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Session VI. Heavy Rain Aerodynamics

N91-24180

Status of Heavy Rain Tests
Gaudy Bezos, NASA Langley

A STATUS REPORT

ON THE

HEAVY RAIN EFFECTS PROGRAM

BY

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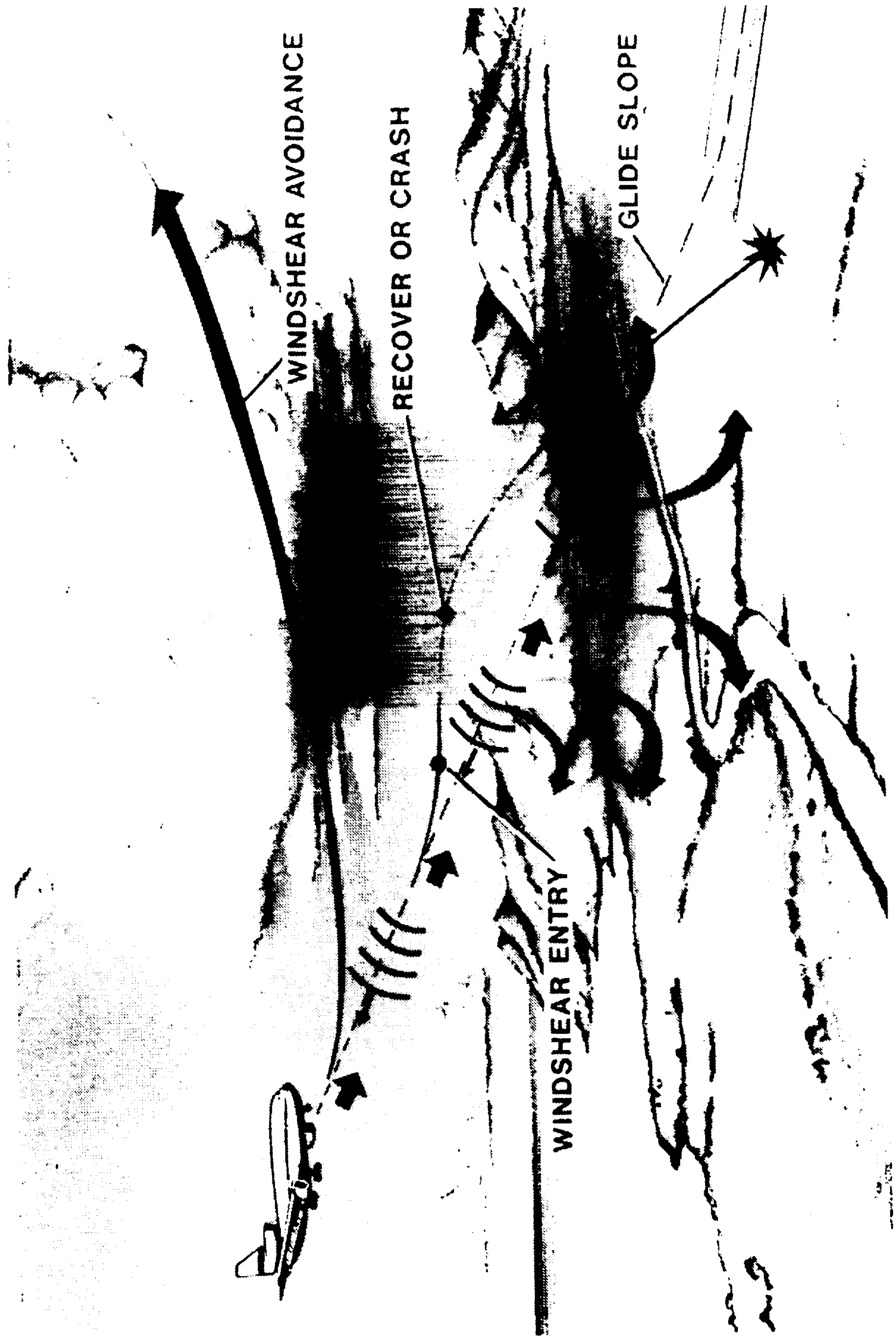

WINDSHEAR AVOIDANCE
RECOVER OR CRASH
GLIDE SLOPE
WINDSHEAR ENTRY

AVIATION SAFETY CONCERN: RAIN

CHARACTERISTICS:

- Highly-concentrated
- Short-duration

WHY:

- Windshear and severe rain partners
- 10 out of 25 windshear accidents occurred in a rain environment
- 5 out of 10, severe rainstorm present

THE HEAVY RAIN EFFECTS PROGRAM

OBJECTIVES:

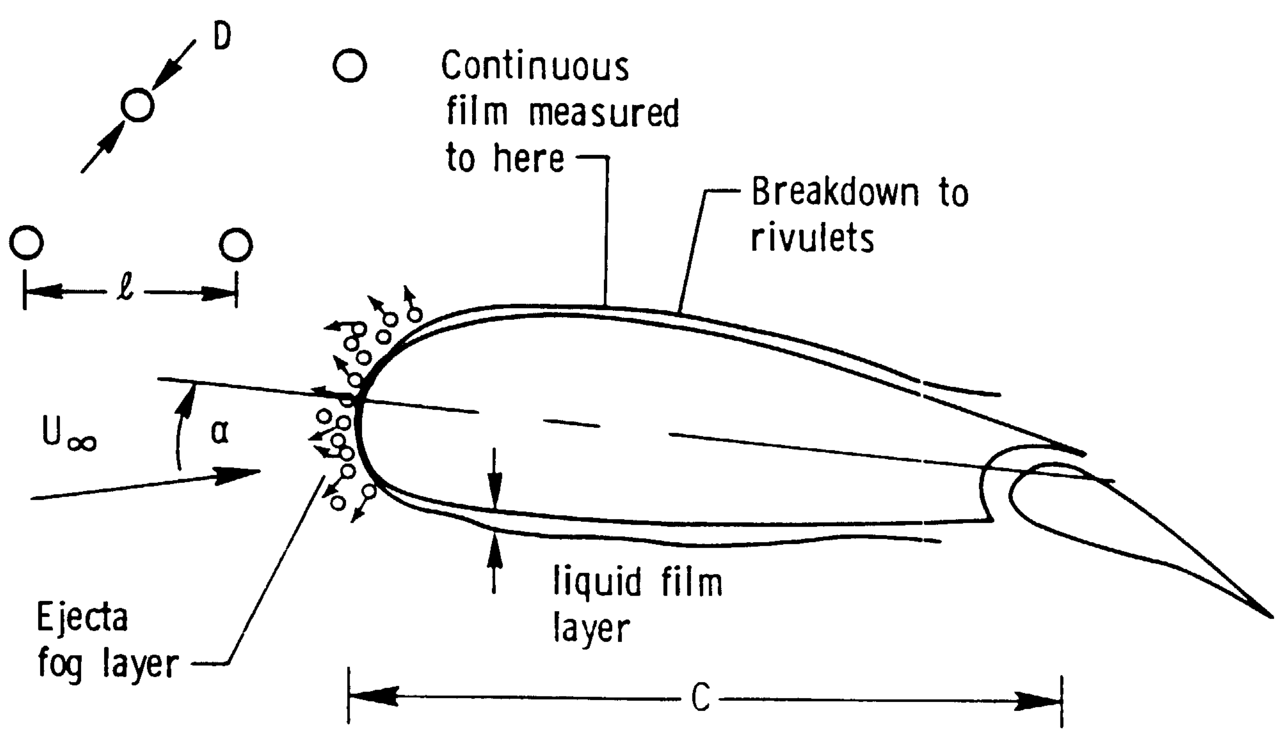
To Determine:

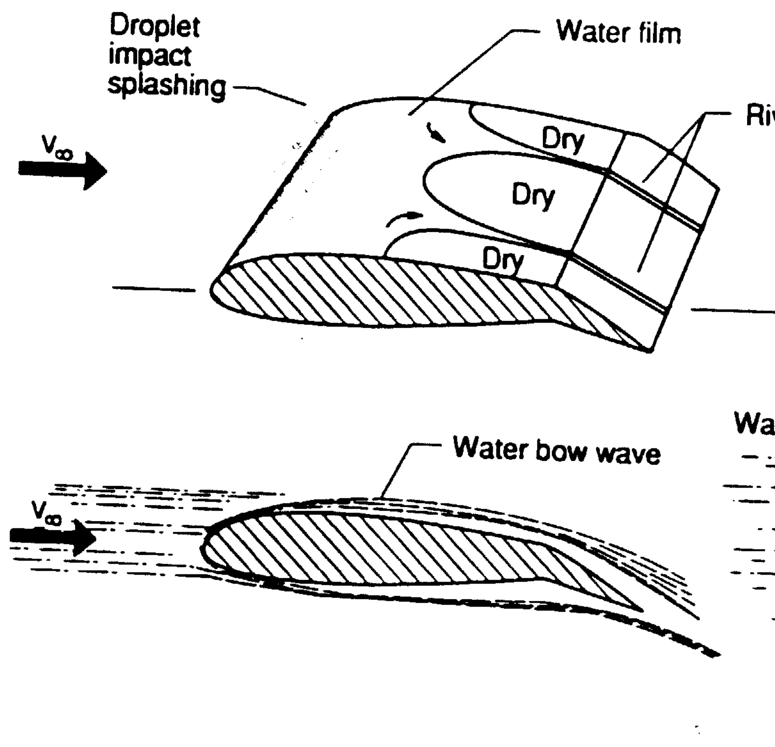
- **The effect of rain on aircraft performance**
- **The consequences of the effect during a microburst encounter**

OVERVIEW

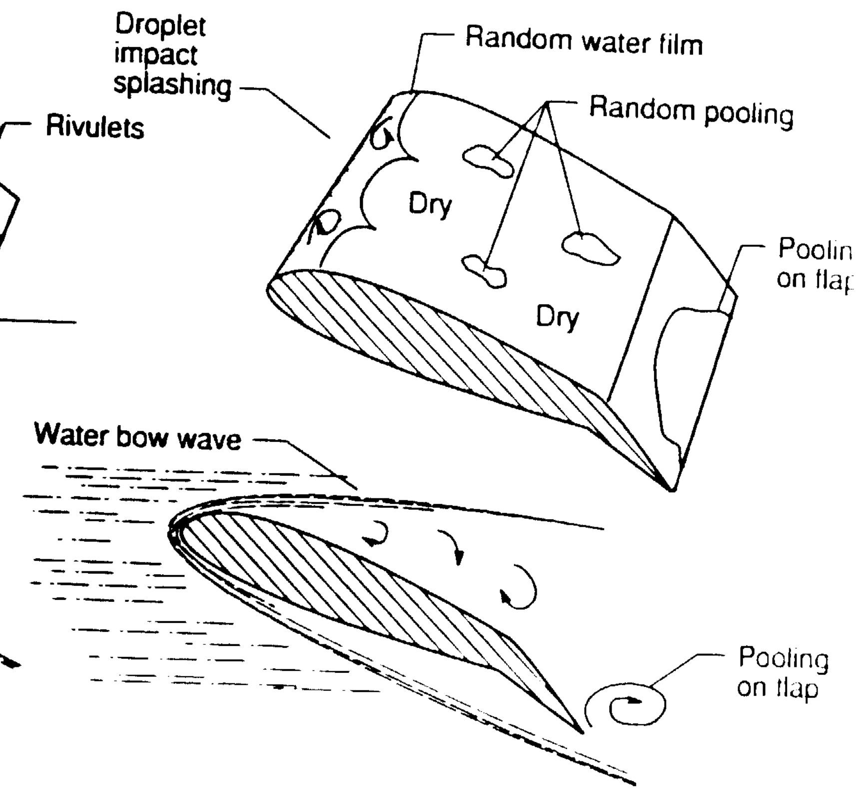
- Two-phase flow dynamics
- Wind tunnel results
- Issues
- Large-scale results
- Future plans
- Summary remarks

