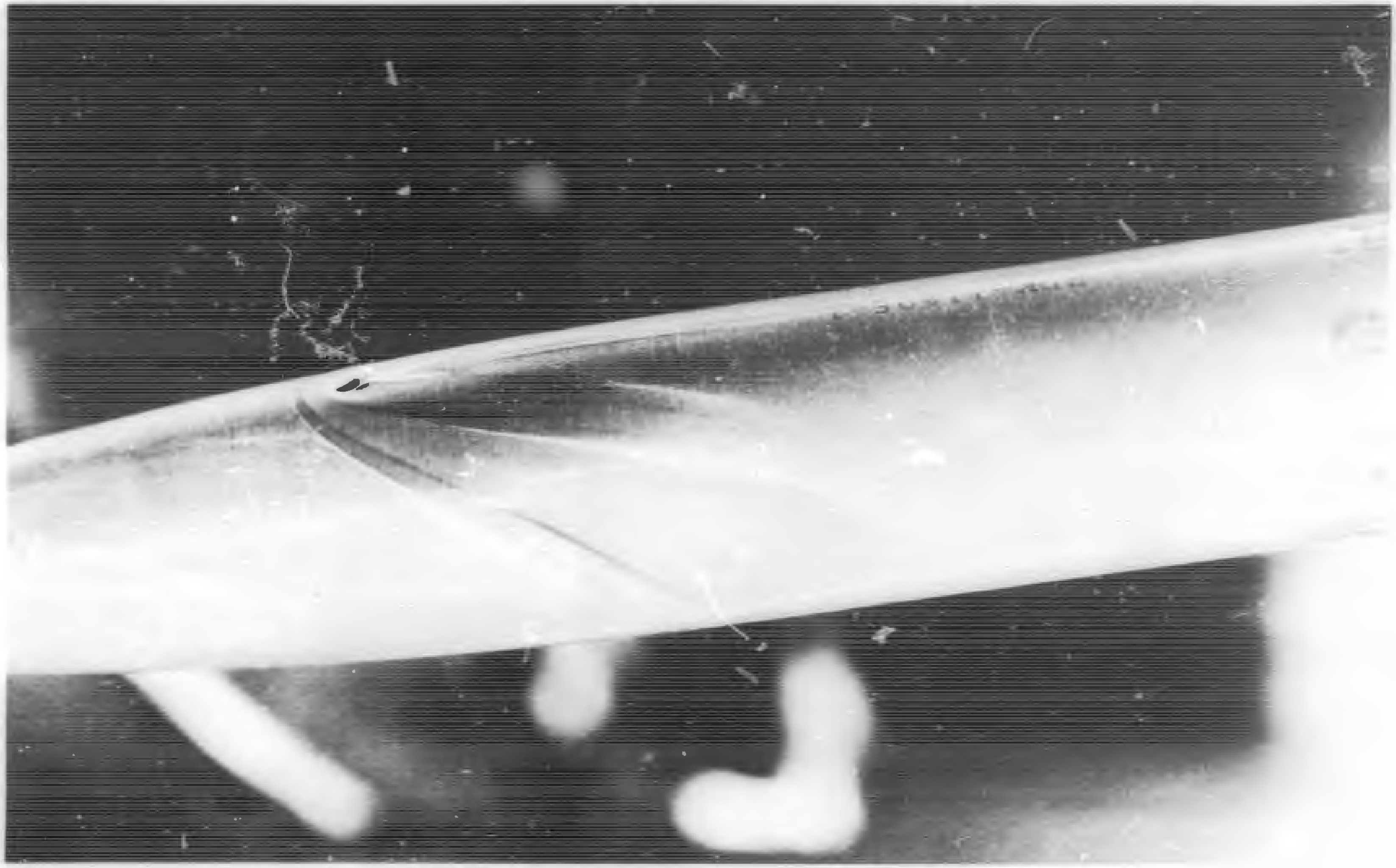

FIGURE E-8b. REACTION JET FOR $B_1C_1X_1$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_\infty = 100$

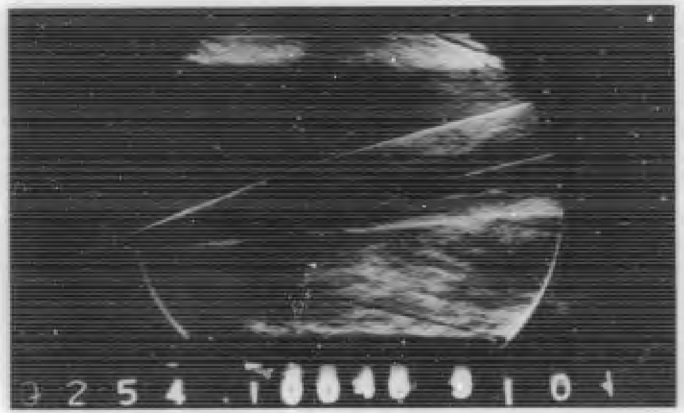

FIGURE E-8c. REACTION JET FOR $B_1C_1X_1$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_{\infty} = 40$

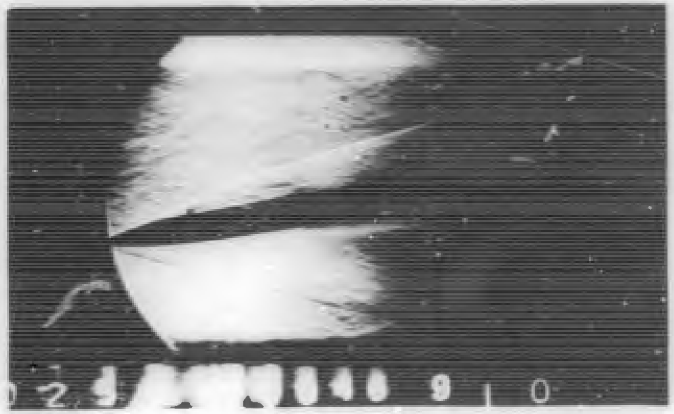

FIGURE E-8d. REACTION JET FOR $B_1C_1X_1$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_{\infty} = 100$

