

HYDRONAUTICS, Incorporated

NASA CR-132365

~~31708~~  
File with N 74-17959

MODEL EXPERIMENTS TO EVALUATE  
VORTEX DISSIPATION DEVICES  
PROPOSED FOR INSTALLATION  
ON OR NEAR AIRCRAFT RUNWAYS

By Robert E. Kohl

Distribution of this report is provided in the  
interest of information exchange. Responsibility  
for the contents resides in the author or organi-  
zation that prepared it.

Prepared under Contract No. NAS1-11389  
HYDRONAUTICS, Incorporated  
Laurel, Md.  
for Langley Research Center  
National Aeronautics and Space Administration

1. Report No. NASA CR-132365		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle MODEL EXPERIMENTS TO EVALUATE VORTEX DISSIPATION DEVICES PROPOSED FOR INSTALLATION ON OR NEAR AIRCRAFT RUNWAYS			5. Report Date August 1973		
			6. Performing Organization Code		
7. Author(s) Robert E. Kohl			8. Performing Organization Report No.		
9. Performing Organization Name and Address HYDRONAUTICS, Incorporated 7210 Pindell School Road Laurel, Maryland 20810			10. Work Unit No. (TRAIS)		
			11. Contract or Grant No. NAS1-11389		
12. Sponsoring Agency Name and Address National Aeronautics and Space Adm. Langley Research Center Hampton, Virginia 23365			13. Type of Report and Period Covered		
			14. Sponsoring Agency Code		
15. Supplementary Notes					
16. Abstract The effectiveness of various vortex dissipation devices proposed for installation on or near aircraft runways is evaluated on basis of results of experiments conducted with a 0.03-scale model of a Boeing 747 Transport Aircraft in conjunction with a simulated runway. The test variables included type of vortex dissipation device, mode of operation of the powered devices, and altitude, lift coefficient and speed of the generating aircraft. A total of fifteen devices was investigated. The evaluation is based on time sequence photographs taken in the vertical and horizontal planes during each run.					
17. Key Words Suction and Blowing slots Dissipation device Distortion Vortex Trajectory			18. Distribution Statement Distribution of this report is provided in the interest of information exchange. Responsibility for the contents resides in the author or organization that prepared it.		
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page)		21. No. of Pages	22. Price

TABLE OF CONTENTS

	Page
INTRODUCTION.....	1
DESCRIPTION OF BASIC AIRCRAFT MODEL.....	2
DESCRIPTION OF RUNWAY AND VORTEX DISSIPATION DEVICES.....	2
TEST APPARATUS AND PROCEDURES.....	7
TEST PROGRAM.....	9
PRESENTATION AND DISCUSSION OF RESULTS.....	12
REFERENCES.....	16

LIST OF FIGURES

(Figures follow page 16 in sequence)

- Figure 1 - Basic Model of Boeing 747 Aircraft.....
- Figure 2 - Leading Edge Devices and Flaps for Flaps  
30 Configuration.....
- Figure 3 - Structural Details of False Bottom Module.....
- Figure 4 - Details of Model of Transverse Barrier.....
- Figure 5 - Details of Model of Longitudinal Barrier.....
- Figure 6 - Details of Model of Longitudinal Suction  
Slots.....
- Figure 7 - Details of Method Used to Block Off Portions  
of Suction Slot.....
- Figure 8 - Details of Model of Transverse Suction  
Slot.....
- Figure 9 - Details of Model of Longitudinal Blowing  
Slots.....
- Figure 10 - Removable Additions Made to Blowing Slots  
in an Attempt to Improve their Effectiveness..
- Figure 11 - Details of Model of Transverse Blowing  
Slots.....
- Figure 12 - Photographs of Various Vortex Dissipation  
Devices Installed on Runway.....
- Figure 13 - Cross Section of Photographic Test Section....
- Figure 14 - Bare Runway - Unaltered Vortex Wake for Flaps  
30 Condition,  $C_L = 1.70$  and Altitude = 13.4  
Meters.....

- Figure 15 - Bare Runway - Unaltered Vortex Wake for Flaps 30 Condition,  $C_L = 1.17$  and Altitude = 13.4 Meters.....
- Figure 16 - Bare Runway - Unaltered Vortex Wake for Flaps 30 Condition,  $C_L = 1.69$  and Altitude = 21.3 Meters.....
- Figure 17 - Bare Runway - Unaltered Vortex Wake for Flaps 30 Condition,  $C_L = 1.16$  and Altitude = 21.3 Meters.....
- Figure 18 - Bare Runway - Unaltered Vortex Wake for Flaps 30 Condition,  $C_L = 1.68$  and Altitude = 30.5 Meters.....
- Figure 19 - Bare Runway - Unaltered Vortex Wake for Flaps 30 Condition,  $C_L = 1.11$  and Altitude = 30.5 Meters.....
- Figure 20 - Device A-Effect on Vortex Wake for Flaps 30 Condition,  $C_L = 1.69$  and Altitude = 30.5 Meters.....
- Figure 21 - Device A-Effect on Vortex Wake for Flaps 30 Condition,  $C_L = 1.13$  and Altitude = 30.5 Meters.....
- Figure 22 - Device A-Effect on Vortex Wake for Flaps 30 Condition,  $C_L = 1.66$  and Altitude = 21.3 Meters.....
- Figure 23 - Device A-Effect on Vortex Wake for Flaps 30 Condition,  $C_L = 1.14$  and Altitude = 21.3 Meters.....
- Figure 24 - Device A-Effect on Vortex Wake for Cruise Condition,  $C_L = 0.96$  and Altitude = 30.5 Meters.....

- Figure 25 - Device B-Effect on Vortex Wake for Flaps 30  
Condition,  $C_L = 1.70$  and Altitude = 13.4  
Meters.....
- Figure 26 - Device B-Effect on Vortex Wake for Flaps 30  
Condition,  $C_L = 1.13$  and Altitude = 13.4  
Meters.....
- Figure 27 - Device B-Effect on Vortex Wake for Flaps 30  
Condition,  $C_L = 1.16$  and Altitude = 21.3  
Meters.....
- Figure 28 - Device B-Effect on Vortex Wake for Flaps 30  
Condition,  $C_L = 1.69$  and Altitude = 21.3  
Meters.....
- Figure 29 - Device B-Effect on Vortex Wake for Flaps 30  
Condition,  $C_L = 1.68$  and Altitude = 30.5  
Meters.....
- Figure 30 - Device B-Effect on Vortex Wake for Flaps 30  
Condition,  $C_L = 1.13$  and Altitude = 30.5  
Meters.....
- Figure 31 - Device C with  $V_s/U = 0.0898$  - Effect on  
Vortex Wake for Flaps 30 Condition,  
 $C_L = 1.79$  and Altitude = 30.5 Meters.....
- Figure 32 - Device C with  $V_s/U = 0.0718$  - Effect on  
Vortex Wake for Flaps 30 Condition,  
 $C_L = 1.75$  and Altitude = 30.5 Meters.....
- Figure 33 - Device C with  $V_s/U = 0.0598$  - Effect on  
Vortex Wake for Flaps 30 Condition,  
 $C_L = 1.79$  and Altitude = 30.5 Meters.....

- Figure 34 - Device C with  $V_s/U = 0.0479$  - Effect on  
Vortex Wake for Flaps 30 Condition,  
 $C_L = 1.68$  and Altitude = 30.5 Meters.....
- Figure 35 - Device C with  $V_s/U = 0.0898$  - Effect on  
Vortex Wake for Flaps 30 Condition,  
 $C_L = 1.77$  and Altitude = 13.4 Meters.....
- Figure 36 - Device C with  $V_s/U = 0.0718$  - Effect on  
Vortex Wake for Flaps 30 Condition,  
 $C_L = 1.75$  and Altitude = 13.4 Meters.....
- Figure 37 - Device C with  $V_s/U = 0.0598$  - Effect on  
Vortex Wake for Flaps 30 Condition,  
 $C_L = 1.81$  and Altitude = 13.4 Meters.....
- Figure 38 - Device C with  $V_s/U = 0.1197$  - Effect on  
Vortex Wake for Flaps 30 Condition,  
 $C_L = 1.77$  and Altitude = 13.4 Meters.....
- Figure 39 - Device C with  $V_s/U = 0.0598$  - Effect on  
Vortex Wake for Cruise Condition,  
 $C_L = 0.70$  and Altitude = 13.4 Meters.....
- Figure 40 - Device C1 with  $V_s/U = 0.1197$  - Effect on  
Vortex Wake for Flaps 30 Condition,  
 $C_L = 1.77$  and Altitude = 13.4 Meters.....
- Figure 41 - Device C1 with  $V_s/U = 0.0898$  - Effect on  
Vortex Wake for Flaps 30 Condition,  
 $C_L = 1.79$  and Altitude = 13.4 Meters.....

- Figure 42 - Device C1 with  $V_s/U = 0.0718$  - Effect on  
Vortex Wake for Flaps 30 Condition,  
 $C_L = 1.83$  and Altitude = 13.4 Meters.....
- Figure 43 - Device C1 with  $V_s/U = 0.0718$  - Effect on  
Vortex Wake for Flaps 30 Condition,  
 $C_L = 1.83$  and Altitude = 30.5 Meters.....
- Figure 44 - Device C1 with  $V_s/U = 0.0898$  - Effect on  
Vortex Wake for Flaps 30 Condition,  
 $C_L = 1.79$  and Altitude = 30.5 Meters.....
- Figure 45 - Device C1 with  $V_s/U = 0.1197$  - Effect on  
Vortex Wake for Flaps 30 Condition,  
 $C_L = 1.77$  and Altitude = 30.5 Meters.....
- Figure 46 - Device C2 with  $V_s/U = 0.1625$  - Effect on  
Vortex Wake for Flaps 30 Condition,  
 $C_L = 1.79$  and Altitude = 30.5 Meters.....
- Figure 47 - Device D with  $V_s/U = 0.0898$  - Effect on  
Vortex Wake for Flaps 30 Condition,  
 $C_L = 1.79$  and Altitude = 13.4 Meters.....
- Figure 48 - Device D with  $V_s/U = 0.0898$  - Effect on  
Vortex Wake for Flaps 30 Condition,  
 $C_L = 1.77$  and Altitude = 30.5 Meters.....
- Figure 49 - Device E with  $V_b/U = 0.1617$  - Effect on  
Vortex Wake for Cruise Condition,  
 $C_L = 0.67$  and Altitude = 30.5 Meters.....
- Figure 50 - Device E1 with  $V_b/U = 0.1617$  - Effect on  
Vortex Wake for Cruise Condition,  
 $C_L = 0.67$  and Altitude = 30.5 Meters.....

- Figure 51 - Device E2 with  $V_b/U = 0.270$  - Effect on Vortex Wake for Cruise Condition,  $C_L = 0.67$  and Altitude = 30.5 Meters.....
- Figure 52 - Device E3 with  $V_b/U = 0.270$  - Effect on Vortex Wake for Cruise Condition,  $C_L = 0.67$  and Altitude = 30.5 Meters.....
- Figure 53 - Device E4 with  $V_b/U = 0.270$  - Effect on Vortex Wake for Cruise Condition,  $C_L = 0.67$  and Altitude = 30.5 Meters.....
- Figure 54 - Device E5 with  $V_b/U = 0.270$  - Effect on Vortex Wake for Cruise Condition,  $C_L = 0.67$  and Altitude = 30.5 Meters.....
- Figure 55 - Device F with  $V_s/U = 0.408$ ,  $V_b/U = 0.270$  - Effect on Vortex Wake for Cruise Condition,  $C_L = 0.67$  and Altitude = 30.5 Meters.....
- Figure 56 - Device F with  $V_s/U = 0.408$ ,  $V_b/U = 0.270$  - Effect on Vortex Wake for Flaps 30 Condition,  $C_L = 1.80$  and Altitude = 13.4 Meters.....
- Figure 57 - Device F with  $V_s/U = 0.490$ ,  $V_b/U = 0.324$  - Effect on Vortex Wake for Flaps 30 Condition,  $C_L = 1.81$  and Altitude = 13.4 Meters.....
- Figure 58 - Device F with  $V_s/U = 0.613$ ,  $V_b/U = 0.405$  - Effect on Vortex Wake for Flaps 30 Condition,  $C_L = 1.77$  and Altitude = 13.4 Meters.....
- Figure 59 - Device F with  $V_s/U = 0.327$ ,  $V_b/U = 0.216$  - Effect on Vortex Wake for Flaps 30 Condition,  $C_L = 1.68$  and Altitude = 13.4 Meters.....

- Figure 60 - Device F with  $V_s/U = 0.490$ ,  $V_b/U = 0.324$  -  
Effect on Vortex Wake for Flaps 30 Condition,  
 $C_L = 1.75$  and Altitude = 30.5 Meters.....
- Figure 61 - Device F with  $V_s/U = 0.613$ ,  $V_b/U = 0.405$  -  
Effect on Vortex Wake for Flaps 30 Condition,  
 $C_L = 1.79$  and Altitude = 30.5 Meters.....
- Figure 62 - Device F with  $V_s/U = 0.327$ ,  $V_b/U = 0.216$  -  
Effect on Vortex Wake for Flaps 30 Condition,  
 $C_L = 1.65$  and Altitude = 30.5 Meters.....
- Figure 63 - Device F with  $V_s/U = 0.408$ ,  $V_b/U = 0.270$  -  
Effect on Vortex Wake for Flaps 30 Condition,  
 $C_L = 1.80$  and Altitude = 30.5 Meters.....
- Figure 64 - Device F1 with  $V_s/U = 0.408$ ,  $V_b/U = 0.270$  -  
Effect on Vortex Wake for Cruise Condition,  
 $C_L = 0.67$  and Altitude = 30.5 Meters.....
- Figure 65 - Device F1 with  $V_s/U = 0.408$ ,  $V_b/U = 0.270$  -  
Effect on Vortex Wake for Flaps 30 Condition,  
 $C_L = 1.77$  and Altitude = 30.5 Meters.....
- Figure 66 - Device F1 with  $V_s/U = 0.490$ ,  $V_b/U = 0.324$  -  
Effect on Vortex Wake for Flaps 30 Condition,  
 $C_L = 1.83$  and Altitude = 30.5 Meters.....
- Figure 67 - Device F1 with  $V_s/U = 0.613$ ,  $V_b/U = 0.405$  -  
Effect on Vortex Wake for Flaps 30 Condition,  
 $C_L = 1.67$  and Altitude = 30.5 Meters.....
- Figure 68 - Device F1 with  $V_s/U = 0.327$ ,  $V_b/U = 0.216$  -  
Effect on Vortex Wake for Flaps 30 Condition,  
 $C_L = 1.65$  and Altitude = 30.5 Meters.....

- Figure 69 - Device F1 with  $V_s/U = 0.408$ ,  $V_b/U = 0.270$  -  
Effect on Vortex Wake for Flaps 30 Condition,  
 $C_L = 1.80$  and Altitude = 13.4 Meters.....
- Figure 70 - Device F1 with  $V_s/U = 0.490$ ,  $V_b/U = 0.324$  -  
Effect on Vortex Wake for Flaps 30 Condition,  
 $C_L = 1.81$  and Altitude = 13.4 Meters.....
- Figure 71 - Device F1 with  $V_s/U = 0.613$ ,  $V_b/U = 0.405$  -  
Effect on Vortex Wake for Flaps 30 Condition,  
 $C_L = 1.78$  and Altitude = 13.4 Meters.....
- Figure 72 - Device G with  $V_b/U = 0.129$  - Effect on  
Vortex Wake for Flaps 30 Condition,  
 $C_L = 1.67$  and Altitude = 30.5 Meters.....
- Figure 73 - Device G with  $V_b/U = 0.194$  - Effect on  
Vortex Wake for Flaps 30 Condition,  
 $C_L = 1.82$  and Altitude = 30.5 Meters.....
- Figure 74 - Device G with  $V_b/U = 0.194$  - Effect on  
Vortex Wake for Flaps 30 Condition,  
 $C_L = 1.82$  and Altitude = 13.4 Meters.....
- Figure 75 - Device G with  $V_b/U = 0.129$  - Effect on  
Vortex Wake for Flaps 30 Condition,  
 $C_L = 1.68$  and Altitude = 13.4 Meters.....
- Figure 76 - Device G with  $V_b/U = 0.323$  - Effect on  
Vortex Wake for Flaps 30 Condition,  
 $C_L = 1.76$  and Altitude = 13.4 Meters.....

- Figure 77 - Device G1 with  $V_b/U = 0.162$  - Effect on Vortex Wake for Cruise Condition,  $C_L = 0.71$  and Altitude = 13.4 Meters.....
- Figure 78 - Device G1 with  $V_b/U = 0.129$  - Effect on Vortex Wake for Flaps 30 Condition,  $C_L = 1.68$  and Altitude = 13.4 Meters.....
- Figure 79 - Device G1 with  $V_b/U = 0.162$  - Effect on Vortex Wake for Flaps 30 Condition,  $C_L = 1.81$  and Altitude = 13.4 Meters.....
- Figure 80 - Device G1 with  $V_b/U = 0.194$  - Effect on Vortex Wake for Flaps 30 Condition,  $C_L = 1.83$  and Altitude = 13.4 Meters.....
- Figure 81 - Device G1 with  $V_b/U = 0.243$  - Effect on Vortex Wake for Flaps 30 Condition,  $C_L = 1.80$  and Altitude = 13.4 Meters.....
- Figure 82 - Device G1 with  $V_b/U = 0.129$  - Effect on Vortex Wake for Flaps 30 Condition,  $C_L = 1.68$  and Altitude = 30.5 Meters.....
- Figure 83 - Device G1 with  $V_b/U = 0.162$  - Effect on Vortex Wake for Flaps 30 Condition,  $C_L = 1.79$  and Altitude = 30.5 Meters.....
- Figure 84 - Device G1 with  $V_b/U = 0.194$  - Effect on Vortex Wake for Flaps 30 Condition,  $C_L = 1.80$  and Altitude = 30.5 Meters.....
- Figure 85 - Device G1 with  $V_b/U = 0.243$  - Effect on Vortex Wake for Flaps 30 Condition,  $C_L = 1.79$  and Altitude = 30.5 Meters.....

Figure 86 - Device G2 with  $V_D/U = 0.270$  - Effect on  
Vortex Wake for Cruise Condition,  
 $C_L = 0.70$  and Altitude = 13.4 Meters.....

## INTRODUCTION

HYDRONAUTICS, Incorporated was requested to conduct a comprehensive program of model experiments to investigate the feasibility of various devices proposed for installation on or near aircraft runways (References 1 and 2). The primary objective of this program was to evaluate these devices from the standpoint of their ability to dissipate trailing vortices in the vicinity of airports caused by takeoff and landing of aircraft.

The subject investigation is part of a broad overall program currently underway dealing with the problem of trailing vortices generated by large aircraft including the development of practical means for dissipating their effects which could be hazardous to following aircraft. Related experimental programs conducted by HYDRONAUTICS in this respect are those of References 3 and 4.

To accomplish the objectives of the subject program, tests were conducted in the HYDRONAUTICS Ship Model Basin (HSMB®) with the existing 0.03-scale model of the Boeing 747 Transport Aircraft in conjunction with a simulated runway using the experimental techniques developed for the investigations of References 3 and 4. The test variables included type of vortex dissipation device, mode of operation of the powered devices, and altitude, lift coefficient and speed of the generating aircraft. A total of fifteen different devices was investigated.

This report describes the aircraft model, simulated runway, vortex dissipation devices and test apparatus; outlines the procedures used in the experiments; summarizes the test program; and presents the test results principally in the form of time sequence photographs. The test results are also summarized in tabular form and are briefly discussed. In addition, a brief examination is made of the full-scale power requirements for some of the powered devices.

#### DESCRIPTION OF BASIC AIRCRAFT MODEL

The existing 0.03-scale model of the Boeing 747 Transport Aircraft was used for the subject experimental program. Figure 1 shows the basic model in a configuration representing the Cruise Condition and Figure 2 shows the model with the leading edge devices and flaps attached to represent the Flaps 30 Condition. Model and prototype details are given in Reference 4.

#### DESCRIPTION OF RUNWAY AND VORTEX DISSIPATION DEVICES

Components of the existing HSMB false bottom were assembled to simulate the basic aircraft runway as well as to provide a quick means for installing and removing models of the alternative vortex dissipation devices. The assembly consisted of six 4.88 m wide by 3.05 m long false-bottom modules joined together for a total model runway length of 29.28 m. The structural details of an individual module are shown by the photographs in Figure 3. Each of the modules is a self-contained floodable unit fabricated of galvanized steel trusses and flotation tanks

and decked with 1.0-inch thick fir marine plywood. Each module is also equipped with outrigger supports to carry the decking needed to cover the space between the edge of the module and the basin wall. The six modules used were launched individually, sunk by venting the flotation tanks by hose connection to the atmosphere, and towed by the carriage into position in the test section. Once positioned, the modules were bolted together at their flanged connections so that the longitudinal beams were structurally continuous. A 16 gage aluminum sheet was used as decking between the edges of the modules and the basin walls.

The various vortex dissipation devices investigated are described by means of Table 1 which also indicates their principle of operation and makes reference to the figures where the details of each device can be seen. The devices designated only by a letter represent the systems as originally conceived and designed, whereas those designated by a letter-number combination represent changes in mode of operation and/or additions to the original devices. The philosophy of these changes is discussed in the section on Test Program. Including all combinations, a total of 15 different devices was tested.

TABLE 1  
Vortex Dissipation Devices Tested

Designation	Type	Description and Principle of Operation	Fig. Showing Model Details
A	Solid Transverse Barrier	A rectangular solid fence situated across the runway designed to disrupt the axial flow of the vortex and thus produce rapid growth of the cores and general disarrangement of the high energy centers.	4
B	Longitudinal Barriers	Intermittent fences representing landscaping situated along the sides of the runway which are intended to either constrain or disrupt the vortex system by proximity to or passage over the barriers.	5
C	Longitudinal Suction Slots	Consists of rectangular slots situated along each side of the runway. Suction supplied to alter the normal vortex trajectories so that the vortices are drawn into the slots or at least close to the ground where they will quickly dissipate their energy.	6
C1	Intermittent Longitudinal Suction Slots	Same as Device C except that the slot length along each side of the runway is divided into 6 equal sections and fluid is only drawn into every other section. The remaining sections are blocked off. The scheme here is to generate an uneven flow which would distort the vortex trails as well as alter their trajectories.	6 and 7
C2	Intermittent Longitudinal Suction Slots	Same as Device C except that the slot length is divided into 12 equal sections with fluid only drawn into every other section while the remaining sections are blocked off. Principle is same as for Device C1.	6 and 7
D	Transverse Suction Slot	Consists of rectangular slot situated across the runway. As with Device C1 suction is applied to draw the vortices either into the slot or near the ground.	8

TABLE 1-(Continued)

Designation	Type	Description and Principle of Operation	Fig. Showing Model Details
E	Longitudinal Blowing Slots	A system in which fluid is discharged vertically upward through rectangular slots located along each side of the runway thus creating jet sheets which are designed to constrain the vortices laterally until their energy is dissipated.	9
E1	Intermittent Longitudinal Blowing Slots	Same as E except that the slot length along each side of the runway is divided into 24 equal sections, and fluid is only discharged through every other section; the remaining sections are blocked off. The object is to generate uneven flow to distort as well as constrain the vortex trails.	9 and 10
E2	Intermittent Longitudinal Blowing Slots	Same as Device E except that the slot lengths are divided into 12 equal sections with fluid only discharged through every other section while the remaining sections are blocked off. The principle is the same as for Device E1.	9 and 10
E3	Intermittent Longitudinal Blowing Slots	Same as Device E except that the slot lengths are divided into 12 equal sections with fluid only discharged through the second, sixth and tenth sections (downstream to upstream) while the remaining sections are blocked off. Principle is the same as for Device E1.	9 and 10
E4	Intermittent Longitudinal Blowing Slots	Same as Device E2 except that a 45° deflector is located at the nozzle outlet to direct the jet flow more toward the center of the runway. The purpose of changing the jet flow direction is to constrain the vortices vertically as well as laterally, and thus hasten vortex disruption.	9 and 10
E5	Intermittent Longitudinal Blowing Slots	This device is the same as E4 except that fluid is discharged as noted for Device E3.	9 and 10

TABLE 1 (Concluded)

Designation	Type	Description and Principle of Operation	Fig. Showing Model Details
F	Alternate-Intermittent Longitudinal Suction Slots and Blowing Slots	A system incorporating powering equipment for both suction and blowing through slots located along each side of the runway. The slot lengths are divided into 12 equal sections. The first section is blocked off; fluid is drawn into the second section; the third section is blocked off; and fluid is discharged through the fourth section. This pattern is repeated for the entire slot lengths. The flow reversal in combination with gaps in the jet sheet are designed to cause large distortion of the vortex trails.	9 and 10
F1	Alternate-Intermittent Longitudinal Suction Slots and Blowing Slots	This device is the same as F except that a 45° deflector is located at the nozzle opening. The purpose of the deflector is the same as described in F4.	9 and 10
G	Transverse Blowing Slots	A system in which fluid is discharged through a slot located across the runway. The jet sheet thus directed is intended to disrupt the axial flow of the vortex trails thus producing rapid growth and disarrangement of the high energy cores.	11
G1	Transverse Blowing Slots	Same as Device G except that a 45° deflector is located at the nozzle outlet angling the jet sheet upstream to produce a component of jet sheet velocity opposite to the vortex axial flow with the intention of providing more efficient vortex disruption.	11 and 10
G2	Intermittent Transverse Blowing Slots	Same as Device G1 except that the slot length is divided into 4 equal sections and fluid is only discharged through the two outermost sections. Since the vortices move away from the centerline of the runway there is no need for a jet in the central area.	11 and 10

For the active vortex dissipation devices which employed suction and blowing slots (Devices C through H), the pumping system consisted of standard DC motor-driven outboard propellers located in 0.15 m diameter cylindrical ducts and attached to each nozzle section (See Figure 6). Standard battery chargers were used as the power source for the motors. Changing from suction to blowing was accomplished simply by reversing the rotation of the propellers by changing polarity of the input to the DC motors. The ranges of velocities and flow rates developed in the blowing and suction slots are presented in full-scale dimensions in Table 2 in the section on Test Program.

Photographs of several of the devices installed on the runway are presented in Figure 12.

#### TEST APPARATUS AND PROCEDURES

All of the experiments for the subject investigation were conducted in the HYDRONAUTICS Ship Model Basin (HSMB). Details of the model basin, towing carriage, force measurement system and flow visualization system normally used for trailing vortex studies are given in Reference 4. However, in the present case, it was necessary to make several changes in the photographic test section to accommodate installation of the false bottom. Briefly the changes consisted of moving the vertical photographic grid and lighting system up against the basin walls. A revision in the design of the light support system was required to position the lights as needed. Figure 13 shows the revised arrangement of the photographic test section.

Also, it was necessary to use the tilt table support system of the HSMB Planar Motion Mechanism in lieu of that shown in Reference 4. This was necessary to provide the longer tow struts and thus the depth and altitude range required for the runway experiments.

The test procedures followed in the present investigation were generally similar to those developed during earlier vortex studies in HSMB (References 3 and 4). The specific procedure used for a typical test run involving either the basic runway or the runway equipped with one of the vortex dissipation devices was as follows:

1. With the towing carriage at rest, the aircraft model was set at an angle of attack necessary to provide the desired lift coefficient  $C_L$  and at the desired altitude above the runway.
2. The towing carriage was then accelerated until it reached the prescribed constant speed and, as the model entered the photographic section, dye was ejected from its wingtip at the pressure required to make the dye speed about equal to the model speed.
3. Sequential photographs were initiated at the time the model entered the central portion of the photographic section and were maintained until the dye trace had essentially dissipated.

In the case of the powered devices, the pumping system was energized just as the model passed over the center of the runway. The reason for attempting to match the dye ejection speed with the model speed was to minimize any possible effect of the dye stream on the vortex. Further, as determined during previous experiments, the dye concentration was set to provide a solution which was as close to neutrally buoyant as practical.

#### TEST PROGRAM

The test program for the subject investigation was carried out in accordance with the broad framework established by the Contract of Reference 1. The test philosophy, as specified in this contract, was to examine in detail only those devices which, after a cursory examination, showed promise. In addition, by mutual agreement between personnel of NASA Langley Research Center and HYDRONAUTICS, certain changes in the mode of operation and additions to the powered devices were made in an effort to enhance their vortex dissipation effectiveness (See section on Description of Runway and Vortex Dissipation Devices).

The test program as it finally evolved is presented in Table 2 which lists the vortex dissipation device, the aircraft lift coefficient and altitude above the runway, the configuration of the basic aircraft, the velocity ratio (defined as the ratio of velocity through suction and/or blowing slots to model speed) for the powered devices, and the velocity and flow rate (converted to full scale) through the suction and/or blowing slots.

TABLE 2  
Test Program

Device	$C_L$	Aircraft Altitude meters	Aircraft Configuration	$\frac{V_s}{U}$	$\frac{V_b}{U}$	$V_b$ m/sec	$V_s$ m/sec	$Q_b$ $m^3/sec$	$Q_s$ $m^3/sec$
None	1.70	13.4	Flaps 30						
None	1.17	13.4	Flaps 30						
None	1.69	21.3	Flaps 30						
None	1.16	21.3	Flaps 30						
None	1.68	30.5	Flaps 30						
None	1.11	30.5	Flaps 30						
A	1.69	30.5	Flaps 30						
A	1.13	30.5	Flaps 30						
A	1.66	21.3	Flaps 30						
A	1.14	21.3	Flaps 30						
A	0.95	30.5	Cruise						
B	1.70	13.4	Flaps 30						
B	1.13	13.4	Flaps 30						
B	1.16	21.3	Flaps 30						
B	1.69	21.3	Flaps 30						
B	1.68	30.5	Flaps 30						
B	1.13	30.5	Flaps 30						
C	1.79	30.5	Flaps 30	0.0898			6.84		10,590
C	1.75	30.5	Flaps 30	0.0718			6.08		9,400
C	1.79	30.5	Flaps 30	0.0598			4.56		7,050
C	1.68	30.5	Flaps 30	0.0479			3.65		5,660
C	1.77	13.4	Flaps 30	0.0898			6.84		10,590
C	1.75	13.4	Flaps 30	0.0718			6.08		9,400
C	1.81	13.4	Flaps 30	0.0598			4.56		7,050
C	1.77	13.4	Flaps 30	0.1197			9.12		14,130
C	0.70	13.4	Cruise	0.0598			4.56		7,050
C1	1.77	13.4	Flaps 30	0.1197			9.12		7,050
C1	1.79	13.4	Flaps 30	0.0898			6.84		5,300
C1	1.83	13.4	Flaps 30	0.0718			6.08		4,700
C1	1.83	30.5	Flaps 30	0.0718			6.08		4,700
C1	1.79	30.5	Flaps 30	0.0898			6.84		5,300
C1	1.77	30.5	Flaps 30	0.1197			9.12		7,050
C2	1.79	30.5	Flaps 30	0.1625			12.38		9,600
D	1.79	13.4	Flaps 30	0.0898			6.84		1,760
D	1.77	30.5	Flaps 30	0.0898			6.84		1,760

TABLE 2 (Concluded)

Device	$C_L$	Aircraft Altitude meters	Aircraft Configuration	$\frac{V_s}{U}$	$\frac{V_b}{U}$	$V_b$ m/sec	$V_s$ m/sec	$Q_b$ m <sup>3</sup> /sec	$Q_s$ m <sup>3</sup> /sec
E	0.67	30.5	Cruise		0.1617	12.32		3170.	
E1	0.67	30.5	Cruise		0.1617	12.32		1590.	
E2	0.67	30.5	Cruise		0.270	20.57		2700.	
E3	0.67	30.5	Cruise		0.270	20.57		1330.	
E4	0.67	30.5	Cruise		0.270	20.57		2700.	
E5	0.67	30.5	Cruise		0.270	20.57		1330.	
F	0.67	30.5	Cruise	0.408	0.270	20.57	31.12	1330.	2010
F	1.80	13.4	Flaps 30	0.408	0.270	20.57	31.12	1330.	2010
F	1.81	13.4	Flaps 30	0.490	0.324	24.69	37.34	1590.	2400
F	1.77	13.4	Flaps 30	0.613	0.405	30.88	46.67	1980.	3000
F	1.68	13.4	Flaps 30	0.327	0.215	16.46	24.90	1080.	1610
F	1.75	30.5	Flaps 30	0.490	0.324	24.69	37.34	1590.	2400
F	1.79	30.5	Flaps 30	0.613	0.405	30.88	46.67	1980.	3000
F	1.65	30.5	Flaps 30	0.327	0.215	16.46	24.9	1080.	1610
F	1.80	30.5	Flaps 30	0.408	0.270	20.57	31.12	1330.	2010
F1	0.67	30.5	Cruise	0.408	0.270	20.57	31.12	1330.	2010
F1	1.77	30.5	Flaps 30	0.408	0.270	20.57	31.12	1330.	2010
F1	1.83	30.5	Flaps 30	0.490	0.324	24.69	37.34	1590.	2400
F1	1.67	30.5	Flaps 30	0.613	0.405	30.88	46.67	1980.	3000
F1	1.65	30.5	Flaps 30	0.327	0.215	16.46	24.90	1080.	1610
F1	1.80	13.4	Flaps 30	0.408	0.270	20.57	31.12	1330.	2010
F1	1.81	13.4	Flaps 30	0.490	0.324	24.69	37.34	1590.	2400
F1	1.78	13.4	Flaps 30	0.613	0.405	30.88	46.67	1980.	3000
G	1.67	30.5	Flaps 30		0.129	9.85		425.	
G	1.82	30.5	Flaps 30		0.194	14.78		623.	
G	1.82	13.4	Flaps 30		0.194	14.78		623.	
G	1.68	13.4	Flaps 30		0.129	9.85		425.	
G	1.76	13.4	Flaps 30		0.323	24.63		1050.	
G1	0.71	13.4	Cruise		0.162	12.32		538.	
G1	1.68	13.4	Flaps 30		0.129	9.85		425.	
G1	1.81	13.4	Flaps 30		0.162	12.32		538.	
G1	1.83	13.4	Flaps 30		0.194	14.78		623.	
G1	1.80	13.4	Flaps 30		0.243	18.47		793.	
G1	1.68	30.5	Flaps 30		0.129	9.85		425.	
G1	1.79	30.5	Flaps 30		0.162	12.32		538.	
G1	1.80	30.5	Flaps 30		0.194	14.78		623.	
G1	1.79	30.5	Flaps 30		0.243	18.47		793.	
G2	0.70	13.4	Cruise		0.27	20.57		453.	

Notes: All dimensional quantities are for full scale.

$V_s$  = Fluid velocity through slot (Suction).

$V_b$  = Fluid velocity through slot (Blowing).

$U$  = Aircraft speed; assumed landing speed = 76.2 m/sec.

$Q_s$  = Flow rate through slot (Suction).

$Q_o$  = Flow rate through slot (Blowing).

## PRESENTATION AND DISCUSSION OF RESULTS

To permit independent evaluation, the results of each of the test runs listed in Table 2 are presented in the form of a series of time sequence photographs in Figures 14 through 88. These photographs show the vortex behavior, as indicated by the dye traces, from the time the model enters the cameras' field of view until either the dye dissipates or the vortex moves beyond the influence of the vortex dissipation device. Two simultaneous views, of the vortex are presented side by side; one from the side looking across the runway and one from the top looking down on the right wing.

Because the model speed and picture frame rate varied from run to run, a method of normalizing the time elapsed corresponding to each pair of frames was adopted, and is shown by the numerals between each pair of photographs in each of the figures. The normalized time (or period)  $N$  is defined as the time required for the aircraft to travel a distance of one wing-span at any given aircraft speed. The starting point or "zero time" for all cases is defined as the instant the wingtip reaches the reference line on the runway (center of the viewing area) which appears as a heavy line on the first pair of pictures in each group. Each case is represented by eight pairs of frames selected to best define the vortex behavior covering the time of interest.

The test results illustrated by Figures 14 through 88 are summarized by Table 3 which gives a brief qualitative appraisal of the relative effectiveness of the various vortex dissipation devices tested. The evaluations were made on basis of a careful examination of the original 35 mm color film strip records and, to some extent, on direct observations made during the tests. In this respect, it should be mentioned that, although the black and white reprints presented are clear, the contrast between the dye traces cannot be expected to be as sharp as with the original color film.

In considering the practical aspects of the slot suction and blowing systems, it is necessary to calculate the size and power of the full-scale airport installations corresponding to the model test systems. Extrapolation to full scale is easily made by increasing all model dimensions in accordance with a linear scale ratio of  $33\frac{1}{3}$ , and increasing all velocities by the ratio of full-scale flight speed to model test speed. The largest, most powerful and most costly ground system will result therefore when the model speed is least. Full-scale flight conditions are taken as typical for the landing of a Boeing 747 at a lift coefficient of 1.8 and flight speed of 118 knots. The system which appeared to be most effective as a vortex disruptor consisted of alternate blowing and suction slots along the edge of the runway. For this configuration, the primary power loss occurs in the lost kinetic energy of the jet, provided of course, suitably large ducts are used to convey the air from the suction slots to the blowing slots. The scaled up model system would have

the following characteristics based on the model test velocity of 4.7 knots: (1) a series of ten modular fan and duct units extending perhaps 500 meters along each edge of the runway, (2) modular duct units having 50 meters of suction slot and 50 meters of blowing slots, (3) a connecting duct and fan system reaching 6 meters in diameter and requiring less than 750 horsepower per duct and (4) a total horsepower requirement of 7500. It would be possible to make some trade-offs between power and duct size and hence cost; however, the duct and fan diameter could not be drastically reduced over that given above without incurring substantial power increases.

A comparison of the system represented at landing conditions of the Boeing 747 and model test speeds of 7.1 knots (12 ft/sec) would result in a marked reduction in power required to 250 horsepower per unit if the 6 meter duct is retained. Clearly for this case, a cost trade-off analysis would lead to a higher power figure and a reduced size and cost of the in-ground duct system. It appears possible that some system of this type could be built incorporating heaters to be used as fog dispersal units in a manner successfully demonstrated at the Orly Airport in France. It can only be conjectured at this point whether such a combined system would be economically justified.

TABLE 3

## Evaluation of Relative Effectiveness of Various Vortex Dissipation Devices Tested

(Evaluations are based on photographic records and direct underwater observations made visually during the tests)

Device	Adjective Rating	Brief Description
A	Slightly Effective	Vortex for both lift coefficients intersected the barrier in the 21.3-meter altitude case resulting in localized separation with consequent localized disruption of the vortex trail. Vortex did not actually contact barrier in 30.5-meter altitude case but was distorted somewhat and then tended to recover its original form once past the barrier. (Figures 20 through 24).
B	Effective	Vortex was essentially constrained between the barriers. (Figures 25 through 30).
C, C1, C2	Ineffective	Vortex trajectory apparently was not influenced by the flow being drawn into suction slots for any of the conditions tested but a slight dispersion of the vortex was observed as it passed over the slot nozzle. (Figures 31 through 46).
D	Ineffective	Vortex was essentially unaffected by the device for all conditions tested. (Figures 47 and 48).
E	Moderately Effective	Vortex did not penetrate the jet sheet and was carried upward with it. (Figure 49).
E1, E2, E3	Moderately Effective	Vortex did not penetrate intermittent jet sheet; oscillatory distortions of various periods and amplitudes depending on magnitudes of suction and blowing velocity ratios were produced in the vortex trail which was carried upward by the jet. The greatest distortions and consequently the quickest vortex disruptions were produced by the highest blowing velocity ratios. (Figures 50 through 52).
E4, E5	Moderately Effective	Vortex behavior was essentially the same as that produced by Devices E1, E2, and E3 except that vortex moved toward center of runway as well as upward. (Figures 53 and 54).
F, F1	Effective	Vortex was essentially constrained from moving laterally with relatively large oscillatory distortions leading to disruption of the vortex trail being produced. (Figures 55 through 71).
G	Moderately Effective	Distortion, localized separation, and disruption of the vortex, becoming progressively more pronounced at the higher velocity ratios, were produced by the jet sheet in the 13.4-meter altitude case, but vortex was unaffected in the 30.5-meter altitude case. (Figures 72 through 76).
G1	Moderately Effective	Distortion, localized separation, and disruption of the vortex were produced by the jet sheet in both altitude cases; the most pronounced effects being at the higher velocity ratios. (Figures 77 through 85).
G2	Ineffective	Some distortion of the vortex was produced but without separation or breakup. (Figure 86).

Note: The most rapid dissipation of the vortex trail was produced in order by Devices B and F1.

REFERENCES

1. National Aeronautics and Space Administration, Langley Research Center Contract No. NAS1-11389.
2. HYDRONAUTICS, Incorporated Proposal entitled "Experimental Evaluation of Devices Proposed for Installation on or near Runways to Dissipate Aircraft Trailing Vortex Effects in Vicinity of Airports," Submitted to NASA Langley Research Center, 25 August 1972.
3. Miller, E. R., Jr. and Brown, C. E., "An Experimental Study of Trailing Vortex Wakes Using a Large Towing Tank," HYDRONAUTICS, Incorporated Technical Report 7105-1, August 1971.
4. Kirkman, K. L., Brown, C. E., and Goodman, A., "Evaluation of Effectiveness of Various Devices for Attenuation of Trailing Vortices Based on Model Tests in a Large Towing Basin," HYDRONAUTICS, Incorporated Technical Report 7207-1, January 1972.

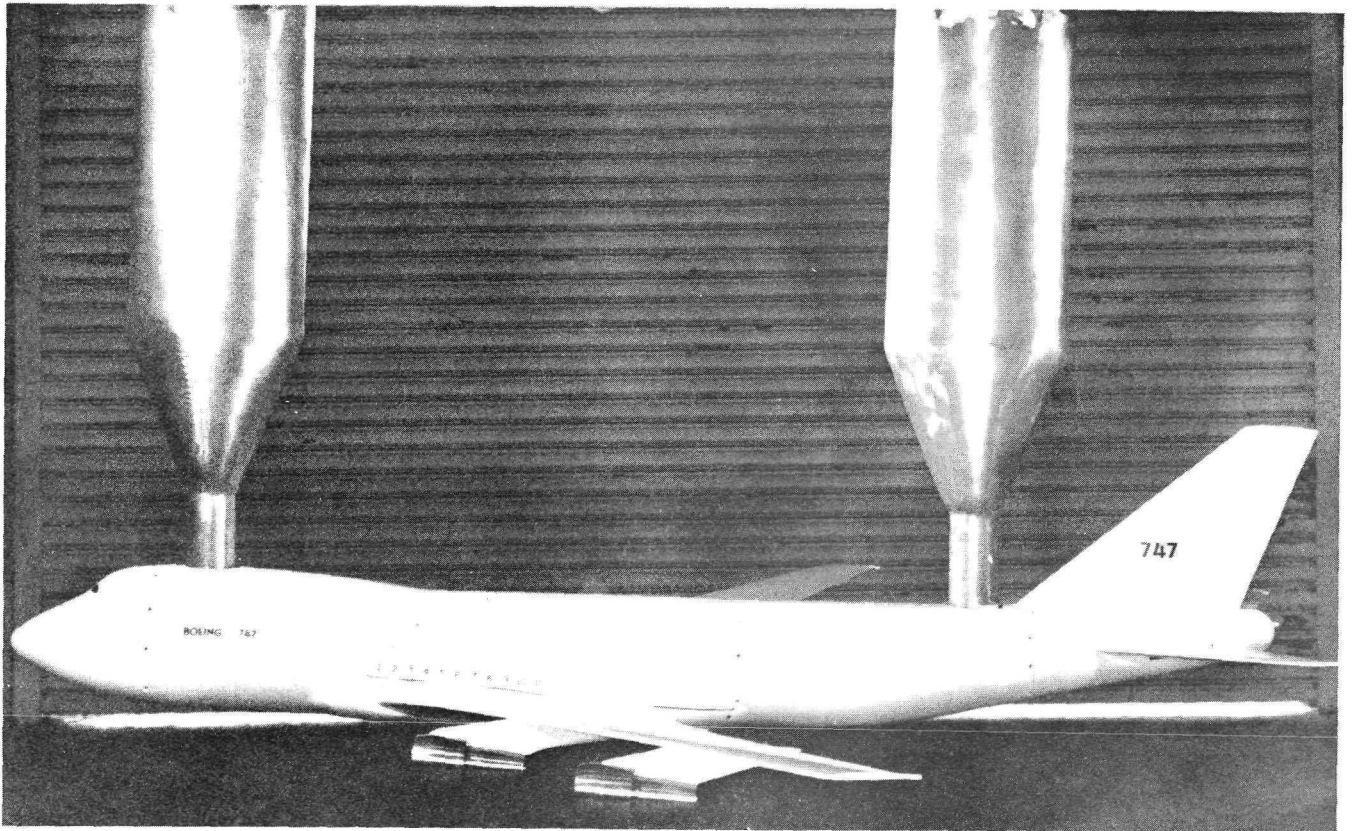
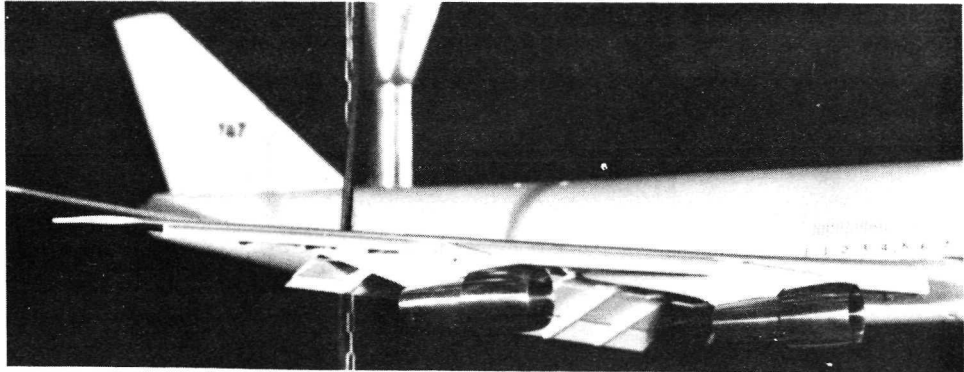
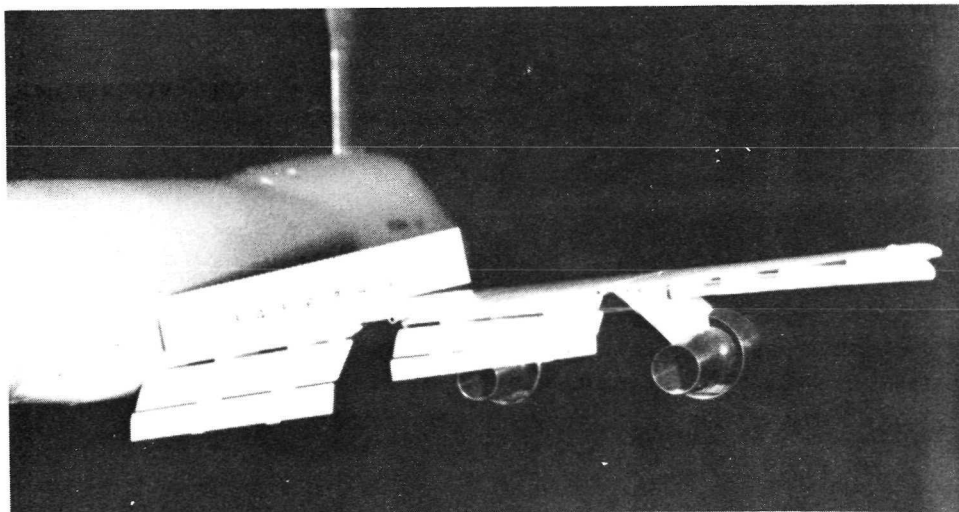


FIGURE 1 - BASIC MODEL OF BOEING 747 AIRCRAFT

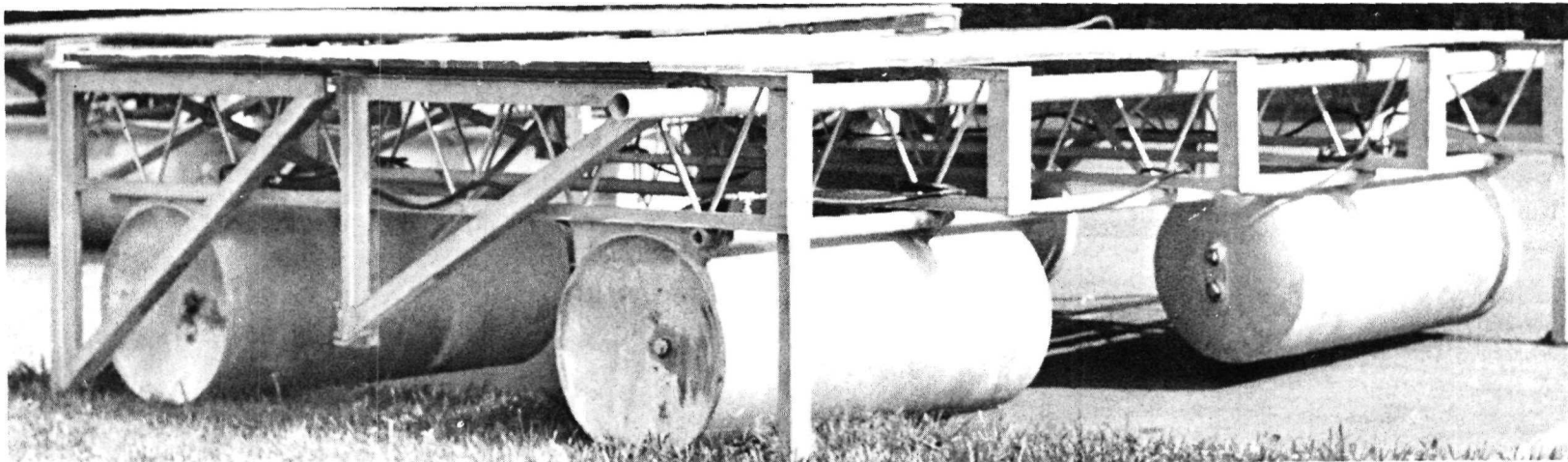


LEADING EDGE DEVICES

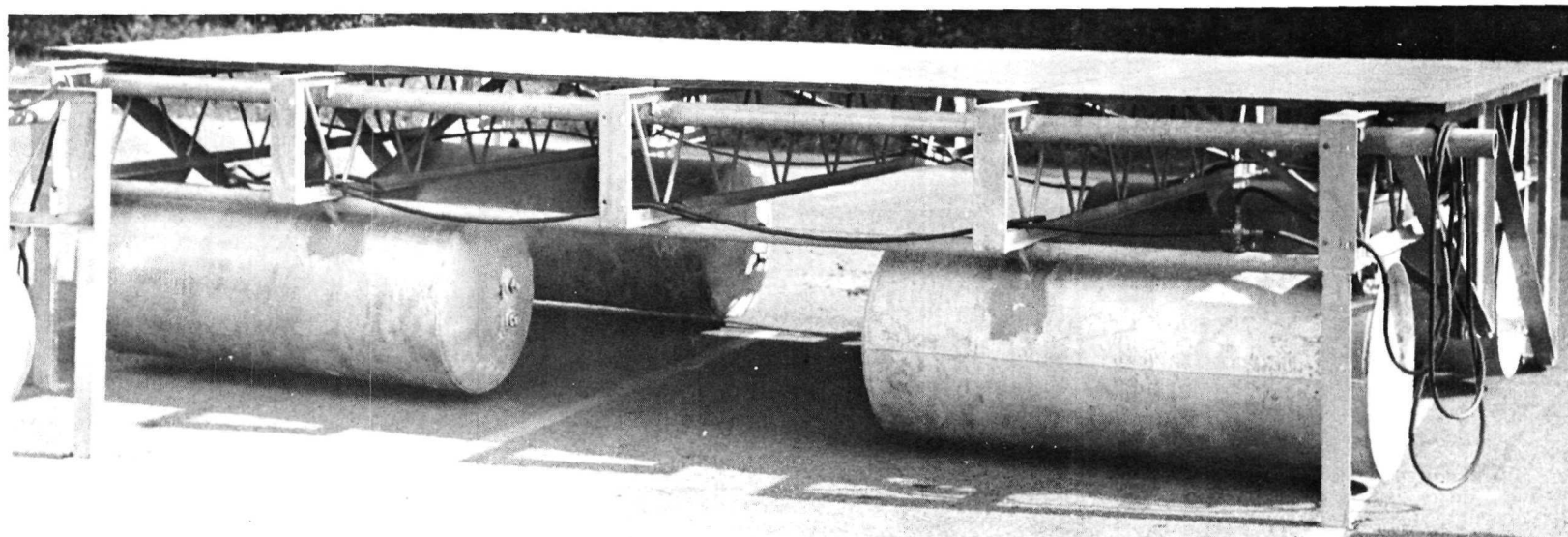


FLAPS

FIGURE 2 - LEADING EDGE DEVICES AND FLAPS FOR FLAPS 30 CONFIGURATION

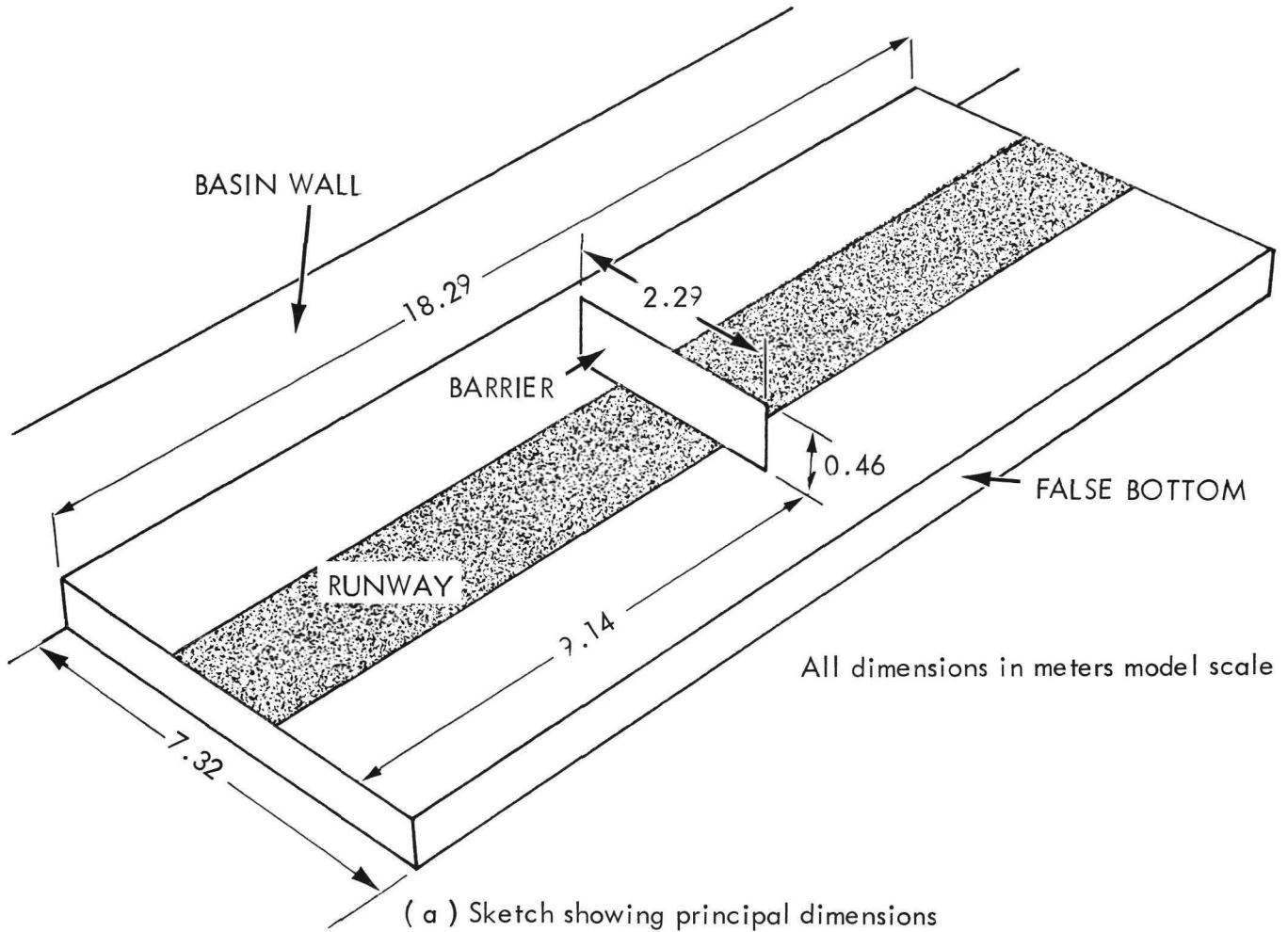


(a) SIDE DETAIL



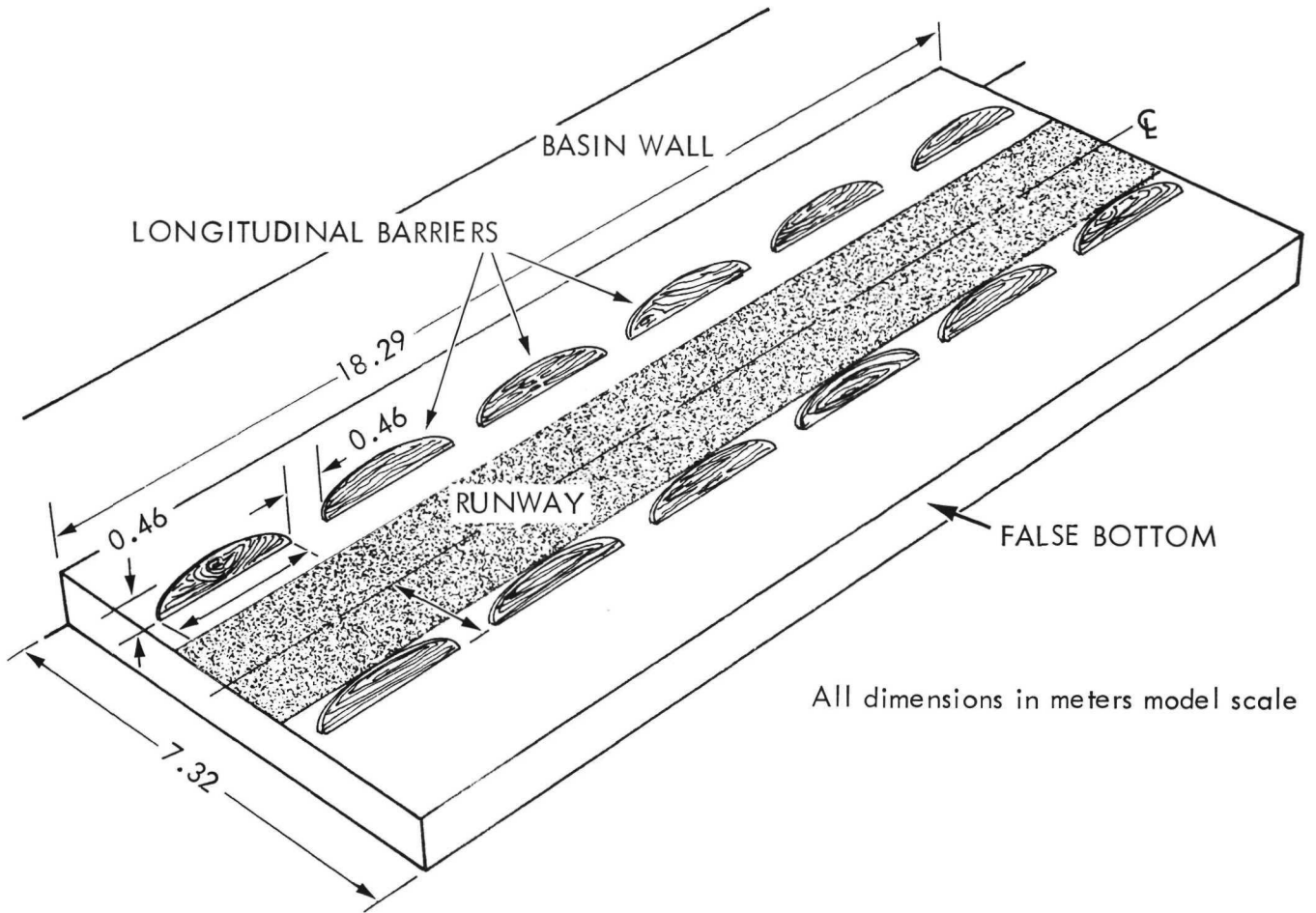
(b) END DETAIL

FIGURE 3 - FALSE BOTTOM MODULES

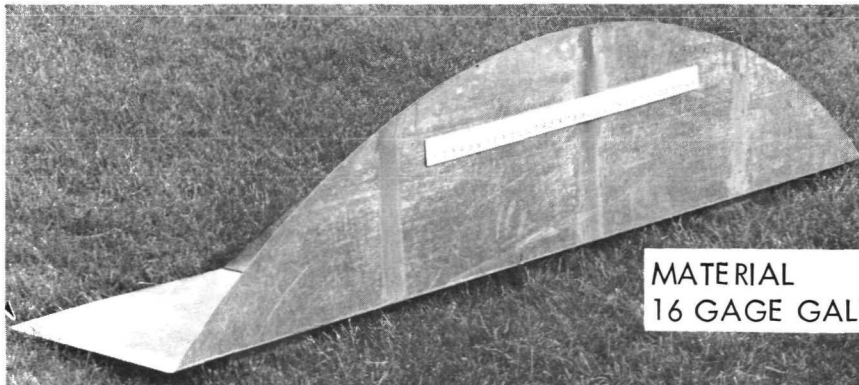


(b) Close-up view of model

FIGURE 4 - DETAILS OF MODEL OF TRANSVERSE BARRIER

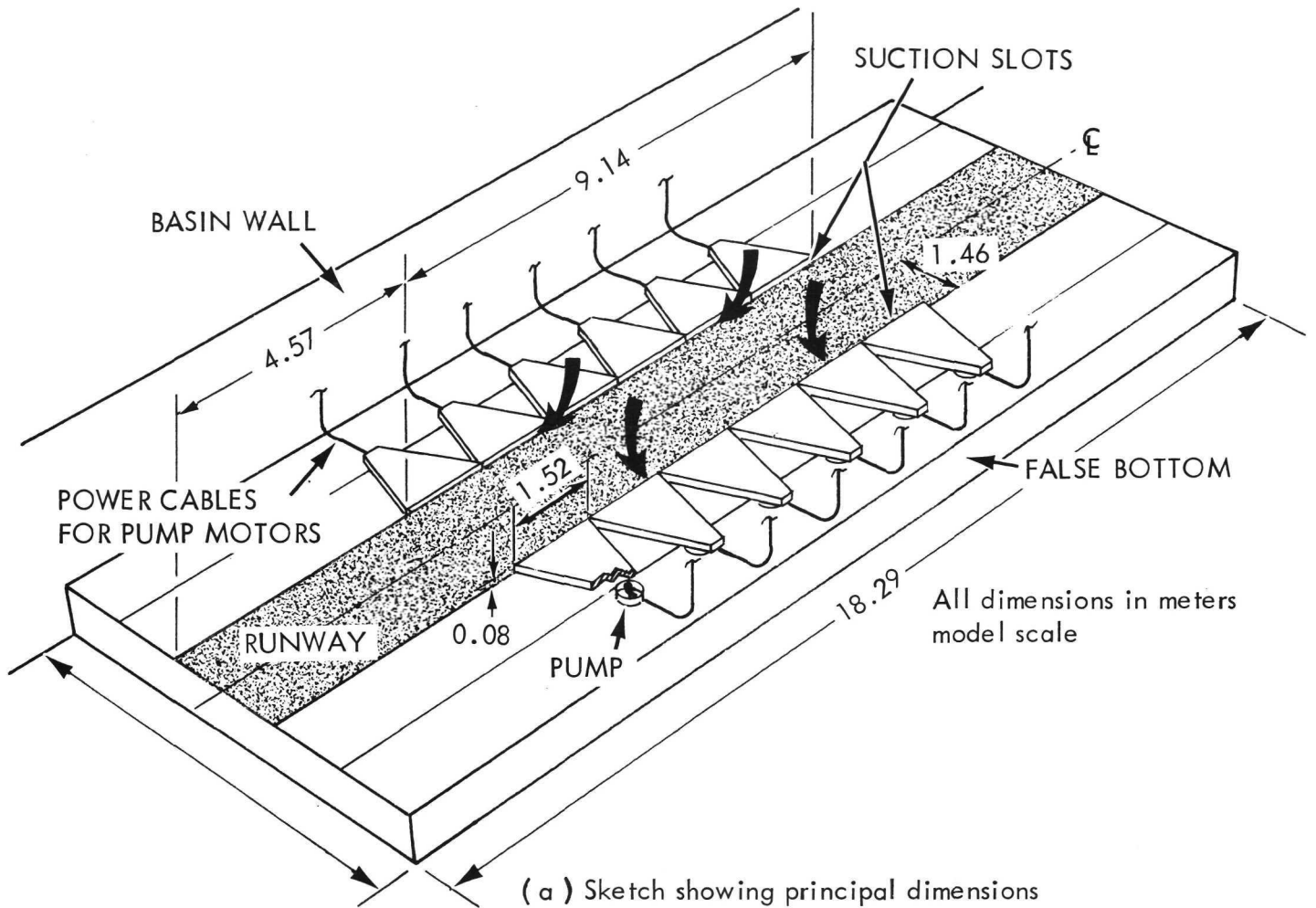


(a) Sketch showing principal dimensions

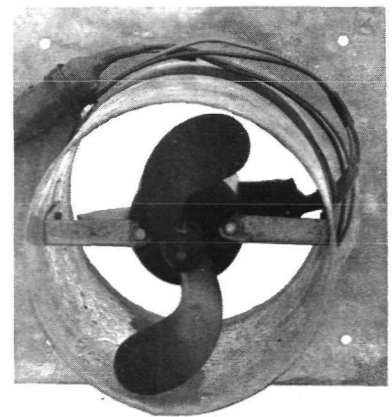


(b) Close-up view of model

FIGURE 5 - DETAILS OF MODEL OF LONGITUDINAL BARRIERS



(b) Close-up of one section of suction slot models



(c) Close-up of pump

FIGURE 6 - DETAILS OF MODEL OF LONGITUDINAL SUCTION SLOTS

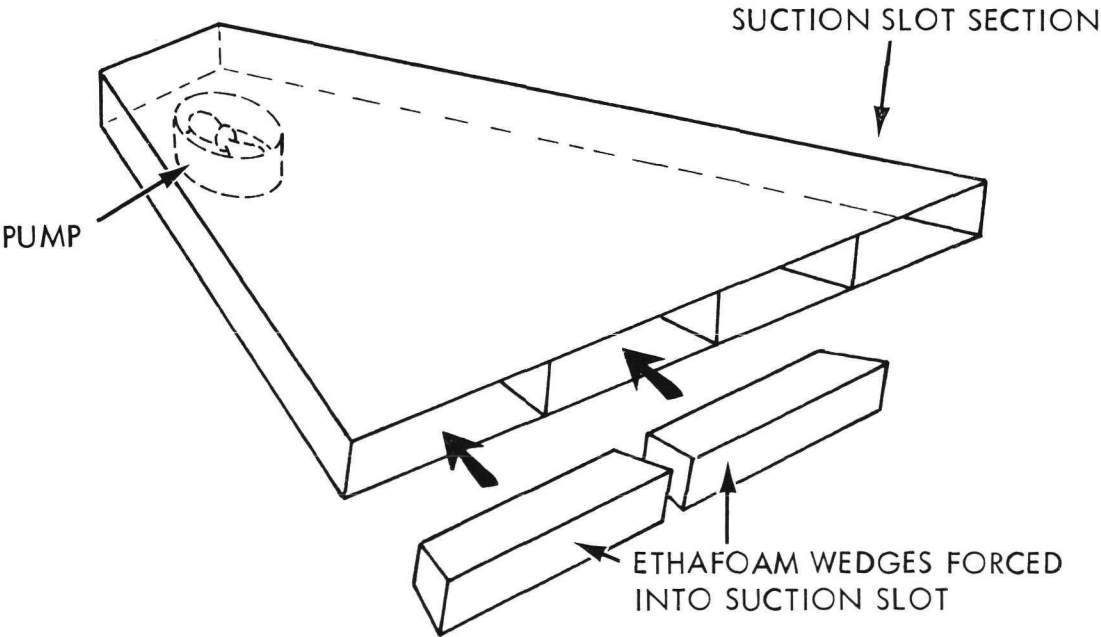


FIGURE 7 - DETAILS OF METHOD USED TO BLOCK OFF PORTIONS OF SUCTION SLOT

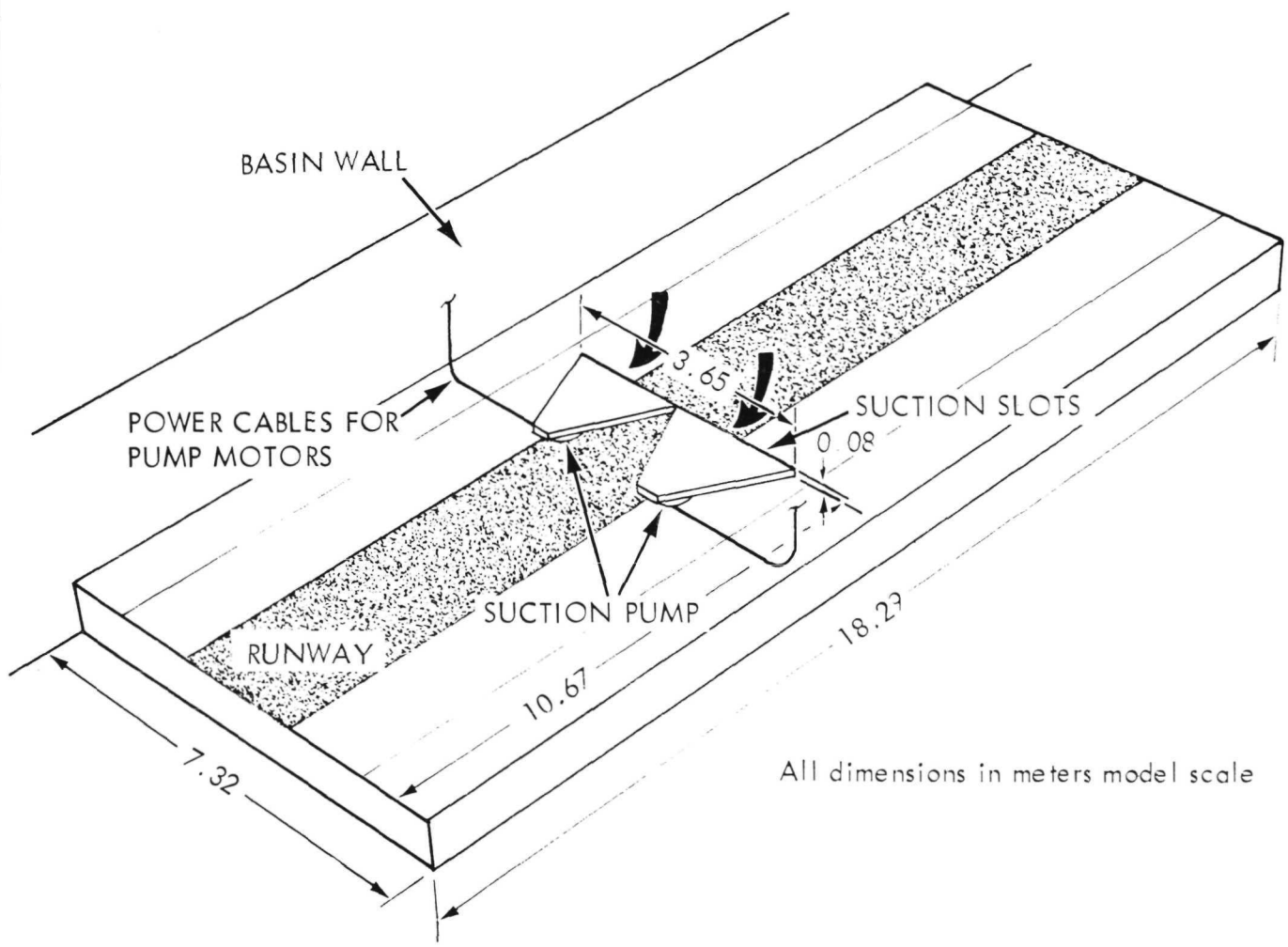
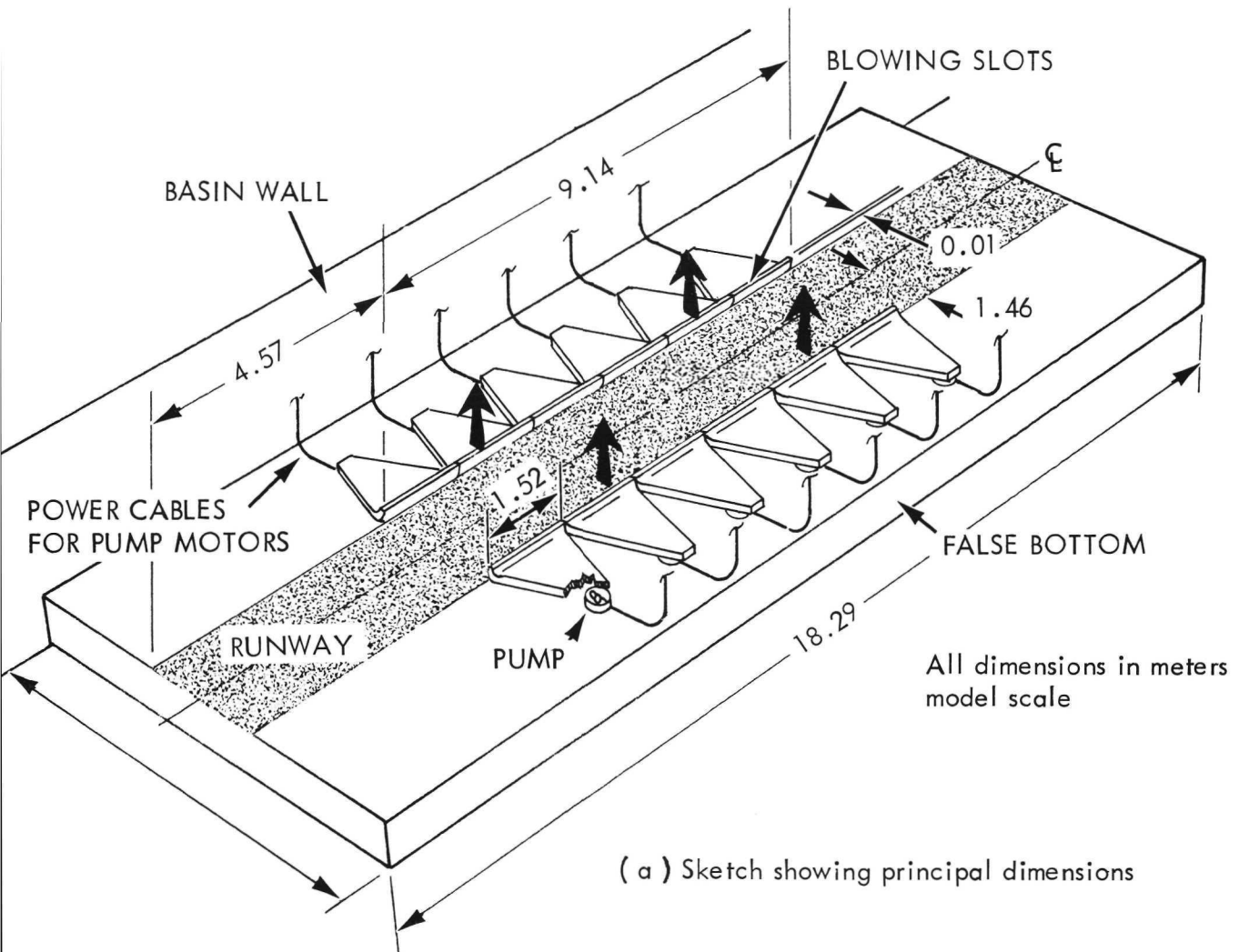
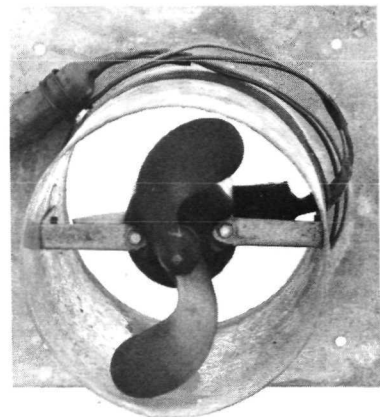


FIGURE 8 - DETAILS OF MODEL OF TRANSVERSE SUCTION SLOT

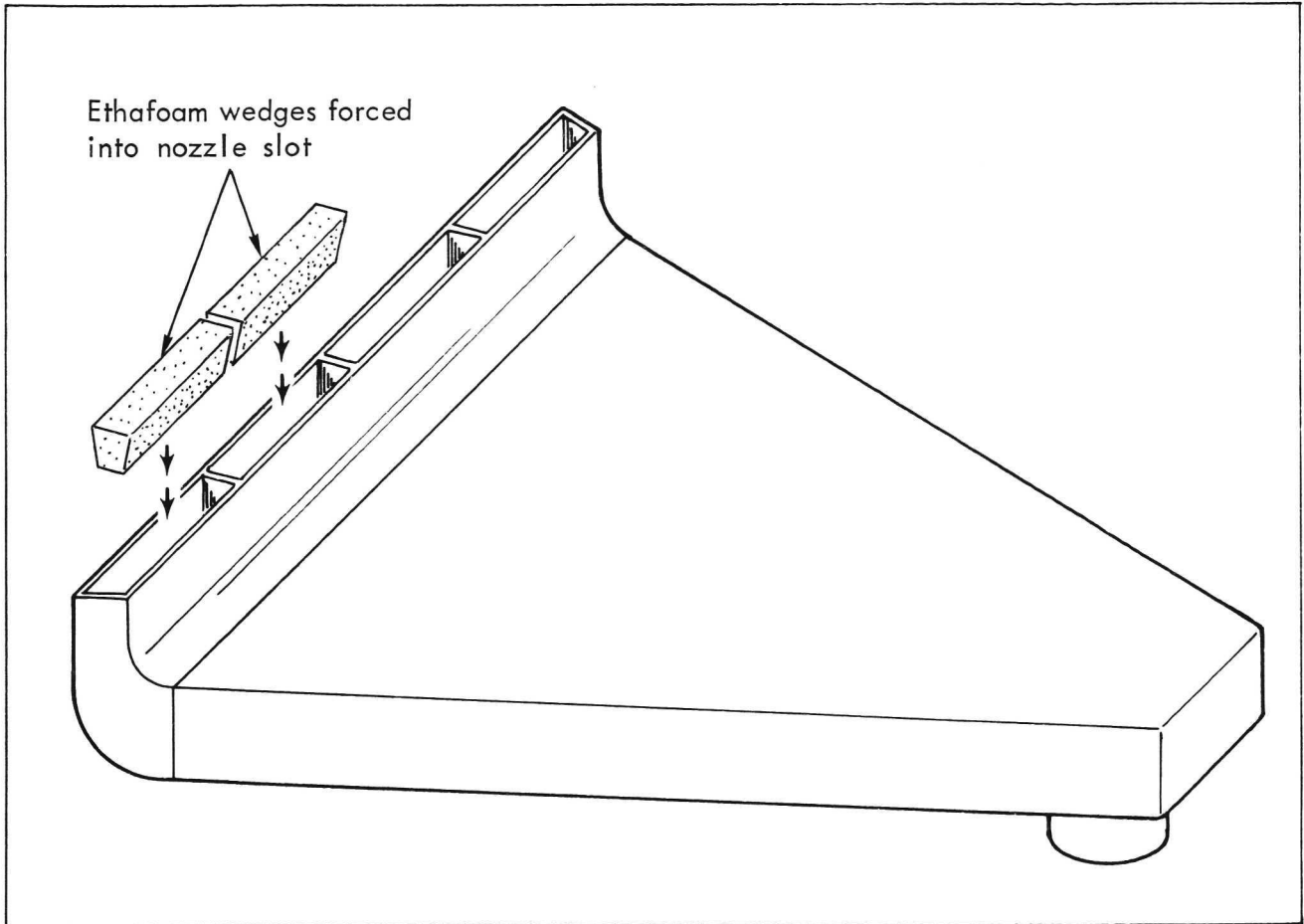


( b ) Close-up of one section of blowing slot models

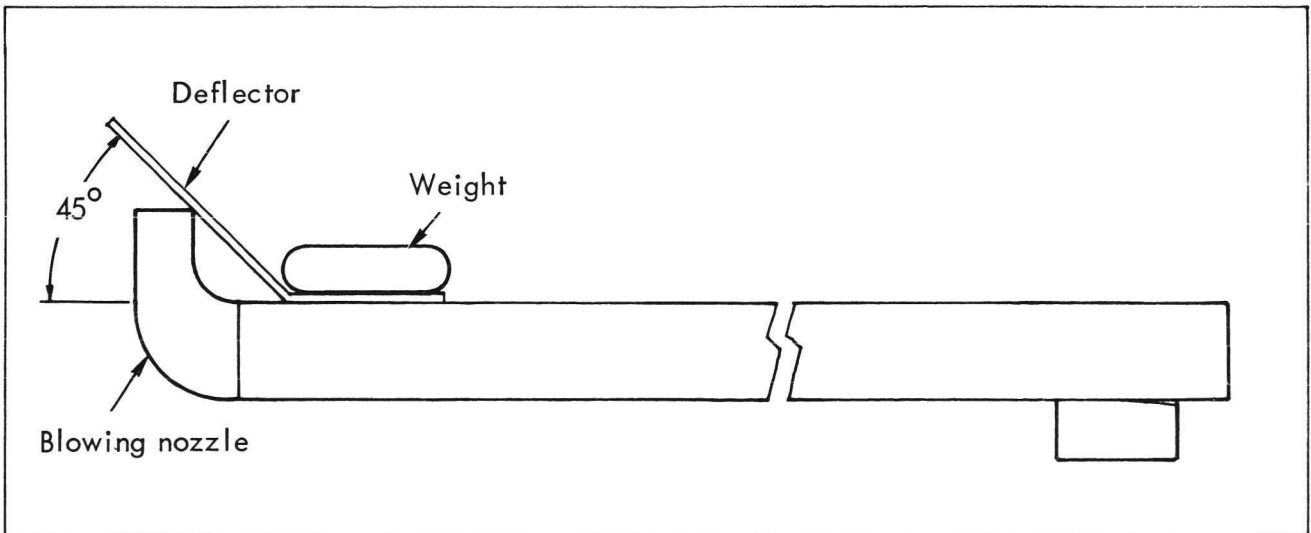


( c ) Close-up of pump

FIGURE 9 - DETAILS OF MODEL OF LONGITUDINAL BLOWING SLOTS



(a) METHOD USED TO BLOCK OFF PORTIONS OF BLOWING SLOTS



(b) 45° DEFLECTOR INSTALLED ON BLOWING SLOT TO DIRECT FLOW TOWARD CENTER OF RUNWAY

FIGURE 10 - REMOVABLE ADDITIONS MADE TO BLOWING SLOTS IN AN ATTEMPT TO IMPROVE THEIR EFFECTIVENESS

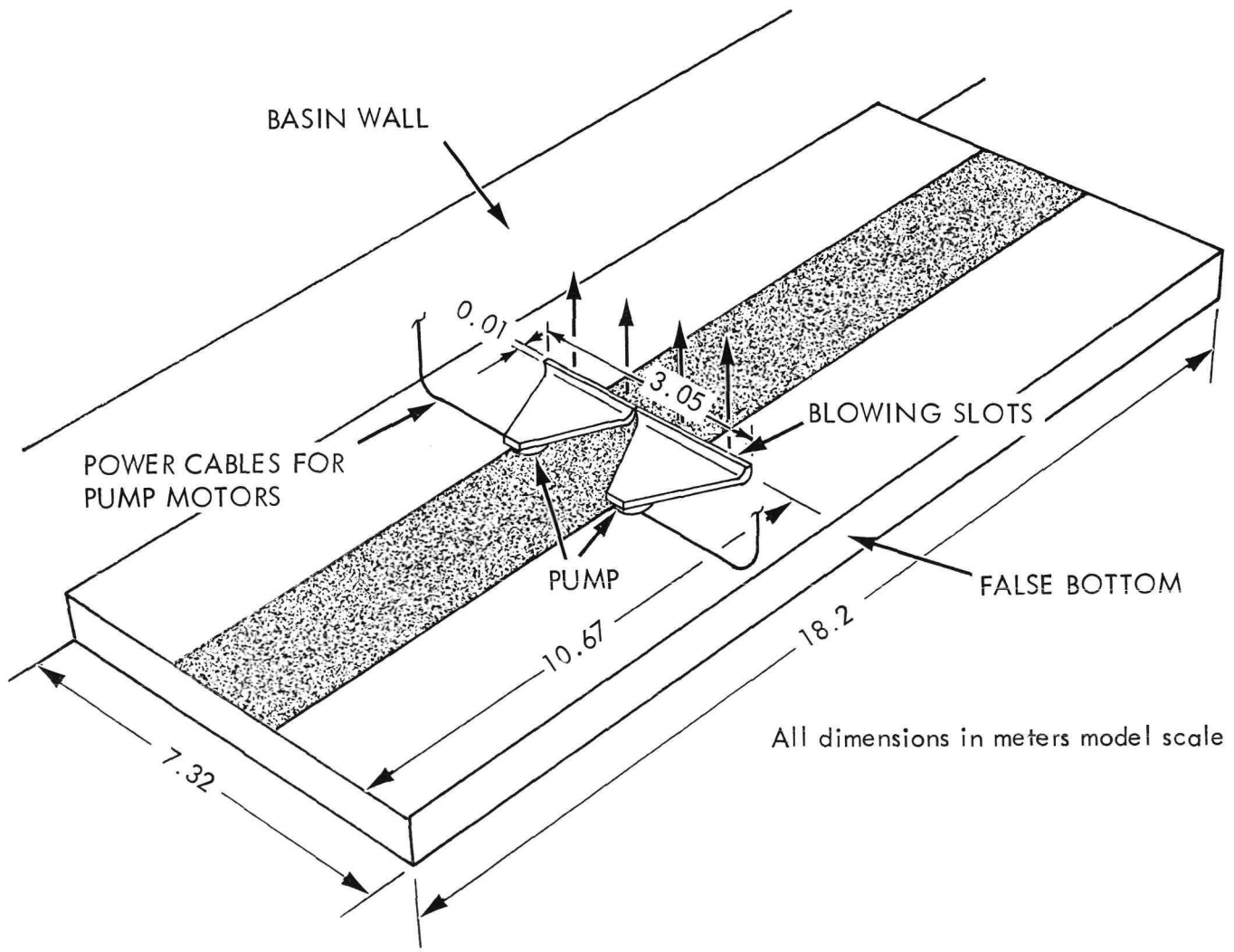
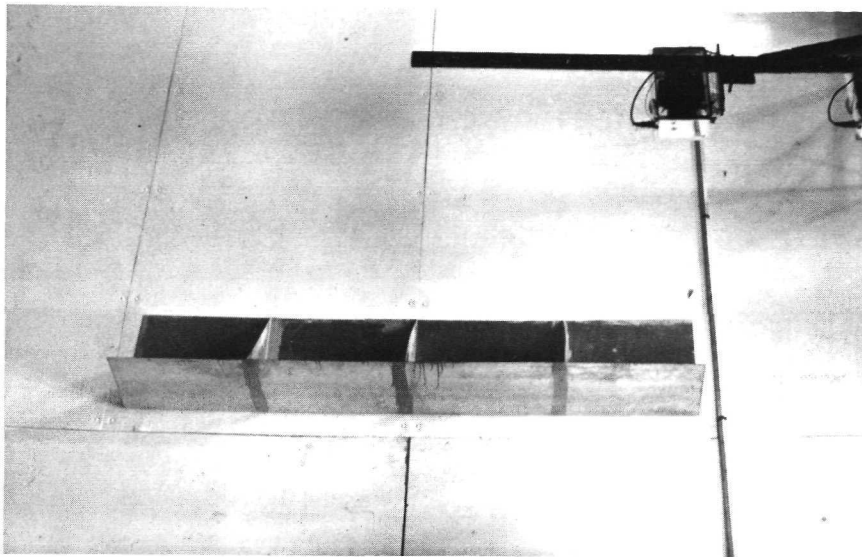
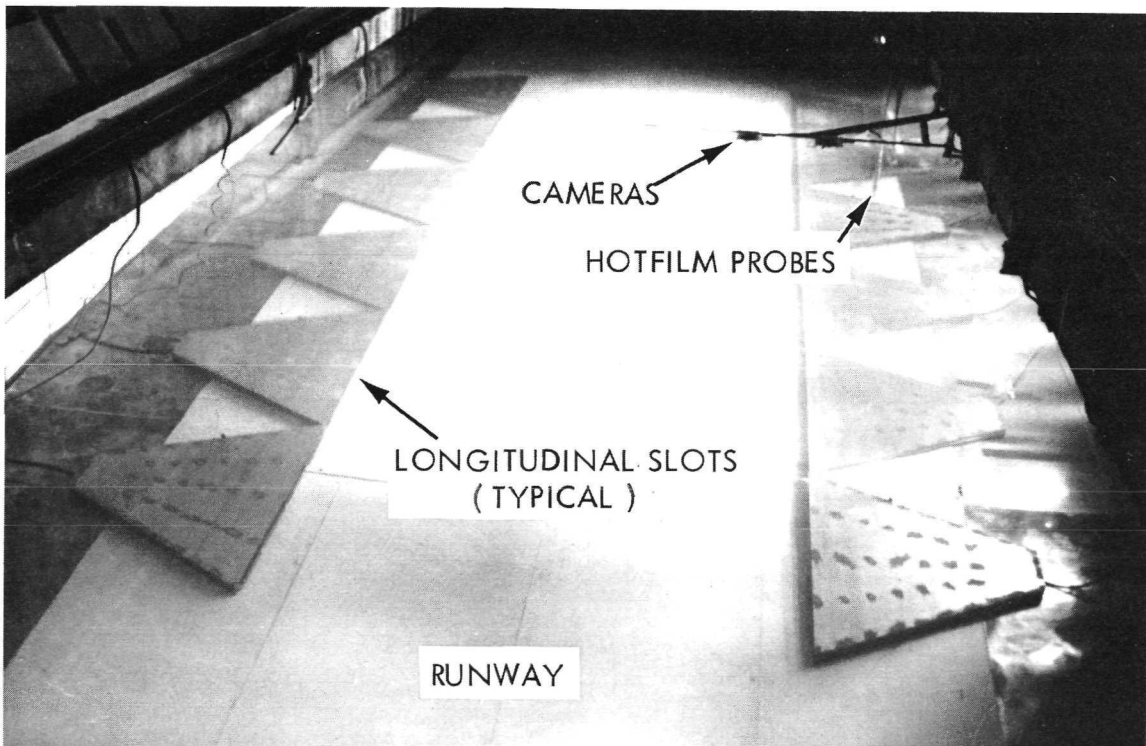


FIGURE 11 - DETAILS OF MODEL OF TRANSVERSE BLOWING SLOT

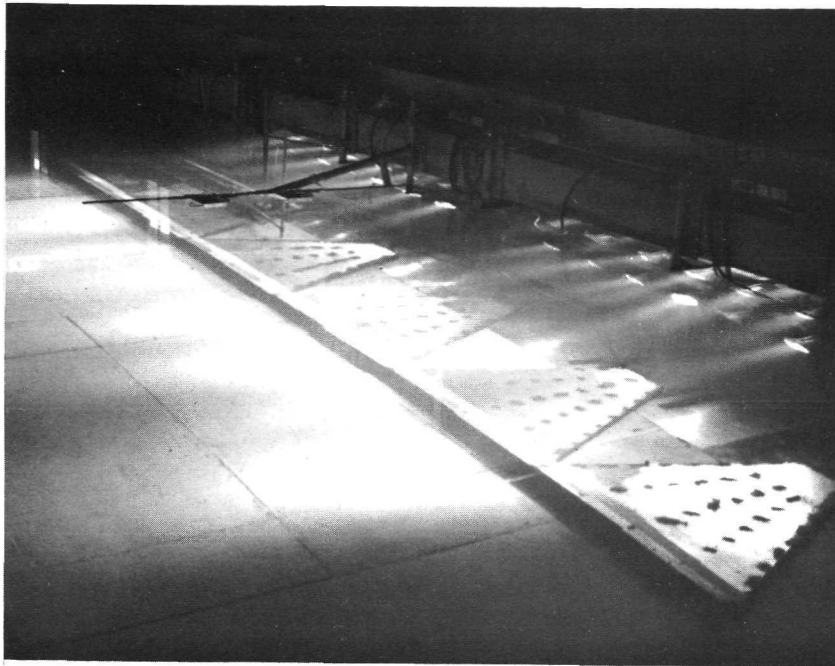


( a ) Transverse barrier

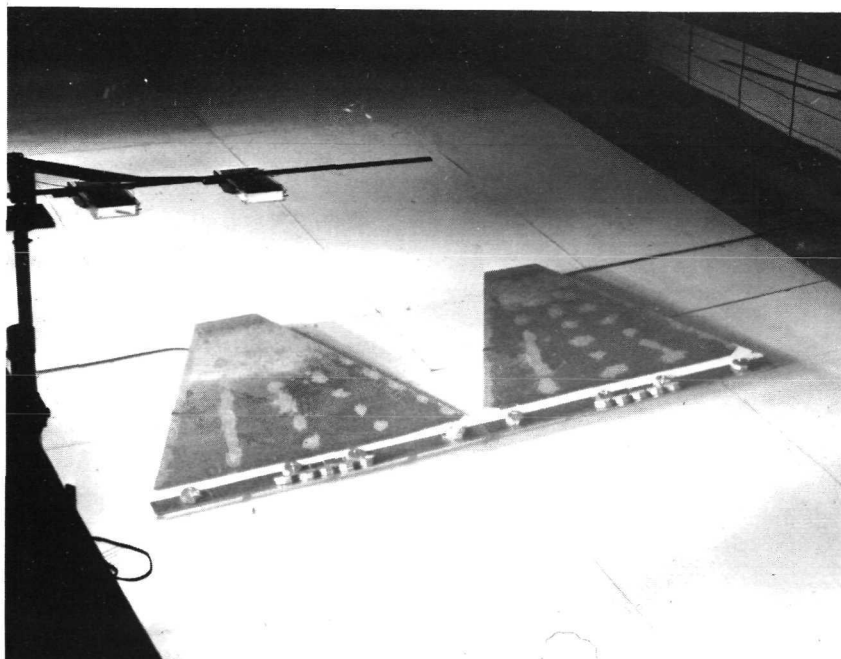


( b ) Longitudinal suction slots

FIGURE 12 - PHOTOGRAPHS OF VARIOUS VORTEX DISSIPATION DEVICES INSTALLED ON RUNWAY



( c ) Longitudinal blowing slots



( d ) Transverse blowing slots with 45 degree deflectors installed

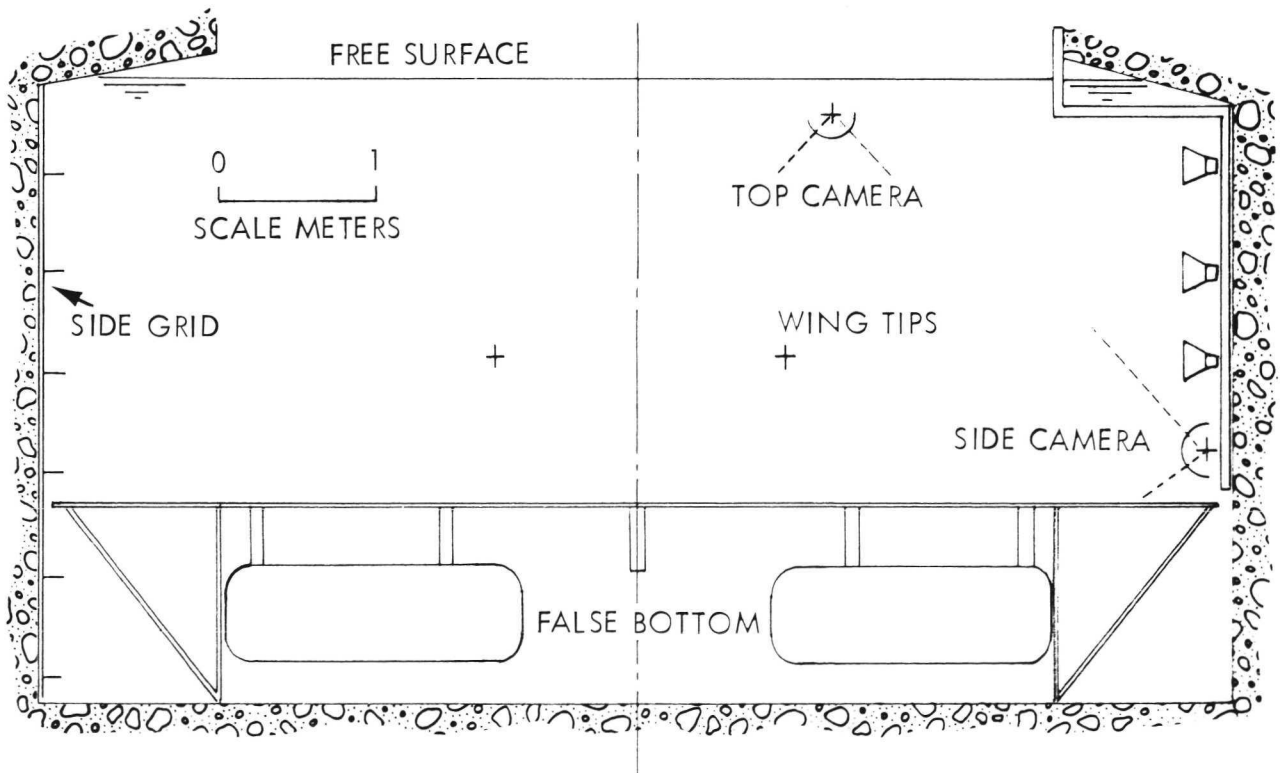
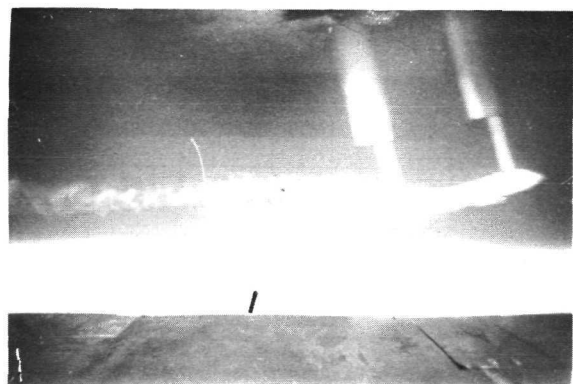
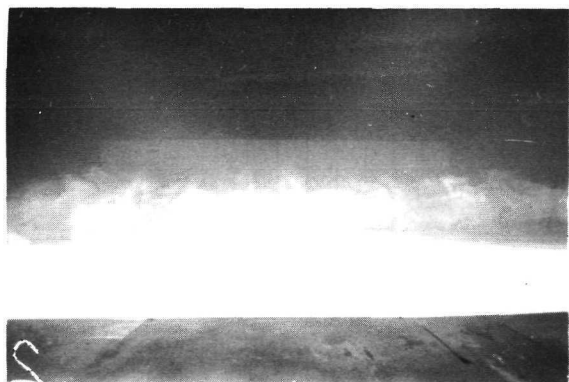
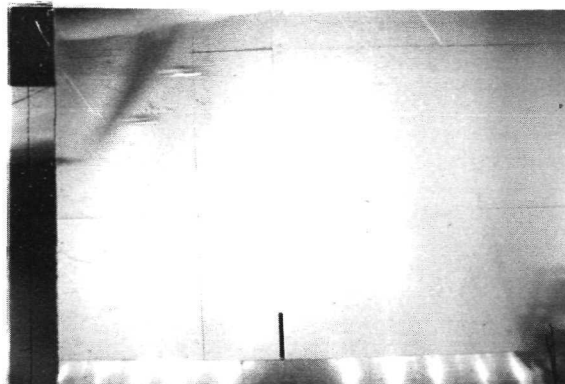


FIGURE 13 - CROSS SECTION OF PHOTOGRAPHIC TEST SECTION FOR RUNWAY TESTS

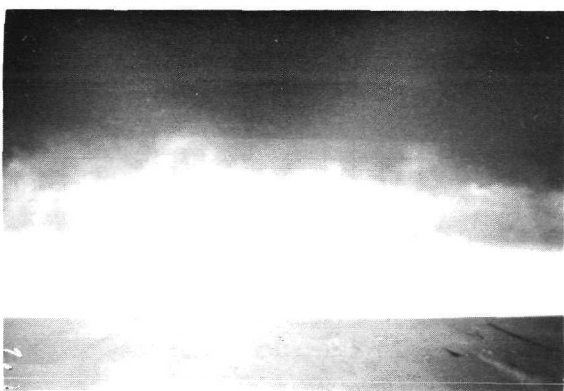
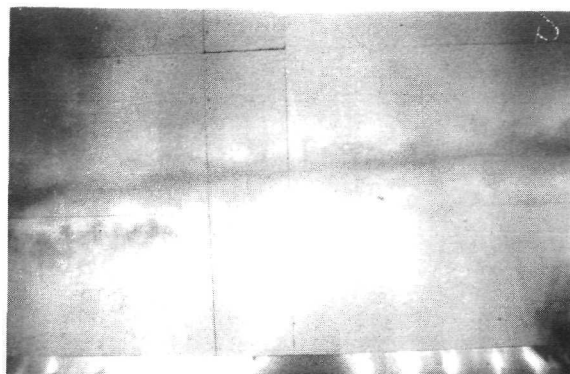


N

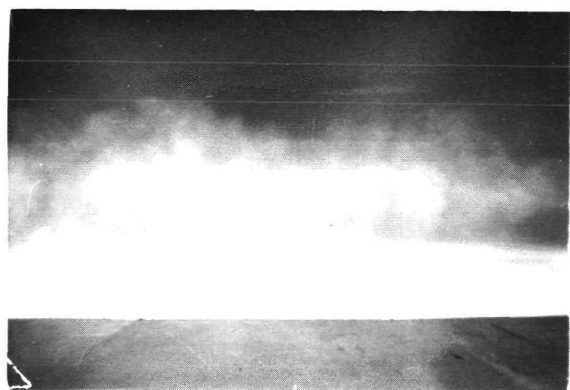
1.1



3.6



6.1



8.7

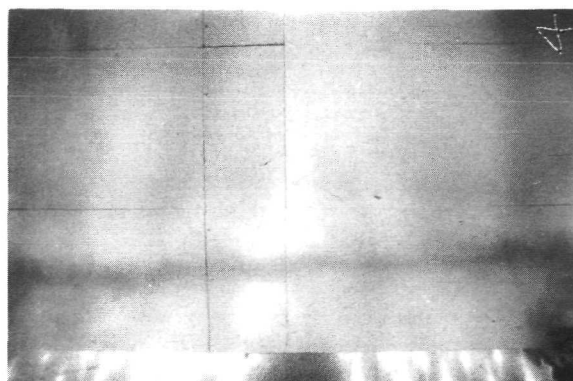
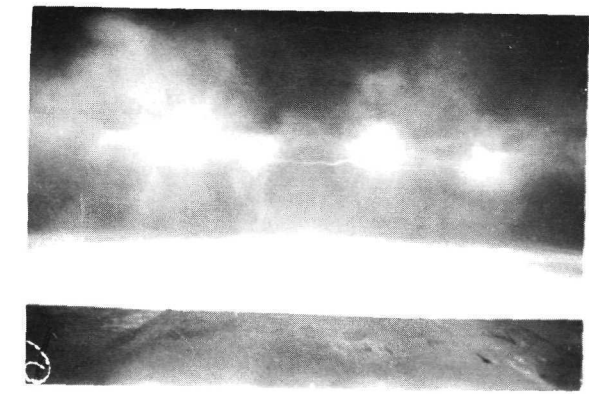
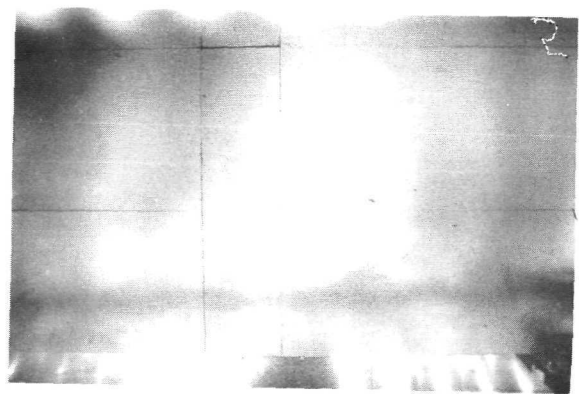


