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Proceedings and Minutes of the

NATIONAL ICING FACILITIES COORDINATION MEETING

FEDERAL AVIATION ADMINISTRATION

FAA * NASA * DOD

APR 1 1985

INDUSTRY

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ATLANTIC CITY AIRPORT, NEW JERSEY

ON:

SEPTEMBER 23 - 24, 1980

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MINUTES OF:

NATIONAL ICING FACILITIES

COORDINATION MEETING

FAA ** NASA ** DOD

INDUSTRY

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SYMPOSIUM THEME

Industry's demand for aircraft icing test facilities has reached a point where a coordinated effort is necessary to establish a national level program for both improving existing facilities and developing new icing test facilities. In January of 1980, the cognizant government agencies, FAA, NASA and DOD, initiated this effort during the first National Icing Facilities Coordination Meeting.

The main theme for the current symposium emphasizes establishment of an industry consensus on the requirements for National Icing Facilities not only for certification, but for research and development purposes as well. This consensus must satisfy both present icing test facilities requirements and the needs foreseen for the future. These facilities are required to facilitate more timely and less costly icing research and icing certification.

NATIONAL ICING FACILITIES

COORDINATION MEETING

OVERVIEW

The joint industry and government symposium on National Icing Facilities requirements was convened to establish a common foundation of knowledge regarding existing test procedures and facilities. Starting with this understanding of the existing capabilities, limitations and public availability, it was desired to obtain a consensus on the viability of current test facilities for icing research, development and certification. This industry consensus was necessary to determine the improvements required for current facilities and the need for future new facilities. It is anticipated that the results of this effort will be the establishment of a Task Force to develop a National Icing Facilities program plan. The FAA Technical Center has agreed to coordinate and lead the effort in establishing specific recommendations for facilities requirements to be reviewed by NASA, DOD and industry.

NATIONAL ICING FACILITIES COORDINATION MEETING

1.0 EXECUTIVE SUMMARY

1.1 OVERVIEW OF KEY ISSUES

The current state of facilities for icing research, development and certification is inadequate in many aspects. Specific deficiencies have been identified in the areas of facility size, icing modeling, model fidelity and icing instrumentation. In addition, operational limitations of operating speeds, altitudes and time on station have been identified for inflight icing facilities.

The impact of these current icing facility limitations can best be illustrated by the example of helicopter icing certification. The manufacturer consensus was that a minimum of \$5,000,000 is currently required to attain icing certification and that finding the natural icing conditions specified in the current FAA certification criteria could take anywhere from 3 - 5 years. These criteria and the lack of any existing National Icing Facilities has the potential for negatively impacting the U. S. helicopter manufacturers as well as fixed wing manufacturers. Foreign manufacturers have already initiated the lengthy and expensive certification data collection process which could endanger the balance of trade and the preeminence of U. S. equipment in use in this country and abroad.

Recognizing the current limitations on the federal budget and the need for fiscal restraint, it still appears that the need for a National Icing Facilities Program is crucial. The key elements to this program have been defined by the joint industry/government symposium as:

- Current Icing Test Facilities are seriously lacking in their capabilities
- A government Task Force should be convened to develop a National Icing Facilities Program.
- A critical need exists for rehabilitation of the NASA Lewis Research Center Altitude Wind Tunnel.
- Steps should be taken immediately to insure continued availability and utilization of the Ottawa Spray Rig.
- An improved National inflight icing simulator is needed to expedite icing certification and reduce costs.
- An airborne icing research test bed is needed to develop data for correlation of natural icing conditions with wind tunnel data, tanker data, etc.
- An array of National Icing Facilities is required to adequately address the critical icing certification issue.
- An industry Advisory Group should be established to maintain industry/government liaison and to insure accelerated action from industry.

1.2 INTRODUCTION

The first joint industry/government National Icing Facilities Coordination meeting was organized and hosted by the Federal Aviation Administration (FAA). The meeting was held at the FAA's Technical Center at Atlantic City, New Jersey on September 23, 24, 1980. The primary purpose of this meeting was to obtain industry consensus on National Icing Facilities requirements to facilitate FAA recommendations regarding a National Facilities Effort. This effort would include icing facilities for the testing of both fixed wing and rotorcraft airframes, engines/nacelles, components and ice protection systems.

The meeting convened at 9:00 A.M. in the auditorium of the new FAA Technical Center Building. The agenda was designed for an Icing Facilities Overview presentation on the first day and Industry Panel discussions on the second day.

Mr. Tom O'Brien, Deputy Director of the FAA Technical Center, opened the meeting and welcomed technical representatives of various FAA, National Aeronautics and Space Administration (NASA), and Department of Defense (DOD) agencies involved in icing research, and official representatives of such industry organizations as the General Aviation and Manufacturers Association (GAMA), Helicopter Association of America (HAA) and the Aircraft Industries Association (AIA).

Mr. O'Brien briefly described the air traffic control computer facilities, the flight simulators, the inventory of nav aids, the flight line and the current helicopter flight safety R & D program at the Technical Center. He followed these descriptions with a concise statement of his reason for convening the icing symposium:

"We have concluded that if we had to use the natural means of getting our icing data, it would take us three to five years, and this is beyond the practical expectations in which we can expect engineering and businessmen to deal in certifying their equipment."

Mr. "JB" McCollough, Chief of the Flight Safety Research Branch, described the three basic work areas of the branch. These included General Aviation, Transport and Helicopter research activities. Following his presentation, Mr. McCollough introduced Mr. Dick Adams, Manager of the Helicopter Flight Safety Research and Development Program and the meeting chairman.

Mr. Adams briefly summarized the meeting objectives and outlined the plan of attack designed to satisfy those objectives.

1.3 AGENDA REVIEW

First, a detailed government overview was presented in which technical representatives of various government agencies presented information regarding their existing icing facilities, planned improvements, anticipated developments in icing research technology and requirements, and an indication of the availability of industry access to these facilities. Presentations were made by the following organizations and/or facilities:

- FAA Technical Center
- U. S. Army Aviation Research and Development Command (AVRADCOM)
- U. S. Army Aviation Engineering Flight Activity
- U. S. Army Applied Technology Laboratory
- U. S. Army Cold Regions Research and Engineering Laboratory Facilities
- U. S. Naval Air Propulsion Test Center (Engine Icing Test Facilities)
- U. S. Air Force Eglin Climatic Laboratory
- U. S. Air Force Flight Test Center (Edwards Air Force Base)
- U. S. Air Force Tullahoma Facility (Arnold Engineering Development Center)
- NASA-Lewis Research Laboratory
- National Research Council (NRC) Ottawa Spray Rig (Presentation by FAA Technical Center)
- Flight Systems, Incorporated (Private contractor)

Following these facilities overviews, representatives of various industry groups presented their organization's consensus of icing facility requirements, with particular emphasis on the role that these facilities may, or should, play in the certification process particularly as regards flight in known icing conditions. The industry consensus views were presented by the following groups:

- General Aviation Manufacturers Association
- Helicopter Association of America
- Aircraft Industries Association

The final element of the agenda was a general question and answer session in which the overall subject of the development of a National Icing Facilities Program Plan, as outlined in Figure 1, was discussed in some detail.

NATIONAL ICING FACILITIES COORDINATION MEETING

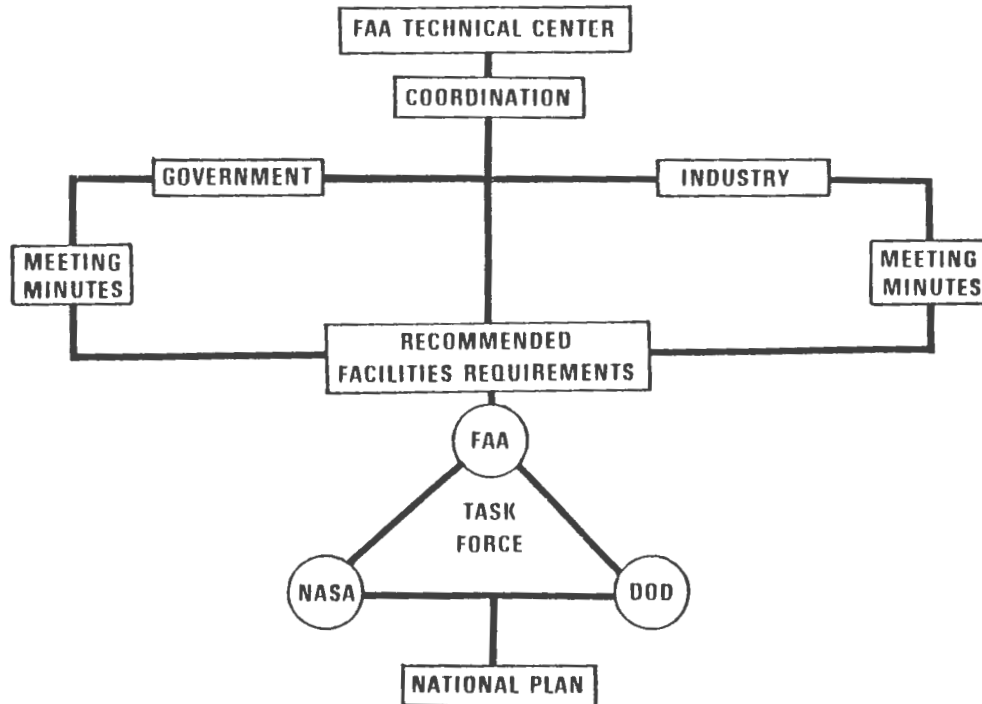


Figure 1

1.4 CONCLUSIONS AND RECOMMENDATIONS

The major conclusions and primary recommendations resulting from the joint industry conference on National Icing Facilities are briefly summarized here. For ease of reference, these findings have been subdivided into lists of current facility limitations, proposed facility improvements and three separate views of the industry consensus achieved at this symposium.

CURRENT FACILITY LIMITATIONS

- Physical size limitations - these range from limitations in the icing cloud size generated by airborne tankers or ground based spray rigs to limitations in test section model size for wind tunnels and engine test cells.
- Cloud parameter instrumentation limitations - a universal need was identified for better instrumentation to more quantitatively identify the characteristics of droplet size, liquid water content, etc., that constituted the test environment.

- Operational limitations - operating ranges of speed, altitude, and time on station need to be expanded at both ends of the spectrum in order to better satisfy existing certification criteria.
- Availability limitations - industry's use of government owned facilities are available on a non-interference basis and normally require government sponsorship.

PROPOSED FACILITY IMPROVEMENTS

- In-flight Icing Facility - an improved In-flight National Icing Facility (flying tanker) should be developed
 - ✓ Cloud size - increase to 72' x 16'
 - ✓ Airspeed range - 80 to 300 knots
 - ✓ Test duration - increase by 50% (over HISS)
- Altitude Wind Tunnel (AWT) - the NASA Lewis Research Center Altitude Wind Tunnel should be rehabilitated and configured into a large scale icing research facility. This should be done in as short a time frame as possible.
- Icing Research Tunnel (IRT) - improve the NASA Lewis Research Center Icing Research Tunnel to accommodate the following:
 - ✓ Size - as large as possible
 - ✓ Speed range - 10 - 300 knots
 - ✓ LWC range - 0.1 to 3.0 gm/m³
- Ottawa Spray Rig (OSR) - arrangements should be made for continued use of this facility including:
 - ✓ Staffing - provide cross-training to U. S. icing research engineers
 - ✓ Cloud Size - increase by 25%
 - ✓ Location - evaluate feasibility of move to U. S.
- Test Bed Aircraft - an instrumented icing research vehicle should be developed to correlate data from natural icing with wind tunnel data, tanker data, etc.

INDUSTRY CONSENSUS

The industry views were quite supportive of one another from both a facilities requirements viewpoint and a facilities utilization viewpoint. However, in order to cover all those needs in a comprehensive manner, to demonstrate the specific areas of agreement and to insure that everyone's viewpoint is documented (and reviewed), the following summaries were developed for each of the major industry groups represented.

GAMA Consensus

1. Modify the HISS test bed for use by general aviation (G. A.) in the low airspeed regime.

2. Provide the KC-135 tanker for use in the high airspeed regime.
3. Rehabilitate the NASA Lewis AWT for use in full scale G. A. aircraft tests.
4. Continue the use of inflight tankers and develop certification criteria for tanker testing.
5. Develop the ability to simulate cloud physics tailored to icing tunnels for each class of aircraft.
6. Define the role for icing shape tests in the certification process.
7. Reevaluate the FAR Part 25 icing envelope.
8. Continue the use of the Ottawa Spray Rig and, at some future date, develop that capability here in our own country.
9. Develop an airborne inflight simulator on a high priority basis
10. Investigate the correlation of icing tunnel tests, inflight tanker tests and natural ice encounters.
11. Increase government funding to develop improved airborne spray system capabilities.
12. Pursue the establishment of a National Task Force for Icing Facilities requirements.
13. Update and modernize the icing certification criteria.
14. Establish icing facilities requirements so that icing simulation data can be used in lieu of natural icing data for certification purposes.

HAA Consensus

1. There is a critical need for additional research in the areas of:
 - Droplet Trajectory
 - Model Similitude
 - Modeling Icing
 - Icing Criteria
2. Certification of a helicopter in an icing environment should include an orderly progression of events from:
 - Laboratory development
 - Hover in artificial icing
 - Forward flight in artificial icing
 - Flight in natural icing
3. The helicopter industry has no need for improvements in the engine test facilities.
4. Conclusions regarding the NASA Lewis Icing Facilities:
 - The AWT facility is marginal in cross-sectional test area.
 - It is imperative that either the AWT, the IRT or any new national tunnel facility have an LWC range from 3.0 gm/m³ to less than 1.0 gm/m³. Currently, the FAA max continuous stratiform icing region (<1.0 gm/m³) can not be tested in the Lewis facility.

- Icing laboratory actions required include:

- ✓ Improve Icing Simulation (for IRT)

- a) Lower Speed Capability
 - b) Increased Range of LWC
 - c) Modern LWC and Droplet Size Instrumentation

- ✓ Larger Test Section

- a) IRT - Use of Secondary Test Section
 - b) AWT Conversion to Icing Facility
 - c) Provisions for Model Testing

5. Conclusions regarding the Ottawa Spray Rig

- Retain and nurture the continued use of the facility.
- Train U. S. Personnel in the operation and use of the OSR.
- Consider relocating the facility in the U. S.
- Increase the cloud size 25%.
- Develop the technology to extrapolate OSR results to forward flight.

6. Inflight artificial Icing Facilities

- Increase the cloud size of the HISS tanker.
- Improve the KC-135 speed range on both sides of its current operating speeds.
- Continue design studies on C130 tankers.

AIA Consensus

1. Fixed Wing views:

- Airborne inflight simulators should be developed on a high priority basis.
- A large scale wind tunnel facility is needed in order to test full scale aircraft up to and including the size of small business jets and large components of large transports.
- Correlation of icing tunnel tests or inflight tanker tests and actual icing encounters must be investigated to decrease the cost of certification.
- Review the certification requirements in light of these National Icing Facilities discussions.

2. Helicopter views:

- Critically review the Icing Facilities.
- Reevaluate and validate or redefine the Icing Envelope.
- Conduct an investigation to develop an innovative approach to Icing Certification.

1.5 VALUABLE COMMENTS AND INDICATIONS OF CONCERN

The following significant comments and contributions are only a small sampling of the information transfer which occurred during the General Discussions held on the afternoon of the final day of the conference. They are presented to document the underlying reasons for pursuing a National Icing Facilities program and to document the seriousness of the industry concerns.

Herb Slaughter (AIA/Sikorsky)

"....it costs on the order of \$5,000,000 to start from scratch, design, go through the development test program and get FAA (*icing*) certification for a helicopter."

"....In justifying improvement of the artificial icing facilities, the goal should be to reduce the amount of natural icing required and this goal should be endorsed by the regulatory wing of the FAA."

Jim Daugherty (GAMA)

"....When can we get rid of, and under what conditions, natural icing tests across the board?"

Milt Beheim (NASA Lewis Research Center)

"....They (*the Office of Inspector General*) have recently completed a study of the aeronautics program and one of their recommendations is that for research costs, not facility costs, but research costs that are applicable in the near term to industry activities, should be reimbursed to the government. And that goes way beyond (*current*) user fees for using a facility."

Dick Adams (FAA Technical Center)

"....Bigger and better icing tunnels are needed and the AWT is one step in the right direction....The consensus of this meeting is that there is an identified need to shorten the (*rehabilitation*) schedule (*of the AWT*).

Larry Koegeborhn (Douglas Aircraft)

"....Airframers need the AWT for large components and ice protection system development."

Paul Karmacy (FAA Central Region)

"....The FAA has an obligation to provide up-to-date criteria and up-to-date definition of the icing envelope for different

classes of aircraft. As the FAA, we have an obligation to define an acceptable means of certifying a helicopter for flight in icing conditions now (not in 7 years)."

Dick Adams (FAA Technical Center)

"....The charter of the Task Force would be to first develop a viable National Facilities Program Plan and secure resources to expedite that plan."

Ken Rosen (HAA/AIA/Sikorsky)

"....It seems to me that we have had a real good meeting here and we almost have a consensus, very nearly a consensus. I might add that most of the leading researchers in the United States are here, or representatives of them are here. It seems to me that we have taken a position. It seems to me that we have had that working session and it seems to me that we ought to forward to the various administrators and appropriate government agencies with a very firm recommendation right now. Not only to form a joint working group, which I think is fine, but to step out lively in the area of specific improvements in their current facilities."

Milt Behiem (NASA Lewis Research Center)

"....The unfortunate problem in selling any major facility is that the project that you know could use it will probably be done by the time the facility is done, because each one has about the same time period to accomplishment. Therefore, really a major facility decision is a philosophical decision, on whether or not that capability is required in the future and you may not know in detail who is going to use it and how."

MINUTES OF:

NATIONAL ICING FACILITIES

COORDINATION MEETING

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ON:

SEPTEMBER 23-24, 1980

AGENDA

FAA/INDUSTRY COORDINATION MEETING ON NATIONAL ICING FACILITIES

SEPTEMBER 23, 1980

8:00 - 9:00 a.m.	REGISTRATION	
9:00 - 9:10 a.m.	WELCOME	JOE DEL BALZO, DIRECTOR FAA TECHNICAL CENTER
9:10 - 9:20 a.m.	INTRODUCTORY REMARKS	"JB" McCOLLOUGH, CHIEF FLIGHT SAFETY RESEARCH BRANCH
9:20 - 9:30 a.m.	MEETING APPROACH	RICHARD I. ADAMS (MEETING CHAIRMAN)
9:30 - 10:00 a.m.	FAA TECHNICAL CENTER HELICOPTER ICING R&D EFFORTS	
10:00 - 10:45 a.m.	US ARMY HELICOPTER ICING SPRAY SYSTEM AND OVERVIEW OF RECENT ICING TESTS	HARRY CHAMBERS AND CPT LYNN HANKS
10:45 - 11:15 a.m.	BREAK	
11:15 - 11:40 a.m.	US ARMY ICING RESEARCH HELICOPTER	GENE BIROCCO
11:40 - 12:05 p.m.	US ARMY COLD REGIONS RESEARCH AND ENGINEERING LABORATORY FACILITIES	DAVE MINSK
12:05 - 12:30 p.m.	US NAVAL AIR PROPULSION CENTER ENGINE ICING TEST FACILITIES	VITO TRUGLIO
12:30 - 12:45 p.m.	OTTAWA SPRAY RIG	RICHARD I. ADAMS
12:45 - 2:00 p.m.	LUNCH	
2:00 - 2:25 p.m.	EGLIN CLIMATIC LABORATORY	WAYNE DRAKE
2:25 - 2:50 p.m.	USAF KC-135 & KC-130 TANKERS	1LT CARL WOLF
2:50 - 3:15 p.m.	USAF TULLAHOMA FACILITIES	JAY HUNT
3:15 - 3:45 p.m.	NASA-LEWIS RESEARCH CENTER	M. BEHEIM
3:45 - 4:00 p.m.	SUMMARY AND APPROACH	RICHARD ADAMS
4:00 - 5:00 p.m.	TECHNICAL CENTER BUILDING TOUR	
6:00 - 8:00 p.m.	SOCIAL FUNCTION	

AGENDA

SECOND DAY

SEPTEMBER 24, 1980

9:00 - 9:15 a.m.	GENERAL ANNOUNCEMENTS/COMMENTS	RICHARD I. ADAMS
9:15 - 9:45 a.m.	HAA CONSENSUS	BOB RICHARDSON
9:45 - 10:15 a.m.	AIA CONSENSUS	
10:15 - 10:45 a.m.	GAMA CONSENSUS	JIM DOUGHERTY
10:45 - 11:15 a.m.	BREAK	
11:15 - 12:45 p.m.	GENERAL DISCUSSION	RICHARD I. ADAMS
12:45 - 2:15 p.m.	LUNCH	
2:15 - 3:30 p.m.	GENERAL DISCUSSION (CONTINUED)	
3:30 - 4:00 p.m.	SUMMARY & CONCLUDING REMARKS	RICHARD I. ADAMS

NATIONAL ICING FACILITIES COORDINATION MEETING
SEPTEMBER 23-24, 1980
FEDERAL AVIATION ADMINISTRATION TECHNICAL CENTER
ATLANTIC CITY AIRPORT, NEW JERSEY 08405

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NATIONAL ICING FACILITIES
COORDINATION MEETING

MINUTES

FIRST DAY - SEPTEMBER 23, 1980

FACILITIES OVERVIEW

FAA TECHNICAL CENTER
ATLANTIC CITY AIRPORT, NEW JERSEY 08405

FAA/INDUSTRY COORDINATION MEETING

ON

NATIONAL ICING FACILITIES

WELCOME

TOM O'BRIEN, DEPUTY DIRECTOR

FAA TECHNICAL CENTER

Welcome to the FAA Technical Center, our newest facility. I'm especially pleased to have you all here, particularly the representatives from industry, DOD, DOT, NASA and all our own FAA from all the regions. I want to commend the Helicopter Association of America, as well as the Aerospace Industries Association of America and the General Aviation Manufacturers Association, for the help they provided in pulling this meeting together (Figure 1). You're in our new Technical Center. We have half the people moved in now, about six hundred out of the twelve hundred. This is a building that was provided to us by the local community for fifty million dollars. They issued a bond issuance that was picked up by Prudential Insurance and then they built the building for us. We lease it for twenty years and then it will become the government's. So, we have a good arrangement here. We've already moved about 85% of our computers.

As many of you well know the enroute air traffic is maintained by twenty centers across the United States. We have the equivalent of two center's worth of computers here. Now we also have the computers that go into all the major terminals, what we call the RX3, the latest RX3 Digital Form, the RX3A, and the RX2 which goes into medium density terminals. The Oceanic Centers like San Juan and Honolulu have a version called EARCS. So if you have a chance today, and if there's interest among you, we'll set you up to see our labs.

Our labs are over in the big red block house off to your left as you look outside. There are two floors of computers there, each floor is bigger than a football field. This is where all the air traffic development work is done for the agency, plus we have our own simulators there. We couple this air traffic potential not only with an inventory of the current nav aids, VORs, ILSs, MLSs (Microwave Landing Systems) but also with the latest surface radar for airports, what we call ASDE3.

We also have our own flight line. Our flight line is made up of one 727 (we'll be getting a second 727 in about a month) some turbo-prop powered 580s and several helicopters which we're proud of. We have the CH53, which is the ole' Jolly Green giant. That's our big work-horse. We have a Bell 206, and before the fall is over, Sikorsky will be delivering an S-76. So we have built up a good stable to support a very active helicopter program. Just a few months ago we dedicated an IFR heliport, 150' x 150'. At this heliport we will be installing all the latest lighting configurations to develop IFR approach

TOM O'BRIEN

procedures, as well as fitting it with a Microwave Landing System, so we can now start coupling in the unique performance of a helicopter to the extra capability of an MLS.

As part of our efforts here also at the Center, we are particularly geared toward the improvement of helicopter operations. We have recently developed a helicopter flight safety R&D program, which is geared towards the problems of certification and the regulations of helicopter flights. One area of this program is concerned with helicopter flight in known icing conditions. We anticipate in the future a large percent of the new helicopters will be certified for flight in icing conditions. Three applications for such certificates have already been submitted. We have the Aerospatiale Puma (Figure 2), the Boeing Vertol 234 (Figure 3), the Bell Model 412 (Figure 4) and many others such as the Sikorsky S-76 (Figure 5) are expected. Beautiful, beautiful machines, and there are a lot more coming as shown by the growth projections for civil helicopters (Figure 6).

We have concluded that if we had to use the natural means of getting our icing data it would take us three to five years, and this is beyond the practical expectations that we can expect for engineering and businessmen to deal with in certificating their equipment. Through efforts now such as this coordination meeting, we at the Center hope to be able to form a consensus, and this is the object of this meeting (Figure 7). We want to form an industry consensus of what are the requirements for National Icing Facilities for the future. We have our needs and now we have to develop facilities to meet those needs so we can carry on our business.

I would like to also emphasize that such icing facilities could be used for GA and commercial aircraft, so they are not totally dedicated to helicopters.

Now I hope you have a good meeting and if you want to see our facilities we will arrange it for you. It's my pleasure now to introduce "JB" McCollough, who is the Chief of our Flight Operations Branch. "JB".

"JB" McCOLLOUGH, CHIEF

FLIGHT SAFETY RESEARCH BRANCH

Good Morning! It was pleasant this morning to meet a lot of old friends and associates, and people that I've talked to on the phone and seemed like I knew but have never met face to face. I want to welcome you all here this morning and thank Tom for introducing the Center to you. This morning I would like to tell you just a little bit more about the branch which I'm operating here. We do other things besides helicopter work. We're involved basically in three areas, which include General Aviation, Transport, and Helicopter. We work in General Aviation both in the aircraft and the airman areas for our research. In the transport area we are confined primarily to the advanced technology systems that are coming up. This includes the stability and control which these new systems will provide, the flying qualities that these new advanced systems will provide, the active controls, the digital avionics, etc. You've all heard those terms.

In the Helicopter area we have the responsibility in two particular areas; icing and IFR (Figure 8). When I say IFR, I'm talking about IFR handling qualities, the regulations for certification of the aircraft itself, not the operations regulations and criteria for IFR operations. Within this program, we also support the regions in our technical areas of expertise. We have several efforts going at this time where we are doing this. We are also involved in simulations, not only of the aircraft, but of the systems that are employed, in the evaluation, in the development of these systems, the procedures, and the possibility of using these in agency certification. We work in the crew/machine interface area. When we come up with these new aircraft and systems in our research efforts, how does it impact the man/machine interface? Now back more to the focal point of what this meeting is about. We support, in these two areas of icing and IFR, the agency's Helicopter Operations Research and Development program. We call it the HORD. Maybe you have heard of those things. The areas in those are the responsibility of this organization where, and as part of this, we have picked up and have been assigned, the responsibility in the FAA for leading the FAA's efforts in a National Icing Facilities Program. This meeting today is one of our efforts in that role. Now in our working in this program we also live very closely with the people in Washington, and our main coordination point there is Mr. Tom West, who is here today in the audience. Raise your hand Tom, for those who haven't seen you. I can tell you a lot of stories about Tom when I'm off of the tape here. Welcome Tom, we're glad to have you.

I think my next role here is to introduce to you the Chairman of this meeting, who I'm sure you all know, Mr. Dick Adams. Dick has been with this organization about a year and he's our Program Manager here for Helicopter Flight Safety Research and Development Programs, including all of the areas that you see on the chart (Figure 9). Prior to coming here he was with the Army for about sixteen years. The last seven of that he was Manager of the Icing Research Program there at ATL (Applied Technology Laboratory). He's now currently a member of the

"JB" McCOLLOUGH, CHIEF

AGARD Flight Mechanics Panel Working Group on Rotorcraft Icing and prior to that he was with the Lockheed Georgia Company. I think that's enough time for me this morning to tell you a little bit about who we are and where we are going and welcome you aboard. At this time I would like to turn it over to the "Ice Man", Dick Adams.

RICHARD I. ADAMS, MEETING CHAIRMAN

The Ice Man Cometh is what he meant to say. I too, would like to welcome all my old friends and those that I don't know intimately. Sure appreciate the turn out.

I would like to very briefly summarize the objectives of the meeting and how we are going to go about it. First, the viewgraph that Tom O'Brien showed here (Figure 7) I think illustrates the meeting objectives and industry consensus on National Icing Facilities, not only for certification, but for research and development purposes. (Next viewgraph, please). Now the plan of attack as I'm trying to illustrate here (Figure 10), this morning, in fact, all day today, includes various representatives from various government organizations describing to you the facilities that exist; the capabilities and limitations of these facilities; and whether or not these facilities are available to the industry and under what conditions. Then from that and from the discussions that you've had amongst yourselves so far, we hope that we can develop a consensus of the industry, including the consensus of the need of the future. We are not talking about satisfying needs that exist right now. It's going to take a long time to bring together the facilities that will be required to make icing research and icing certification better and more timely and less costly. (Next viewgraph, please).

Now what are we going to do with this information? On the left side of this viewgraph (Figure 11) you will see government. Back in January of this year we hosted here a meeting of government agencies, FAA, NASA and DOD, and we developed minutes from that meeting (Appendix B). The purpose of this meeting is to get the industry consensus and allow the results of both of those meetings to flow into a recommended facilities requirements effort. We here at the FAA Technical Center have, in essence, volunteered to put this together and staff a letter from the FAA Technical Center to be signed by Headquarters FAA over to DOD, to DDR&E, and to Headquarters NASA. We hope as a result of all this that a Task Force can be established to put together a program plan that will be a national level program, and from that the development of a facilities improvement program as well as development of necessary new icing test facilities can proceed.

I'm going to, in a few minutes, begin the technical presentations by giving an overview of the FAA Technical Center R&D Program in this area. But first, I would like to introduce Charlie Masters, who has done 98% the work in bringing this meeting together. Charlie has some administrative announcements and other comments to make. So Charlie, will you step forward and do that?

CHARLIE MASTERS

Thank you, Dick and good morning! As you know one of the things associated with any meeting of this nature is registration. So I'm assuming that all of you in the auditorium have completed registration. If not, for those of you that may have overlooked it, the registration desk is out in the corridor to my right and to your right as you enter down the ramp. If you did register, there were a number of handouts that were available for you. One of the more important ones was a copy of the agenda, which we will be following the next two days. There were also copies of a paper entitled "The Aircraft Icing Facilities in North America", (Appendix C) by Dr. William Olsen of NASA's Lewis Research Center. We have those available outside for you. There is also the Center Newsletter (Appendix B) available that describes in general our icing efforts here at the Center. For those of you that will be participating in our social activities tonight, there are directions on how to get to the Clubhouse, because that's where it is being held. We will be looking forward to seeing most of you there.

Now, a couple of other things we have to cover. One of the first things that you might be interested in is how do you communicate with your office. Well, for those of you from industry there is a pay phone that is available, across the corridor in the rear of the auditorium, and that's also right behind the men's room. The government employees that have need to get to an FTS or an Autovon line, see me at one of the breaks and we will arrange that for you.

As you noticed, when you came in, there is coffee available and we're asking that you do not bring beverages inside the auditorium. We've had a number of accidents earlier with spillage. Also, we are asking that you do not smoke in the auditorium. There are a couple of areas outside.

Speaking of our social affairs tonight, which are between six and eight pm at the Clubhouse which is about five miles west of here, I would like to see, at the break, those of you that would be interested in attending. Another thing, and that deals with lunch, there will be a bus here that will pick everyone up at the break period, 12:45, and will take you over to the cafeteria for lunch. So you do not need to worry about where it is or how to get there, the bus will take care of that. Also, this precludes your having to drive. If there is anyone that needs reservations or taxi, or anything local that you are having a problem with see me and we'll get it resolved one way or another through the Visitor Affairs Section, or maybe some of it I'll take care of myself. If you anticipate any incoming messages please write this number down, area code 609-641-8200, extension 3334. That is our Conferences and Visitor Affairs Section phone number. If you will have whomever it is that calls you announce that you are in the National Icing Facilities Conference, we'll get the message to you. And if, for some reason, that number is busy, there is another number which is 3059, that's an alternate. One other thing before I finish, and this deals with our tour. This afternoon between 4:00 and 5:00 pm we have planned a tour of the Center's Facilities. At this time could I see a show of hands of those that are planning to attend the tour? I would like to count you. Thank you very much?

TECHNICAL CENTER ICING R&D EFFORTS

RICHARD I. ADAMS

Thank you, Charlie. One thing that I would like to make sure that everybody understands is that we are taping all of the proceedings of the meeting and that there are microphones in the back of the auditorium, so that when questions and answers are provided we need to speak into the microphones so that we get it on tape. The purpose of the tape recording is to assist us in bringing together the minutes of the meeting very accurately and in a very timely manner. If anyone wants to say something off the record during the whole meeting, please let us know and we will flip the tape recorder off. And also if anyone has objections we will erase and destroy the tapes afterwards, whatever suits you.

The overall helicopter icing certification standards research and development program that we put together here in the past year or so, is broken down into five separate areas that you saw listed on JB McCollough's viewgraph (Figure 9). I would like to very briefly touch on each of these areas. Now, when I do this it's going to be done out of sequence, so just bear with me. The reason that I'm doing it out of sequence is because I want to end up talking about the Certification Tools area, that really forms the basis for the national facilities effort that really is the bottom line of this meeting.

I have the first viewgraph here (Figure 9). Now, Standards and Procedures is the last item on the list on the right. The Standards and Procedures effort really is the guts of the overall program. It is the element of the program that brings the results of all of the other elements of the program together, and through continual review of the various standards and advisory material provides short and long term recommended changes to that material. It also allows us to stay abreast of all of these changes in technology and do the thing that we must do with the regions and for the helicopter program, primarily the Southwest region (Jay Shaply and his folks) in assisting them in anyway we can to bring the effect of most recent technology to the existing certification program. (Next viewgraph, please).

Now, one of the first things that we are trying to really get a handle on is the atmospheric icing criteria that exists in FAR 25, Appendix C. I'm sure you are all aware of those requirements. Now the thing that we are trying to do in getting a better handle on the low altitude icing environment, is to take advantage of all of the new data that is being gathered through the meteorological surveys by various organizations (Figure 12). We're working very closely with NASA Lewis. NASA Lewis, as you know, developed the original basis for the requirements that currently exists in FAR 25, Appendix C. So, we will be working very closely with them. We hope that by 1983 we will have a sound basis for new revised criteria. Now, why do we need new or revised criteria? We have found from past research, primarily flight testing, that the British have done, and that the U.S. Army has done, that the existing criteria does not appear to be applicable to the helicopter or other aircraft that operate at low altitudes, below

RICHARD I. ADAMS

10,000 feet, for example. We also have, not I personally, but the FAA, been beaten about the head and shoulders by industry with claims that the criteria are obsolete. So we are trying to do something about it. (Next viewgraph please).

Helicopter Icing Test and Operational Methodology (Figure 13) have been evaluated. In other words, how do you go about certifying helicopters for flight in icing conditions and what are the constraints that need to be applied in the operation of the helicopter in icing conditions? That is, the intentional penetration of icing conditions. That's the thrust of this overall effort and the way we are approaching this is by taking advantage of ongoing programs that you see listed here. Now the schedules that I have here are approximations. I'm sure that there are some deviations, but we are working very closely with the U.S. Army on the UH-1 test program. We have an interagency agreement with the U.S. Army Aviation Research and Development Command for participation and monitorship of all their programs, with the Black Hawk and the AAH, and the CH-47D. We intend to follow very closely the European programs, as well as the U.S. commercial programs. We are working very closely right now with the Southwest region on the certification of the Bell 412 helicopter (Figure 14) and with the Eastern region on the Vertol 234 (Figure 15). So, by this means, we hope to gain the experience and the data necessary to get a better understanding of what certification requirements should be. (Next viewgraph please).

Helicopter Ice Protection System Development and Evaluation concepts are shown on the next viewgraph (Figure 16). The purpose of this element of the program is to make sure that the FAA understands the new concepts that are coming down the pike and that the FAA knows how to go about certifying and regulating aircraft, incorporating some of these new concepts. Now I've looked at many, many concepts here. One of the primary areas is that for rotor icing protection. There are secondary areas that include instrumentation, systems control and display, etc. You can read all these things. (Next viewgraph please).

So, this brings us to the Certification Tools effort (Figure 17) which really gives us the essence of this meeting. One of the basic problems that I think that we concluded existed as the result of all the testing that has taken place in the last ten or fifteen years with helicopters is that if you try to rely on natural icing testing it's going to take three to five years to get enough data to certify. So it's unacceptable, since it's very expensive. In-flight simulation is another technique that can be used to supplement, or augment, natural icing tests, but the facilities are lacking. You'll hear more about that as we go. I'll talk about the Ottawa Spray Rig in more detail later in the day, but the Ottawa Spray Rig itself, although a very useful tool, has limitations. And the tremendous array of icing tunnels and icing chambers that exist over the country also needs to be looked at very closely and possibly improved. Then there are analytical prediction techniques that we have included in the program, and we're working very closely with NASA in their efforts, and also with the UK in their efforts, to improve the analytical models for prediction of the ice shapes and the effects of the shapes, etc. (Next slide, please).

RICHARD I. ADAMS

Now, the slide on the right (Figure 18) you are all familiar with I'm sure. It is a direct extract from the FAR 25, Appendix C, for the continuous maximum conditions. On your right, my left (Figure 19) is a cross plot of these data, the shaded area showing what you can reasonably expect to encounter during the natural icing testing. Now, this is the continuous maximum criteria only, so during natural icing testing, based on our experience so far, this is all you can expect to really see.

The next slide on my right (Figure 20) is the intermittent maximum criteria from FAR 25, Appendix C. Next slide on my left (Figure 21) shows the capabilities of the HISS tanker, the Army's Helicopter Icing Spray System, in relation to these criteria. As you can see, it covers only a very small portion of the overall envelope that needs to be covered or that is specified by the FAR 25, Appendix C.

You're going to hear much about the Helicopter Icing Spray System (Figure 22) later. Could we have the next one (Figure 23) that shows the Ottawa Spray Rig over here? This (Figure 24) is the same plot showing the capabilities and limitations of the Ottawa Spray Rig. Here again you can see that it only covers a small portion of the envelope. Now the one distinct difference between the Ottawa Spray Rig and the Helicopter Icing Spray System that exists now is that the droplet size is variable in the Ottawa Spray Rig. Right now the droplet size for the HISS is pretty well constant. (Next viewgraph, please). Other limitations of the HISS are shown here (Figure 25). So, recognizing all of these facts, we did bring together the government coordination meeting back in January 1980 and this viewgraph (Figure 26) summarizes the key results of that meeting. First of all, NASA has an altitude wind tunnel that has been sitting idle for a number of years, and we concluded at that meeting that this tunnel could be renovated for use for our icing tests for research, development or certification purposes. Milt Beheim from NASA Lewis will describe that facility as well as other facilities later this afternoon. We felt that the Ottawa Spray Rig needed to be retained and possibly improved. We felt that there was a dire need for a national inflight icing simulator, a national tanker, I'll say. The HISS is doing a good job right now. The HISS is involved in high priority military projects. This year, I might mention that, the Army has agreed, through the interagency agreement that exists between the FAA Technical Center and the Army, to allow Bell Helicopter Textron to use the HISS in development testing for their model 412. We feel that an icing research test bed helicopter needs to be available for continual flying to investigate many, the very very many, unknown problem areas that have been identified over the years. The longer I am associated with this field of endeavor the more I realize that it is still a black art, more or less, and there isn't a lot of actual information that exists. There are a lot of phenomenon that we don't understand. The only way we are going to be able to understand those problems is to have a machine that can be flown in icing conditions.

RICHARD I. ADAMS

highly instrumented, that can develop that data for us. That will form a basis for correlation with the other facilities, such as the tunnels, inflight tankers and the array of icing simulation facilities that we hope will exist one day.

And last, we felt that really there was a need for the establishment of a National Task Force to bring all this together to form technical needs, the rationale for the needs, to provide the basis for forming of an overall national program and, as I said before, at that meeting we agreed that the FAA Technical Center would take it upon ourselves to coordinate or try to lead that effort and get letters to NASA and DOD with specific recommendations.

So, this brings us back to the objectives of this meeting, namely to get the consensus of industry on industry's needs. The way we are going to go about doing this I've outlined before, but just to make sure we all understand what we are going to do with this information. Let's refer to the previous flow chart (Figure 11) that will try to lead us to the National Task Force. Finally, the plan of attack is to brief you this morning on the availability on all of the facilities that do exist currently, and the improvement programs, and statements regarding the availability of those facilities to industry.



DEPARTMENT OF TRANSPORTATION

**FEDERAL AVIATION
ADMINISTRATION
TECHNICAL CENTER**



**NATIONAL ICING FACILITIES
INDUSTRY COORDINATION
MEETING**



Figure 1



Figure 2

puma330

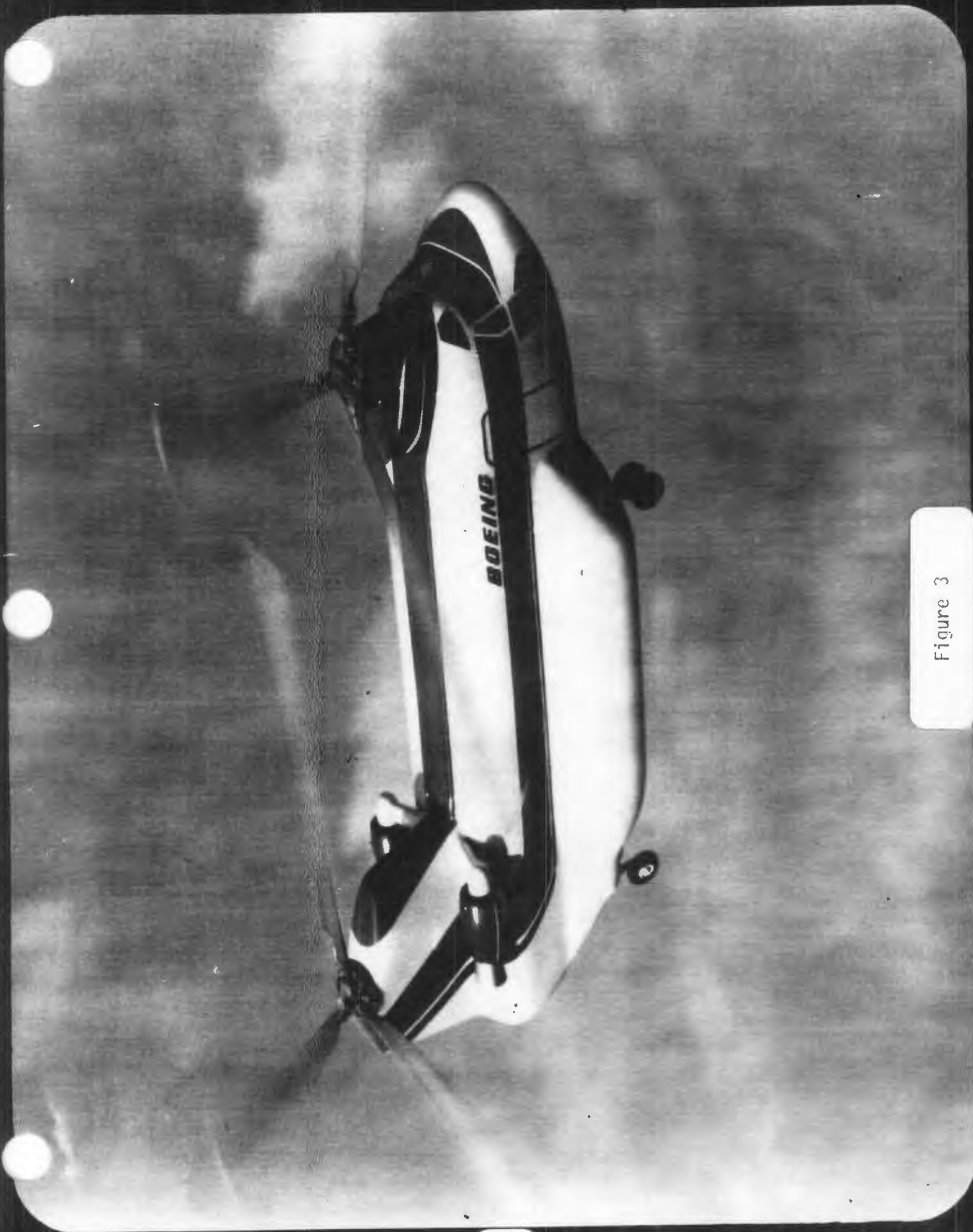


Figure 3

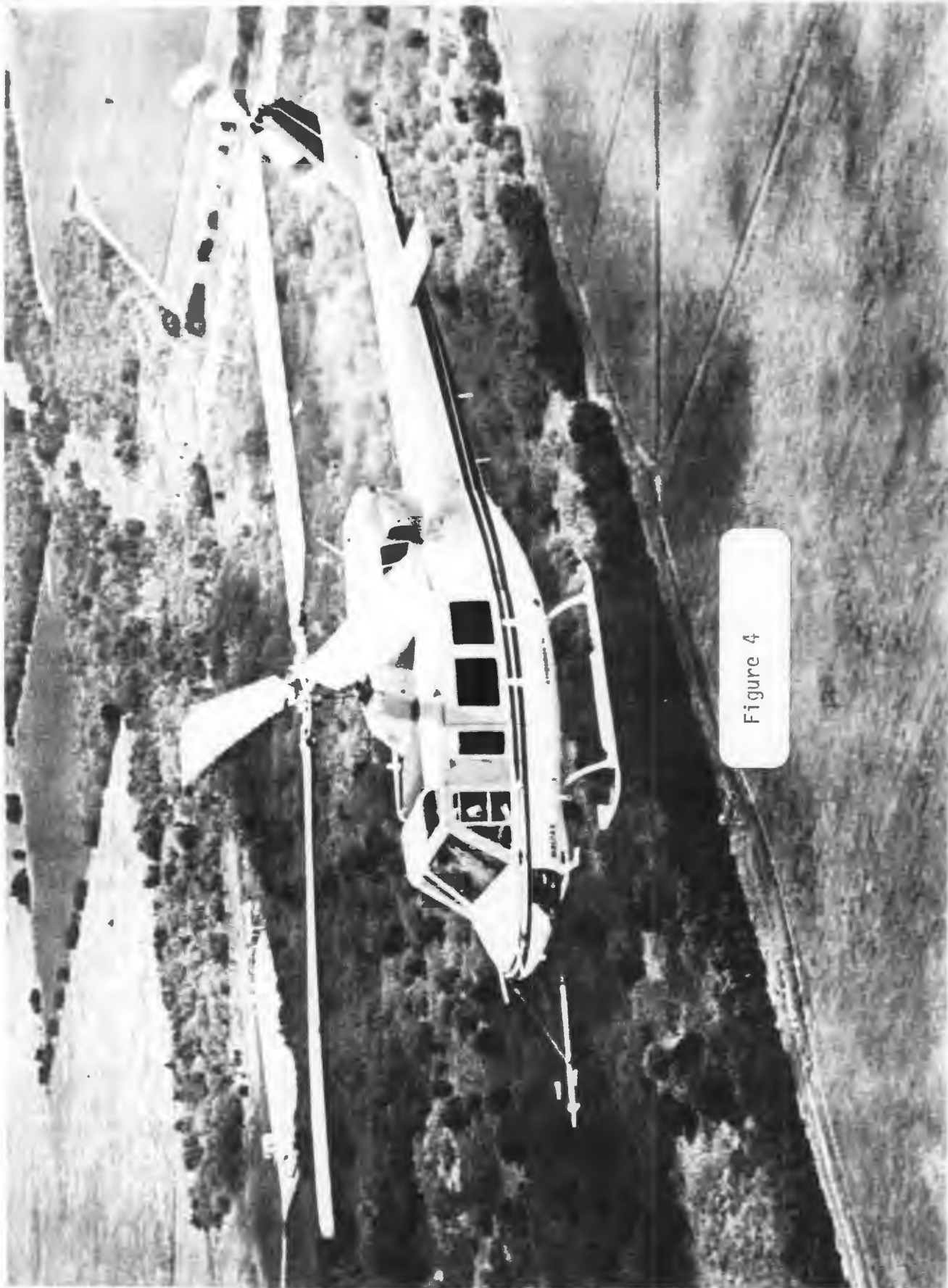


Figure 4

MODEL 412

Bell Helicopter [TEXT]



SIKORSKY™

Figure 5

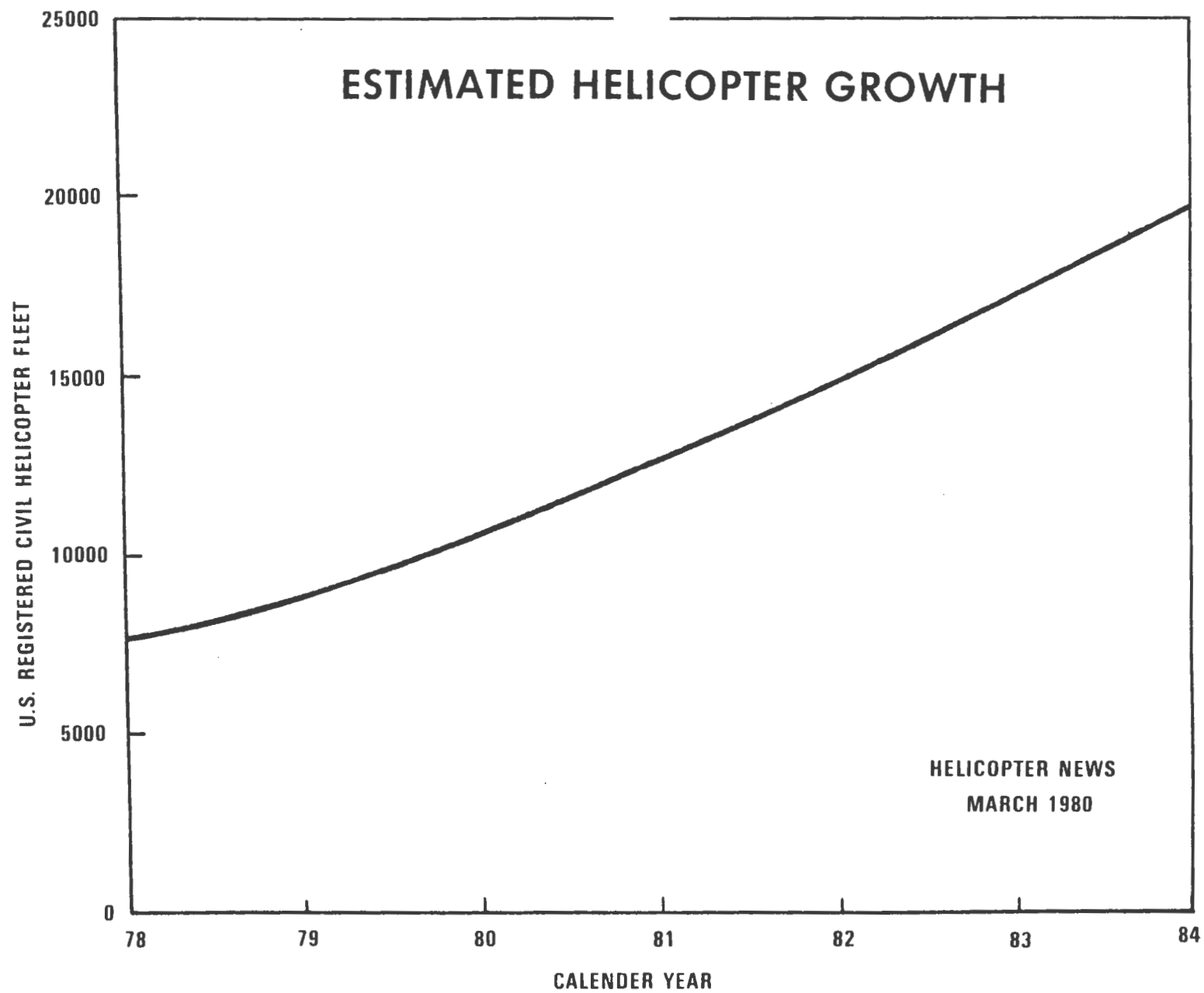


Figure 6

NATIONAL ICING FACILITIES COORDINATION MEETING

OBJECTIVES

- **INDUSTRY CONSENSUS**
- **ICING FACILITIES NEEDS**
 - **RESEARCH**
 - **DEVELOPMENT**
 - **CERTIFICATION**

FEDERAL AVIATION ADMINISTRATION

TECHNICAL CENTER

HELICOPTER ICING

CERTIFICATION STANDARDS AND PROCEDURES OVERVIEW

Figure 8

FAA TECHNICAL CENTER HELICOPTER FLIGHT SAFETY R&D PROGRAM

HELICOPTER ICING CERTIFICATION - R&D PROGRAM

- **ICING CRITERIA**
- **TEST AND OPERATIONAL METHODOLOGY**
- **SYSTEMS DEVELOPMENT AND EVALUATION**
- **CERTIFICATION TOOLS**
 - **NATIONAL FACILITIES**
- **STANDARDS AND PROCEDURES**

NATIONAL ICING FACILITIES COORDINATION MEETING

PLAN OF ATTACK

- GOVERNMENT OVERVIEW
 - EXISTING FACILITIES
 - PLANNING
 - IMPROVEMENTS
 - DEVELOPMENTS
 - INDUSTRY ACCESS
- INDUSTRY POSITION
 - HAA
 - GAMA
 - AIA
 - OTHER