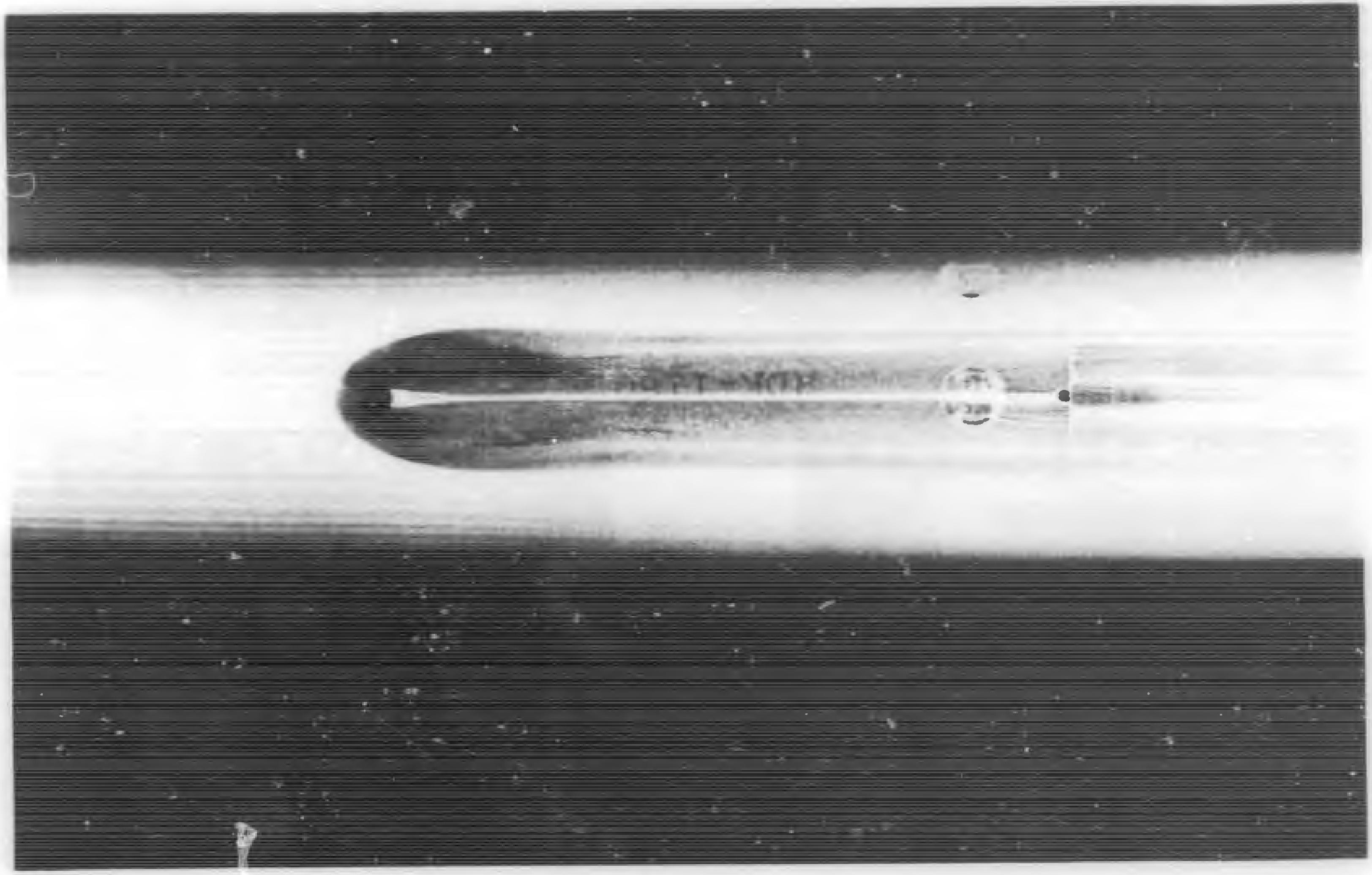

FIGURE E-9a. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 0$

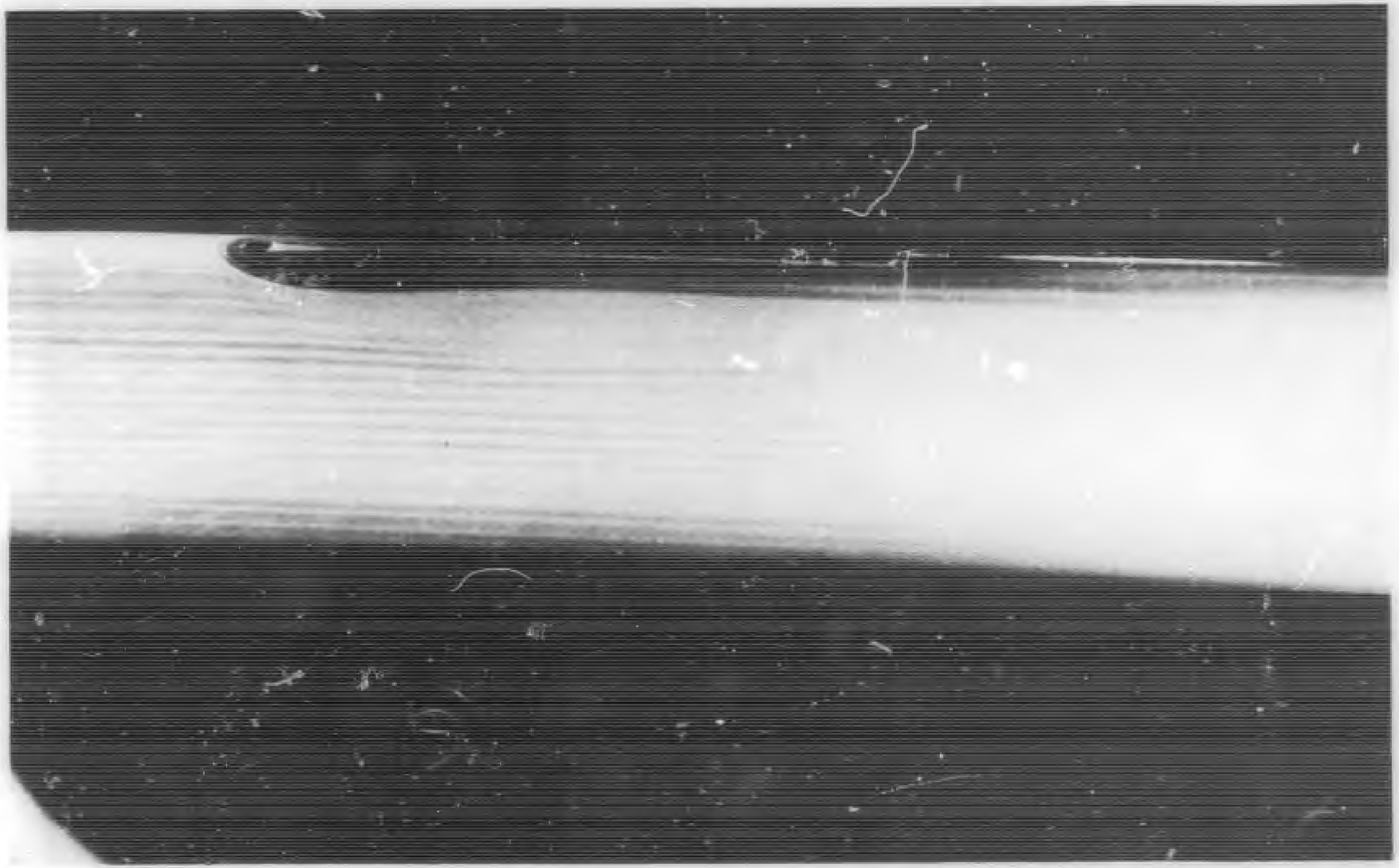

FIGURE E-9b. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 0$

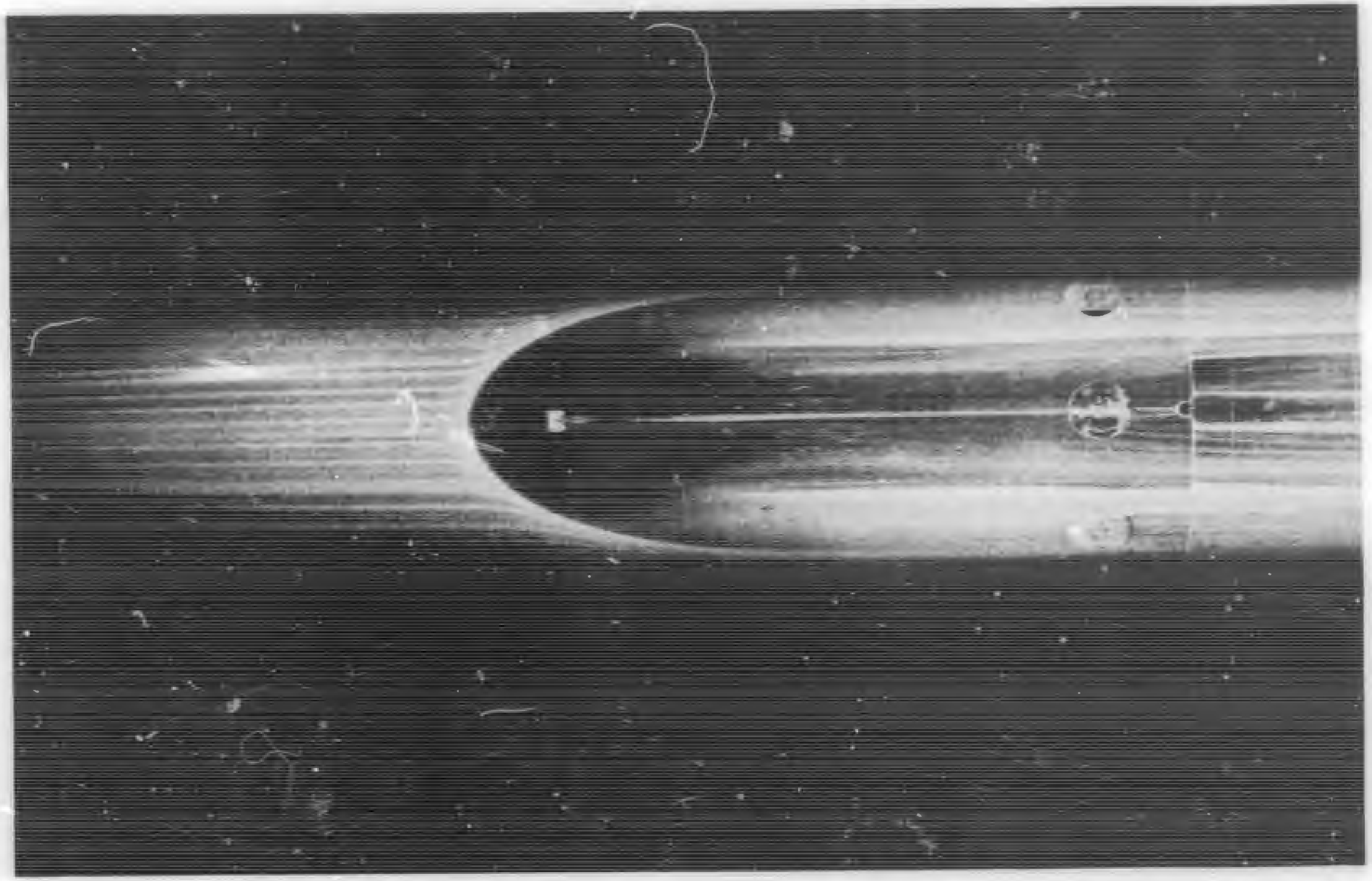

FIGURE E-9c. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_{\infty} = 10$

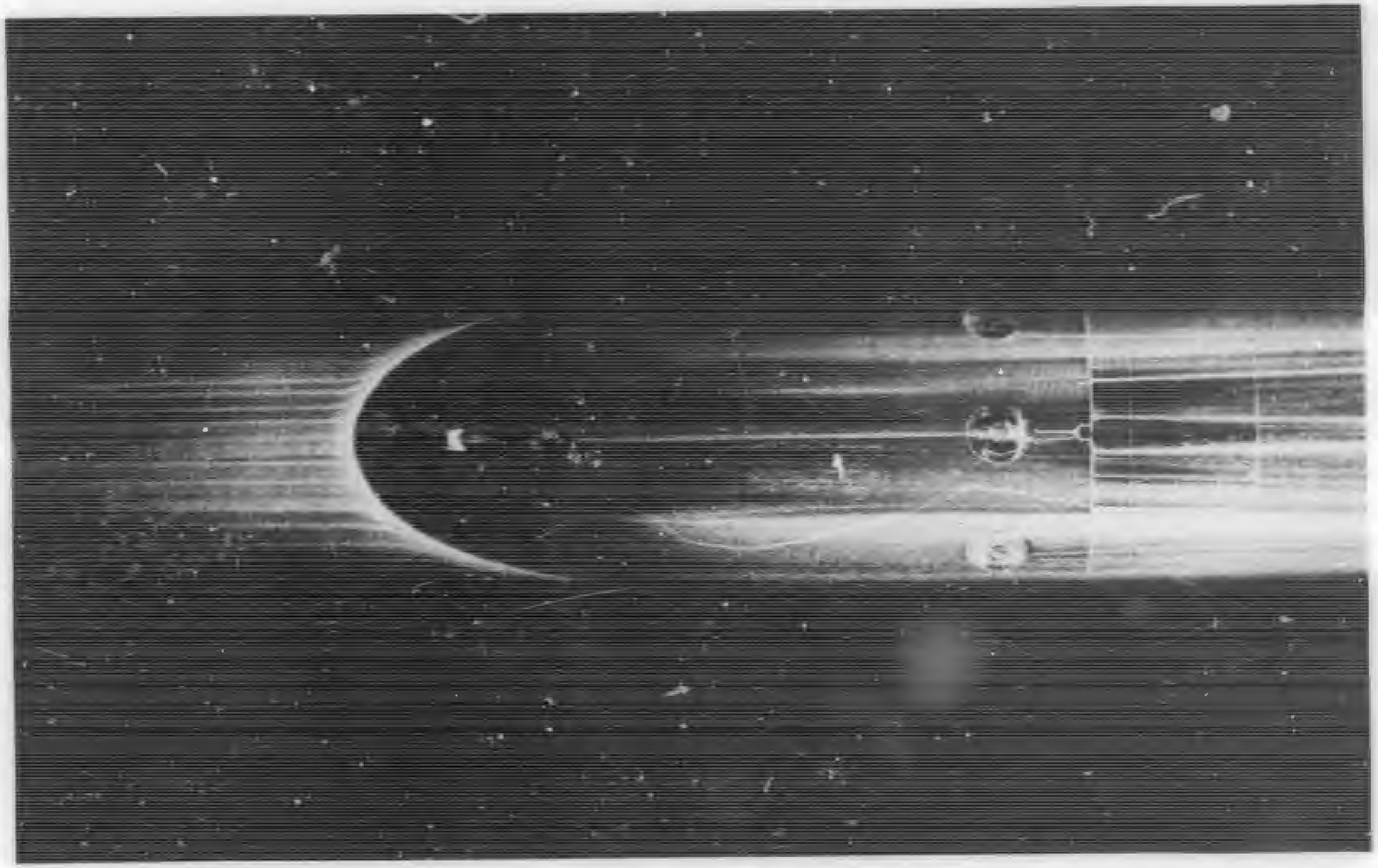

FIGURE E-9d. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 20$

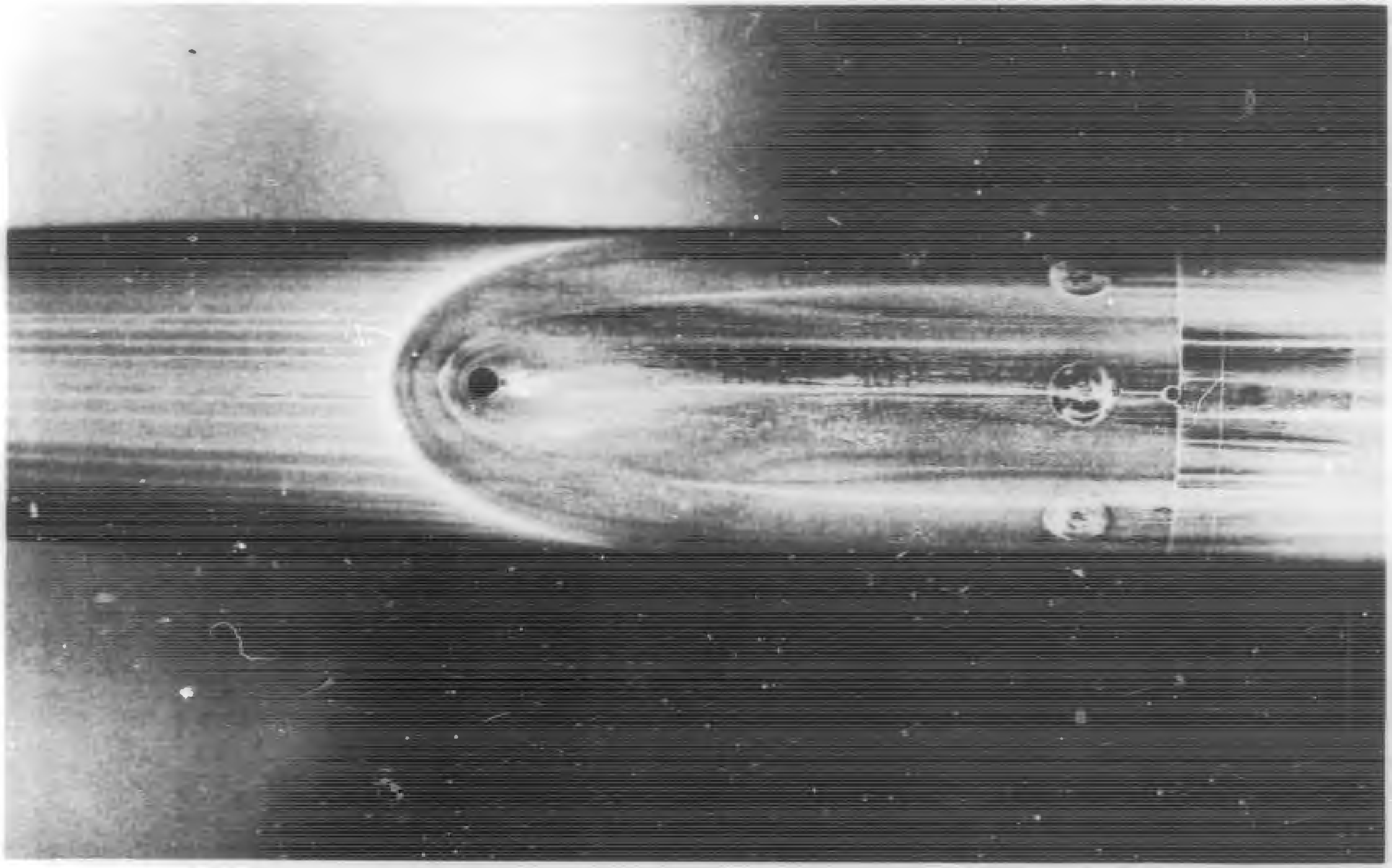

FIGURE E-9e. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 40$

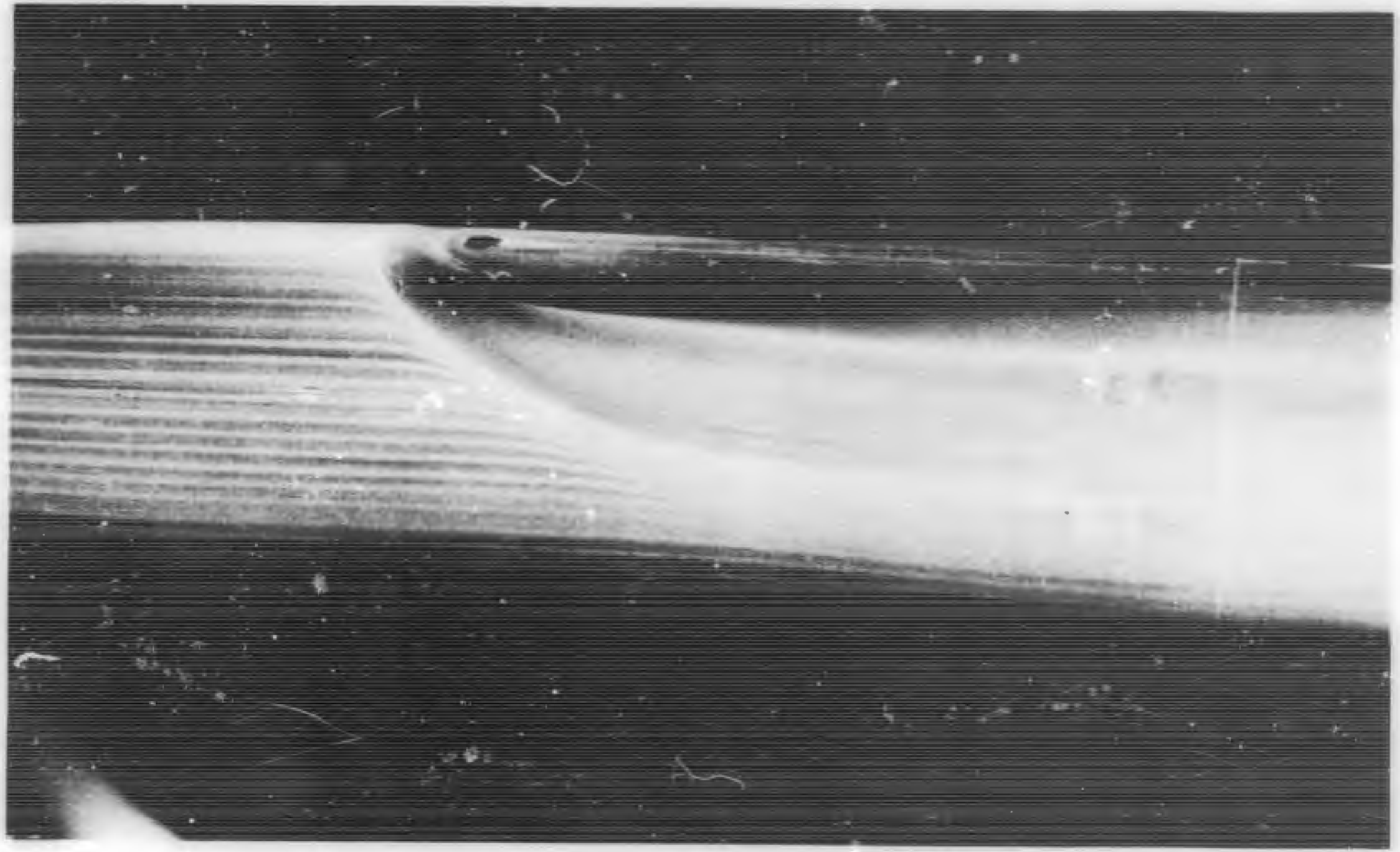

FIGURE E-9f. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 40$

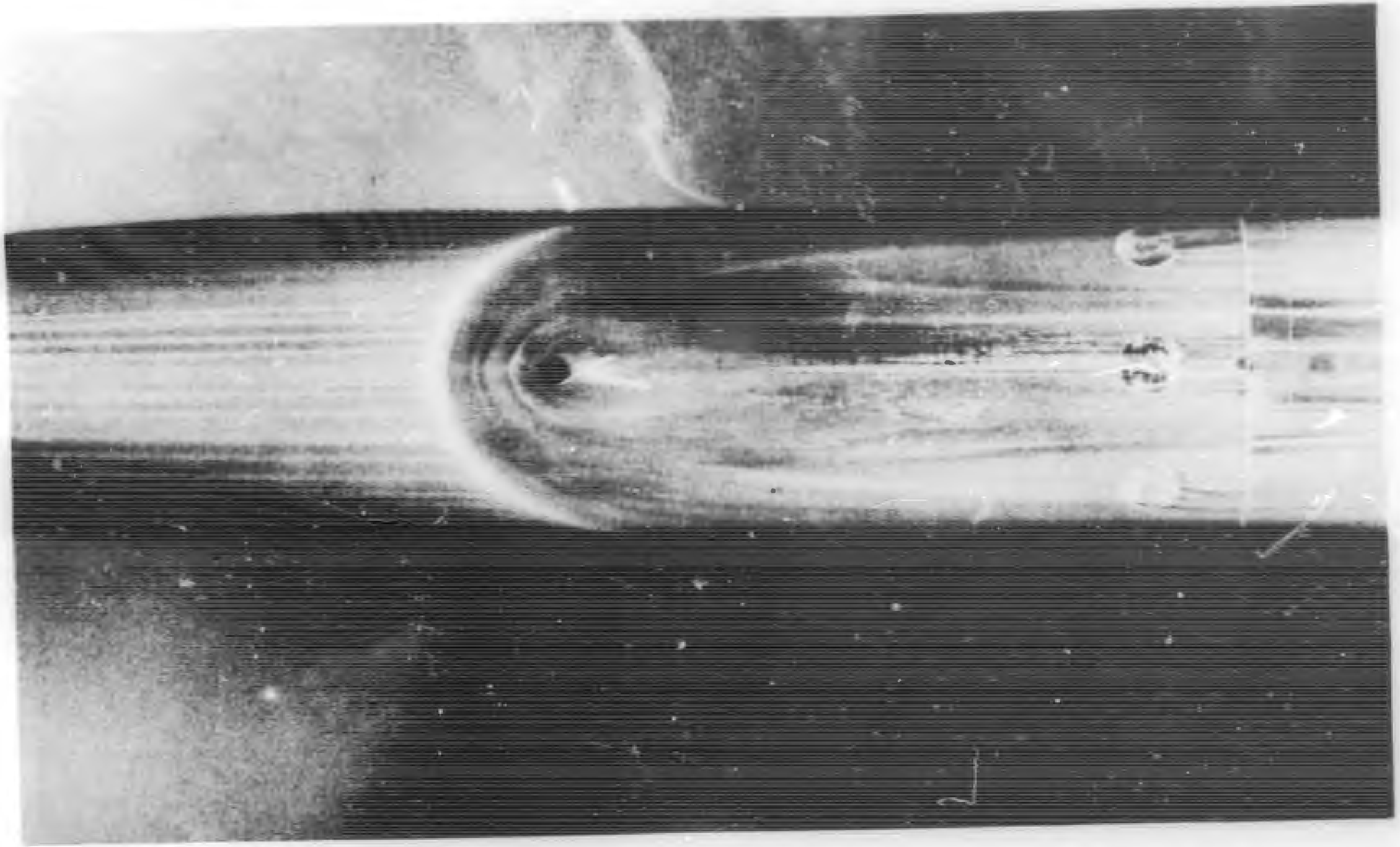

FIGURE E-9g. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_{\infty} = 100$

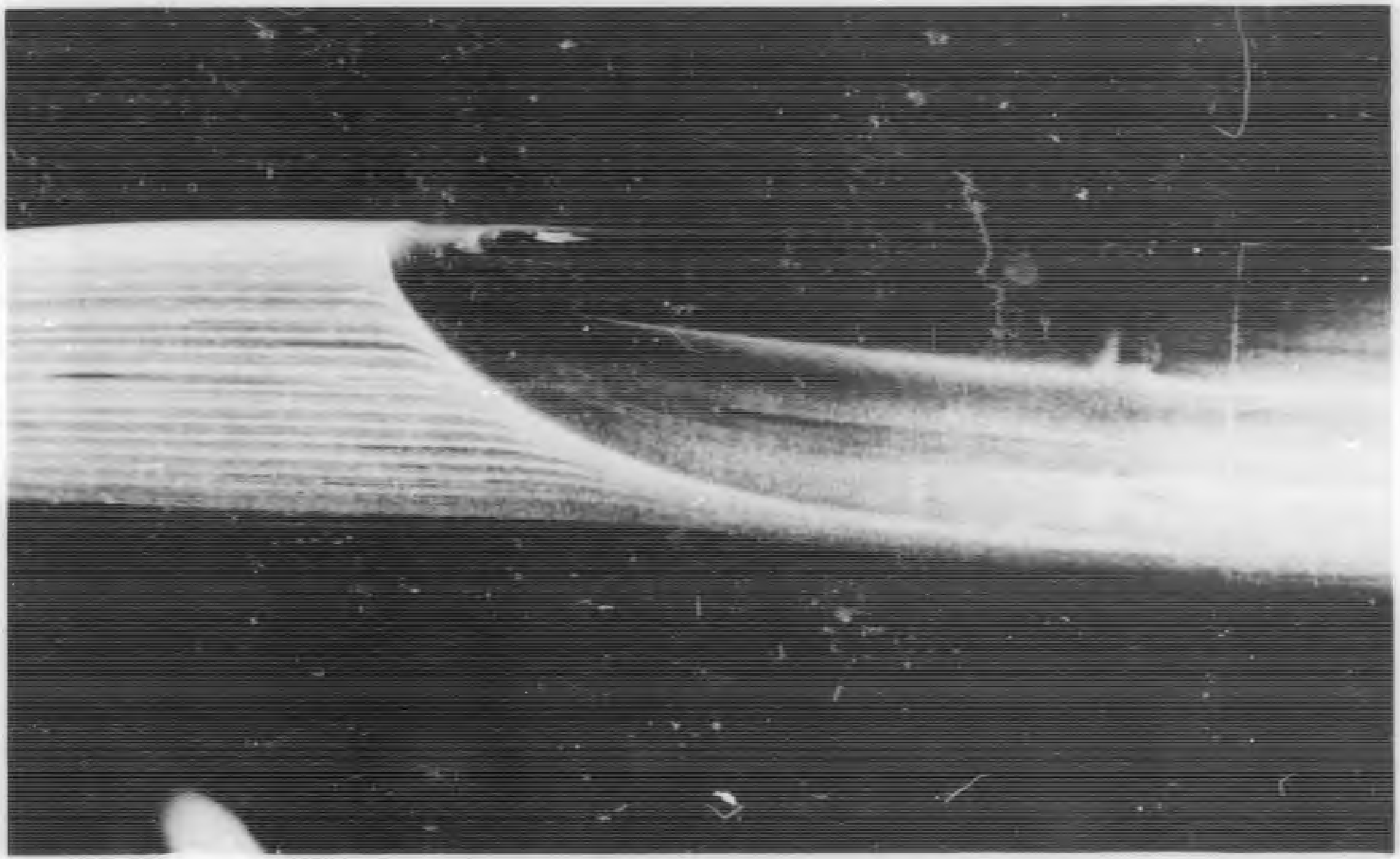

FIGURE E-9h. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 100$

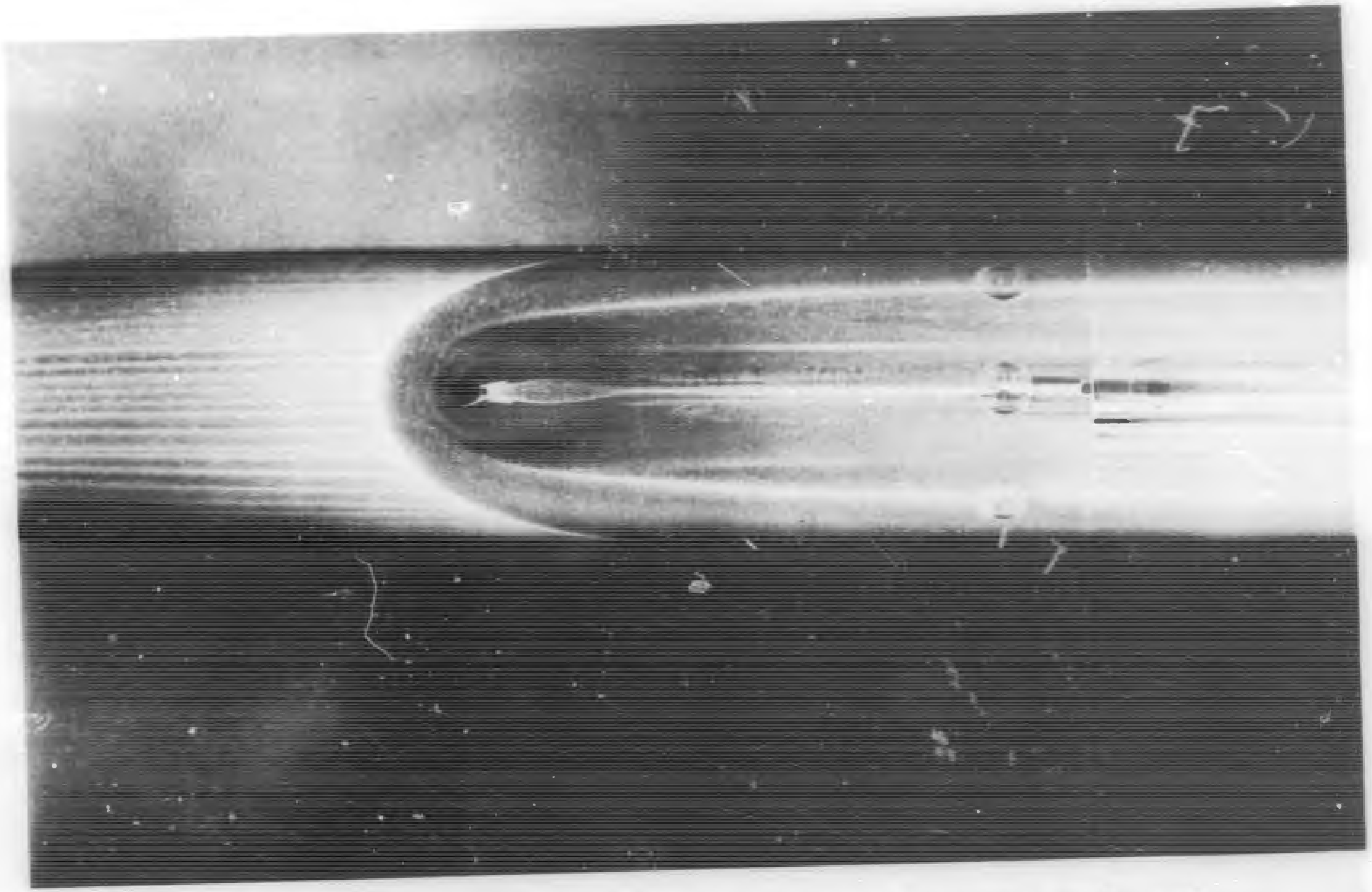

FIGURE E-9i. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 40$

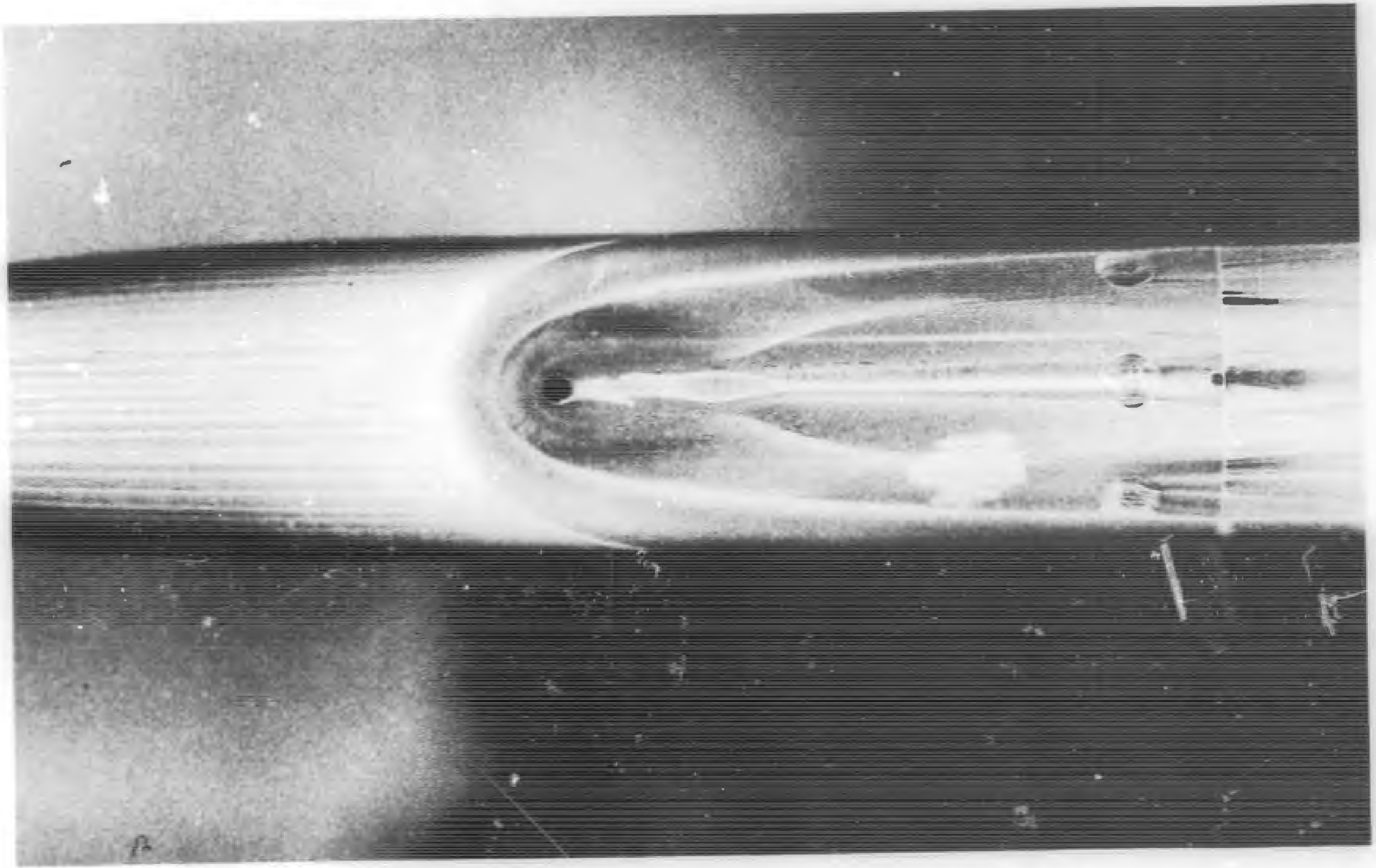

FIGURE E-9j. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_{\infty} = 100$