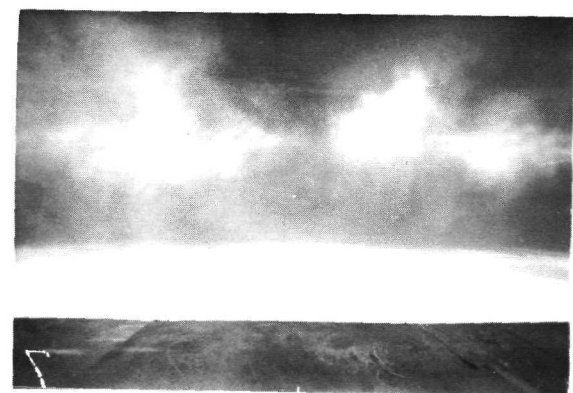
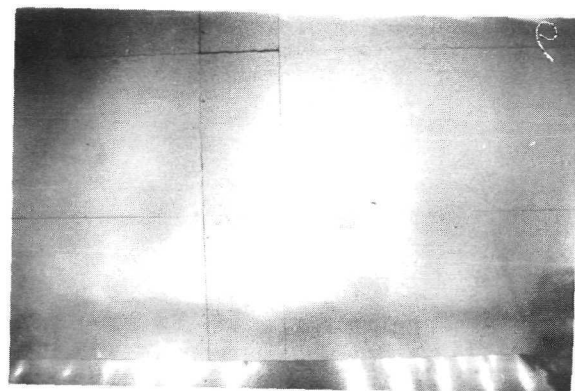
FIGURE 14 - BARE RUNWAY - UNALTERED VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.70$  AND ALTITUDE = 13.4 METERS



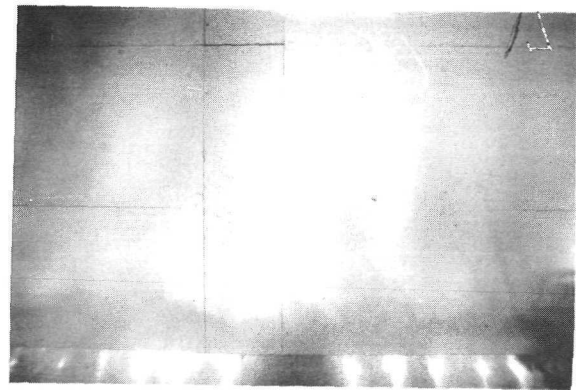
N  
11.3



13.8



16.4



19.0

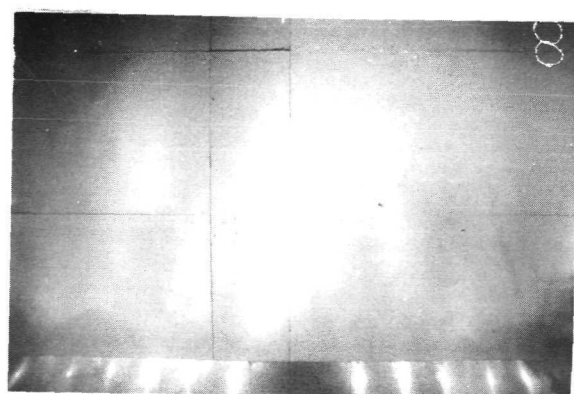
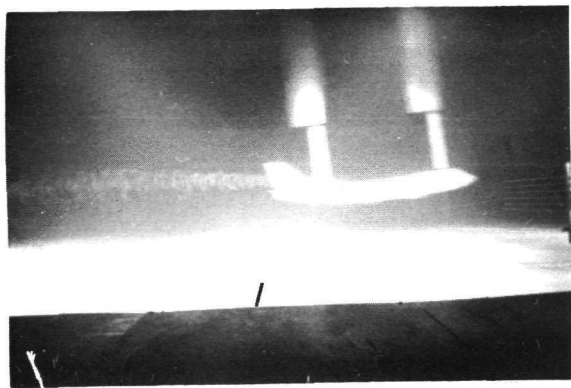
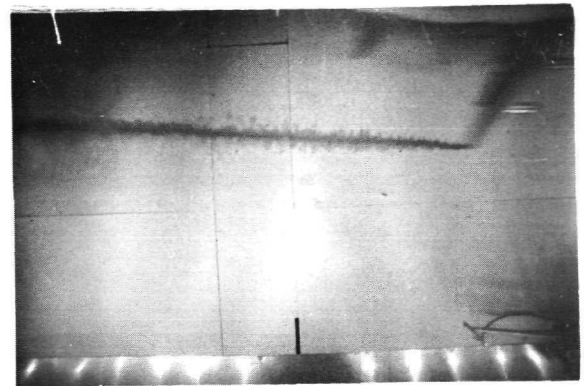


FIGURE 14 - CONCLUDED



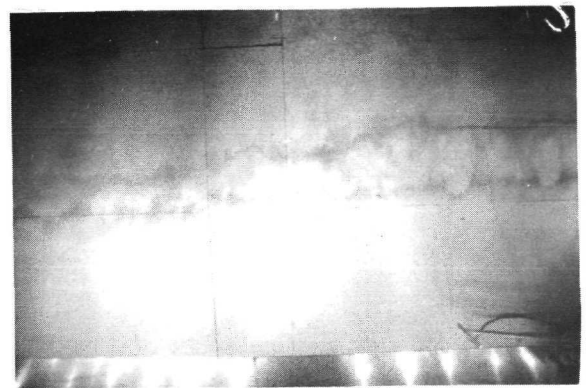
N



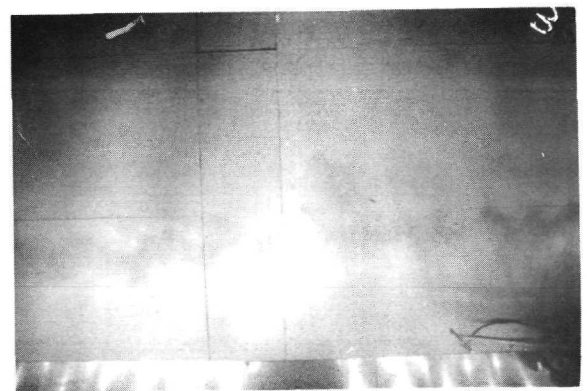
0.5



3.0



5.6



8.1

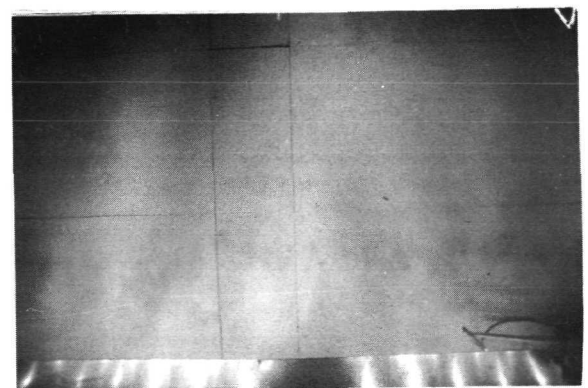
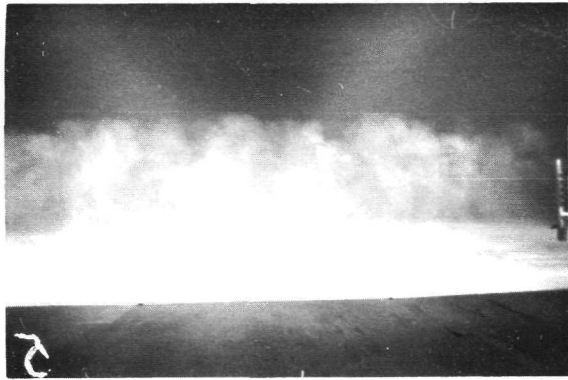
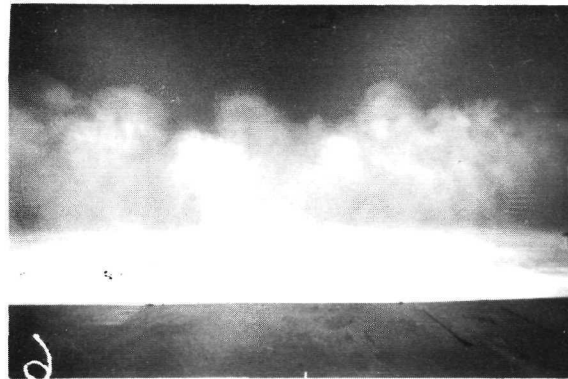
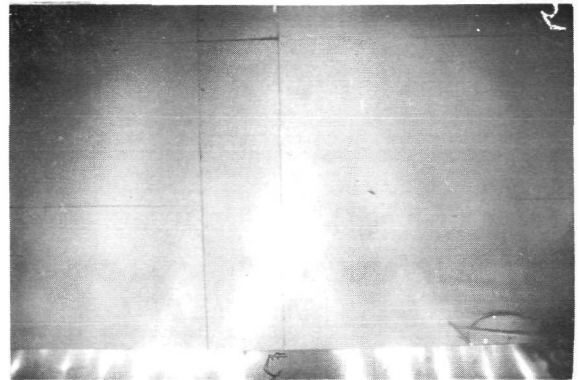


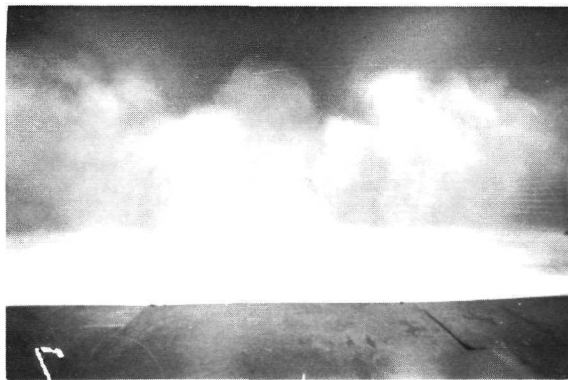
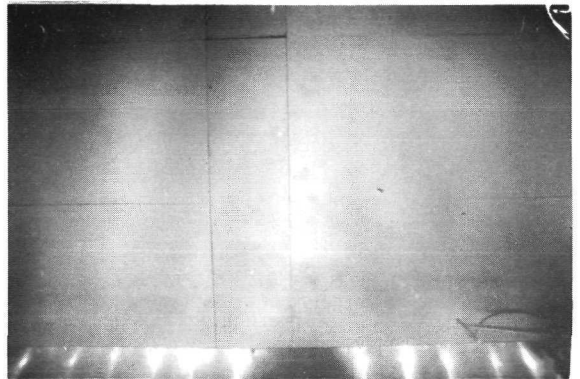
FIGURE 15 - BARE RUNWAY - UNALTERED VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.17$  AND ALTITUDE = 13.4 METERS



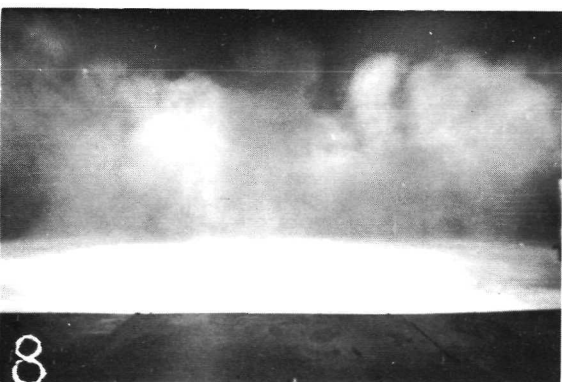
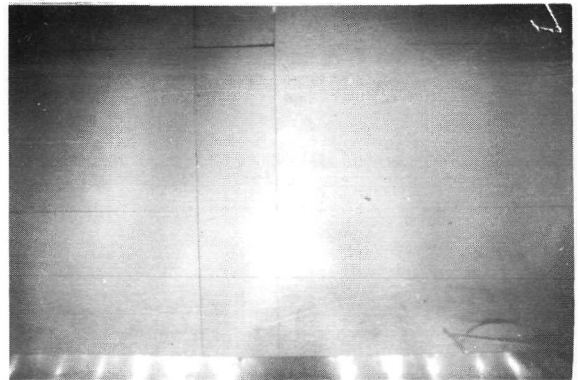
N  
10.7



13.2



15.8



18.3

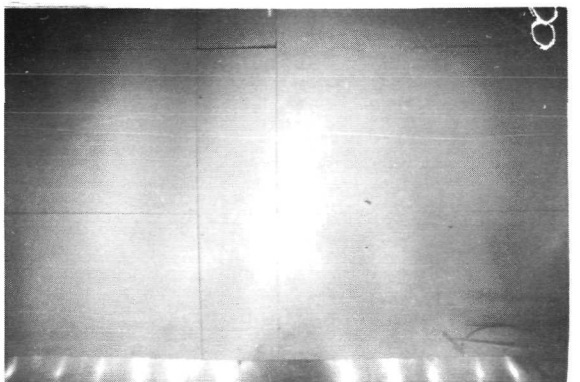
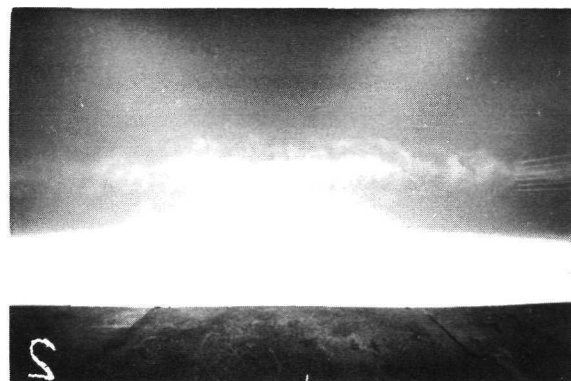
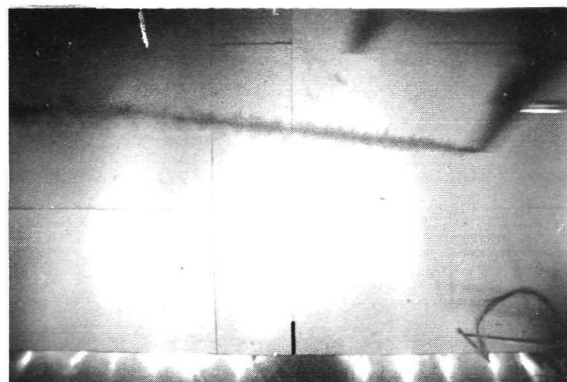


FIGURE 15 - CONCLUDED

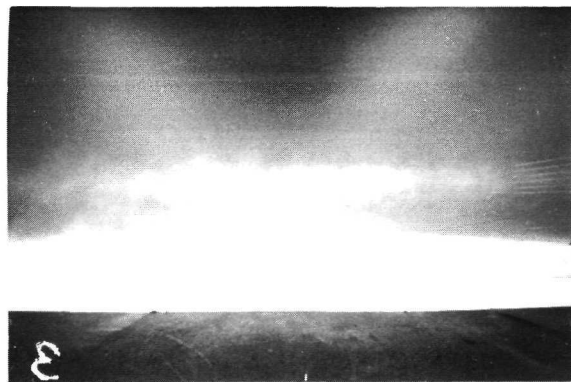
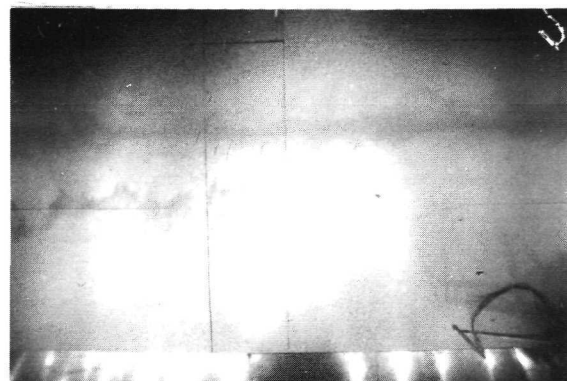


N

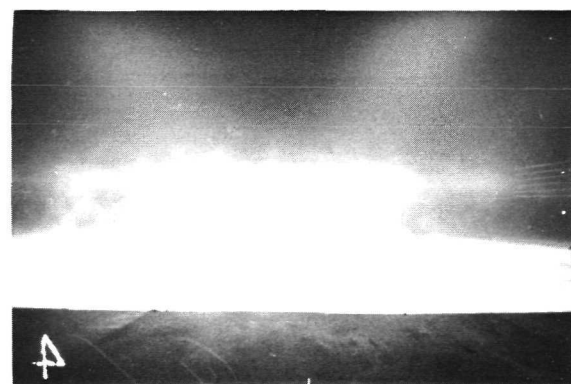
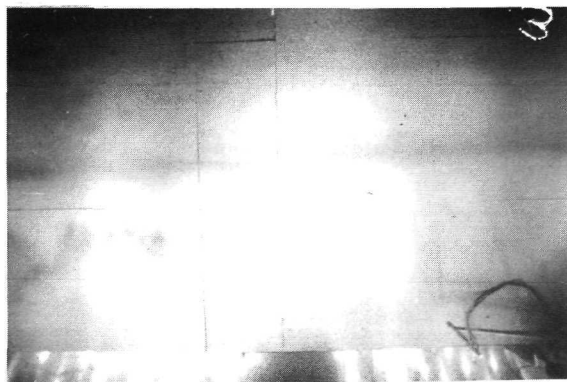
0.5



3.1



5.6



8.2

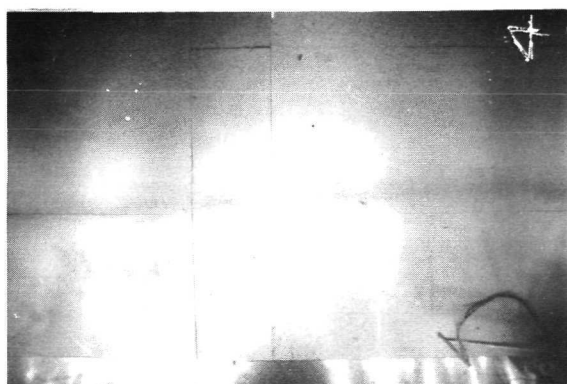
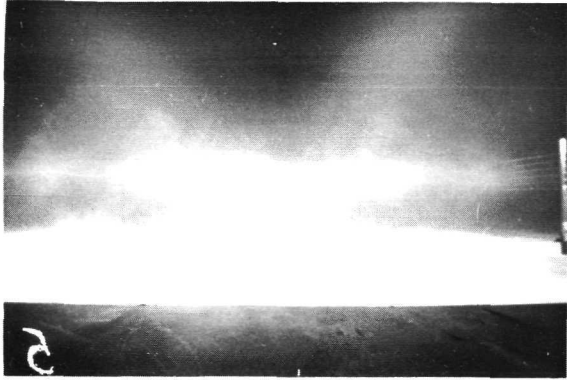
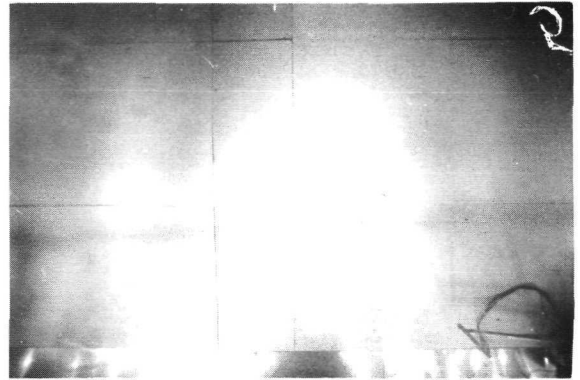


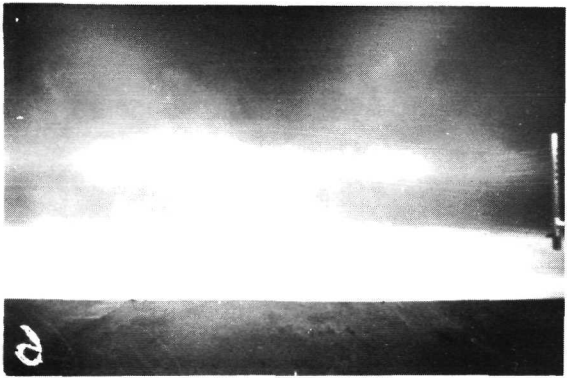
FIGURE 16 - BARE RUNWAY - UNALTERED VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.69$  AND ALTITUDE = 21.3 METERS



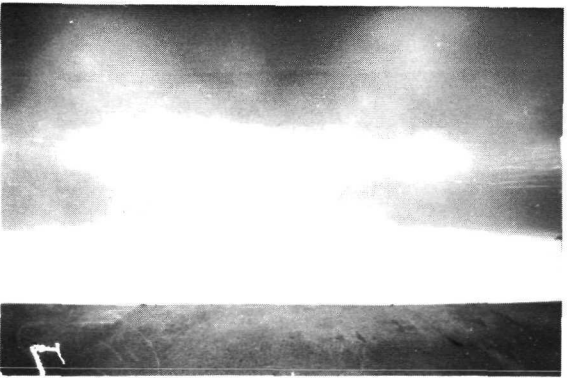
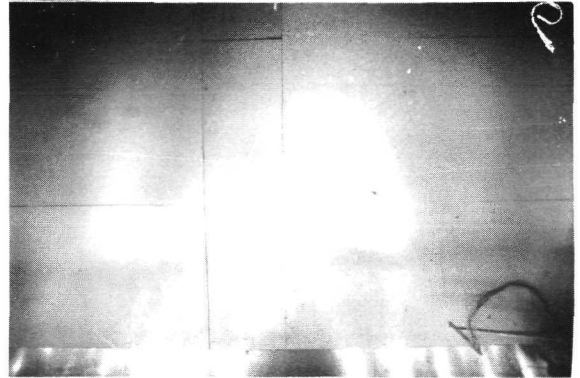
N



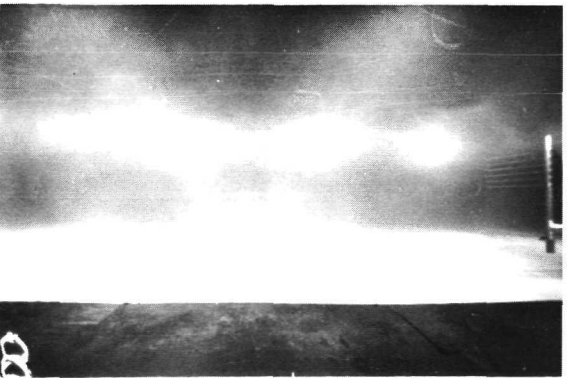
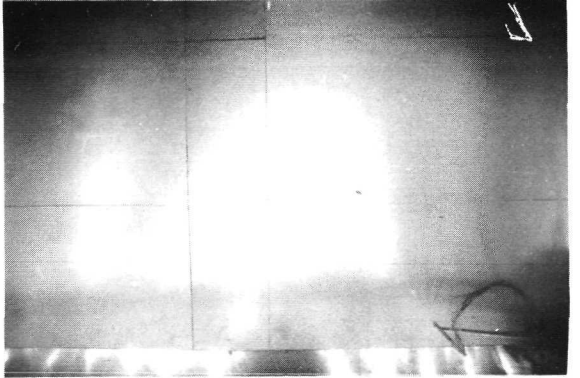
10.7



13.3



15.8



18.4

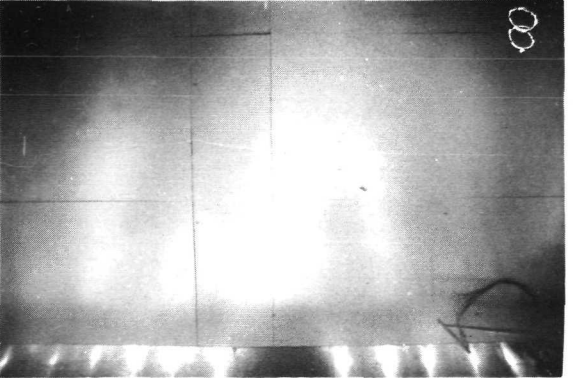


FIGURE 16 - CONCLUDED

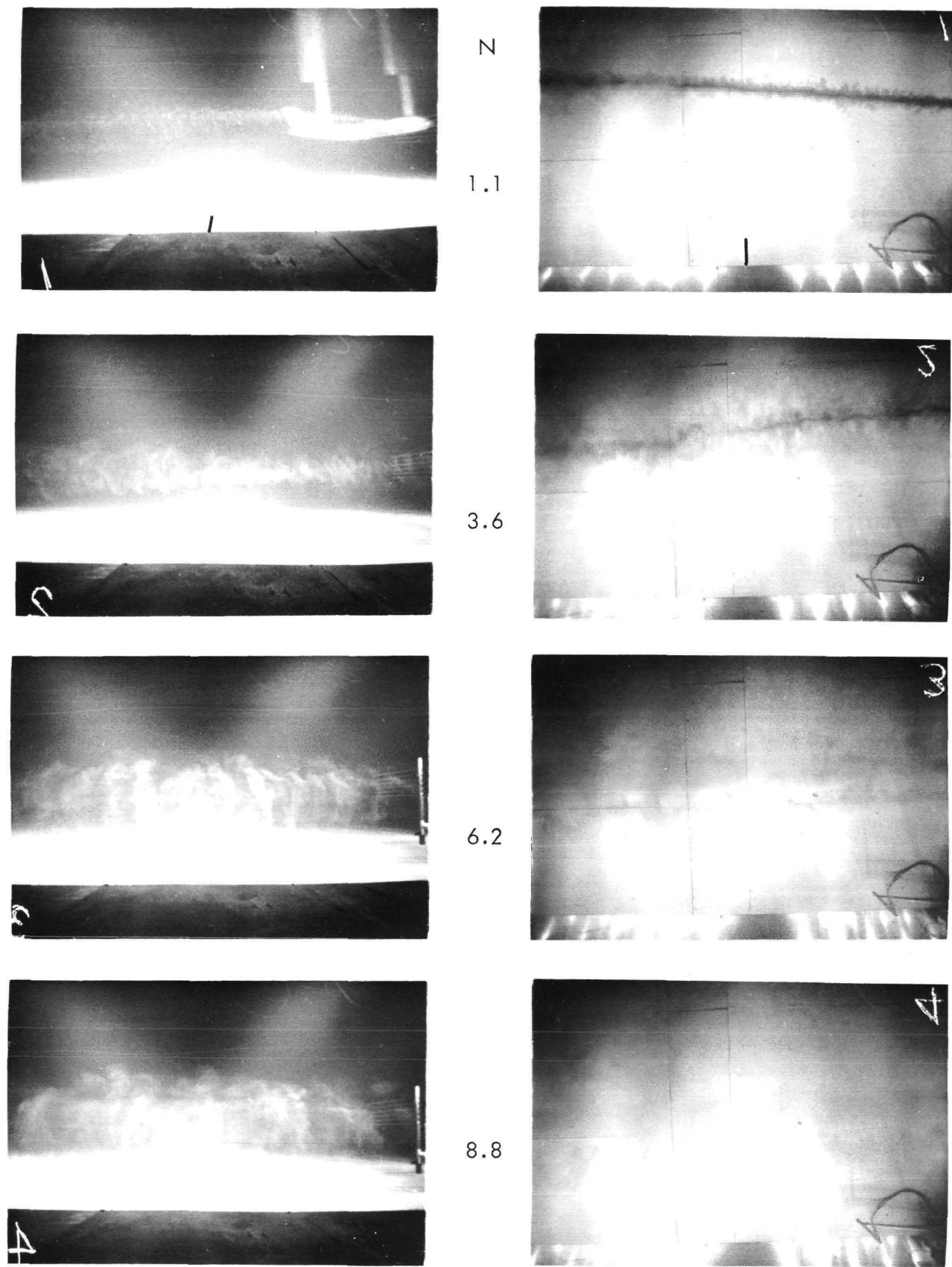
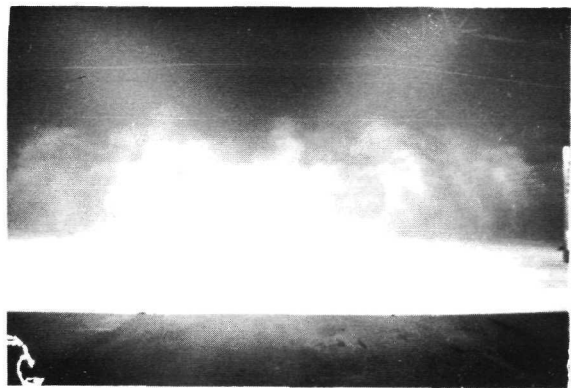
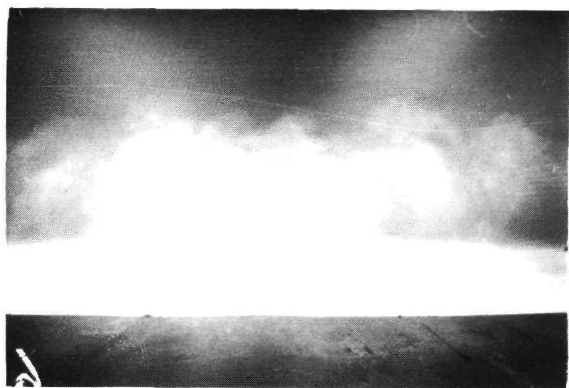
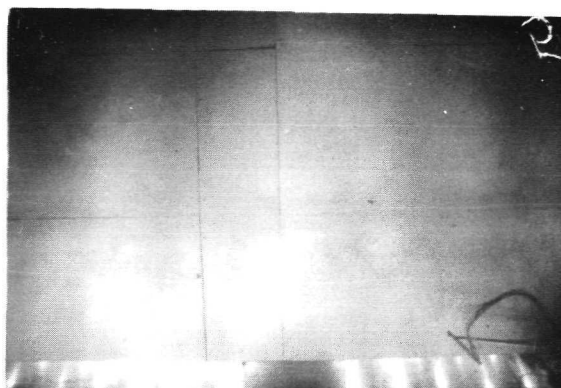


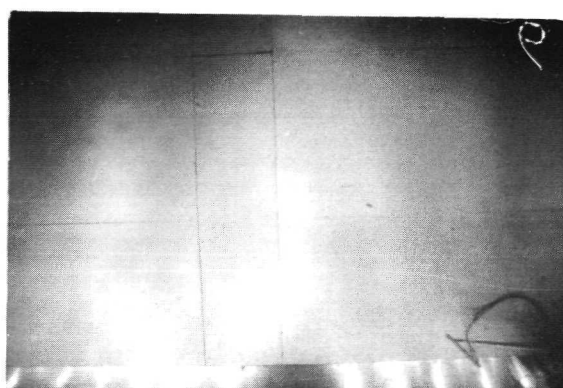
FIGURE 17 - BARE RUNWAY - UNALTERED VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.16$  AND ALTITUDE = 21.3 METERS



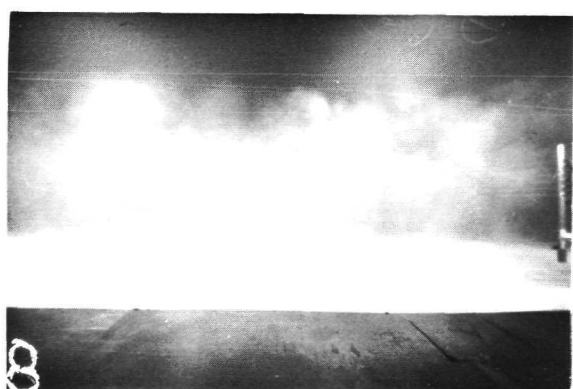
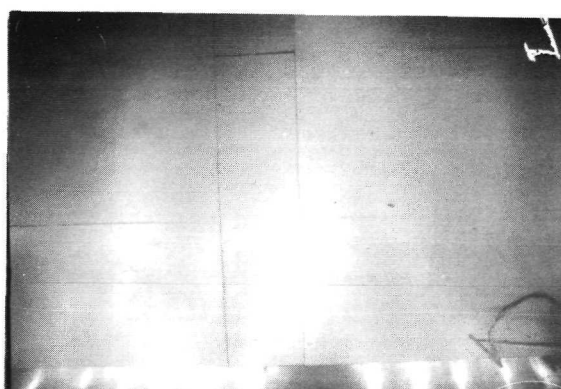
N  
11.3



13.9



16.4



19.0

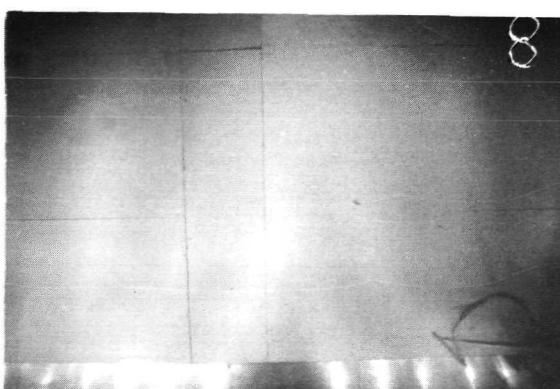
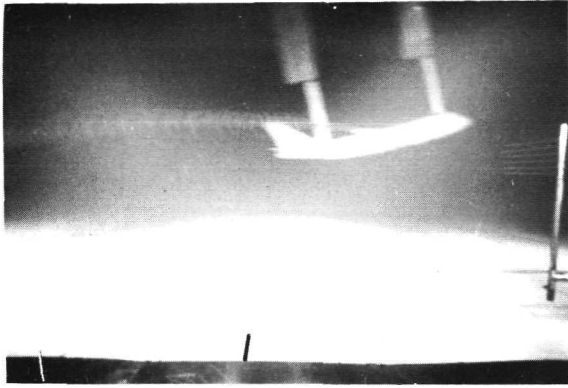
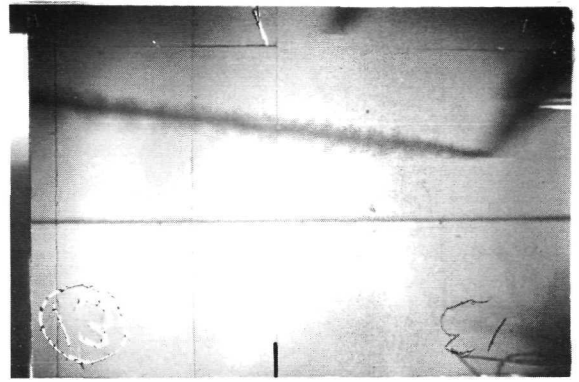


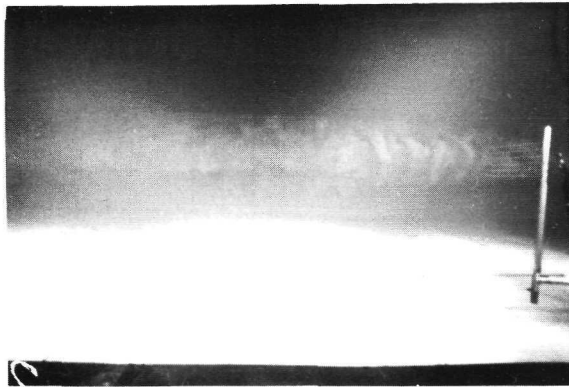
FIGURE 17 - CONCLUDED



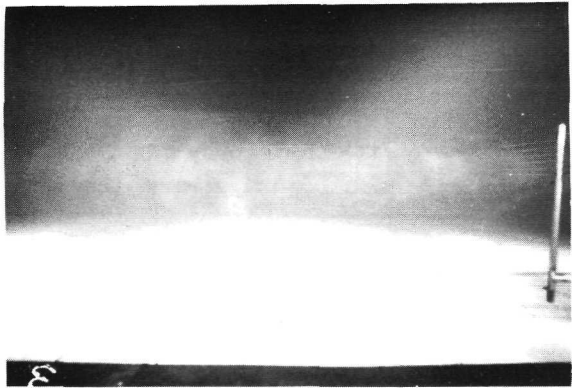
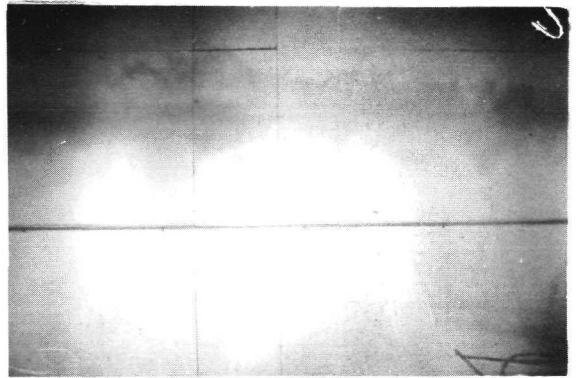
N



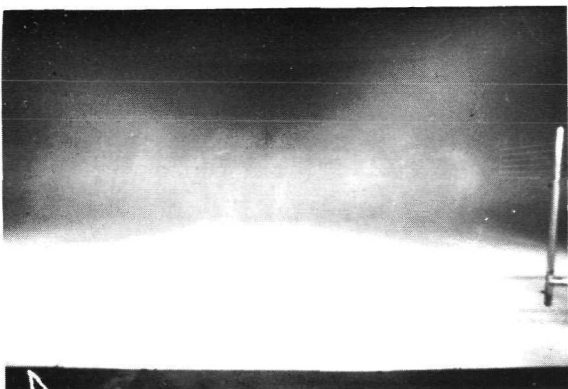
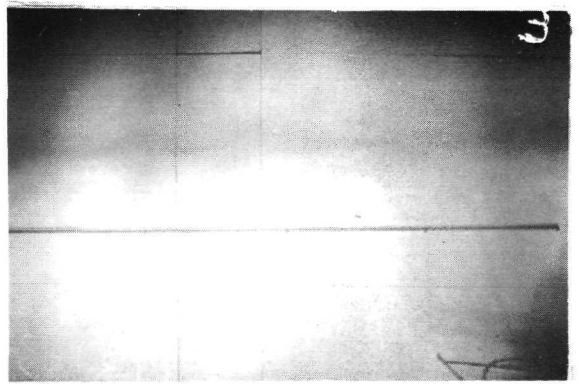
0.5



3.0



5.6



8.1

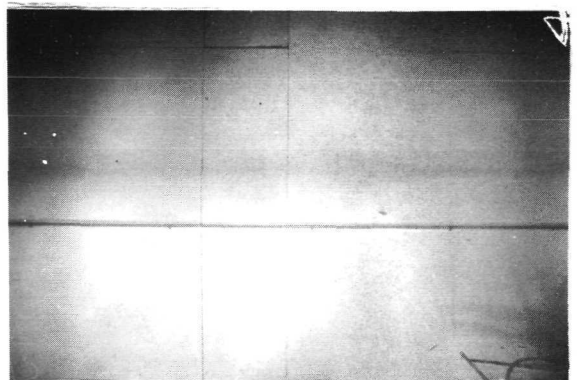
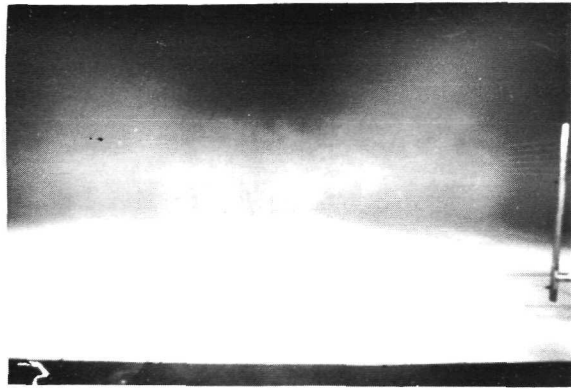
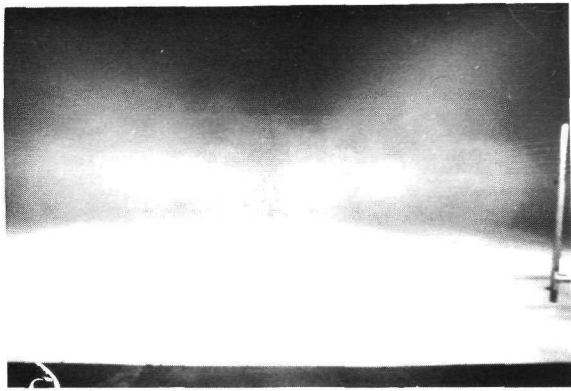
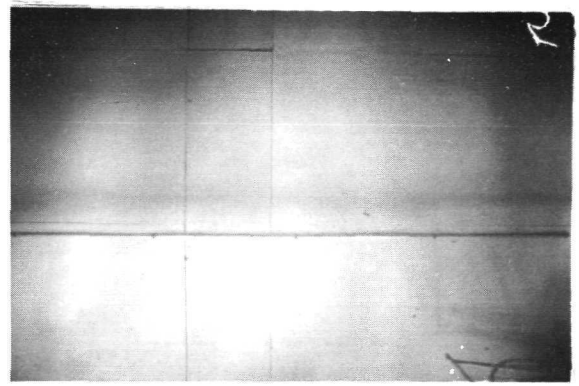


FIGURE 18 - BARE RUNWAY - UNALTERED VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.68$  AND ALTITUDE = 30.5 METERS

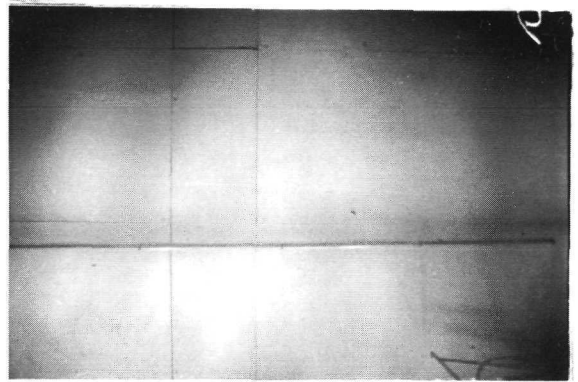


N

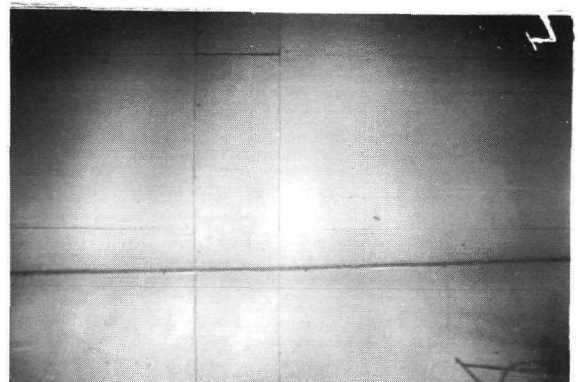
10.7



13.2



15.8



18.3

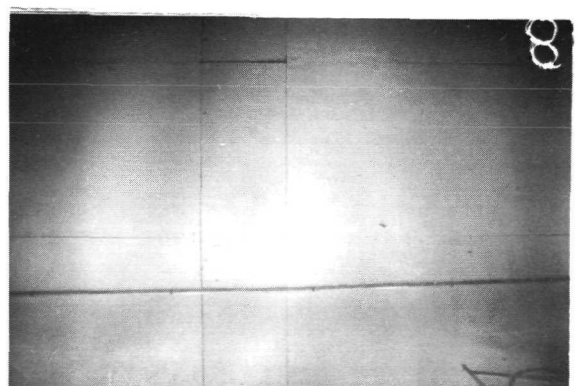
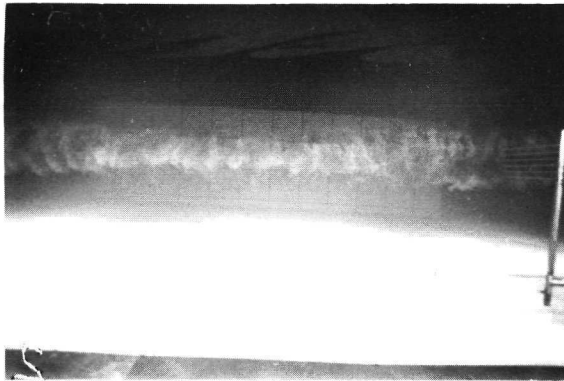
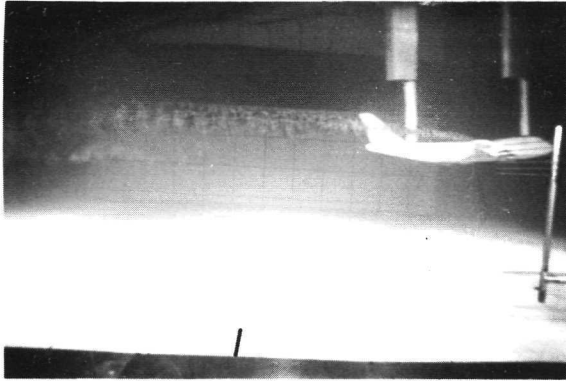
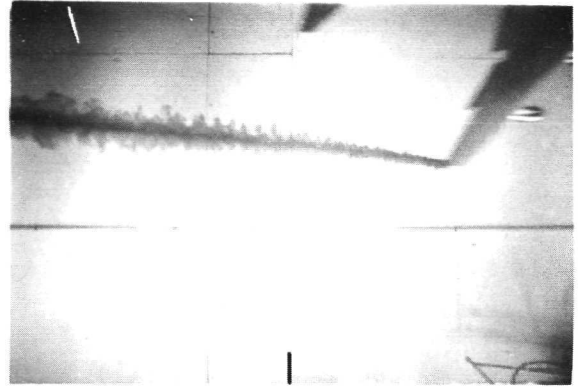


FIGURE 18 - CONCLUDED

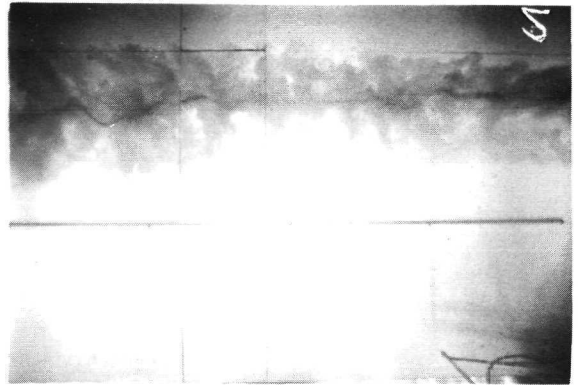


N

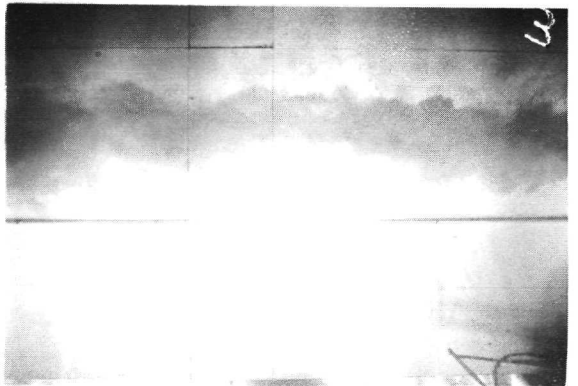
0.3



2.9



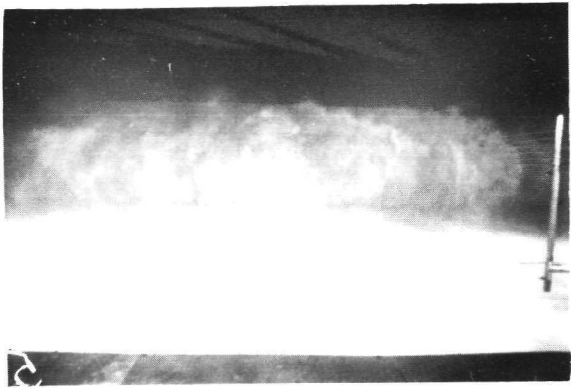
5.4



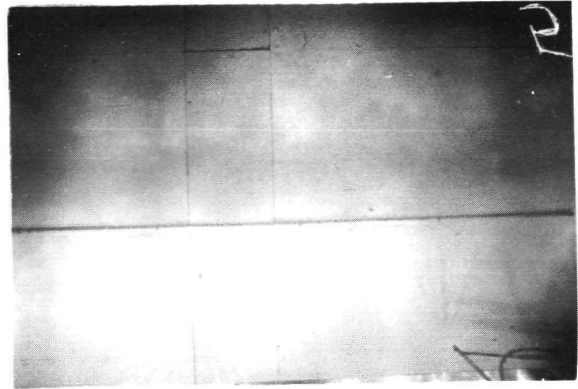
8.0



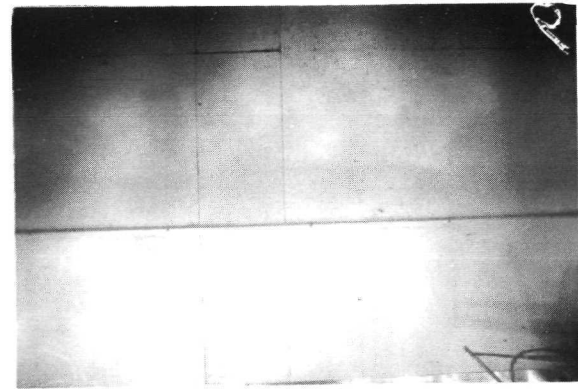
FIGURE 19 - BARE RUNWAY - UNALTERED VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.11$  AND ALTITUDE = 30.5 METERS



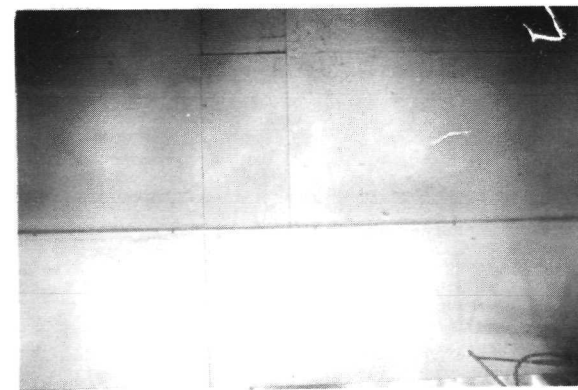
N  
10.5



13.1



15.6



18.2

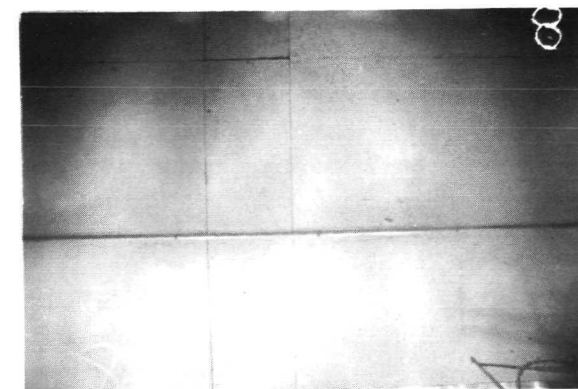
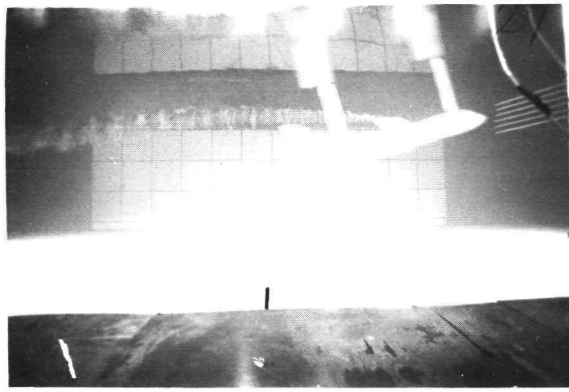
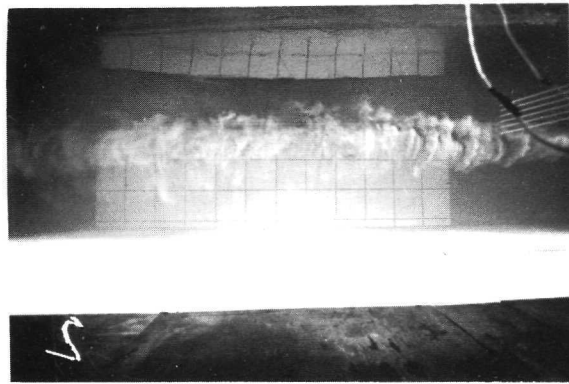
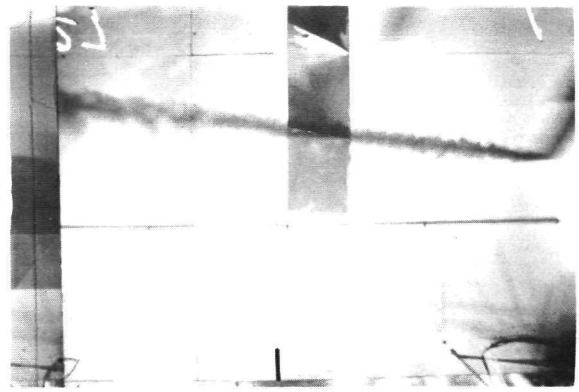


FIGURE 19 - CONCLUDED

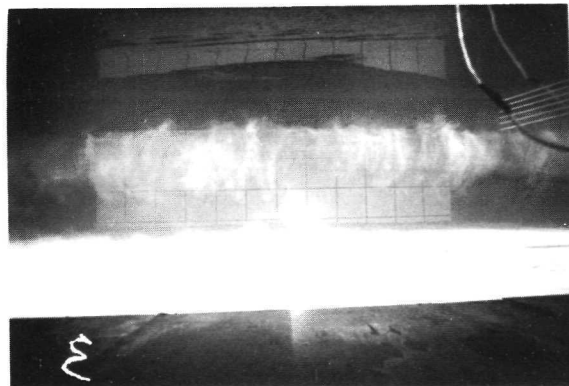
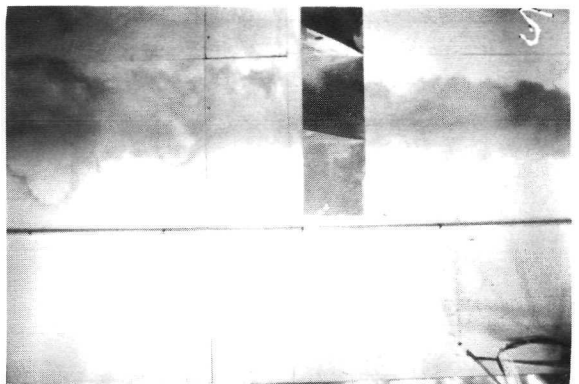


N

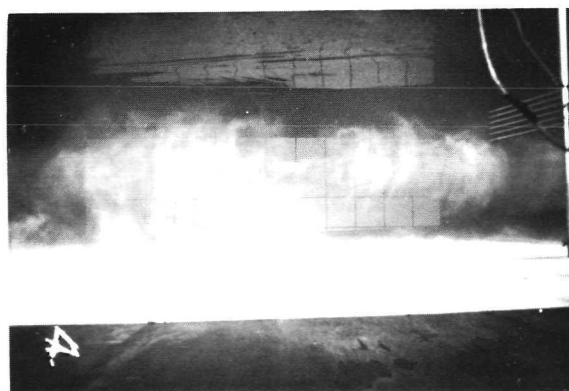
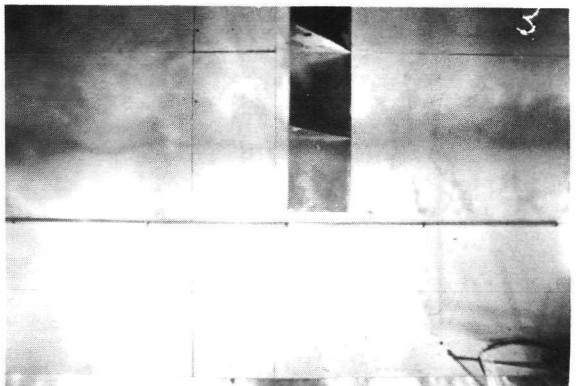
0.5



3.1



5.6



8.16

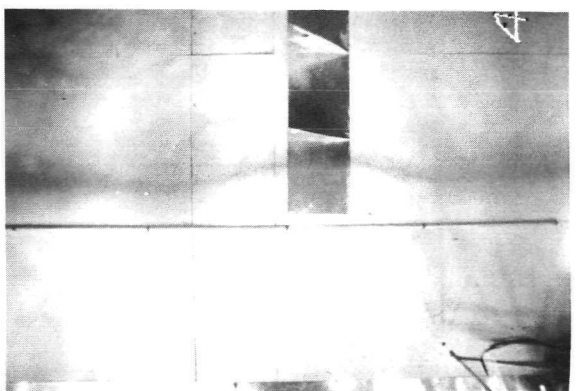
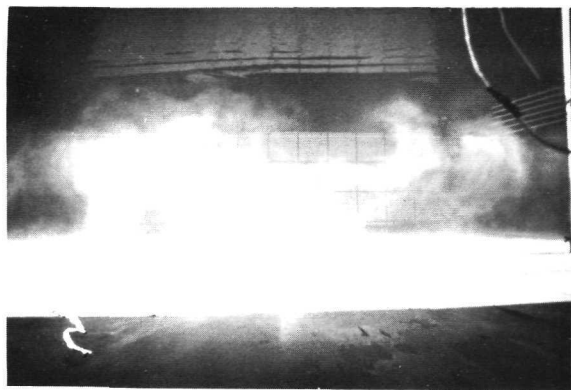
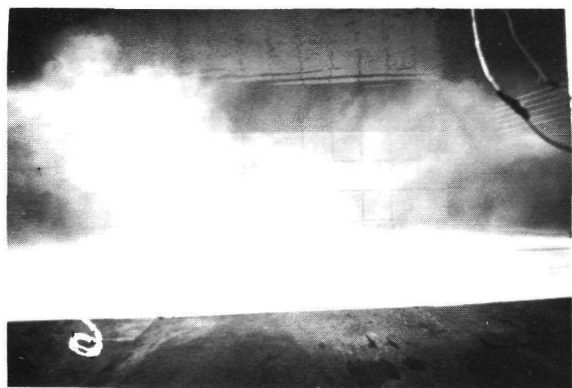
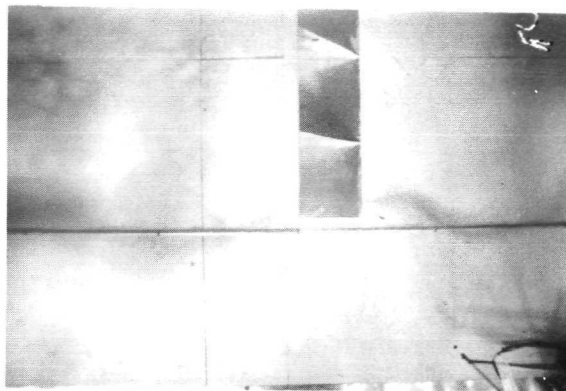


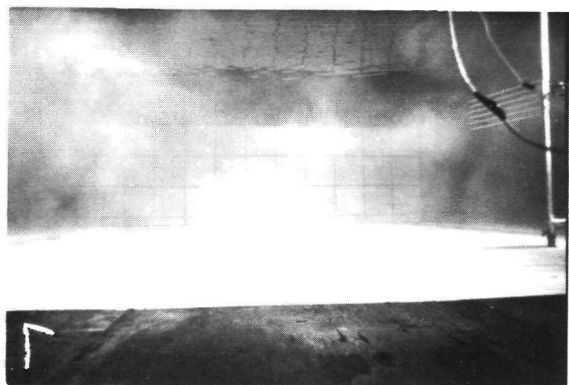
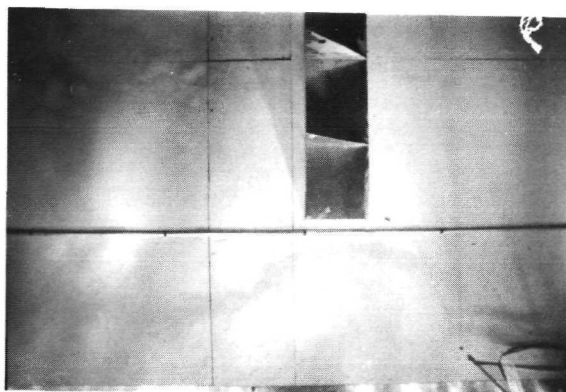
FIGURE 20 - DEVICE A-EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.69$  AND ALTITUDE = 30.5 METERS



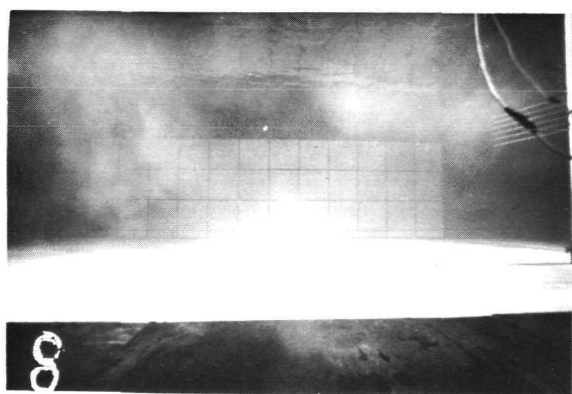
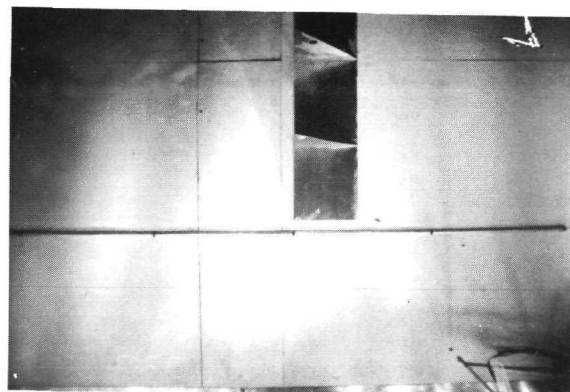
N  
10.7



17.1



24.7



35.0

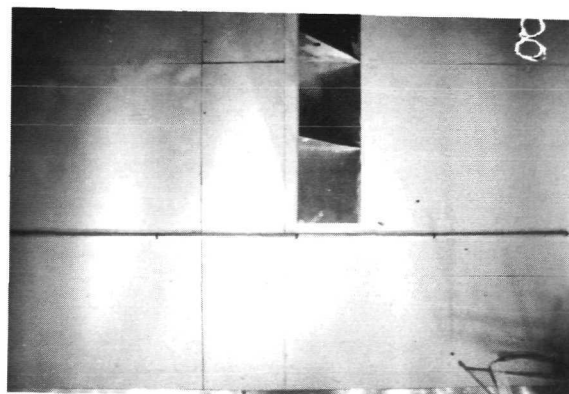


FIGURE 20 - CONCLUDED

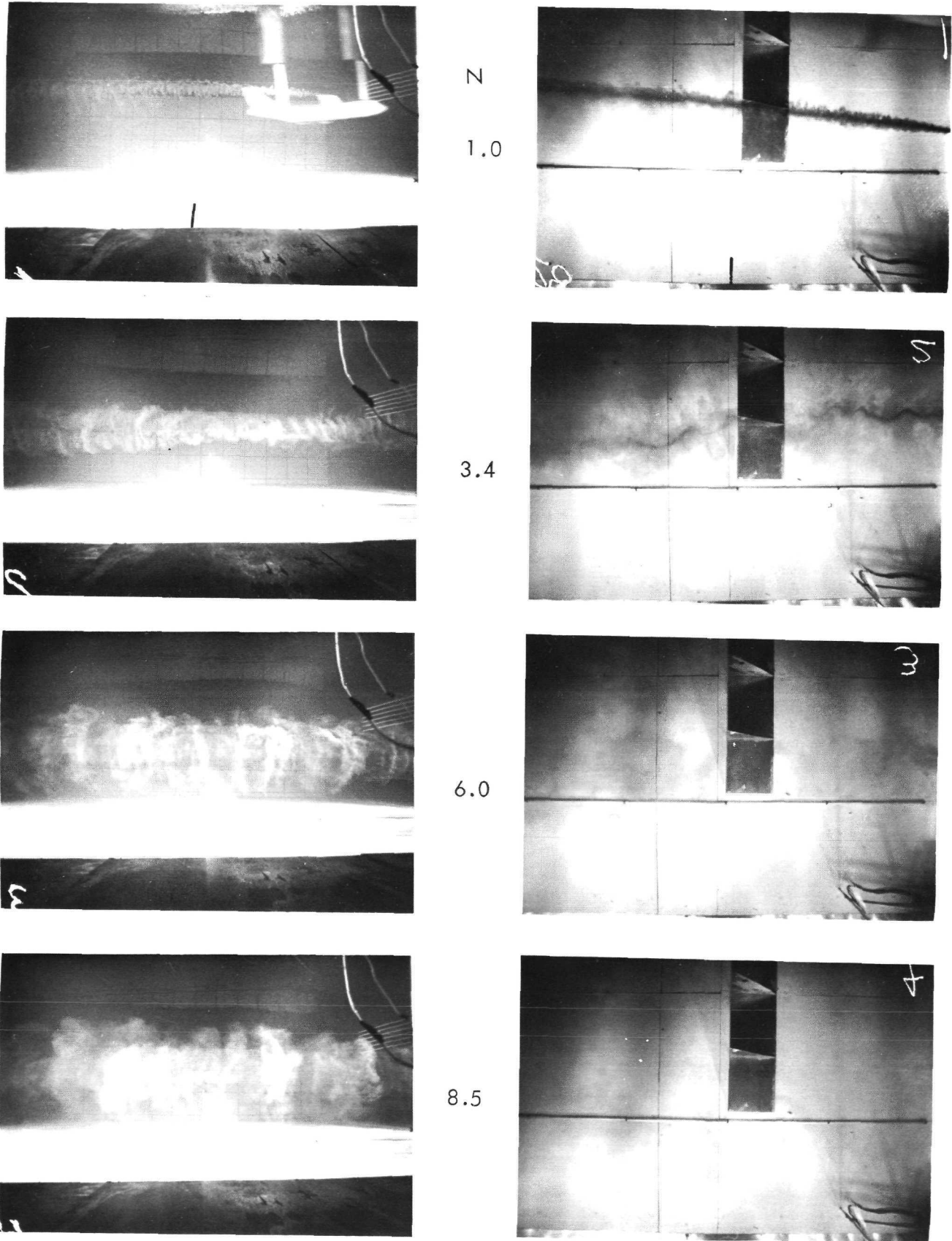
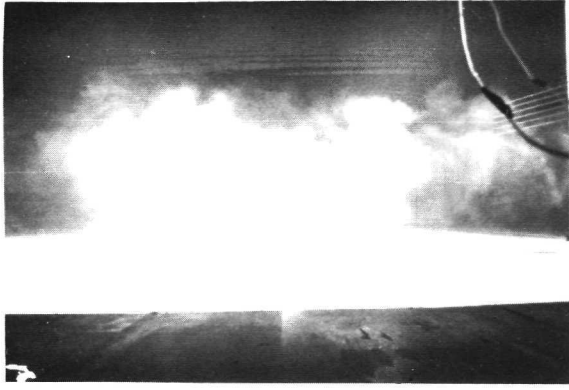
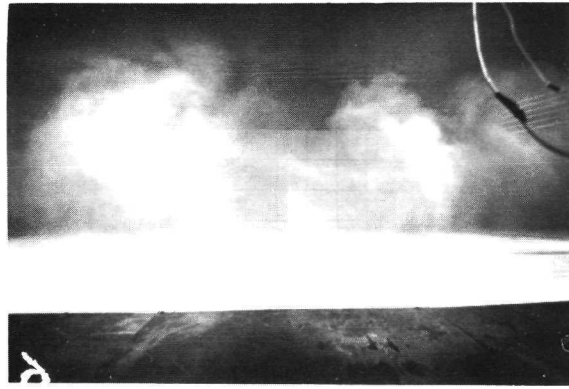
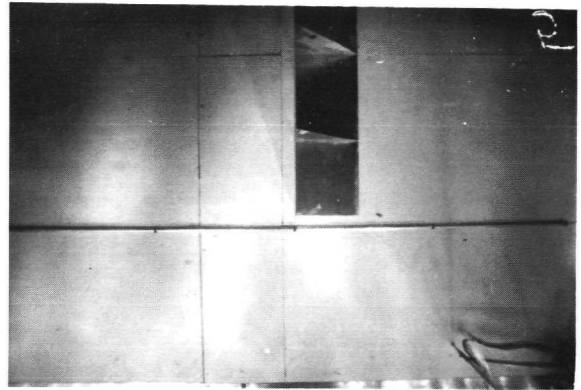


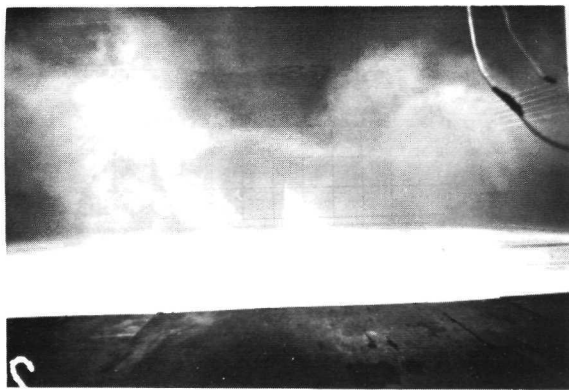
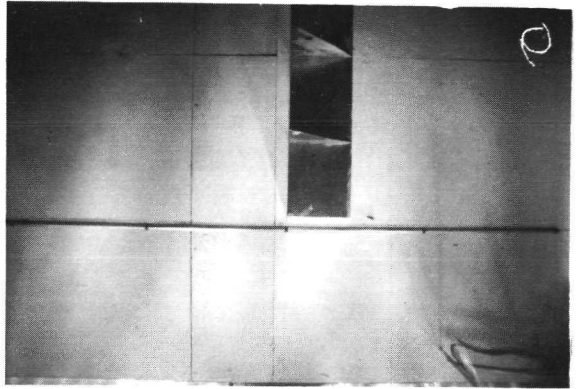
FIGURE 21 - DEVICE A-EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.13$  AND ALTITUDE = 30.5 METERS



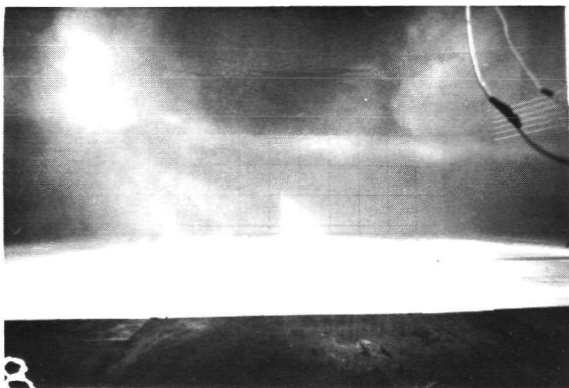
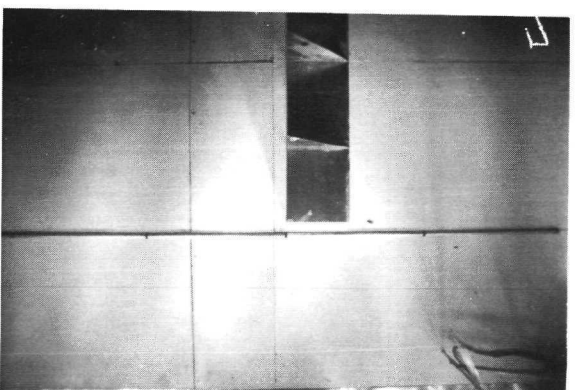
N  
11.1



17.5



25.1



35.3

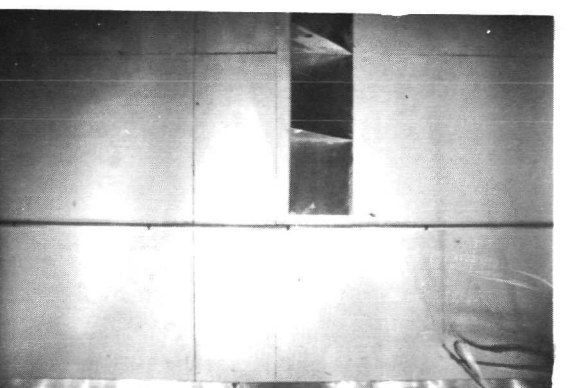


FIGURE 21 - CONCLUDED

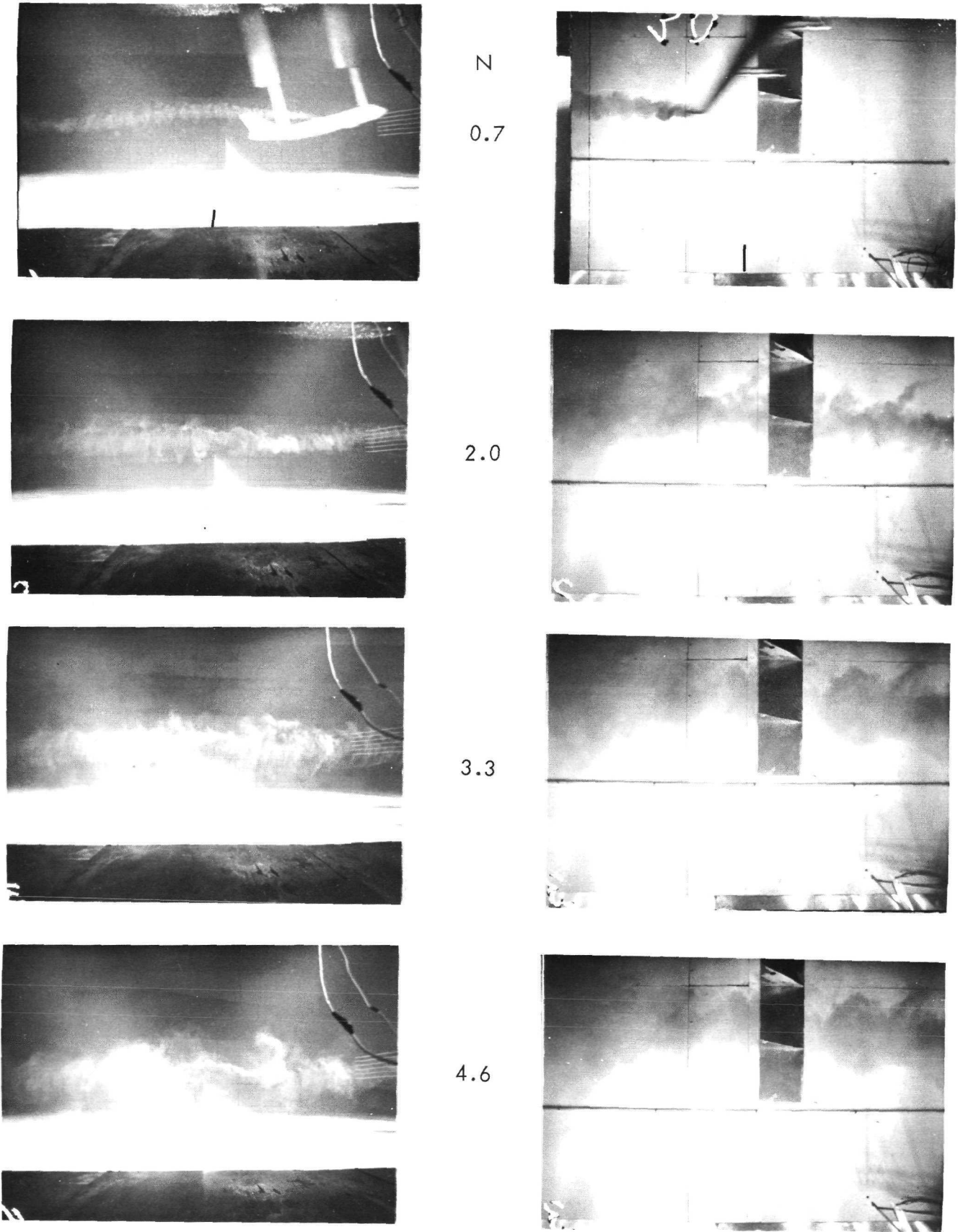
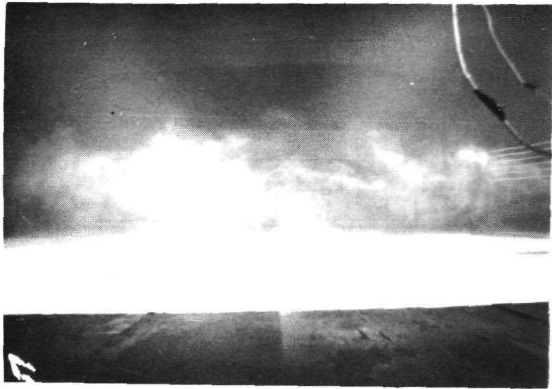
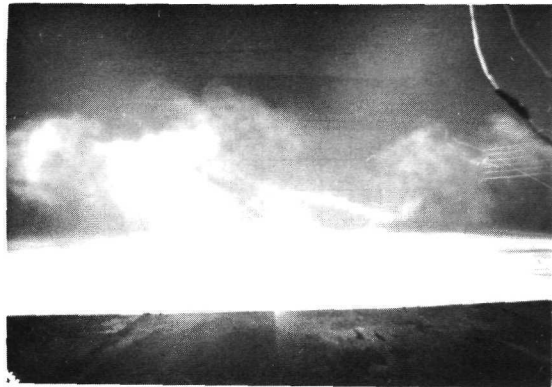
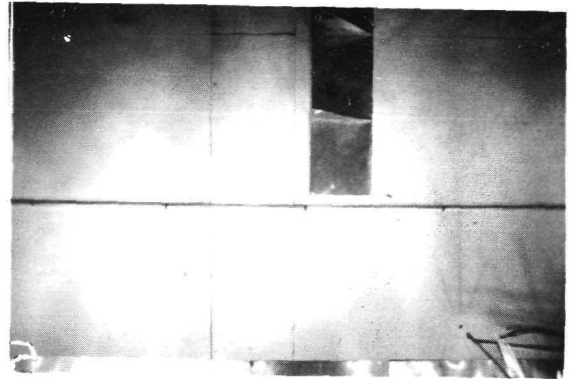


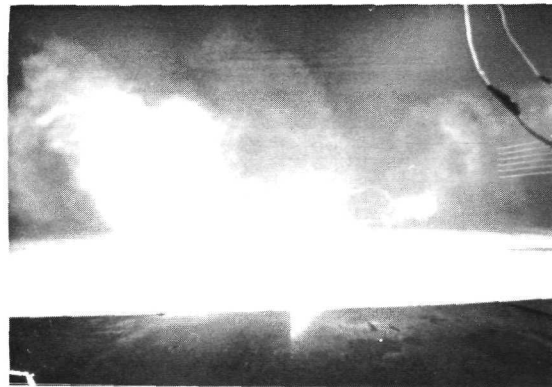
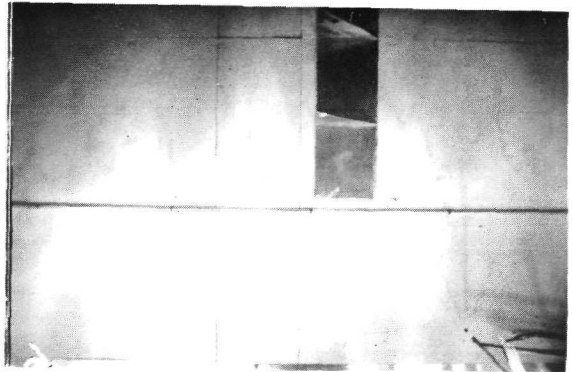
FIGURE 22 - DEVICE A-EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.66$  AND ALTITUDE = 21.3 METERS



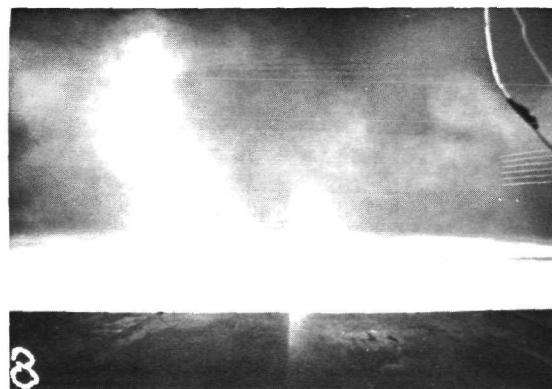
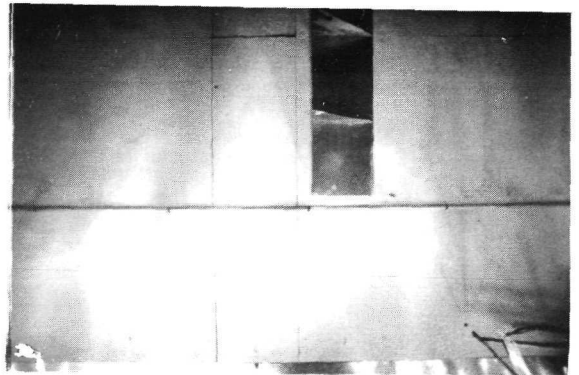
N  
5.8



8.4



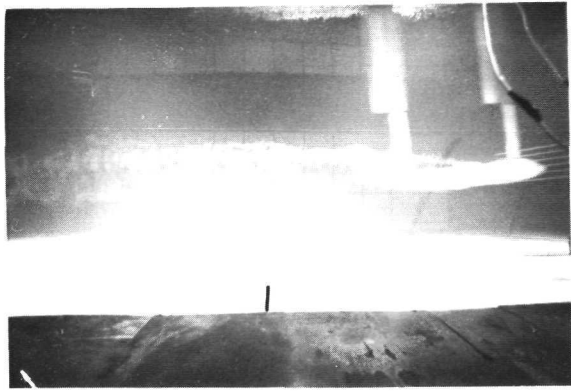
10.9



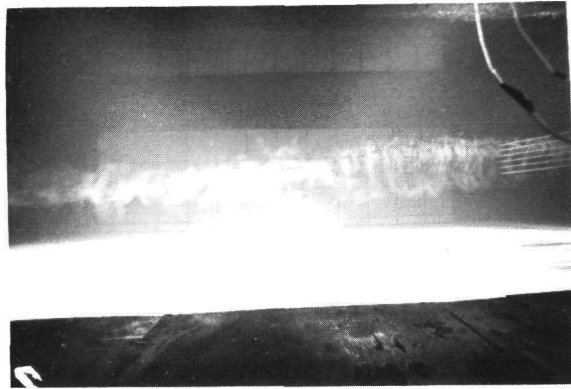
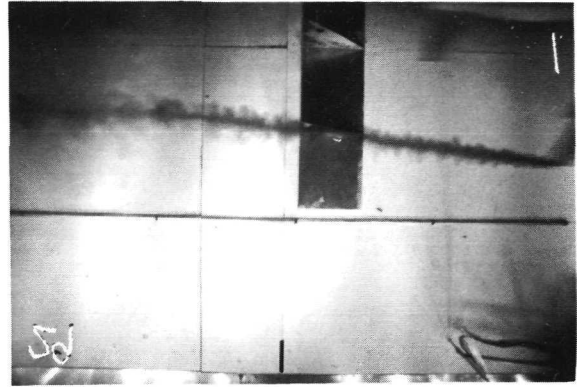
13.5



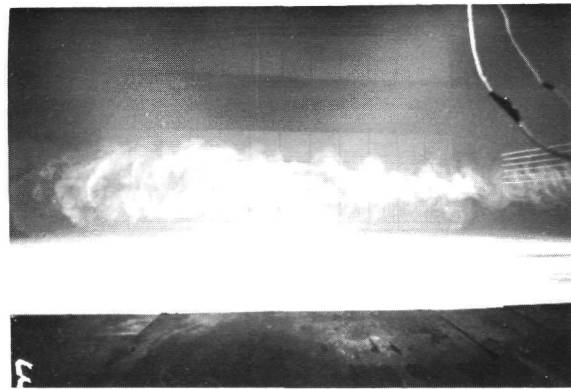
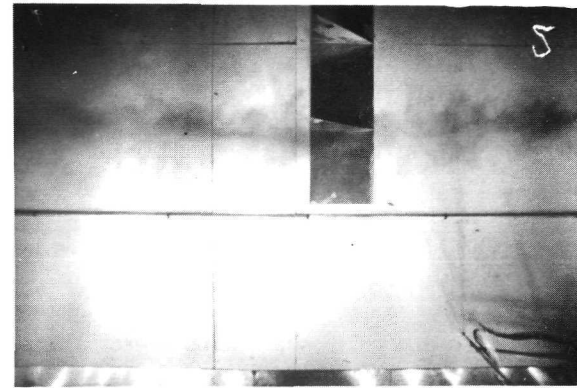
FIGURE 22 - CONCLUDED



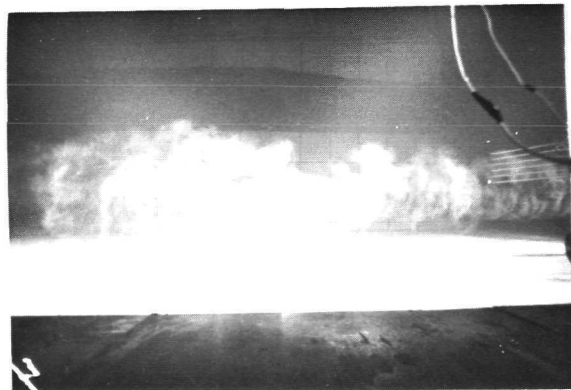
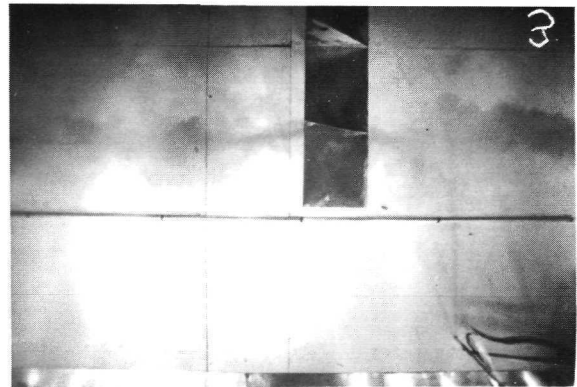
N  
1.0



2.3



3.5



4.8

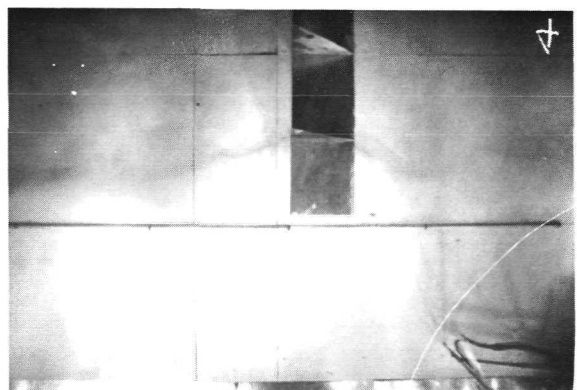
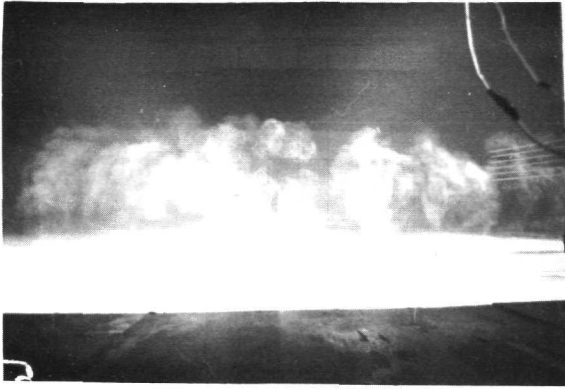
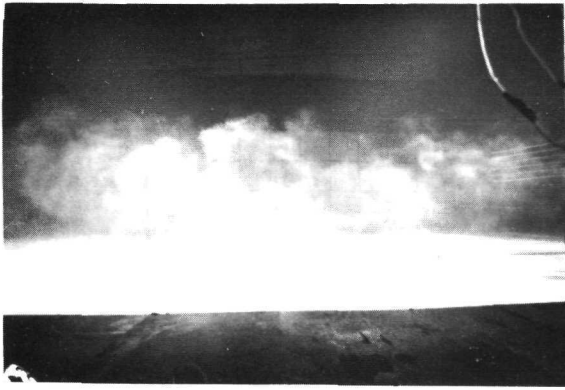
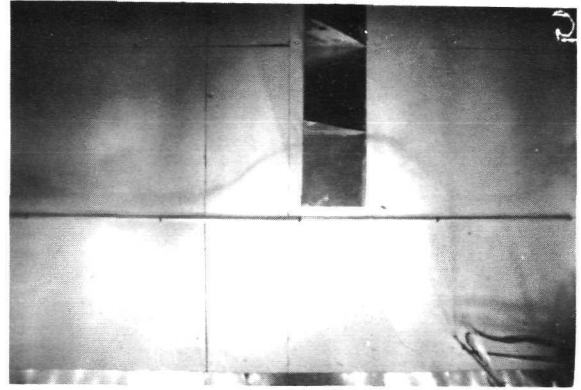


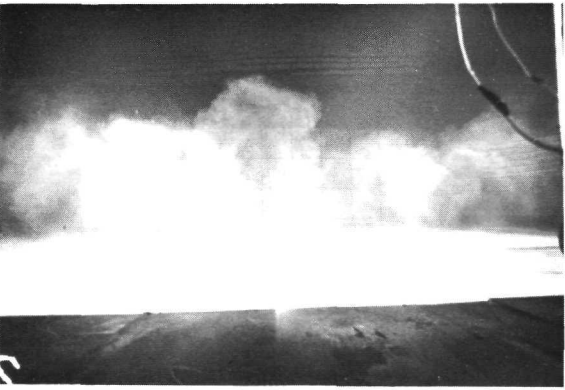
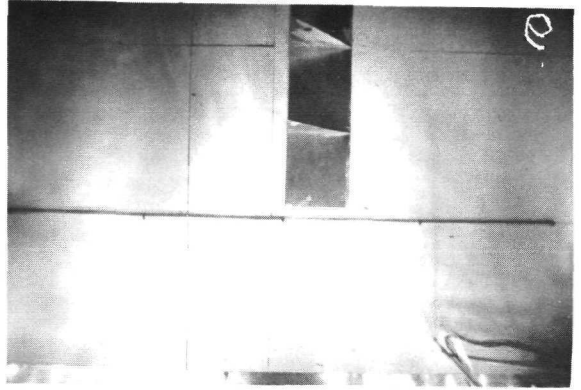
FIGURE 23 - DEVICE A-EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.14$  AND ALTITUDE = 21.3 METERS



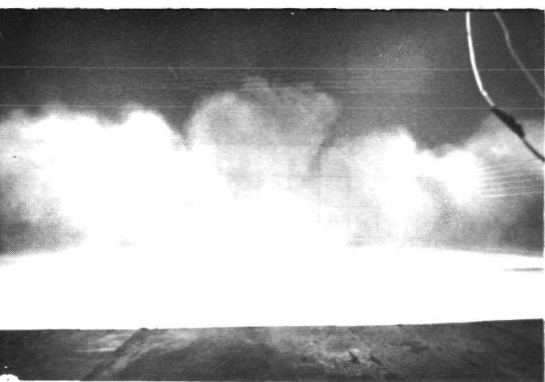
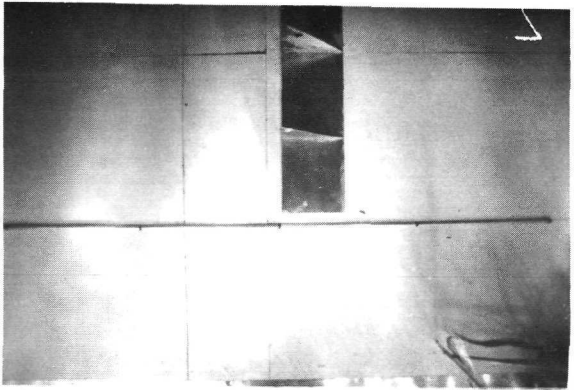
N  
6.1



8.6



11.2



13.7

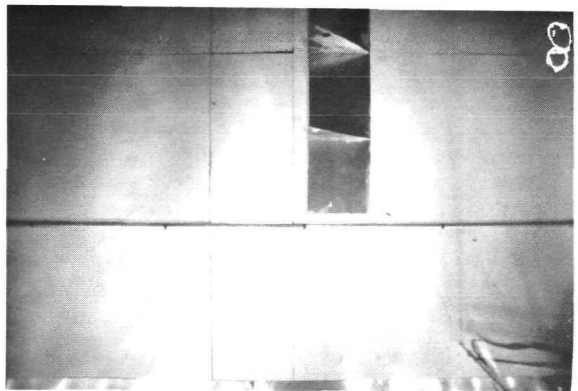
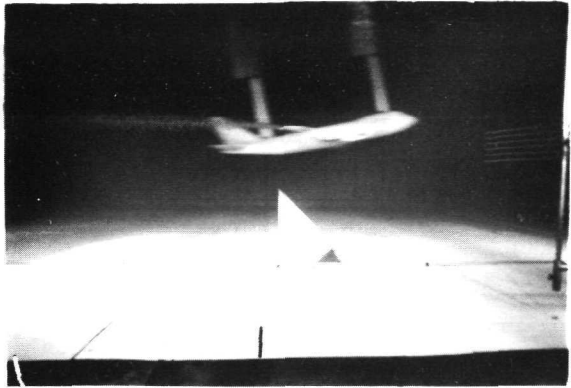
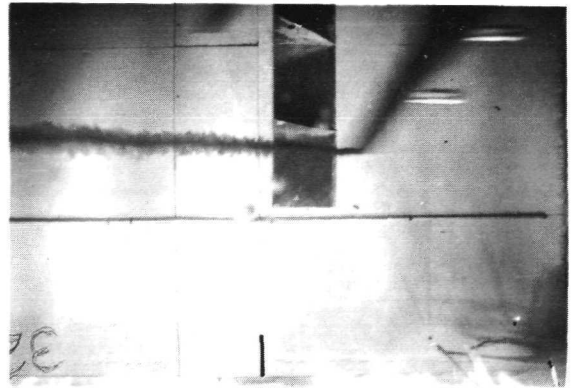


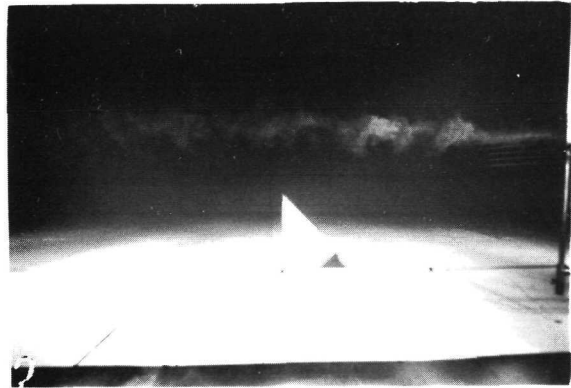
FIGURE 23 - CONCLUDED



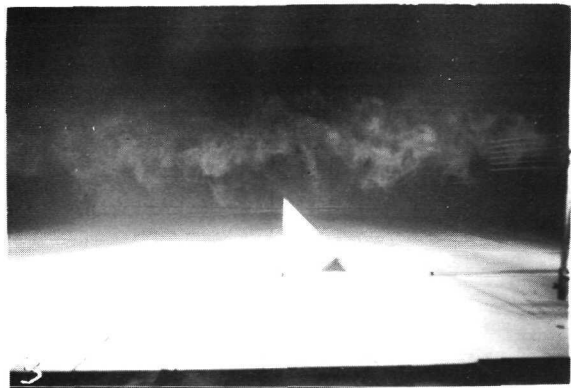
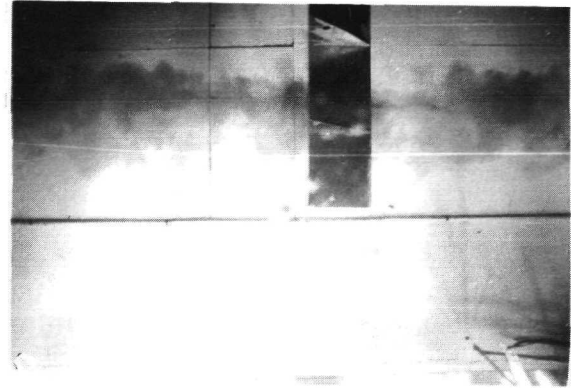
0



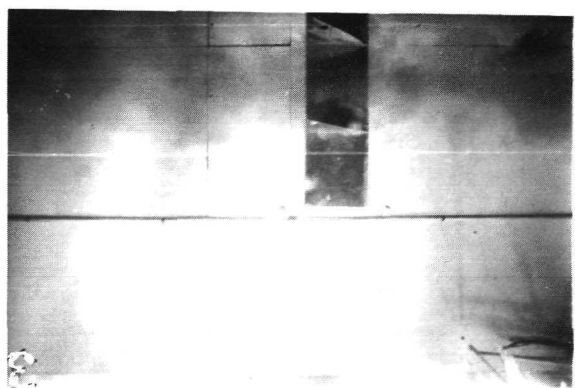
0



2.6



5.1



7.7

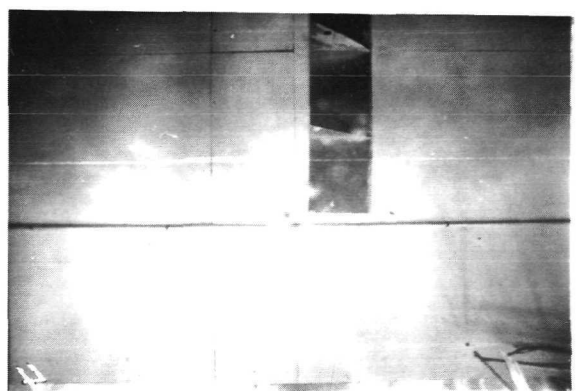
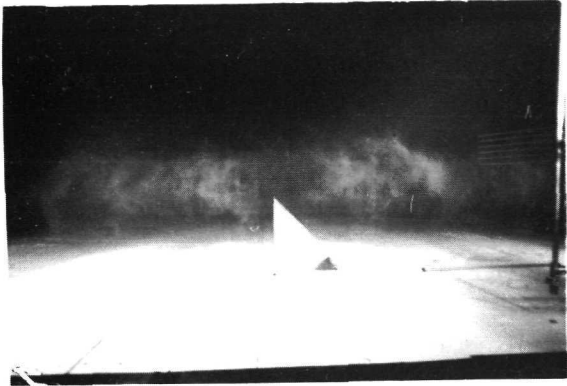
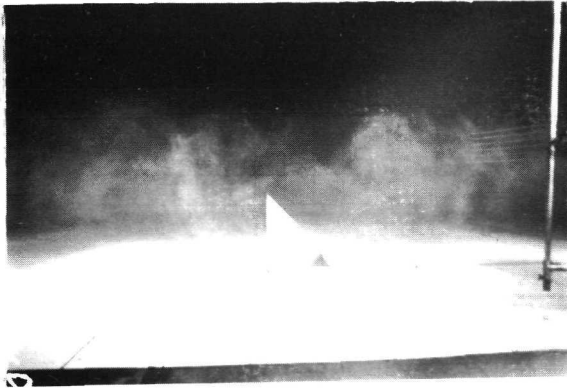
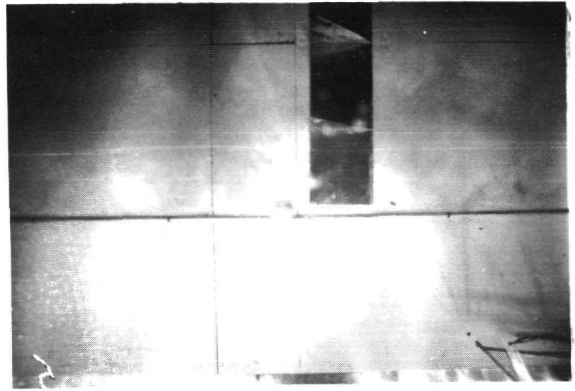


FIGURE 24 - DEVICE A-EFFECT ON VORTEX WAKE FOR CRUISE CONDITION,  $C_L = 0.96$  AND ALTITUDE = 30.5 METERS

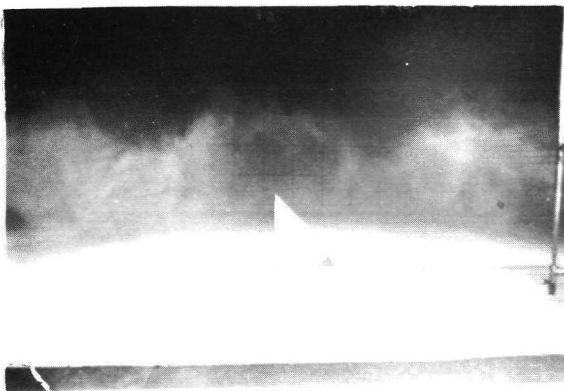
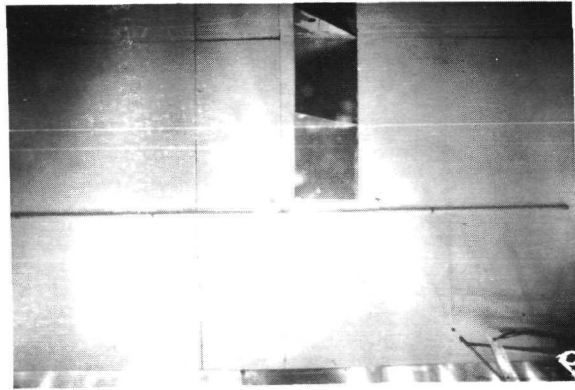


N

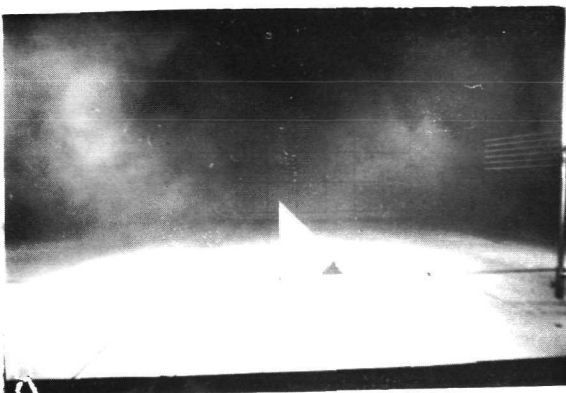
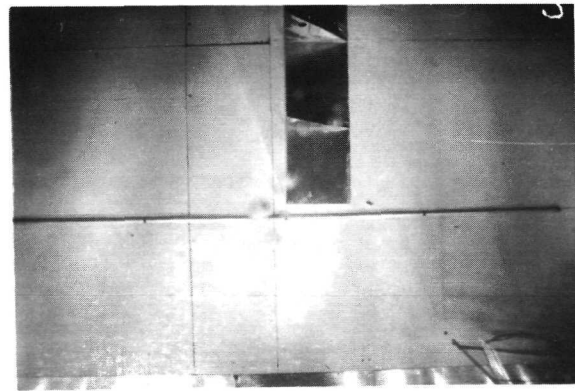
10.2



16.6



24.2



34.4

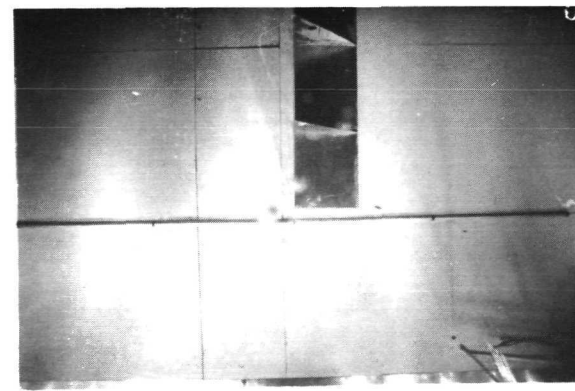


FIGURE 24 - CONCLUDED

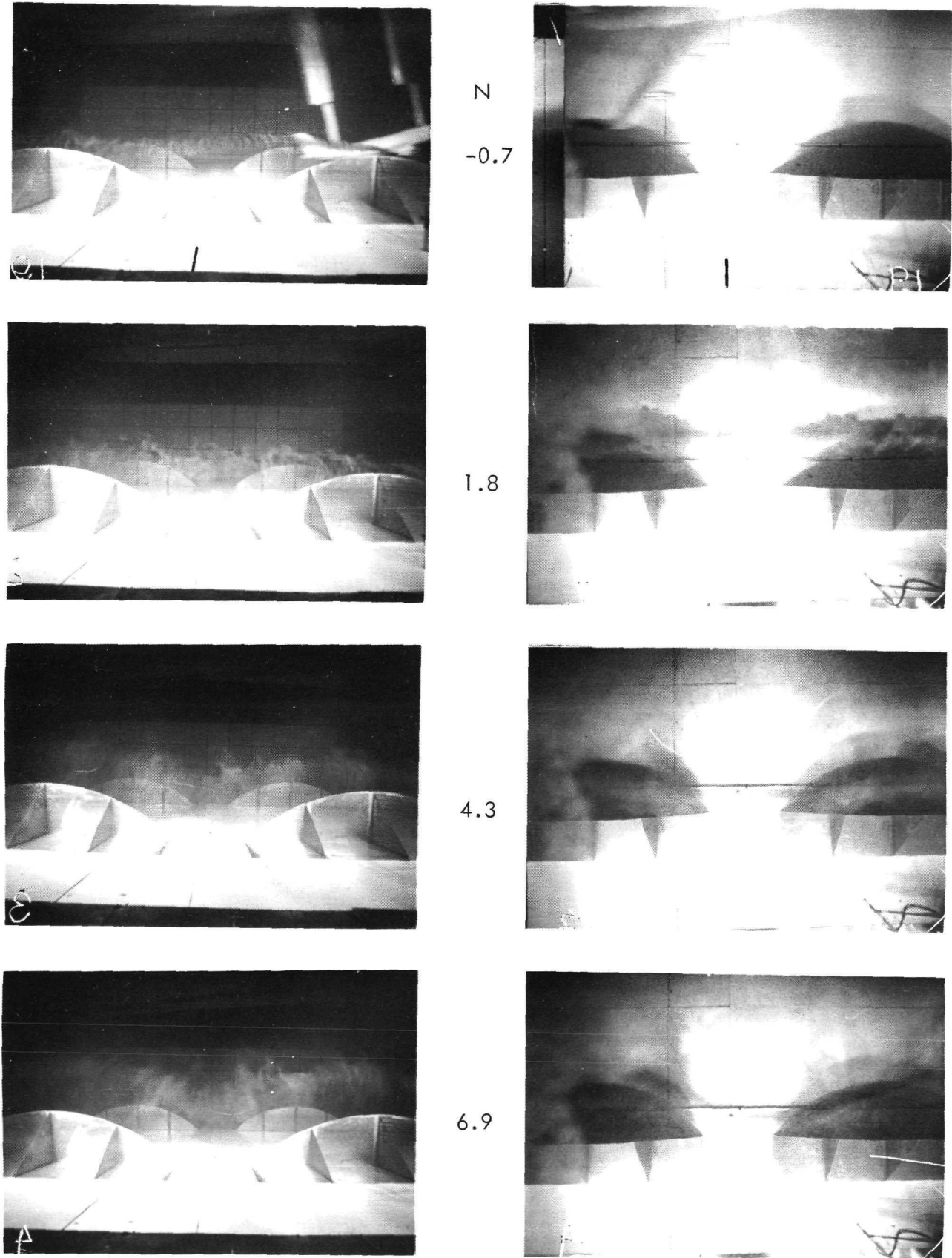
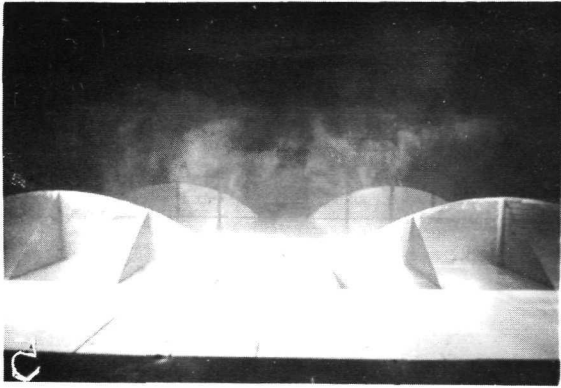
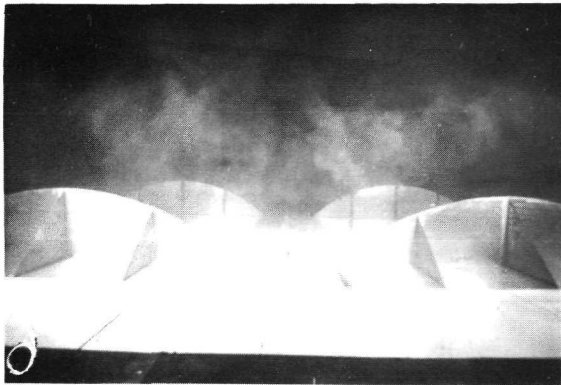
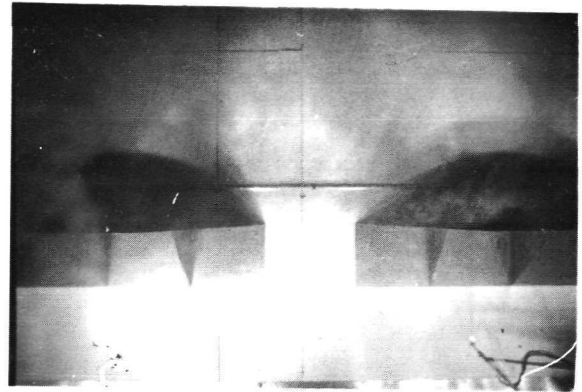