Figure 10

NATIONAL ICING FACILITIES COORDINATION MEETING

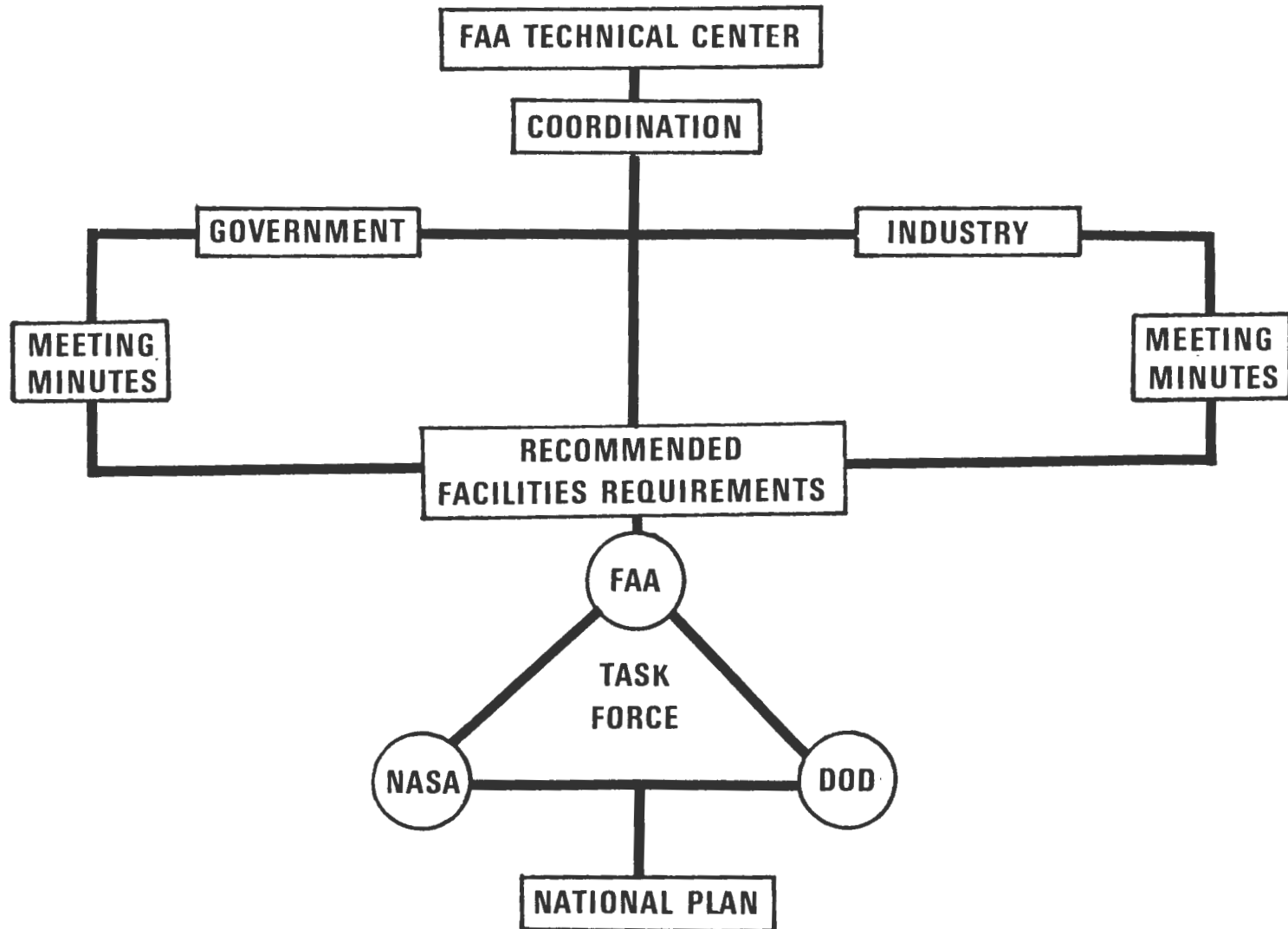


Figure 11

HELICOPTER ICING ATMOSPHERIC CRITERIA

	FY80	FY81	FY82	FY83	FY84	FY85
METEROROLOGICAL SURVEYS						
NAVAL RESEARCH LAB						
CONTRACTUAL SURVEYS						
U.S. ARMY						
U.S. AIR FORCE						
UNITED KINGDOM						
FED REPUBLIC OF GERMANY						
FRANCE						
FAA/NASA						
METEROLOGICAL CRITERIA ASSESSMENT						

Figure 12

HELICOPTER ICING TEST AND OPERATIONAL METHODOLOGY

PARTICIPATION IN EXISTING CERTIFICATION & OPERATIONAL PROGRAMS (CANDIDATE PROGRAMS)

UH - 1H U.S. ARMY
UH - 60A U.S. ARMY
AAH U.S. ARMY
CH - 47D U.S. ARMY
WG - 34 RAF
CH - 47D RAF
BK - 117D FRG
SA - 330 FRANCE
A - 109 ITALY
CH - 124 CANADA
234 VERTOL
412 BELL
S-76 SIKORSKY

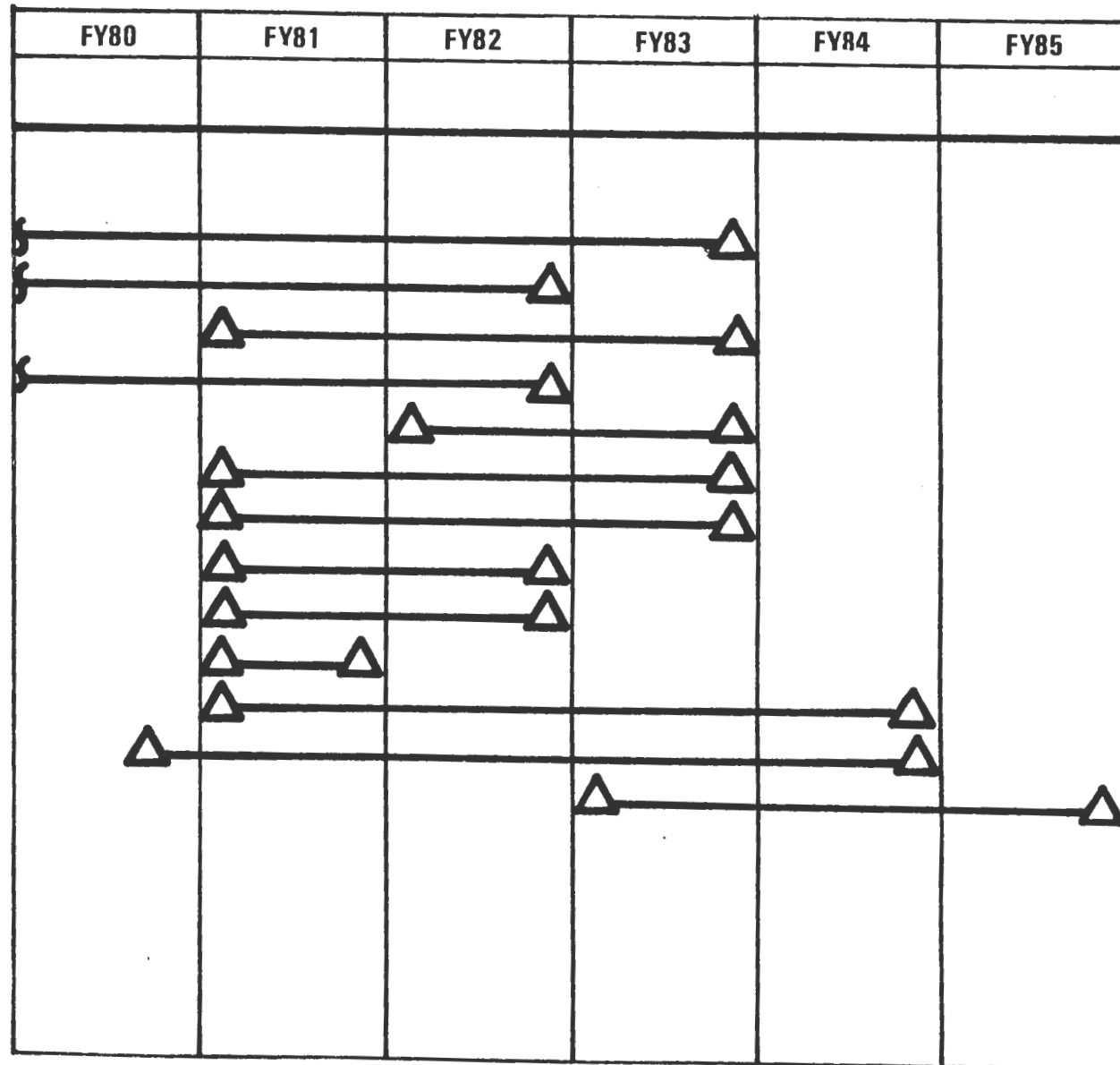


Figure 13

ICING CERTIFICATION

BELL 412

- **FAA TECHNICAL CENTER GUIDELINES**
 - **PROPOSED - MAY 21, 1980**
- **HISS COMMITTED**
 - **TECHNICAL CENTER IA WITH ARMY**
- **INTERIM CRITERIA**
 - **BASED UPON PROPOSED GUIDELINES**
 - **TARGET - OCTOBER 1, 1980**
- **COOPERATIVE EFFORT**
 - **TECHNICAL CENTER**
 - **ASSISTANCE**
 - **MONITORSHIP**

Figure 14

ICING CERTIFICATION

BOEING-VERTOL MODEL 234

- EASTERN REGION CONCURRENCE
 - CH-47D FLIGHT TEST BASE
 - 234 LIMITED ENVELOPE
 - -10°C
 - 10,000 FT
 - CLOUD CEILING
 - ESCAPE ROUTE
 - ON BOARD INSTRUMENTATION
- FAA TECHNICAL CENTER PARTICIPATION
 - CONSULTANT
- FAA CONCERN
 - TRANSPORT CATEGORY
 - LEVEL OF SAFETY
 - FULL ENVELOPE

Figure 15

HELICOPTER ICE PROTECTION SYSTEM DEVELOPMENT & EVALUATION

CONCEPTS

- ROTOR BLADE PROTECTION
 - CYCLIC ELECTROTHERMAL
 - MICROWAVE
 - VIBRATORY
 - PNEUMATIC BOOT
 - ELECTRO - IMPULSE
 - ICE PHOBIC COATINGS
- INSTRUMENTATION
 - DETECTION/SENSING/QUANTIFICATION
 - LWC — ICE CRYSTAL — DROP SIZE — RATE
 - INFRARED
 - ULTRASONIC
 - MECHANICAL
 - LASER SPECTROMETRY
 - LASER HOLOGRAPHY

SYSTEM CONTROL & DISPLAY

- INTEGRATING RATE
- ICING SEVERITY LEVEL
- ICE CRYSTAL WARNING
- FREEZING RAIN WARNING
- VISUOMETERS

Figure 16

ICING CERTIFICATION TOOLS

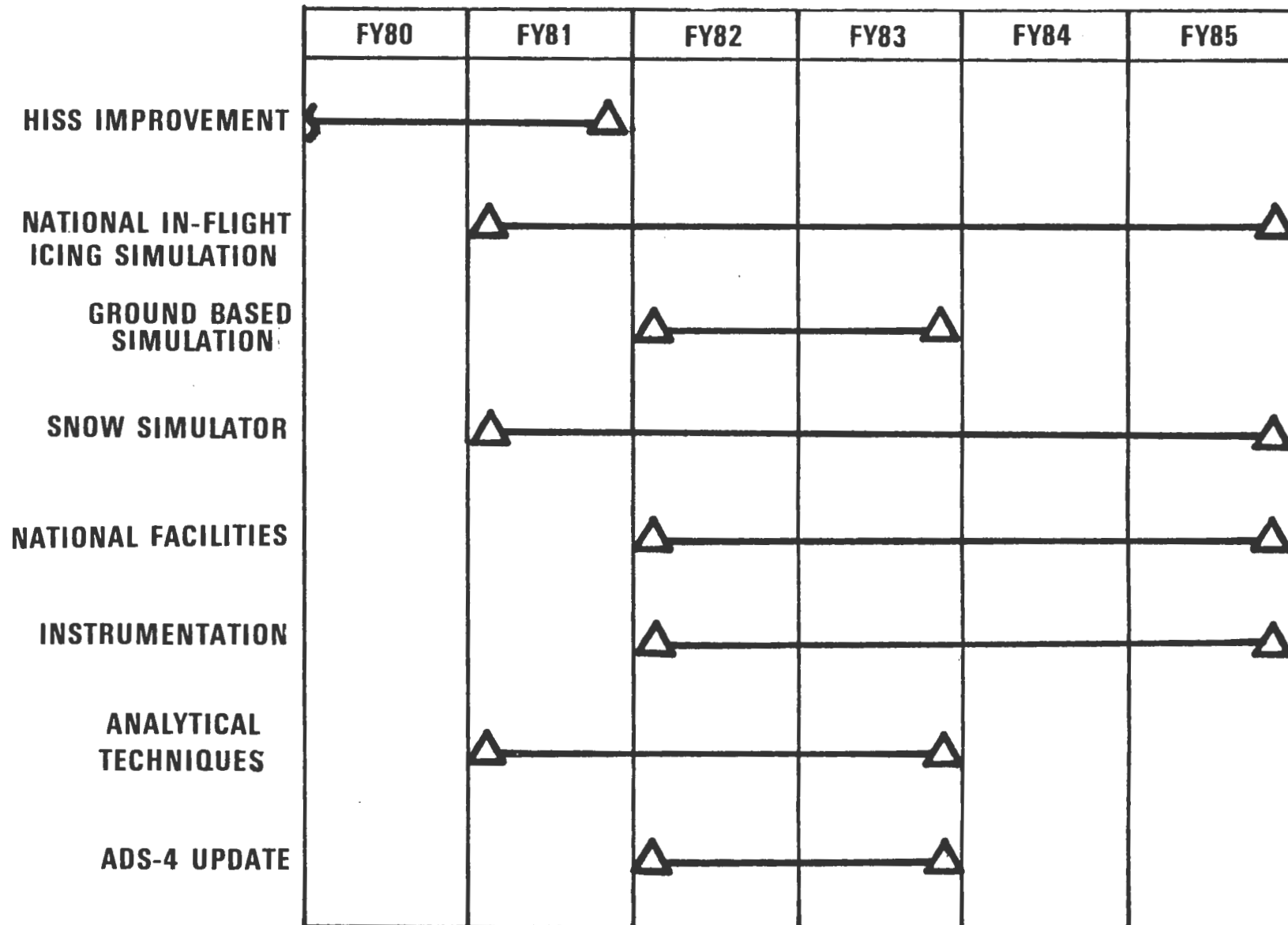


Figure 17

CONTINUOUS MAXIMUM (STRATIFORM CLOUDS)
ATMOSPHERIC ICING CONDITIONS
LIQUID WATER CONTENT VS MEAN EFFECTIVE DROP DIAMETER

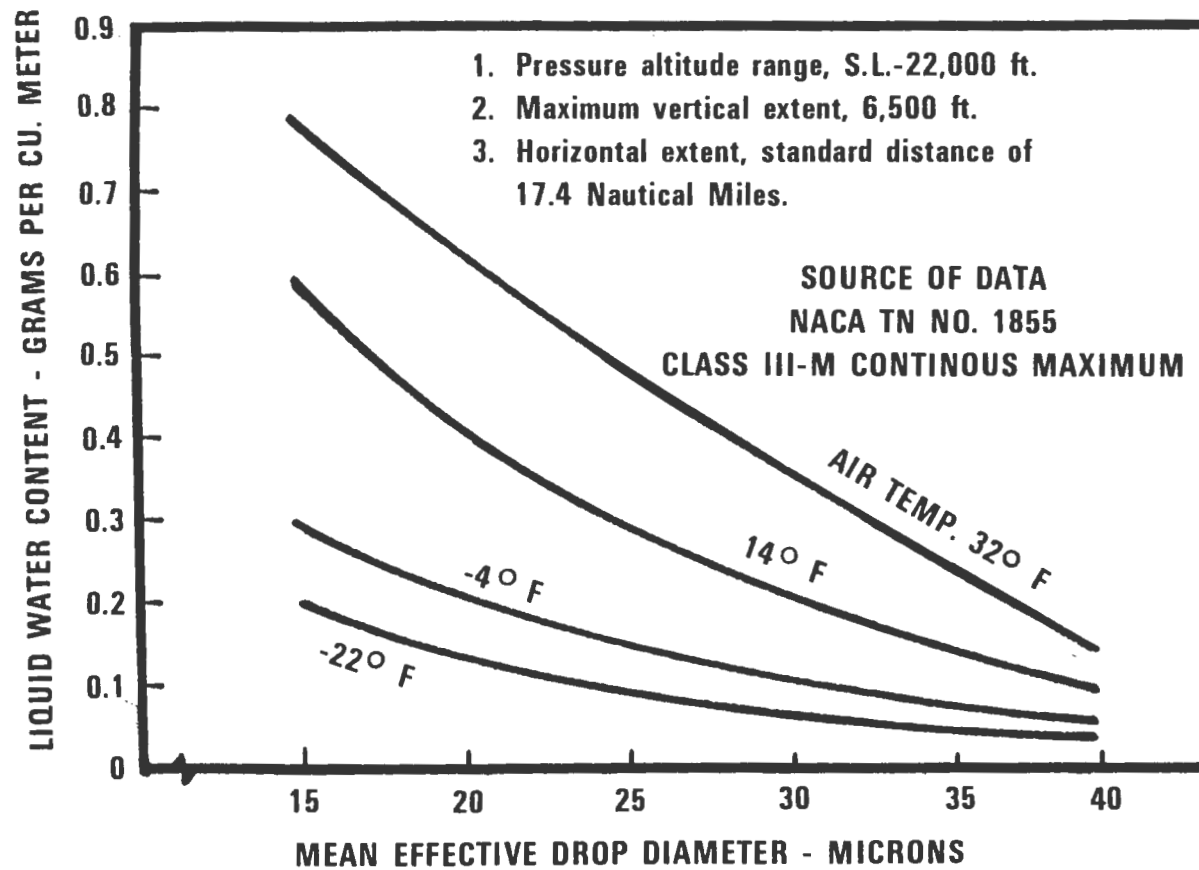


Figure 18

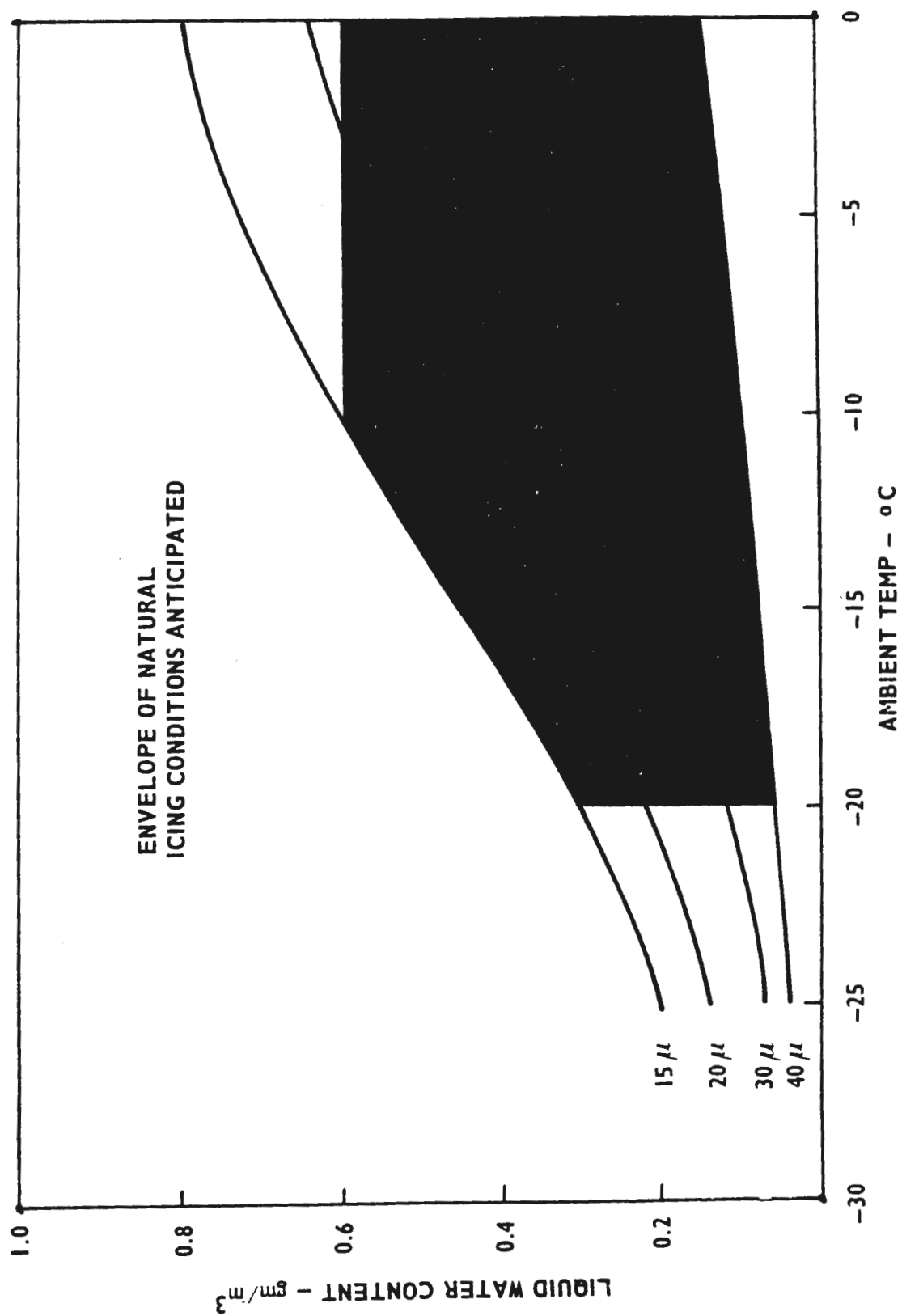


Figure 19

INTERMITTENT MAXIMUM CUMULIFORM CLOUDS)
ATMOSPHERIC ICING CONDITIONS
LIQUID WATER CONTENT VS MEAN EFFECTIVE DROP DIAMETER

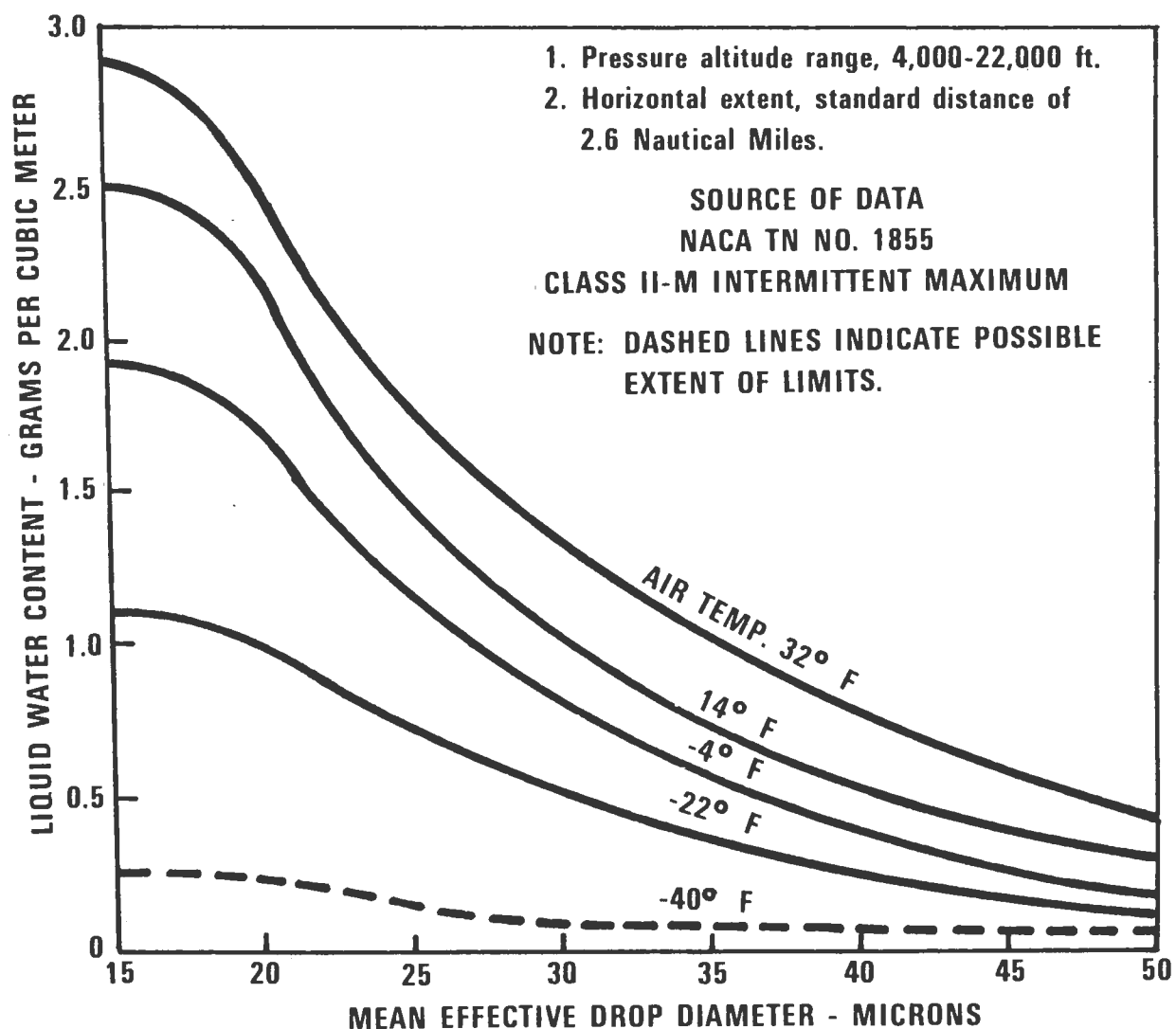


Figure 20

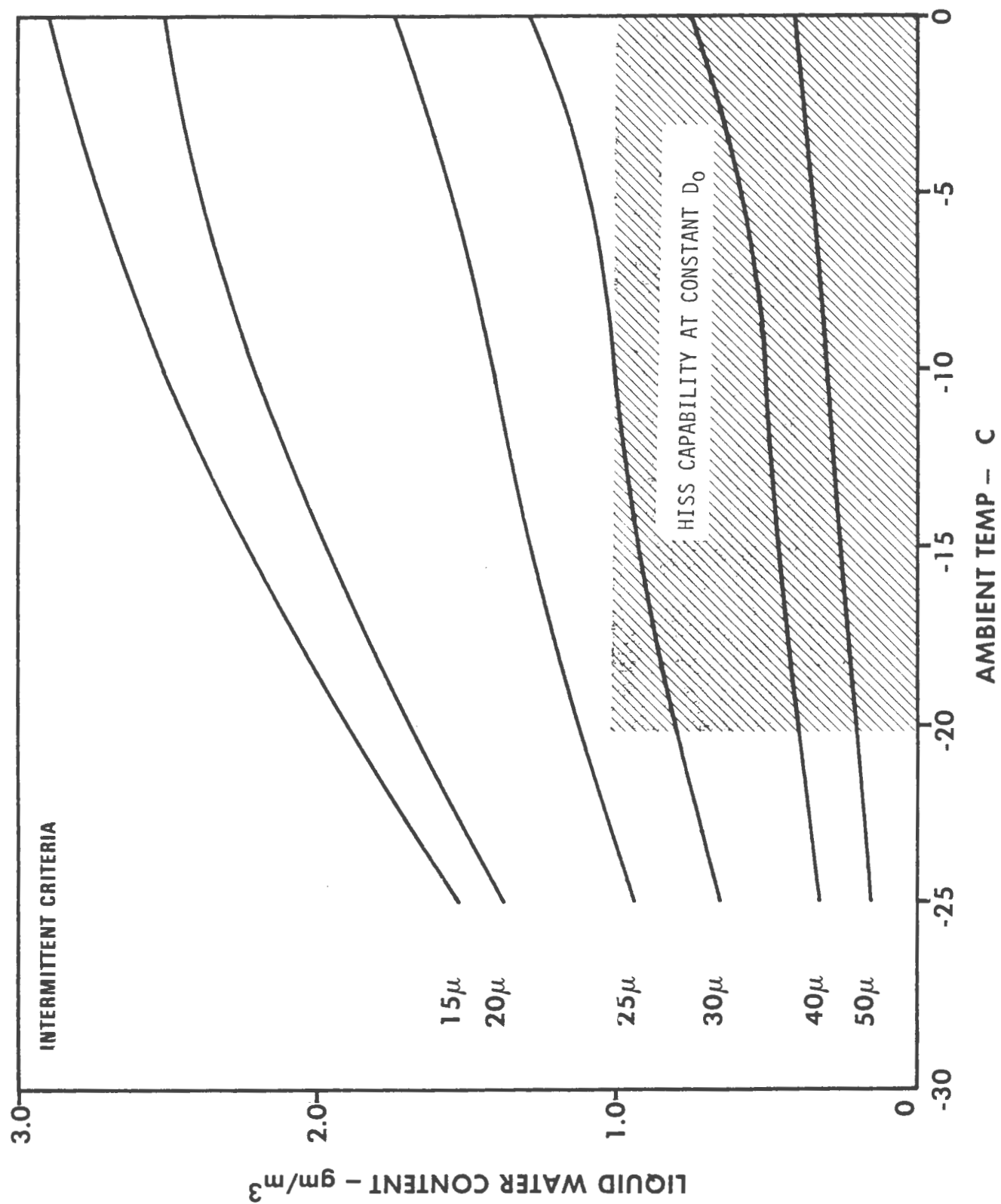


Figure 21

Figure 22

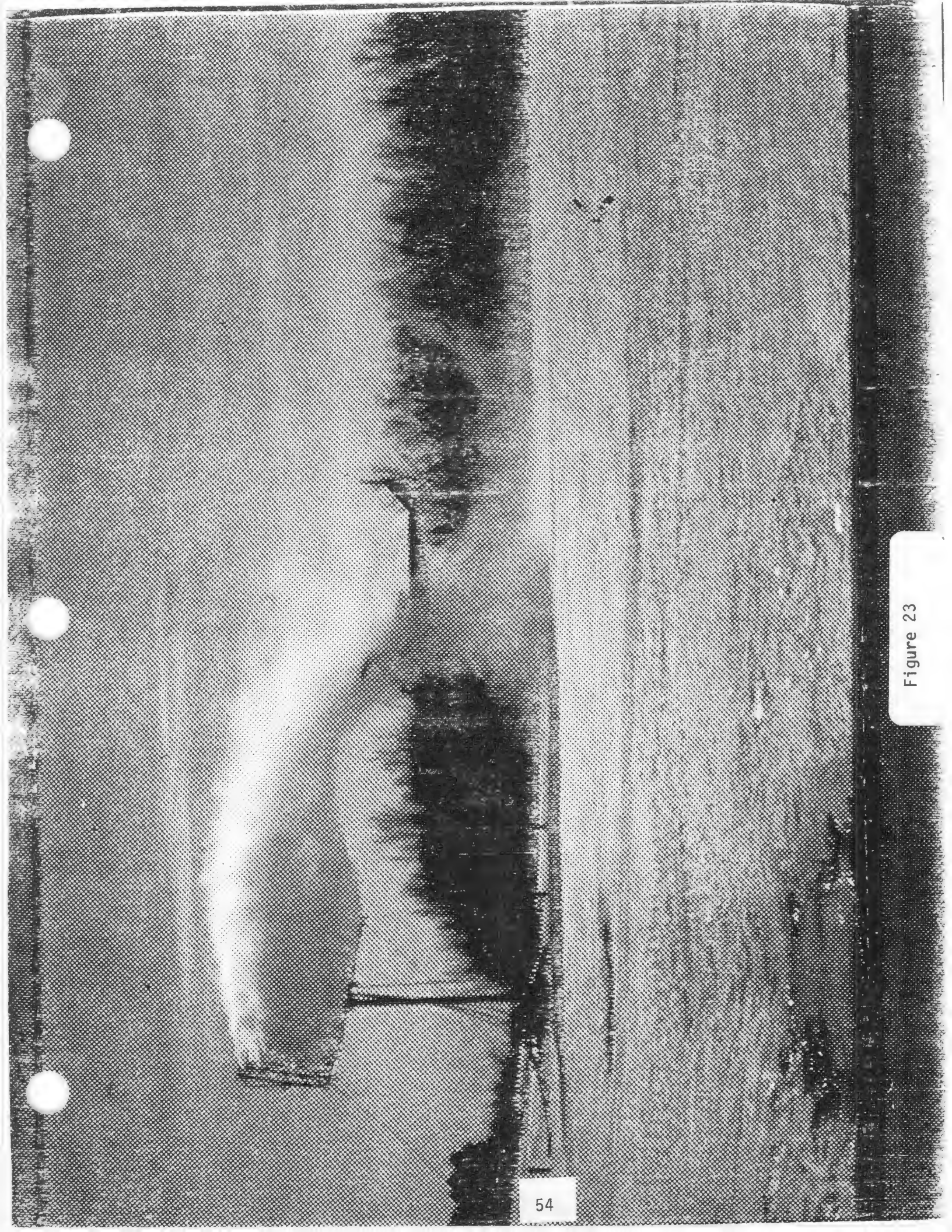


Figure 23

55

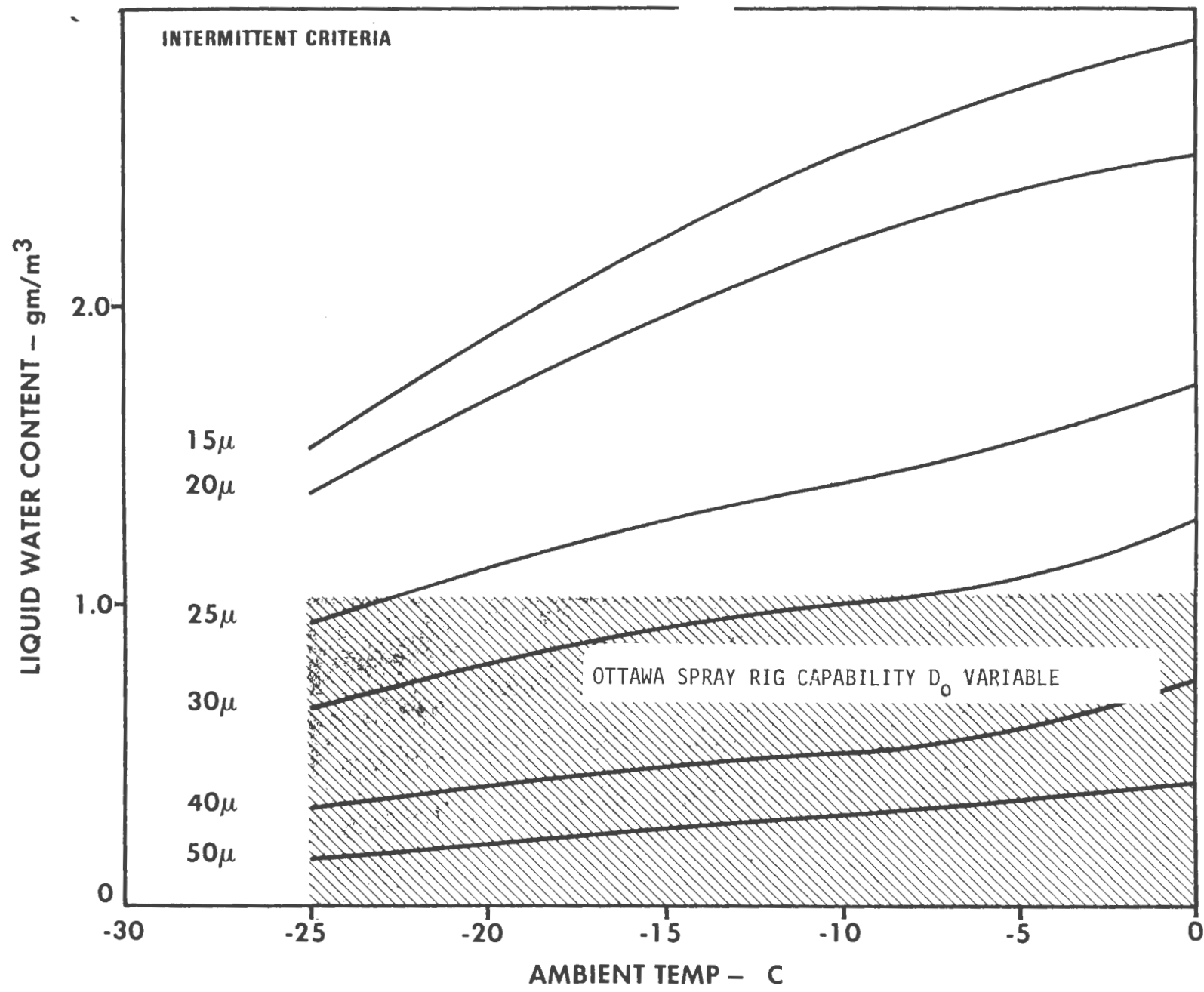


Figure 24

HISS

- **KNOWN PROBLEMS/QUESTIONS**
 - **CLOUD SIZE**
 - TOO SMALL FOR TOTAL A/C EMERSION
 - **CLOUD QUALITY**
 - IMPROVED MVD
 - FINAL DATA ANALYSIS
 - PHASE III - IN PLANNING
 - **DOWNWASH/TURBULENCE**
 - ROC/ATTITUDE - 500 FPM
 - **AIRSPEED RANGE LIMITED**
 - 60-100 KIAS
 - **ENDURANCE FOR TEST**
 - 1.0 HOUR LWC 0.25 gm/m³
 - 10 MIN LWC 1.0 gm/m³
 - **VISUAL/PHOTO OBSERVATIONS**
 - DIFFICULT
 - INACCURATE

Figure 25

HELICOPTER ICING CERTIFICATION TOOLS

NATIONAL RESOURCES EFFORT

- **NATIONAL MEETING - JANUARY 16, 1980**
 - **FAA TECHNICAL CENTER HOSTED**
 - **NASA**
 - **DOD**
- **KEY RESULTS**
 - **NASA AWT REHABILITATION**
 - **RETAIN OTTAWA SPRAY RIG**
 - **NATIONAL IN-FLIGHT SIMULATOR**
 - **ICING RESEARCH TEST BED**
 - **NATIONAL TASK FORCE**
 - **PREPARE PROGRAM**
 - **OTHER IMPROVEMENTS**

Figure 26

RICHARD I. ADAMS: MEETING CHAIRMAN

So with those primary remarks, I would like now to introduce the Representative from the U.S. Army Aviation Research and Development Command who owns the U.S. Army's inflight tanker we call HISS, Mr. Harry Chambers. Now, Harry and Captain Lynn Hanks, who is a test pilot from Edwards Air Force Base and an old friend of mine, will give you a run-down on the status of the HISS and the improvement programs that are taking place and also to take this opportunity to give you a real brief overview of some of the test results that have come out of this past winter's effort. Harry!

U.S. ARMY AVIATION RESEARCH AND DEVELOPMENT COMMAND

HARRY CHAMBERS, REPRESENTATIVE

Thank you very much Dick. I feel like passing out cigars now. I notice that there are a lot of people sitting in the back of the auditorium today and I think Dick passed the word out that we are going to have a practical demonstration on the HISS this morning. So all you people in the back will stay dry, more than likely. (Put the first slide on, please).

As Dick said, my name is Harry Chambers, I'm with the U.S. Army Aviation Research and Development Command and our short name is AVRADCOM (Figure 1). We are located in St. Louis, Missouri and we have a unique responsibility, which is the airworthiness qualification of all Army aircraft. It is a process which is very similar to the FAA certification efforts. Also, here today is Lynn Hanks. He's with the U.S. Army Aviation Engineering Flight Activities. We refer to that as AEFA. They are located at Edwards Air Force Base, California. One of their missions in life is to conduct the airworthiness qualifications of Army aircraft as asked by AVRADCOM. Dick Adams has asked us to appear here today so that we can more or less acquaint you with the test itself. (Next slide, please Figure 2).

I think most people already know that we do use a HISS for the initial qualification testing of Army helicopter to fly under icing conditions. That's not the end of it, though. We still verify the capabilities of the aircraft to fly under icing conditions by actually going into the natural icing conditions themselves. The final qualification is done under natural icing, and that's where we get our verification. Now, right now, Captain Lynn Hanks will be coming up and he will have a very interesting presentation which will cover application of the HISS, and its use. He will also show you a very interesting movie which is on a Brand Y helicopter, and following Captain Hanks, I'll go ahead and cover the advantages of having the HISS and the qualification or the certification effort of helicopters. I'll also cover our current and future HISS development plans and then also I will cover the use of the HISS by industry. What we're saying is that the HISS will be made available through the FAA. Lynn!

U.S. ARMY AVIATION ENGINEERING FLIGHT ACTIVITIES

MAJOR LYNN HANKS

As Harry said I'm with the Engineering Flight Test Activity at Edwards Air Force Base. Each year we are asked to do some icing tests and it seems to be in the past few years our total winter commitment takes just about everybody out there to conduct as many programs as we have. This coming year we'll have five programs, and I'll discuss those at the end of this briefing as to what we plan on doing this year. (Next slide, please, Figure 4).

Toward the end of the the Vietnam War, all of the priorities that were associated with having systems available to fight in Southeast Asia began to decline and the priorities of people who had an operational requirement in Europe began to incline to the point that the Commanders are now worried about whether they can operate in the typical European scenario of the balloon going up in the winter time on an IFR day. We look around and we see that we don't have any Army aviation aircraft that can operate in this environment, or at least a lot of people thought that we couldn't. So we wanted to identify what types of aircraft we had that could or could not, and maybe establish an envelope that current aircraft can fly in. So in order to do that AVRADCOM, in those days it was called AVSCOM, wanted to develop an artificial icing spray system. We call it the HISS, affectionately, Helicopter Icing Spray System. In that we could simulate icing conditions in a VFR environment and take a look at the icing requirements on aircraft in a safe manner before we go blasting into an IFR situation in a condition from which we cannot extricate ourselves very readily. So this is the first rendition of that (Figure 5). Single spray boom, the cloud was only four or five feet deep and sixty feet wide and we had a lot of problems with particle size. Very, very large particles, so we got much more severe icing conditions in some cases. In other cases it was not representative of a natural icing environment. Things like small particles being able to turn corners were not available in this environment. We had to go into a natural environment to totally simulate that. (Next slides please, Figures 6 and 6A).

Next is a kind of a history of what has happened with the Army program since then. We conducted initial tests with this limited artificial spray system through the early seventies and we evaluated the UH-1H model, the Cobra, the AH-1G, the OH-58A model helicopter, the CH-47C, the AH-1Q model TOW Cobra, and we also looked at many ways for quick, cheap fixes to some of these aircraft to give them some kind of icing capabilities. Minimum costs, quick reaction to the field problems, and that, involves things like the UH-1 heated windshield, and the icing rate meters, so that people could tell what kind of conditions they were flying in. We also did some early development work on the UH-1 Lockheed Icing Protection System. Then realizing

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a lot of the problems that we had with our spray system, we wanted to improve that, so we went to a dual boom configuration, to double the thickness of the cloud so that we could get ice formations on a lot more of the fuselage and the rotor system all at the same time. (Next slide, Figure 7).

We also, with this older type HISS spray system, did the government competitive test on the UTAAS in which Sikorsky Helicopter's, Black Hawk, was the winner. But we also were able to fly the YUH-61, the Boeing candidate in these conditions in Alaska in 1976. We conducted some ice phobic coating tests, some quick fixes again to the fleet that's out there right now, so that we could have some stuff that we could smear on the blades and the ice wouldn't stick, trying to find a compound that would work. Those tests are still ongoing. As other aircraft came into the inventory, the Black Hawk and fiberglass rotor blades for the Chinook Helicopter, all of these things each year, as they come up we try to evaluate these new systems in this artificial icing environment. At the end of 1979 we embarked on another program to modify and improve our HISS, trying to get particle sizes that are more representative of the natural environment. We wanted to try to get better atomization and try to fill up with an environment that more closely simulates this natural environment. We realize that this is a big, big order to fill and we're having to do it stage by stage, because there's not enough money available in anybody's pocket right now to do what it takes to give us what we think would be representative of this environment. So, with a minimal amount of money and a lot of good ideas in consulting with all of the "experts" in this field, we came up with what we think is a much better system, the one that we have used this past year and it looks like we will be using this coming year. After describing what we use and what is available now, then I want to discuss two separate programs, the CH-47 Delta Model Boeing Chinook, the Big Chinook, icing tests and some of the results and how they relate to this artificial environment that was conducted this past year. Also, I want to discuss a program that is much closer to me, since I conducted it, and that's the Black Hawk Icing Program for the past year. I have a quick flick to show you on the Black Hawk.

This is the very first HISS (Figure 8) back in 1972 which was initially qualified. Single boom, the nozzles are of All American Engineering design. It turns out that the design required a heck of a lot more bleed air atomization mass flow than was available with the system. That's the reason we ended up with these big water drop-lets. You'll notice how thin the cloud is here. (Next slide please).

The next rendition of the HISS you will see here (Figure 9). If you look very closely there is a trapeze looking arrangement below that horizontal upper boom and the two clouds from those two sprays bars merge at approximately 100 feet standoff distance, from

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that thing, and you end up with one cloud. This is the configuration that was used for about five years. At the end it had the problem of having these large water droplets. (Next slide, Figure 10).

In order to know what this environment was, the state-of-the art of 1972 to roughly a few years ago was, an oil droplet slide technique or a gelatin slide technique for analyzing the droplet size in the spray plumes. There was really no good hardware around to get you accurate information representing what this artificial environment was. This B-52 looks like a jumped up slide here but that really was done at Edwards in about 1973. We had an oil slide droplet type of device that was used to calibrate the Air Force KC-135 and C-130 tankers back in those days and we didn't get any useful information from this but it was kind of fun to do. Eventually the calibration that was used, the aircraft was obtained from Calspan, used an oil or a gelatin slide technique. (Next slide, please Figure 11).

Now you will see this is a representative picture of the kind of ice that was obtainable in this artificial environment. This is the YUH-61, the Boeing candidate for the UTAAS Program. You will see the globular texture of this icing was solved because of the large droplet size associated with our spray plumes back in those days. (Next slide, please Figure 12).

To improve our system we wanted to take advantage of all the knowledge we had of the shortcomings of our system. We wanted to do some nozzle ground tests to find just what kind of bleed air pressures and water flow rate we needed for individual nozzles, to give us particle sizes that would be representative to the natural conditions. We are going to confirm this in the wind tunnel and I think we had a program with Boeing, I believe, to conduct this icing wind tunnel test and I think that was done at NASA Lewis. We wanted to confirm these results in an airborne environment and we did that this past year using the JUH-1H with a laser nephelometer installed from Meteorological Research Incorporated. We wanted to modify our system based on the best results we could obtain from all of these different types of evaluations. We then wanted to see how this better system, if we could get one, would perform using it operationally and evaluating the characteristics of the airplane in an artificial environment and comparing those with moving on to this natural environment.

So we have a little rig we hooked up in the hangar and put all kinds of different nozzles that somebody thought might work. It turns out that hydraulic type nozzles seemed to work really fine for this and we count the droplets on paper and in the little bins here and come up with what we thought would be good candidates to use in the wind tunnel. (Next slide, Figure 13).

This is the All American Engineering nozzle that was installed on the old HISS. It was not a very good performer for the available

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conditions, and the next slide shows what we ended up putting on our aircraft (Next slide, Figure 13A). This is a Sonic Core development, or Sonic Development Corporation, Sonic Core Model 1258D. We found that this nozzle gives us a much better particle size and distribution. We have gone through about a dozen different types of nozzles before we settled on this particular one and this is the nozzle that is now installed on our aircraft (Figure 14).

This slide is a little busy but it kind of shows you the type of improvement that we got by going to a nozzle that was better capable of using the existing water pressures and air pressures to give us good particle sizes. You will see that the All American nozzle way up there falls way outside of the acceptable ranges of droplet sizes. Just about every nozzle that we looked at other than that one has some range that was good. The Sonic Core nozzle was chosen for a variety of reasons. I'm not even sure what all of those are, since I wasn't very intimately involved with what that program did, but based on some of this data, the Sonic Core nozzle was picked as the best candidate and was the one that was evaluated in flight. (Next slide, Figure 15).

It was also the one that most of the data was obtained from the wind tunnel test. This slide is an artist's rendition of how that thing was set up and the test results from the wind tunnel very closely represents what we found in flight. Well, let's talk about some of the problems that we've had with our inflight simulation.

Originally we stuck the Sonic Core nozzles on every station available on our spray boom and after we went back and did a few calculations we found that the nozzle area, the spray area for the atomization bleed air from the engines, and also the water nozzle area was too great and we were not getting into the ball park of these good atomization properties. It turned out that we had too many nozzles mounted on our spray boom, so in order to get back to the area where we had good atomization pressure and good break up of these particles with the nozzle, we had to restrict the number of nozzles. This (Figure 16) shows what happens if you stick too many nozzles on the boom and these criteria are not met. We ended up getting all kinds of ice all over our boom and we didn't like that at all. Now, in restricting the number of nozzles and getting a uniform cloud, we ended up having to take the nozzles off the outrigger portions of our spray boom, which you saw in the earlier slides. So now we only have a cloud that's roughly thirty-two feet wide by eight feet deep. You'll see here a UH-1 aircraft immersed in that cloud (Figure 17) and you'll see that the aircraft is not totally immersed. The rotor system does not totally fit into that cloud, but a large portion of it does. Of course, the bigger the aircraft the more problem that we have with this, with portions of the rotor system being outside of the cloud for a given period of time. You also see here that the two spray clouds (Next slide, Figure 18) associated with the upper and lower booms converge at some distance back there. I have a slide later that shows sort of where that happens.

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You also see that the depth of that cloud, the eight feet, does not even on a UH-1 helicopter, which is not that large, totally immerse the entire aircraft. In some cases that's good. In other words we can do tests on the rotor system only, or we can go and do test on the fuselage only and we don't have to worry about, maybe the safety aspects of looking at a rotor system that's not protected while we're looking at some feature associated with the fuselage only, selective testing. (Next slide, Figure 19).

The inflight tests culminated in a calibration effort conducted this past winter using a Meteorological Research Incorporated laser nephelometer system to try to determine the particle sizes and the distribution within our clouds with these new nozzles installed. All of this was conducted concurrently with all the testing that was going on with the Black Hawk and the D Model Chinook. This is a picture of the JUH-1H helicopter that had this Meteorological Research Incorporated equipment installed. I think I have a close up on the next slide (Figure 20) of what some of those look like. The straight plume from our cloud converges with the wake turbulence from the Chinook at some distance associated with the air speed of the Chinook. You see here that at sixty knots that convergence is somewhere around 100 feet at 90 knots which has so far been our typical icing air speed, mostly because of limitations of our spray tanker, namely the amount of power that it takes to drag that big heavy thing through the air. Ninety knots appeared to be the best test airspeed for us and you'll see there that we have available to us anywhere from about 200 feet standoff from the boom right up to where the cloud is no longer converging. We find that about 125 to 150 feet is a good distance to use operationally because you get good cues on station keeping and that kind of thing and cloud as well as staying out of the wake turbulence and staying in a position where the two clouds have converged. (Next slide, please, Figure 21).

This is what I thought was coming up next. This, the Axial Scattering Probe I think is their name for it, and it is a laser nephelometer device that measures very small droplets. It allows the input from this to go on mag tape and is computer analyzed and we get a whole bunch of different bins of different particle sizes and how many of them fell in that during this particular encounter. The ranges of particle sizes that this device can measure are fairly limited. It goes down to a very small range, but it does not do well in a larger range. The next slide (Figure 22) shows a picture of a cloud particle spectrometer, and it measures the much larger droplets, if there are any. Fortunately, not like the old HISS environment, this device did not measure very many of these large droplets. So, we end up with a particle distribution that's more representative of the natural environment.

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This (Figure 23) is a recap of what it looks like from the top of our cloud to the bottom of our cloud, roughly eight feet in diameter. A lot depends on how much air pressure we have available and how much water we spray and things like that. If you look at the 4, 9, and 14 gallon per minute lines there and the liquid water content associated with each one of those, you'll notice that the cloud is not symmetric in liquid water content. That is, that due to gravitational sorting more of the liquid water content is associated with the bottom of the cloud than it is with the top of the cloud. You'll also see that the liquid water content is not uniform over the cloud surface. I think it would be virtually impossible to get that. A time average of where you can stay in the clouds, that is your station keeping capability in this environment, is such that the aircraft actually sees a kind of average of what that bulb looks like there. We found that we could get comparable results in an artificial environment with all of these time average factors involved here, to what a natural icing environment would look like, by going to what would be an integration of that across the cloud's surface. (Next slide, Figure 24).

This is a particle size distribution chart that shows you roughly what we had, what we have now and where we are trying to go. The dash line represents a natural icing cloud, a stratiform type cloud. The 1980 HISS cloud box there is where we are now. In other words we are an order of magnitude better than where we were over in this big huge box off to the right. We had very large particles, a lot of them associated near the bottom of the cloud, little ones at the top of the cloud, but they weren't even in the normal range of the natural stratiform type cloud. We think we've made a giant step toward a better icing artificial simulation, but we think there is still probably some room for improvement. (Next slide, Figure 25).

Just to show you, actually a comparison of what you saw before, with a big globular texture of the icing simulated on the Boeing UTAAS. Take a look at the texture of the ice accumulated here in the artificial environment, you read them and you can tell that artificial is the yellow ice. We put sea dye marker in our water to distinguish it from a natural environment and it makes it more photographically esthetic. You'll see the crystalline structure of that ice. We have another slide taken in a natural environment or after a natural icing exposure of roughly the same configurations, the same conditions, the same temperature and you'll notice the similarity of those. That roughly is the same kind of plume. As we go through the results of these tests, the past year of testing, you'll notice more and more of this, a lot of similarity now with the artificial icing that we are able to accumulate behind our HISS and the natural environment. We have a lot of comparabilities and we're very happy with that. We realize that we still have some shortcomings, but we think we know what those are and we're headed that way. (Next slide, Figure 26).

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This is artificial ice accumulation on the stabilizer bar on the UH-1. The next slide, Figure 26A, is after an icing encounter, a natural encounter of roughly the same type of environment. (Next slide, Figure 27).

This is a picture of a natural icing accumulation after flying in the conditions where the particle sizes are very small and this is a barrier filter on the UH-1. It's kind of a particle separator associated with the Huey and in the past natural icing tests we've always gotten ice on those filters, but we've never been able to get ice on those filters in the artificial environment. We are not able to do that. I don't have a good slide of it. We have accumulations roughly the same, very comparable to the comparisons you saw in the other two slides.

The thing I want to do now is take two programs that were done last year and show you some of the things that we identified in the artificial environment and in some cases I'm able to show you comparisons of artificial and natural conditions, very similar type of icing environments. And to show how we were able to identify a lot of problems in this artificial environment before we ever had to go into the natural environment. That's where we are hanging out hats in the Army, because we are able to get all the big guys, the things that are going to hurt somebody, identified early, so when it comes time to go into this natural environment we have some degree of confidence that we are going to be able to survive. (Next side, Figure 28).

This is a FOD (foreign object damage) screen that is installed on a CH-47 D model from the Boeing Chinook, and it is there to protect against FOD and also against ice. You'll notice that ice crystalline structure is pretty much obstructed along the entire forward surface of that engine inlet or the screen itself. There is a reverse flow in proportion to this that you can't really see on the back side of that cone. Air can be taken into the engine from the reverse side and therefore you don't flame your engine out and you don't really suffer that great of a performance penalty with these, probably more from a drag point of view than an engine power point of view. But, the next slide shows roughly the same thing (Figure 29). The thing off the left hand side there is what I'm trying to show, it doesn't show it that well. It was taken with a fish eye lens out of the aircraft, in flight, in a natural environment and you'll see that same screen with the same type of a texture. Not a very good shot, but that's one of our problems in the natural environment, really getting good photography. You also see the ice accumulated on that aft pylon in this natural environment, which is very representative of the same thing we found in the artificial environment. This is a little out of focus, I think, but a problem that we identified very early in the artificial testing was this aft transmission oil cooler directly exposed to these icing conditions, and below certain temperatures this cooler is sort of

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shut off from the rest of the system and it ices over and gets ice on Cannon plugs. Things like that, that tell you, you don't have any pressure, or that you've got chips and things like that in your oil. We had many false indications associated with this environment and they went back and sealed these things off from the environment and cured those kind of problems. That kind of thing would kind of give you a nice little heart stop if you're in the middle of the clouds and you look down and you don't have any more transmission oil pressure.