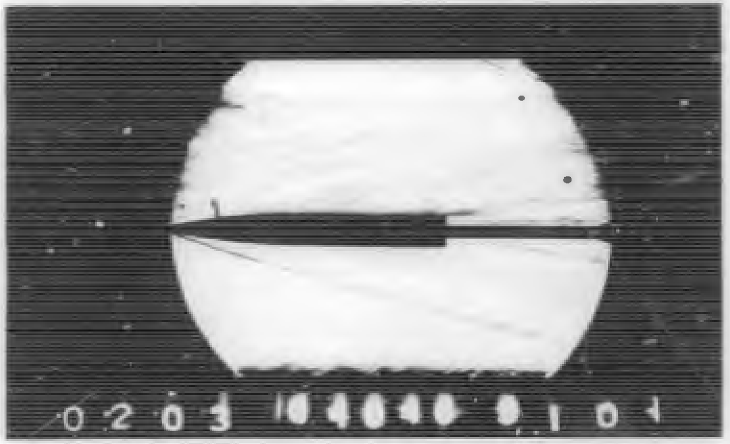

FIGURE E-9k. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 0$

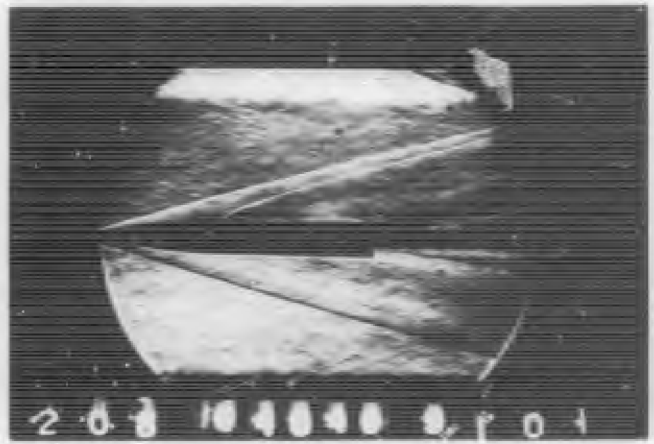

FIGURE E-9l. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 40$

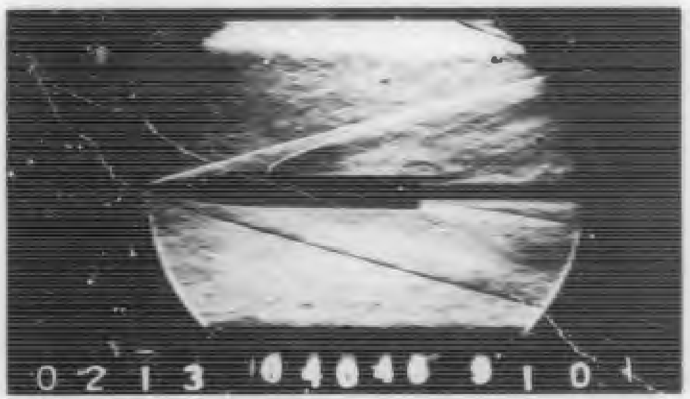

FIGURE E-9m. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 100$

FIGURE E-10a.   REACTION JET FOR $B_1C_1X_2$ WITH α = 5 DEGREES; P_{oj}/P_{∞} = 40

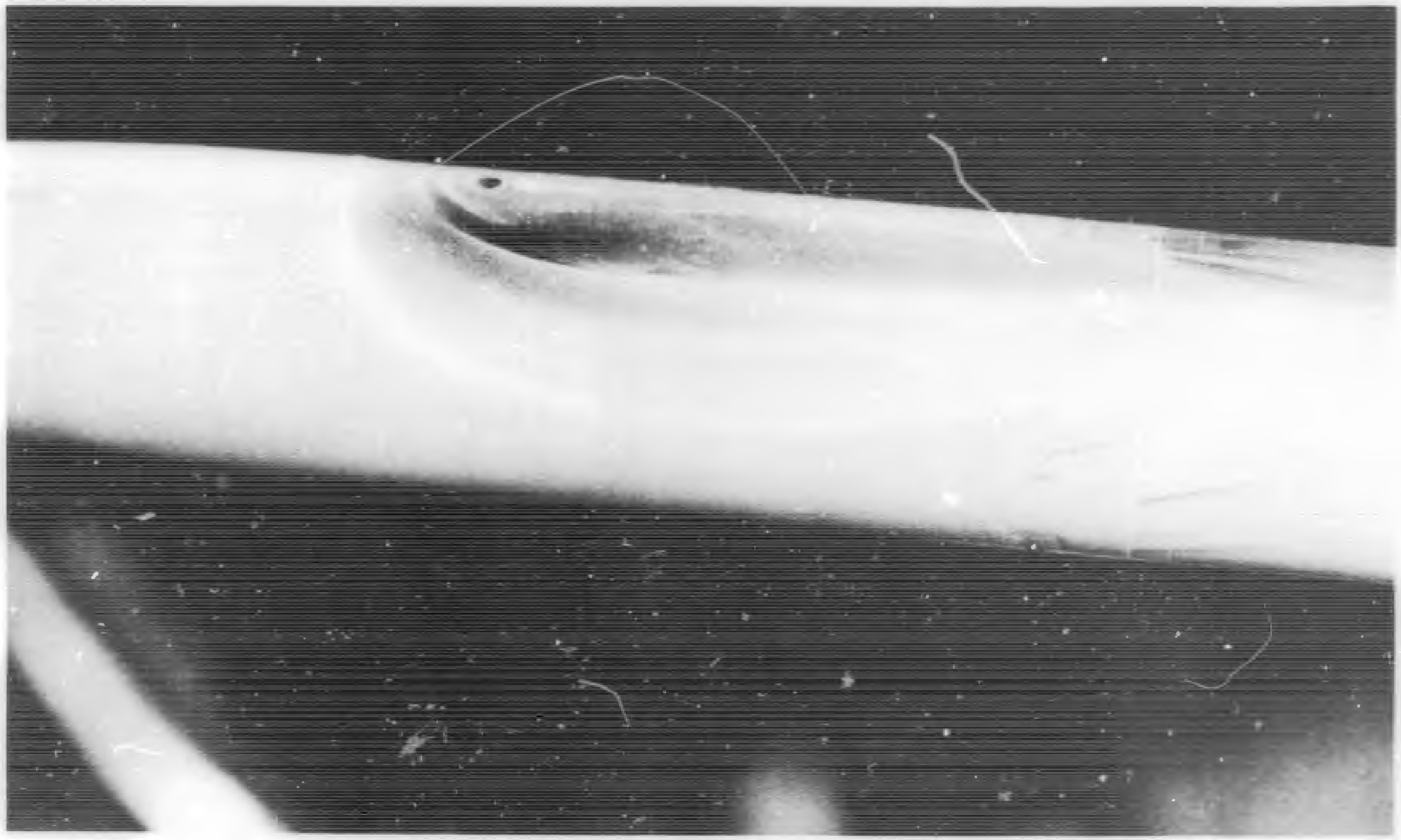

FIGURE E-10b. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_\infty = 100$

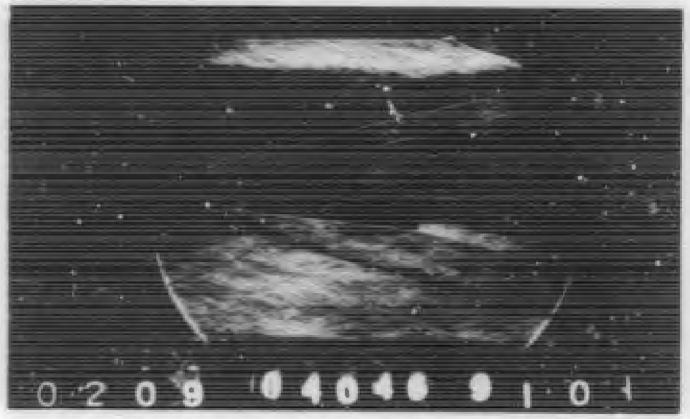

FIGURE E-10c. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_{\infty} = 40$

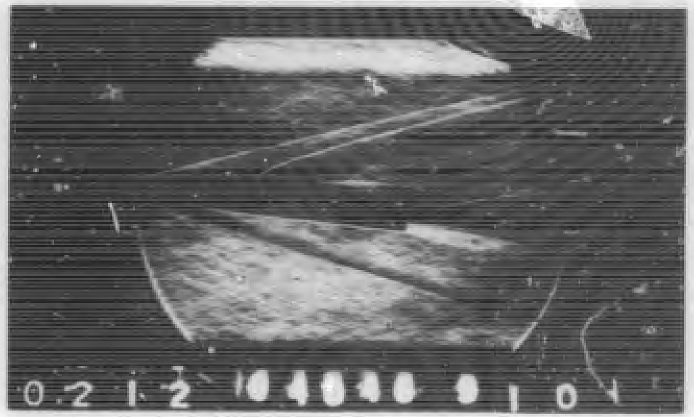

FIGURE E-10d. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_{\infty} = 100$

FIGURE E-11a. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_\infty = 40$

FIGURE E-11b. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_\infty = 100$

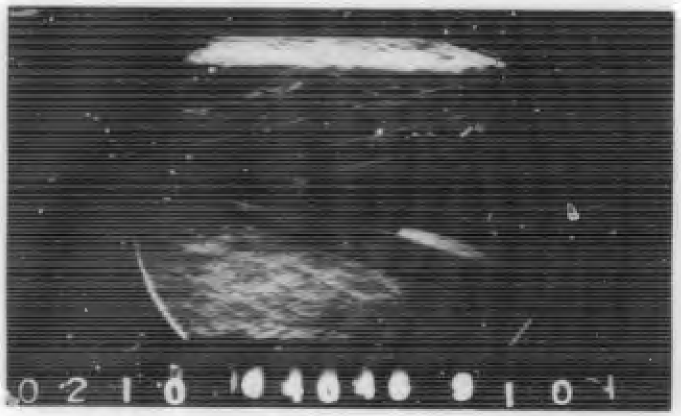

FIGURE E-11c. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_{\infty} = 40$

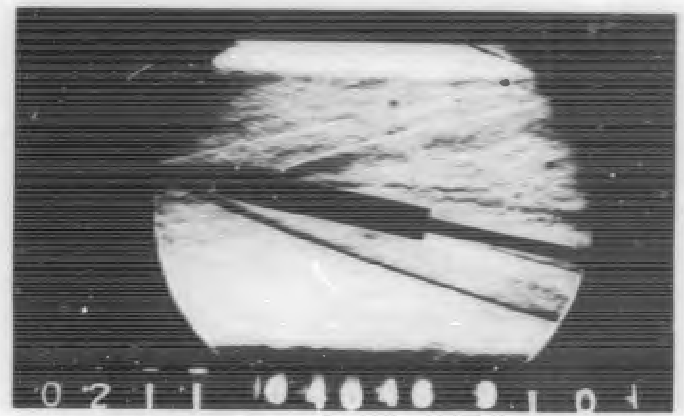

FIGURE E-11d. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_{\infty} = 100$

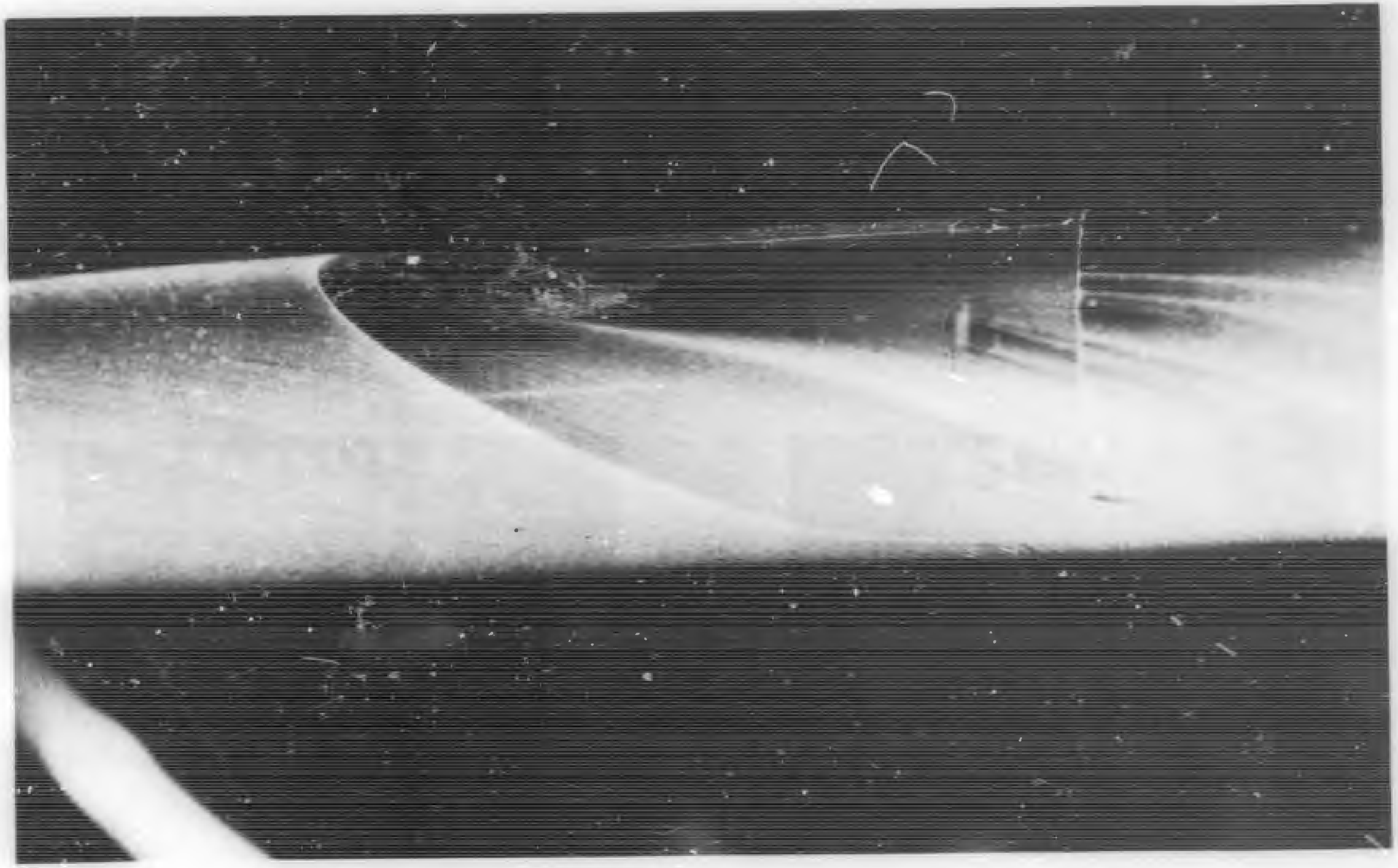

FIGURE E-12a. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = -5$ DEGREES: $P_{oj}/P_{\infty} = 40$

FIGURE E-12b. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_\infty = 100$

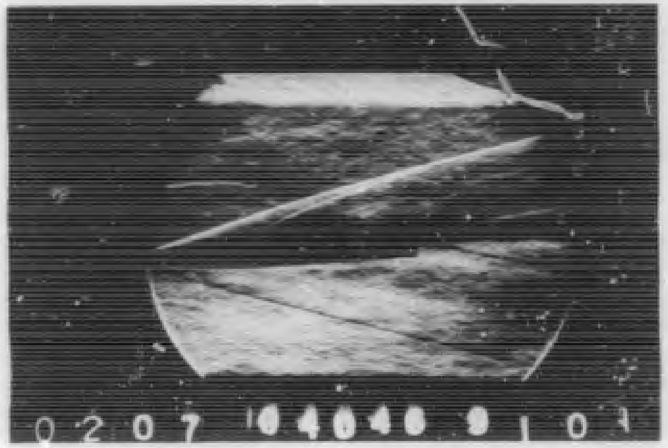

FIGURE E-12c. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_\infty = 40$

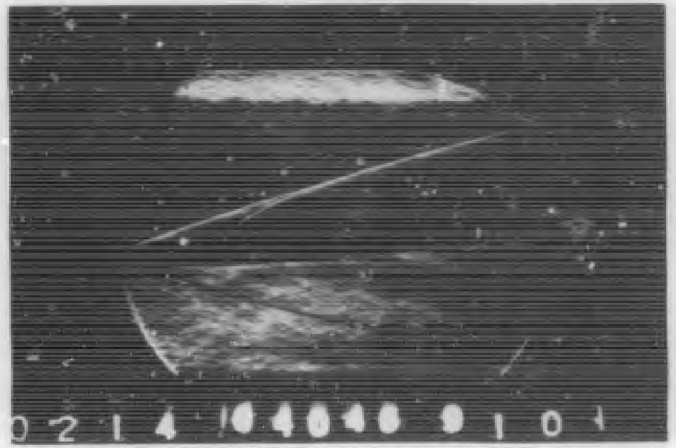

FIGURE E-12d. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = -5$ DEGREES; $P_{oj}/P_\infty = 100$

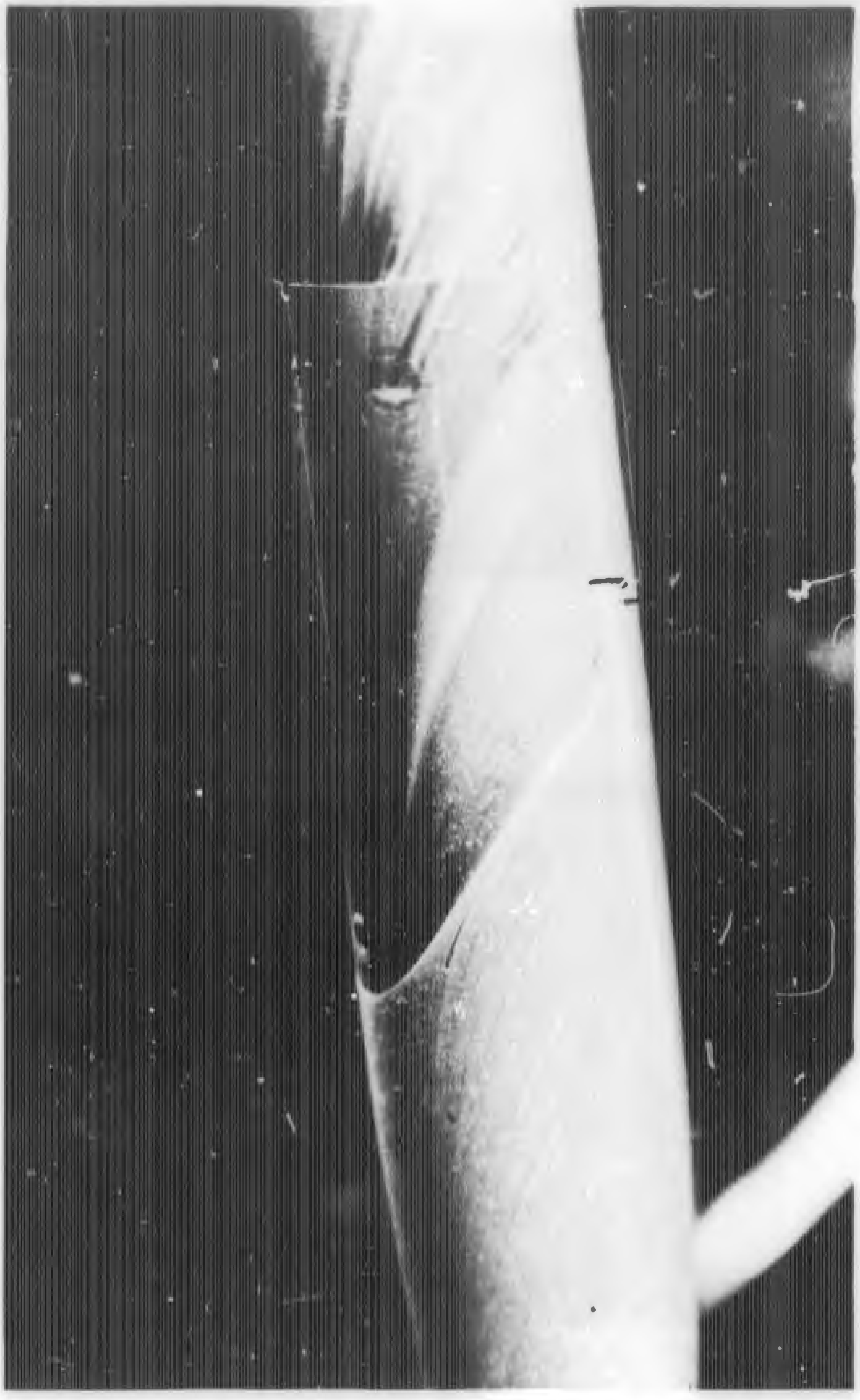

FIGURE E-13a. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_{\infty} = 40$