RAINDROPS INTERACTING WITH AN AIRFOIL

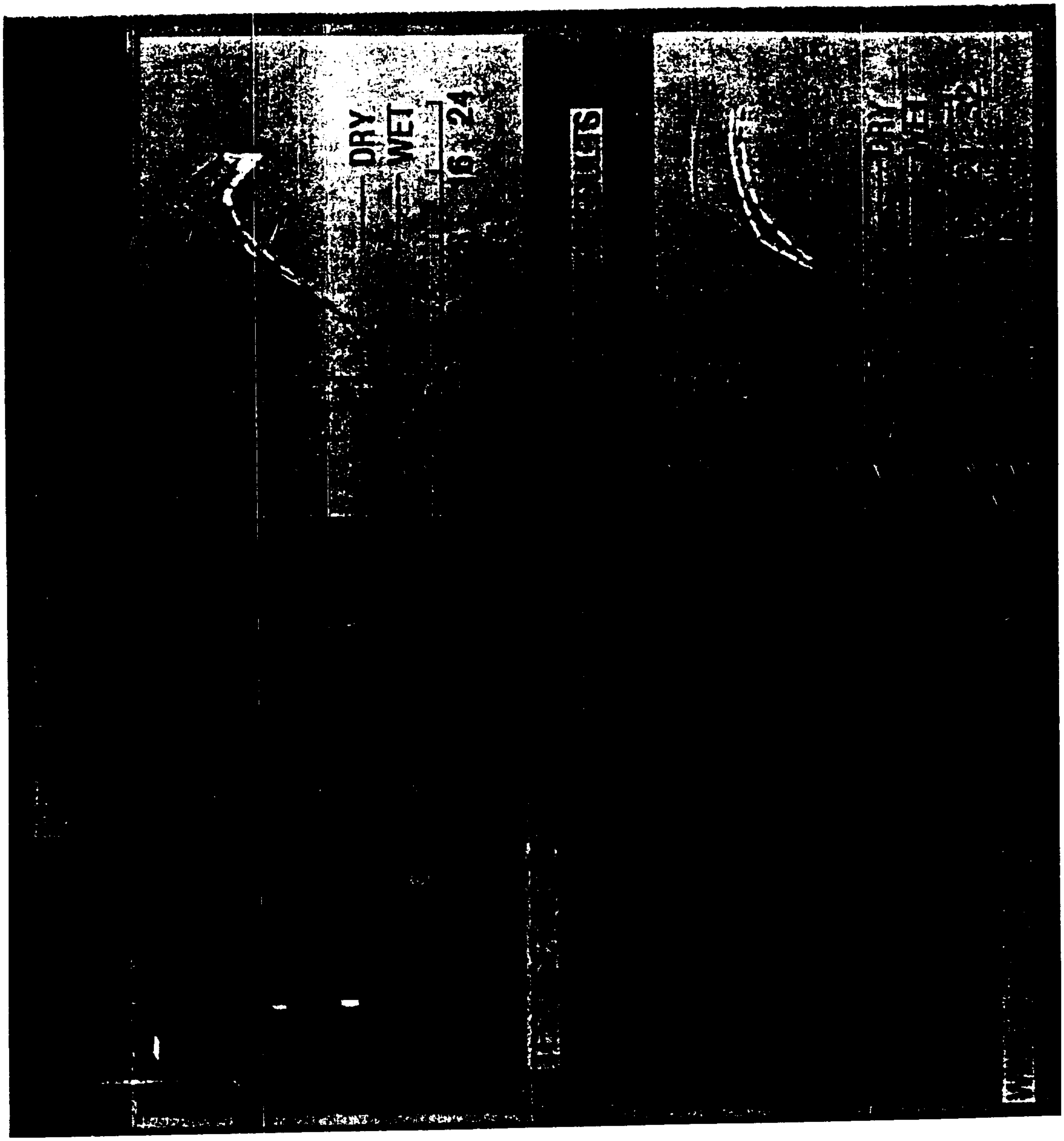


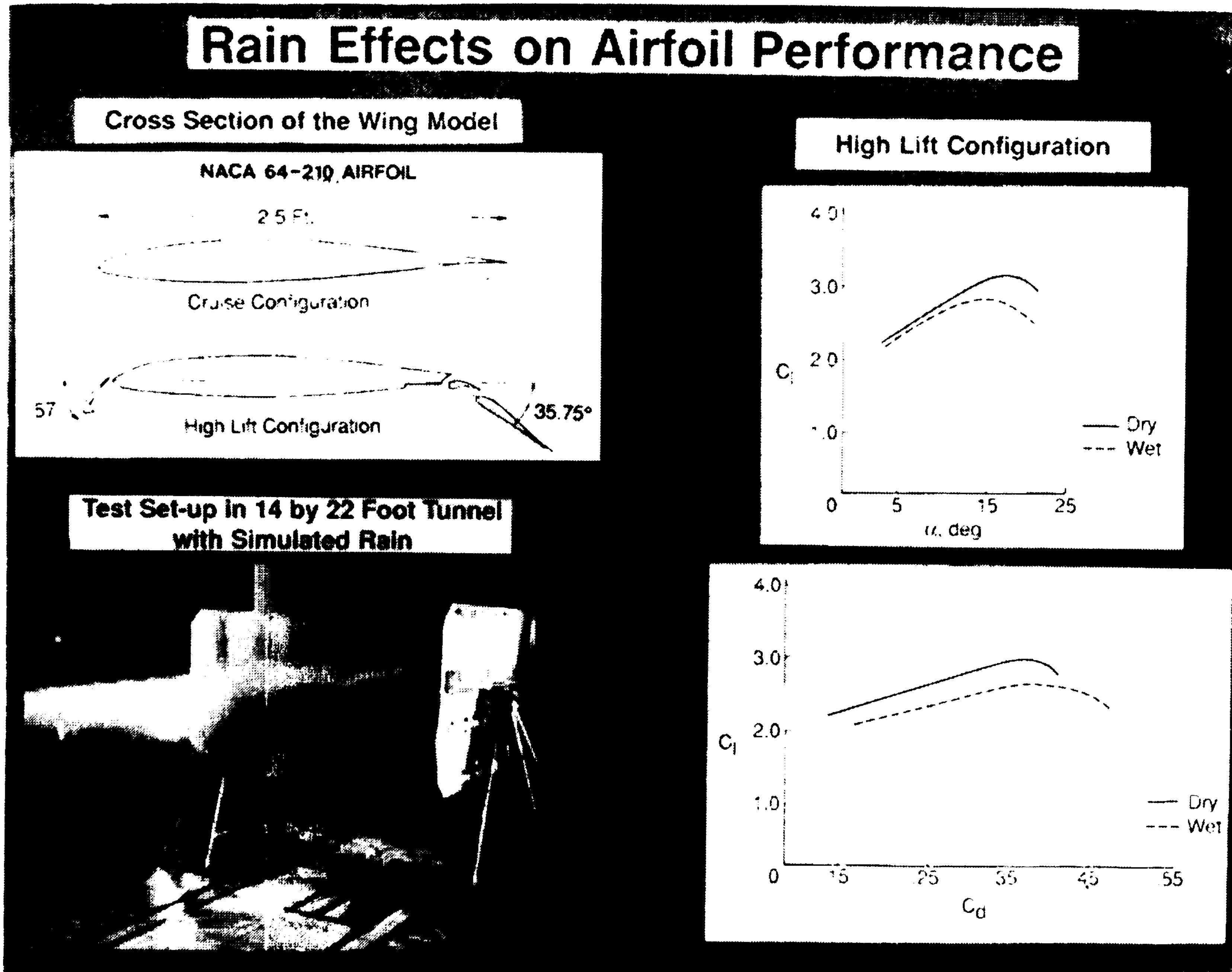


Attached wing water flow.



Stalled wing water flow.


DRY
WET


Rain Effects on Airfoil Performance
Cross Section of the Wing Model
NACA 64-210 AIRFOIL
2.5 Ft.
Cruise Configuration
57°
35.75°
High Lift Configuration
Test Set-up in 14 by 22 Foot Tunnel with Simulated Rain
High Lift Configuration
4.0
3.0
2.0
1.0
0
C_l
5
15
25
α, deg
Dry
Wet
4.0
3.0
2.0
1.0
0
C_l
.15
.25
.35
.45
.55
C_d
Dry
Wet

WIND TUNNEL TEST RESULTS (1982-1988)

- Rain has an effect on airfoil performance

- Rain affects:
  - Maximum lift capability
  - Stall angle of attack
  - Drag

- Magnitude of the effect is dependent on:
  - Rainfall rate
  - Airfoil geometry
  - Slat/flap deflection

ISSUES

- The scaling of the small-scale results to full-scale aircraft

- The accurate simulation of natural rain

- The acquisition of:

  Natural rain data, i.e.:
  - Rainfall Rate
  - Probability of a Rain Event
  - Droplet Size and Distribution