A problem identified last year, or actually the year before, with the CH-47 C Model Glassblade program, was that the fuel vents on the Chinook would ice over and the fuel cells would collapse because of trying to suck fuel out of something that was not vented. A little quick fix that Boeing came up with was this little conical thing over that fuel vent in the top part of the picture. This artificial environment that we had gave us the capability to explore these fixes before we had to go into this natural environment and you'll see here (Figure 30) that it worked quite well. (Next slide Figure 31).

We are able to locate devices that you can stick on the helicopter to determine what icing rates are. This is a very crude device called a "Harvy Smith" or something like that, that the British use. With a pilot and a stop watch and some tables on airspeed, you can see how many centimeters or millimeters of ice you have accumulated in X numbers of minutes and you enter a table and find out what your average liquid water content was for the duration of whatever you're timing. This was installed on the B model and was found to work quite well. We identified very early in the program a problem that the D Model still suffers from, that is, blade damage due to shedding of the ice. An awful lot of ice is allowed to accumulate on the rotor blades before shedding and also there is an awful lot of ice that is allowed on unprotected portions of the main rotor system of the D model Chinook. When this stuff comes off, such as when you come down below freezing level, the big chunks of ice come flying off the main, the forward rotor, and hit the bottom of the blades on the aft rotor and cause nice big "dings" in these fiberglass blades that are so neat, and this is a fairly significant piece of damage to the blade. All field repairable, of course, but still something that can stop the program.

The next group of slides are associated with the Sikorsky UH-60 Black Hawk helicopter and the icing tests that were conducted this past winter. (Next slide, Figure 32)

This, for those of you who haven't seen the Black Hawk, is kind of a cockpit shot, in flight, everything working, flying around in an icing environment and the main thing that I wanted to show you here is the complexity of a large, tactical helicopter cockpit. This illustrates

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the need for very simple systems, something that you can turn on and forget it, because there are too many other things going on, as you can see here. There are a lot of things to look at and we don't really need to be looking at our deicing system. (Next slide, Figure 33).

This is a picture of the Black Hawk behind the HISS (Next slide, Figure 33A). This configuration you see here is with the IR, infrared suppressor, device installed and you can't really see too well in that shot, but there is a AOT 144 IR jammer installed. All kinds of neat beauties that are on modern tactical helicopters. That's sort of what it looks like if you are standing on the ramp of that Chinook, looking out, while we are doing an icing test. (Next slide, Figure 34).

The artificial conditions, which we investigated with the Black Hawk this year, are shown here. The black dots are the ones that we actually went to, the little squares that are not filled are the ones the were done in a year previous to that. The testing got started way too late and an awful lot of mechanical problems not associated with the deice system caused very little to be done during that year. You'll see the kind of a matrix that we are trying to go for, to hit all of these different types of conditions to build ourselves an envelope and that's where we were headed in the artificial environment. The important part of that envelope is to the upper left. If you draw a diagonal from the bottom left to the upper right of that matrix, the things to the upper left side of that line would be the things that are important. These kinds of things you are going to run into in nature all the time, where the stuff to the lower right of that are not nearly as important, but those conditions can exist for short periods of time and you'll see a little slant across a couple of those conditions where we only evaluated for fifteen minutes, which, believe me, is a long time, in those type of severity in icing conditions.

This is a little shot (Figure 35) of the natural icing conditions which we actually went to during the evaluation this year and you'll see that those conditions do evolve to the upper left hand side of that line that I was telling you about. Of course, these are the conditions found in the Minneapolis-St. Paul area in February and March in one winter. This falls back to this icing data base that we've been talking about, the things that we need to develop and the kinds of data that need to be available so that we know really what kind of conditions we need to evaluate in an artificial environment to make sure we have got all the bases covered.

This is a picture (Figure 36) of ice accumulated in the artificial environment on the cold air inlet to the IR suppressor. That's an unprotected area and it didn't really matter, nothing behind really hurts anything. The same picture taken in a natural icing condition is shown next (Figure 37). The texture of the ice is similar, very similar, and

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we think that these kinds of fuselage icing are very comparable from the artificial to the natural environment behind our tanker at this time. (Next slide, Figure 37A).

So the problems that we identified with the Black Hawk very early, that is in the artificial environment, before we ever had the chance to go into the natural environment, was the freezing up, or the icing, in the applied position of the centrifugal droop stops and flapping restraints associated with the articulated head of the Black Hawk. If you see a restrainer in the upper part of the picture there, hooked up to an arm, its all iced over, that's the flapping restrainer. The droop stop is sort of down behind that little silver area towards the bottom of the picture there. You can't see it very well from here, but I'll show you the same type of a picture taken after similar conditions in a natural environment (Figure 38) and you'll see the similarity in the icing accumulation and particularly in the results. That is, the droop stop and flapping restrainers themselves icing in that same position in both environments. We knew that was going to happen to us before we got into the natural environment, and we had a large margin of confidence in this system whether they would or would not work. In this case we knew they wouldn't work and planned for it. It is safe to shut the aircraft down as long as you have some control of the wind conditions. That is, if you had high gusty winds you probably wouldn't want to shut that aircraft down with those devices in the wrong position. I shut one down with winds at approximately 18 knots and it kind of scared me. I don't think I would want to go to the 45 knot limit with the aircraft with those devices in the wrong position. (Next slide, Figure 39).

Natural icing conditions are so variable and there are so many things that we don't know about it. I wanted to show you a couple of pictures of icing accumulations on the little visual probe that we have. We have a little OH-6 tail rotor blade section that we stick on everything that we fly, so we have some standard of comparability between every program all the way back from 1972 up until now. I wanted to show the variability of the ice that can accumulate in identical temperature and liquid water content as shown on the Rosemont probe. This particular ice accumulation, the accretion, came over about an hour and a half to two hours worth of flying at about minus 6 degrees Centigrade and a liquid water content of about .25, which is an average liquid water content. You'll see that this is a very powdery looking stuff, and to me that tells me that we have some very, very small particles associated with the environment that we are flying in.

The next picture (Figure 40) was taken under the same conditions that I told you about, the same numbers. But you'll see that the particle size must have been horrendous, the grotesqueness of that ice is just staggering and sitting there looking out the window at it,

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you just didn't believe that anything like that could happen. All of these things were within like a degree and tenths of grams similar over the same type of number of minutes of ice accretion. It's just unbelievable that particle size can make that much difference in your ice accretion, but there it is. Looking at the grotesqueness of this ice, I want to show you another picture (Figure 41) that was taken with a hand held camera out the dog-house type overhead portion of the cockpit, with a 35 mm camera, 1000th of a second exposure with high speed Ektrachrome film. The camera stops the rotor. You see the same type of ice formation on the unprotected portions of the main rotor system. The grotesqueness of this ice is evident here, just as it was from the visual probe that I showed you before. That was taken on the same flight. You'll see that the same type of ice accumulation on the leading edge of that blade.

This is the kind of ice accumulation that we are able to simulate with our HISS. We have no control over this droplet size, what ever we get is what we get. We can document that, we know what it is, but we can't control it. We can't get a small particle size and go back to the same conditions with a large particle size. There is a big limitation of our system. This is what we got with artificial. The next shot (Figure 42) is something which is very similar in particle size in a natural environment to that artificial condition, and then the last shot (Figure 43) is just grotesqueness showing you the difference between what you actually get and what we can simulate. Nice smooth accumulations if you get conditions that are comparable to artificial environment, but there's a whole bunch of environments out there that we can't simulate and to get those right now we've got to go to natural conditions to confirm that. One of the big things that we found out this year in an artificial environment is that the nice near aerodynamic shape of the fuselages that are coming out nowadays in modern helicopters helps you keep the ice off of the nose of the airplane, but the only thing that is anti-iced on the front of that aircraft is your pilot and copilot's windshields. The center, the chin bubbles and the overhead portion, side windows and all are not. Due to the aerodynamic structuring of those surfaces, we just don't accumulate ice on those things and its a very big plus, means you don't have to pay a big penalty to keep all the surfaces cleared by putting electrical systems which are historically not dependable.

What I was talking about, there are things that you cannot identify in the natural icing environment. I want to show you a very dramatic representation of something that we had no idea that we would run into (Figure 44). After having been exposed to this artificial environment, we jumped off into the natural environment expecting to confirm all these good things that we had learned in the artificial environment. Lo and behold we came up with a large change in the power required associated with driving the main rotor, actually the rotor systems, through the air due to the increase of the

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ice on the rotor system over the deice cycle. So, a very busy slide and I'm sure you cannot read any of the words there, so I will try to explain it to you. The bottom scales time representation in seconds of which between the two big pulses here on the bottom, the two big step-type inputs there, representing the deice cycle of the main rotor system is roughly three and a half minutes. That is, the deice system to the main rotor system is cycling roughly every three and a half minutes, depending on what the outside condition is. The top scale in blue is showing the collective position. The pilot probably had his hand on the collective lever, holding it in one spot, it's that steady and that's roughly the way you fly around in an IFR condition in the Black Hawk helicopter. You set the collective somewhere and you cruise at whatever airspeed that gives you and you're flying very much like you do in a fixed wing with the power setting fixed. The black line is indicated airspeed and if you look at the scales there's about a seven knot change in airspeed over that three and half minutes. It tells you that you lose airspeed as you accumulate ice on the rotor system. You allow the ice to build up so that later on you can pulse the rotor and warm up the blades and let that ice fly off. So we've got an airspeed variation that's going on and superimposed on this fixed power setting. The red line is altitude which is about as good as I can do in an IFR environment. The next two scales are the number one and number two engines, broken out as the power required, that is horsepower for each one of the engines, which is in black, fuel flow, which is in blue and the exhaust gas temperature which is in red here. You look at the scales, pick off some numbers, and you'll see that over this three and a half minute period each one of our engines is now required to pick up an additional two hundred fifty horse power, or a total of five hundred horse power out of three thousand which is what the aircraft is capable of. This increase is just to allow ice to accumulate on a main rotor system. Now that has a lot of significance. You cannot set the power on the aircraft so high such that as you accumulate this additional five hundred horse power, you see some engine lag. You also have to pay the penalty of the additional fuel flow required to generate this five hundred horse power and when you turn on all of the anti-icing systems associated with the typical modern deicing, antiiced aircraft, you're working very close to continuous limits at cruise. We had to back off on our power setting sometimes to keep from exceeding engine temperature limitations. This we did not expect, since we had no indication, in the artificial environment, that this was going to happen. We owe this to not being able to simulate particle size very well. This was the worst condition we ever saw and these conditions we saw in as little as minus 6 degree outside air temperatures and a liquid water content of about .25, which most people think is not a very severe icing condition, but as you can see right here, if you are looking at performance, it is. It's a very significant icing condition, and based on these kinds of results and finding out that where there are a lot of things that you can figure out in a natural environment that you

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cannot simulate in this artificial environment, we think that these two things must go hand in hand at least for now, at least until we can simulate the total environment in the artificial manner. The natural icing is going to have to be tagged on the end of the artificial just to make sure that we haven't missed anything. We would have totally missed this very significant performance problem if we had stopped at artificial icing and said "yea, guys go do it!"

I've got about a six minute film that is not intended to show you anything about the Black Hawk, even though that's the only thing that is in it. It is more intended to show our philosophy about how we, the U.S. Army, go about qualifying a production system to operate in icing conditions. Now, a little bit of explanation. The first part of the film is going to show you some things that were done in the artificial environment. You'll see the Black Hawk flying behind the HISS and things like that. One sequence is from last, actually two years ago, testing where ice comes off of the main rotor system (shown) in high speed photography, and you'll see the ice shed after allowing icing to accumulate on the leading edge. You'll see two sets of natural icing photographs that were taken in two different configurations. The aircraft, the Black Hawk, is capable of being set up in an infrared suppressed version and standard utility, and both of those configurations are in here. I think the IR is first and the standard configuration is last. One word of explanation. A camera that was used to photograph accumulations on the horizontal stabilator is mounted 90° to the way you see the world and when those sequences come on you'll kind of rotate your head a little bit or figure which way is up and I'll try to explain those to you as we get them.

The main thing to observe by the original first part of the film here is that the HISS, or the Black Hawk, is not totally immersed in the environment. As a matter of fact, we did very little in the way of fuselage ice investigations this year since it was done quite well last year. If you watch real close you can see ice leaving the leading edge of the blade. There goes some, you see the size of the particles associated with these deice cycles. Believe it or not, we never heard anything hit the top of the aircraft, and we never saw any particles coming back to hit the aircraft. Observers told us that pieces were coming off and going in engines and things like that, but we never identified that. These were contractor development tests conducted two years ago to set the on and off time cycles for the system. Here is that 90° out shot that you'll see, artificial ice accumulation on the empennage. This is a natural icing accumulation. All the white stuff is obviously ice and this is in the IR suppressed configuration. The little orange box there is where that camera is located that is taking that picture aft. You'll notice here that the aircraft is exposed to a condition that had an awful lot of very small particles associated with it. Every little rivet head on the tail boom there has a little ice particle associated with it. You get dizzy when you look at this.

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The icing condition here was roughly minus seven and a half degrees (-7.5°C) and .15 grams per cubic meter for about 90 minutes, an hour and a half. It turns out that ice accretes on roughly anything that is a good drag device, so if you want to minimize the drag on the airplane you start looking at all those spots. The natural icing accumulation, of ice, on the empennage, you'll see is very similar to what you saw in artificial. A little high speed photography showing the cleanliness of the blades and you'll see ice accumulating on the unprotected portion on the main rotor hub inflight. Again, every place that there is a protrusion or a interruption in the nice air flow over the aircraft, you're going to get an ice particle, or stagnation point. The aircraft is in the standard utility configuration here. The IR suppressors are not installed and the big benefit that you get from that is that you don't accrete too much ice or nearly as much ice on the empennage, which means we didn't have any problems on the IR configuration either. But, just to document it, evidently exhaust gas impingement has helped with the empennage area in the standard utility configuration. Here is only a little touch of ice on the stabilator at the very outboard tip. That's on the left side, the other side gets a little bit more ice, due to the inherent slip, but not too much. Here is a very good picture of the ice accumulations on the hub area of the aircraft. Fortunately, we're getting more and more airplanes that have a very nice clean main rotor hub area which helps us out considerably. As dirty as this hub area is, you can see that it gets an awful lot of ice, and some of the problems associate with this system are directly associated with the dirtiness of that area. You ought to know what happens if you let the ice accumulate on the windshield wipers and had to use them. Where's the ice going to go? And this (the ice) isn't going to enter your engines or whatever. I think here in a second you'll see the windshield wiper (ice) turn loose and all the ice is going to hit down stream. Pretty good size particles there. Evidently most of the ice does not go into the engine, although we're sure that there are some pieces that must. I think that as this sequence goes on here there is a small particle that comes off of the walk area just forward of the engine inlet. Right about now. Here, you have to watch very closely. That particle does go into the engine. So we do know that we're getting ice that goes in there and the particle separator is doing its thing. There goes the piece right down the tube now. We also wanted to know what happened when you forget and leave your landing light down and you get ice all over the light and you turn it on and there it goes. It heats itself up and anti-ices itself. De-ice, I guess. This is the accretion on the empennage section with the standard tailpipe configuration. You'll see the nice benefits of the exhaust gas impingement effect. Nice warm air keeping the ice off the tail feathers.

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I think you can see now that you have had a chance to hear Captain Hanks and see the movie that there are some very interesting advantages that begin to drop out and fall into place, advantages of the HISS (Figure 45). First of all, it does provide a nice environment which is similar to the natural icing conditions as we have found out recently. Now that we do have this artificial icing capability, we can maximize the test time, because we're not dependent on any type of natural icing conditions. As you've seen just by looking at the characteristics of the clouds, that by using the HISS we have a built-in safety valve and that means if anything begins to happen to the aircraft with the icing accumulation which is unacceptable, if anything starts to fail in the anti-icing or de-icing system, we can immediately vacate the icing environment and we can set the aircraft down. We also now have the capability for a lot of test flexibility, that is, we can control the liquid water content of the HISS up to about 1 gram (gm/m^3) now and we can also have some control over temperature by varying the altitude of the aircraft. You don't have this flexibility when you're in a natural icing condition. You have to sit there, wherever you're at, you have to sit there and wait and you can't do very much. Some of the side effect of that is that you can do some very expeditions optimization of any type of de-icing or anti-icing systems. In preparation for the icing season, its very easy to make adjustments on your cycle time, your voltages and currents, things like that. Get the aircraft up, subject it to some short icing test, and if you have to come back down you can make more adjustments, until you feel like you have the systems optimized.

As Captain Hanks point out too, I don't know if it's dense or not, but it has worked out, and we can selectively ice-up the test aircraft. We can do the rotor, we can do the fuselage, sort of selectively without hurting ourselves. Another advantage that we have, probably the final one, and that is, by having the artificial environment we can put a chase aircraft outside that cloud and we can take photographs and we can actually document, as you have seen on the film here, everything that's happening as it is happening. We don't have to wait until we get back down to the ground to see what has occurred. By that time we probably lost a lot of our ice. Now as far as the current and the future HISS development, we would like to do some improvements on the HISS.

One of them is to try and improve the performance envelope. As was mentioned by Captain Hanks, the airspeed limit on the aircraft now is about 90 knots, mainly because of the power and also because of dynamics. We would like to improve on this performance envelope and we would like to get the airspeed out as far as we can so that we can test the helicopters at their true (operational) airspeed. We would also like to improve the HISS dynamics. The main problems we have had with it are oscillations caused by heavy vibrations of the aircraft (the HISS) and we would like to get these damped out. We

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would also like to increase the airflow to the boom, as well as to increase the cloud size, at least to more or less fall out together. Right now the need for this is a documented flight test program and what they are trying to do is to improve the airflow in the HISS. They have done this by patching up some of the air leaks we have. We are also going to try to tune the boom to get rid of the vibrations that we had during this last icing season. In the short term effort, another thing that we are going to be looking at, and that is going to be coming up this next icing season in conjunction with the FAA, we want to look at the impact of solar radiation on the ice crystal content and the humidity effects on the artificial icing cloud that we do have. We've got somewhat of a handle on it, but we don't really have a good handle on that right now. As far as the long term effort goes, we are looking at a totally new redesigned physical configuration and we are looking at probably a twenty-one month effort, starting about fiscal year 82 time frame. We are looking at the use of a CH-47 D Chinook which is a modernized CH-47 C, which is the aircraft we have seen here this morning. The CH-47 D has essentially given us an increased gross weight, up to 50,000 pounds, as well as more power. As a goal, and this is being worked out with the FAA too, we would like to have the capability, which are your bottom five bullets (Figure 46) down there. We're going to have quite a problem with it, but that's what we are going to be striving for.

Last but not least, how does this affect you people (industry representatives) out there? Well, you can have the use of the HISS, we're making it available to industry by request through the FAA (Figure 47). As Dick Adams, I believe has already pointed out to you earlier, Bell Helicopter will have the first test aircraft go on this next icing season and it will be flown behind the HISS in about a ten hour program. If you're going to use the HISS or rather we will support you, we will provide the HISS to you so you can fly the test aircraft behind it. There are certain priorities naturally and of course, DOD priorities come first. But we'll have our first wet run next icing season and see how it works out with Bell. We don't see any problems. We still feel that we can get all the testing done.

Next, the HISS is operated and maintained by AEFA. They are the sole operators of the aircraft. All industry has to do if they want to have an aircraft tested behind the HISS is just provide an instrumented test aircraft and AEFA will spray for you and how you want it. Also, we've had a lot of experience now in icing tests at AVRADCOM and AEFA and we feel we can pass a lot of that information on to you. So, we're available to you to provide some type of test expertise and technical expertise to you, if you need it. Current costs for operating the HISS, right now, runs about \$2300 per flight hour. There is also a mutual support cost involved in the operation of the HISS and this is because we have to ferry the aircraft to the site, we have to ferry it back, we have maintenance support of the aircraft and things like this.

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This type of support is only prorated amongst all the agencies who are involved with the flight testing. In other words, you may have four different test aircraft and throughout the testing there's going to be four different test boxes and everybody is prorated in equal amounts for this mutual support. The current testing site we have been using lately now is St. Paul, Minnesota, which has been a super test site. Our testing season runs during December, January, February and March, and we would like to get started around the first part of December, and then we will have about a two weeks grace at the end of December for the Christmas holidays and New Years.

I've put down points of contact for you folks who are interested in the use of the HISS (Figure 48). First of course would be myself, and I have Colonel Frankenburger down here because he is the Director of Flight Test out at AEFA. Captain Hanks is here today to make the presentation for him, since he was not available.

Were there any questions? I believe there was someone out there who has a question to be addressed to Captain Hanks.

- Q. Yes, my questions was, What flight time was in the HISS? How long can you dispense the water?
- A. It all depends on how much water or actually what kind of flow that you're using, or what kind of conditions you're trying to simulate. If you're trying to simulate a very heavy icing condition, the amount of water that you can carry can limit the amount of time that you can fly. Typically, we can carry enough water to give you up to 1 gram per cubic meter for 1.1 hours. I think that is what it amounts to. That is predicated on the fuel capabilities of the HISS. The aircraft can fly about 1.7 hours before it gets very close to its fuel reserve and it takes roughly that additional 6 tenths of an hour to get to and from the test site, particularly when you are off in the St. Paul area, TCA (Terminal Control Area), and all that kind of thing.
- Q. I have a second question. Second question is, What's the maximum speed that you could test at?
- A. Question was, What's the maximum speed that we can ice the aircraft? At present 90 knots is all that we are flying, i.e., 90 knots true. The main reason for that is that our boom is a very elastic thing and when you fly in any kind of turbulence at all, it likes to oscillate and vibrate and move around and it gets rather scary. So, we've limited the airspeed to about 90 knots and that all came about because that's a typical UH-1 cruise IFR airspeed. Airplanes nowadays, like the Black Hawk, are going to be cruising at roughly 120 knots in this IFR condition. It can actually cruise faster than that if you got enough power there. We hope after the program, that's going on now, is concluded, that this winter we'll be able

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to ice at 120 knots indicated. That's what we hope to do. That is probably a maximum that the current system will be able to do. A Chinook can go faster than that, but when you're dragging all that garbage thru the air, it's not very likely that we will be able to get near the level flight speed capability of a slick airplane. Yes sir?

Dick, you probably want these people to identify themselves, don't you?

- Q. Ken Rosen, Sikorsky Aircraft representing the HAA/AIA. I have several questions. One (thing) I would like to make sure everyone realizes is that the Black Hawk is equipped with an anti-iced particle separator and inlet and as such can take significant chunks of ice going into that engine inlet without FODing the engine. Some of you may have wondered how that could have happened. Also when you looked at the picture, you may have wondered how what appeared to be an inlet was icing up. Well, it wasn't an inlet, it was a cooling scoop behind the inlet. I thought I would make that point because it may have crossed some of your minds. I would like to ask Captain Hanks a question that I guess I've never asked you. That is, do you attribute the difference in power, the increased power requirement between the artificial environment and the natural icing environment to droplet size or to coverage? Do you believe that, one question that has crossed my mind is that, you have made super strides in getting a representative droplet size, but to some extent, at the expense of coverage. And do you believe that some of the difference that you notice was due to the extent of that coverage?
- A. My personal opinion on that is that it is due to the icing type. That is the difference that you saw on the visual probe with the way the ice accretes in an ice flow aerodynamic shape with the very small particles. Then we get the big particles or whatever other things that are involved in icing type, not just using particle size as one of them. There's probably a heck of a lot of things out there that we don't even know about now that effects the size, shape and characteristics of the ice that accretes on any of these surfaces. I think that it is icing type that we are not able to simulate, and that is the reason for the thing that escaped us in the artificial environment was i.e., finding the power required increase that we did eventually find in the natural environment.
- Q. Dr. Rosen, the third question that I have relates to plans that you have, Harry. One of the things that was obvious from your chart, is that you did plan to significantly increase the cloud volume, the cloud size, cloud cross section and in addition to that you also showed a significant plan to increase the liquid water content. Approaching what, I guess, we would call the

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intermittent maximum level, I might add that I am somewhat concerned in the plan that you also provide adequate time on station. When you increase the liquid water content from the present level of 1 gram per cubic meter to 3 grams per cubic meter, and you increase the cloud size to a 30 X 60 from the present, something like 8 X 32, one can expect to have a significant increase in the amount of water that you're going to be consuming. It's therefore, important that when you lay out your plans that you include the time, a reasonable time, for artificial icing tests, which probably shouldn't be less than 30 minutes or an hour, maybe an hour and a half. I would say an hour is a reasonable time to shoot for.

- A. Harry Chambers, well, you had a lot of questions there Ken, I'll try to answer them all, but right now we have a reduced width in the cloud which is 32 feet. That's because we can't use the air pressure. If we can get the air pressure built up and get all leaks out of the aircraft (bleed air system) we may be able to use the air pressure. That's going to be an effort that's going to be done a little bit later. It won't be this year. We may have a little bit better cloud. The long range plans now that we have after this coming icing test, we are hoping to initiate a modification of the aircraft to put an APU in there so that we can provide more air pressure and maybe we can open the cloud width by running the air out through the outrigger and then, of course, we'll probably have some more work to do with the dynamics of the HISS itself. We feel that this is essentially as far as we can go in the current configuration we are in now. The current situation with the aircraft, what we want to do, is to go to a new reconfigure boom. Now as far as that, there are two things; there are plans and there are goals. We're not sure exactly what we can do yet. We would like to achieve a cloud that's 30 X 60, but we are not sure we are going to get there. That's going to be an awful big boom. We would like to put more water in the aircraft. We're not sure how far we can go there. We're looking at going to a CH-47D because we can have heavier gross weight capability, so in doing this we're going to be pumping more water out. The means we have to carry more water or we're gonna have less time on station, like you were alluding to over there. How much time do we need? We feel that we should at least need fifteen minutes under the heavy icing conditions, then you have an opportunity to exercise the deicing systems and it's more or less consistent with the intermittent conditions and then we can look at the effects on the fuselage too. That's a long way down the pike. I'm hoping that we will have funding to start this effort this fiscal year 81, 82 and I feel that's gonna be about a twenty-one month effort, in order to get it going. Does that answer your question, Ken?

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- Q. I think reasonably.
- A. I wasn't trying to side step you or anything like that.
- Q. The only concern that I have is the quantity of water that you can carry, particularly with large clouds, with a higher liquid water content. We must take a very careful look at that particular situation.
- A. Well, we recognize, right now we have an 1800 gallon tank in the aircraft and if you start pumping now at 1 gram with thirty minutes, I think, we have about thirty minutes of time with 1 gram and if you start pumping out 3 grams, you've got 10 minutes. So we know right there that we're gonna be running into problems. And also even more important is the cloud characteristics. So we've recognized we have a way to go, we don't know how far we're going to get, but we do have a goal and we're going to try to achieve that.

RICHARD I. ADAMS

Can I intervene for just a second. I think that Ken, your question is a fantastic question and I think that I mentioned earlier a national inflight icing simulator or tanker. My personal opinion is that I don't think that the HISS in its present configuration can satisfy the total requirement. I think that there needs to be a new look. I think that it's going to take a while to come up with that national icing facility. In the meantime, we're gonna have to do the best we can with the HISS. But our objectives are basically what Harry has outlined here, so far. We would like your input now, tomorrow, due to the overall statements that are being made here. I think that this is a very fine presentation from Harry and from Len and I think that deserves a round of appreciation, don't you?

Now we are running into break time and there's a couple of announcements that I would like to make. Number one, this building, as you noticed, is in the construction stage. It's not completed. It's partially occupied but it has not been bought off by the FAA yet. So there are two precautions I would like to pass on to you. One is, please do not go into an area that is cordoned off by barriers, because that is the construction area and it's owned by the contractor right now, not owned by the FAA. Another precaution is that in the event of a fire alarm, please exit on the left side of the auditorium. Do not exit through the lobby. I don't know the complete rationale for that, but it's simple, that takes you right outside.

To answer Harry's question about the handouts and minutes. We plan to have, or assemble, copies of each of the viewgraphs, of everybody's presentation and we will include that in the minutes that we publish later. A few of the presenters have brought copies of their presentations and there is some additional information. NASA Lewis has brought a copy of a facilities outline or breakdown and those of you who are interested right now in taking these kinds of things home with you, stop at the registration desk and pick up the copies. Now there aren't enough to go around, of these things, so please take only the copies that you need for your organization. We are now at 11:00 and we need to be back in here by 11:15, so we will have a fifteen minute coffee break.

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(AVRADCOM)**

ST LOUIS, MISSOURI

**RESPONSIBLE FOR AIRWORTHINESS QUALIFICATION
OF ALL ARMY AIRCRAFT**



**US ARMY AVIATION ENGINEERING FLIGHT ACTIVITY
(AEFA)**

EDWARDS AFB, CALIFORNIA

**CONDUCT AIRWORTHINESS QUALIFICATION
OF ARMY AIRCRAFT AS TASKED BY AVRADCOM**

80/544

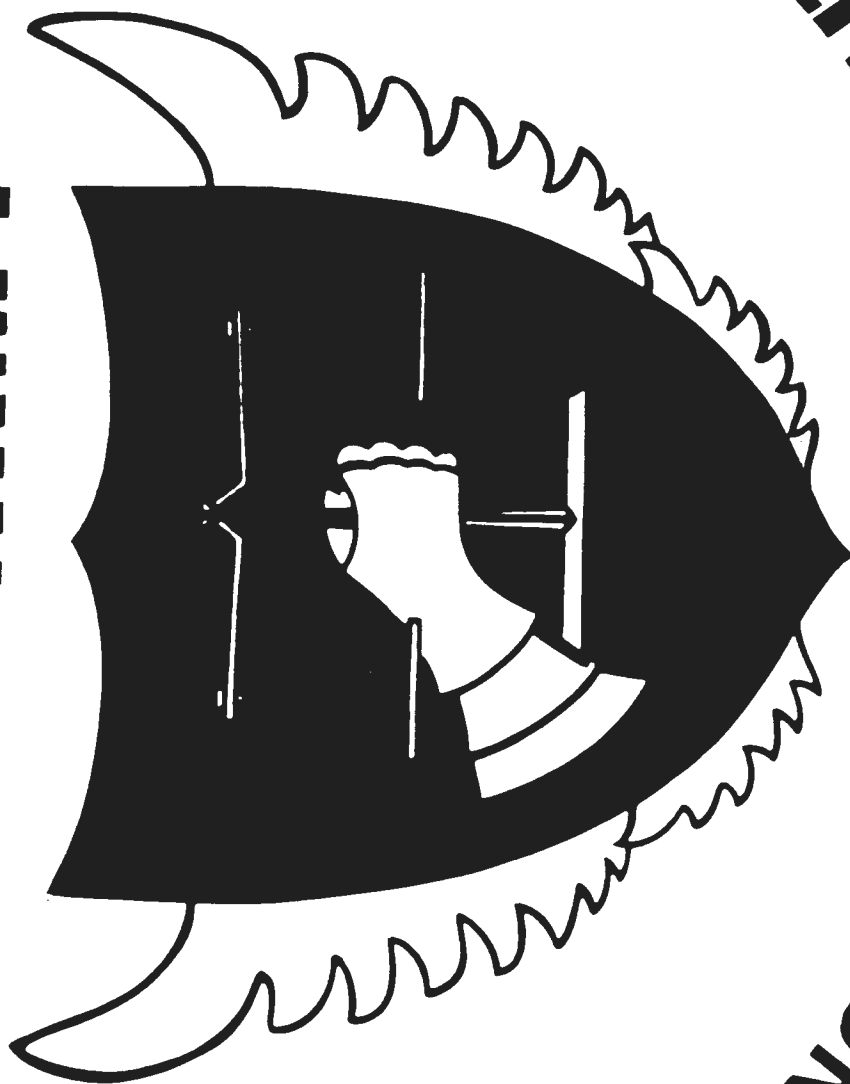
Figure 1

QUALIFICATION OF ARMY HELICOPTERS FOR FLIGHT INTO ICING CONDITIONS

- INITIAL QUALIFICATION TESTING OF HELICOPTERS IS CONDUCTED USING THE US ARMY JCH-47C HELICOPTER ICING SPRAY SYSTEM (HISS) TO PRODUCE AN ARTIFICIAL ICING ENVIRONMENT
- FINAL QUALIFICATION IS CONDUCTED UNDER NATURAL ICING CONDITIONS. VERIFIES ARTIFICIAL ICING TEST RESULTS

Figure 2

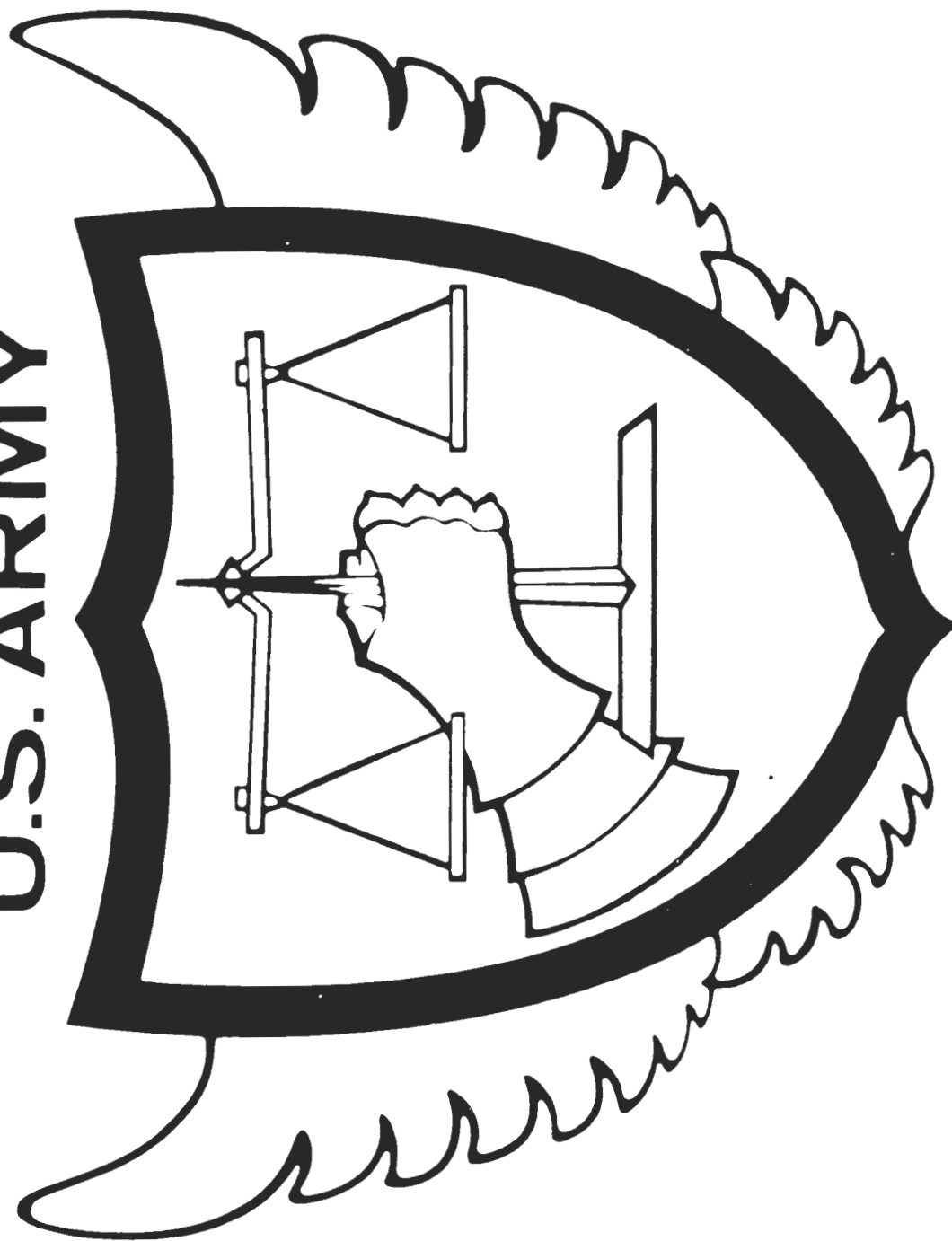
U.S. ARMY



AVIATION FLIGHT ENGINEERING ACTIVITY

Figure 3

U.S. ARMY



HELICOPTER ICING SPRAY SYSTEM

Figure 4



Figure 5

SIMULATED ICING TEST CHRONOLOGY

- 1972 - HISS DEVELOPMENT, SINGLE BOOM CONFIGURATION
- 1973 - TESTS: UH-1H, AH-1G
- 1974 - TESTS: AH-1G, CH-47C, AH-1Q, UH-1H HEATED WINDSHIELD
- 1975 - TESTS: UH-1H LOCKEED ICE PROTECTION SYSTEM
 - HISS MODIFICATION, DUAL BOOM CONFIGURATION

Figure 6

SIMULATED ICING TEST CHRONOLOGY CONT.

- 1976 - TESTS: YUH-60, YUH-61
- 1978 - TESTS: UH-1H ICEPHOBIC COATINGS
- 1979 - TESTS: UH-1H KIT A, UH-1H KIT A,
UH-60A, CH-47C FIBERGLASS ROTOR
BLADES
- HISS MODIFICATION, SPRAY NOZZLE
REPLACEMENT
- 1980 - CH-47D, UH-60A, UH-1H ICEPHOBIC
COATINGS

Figure 6A



Figure 7



Figure 8



Figure 9

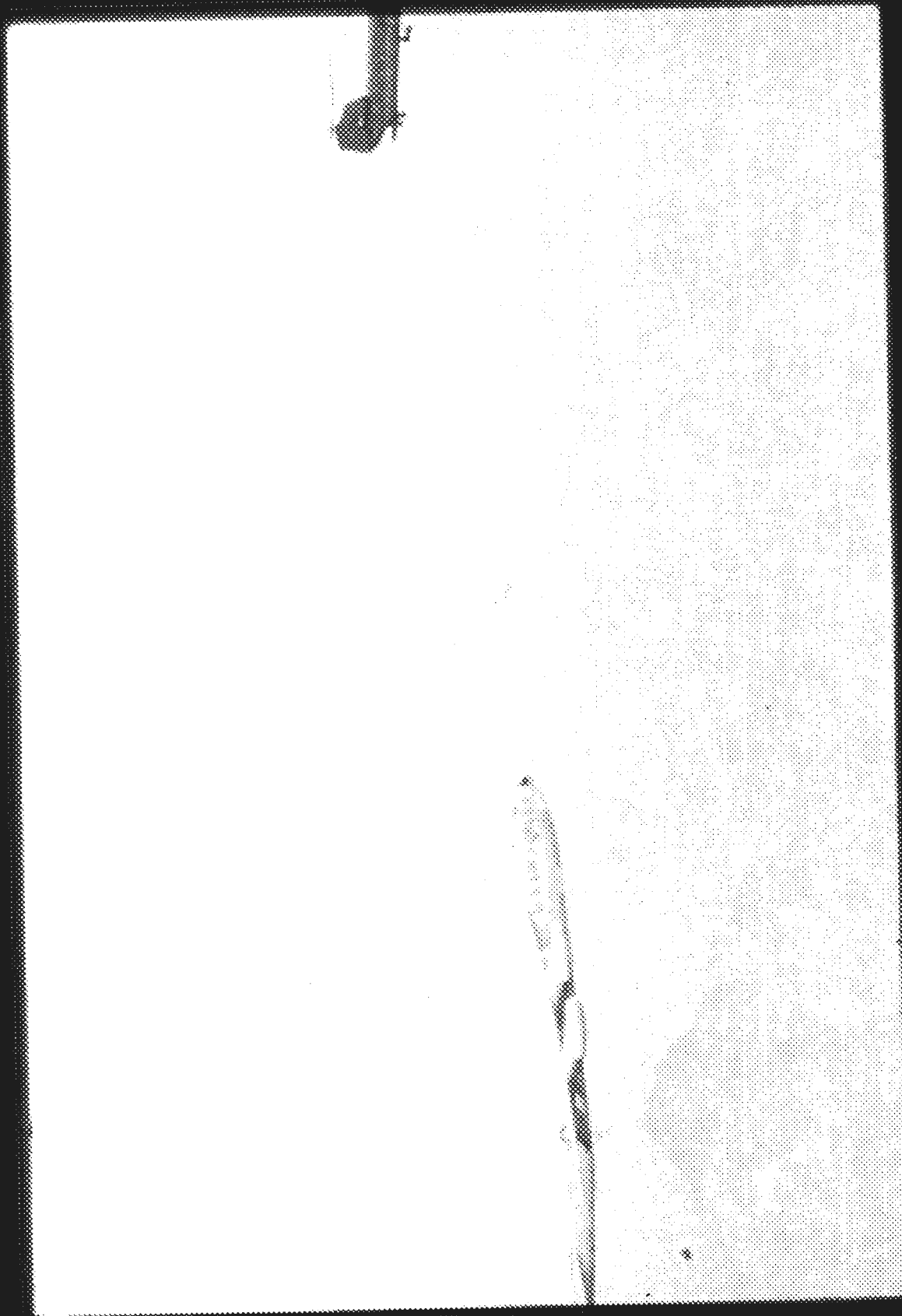


Figure 10



Figure 11

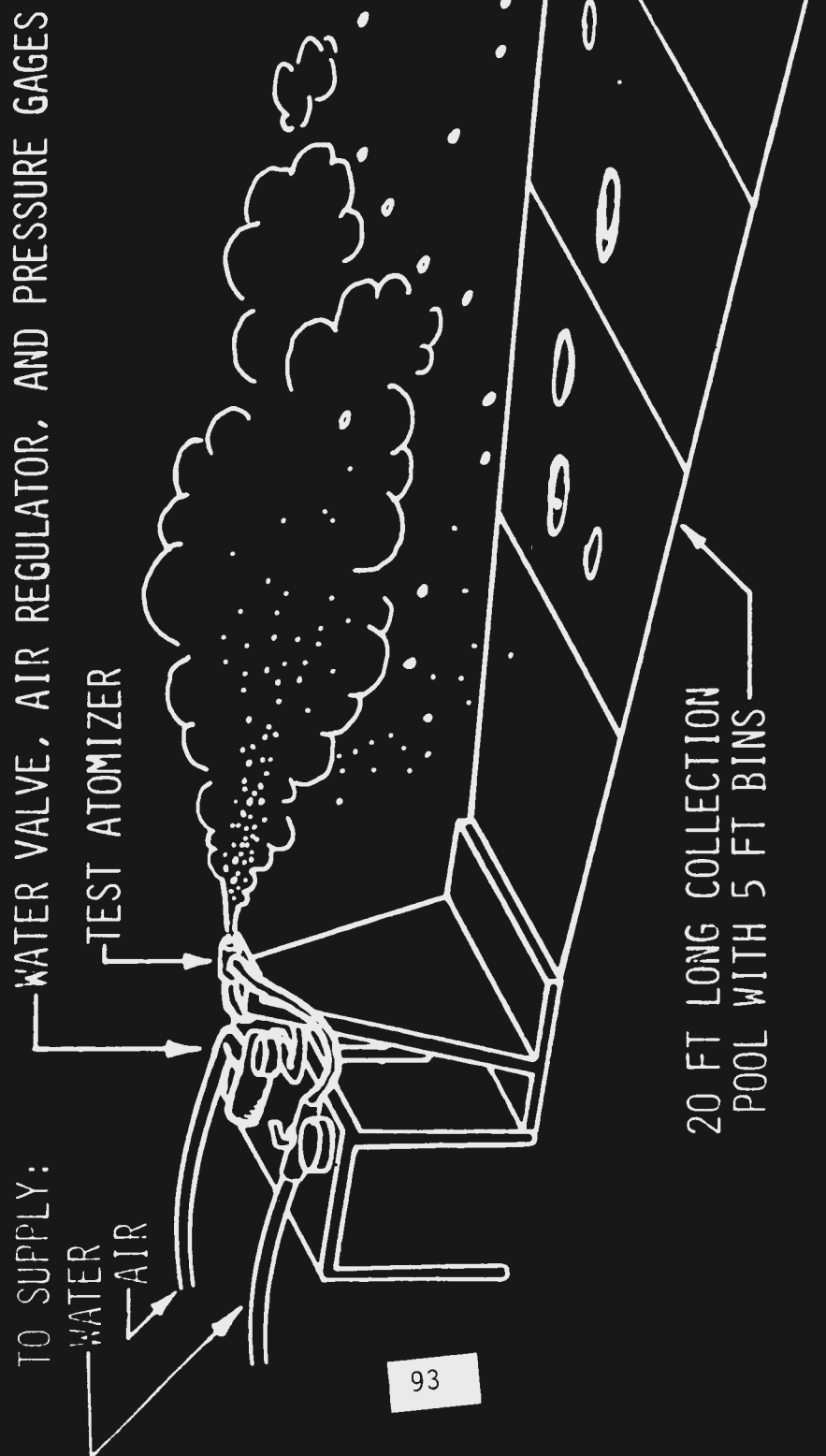


Figure 12

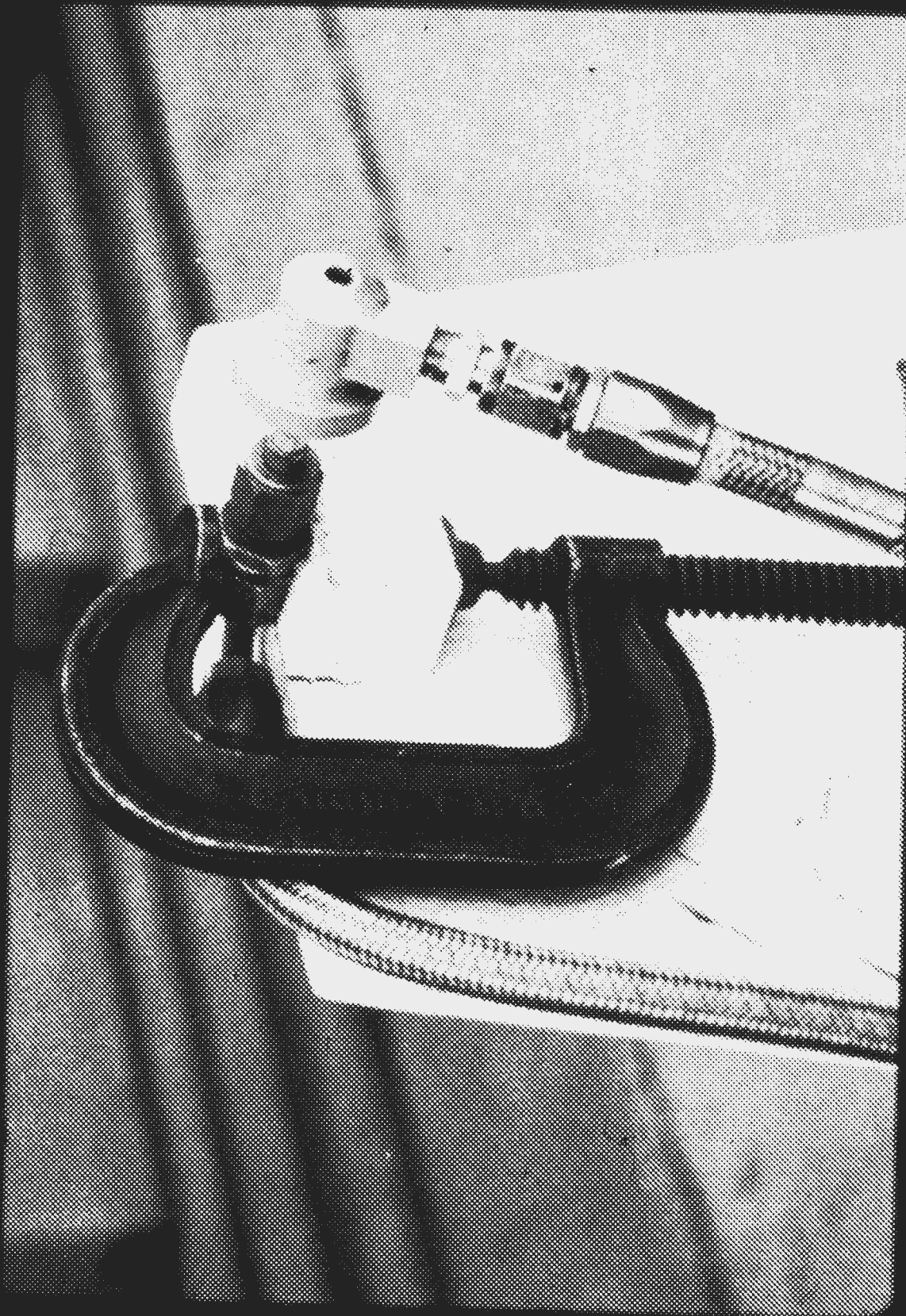


Figure 13



Figure 13A

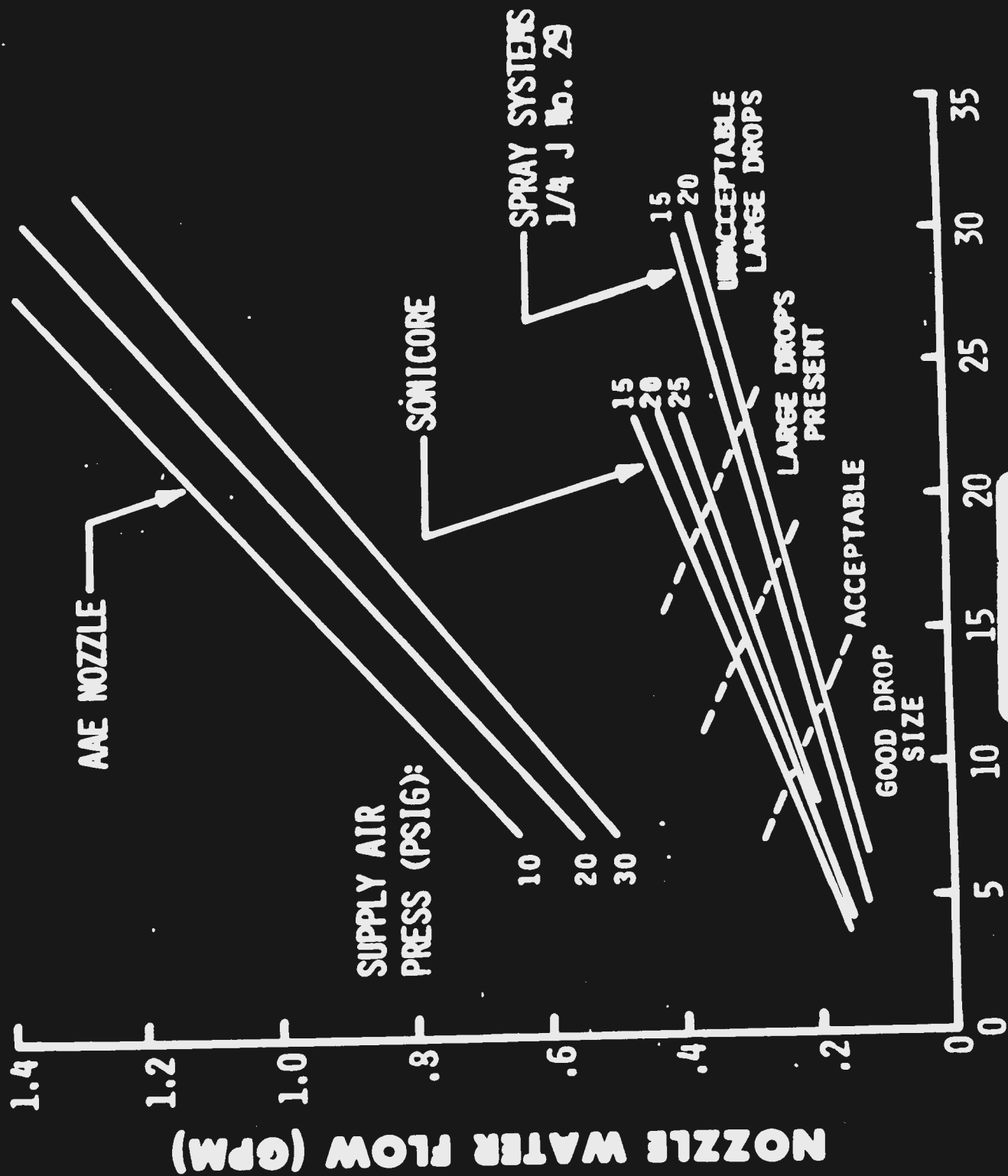


Figure 14

INSTRUMENTATION PLATFORM WITH
PARTICLE MEASURING SPECTROMETER

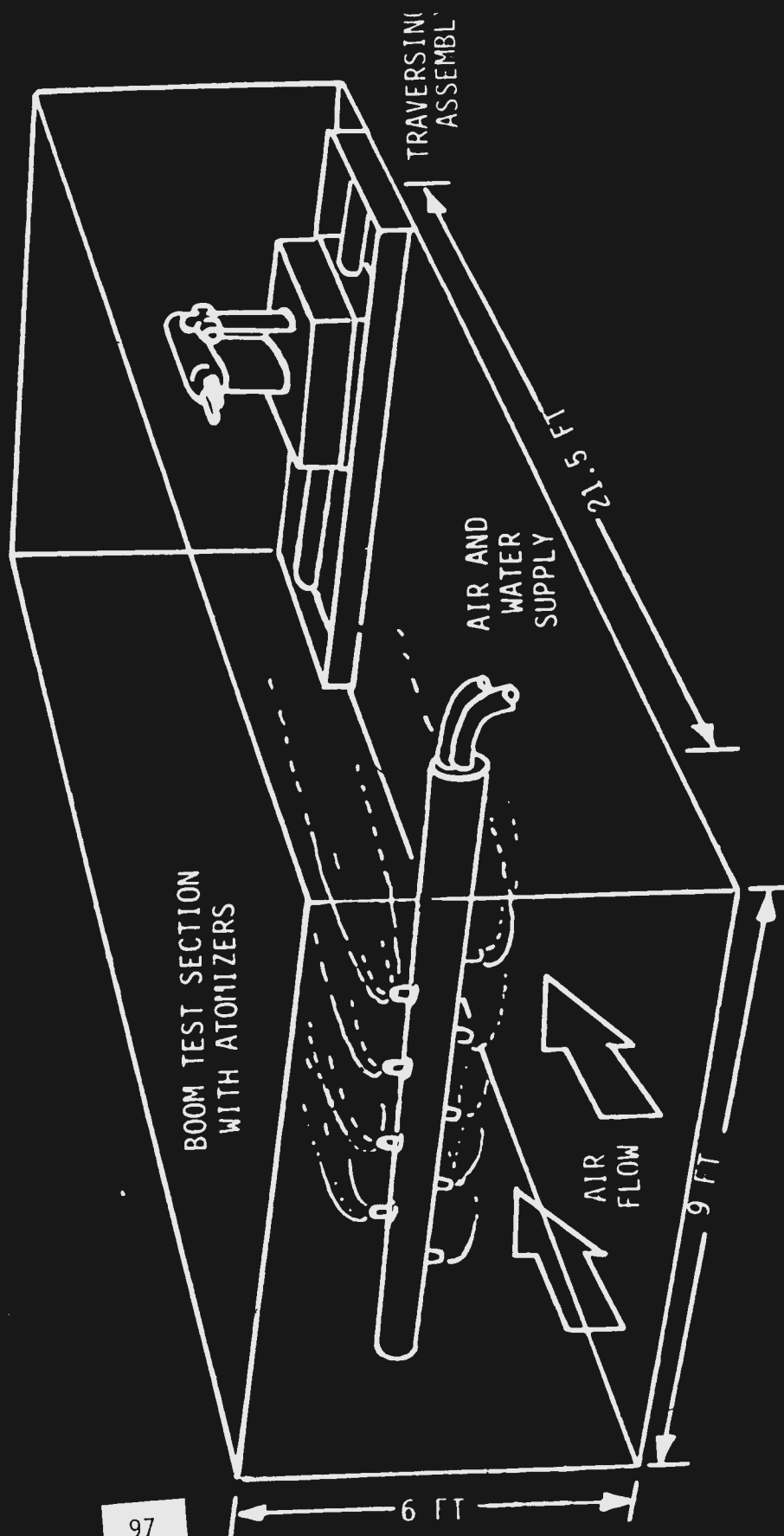


Figure 15



Figure 16

Figure 17

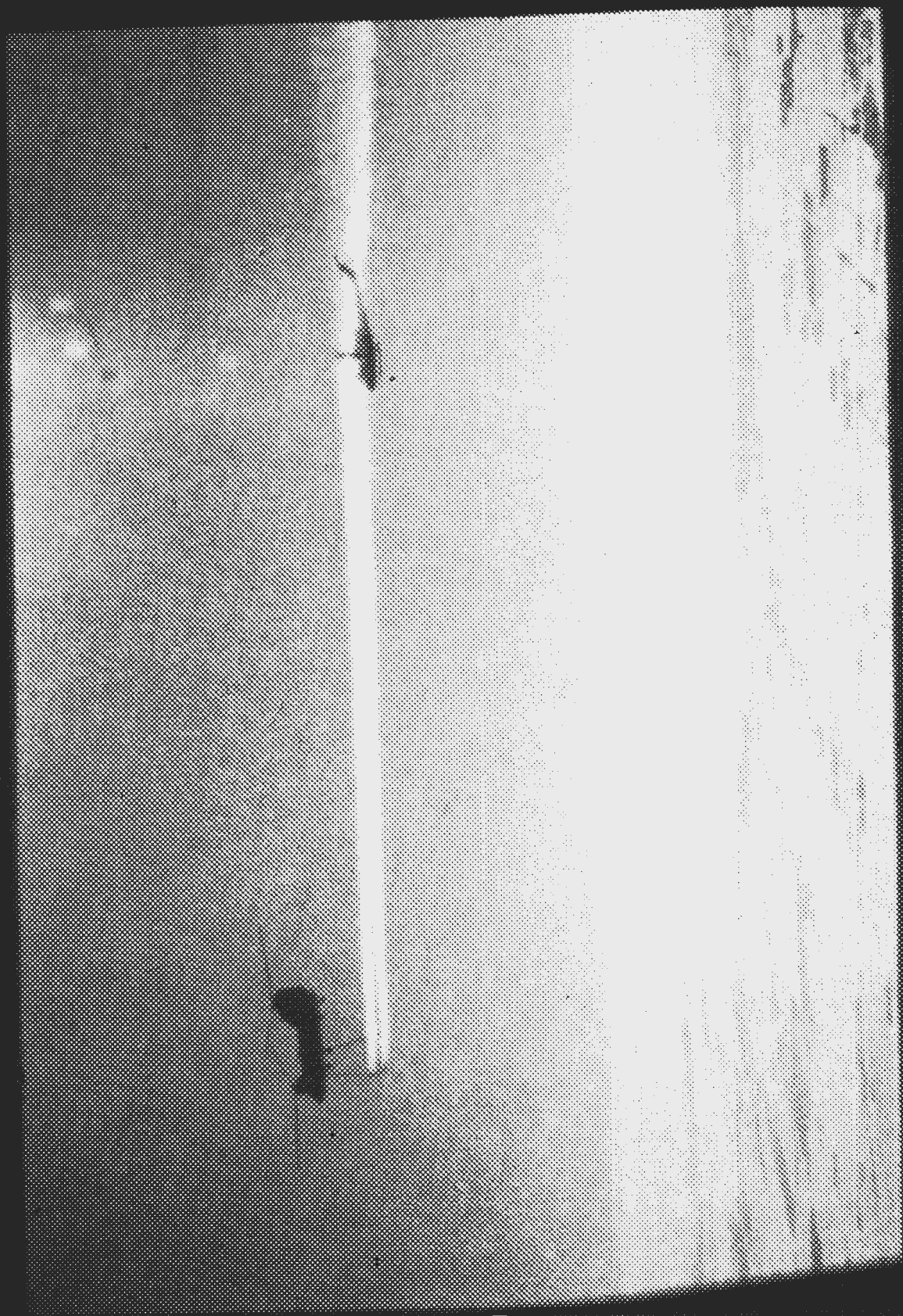


Figure 18

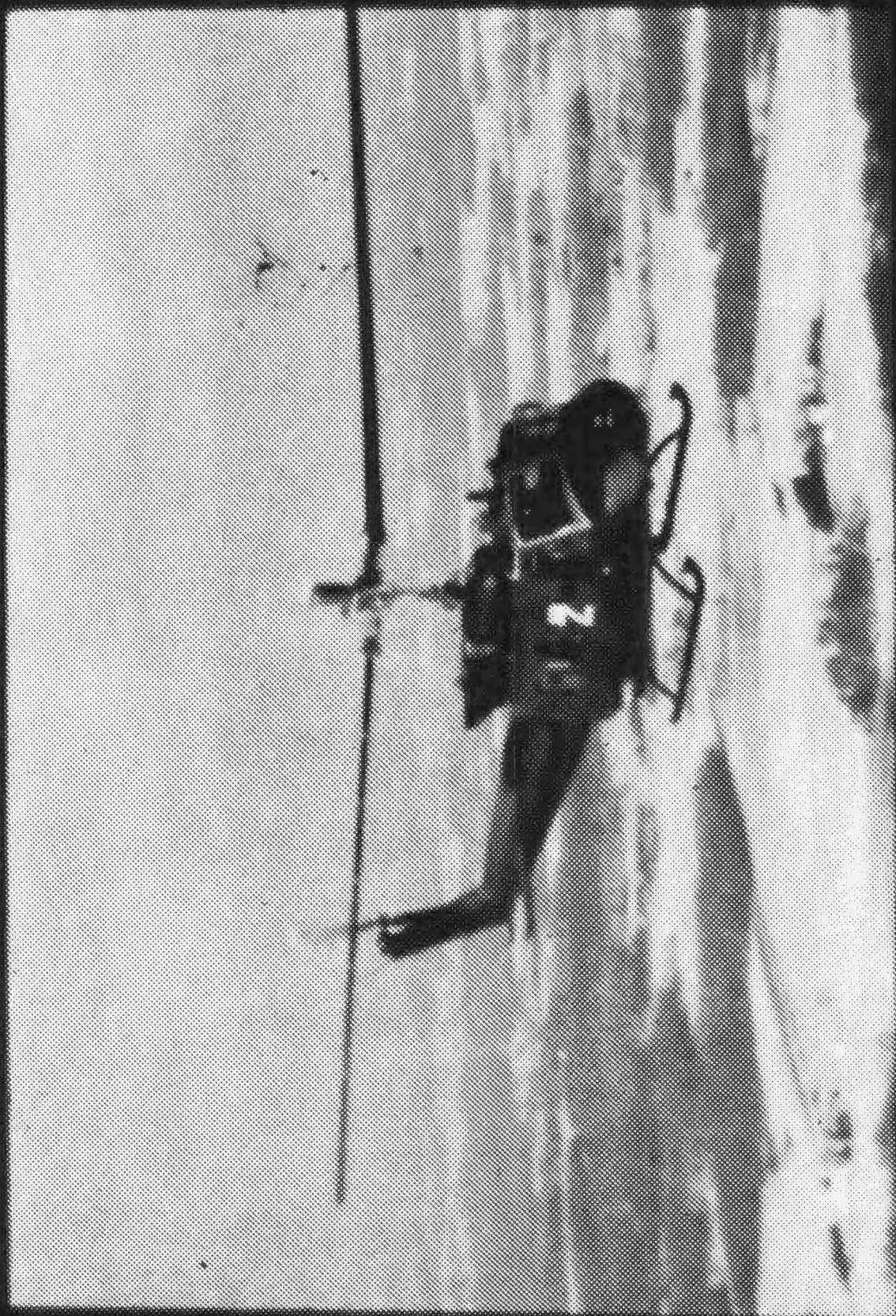


Figure 19

DISTANCE FROM SPRAY BOOMS (FT)