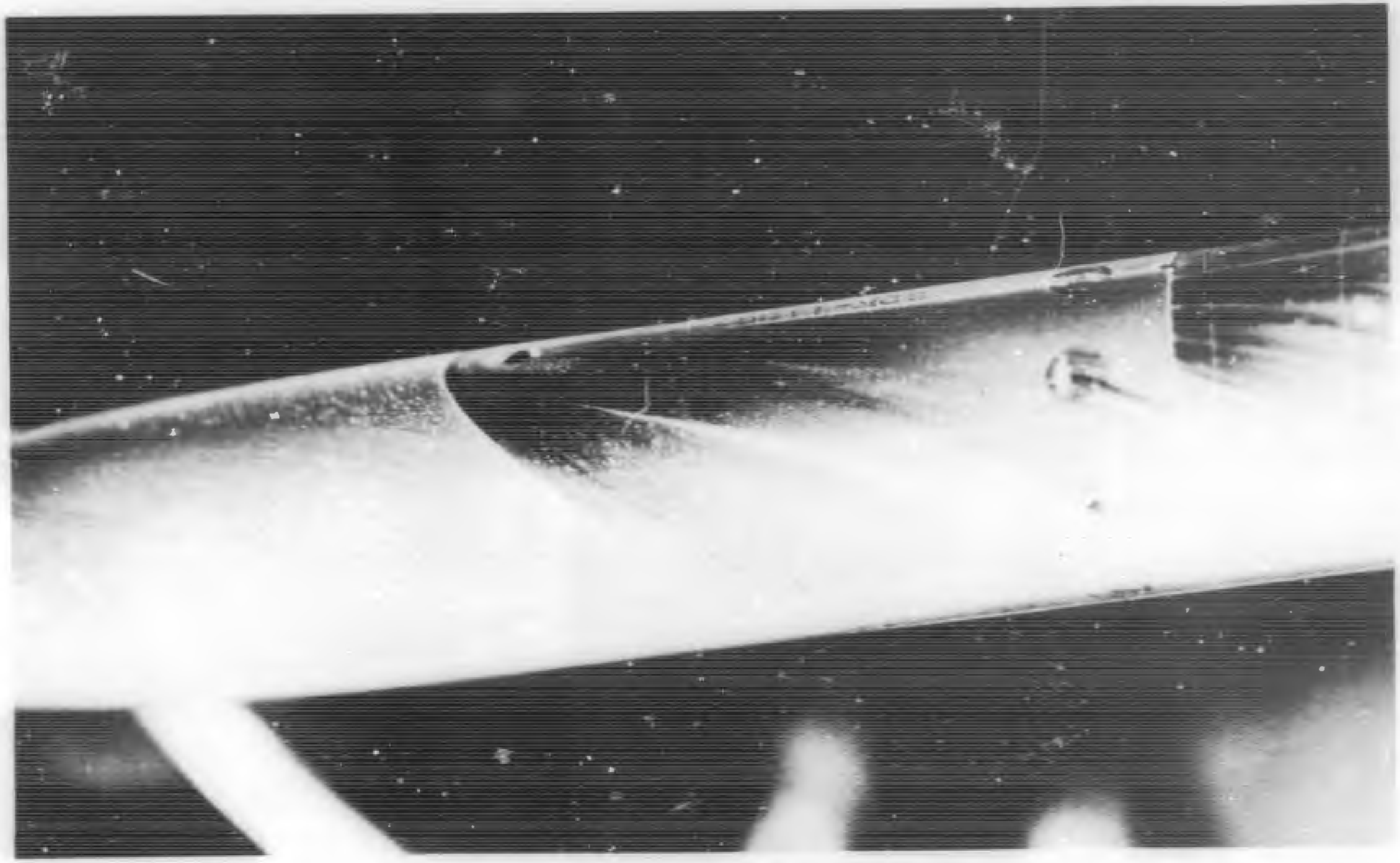

FIGURE E-13b. REACTION JET FOR $B_1C_1X_2$ WITH α = -10 DEGREES; P_{oj}/P_{∞} = 100

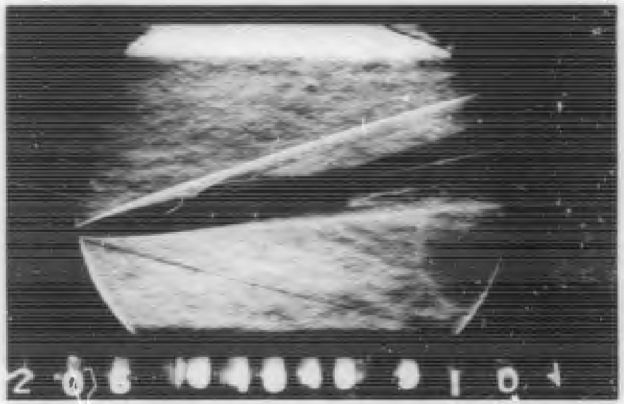

FIGURE E-13c. REACTION JET FOR $B_1C_1X_2$ WITH α = -10 DEGREES; P_{oj}/P_∞ = 40

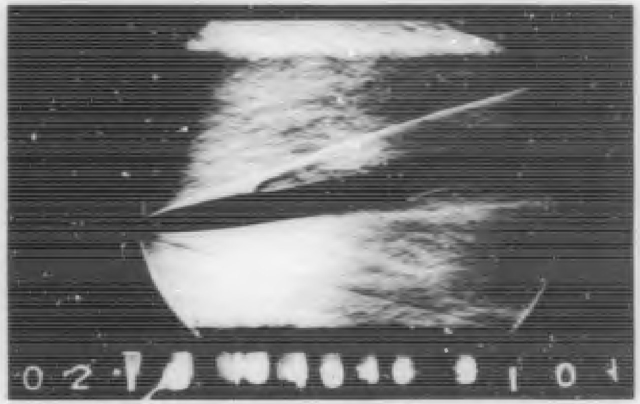

FIGURE E-13d. REACTION JET FOR $B_1C_1X_2$ WITH α = -10 DEGREES; P_{oj}/P_∞ = 100

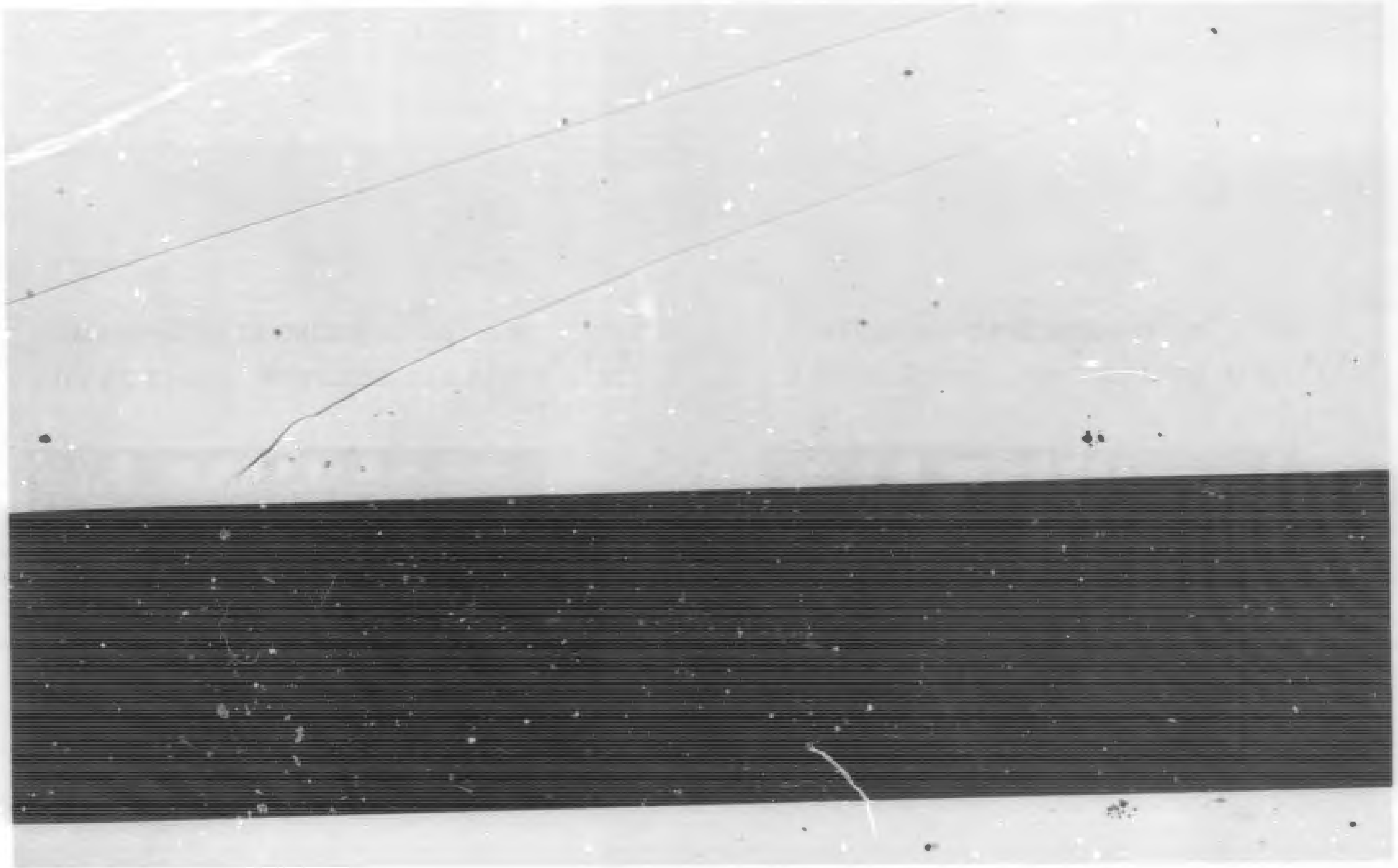

FIGURE E-14a. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 40$

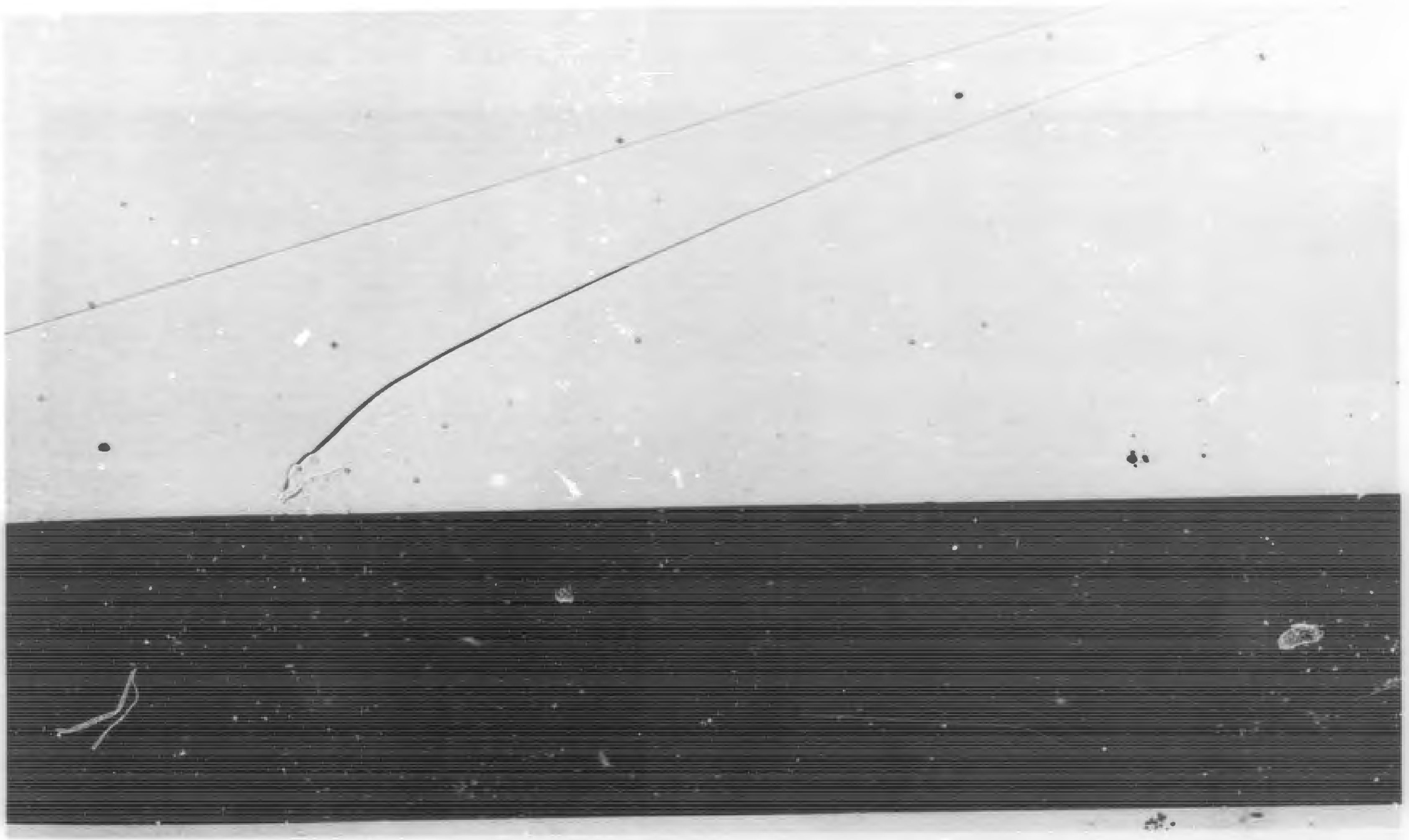

FIGURE E-14b. REACTION JET FOR $B_1C_1X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_{\infty} = 100$

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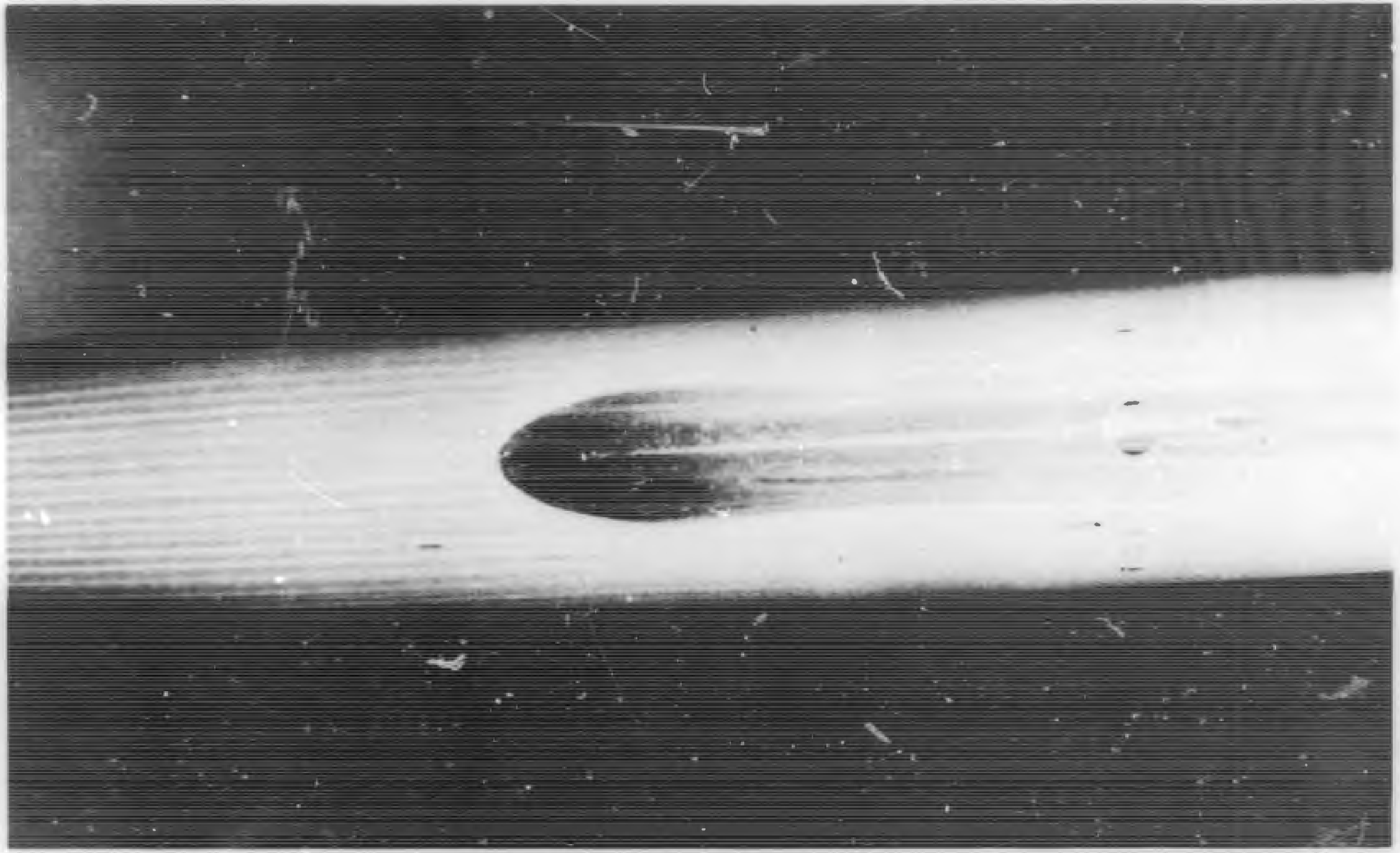

FIGURE E-15a. REACTION JET FOR $B_1S_{1L}X_2$ WITH α = 0 DEGREES; $P_{oj}/P_\infty = 0$

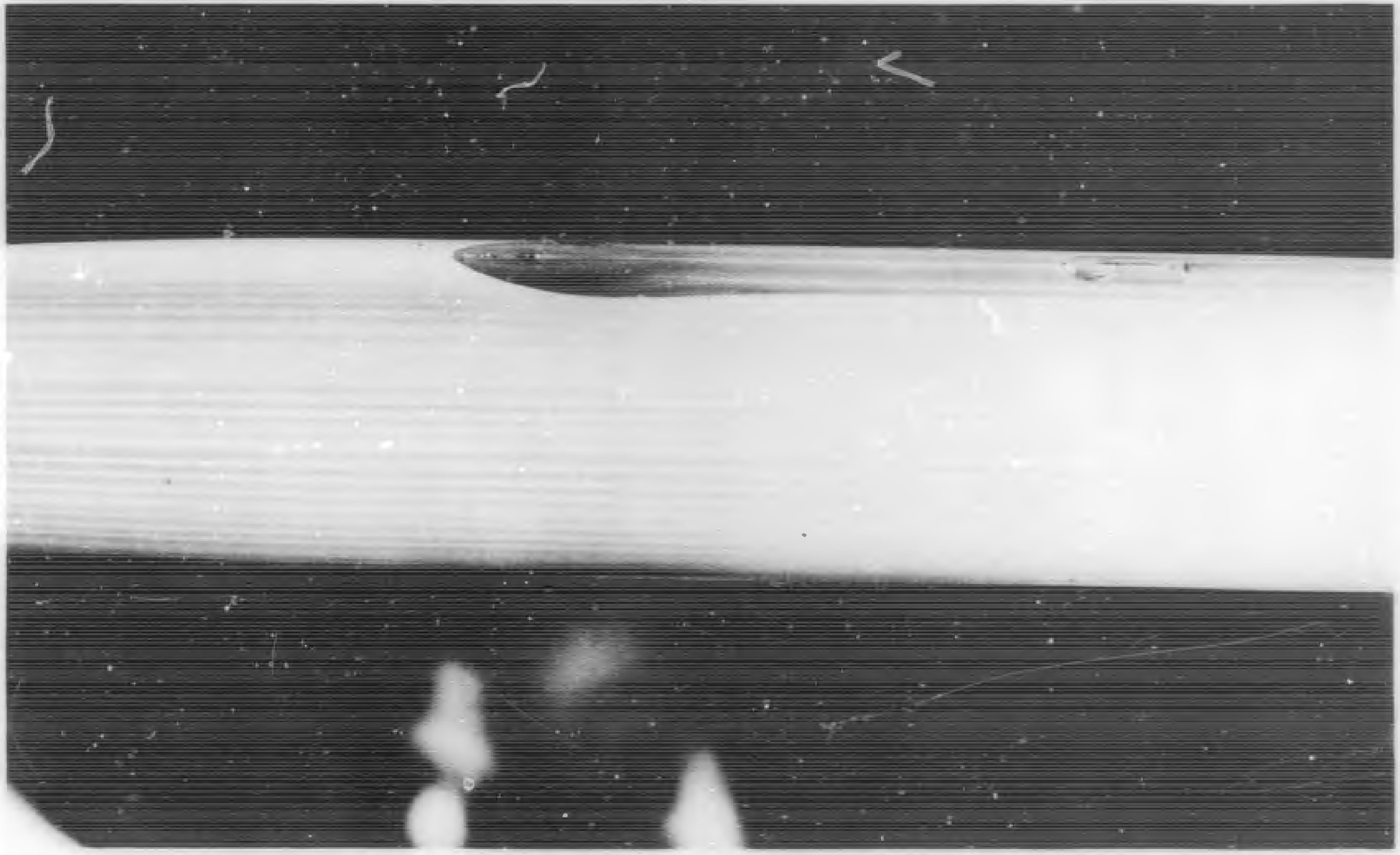

FIGURE E-15b. REACTION JET FOR $B_1S_{1L}X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 0$

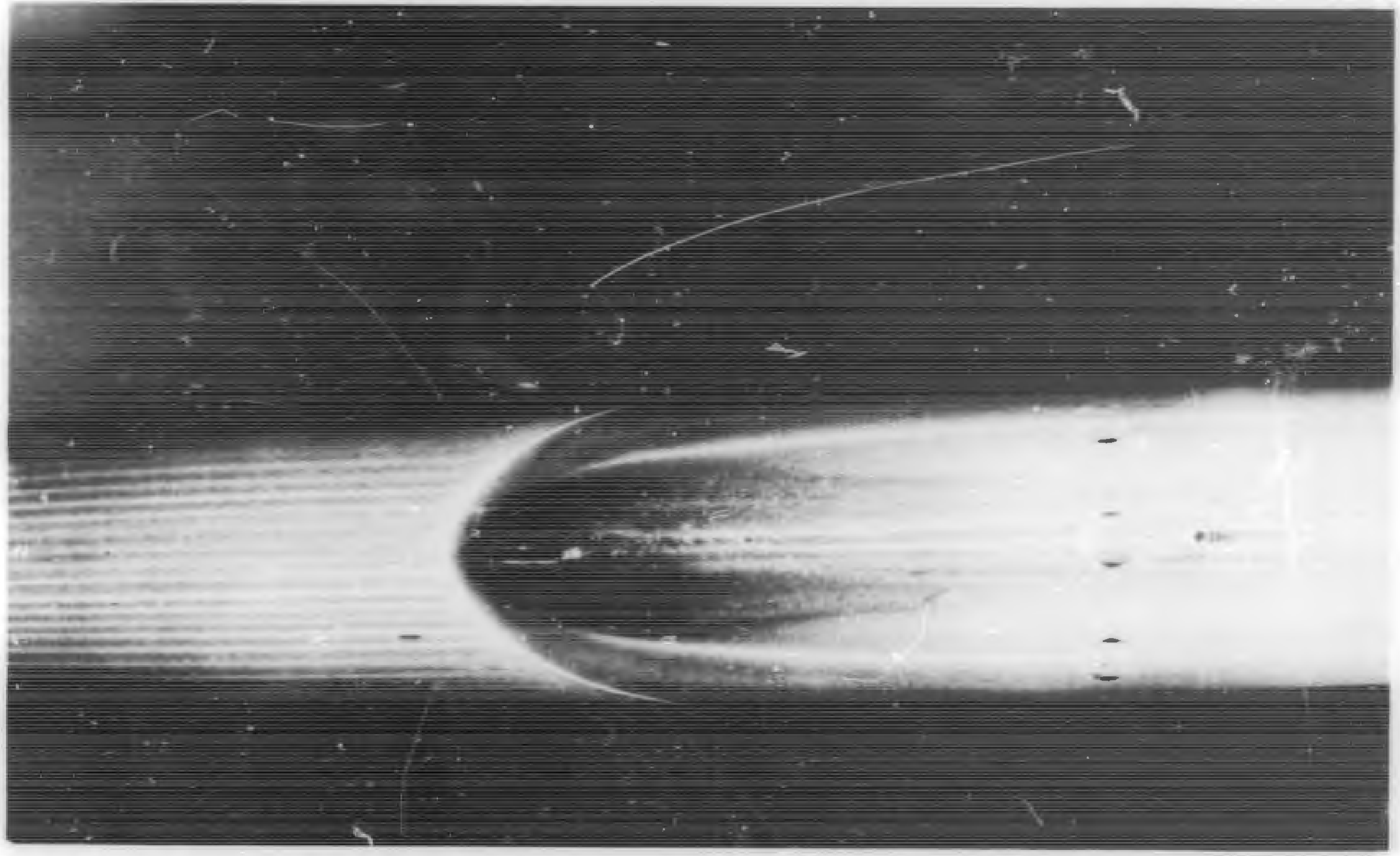

FIGURE E-15c. REACTION JET FOR $B_1S_{1L}X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 40$

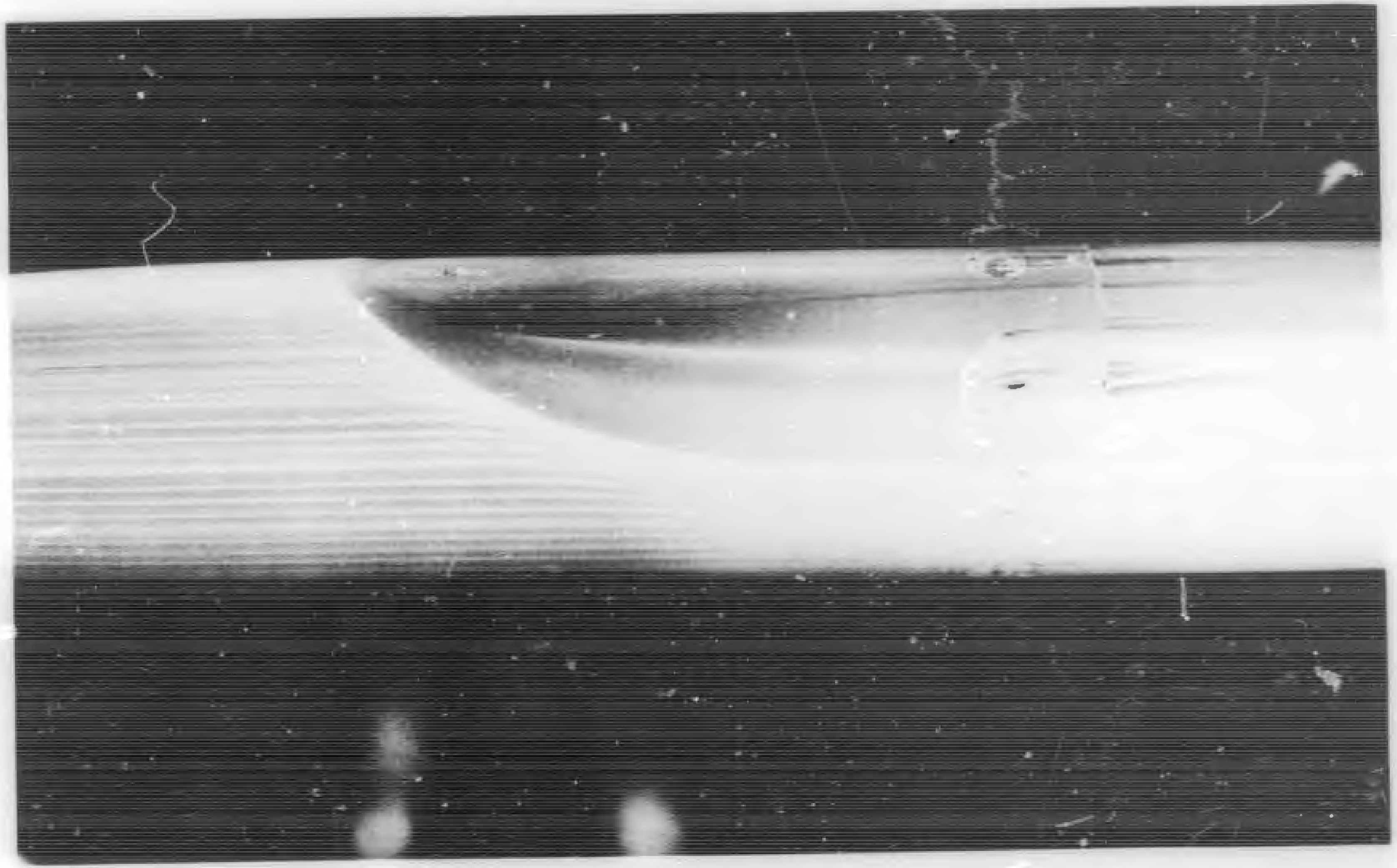

FIGURE E-15d. REACTION JET FOR $B_1S_{1L}X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 40$