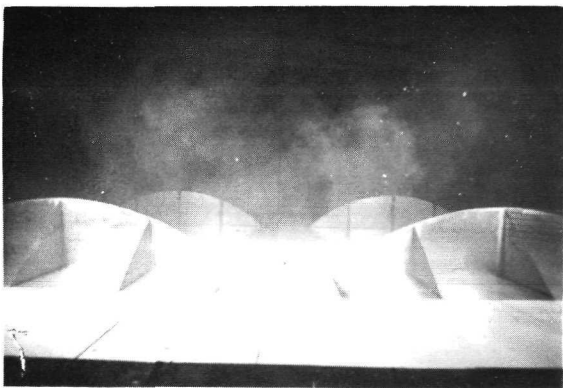
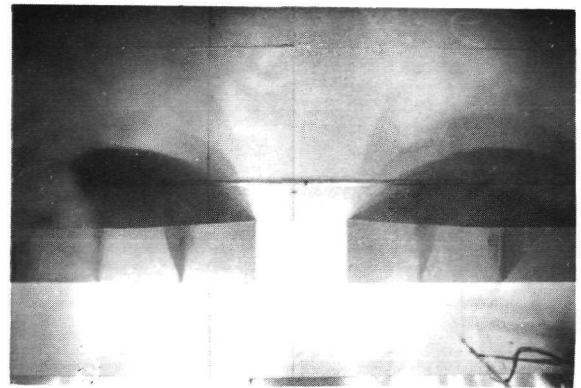
FIGURE 25 - DEVICE B-EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.70$  AND ALTITUDE = 13.4 METERS



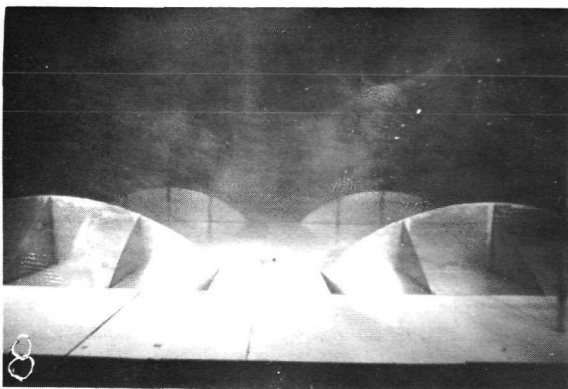
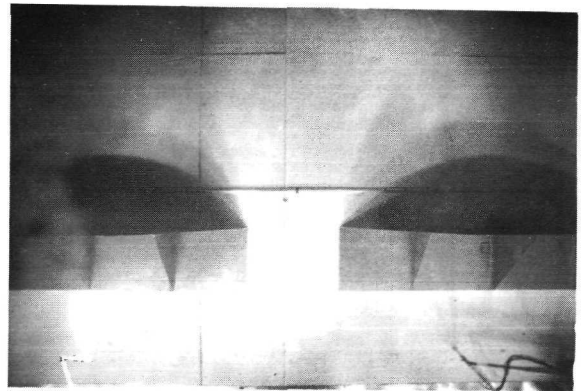
N  
10.7



14.6



18.4



23.5

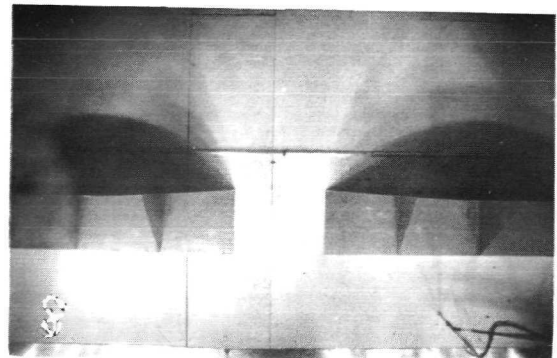
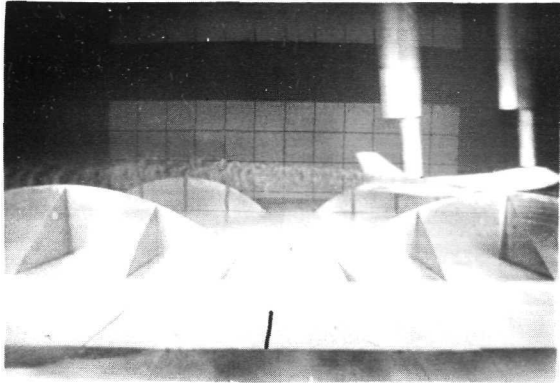
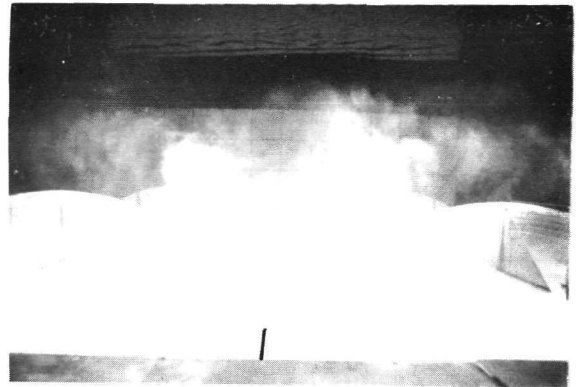


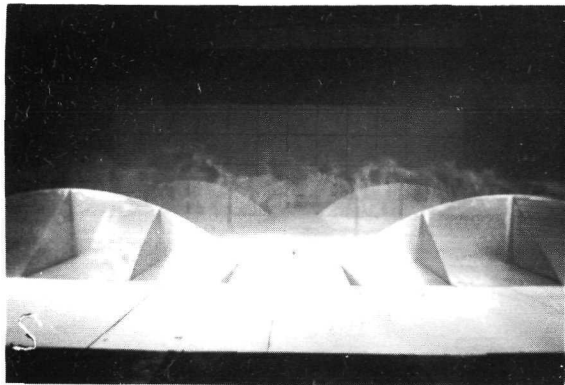
FIGURE 25 - CONCLUDED



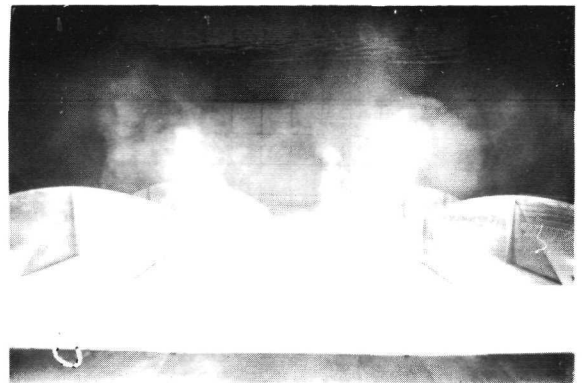
N 1.0



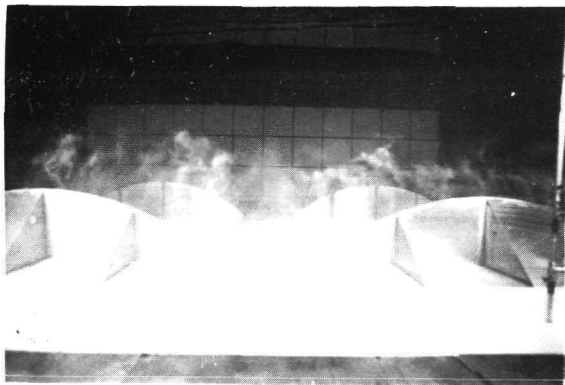
11.2



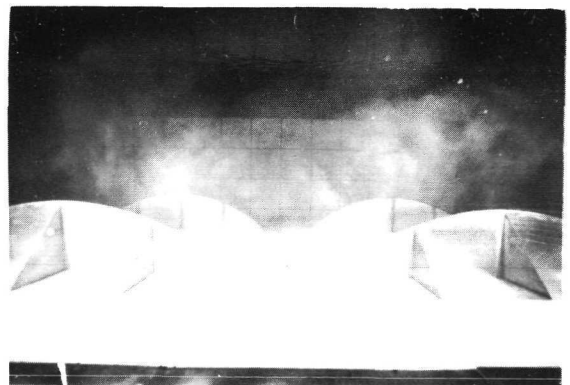
3.6



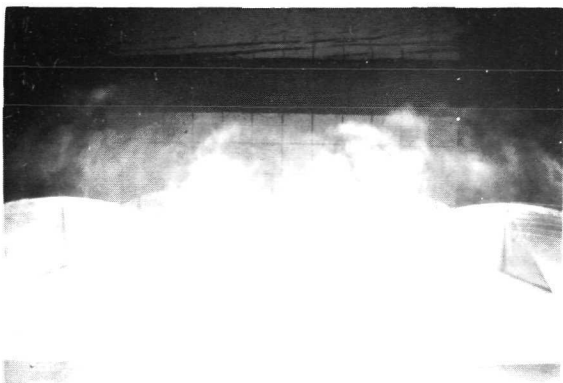
16.3



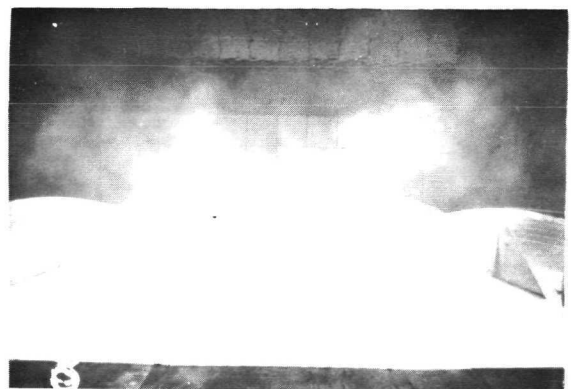
6.1



21.4

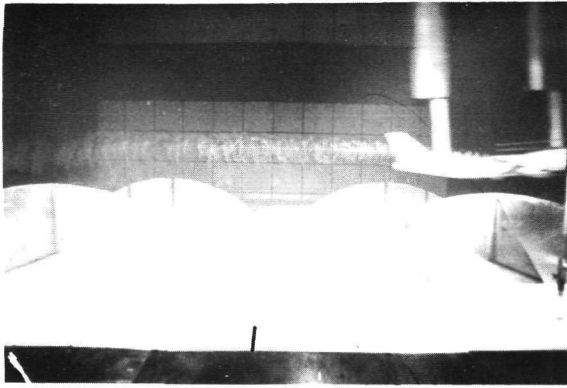


8.6

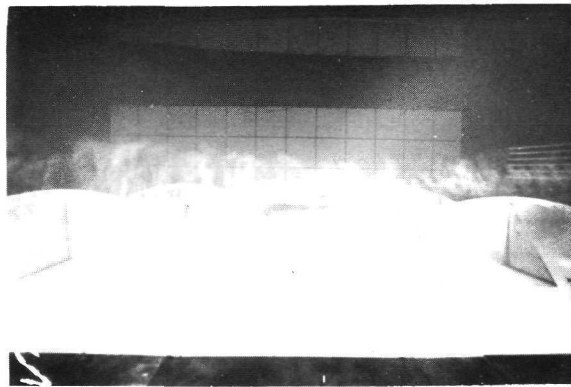
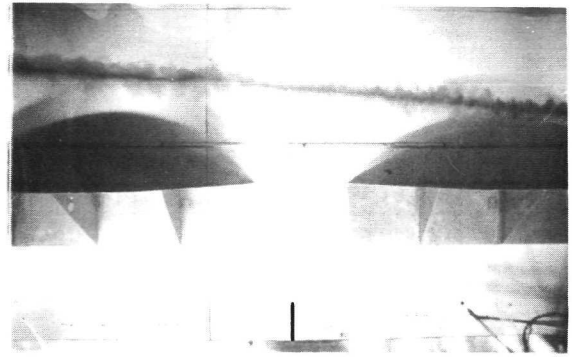


26.5

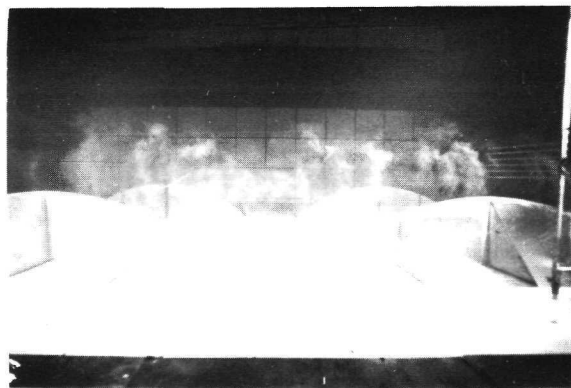
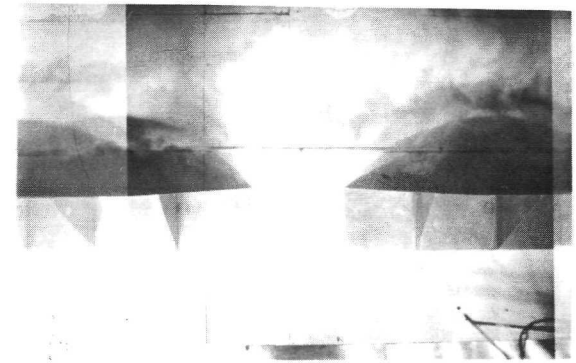
FIGURE 26 - DEVICE B-EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.13$  AND ALTITUDE = 13.4 METERS



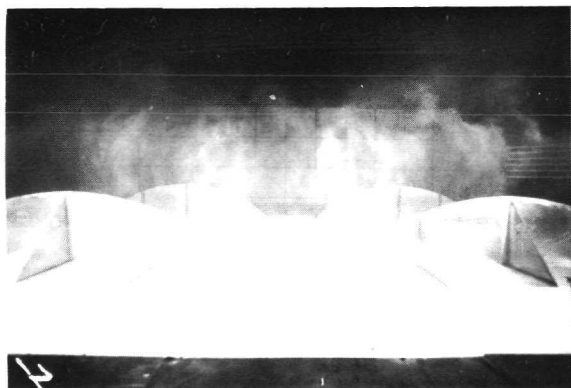
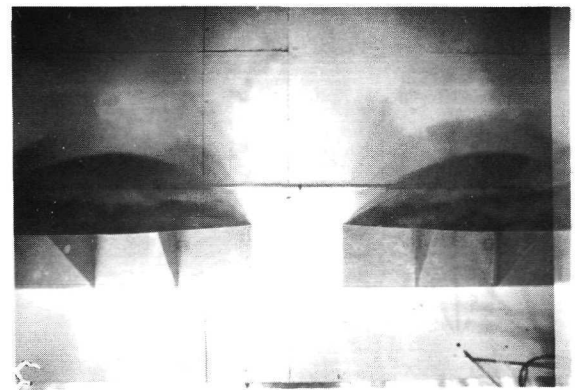
N  
1.3



3.9



6.5



11.6

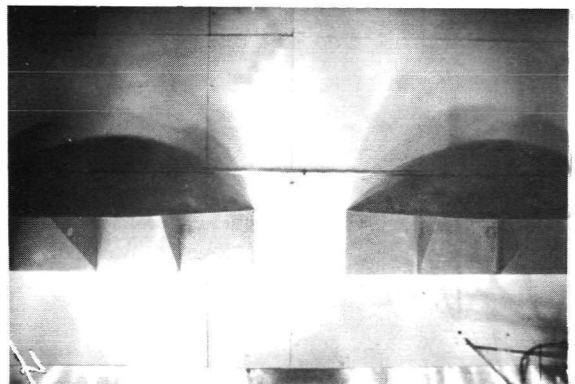
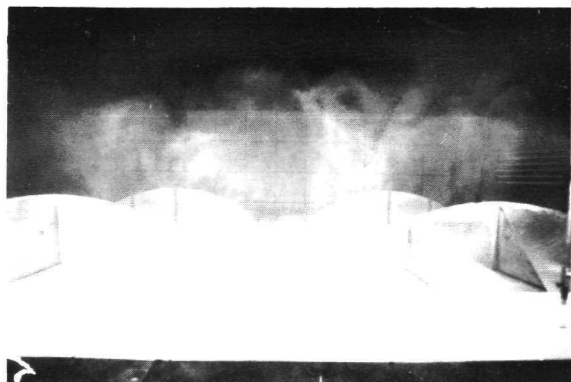
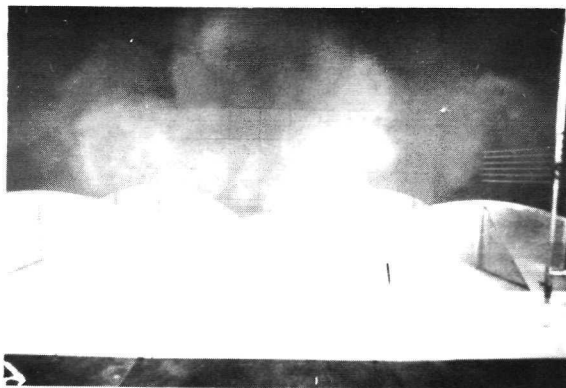
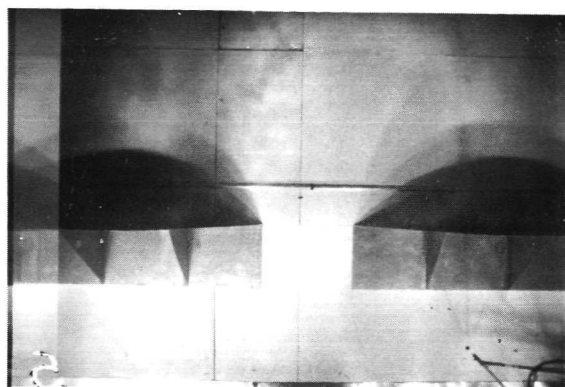


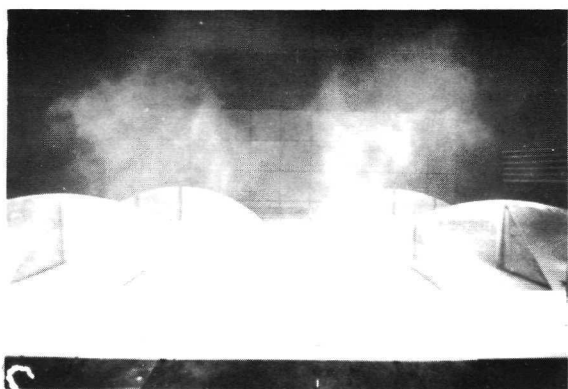
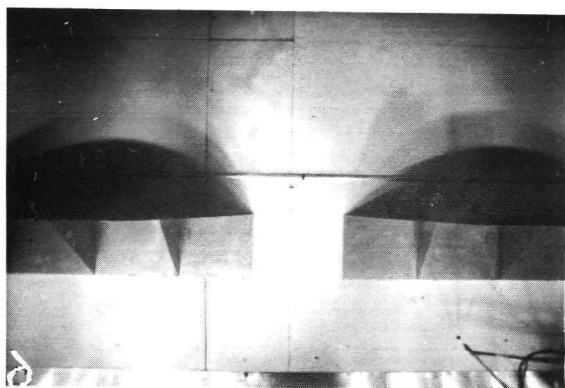
FIGURE 27 - DEVICE B-EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.16$  AND ALTITUDE = 21.3 METERS



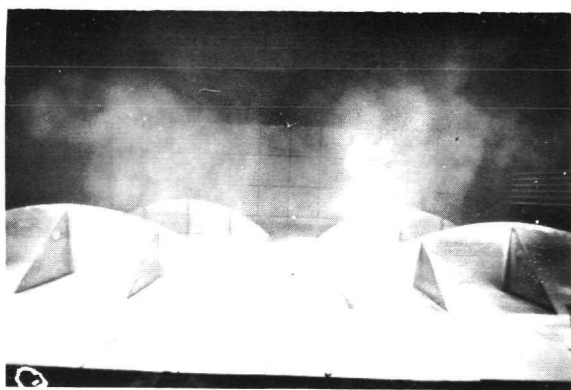
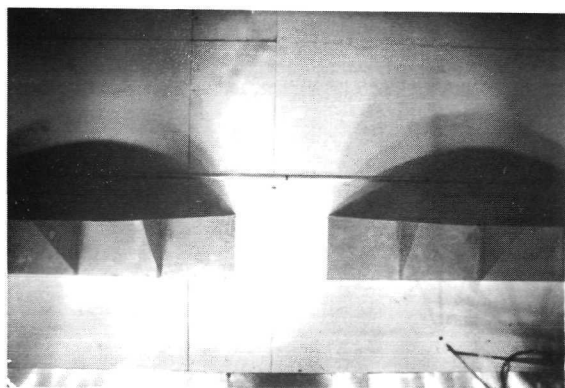
N  
14.1



19.2



24.3



29.4

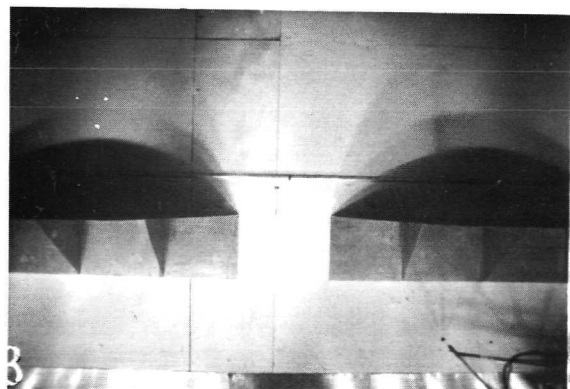
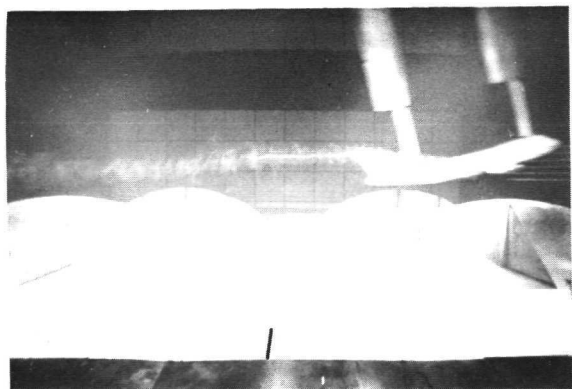
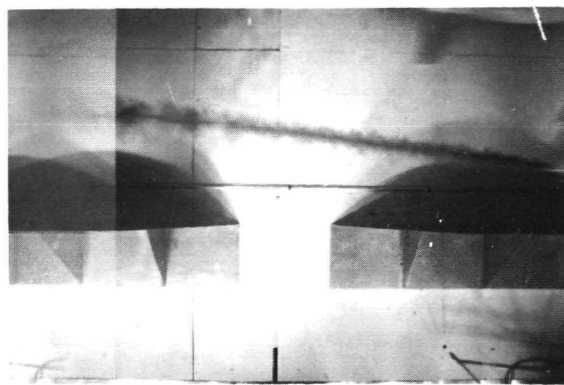


FIGURE 27 - CONCLUDED

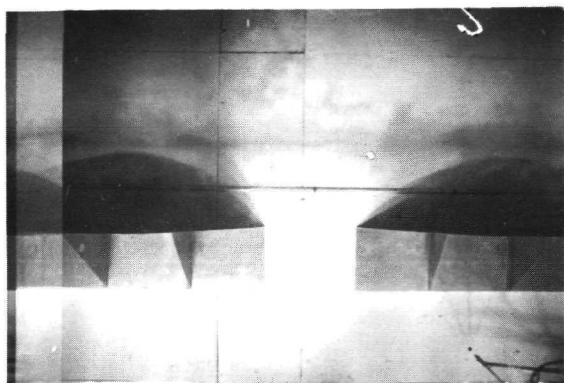


N

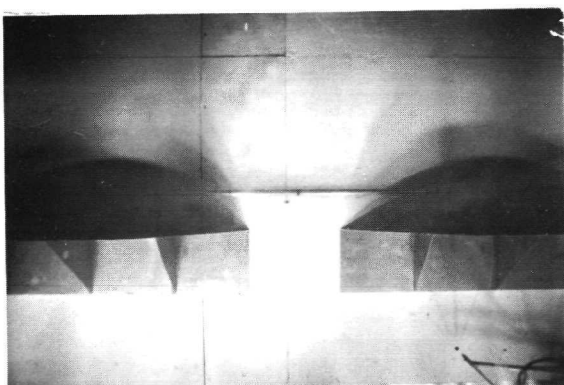
1.1



3.7



7.5



12.6

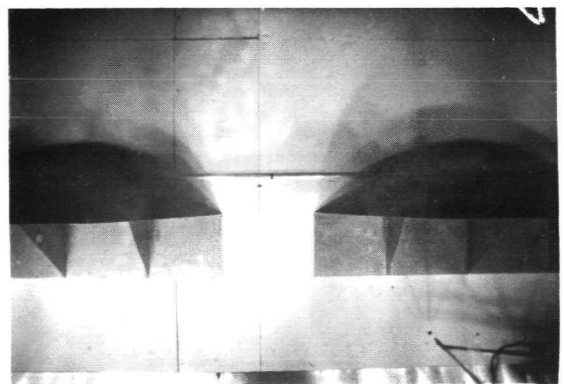
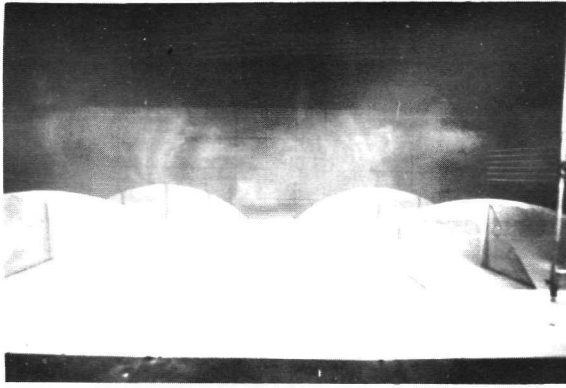
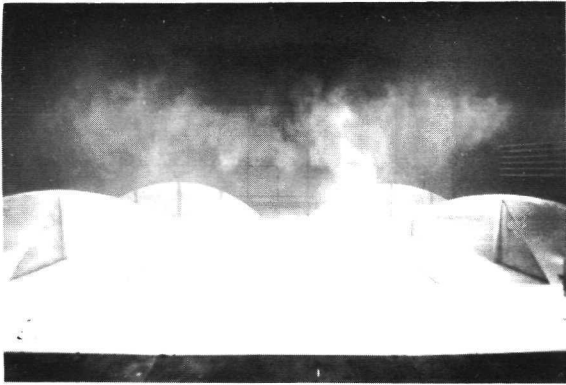
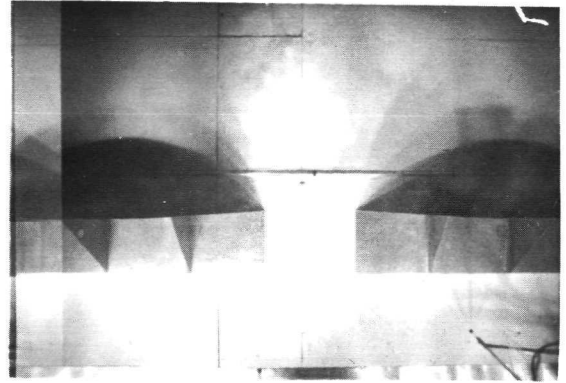


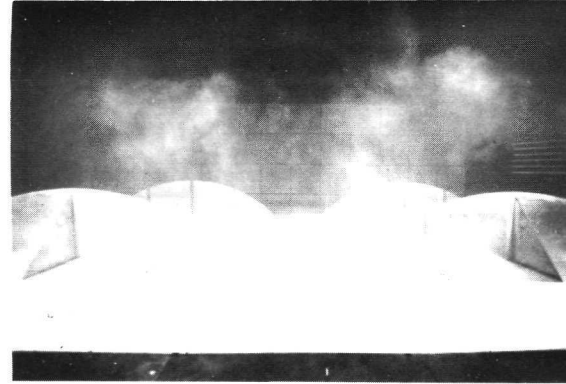
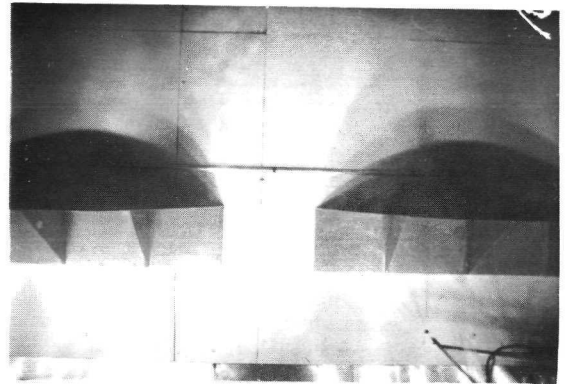
FIGURE 28 - DEVICE B-EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.69$  AND ALTITUDE = 21.3 METERS



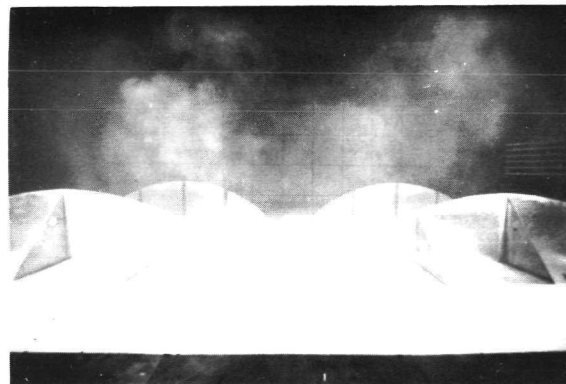
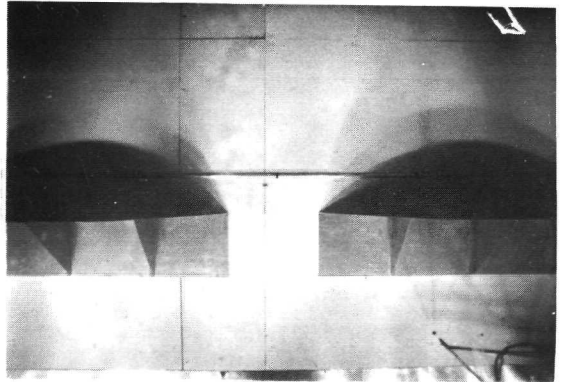
N  
15.2



20.2



25.3



30.4

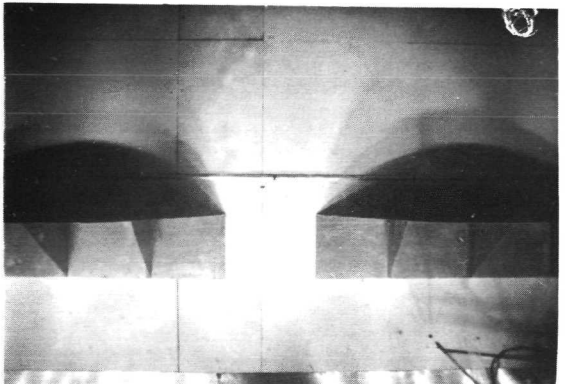
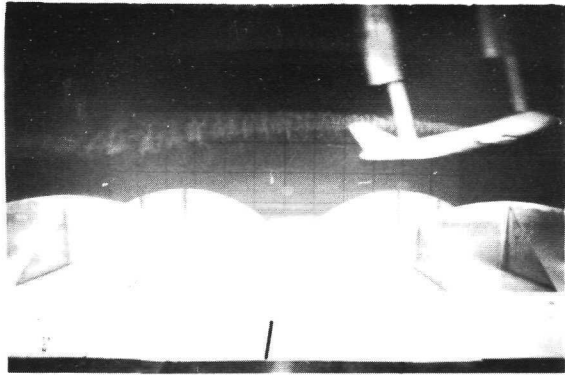
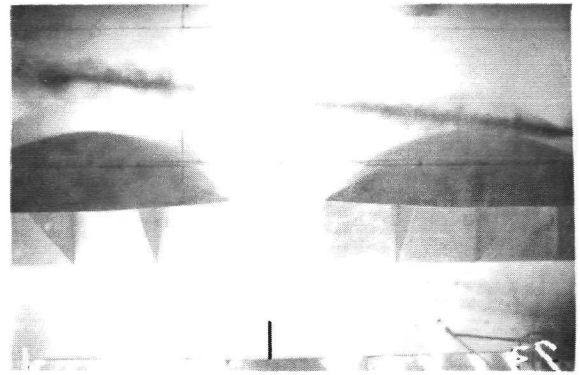


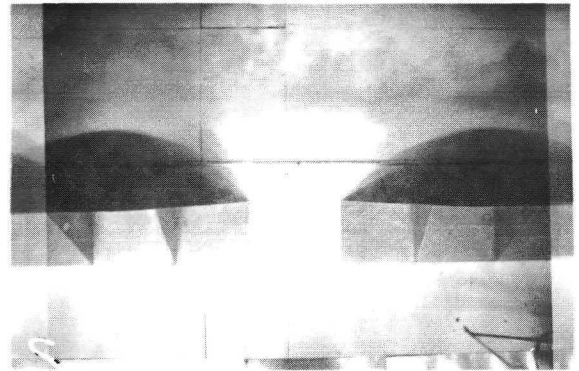
FIGURE 28 - CONCLUDED



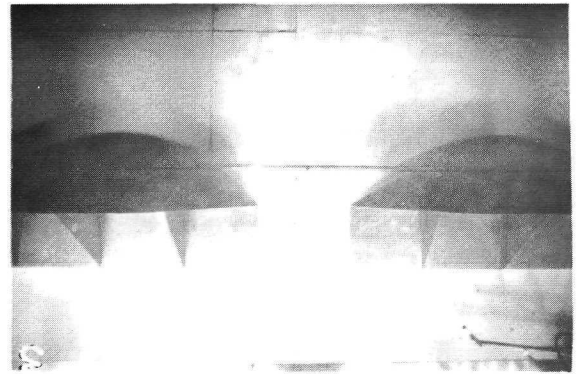
N  
1.0



4.8



8.6



12.5

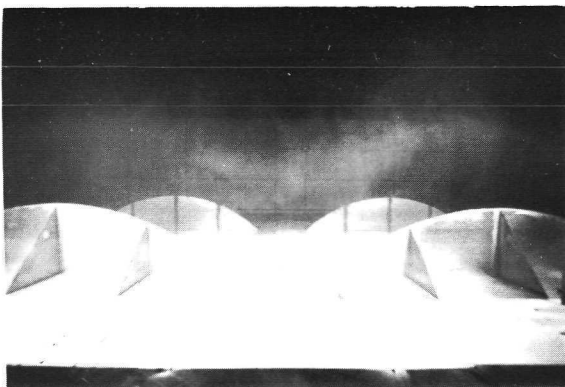
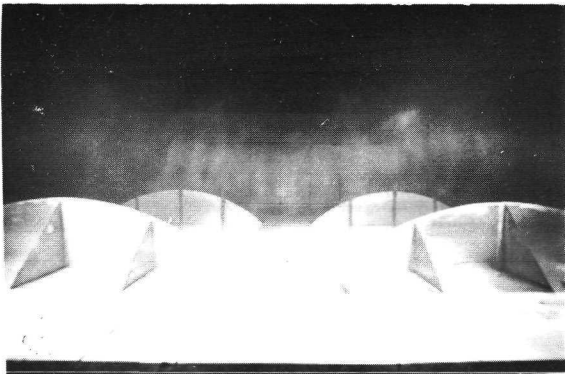
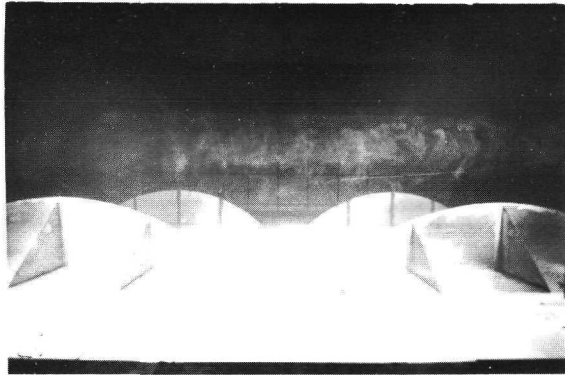
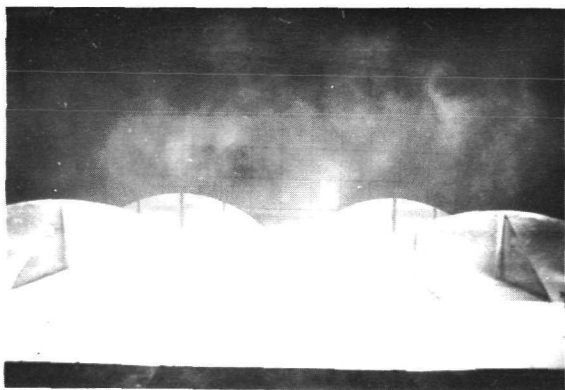
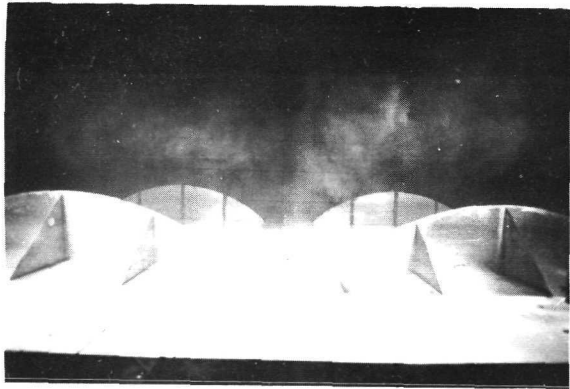
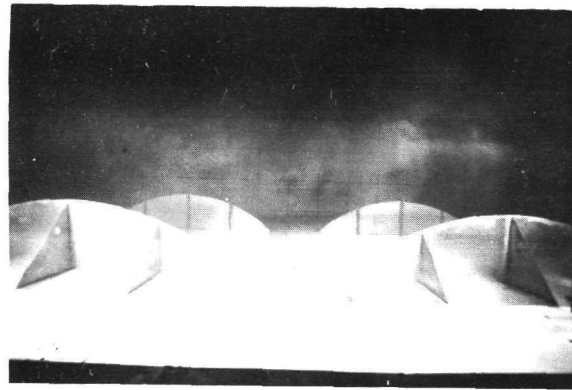
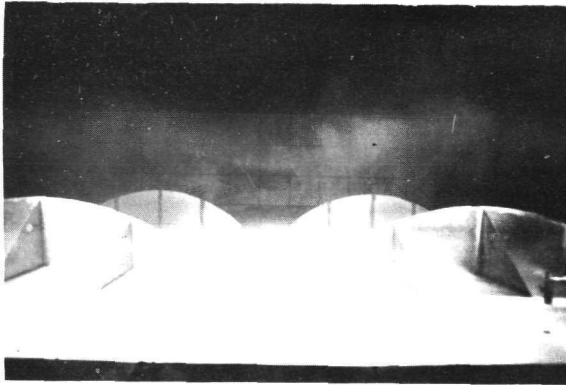
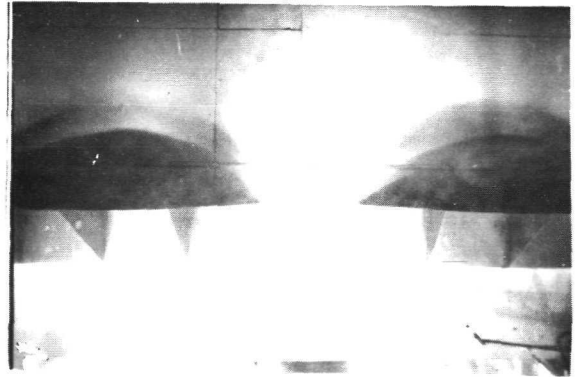


FIGURE 29 - DEVICE B-EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.68$  AND ALTITUDE = 30.5 METERS

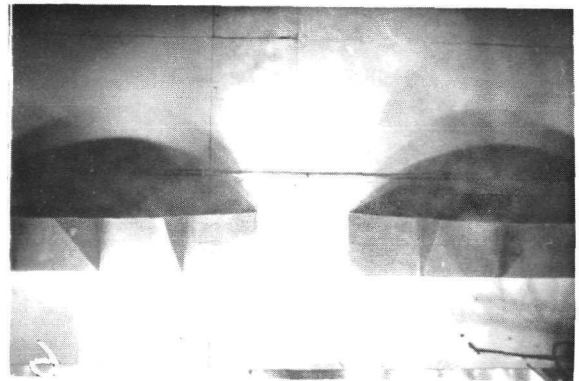


N

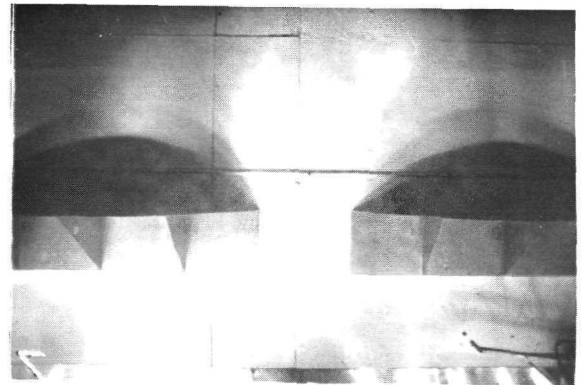
16.3



20.1



23.9



27.8

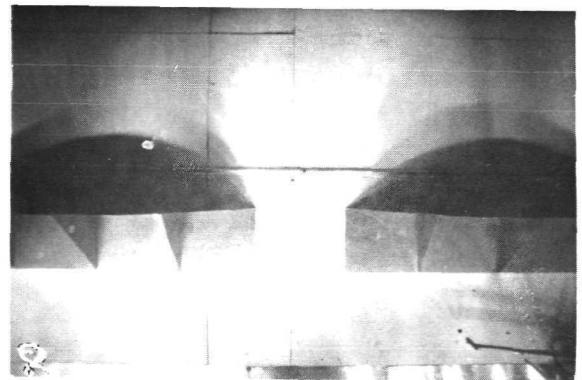
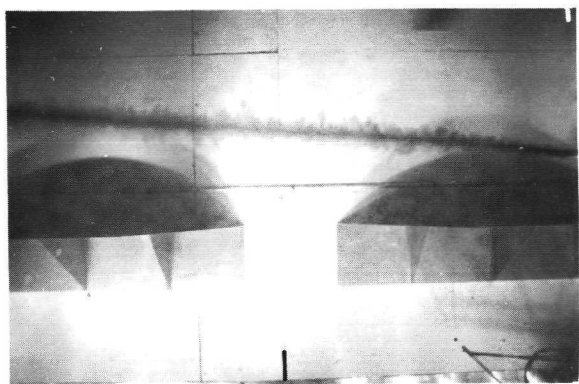
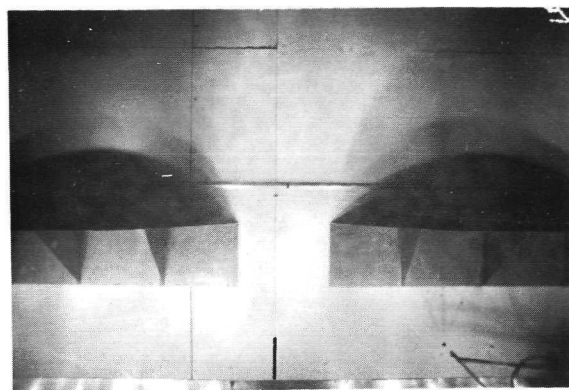


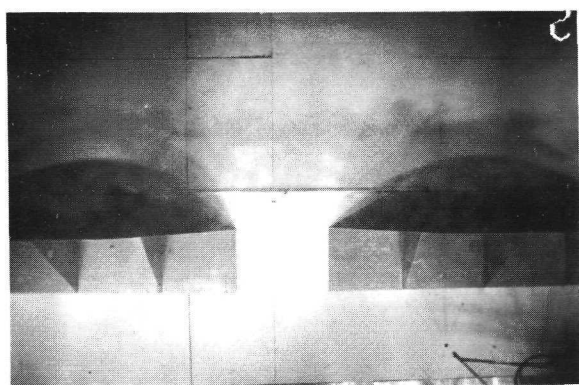
FIGURE 29 - CONCLUDED



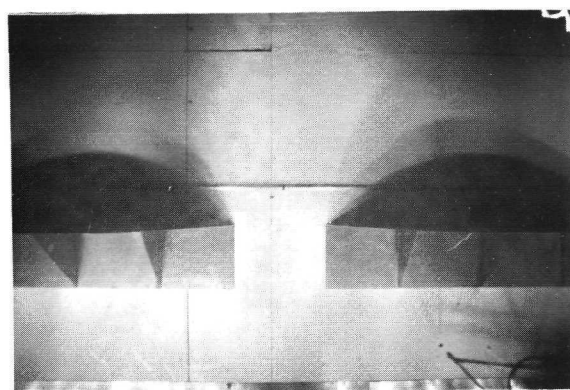
N 0.9



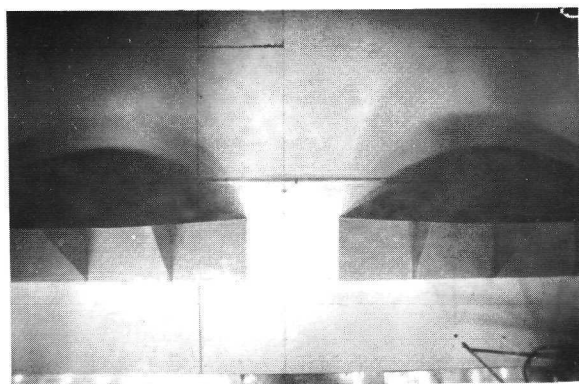
16.3



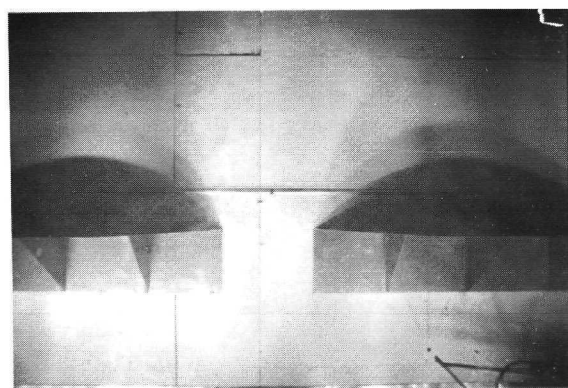
4.8



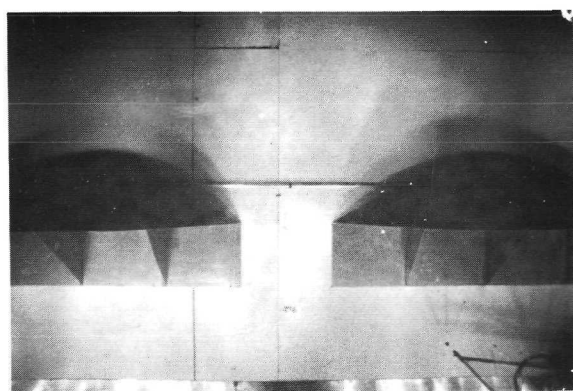
20.1



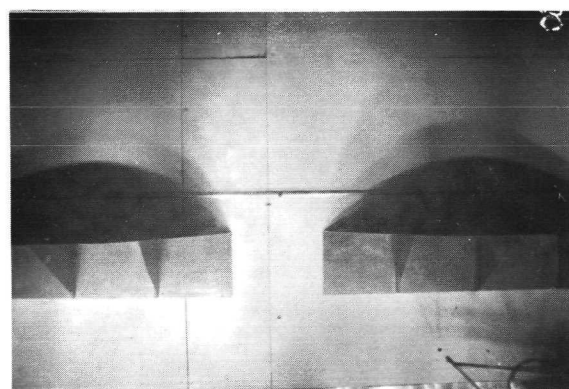
8.6



23.9

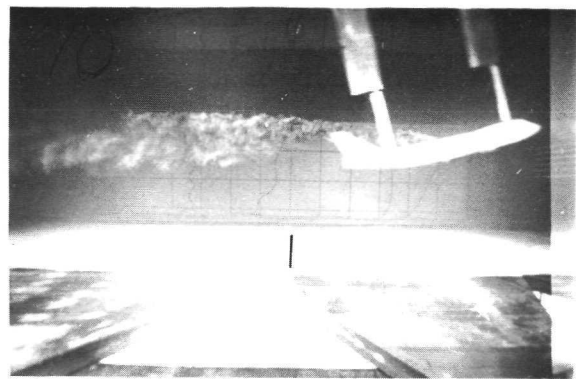


12.5



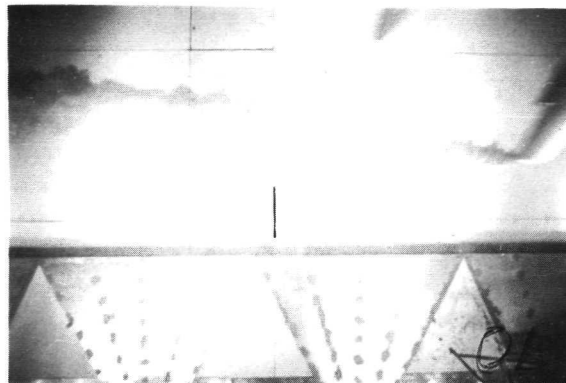
27.8

FIGURE 30 - DEVICE B-EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.13$  AND ALTITUDE = 30.5 METERS

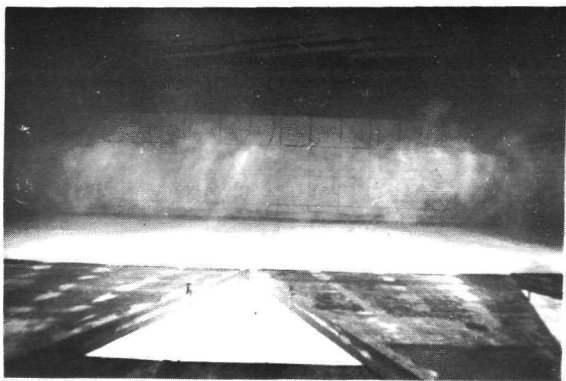
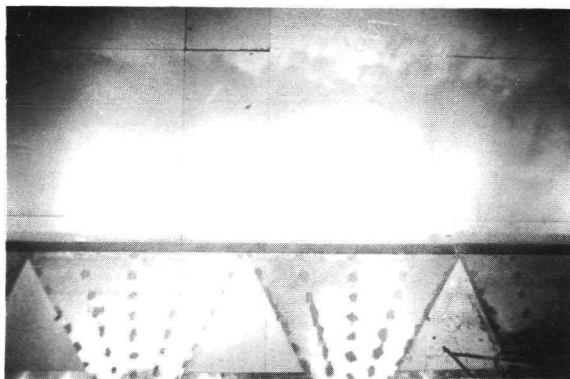


N

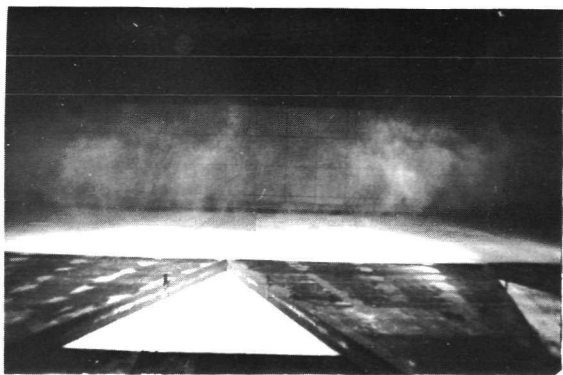
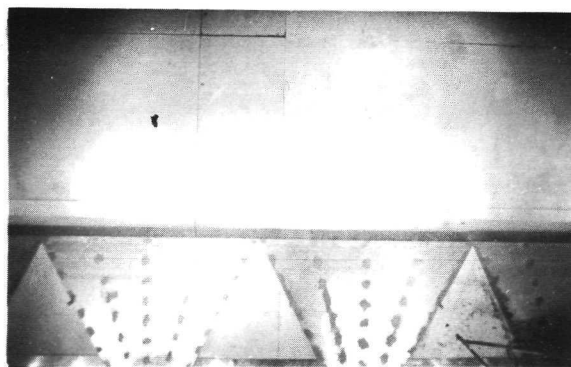
0.9



3.6



6.4



9.1

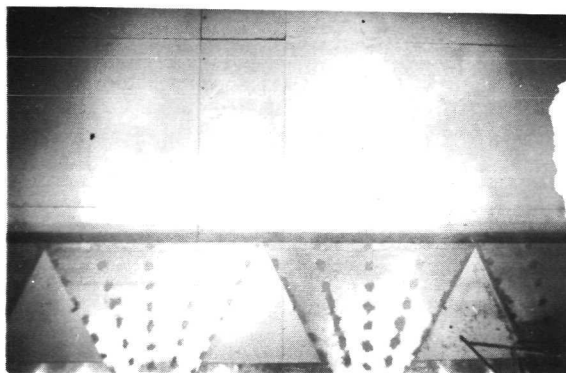
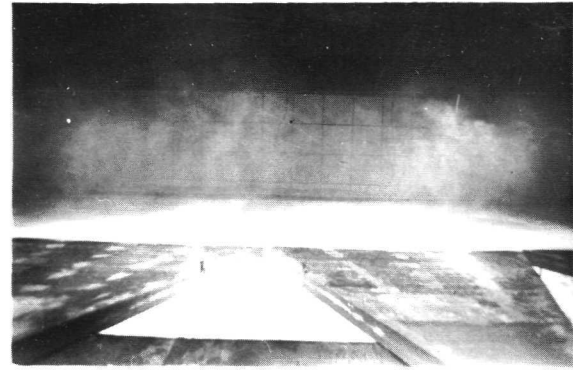
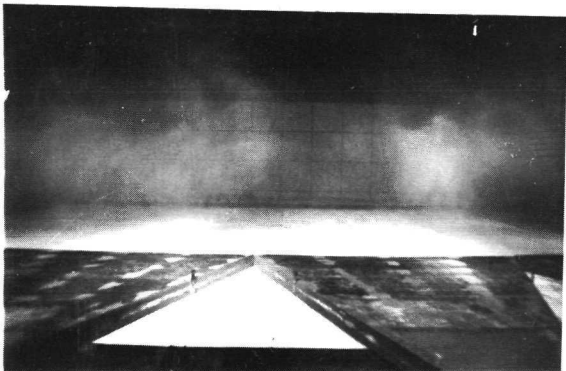
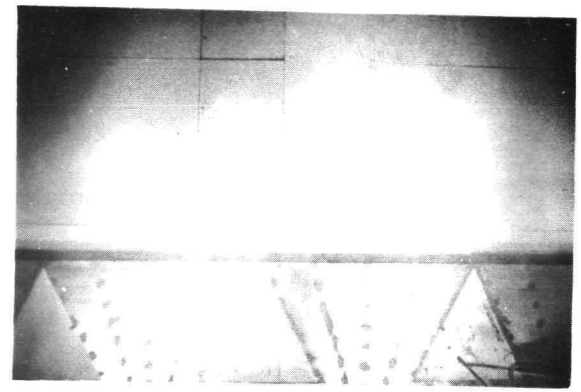


FIGURE 31 - DEVICE C WITH  $V_s / U = 0.0898$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.79$  AND ALTITUDE = 30.5 METERS

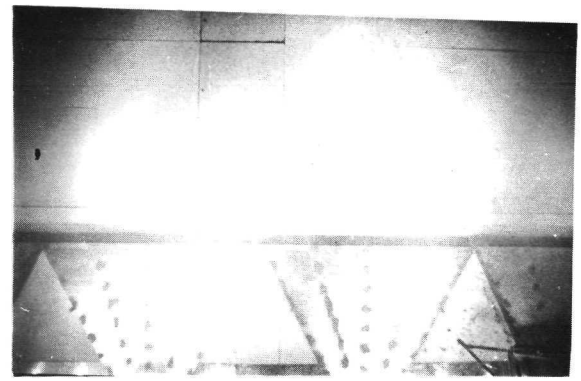


N

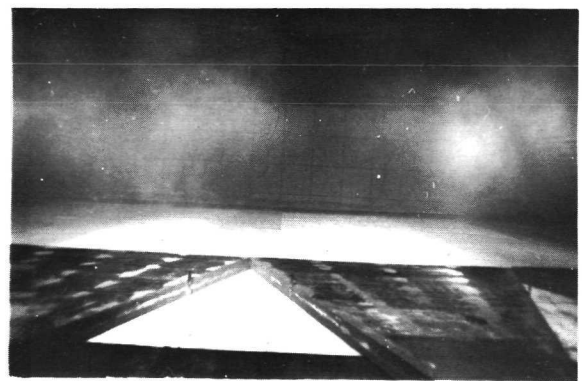
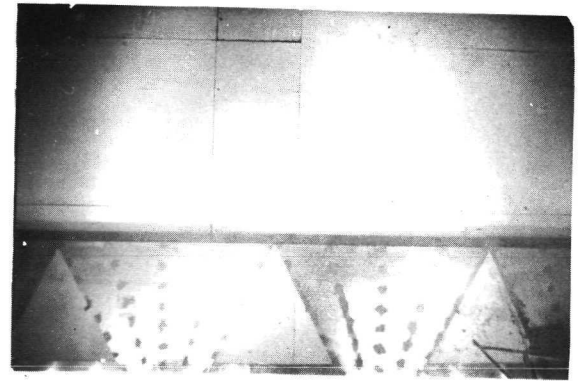
11.8



15.9



20.0



24.0

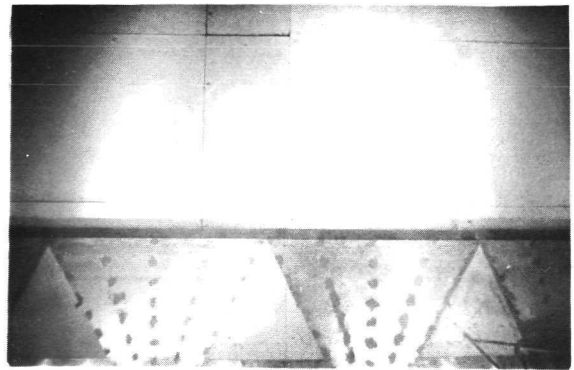
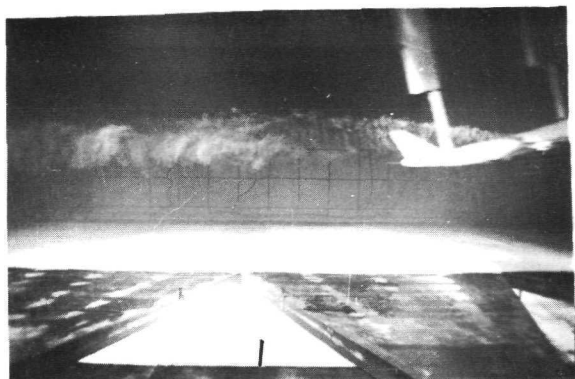
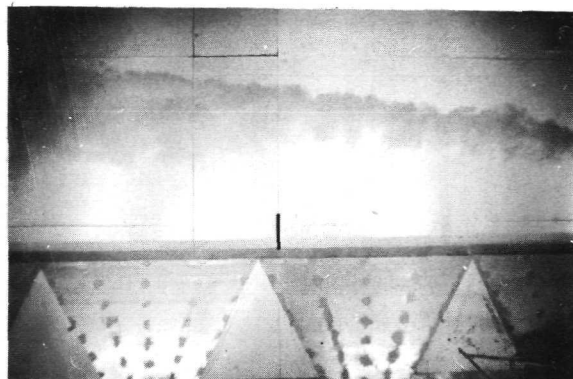


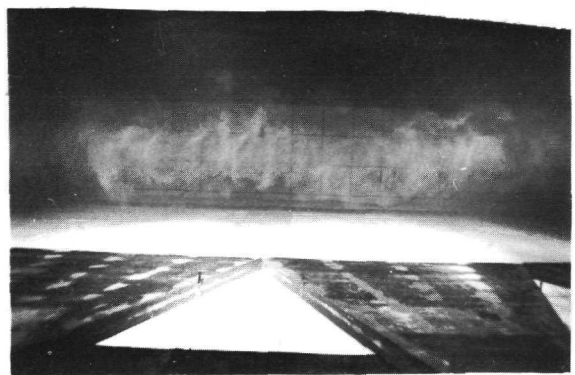
FIGURE 31 - CONCLUDED



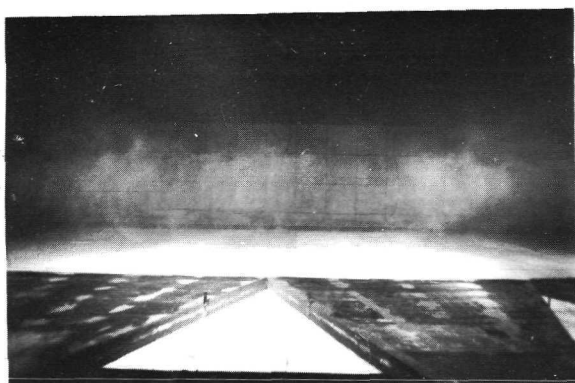
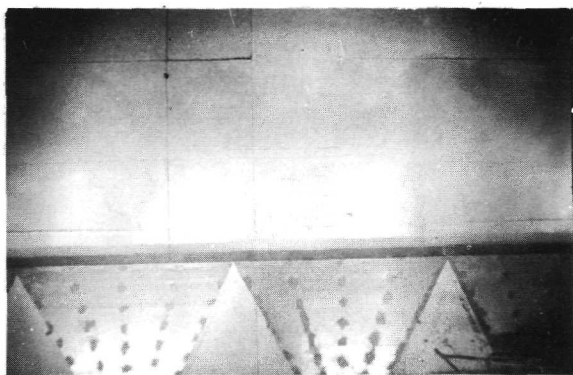
N



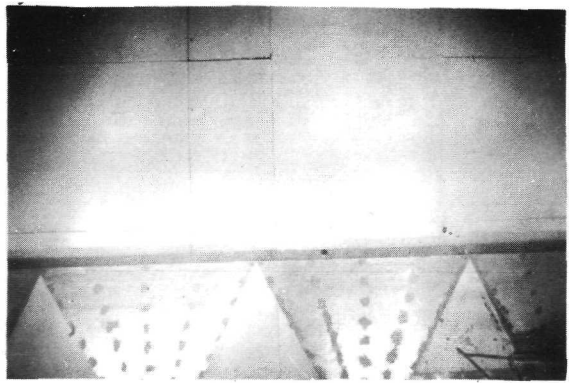
1.5



4.9



8.3



11.7

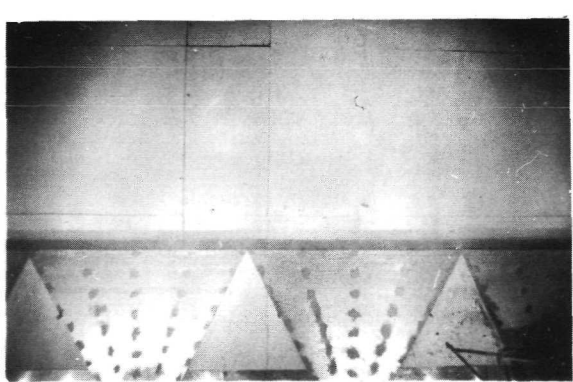
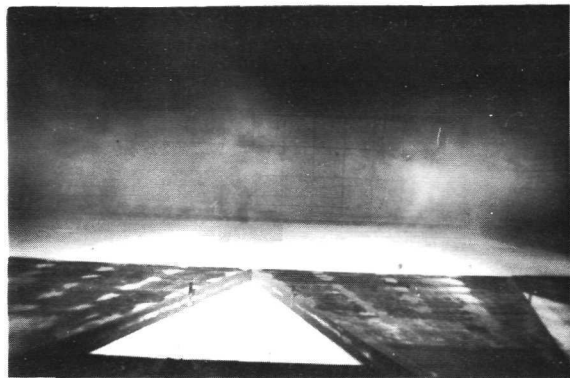
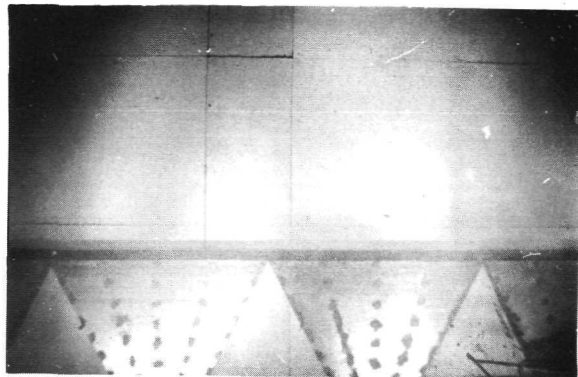


FIGURE 32 - DEVICE C WITH  $V_s / U = 0.0718$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.75$  AND ALTITUDE = 30.5 METERS

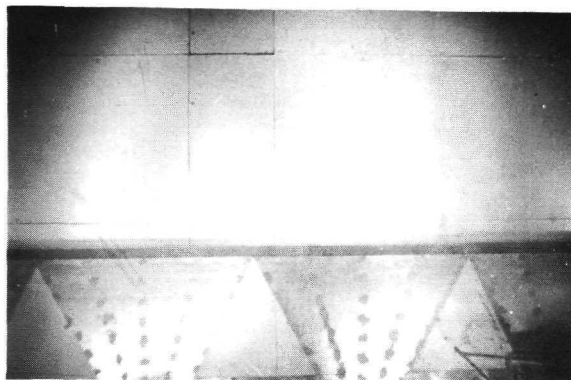


N

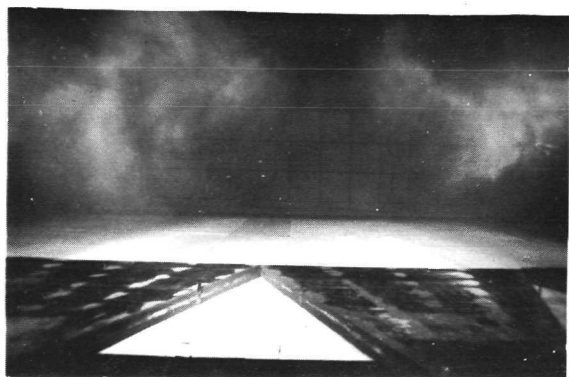
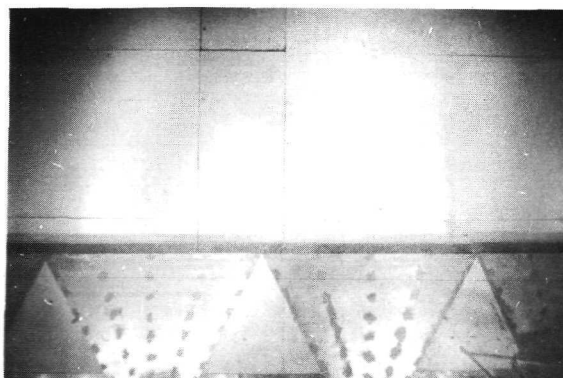
15.1



19.9



25.0



30.1

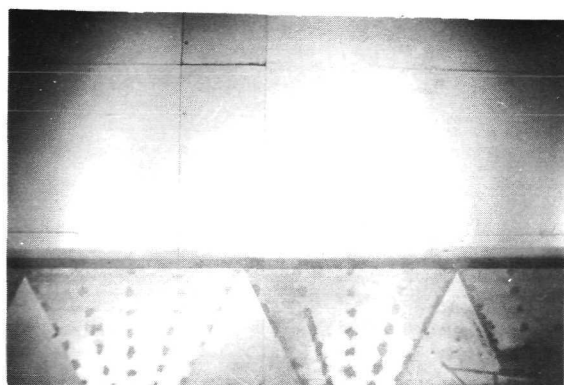
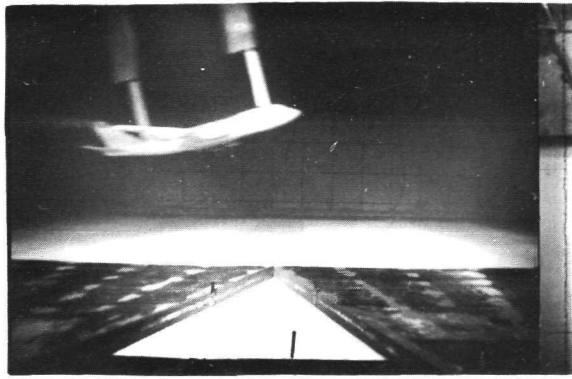
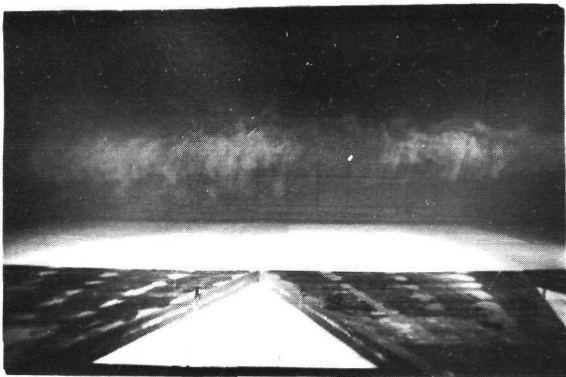
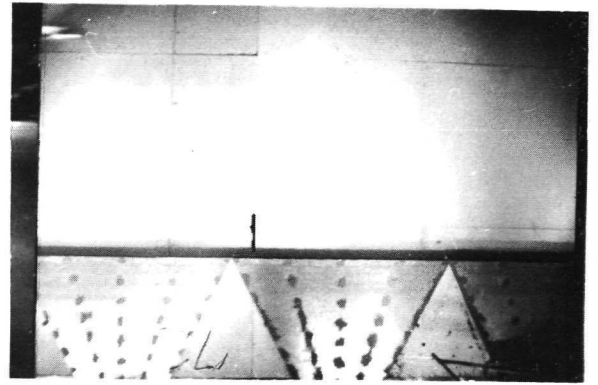


FIGURE 32 - CONCLUDED

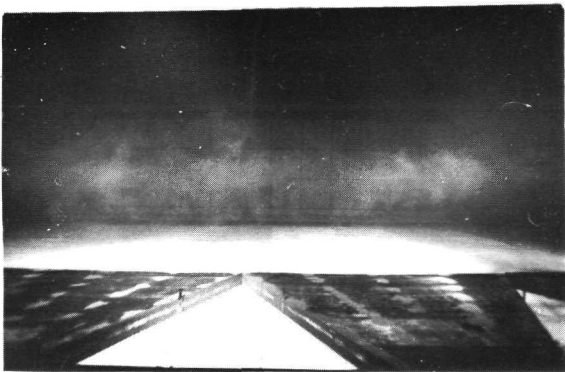
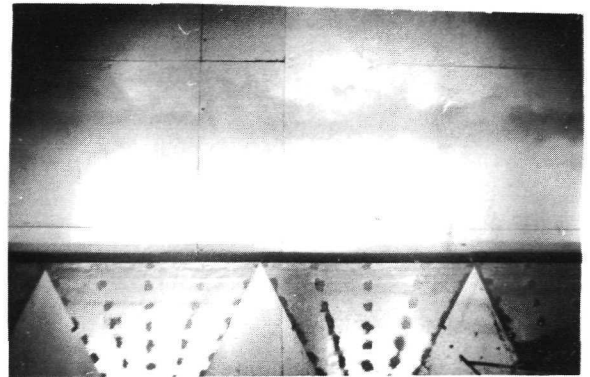


Z

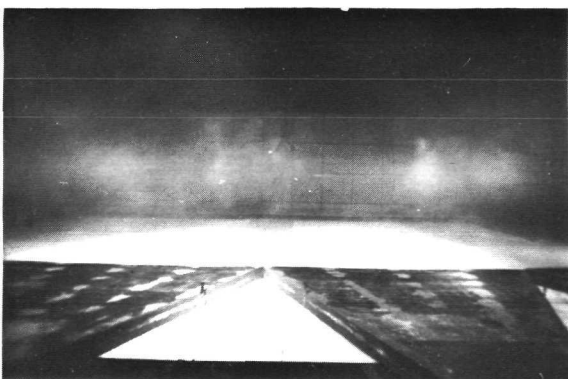
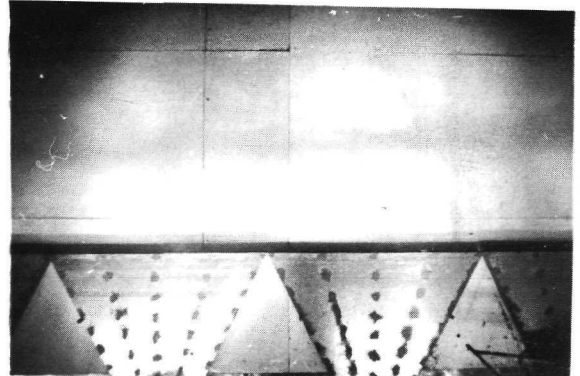
-1.1



3.0



7.1



11.1

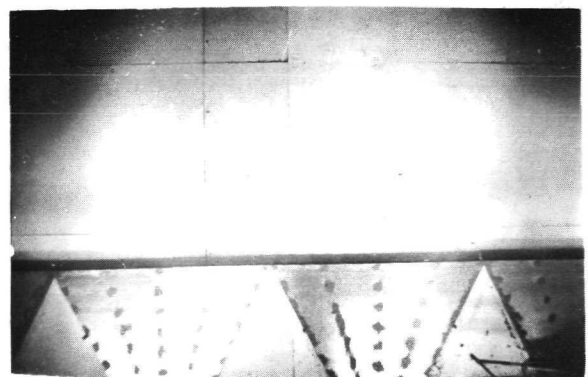
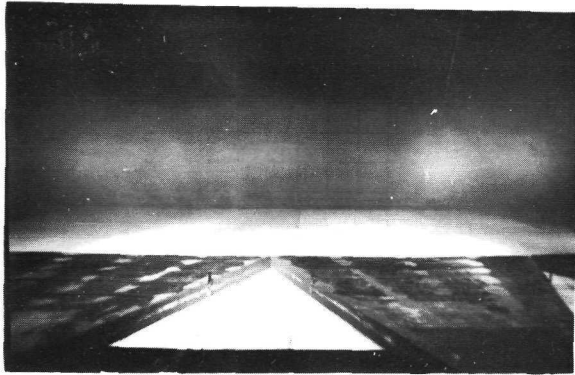
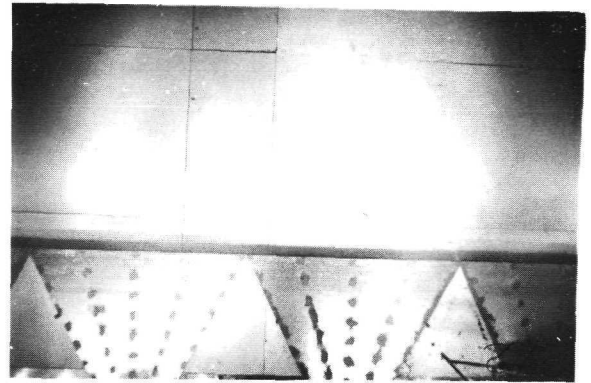


FIGURE 33 - DEVICE C WITH  $V_s / U = 0.0598$  - EFFECT ON VORTEX WAKE FOR FLAPS 30  
CONDITION,  $C_L = 1.79$  AND ALTITUDE = 30.5 METERS

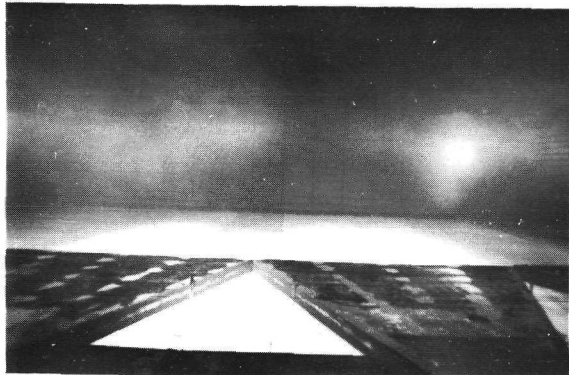
HYDRONAUTICS, INCORPORATED



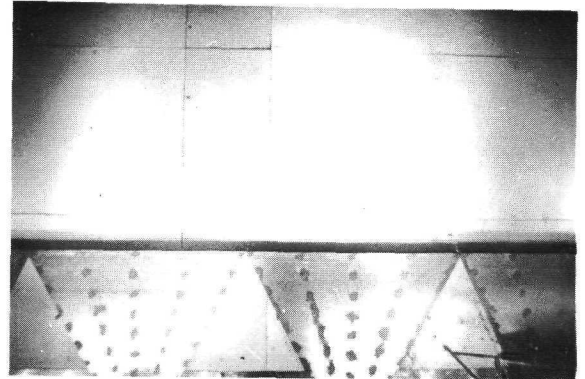
N



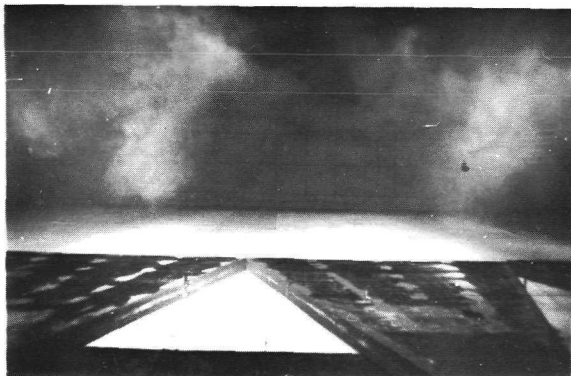
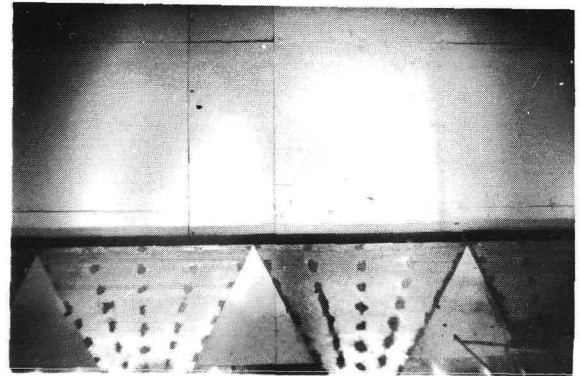
15.2



21.4



27.5



33.6

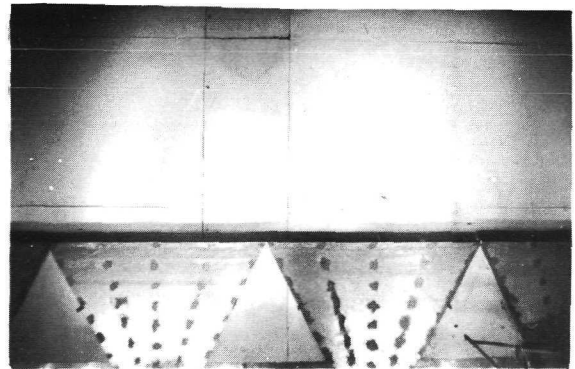
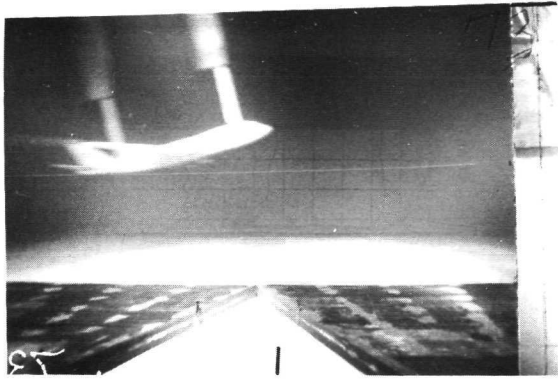
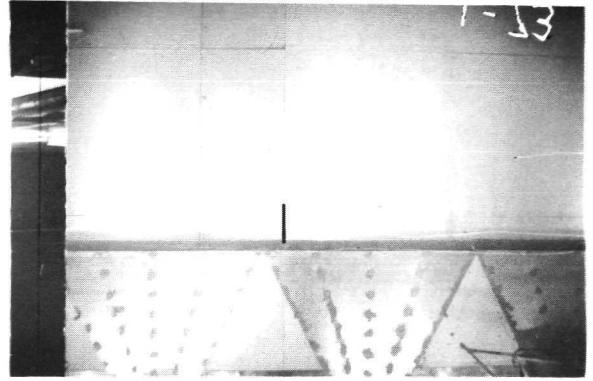


FIGURE 33 - CONCLUDED



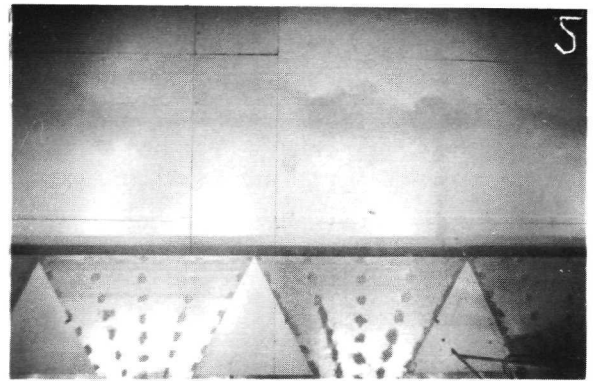
N  
-1.2



3.9



9.0



14.1

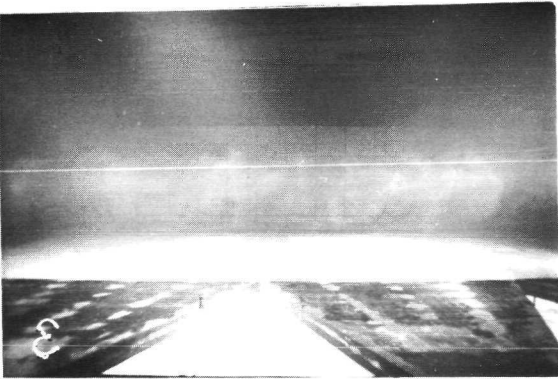
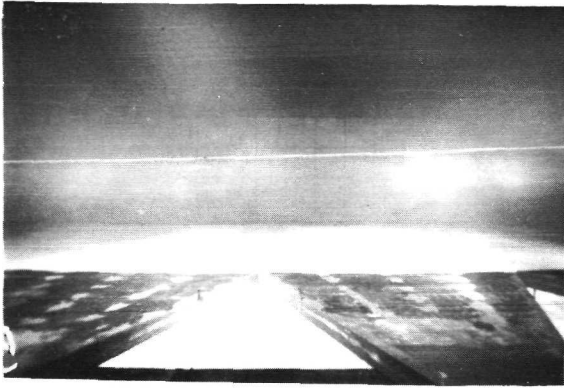
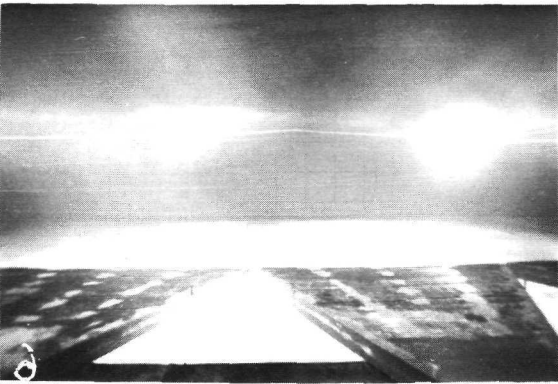
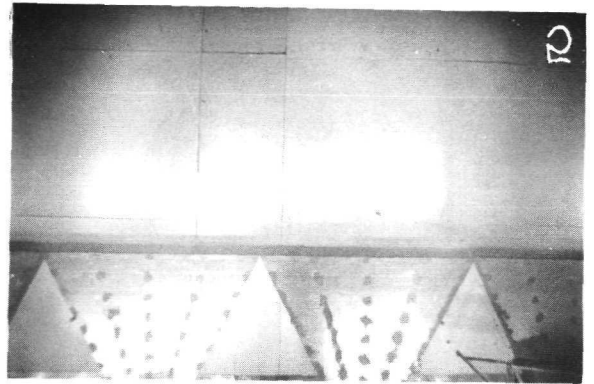


FIGURE 34 - DEVICE C WITH  $V_s/U = 0.0479$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.68$  AND ALTITUDE = 30.5 METERS

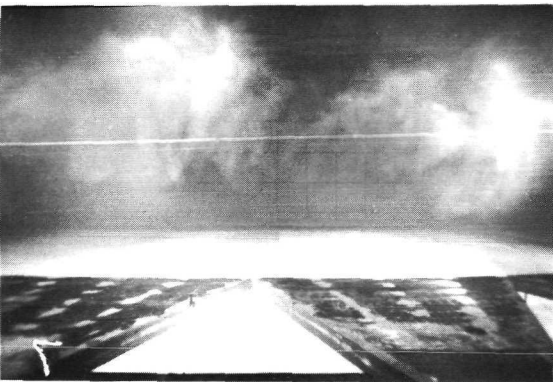
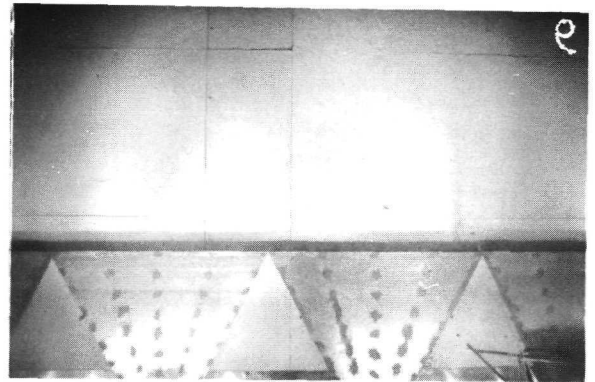
HYDRONAUTICS, INCORPORATED



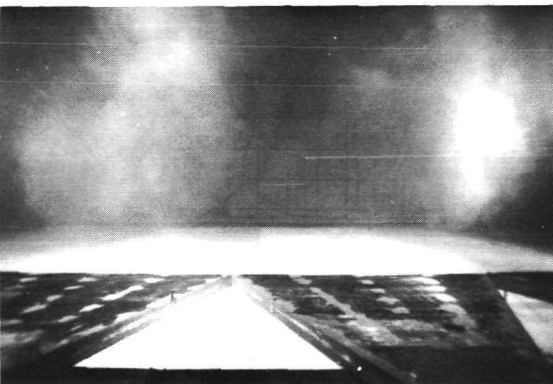
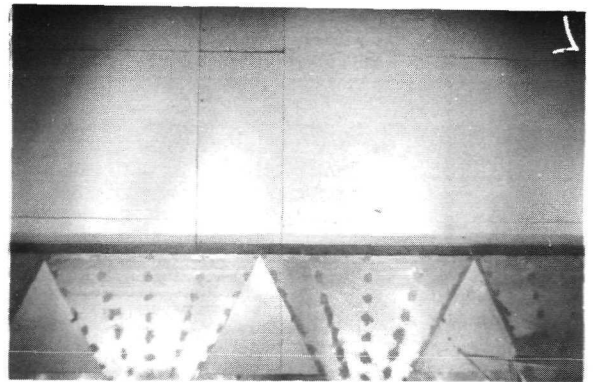
N  
19.2



26.9



34.5



42.2

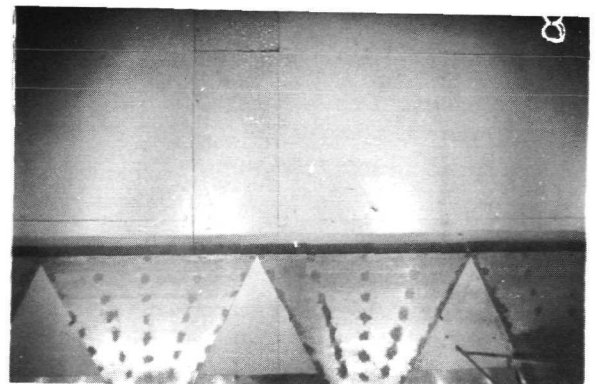
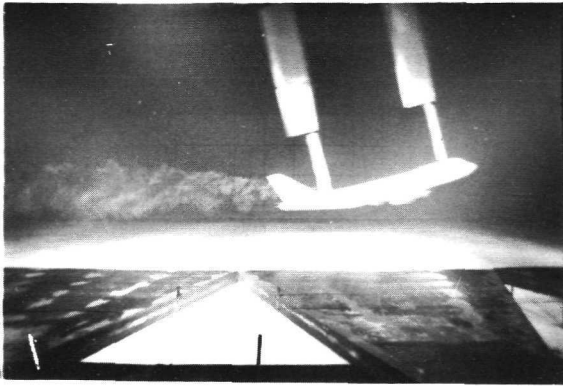
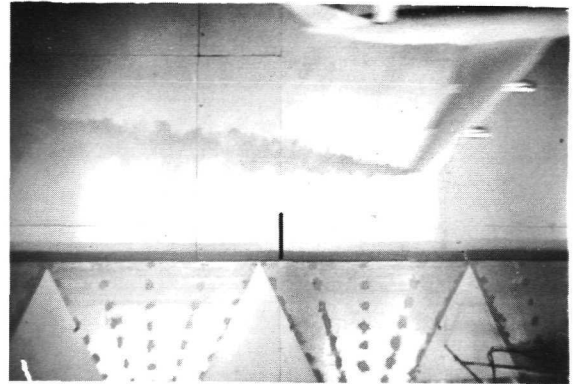


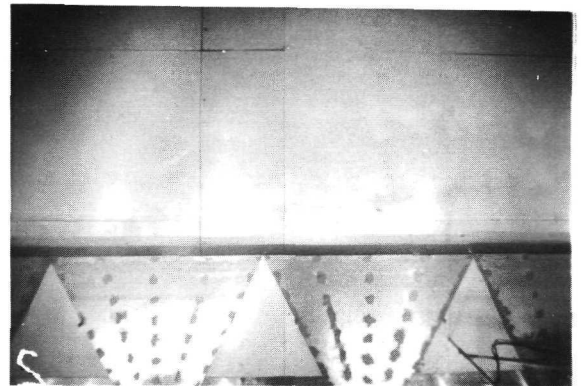
FIGURE 34 - CONCLUDED



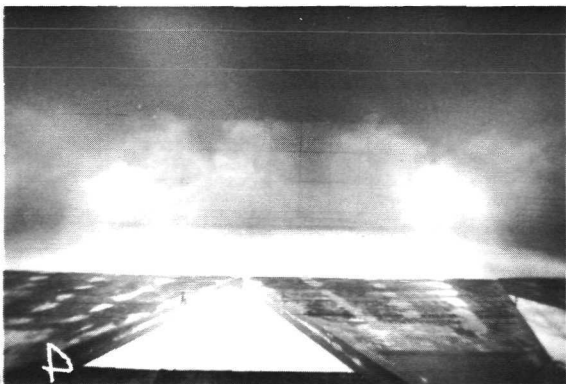
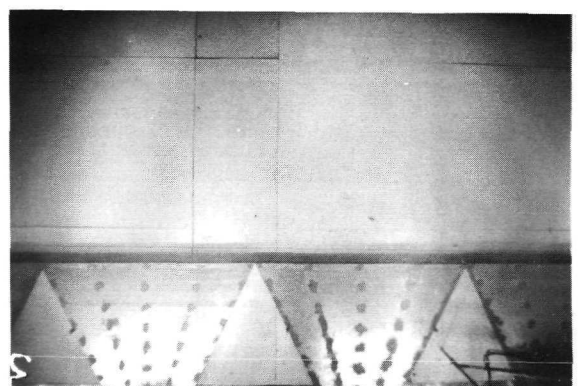
N  
0.7



3.4



6.1



8.8

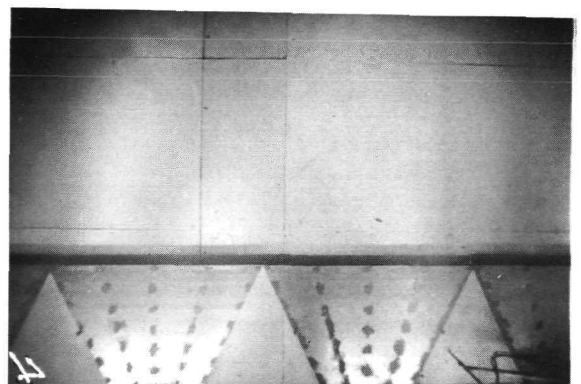
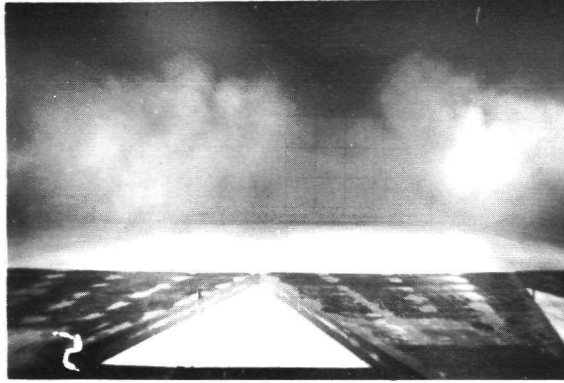
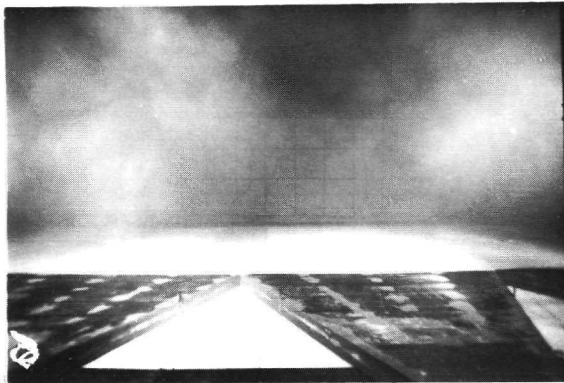
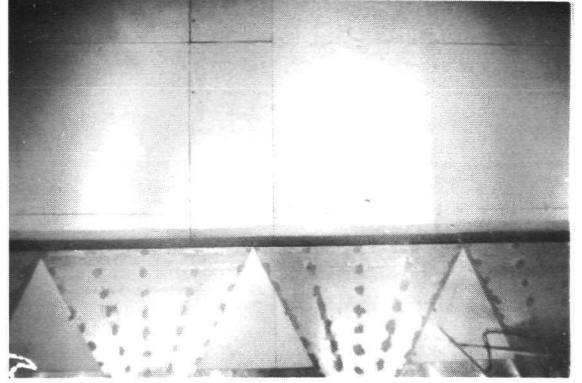


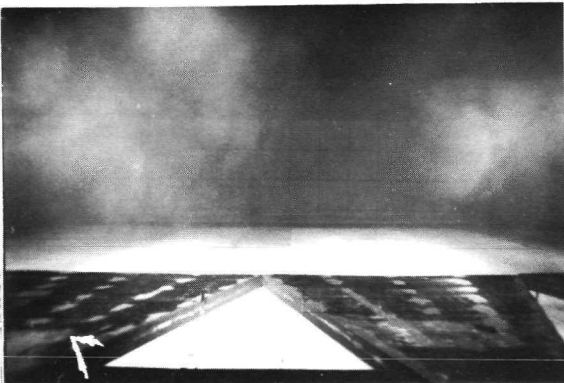
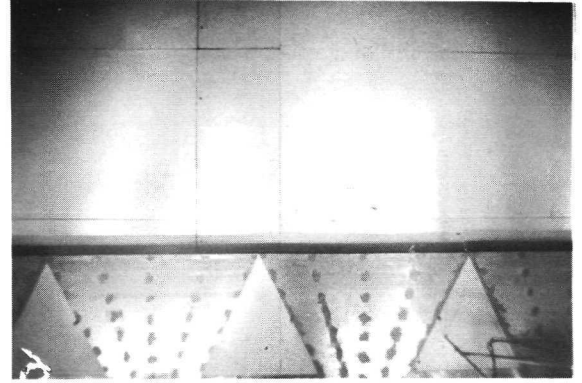
FIGURE 35 - DEVICE C WITH  $V_s/U = 0.0898$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.77$  AND ALTITUDE = 13.4 METERS



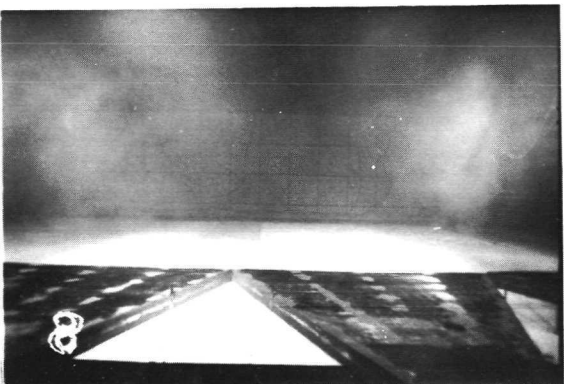
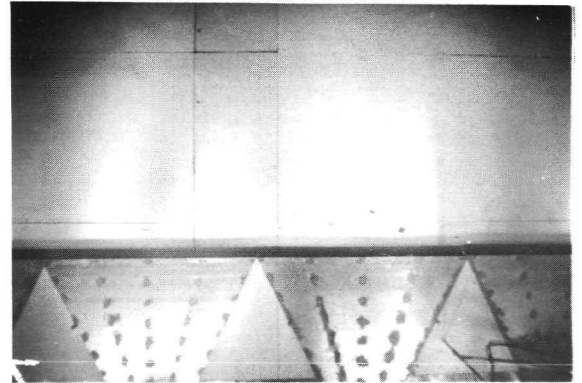
N  
11.6



15.7



19.7



23.8

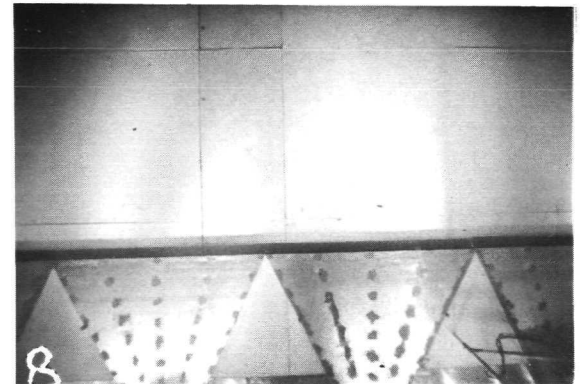
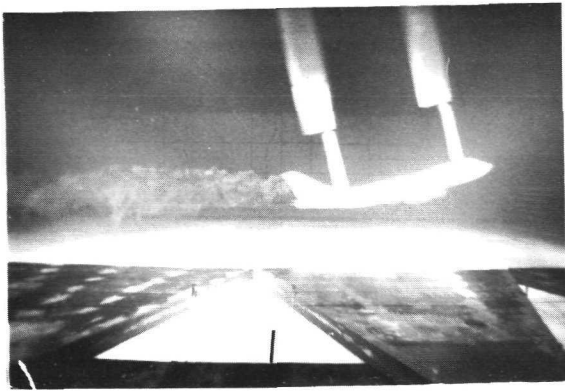
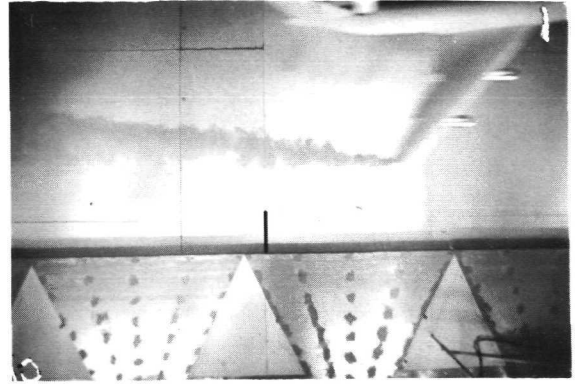


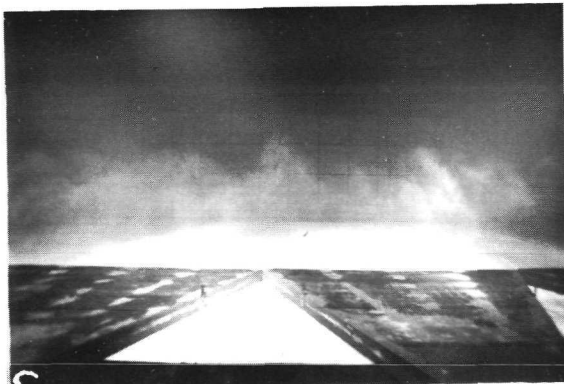
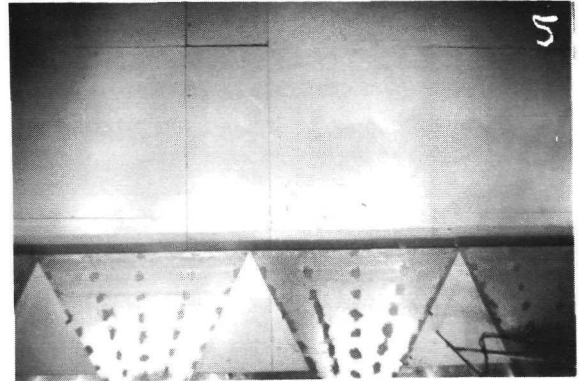
FIGURE 35 - CONCLUDED



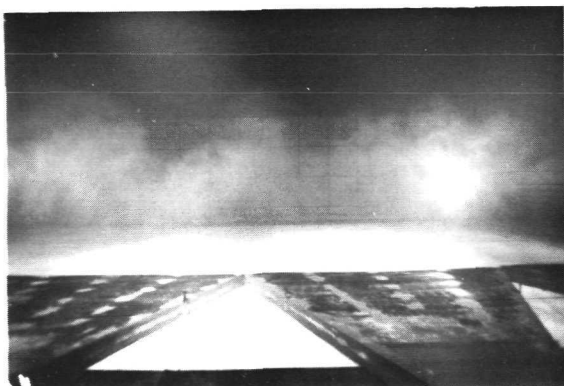
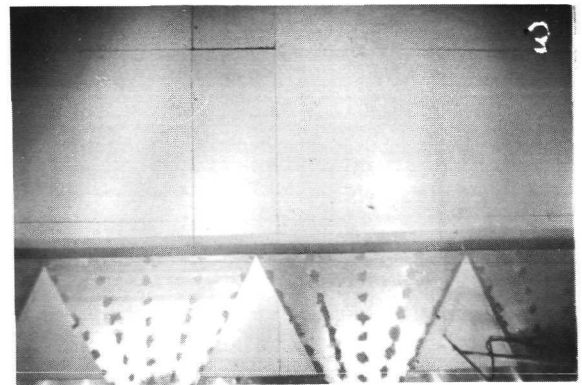
N  
0.5