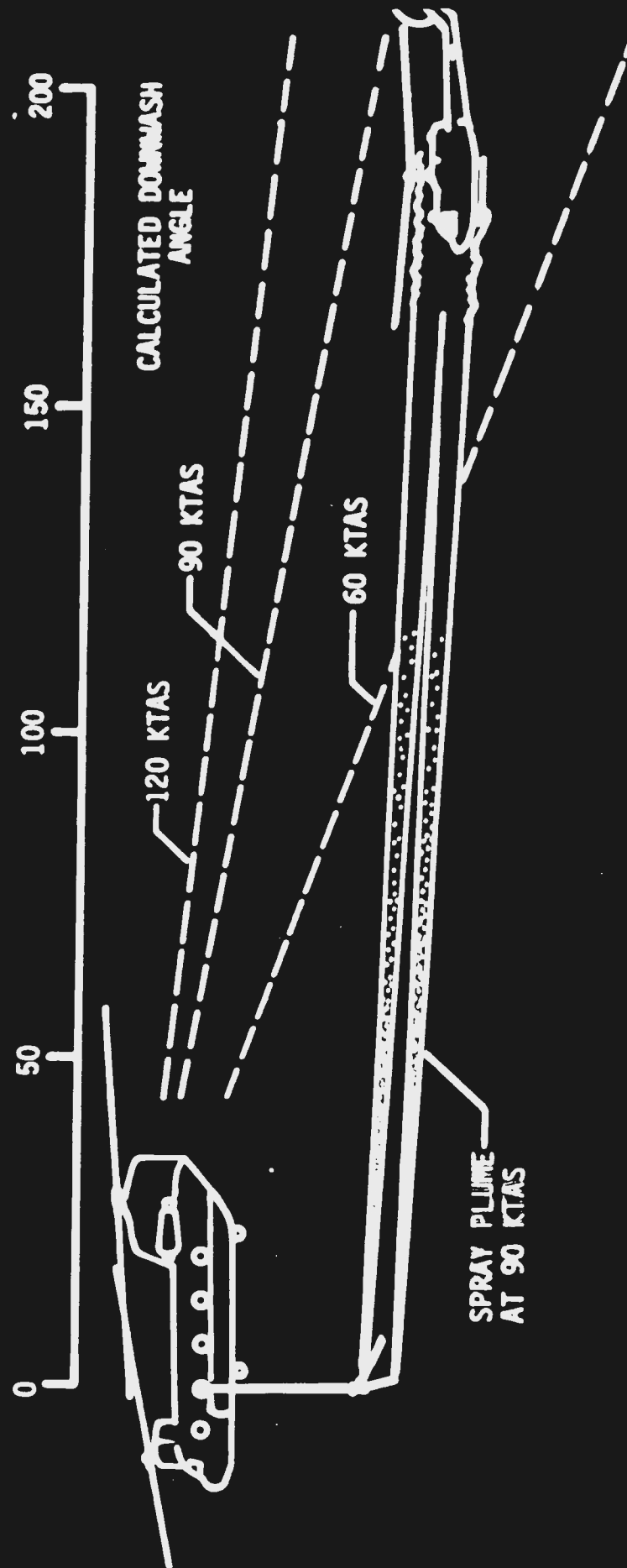


Figure 20



Figure 21

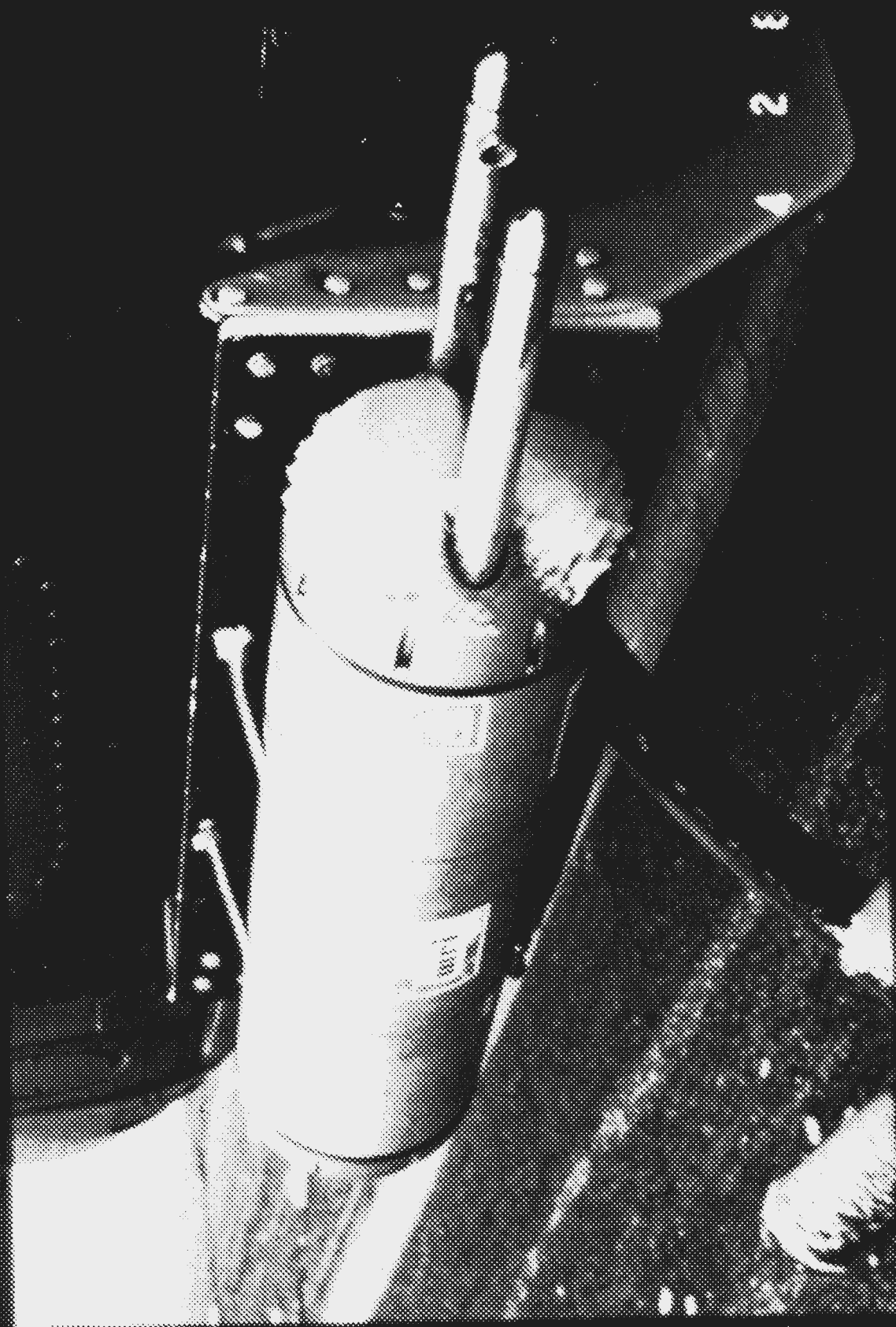


Figure 22

VISIBLE CLOUD

105

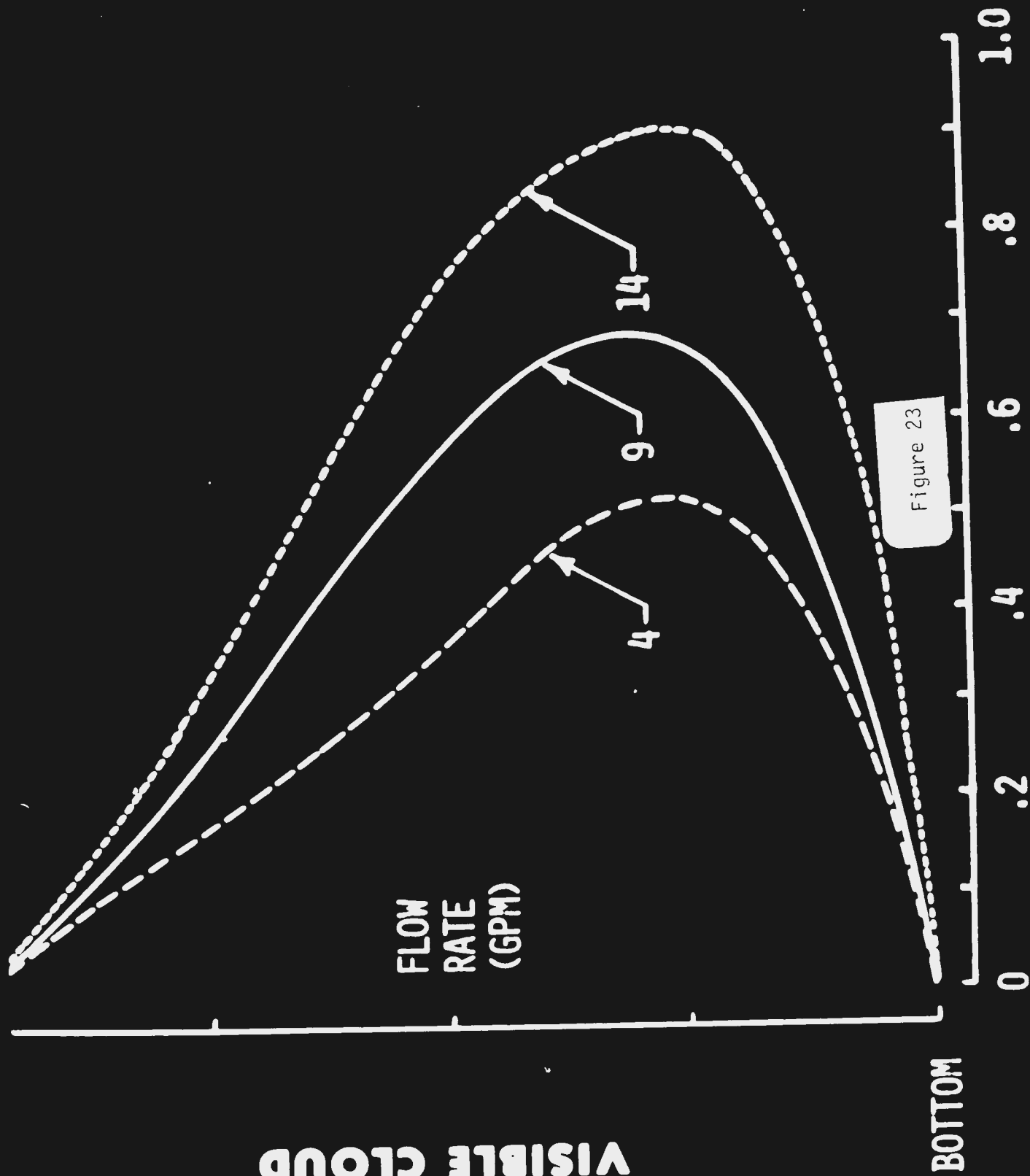
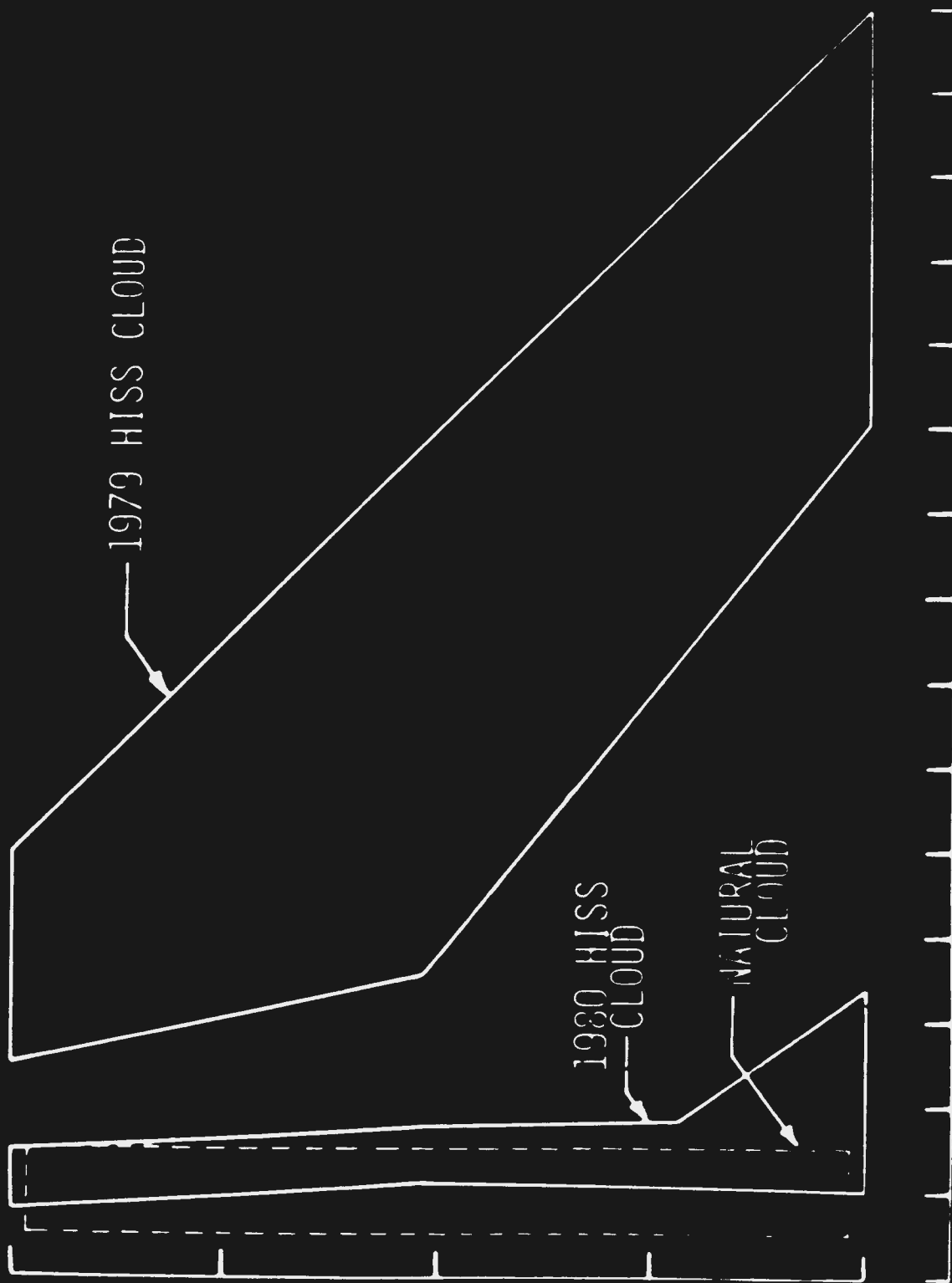


Figure 23

VISIBLE CLOUD



MEDIAN VOLUMETRIC DIAMETER (MICRONS)

Figure 24



Figure 25

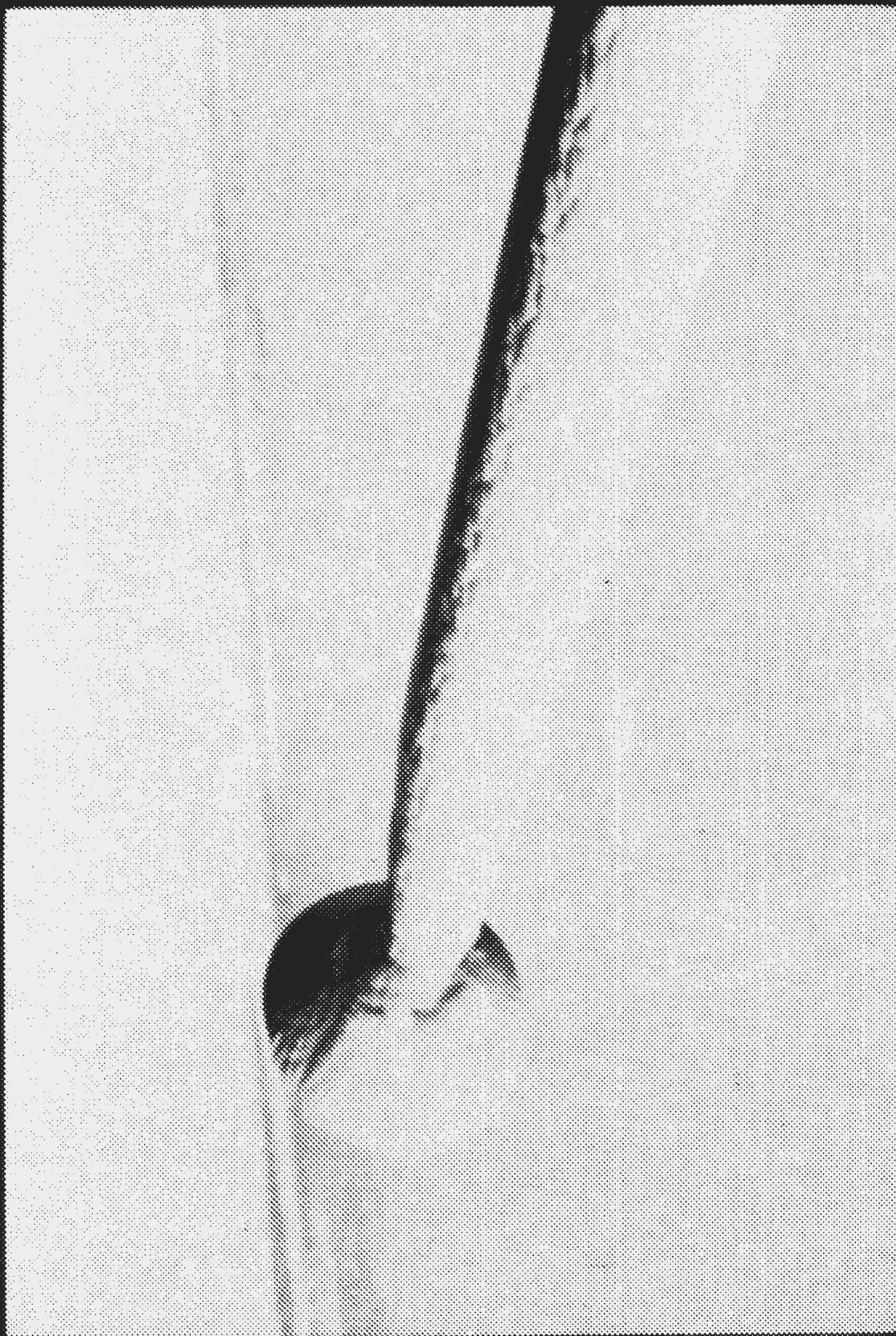


Figure 26

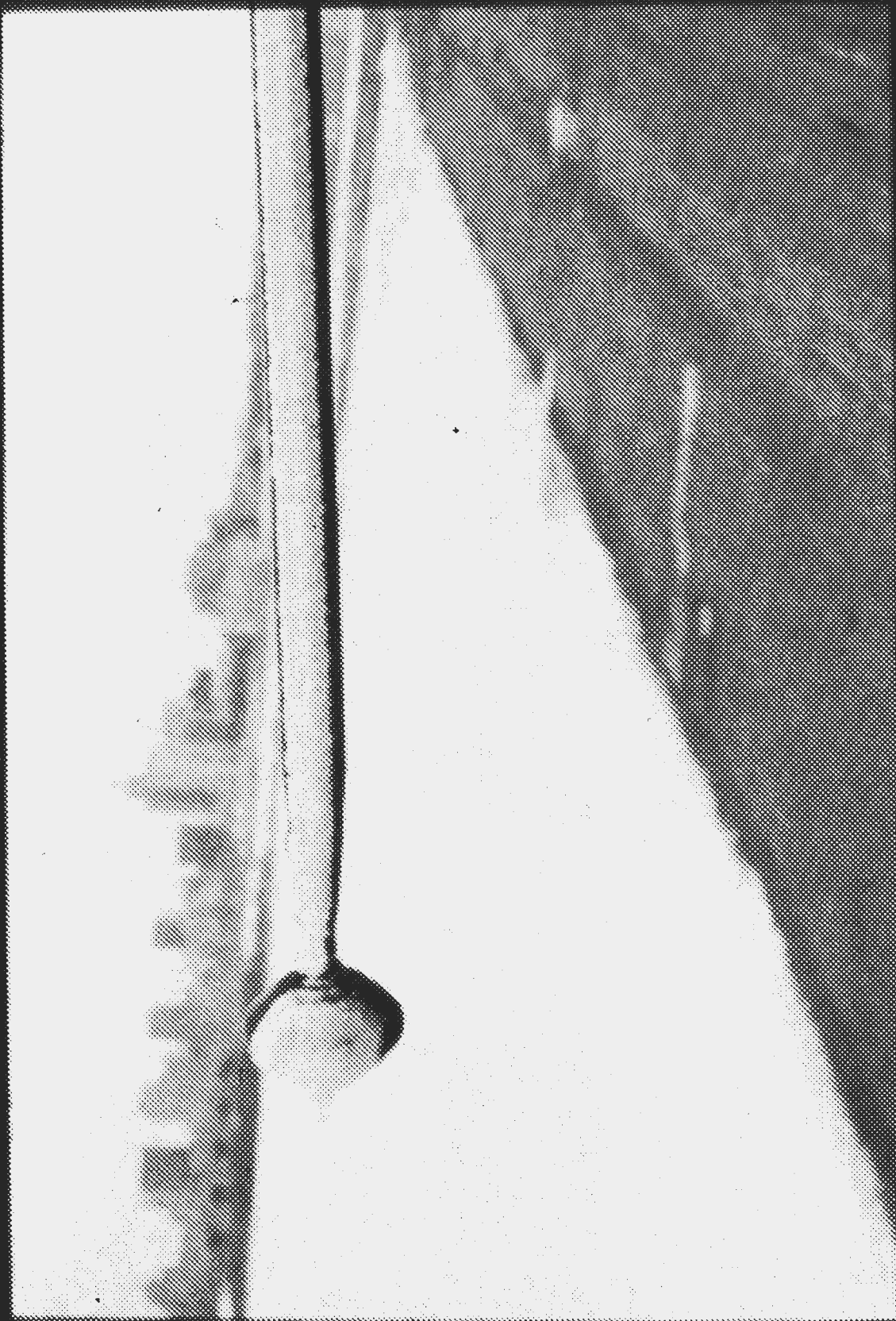


Figure 26A

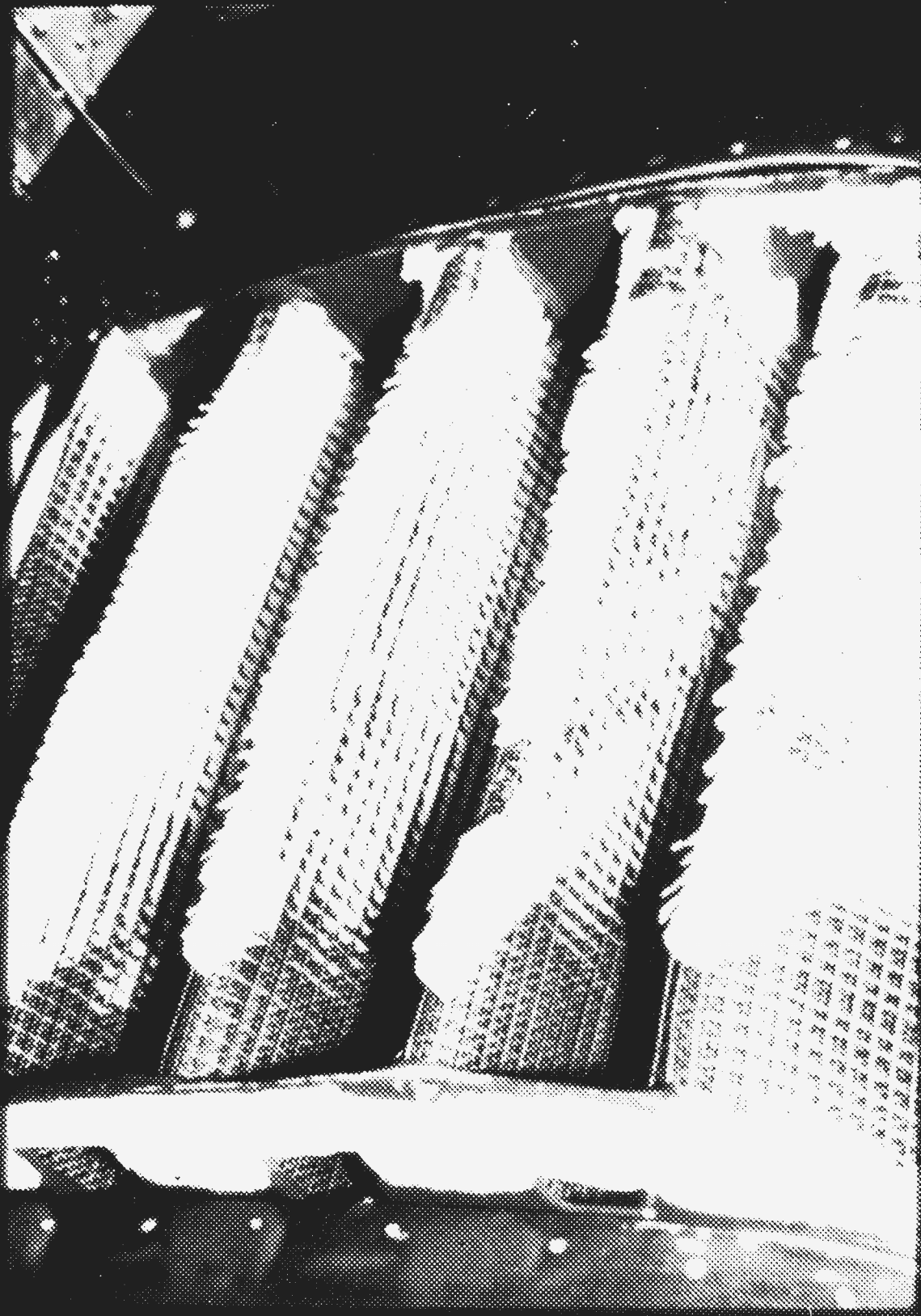


Figure 27

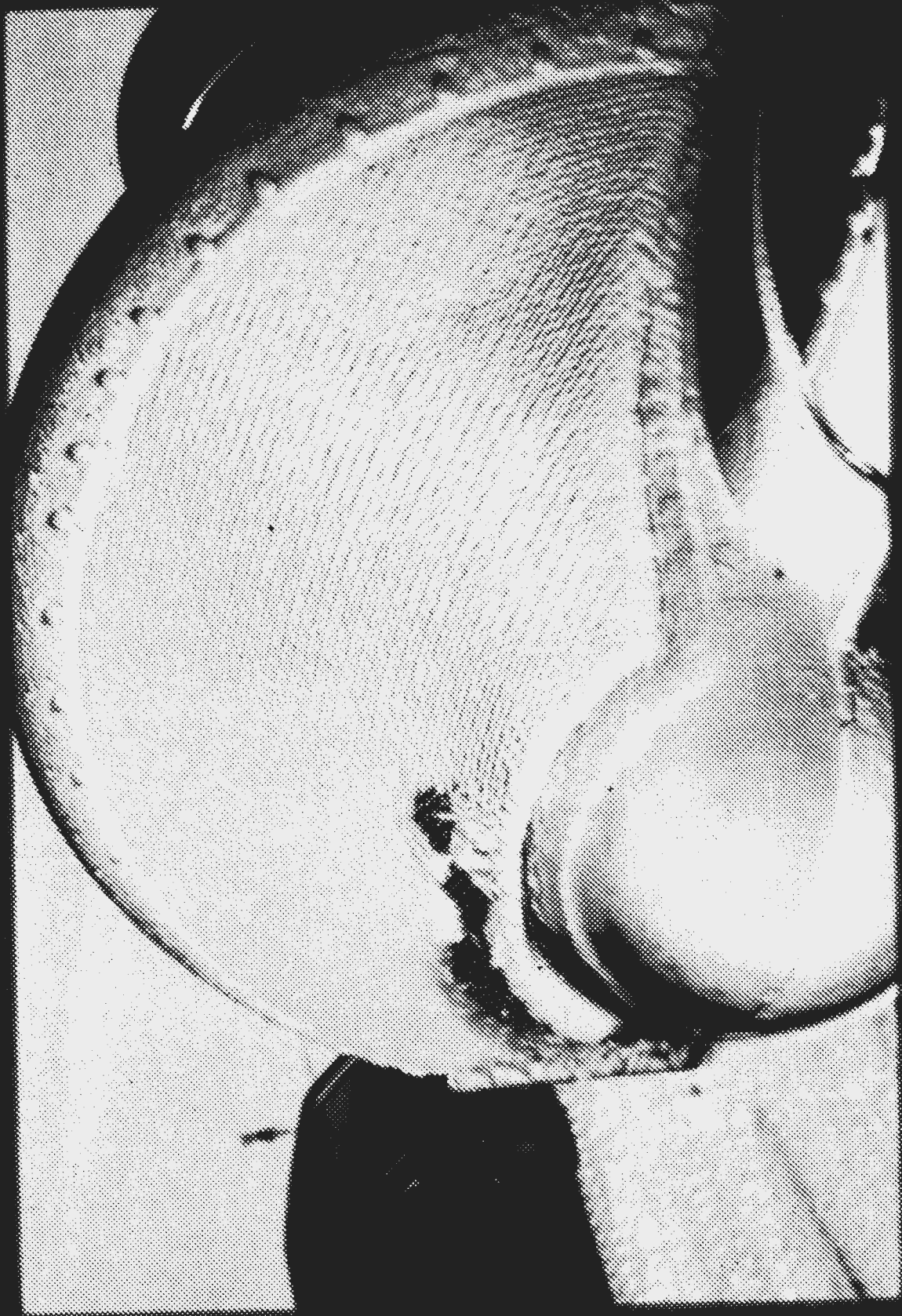


Figure 28



Figure 29

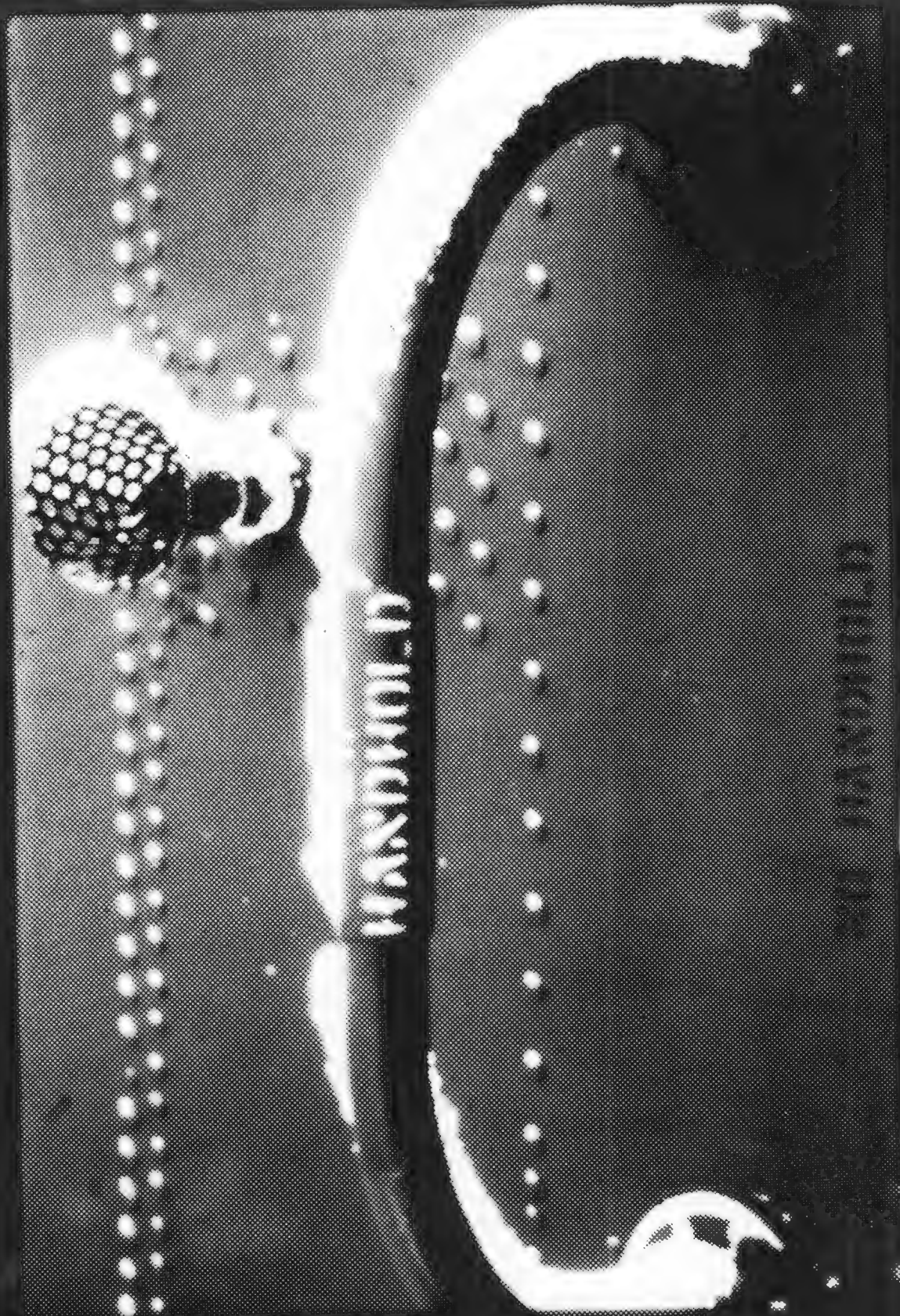




Figure 1

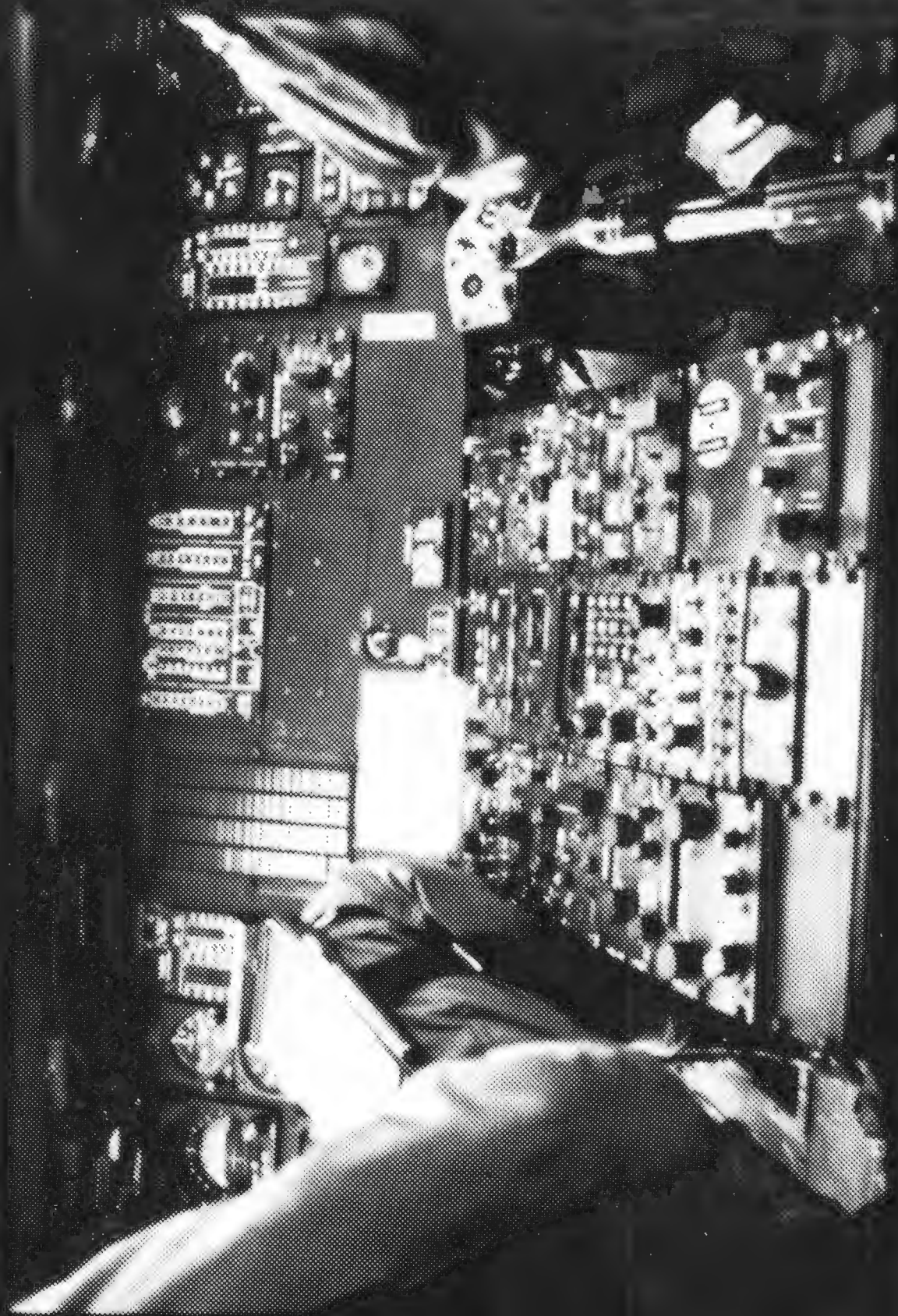


Figure 32

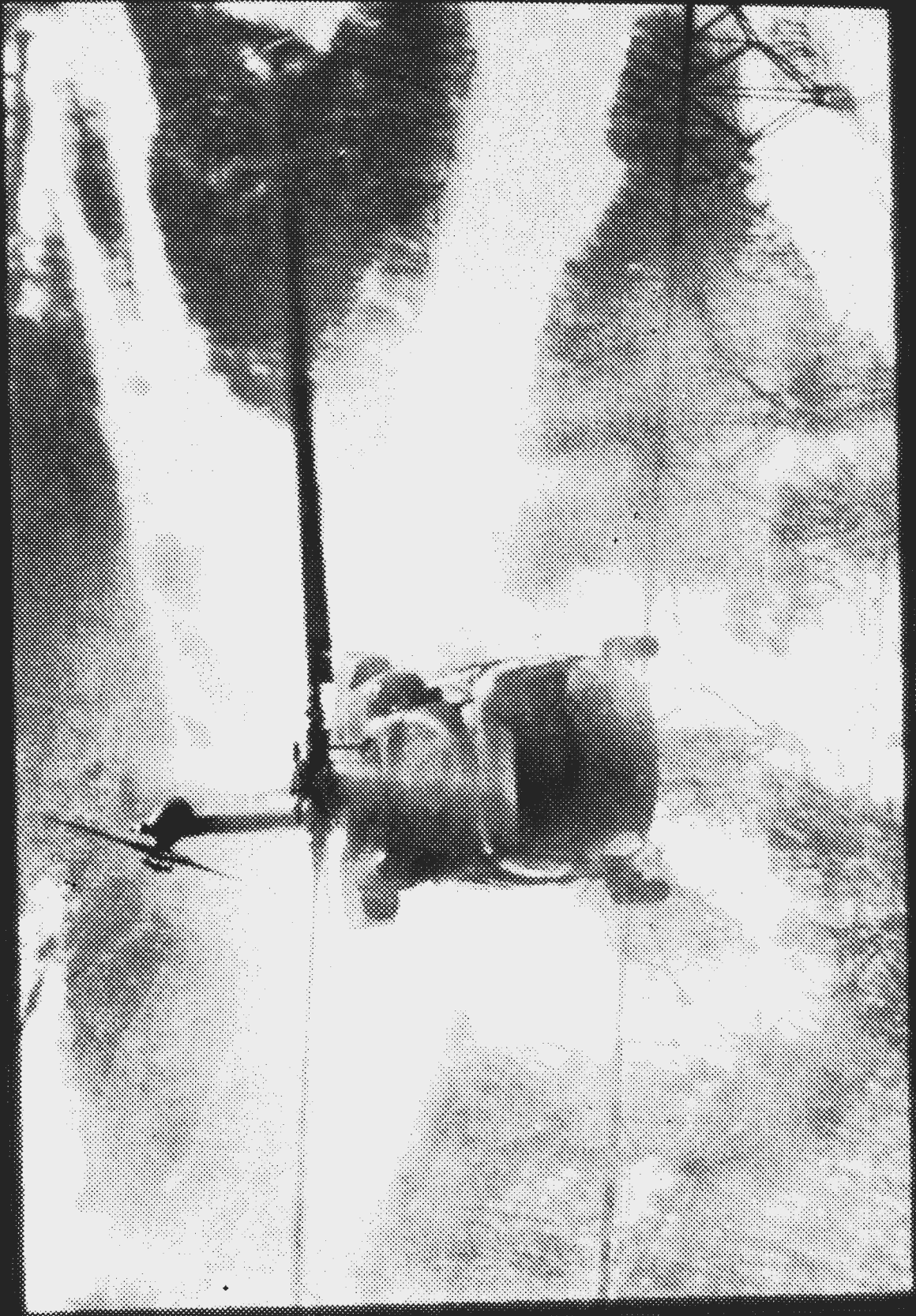


Figure 33

ICER-III

ARTIFICIAL ICING TEST CONDITIONS

TEMPERATURE °C	LIQUID WATER CONTENT (gm/m ³)			
	0.25	0.5	0.75	1.0
-5		□	□	
-10		□		
-15	●	●		
-20	●	●	●	●

□ 1979 Icing season STANDARD TAILPIPE CONFIGURATION

● 1980 Icing season IR SUPPRESSOR CONFIGURATION

/ - 15 minute maximum

Note: - 90 KTAS, average GW 16,440, 100% rotor speed, 354.3 cg (mid) All anti-ice and deice systems "ON"

Figure 34

BLACK HAWK

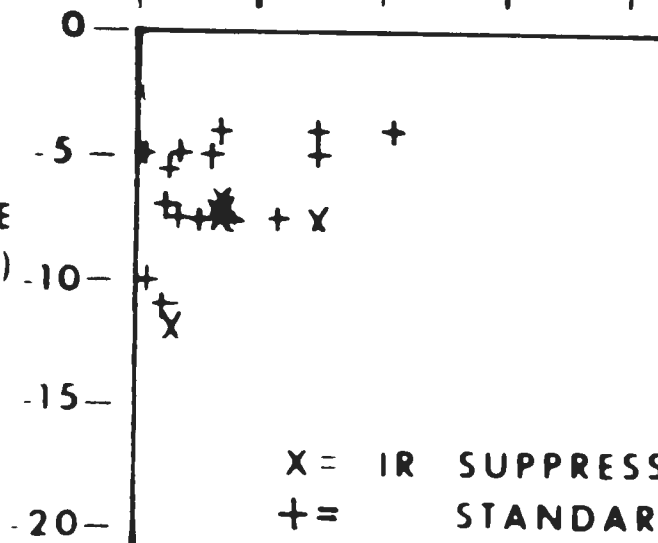
ICER-III

NATURAL ICING 1, 2 TEST CONDITIONS

LIQUID WATER CONTENT (gm/m³)

0 0.25 0.5 0.75 1.0

OUTSIDE AIR
TEMPERATURE
(°C)



X = IR SUPPRESSOR CONFIGURATION
+ = STANDARD CONFIGURATION

- Notes: 1 Rotor speed 100%
Average GW 16,500 lb
Airspeed 85 to 145 KTAS
Average CG 355.0 in.
2 Each condition at least 15 minutes