  Droplet impacting dynamics data

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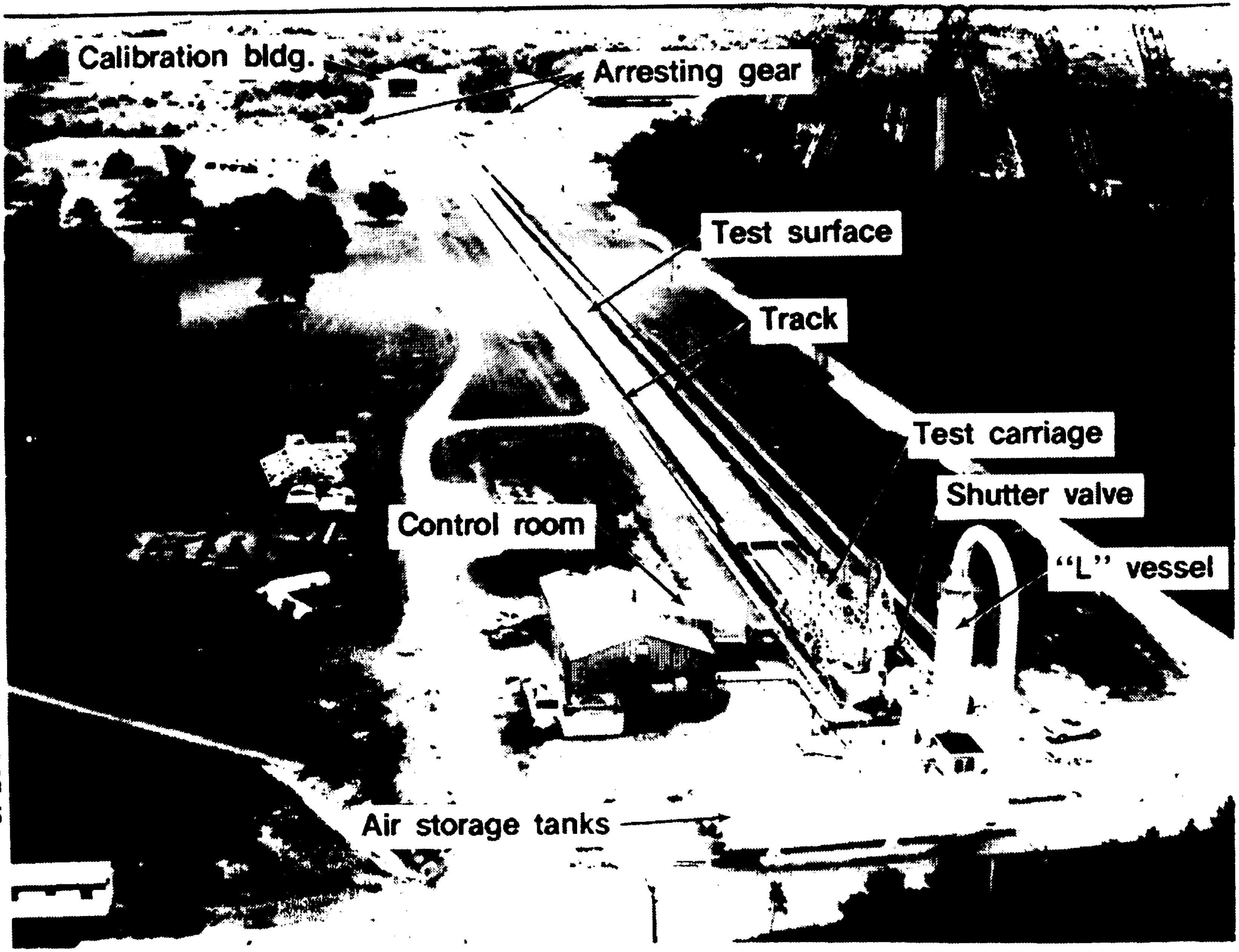
AIRCRAFT LANDING DYNAMICS FACILITY



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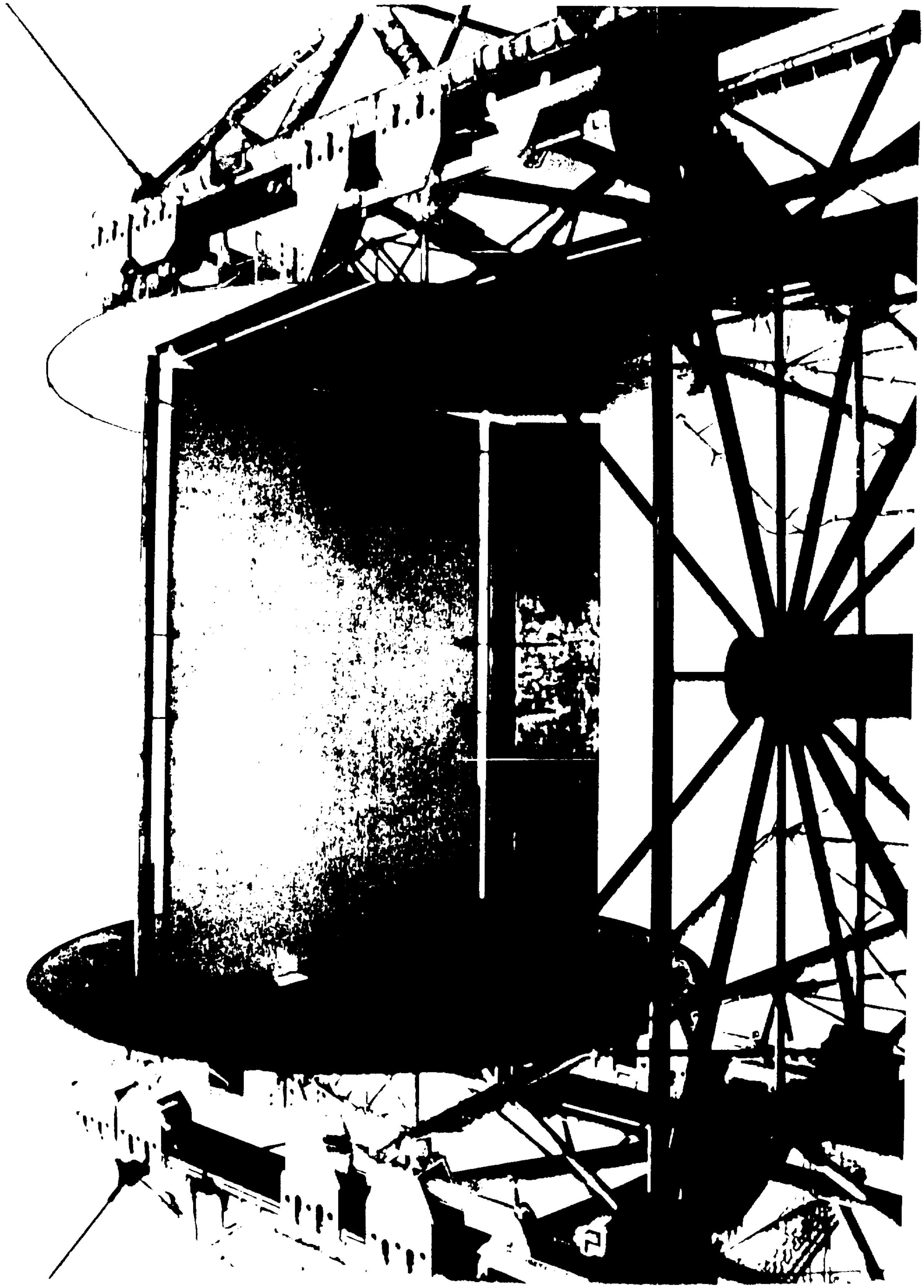