3.9



7.4



10.8

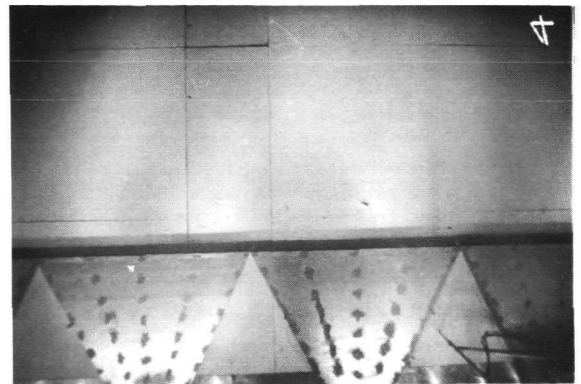
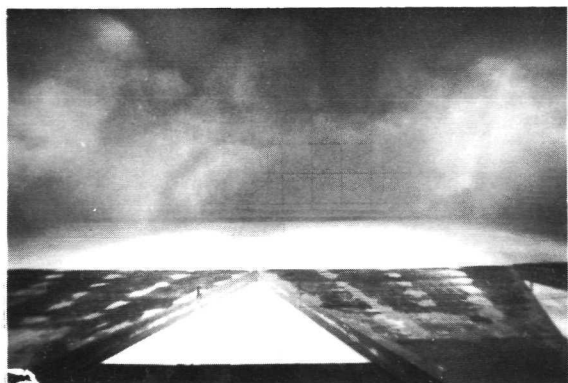
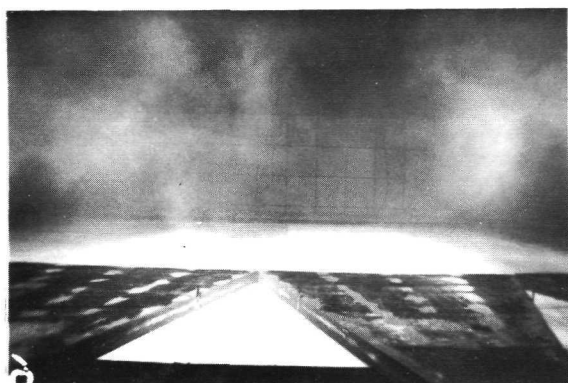
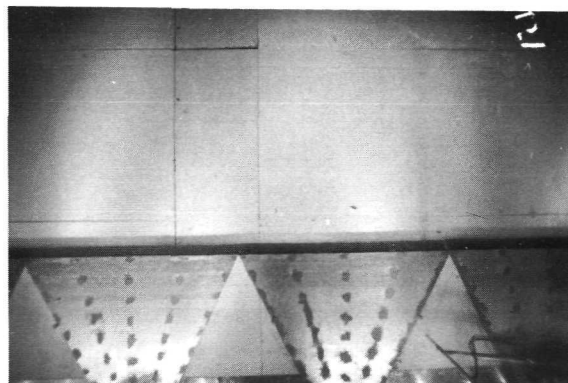


FIGURE 36 - DEVICE C WITH  $V_s/U = 0.0718$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.75$  AND ALTITUDE = 13.4 METERS

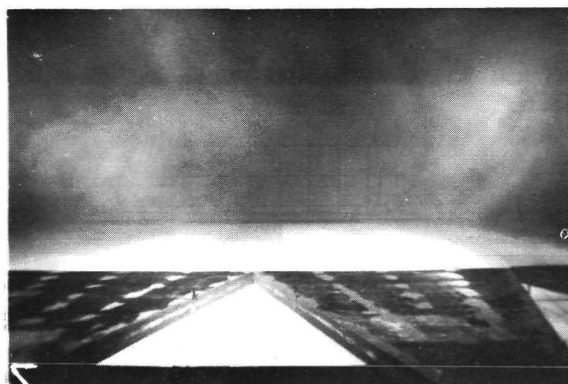
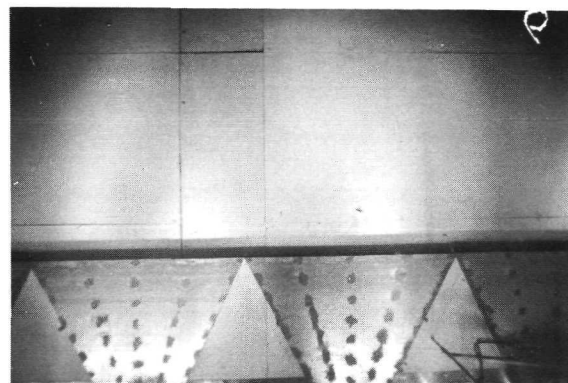
HYDRONAUTICS, INCORPORATED



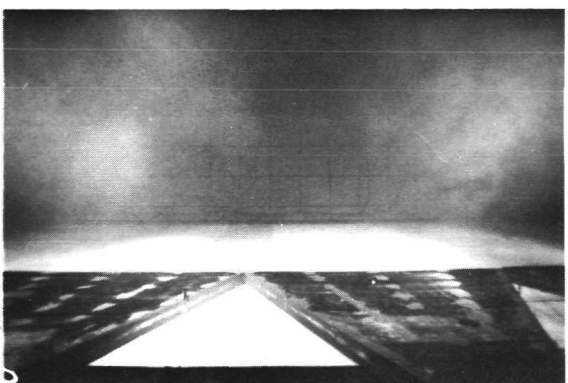
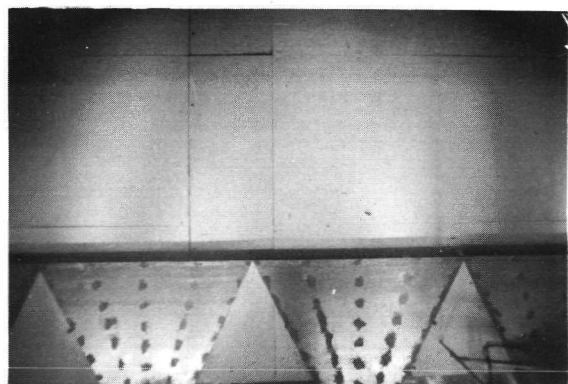
N  
14.2



19.3



24.4



29.5

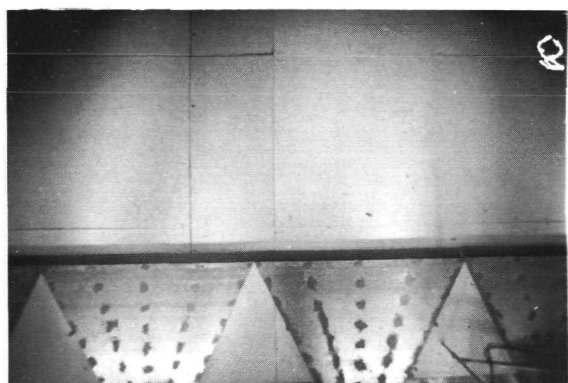
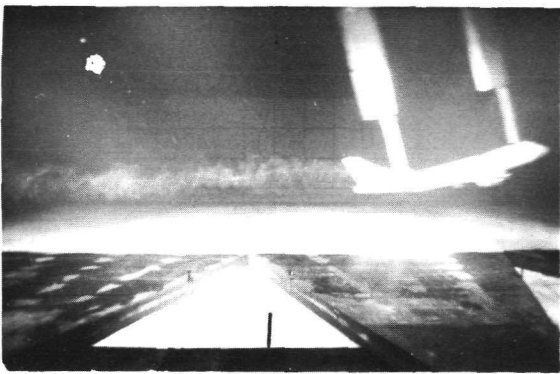
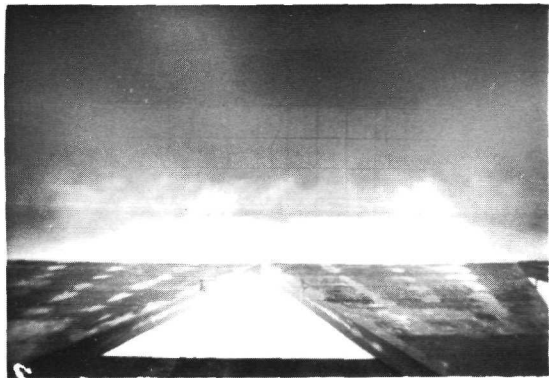
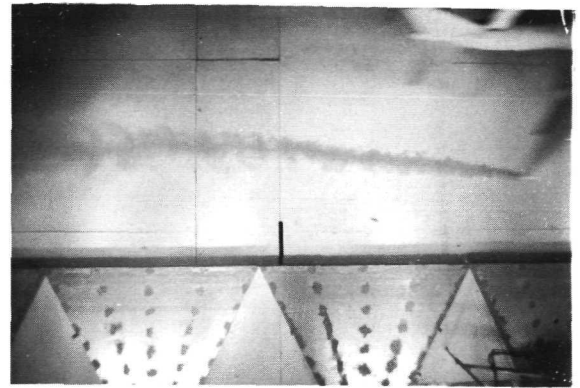


FIGURE 36 - CONCLUDED

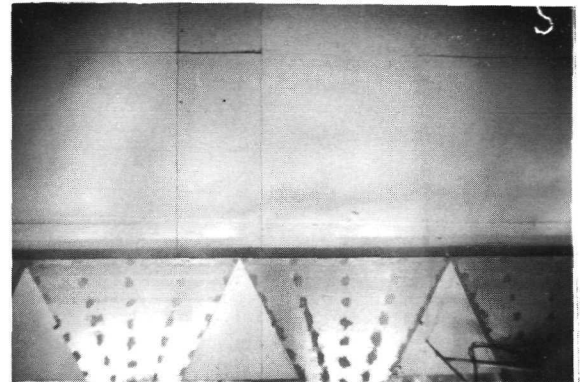
HYDRONAUTICS, INCORPORATED



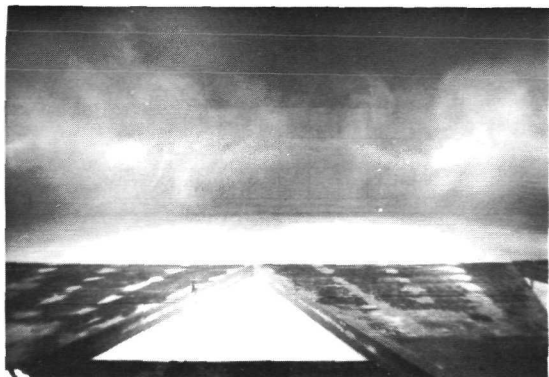
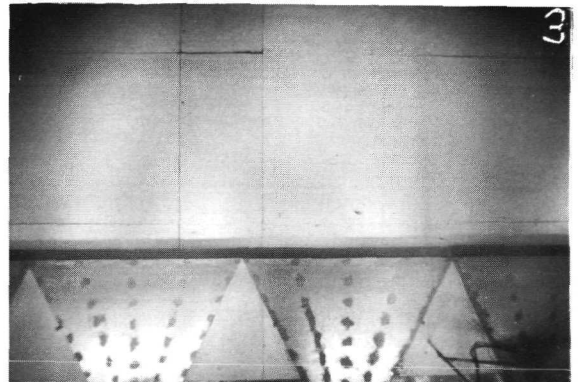
1.2



5.2



9.3



13.4

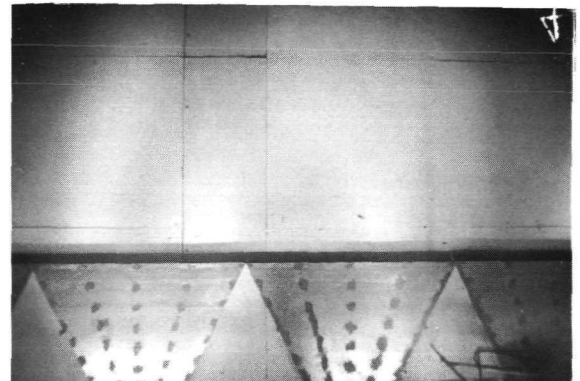
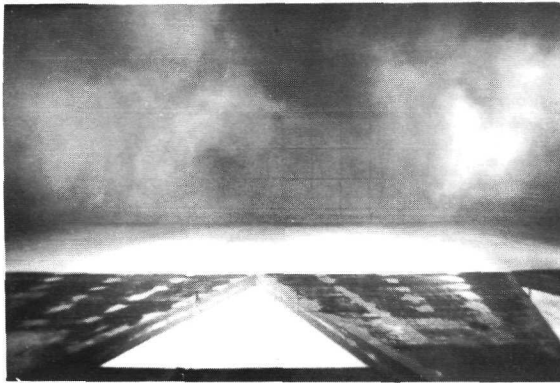
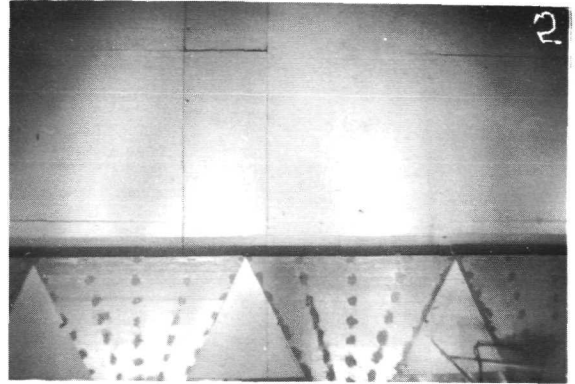


FIGURE 37 - DEVICE C WITH  $V_s/U = 0.0598$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.81$  AND ALTITUDE = 13.4 METERS

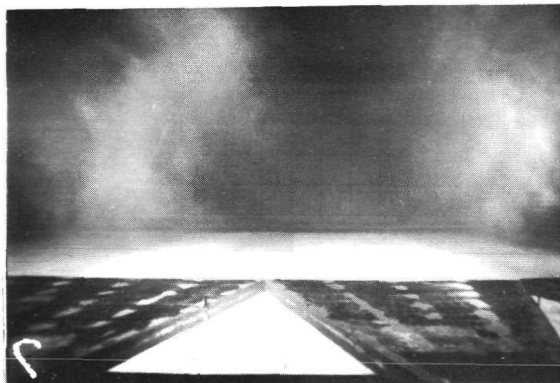
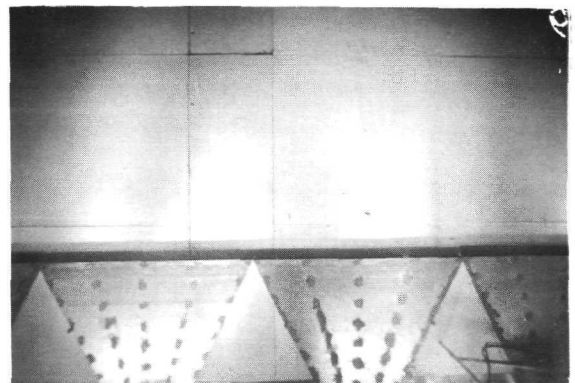
HYDRONAUTICS, INCORPORATED



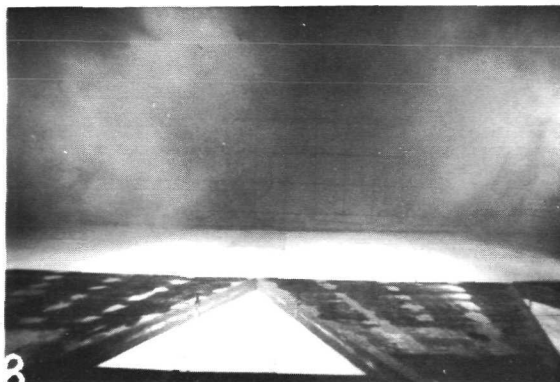
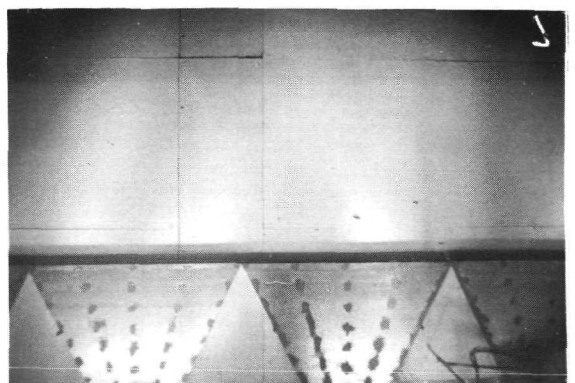
N  
17.5



23.6



29.7



35.8

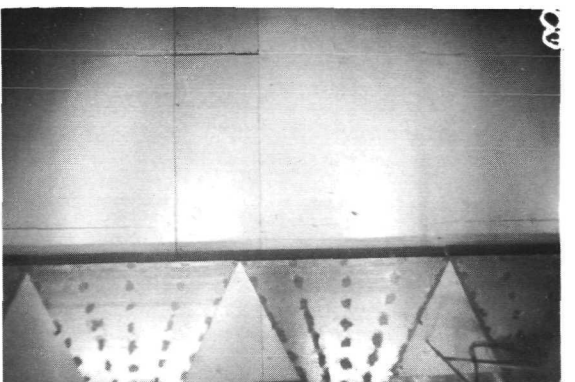
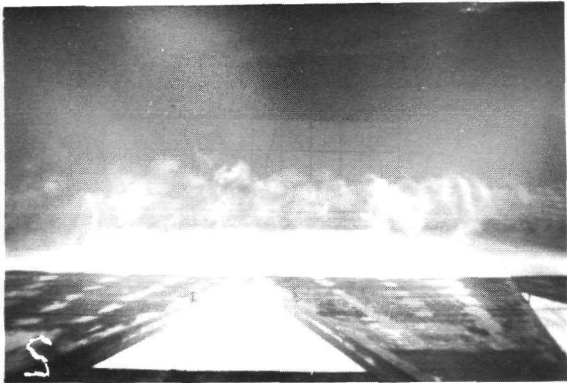
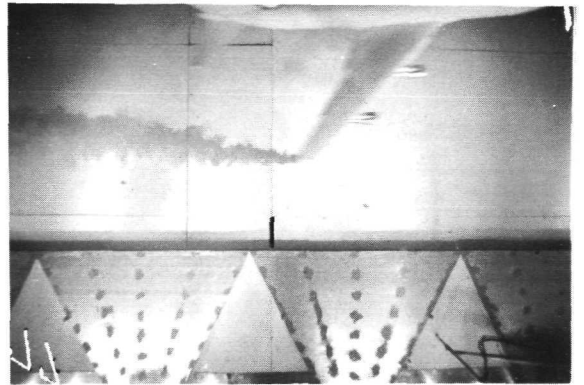


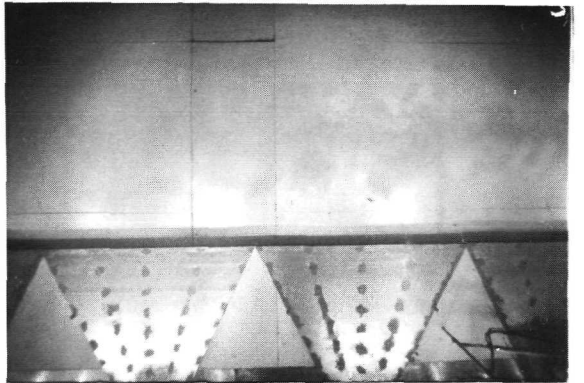
FIGURE 37 - CONCLUDED



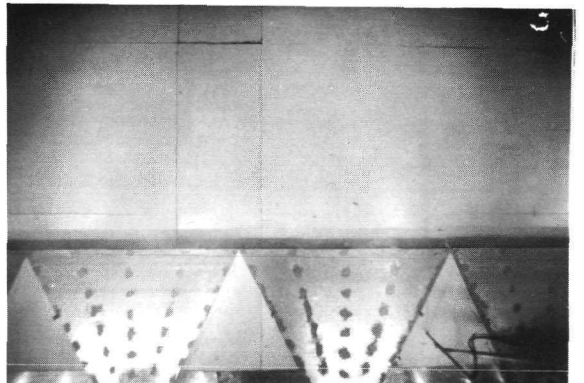
N  
0.07



2.1



4.2



6.2

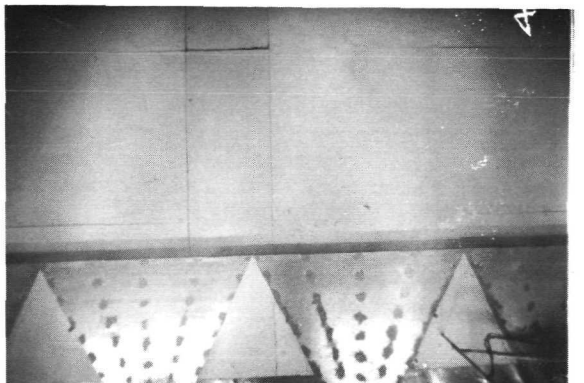
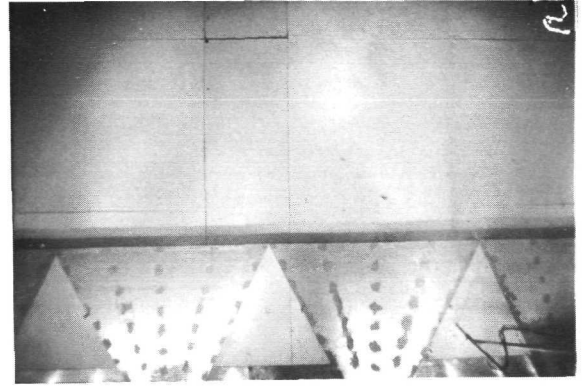


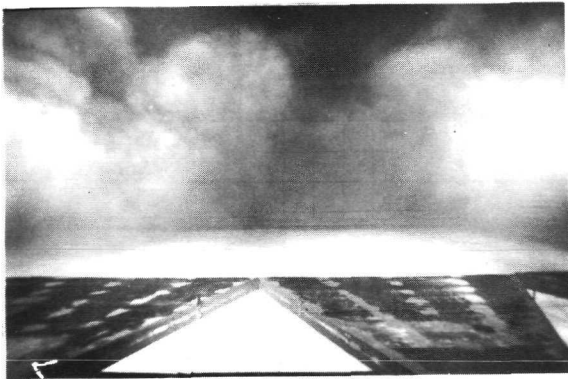
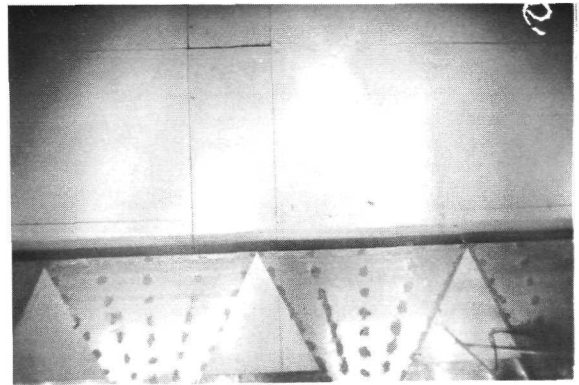
FIGURE 38 - DEVICE C WITH  $V_5/U = 0.1197$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.77$  AND ALTITUDE = 13.4 METERS



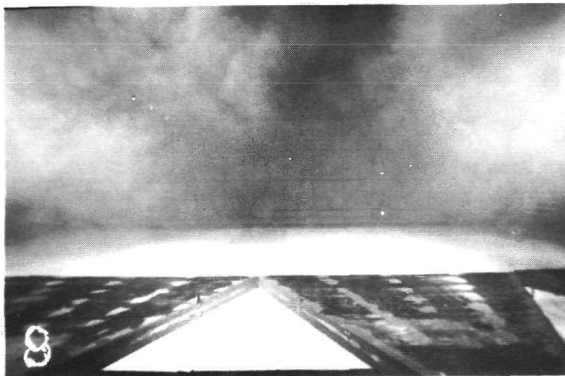
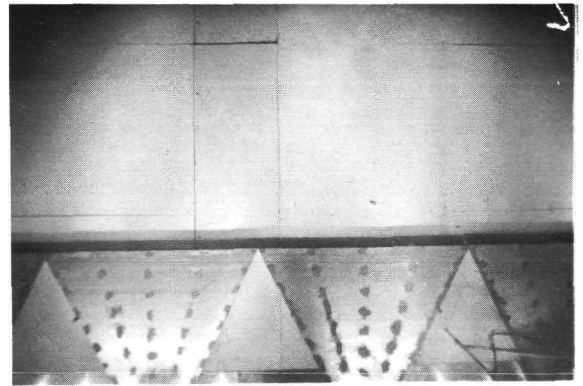
N  
8.2



11.3



14.4



17.4

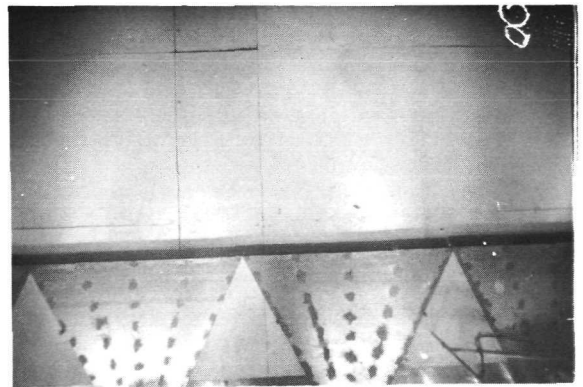
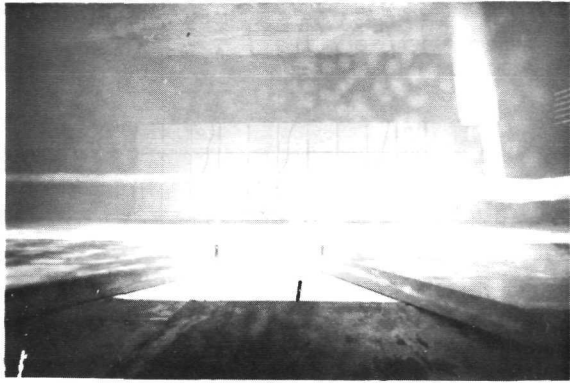
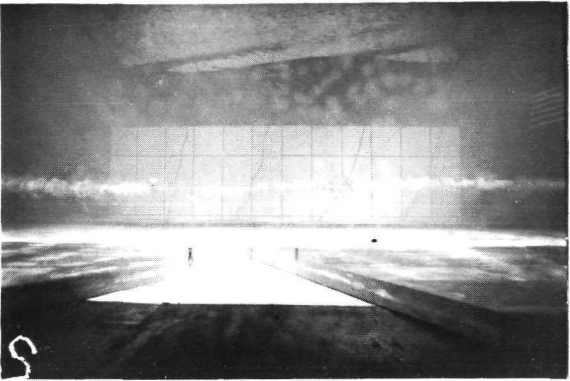
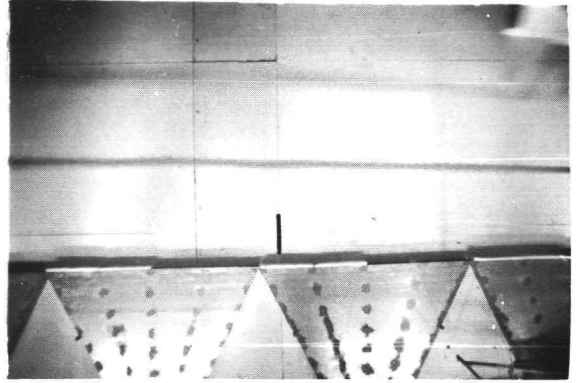


FIGURE 38 - CONCLUDED

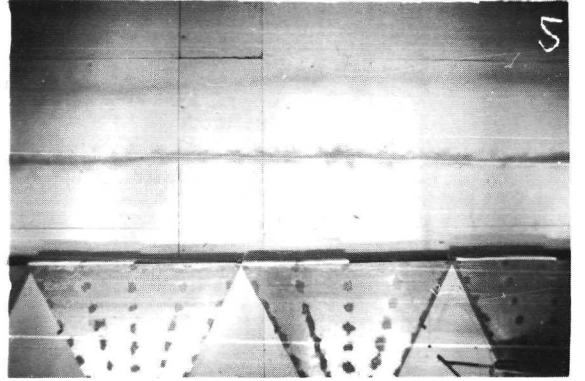
HYDRONAUTICS, INCORPORATED



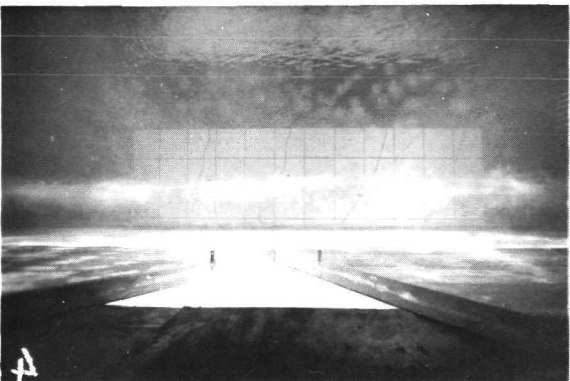
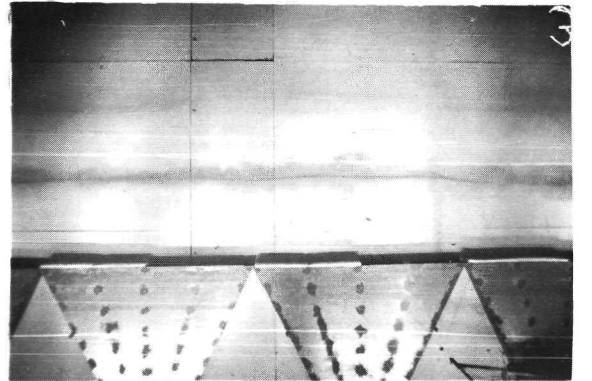
N  
1.7



5.7



9.8



13.9

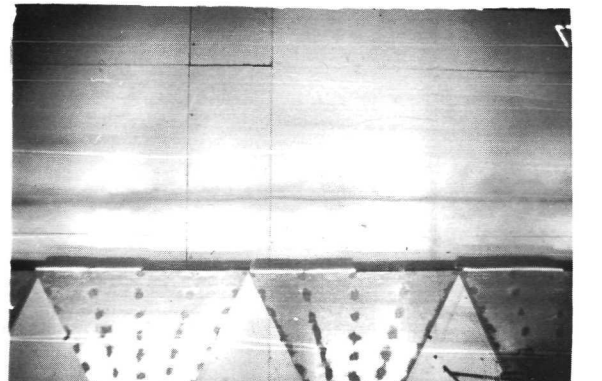
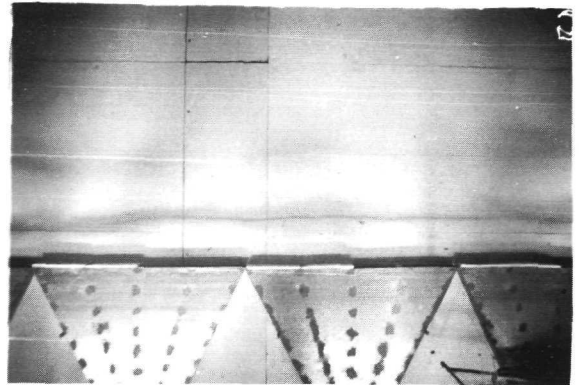


FIGURE 39 - DEVICE C WITH  $V_s/U = 0.0598$  - EFFECT ON VORTEX WAKE FOR CRUISE CONDITION,  $C_L = 0.70$  AND ALTITUDE 13.4 METERS

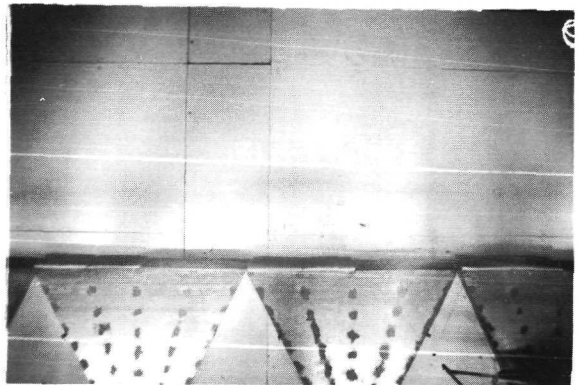
HYDRONAUTICS, INCORPORATED



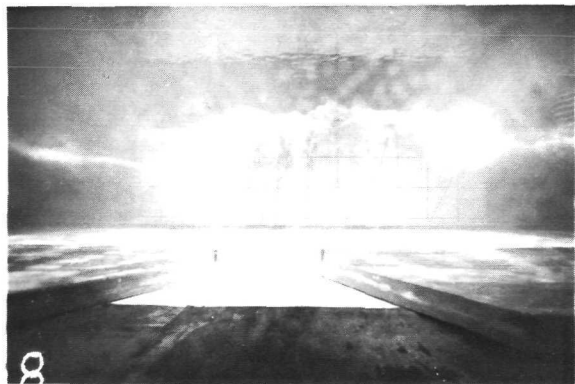
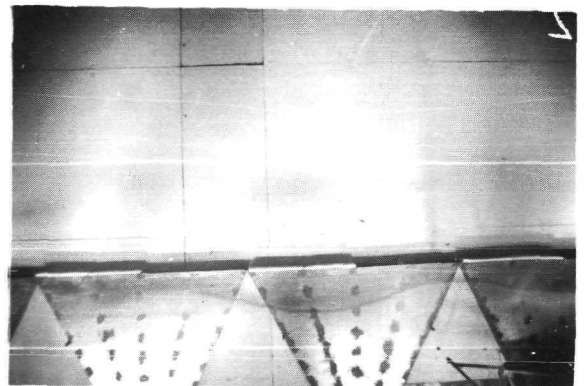
N  
18.0



24.1



30.2



36.4

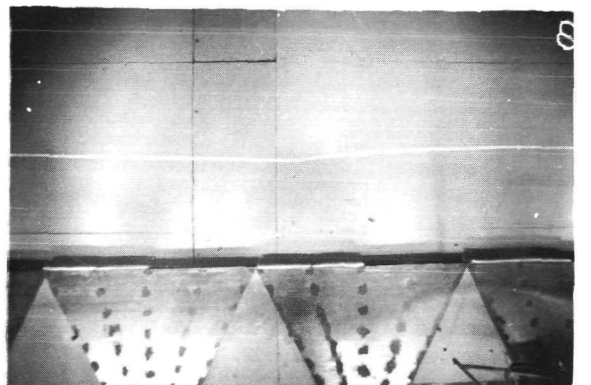
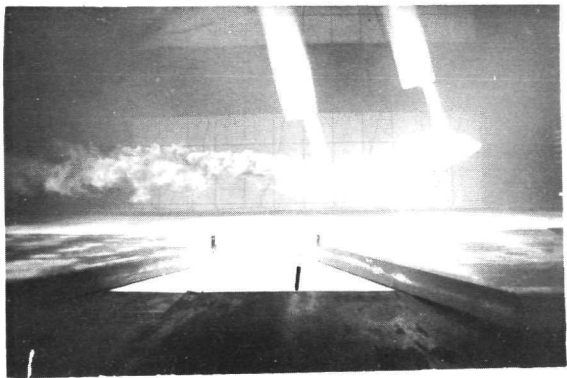
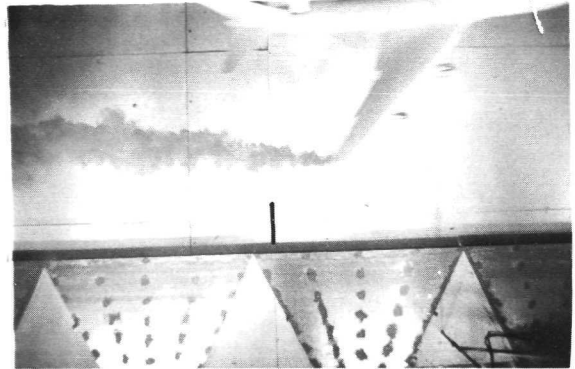


FIGURE 39 - CONCLUDED

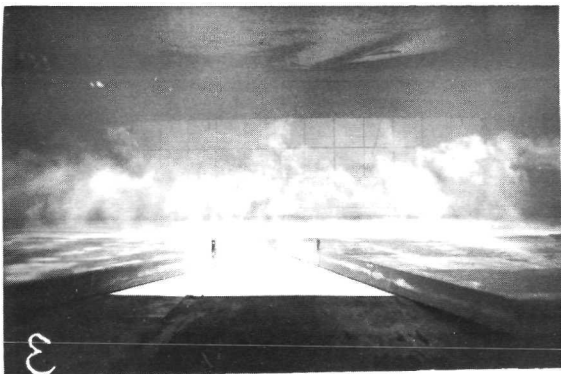
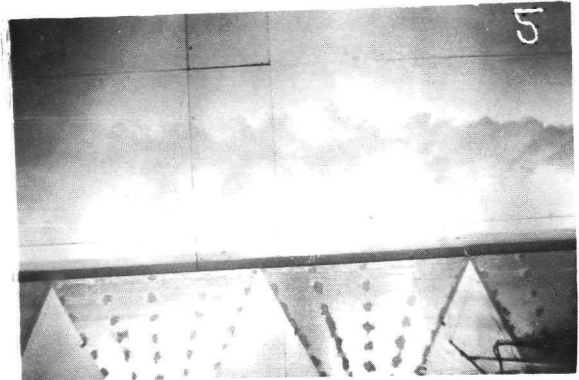


N

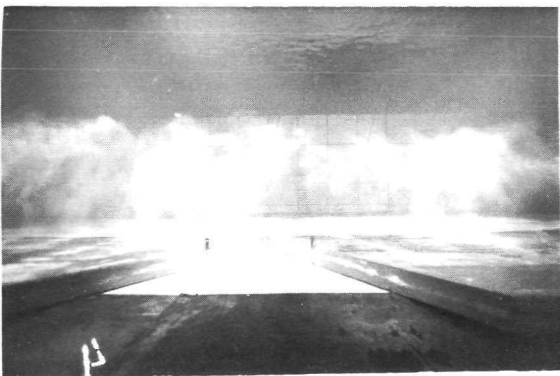
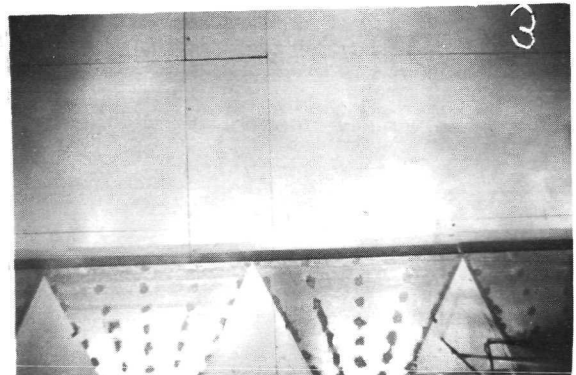
0.3



2.3



4.4



6.4

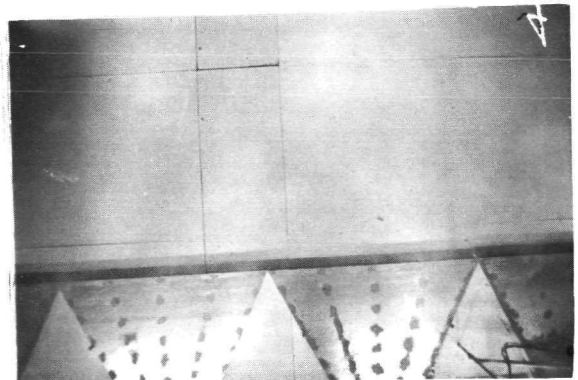
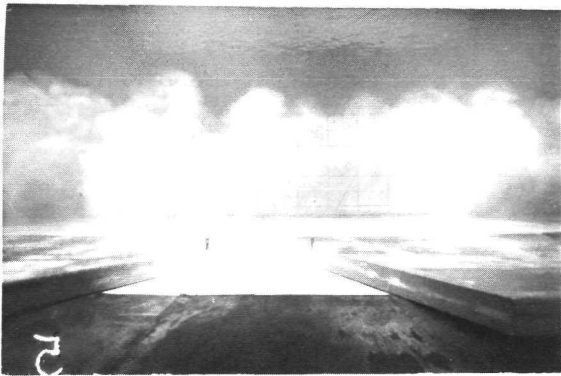


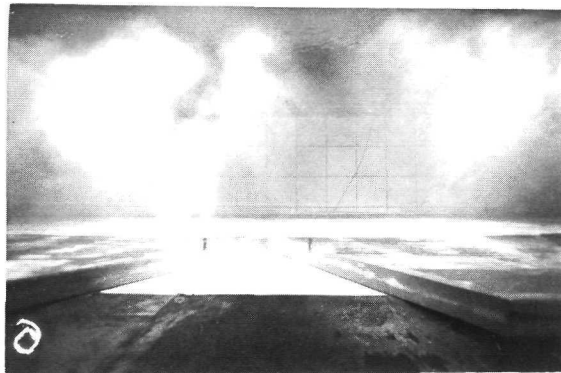
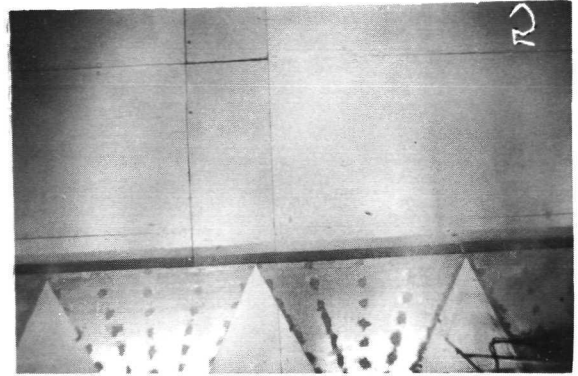
FIGURE 40 - DEVICE C1 WITH  $V_s/U = 0.1197$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.77$  AND ALTITUDE = 13.4 METERS

HYDRONAUTICS, INCORPORATED

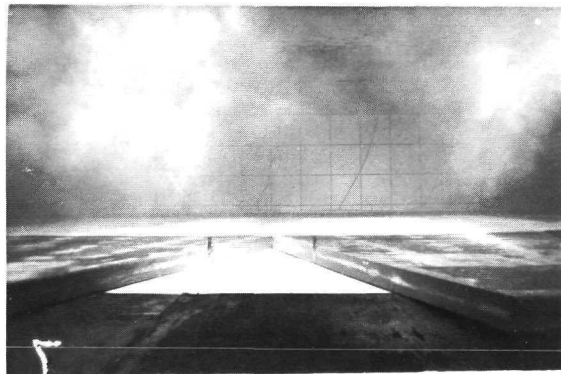
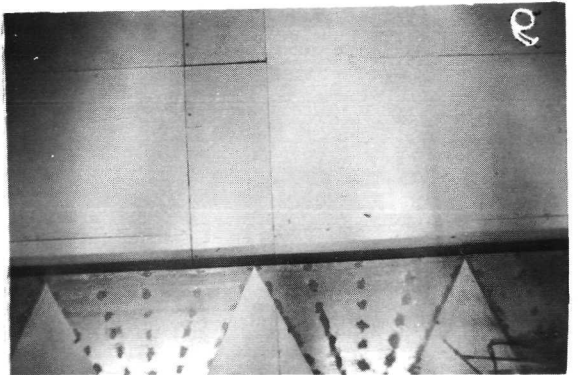


N

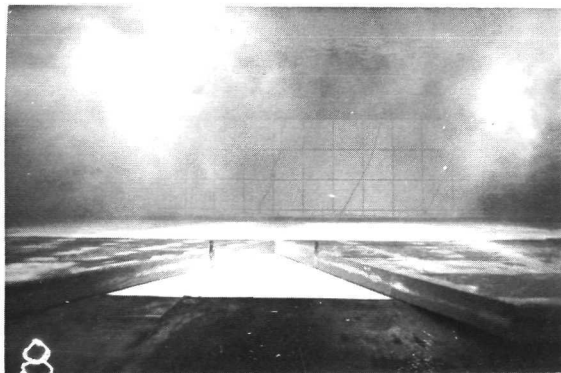
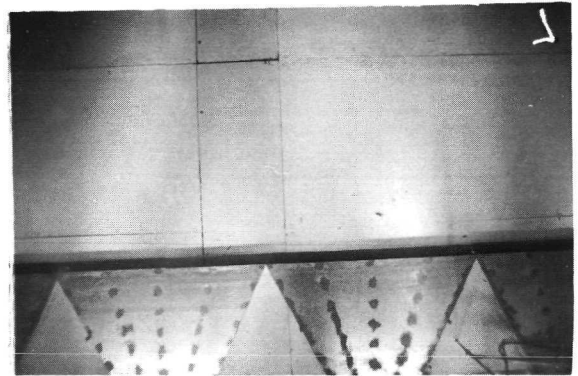
8.4



11.5



14.6



17.6

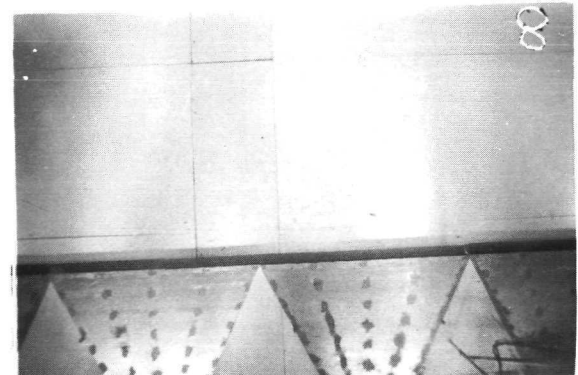
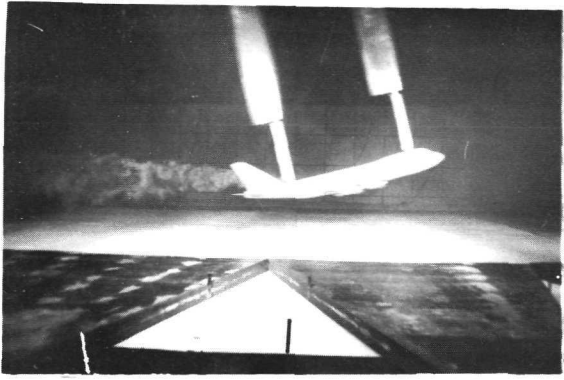
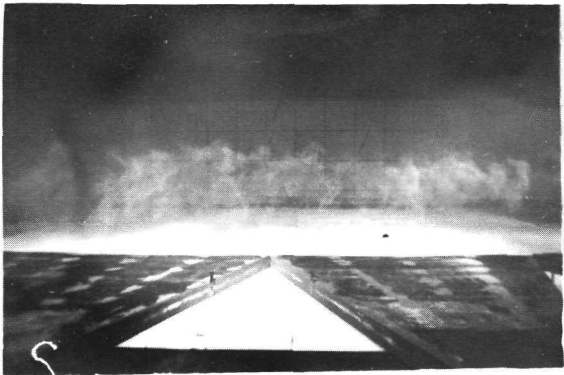
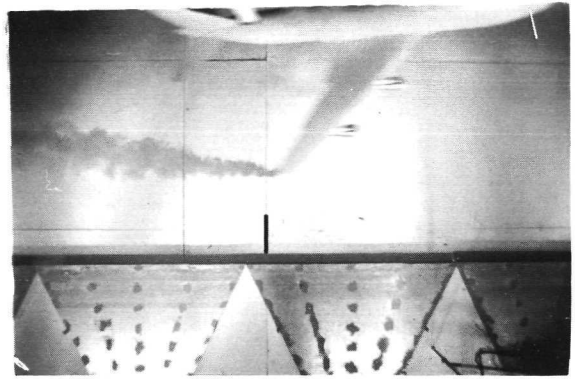


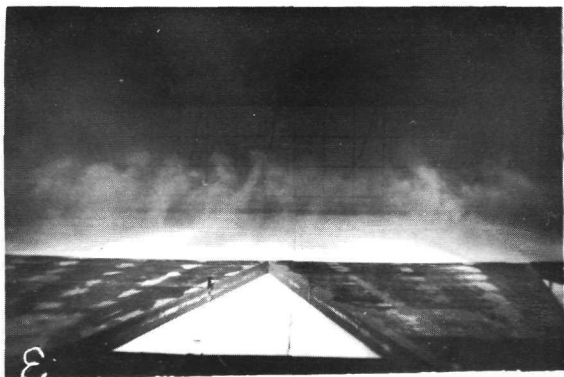
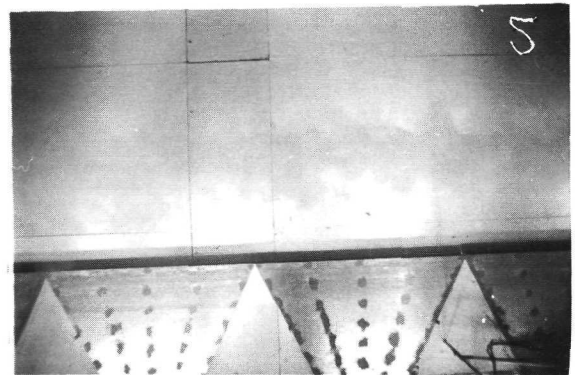
FIGURE 40 - CONCLUDED



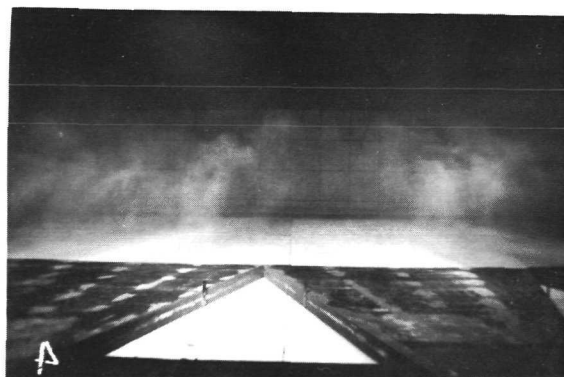
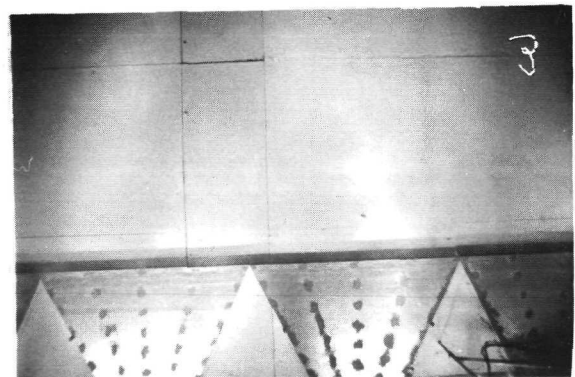
Z  
0



2.7



5.4



8.2

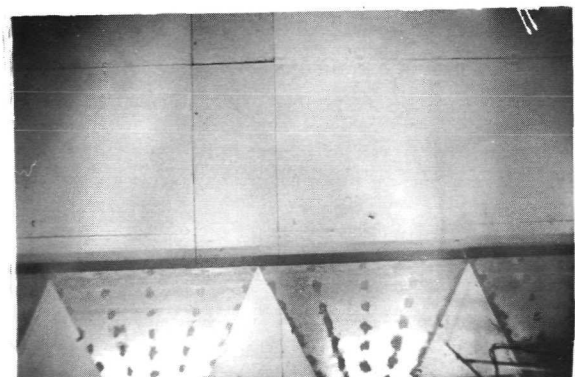
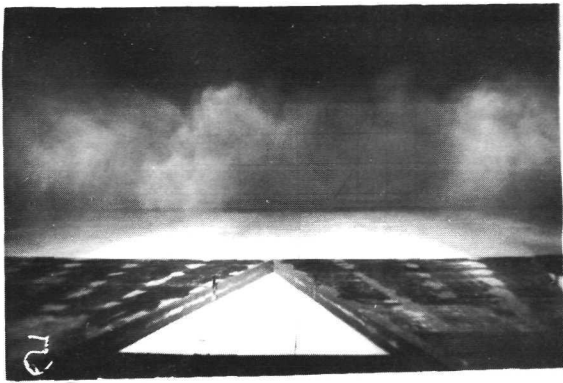
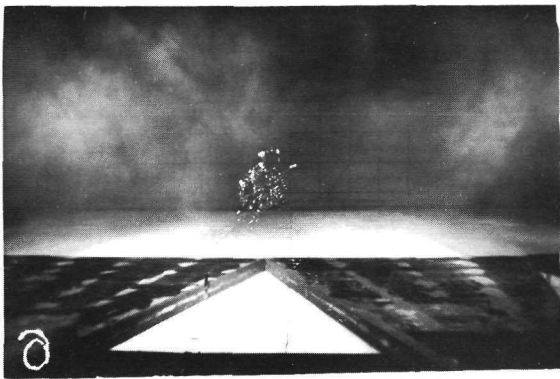
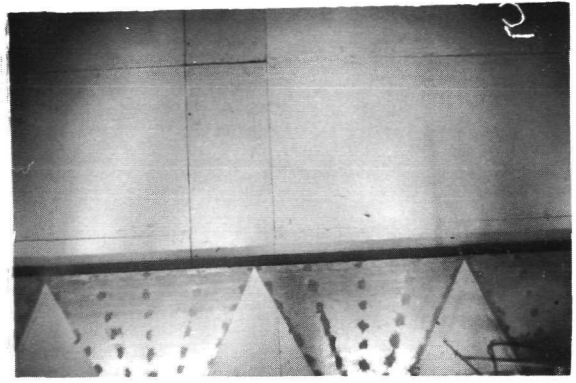


FIGURE 41 - DEVICE C1 WITH  $V_s/U = 0.0898$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.79$  AND ALTITUDE = 13.4 METERS

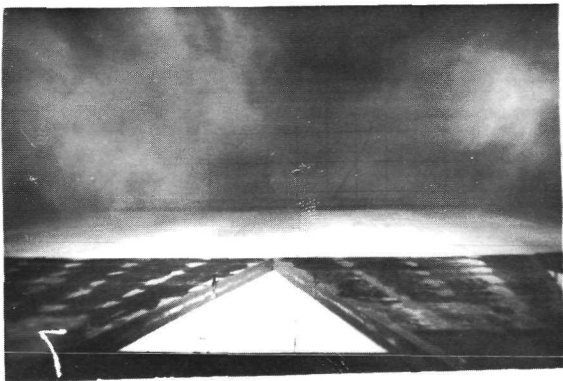
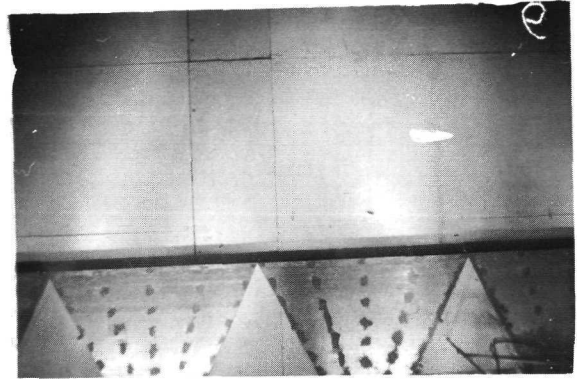
HYDRONAUTICS, INCORPORATED



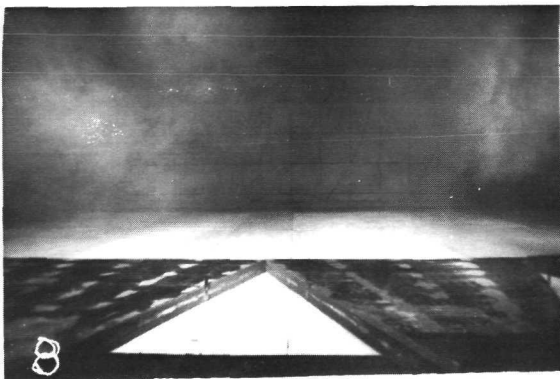
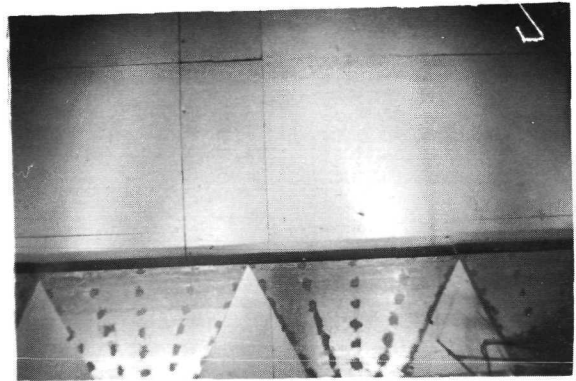
N  
10.9



15.0



19.1



23.1

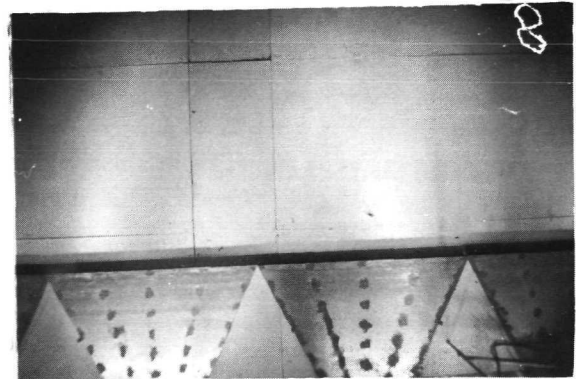
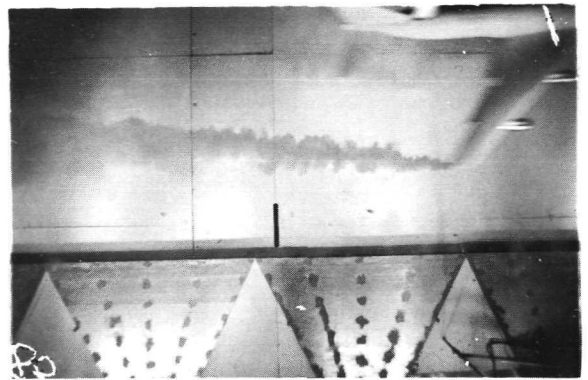


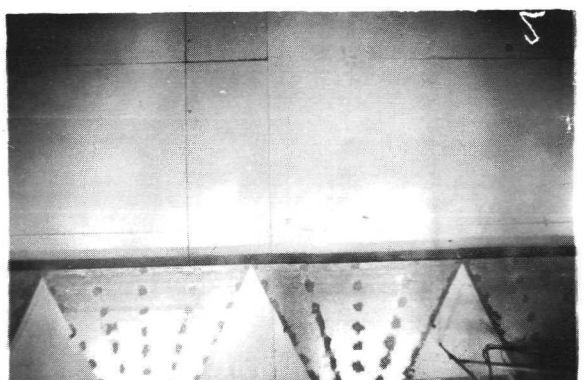
FIGURE 41 - CONCLUDED



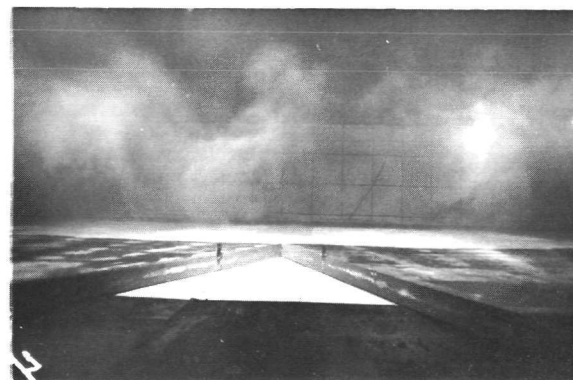
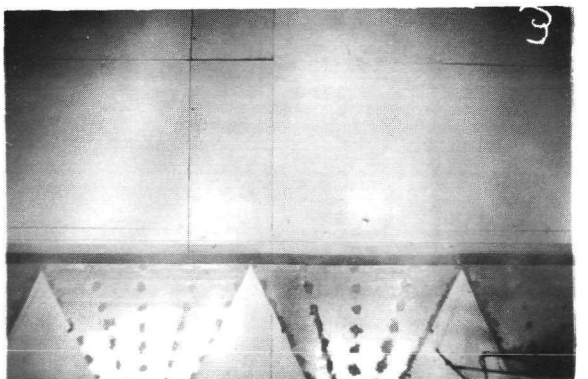
N  
0.3



3.7



7.5



10.5

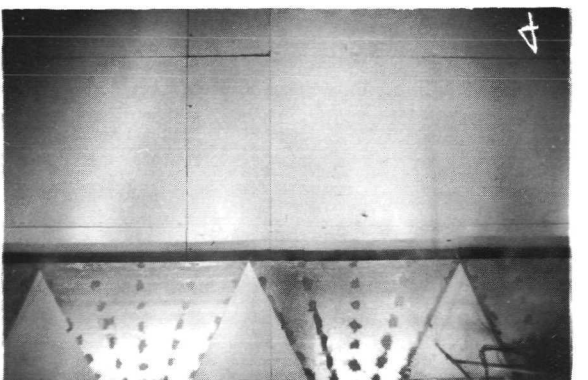
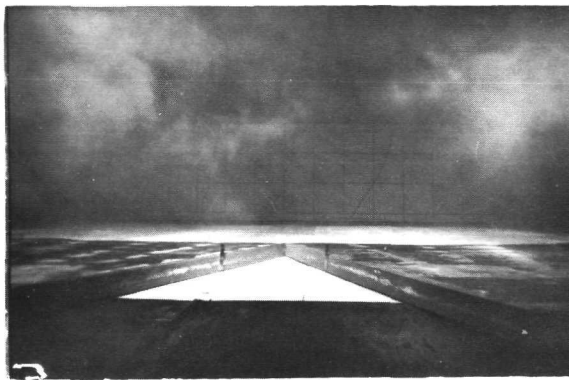
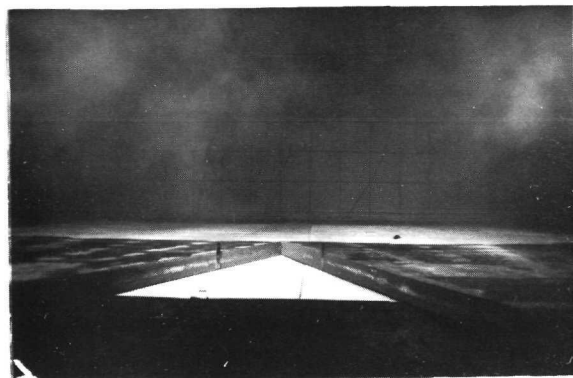
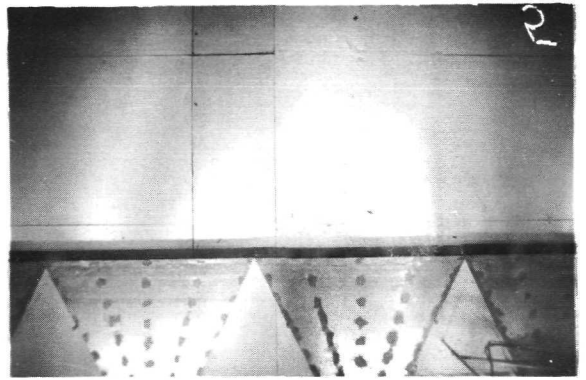


FIGURE 42 - DEVICE C1 WITH  $V_s/U = 0.0718$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.83$  AND ALTITUDE = 13.4 METERS

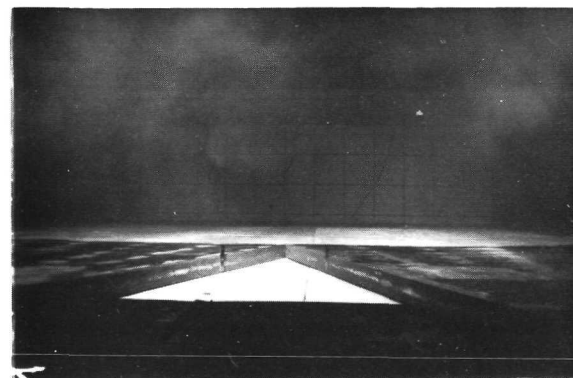
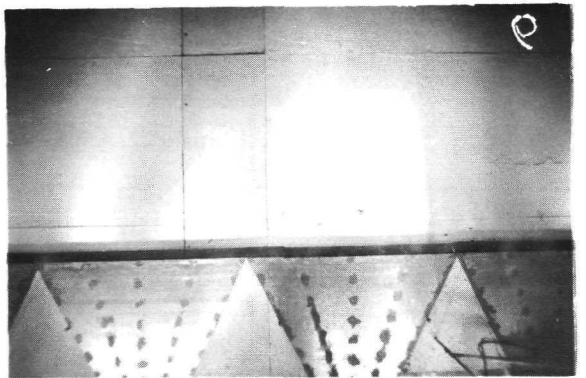


N

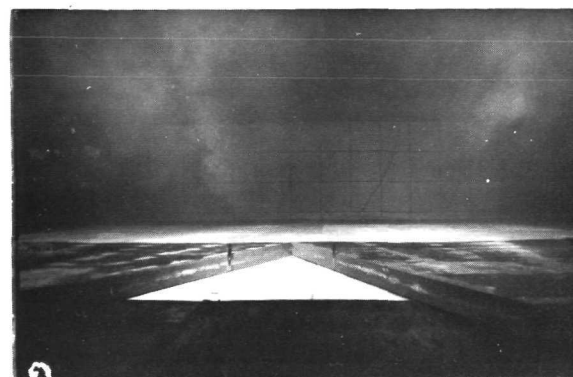
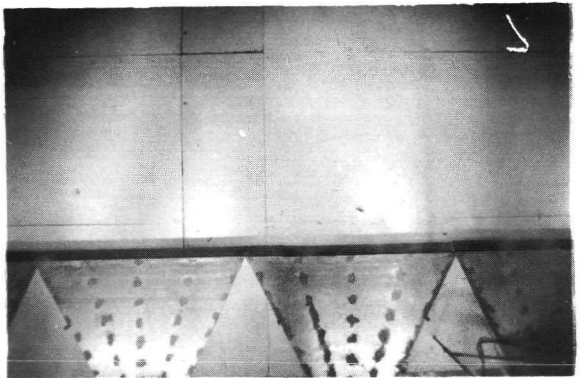
13.9



19.0



24.1



29.2

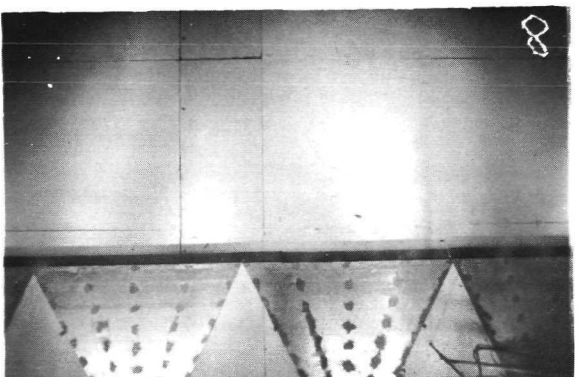
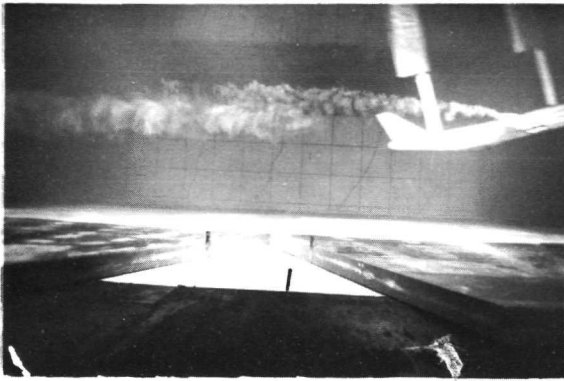
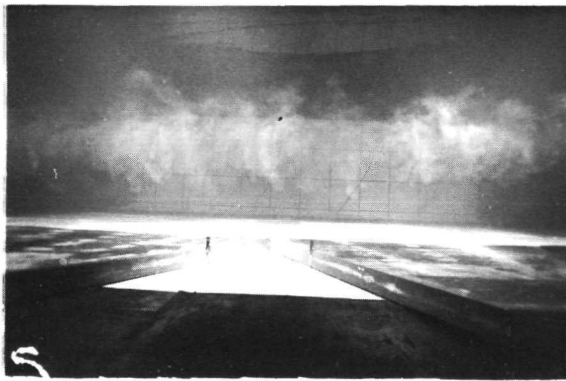
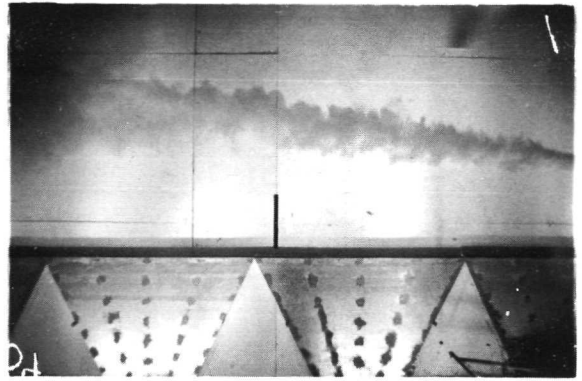


FIGURE 42 - CONCLUDED

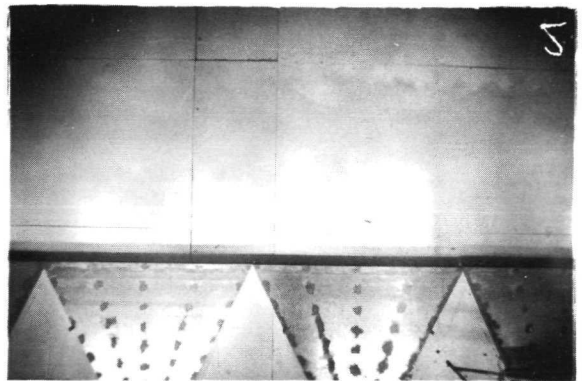


N

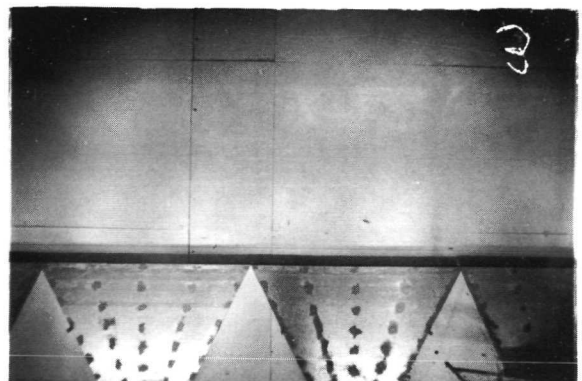
1.1



4.5



7.9



11.3

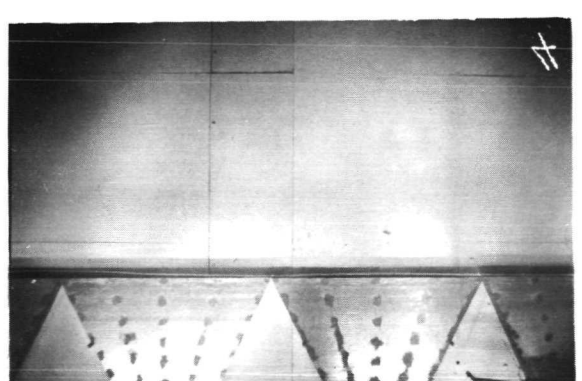
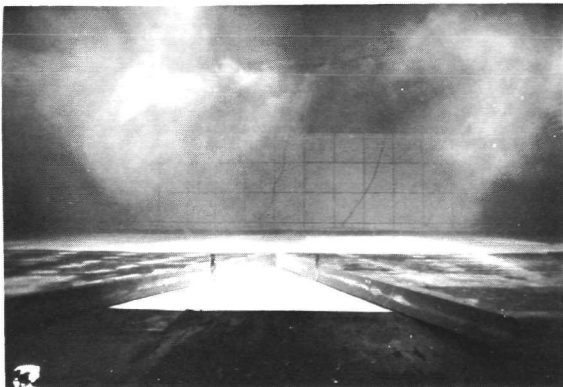
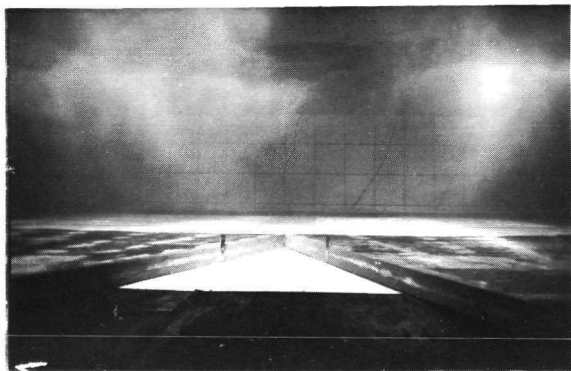


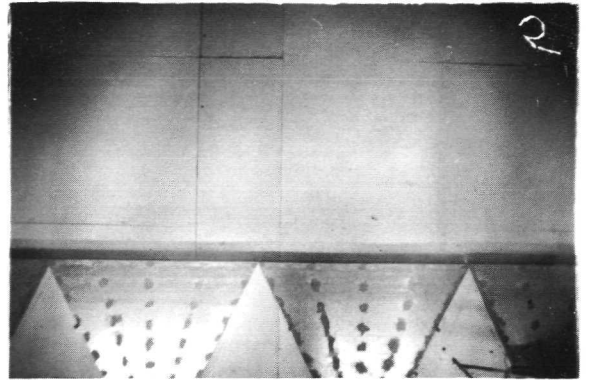
FIGURE 43 - DEVICE C1 WITH  $V_s/U = 0.0718$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.83$  AND ALTITUDE = 30.5 METERS

HYDRONAUTICS, INCORPORATED

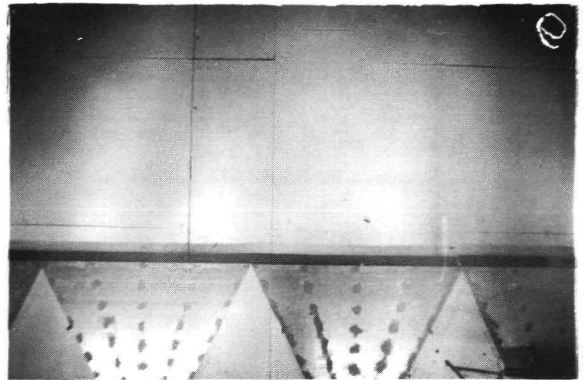


N

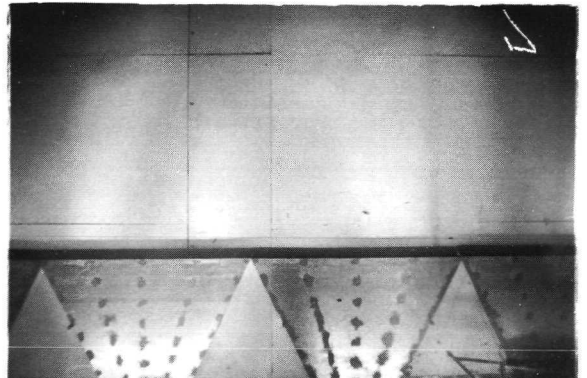
14.7



19.8



24.9



30.0

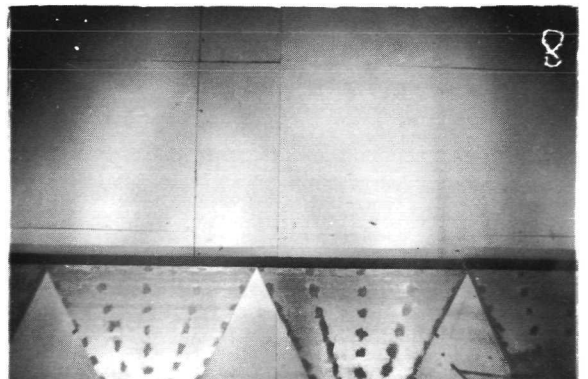
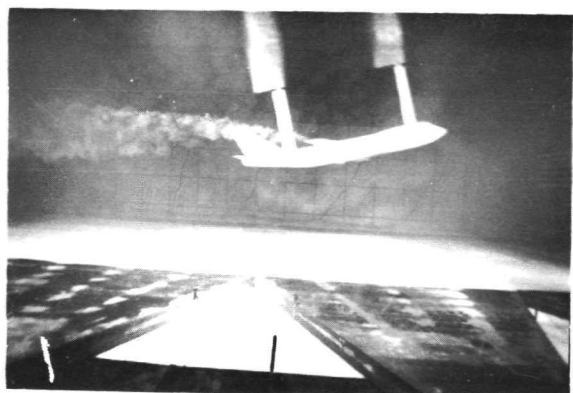
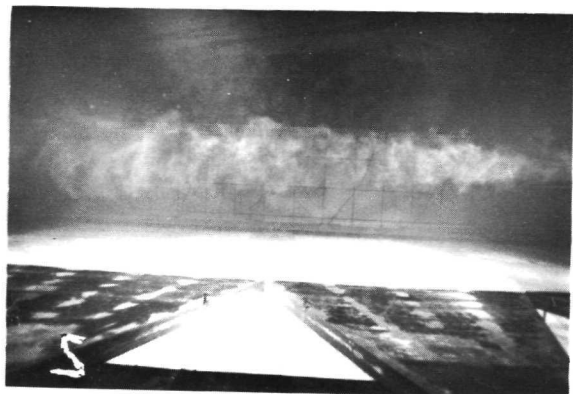


FIGURE 43 - CONCLUDED

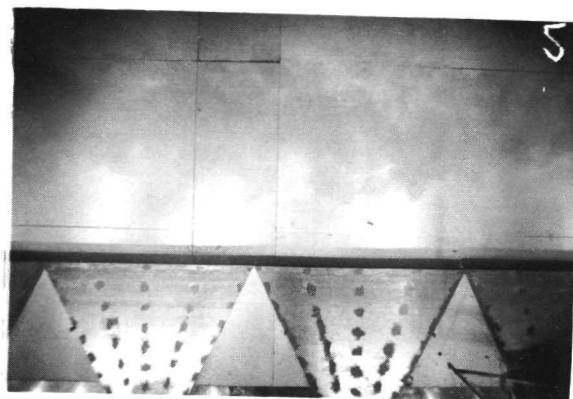
HYDRONAUTICS, INCORPORATED



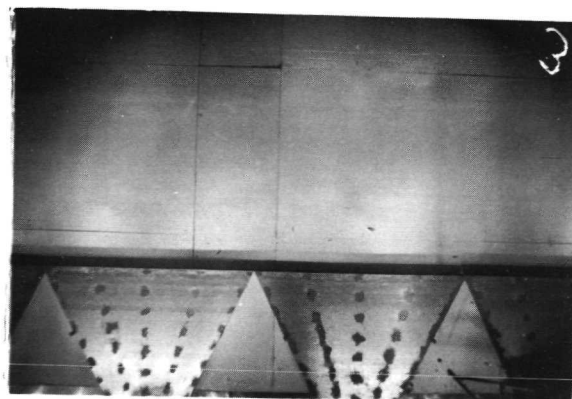
N  
0.1



2.9



5.5



8.3

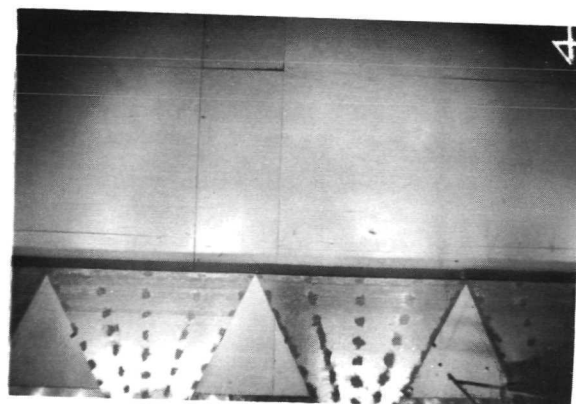
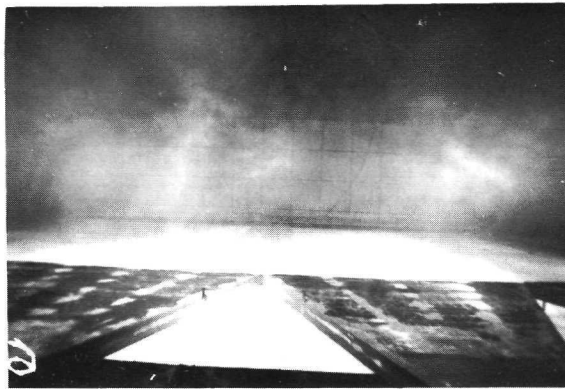
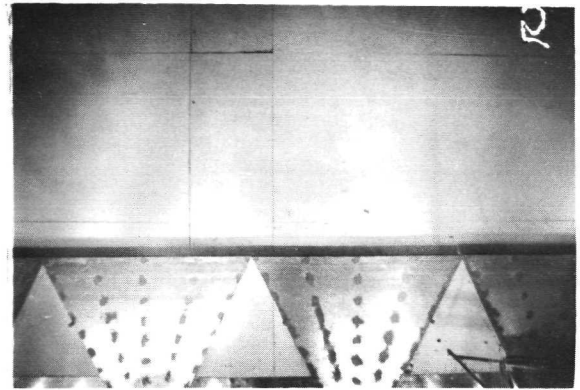


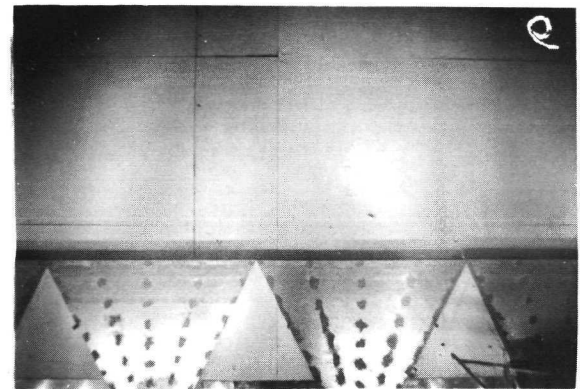
FIGURE 44 - DEVICE C1 WITH  $V_s/U = 0.0898$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.79$  AND ALTITUDE = 30.5 METERS



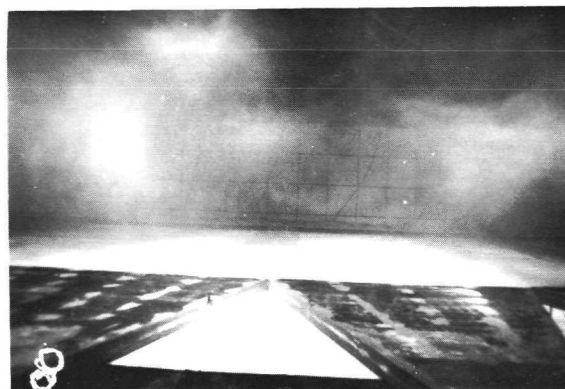
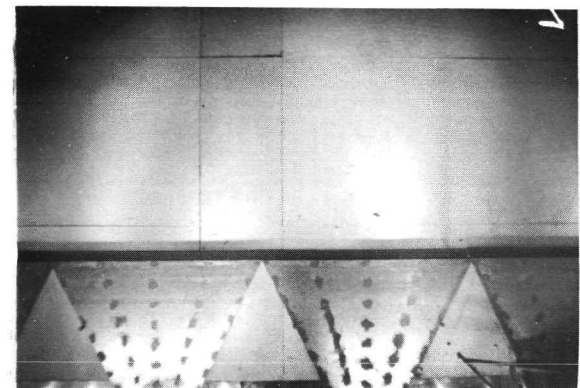
N  
11.0



15.1



19.2



23.2

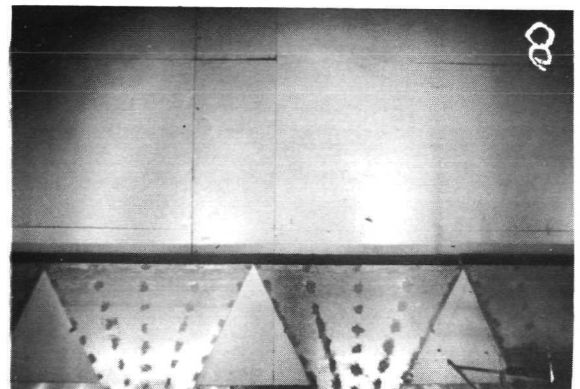
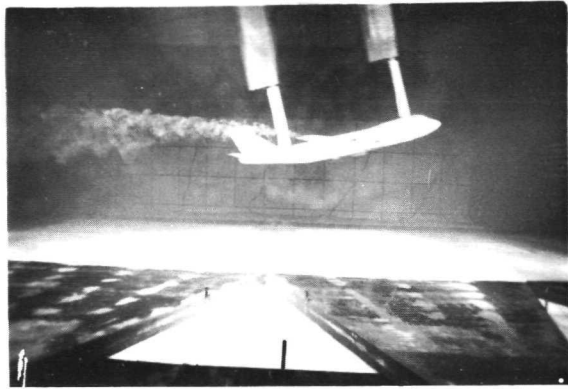
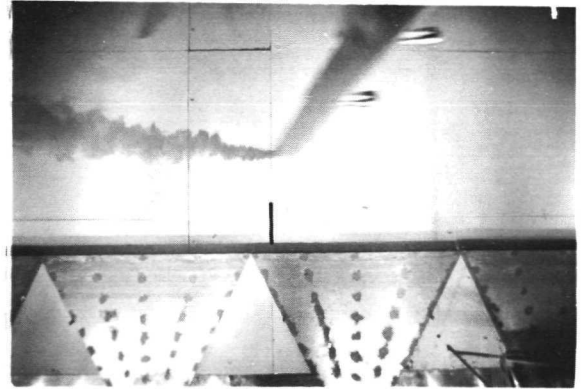


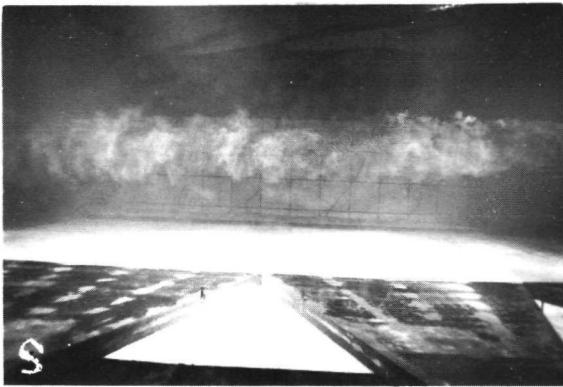
FIGURE 44 - CONCLUDED



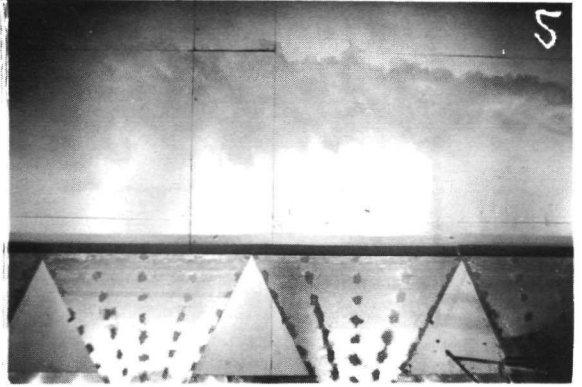
N



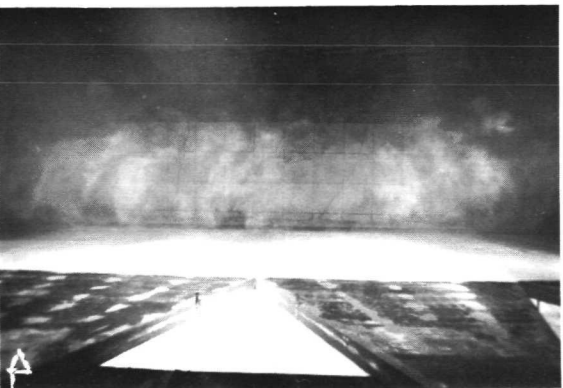
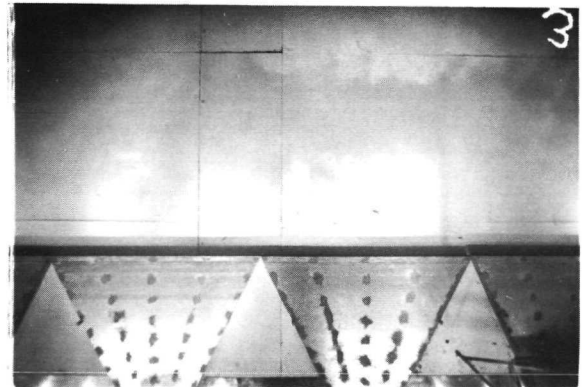
0



2.0



4.1



6.1

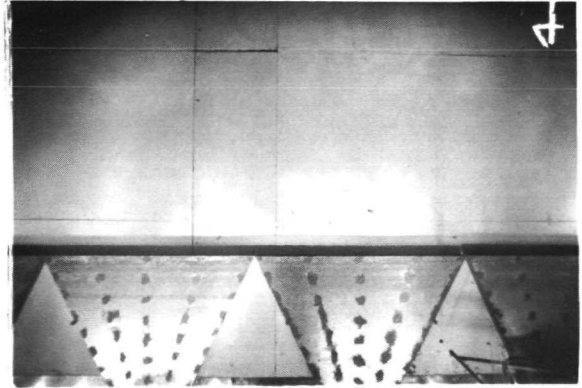


FIGURE 45 - DEVICE C1 WITH  $V_s/U = 0.1197$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.77$  AND ALTITUDE = 30.5 METERS

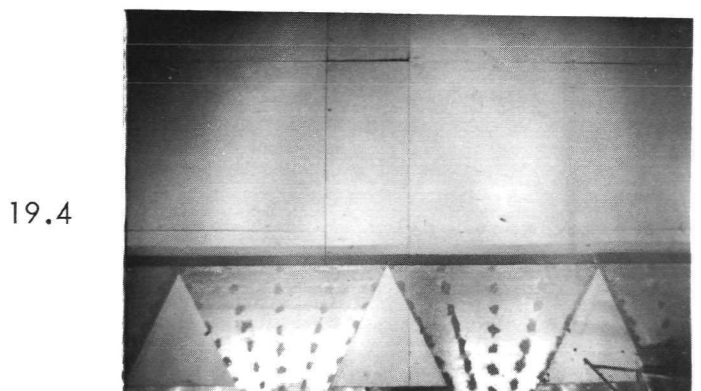
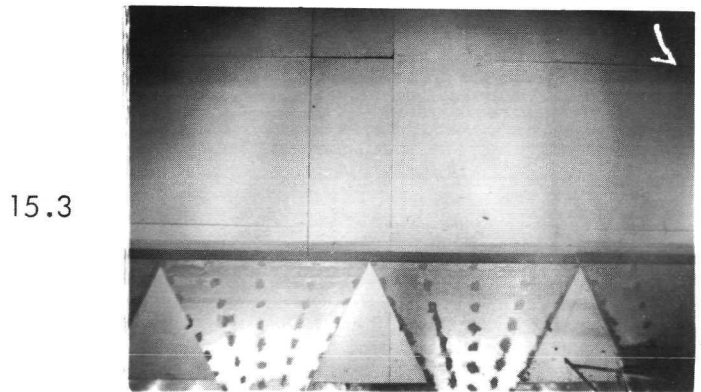
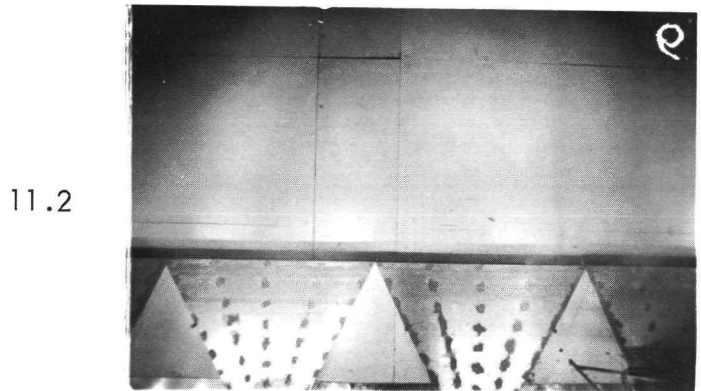
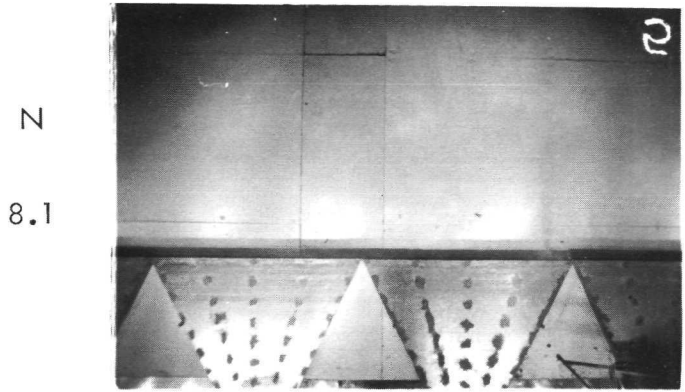
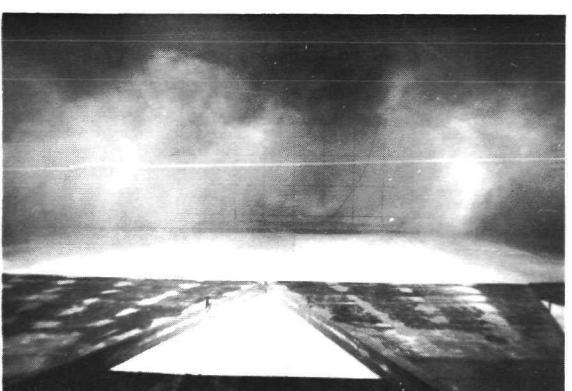
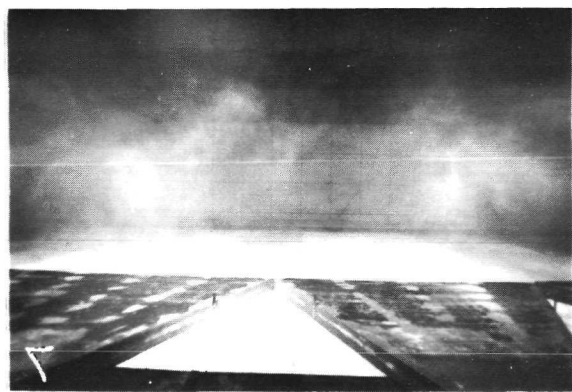
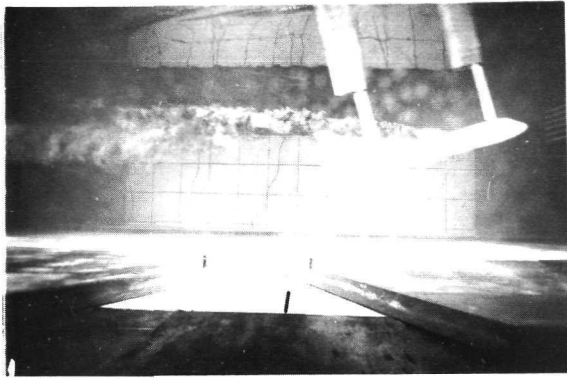
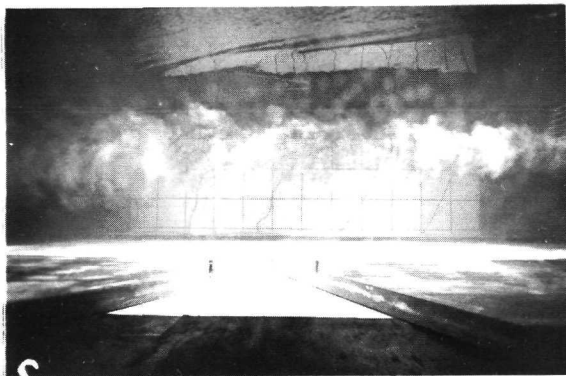
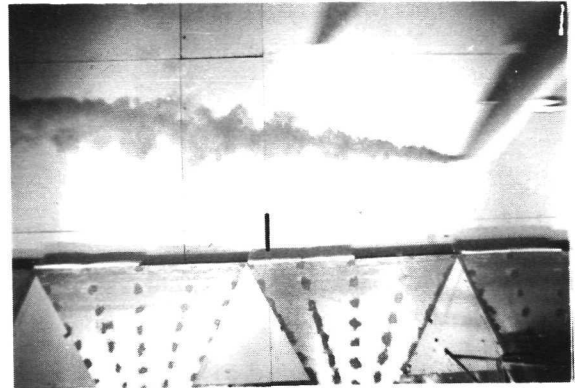


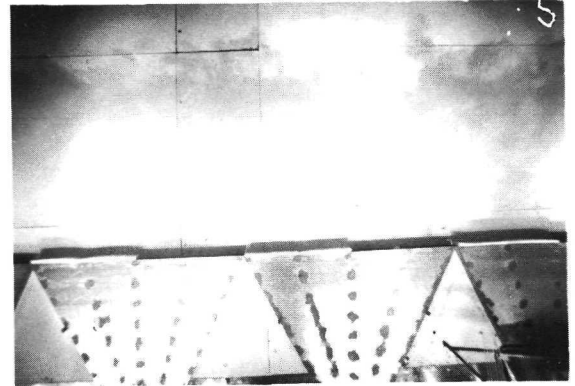
FIGURE 45 - CONCLUDED



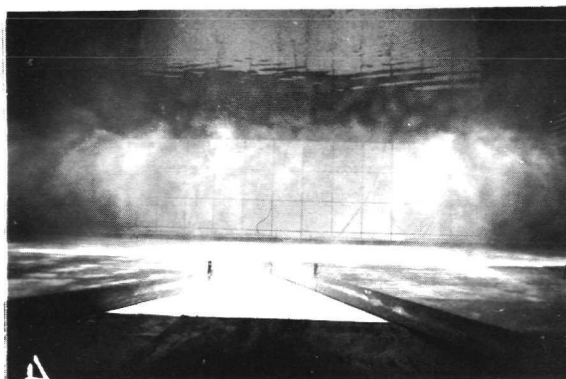
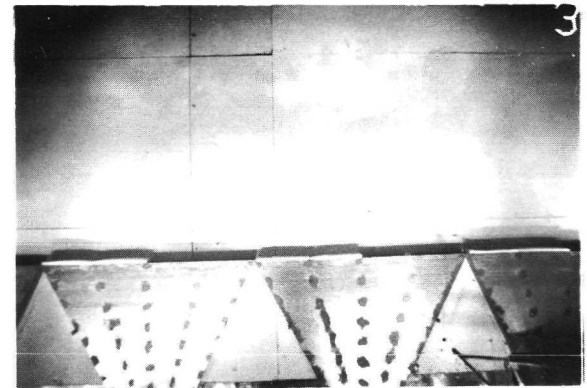
N  
0.7



3.4



6.1



8.8

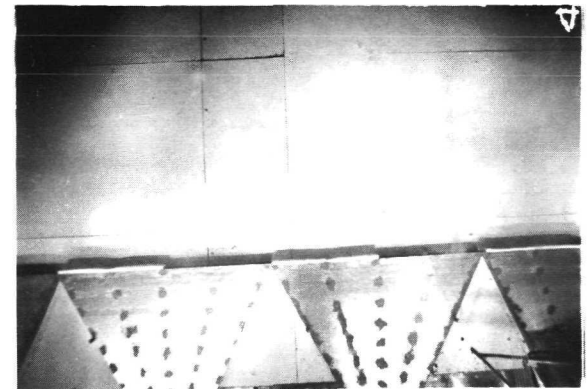
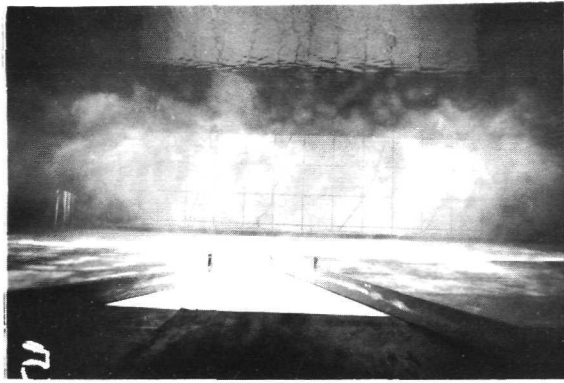
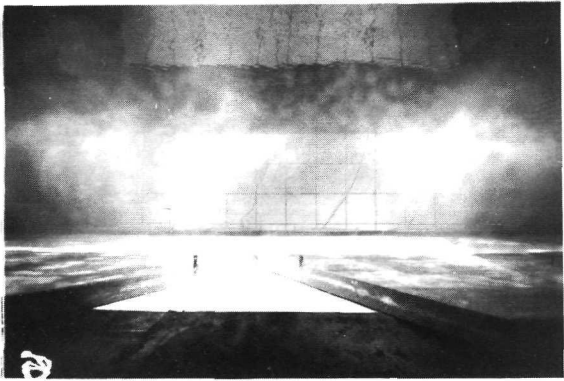
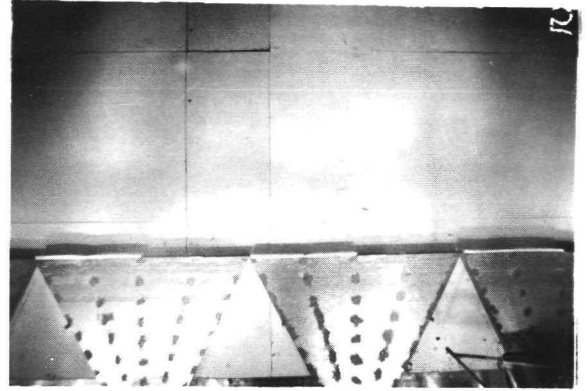


FIGURE 46 - DEVICE C2 WITH  $V_s/U = 0.1625$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.79$  AND ALTITUDE = 30.5 METERS

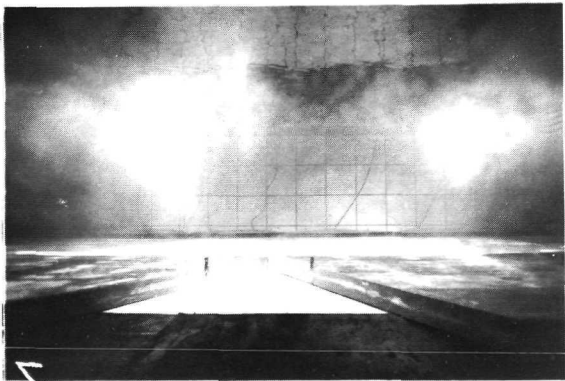
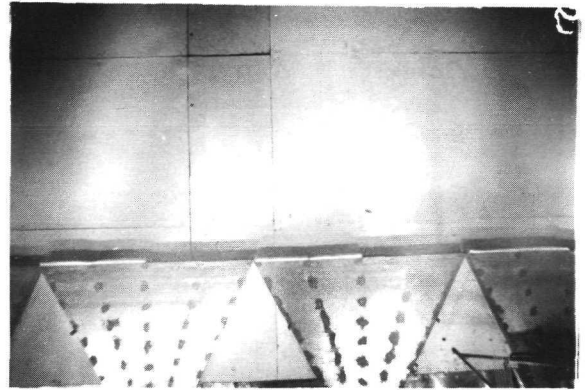
HYDRONAUTICS, INCORPORATED



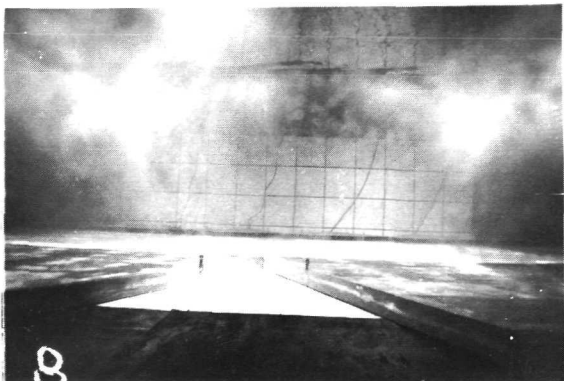
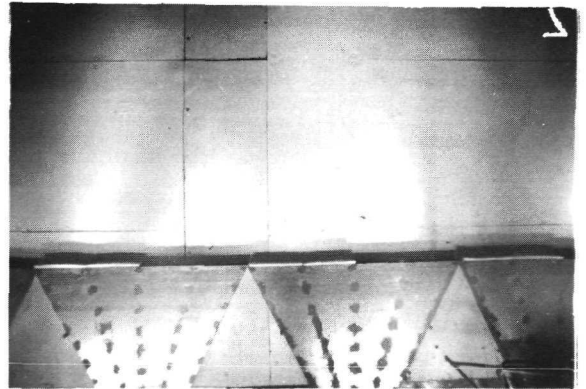
N  
11.6