Figure 35



Figure 36



Figure 37

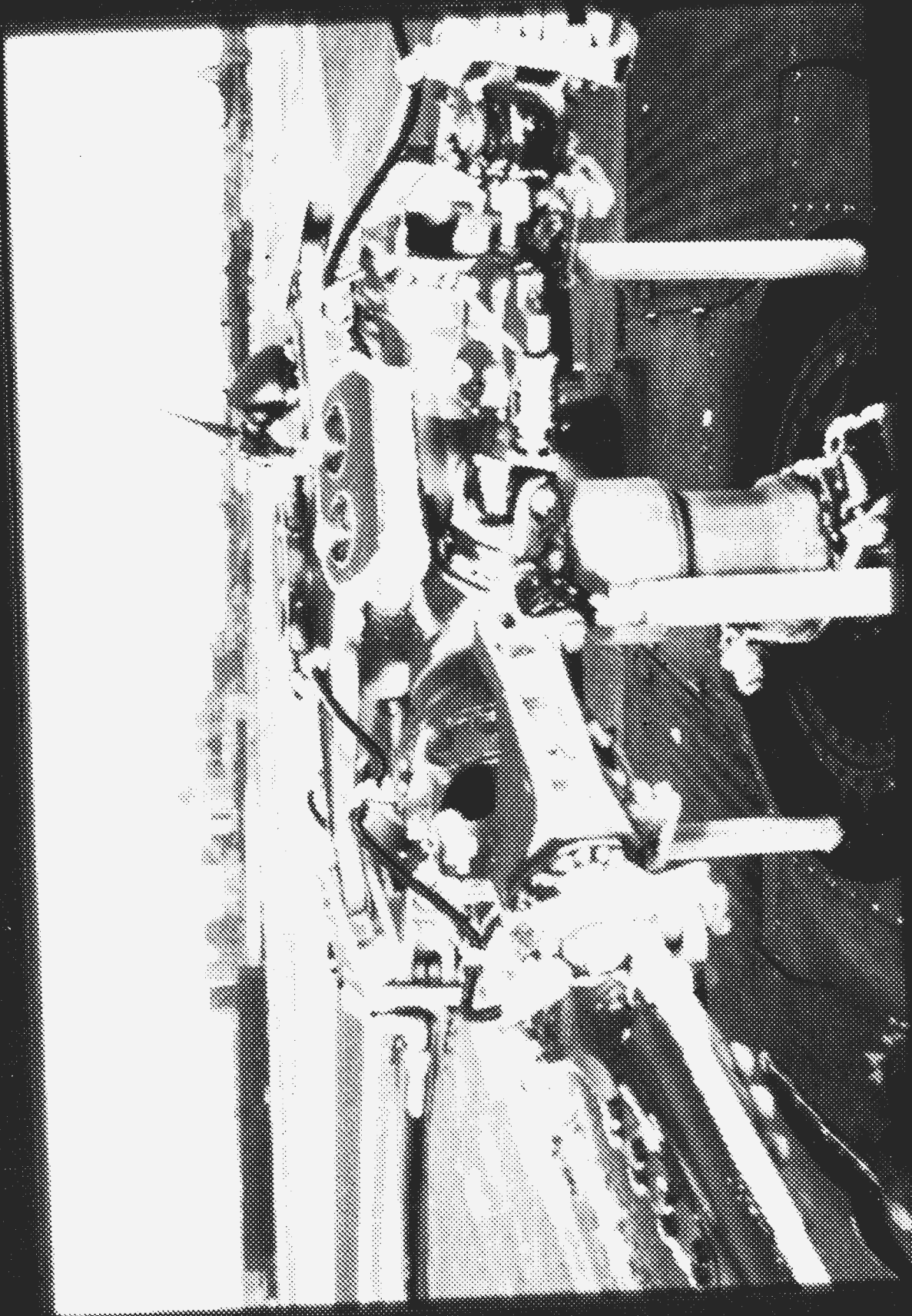


Figure 37A

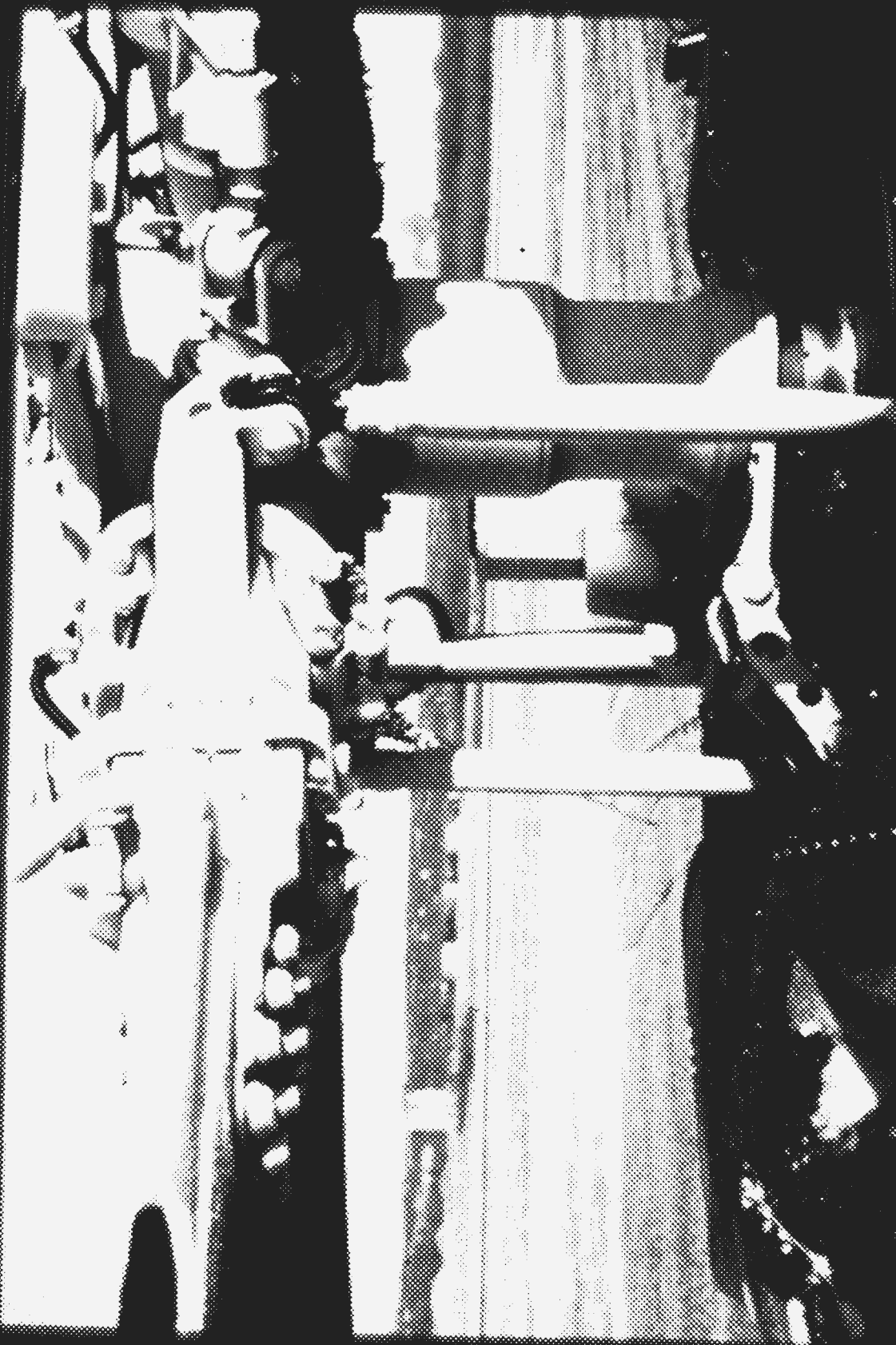


Figure 38

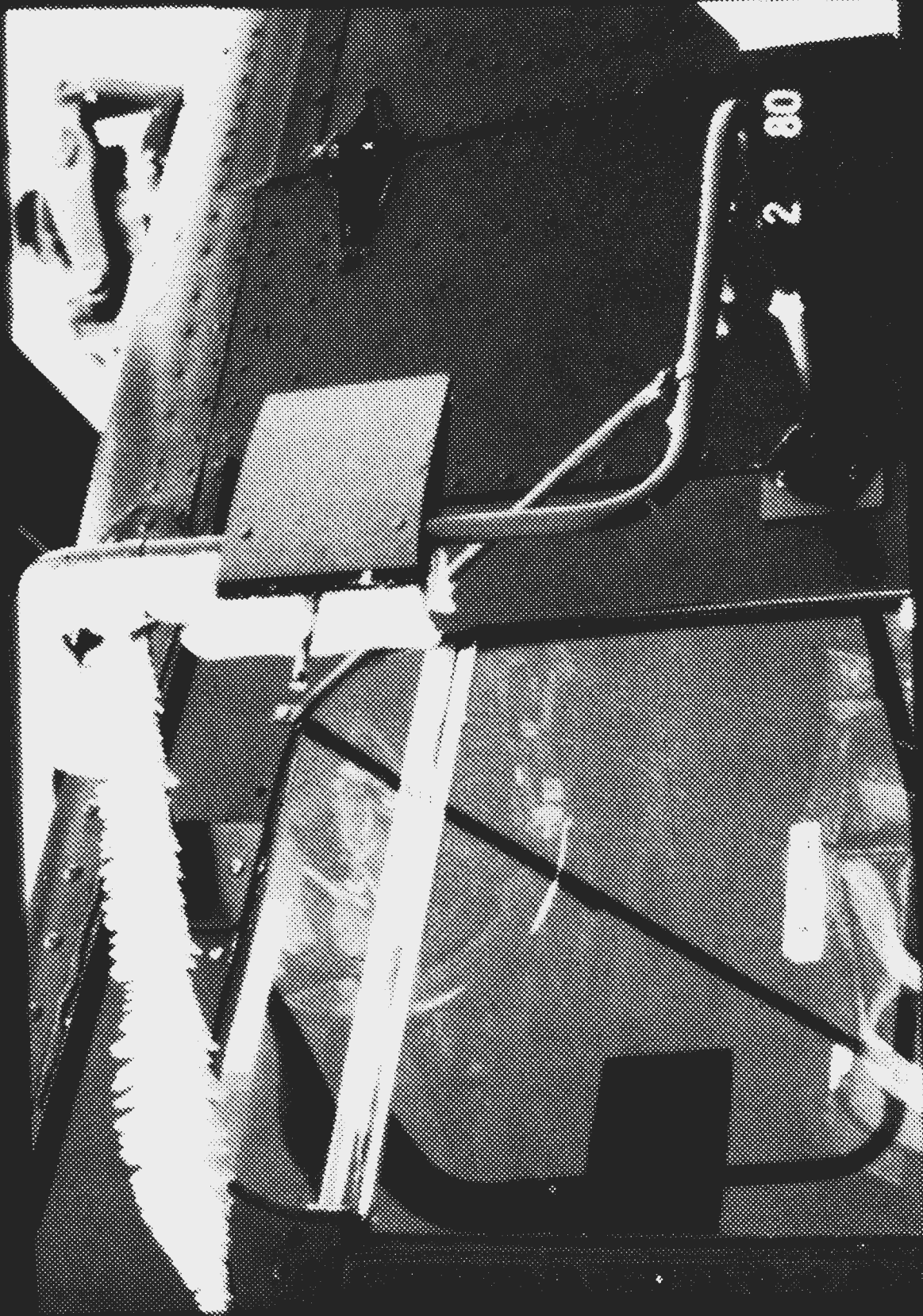


Figure 39



Figure 10



Figure 41

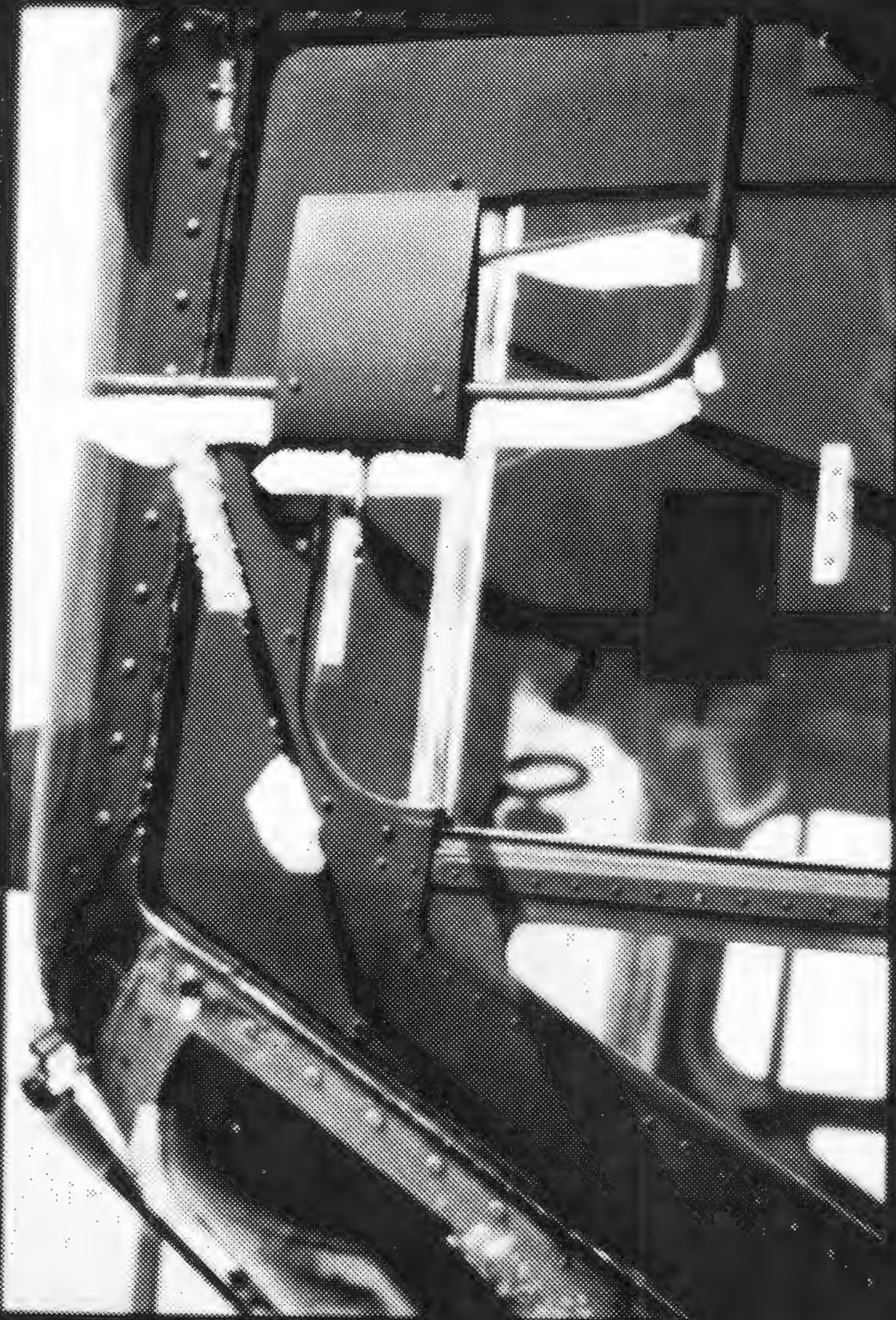


Figure 42



Figure 43

FIGURE BLADE DE-ICE CYCLE

GROSS WEIGHT	CG LOCATION	UN-00A	UBA S/N 77-22717	DENSITY ALTITUDE	DAT	AVG ROTOR SPEED (RPM)	AVG TRUE AIRSPEED (KT)
(LB)	LONG (°S) LAT (°N) DBL			(°T)	(DEG C)		
16560	354.6 (N10) -0.3 (N1)			2200	-7.5	290	122

NOTES: 1. I.R. SUPPRESSORS INSTALLED

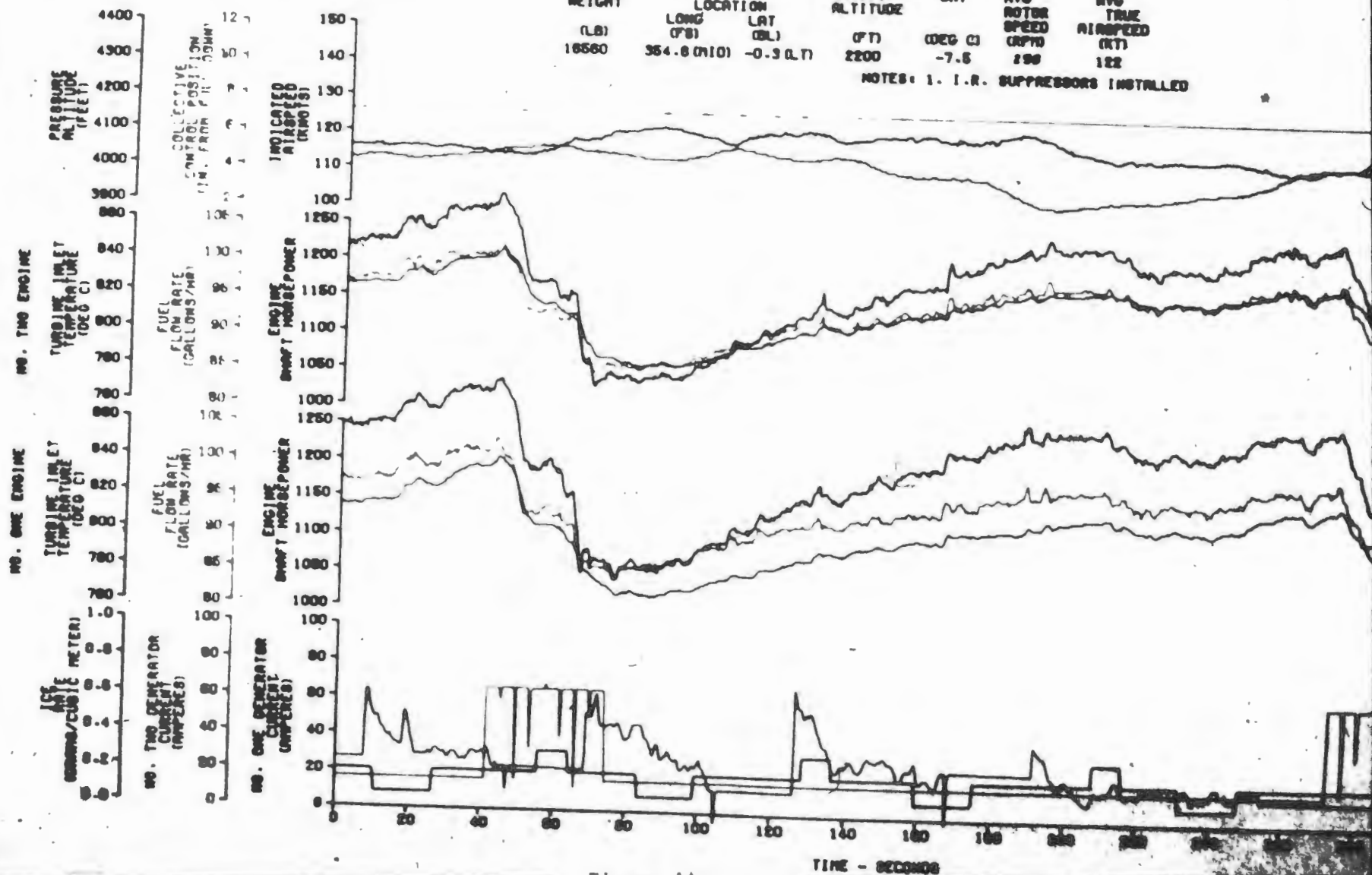


Figure 44

ADVANTAGES OF THE HISS

- PROVIDES AN ICING ENVIRONMENT SIMILAR TO NATURAL ICING CONDITIONS
- MAXIMIZES TEST TIME. NOT DEPENDENT ON NATURAL ICING
- SAFETY VALVE. TEST AIRCRAFT CAN IMMEDIATELY VACATE ICING ENVIRONMENT
- ALLOWS TEST FLEXIBILITY. CAN CONTROL LWC AND ALSO TEMPERATURE BY VARYING ALTITUDE
- ALLOWS EXPEDITIOUS OPTIMIZATION OF DE-ICING/ANTI-ICING SYSTEM PERFORMANCE PRIOR TO QUALIFICATION TESTS.
- ALLOWS SELECTIVE ICING CAPABILITY, IE ROTOR SYSTEM, WINDSHIELDS, ENGINES, FUSELAGE, ETC
- ALLOWS CAPABILITY FOR IMMEDIATE INFLIGHT PHOTOGRAPHIC DOCUMENTATION OF ICE ACCUMULATION

CURRENT AND FUTURE HISS DEVELOPMENT

SHORT TERM

- IMPROVE JCH-47C PERFORMANCE ENVELOPE
- IMPROVE HISS DYNAMICS
- INCREASE AIR FLOW TO BOOM
- INCREASE CLOUD SIZE
- DETERMINE IMPACT OF SOLAR RADIATION, ICE CRYSTAL CONTENT AND HUMIDITY EFFECTS ON ARTIFICIAL ICING

LONG TERM

- REDESIGNED HISS BOOM CONFIGURATION
- POSSIBLE USE OF CH-47D
- AS A GOAL, DEVELOPE HISS WITH FOLLOWING CAPABILITIES
 - LWC 0-3 GM/M³
 - DROPLET SIZE 10-40 MICRONS
 - PRESSURE ALTITUDE 0-12,000 FT
 - AIRSPEED 30-150 KTS
 - CLOUD SIZE 30 FT × 60 FT

Figure 46

USE OF THE HISS BY INDUSTRY

- AVAILABLE TO INDUSTRY BY REQUEST THROUGH THE FAA.
- PRIORITY OF TESTING ESTABLISHED (I.E., DOD PROJECTS HAVE FIRST PRIORITY).
- HISS IS OPERATED AND MAINTAINED BY AEFA
- AVRADCOM AND AEFA WILL PROVIDE NECESSARY COORDINATION WITH INDUSTRY TO ESTABLISH TEST AND TECHNICAL ASSISTANCE
- CURRENT COST TO INDUSTRY FOR HISS SUPPORT IS APPROXIMATELY \$2,300/FLIGHT HOUR. THERE IS ALSO A MUTUAL SUPPORT COST
- CURRENT SITE FOR ICING TESTS IS ST PAUL, MN. TEST SEASON IS DEC, JAN, FEB, AND MAR

Figure 47

POINTS OF CONTACT

COMMANDER
US ARMY AVIATION RESEARCH AND DEVELOPMENT COMMAND
ATTN: DRDAV-DI
4300 GOODFELLOW BLVD
ST. LOUIS, MO 63120
PH COMM (314) 263-1708
POC HARRY CHAMBERS

COMMANDER
US ARMY AVIATION ENGINEERING FLIGHT ACTIVITY
ATTN: DAVTE-T
EDWARDS AFB, CA 93523
PH COMM (805) 277-2271
LTC FRANKENBERGER

Figure 48

U.S. ARMY ICING RESEARCH HELICOPTER

INTRODUCTION: RICHARD I. ADAMS

Our speaker is from the U.S. Army Applied Technology Laboratory at Fort Eustis, Virginia. That's the organization that I was with for 16 years before I came to the FAA last year. The person who will be talking to you on this subject will be Mr. Gene Birocco. Gene actually replaced me when I left ATL and he is going to be talking about the JUH-1H icing research helicopter that you heard mentioned here before. Gene!

MR. GENE BIROCCO

U.S. ARMY APPLIED TECHNOLOGY LABORATORY

Good Morning! I think that Lynn and Harry are going to be a tough act to follow, I thought that was a fantastic presentation. You're going to see a little bit of duplication of what I have to present to you because our test aircraft, the JUH-1H, which you see on the slide, (Figure 1), has been heavily involved in some of the AVRADCOM programs over the last couple of years and it's been heavily tested by these organizations.

When you talk about icing research involvement in the Applied Technology Laboratory, the center of that activity has been a modified, one of a kind, UH-1 aircraft. The aircraft was modified under contract to Lockheed, California in the 1973-74 time frame. For the purposes of developing and optimizing and testing a cyclic thermal deicing system, the testing on that aircraft has proceeded on a yearly basis and the optimization of this system was completed in approximately 1978, I believe. Since that time, the aircraft has been used more as a test aircraft to test other concepts and other ideas. (next viewgraph, please, Figure 2).

This is a summary of the presentation I have for you this morning. I will give you a description of the test aircraft with configuration changes that were made to it from an ice protection standpoint. Next, the capabilities of the aircraft, the accomplishments that it claims over the years, the present status of the aircraft and the future plans that we have for it. Then, from an ATL standpoint, our attitude towards the continuing need for an icing test bed aircraft and some open R&D uses that we see that could be resolved on an icing test bed aircraft.

This (Figure 1) also shows a brief description of the ice protection system that was provided on the aircraft. We have heated glass windshields, the main and tail rotor blades cyclic electrothermal deicing, and there are two, at the present time there are actually three, ice detectors on the aircraft. There is a Leigh Mark 10 aircraft integrating rate unit which is used for controlling flight deice cycles. And then there are also a Rosemount Model 871 ice detector and a Leigh Mark 12 ice detector on the aircraft. (next viewgraph, please, Figure 3).

The aircraft over the last two years, and hopefully again this year, will carry a cloud parameter instrumentation package which includes an axial scattering spectrometer probe which measures water droplets in the 2 to 45 micron range and then two interchangeable devices, which are not used simultaneously. A cloud particle spectrometer measures the 35 to 300 micron droplet size and a precipitation particle spectrometer which measures the 140 to 2100 micron droplets. This coming winter, in conjunction with some requirements that we have picked up from the FAA through the interagency agreement, we are also interested in looking at the effects of solar radiation, relative humidity and ice crystal content, both in the natural and the simulated environment. We are planning to include in our package a pyroheliometer which will measure total solar

radiation dosage, a hygrometer for relative humidity measurements which we found to be a very interesting parameter, particularly in the simulated environment and a Turner-Radke device, a little laser type device for measuring ice crystal content. We noted occasions where the aircraft appears to be in what we term, what the AEFA folks term, visible moisture and yet the ice detectors are not measuring an appreciable liquid water content and we are not getting any appreciable accretion on the aircraft. We suspect that what we're flying in is a partially or fully glaciated cloud with very high crystal content. As I mentioned earlier the aircraft also has two Leigh ice detectors on the aircraft and a Rosemount ice detector and cockpit display. The Rosemount unit is basically identical to the one that is on the Black Hawk except for five volt versus twenty-eight volt, meter lighting. (Next viewgraph, please, Figure 4).

This, very quickly, is some of the instrumentation that is currently on the aircraft and has been recorded. The top block instrumentation is displayed in the cockpit and has to be manually recorded. The second block that appears in our PCM parameters. (Next viewgraph, please, Figure 5).

As are the ones at the top and then we have some FM parameters. There are considerable other instruments that have been on the aircraft over the years and are presently not being used in terms of blade surface temperatures, some structural parameters and things of this type.

This (Figure 6) is a drawing of the main rotor blade. It shows you the fashion in which the blade on the UH-1 is zoned as opposed to the Black Hawk, the AAH and the prototype system we have flown on the CH-47. This blade is zoned in a span-wise fashion. It's zoned into 6 zones and it provides a very convenient capability for being used as a back up system or a safety valve, more or less, in testing other approaches. In the event the aircraft does get into a problem of some type where you encounter asymmetric shed, activating the rotor blade deice system which proceeds in from the tip, that actually cleans off the blade very quickly or at least the major contributor to the unbalanced condition. (Next slide, please, Figure 7).

The blade features a span-wise power density taper which takes advantage of the natural aerodynamic heating which occurs on the blade. You can see the power density down on the tip of the blade actually is only on the order of 11 to 12 watts per square inch and it goes up as high as 25 to 26 watts per square inch at the inboard section of the blade. (Next slide, please, Figure 8).

And this is just a cutaway that shows the heater blanket. There is a stainless steel erosion shield on the blade and it is basically an S-coil heater element, stainless steel, is the element itself. (Next slide, please, Figure 9).

The system was originally designed to allow three different voltages to be applied to the blankets, 160, 200 and 230 volts. At the present time the highest and lowest voltage settings are no longer used.

GENE BIROCCO

We use 200 volts only and this has been found to be adequate for all the conditions that we've experienced thus far. (Next slide, please, Figure 10).

This is a duplication of a slide that Lynn Hanks showed you earlier. This is one of the Meteorology Research Incorporated probes that's on the aircraft, the axial scattering probe which measures the LWC of the smaller droplet sizes. (Next slide, please, Figure 11).

This is the largest device, the precipitation particle spectrometer which measures the 140 to 2100 micron droplet size. (Next slide, please, Figure 12).

This shot shows you two of the ice detectors on the aircraft. On the left hand side the rectangular looking unit is the Rosemount and that painted orange station is the Leigh Mark 10 which actually controls the rotor blade deice system on the aircraft. On the right hand side, at the present time planted in the other air intake, is a Leigh Mark 12. We've had these devices on the aircraft for two seasons now in addition to the MRI droplet package and we've actually gotten very good agreement between the three ice detectors and the laser nephelometers as far as liquid water content, well within what a reasonable person could expect from it. These devices are mounted at different positions on the aircraft. (Next slide, please, Figure 13).

This just shows a picture of the aircraft in flight. Sitting on top of the slip ring canister is a hub mounted camera. We've only had moderate success with this camera and it's one area which we really feel is in need of additional work. The capability to take inflight shots in natural icing conditions to see what the rotor blades are actually doing, we feel is invaluable and unfortunately, to date as I said, we've only had moderate success. We had a camera on the aircraft two years ago that gave fairly decent pictures. The camera was on the aircraft last year, but we had a great deal of trouble with it. It seems it spent more time in the shop than it did on the aircraft. At the present, the Applied Technology Lab has an in-house program in which they're trying to develop a camera system that will actually mount inside the aircraft on the floor of the test aircraft and shoot through a window on the door with a strobe system for lighting to enable us to take pictures of the under side of the blade to see what's going on. We're hoping that with a system of this type we can get some good pictures have a system that will be more reliable because of the more benign environment inside the test aircraft. (Next slide, please, Figure 14).

That slide doesn't show as well as I thought it would. It shows the aircraft with the IR suppressor on. (Next slide, please, Figure 15).

The aircraft has also been flown with the standard tailpipe. I think, to date, the only difference that has actually been experienced between the tailpipe configurations is with the IR suppressors on the aircraft. Strangely enough we seem to get less ice accumulation on the tail surface of the aircraft. (Can I have the next slide, Figure 16).

GENE BIROCCO

The electrothermal deicing system on the JUH-1H was actually designed for liquid water content up to 3 grams per cubic meter. This is a feature that is kind of unique to this aircraft, as far as aircraft in the Army inventory or those projected to be in the Army inventory over the next few years. The AAH and the Black Hawk both are designed for liquid water content up to about 1 gram per cubic meter, so we feel like the UH-1 has the capability that is kind of unique. It's designed for outside air temperatures down to minus 20 degrees centigrade. You'll probably recognize that this criteria is just a little different from the FAR Part 25 criteria. One of the first things that Lockheed has done for us was to look at the design criteria for the helicopter environment specifically and recommend a criteria that was a little less stringent than FAR Part 25. We're finding, nevertheless, that it is still quite stringent compared to what we've actually experiencing in flight. The UH-1 has a 30 KVA AC generator on it which, except for providing power to a 200 amp TR (transformer rectifier), is dedicated exclusively to the ice protection system on the aircraft. You can see that it's quite a power load to provide this type of a capability. The aircraft features, as I said before, chord-wise heating for spanwise shedding and we feel that this is ideal for a backup system. The aircraft has been used for backup tests for kit A, as it is affectionally known. Kit A was partial protection that the Army attempted to qualify on the UH-1 two years ago which include heated glass windshields, an ice detector, cockpit display, liquid water content and an accurate OAT sensor and a spacer to provide additional clearance between the tail rotor and the FM whip antenna. The UH-1 was used as a test-bed aircraft for that system. It enabled us to safely and confidently probe the natural environment with an unprotected aircraft, knowing that we could activate the rotor blade deice system in the event that we got into any kind of problem and quickly clean up the rotor blade. Kit A never achieved qualification status due to a variety of problems. One of the biggest ones, actually, is that we finally determined that a display of liquid water content alone was felt to be an inadequate display for the pilot. I think Lynn Hanks mentioned earlier that there is an awful lot of things going on up in the cockpit and to expect the pilot to monitor one instrument continuously, was not realistic. As a result Kit A was not qualified. That's probably the biggest single reason it failed to achieve qualification status. The aircraft actually flew on the order of seven hours in a natural icing environment. We really never experienced a serious problem due to the rotor system to where it was necessary to activate the rotor blade deice system to clean the rotor system up. During the past winter season the aircraft has been used for testing ice phobic coatings. The Applied Technology Lab is very interested in ice phobic coatings. It's certainly gotten to be recognized as a high risk approach to ice protection, but we've got a tremendous fleet of aircraft, including an OH-58A, UH-1, Cobras, that do not have rotor blade ice protection, are not really practical candidates for electrothermal systems and the Army's going to be operating these aircraft well into the 90's. In order to attempt to provide some type of partial capability, interim capability, limited capability for these aircraft, we're looking into ice phobic coatings, recognizing that it is a high risk endeavor. The UH-1, in all fairness, does have

GENE BIROCCO

some problems as far as being an icing test bed aircraft. It is a single engine aircraft and there is always the possibility of an engine failure in IFR flight. We've had this fact pointed out to us by the AEFA personnel who fly the aircraft. They are somewhat reluctant to continue to fly the aircraft yearly. The other problem which concerns us is the tetering rotor system, for continuously probing, deliberately probing the IFR environment. They're concerned by severe turbulence in the IFR conditions and icing conditions. (Next viewgraph, please, Figure 17).

Accomplishments include a great deal of HISS testing over the years. The aircraft has spent at least three test seasons in the Ottawa Spray Rig. We've got quite a bit of natural icing time on the aircraft and in two different test seasons we've been able to get some exposure to freezing rain and drizzle. Our earliest thoughts in operating the aircraft in freezing rain and drizzle, we expected it to be a very severe environment. The only thing that we can say from the very limited experience we have had thus far is that its not been as severe an environment as we had originally expected. We had originally anticipated that the attempt to protect the aircraft for flight in freezing rain for full chord protection, we had expected full chord impingement on the blade. We've not actually found that to be the case. The aircraft, as mentioned earlier, has been used for Kit A qualification test support. Its been used for ice phobic coating flight test support and right now at this point, the plans call for it to be used in that mode again this winter season. I'll tell you a little bit more about our future plans later. The aircraft has been used, as you've seen from Lynn Hanks' presentation, for test calibration and cloud parameter investigations and we hope to use it in that fashion again this winter season. Its also been used for some natural icing cloud characterization, hoping to eventually gather enough data, in combination with other investigators, to eventually redo the design criteria, that we're living with at this point, which has proved to be quite severe compared to what we're actually finding in flight. (Next viewgraph, please, Figure 18).

The present status of the test aircraft. We're planning to use it during the 1980-81 test season in support of a joint Army/FAA test program, which includes ice phobics, furthering our endeavors with ice phobics, some additional HISS calibration work. I think that the AEFA folks and Harry Chambers had mentioned earlier that they're hoping to make some changes to the aircraft (HISS) before this coming winter season which will probably amount to stopping up the leaks in the system and removing some of the unnecessary valving, and reducing pressure drops. Nevertheless it's going to require some additional calibration work. We're also going to use the aircraft and the cloud parameter package that's on the aircraft to pursue some FAA R&D objectives, which the Army also is interested in by the way, which includes looking at the affects of solar radiation, relative humidity and ice crystal content on use of simulated environments. The FAA is very interested in these topics in line with their program to eventually come up with a national inflight test facility. At the present time the configuration of the aircraft is such that before we can embark on a program, since we're

GENE BIROCCO

planning to use the aircraft for many more test seasons, a hardware update is really necessary. The system was originally designed to be flown for a year or two. It was put together as quickly as possible in order to get something flying in order to test the concept. The (circuit) cards on the controller electronic boxes are actually hot wired as opposed to a more production type of an installation. They've caused us difficulty, on and off, over the years. We've had problems with field fixes and solder points that have caused mysterious problems that have been hard to run down. The maintenance on the aircraft is very complex and time-consuming because of the nonproduction configuration. At the present time we are contracting annually with the Dynamic Controls Corporation which supplies control systems for the Black Hawk and AAH and who also designed the control system for the UH-1 for trouble shooting and repair capabilities on the aircraft. The AEFA folks are capable of handling the day to day routine maintenance on it. But when it gets down to a trouble shooting situation, we have to call Dynamic Controls. The preflight functional test is quite cumbersome and time consuming. It takes two pilots to conduct and is a rather time consuming process. One thing that would ideally be done to the hardware would be to automate this functional test procedure. We think that it could be actually brought down to a five to ten minute test. The heater blankets at the present time on the main rotor blades have some suspect voids in them that we have known about for two years and have been monitoring. These voids are not growing and don't appear to be causing any problems at this point, but they are something that could throw a kink into a test program. I'm not attempting to paint an overly bleak picture of the aircraft as a test bed, but the fact is, that if it continues to be used as a test bed aircraft, some major hardware update is necessary in order for it to be a practical tool. Can be have the next 35 mm slide.

This shot (Figure 19) you have seen already many times today, lets go on to the next one. That's our HISS aircraft. This is the test aircraft hovering in the Ottawa Spray cloud. (The next slide please, Figure 20).

These are some of the ice formations from the very early HISS cloud. You can see the heavy ice formation around the transparent areas that we got out of the old HISS cloud with the large droplet size. (Next slide, please, Figure 21).

This is the natural environment that shows the much more limited accumulations. (Next slide, please, Figure 22).

Personally, I didn't coordinate this presentation with the AEFA folks. I think you have seen quite a bit of this. This is natural icing on the horizontal stabilizer on the UH-1 and the next slide shows some of the old HISS cloud formations on the stabilizer. (Next slide, please, Figure 23).

This slide doesn't show very well, but this is a shot of the rotor blade after one of the freezing rain flights. You can see that there's really not a lot of ice formation on the blade. (Next slide, please, Figure 24).

GENE BIROCCO

This is another shot of the forward area of the aircraft after a freezing rain flight. You can see that what you're getting is a pebbly formation of ice, not unlike the old HISS cloud. (Next slide, please, Figure 25).

And this once again is after a freezing rain flight. (Next viewgraph, please, Figure 26).

I didn't run out of steam when I got to this point. The future is very cloudy. At the present time our funding has been zeroed out and we had hoped to use 318 (the test bed JUH-1H) this coming winter test season for some additional ice-phobic work, as I indicated earlier. The funding picture has been changing very frequently here over the last few months. At the present time, as I said, we are zeroed out. We're hoping that the funding picture will change and allow us to operate the aircraft again this coming test season. Beyond fiscal year 1981, the Applied Technology Lab does not have plans that call for the use of the JUH-1H aircraft in its icing programs. At that point our icing programs calls for us to move on to the development of new concepts, the most notable of which is the vibratory concept. The annual use of the aircraft because of the size of our annual budget, cannot continue and also allow us to get into the development of new concepts. We hope that during this meeting in the next day or so we'll have the opportunity to talk about the possibilities of joint programs between other DOD organizations and the Applied Technology Lab, but at this point we don't feel that the funding will allow us to continue to solely operate the aircraft on a yearly basis. (Next slide, please, Figure 27).

We do feel committed that there is a continuing need for an icing test bed aircraft. The possibilities for that aircraft, of course, will include the UH-60, the S-76, the Bell Model 412. There is a possibility, with a hardware update, of using the JUH-1. I guess our thinking at this point is that more of a production system aircraft will be more practical to attempt to use on a yearly basis because of the availability of spare parts. Sponsoring agency is another question that ought to be discussed. Agencies that we see that might be interested will include the Army, the Navy, the Air Force, FAA, NASA, and combinations of the above. The Army certainly has got the most interest in the area. I guess we would like to suggest the possibility perhaps of more joint participation in these programs in the future, as one way to allow to continue to operate a test bed aircraft. (And the final slide please, Figure 28).

These are some of the open R&D issues that we see that need to be addressed with the test bed aircraft. Refined design criteria with emphasis on low altitude is probably the biggest issue that remains open. As I mentioned earlier, from Lynn Hanks' presentation you've seen that the design criteria is actually very severe. I'm sure that you're all well aware of the extreme penalties that are associated with providing that protection and we'd like very much to take a look at refining that criteria into something more in line with what we're actually experiencing in flight or prove finally that the conditions

GENE BIROCCO

that we're including in our design criteria are valid design points. Partial ice protection systems is another area that we feel is (in need of) additional R&D work. Things like Kit A and ice phobics which really, as we see it, is Kit A with ice phobics, because we feel that even with ice phobics, the need exists for a cockpit display to allow the practical use of any partial envelope that you might demonstrate. Cockpit displays for aircraft with partial envelope capabilities is another area which requires some additional work. As I mentioned earlier one of the problems that we found with Kit A was that the use of liquid water content display alone was not a practical approach for allowing the pilot to use the partial capability. It's just too much of a job to attempt to monitor that device continuously. And by-the-way, regarding the ice phobic coating program from this past winter season, the AEFA organization has come up with a very similar conclusion once again. We see a need for additional work to enable us to correlate between simulated and natural environment. Along these lines the question of solar radiation and relative humidity and ice crystal content in natural and simulated clouds needs to be addressed. We feel that there's a need to continue to evaluate the effectiveness of ice phobic coatings on rotor blades. There's a fantastic payoff in this area if we can find a compound that can work. From the laboratory's standpoint we are trying to home in on one coating. We'll use the coating again this coming year that we used last year. The coatings used last year are actually second generation versions of coatings that we flew with three years ago. We feel from the standpoint of eventually improving the capability of ice phobics, we need to home in on one coating, however, the chemists that are involved with these coatings are daily coming up with different ways to compound these things that might get different results. So we feel that there's a need to continuously look at the ice phobics area.

I'll just quickly run through some of these. I see Dick standing over there. I feel his weight standing by, it must be running close to time.

There's a need to obtain better correlation between natural icing and formations produced under artificial icing conditions through improved photographic techniques. This gets back to some of the things that Lynn Hanks spoke to earlier. We see icing formations in artificial clouds and natural clouds, which we would think are very similar conditions, or on different days natural icing clouds that we think are very similar and yet that are very different icing formations. We don't understand all the mechanisms of those formations, yet. Demonstration of repeatability in test results is another problem area. We've had considerable difficulty over the years in getting repeatability of test results from one day to the next. Another area that is of interest especially on aircraft like the Black Hawk and AAH, is effects of blade heater zone failure on systems operations. I believe the Black Hawk system, Ken, you can correct me if I'm wrong, but I believe the Black Hawk system actually shuts itself down when it experiences one failure. The AAH, on the other hand, is going to allow the aircraft to continue to operate with one zone on opposing blades shut down.

GENE BIROCCO

The need exists to determine the effects of freezing rain and drizzle and snow and ice conditions on the helicopter and ice protection systems. This is an area in which not much work has been done up to this point because frankly we've been very concerned about the severity of conditions. I find that when I talk to some of the user types who operate frequently in Europe, these people frequently express concern, a desire for a capability to operate in freezing rain. They say it is a big problem for them in Europe. It's an area that some additional work needs to be done and we may have a capability that we don't even know we have. Maybe we have overestimated the severity of the condition. Quantification of overall effects of ice accumulation on helicopter performance, identification of separate contributions to performance degradation due to ice protection system operation on helicopter performance degradation. I think that some of the things that Lynn showed you on the Black Hawk were quite interesting and point out the need for some additional work of this type. And then quantification of the freezing rain, drizzle, snow and mixed test condition environments. I don't represent this to be a complete list. Its a list that could probably go on and on and on. That concludes my presentation. If there are any questions. (Someone else speaking - Richard I. Adams) I suggest that we should hold the questions for a later time at this session. I trust you took notes and will have questions. The reason is that we're running a little behind schedule. A very fine presentation Gene, appreciate it very much.

TEST BED UH-1H

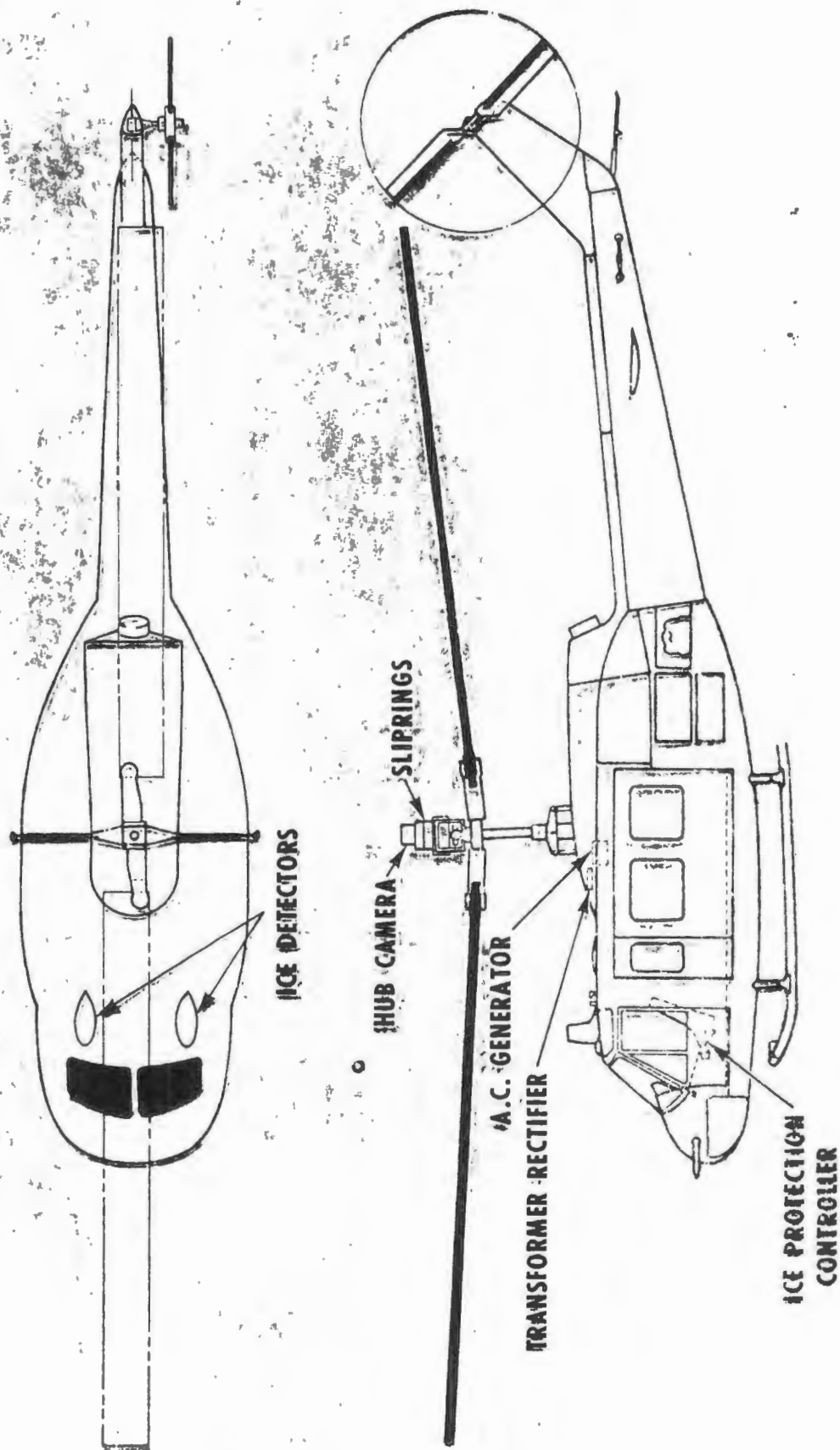


Figure 1

US ARMY APPLIED TECHNOLOGY LABORATORY ICING R&D TEST BED AIRCRAFT

JUH-1H S/N 70-16318

DESCRIPTION OF TEST AIRCRAFT

- CONFIGURATION CHANGES
- CAPABILITIES
- ACCOMPLISHMENTS
- PRESENT STATUS
- FUTURE PLANS

CONTINUING NEED FOR AN ICING TEST BED AIRCRAFT

OPEN R&D ISSUES

Figure 2

CLOUD PARAMETER INSTRUMENTATION PACKAGE

AXIAL SCATTERING SPECTROMETER PROBE (2-45 μ m)

CLOUD PARTICLE SPECTROMETER (35-300 μ m)

PRECIPITATION PARTICLE SPECTROMETER (140-2100 μ m)

PYROHELIOMETER (SOLAR RADIATION)

HYGROMETER (RELATIVE HUMIDITY)

TURNER-RADKE DEVICE (LASER TYPE DEVICE FOR ICE CRYSTAL CONTENT)

LEIGH MARK X ICE DETECTOR AND INTEGRATING RATE UNIT

LEIGH MARK XII ICE DETECTOR AND INTEGRATING RATE UNIT

ROSEMOUNT MODEL 871 ICE DETECTOR AND MODEL 512P RATE UNIT

Figure 3

Airspeed (ship's)
 Altitude (ship's)
 Fuel flow
 Fuel used
 Engine torque
 Engine inlet screen differential pressure
 Main rotor speed
 Rosemount OAT
 Lewis OAT (vertical tail fin)
 Rosemount LWC
 Leigh Mark 10 LWC
 Leigh Mark 12 LWC
 Leigh Mark 10 IRU
 Leigh Mark 12 IRU
 Leigh ice detector bleed air pressure
 Rosemount ice detector bleed air pressure

(2) Recorded on magnetic tape:

PCM Parameters

Control position:

Longitudinal
 Lateral
 Directional
 Collective
 Engine torque
 Fuel flow
 Fuel used
 Airspeed (ship's)
 Altitude (ship's)
 Main rotor speed
 Engine inlet screen differential pressure

Figure 4

Aircraft attitude:

Pitch

Roll

Yaw

Aircraft rates:

Pitch

Roll

Yaw

Outside air temperature

Rosemount LWC

Leigh Mark 10 LWC

Lewis OAT (vertical tail fin)

Cambridge dew point temperature

CG normal acceleration

Leigh Mark 10 IRU present sum

Leigh Mark 10 IRU last sum

FM Parameters

CG lateral acceleration

Pilot seat acceleration

Lateral

Vertical

Main rotor pitch link axial load

Tail rotor pitch link axial load

Figure 5

MAIN ROTOR BLADE HEATER

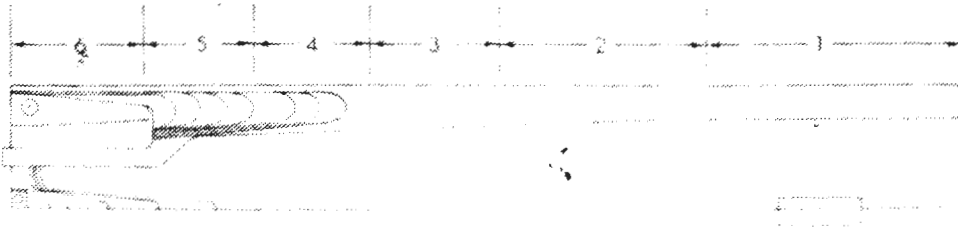


Figure 6

SPANWISE POWER DENSITY DISTRIBUTION

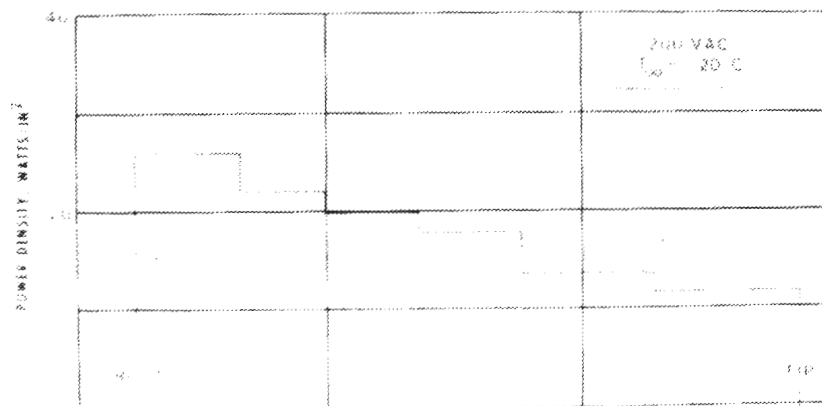


Figure 7

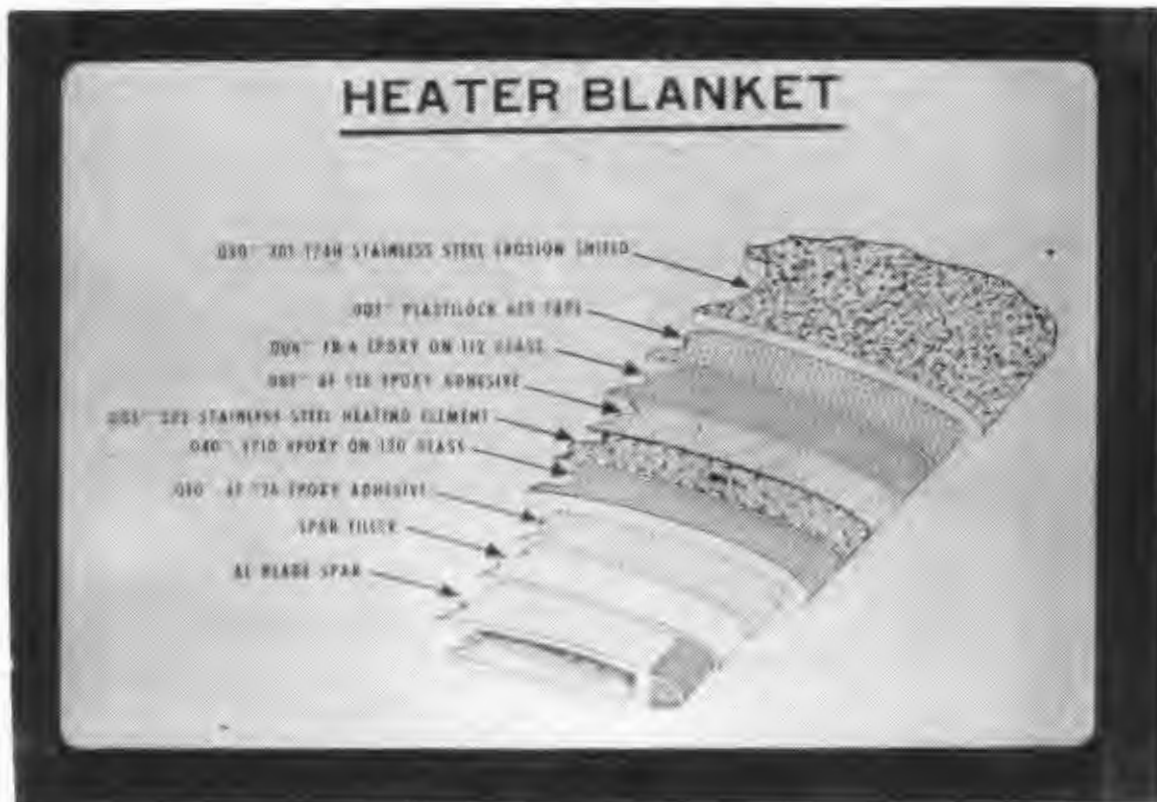


Figure 8

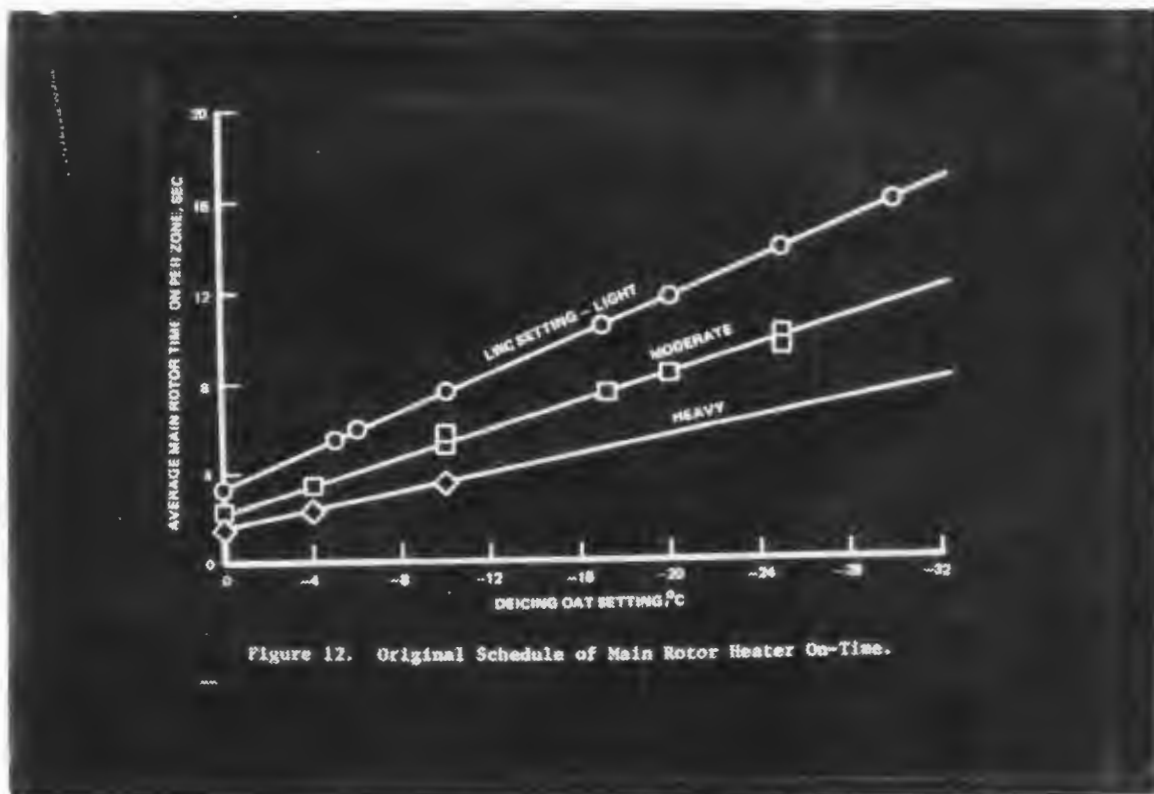


Figure 12. Original Schedule of Main Rotor Heater On-Time.