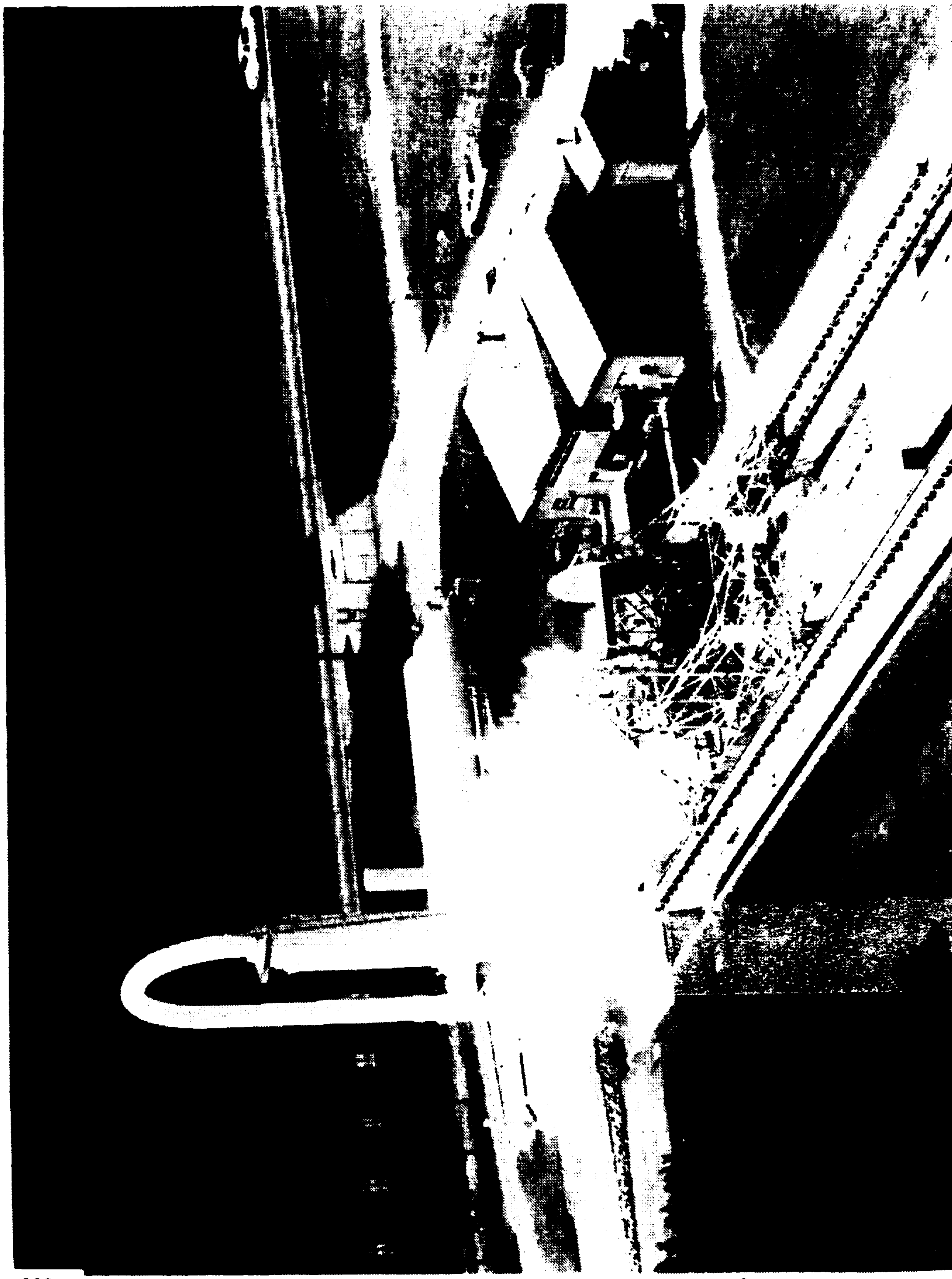

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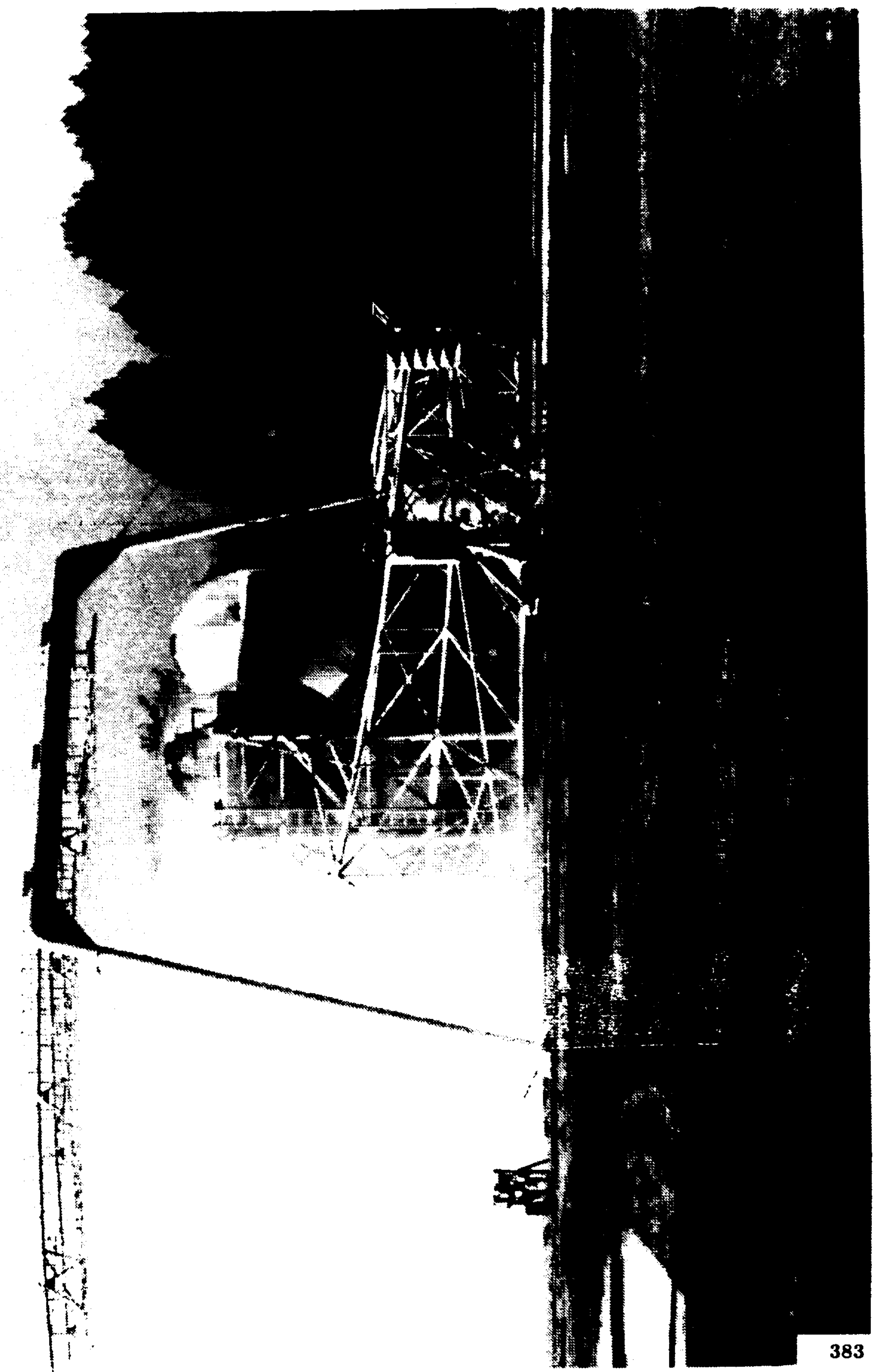