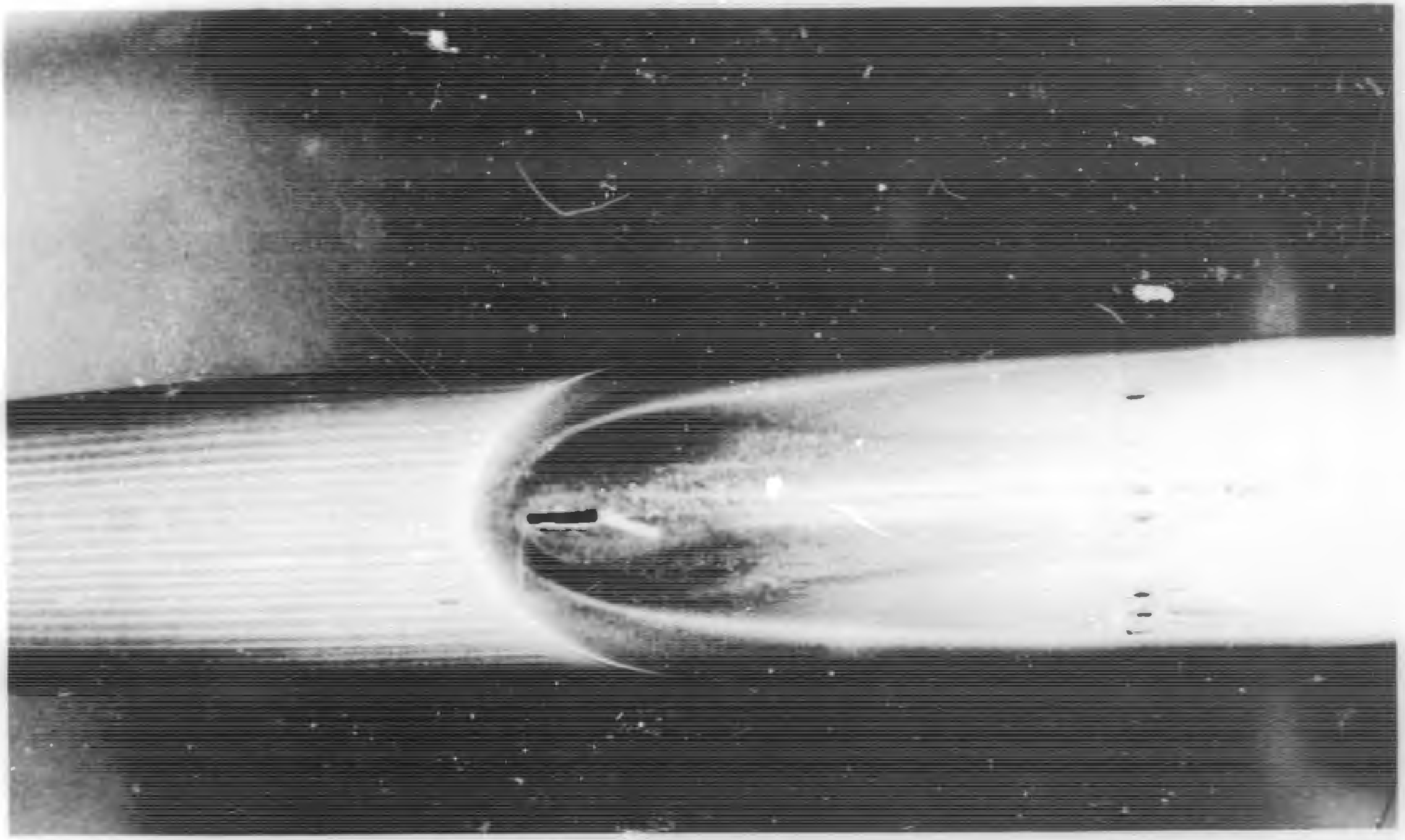

FIGURE E-15e. REACTION JET FOR $B_1S_{1L}X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 100$

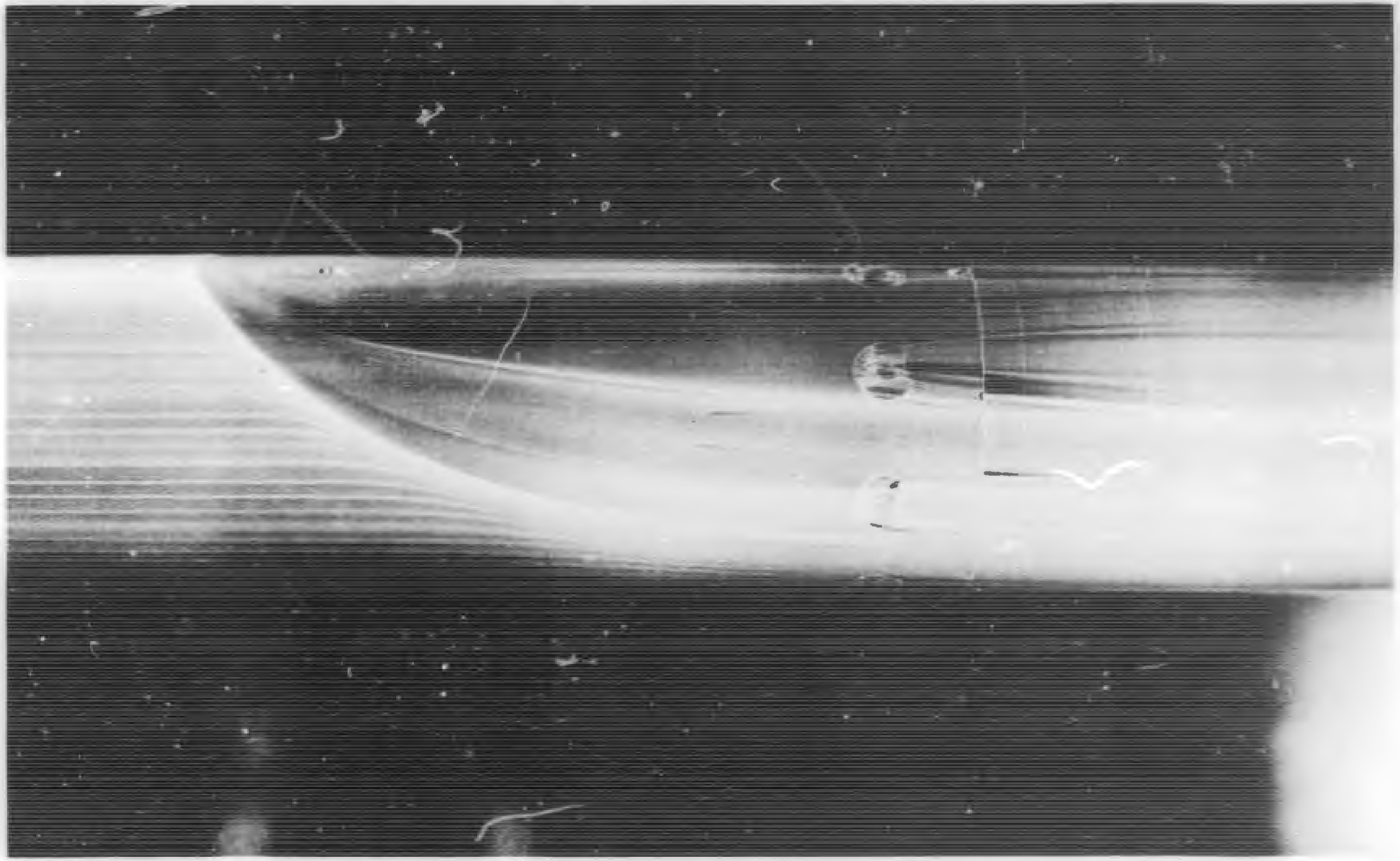

FIGURE E-15f. REACTION JET FOR $B_1S_{1L}X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 100$

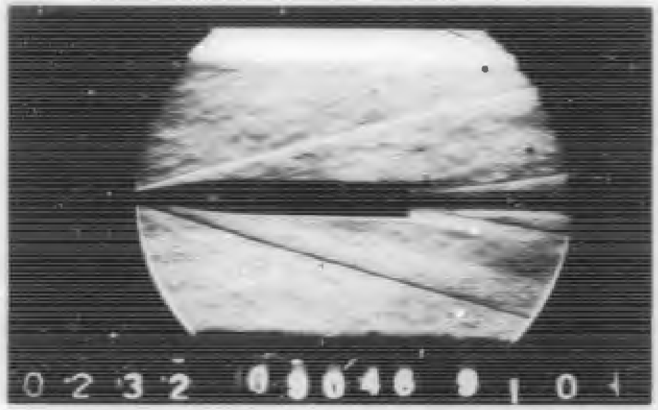

FIGURE E-15g. REACTION JET FOR $B_1S_{1L}X_2$. WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 0$

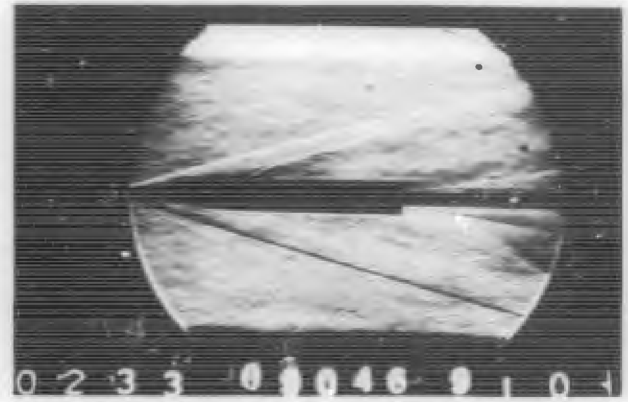

FIGURE E-15h. REACTION JET FOR $B_1S_{1L}X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 40$

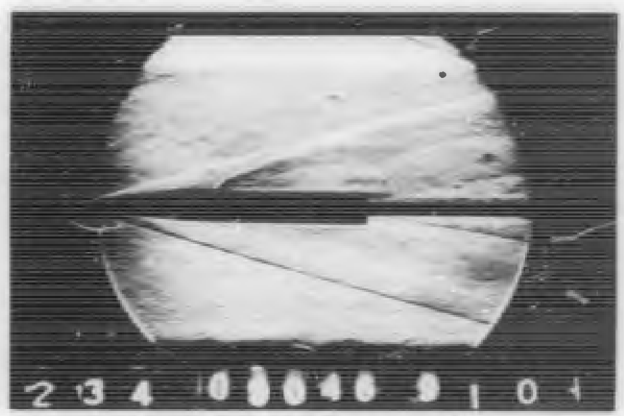

FIGURE E-15i. REACTION JET FOR $B_1S_{1L}X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 100$

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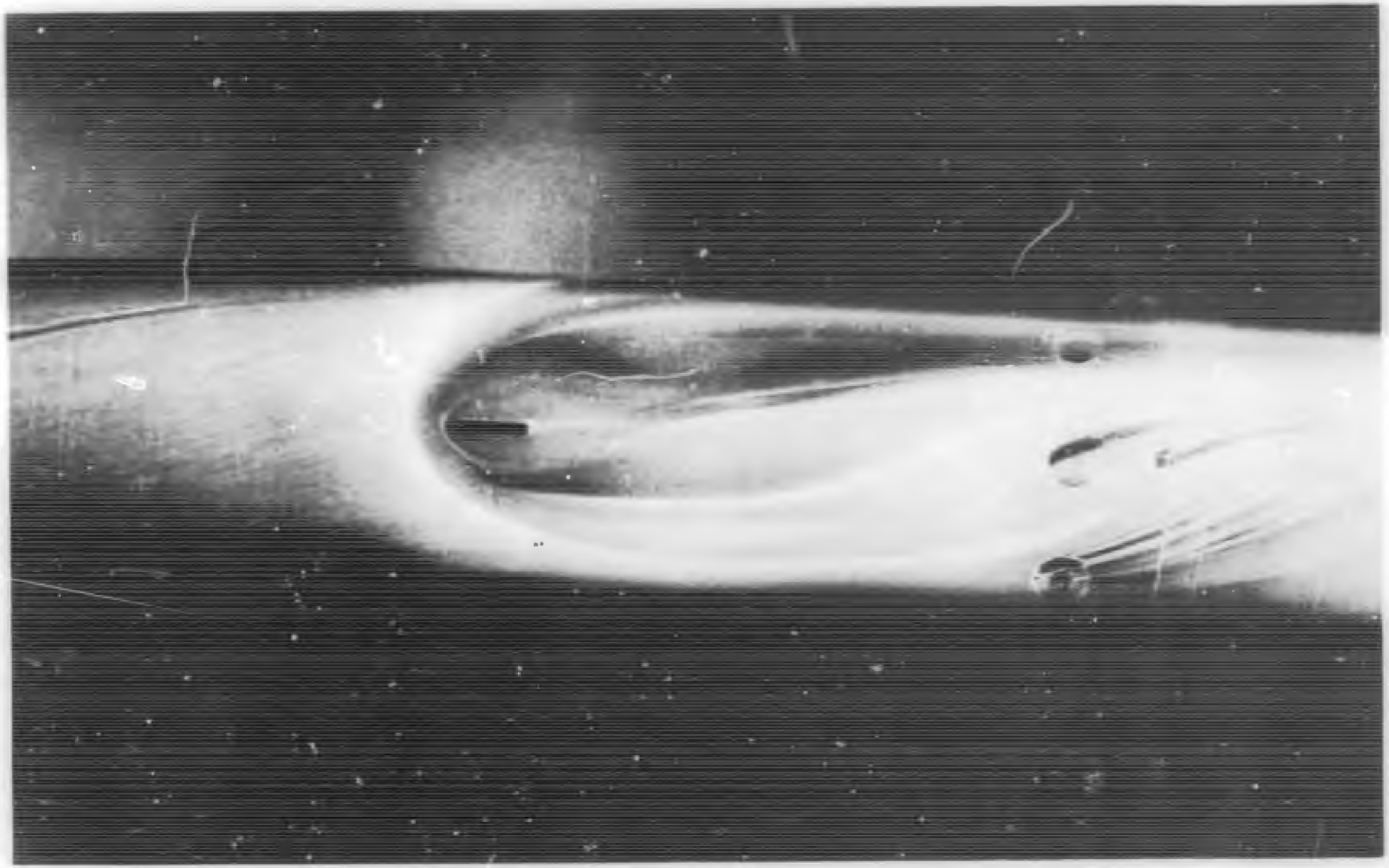

FIGURE E-16a. REACTION JET FOR $B_1S_{1L}X_2$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_\infty = 40$

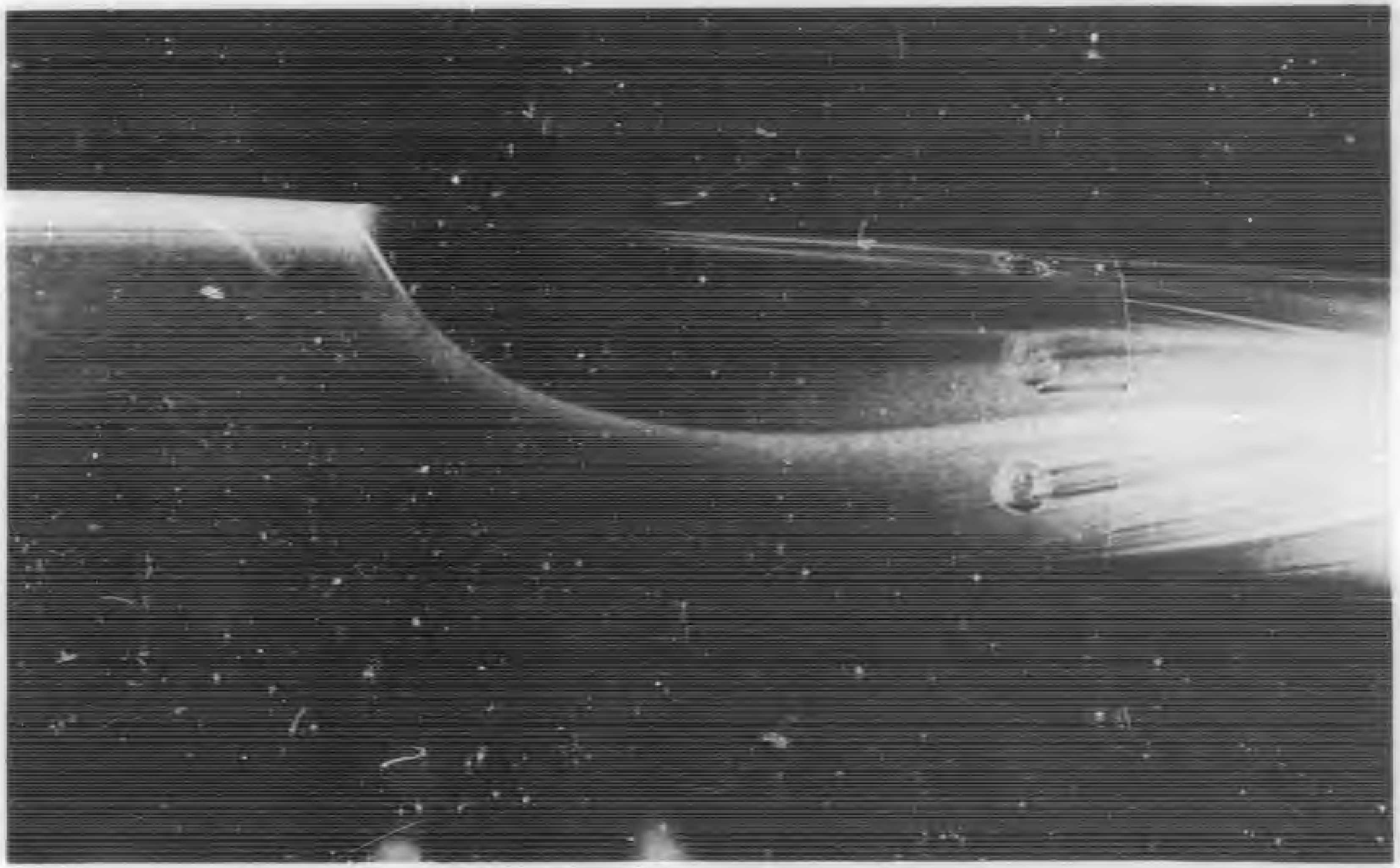

FIGURE E-16b. REACTION JET FOR $B_1S_{1L}X_2$ WITH α = 5 DEGREES; $P_{oj}/P_\infty = 40$

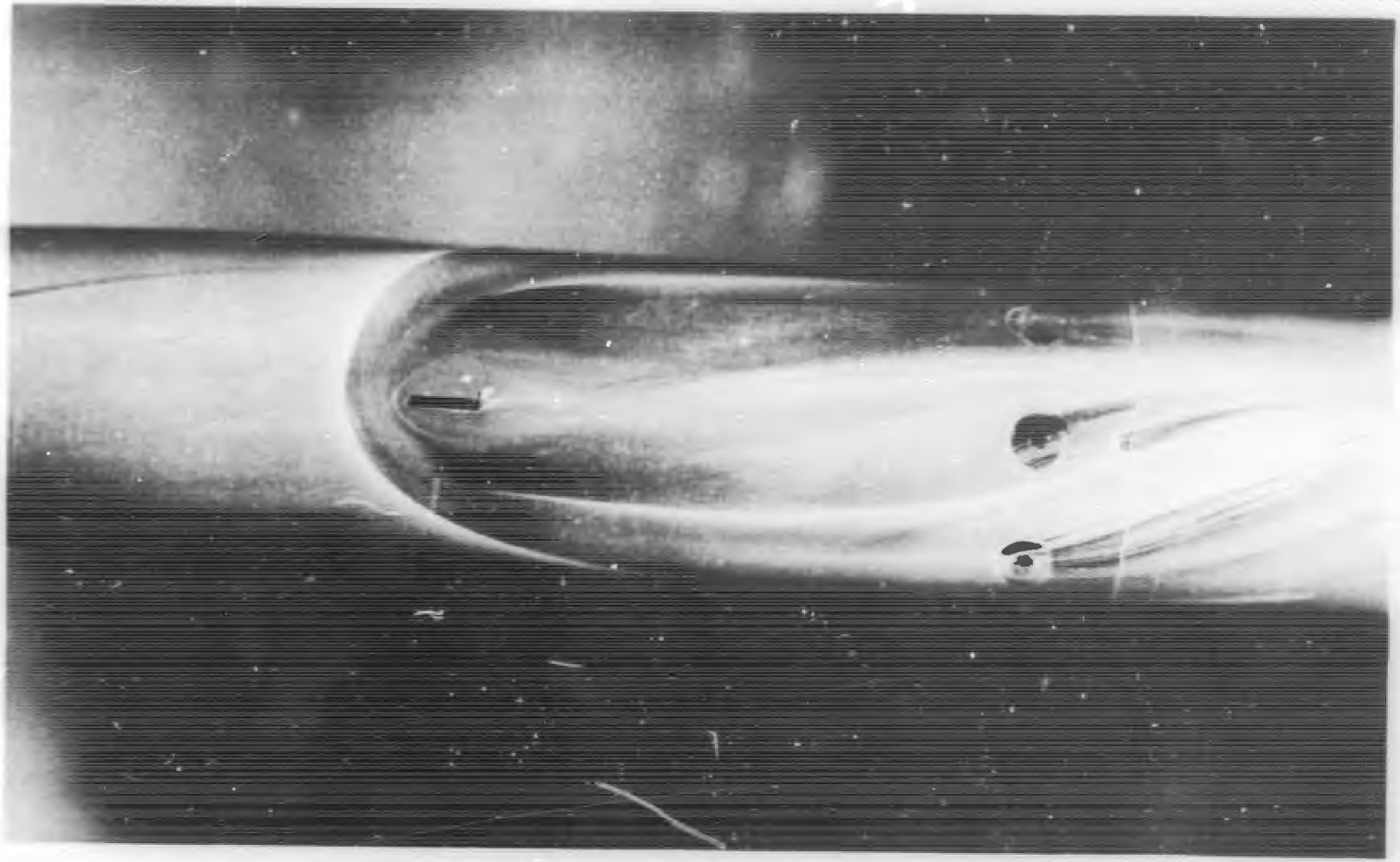

FIGURE E-16c. REACTION JET FOR $B_1S_{1L}X_2$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_\infty = 100$