Figure 9

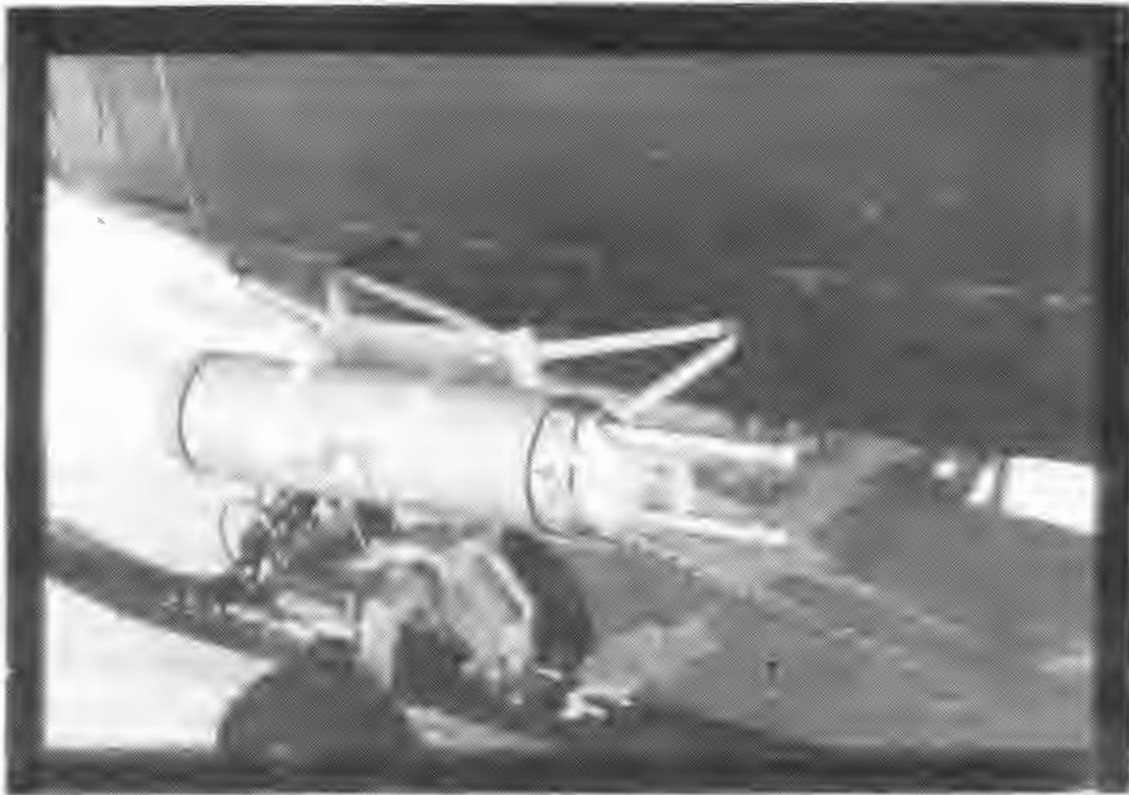


Figure 10

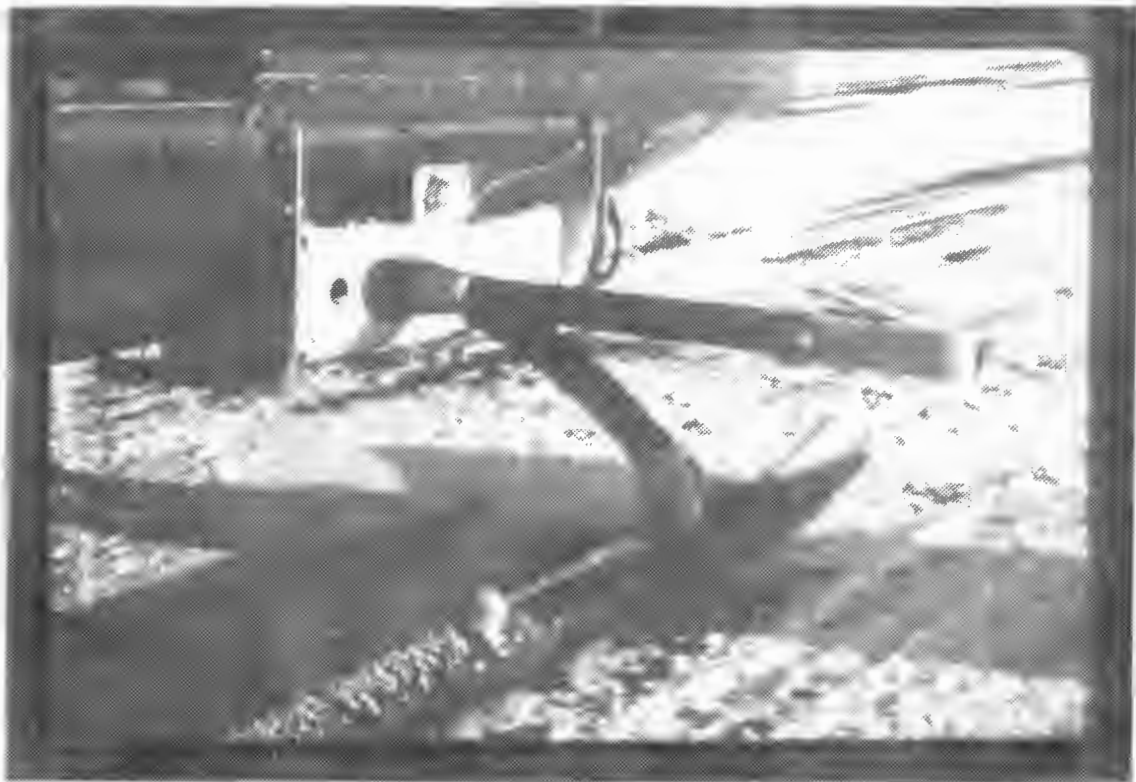


Figure 11



Figure 12



Figure 13



Figure 14



Figure 15

JUH-1H S/N 70-16318 CAPABILITIES

ROTOR DEICE SYSTEM DESIGNED FOR:

- LWC'S UP TO 3.0 GM/M^3
- OAT'S TO -20°C

CHORDWISE HEATING FOR SPANWISE SHEDDING

- IDEAL FOR BACK-UP SYSTEM
 - KIT "A"
 - ICE PHOBICS

SINGLE ENGINE

TEETERING ROTOR SYSTEM

ACCOMPLISHMENTS

- HISS TESTING
- OTTAWA SPRAY TESTING
- NATURAL ICING TESTING
- FREEZING RAIN & DRIZZLE
- KIT "A" QUALIFICATION TEST SUPPORT
- ICE PHOBIC COATING FLIGHT TEST SUPPORT
- HISS CALIBRATION AND CLOUD PARAMETER INVESTIGATIONS
- NATURAL ICING CLOUD CHARACTERIZATION

Figure 17

JUH-1H 70-16318 PRESENT STATUS

- SUPPORT OF ARMY/FAA 1980-81 FLIGHT TEST PROGRAM
 - ICE PHOBICS
 - HISS CALIBRATION
 - FAA R&D OBJECTIVES
 - SOLAR RADIATION
 - RELATIVE HUMIDITY
 - ICE CRYSTAL CONTENT
- HARDWARE UPDATE NECESSARY
 - CONTROL SYSTEM CURRENTLY HARDWIRED
 - MAINTENANCE COMPLEX & TIME CONSUMING
 - PRE-FLIGHT FUNCTIONAL TEST IS CUMBERSOME
 - HEATER BLANKETS HAVE SUSPECT VOIDS

Figure 18



Figure 19



Figure 20

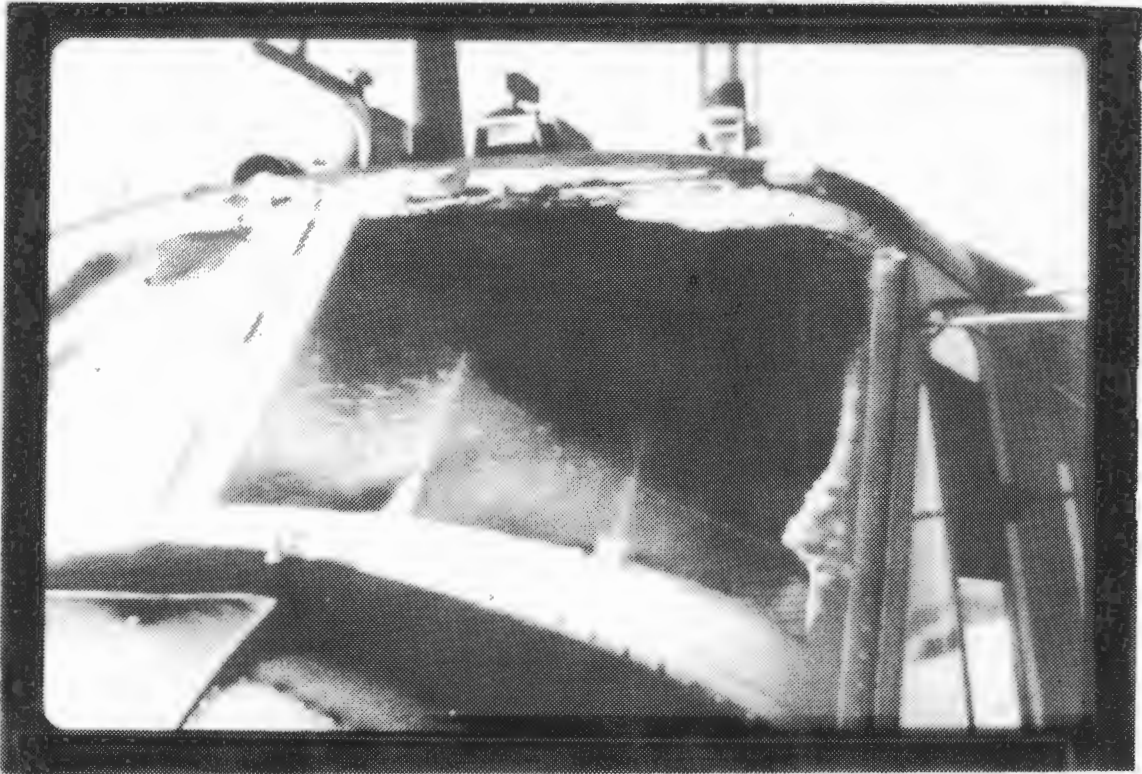


Figure 21

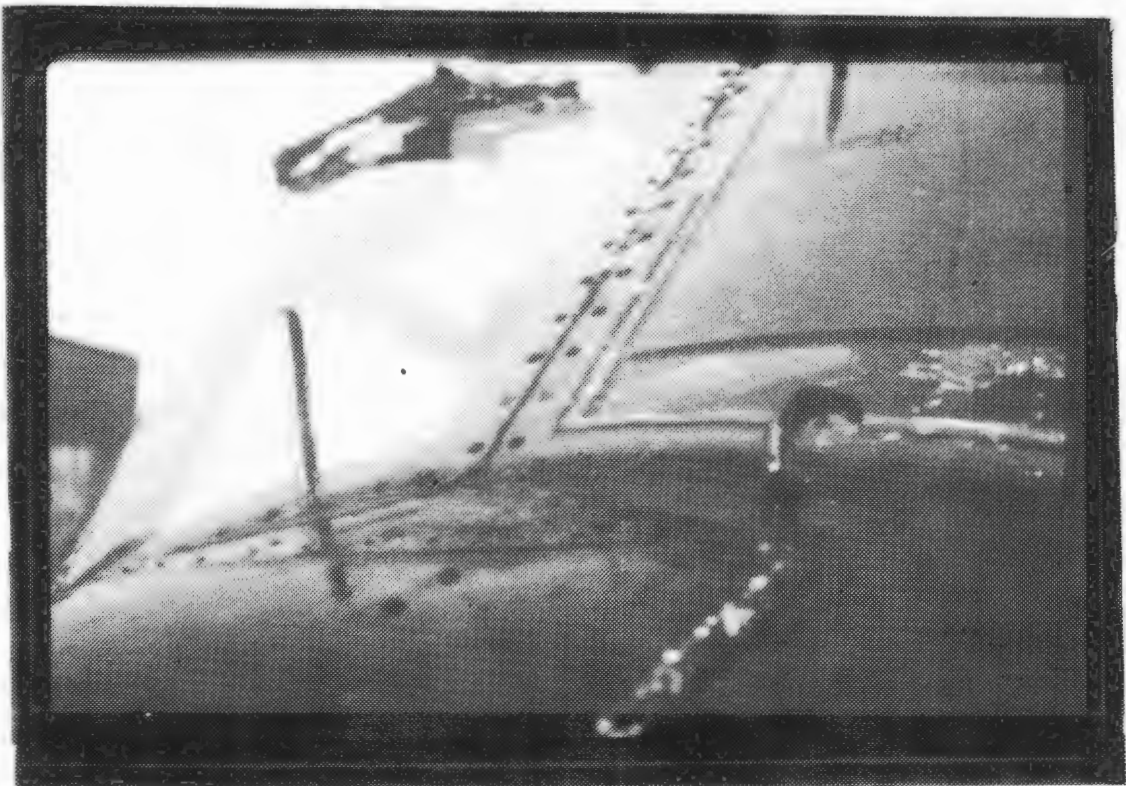


Figure 22

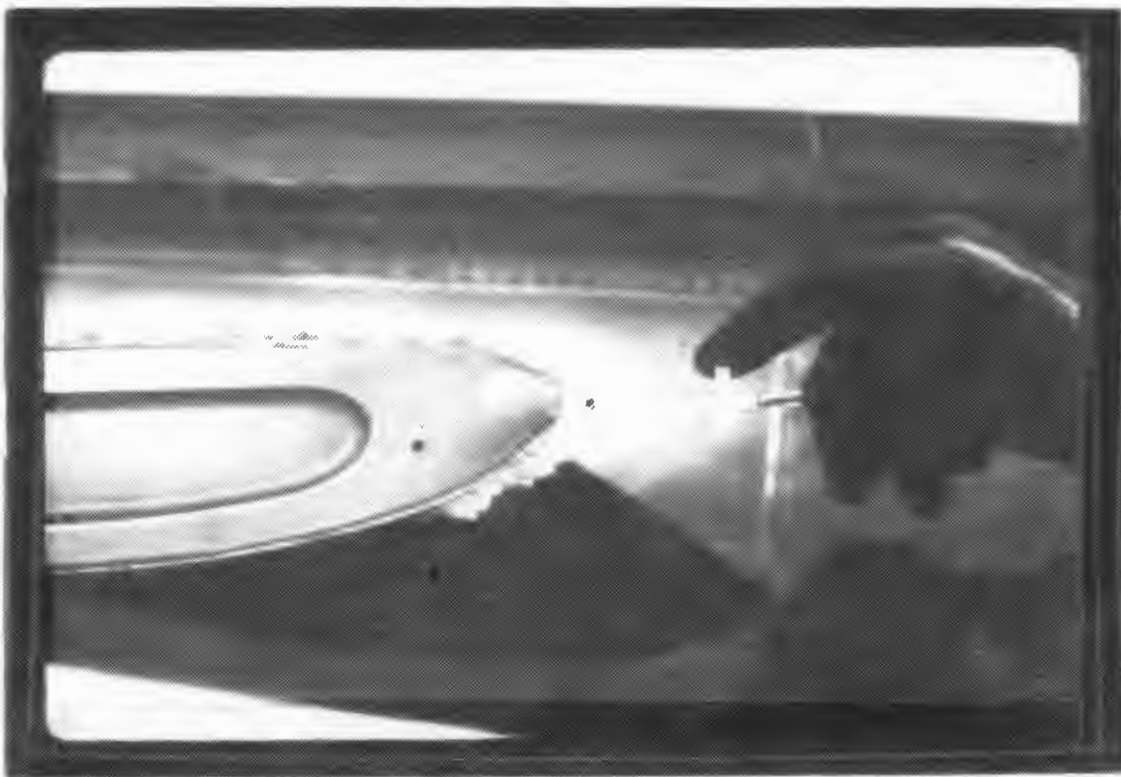


Figure 23

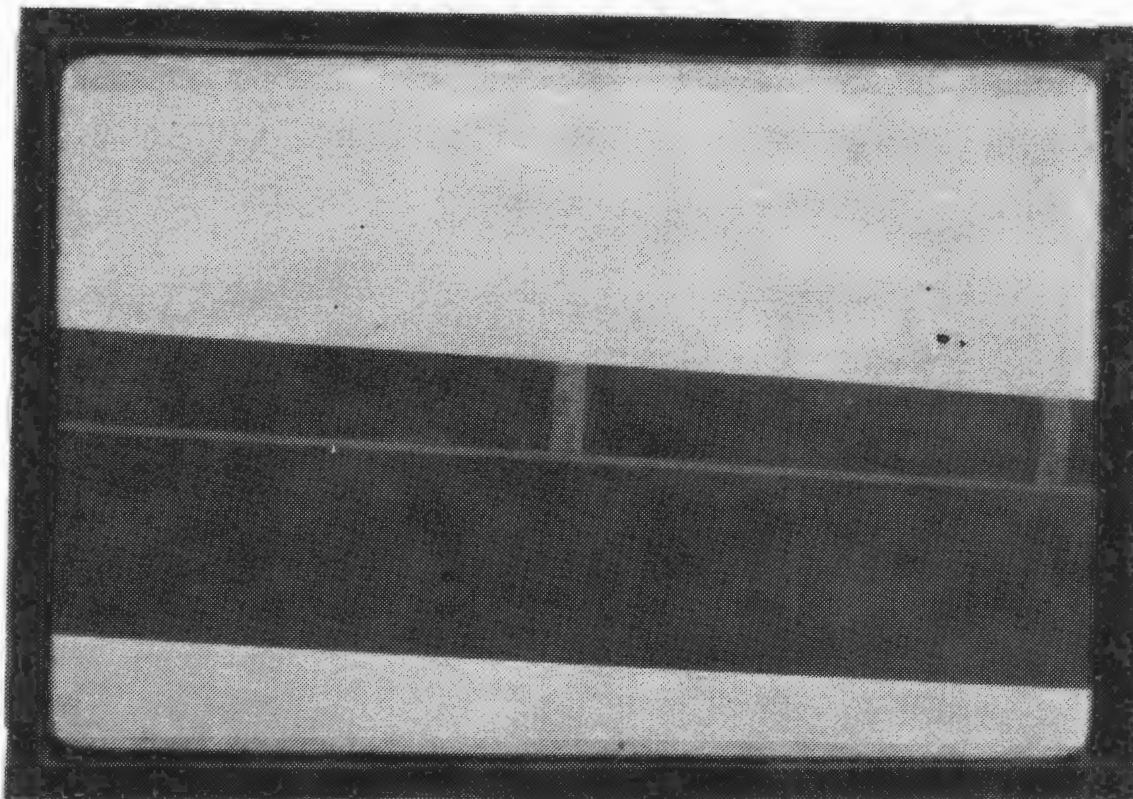


Figure 24

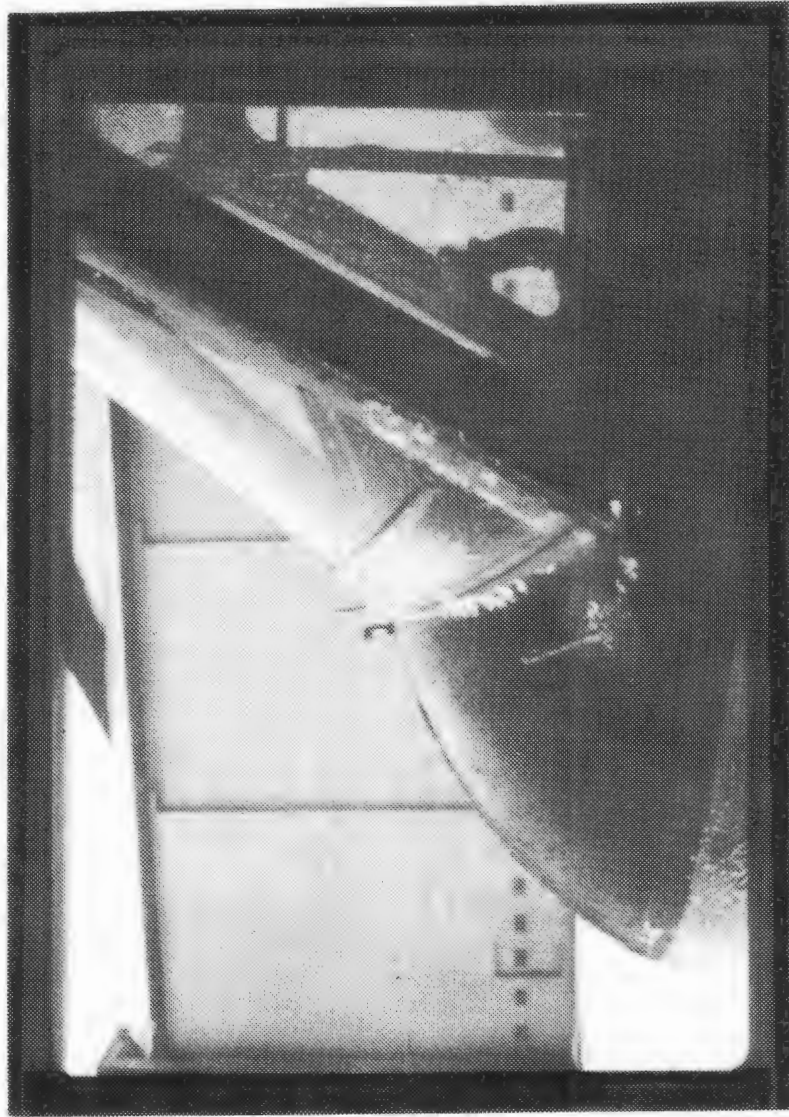


Figure 25

FUTURE PLAIS



Figure 26

CONTINUING NEED FOR AN ICING TEST BED AIRCRAFT

UH-60A

S-76

BELL MODEL 412

JUH-1H

SPONSORING AGENCY

} ?

• ARMY

• NAVY

• AIR FORCE

• FAA

• NASA

• COMBINATIONS OF THE ABOVE

} ?

Figure 27

OPEN R&D ISSUES

- REFINE DESIGN CRITERIA WITH EMPHASIS ON LOW ALTITUDE
- PARTIAL ICE PROTECTION SYSTEMS
- COCKPIT DISPLAYS FOR AIRCRAFT WITH PARTIAL ENVELOPE CAPABILITY
- CORRELATION BETWEEN SIMULATED AND NATURAL ENVIRONMENTS
- EVALUATE THE EFFECTIVENESS OF ICE PHOBIC COATINGS ON ROTOR BLADES
- OBTAIN BETTER CORRELATION OF NATURAL ICING FORMATIONS TO FORMATIONS PRODUCED UNDER ARTIFICIAL ICING CONDITIONS THROUGH IMPROVED PHOTOGRAPHIC TECHNIQUES
- DEMONSTRATE REPEATABILITY OF TEST RESULTS
- EVALUATE THE EFFECTS OF BLADE HEATER ZONE FAILURE ON SYSTEM OPERATION
- DETERMINATION OF THE EFFECTS OF FREEZING RAIN AND DRIZZLE, SNOW AND MIXED CONDITIONS ON THE HELICOPTER AND ICE PROTECTION SYSTEMS
- QUANTIFICATION OF THE OVERALL EFFECTS OF ICE ACCUMULATION ON HELICOPTER PERFORMANCE
- IDENTIFICATION OF THE SEPARATE CONTRIBUTION TO PERFORMANCE DEGRADATION DUE TO ICE ACCUMULATION ON THE ROTOR SYSTEM AND AIRFRAME, AND THE EFFECT OF ICE PROTECTION SYSTEM OPERATION ON HELICOPTER PERFORMANCE DEGRADATION
- QUANTIFICATION OF THE FREEZING RAIN AND DRIZZLE, SNOW AND MIXED CONDITION TEST ENVIRONMENTS

Figure 28

U.S. ARMY COLD REGIONS RESEARCH AND ENGINEERING LABORATORY FACILITIES

INTRODUCTION: RICHARD I ADAMS

Dave Minsk, you can start on up this way if you'd like while I talk about you. Dave is with the U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire. I've know Dave for a number of years. Dave's the kind of guy who puts on his mukluks and goes out to the North Pole and the South Pole and places like that where its really cold. They have a lot of interesting facilities up there and that's what Dave is going to tell us about.

DAVE MINSK

Thanks, Dick. Gentlemen. I think that this is a little bit too far south for us to really be discussing icing, so I'll try to give you the proper environment by showing you some of the slides coming up.

The first slide (Figure 1) indicates the presence of the big red castle where the U.S. Cold Regions Research and Engineering Laboratory or CRREL, as we affectionately call it. CRREL is a Corps of Engineers Laboratory, one of the four major Corps Laboratories in the country. It's concerned with providing the Corps, and DOD in general, for that matter, with the means for constructing and operating in cold regions. The facilities, which are located in Hanover, New Hampshire, close by Dartmouth College, with whom we work very closely on many projects, is a unique facility, twenty-four cold rooms in the main building and some other new facilities I'll be describing shortly. These facilities are rather unique and as a result have been made available to industry where similar facilities are not available to the private sector. We have, for instance, supported with not only laboratory studies, but field studies, the voyage of the Manhattan in 1970 through the Northwest passage, studying the ice conditions for a proposed tanker route to the North coast of Alaska near the Canadian Archipelago. We have supported the construction of the Trans-Alaska pipeline and foundation studies, construction techniques, and recently we have started to advise on construction of the gas pipeline, which will go through part of Alaska and then Canada. The Corps is unique within DOD in that it has both civil and military responsibilities. The next slide (Figure 2) will show our main facility. This could have almost have been taken last January or February when we had our drought, no measurable snow fall until about February. We have new facilities which are used primarily for civil works investigation on the long range navigation extension for the Great Lakes and also furtherence of the Corps responsibility and navigation on rivers and harbors, navigation during the winter when ice does impact operation seriously. This facility has a large 80 X 160 clear span cold room which is used for hydraulic studies and can, perhaps, be used for some other studies. Included in this facility is a tilting flume, a refrigerated tilting flume for hydraulic studies and a refrigerated towing basin. The only one of its kind in the country.

I'm going to describe some of the other activities that influence or have some bearing, at least on helicopter or aircraft icing. We are entering the second winter of a major program on the battlefield of obscuration. This is boundary layer meteorology, but it does, because of its nature, have many factors in common with upper altitudes or at least a nap of the earth, and perhaps higher, problems in the upper environment. We were just gearing up for that last winter, but this winter there will be some extensive studies made in the field in Vermont during, and we hope that it will be a heavy snow year, not just for the skiers, but for our studies using such things as holographic

DAVE MINSK

imagery and particle measuring device that we have standardized now, or selected the Nolenberg. Those of you who might be partial, and I think there are two people here at least who are perhaps partial, to the spectron, we went to the Nolenberg because of the large amount of data that is available from 16 Nolenberg devices in the field and particle measurement is still something of an art, rather than a science and therefore it has to build on a lot of the background already in hand. This will be quite a major program and although some details remain to be worked out, I think that if you are interested we can provide you with some additional information. The basic physics of ice, ice formation, the ice substrate interfacial physics has been an ongoing program for a number of years. Every year, all the time, we are discovering something new about that ubiquitous material, water, and its various forms. Ice is a fascinating material that ranges in properties over a tremendous range. Snow, for instance, can range from feathers to almost liquid, ice has almost an equally wide range and the method or details of the factors of formation are so subtle, so imperfectly known that it's often times very, very difficult to obtain a repeatable condition. The slides that I am going to show you, coming up, are of some laboratory tests made under closely controlled conditions, but even there we have a tremendous scattering of results. Don't be surprised therefore, that the field tests, atmospheric icing tests, do show such a wide range under direct controlled conditions. We can corroborate, or back that up very strongly by our wide range of results in the laboratory tests and we have to replicate experiments in order to get some statistical justification or strengthening of our case.

Next slide (Figure 3) does show the test that we have devised for the investigation of ice phobic materials. We have had a program for a few years now testing commercial materials that were provided to us by manufacturers. Some one hundred manufacturers were contacted and provided materials that had already been developed sometimes for other purposes, sometimes specifically for the prevention of ice adhesion. Some 60 of those have under-gone further tests in this apparatus and the rain erosion simulator at the Wright Aeronautical Center. Flight Dynamics Laboratory supported this work for the cruise missile study as well as the Applied Technology Laboratory at Fort Eustis. The preliminary results have been published in a report, detailing ice adhesion tests on coatings subjected to rain erosion. I have a few copies of that report here which I will be happy to give to anyone who is interested and if I run out you can give me your card or address and I'll see that you get a copy.

We have laboratorially established 15 psi as a shear stress for further testing of a candidate material. That is based on the termination of the aerodynamic and the centrifugal forces acting on the blade. Only a very few of the candidate materials have been undergoing further tests in this apparatus, and in the next slide (Figure 4) there is a little more detail shown of this unique device, which has reduced a lot of the

DAVE MINSK

scatter in our test data for gradually eliminating many of the variables in ice testing. This device, which insures pure shear stress application from the interface, has narrowed some of that variability. We recently, about two weeks ago, received some twenty additional materials, silicon based materials, from industry which we are now testing in the laboratory. These will be baseline studies to determine which one of those are potential candidates that should be subjected to rain erosion and further testing in the shear stress apparatus. The tests will continue as long as our money holds out. We do have a basic program that is funded by DARCOM (Department of the Army Readiness Command) that will go into next year. Some of the results of that have been the results of the basic physics of ice formation and also a study on the numerical simulation of ice accretion. The report on that has been issued. We are no longer doing any work on that although we have been working in cooperation or in conjunction with Dr. Losowski in Canada who has been funded by NASA Lewis for additional numerical simulation studies.

I better close now so that we can get back on schedule. If there are any additional details I can provide you about the study that is going on at CRREL and about the facilities that we have, our unique 24 room, cold room complex, and the ice engineering facility, I will be glad to talk that over with anyone.

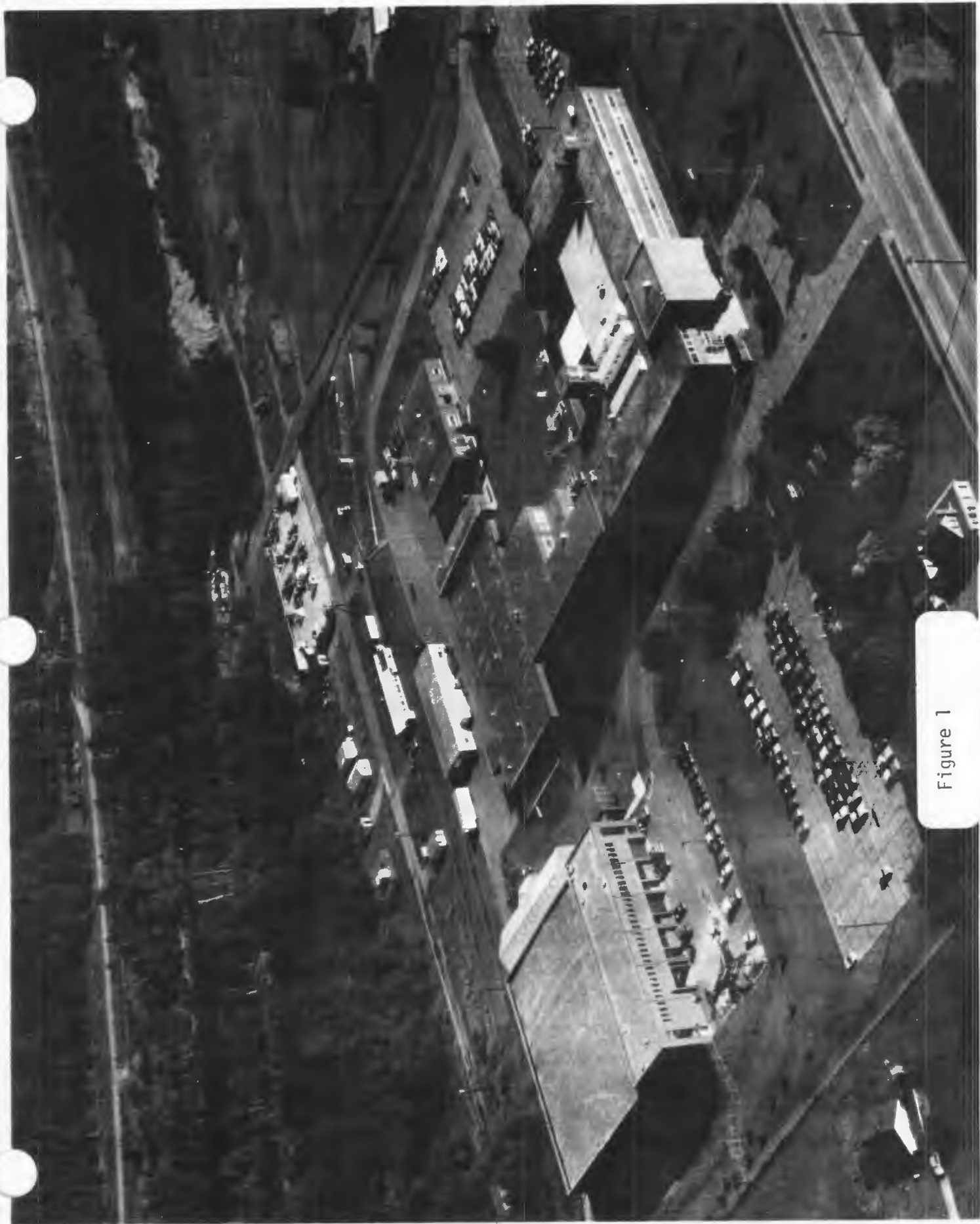


Figure 1

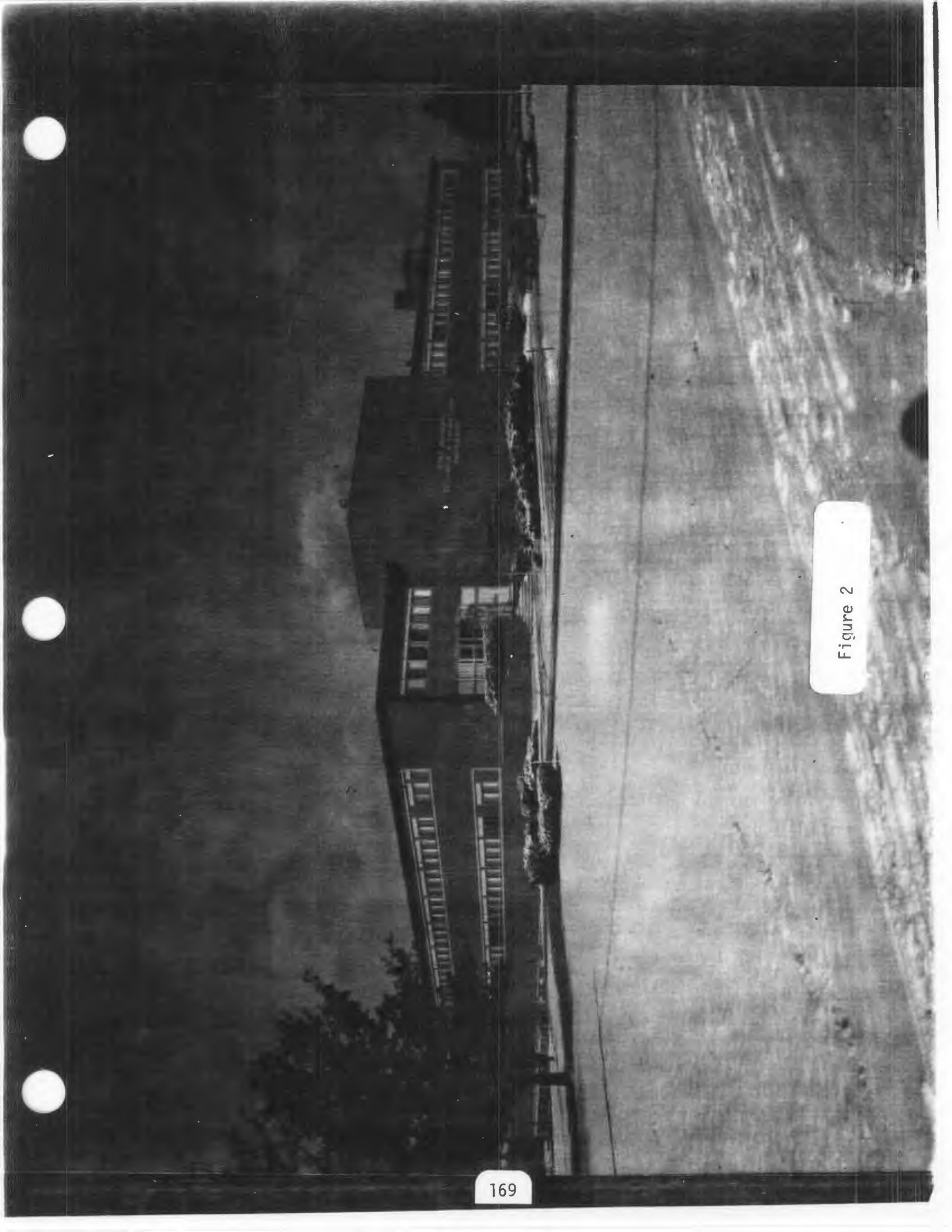


Figure 2

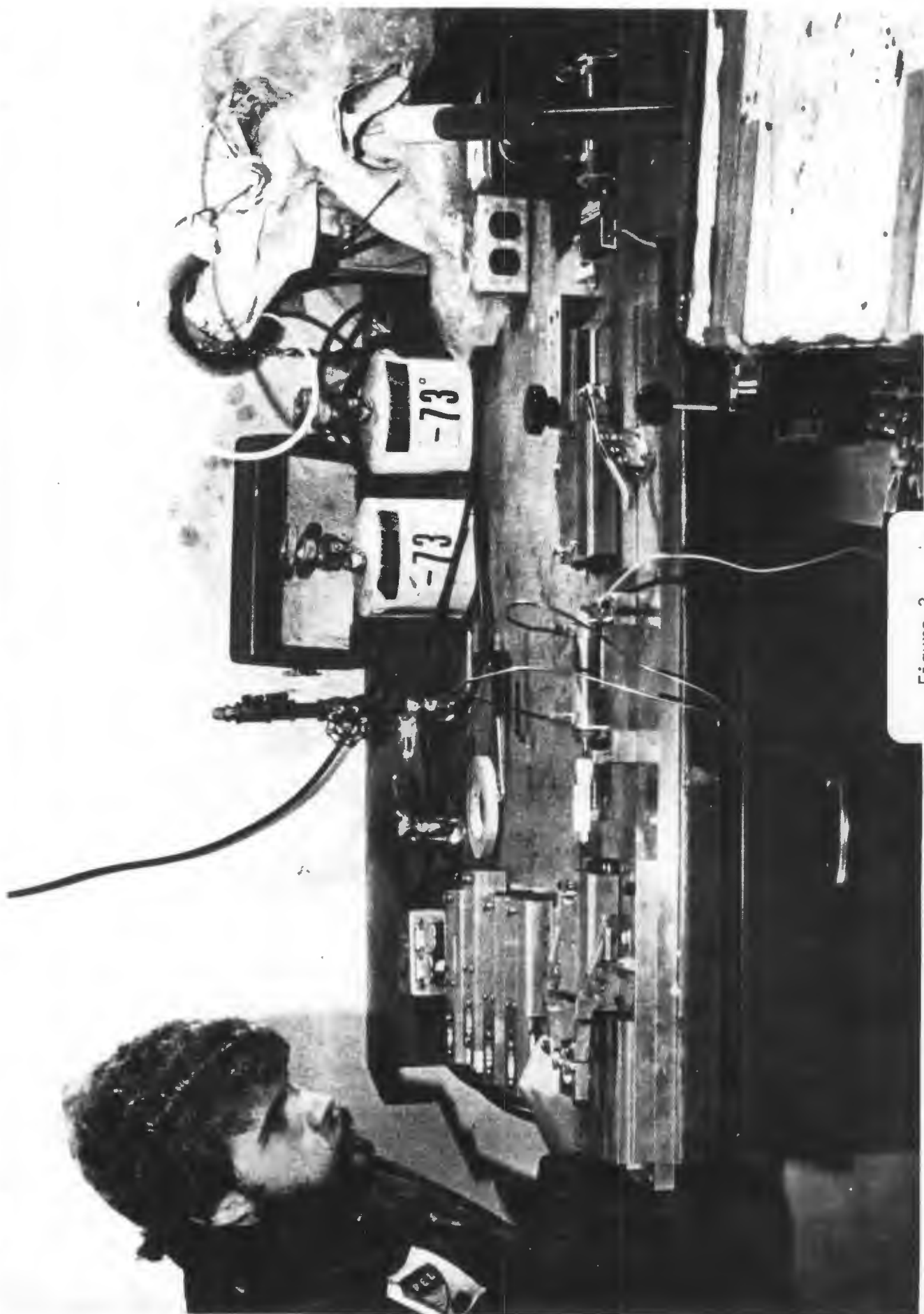


Figure 3



Figure 4

NAVAL AIR PROPULSION CENTER

INTRODUCTION: RICHARD I. ADAMS

The next speaker is Vito Truglio from the U.S. Naval Air Propulsion Center, Trenton, New Jersey. I'm sure most of you are familiar with those facilities. Vito.

VITO TRUGLIO

U.S. NAVAL AIR PROPULSION CENTER, ENGINE ICING TEST FACILITIES

Thank you, Dick. As Mr. Birocco said I think that I am going to have a harder time to follow those previous acts, they were really excellent and it's not easy. I'd like to keep it brief so that we can get out on time. First I'll give a little description or an outline of what I'm going to talk about today. I'll be giving you a description of our facilities and its function and a little bit of description of our cells and our icing installations that we have available. Then I'll talk about our icing envelopes that we have developed and the simulation verification methods that we use. After that I'll show a brief film of a recent ice ingestion and icing test that we have conducted at the center. The Naval Air Propulsion Center is a field activity of the Naval Air Systems Command which is part of the Department of Defense (Figure 1). Our mission is to provide complete tests and engineering support for the Air breathing propulsion systems which include accessories, fuel and lubricants. This support includes research and development, testing and evaluation and assisting in resolving service problems. The funding for our facility is primarily provided by NAVAIR, but a good part is also funded through other government facilities and industrial support. I might add that some industry programs have been conducted at the Center through government funding, which has been a way for us to conduct tests for the industry. Our test cells are primarily made up of a large engine test section and a small engine test section which you can see outlined in this next slide (Figure 2). The large engine test area is made up of three altitude test cells and two sea level test cells. The size of the engines that we have tested in this area are listed to the right. They include the F404, the F401, F402 and the TF30, TF34, J79 and the J52. The capacity is pretty much in the area of 350 pounds per second of air flow and less. Our small engine area is made up of four altitude cells where we have a capacity of approximately 50 pounds, I think that the engines that are being tested in that area are the F107, helicopter engines, such as the T700, T400, T58, T55 and T64. We have a couple of sea level speciality cells where we do considerably smaller special tasks, that include pulse jets, ram air turbines and transmissions. Our icing capabilities are just a part of the number of tests and the kinds of tests that we run at this center. Some of the testing in the icing area that we do are icing environment, simulation, ice ingestion and water ingestion and freezing rain. These programs, I might add, average about one a year at the center. This next viewgraph, Figure 3) gives you some idea of our icing installations as they have most recently been developed. Over the years we have made several improvements in order to perform the most efficient tests that we can. The top area shows our small engine test facilities, and that is made up of a five foot duct where our spray bar assembly is located and our test article is within a three foot distance of the exit plane. I'm sorry, I said five foot duct, that is a four foot duct in our small engine. The engines that we test in this installation are engines that have an air flow of 40 pounds per second or less. The large engine test icing test installation is a direct connect type of installation where we test our large engines up to 350 pounds per second. The setup is

VITO TRUGLIO

similar in that our spray nozzles, atomizing spray nozzles, are located in a five foot section of cloud chamber effect and the individual engine inlet duct is connected to that chamber. This is the primary source of tests that we have conducted, but we do have the possibility of running other kinds of icing tests which we can see by the next viewgraph (Figure 4). Other possibilities includes a wind tunnel type of installation shown at the top which would be converted from our large engine installation where we would have our spray bar set up in a five foot duct to reduce down to an adequately sized diameter duct for either a scaled down version of a test article or a full scale, depending on the particular article. Below, we have another option which doesn't seem to be too much of an interest and that is the altitude means of icing. We have our altitude cells with a spray bar assembly located in a large plenum and our engine is directly connected to a bulkhead and bellmouth. Our capacity at the Center in performing icing tests and in simulating icing environment is largely dependent on our refrigeration capacity, which you can see by our next viewgraph (Figure 5). The airflow at below freezing temperatures is limited to upwards of 300 pounds per second. The individual temperatures that are broken out there are the typical military type temperatures that we duplicate in our tests. The plus 23° condition and the minus 4° condition and the airflow capacities are shown there. Other restrictions or limitations are the individual flow nozzles that we have. The atomizing nozzle that we put in our assembly is limited to the space that we have in our inlet duct and the physical amount of flow per nozzle is limited so that we can control the liquid water content and drop size to a reasonable degree. In addition our distribution, at the low end for reducing the minimum liquid water content, is critical. We can only go down so far in our nozzle in order to get a good distribution in our large ducts.

The next slide (Figure 6) is an effort to show the overall envelope that we have at the Center as far as icing conditions are concerned. This first slide with the capacities is related to our small engine installation. The liquid water content range is roughly someplace less than a half up to about two and a half grams per cubic meter. The droplet size is varying, as you can see, with the liquid water content because of the limitations that I previously mentioned within our nozzle. These again are for our small engine installations which are for air flows of 40 pounds per second or less. Our large engine facility, which is in the next viewgraph (Figure 7), gives us a little bit larger envelope. You can see the guideline shows how that envelope compares to our small engine setup. We have a greater range of liquid water content capabilities and droplet size capabilities and of course, air flow. The air flow, as I mentioned before, has a capacity of up to 350 pounds per second. The means that we have used over the years (there have been many methods that have been tested), to try to verify an icing condition, and we have very closely monitored this with methods that have failed us and we've had a learning process to go through, but we always attempt to calibrate before running any tests to do our best to be able to perform our most efficient tests. The latest methods that we have used to verify icing conditions have been

VITO TRUGLIO

the laser probe, which has been discussed at length in previous presentations, the scatter system spectrometer for small droplets, smaller droplets and the optical arrays probe for large droplets. This has mainly been our main method of counting droplet size, counting droplets and determining droplet size for a particular installation. It also gives us a handle on water distribution or icing distribution across our inlet. We haven't really had the confidence in this probe to depend on it for liquid water content, so our latest method for verifying liquid water content has been to inject a single rotating cyclinder at a known velocity and at the droplet size to be measured from our laser probe to verify liquid water content. Another parameter which we feel has been very important in establishing a good icing environment has been the control of humidity. We use a five mirror type of dewpoint sensor to measure humidity. We have gone through many instruments to accurately measure humidity in a moving airstream but this instrument that we presently use has been found to be the best. We found that humidity does effect the amount of (and) the kinds of icing that we could have. The liquid water content is affected and the droplet size is affected by the dry humidity or wet humidity. These methods have, as I said, been a growing process. We have come a long way, but we feel that they are the best means to verify an icing environment. The icing environment that I have been basically talking about has been really military specs on turbojet and turboshaft and turboprop engines that we have run for the FAR 25 spec, but that is when we do testing with an engine and some part of an inlet connected to it. That pretty much sums up my presentation. This film that I have is for a particular icing test that we ran recently on a cruise missile engine, the F107. This particular test was conducted a couple of years ago and it entailed ice ingestion and icing and the icing was a combination of the specs, the standards set by the FAR 25 standards. We have a partial, to just briefly describe a little bit more before we get into it, the first part of it, because it goes pretty fast, is the ice ingestion of a sheet of ice and that was done with a high speed camera. Second portion, that was a bellmouth installation. The second part of the film is an icing environment test which was done on a gradual basis. The first part was a half a gram condition for one minute and a one gram condition for five minutes. The last section shows a significant amount of ice build up on the inlet to the missile and breakup over that five minute period. The condition was a Mach .65 velocity condition which is typical of a cruising velocity. The temperature was a plus 23° Farenheit for all of the tests. This test was a demonstration and it was done to determine whether there was any need for improvement on the inlet to the missile. The first one is the ice ingestion at 23° Farenheit. There's the size of the slab which we ingested. That size would be determined, based on a military spec, in proportion to the inlet size of the engine. You have to be very quick to watch the ingestion of this sheet, because it happens very quick. Even though this is high speed photography, it happens pretty quick. But its a pretty good shot of that sheet going in. You can see it spread around the outer tips of the wings. There it goes. The results of that particular test was that a stall occurred but recovery was made with out losing the engine power completely. There was also,

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it's not on this film, but we did do a ball ingestion, a one inch diameter ball of ice was ingested and little damage was done. Only the stall occurred similarly, but no other damage, no other significant damage. The next part of the film will be the actual icing environment tests in which 10 microns was the drop size for this particular water content at the 23° Farenheit and .65 Mach number condition. There was really very little buildup on this particular phase of the test in a one minute run. There's the inlet. The small protrusion down into the inlet is a total pressure probe which in this test was not deiced, but which will eventually have a deicing mechanism built into it. The inlet shroud is not deiced and is not at this time. At this point there has not been any attempt to deice it. You can see a slight build up around the upper edge, but not any thing significant. There was a break off. Now, this is a one minute run and then a five minute run at one gram and 20 microns. Again at the same 23° Fareheit condition and Mach .65. Now we have a more significant buildup and we can see the typical type of ice at this droplet size. It's gradual. You can see the red is becoming white at the leading edge. There is going to be a more significant build up of ice on the total pressure probe too. Typical type of ice is a glazed type and a mushroom type of ice spreading. You can see it developing now. And it broke off. That was not any engine problem, that was just a movement in the camera, it got jostled. This is the final segment, a five minute run at the same conditions that you just saw. You'll be able to see a cycle of buildup and breakoff here. The mushrooming effect is more evident in this segment. You can see the "Y", it's forming off the leading edge. There was significant buildup further down in the inlet, which caused the engine to lose a significant amount of thrust. The inlet makes a bend further down stream in the inlet duct before it goes into the engine. You can see that total pressure probe hung in there for quite a bit. I think since you see the cycle a number of times, that should suffice. To conclude I would just like to say that I do have a brief outline of the slides that were shown that I could leave out on the desk, but the attempt here today was to give you an idea of what we do at the Center and to promote questions as to possibilities of kinds of tests that you might want to conduct at the Center. I would be glad to entertain any questions you might have. Thank you!