15.6



19.7



23.8

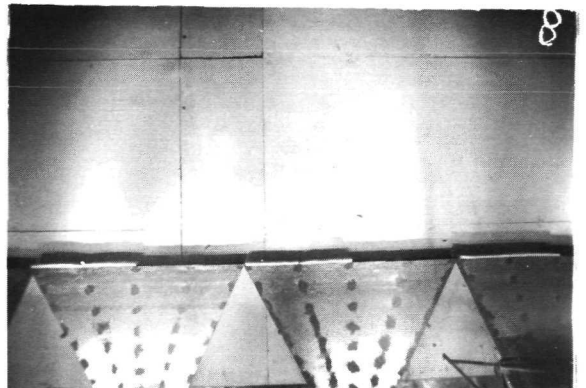
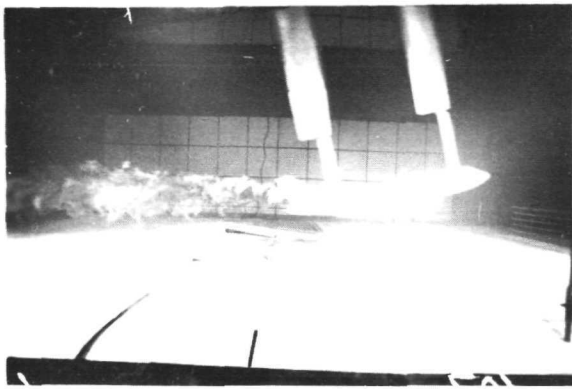
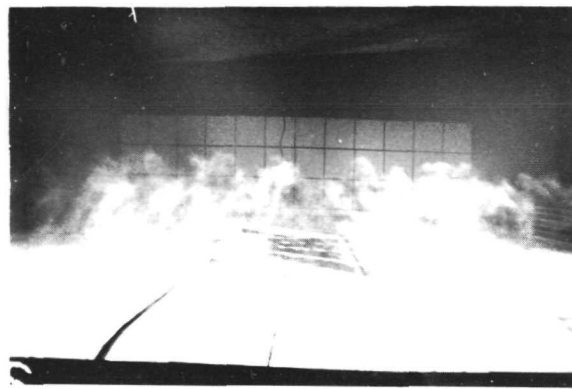
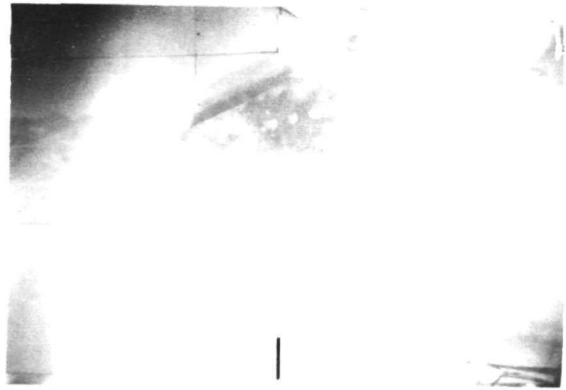


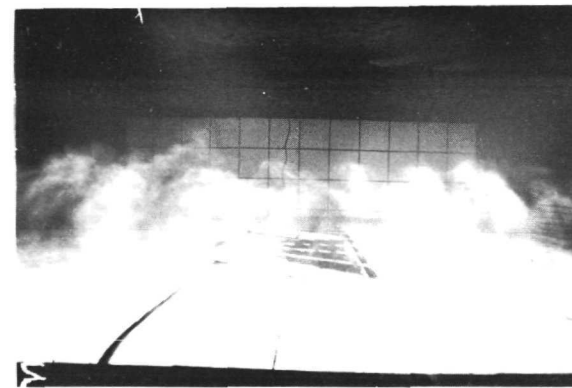
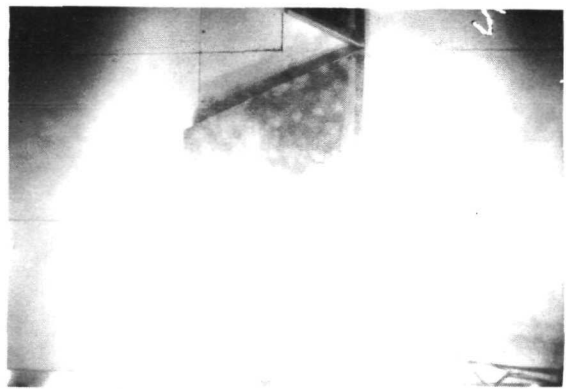
FIGURE 46 - CONCLUDED



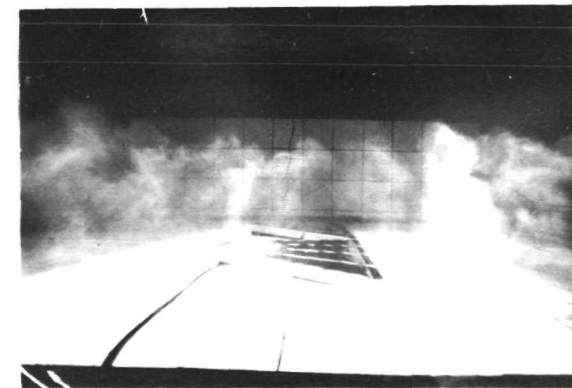
N  
0.6



3.3



6.0



8.8

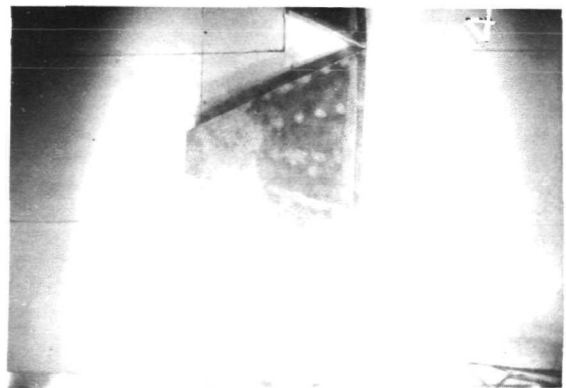
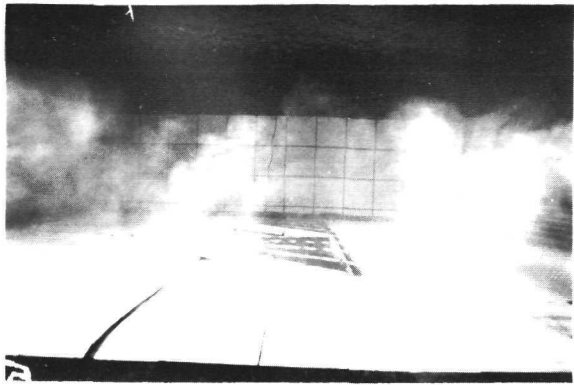
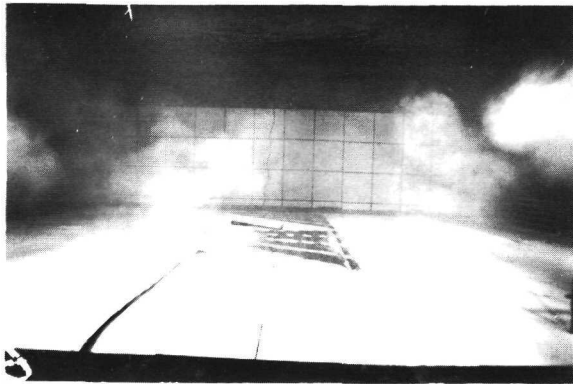
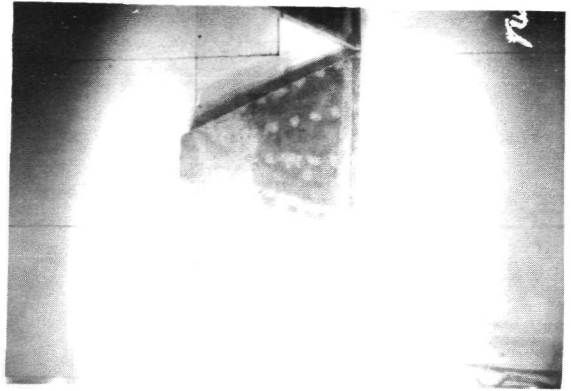


FIGURE 47 - DEVICE D WITH  $V_s/U = 0.0898$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.79$  AND ALTITUDE = 13.4 METERS

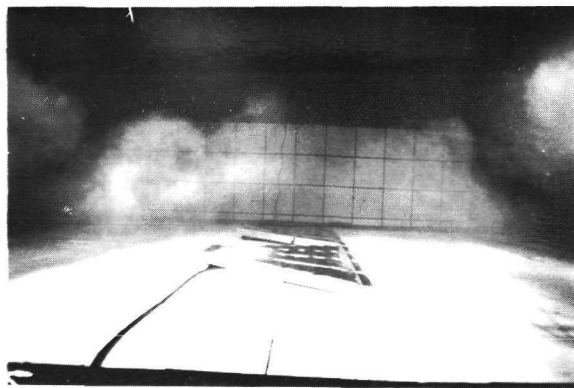
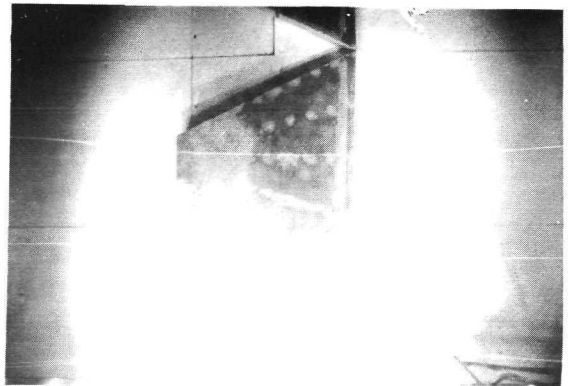
HYDRONAUTICS, INCORPORATED



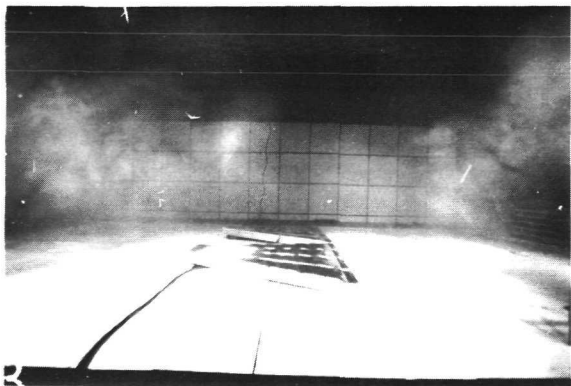
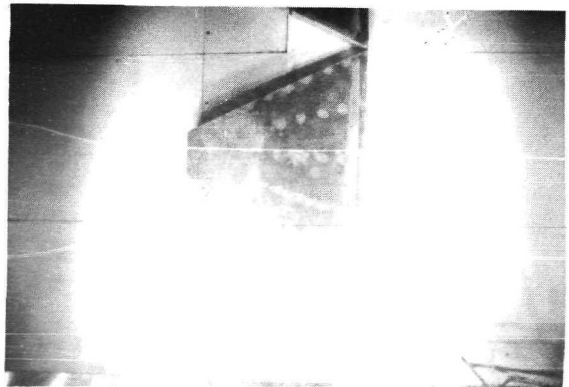
N  
11.5



15.6



19.7



23.7

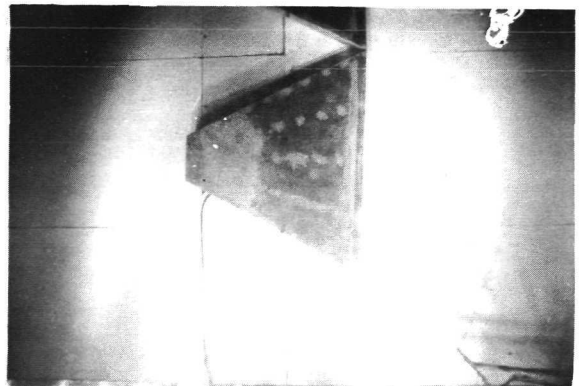


FIGURE 47 - CONCLUDED

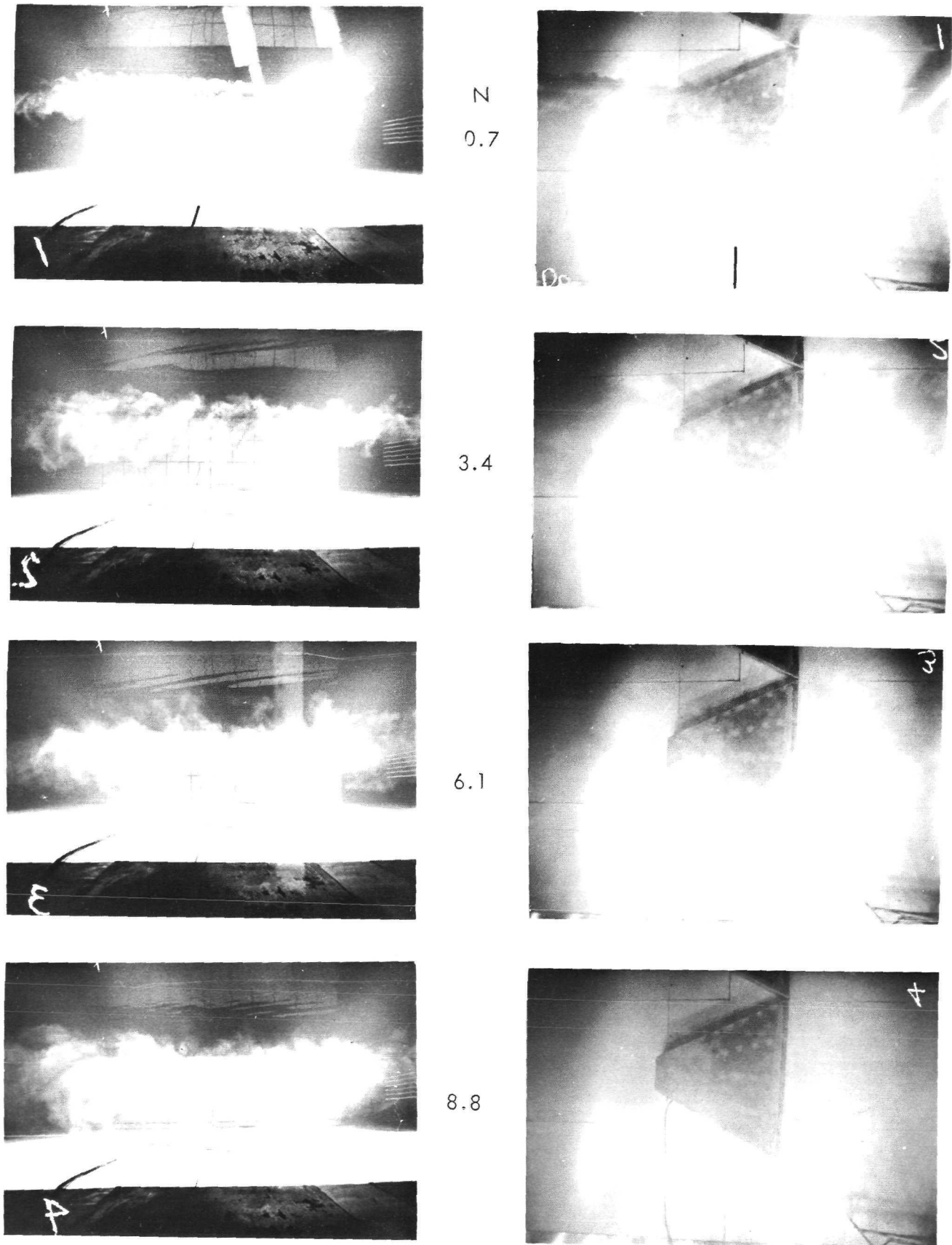
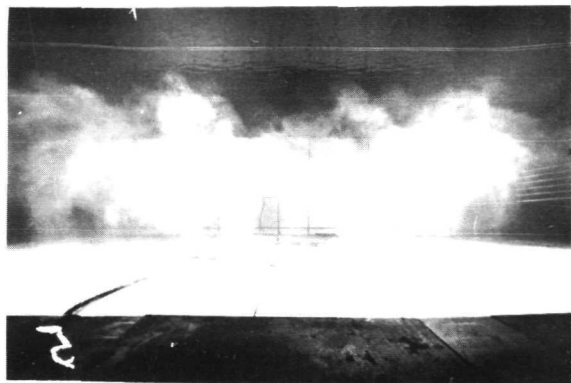
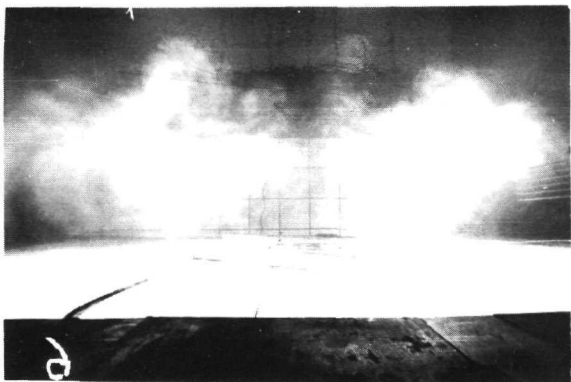
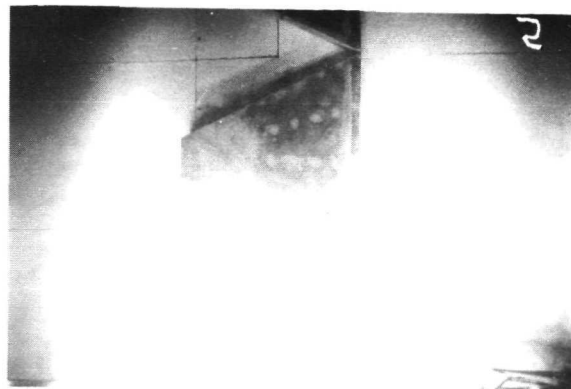


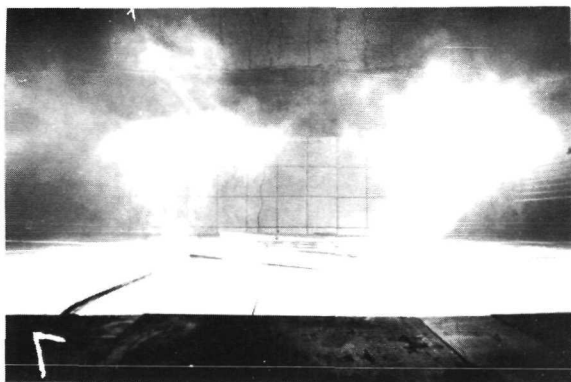
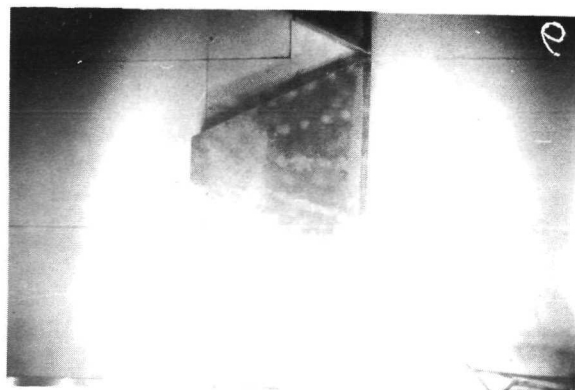
FIGURE 48 - DEVICE D WITH  $V_s/U = 0.0898$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.77$  AND ALTITUDE = 30.5 METERS



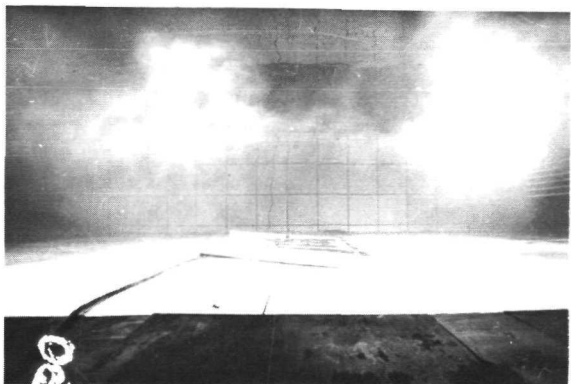
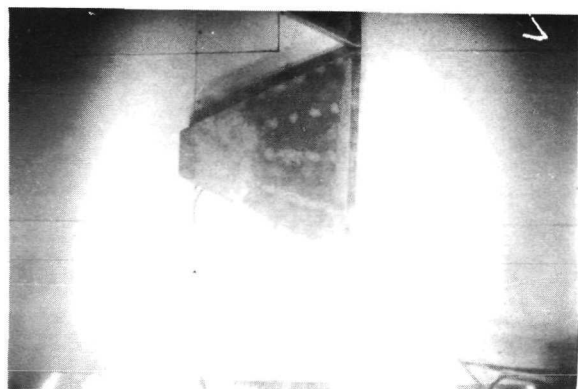
N  
11.6



15.7



19.7



23.8

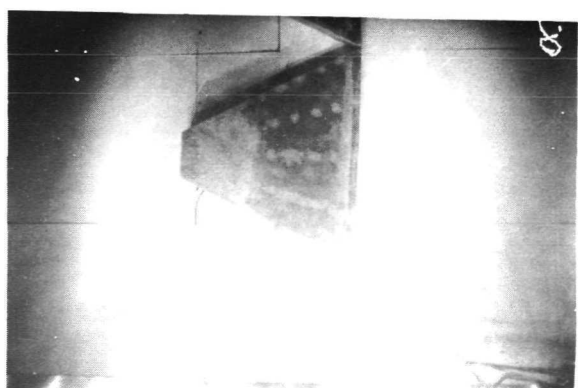
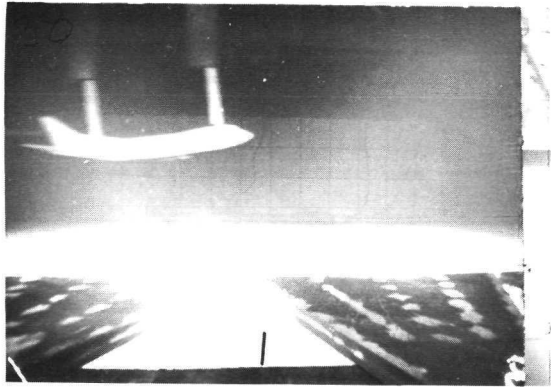
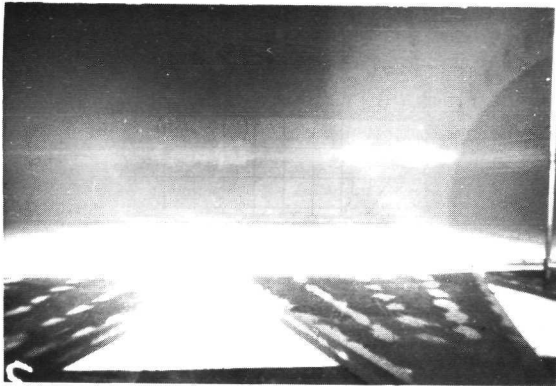
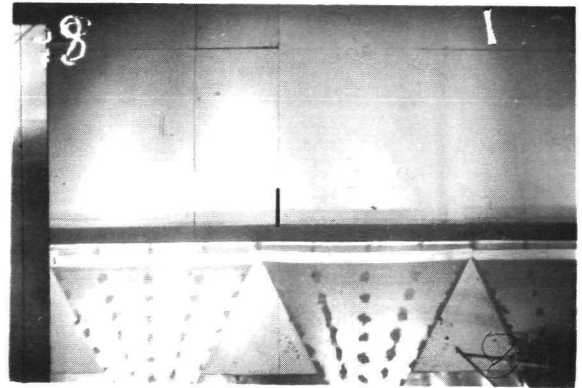


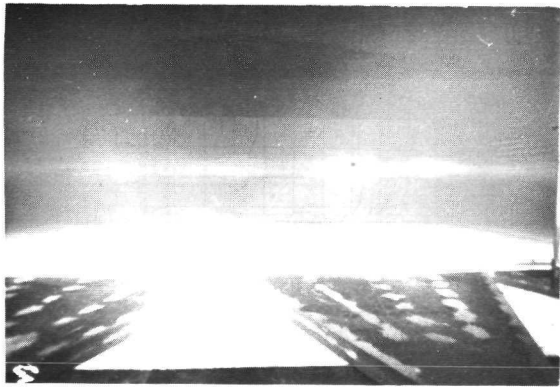
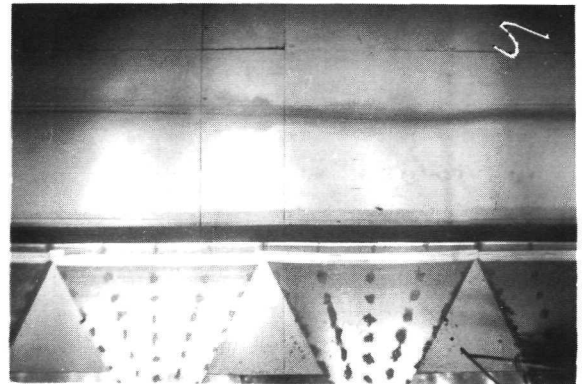
FIGURE 48 - CONCLUDED



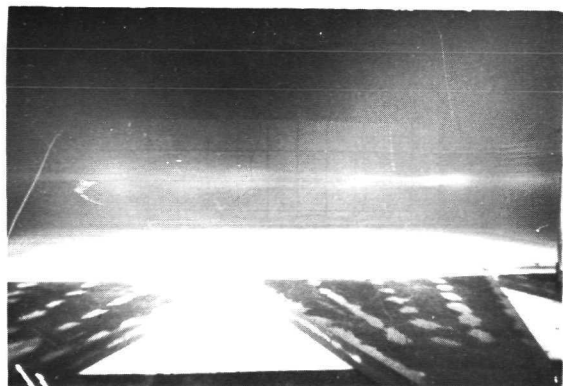
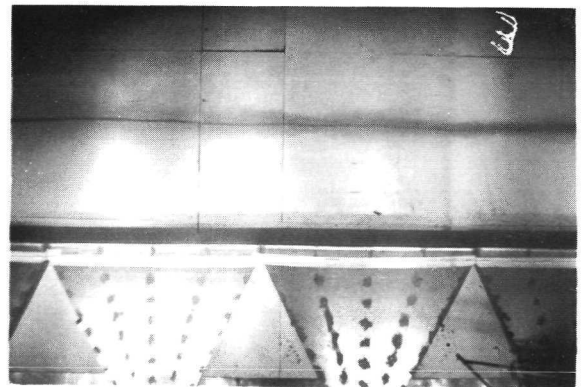
N  
-1.2



6.9



15.1



23.2

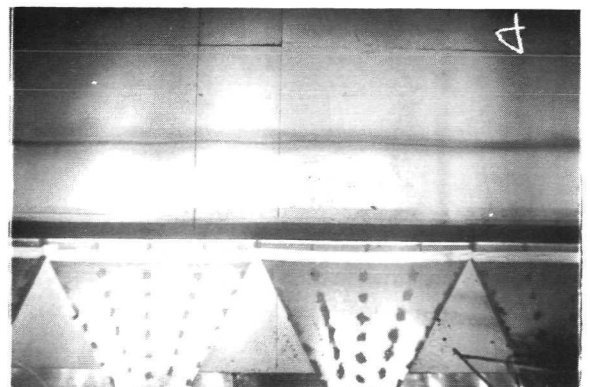
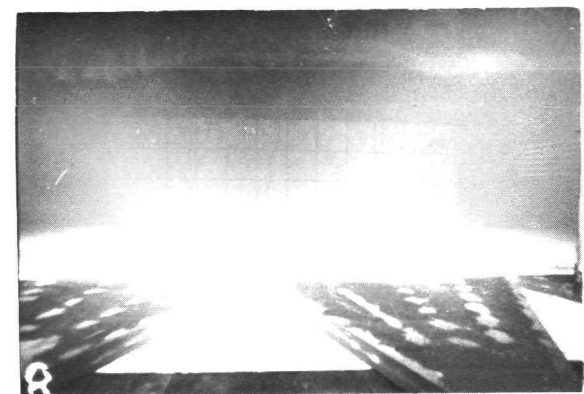
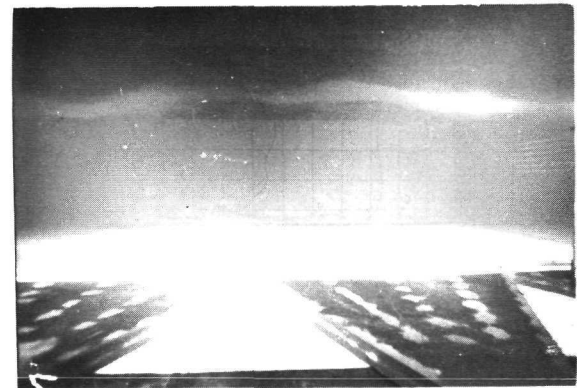
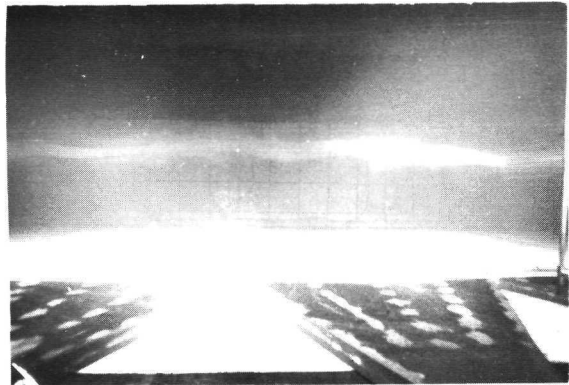
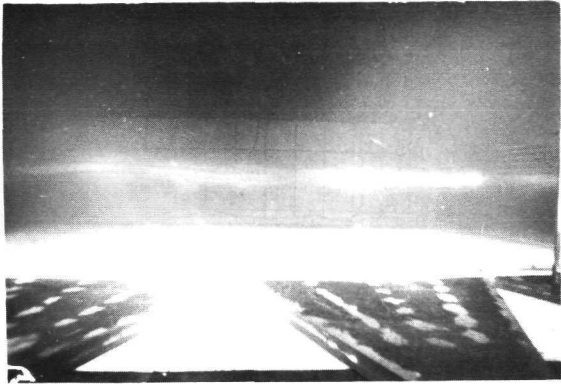
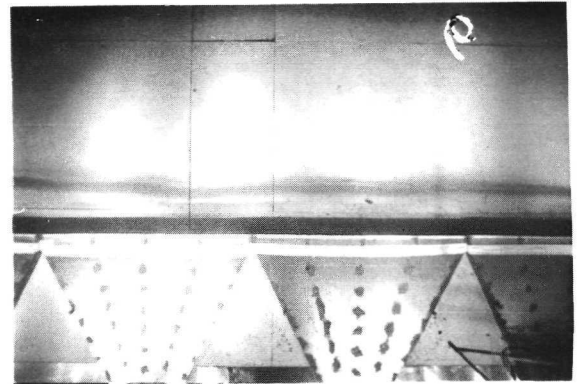
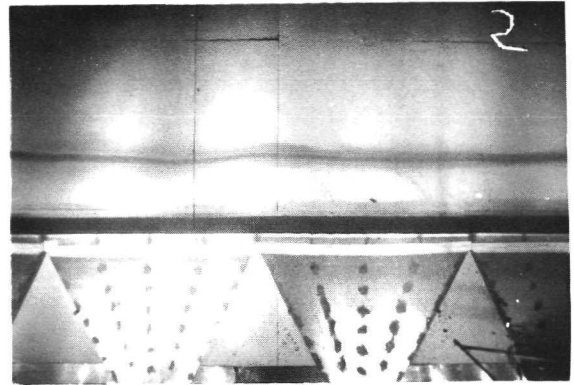


FIGURE 49 - DEVICE E WITH  $V_b/U = 0.1617$  - EFFECT ON VORTEX WAKE FOR CRUISE CONDITION,  $C_L = 0.67$  AND ALTITUDE = 30.5 METERS

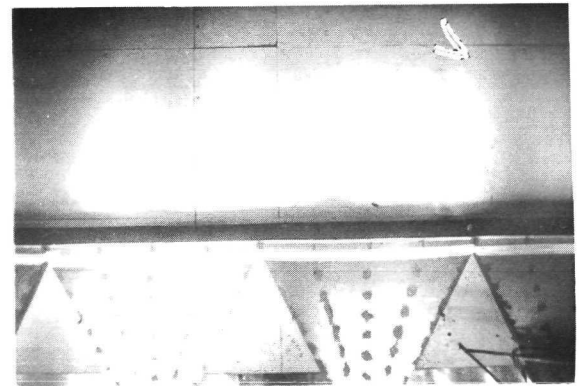


N

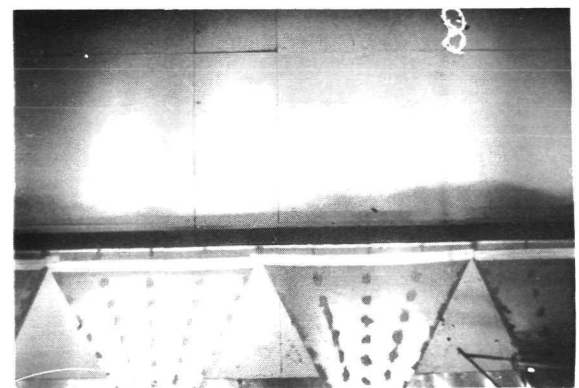
31.4



43.6

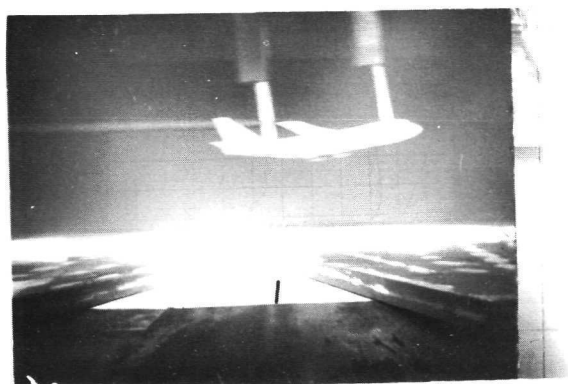


55.9

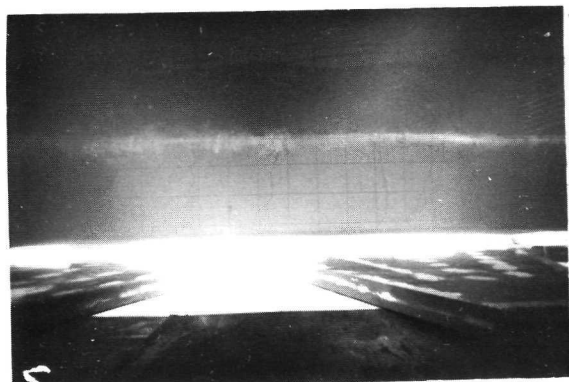
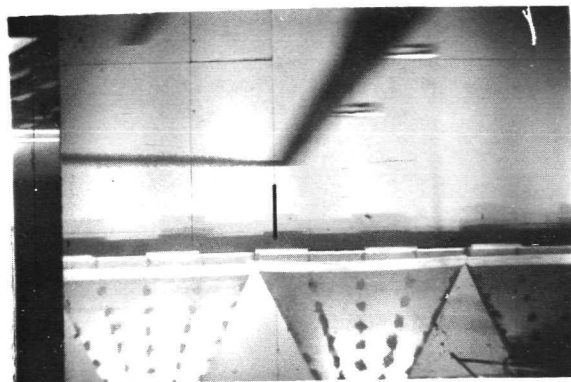


68.1

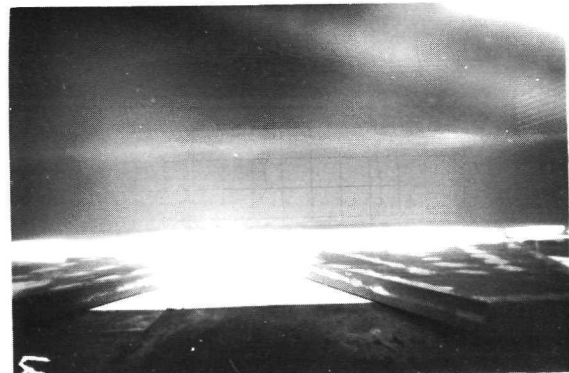
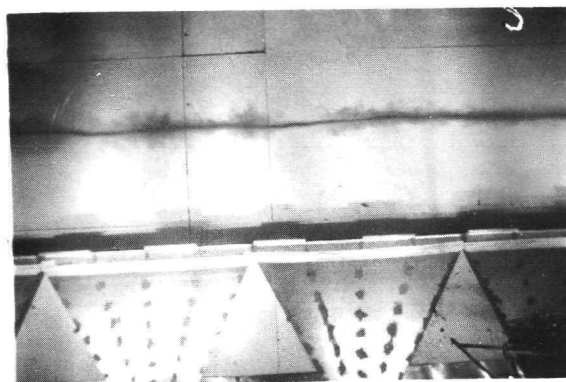
FIGURE 49 - CONCLUDED



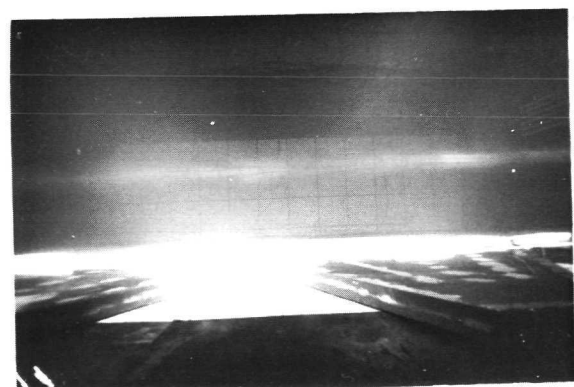
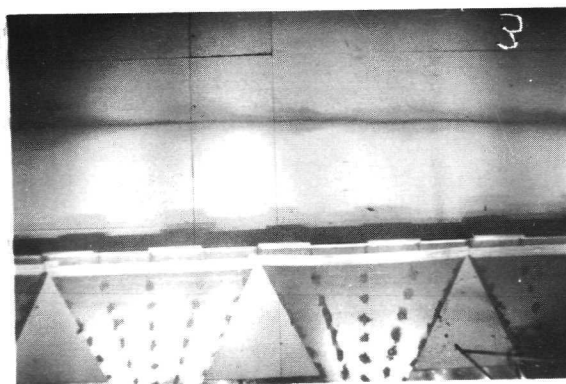
0



8.2



16.3



24.5

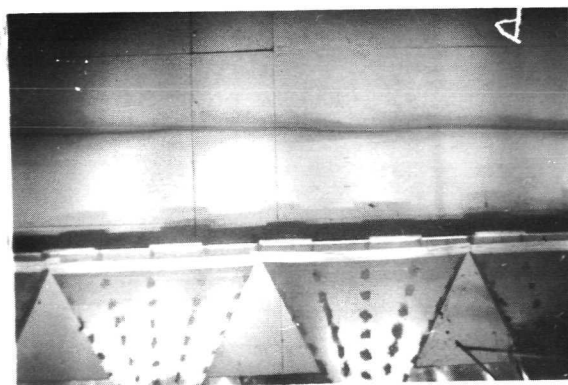
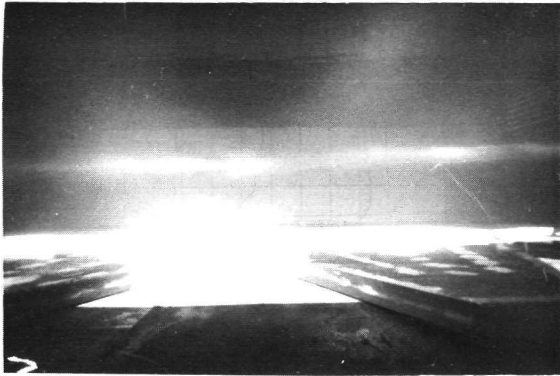


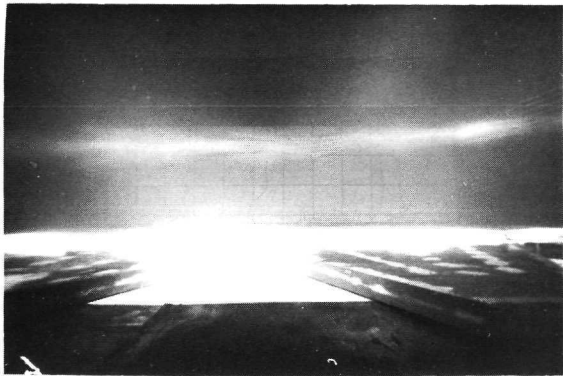
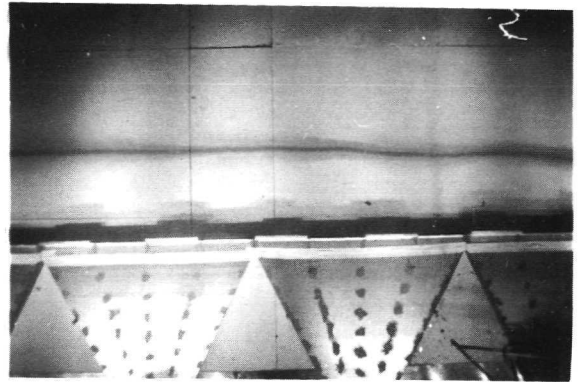
FIGURE 50 - DEVICE E1 WITH  $V_b/U = 0.1617$  - EFFECT ON VORTEX WAKE FOR CRUISE CONDITION,  $C_L = 0.67$  AND ALTITUDE = 30.5 METERS

HYDRONAUTICS, INCORPORATED

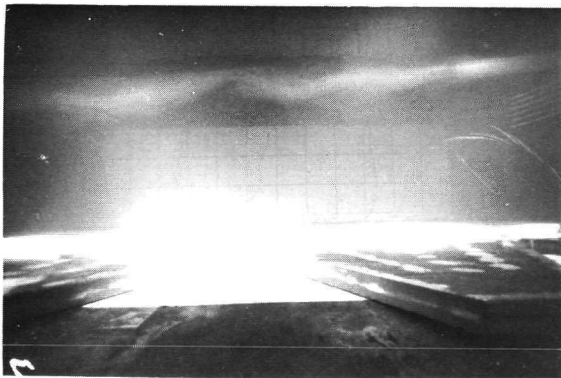
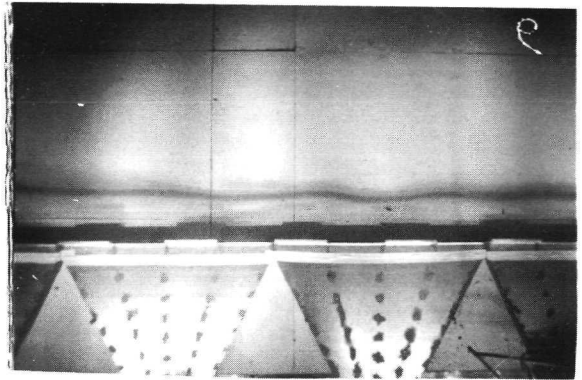


N

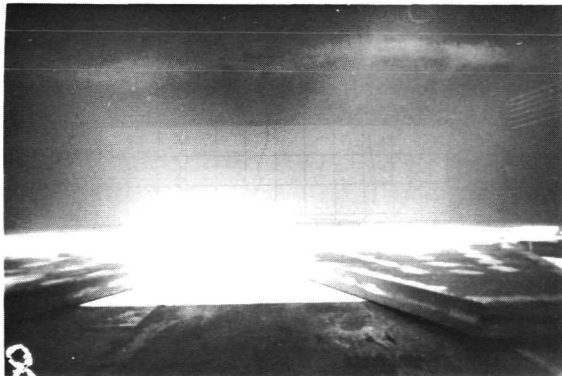
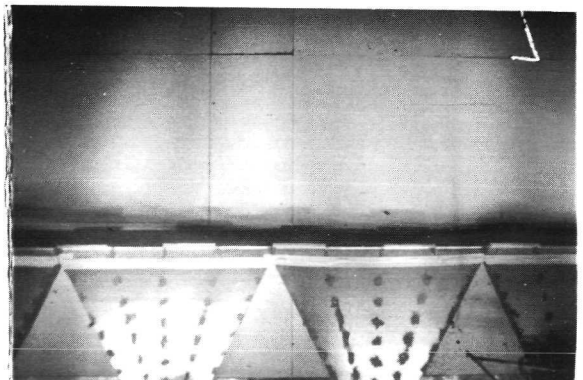
32.7



44.9



57.1



69.4

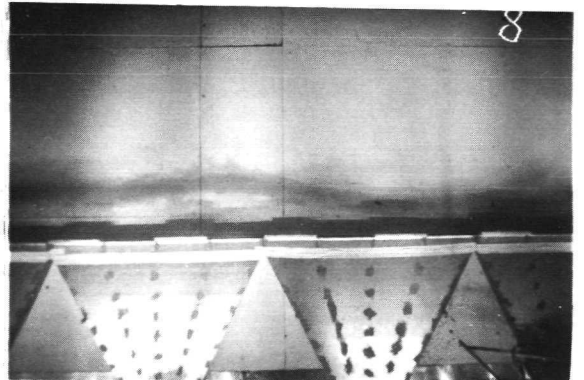
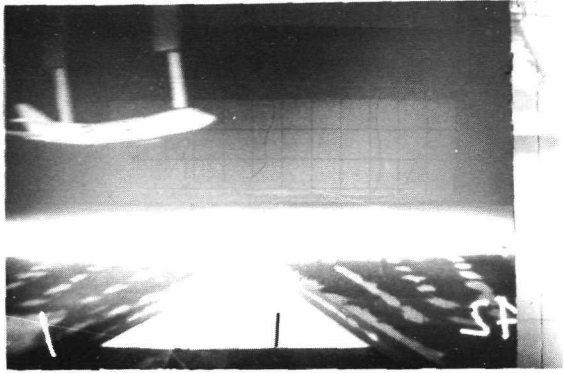
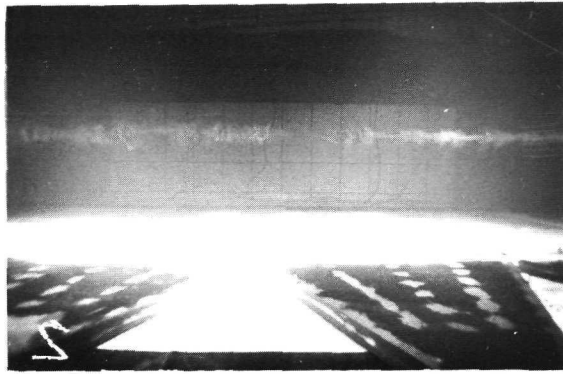
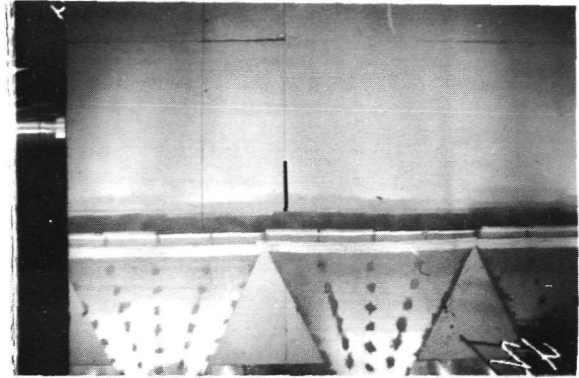


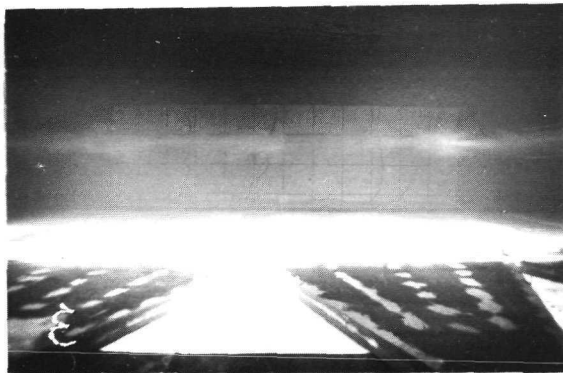
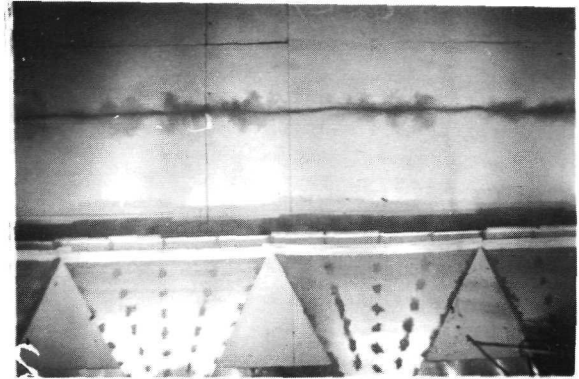
FIGURE 50 - CONCLUDED



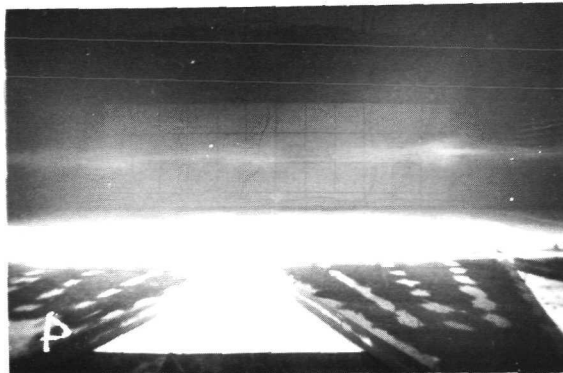
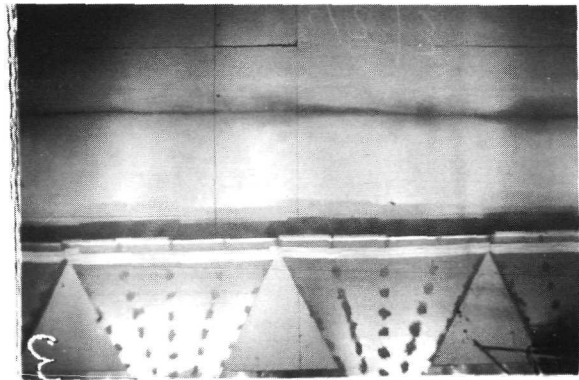
N  
-1.5



6.7



14.8



23.0

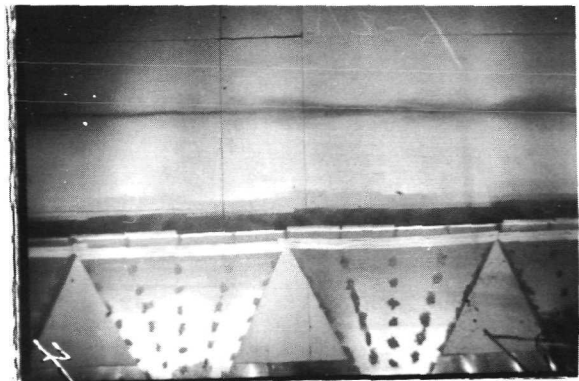
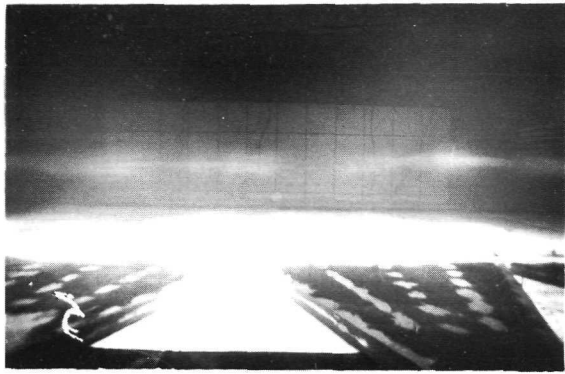
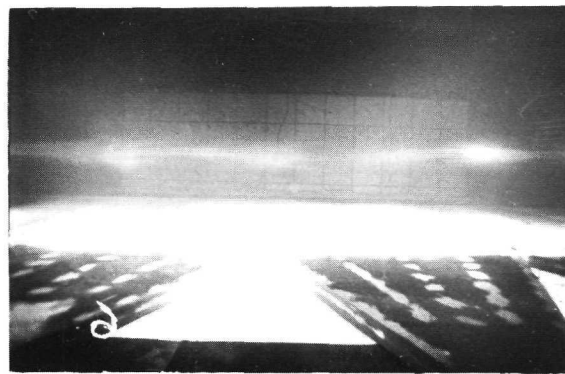
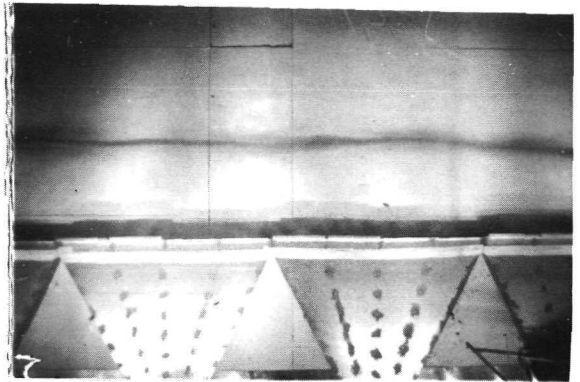


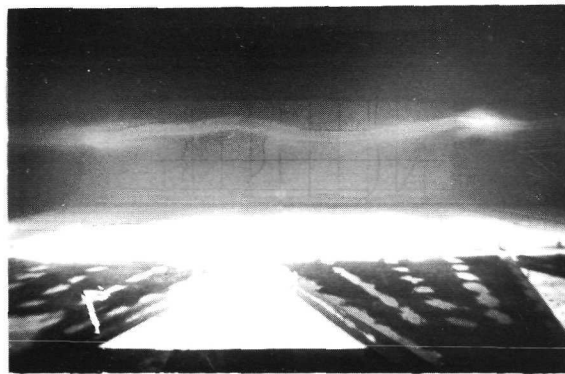
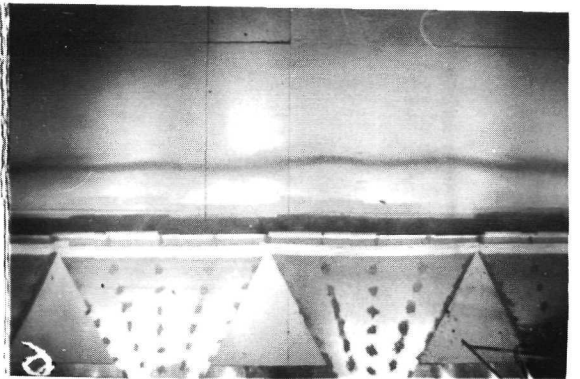
FIGURE 51 - DEVICE E2 WITH  $V_b/U = 0.270$  - EFFECT ON VORTEX WAKE FOR CRUISE CONDITION,  $C_L = 0.67$  AND ALTITUDE = 30.5 METERS



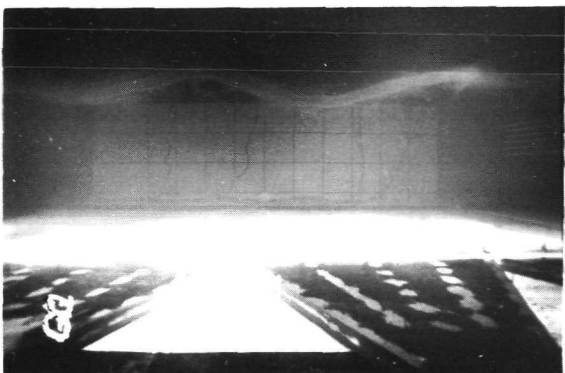
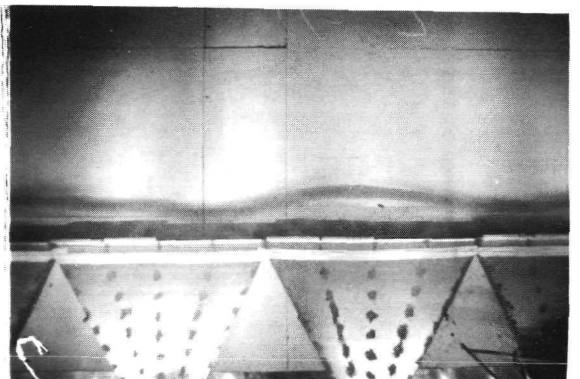
N  
31.1



43.4



55.6



67.9

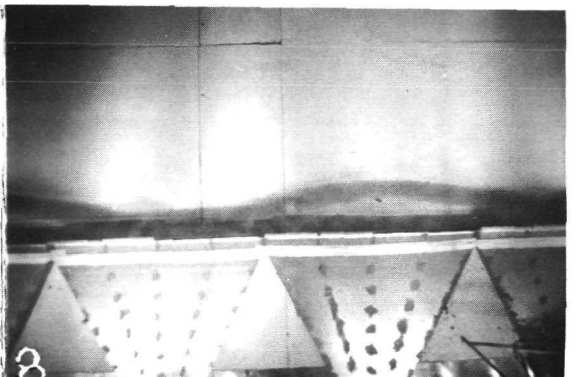
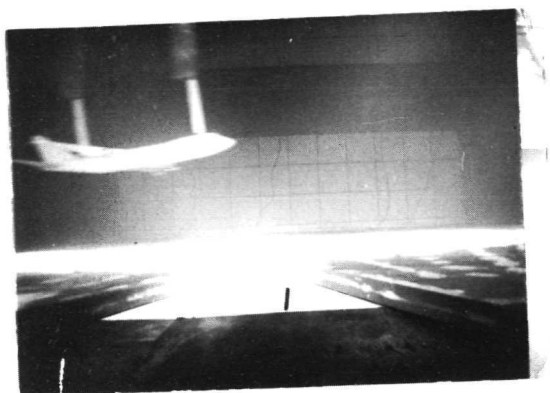
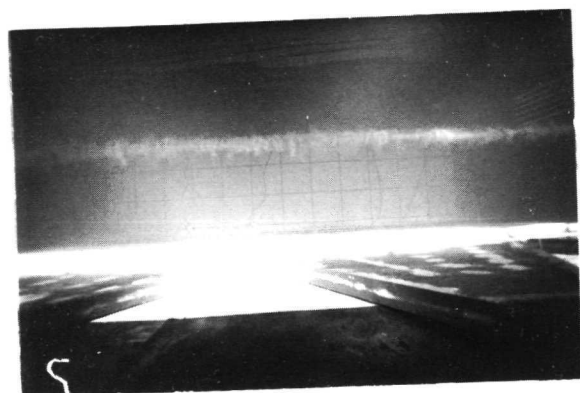
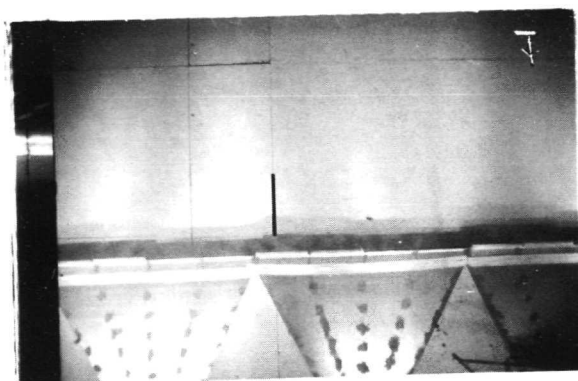


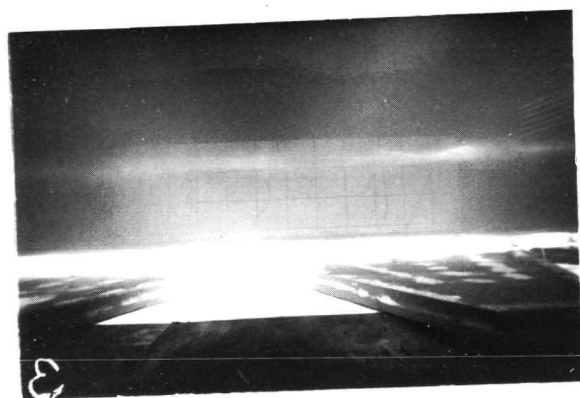
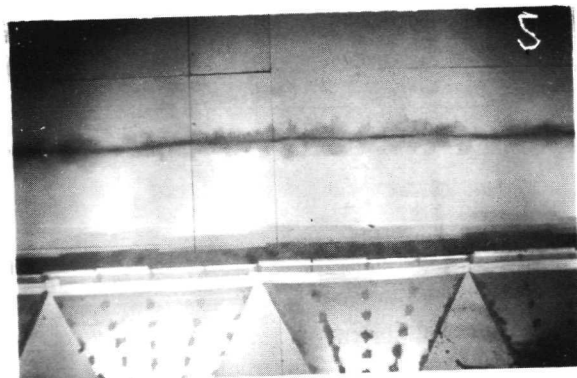
FIGURE 51 - CONCLUDED



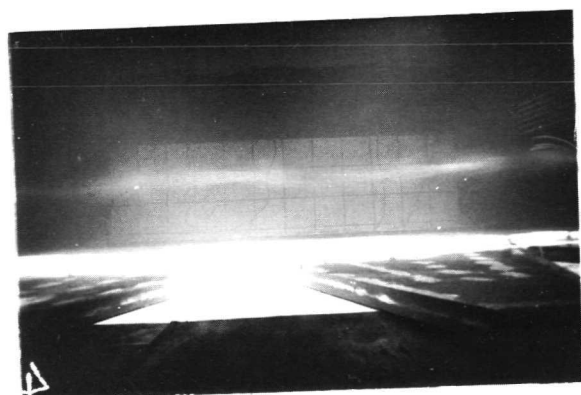
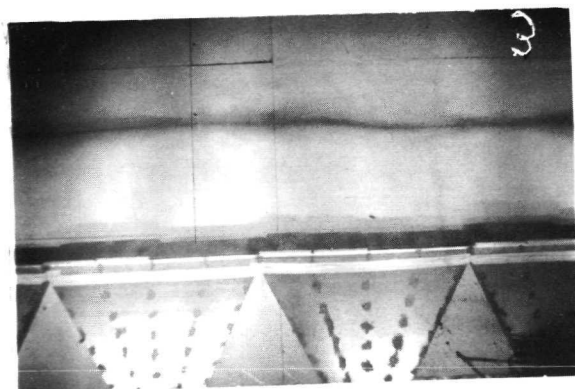
N  
-1.5



6.7



18.9



31.1

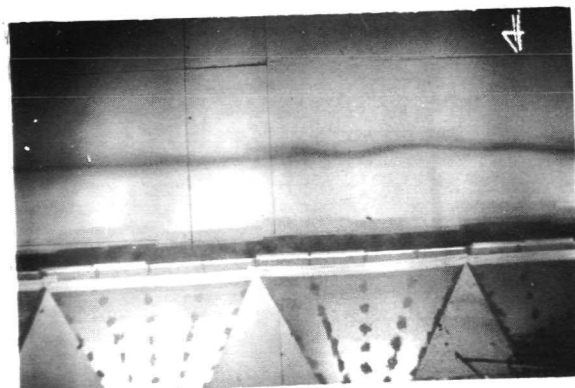
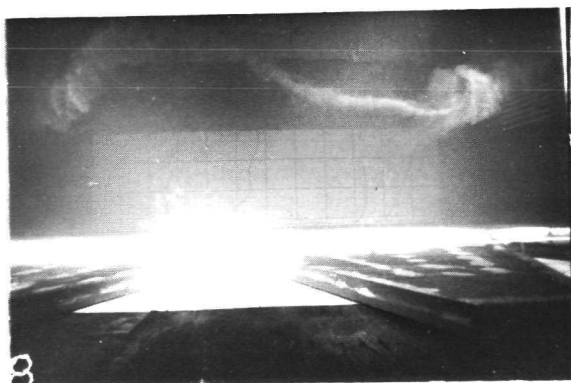
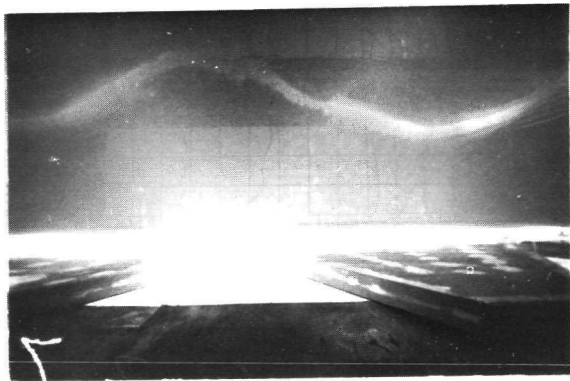
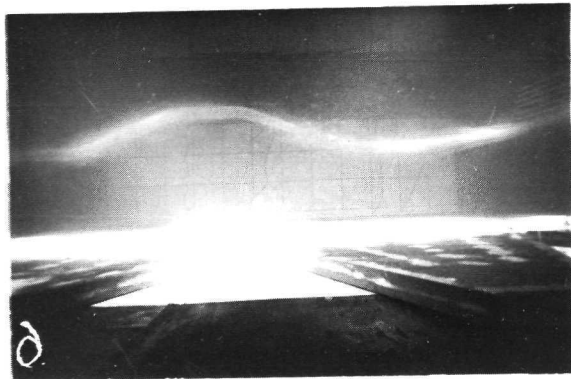
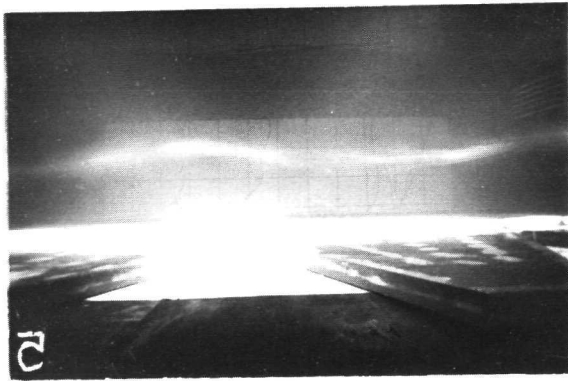
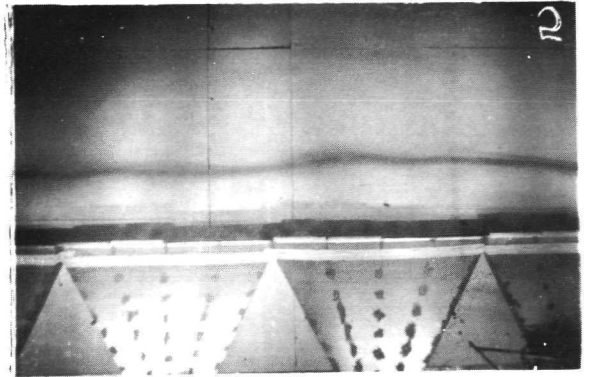


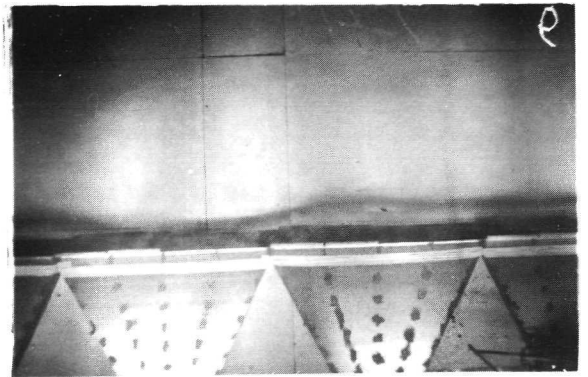
FIGURE 52 - DEVICE E3 WITH  $V_b/U = 0.270$  - EFFECT ON VORTEX WAKE FOR CRUISE CONDITION,  $C_L = 0.67$  AND ALTITUDE = 30.5 METERS



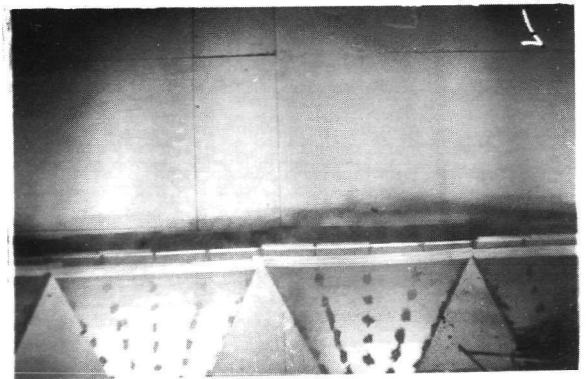
N  
39.3



51.6



63.8



76.0

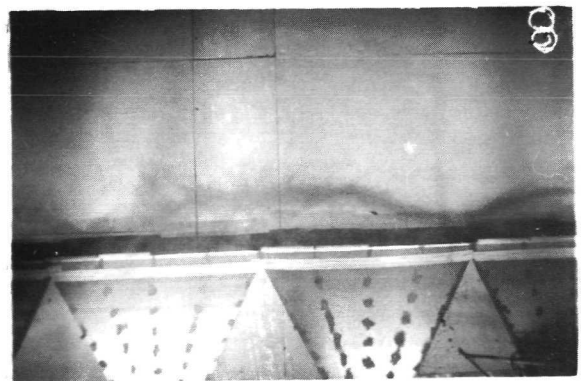
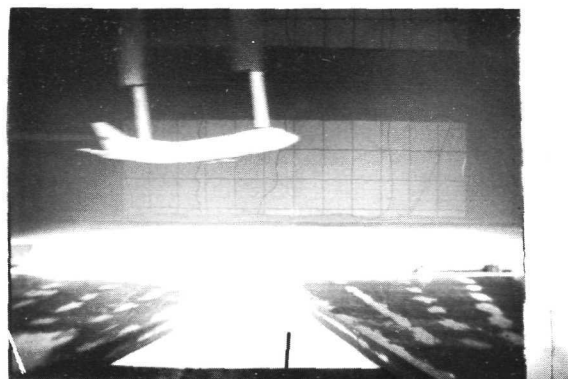
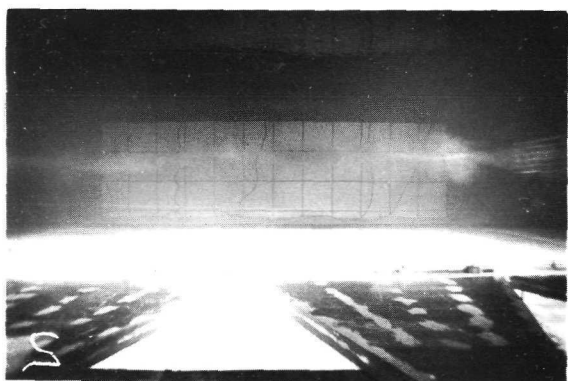
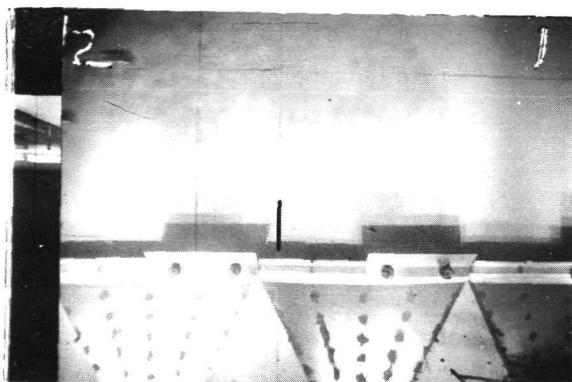


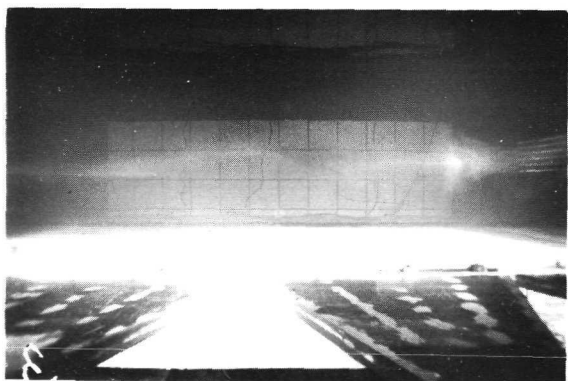
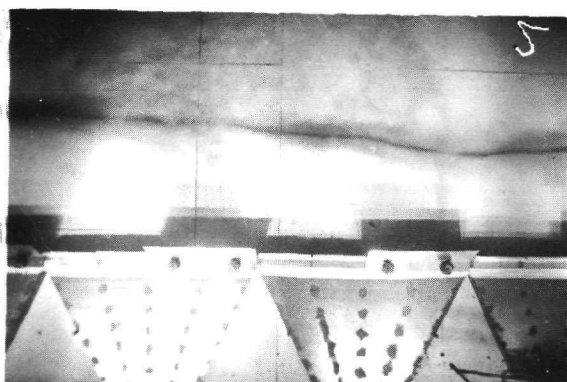
FIGURE 52 - CONCLUDED



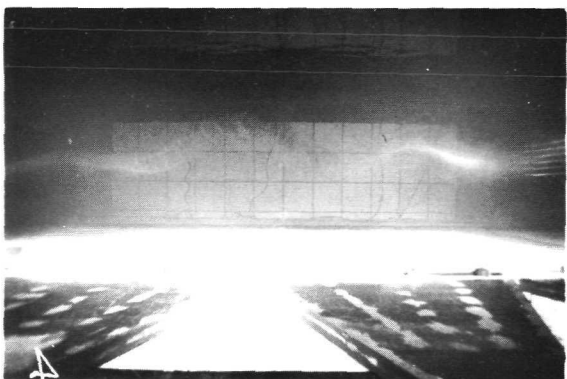
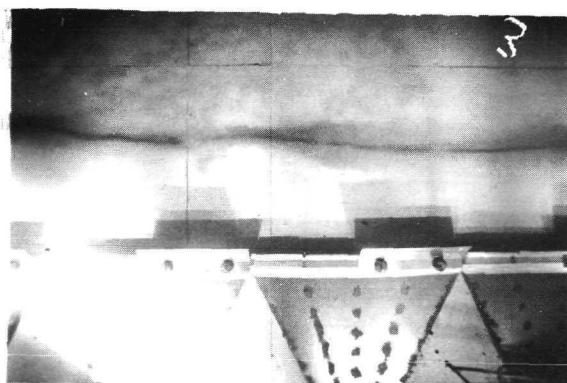
N  
-1.1



19.3



27.5



35.6

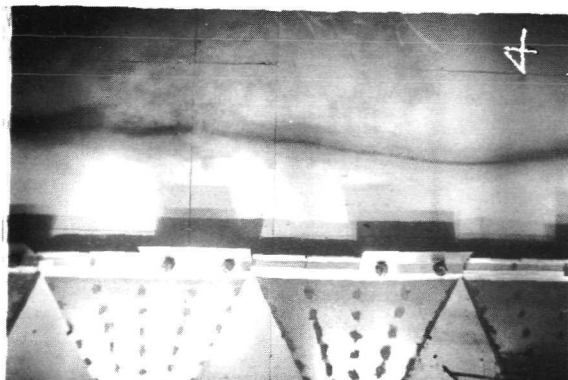
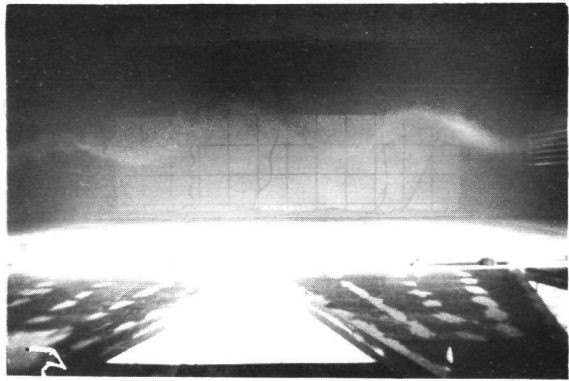
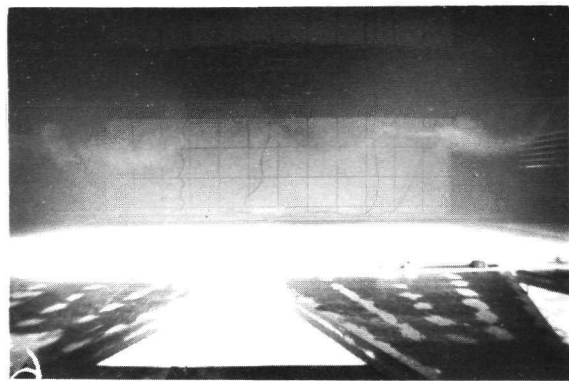
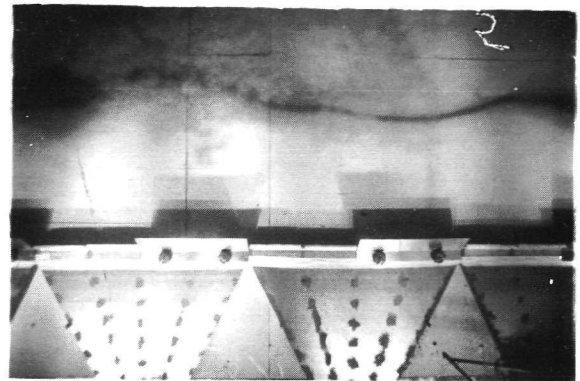


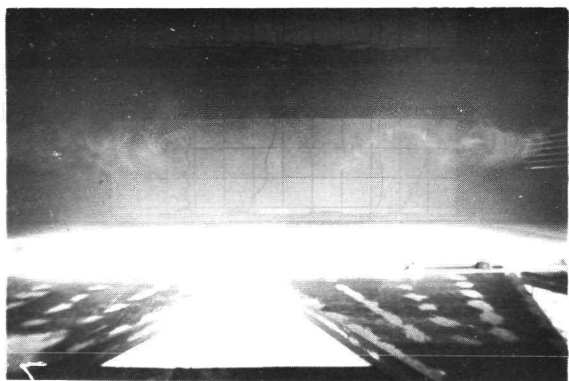
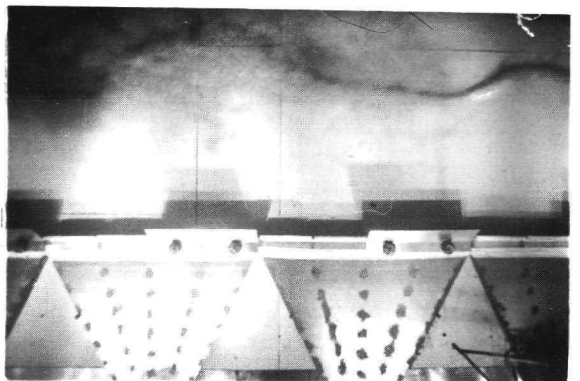
FIGURE 53 - DEVICE E4 WITH  $V_b/U = 0.270$  - EFFECT ON VORTEX WAKE FOR CRUISE CONDITION,  $C_L = 0.67$  AND ALTITUDE = 30.5 METERS



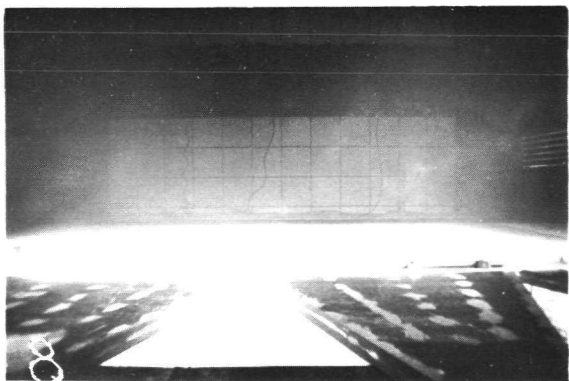
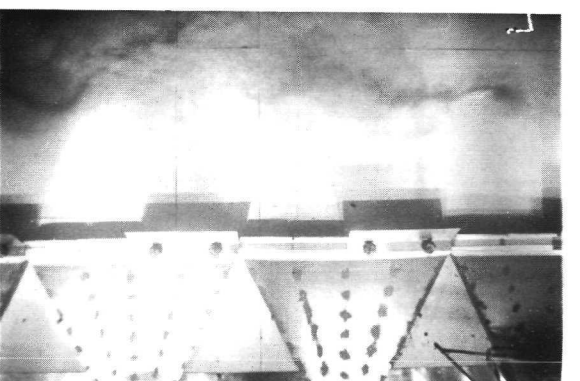
N  
43.8



47.9



52.0



56.0

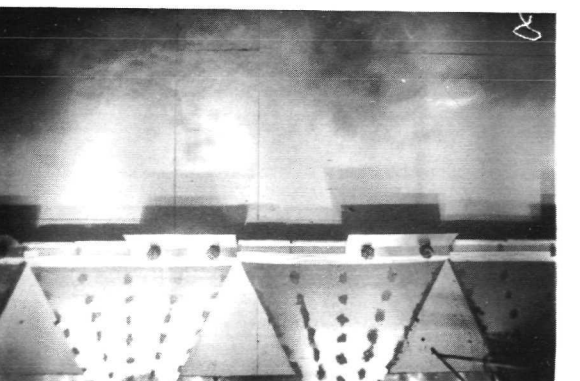
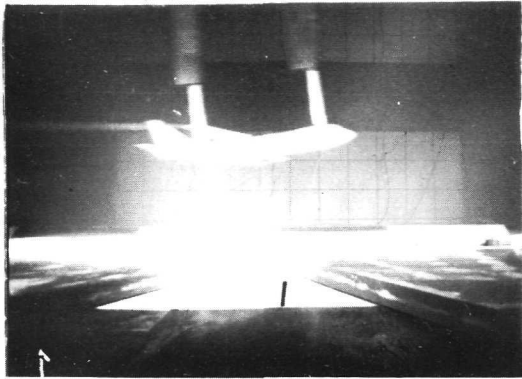
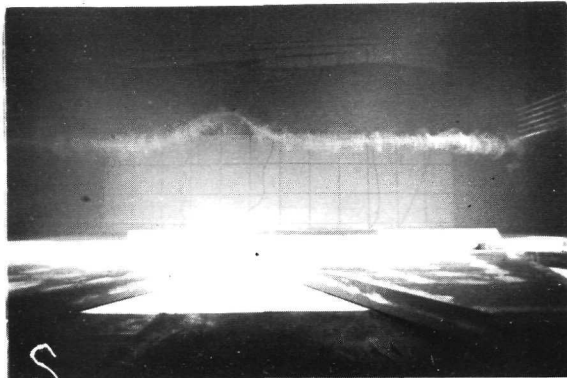
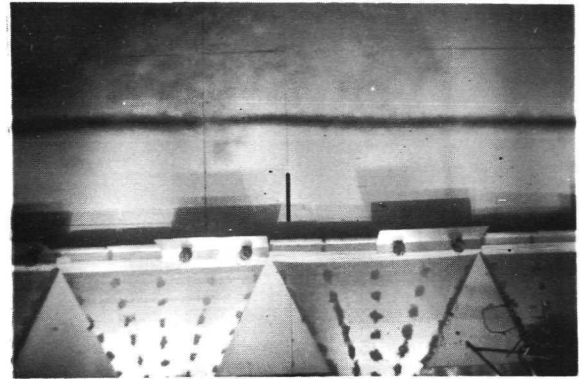


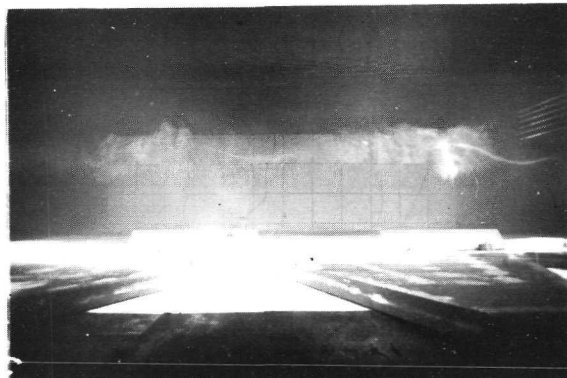
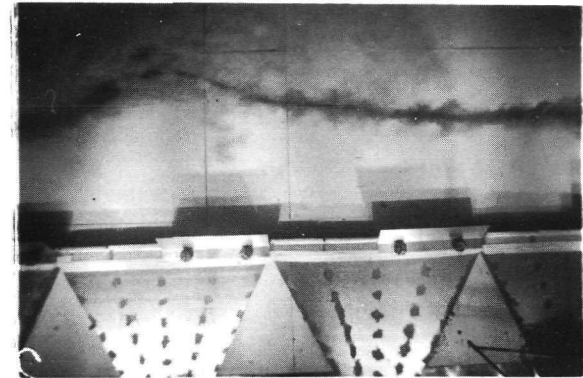
FIGURE 53 - CONCLUDED



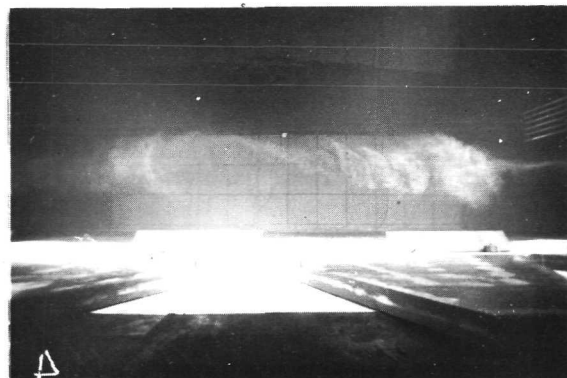
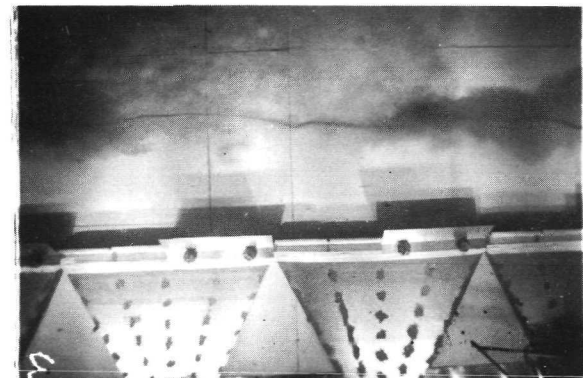
N  
-0.7



7.5



15.6



23.8

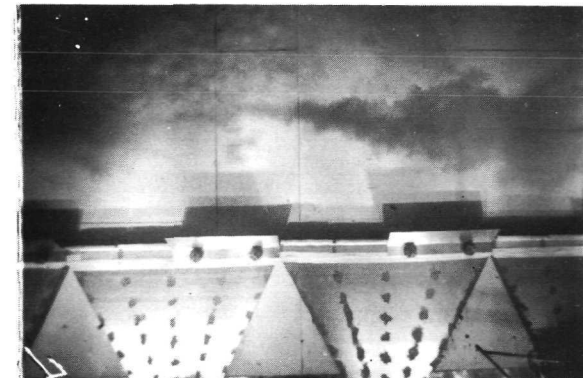
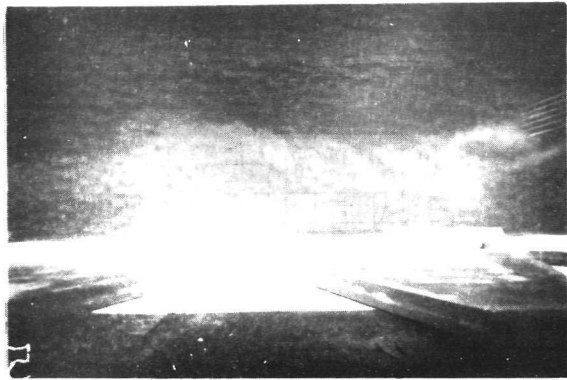
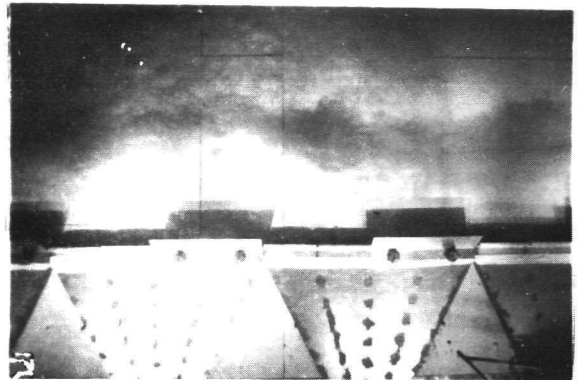


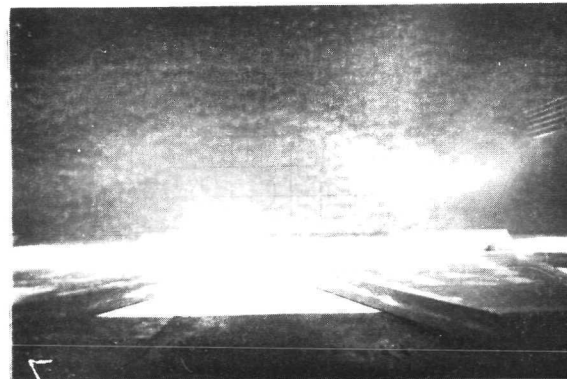
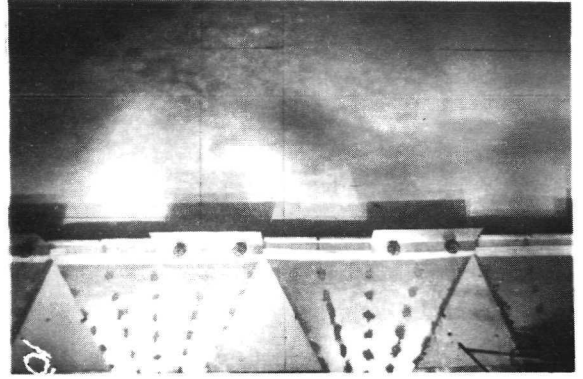
FIGURE 54 - DEVICE E5 WITH  $V_b/U = 0.270$  - EFFECT ON VORTEX WAKE FOR CRUISE CONDITION,  $C_L = 0.67$  AND ALTITUDE = 30.5 METERS



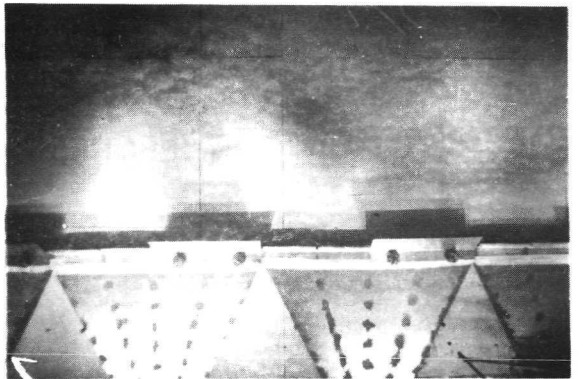
N  
32.0



40.1



48.3



56.5

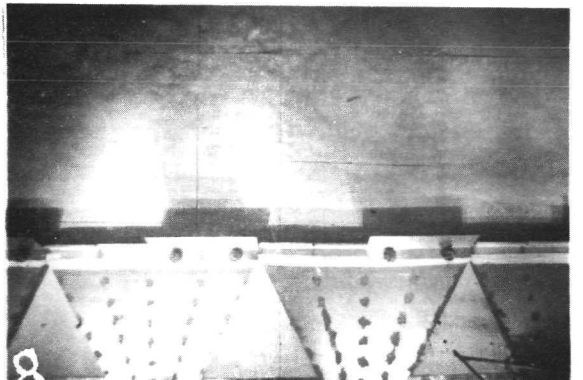
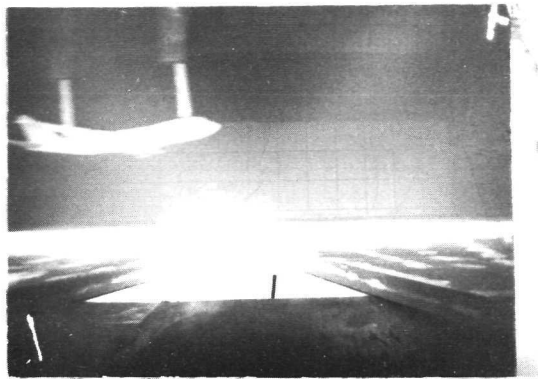
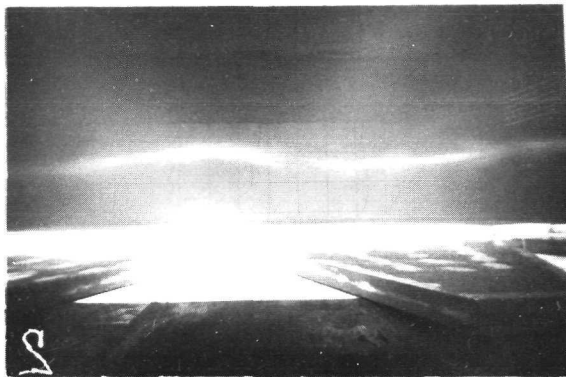
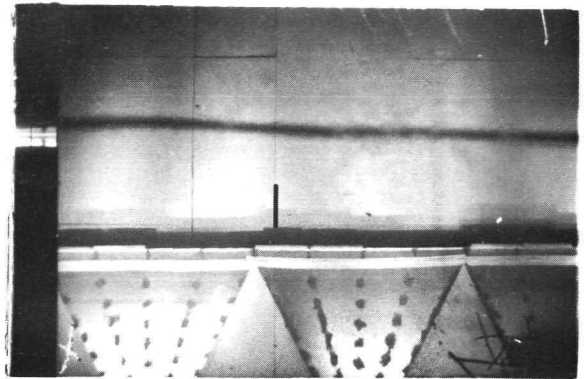


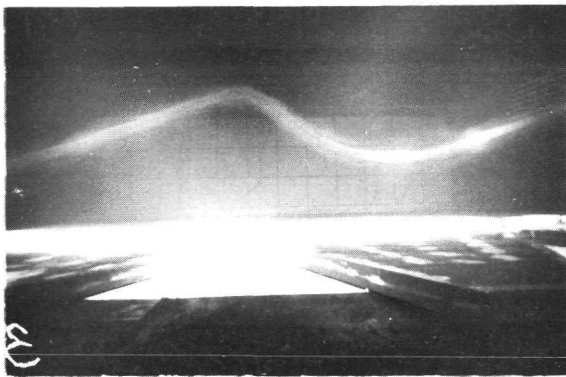
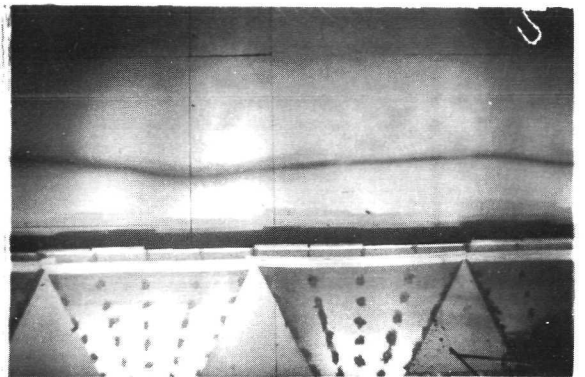
FIGURE 54 - CONCLUDED



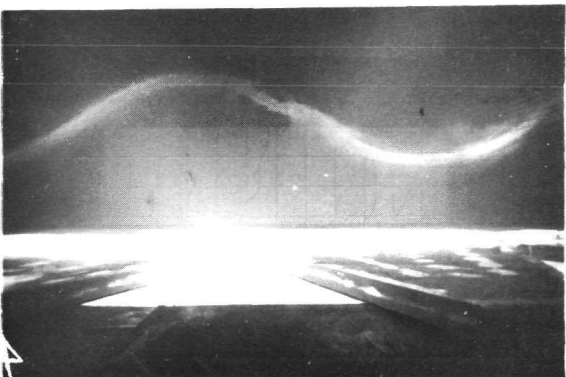
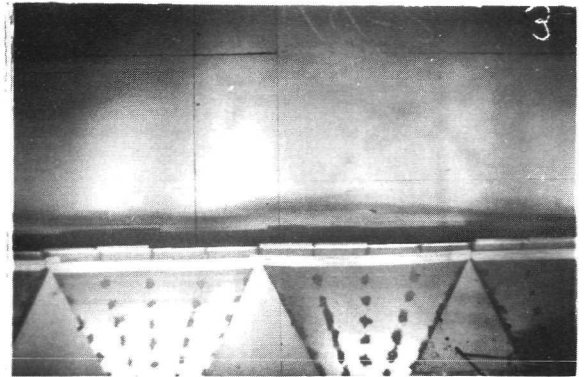
N  
-1.6



31.1



47.4



55.6

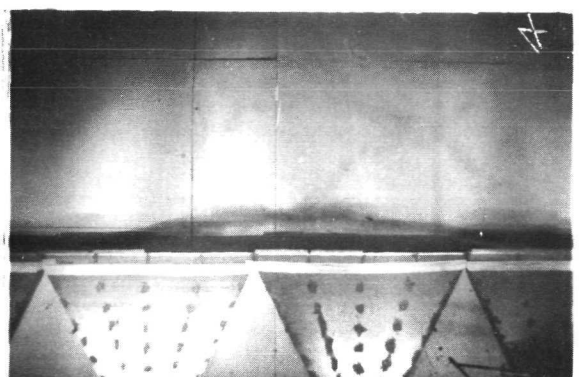
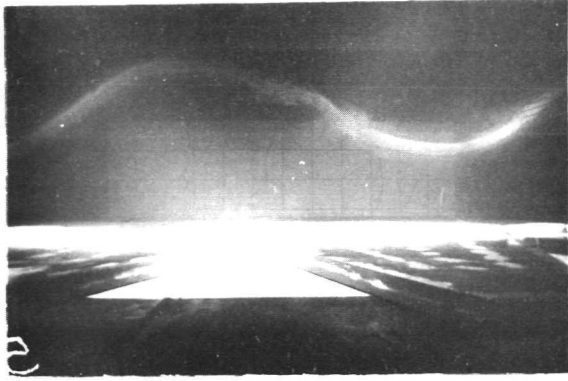
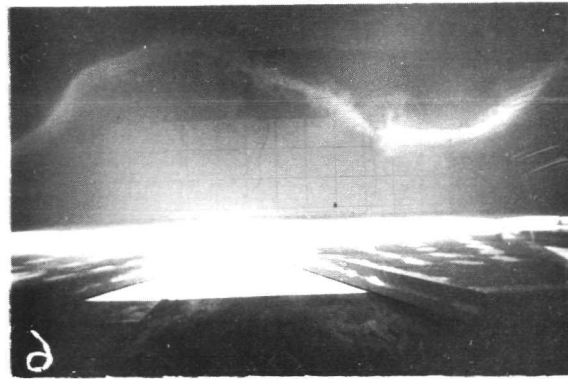
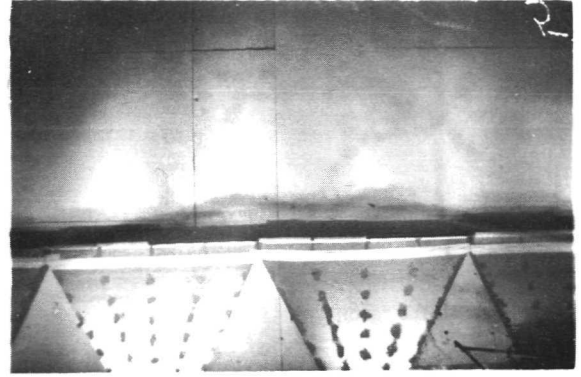


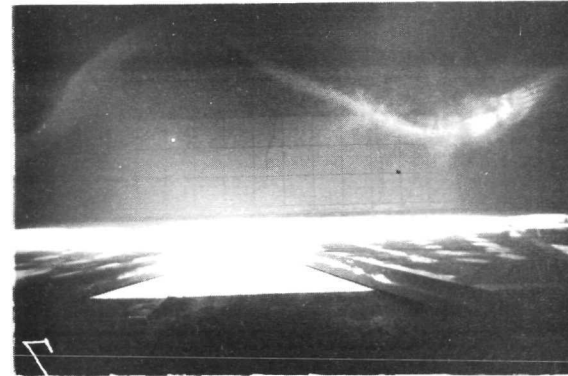
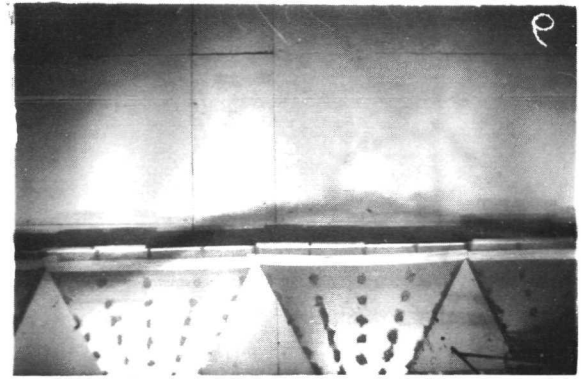
FIGURE 55 - DEVICE F WITH  $V_s/U = 0.408$ ,  $V_b/U = 0.270$  - EFFECT ON VORTEX WAKE FOR CRUISE CONDITION,  $C_L = 0.67$  AND ALTITUDE = 30.5 METERS



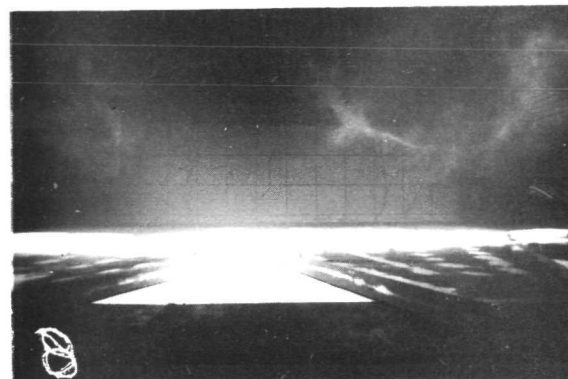
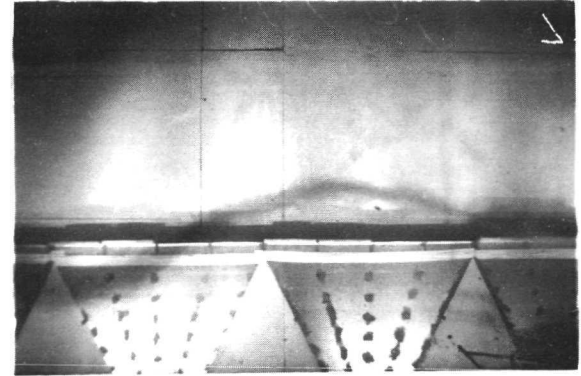
N  
59.7



63.8



67.9



80.1

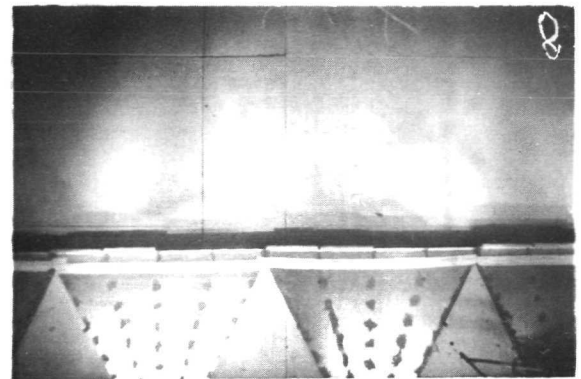
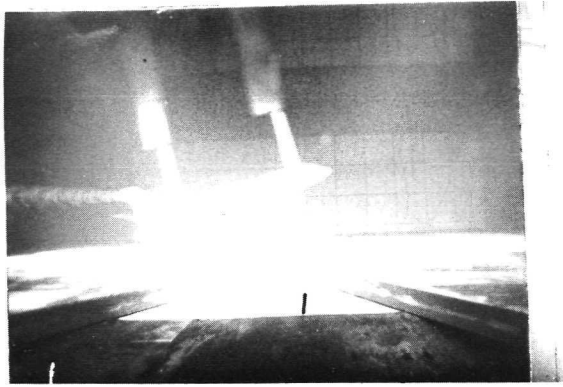
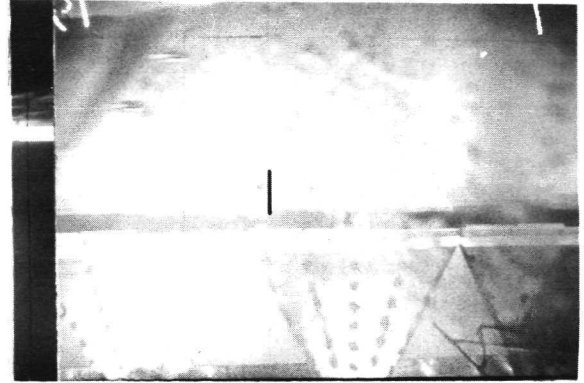


FIGURE 55 - CONCLUDED



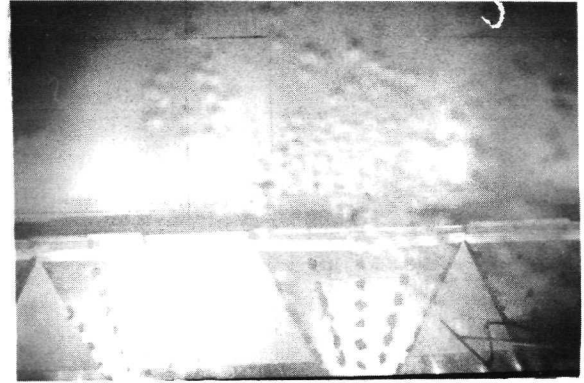
N  
-0.9



7.2



11.3



13.4

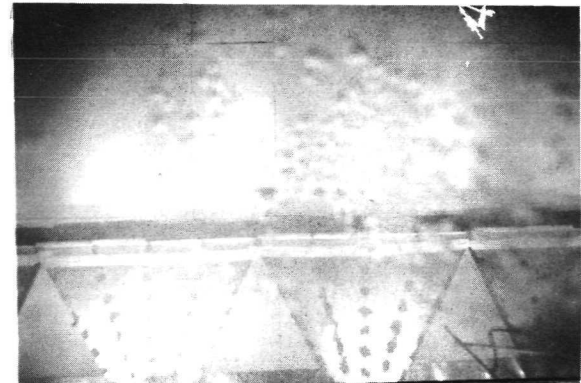
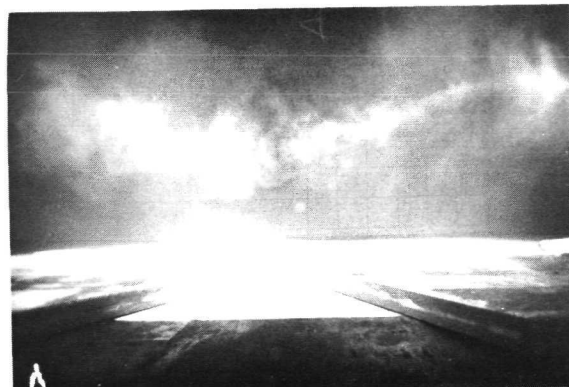
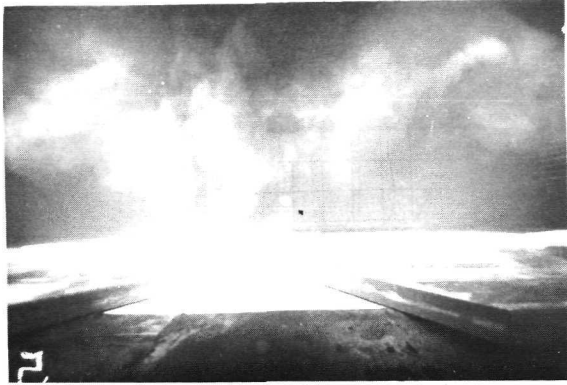
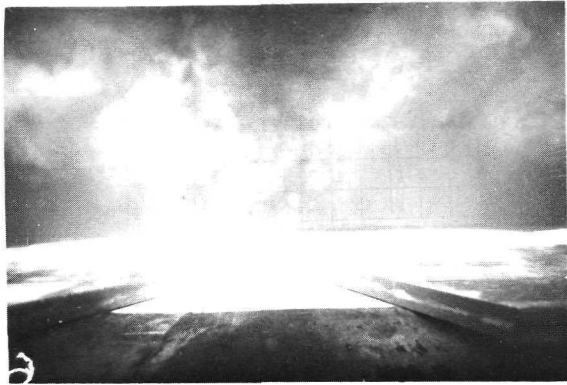
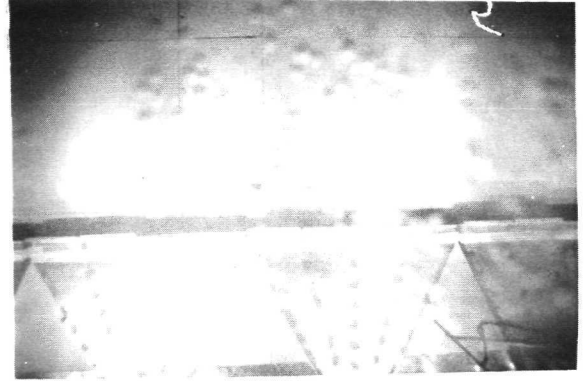