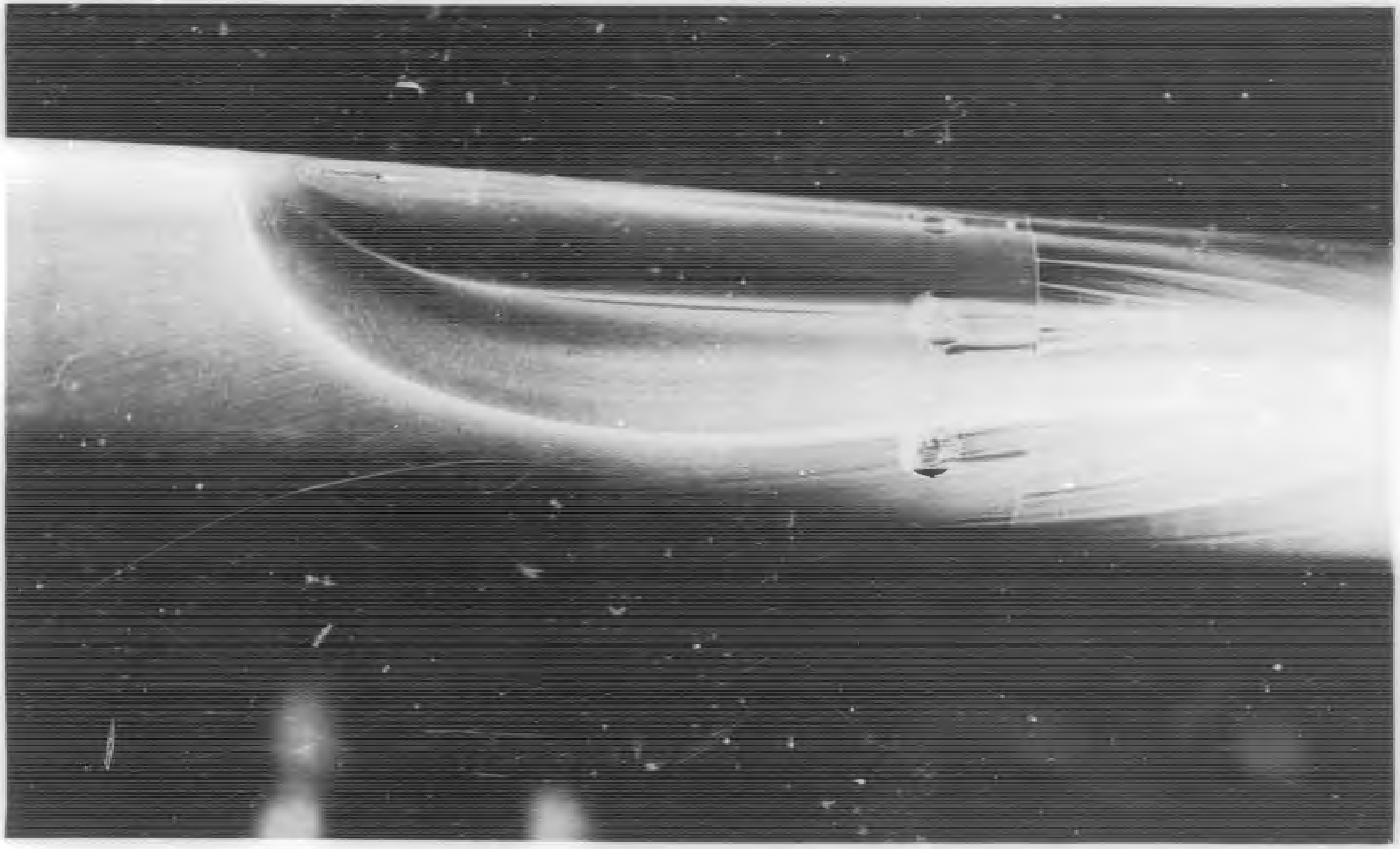

FIGURE E-16d. REACTION JET FOR $B_1S_{1L}X_2$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_\infty = 100$

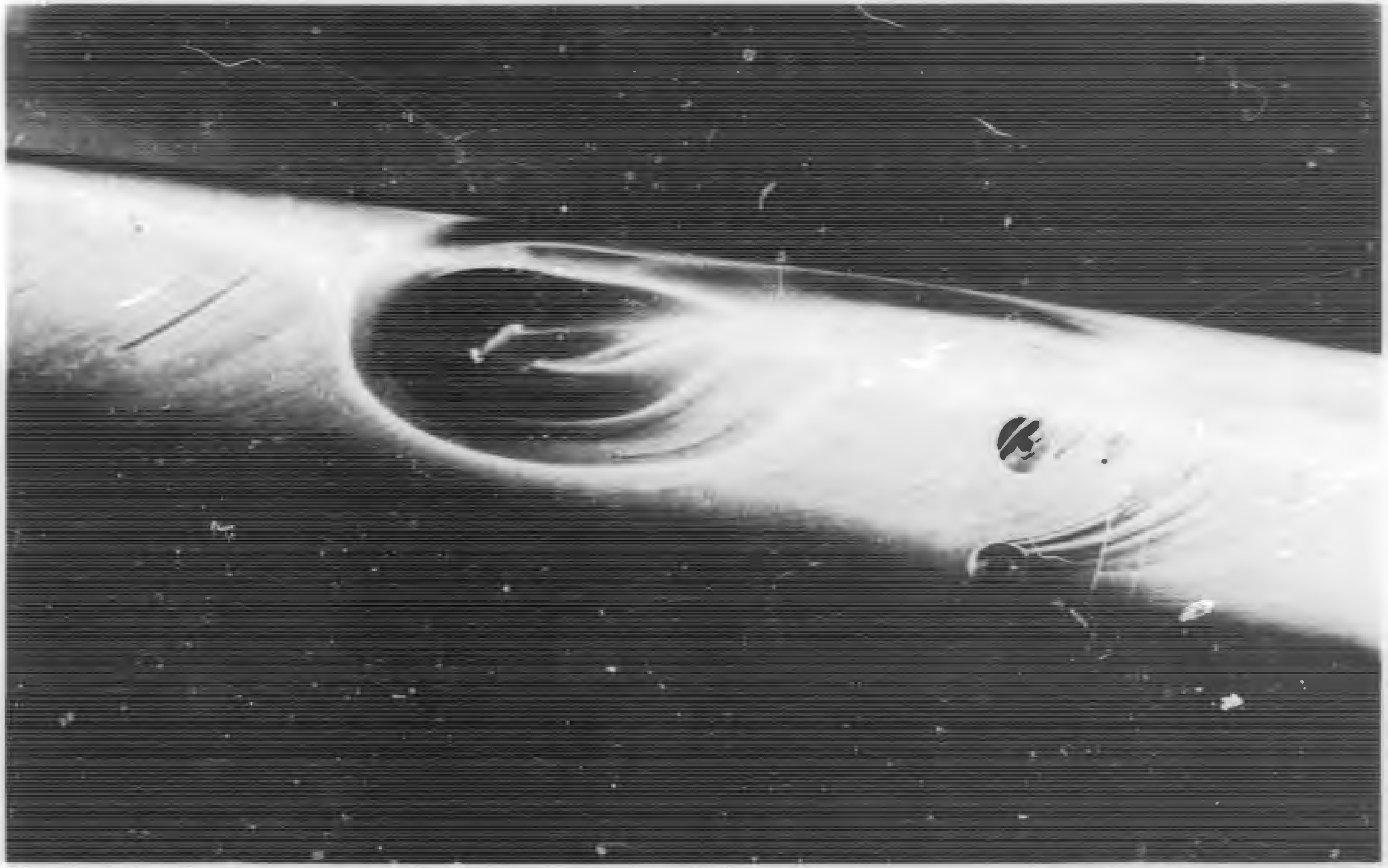

FIGURE E-17a. REACTION JET FOR $B_1S_{1L}X_2$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_\infty = 40$

FIGURE E-17b. REACTION JET FOR $B_1S_{1L}X_2$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_\infty = 40$

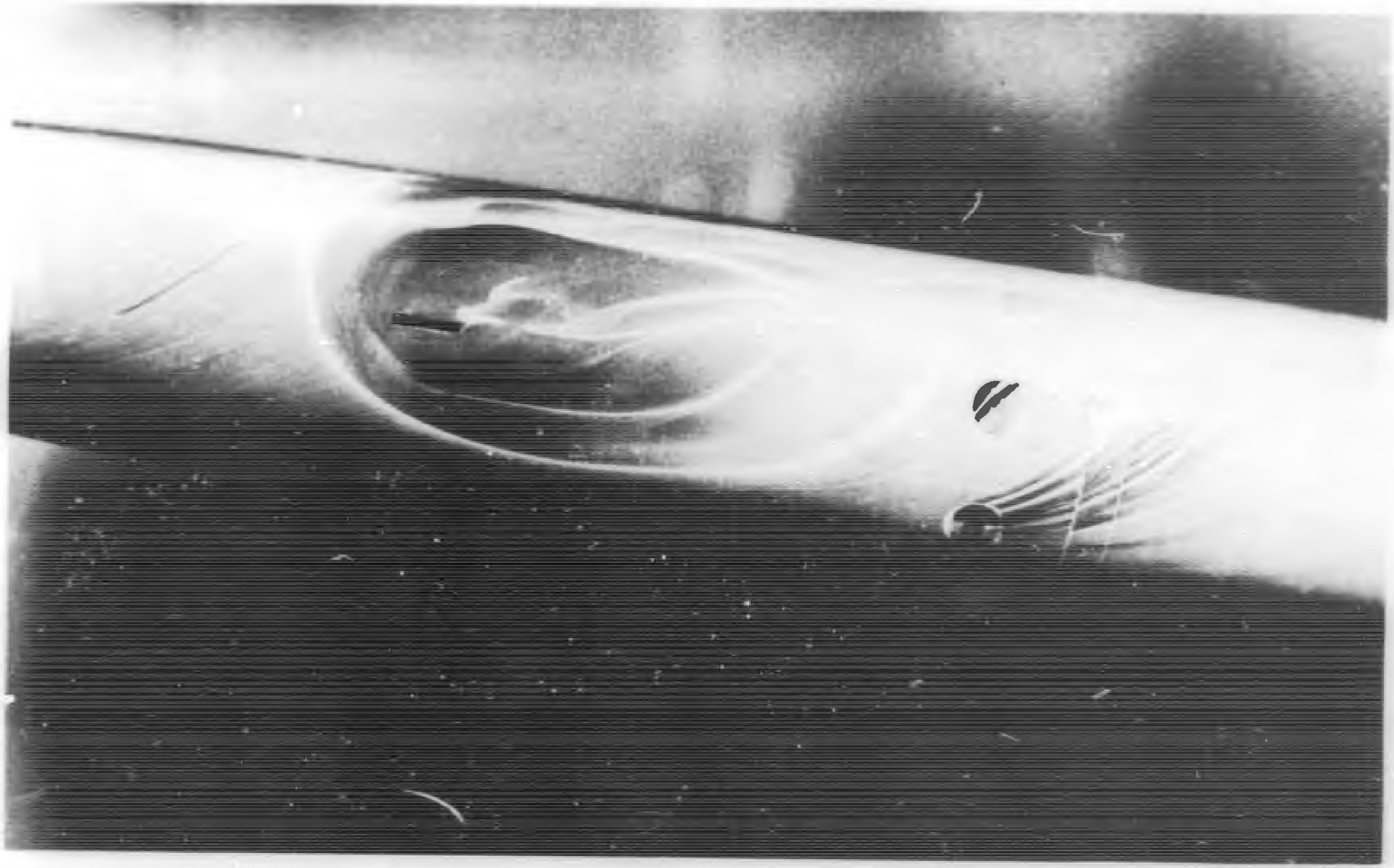

FIGURE E-17c. REACTION JET FOR $B_1S_{1L}X_2$ WITH α = 10 DEGREES; P_{oj}/P_∞ = 100

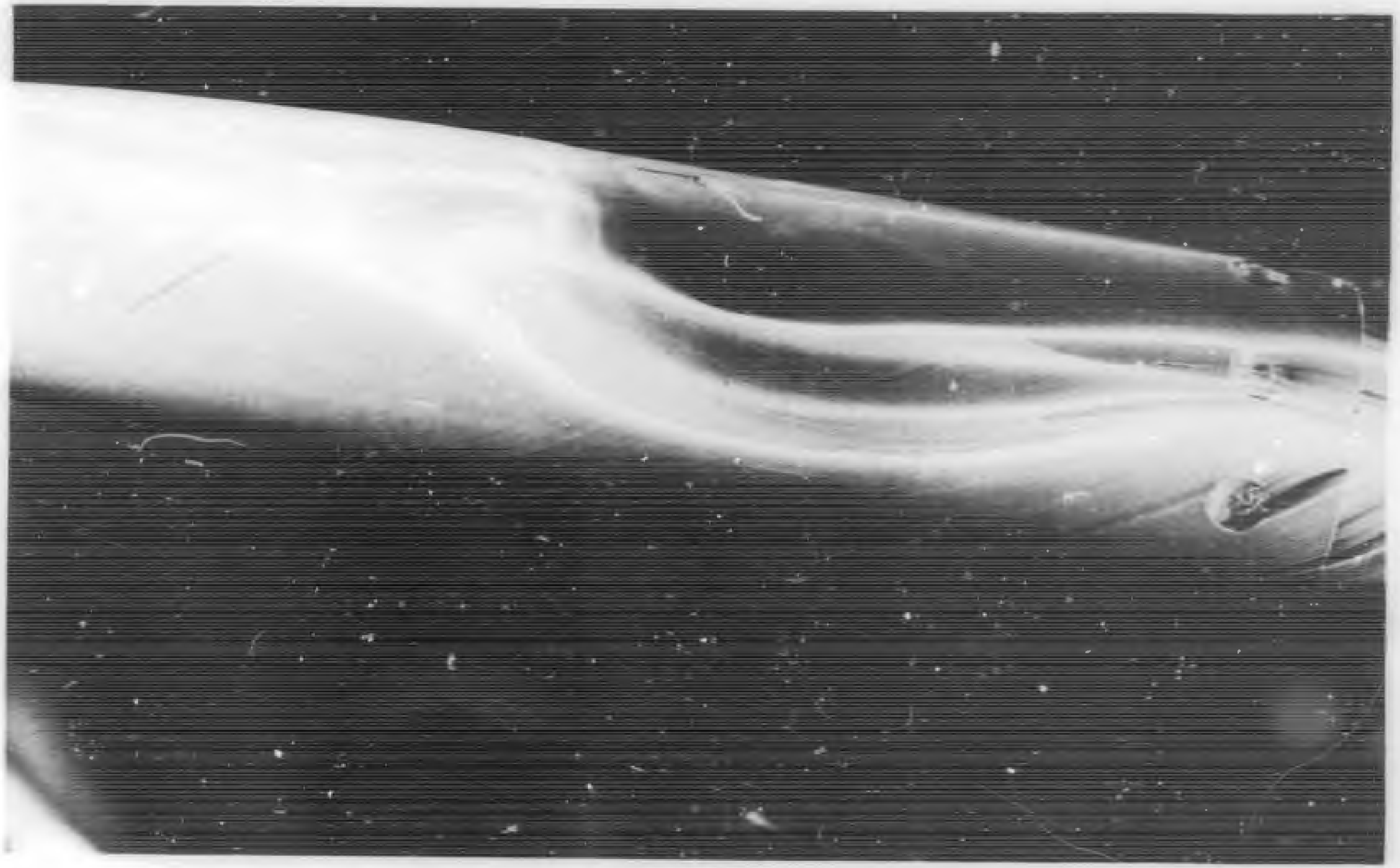

FIGURE E-17d. REACTION JET FOR $B_1S_1L_1X_2$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_{\infty} = 100$

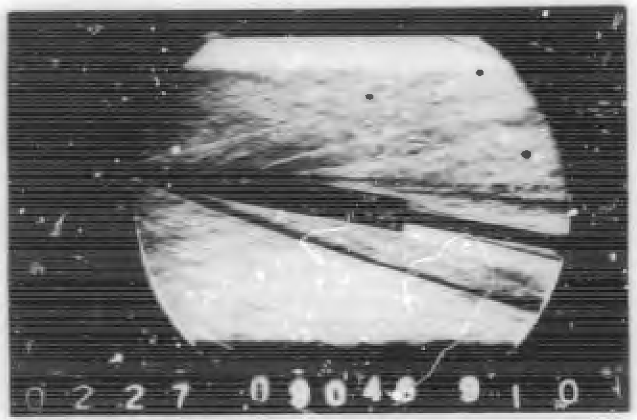

FIGURE E-17e. REACTION JET FOR $B_1S_{1L}X_2$
WITH $\alpha = 10$ DEGREES; $P_{oj}/P_\infty = 40$

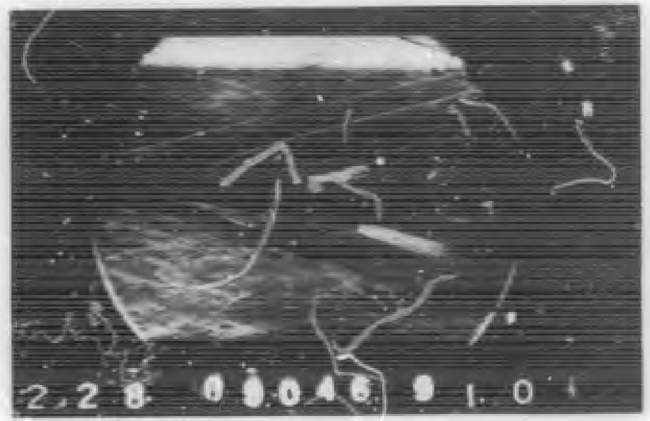

FIGURE E-17f. REACTION JET FOR $B_1S_{1L}X_2$
WITH $\alpha = 10$ DEGREES; $P_{oj}/P_\infty = 100$

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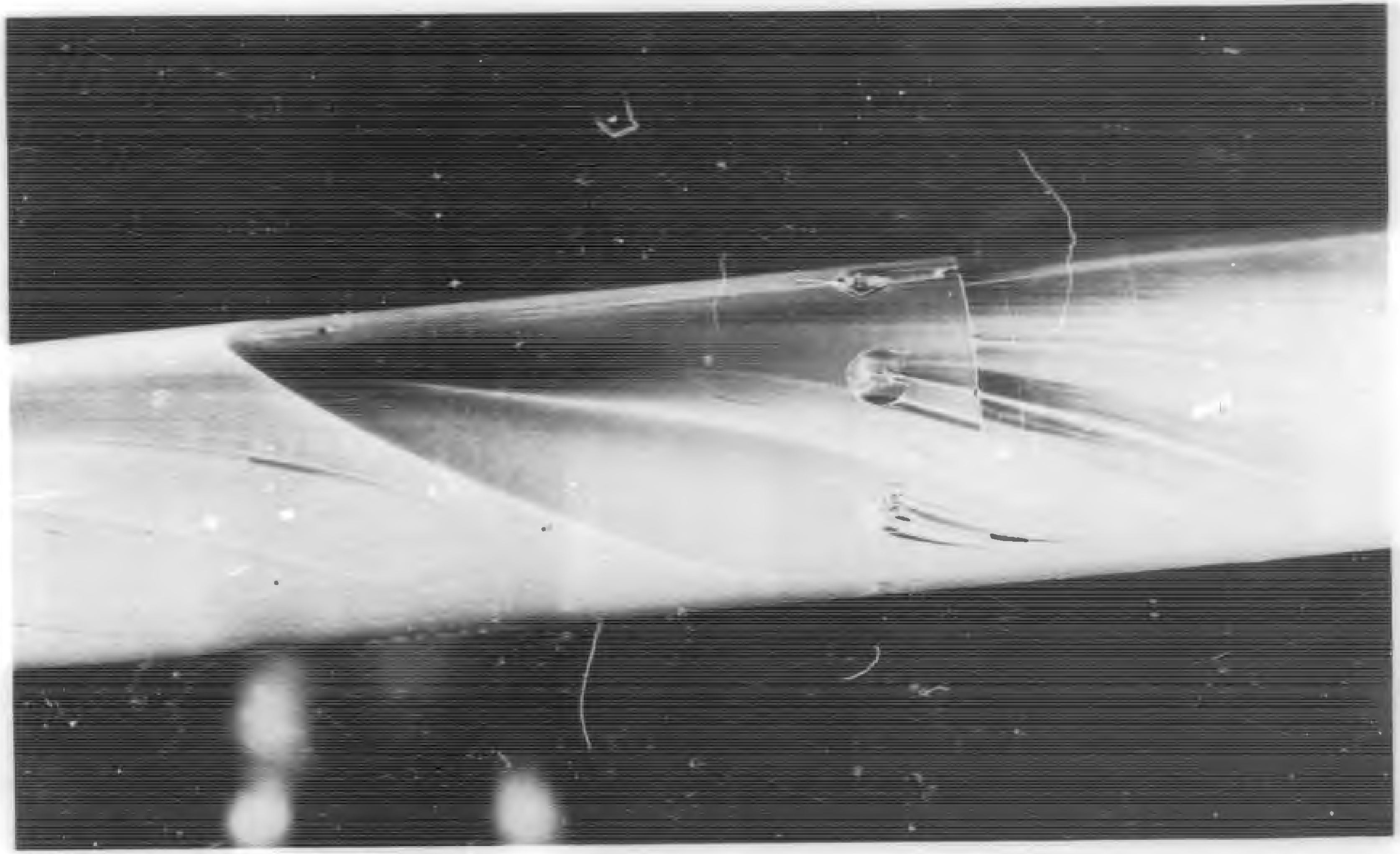