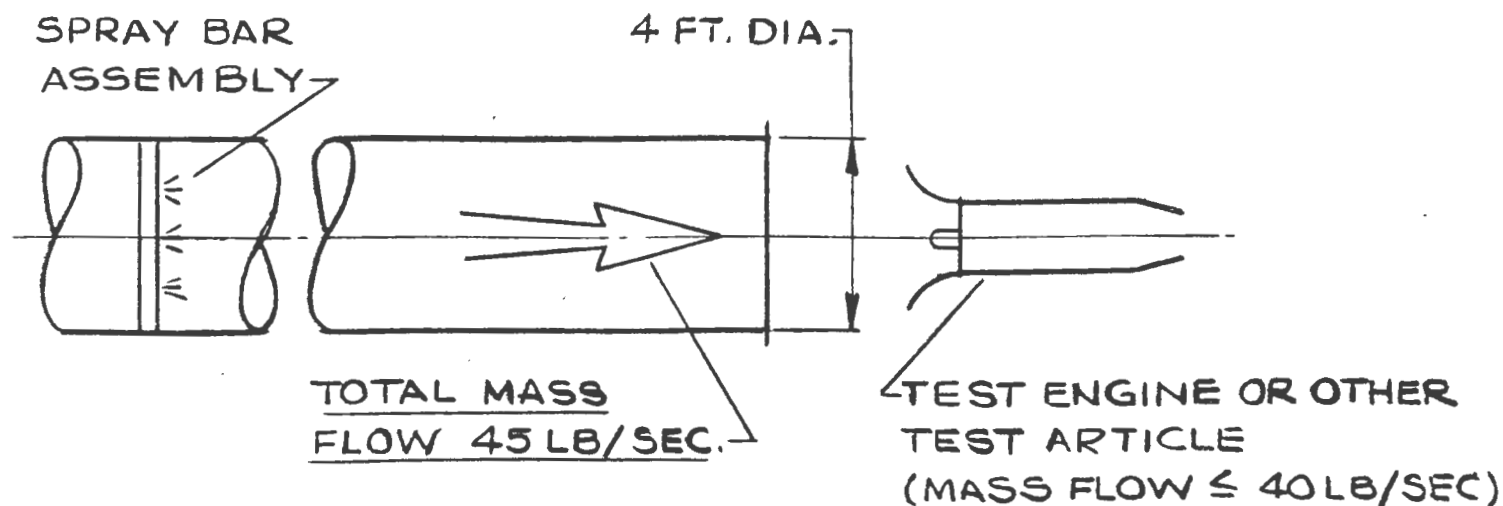
ICING CAPABILITIES
AT THE
NAVAL AIR PROPULSION CENTER
TRENTON, NJ

PRESENTED BY:
VITO J. TRUGLIO
23 SEPTEMBER 1980

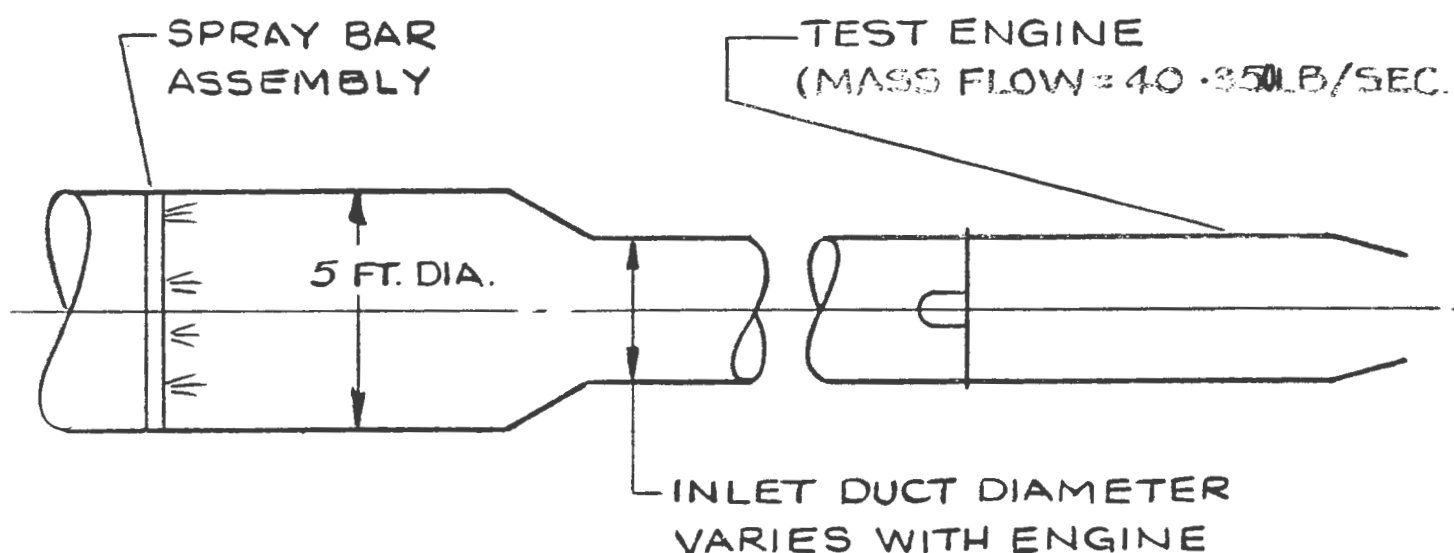
NAPC TEST CELLS

SIZE	TYPE	APPLICATION
LARGE ENGINE	3 ALTITUDE	F404 , F401 , F402 TF30 , TF34 J79 , J52
	2 SEA LEVEL	
SMALL ENGINE	4 ALTITUDE	F107 , T700 , T400 T58 , T55 , T64
	1 SEA LEVEL	PULSE JETS RAM AIR TURBINES DEMISTERS
	1 SEA LEVEL	TRANSMISSIONS

Figure 2

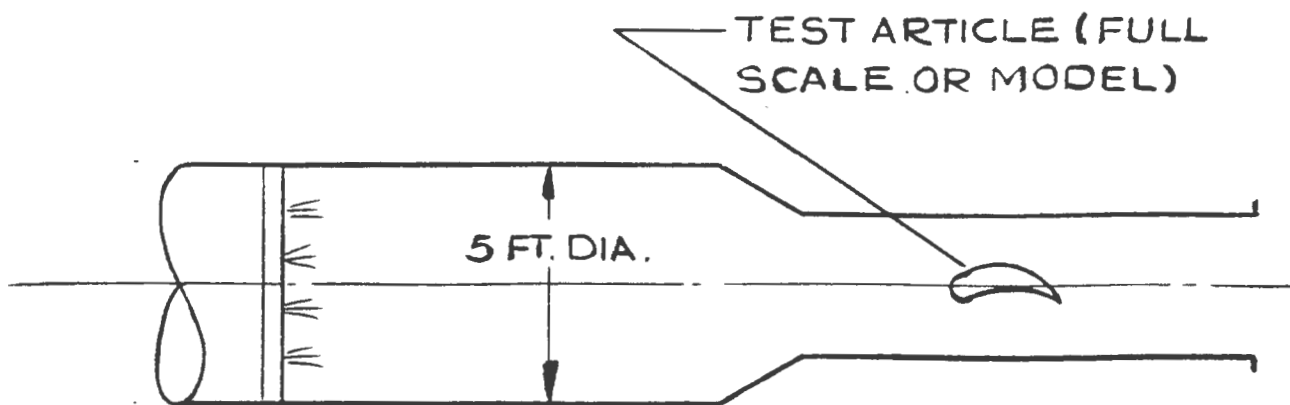


SMALL ENGINE ICING TUNNEL (FREE JET)

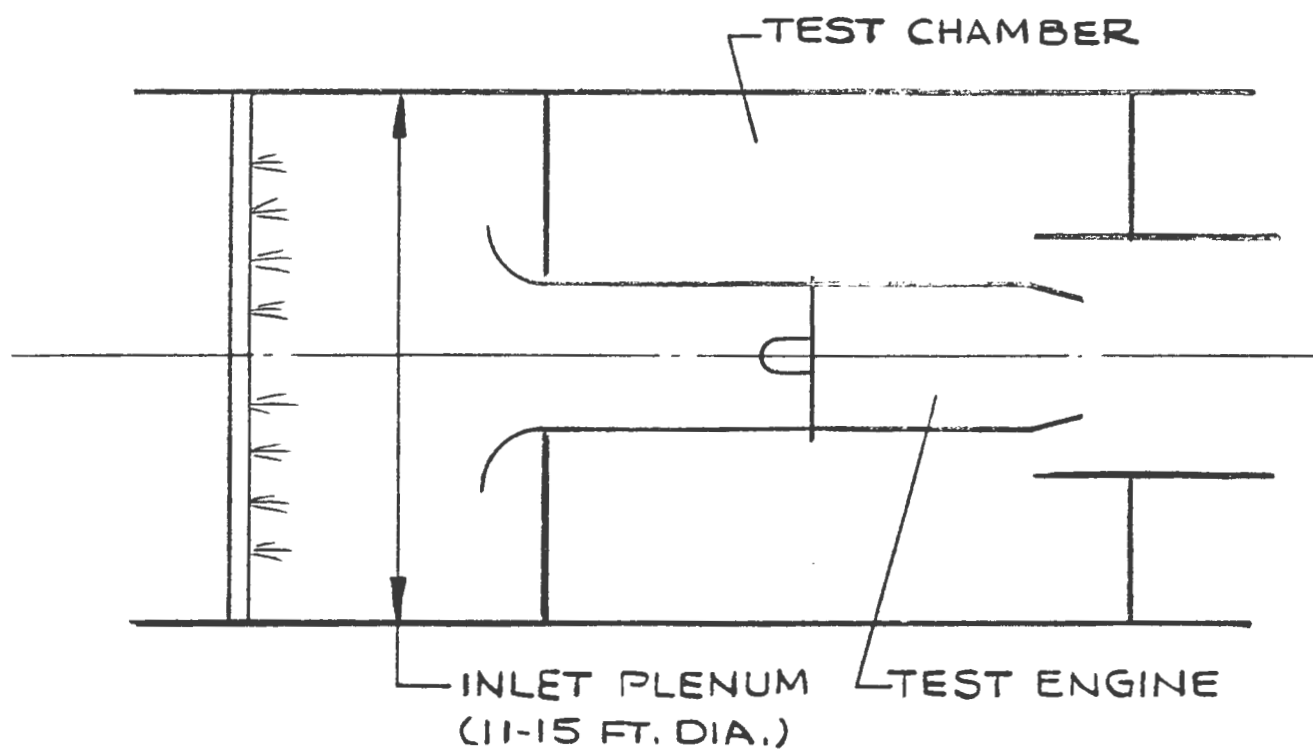


LARGE ENGINE ICING (DIRECT CONNECT)

PRIMARY TYPES OF ICING TESTS AT NAPC



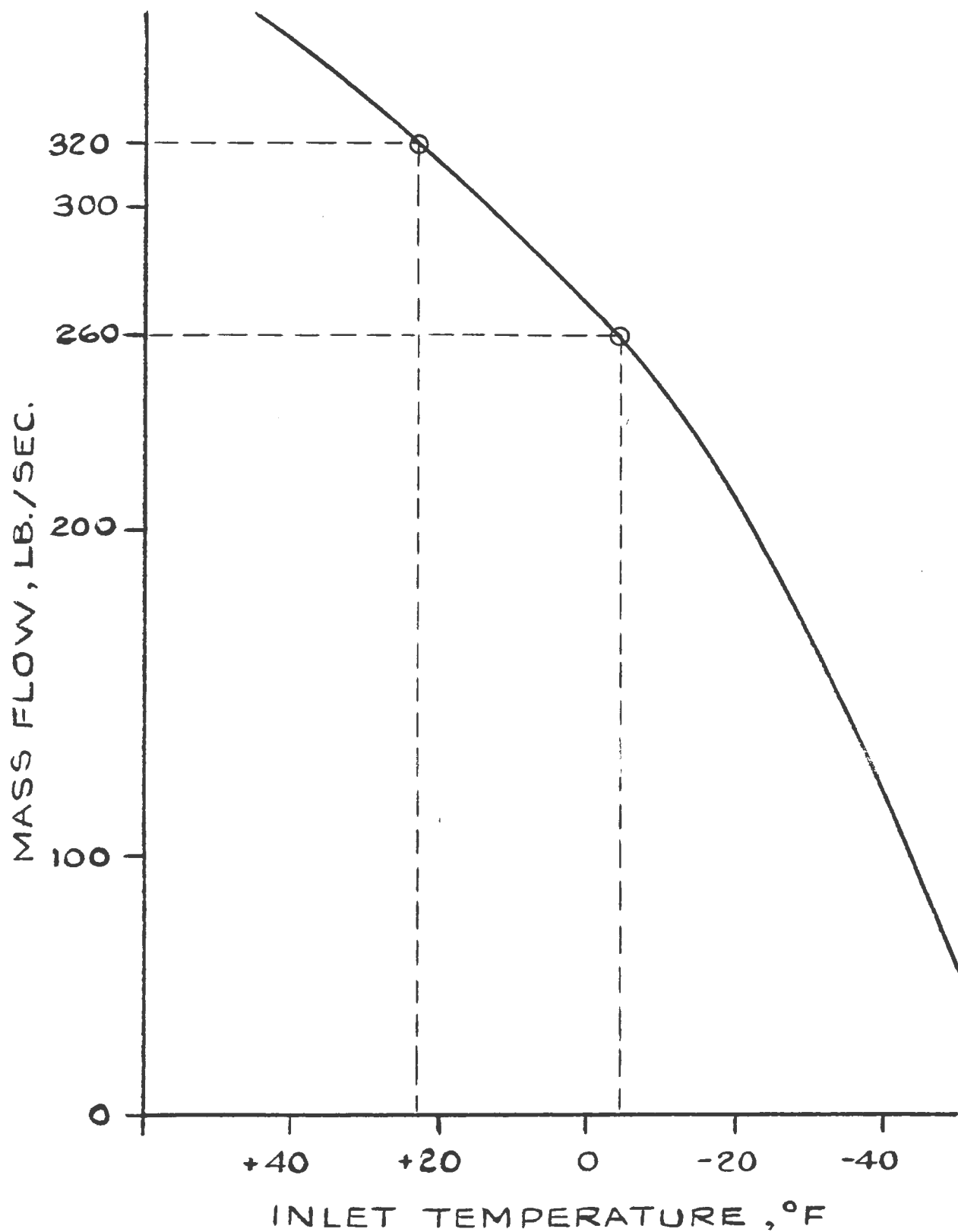
WIND TUNNEL



ALTITUDE

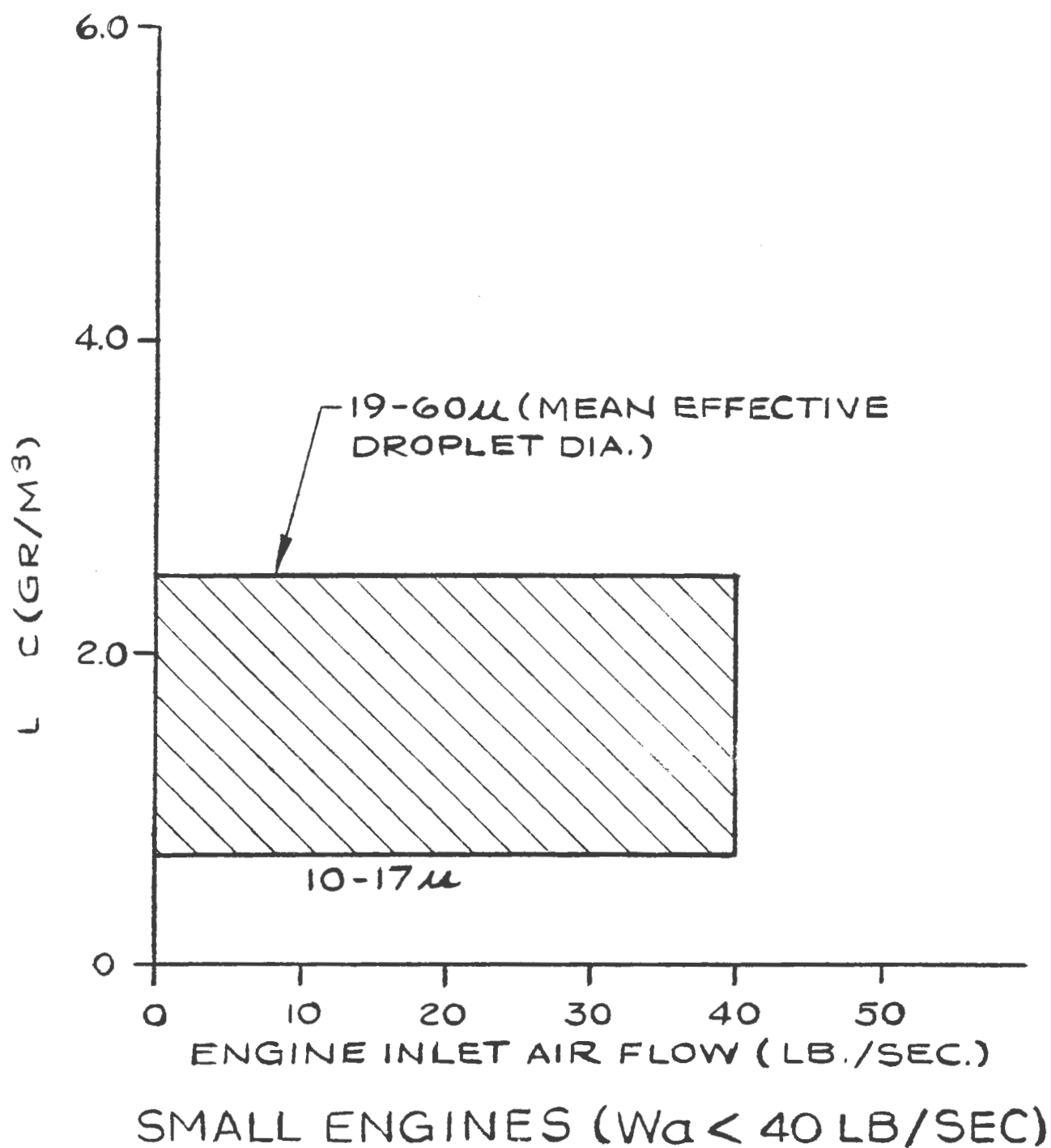
OTHER POSSIBLE TYPES OF ICING TESTS AT NAPC

Figure 4



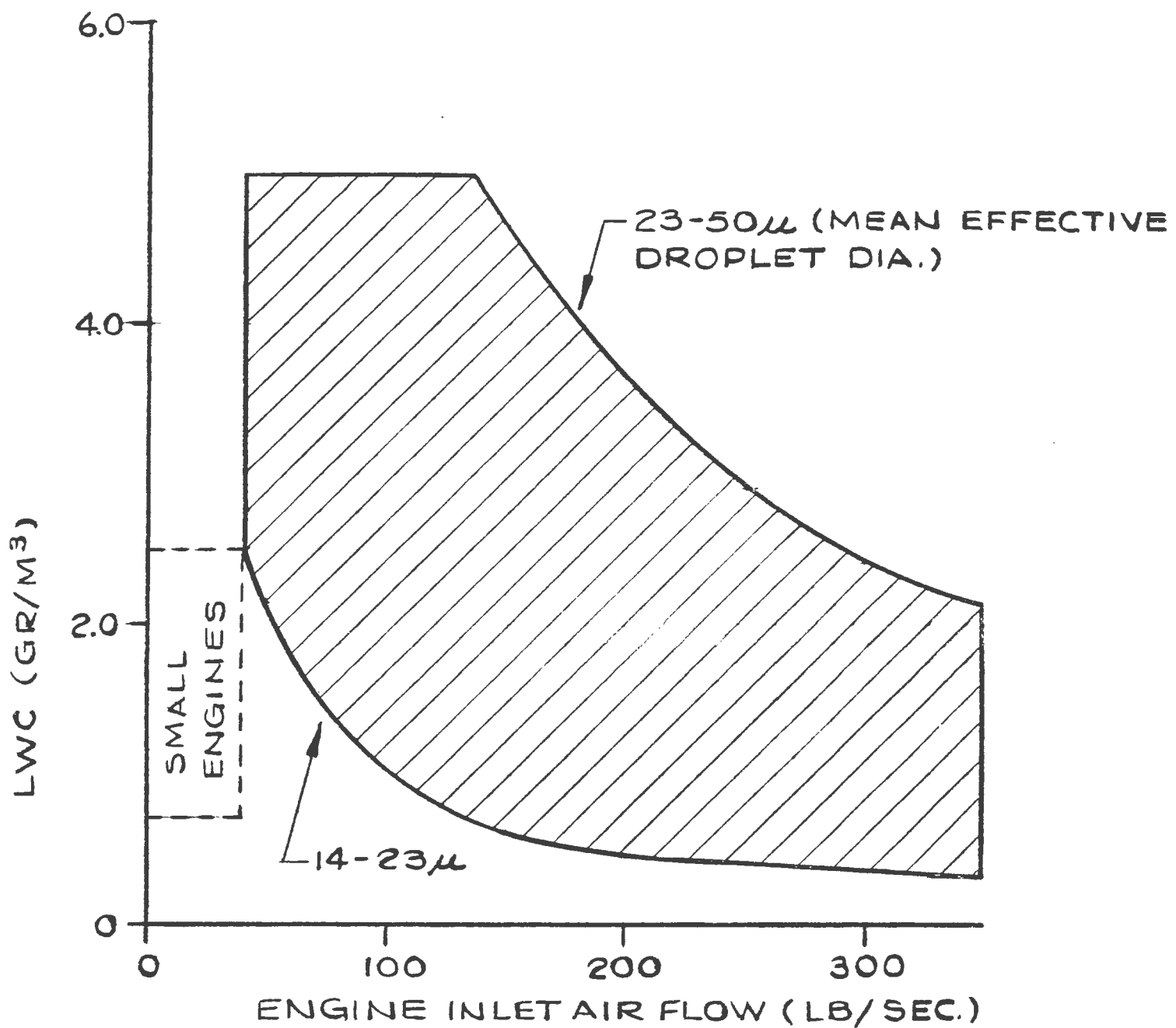
AIR FLOW CAPACITY AT TEMPERATURES
BELOW 40°F

Figure 5



NAPC ICING CAPABILITY

Figure 6



LARGE ENGINES ($W_a = 350$ LB./SEC.)

NAPC ICING CAPABILITY

Figure 7

OTTAWA SPRAY RIG

RICHARD I. ADAMS

Thank you, Vito. Let me say a couple of things about the agenda. I want to make a few comments on behalf of Ray Ringer, concerning the NRC Ottawa Spray Rig. At 12:45 we're suppose to depart here and there will be some buses outside to take us over to the cafeteria on the old base for lunch and then we get back here at 2:00. Before lunch, before we go, as we're getting on the buses, would Wayne Drake and Jay Hunt identify themselves to me. I have not yet had the pleasure of meeting them and they will be speaking after lunch.

The 35mm slide on the right screen (Figure 1) you've seen before. It is the Ottawa Spray Rig. I've asked Ray Ringer who is the chief of the Low Temperature Laboratory of the National Research Council of Canada, the owner of the Ottawa Spray Rig to be here today to tell us about their facilities. He contacted me and apologized and said that he couldn't make it, so I will attempt to give you a summary of where that facility stands.



Figure 1

RICHARD I. ADAMS

It has been used for the past 22 years in two configurations. What you see here is the most recent configuration. It consists of a sizeable spray bar that is about 75 feet wide and 15 feet high, stands about 75 feet in the air and the water droplets are aspirated by steam. What you see of the cloud primarily is the very, very small droplets in order of 2, 3 microns of the stream that has very little effect on the catch efficiencies and presumably very little effect on the test results. The facility has been used over the years to clear various aircraft for flight into natural icing conditions and really has been a unique tool for certification purposes of some of the foreign aircraft. Last year, however, the Canadian government announced that in March of 1980 the facility would be closed down. This was primarily because they had been working in the field of aircraft icing research for a number of years. Since their primary charter was basic research, they felt that they had reached the point of diminishing return.

But they did offer, through the NATO panel $\bar{X}$, as a matter of fact, to keep the facility open if members of the NATO countries would make known their specific requirements. So, I and Ted Carter from Sikorsky, as members of the AGARD working group 09, got together and contacted industry and government agencies and we did identify some specific requirements and the Canadian government has now reversed that decision. They have agreed to keep it open until 1985 on an "as needed" basis. Also that's somewhat dependent upon the availability of experienced personnel to operate the facility. I don't know what's going to happen to it after 1985. Our basic feeling, or my basic feeling, is that a facility of that type is still needed, and at least until we can find a suitable replacement for that type of facility, possibly in the form of another ground based facility of that type or possibly in the form of tankers that we have confidence in, or suitable icing tunnels. I think that this is one thing that we need to consider very, very thoroughly during our discussions tomorrow. It's lunch time now and that's all I will say right now. Let's try our best to be back here seated and ready to go at 2:00. Thank you.

AFTERNOON SESSION - SEPTEMBER 23, 1980

FACILITIES OVERVIEW (continued): RICHARD I ADAMS (Meeting Chariman)

Herb Slaughter and Bob Richardson would like to have a caucus, two different caucuses really. One for the HAA and one for the AIA. We have two conference rooms identified scheduled for 4:00. The conference rooms do not have numbers as yet, but we will direct you to those rooms. So, when we conclude the meeting this afternoon about 4:00 just get with me and Charlie Masters and we'll get you to the right place.

We intend to go through the rest of the afternoon without a break, from 2:00 to 4:00. We took a late lunch really to synchronize ourselves away from the heavy traffic at the cafeteria. Therefore, we felt that two hours without a break wouldn't hurt us too much. I would like to get another show of hands on those who would, who think their going to participate in the social event this evening at the club house.

The next speaker this afternoon is Wayne Drake from the Eglin Climatic Laboratory, Eglin Air Force Base, Florida. Wayne indicates that he's on vacation today. Sure appreciate Wayne taking his own time to come up here to tell us about his facilities. They are rather important facilities. I visited him once before years ago, but I understand that they've had lots of changes down there, so Wayne, come on up and give us a description of the facilities.

EGLIN CLIMATIC LABORATORY

WAYNE DRAKE

Thank you for the introduction there, Mr. Adams. I have about a 25 slide briefing here. A little description of some of our past tests that we've had and if you will turn the slide projector on, we'll be ready (Figure 1).

Eglin is located in the panhandle of west Florida, as you can see here (Figure 2).

This (Figure 3) is the aerial view of the Climatic complex. This (Figure 4) is the main chamber of our largest facility at the Climatic Laboratory. It measures about 250 feet wide, about 200 feet deep and 70 feet tall in the center. There's a parent structure on the back side of the building that was built for the C5 test. The chamber was plenty wide, but it wasn't quite deep enough, it's a 60 foot deep by 80 foot wide structure just for the tail section to extend into. The temperature capability of the climatic lab is as low as minus 90° Fahrenheit. Our normal low temperature test though is minus 65°. Our high temperature test can run as high as 165° Fahrenheit. During the engine runs for all aircraft we can maintain up to about 600 pounds per second engine air (makeup air). That air that we ingest into the chamber is also conditioned air so that if we are running a minus 65° test we'll be ingesting air into the chamber at minus 65 and as high as 600 pounds per second. The spherical tanks and cylindrical tanks there contain metholyn chloride and calcium chloride, about 160,000 gallons in each and we use that as the heat sink that we prechill prior to the engine runs to cool the air down. Our hot phase testing is handled by the boiler plant with a total capacity of about 12,000, I'm sorry, about 55,000 pounds of steam per hour. This is used for heating air makeup also in the conditioning of the air itself. The refrigeration capacity for the Climatic Lab that chills the main chamber is approximately 12,000 tons at plus 70. Here (Figure 5) you can see a 180 degree view of the Climatic Lab, some of the facilities and part of the associated network.

The Climatic Lab first started testing in May of 1947. Here (Figure 6) you can see some of the initial tests that were conducted there. At that time, of course, the air makeup system was not incorporated in the facility, because the air requirements were not needed at that time. This was a later on addition.

This (Figure 7) is the latest of our chambers and a list (Figure 8) also of the capabilities within those chambers. You can see, primarily most all of the chambers have temperature capabilities. We have one altitude chamber which is a small room size chamber, but primarily all of our testing is done at sea level.

WAYNE DRAKE

We also not only test machines, but we also test the man/equipment interface. Here (Figure 9) is some survival training for the Coast Guard out of Mobile. They just completed a survival training course and before they are deployed to the Arctic they are brought to the lab for a actual day of environmental survival at these conditions. The condition of the lab now is minus 45° Fahrenheit with about a 4 to 5 feet pile of snow that they can build their little shelters in and learn to use the survival gear that they have on board the helicopters.

This (Figure 10) is a composite of the C-5 when it was in the lab. We also got to do motion testing within the lab. Here (Figure 11) you can see a H-7 in the foreground of the C-5 and various other equipment scattered all around the floor.

This (Figure 12) is the AWACS E380 undergoing Arctic tests at minus 65.

This is the B-52 (Figure 13). The test here was not of the aircraft itself, but it was a test of some deicing equipment that was designed to remove this kind of snow and ice buildup on the exterior of the aircraft. The deicing equipment itself was nothing but just a small turbine engine that directed the exhaust flash directly to the surface to blow the snow away and melt the ice.

These cobweb capsules (Figure 14), as you know, were launched in a north to south orbit so they had possibilities of splashing down in the Arctic. So, they brought the capsules and three test astronauts that are in the capsule at present, and we under went a full splash-down recovery cycle there in the lab. Ambient air temperature is -20° Fahrenheit and the water temperature there is salt water that we pumped out of the bay, there which is about +20°. The three test astronauts stayed in the capsule with about 3 inches of ice to simulate wave action splashing out, freezing out on the capsule. This was also to determine if the hydraulic door would break it free or any other problems they would encounter because of ice buildup.

Also along with this was the frogmen check out (Figure 15) with all his gear, his wetsuit, drysuit combination, any other problems they encounter in these splashdowns.

This (Figure 16) is a freezing rain simulation that we can do there at the lab. Of course, this is just one of many configurations that we can do. This is a power distribution switch that we developed for the Tennessee Valley Authority in Knoxville, Tennessee. Here (Figure 17) you can see about a 1 inch vertical ice buildup on these switches. It took about 4 complete, separate trips to the lab to work out a lot of these problems that were in these switches. Engineering-wise it was an excellent design, but the icing accumulation buildup, and all this, created a whole lot of problems when they went into operation with these switches.

WAYNE DRAKE

Here (Figure 17) you can see how well caged the switch heads are. Now this is just typically about a 1 inch ice buildup, vertical ice buildup and you have a tremendous amount of ice runoff. Again this is strictly a freezing rain type simulation.

This (Figure 18) is the F-16 undergoing solar radiation. The typical skin temperatures that you can encounter during this type of solar tests on the surface, are 160° Fahrenheit and the cockpit there acts very much just like a solar collector. You got a good insulated screen that solar radiation can pass through, so the cockpit itself can exceed temperatures of 180°, even as high as 200° inside the cockpit while it's setting in a stationary configuration like this out on the runway during these extreme solar intensity configurations. The aircraft also is sitting on jacks, up off the floor about 6 inches. This allows us to retract the landing gear and allow operation of all the control systems and hydraulic systems on board the aircraft. The aircraft is also tied securely with the cables as you can see. They are restrained properly aft, so that when they run the aircraft at mil power or even into after burner the aircraft will sit there securely on the jacks.

This (Figure 19) is a test on the F-16 of some icing or series of icing tests that we've been completing, over the past couple of years. Right here we're simulating the aircraft sitting on the runway on a film of water with the runway just slightly damp. You can see a vortex form from the intake with the air going into the intake. This, where your ambient air temperatures are about 32° or 31°, creates an icing problem with the aircraft where the engine gets ice while it's just sitting on the ground, from the wet runway.

This (Figure 20) is about the same condition except it's more of a wet runway, one-eighth of inch of water or deeper sitting under the intake. You get the same conditions except the droplets are much bigger, where here it's just sucking up water drops going into the intake.

The inflight simulation of the aircraft here (Figure 21) is still sitting on jacks. If you will notice out in front of the aircraft, in front of the intake, you'll see two pieces of equipment. This is our laser interferometer and the plastic shielding around it is strictly an environmental closer. What this does, it allows us to measure the droplet diameters and velocities in the cloud that we are subjecting the aircraft intake to. This is just two parallel laser beams that are focused into a common point, an intersection point and we're looking at that intersection point. The blast scatter at the intersection point is collected by the piece of equipment on the left and then that is, again, analyzed to give us our droplet diameters.

WAYNE DRAKE

Here (Figure 22) you can see the slide of the interferometer. It's not actually in the test cell there, its during the calibration mode here where you can see the intersecting beam and then the receiver opened up as the collection lands. The signal we get is just a DC with an AC ripple on it and that AC/DC ratio which gives us a droplet diameter for each drop as it passes through that small sample volume.

This (Figure 23) is the actual sample volume here magnified. You can see a fringe pattern set up from the intersection of two laser beams and as the drop passes across these you get a frequency and that frequency determines the velocity of the drop, because we know the spacing of these fringe patterns. There are about 13 microns in this particular setup here. This allows us to make a measurement in ranges of like 8 to 80 microns, then we also have other ranges like 60 to 180, 150 to 300, on up as high as 5 millimeters. Of course we have to do for a larger beam so we run it through a beam expander, and still its the same principle.

This (Figure 24) is a model size disperse aerosol generator that we have. We use it to calibrate the interferometer and also check its calibration from time to time. These drops here are 45 microns in diameter and it was taken with a microscope and a strobe with a camera attached to the microscope.

This (Figure 25) is an engine face on the F-16 after a 15 minute subjection to an icing cloud. You can see there is a substantial amount of ice built up on the inlet guide vanes of the aircraft. The aircraft now has been under a lot of modifications, there are changes, hollow flaps with heated air from 13 stage bleed, various other configurations trying to eliminate these icing problems with the aircraft.

This (Figure 26) is typical FOD damage from ice on the first stage of the F-16. Here you can see some blades curled. We have curled as many as 13 blades in just one icing, where the aircraft will be just sitting there with a little ice on it and then they go to military power and this ice breaks loose and goes back through the intake.

This (Figure 27) is the Black Hawk, I'm sure you all know a little bit about this aircraft. This was undergoing Arctic tests at the time of this slide. That's minus 65°.

This is the inlet icing where we are doing some icing on the intake screen of this helicopter. Notice the helicopter, again, is tied down securely to the floor, or to this helicopter tiedown box, and this in turn is anchored securely to the floor, just in case, during the test we lose a blade or something like that goes wrong. We try to maintain as safe a testing condition as possible.

WAYNE DRAKE

This is the 214 helicopter (Figure 28) when it was in the lab several years ago during a showering and here (Figure 29) we are doing a rotor blade icing. Our spray frame that we have suspended here are air atomized spray frames. Our configuration at the lab there allows use of slightly higher pressure air vents than available from bleed air from aircraft so our air pressure ratio maybe 40 on the water and maybe 80 PSI or 100 PSI on the air. We change our nozzle tips to produce different size driplets and we can vary liquid water content from .25 grams per meter cubed to as high as 3 or 4 or however we want to. Normally we only go about .5 to 1.5, though, for most of these tests.

This (Figure 30) is typical ice shedding from a rotor blade from a helicopter.

This (Figure 31) is a closeup of just one single nozzle on our spray frame. They are also steam jacketed and that steam, of course, keeps the nozzle hot to keep it from freezing up during these tests because a lot of time we have 45-50 mile an hour winds blowing through the frame toward the test item. We use our wind machines to do that with.

This (Figure 32) is the A-10 aircraft undergoing the icing tests. Here we were looking at ice buildup on the refueling portion of the aircraft, just to determine any problems they might have during refueling with the little ice on the refueling door. These tests also brought about some questions about the Gatling guns sticking out there in the front getting ice formed over the gun barrels themselves. This led on to a future test of the gun barrels individually, just to determine any problem that they might encounter with ice plugging the barrels, such as firing the guns possibly causing damage to the gun itself.

That's a quick runover of the lab. Anybody have any quick questions I think we're within our allotted time here. But if there are an other detailed questions, feel free to contact myself or Mr Richard Toliver of the Climatic Laboratory and we will be more than happy to discuss the specific detail questions that you may have concerning icing and our capability in aiding in any kind of testing that we can do for you. Thank you!

Climatic LABORATORY

EGLIN AFB
Florida



Figure 1

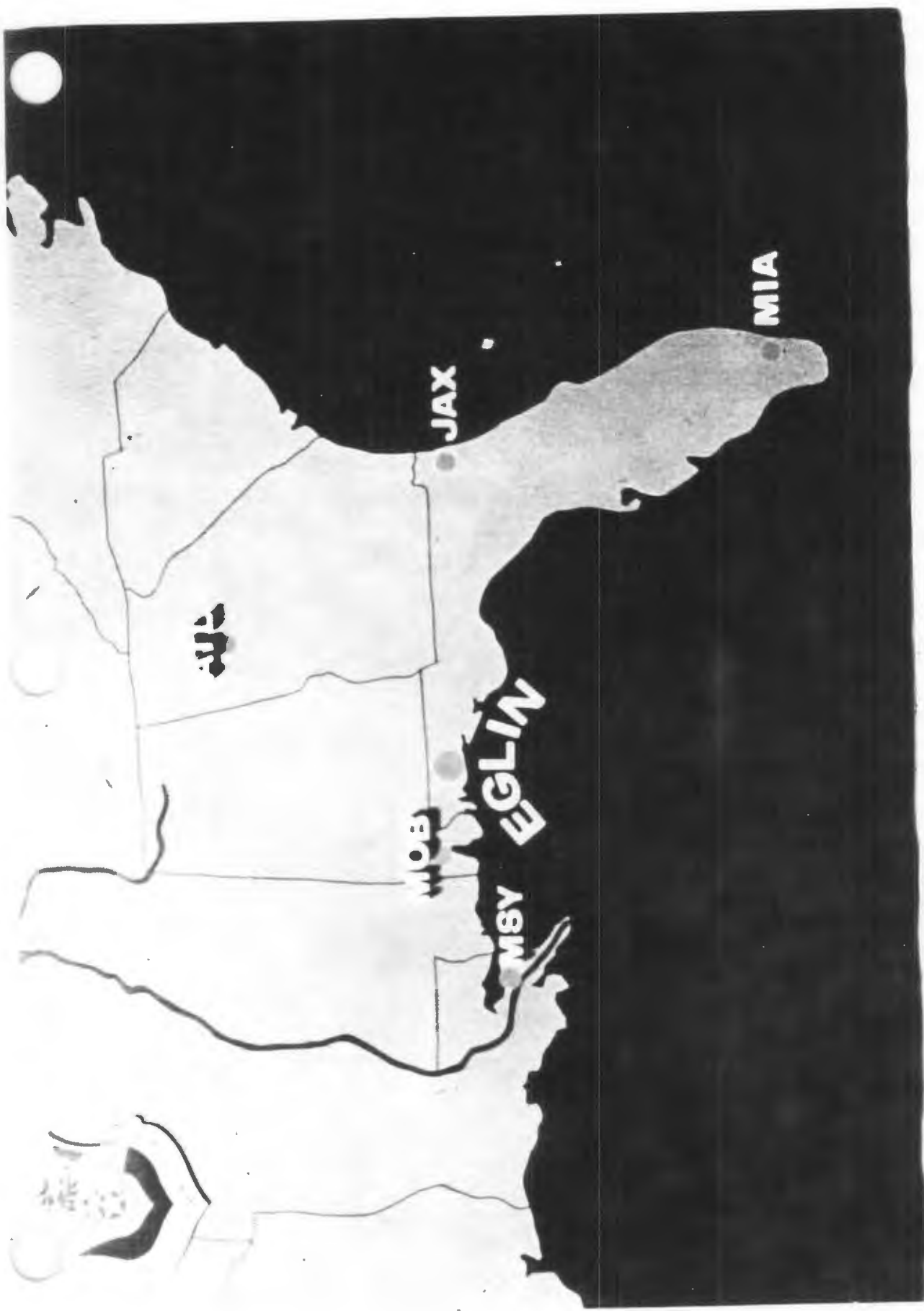


Figure 2



CLIMATE LAB

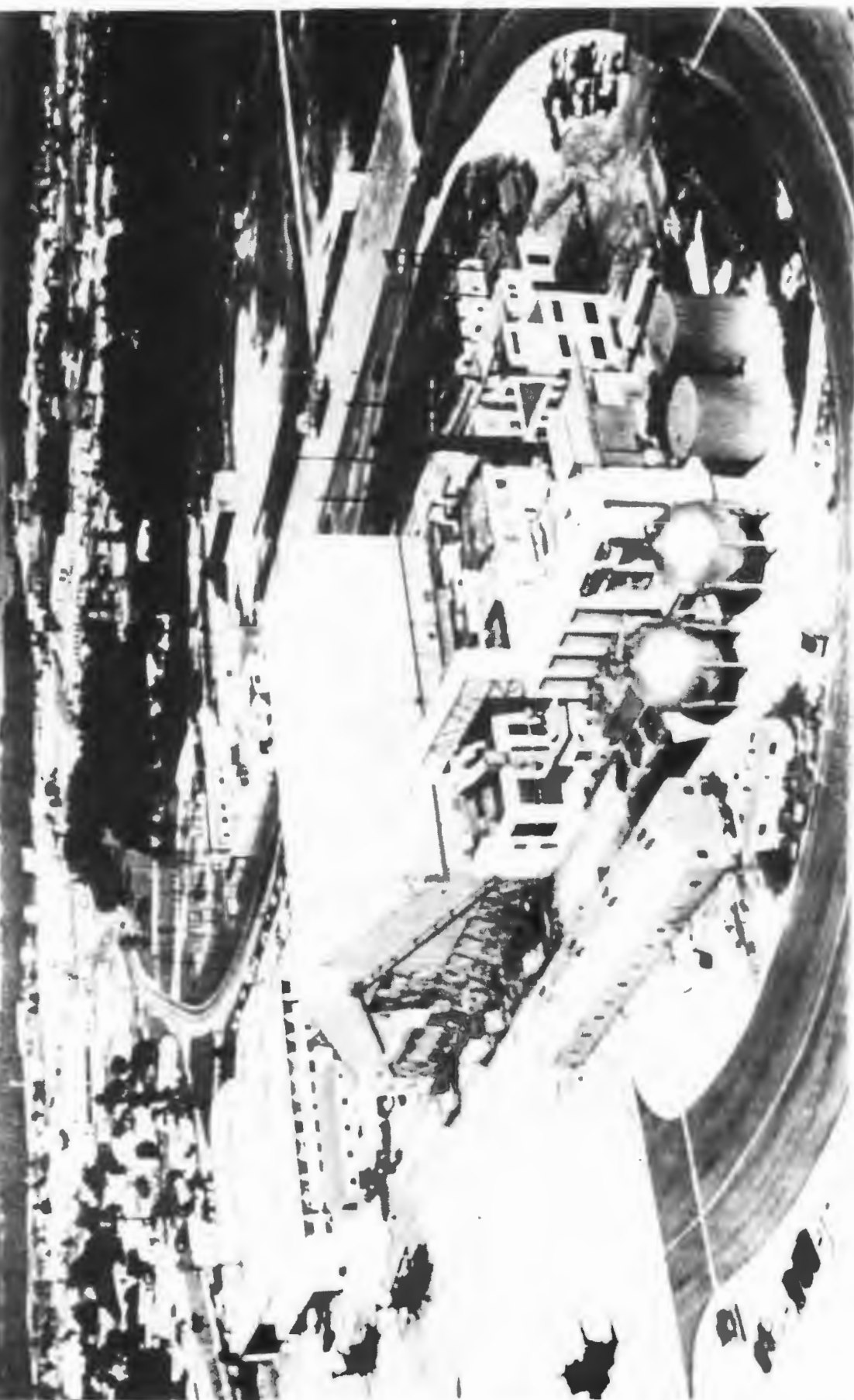
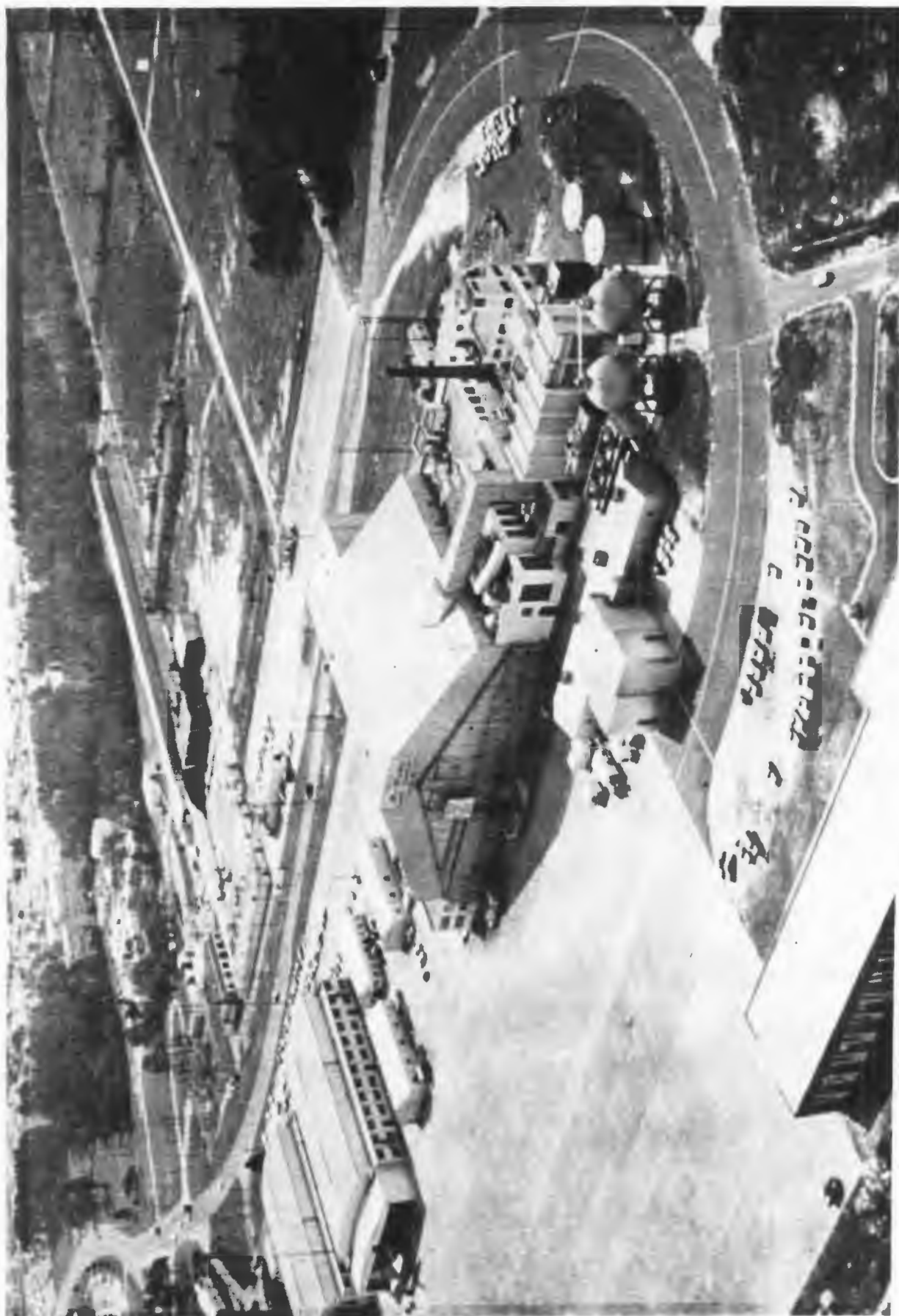


Figure 4

Figure 5



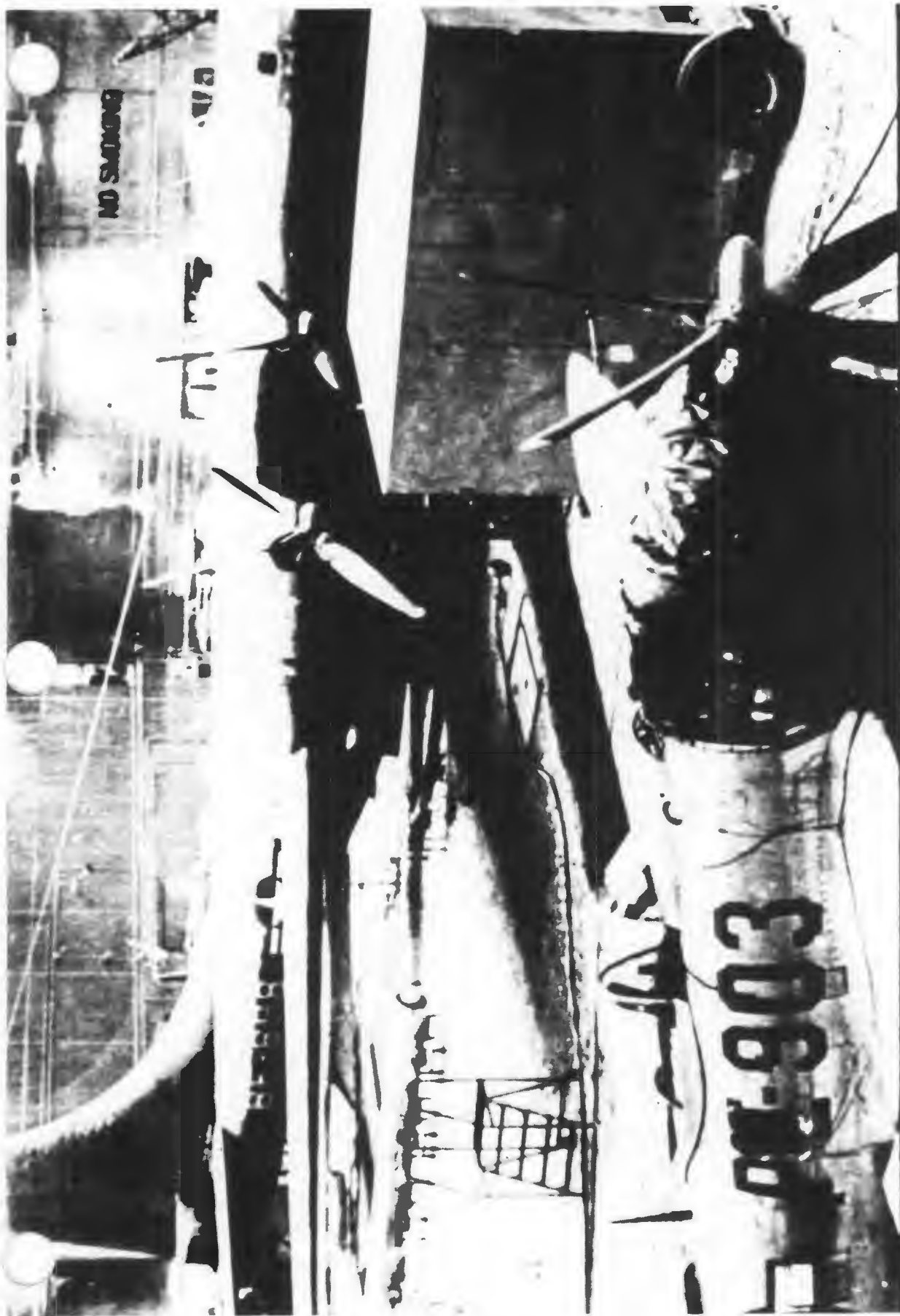


Figure 6

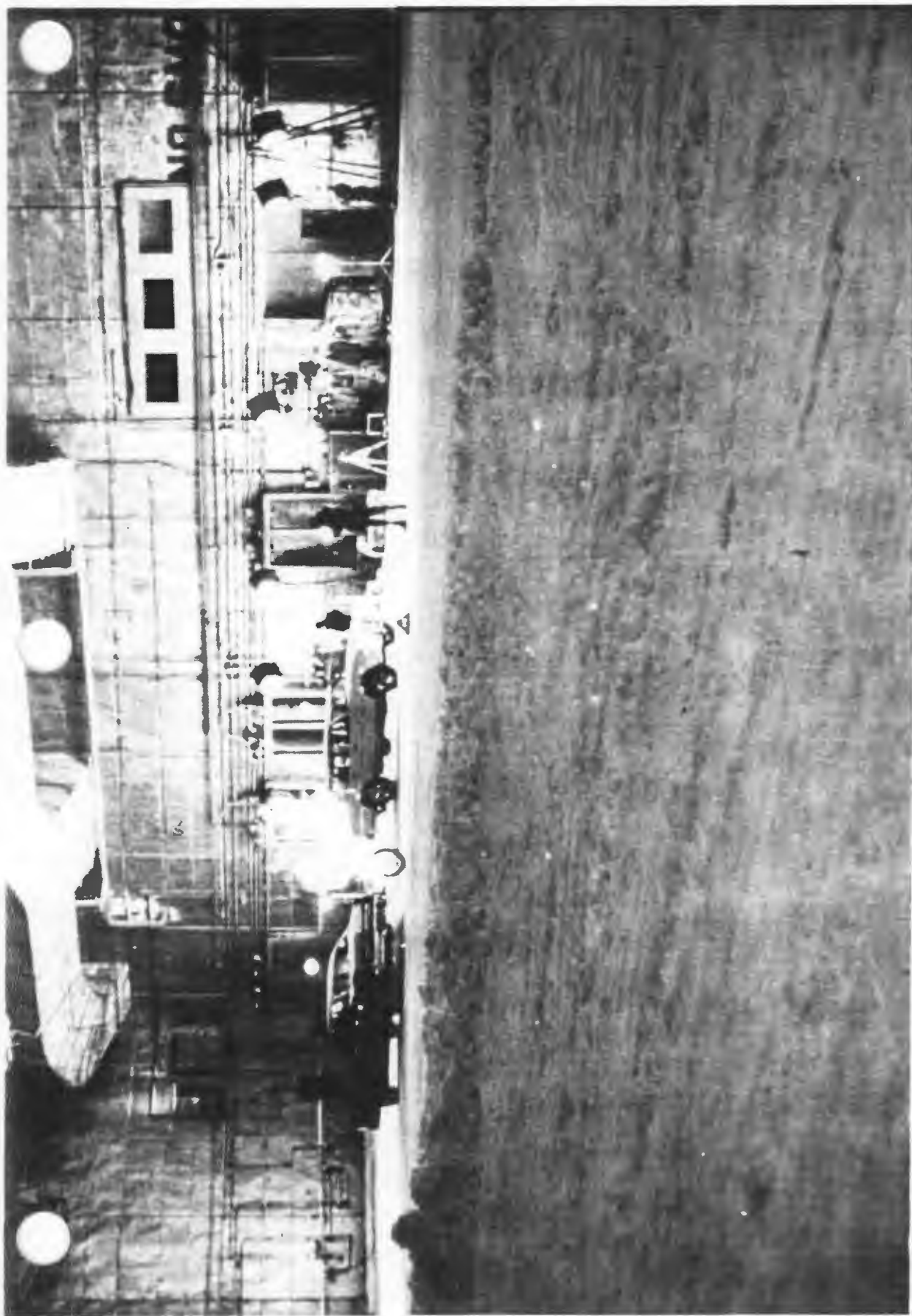


Figure 7

TEST CHAMBER SIZES CAPABILITIES

SIZES CAPABILITIES															
AREA/ CHAMBER	SIZE IN FT	CAPABILITIES													
		SOLAR RAD	ALTITUDE	FUNGUS	SALINITY	TEMP	ICING	HUMIDITY	SNOW	RAIN	WIND	AIR MAKE-UP	SAND DUST	DYNAMIC TESTING	
MAIN CHAMBER	250 X 271 X 70	•				•	•	•	•	•	•	•	•	•	
ENGINE/ EQUIP	130 X 30 X 30	•				•	•	•	•		•	•		•	
ALL WEATHER ROOM	34 X 20 X 10	•				•	•	•	•		•	•	•	•	
SALT SPRAY	12 X 50 X 16	•			•	•	•	•	•		•		•	•	
TEMP/ALTITUDE	10 X 13 X 7		•			•	•	•	•					•	
DESERT	12 X 12 X 9	•				•	•	•	•					•	
HOT	12 X 12 X 9					•	•	•	•					•	
COLD	12 X 12 X 9					•	•	•	•					•	
TROP/MARINE	12 X 12 X 9			•		•	•	•	•					•	
JUNGLE	12 X 12 X 9			•		•	•	•	•	•				•	
SUN WIND RAIN						•	•	•	•	•	•		•	•	