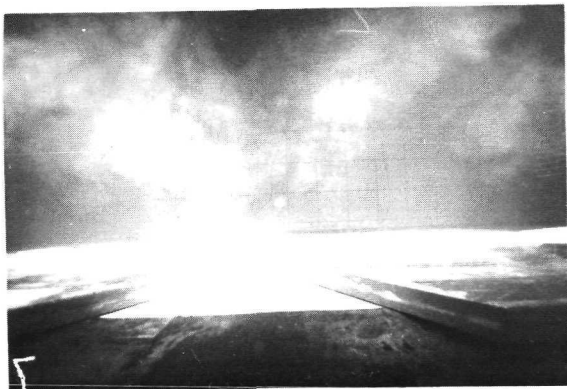
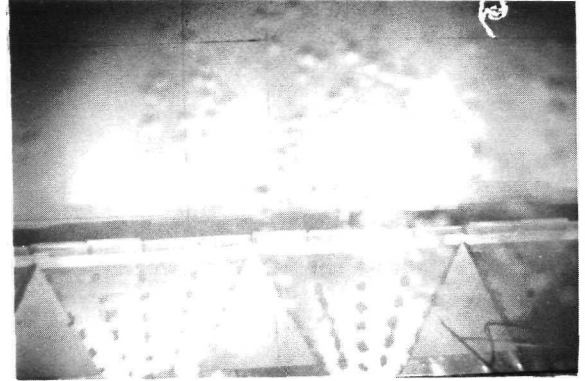
FIGURE 56 - DEVICE F WITH  $V_s/U = 0.408$ ,  $V_b/U = 0.270$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.80$  AND ALTITUDE = 13.4 METERS



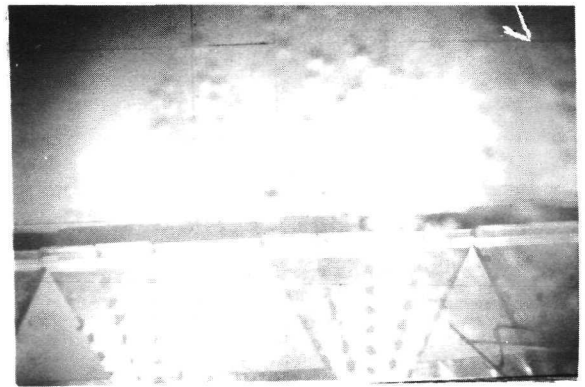
N  
17.4



19.5



21.5



25.6

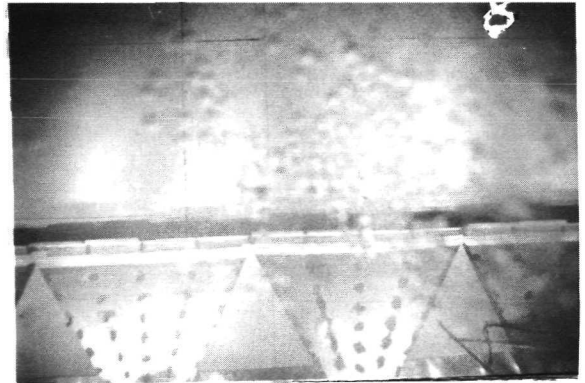
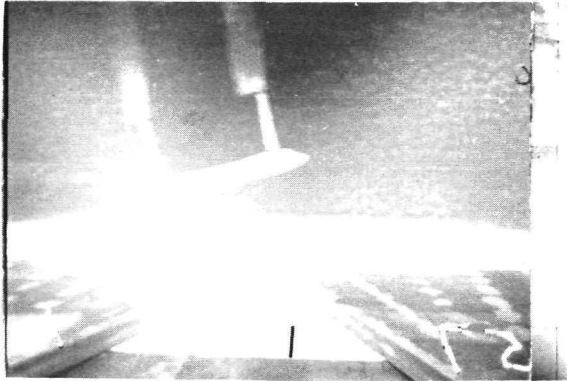
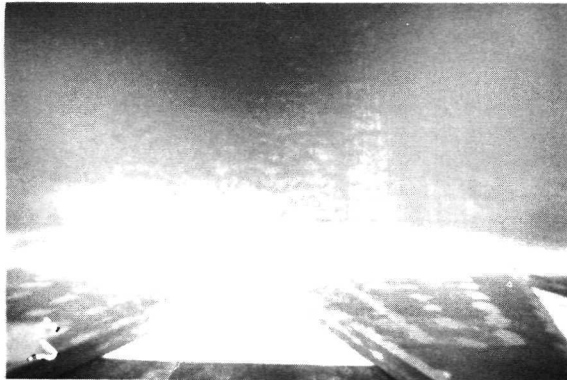
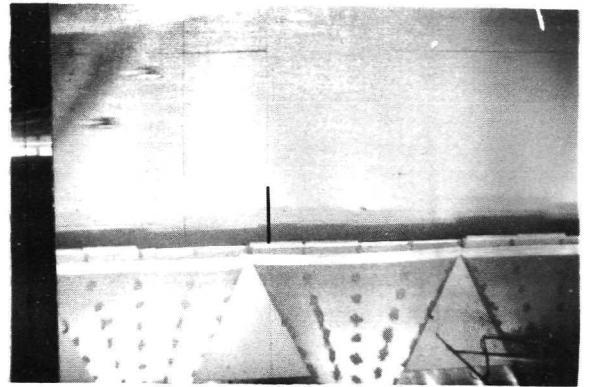


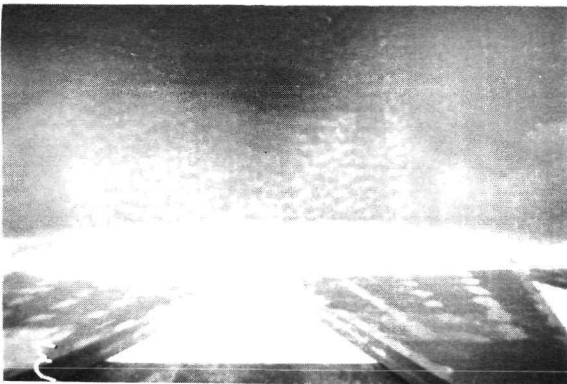
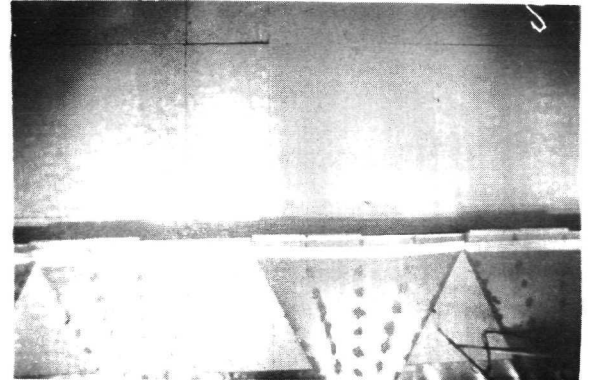
FIGURE 56 - CONCLUDED



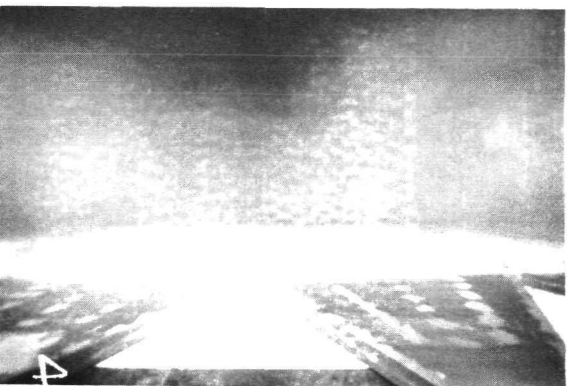
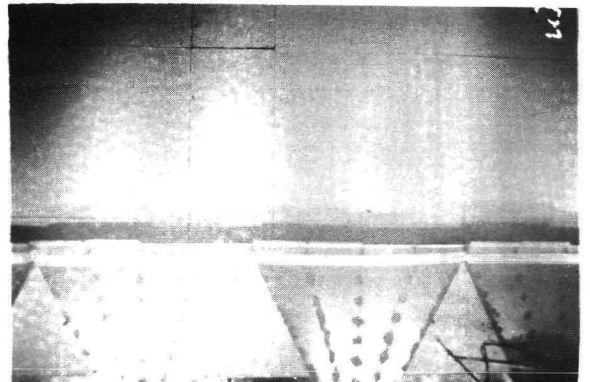
N  
-1.0



4.1



7.5



10.9

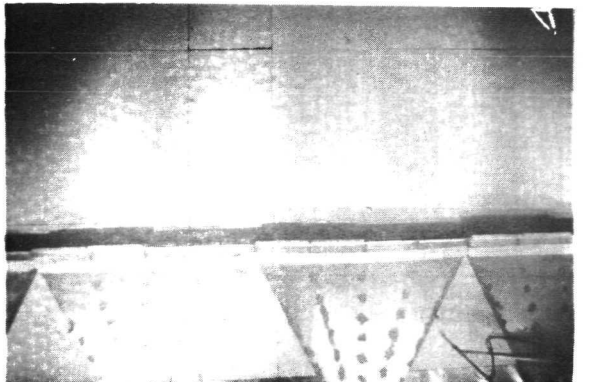
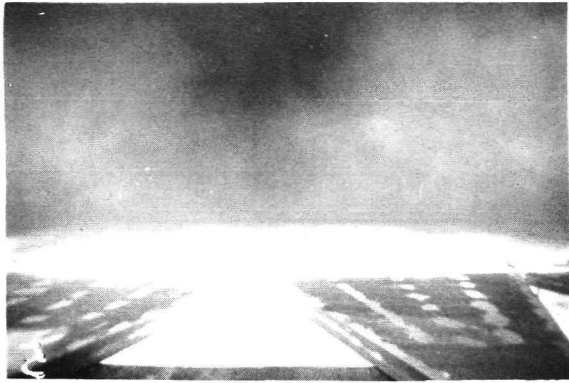
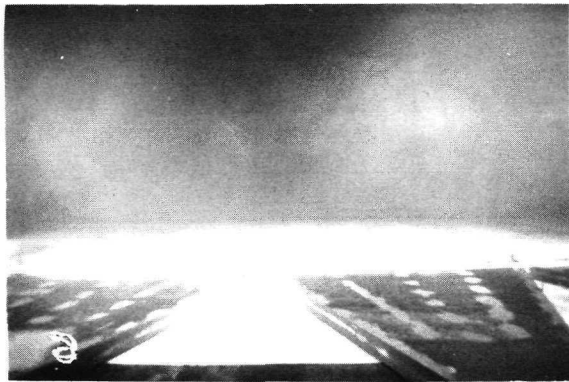
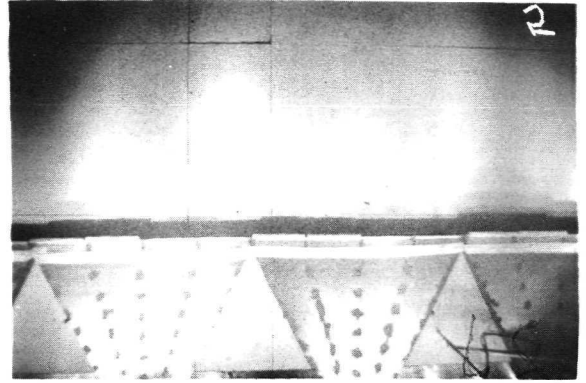


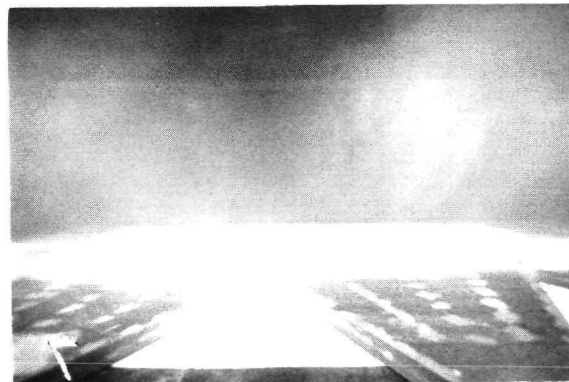
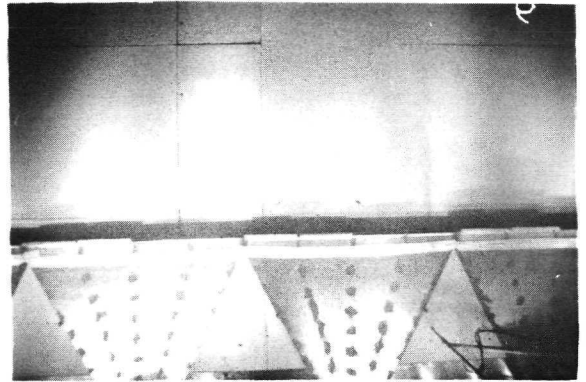
FIGURE 57 - DEVICE F WITH  $V_s/U = 0.490$ ,  $V_b/U = 0.324$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.81$  AND ALTITUDE = 13.4 METERS



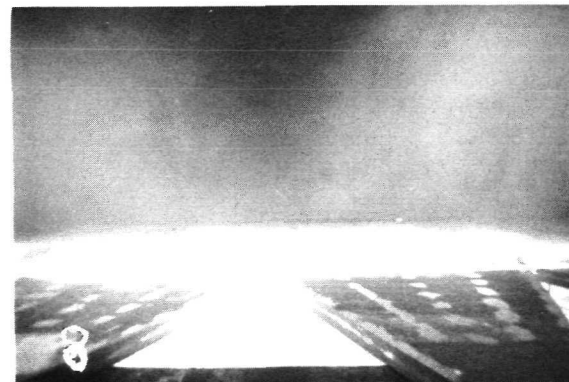
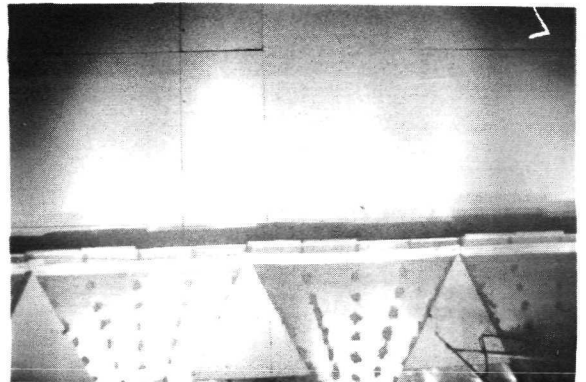
N  
14.3



17.7



22.8



27.9

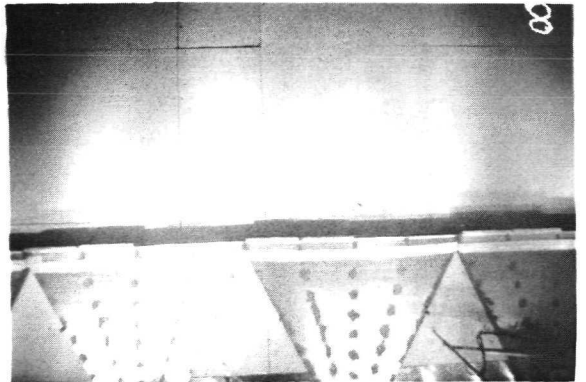
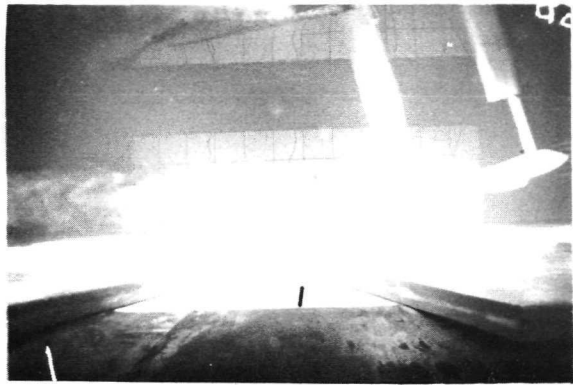
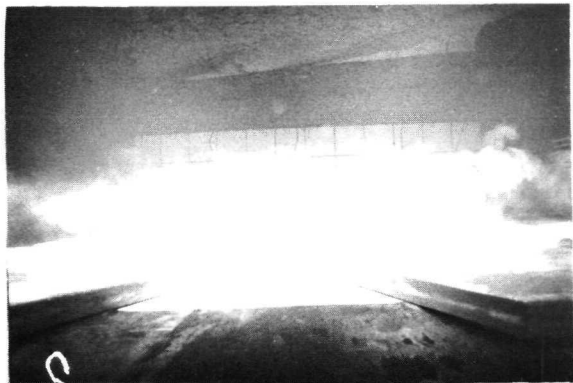
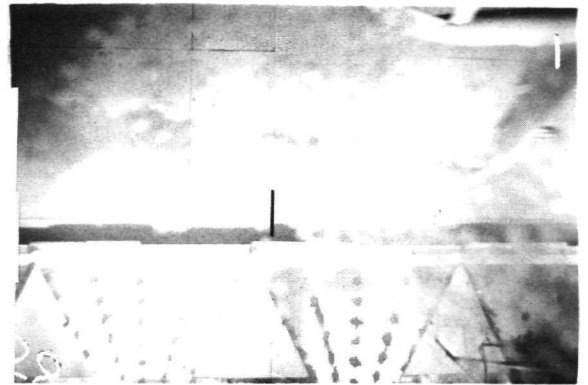


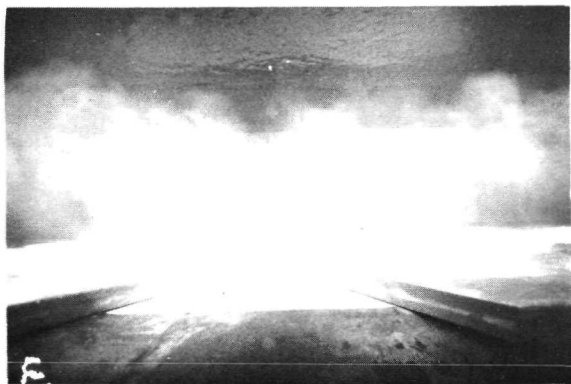
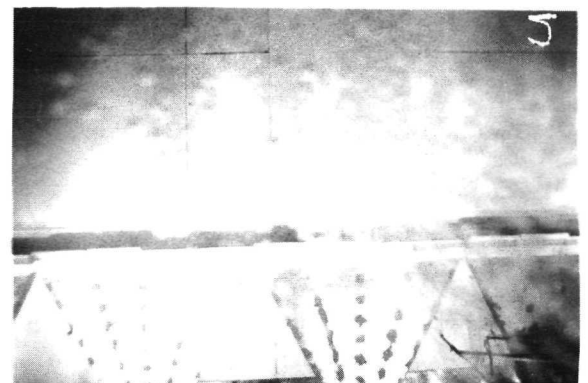
FIGURE 57 - CONCLUDED



N  
1.0



3.7



7.9



11.9

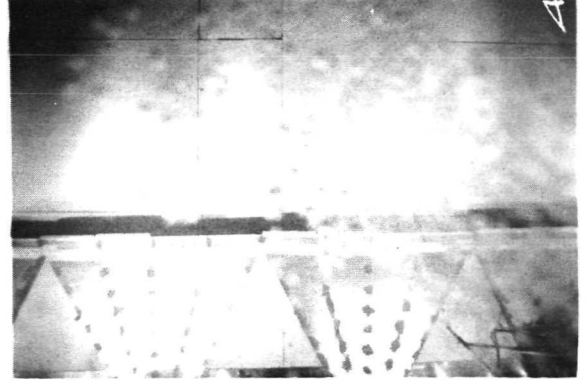
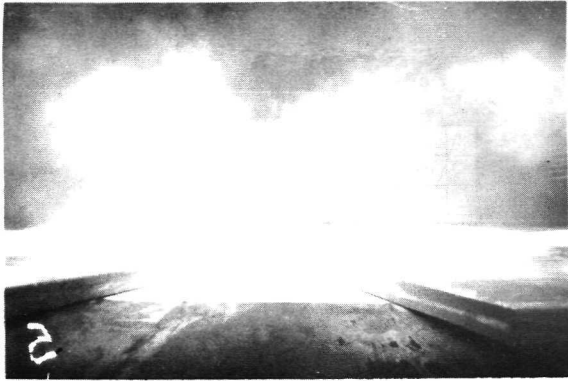
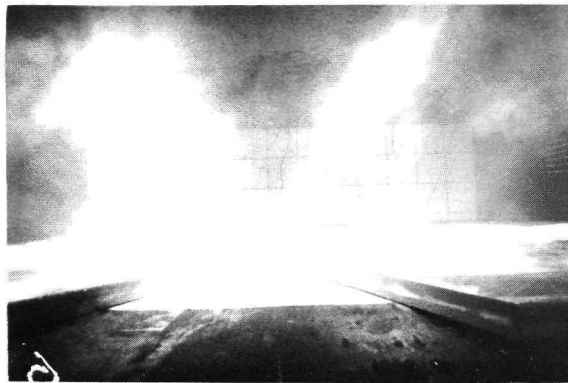
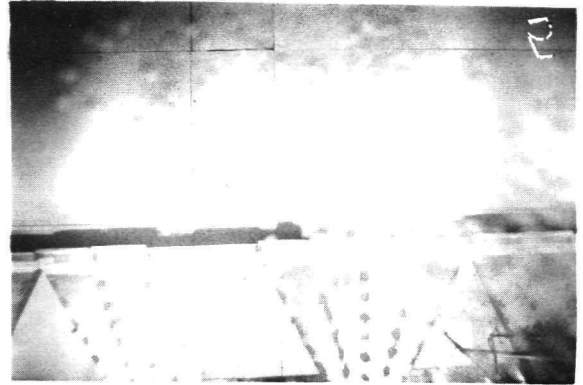


FIGURE 58 - DEVICE F WITH  $V_s/U = 0.613$ ,  $V_b/U = 0.405$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.77$  AND ALTITUDE = 13.4 METERS

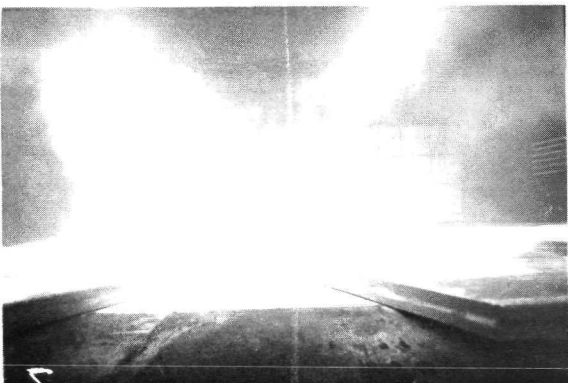


N

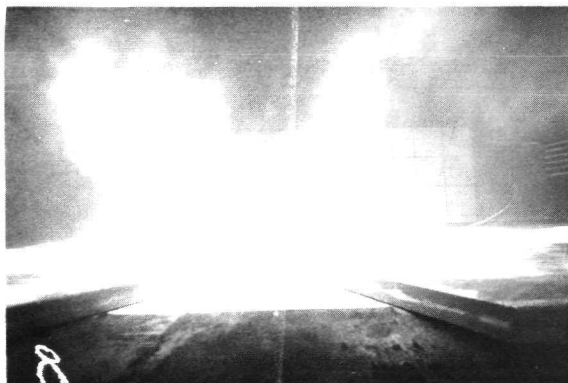
13.2



17.3



21.4



25.4

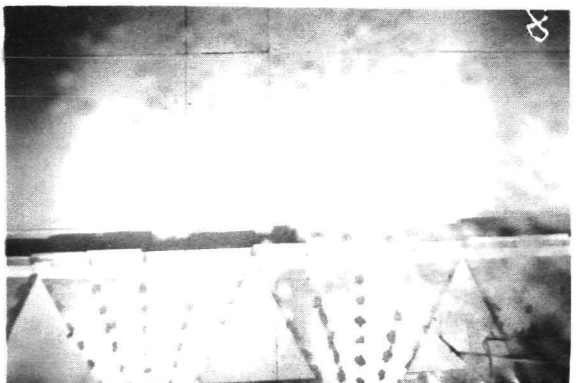
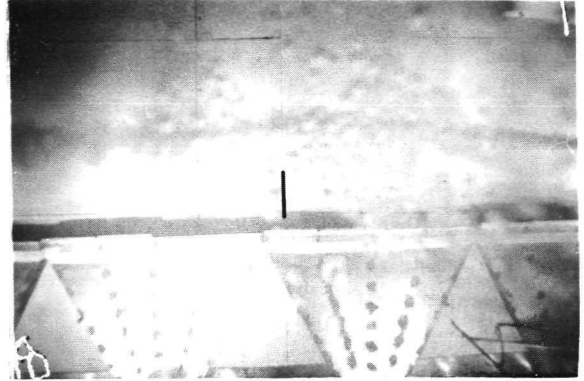


FIGURE 58 - CONCLUDED

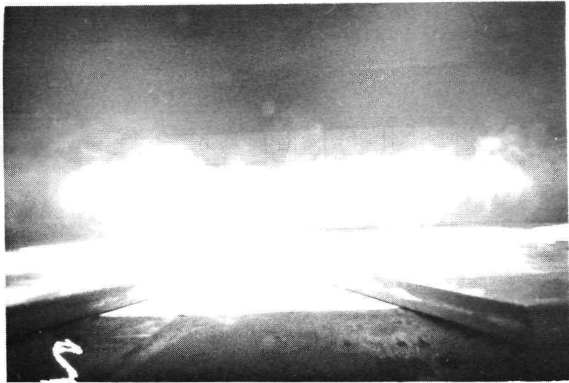


N

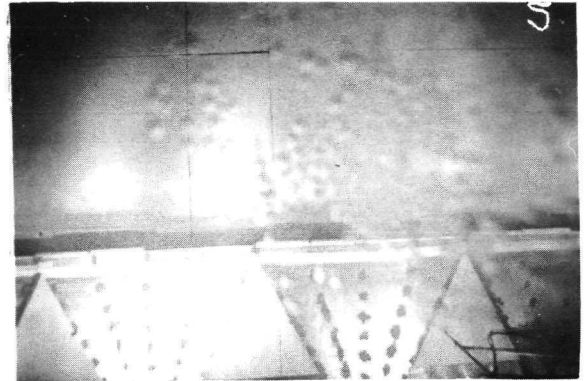
1.6



6.7

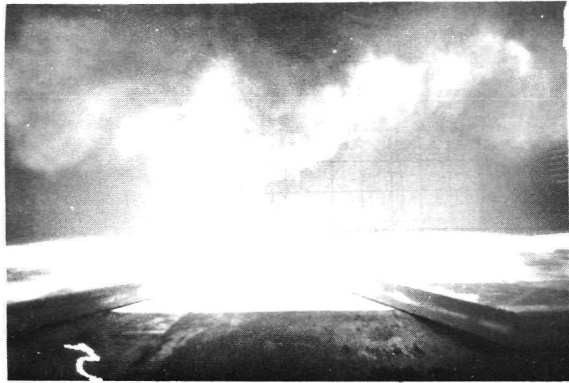


11.8

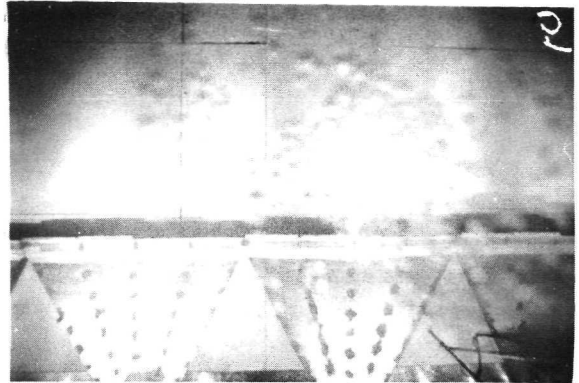


16.9

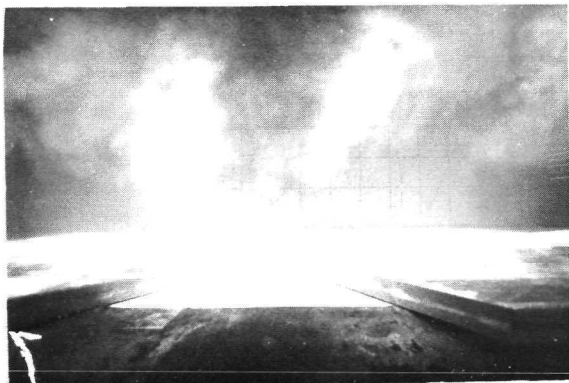
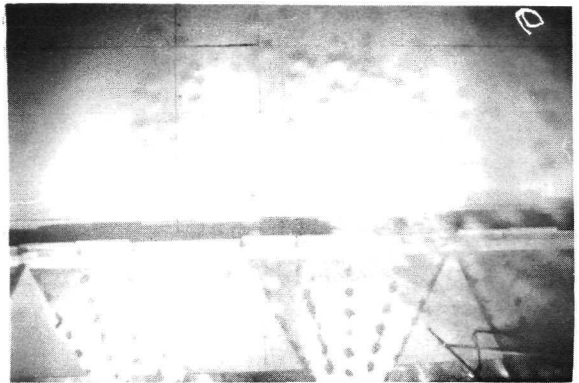
FIGURE 59 - DEVICE F WITH  $V_s/U = 0.327$ ,  $V_b/U = 0.216$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.68$  AND ALTITUDE = 13.4 METERS



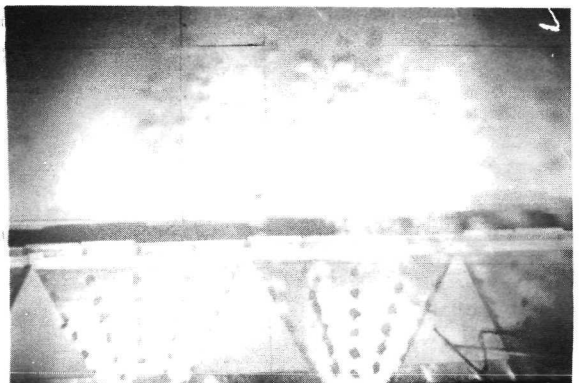
N  
19.4



22.0



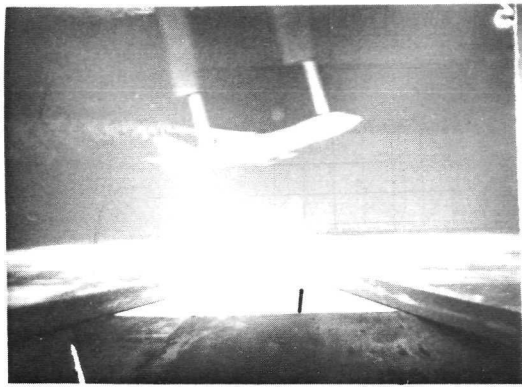
24.5



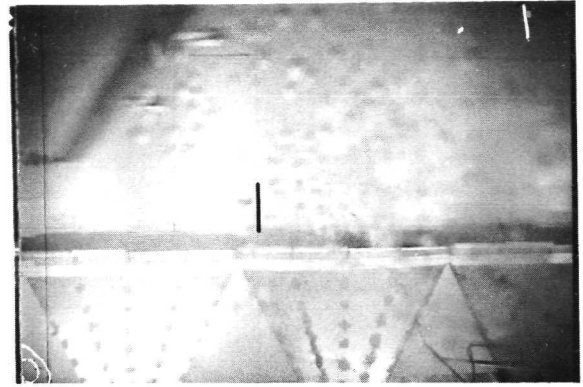
27.1



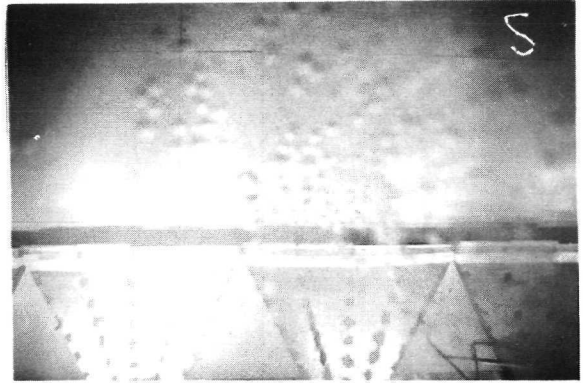
FIGURE 59 - CONCLUDED



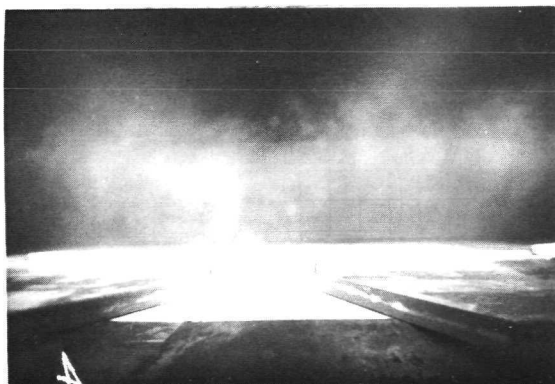
N  
-0.7



4.4



7.8



12.9

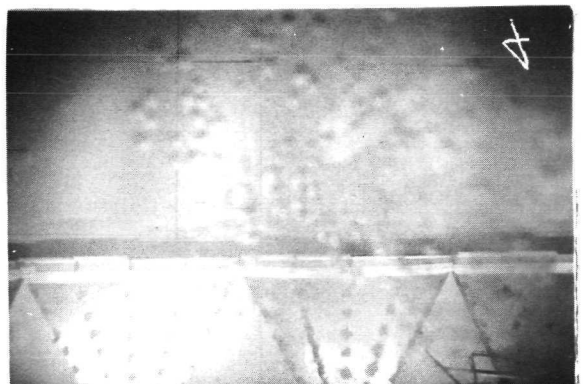
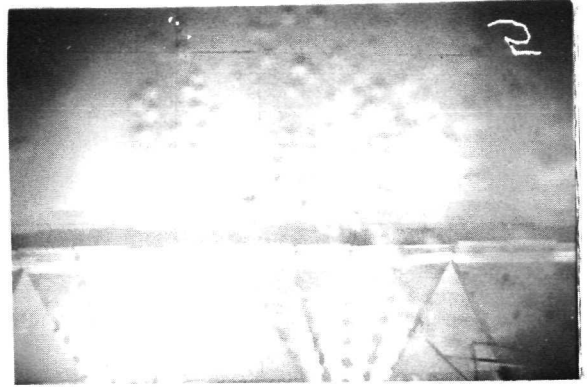


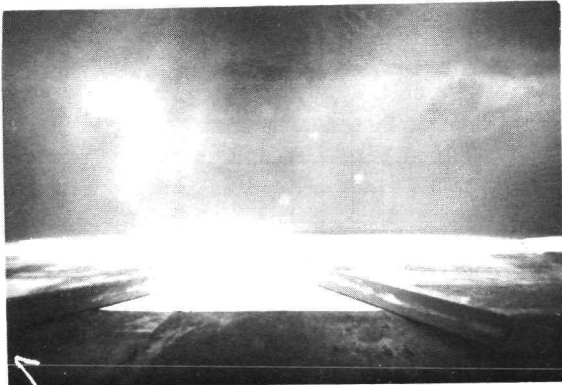
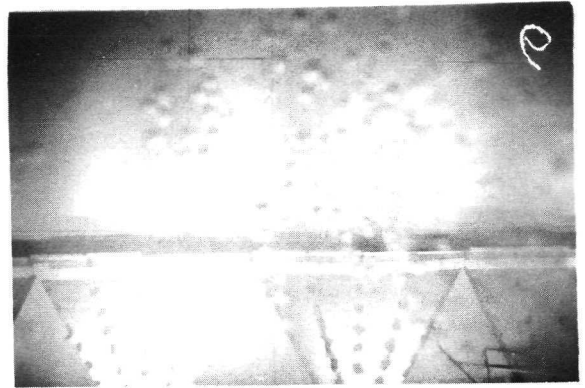
FIGURE 60 - DEVICE F WITH  $V_s/U = 0.490$ ,  $V_b/U = 0.324$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.75$  AND ALTITUDE = 30.5 METERS



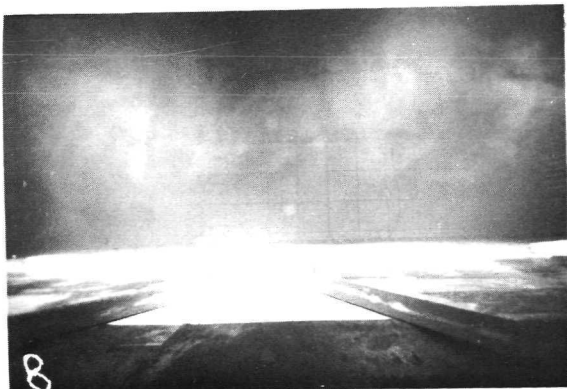
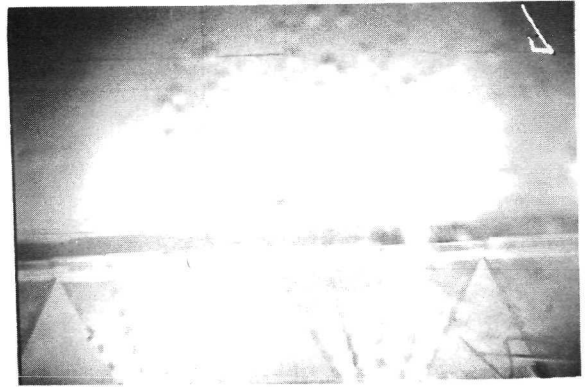
N  
16.3



19.7



23.2



26.6

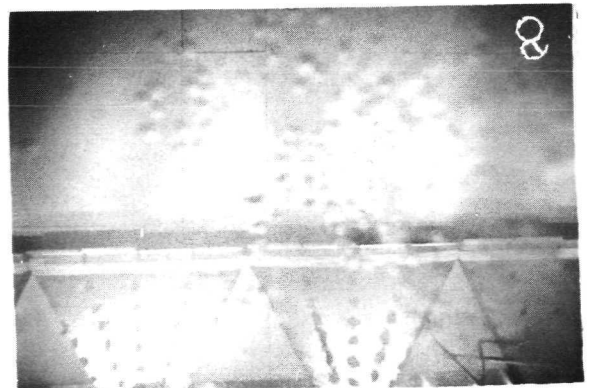
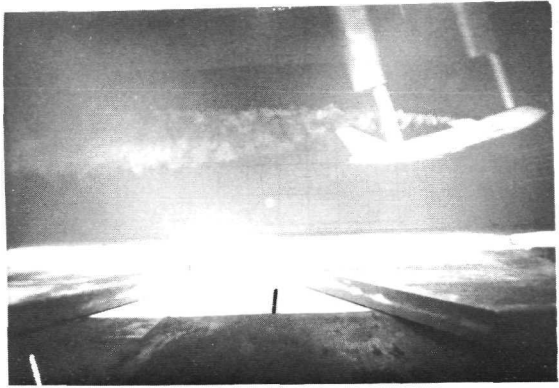
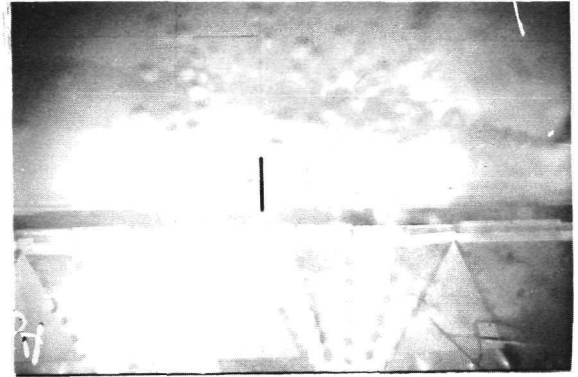


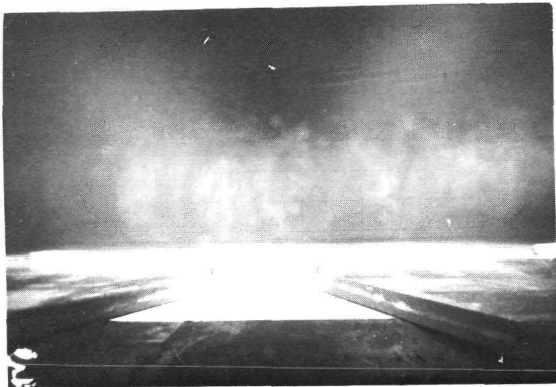
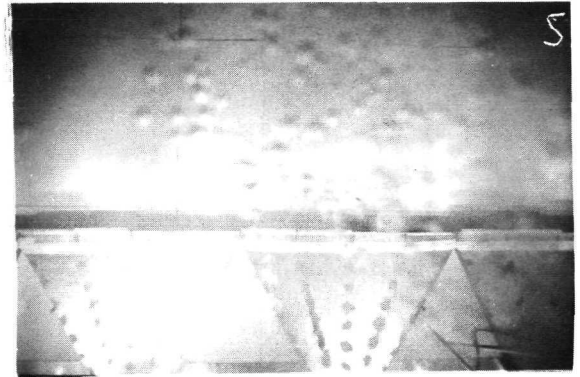
FIGURE 60 - CONCLUDED



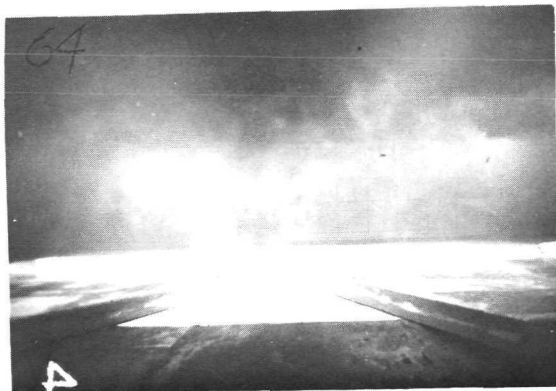
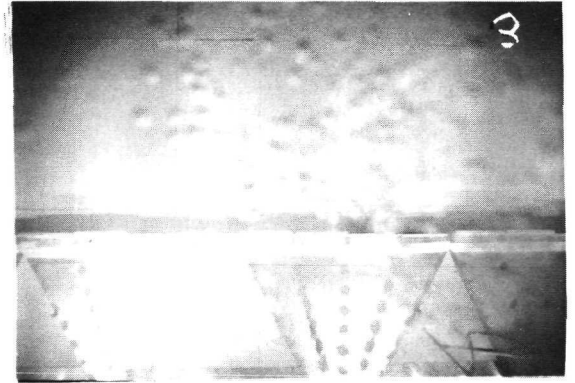
Z  
1.0



5.1



9.2



13.3

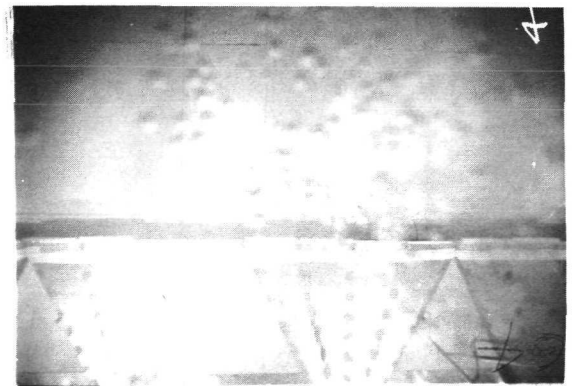
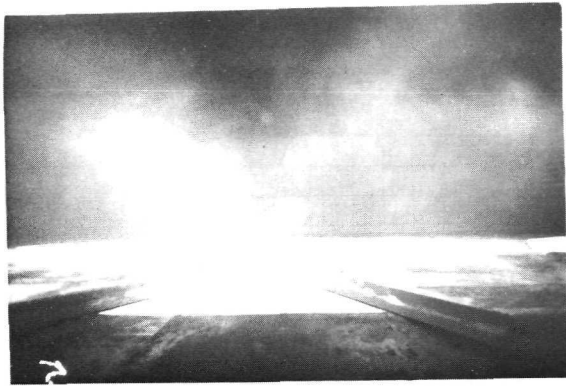
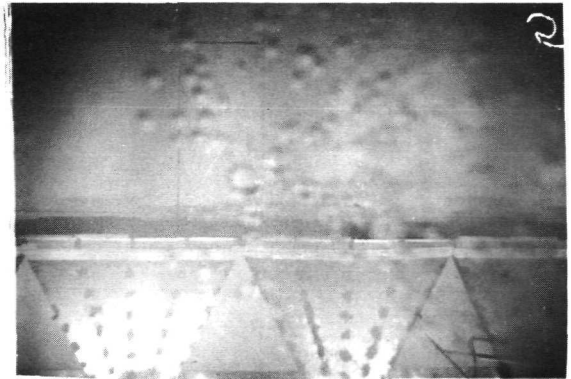


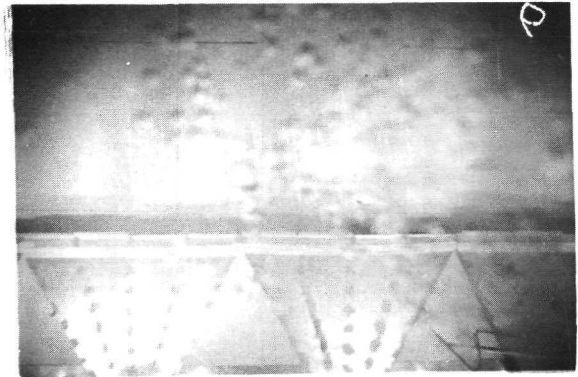
FIGURE 61 - DEVICE F WITH  $V_s/U = 0.613$ ,  $V_b/U = 0.405$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.79$  AND ALTITUDE = 30.5 METERS



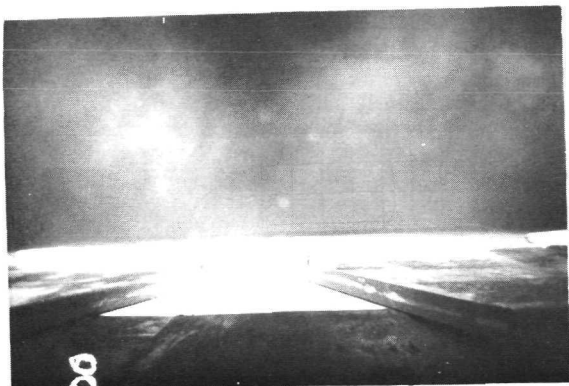
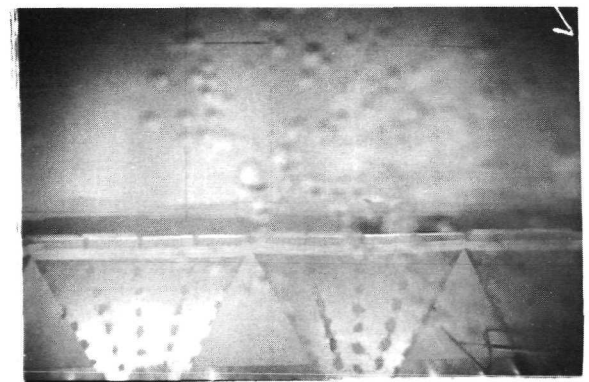
N  
17.3



20.1



22.8



25.5

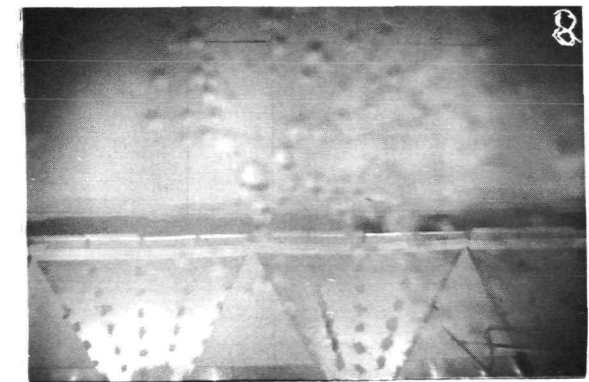
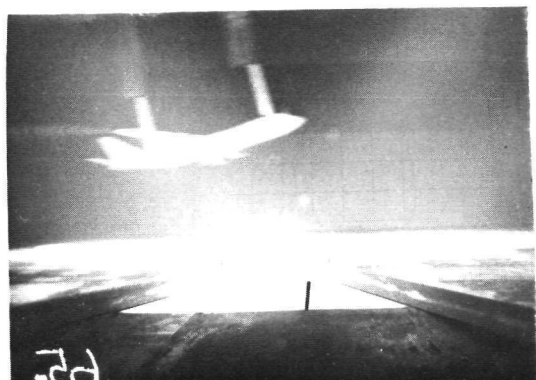
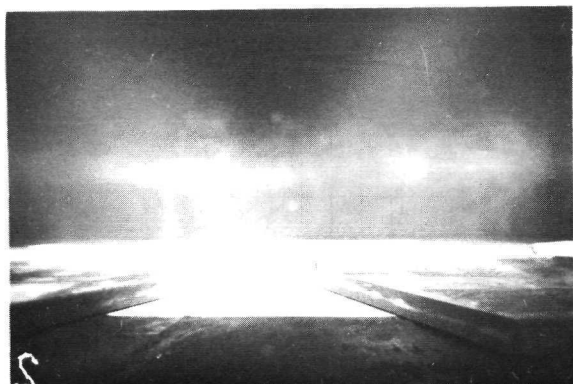
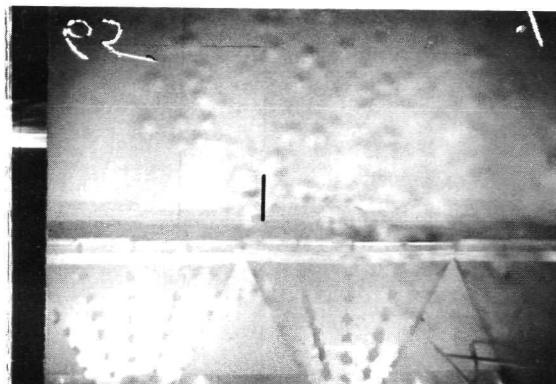


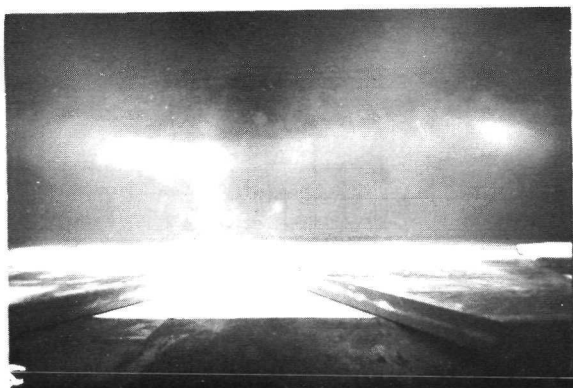
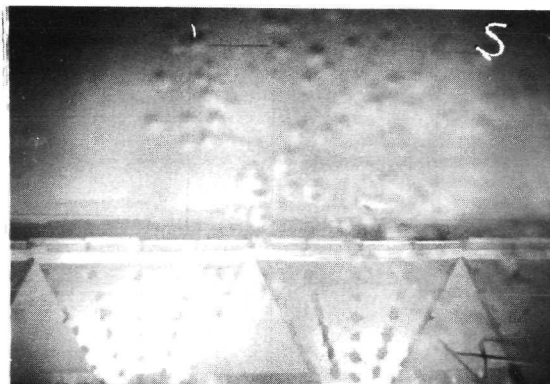
FIGURE 61 - CONCLUDED



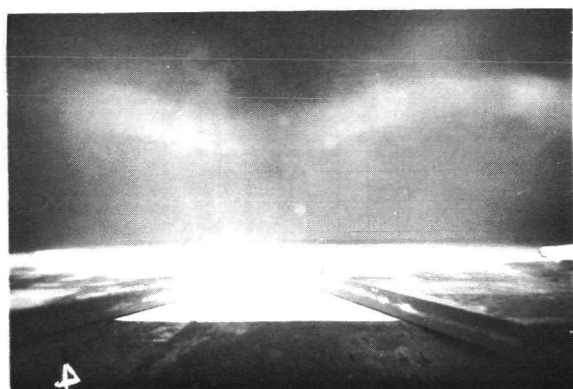
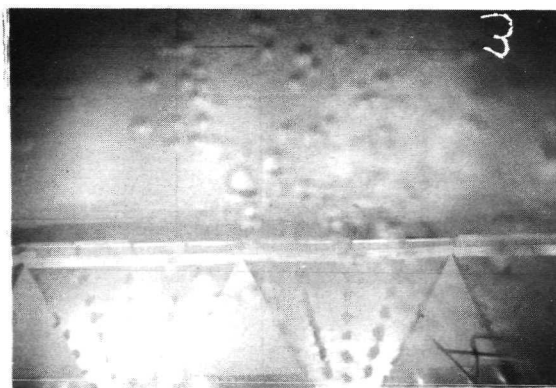
N  
-1.1



9.1



16.7



21.8

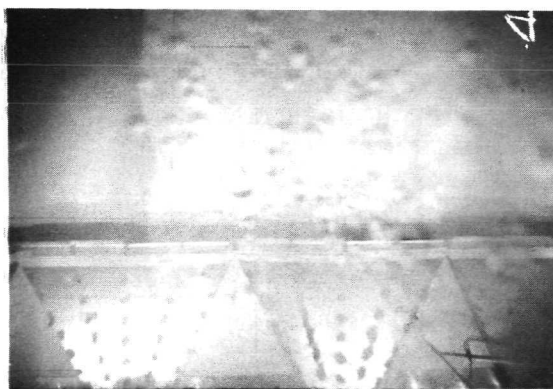
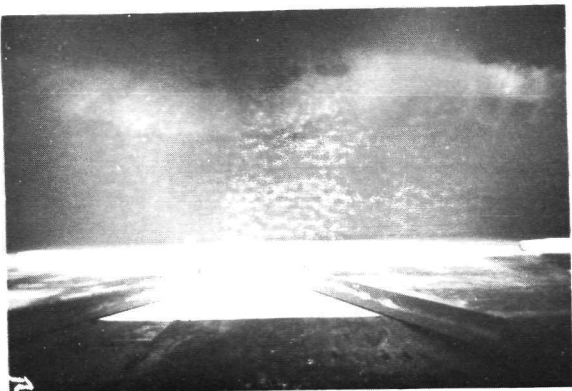
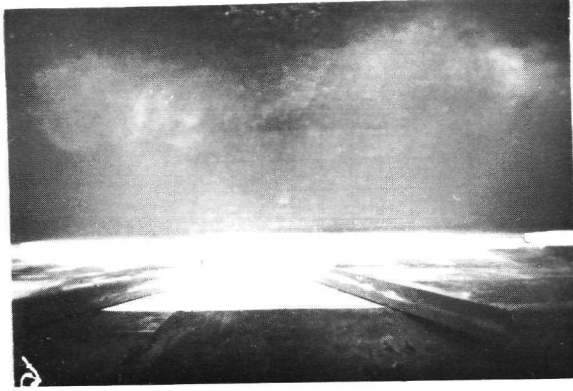
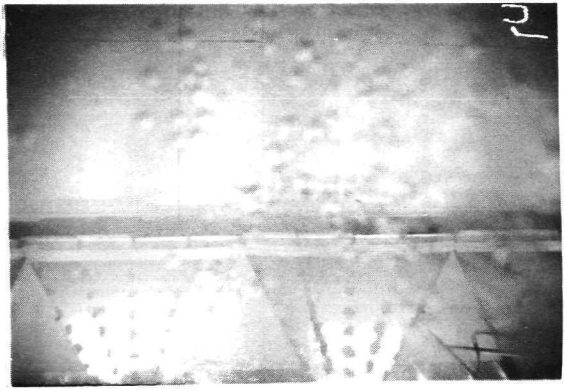


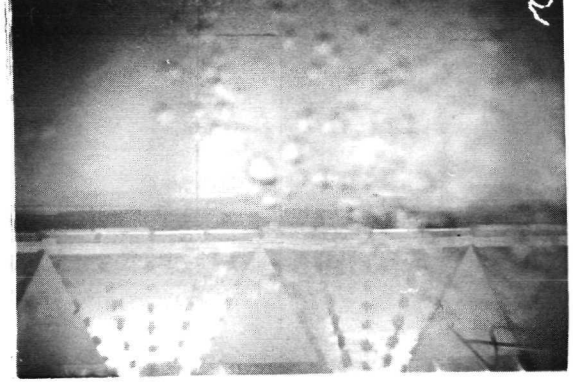
FIGURE 62 - DEVICE F WITH  $V_s/U = 0.327$ ,  $V_b/U = 0.216$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.65$  AND ALTITUDE = 30.5 METERS



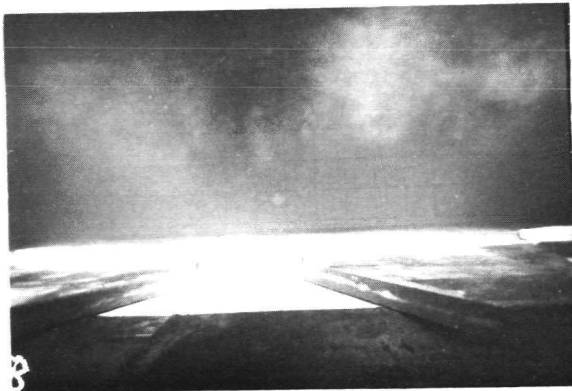
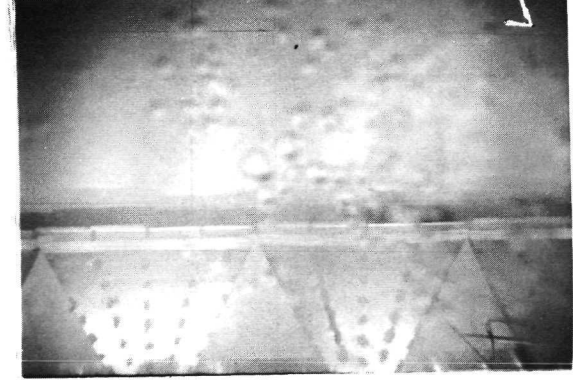
N  
24.4



26.9



29.5



32.0

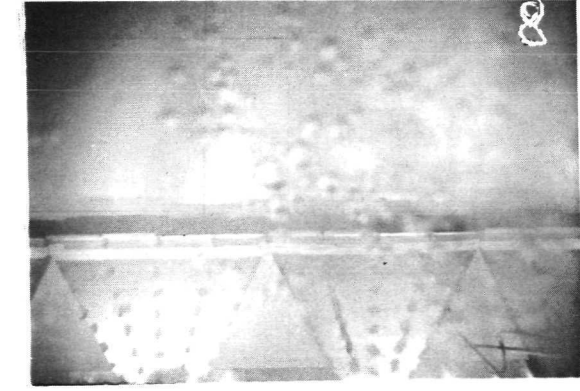
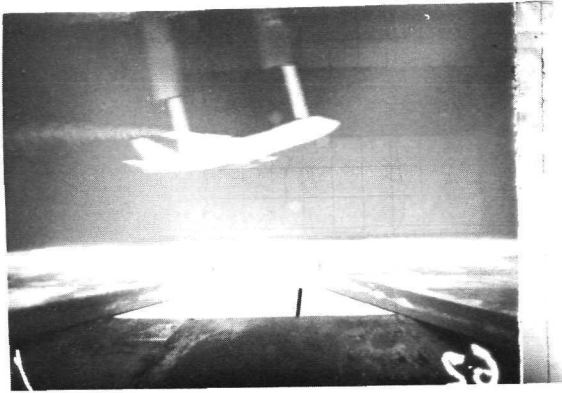


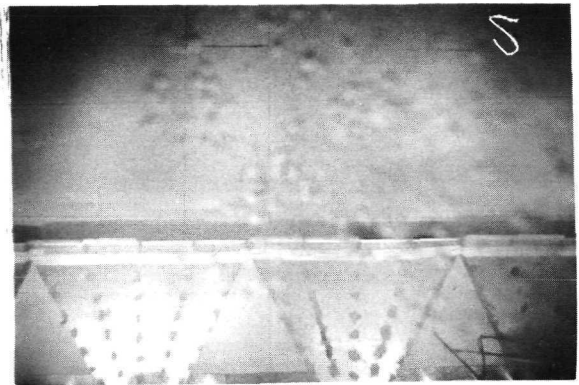
FIGURE 62 - CONCLUDED



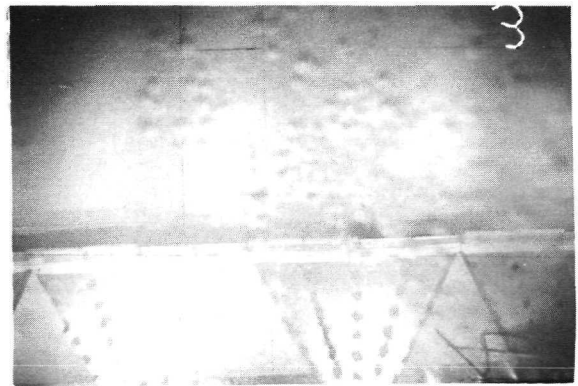
N  
-0.8



9.4



13.5



17.6

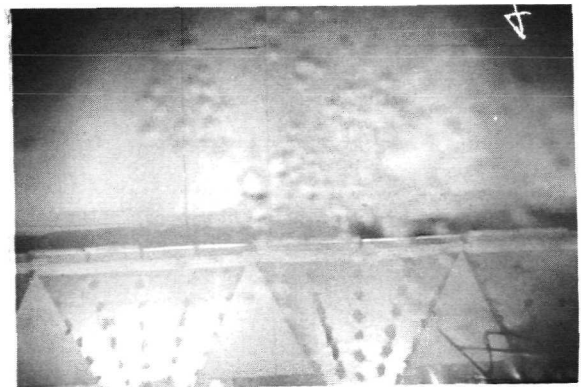
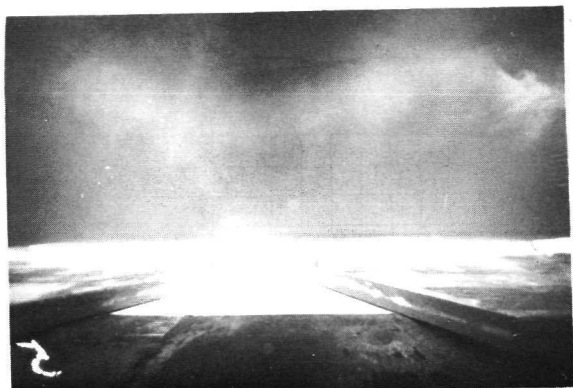
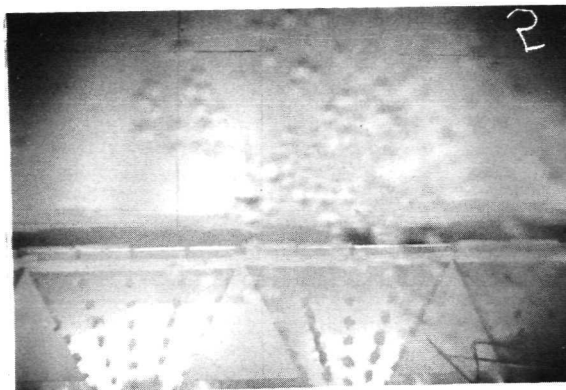


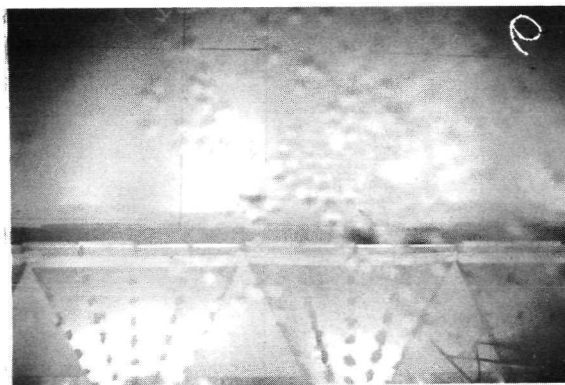
FIGURE 63 - DEVICE F WITH  $V_s/U = 0.408$ ,  $V_b/U = 0.270$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.80$  AND ALTITUDE = 30.5 METERS



N  
21.6



25.7



29.8



33.9

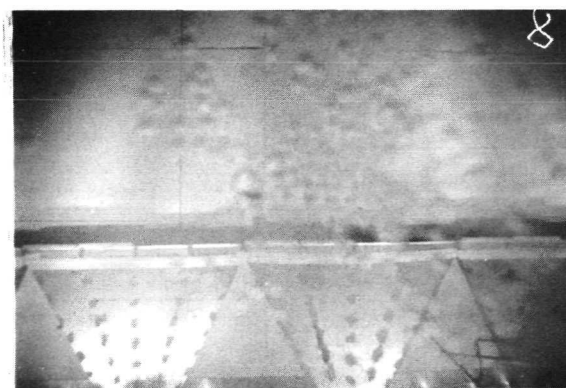
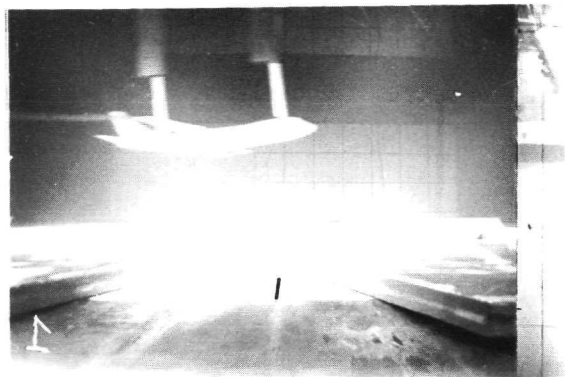
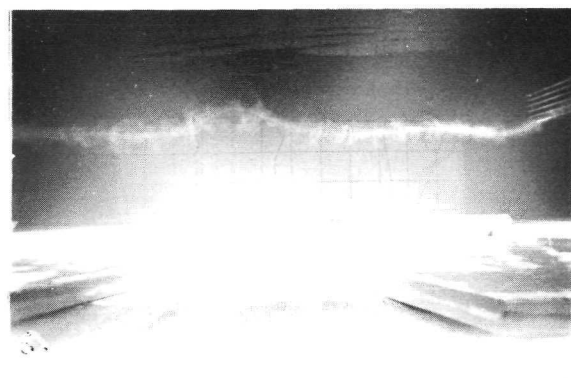
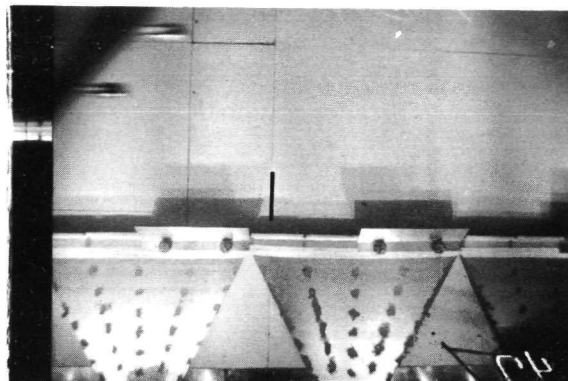


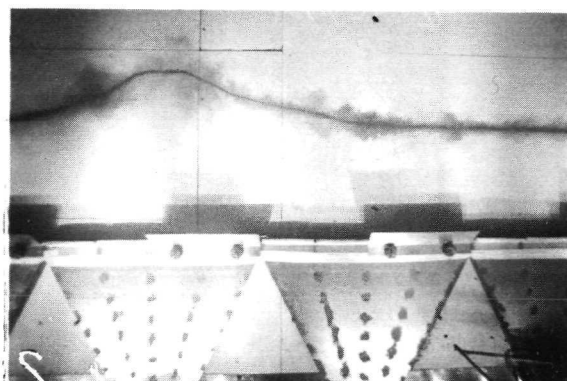
FIGURE 63 - CONCLUDED



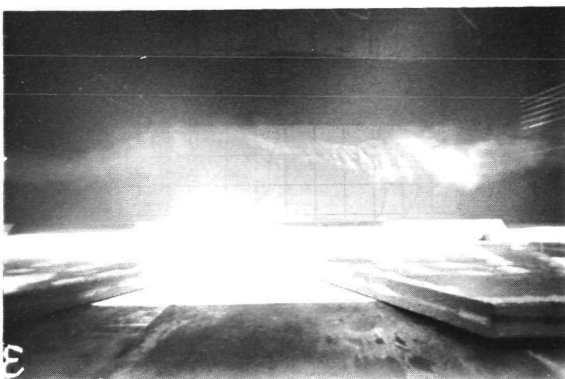
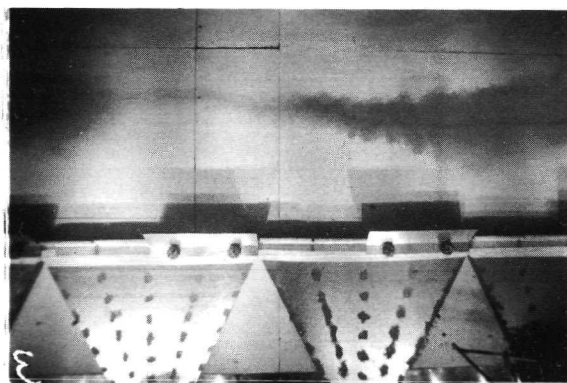
N  
-0.9



3.2



11.4



15.4

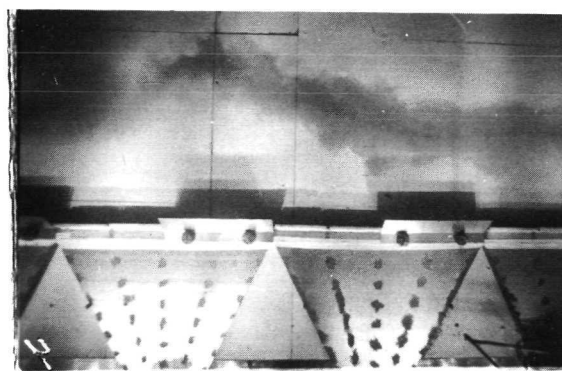
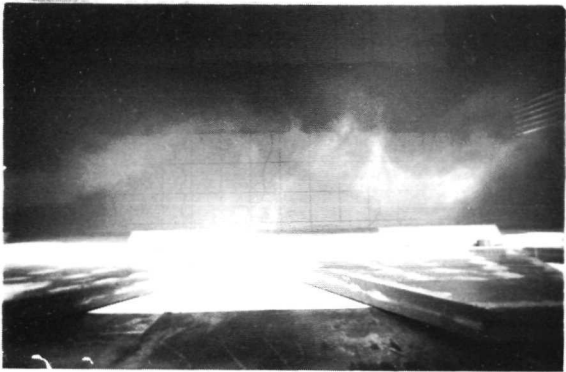
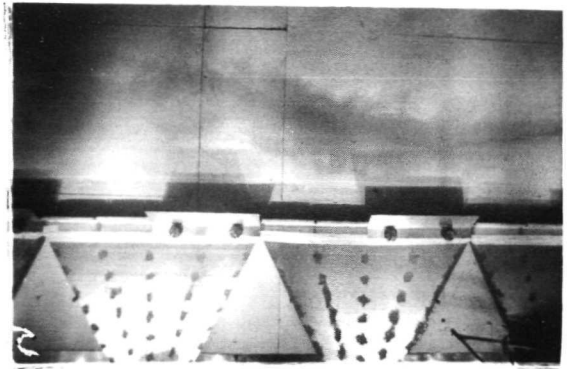


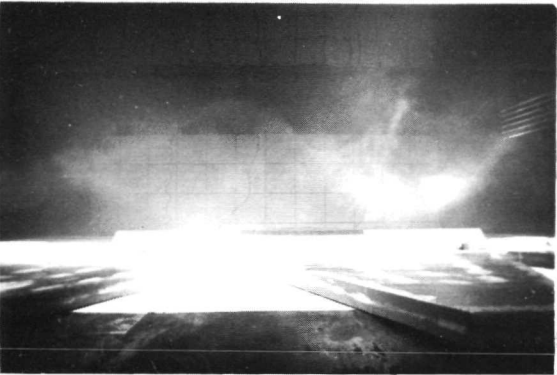
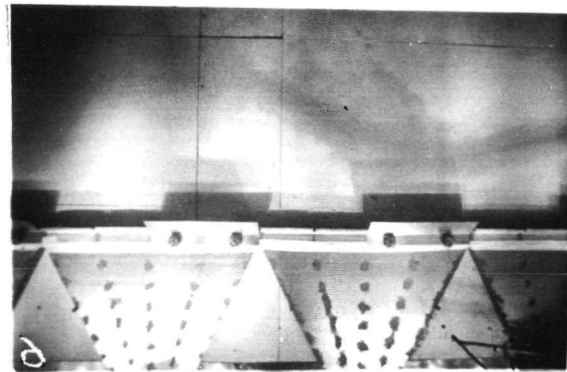
FIGURE 64 - DEVICE F1 WITH  $V_s/U = 0.408$ ,  $V_b/U = 0.270$  - EFFECT ON VORTEX WAKE FOR CRUISE CONDITION,  $C_L = 0.67$  AND ALTITUDE = 30.5 METERS



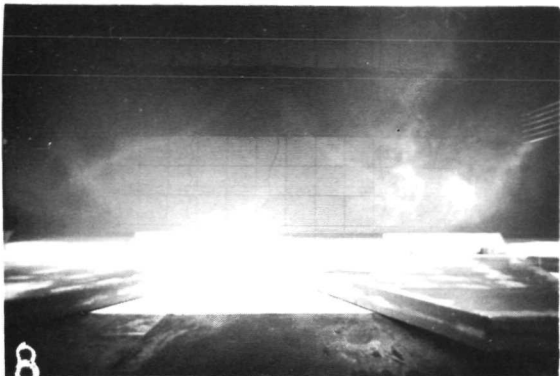
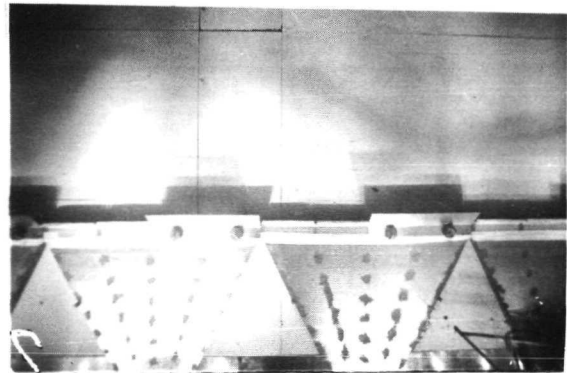
N  
19.5



23.6



27.7



31.8

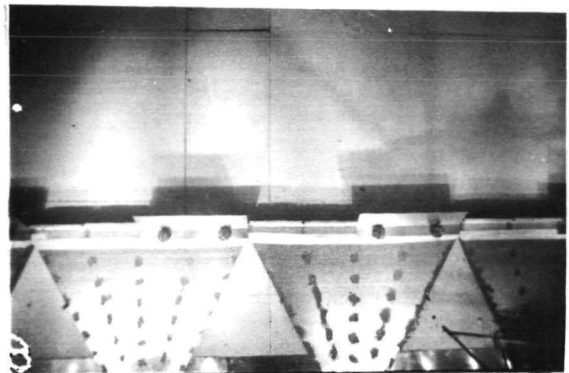
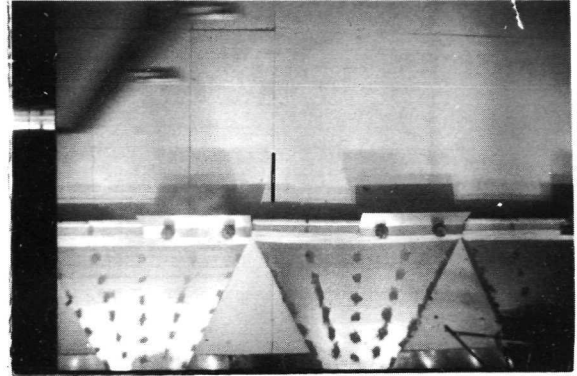


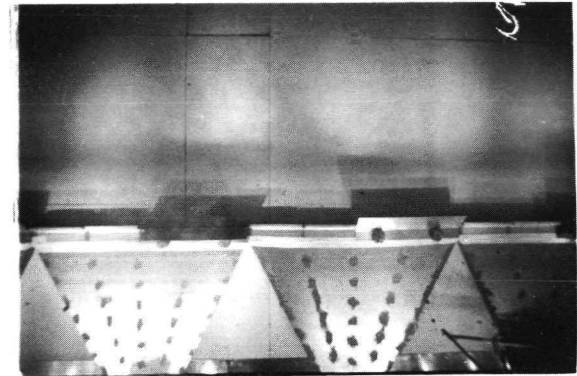
FIGURE 64 - CONCLUDED



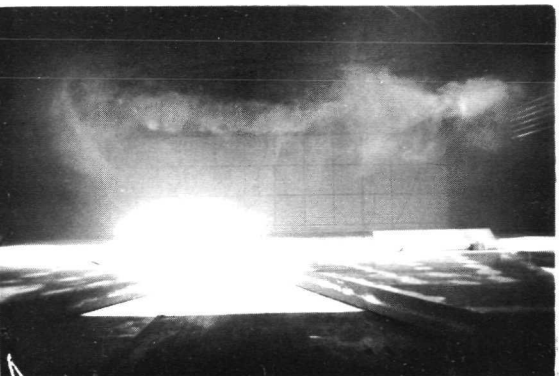
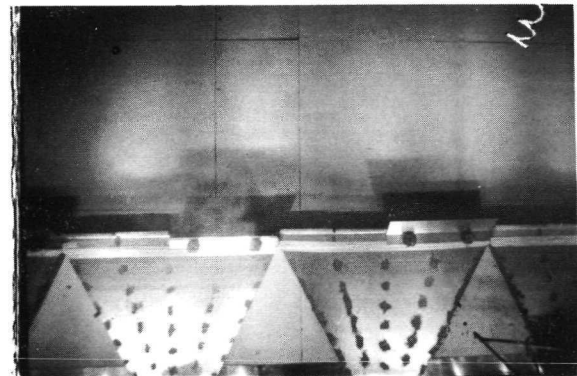
N  
-0.7



11.5



19.7



23.8

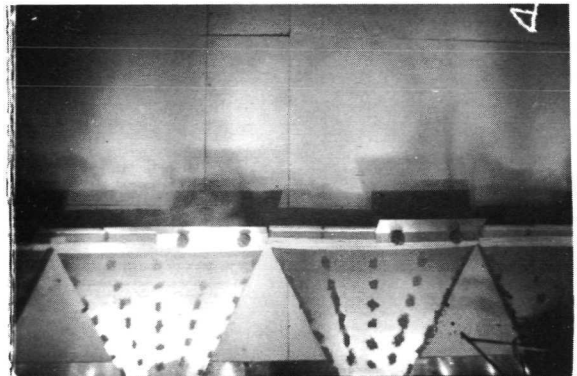
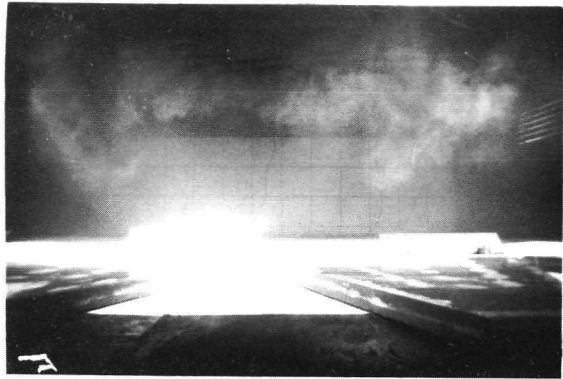
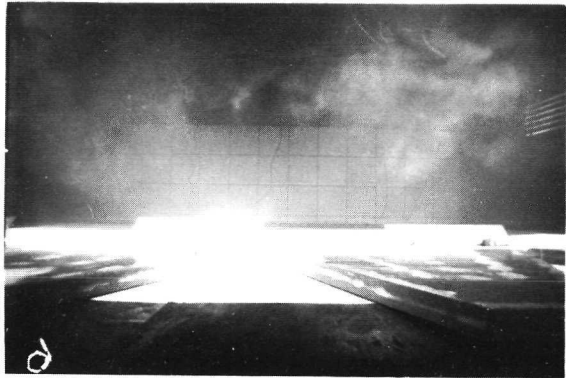
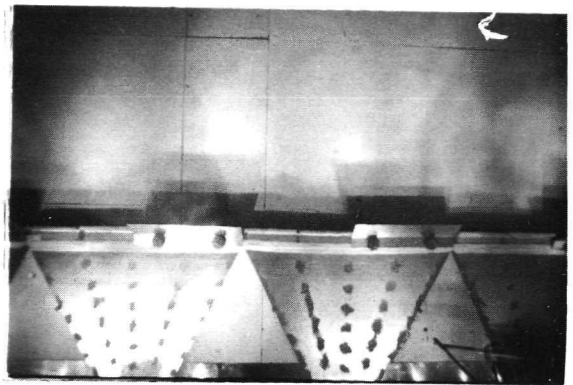


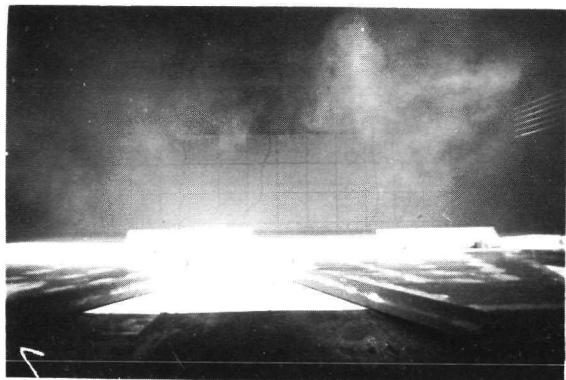
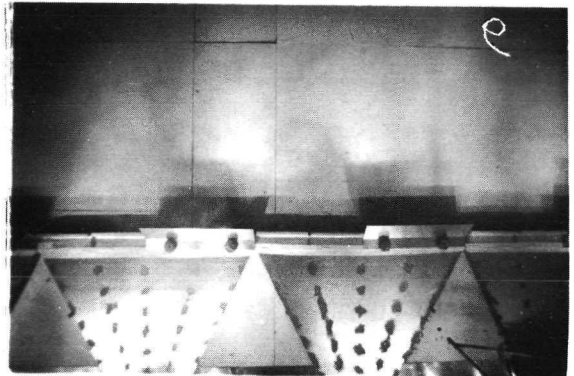
FIGURE 65 - DEVICE F1 WITH  $V_s/U = 0.408$ ,  $V_b/U = 0.270$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.77$  AND ALTITUDE = 30.5 METERS



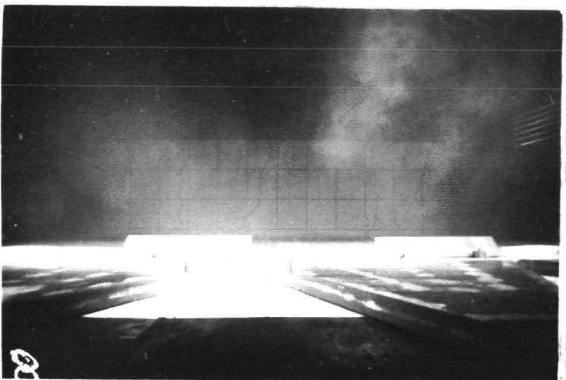
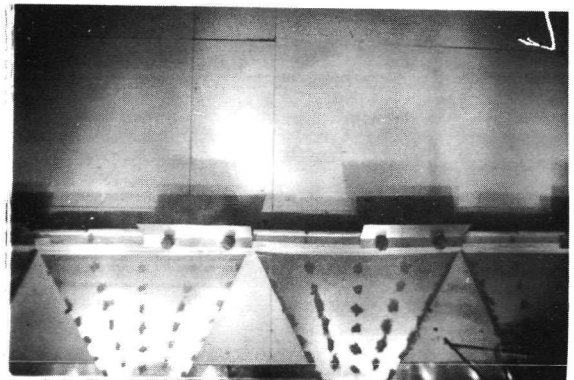
N  
27.9



31.9



36.0



44.2

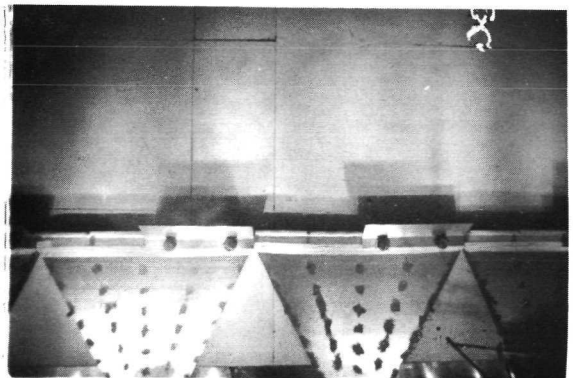
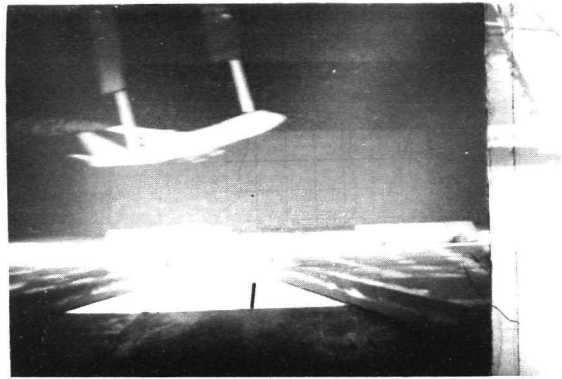
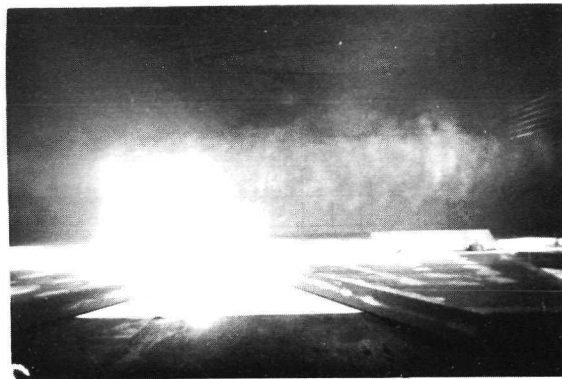
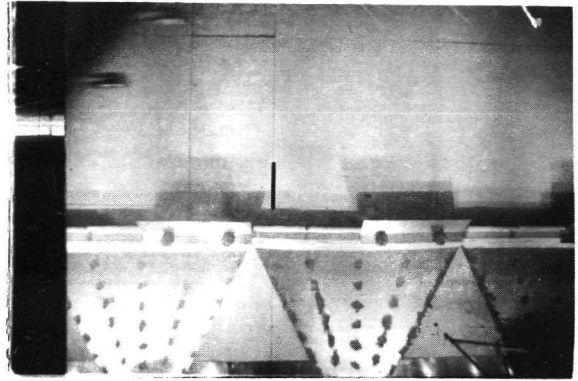


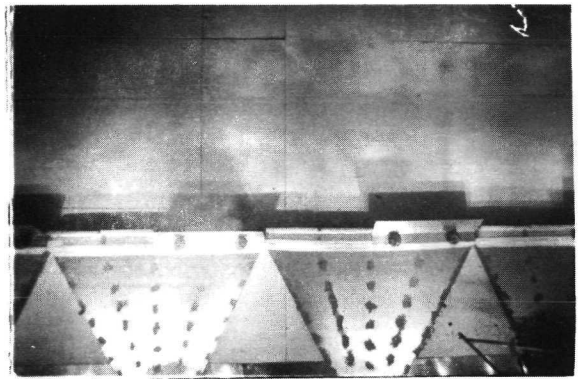
FIGURE 65 - CONCLUDED



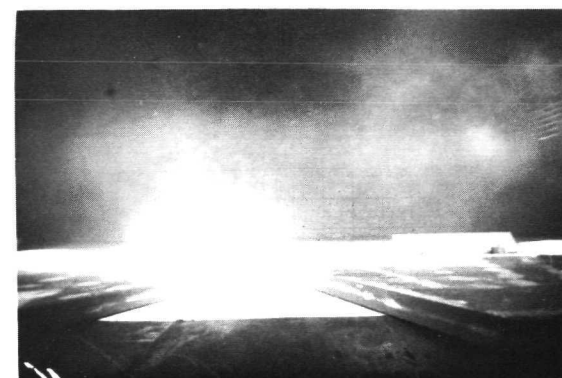
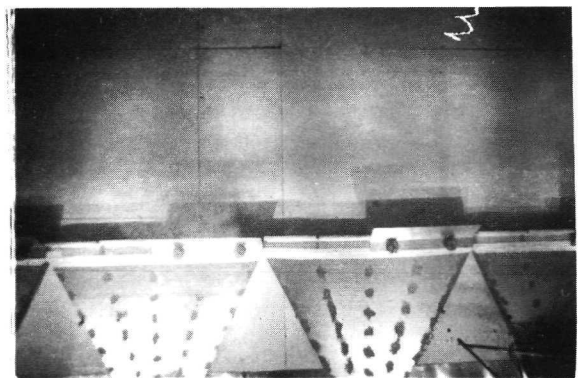
N  
-0.9



4.2



7.6



12.7

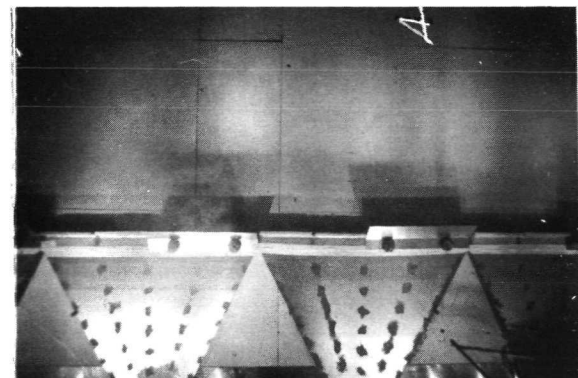
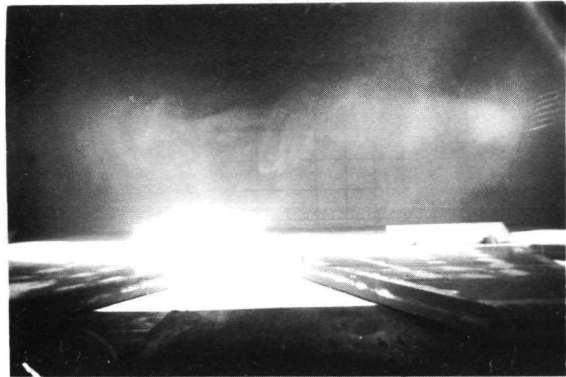
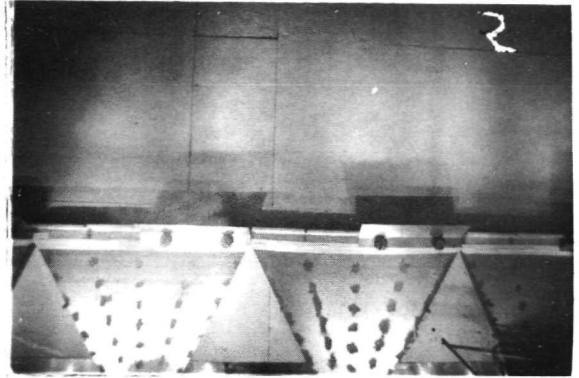


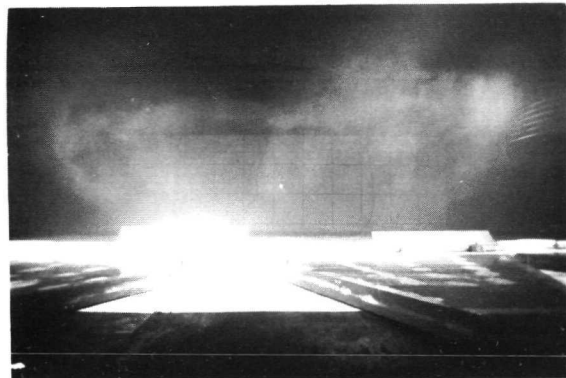
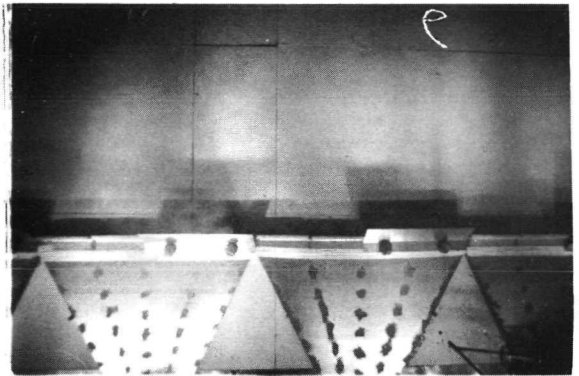
FIGURE 66 - DEVICE F1 WITH  $V_s/U = 0.490$ ,  $V_b/U = 0.324$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.83$  AND ALTITUDE = 30.5 METERS



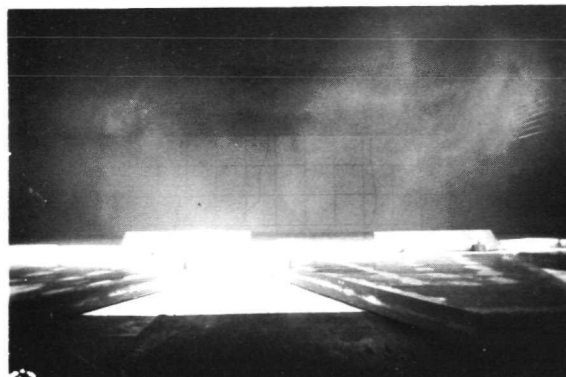
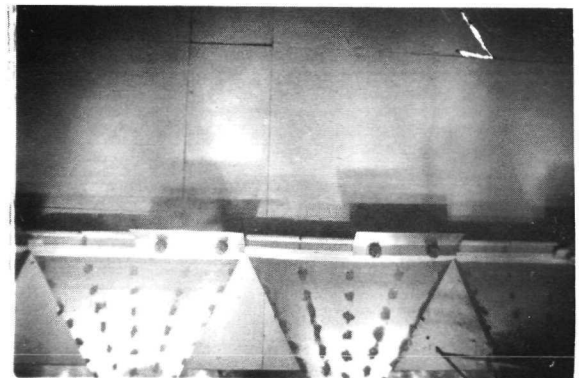
N  
16.1



17.8



21.2



24.6

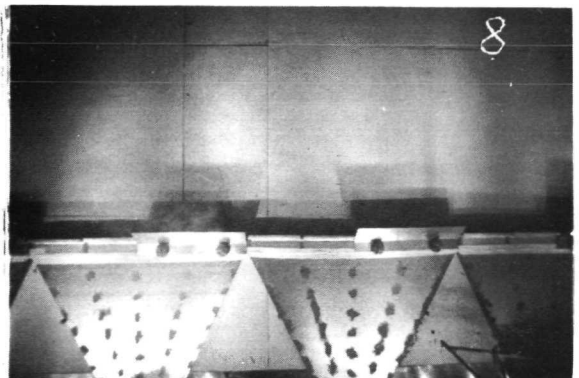
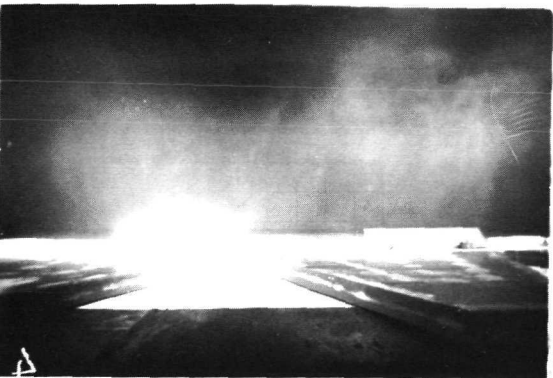
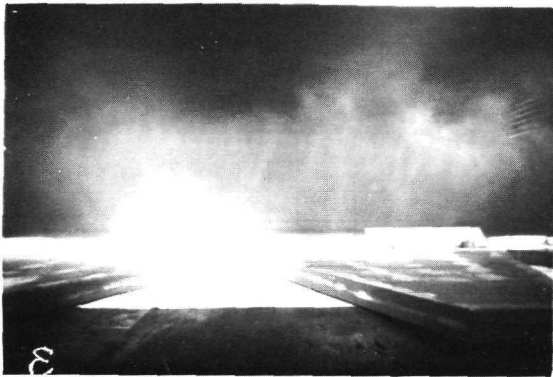
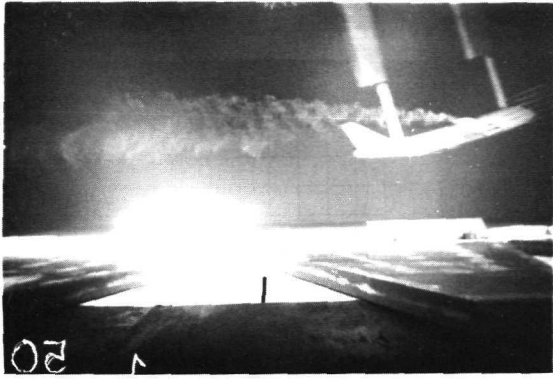
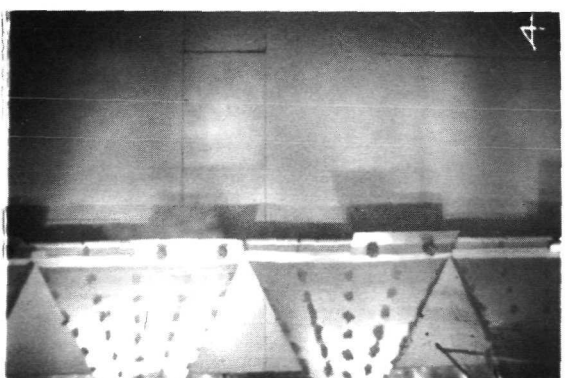
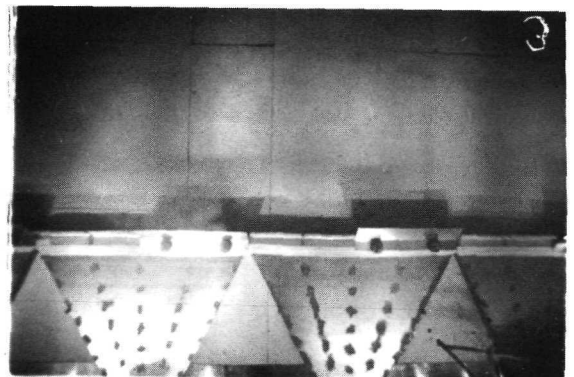
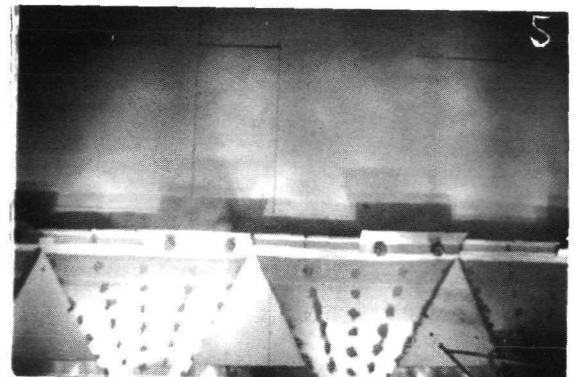
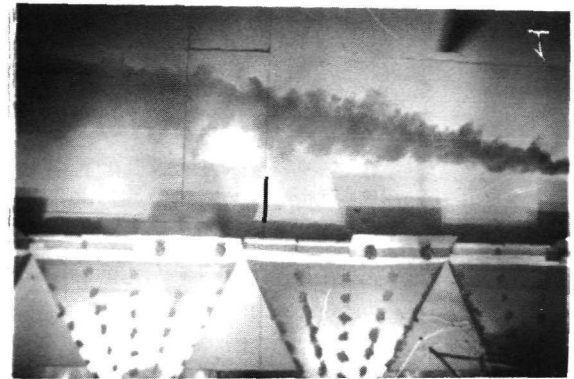


FIGURE 66 - CONCLUDED



N  
1.1

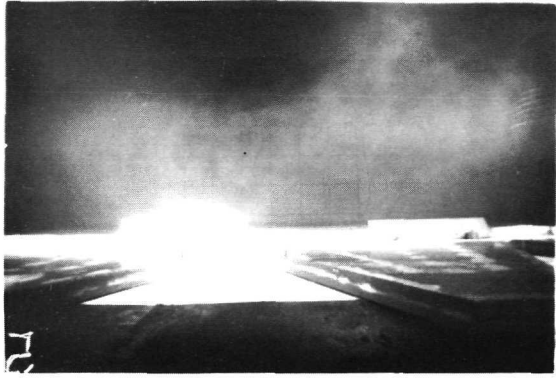


7.9

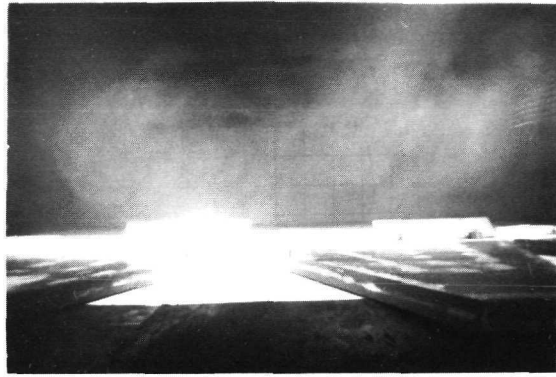
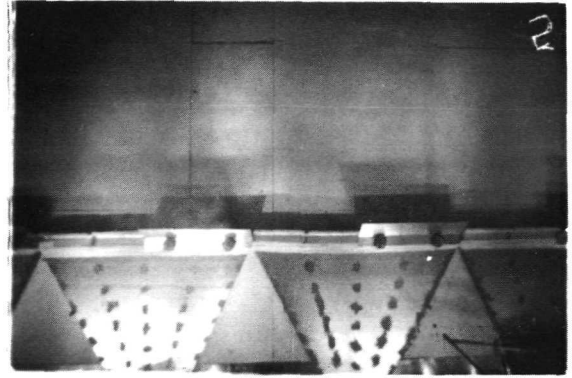
13.4

16.1

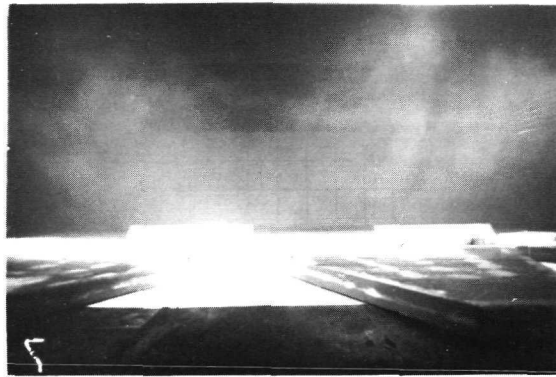
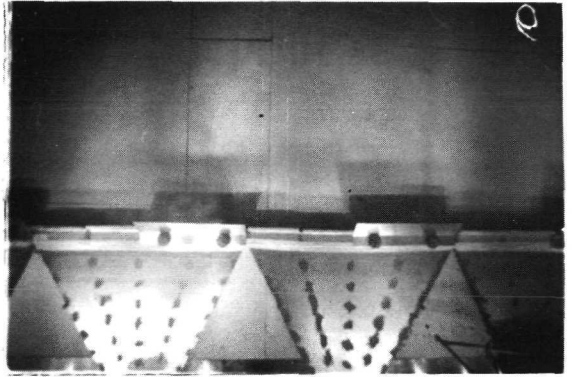
FIGURE 67 - DEVICE F1 WITH  $V_s/U = 0.613$ ,  $V_b/U = 0.405$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.67$  AND ALTITUDE = 30.5 METERS