FIGURE E-18a. REACTION JET FOR $B_1S_{1L}X_2$ WITH α = -5 DEGREES; P_{oj}/P_∞ = 40

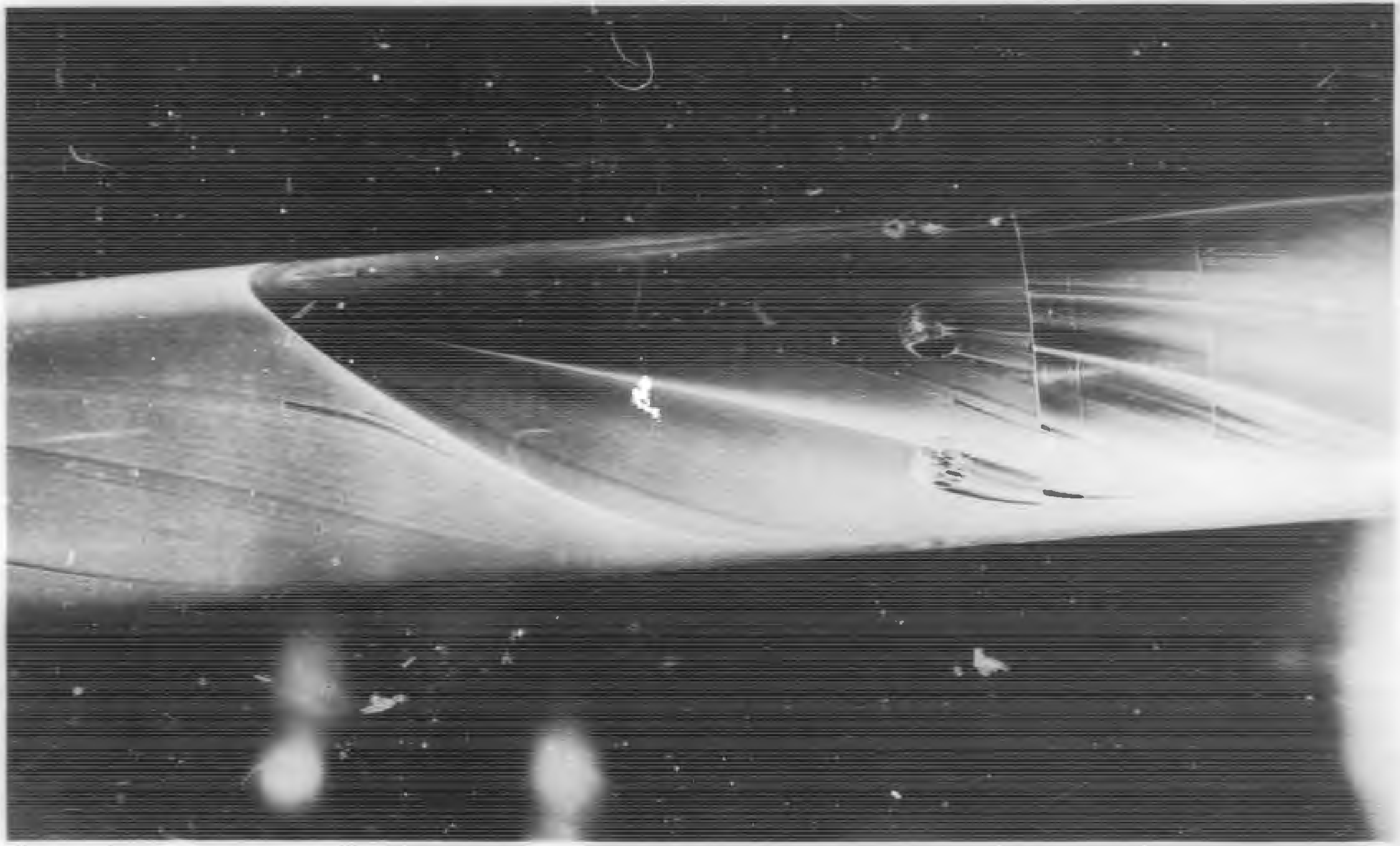

FIGURE E-18b. REACTION JET FOR $B_1 S_{1L} X_2$ WITH α = -5 DEGREES; P_{oj}/P_∞ = 100

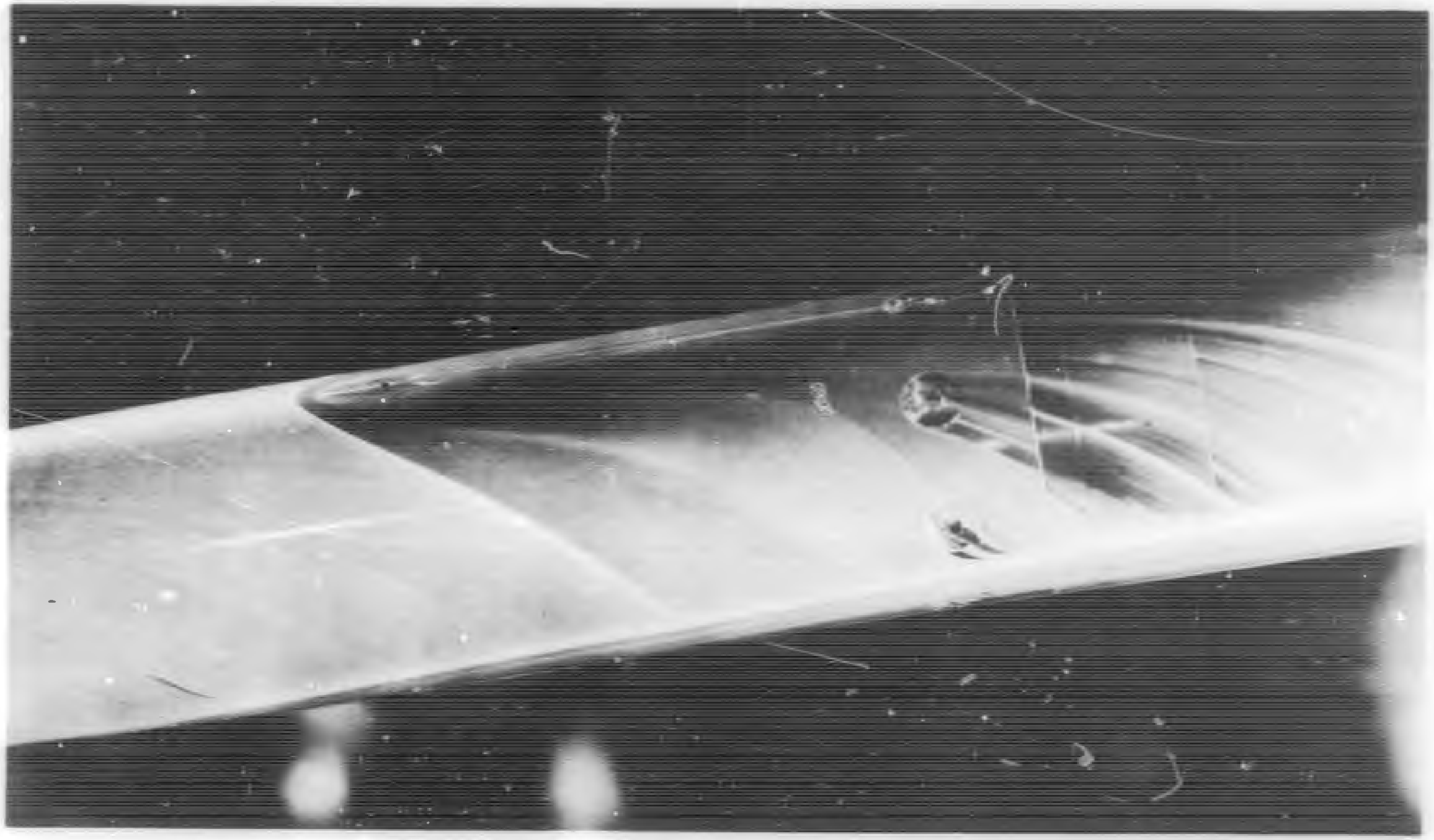

FIGURE E-19a. REACTION JET FOR $B_1S_{1L}X_2$ WITH α = -10 DEGREES; P_{oj}/P_∞ = 40

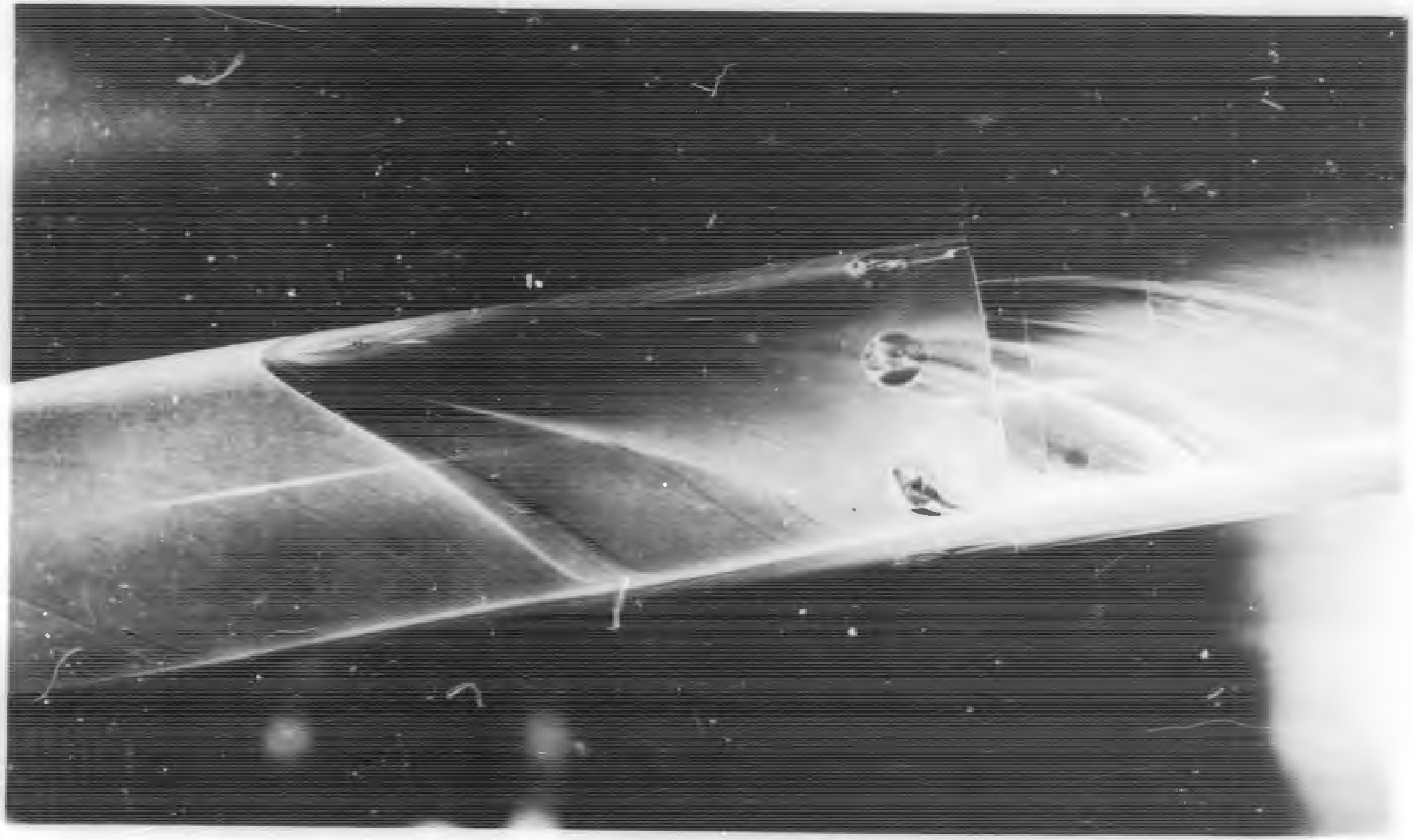

FIGURE E-19b. REACTION JET FOR $B_1S_{1L}X_2$ WITH $\alpha = -10$ DEGREES; $P_{oj}/P_\infty = 100$

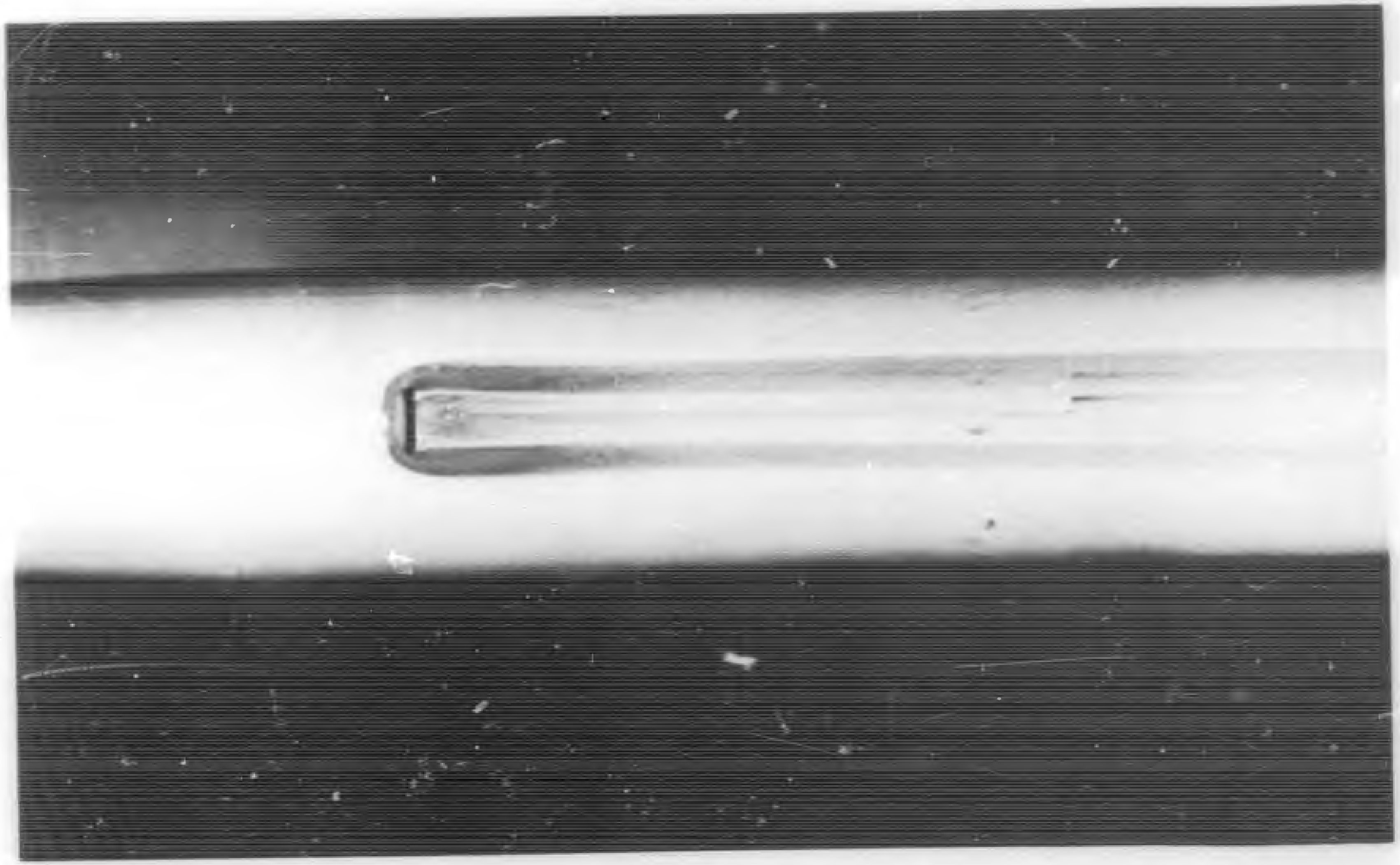

FIGURE E-20a. REACTION JET FOR $B_1S_{1T}X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_{\infty} = 0$

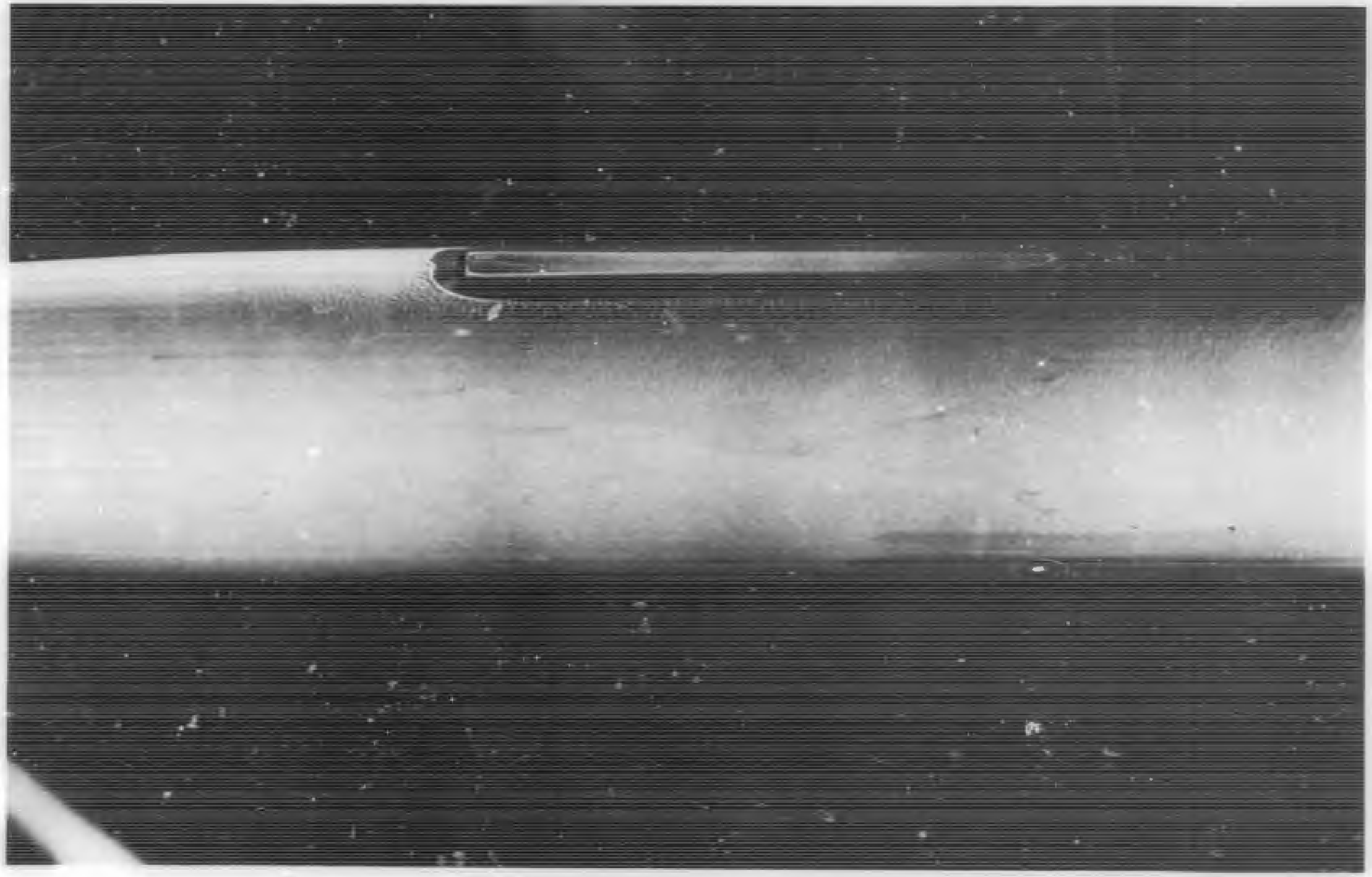

FIGURE E-20b. REACTION JET FOR $B_1S_{1T}X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 0$

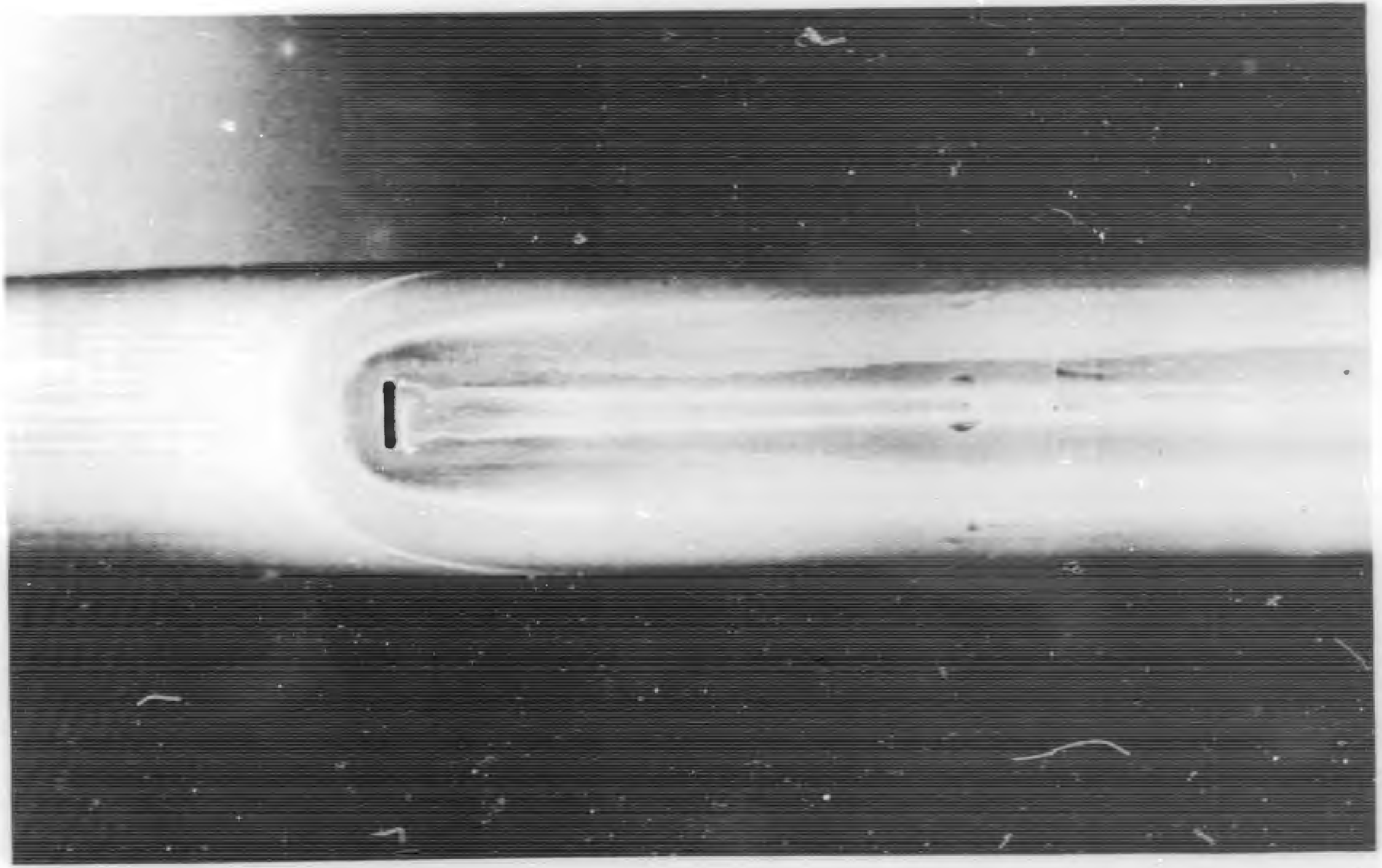

FIGURE E-20c. REACTION JET FOR $B_1S_{1T}X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_{\infty} = 40$