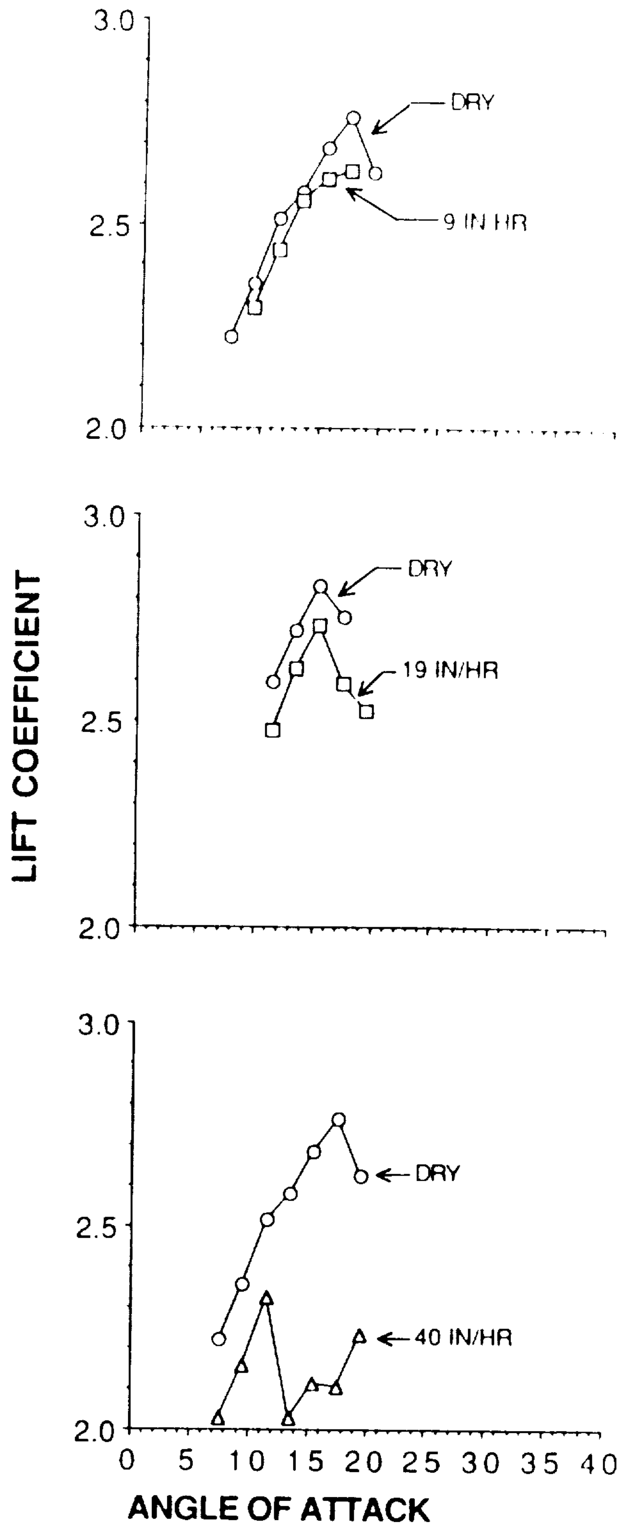
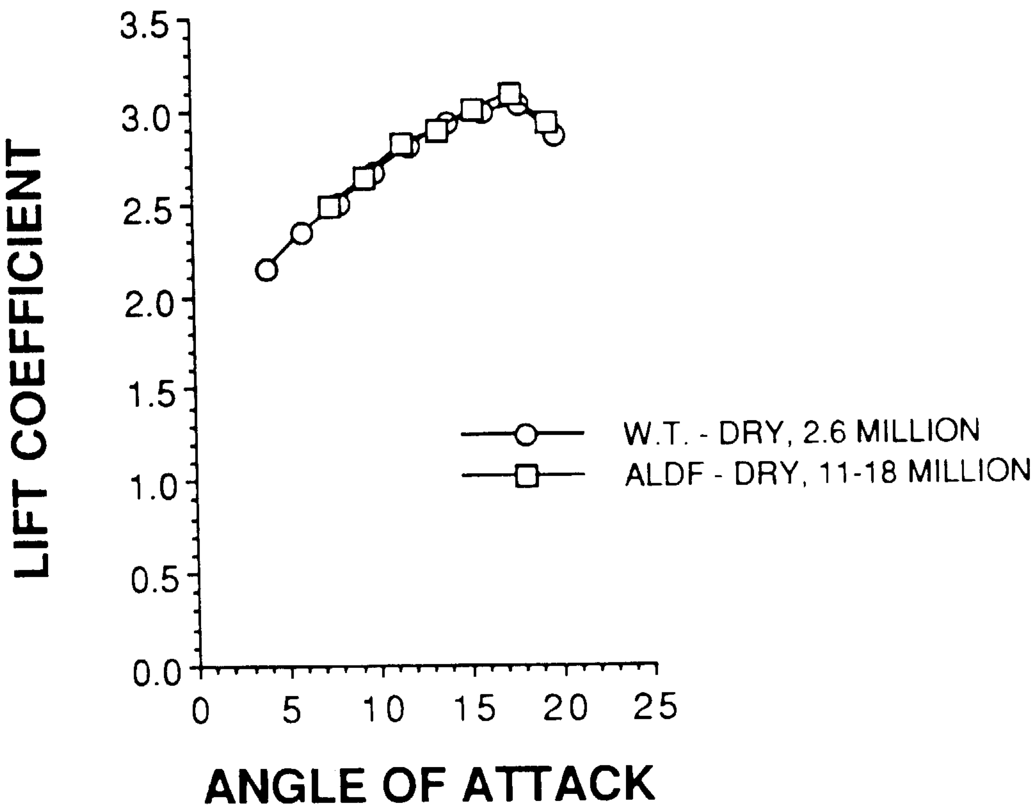
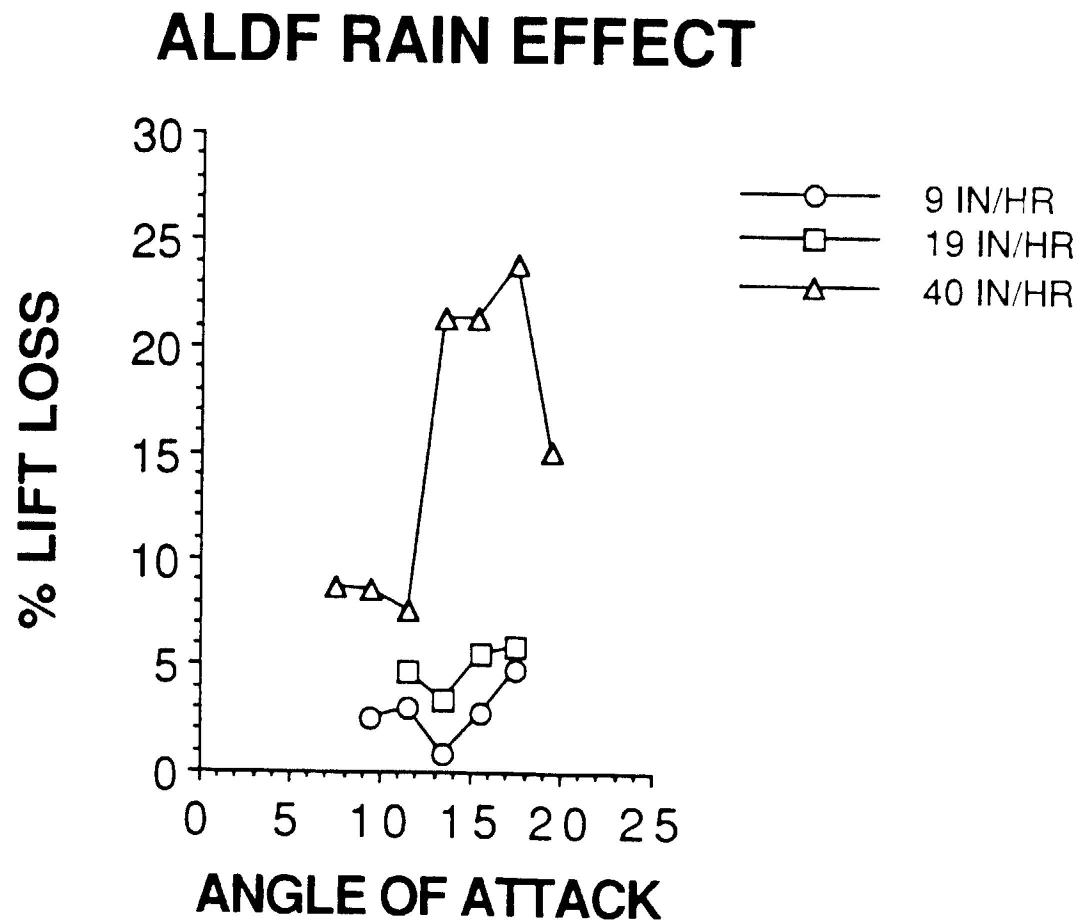