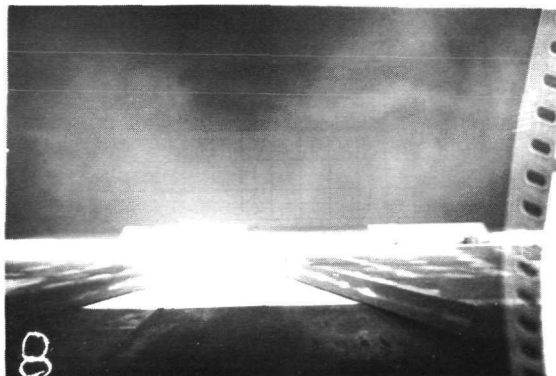
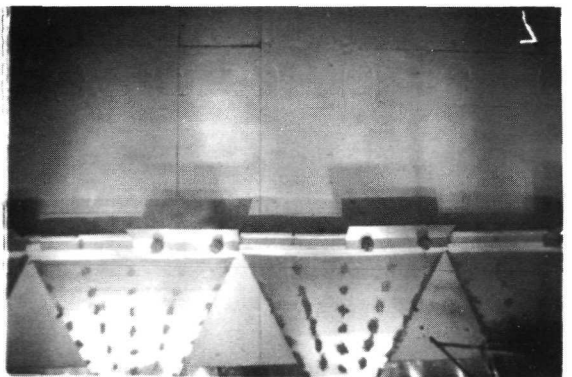
N  
18.8



21.5



24.3



27.0

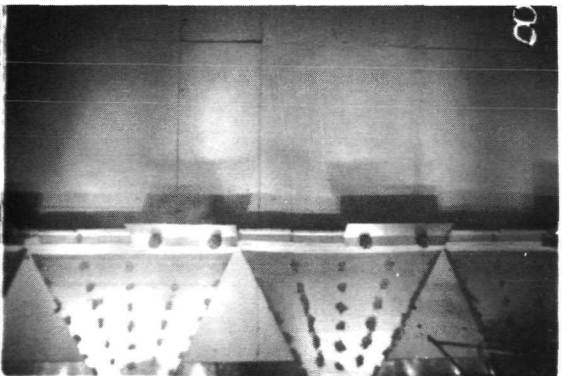
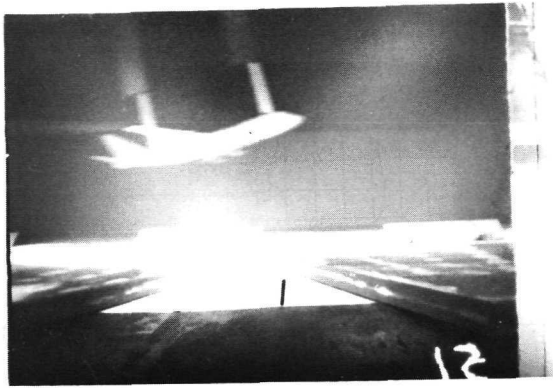
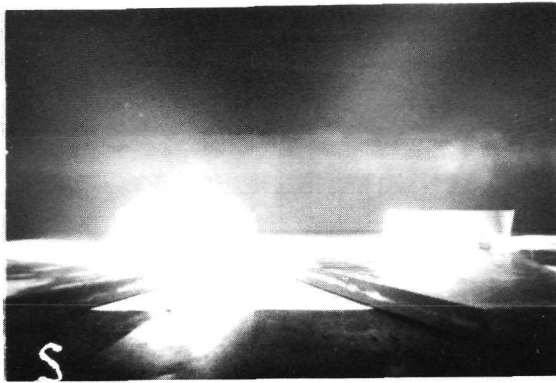
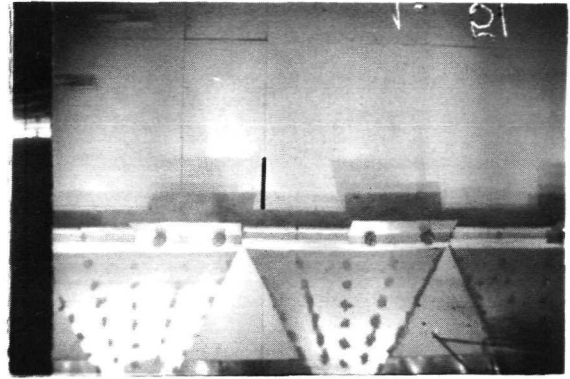


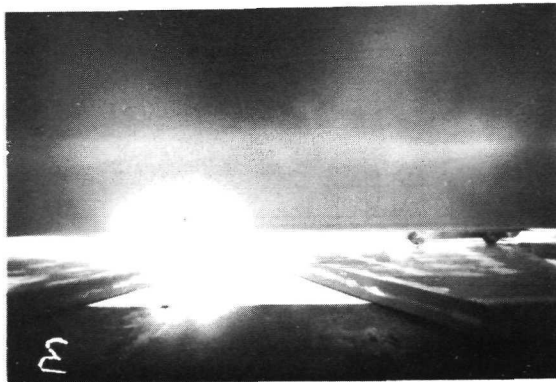
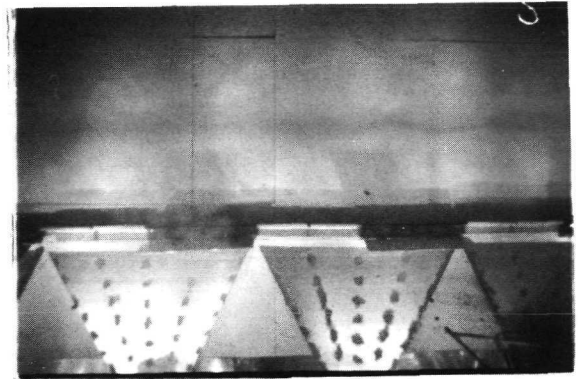
FIGURE 67 - CONCLUDED



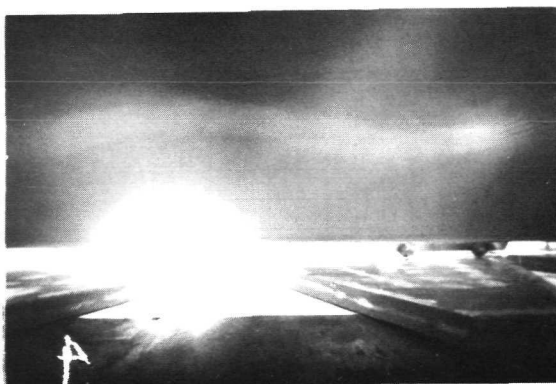
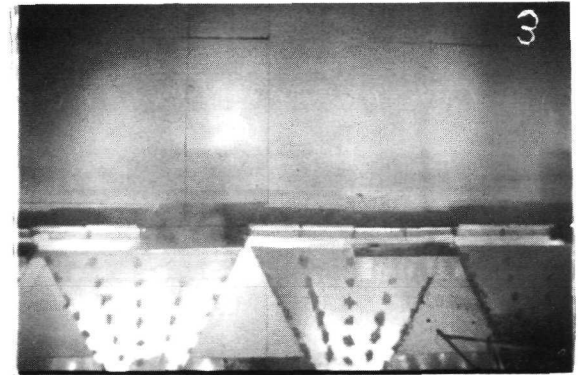
N  
-0.9



6.7



11.8



16.9

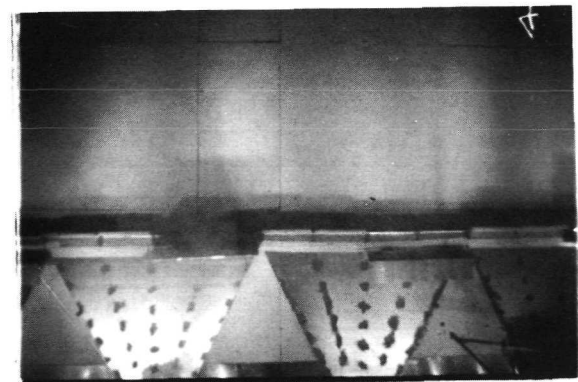
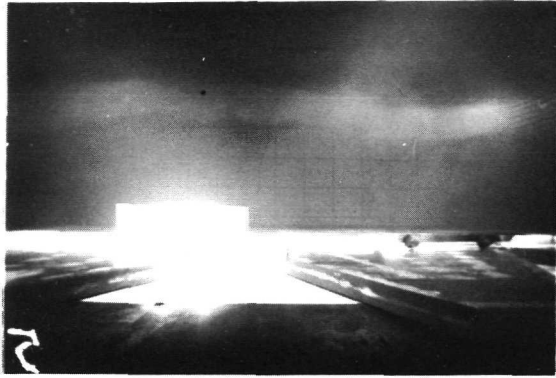
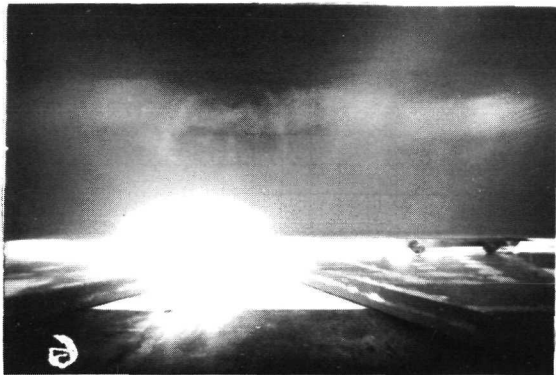
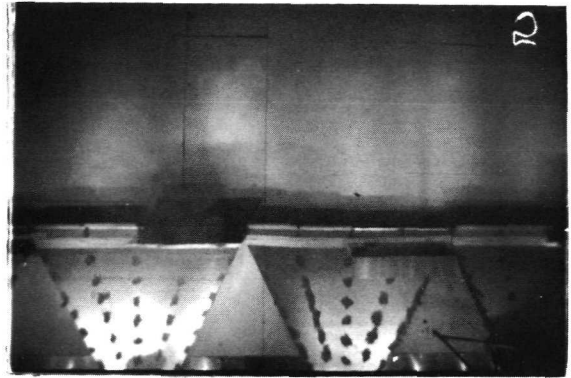


FIGURE 68 - DEVICE F1 WITH  $V_s/U = 0.327$ ,  $V_b/U = 0.216$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.65$  AND ALTITUDE = 30.5 METERS

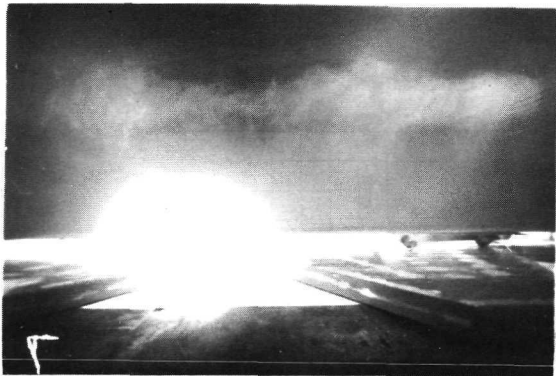
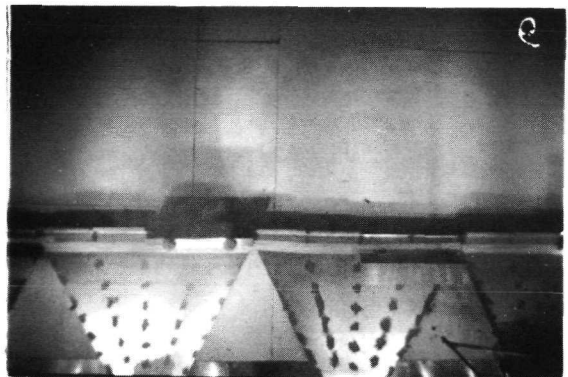
HYDRONAUTICS, INCORPORATED



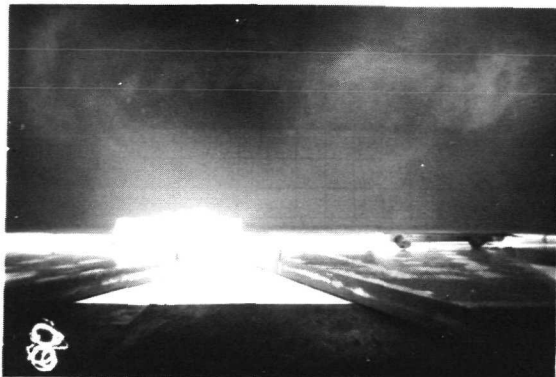
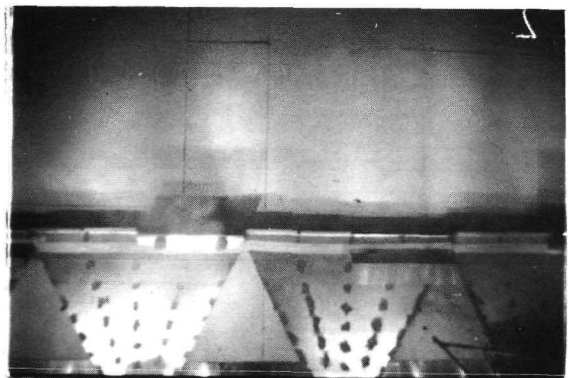
N  
19.5



22.0



24.6



29.7

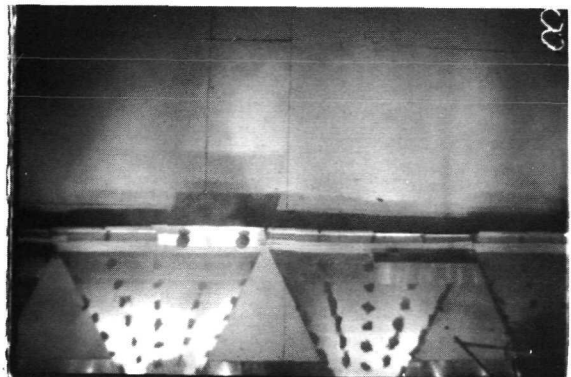
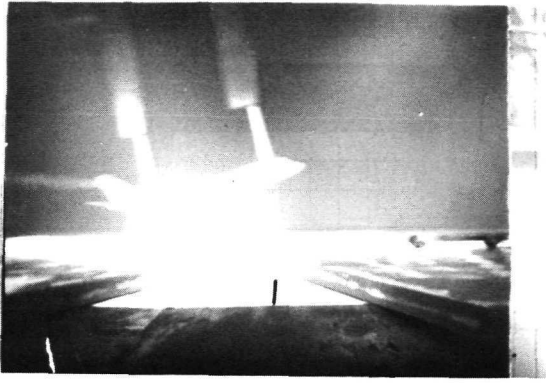
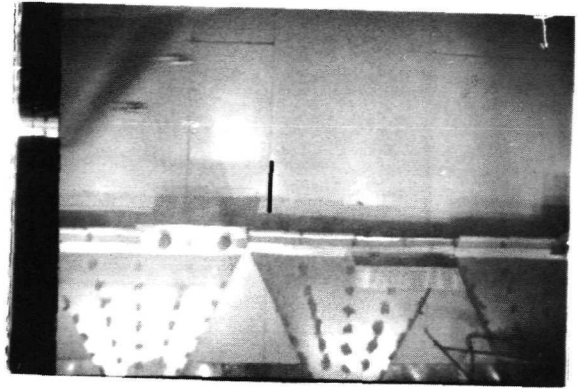


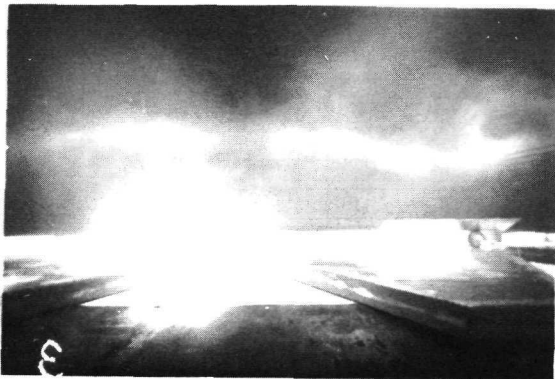
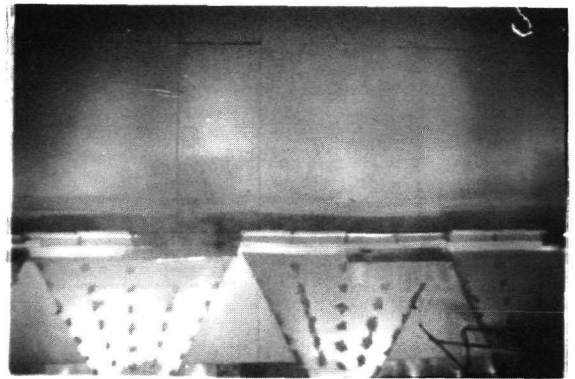
FIGURE 68 - CONCLUDED



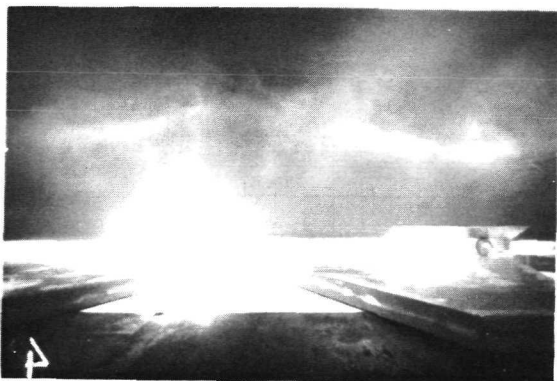
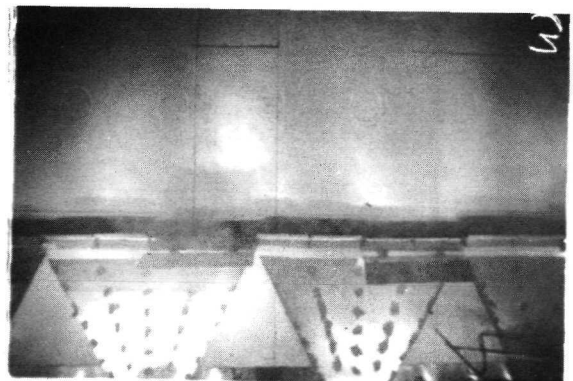
N  
-0.9



5.2



9.3



11.3

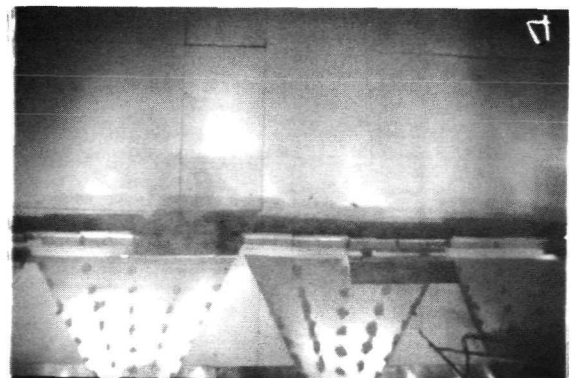
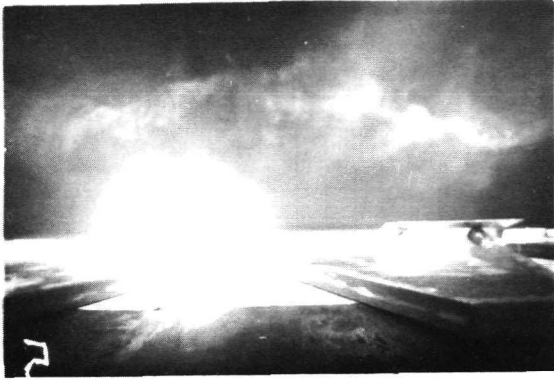
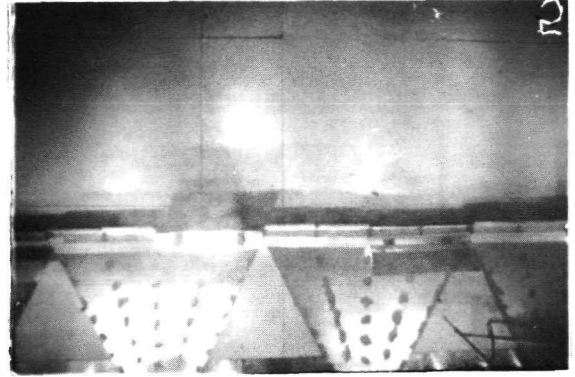


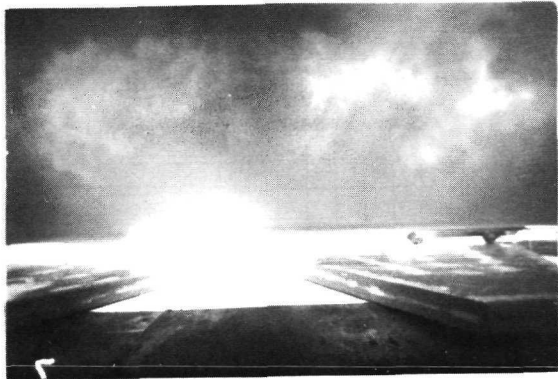
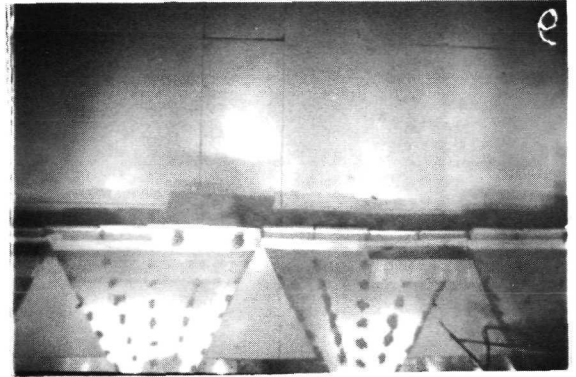
FIGURE 69 - DEVICE F1 WITH  $V_s/U = 0.408$ ,  $V_b/U = 0.270$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.80$  AND ALTITUDE = 13.4 METERS



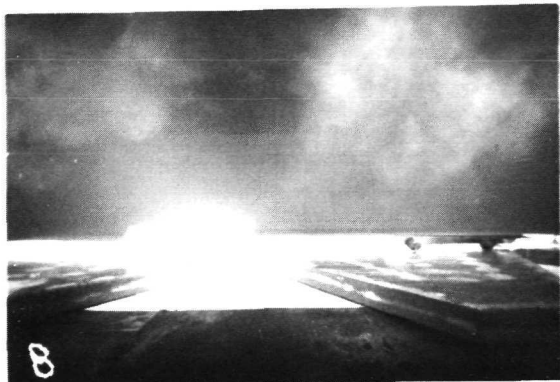
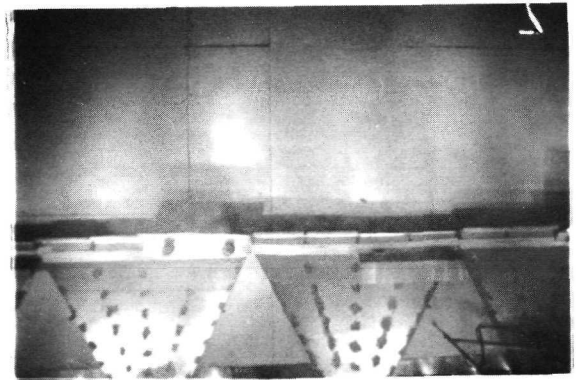
N  
13.3



15.4



17.4



21.5

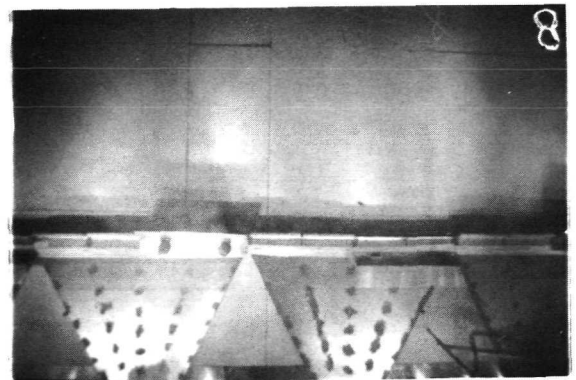
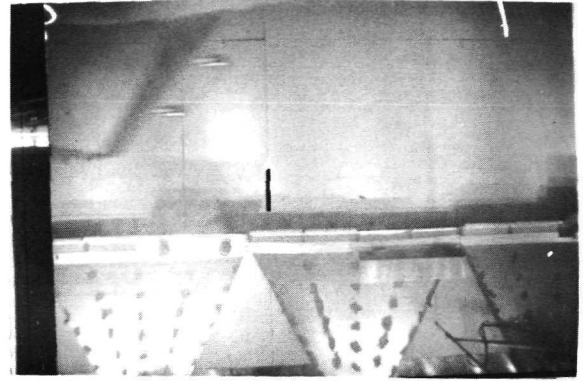


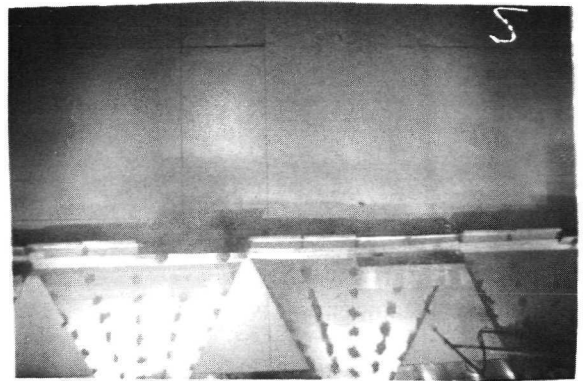
FIGURE 69 - CONCLUDED



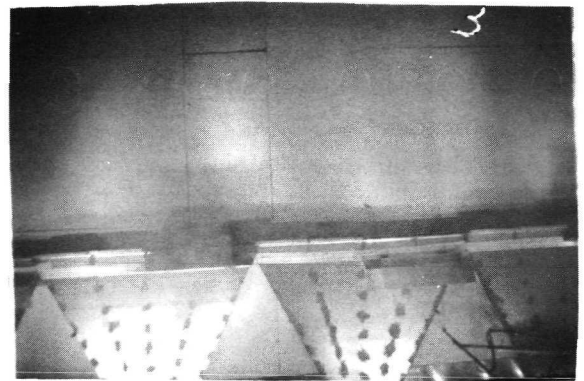
Z  
-0.7



4.4



7.8



9.5

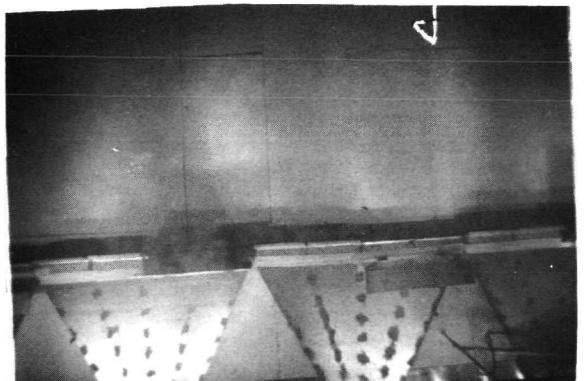
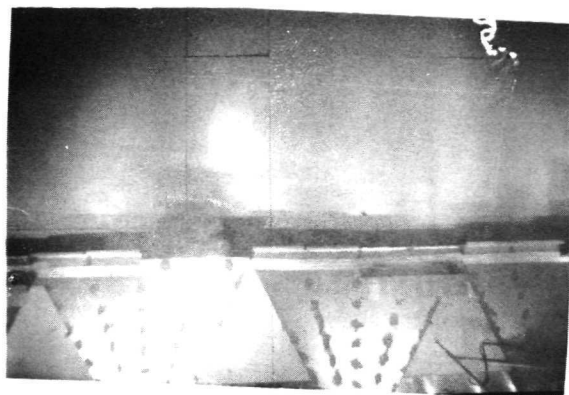


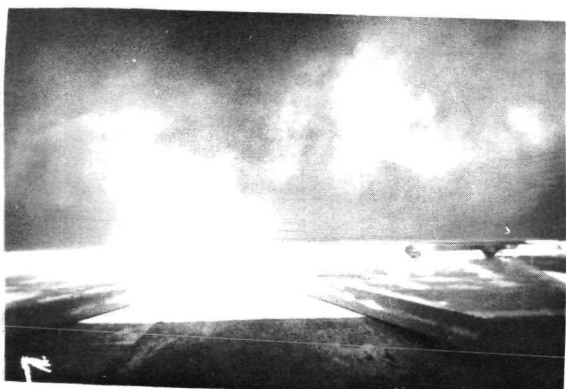
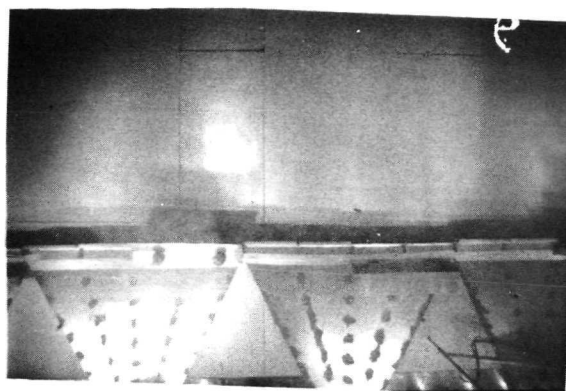
FIGURE 70 - DEVICE F1 WITH  $V_s/U = 0.490$ ,  $V_b/U = 0.324$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.81$  AND ALTITUDE = 13.4 METERS



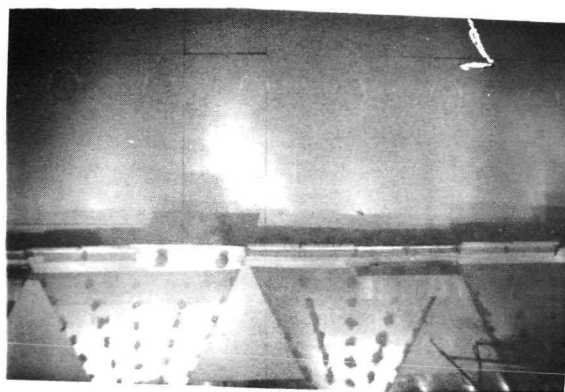
N  
11.2



12.9



14.6



18.0

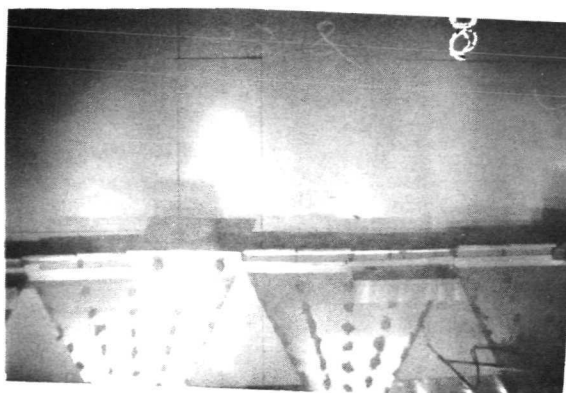
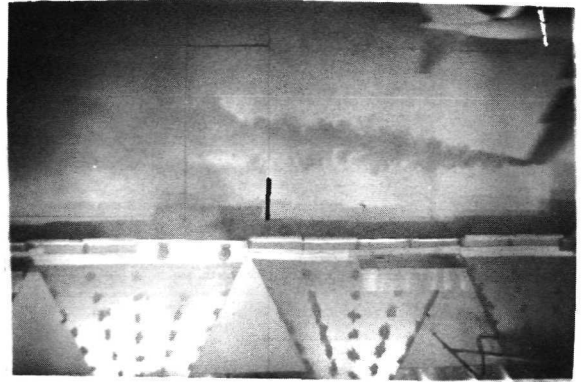


FIGURE 70 - CONCLUDED



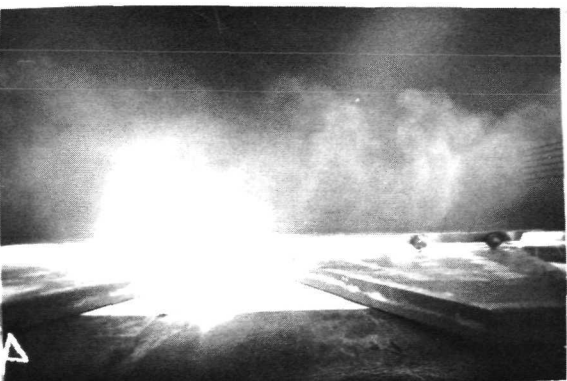
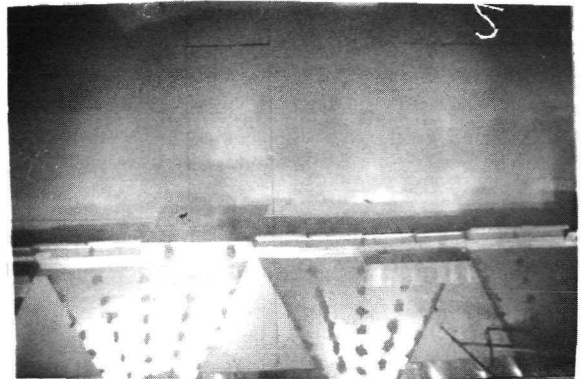
N  
1.2



3.9



6.6



9.3

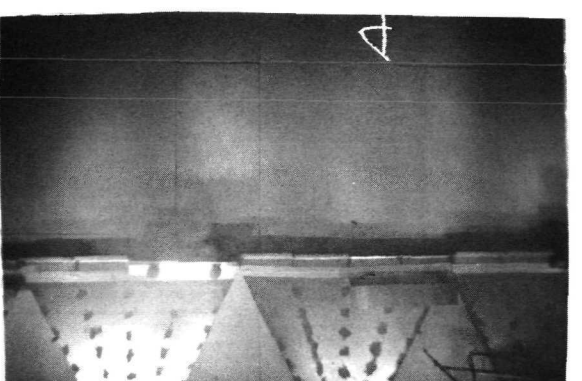
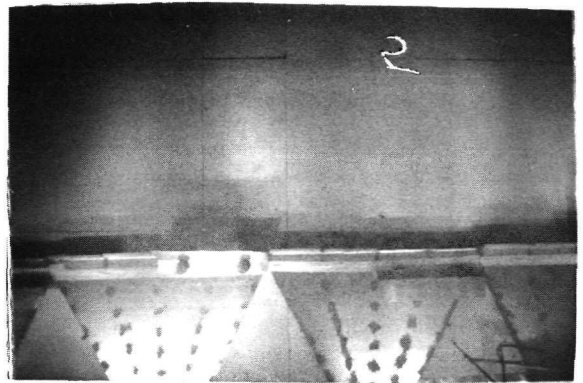


FIGURE 71 - DEVICE F1 WITH  $V_s/U = 0.613$ ,  $V_b/U = 0.405$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.78$  AND ALTITUDE = 13.4 METERS

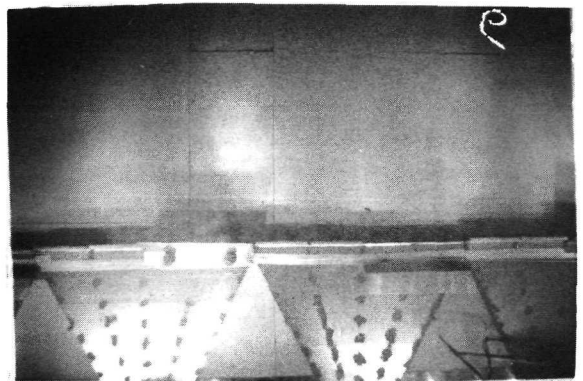
HYDRONAUTICS, INCORPORATED



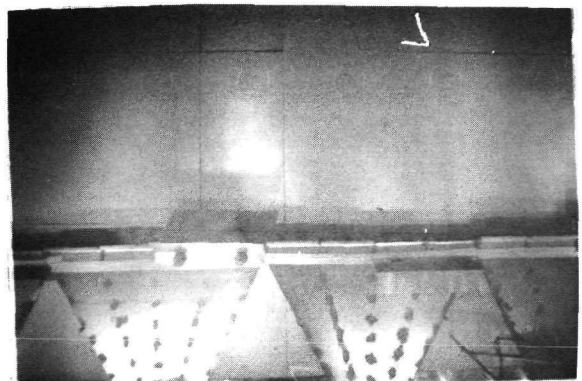
N  
12.1



14.8



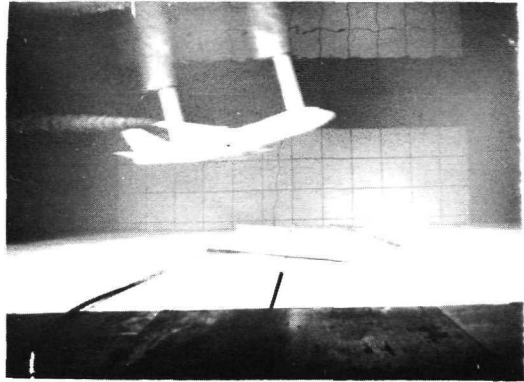
16.1



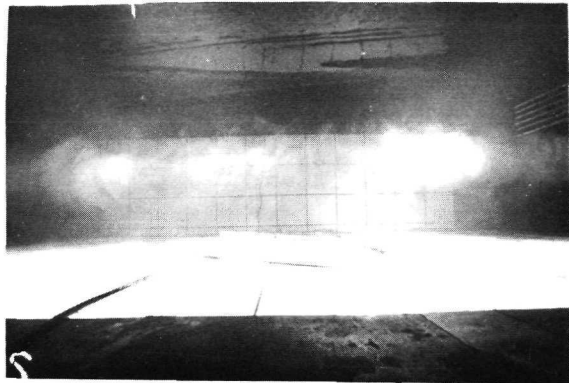
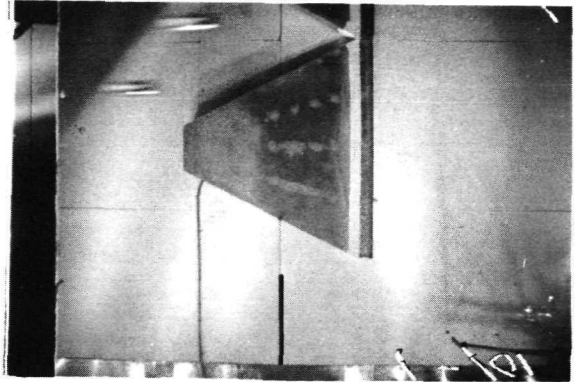
18.9



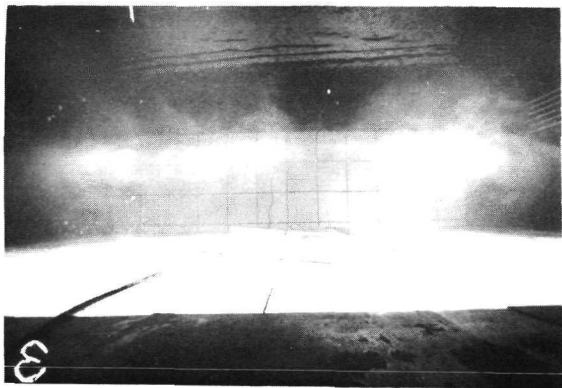
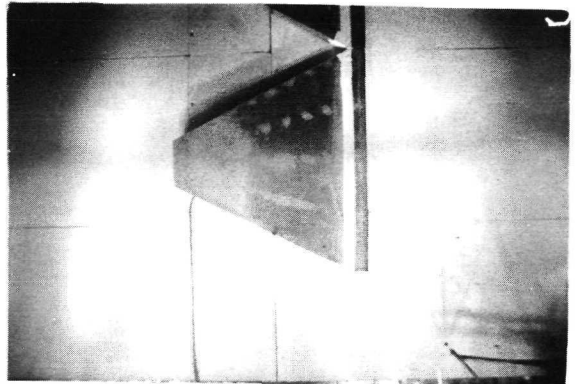
FIGURE 71 - CONCLUDED



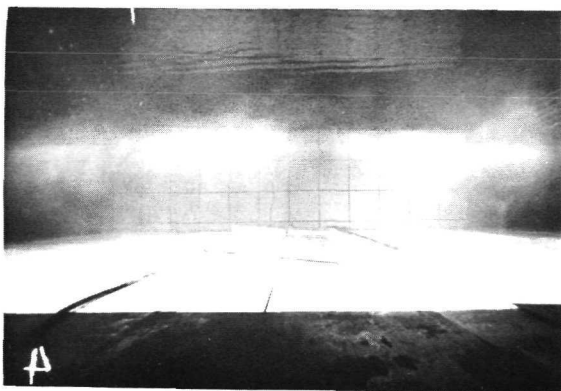
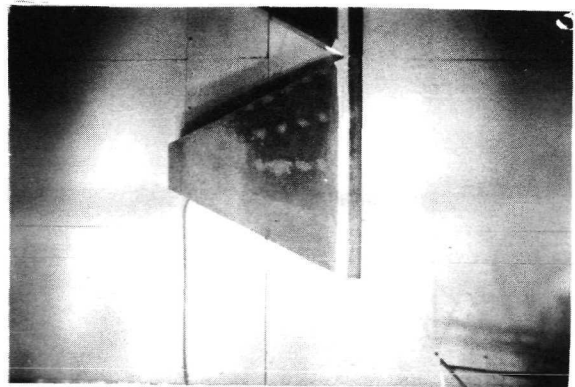
N  
-0.8



5.8



11.9



17.0

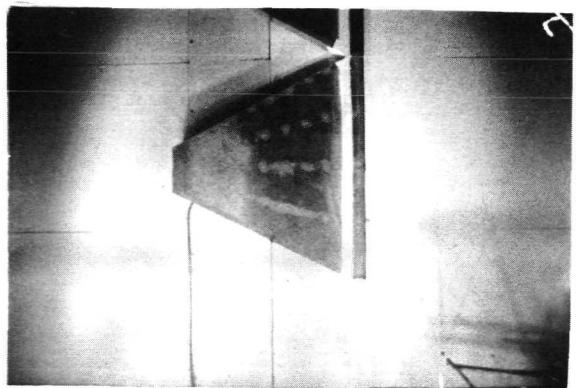
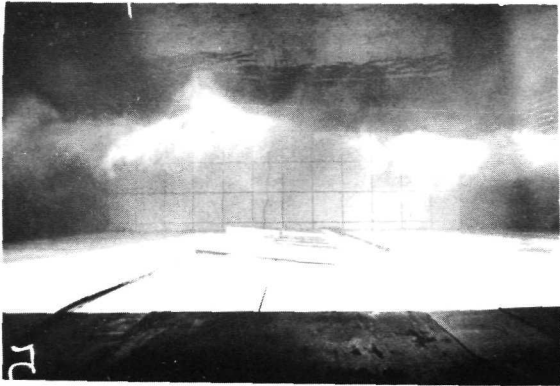
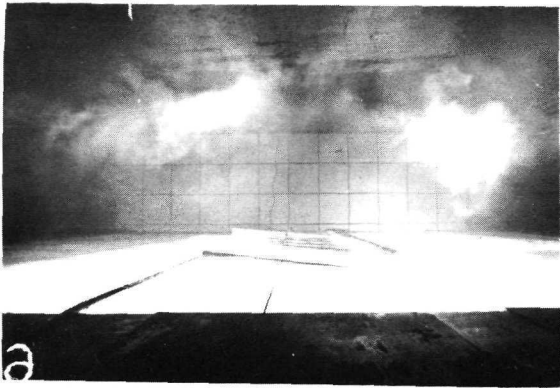
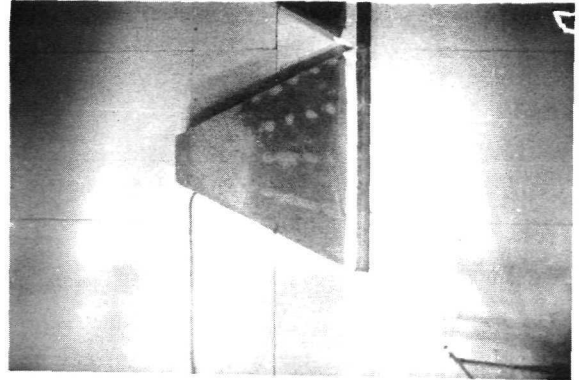


FIGURE 72 - DEVICE G WITH  $V_b/U = 0.129$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.67$  AND ALTITUDE = 30.5 METERS

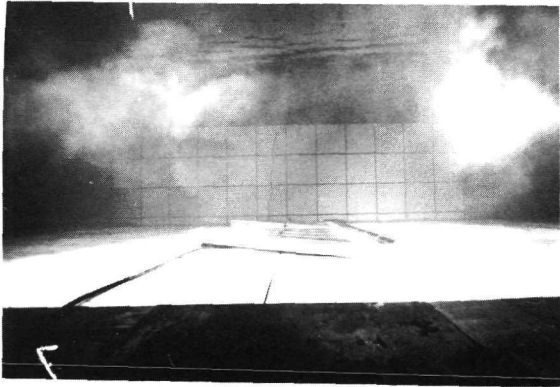
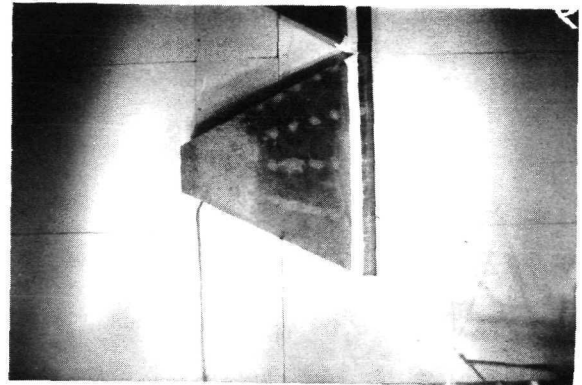
HYDRONAUTICS, INCORPORATED



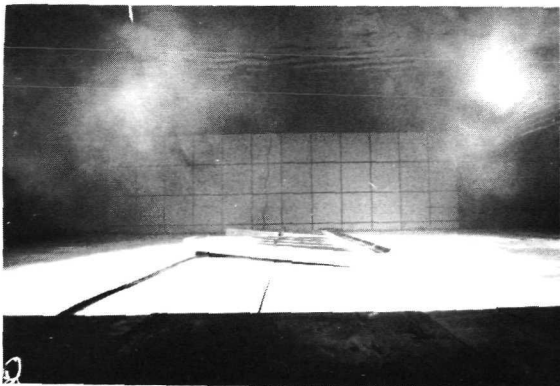
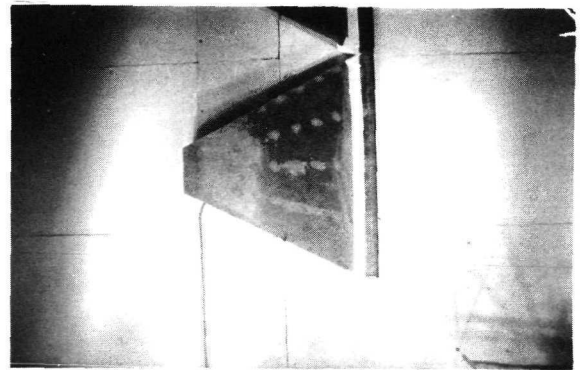
N  
22.1



27.2



32.3



37.5

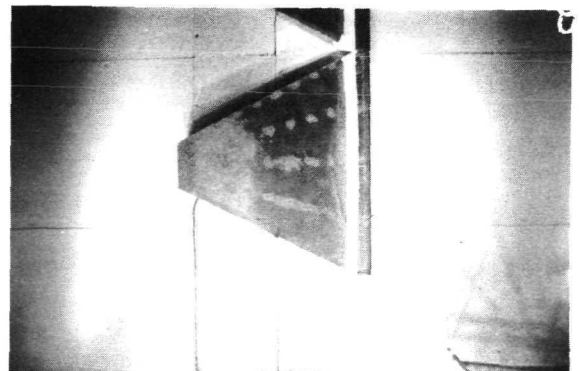
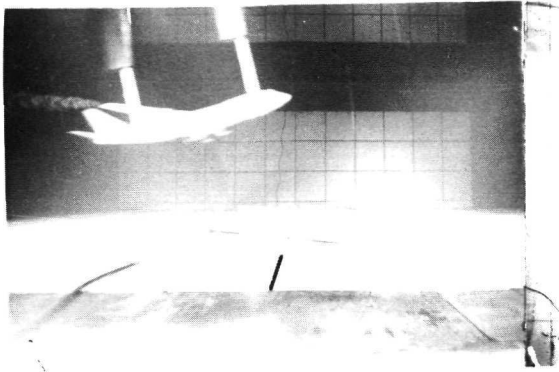
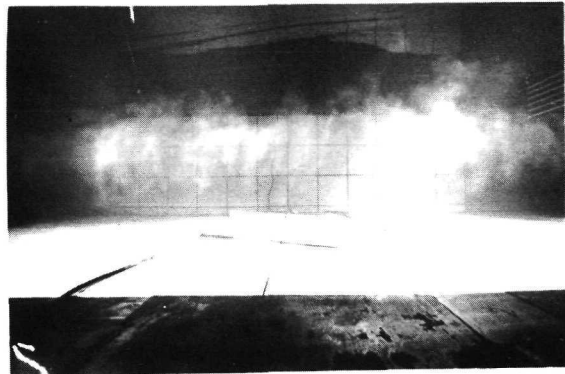
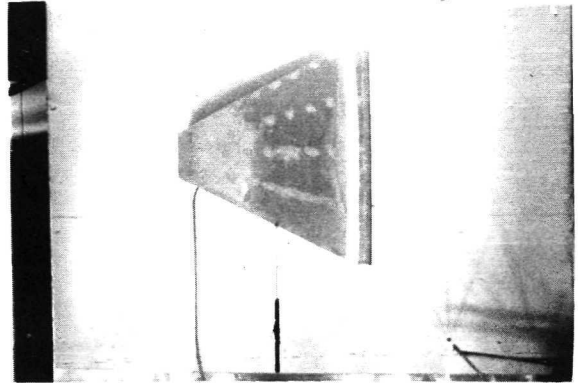


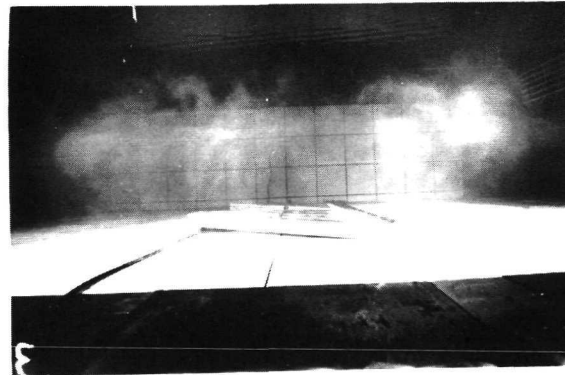
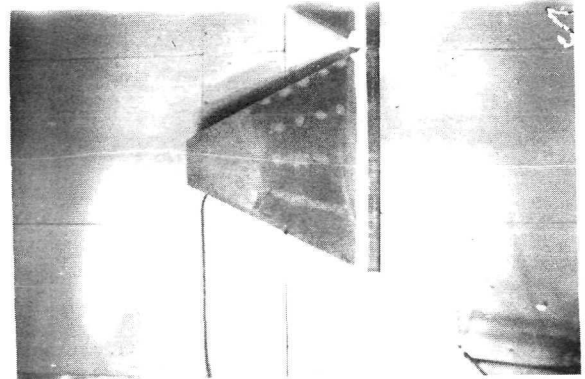
FIGURE 72 - CONCLUDED



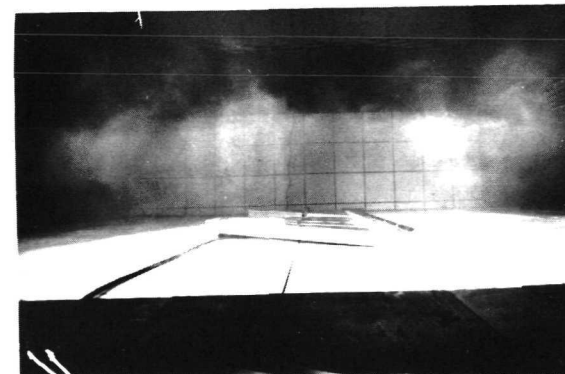
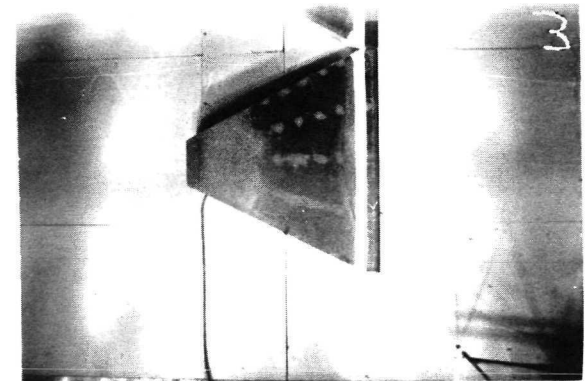
N  
-1.1



5.7



10.8



14.2

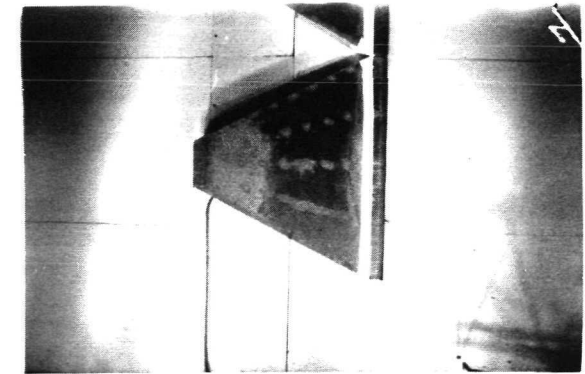
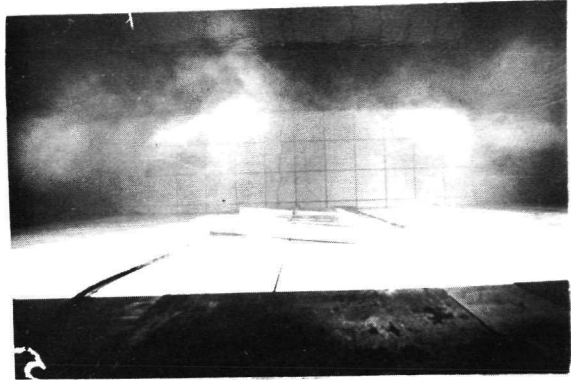
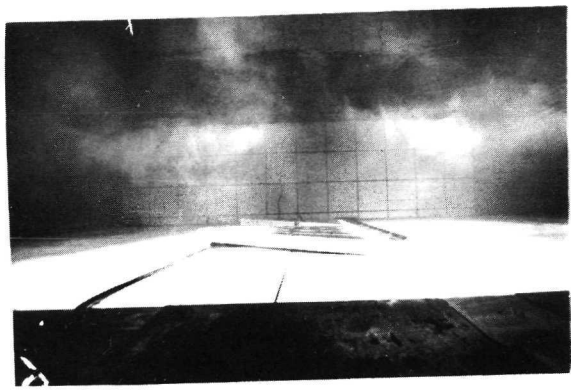
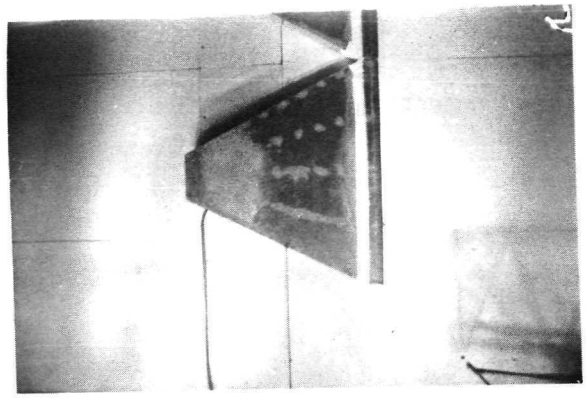


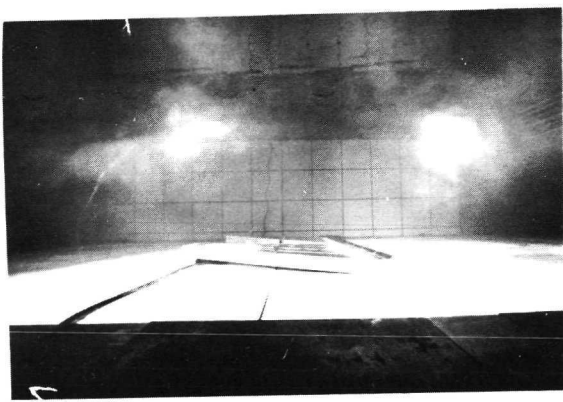
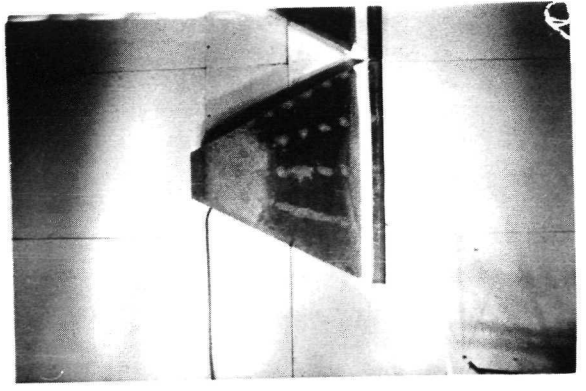
FIGURE 73 - DEVICE G WITH  $V_b/U = 0.194$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.82$  AND ALTITUDE = 30.5 METERS



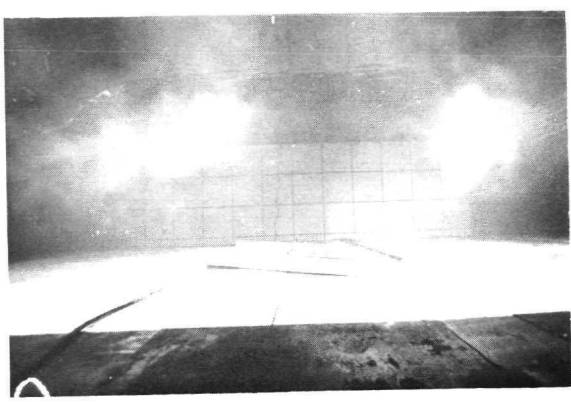
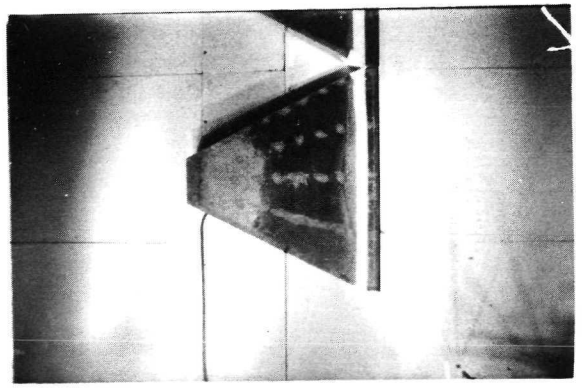
N  
17.6



22.7



27.8



31.2

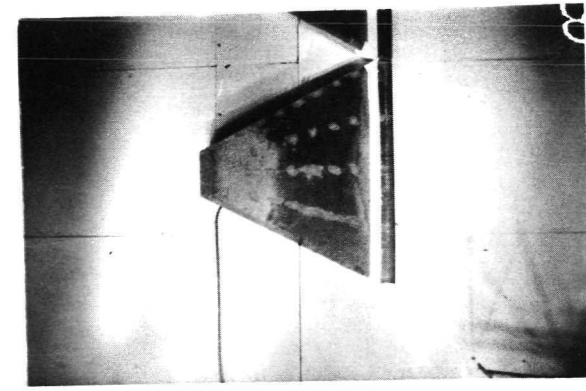
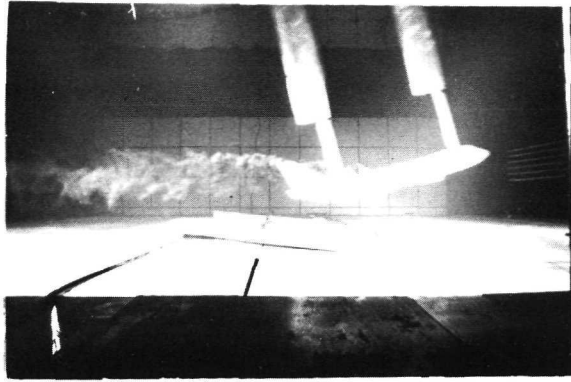
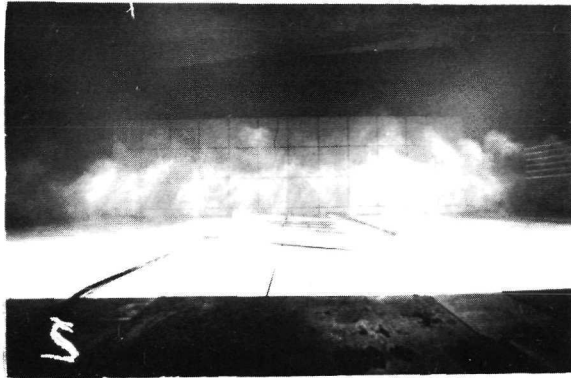
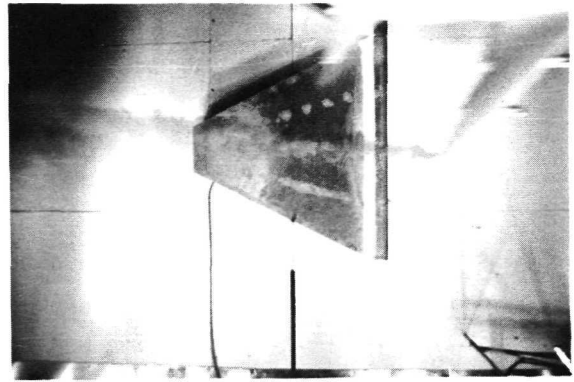


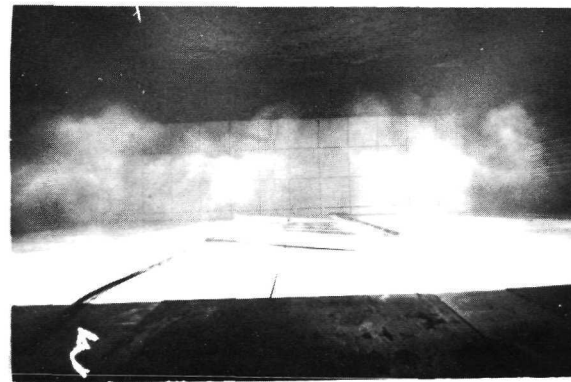
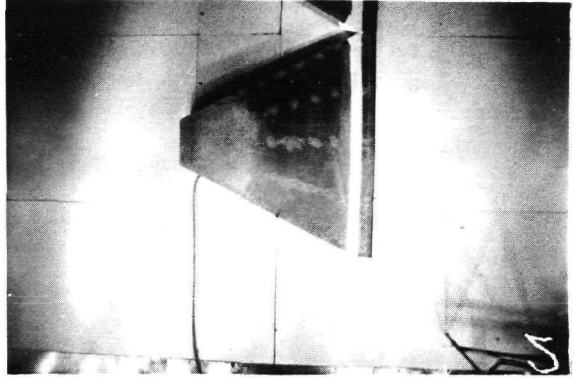
FIGURE 73 - CONCLUDED



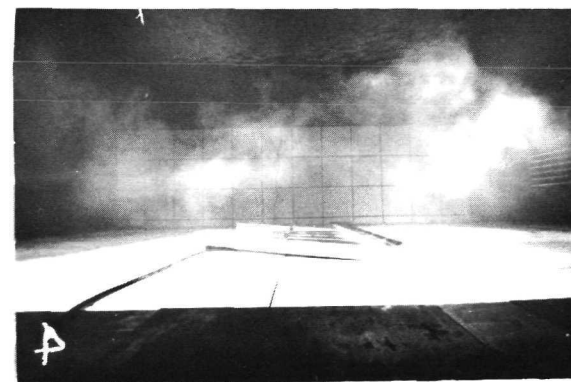
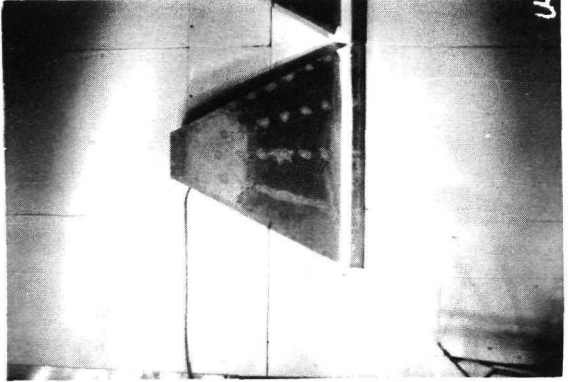
N  
0.6



4.0



7.4



12.5

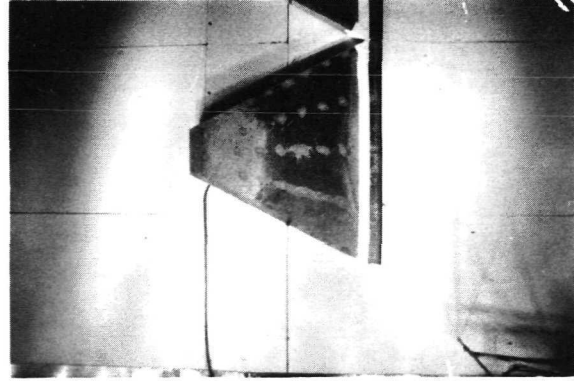
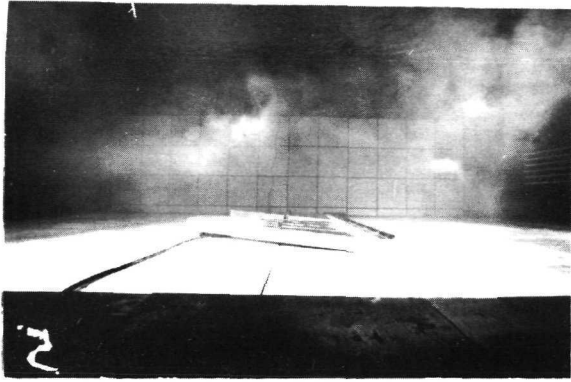
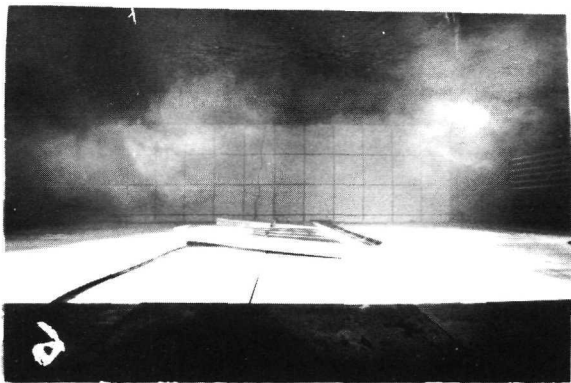
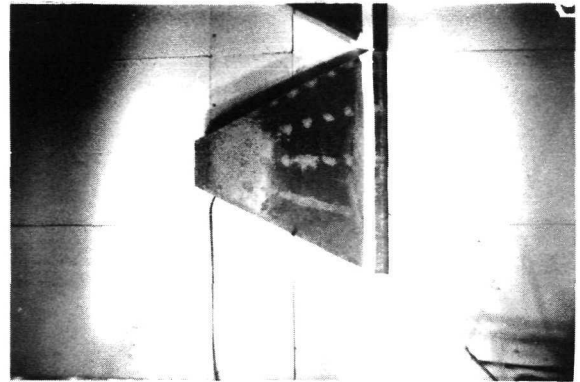


FIGURE 74 - DEVICE G WITH  $V_b/U = 0.194$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.82$  AND ALTITUDE = 13.4 METERS

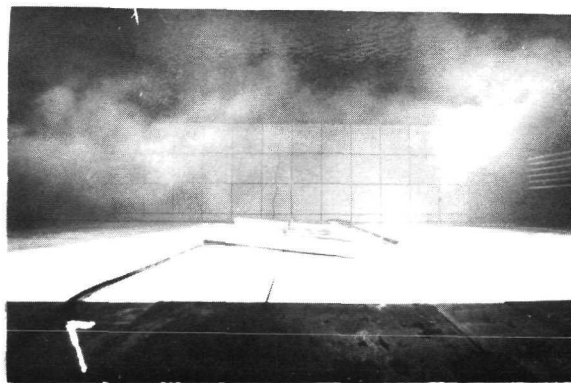
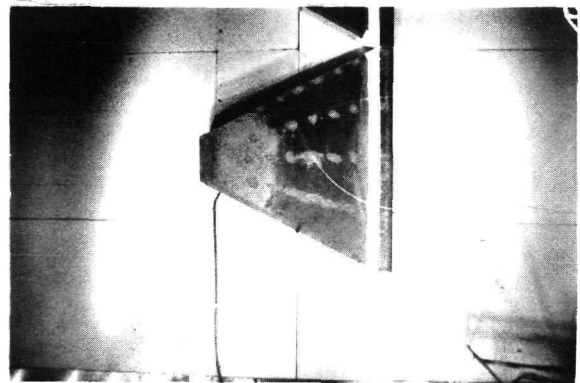
HYDRONAUTICS, INCORPORATED



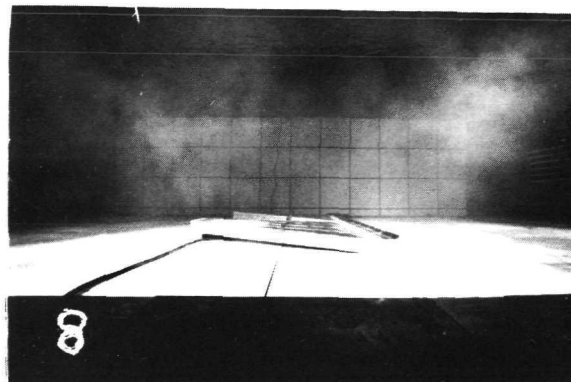
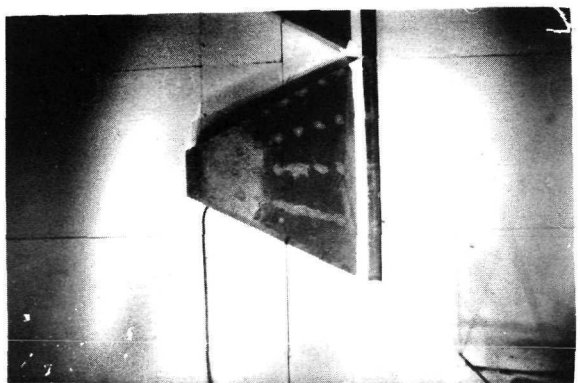
N  
15.9



19.3



22.7



26.1

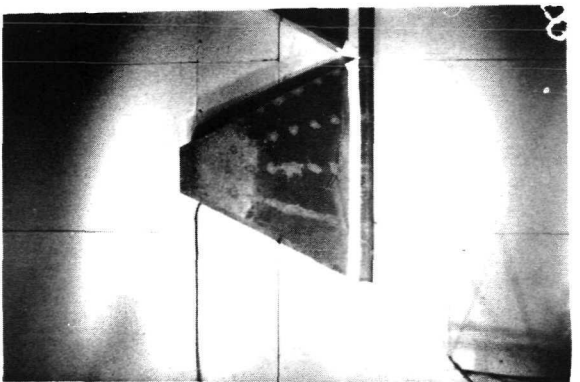
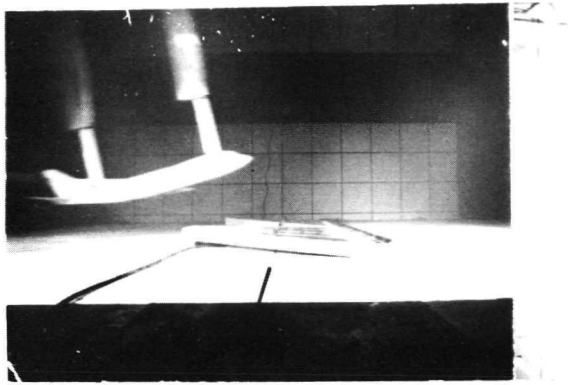
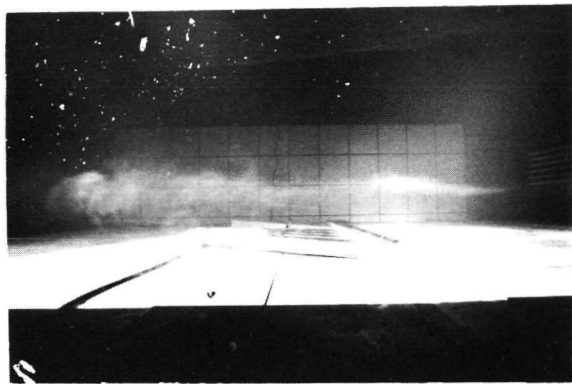
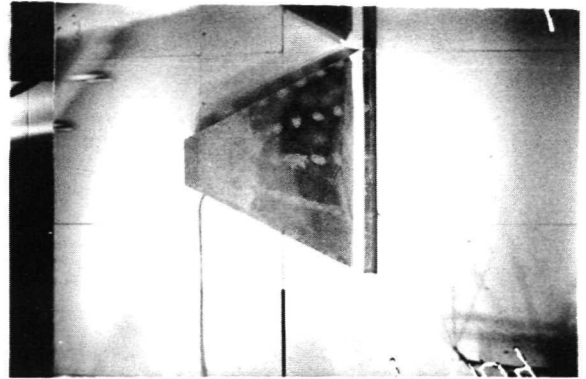


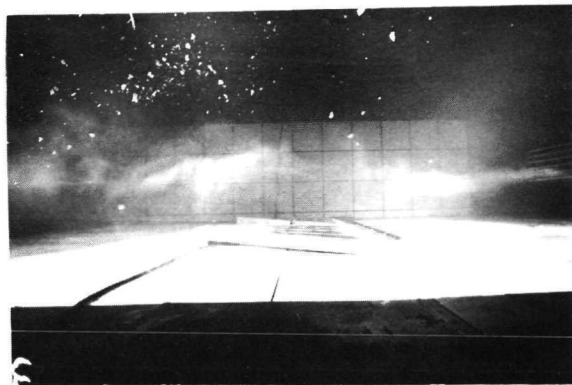
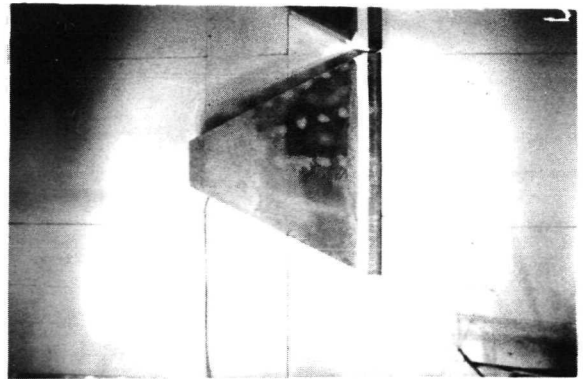
FIGURE 74 - CONCLUDED



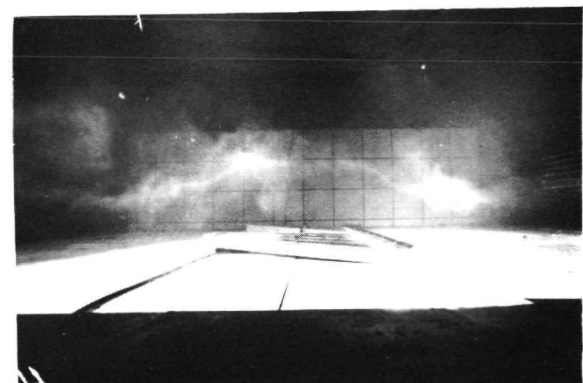
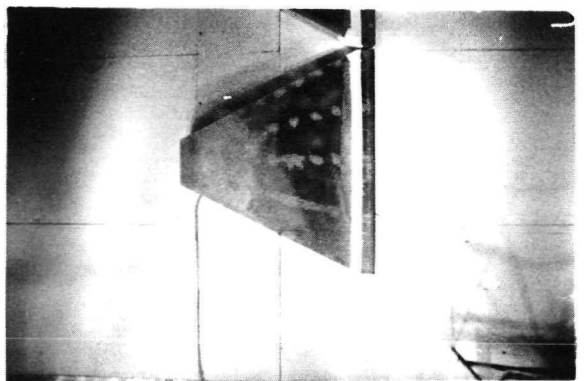
N  
-1.4



3.8



8.9



11.4

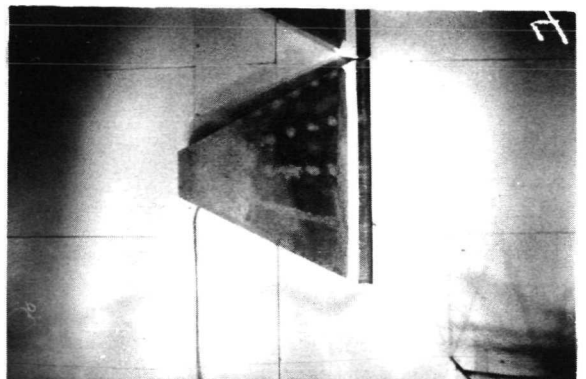
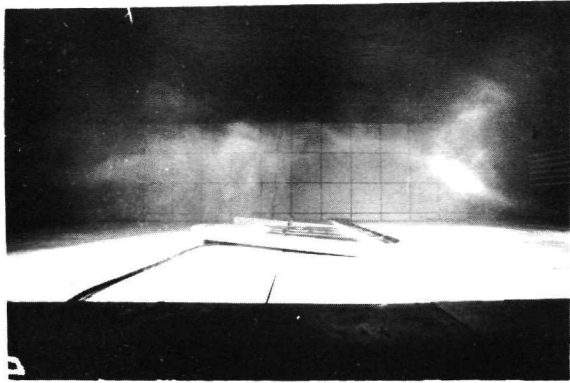
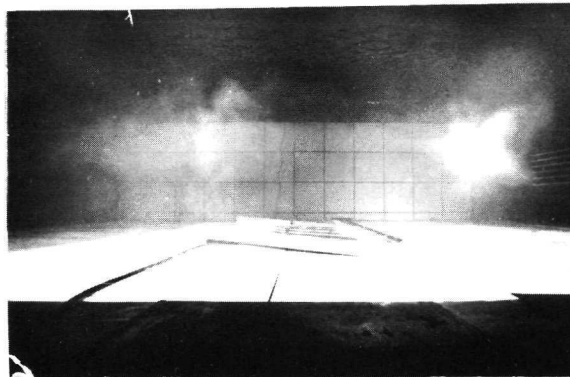
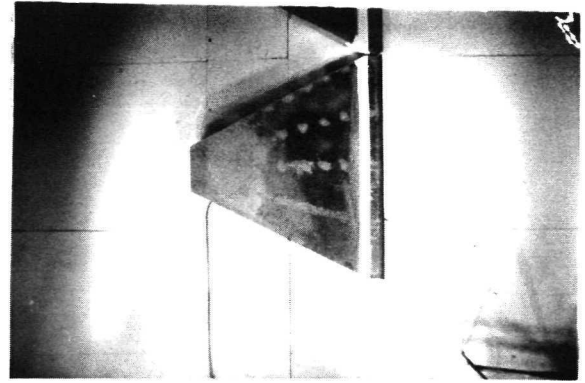


FIGURE 75 - DEVICE G WITH  $V_b/U = 0.129$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.68$  AND ALTITUDE = 13.4 METERS

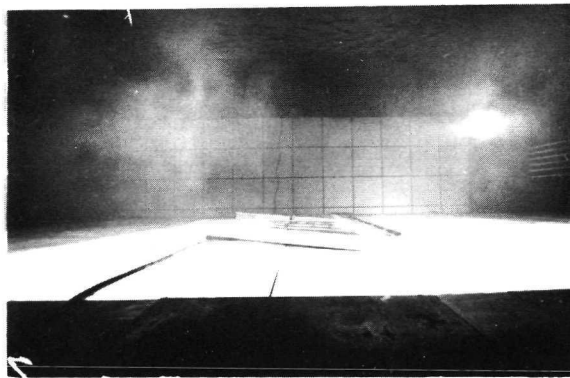
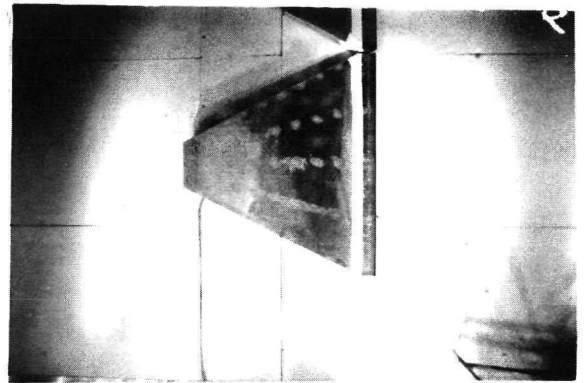


N

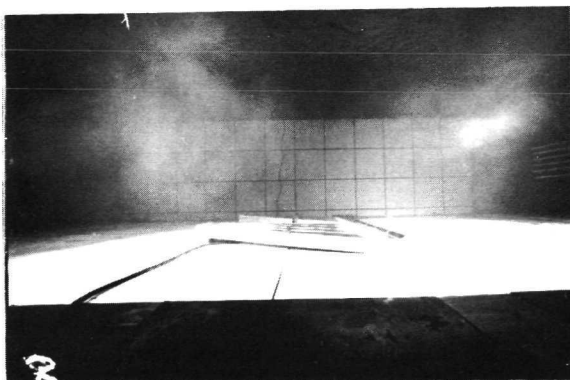
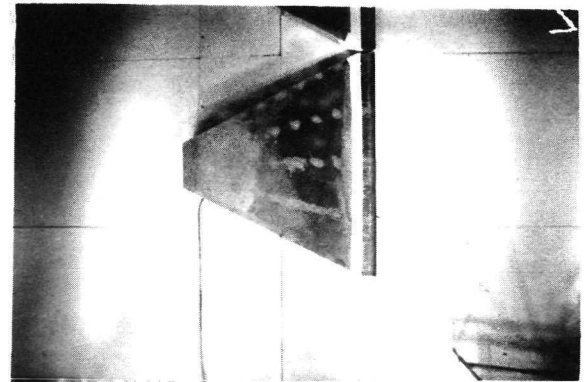
13.9



16.5



19.1



21.6

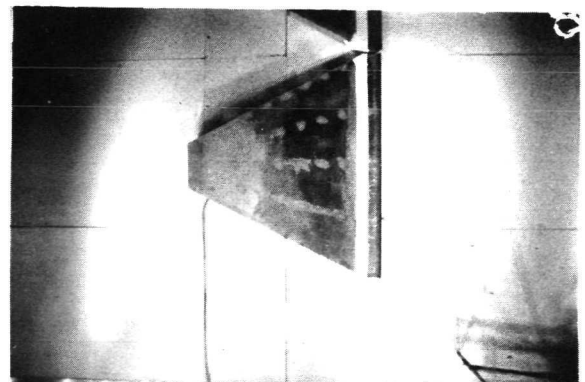
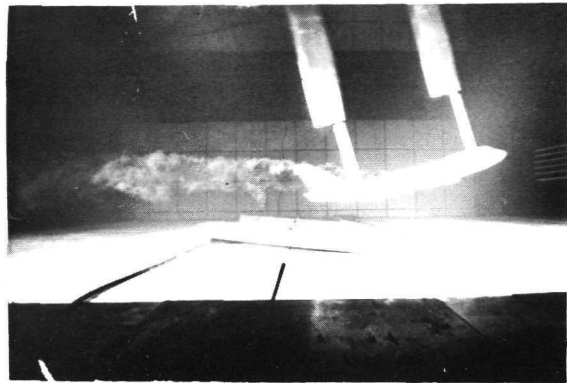
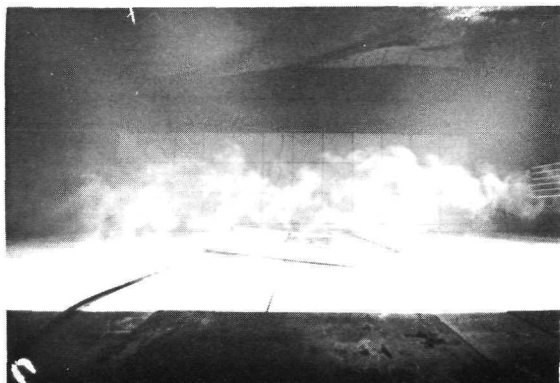
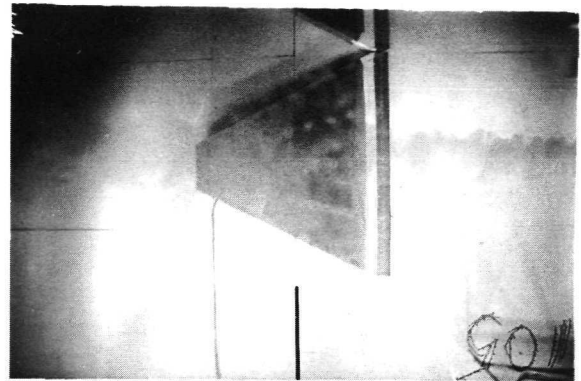


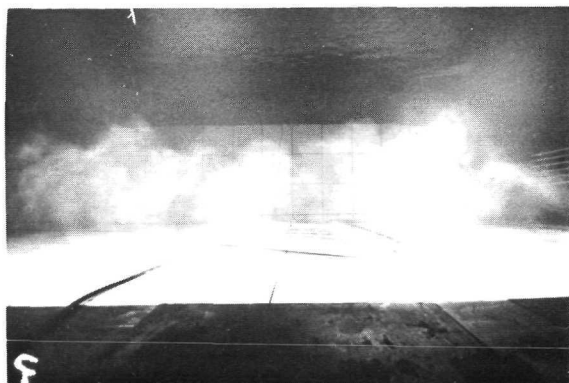
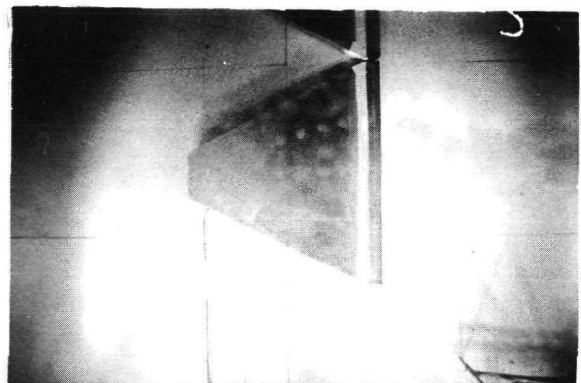
FIGURE 75 - CONCLUDED



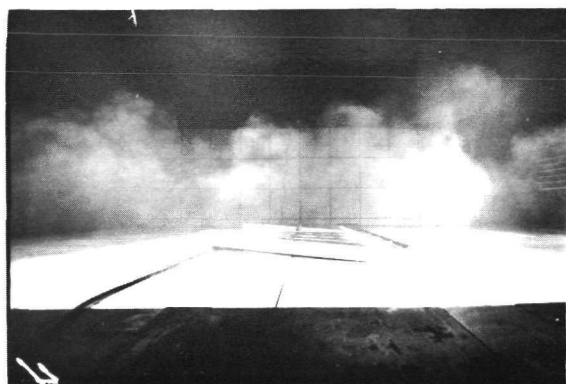
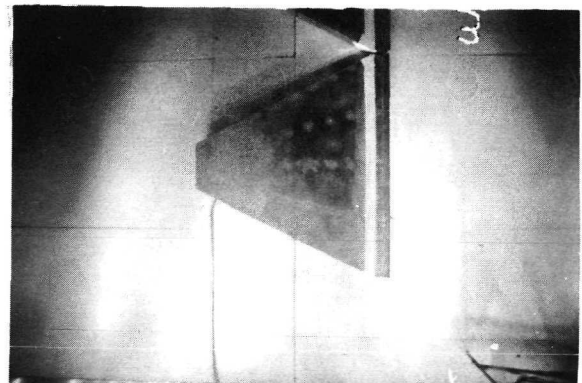
N  
0.5



2.6



5.6



7.7

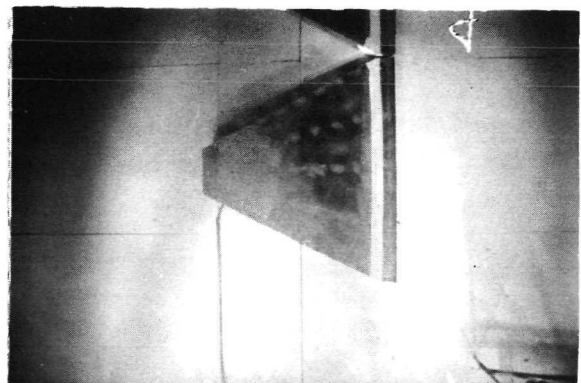
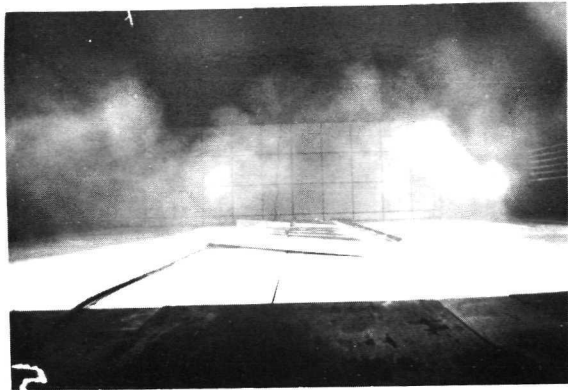
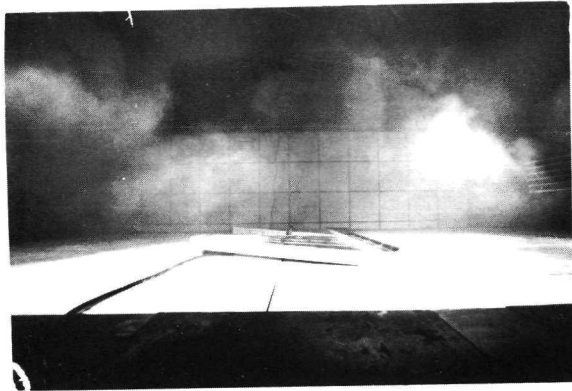
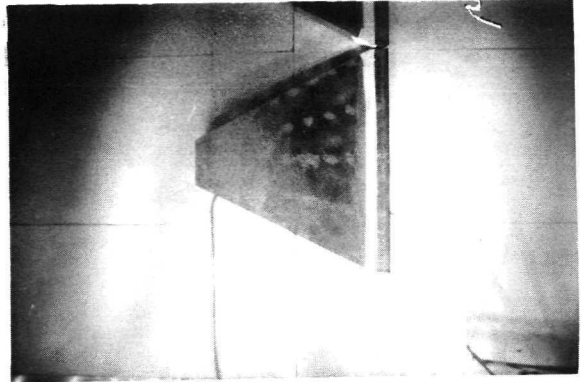


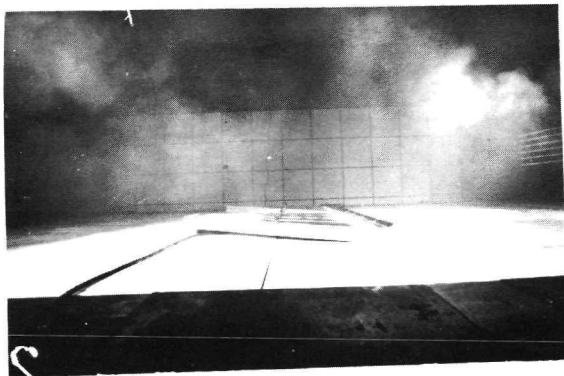
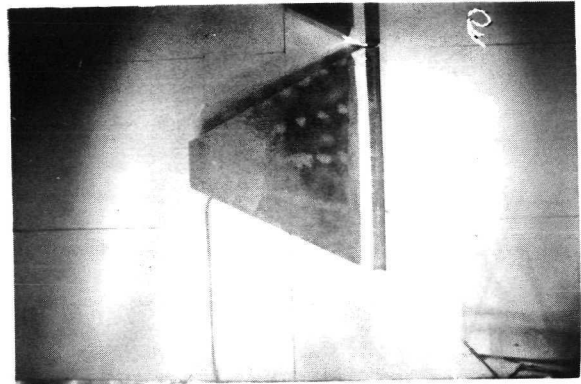
FIGURE 76 - DEVICE G WITH  $V_b/U = 0.323$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.76$  AND ALTITUDE = 13.4 METERS



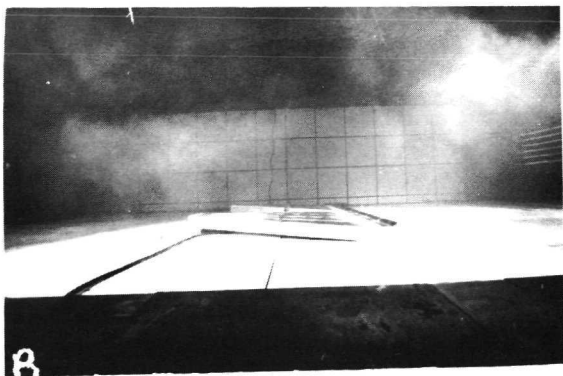
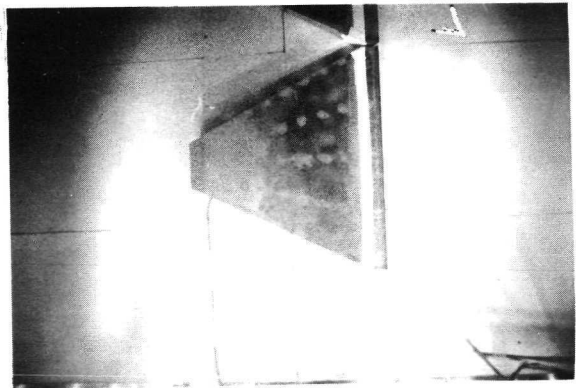
N  
10.7



12.8



14.8



16.9

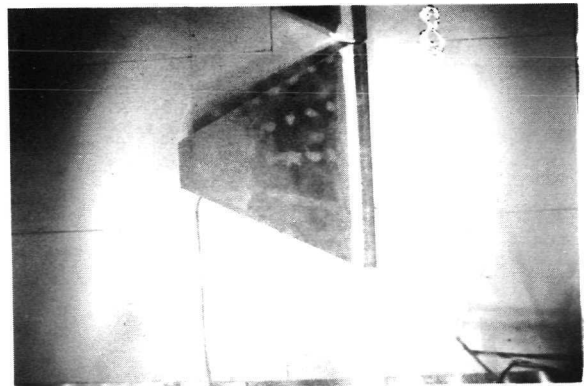
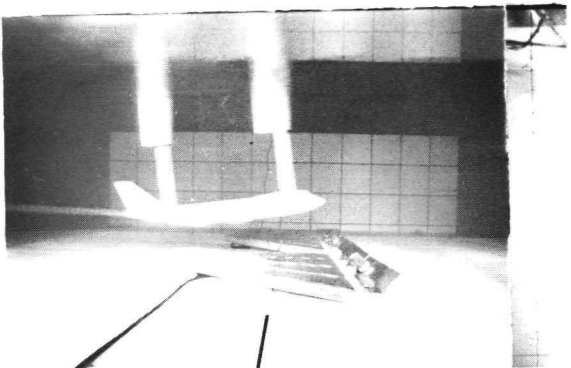
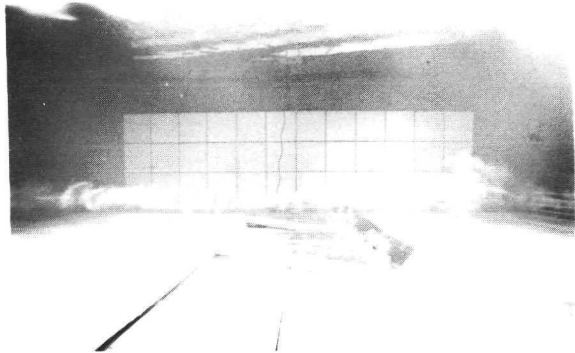
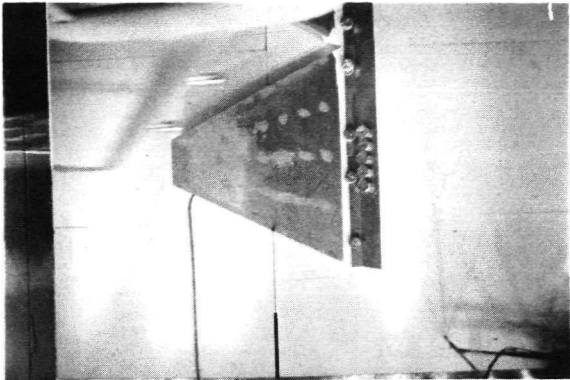


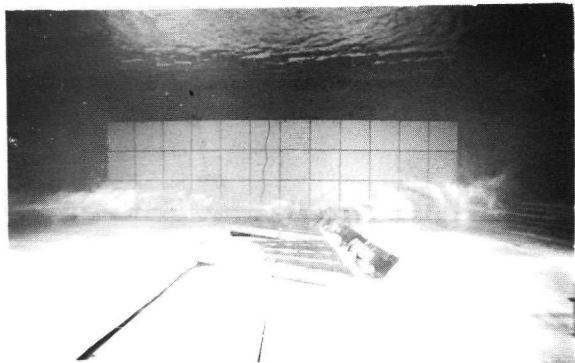
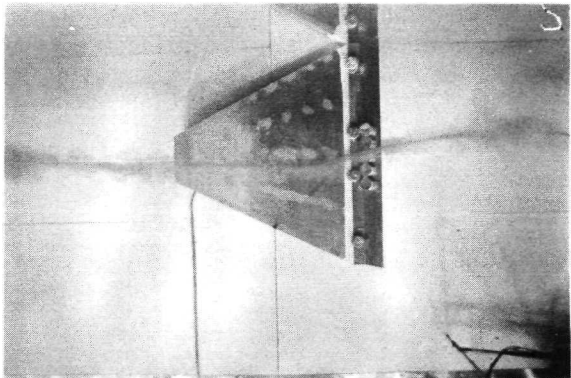
FIGURE 76 - CONCLUDED



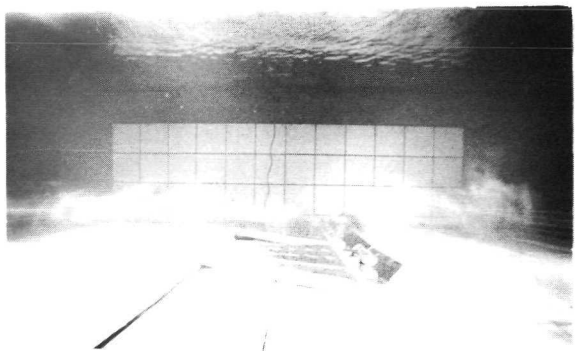
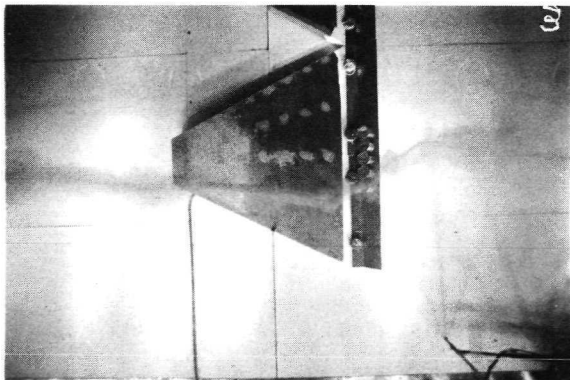
N  
-0:8



5.4



9.5



13.5

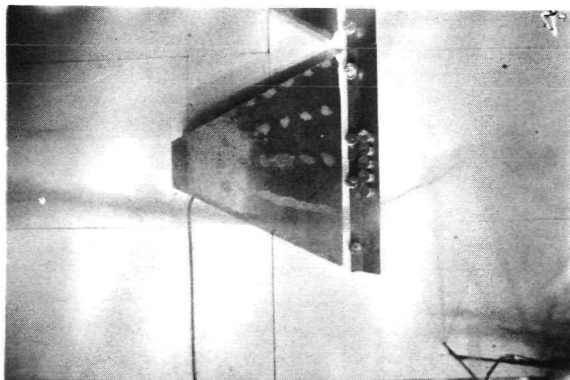
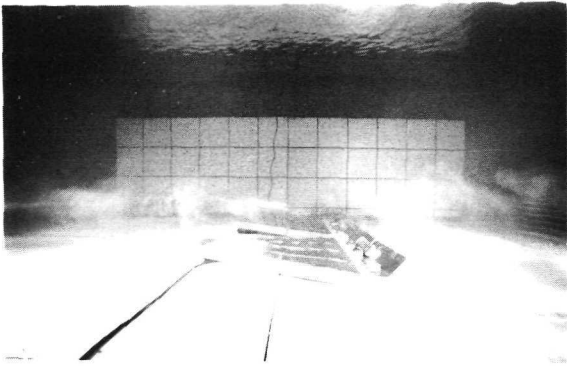
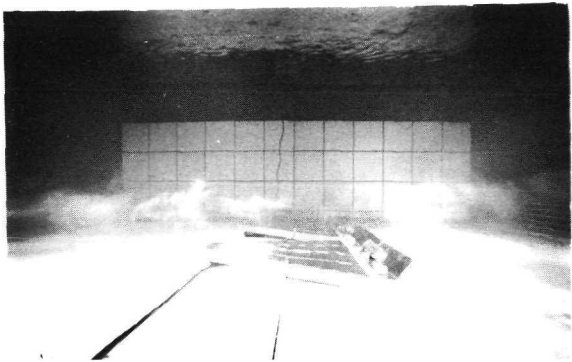
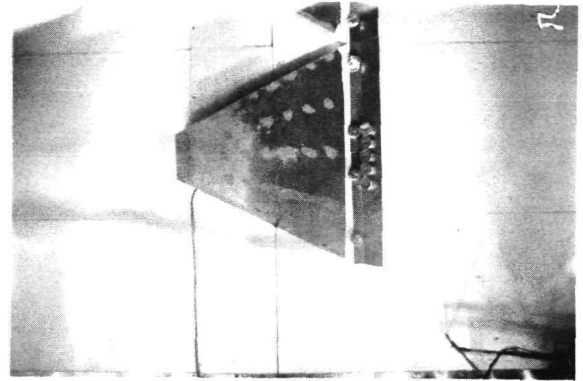


FIGURE 77 - DEVICE G1 WITH  $V_b/U = 0.162$  - EFFECT ON VORTEX WAKE FOR CRUISE CONDITION,  $C_L = 0.71$  AND ALTITUDE = 13.4 METERS

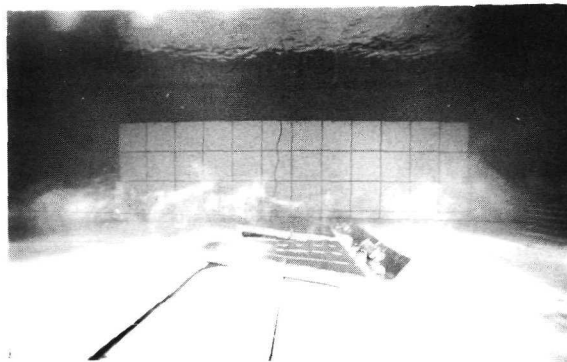
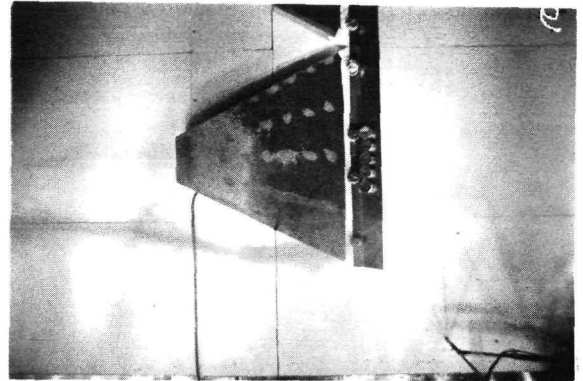
HYDRONAUTICS, INCORPORATED



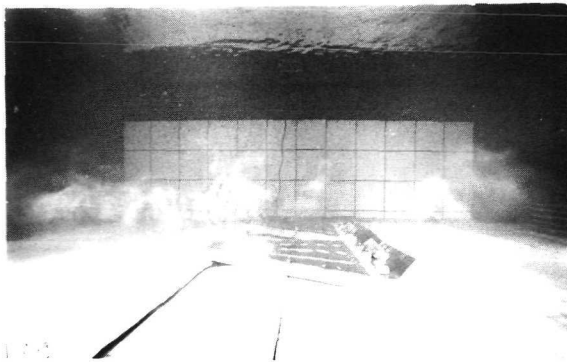
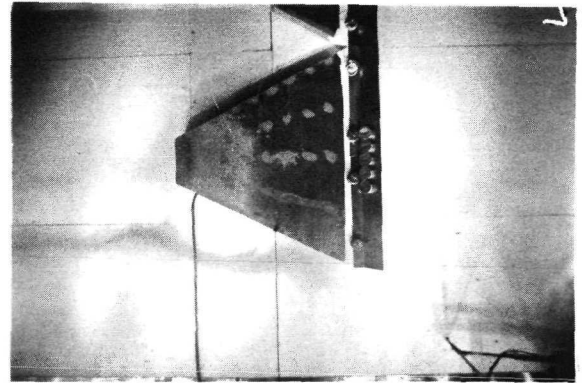
N  
17.6