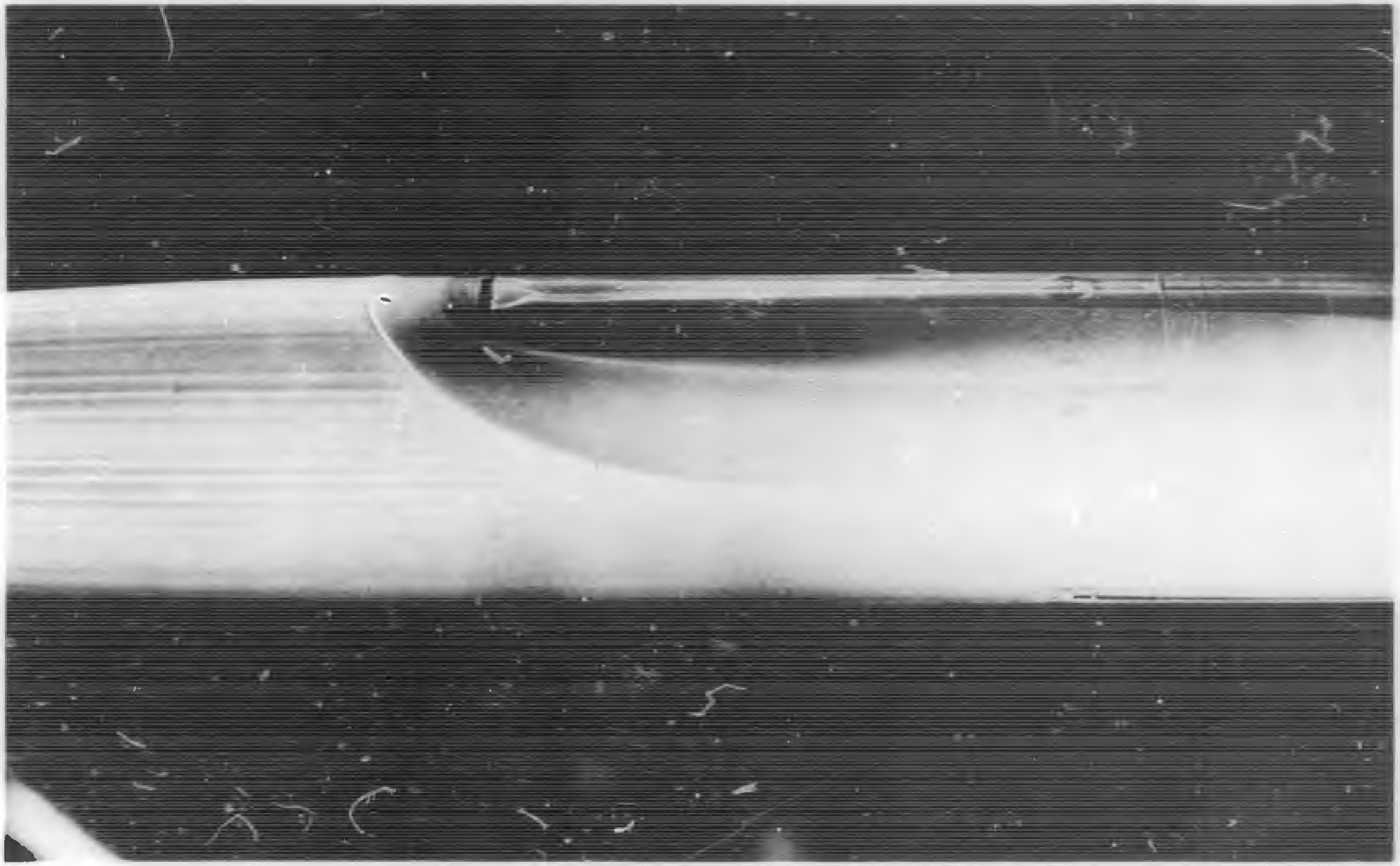

FIGURE E-20d. REACTION JET FOR $B_1S_{1T}X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 40$

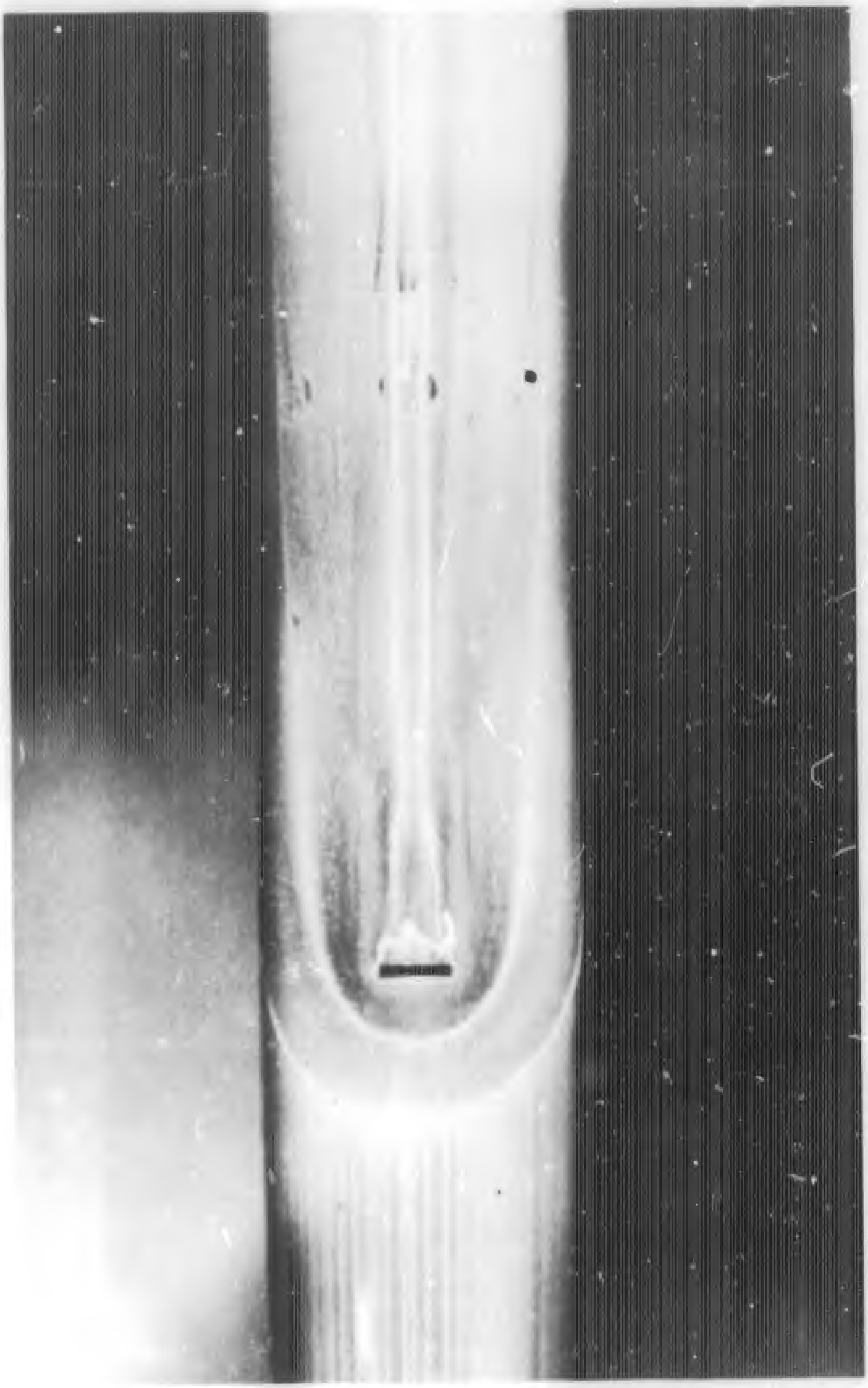

FIGURE E-20e. REACTION JET FOR $B_1S_{1T}X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 100$

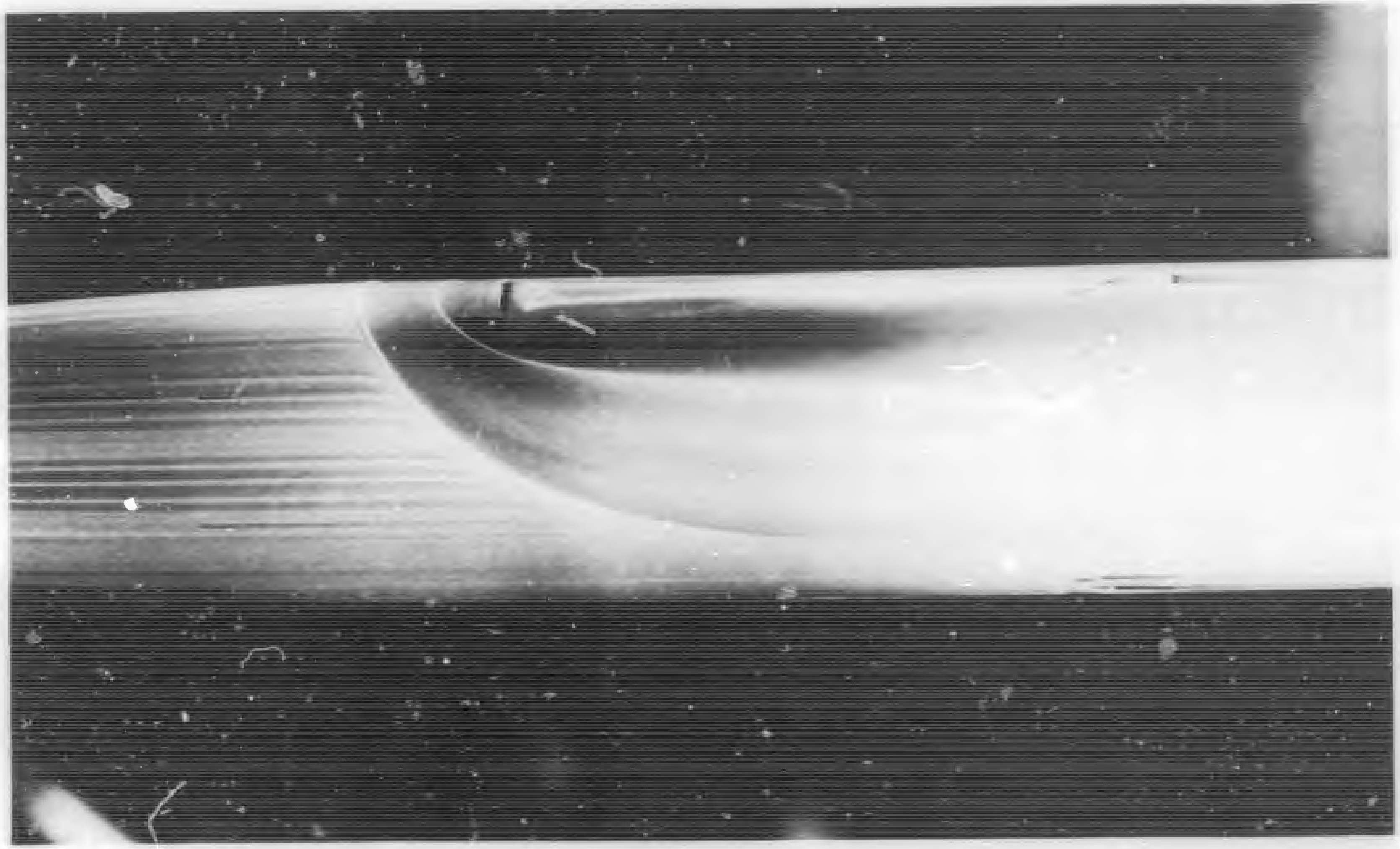

FIGURE E-20f. REACTION JET FOR $B_1S_{1T}X_2$ WITH $\alpha = 0$ DEGREES; $P_{oj}/P_\infty = 100$

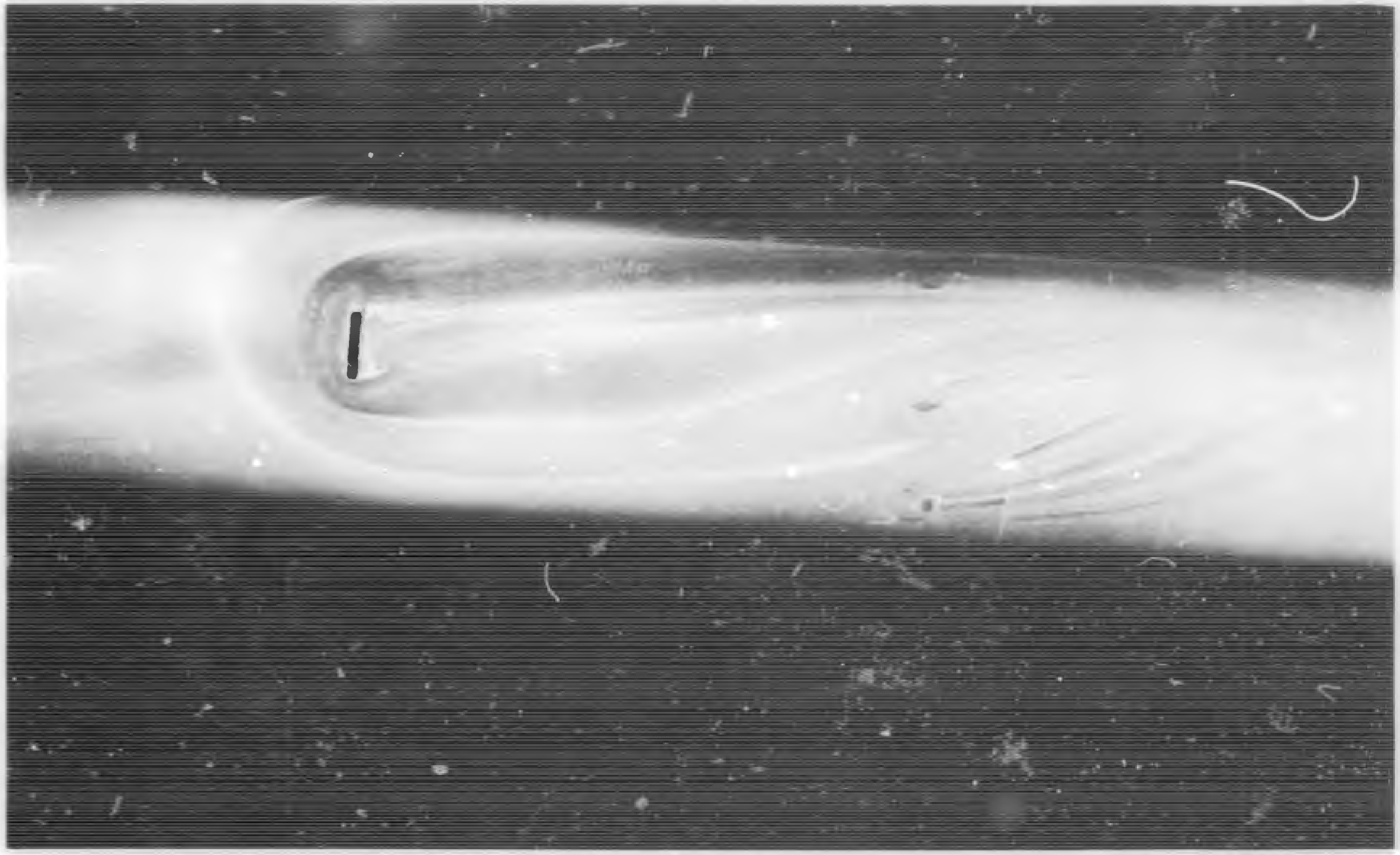

FIGURE E-21a. REACTION JET FOR $B_1S_{1T}X_2$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_\infty = 40$

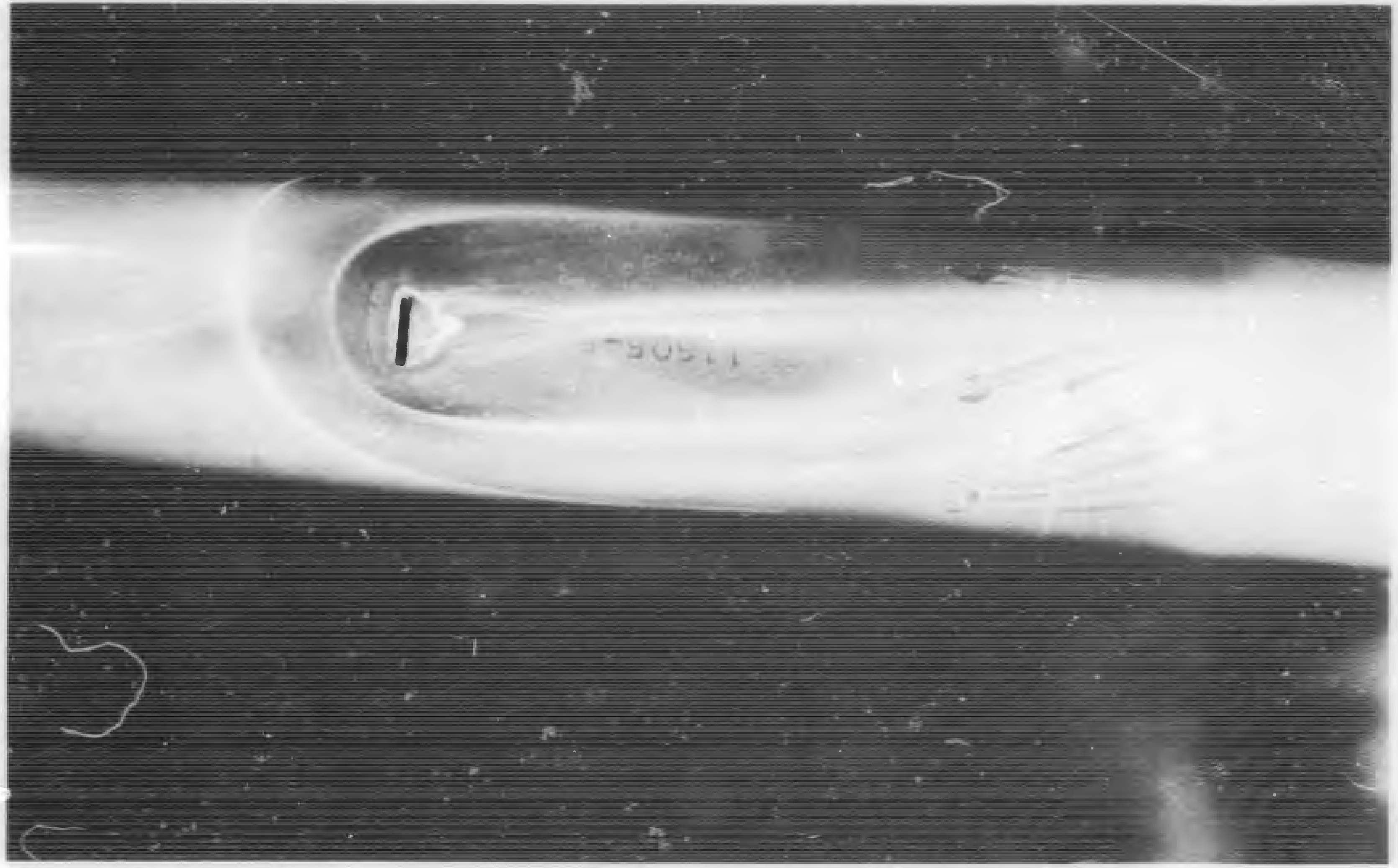

FIGURE E-21b. REACTION JET FOR $B_1S_{1T}X_2$ WITH $\alpha = 5$ DEGREES; $P_{oj}/P_\infty = 100$

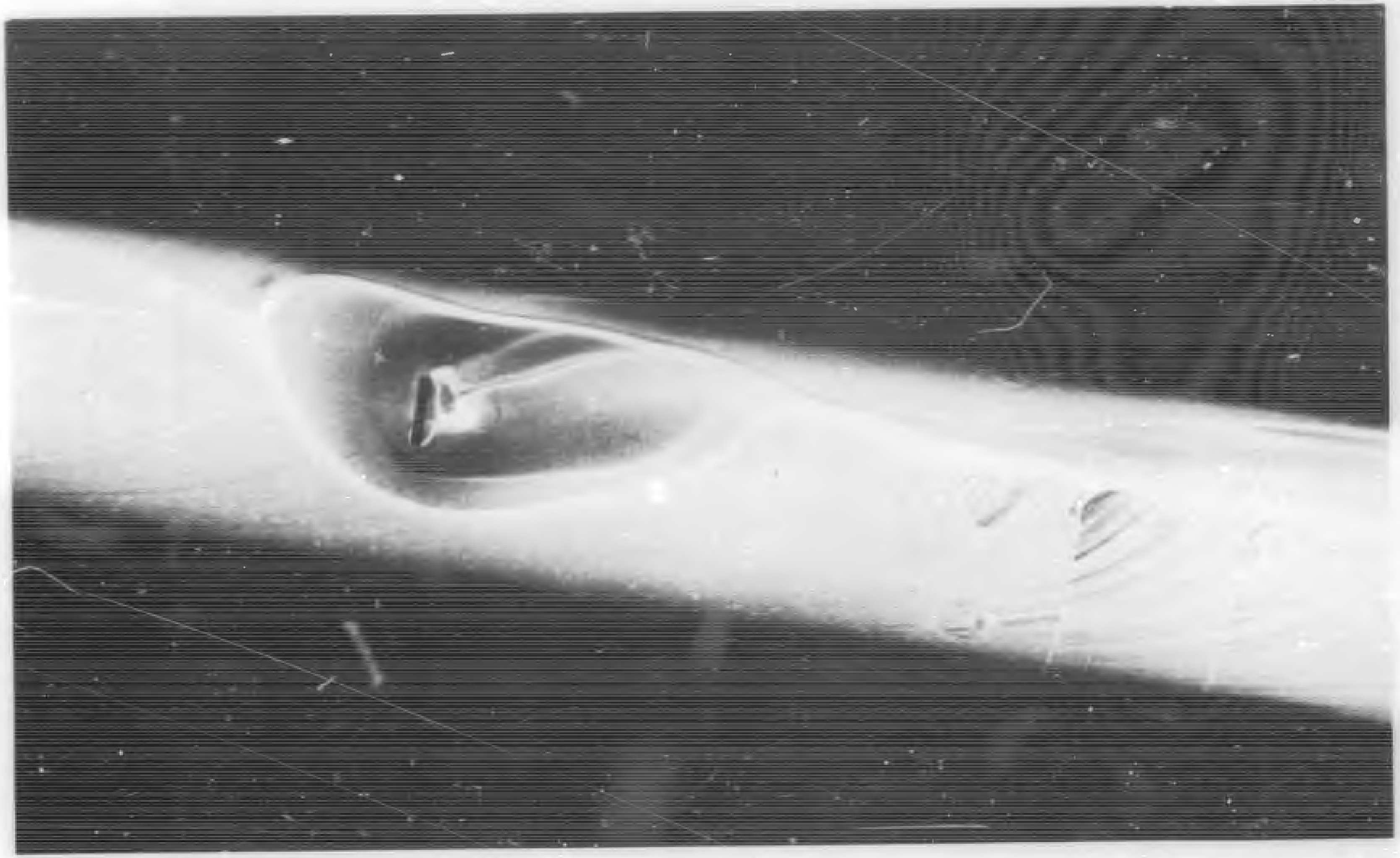

FIGURE E-22a. REACTION JET FOR $B_1S_{1T}X_2$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_\infty = 40$

FIGURE E-22b. REACTION JET FOR $B_1S_{1T}X_2$ WITH $\alpha = 10$ DEGREES; $P_{oj}/P_{\infty} = 100$

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13. ABSTRACT

An oil flow test has been conducted to obtain flow patterns in the vicinity of a transverse sonic jet ejecting from a body of revolution into an oncoming supersonic flow of $M_{\infty} = 1.75$, 2.0, 3.0, 4.0, and 4.5. The angle of attack was ±10 degrees with jet total-to-free stream static pressure ratios up to 100. The jet was oriented to various angular positions at several longitudinal body locations.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Oil flow						
Sonic reaction jet						
Body of revolution						
Mach number range 1.75 to 4.5						
Angle of attack						