ALDF HIGH-LIFT DATA



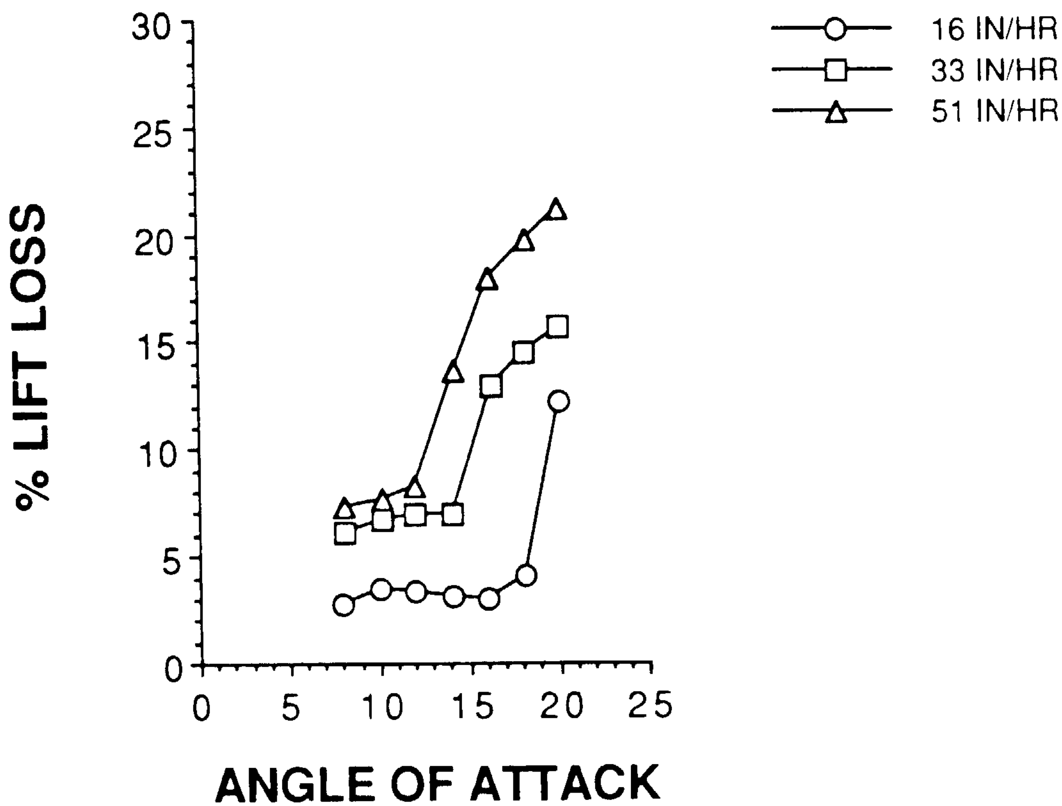
REYNOLDS NUMBER EFFECT



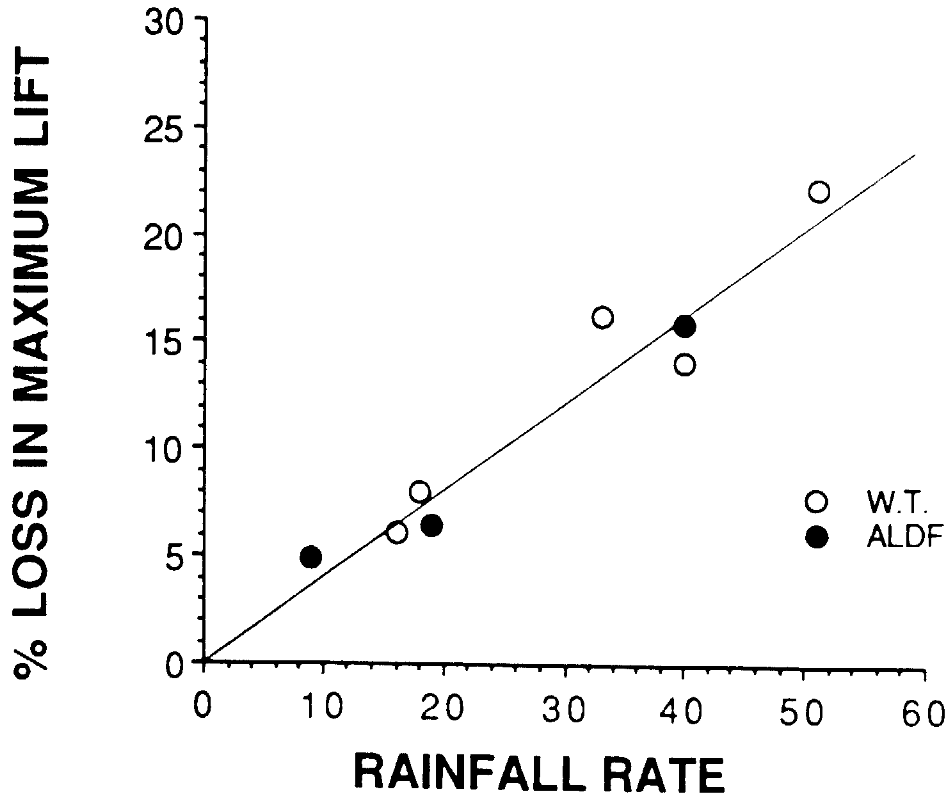


ALDF RAIN EFFECT
% LIFT LOSS
30
25
20
15
10
5
0
0
5
10
15
20
25
ANGLE OF ATTACK
9 IN/HR
19 IN/HR
40 IN/HR

WIND TUNNEL RAIN EFFECT



RAIN EFFECT ON MAXIMUM LIFT CAPABILITY



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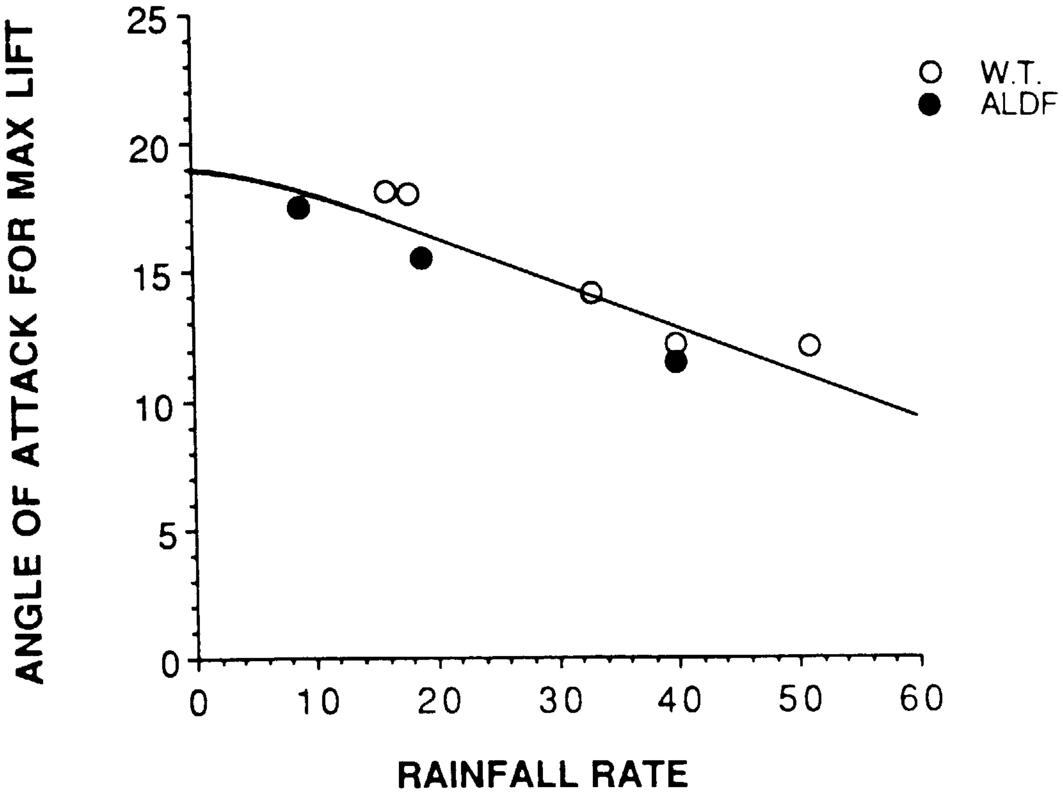
RAIN EFFECT ON STALL ANGLE OF ATTACK



FUTURE PLANS

- Complete new wind tunnel rain spray system
- Conduct wind tunnel tests on 2D-section and full configuration models
- Obtain further insights into two-phase flow dynamics

SUMMARY REMARKS

- Large-scale data acquired at three rainfall rates
- Established similar trends between ALDF and the wind tunnel
- Plan to acquire full configuration data in the 14- by 22-Foot Subsonic Tunnel

Status of Heavy Rain Tests - Questions and Answers

Q: RICHARD DUBINSKY (Sky Council) - What influence and/or relationships do you expect for extreme ranges of drop size distributions in heavy rain for microburst and shears, etc.?

A: GAUDY BEZOS (NASA Langley) - I'm not familiar with the drop size distributions that have been measured inside wind shear environments of severe thunderstorms. If there is data available it's a very small data base. I can only share with you my experiences in trying to form droplets in a wind tunnel and at the ALDF facility. In the wind tunnel environment, we've noticed that the difference between the exit velocity of the water from the nozzle and the free-stream velocity we wanted to accelerate the drops to, made a great difference in the shape and size of the drops themselves. Anything larger than 2 mm in size would actually shatter and form much smaller drops. So the wind tunnel test technique gave us an average drop size of about 1.5 mm. At ALDF we used commercial nozzles. The spec sheet on those nozzles says that they produce drops from as small as 1/2 mm in size to 4 mm in size. It's very difficult to measure drops in an outdoor facility. We used a sort of a shadow-graph technique. We had a little box with a lens, a camera and a slit in the top. We let the drops fall through the slit and would take a picture of it . By just looking qualitatively at what kind of distribution we got, we did see 1/2 mm size drops and we did see 4 mm size drops and everything in between. The ALDF facility rain system was purposely designed to allow the droplets of all the different sizes to achieve their terminal velocity, + or - 10%, which even for the smallest size drops it would take 14 feet. So the drops did achieve the proper physics involved in forming and falling to the ground. I do know that if you are in a wind shear situation you'll have down drafts and that may entrap the rain that is there and actually force it down a lot harder and maybe the drops themselves will have a different characteristic. There is research, I don't remember the person's name, which looked at drop size distributions in light showers versus severe thundershowers and there is a different distribution.

Q: RICHARD DUBINSKY (Sky Council) - How will you generate and measure different rain drop size distributions for your future wind tunnel experiments?