19.7



21.7



25.9

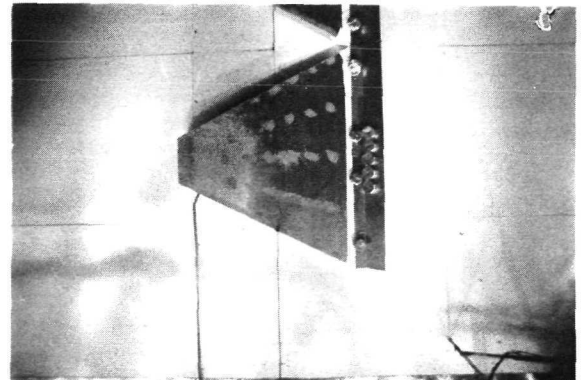
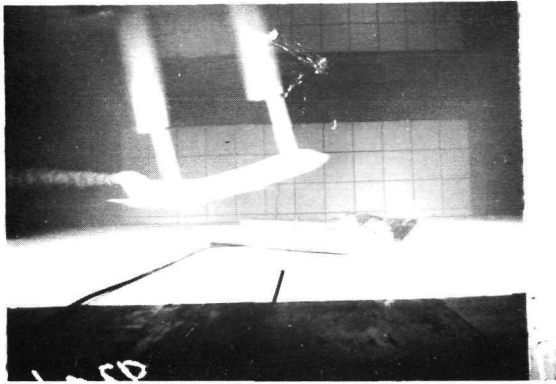
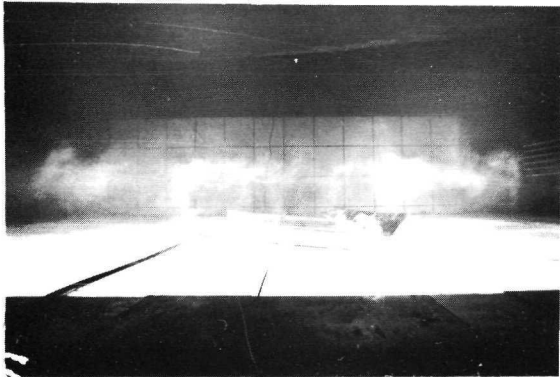
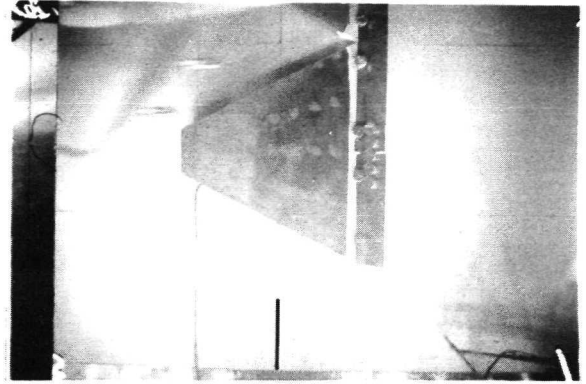


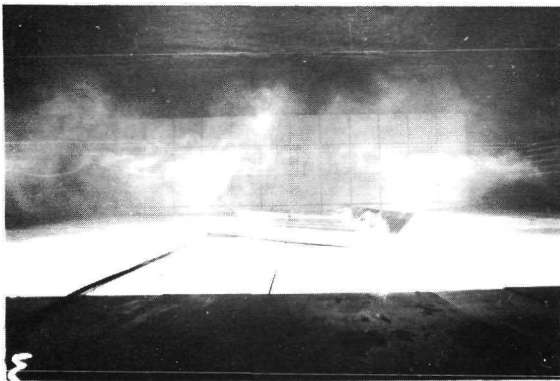
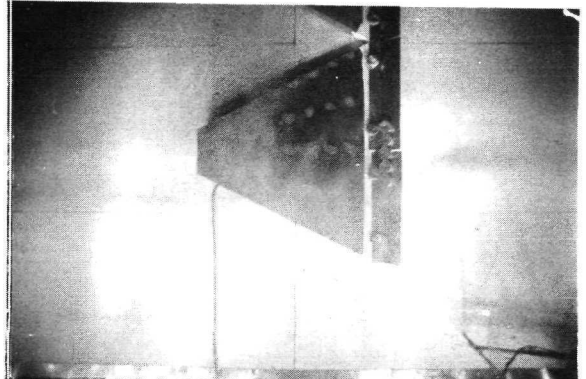
FIGURE 77 - CONCLUDED



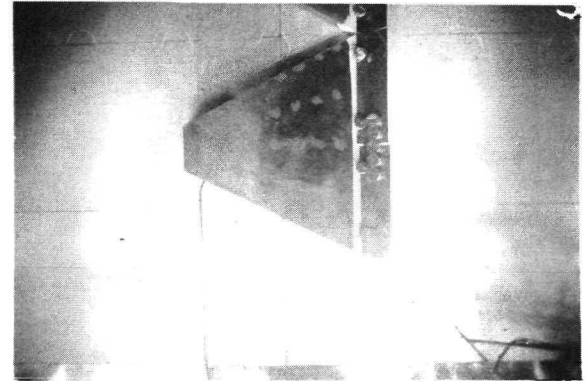
N  
-0.9



4.2



9.3



14.4

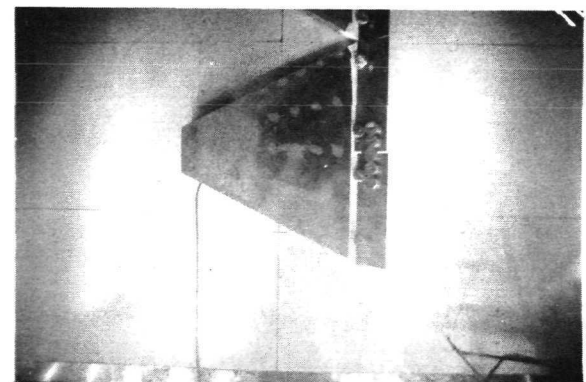
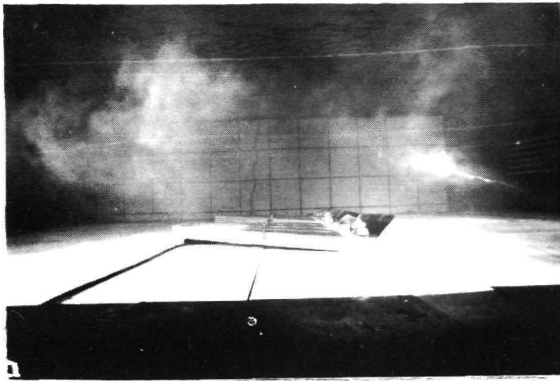
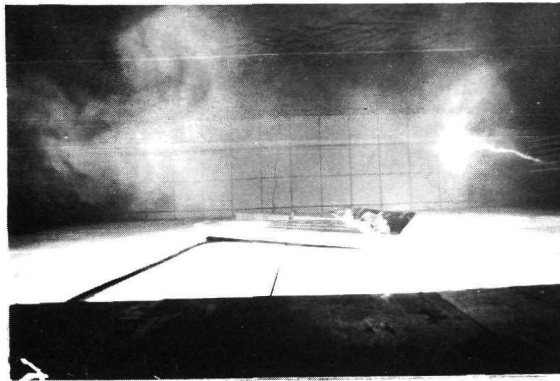
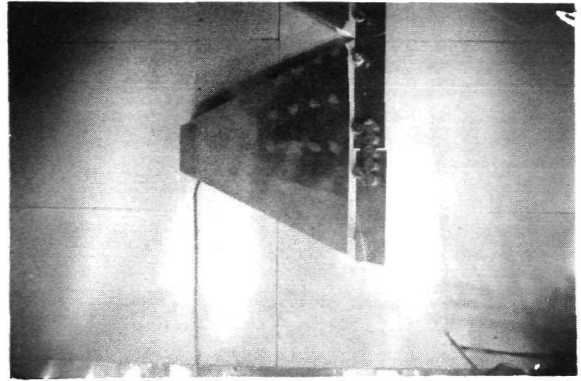


FIGURE 78 - DEVICE G1 WITH  $V_b/U = 0.129$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.68$  AND ALTITUDE = 13.4 METERS

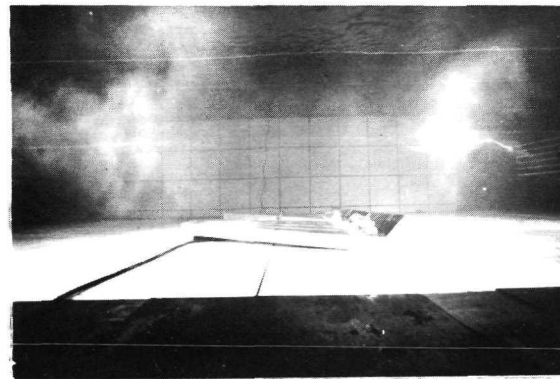
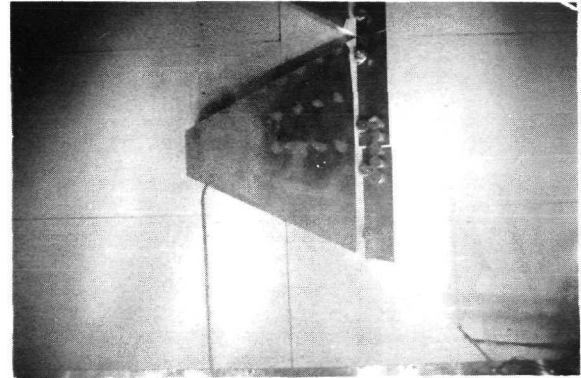
HYDRONAUTICS, INCORPORATED



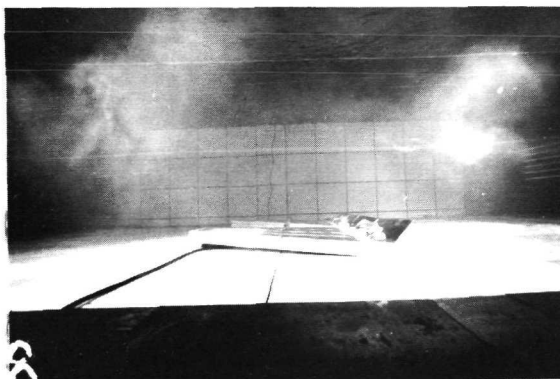
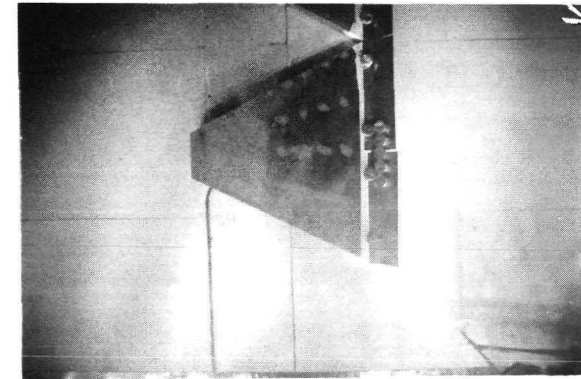
N  
17.0



19.5



22.1



24.6

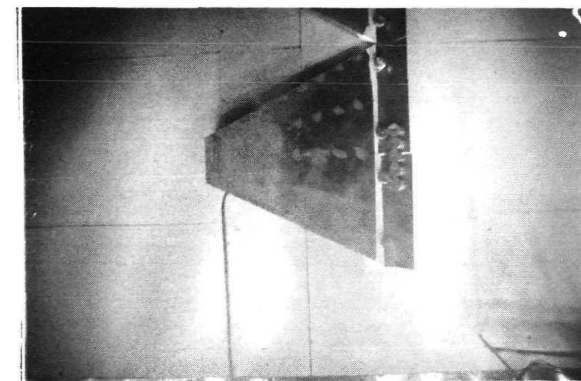
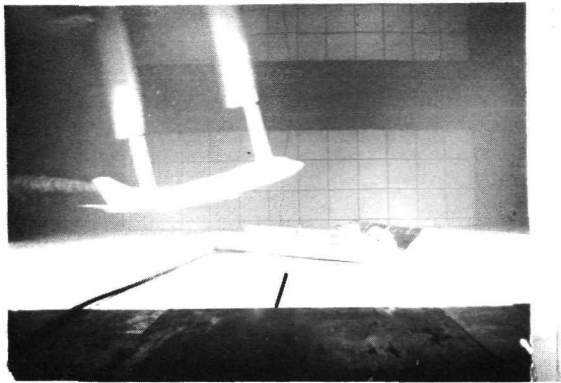
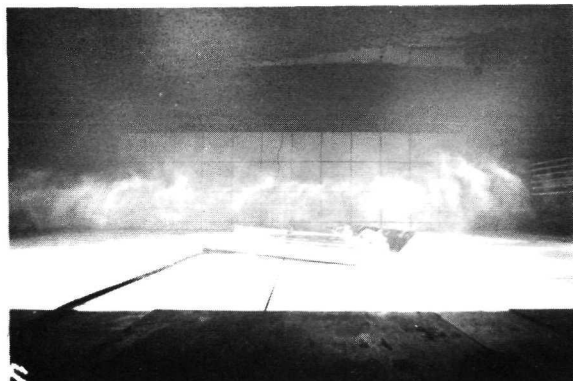
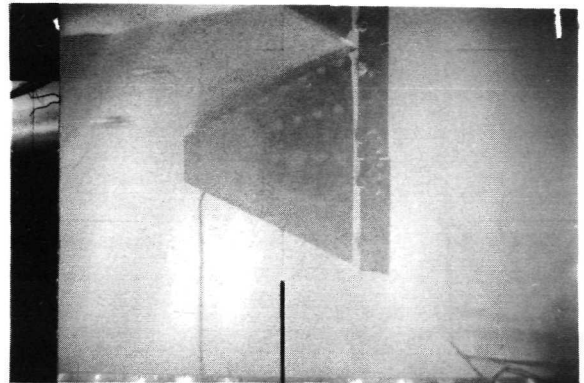


FIGURE 78 - CONCLUDED

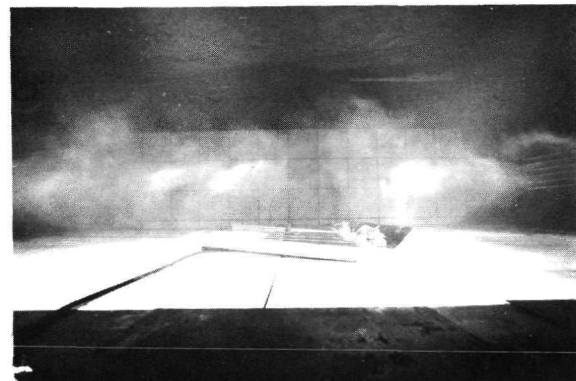
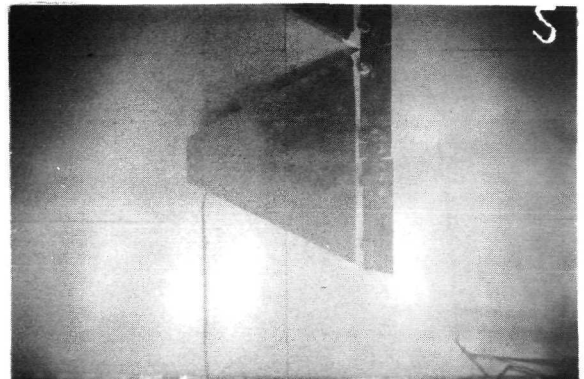
HYDRONAUTICS, INCORPORATED



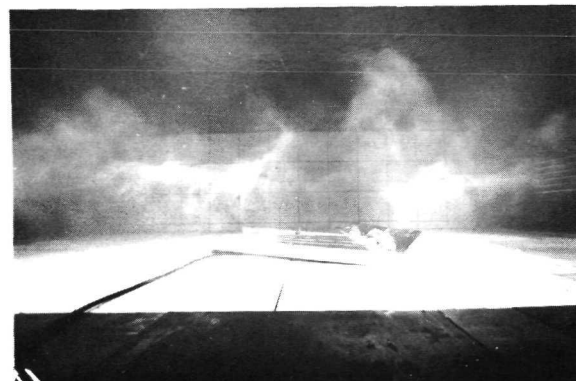
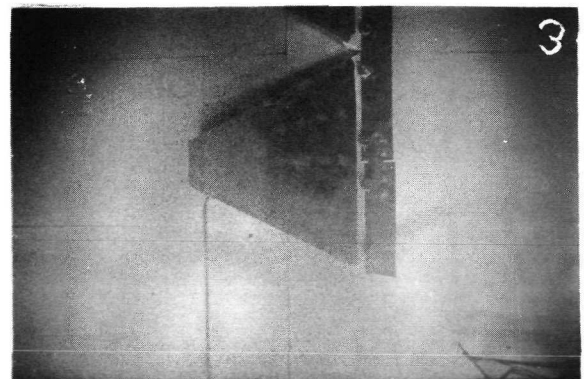
$2.0 \times 10^6$



$3.0 \times 10^6$



$7.0 \times 10^6$



$9.1 \times 10^6$

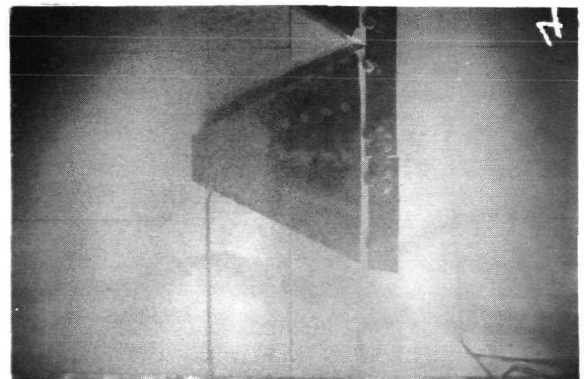
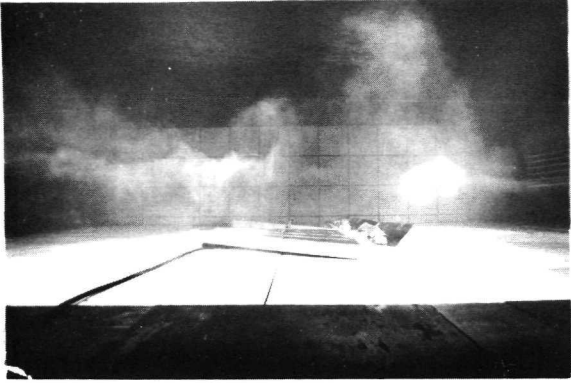
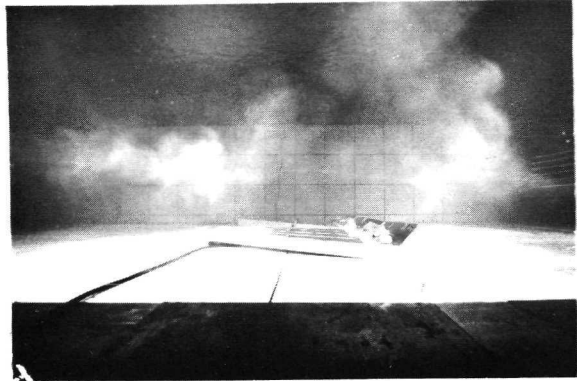
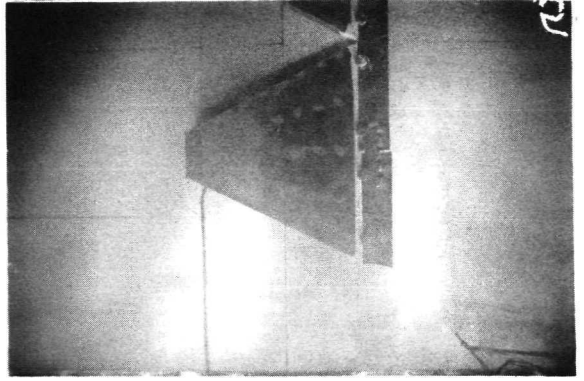


FIGURE 79 - DEVICE G1 WITH  $V_b/U = 0.162$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.81$  AND ALTITUDE = 13.4 METERS

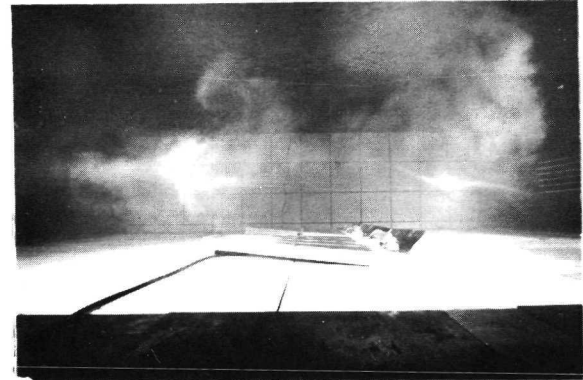
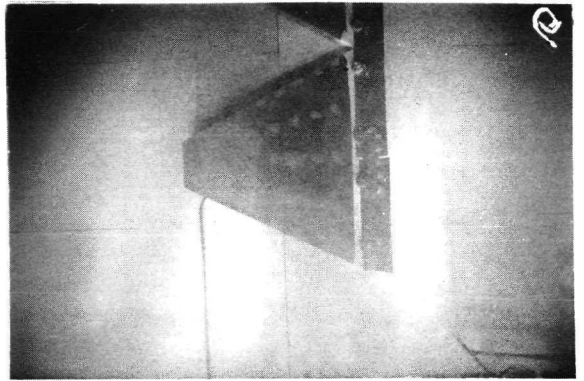


N

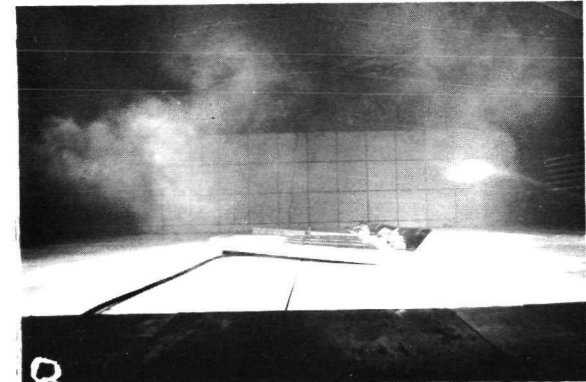
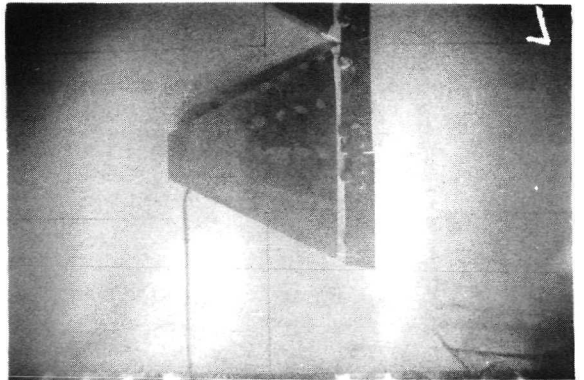
11.2



13.2



15.2



19.3

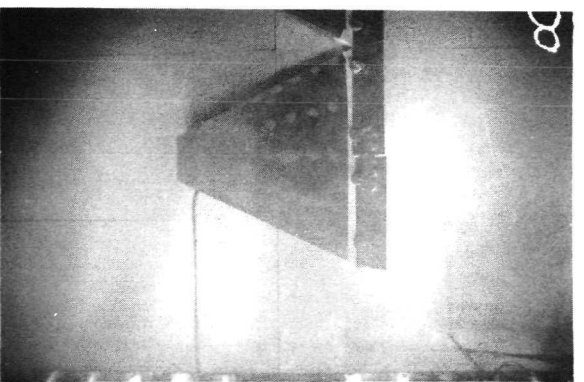
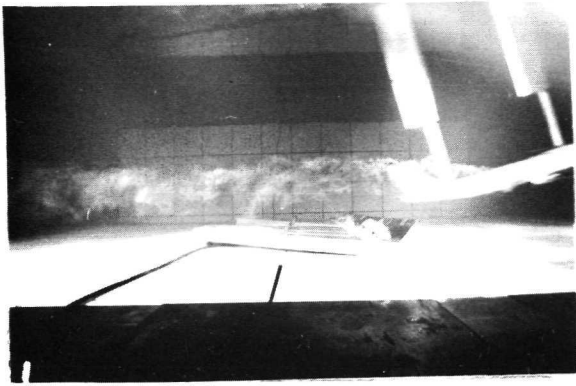
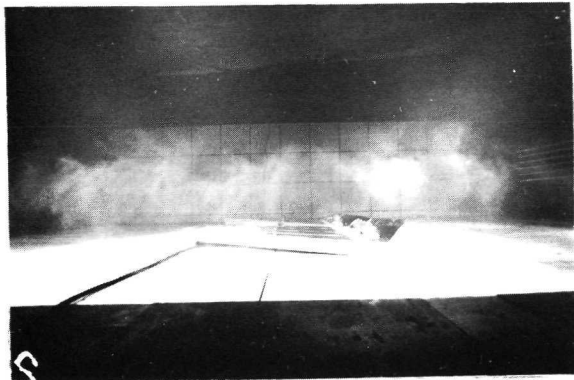
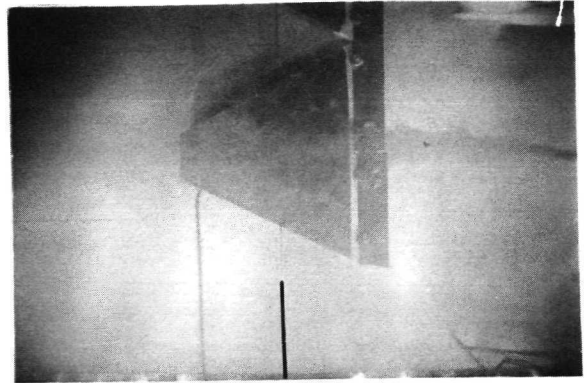


FIGURE 79 - CONCLUDED

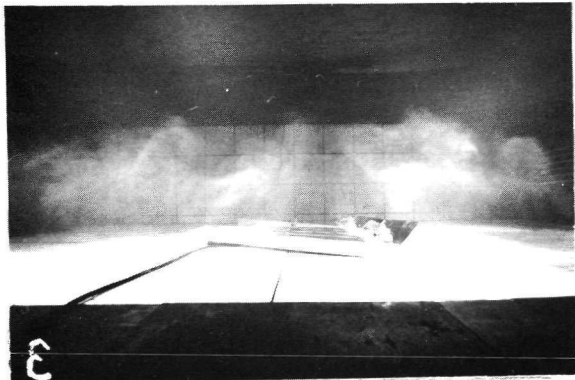
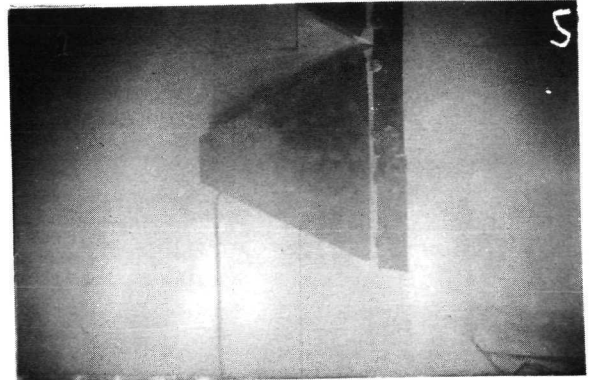


N

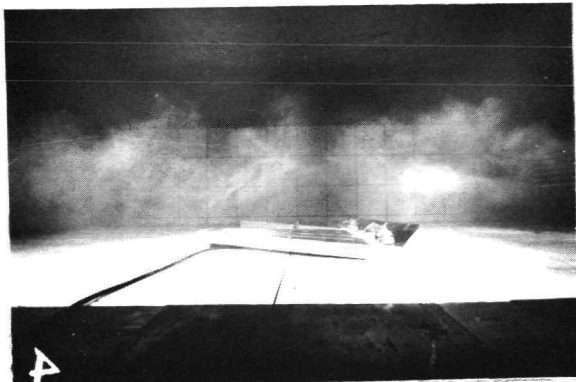
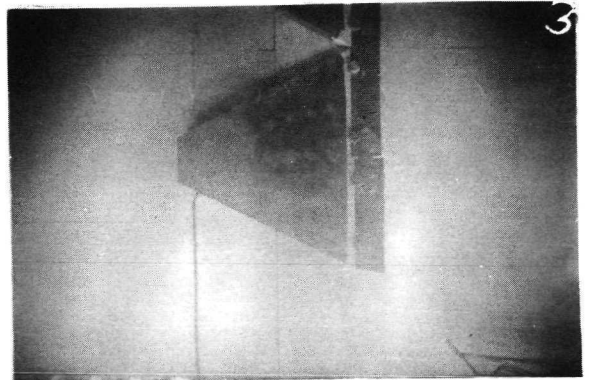
1.3



4.7



6.4



8.1

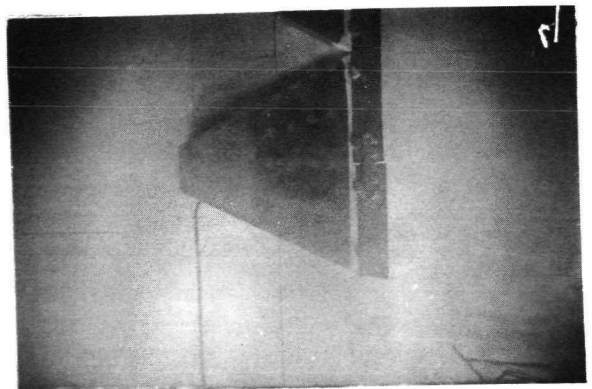
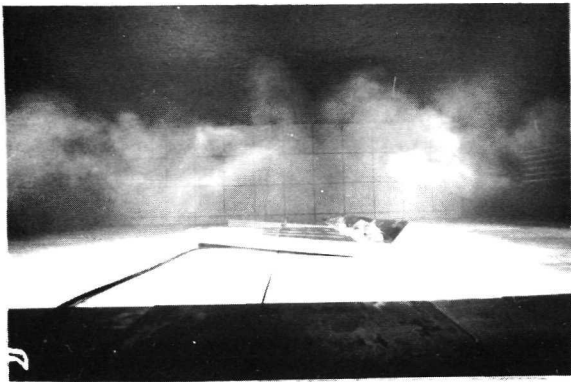
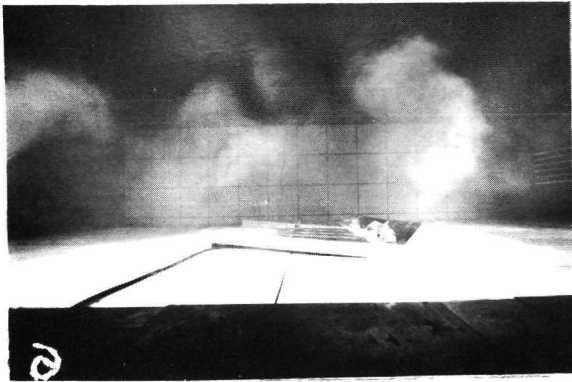
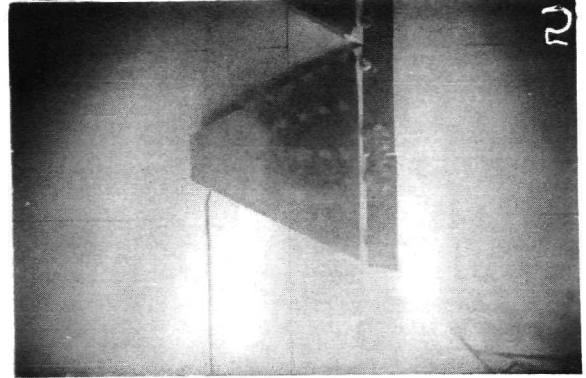


FIGURE 80 - DEVICE G1 WITH  $V_b/U = 0.194$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.83$  AND ALTITUDE = 13.4 METERS

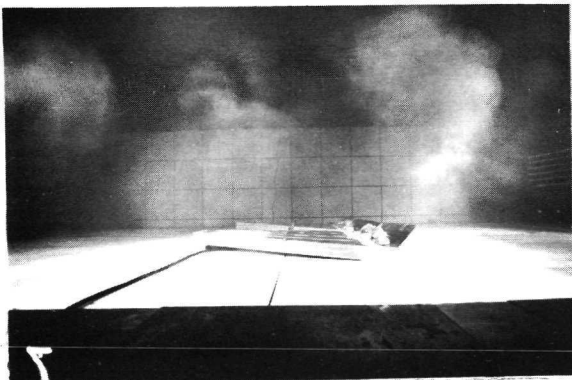
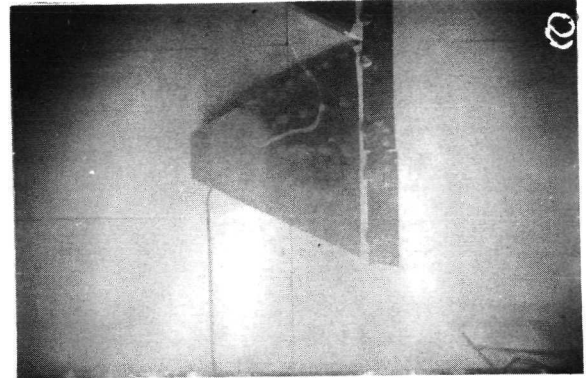


N

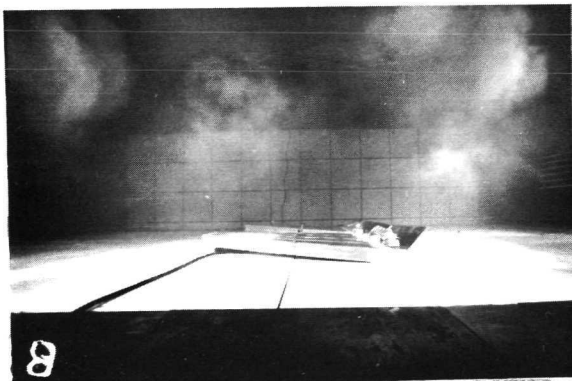
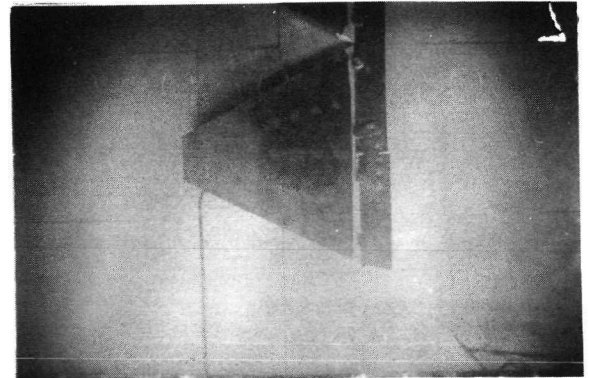
9.8



11.5



13.2



15.0

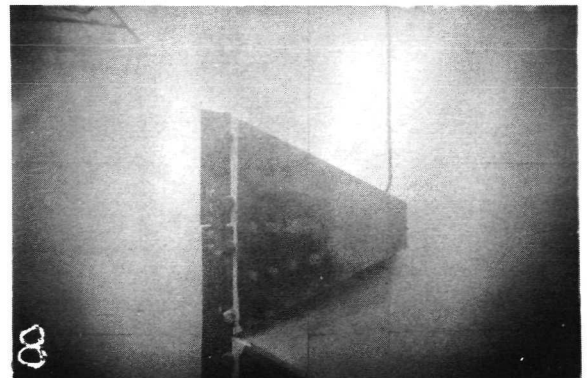
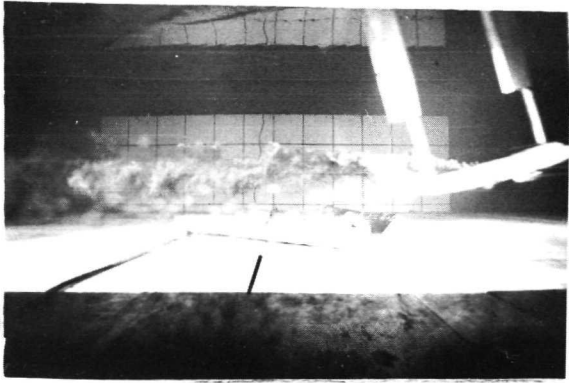
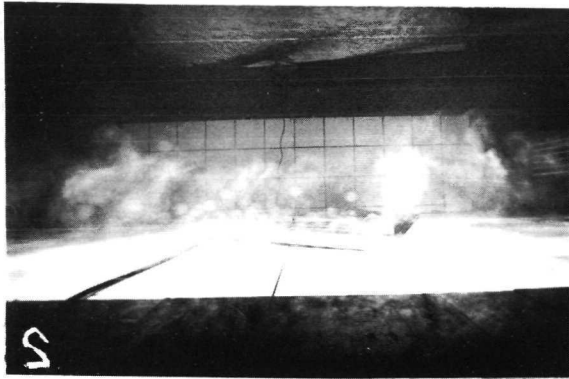
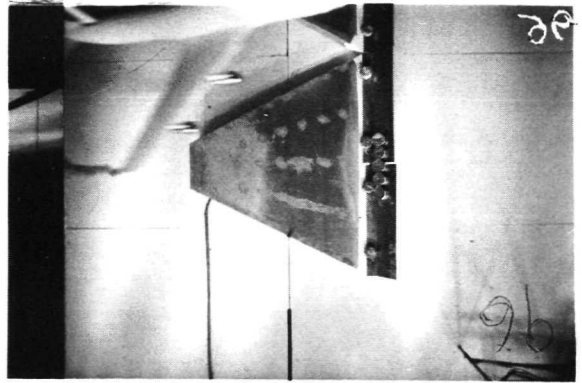


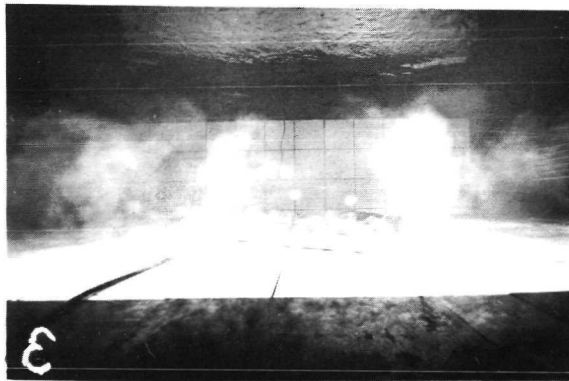
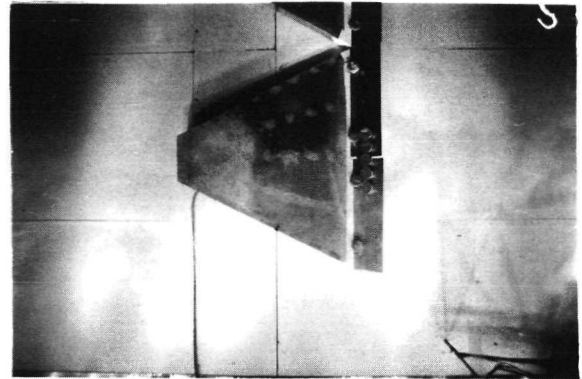
FIGURE 80 - CONCLUDED



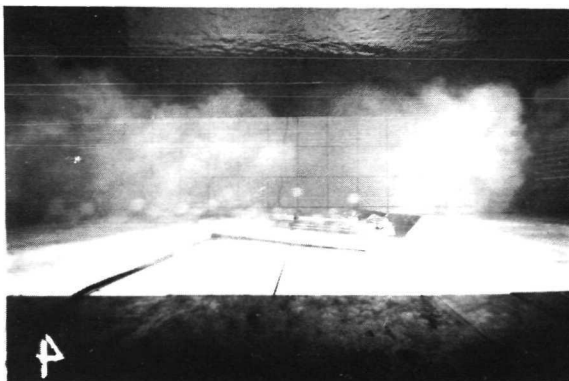
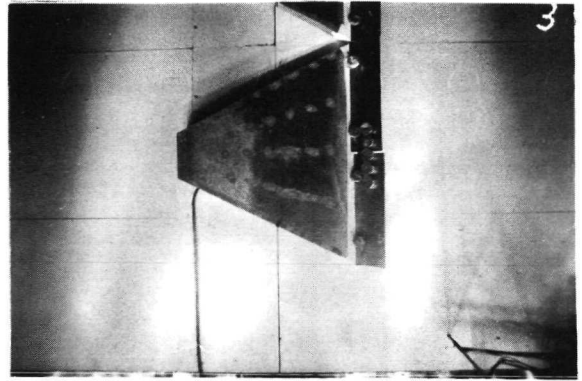
N  
1.3



4.0



6.8



9.5

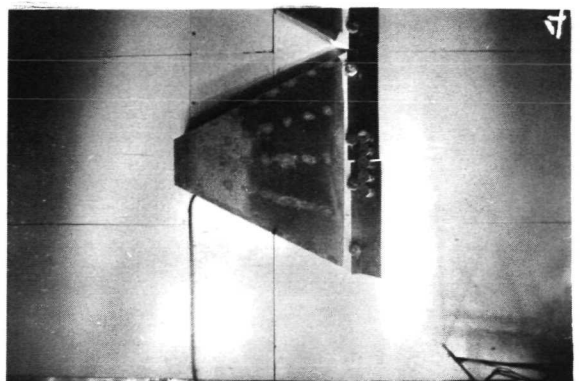
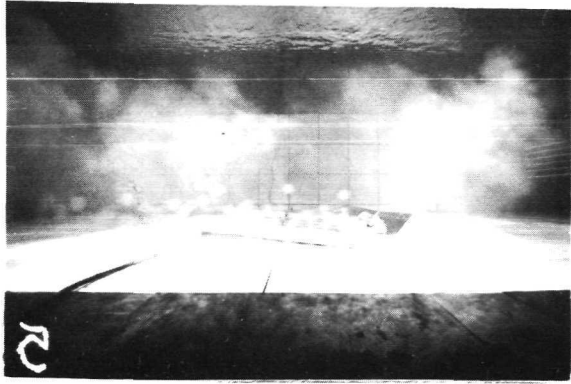
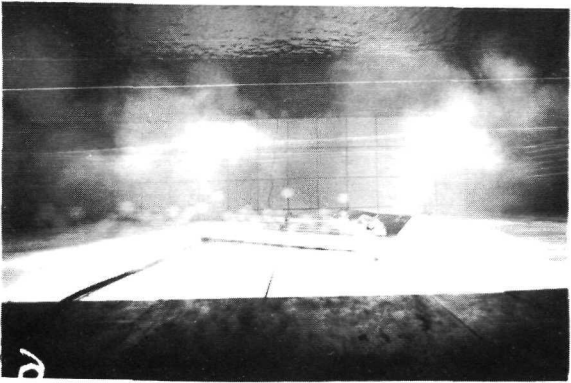
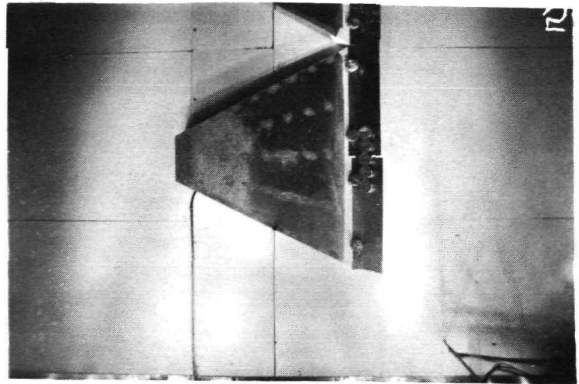


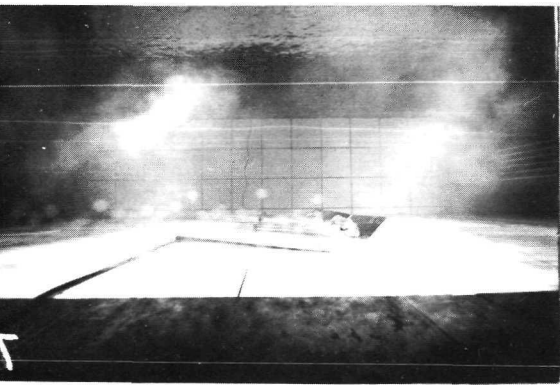
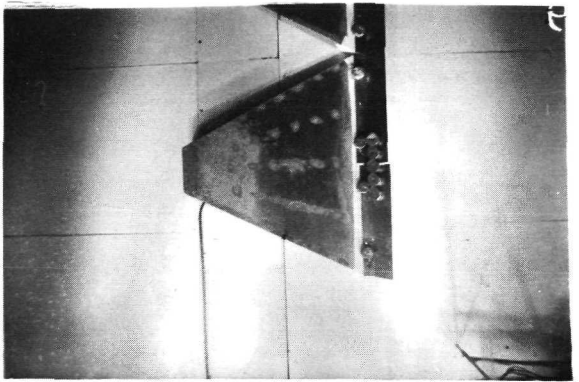
FIGURE 81 - DEVICE G1 WITH  $V_b/U = 0.243$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.80$  AND ALTITUDE = 13.4 METERS



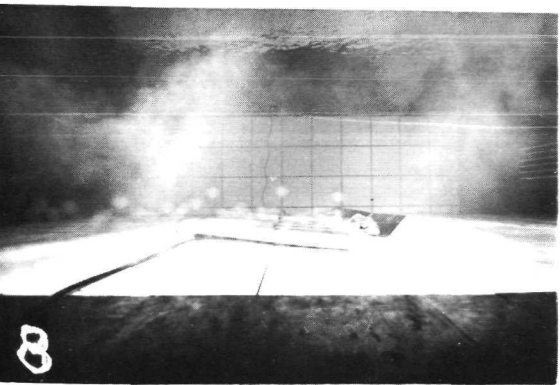
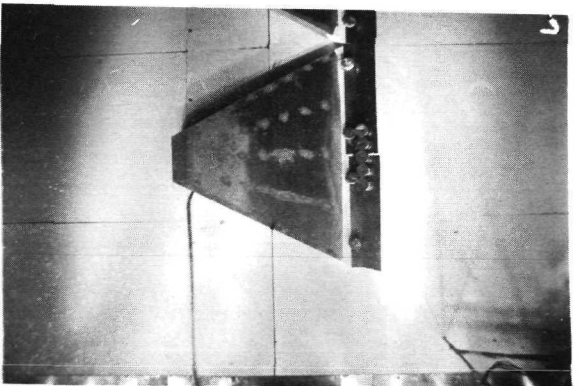
N  
10.8



12.2



14.9



17.7

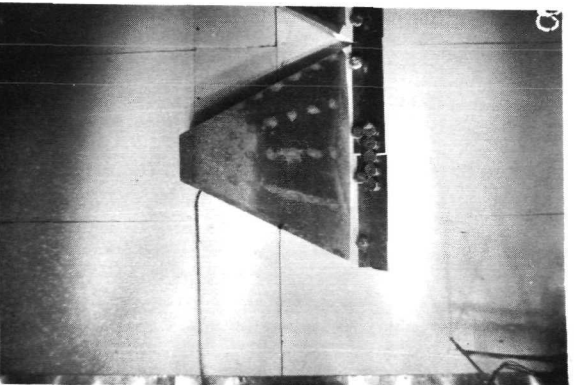
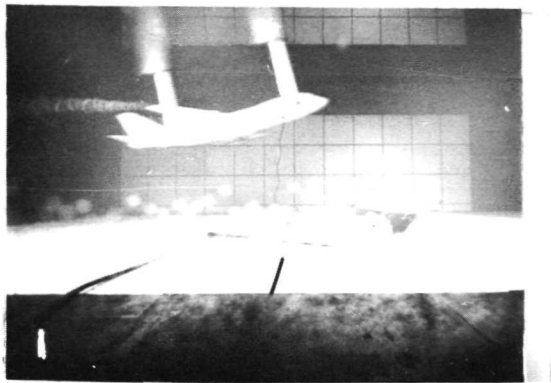
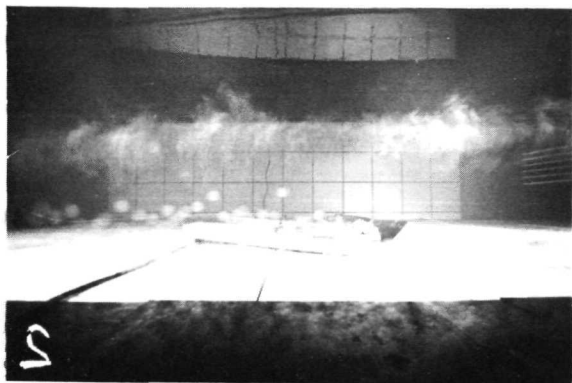
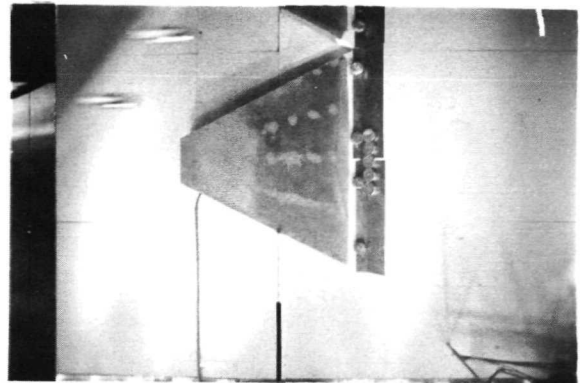


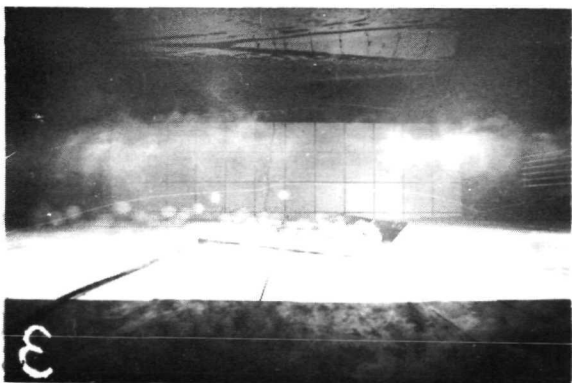
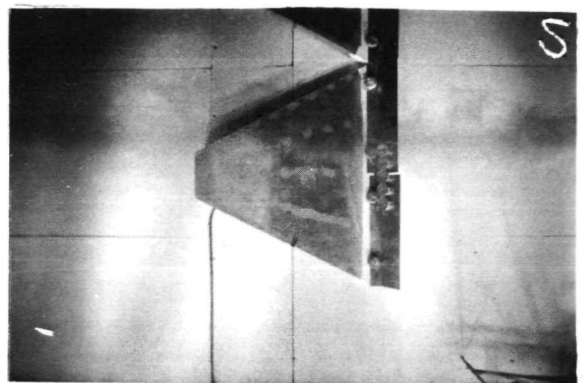
FIGURE 81 - CONCLUDED



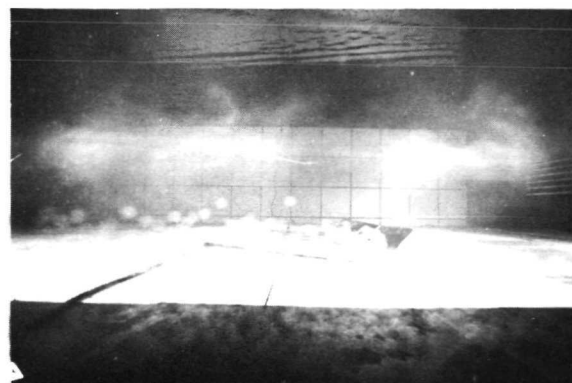
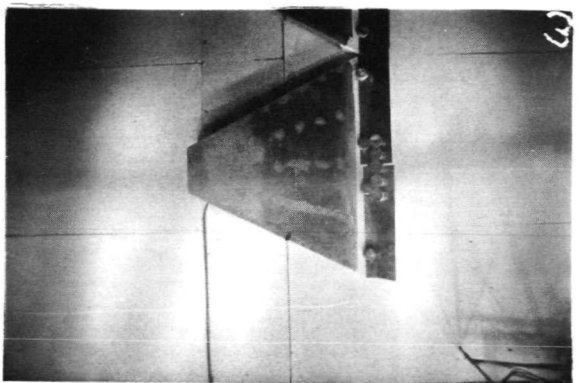
N  
-0.9



4.2



9.3



14.4

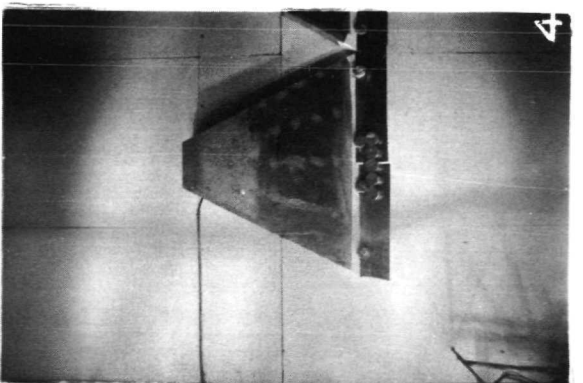
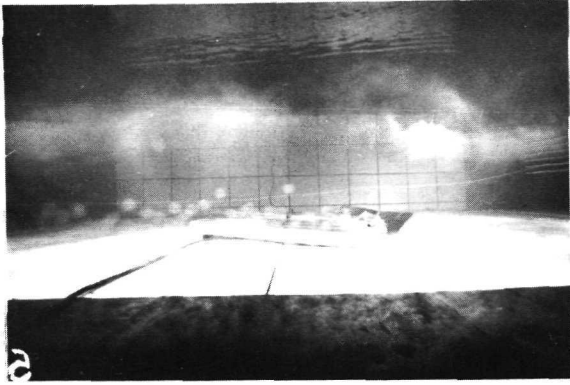
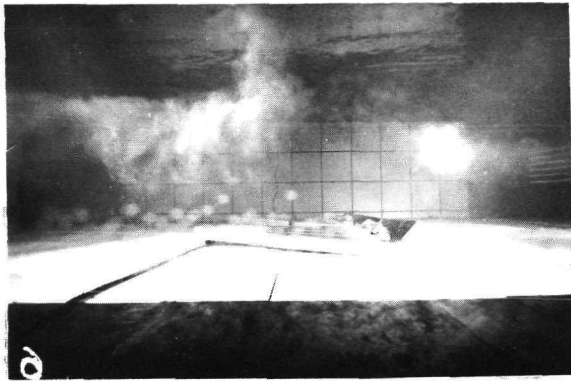
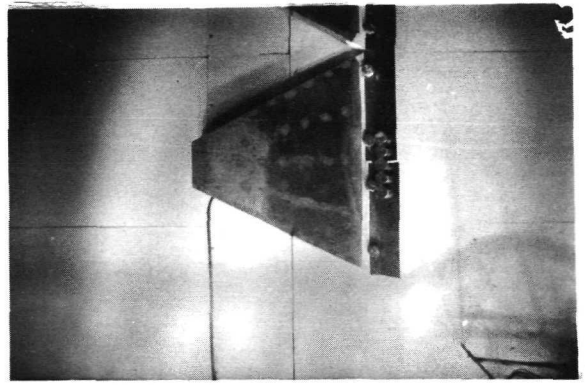


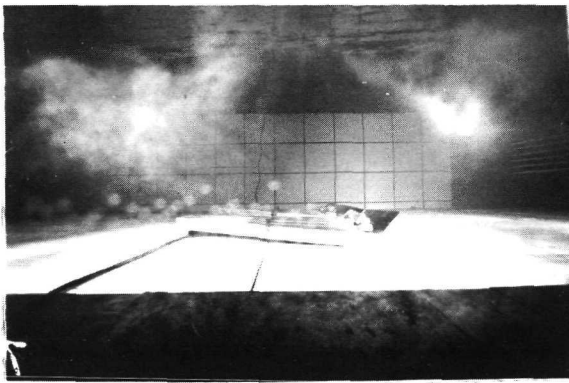
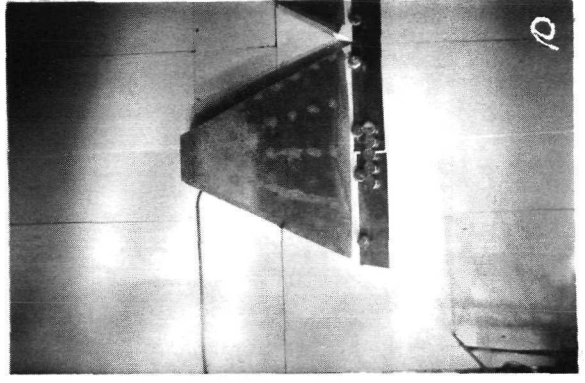
FIGURE 82 - DEVICE G1 WITH  $V_b/U = 0.129$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.68$  AND ALTITUDE  $\approx 30.5$  METERS



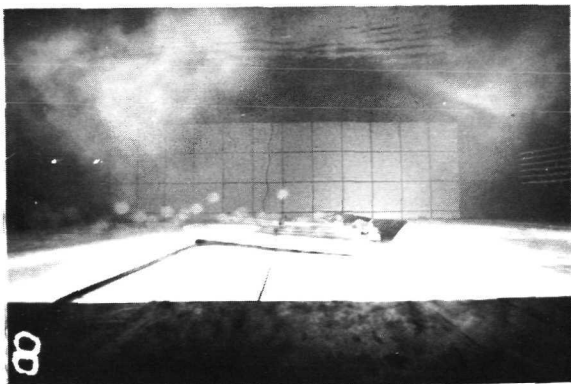
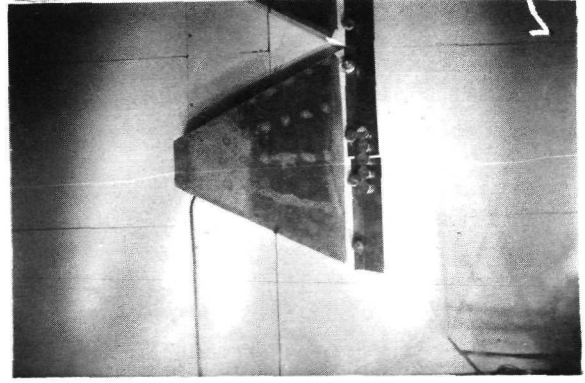
N  
19.5



24.6



29.7



34.9

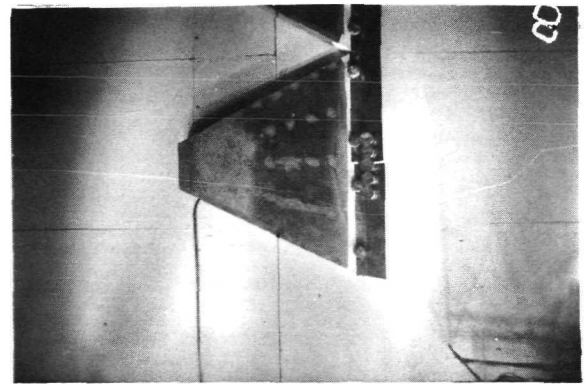
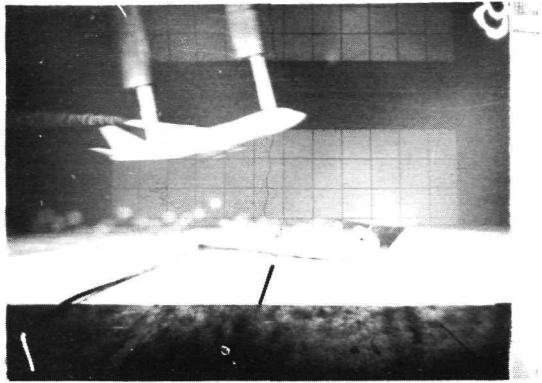
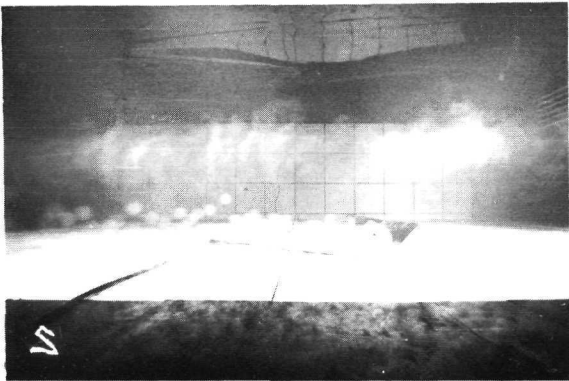
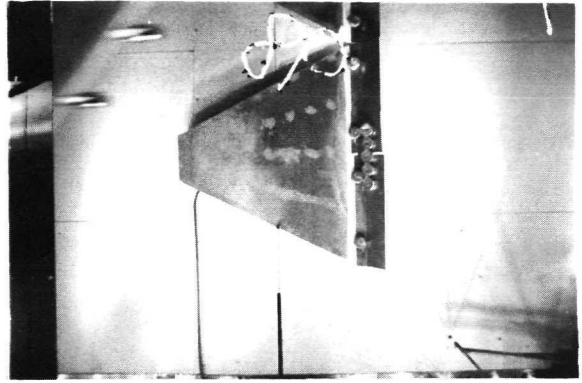


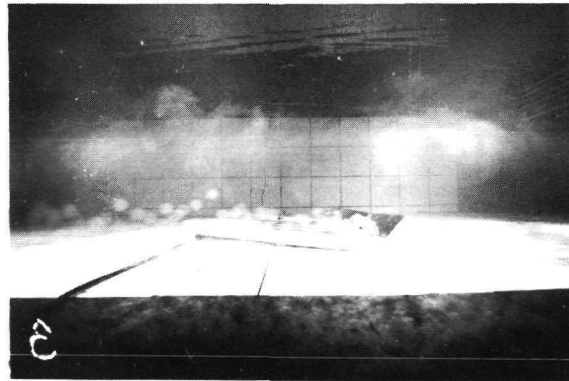
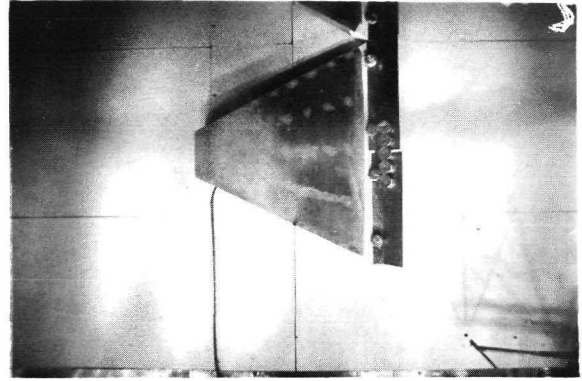
FIGURE 82 - CONCLUDED



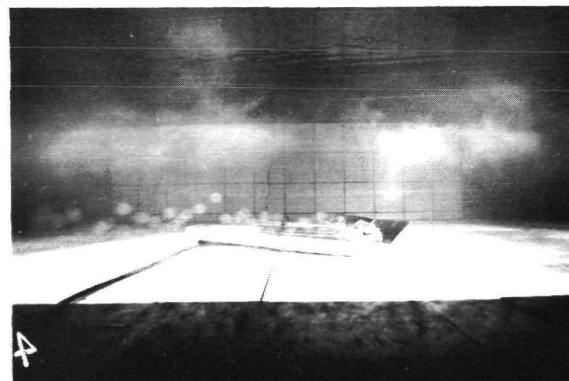
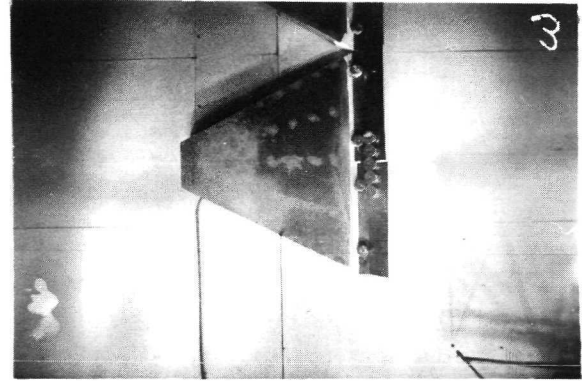
N  
0.9



5.2



9.3



15.4

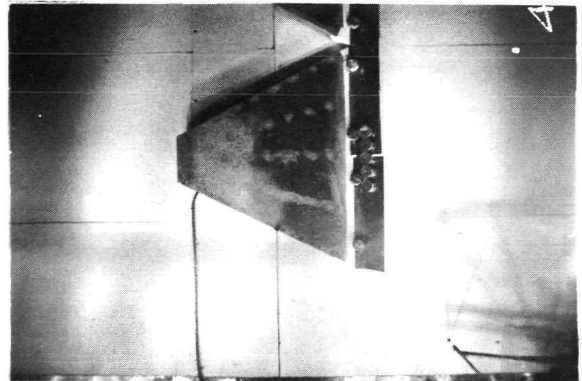
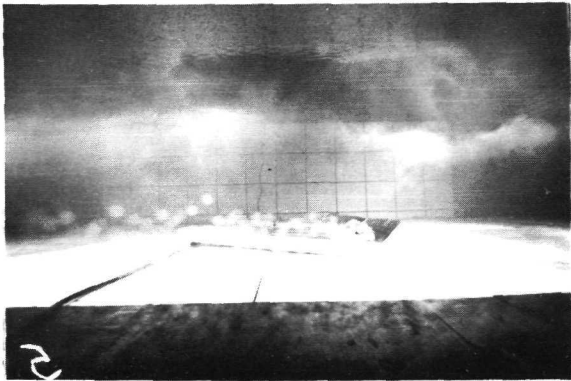
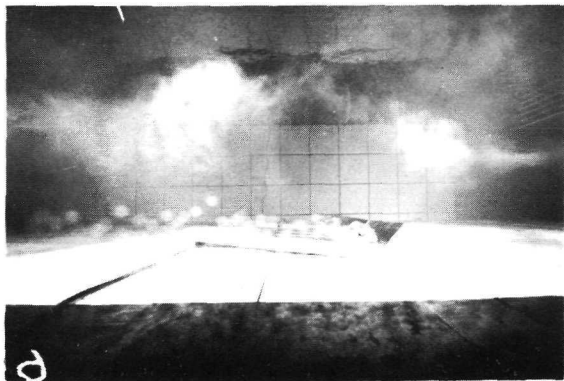
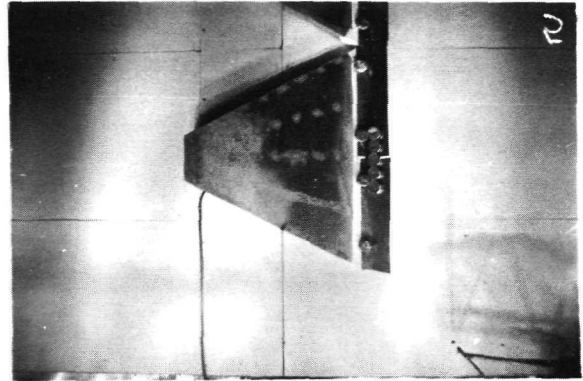


FIGURE 83 - DEVICE G1 WITH  $V_b/U = 0.162$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.79$  AND ALTITUDE = 30.5 METERS

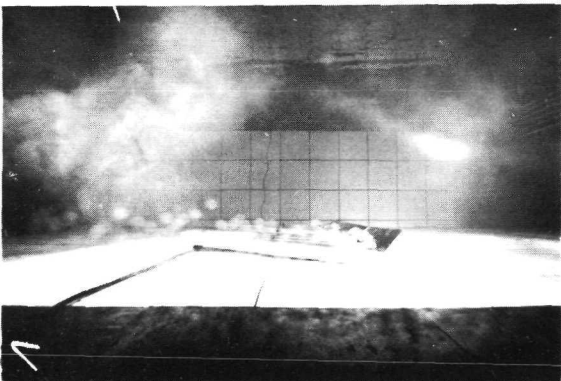
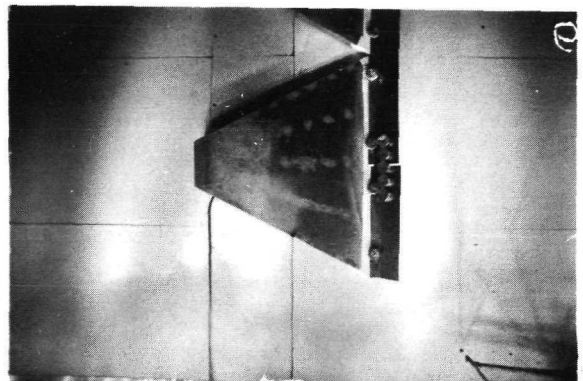
HYDRONAUTICS, INCORPORATED



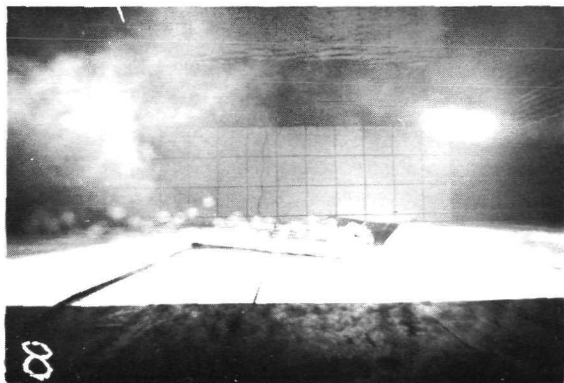
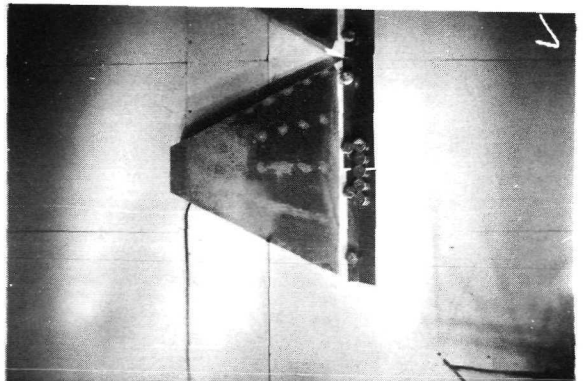
N  
19.5



23.6



29.7



33.8

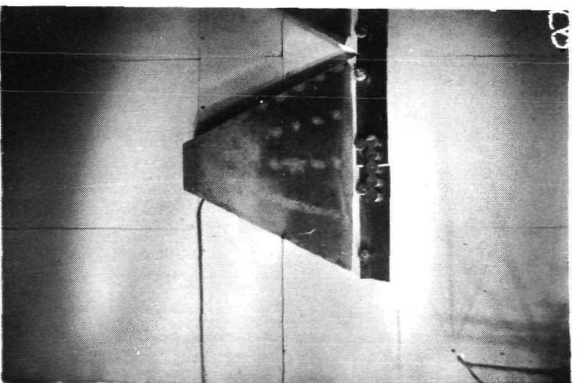
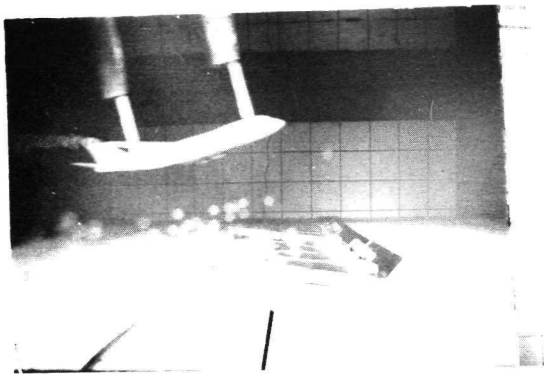
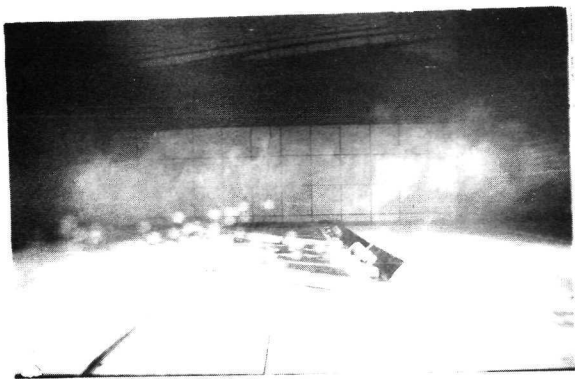
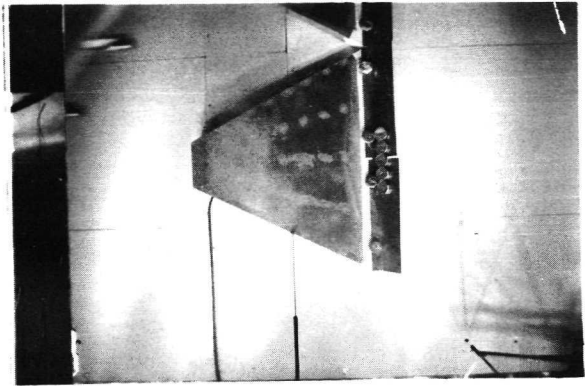


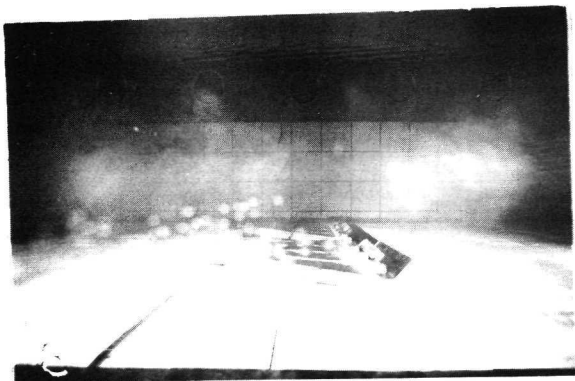
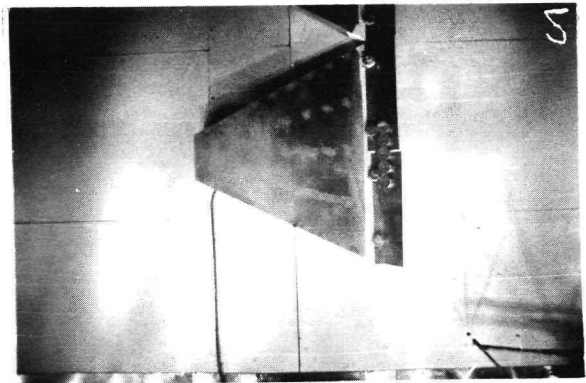
FIGURE 83 - CONCLUDED



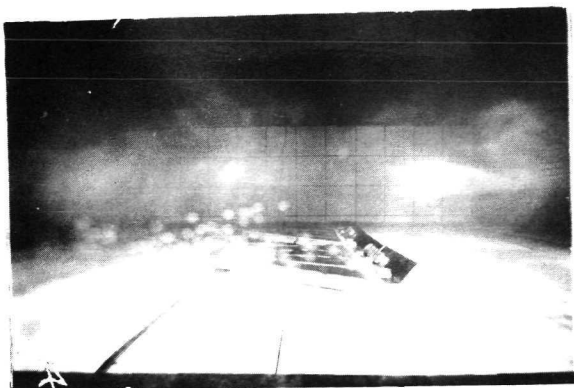
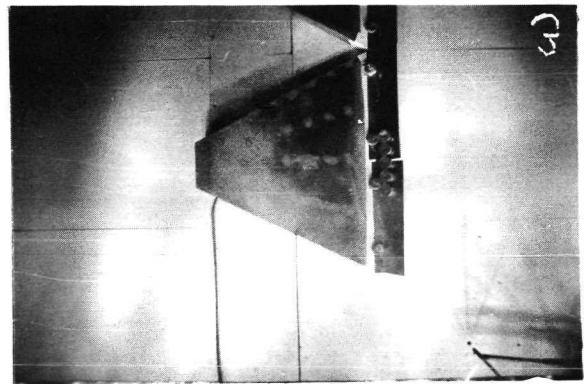
N  
-1.0



5.8



10.9



16.0

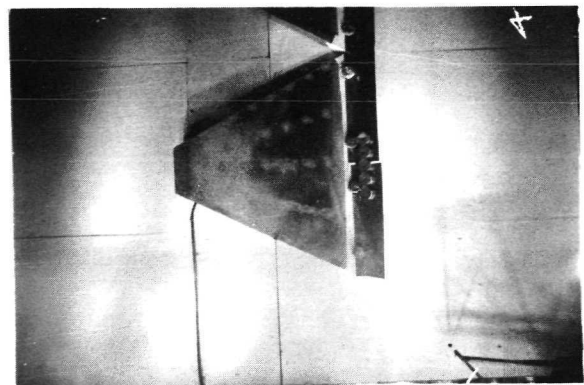
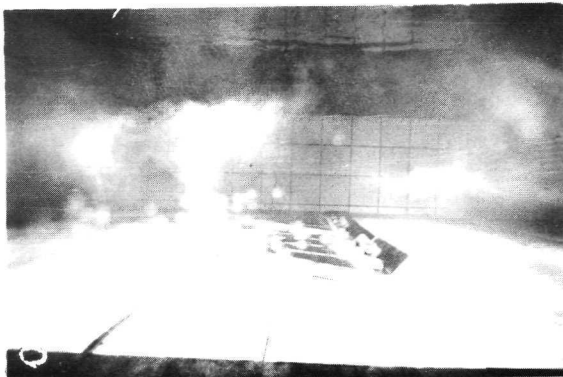
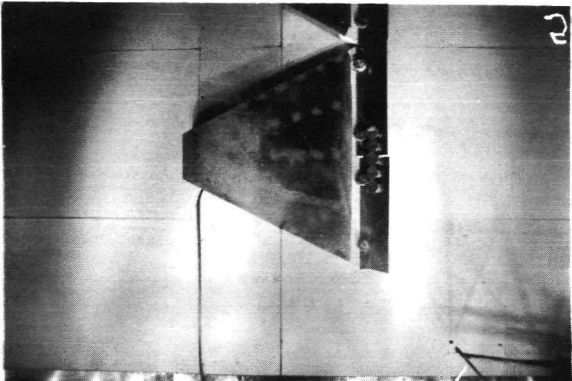


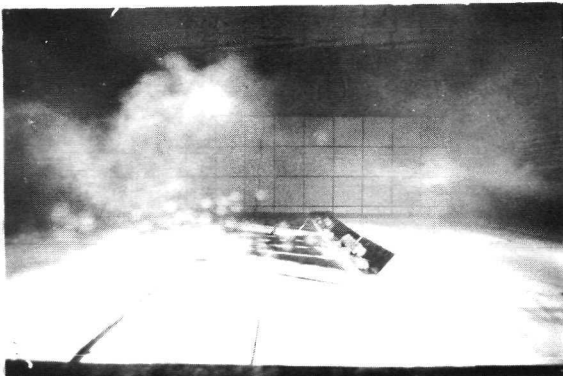
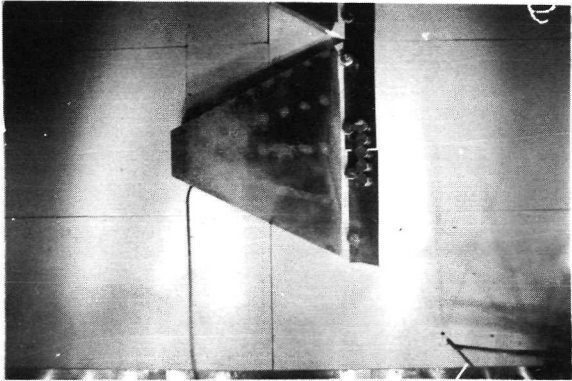
FIGURE 84 - DEVICE G1 WITH  $V_b/U = 0.194$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.80$  AND ALTITUDE = 30.5 METERS



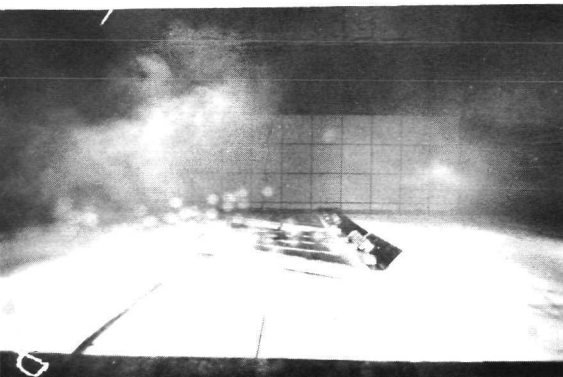
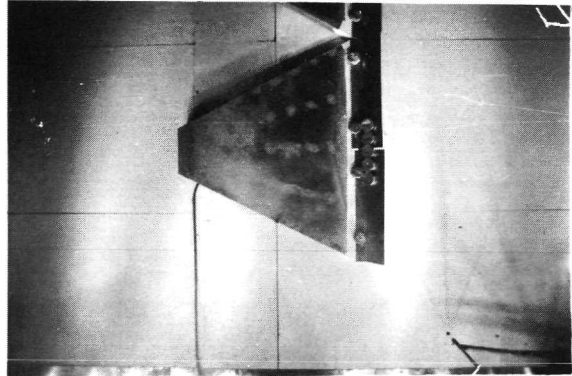
N  
21.1



24.5



27.9



31.3

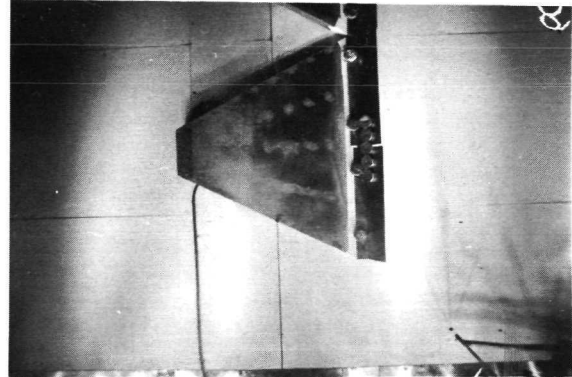
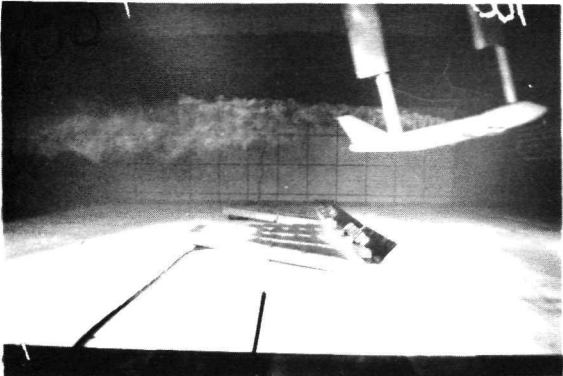
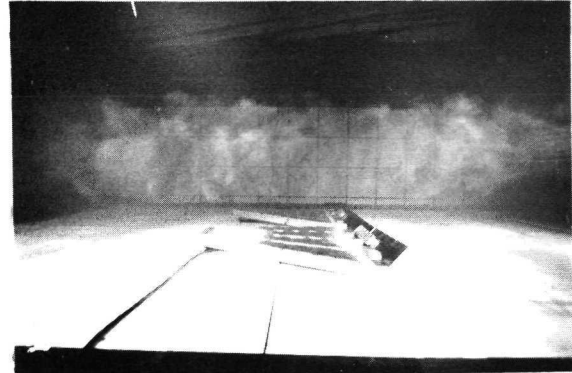
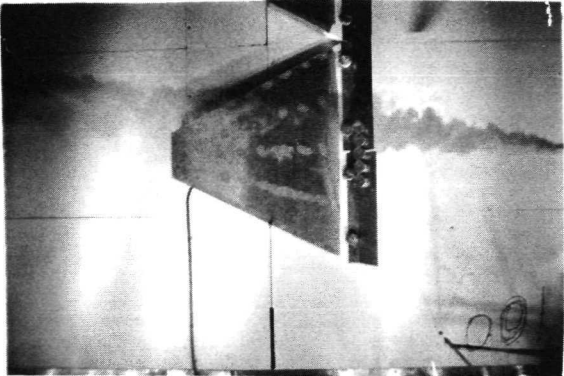


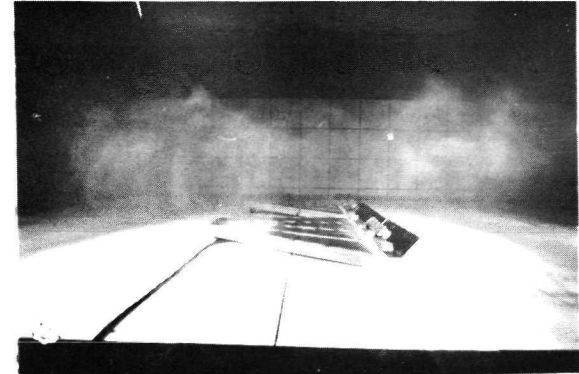
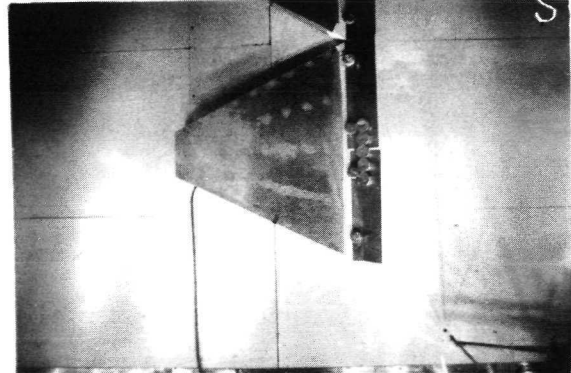
FIGURE 84 - CONCLUDED



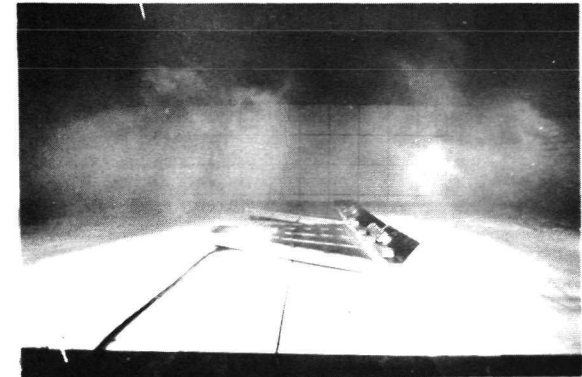
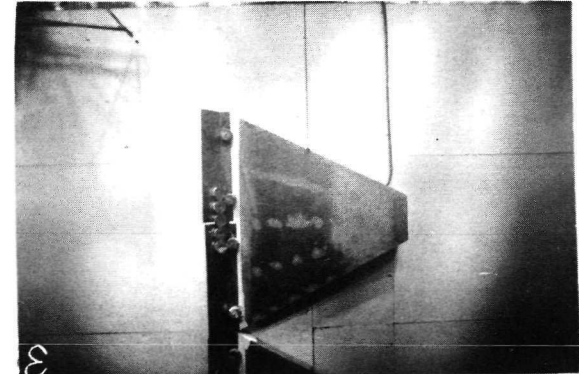
N  
1.1



5.1



10.6



14.7

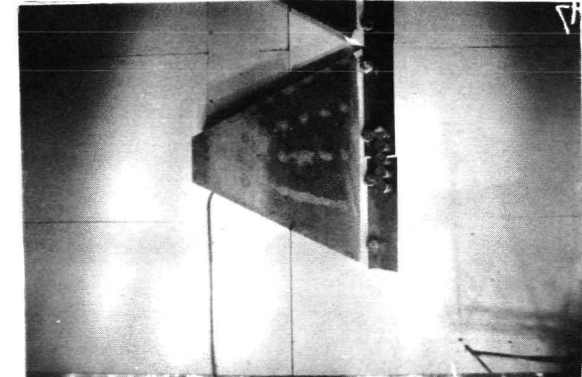
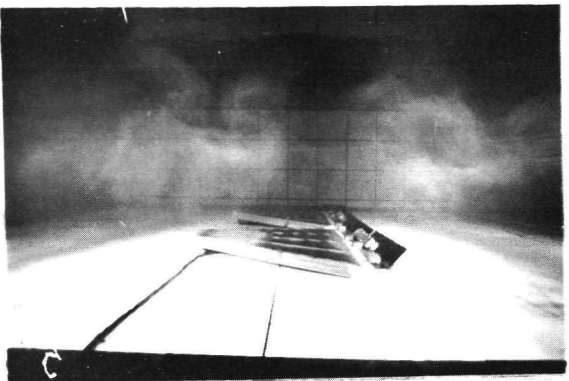
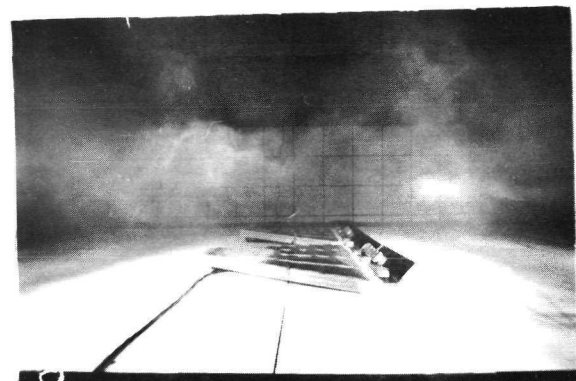
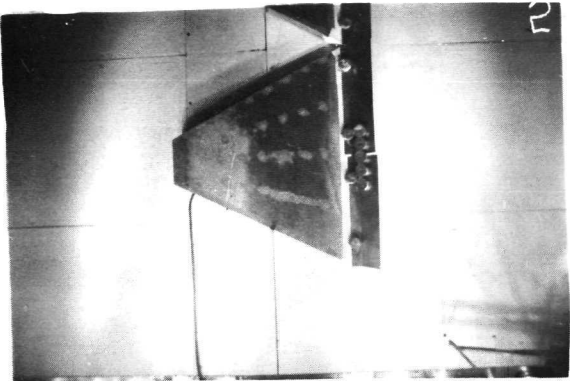


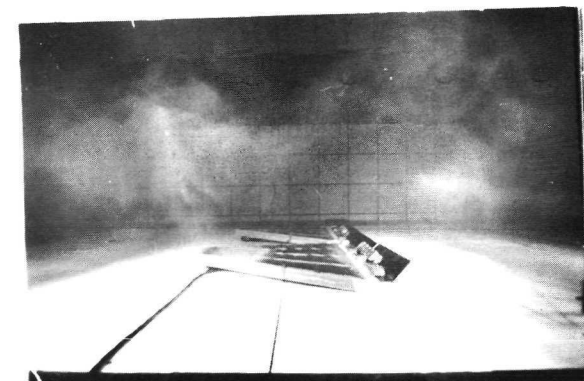
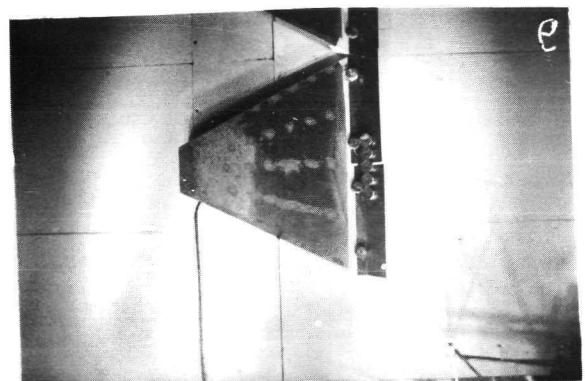
FIGURE 85 - DEVICE G1 WITH  $V_b/U = 0.243$  - EFFECT ON VORTEX WAKE FOR FLAPS 30 CONDITION,  $C_L = 1.79$  AND ALTITUDE = 30.5 METERS



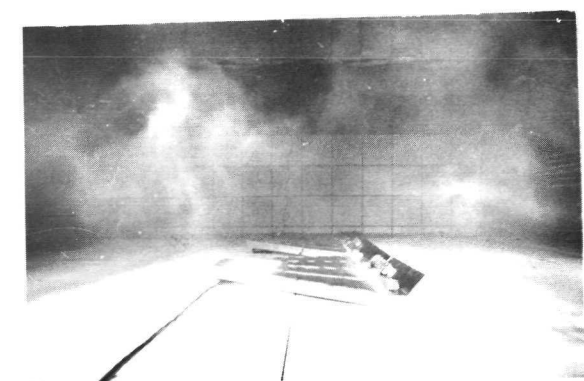
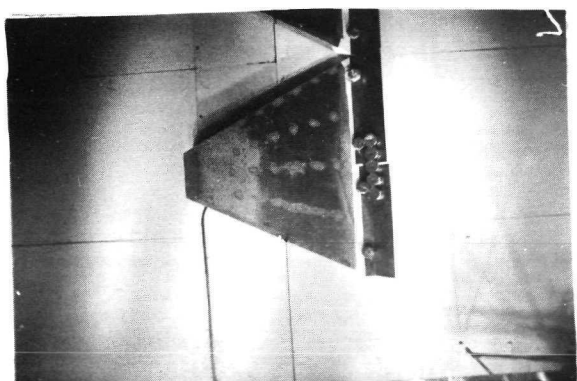
N  
17.4



21.5



24.2



26.9

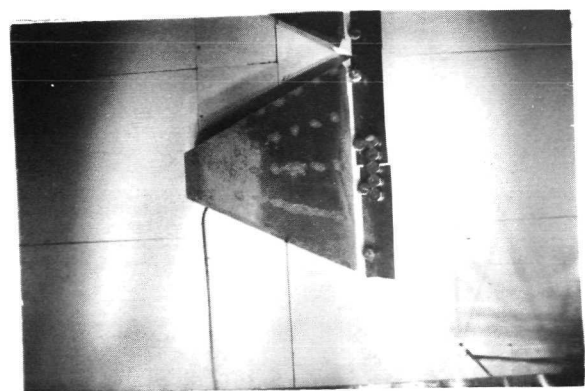
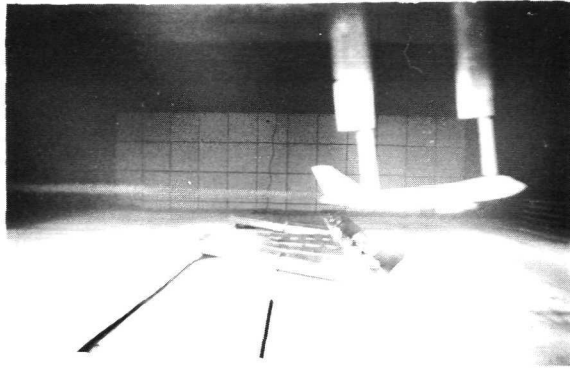
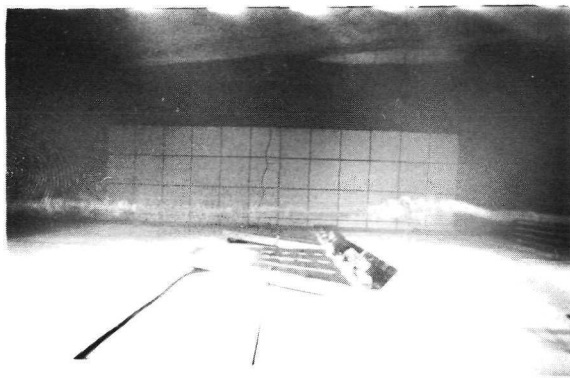
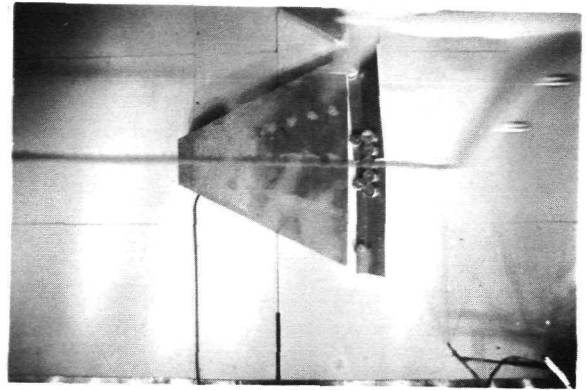


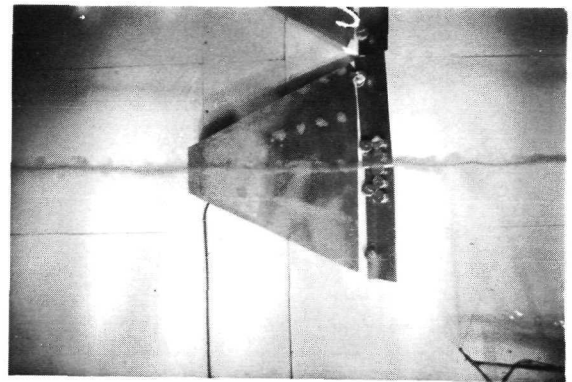
FIGURE 85 - CONCLUDED



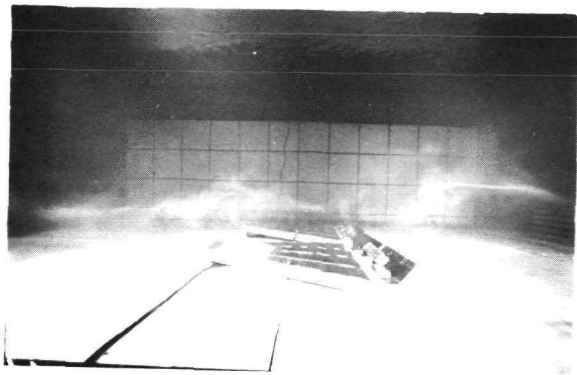
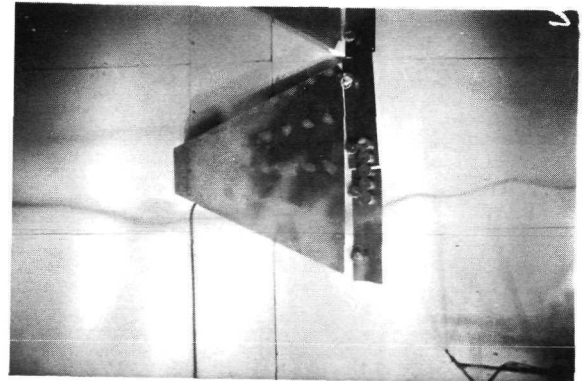
N  
0.7



4.8



13.0



21.1

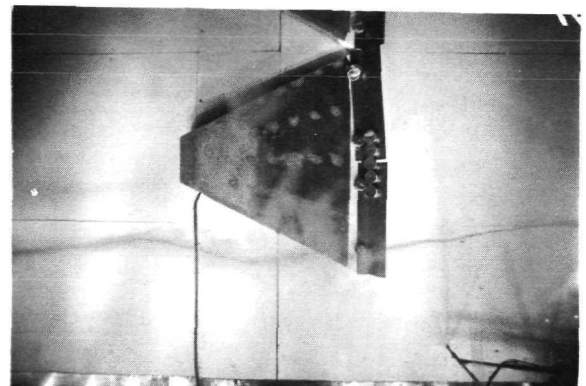
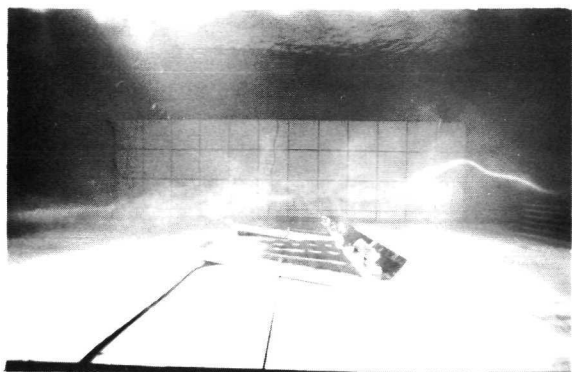
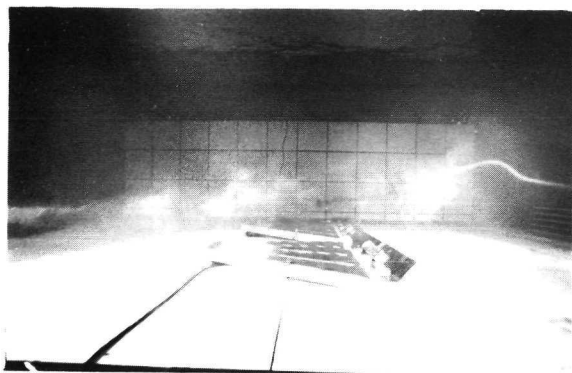
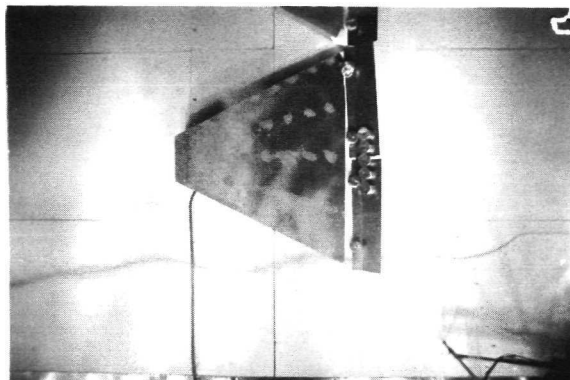


FIGURE 86 - DEVICE G2 WITH  $V_b/U = 0.270$  - EFFECT ON VORTEX WAKE FOR CRUISE CONDITION,  $C_L = 0.70$  AND ALTITUDE = 13.4 METERS

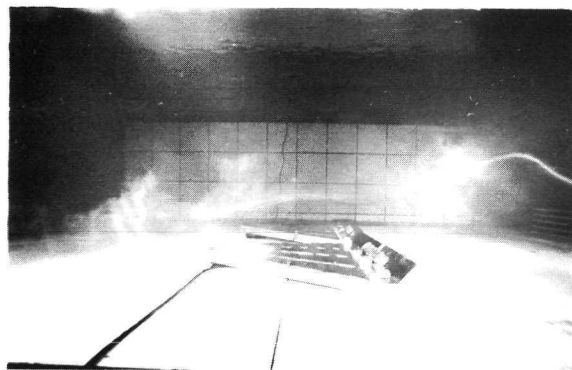
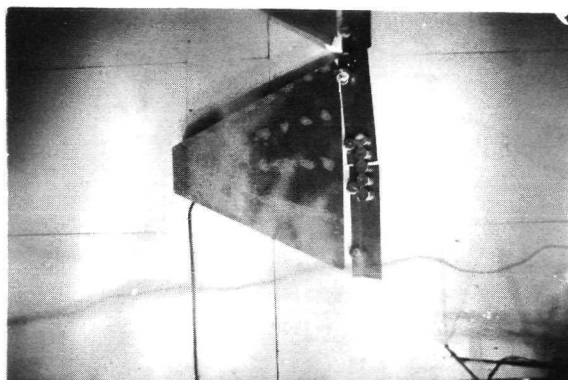


N

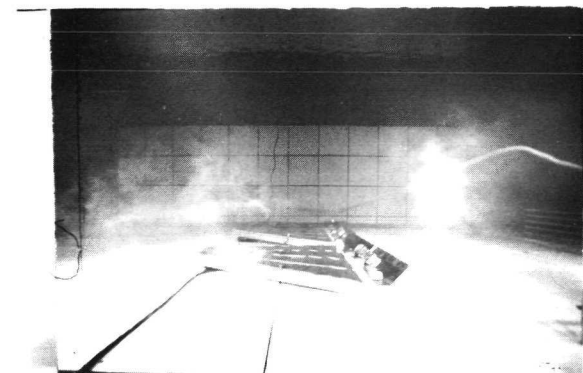
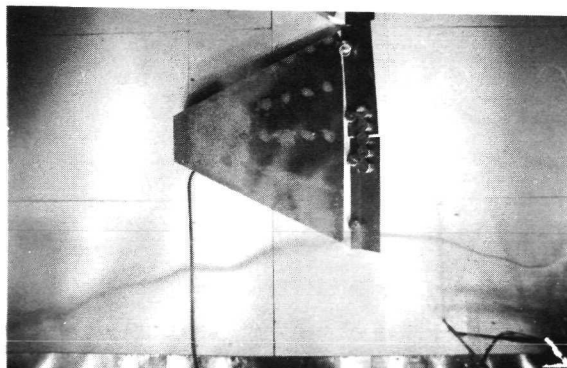
25.2



29.3



35.4



39.5

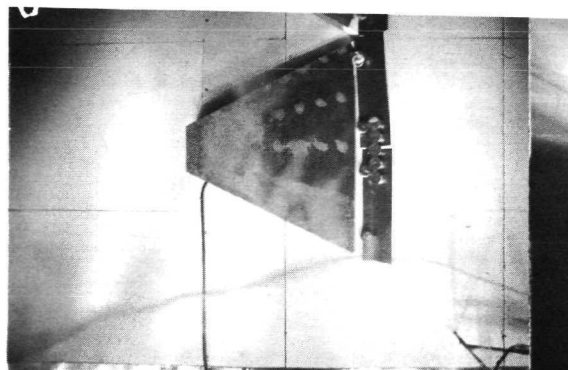


FIGURE 86 - CONCLUDED

HYDRONAUTICS, Incorporated

DISTRIBUTION LIST  
NAS1-11389

	Copies
NASA Langley Research Center Hampton, Va. 23665 Attn: Report and Manuscript Control Office, Mail Stop 180A	1
Raymond L. Zavasky, Mail Stop 115	1
Technology Utilization Office, Mail Stop 139A	1
R. Earl Dunham, Mail Stop 247	5
NASA Ames Research Center Moffett Field, CA 94035 Attn: Library, Mail Stop 202-3	1
NASA Flight Research Center P. O. Box 273 Edwards, Calif 93523 Attn: Library	1
NASA Goddard Space Flight Center Greenbelt, Maryland 20771 Attn: Library	1
NASA Lyndon B. Johnson Space Center 2101 Webster Seabrook Road Houston, Texas 77058 Attn: Library, Code JM6	1
Jet Propulsion Laboratory 4800 Oak Grove Drive Pasadena, Calif 91103 Attn: Library, Mail 111-113	1
NASA Marshall Space Flight Center Huntsville, Alabama 35812 Attn: Library	1
NASA Lewis Research Center 21000 Brookpark Road Cleveland, Ohio 44135 Attn: Library, Mail Stop 60-3	1

HYDRONAUTICS, Incorporated

-2-

NASA John F. Kennedy Space Center  
Kennedy Space Center, Florida 32899  
Attn: Library, IS-DOC-1L 1

National Aeronautics and Space Administration  
Washington, D. C. 20546  
Attn: KSS-10/Library 1  
RA/NASA Headquarters 1

Federal Aviation Administration Headquarters  
800 Independence Avenue  
Washington, D. C. 20540  
Attn: William A. McGowan, Code ARD 562 15

NASA Scientific and Technical Information Facility  
P. O. Box 33  
College Park, Maryland 20740 12  
(plus 1 reproducible) 1