A: GAUDY BEZOS (NASA Langley) - We'll generate the different drop sizes by varying the exit nozzle pressure. We are planning to put our rain system in the settling chamber of our wind tunnel which will minimize the difference between the air stream velocity and the exit velocity of the drops. We hope to be able to keep in tact the drops, the large size drops, like 4 mm in size. We plan to measure the drops using two techniques. We'll again use the shadow-graph photographic technique and we are also developing a laser system that will basically be an unobtrusive device which will allow the drops to cross the sheet of light and then determine its size and its velocity by the width of the interference as it crosses the laser beam.

Q: WALT OVEREND (Delta Airlines) - How, when you conducted rain tests did you overcome the water effect on your sensors or your sensor systems?

A: GAUDY BEZOS (NASA Langley) - The instrumentation that we used to acquire our aerodynamic data were strain gauge load cells and they were unaffected by the rain environment. They were waterproofed before hand. We were able to measure aerodynamic lift and the drag seen by the model without any problem. We also had an on board pitot static system on the carriage to give us true airspeed. That also did not show a difference in and out of the rain environment. But, you have to remember that we were only in the rain environment for 2 seconds so the probability of a drop hitting the pitot static tube at just the right spot to clog it up is kind of unlikely. In the wind tunnel we tried to measure the static pressures on the wing surface and we found that we had great difficulties in doing that because the water would always clog up the line. So we couldn't measure the pressure on the surface of the wing.

Q: WALT OVEREND (Delta Airlines) - What do you see as a change in effect on a three dimensional wing, including tip vortices from your 2 dimensional testing?

A: GAUDY BEZOS (NASA Langley) - The first thing I would like to point out is that we have done some three dimensional testing on very simplistic models. The first one was on a NACA 0012 airfoil section with a generic fuselage and a simple flap. The other was on a NACA 23015 airfoil section model which also had a simple flap system on the trailing edge. The results do indicate there are lift losses and drag increases. The magnitude and the shape of these curves may differ a little bit but we don't expect to see many great changes in our 3-D testing in terms of those characteristics. One thing that we will probably see is an effect of the fuselage and the tail surfaces. We hope to do a section by section test of a full configuration model starting first with the swept wing by itself on a splitter plate, then test the fuselage and tail surfaces, and then put the whole system together to see if we can isolate which areas contribute to performance losses. I did want to point out that testing in a wind tunnel environment or at ALDF is not easy. There are a lot of operational difficulties involved. A wind tunnel wasn't made to have water thrown in it. All the instrumentation must be waterproofed. Our blades, which are wooden, have to be protected from the erosion of the water. We can't test in the wind tunnel during the winter months because whatever residual water is left in the tunnel circuitry actually forms into ice and then when we initially turn the system on it actually digs holes, pits, into the wooden blades. The wind tunnel is not the ideal test technique. It really is a lot of work and effort. At ALDF we've been testing for two years and we've got 36 data points. Now, of those 36 data points we have some repeat points, but it's a very slow process. We are always fighting nature, bad weather and high winds.