Figure 3



Figure 9

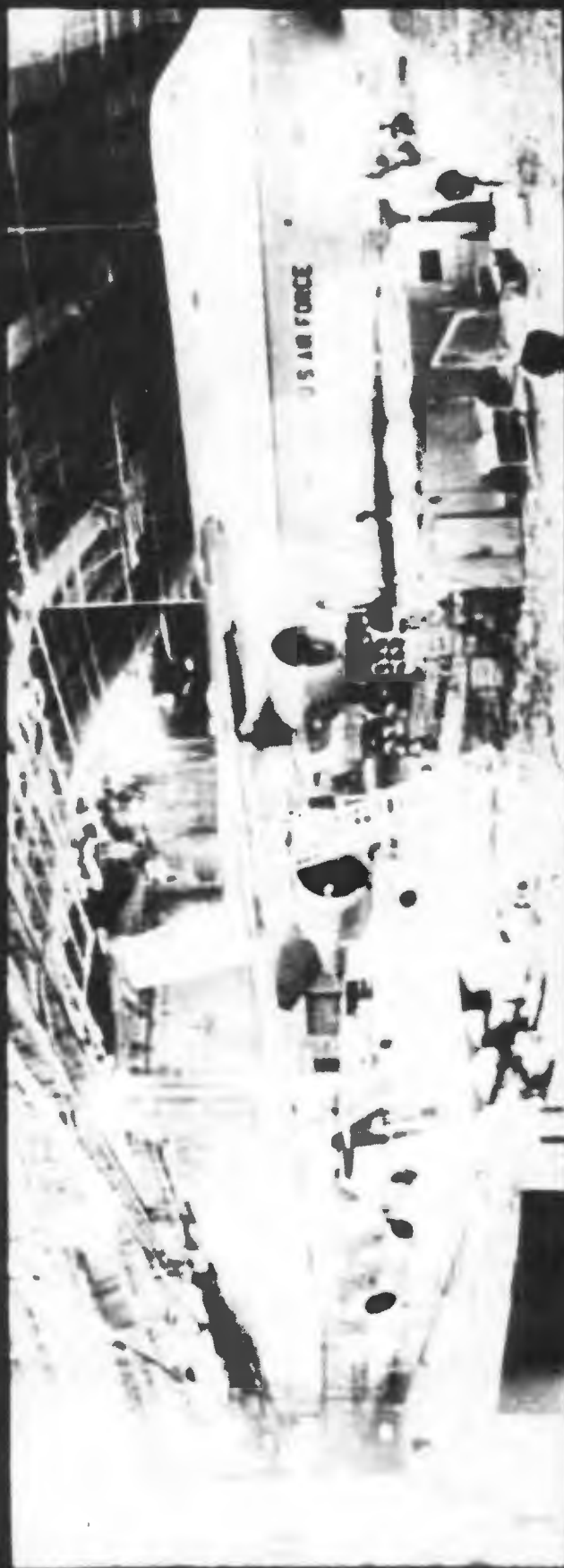


Figure 10

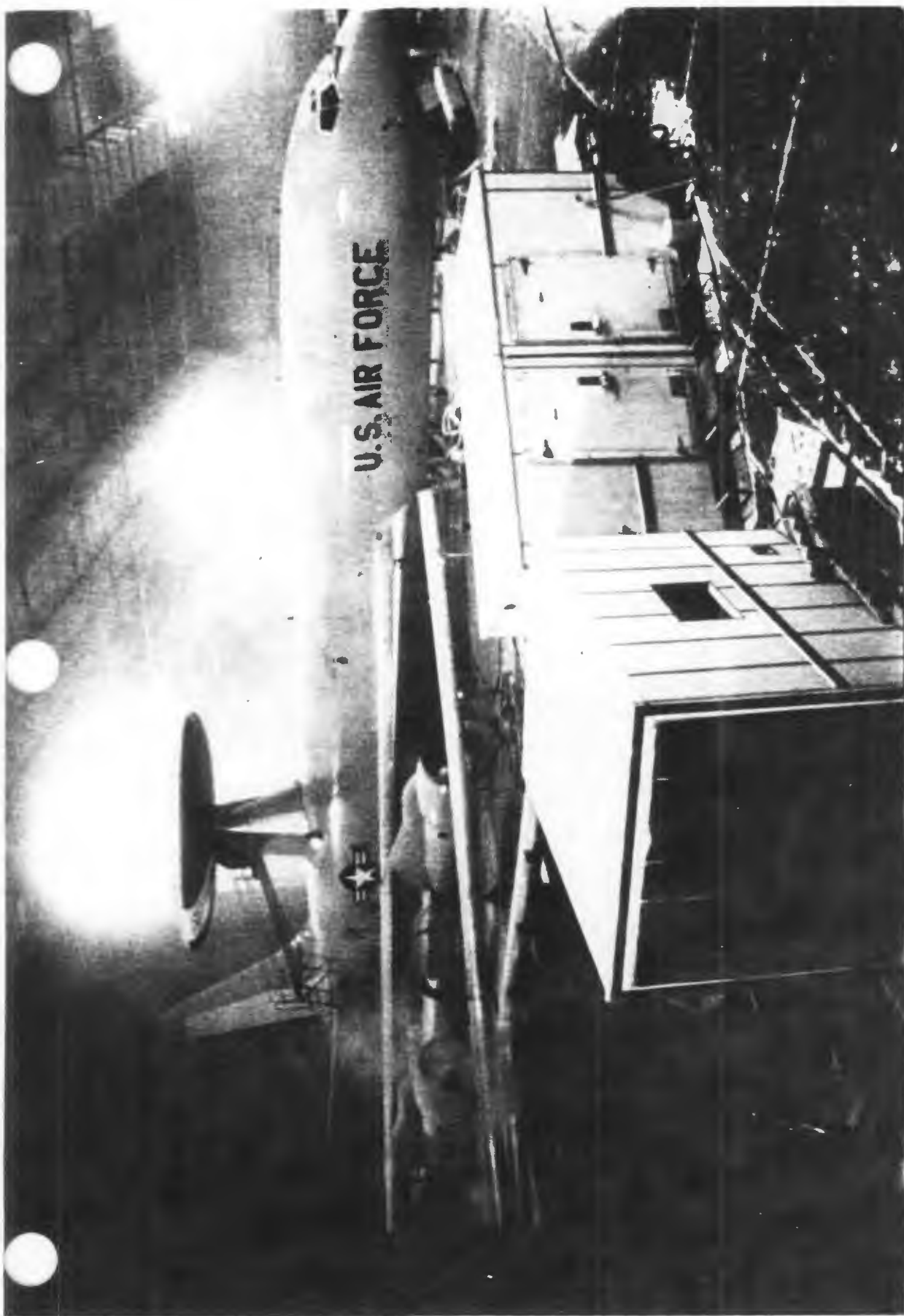


Figure 11

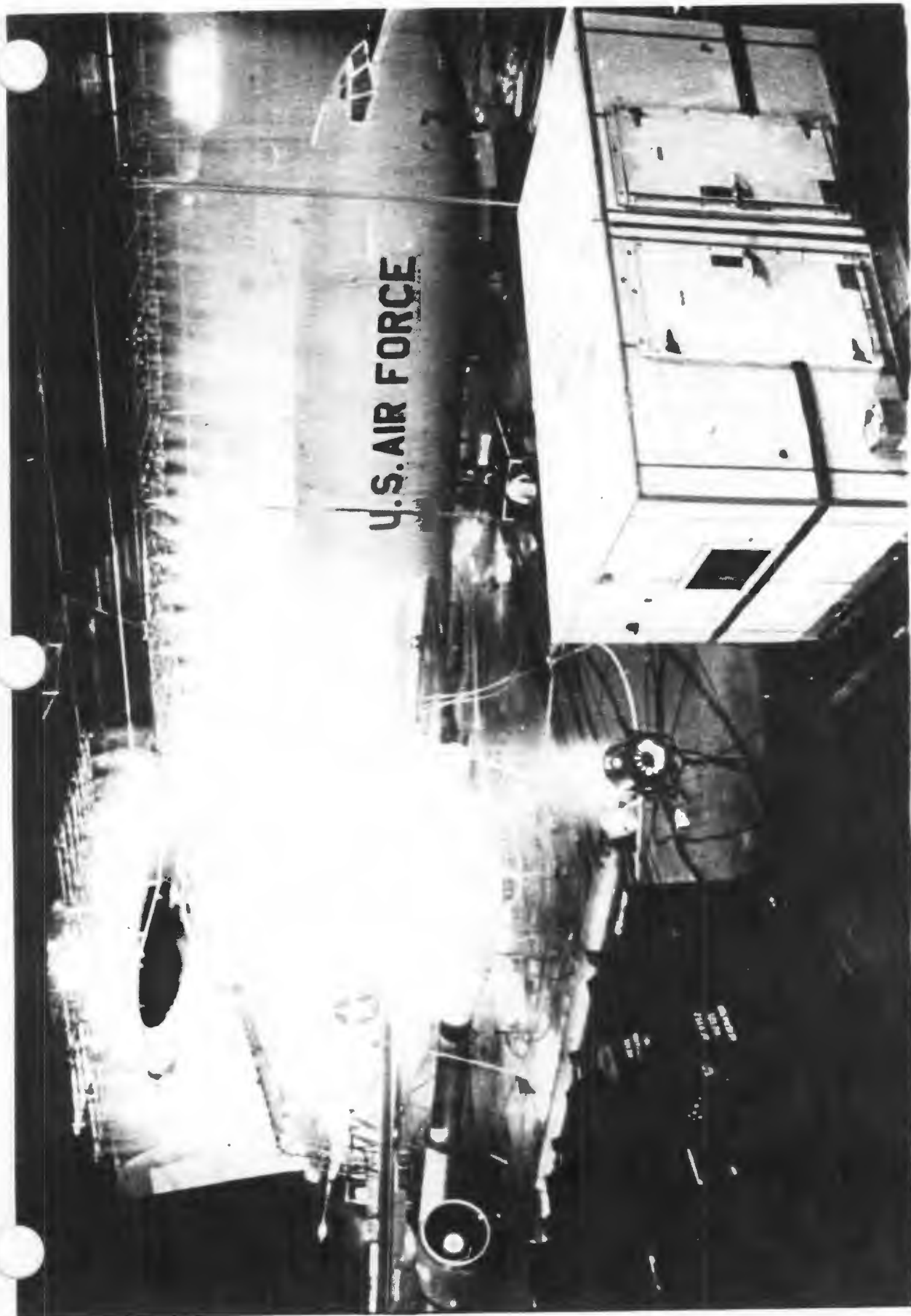


Figure 12

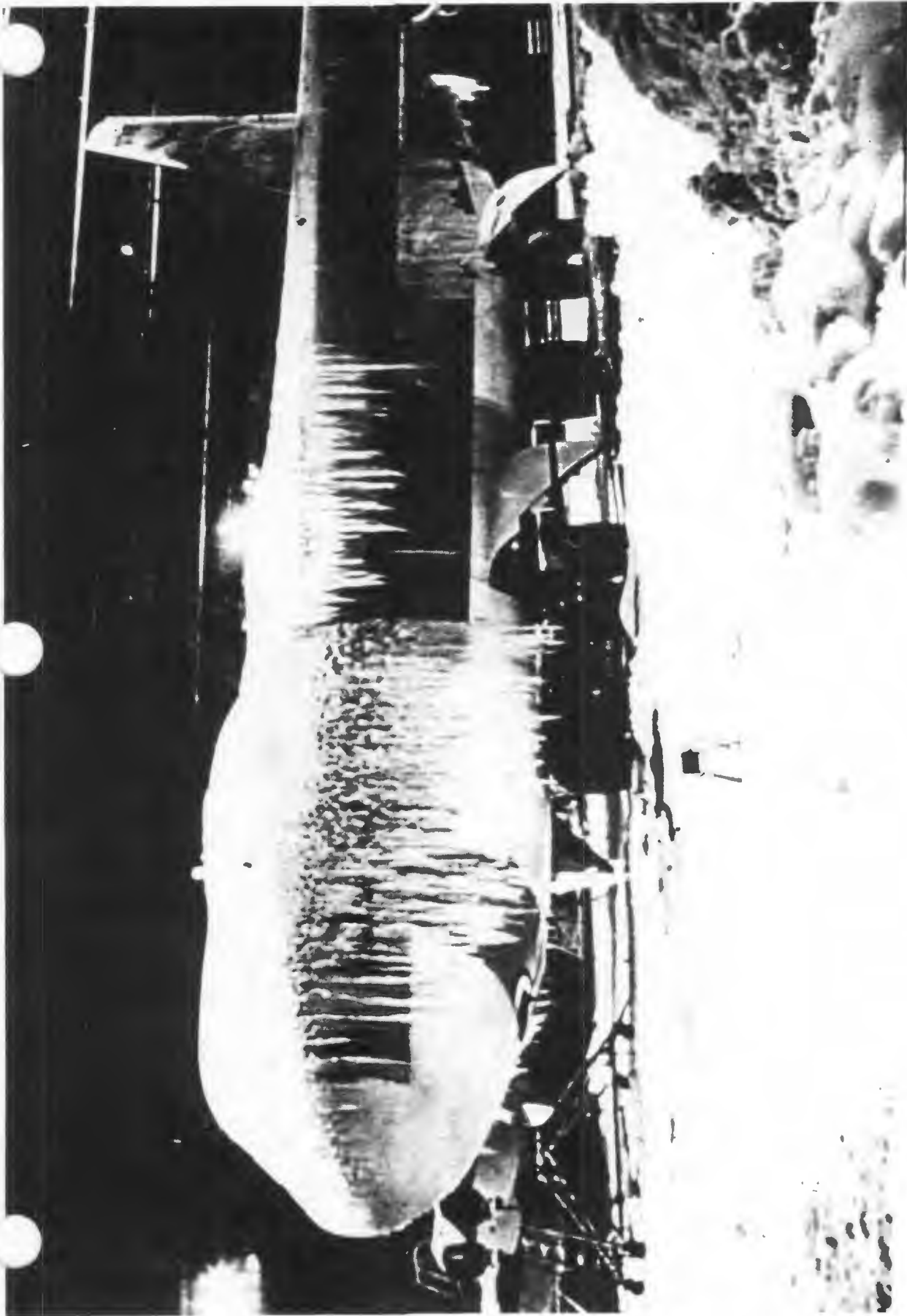


Figure 13



Figure 14



Figure 15

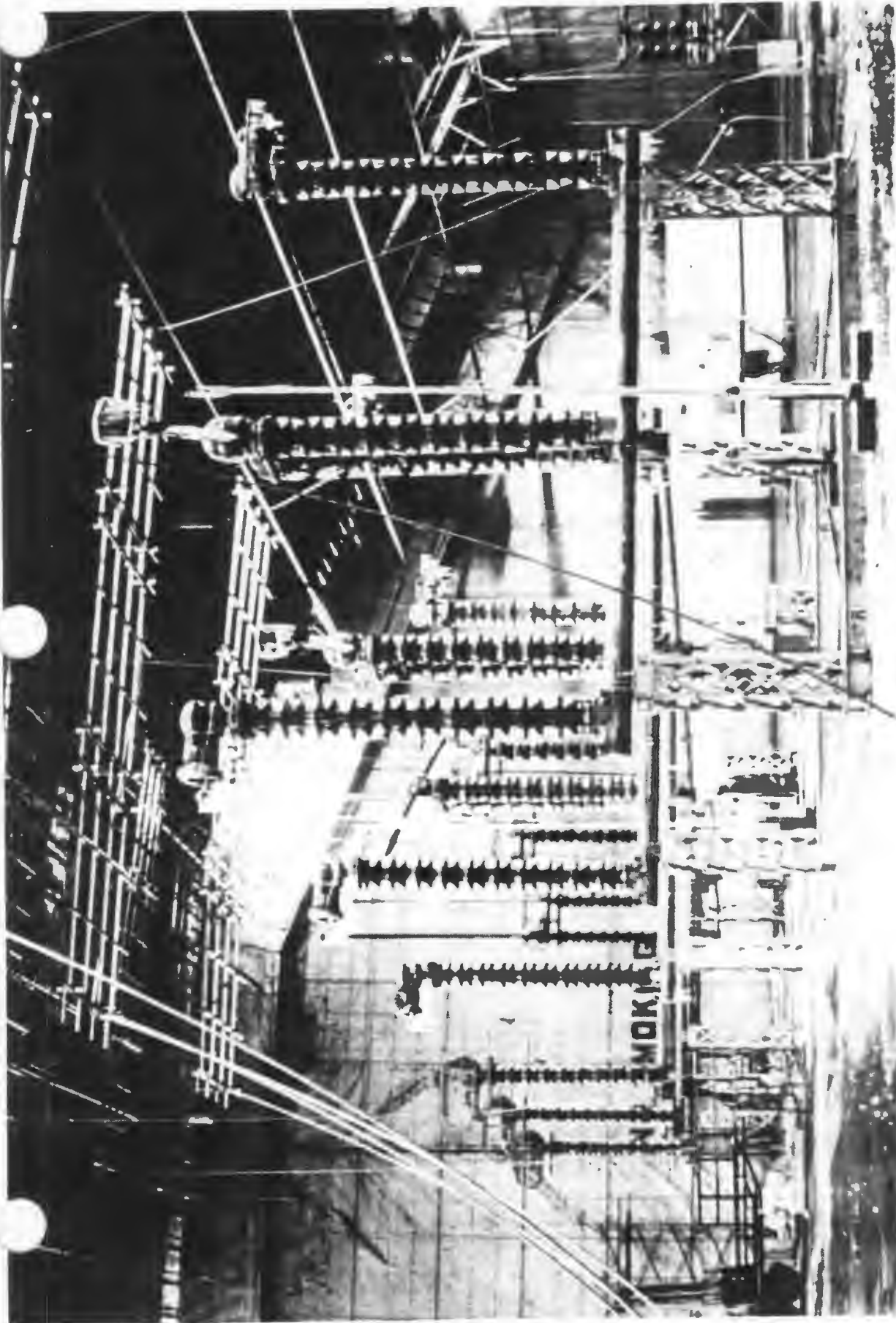
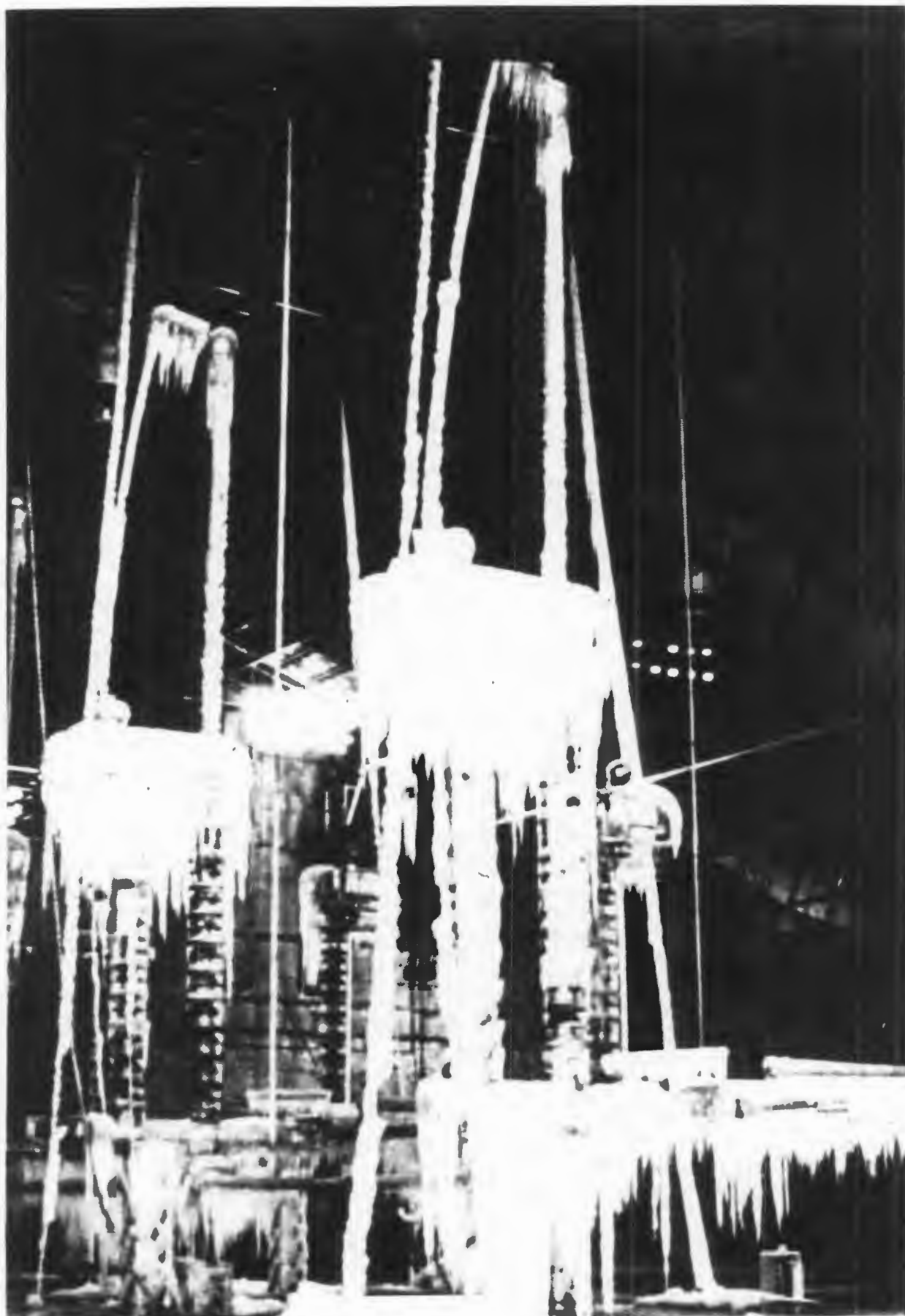


Figure 16



F.A.A. TECHNICAL CENTER
ATLANTIC CITY, NEW JERSEY

Figure 17



Figure 18





Figure 20

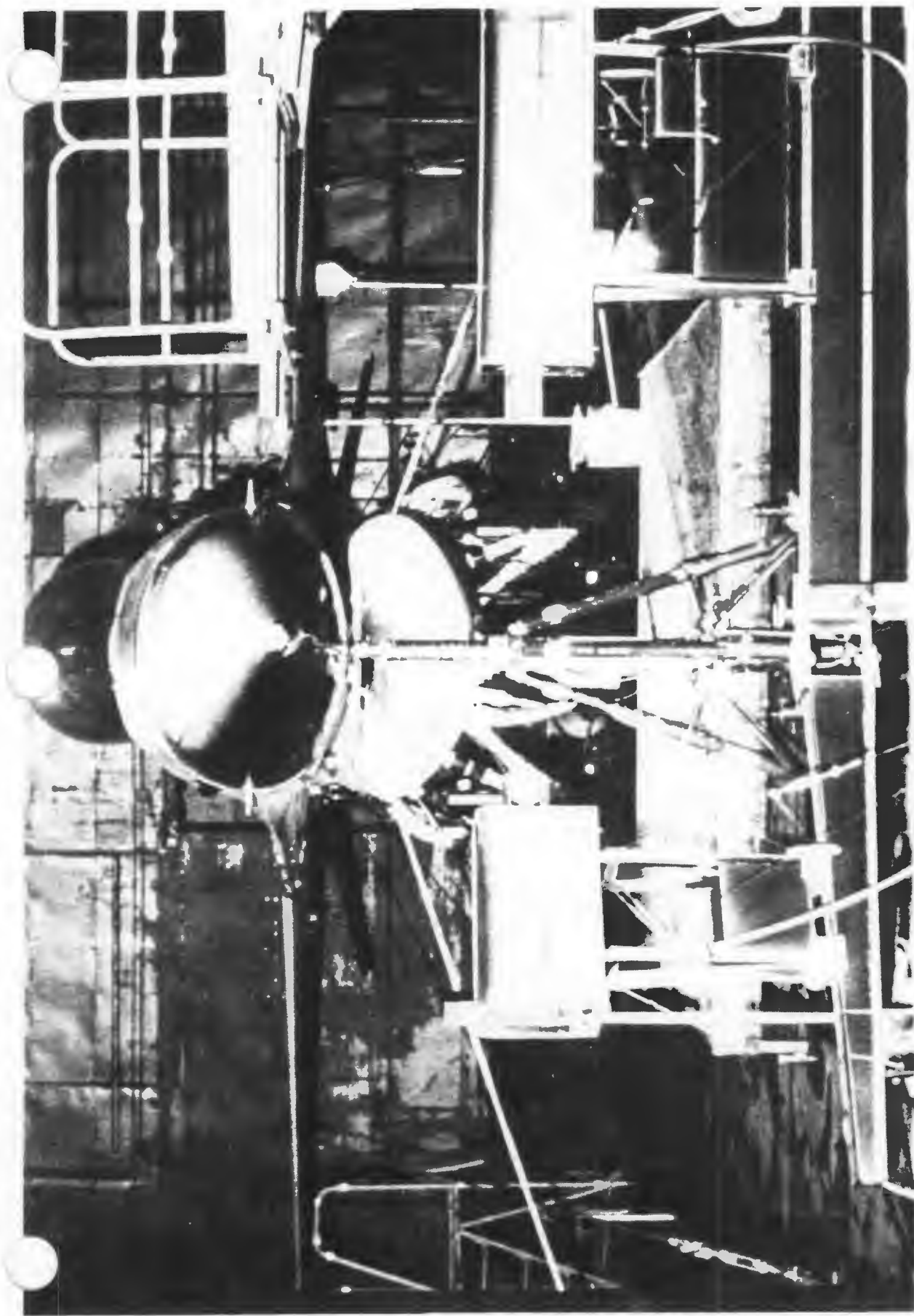


Figure 21

80-7959

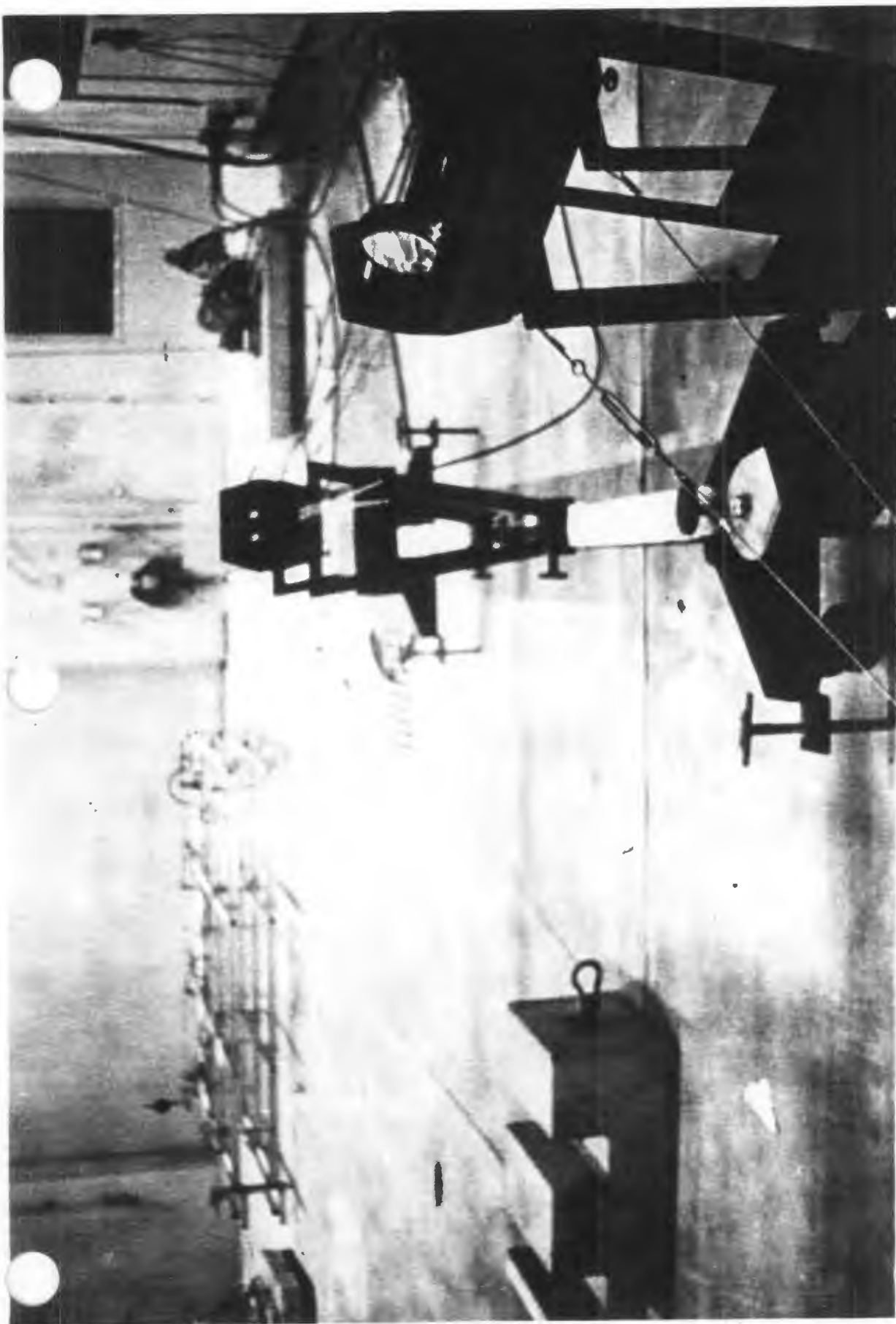


Figure 22

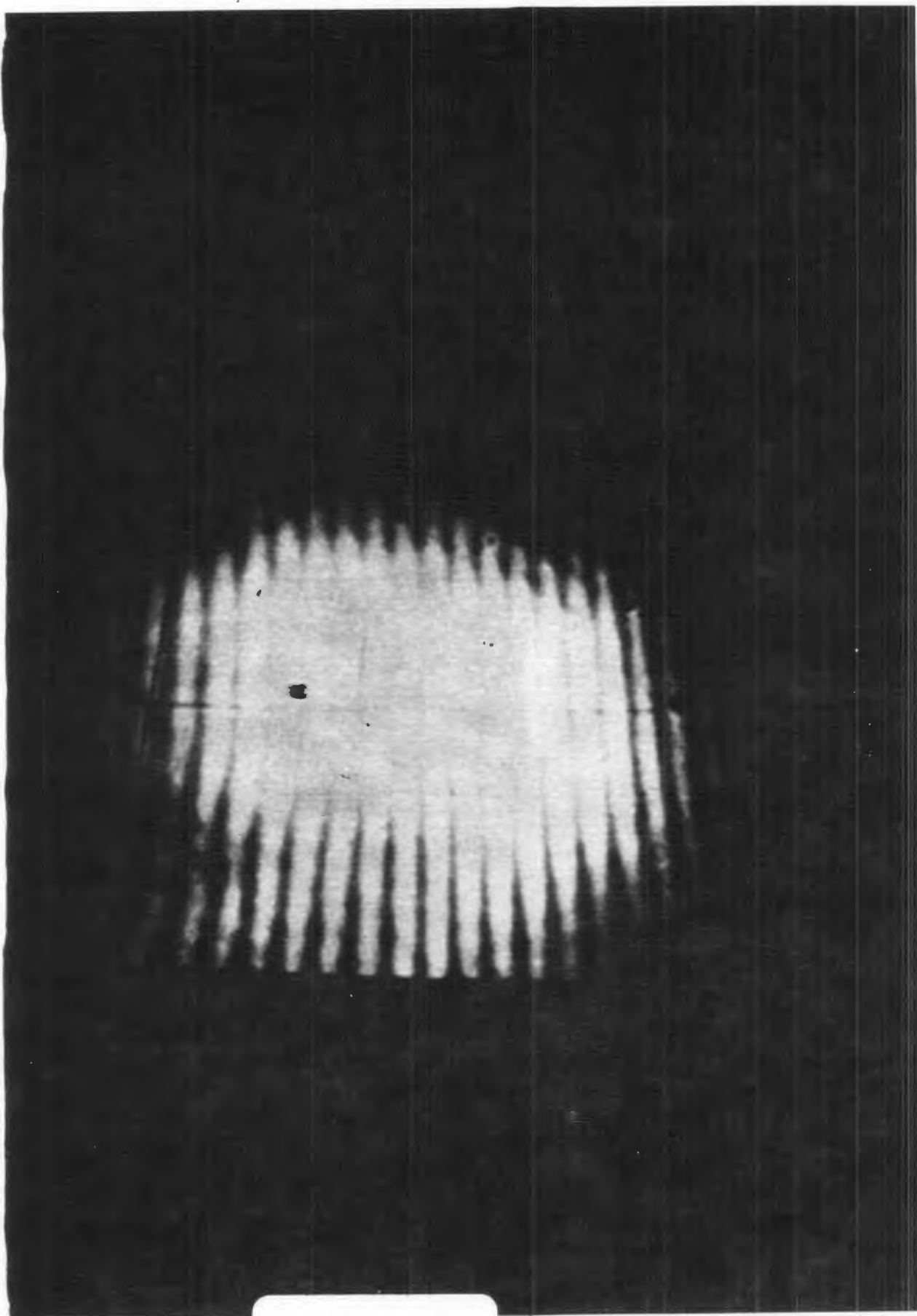


Figure 23



Figure 24

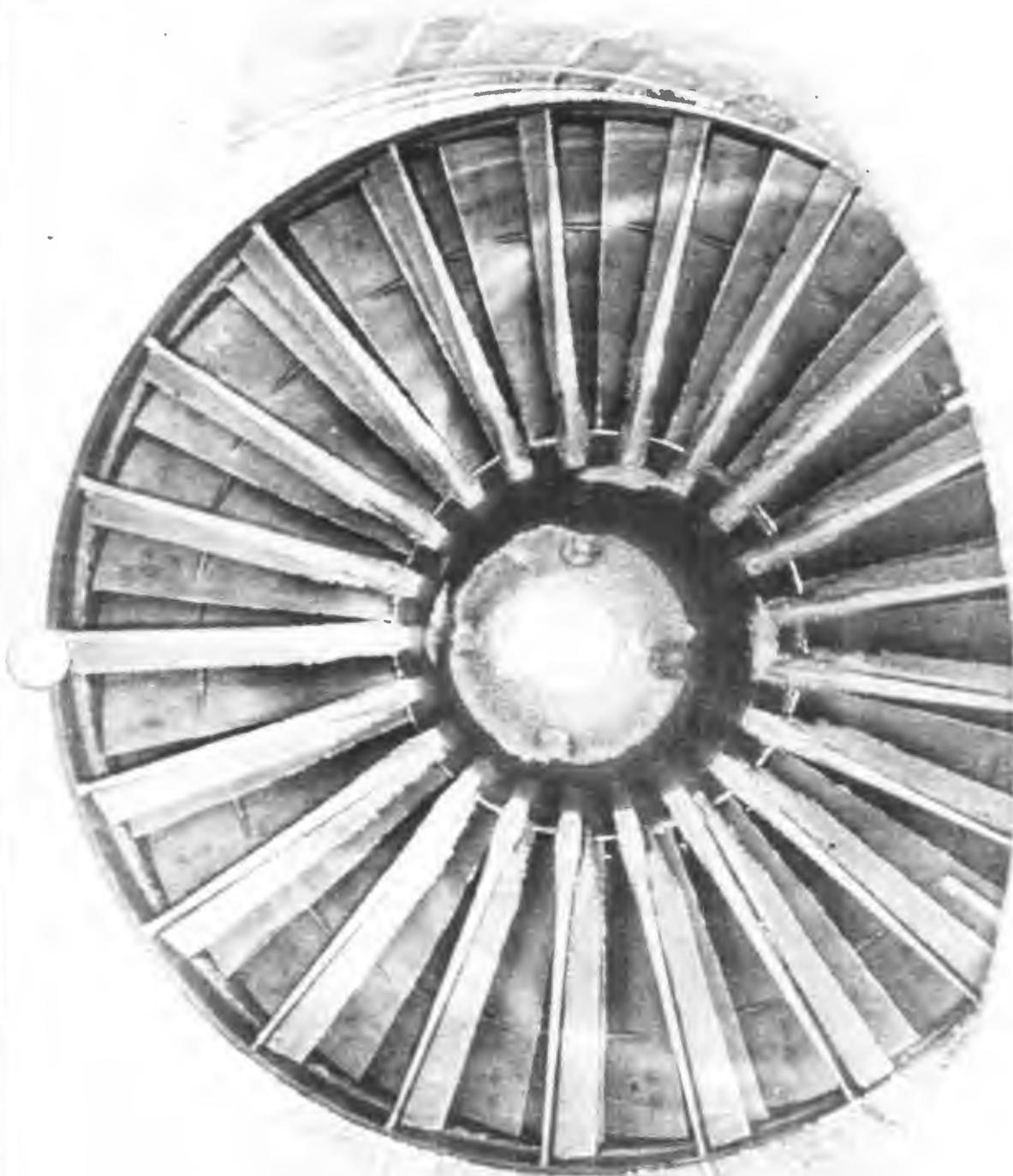


Figure 25

80-7966



Figure 26



Figure 27

80-7960

F.A.A. TECHNICAL CENTER
ATLANTIC CITY, NEW JERSEY



Figure 28

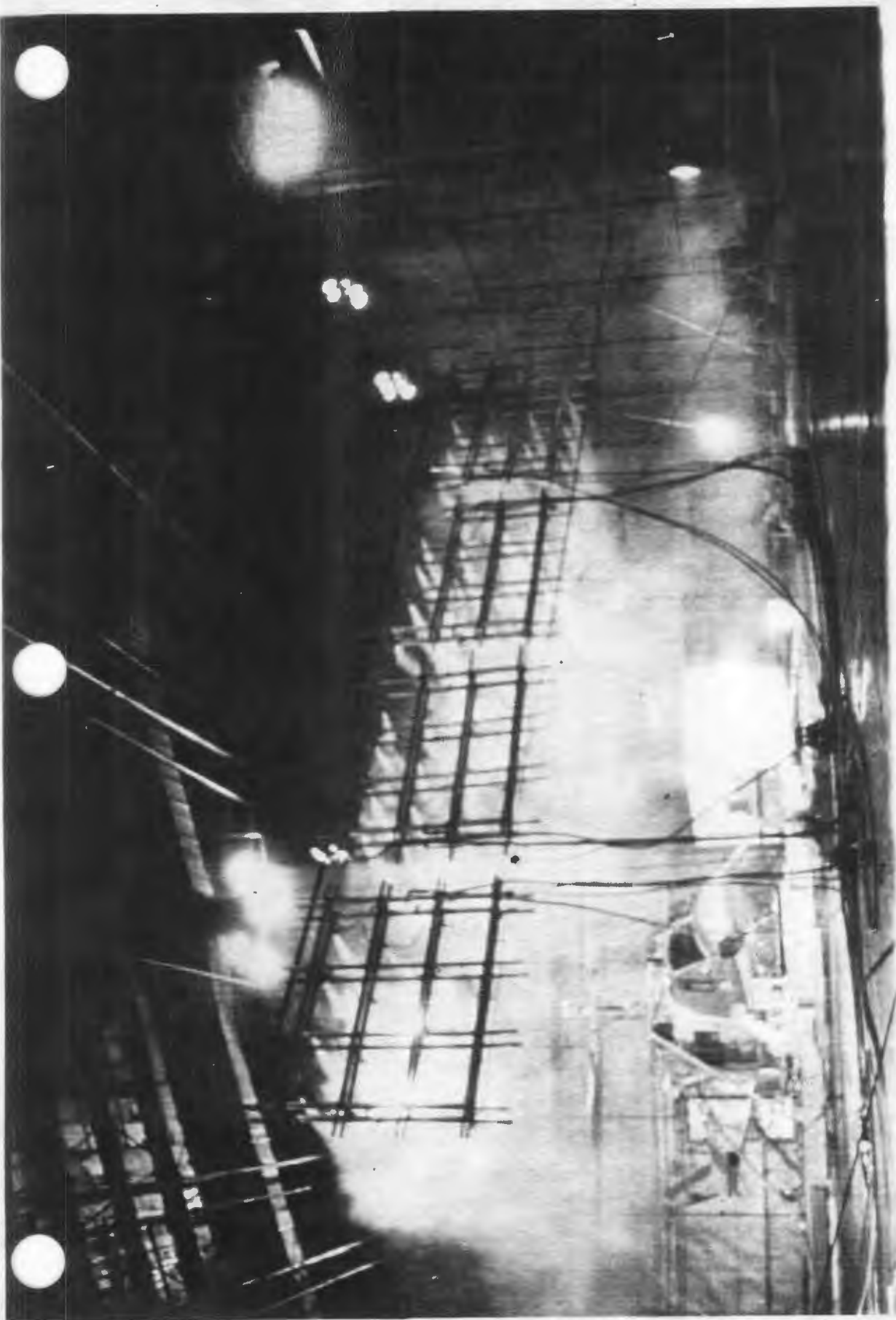


Figure 29

80-7961

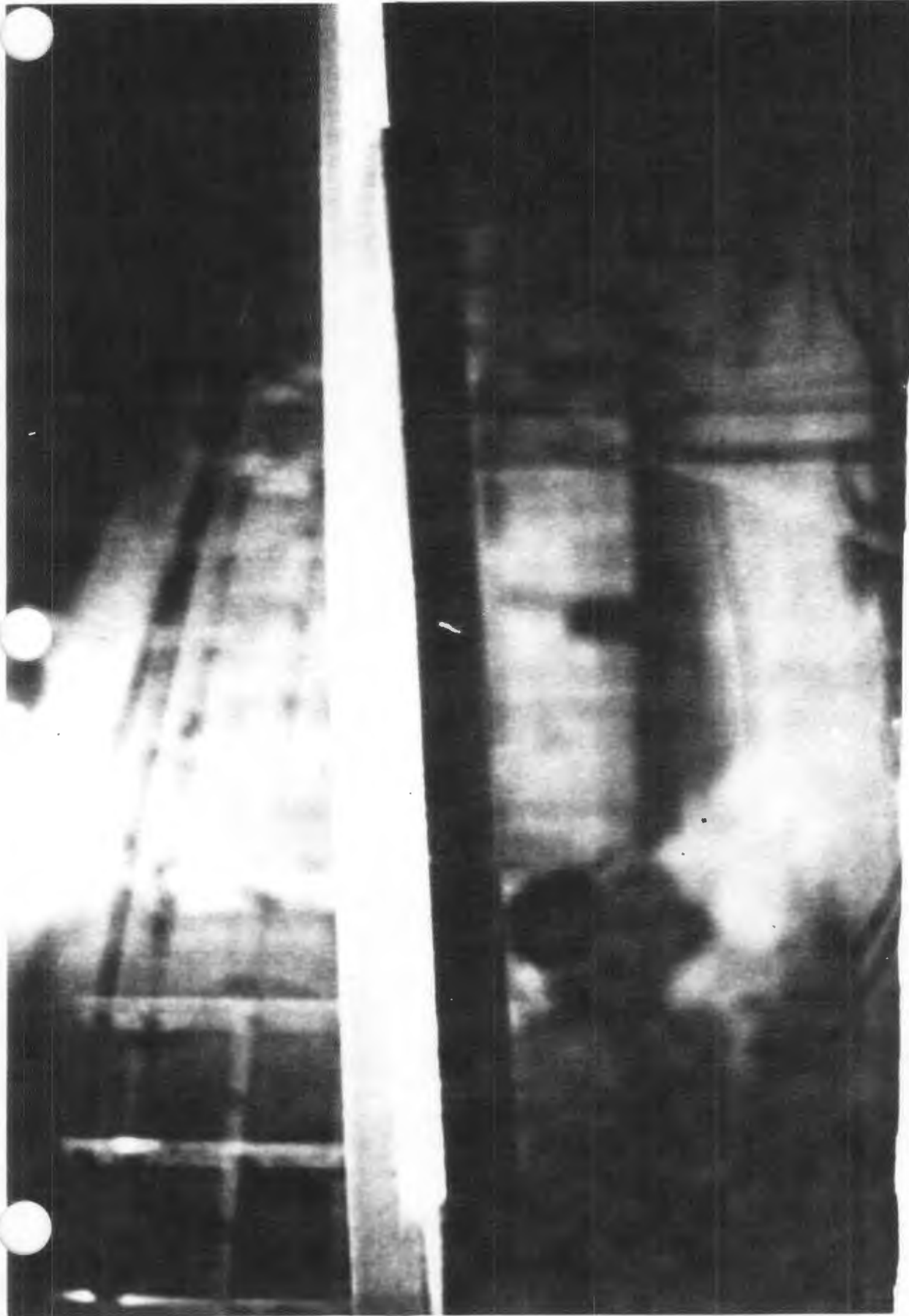
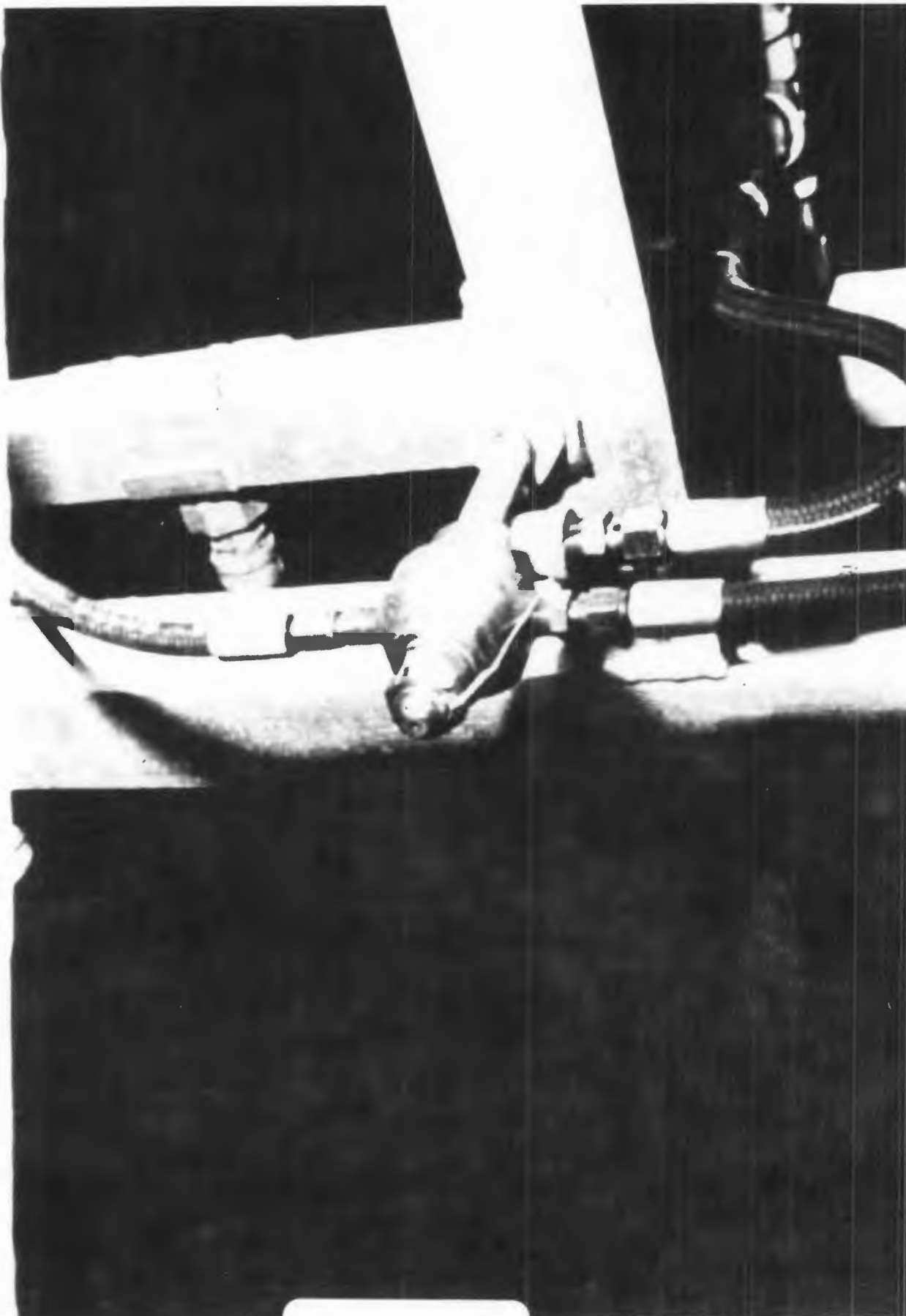


Figure 30

80 - 1946



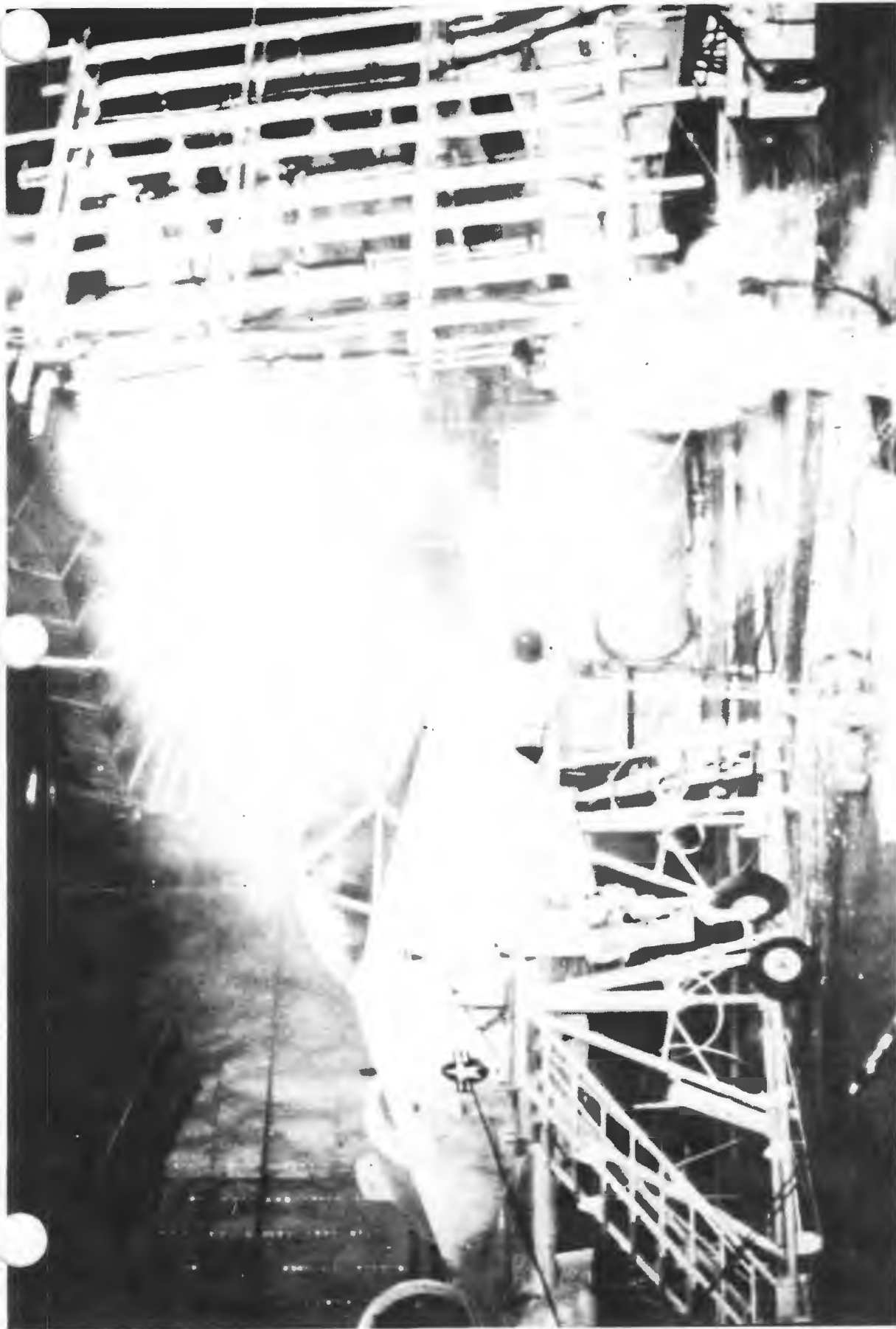


Figure 32

THE



END

Figure 33

80-7949

U.S. AIR FORCE TEST CENTER, EDWARDS AIR FORCE BASE

INTRODUCTION: RICHARD I. ADAMS

Thank you, Wayne, for a most interesting description. The next speaker is Lt. Carl Wolf from the U.S. Air Force Flight Test Center at Edwards Air Force Base and he's going to talk about the KC-135 and the C-130 tanker programs.

LT. CARL WOLF

Good afternoon. I'm going to present this briefing a little bit backwards from the normal format (Figure 1). I'm going to give you the overall history of icing at Edwards last with a semi-short seven minute film on quite a few of the programs that we have done at Edwards and some of the results we've seen. For your information, we did present, or give, copies of our slides out to the lobby there, so if you'd like before you leave, you can take them home with you.

Currently, at the Flight Test Center (Figure 2) we operate the NKC-135 icing spray tanker. This airplane has been operational since the 1950's and during the past year it's undergone several major modifications. One of these is a hygrometer for ambient humidity measurements and also a complete, not redesigned, but refitting of a nozzle array to give us a more realistic droplet distribution. In all honesty, probably as late as a year ago the median droplet diameter (MDD) of our cloud was around 100 microns. This past week we were recalibrating with the new nozzles and from the preliminary data we're up around, or down to actually, around 22 to 36 microns. Some of the other points that I wanted to talk about, one of our resources that is pretty important to our testing, is inflight photography. Again that movie's going to be a good example and from over here this isn't one of our better pictures but we do a lot of photography from the boom pod in the KC-135 (Figure 3). This particular shot is an F-18 in an icing cloud. One of the major things that we use the KC-135 for is photographing ice shedding from the forward part of the aircraft, like during a descent or approach. We'll put the ice on the airplane, move the cloud out of the way by lifting the boom, and then descend to a warmer temperature and observe the shedding from the tanker. In this case we're using Navy chase aircraft, but at the Flight Test Center, we have a whole fleet of aircraft that we use to put engineering observers in to watch the test as they progress. He watches and makes sure that the ice type is correct. He gives constant observations as to thickness.

The next slide (Figure 4) is a typical shot. This one is of an F-16 and you can see this is the old cloud. We don't have any photographs of the new ice, but it does look markedly different. We are currently doing an A-10 program and it's just amazing, as the good Captain was saying earlier, what droplet size will do to you as far as ice and how it looks. Project management, plus the Flight Test Center resources are available to anybody that wants to use them. The standard Air Force program introduction document, I can't remember the form number, will get you access to our tanker aircraft. The cost is approximately \$2500 per flight hour per aircraft. Now that would include the KC-135, if you wanted it, the T-38 or an F-4 photochase and again the engineering manpower. As regards personnel, we currently have two full time engineers working at the Flight Test Center in icing and about ten part-time engineers, who, whenever we do an active program, come out of the woodwork and come together to form a test team. The C-130 isn't built yet. Right now it's being constructed in a palletized mode. I will discuss that in a little while, and it should be operational in January or February of 1981.

LT. CARL WOLF

These (Figure 5) are some of the specifics of the NKC-135 spray system. The operating temperatures we do, on occasion, do clear ice, or as close as we can get to clear ice on the tests at approximately 0° centigrade. These are rare and far between because of the difficulty in just getting real clear ice. Most of our testing is about minus 10 to about minus 20. Liquid water content, it says there .03 to 2 grams per cubic meter, are based on the flow rate. Again we're calibrating the new nozzles, and these are based on analyses of the flow rate and the size of the cloud. Air speed for the KC-135 is 170 to 350 indicated, and the test time is one and a half to two hours. That's for an average 2000 gallon load. We can go up to 4000 gallons of water and double that test time, but we try not to because there's a problem with the aft body tanks, the water freezing in the tanker, and that can take out some of our instrumentation if anything shakes loose and goes through, like the flow meter. Droplet size, like I said, we are currently using a quarter J22 nozzle by Spray Systems. The current data we have gotten, and the final form available to you if you write to use in the not-too-distant future, is about 22 to 36 microns. Again, I mentioned, we've already got the hygrometer and one of the important things that we are coming up with is a laser ranger for accurately determining the separation distances between the tanker and the test aircraft, because just with the change in the volume of the cloud the liquid water content varies dramatically with the separation distance. The next thing that I wanted to talk to you about is our future palletized icing spray system on the C-130.

This is a three view drawing of the palletized icing spray system (Figure 6). Again we have a handout of this which is much easier for you to look at. It's composed of four water tanks with approximately 3200 gallons capacity. I was going to say that the slide over here will go with this one. These (Figure 7) are again the same spec sheet as the KC-135. You notice the liquid water content is a little higher and that's again because we're going at a slower speed. Minimum speed is going to be about 100 knots indicated up to 185, so if you'll notice this slide and that KC-135 slide, we've got the range from 100 knots, or will have the range from 100 knots, to 350 knots covered. The droplet size should be identical to the KC-135. We're using the exact same nozzle array, we'll be taking it off one aircraft and putting it on the other and it will be having the same bleed air and water flow parameters associated with it so we're expecting the calibration to remain constant between the two aircraft.

This was the design cloud for the C-130 (Figure 8) and the three graph axes there are separation distance, cloud diameter and liquid water content. The cloud diameter is based on photographic data from the KC-135. Again we'll reverify that when this actually becomes operational, and the same with the liquid water content. We tried to point out the different corners of the envelope here with our maximum water flow arrangement at minimum airspeed and then the maximum water flow and maximum airspeed, and then the next slide (Figure 9) is showing the flow rate to minimum in both cases there, with the two different airspeeds. That will give you a good idea of the capabilities of the tanker as far

LT. CARL WOLF

as what is the cloud going to be out of the C-130. I want to go over some of the major components of the C-130, just real briefly.

You saw another sheet out there called Specifications. These are just the different components we're putting together to make the palletized icing spray system (Figure 10). Its going to be completely self contained. It's constructed with the C-5 APU, so that it doesn't require the C-130 to provide any bleed to the system. It has an 8KVA generator from a T-38, as well as a T-38 gear box. We're constructing its own pressurized fuel tank.

The water tanks (Figure 11) were from the old C-130 palletized icing spray system. You'll see that in the movie. That had a lot of restrictions to it, one of them was the fact that the water tank didn't have any baffles. You had to be very careful how you maneuvered this thing in flight. They had a lot of warnings in the flight manual that you don't turn too fast or all the water is going to go aft and screw up your c.g. So we've added baffles to eliminate that problem. Water pump specs are there. The nozzle array like I said, is the spray system setup J22. And, this is just the APU instrumentation console that we use for controlling that (Figure 12).

The boom system is going to be pretty interesting (Figure 13). The whole boom will retract and roll back in and it will sit on this portion of the spray rig there, so that we can fly to our test site and return from the test site with the C-130 in the normal flying configuration. For conducting an icing test it will make it a lot easier on us and just help in making the air flow around that boom a little smoother. O.K., that's all on that one.

The icing instrumentation panel (Figure 14) will have basically the same instrumentation as on the KC-135. We're going to add a time code generator so that we can correlate onboard aircraft data with the C-130. The same modification will be made to the KC-135 and again we'll have a hygrometer installation. In this case we're using a radar ranger for the C-130 as a means of accurately measuring separation distance. Right now each time we do an icing test we take a side view photograph, and through photo analyses in measuring all the angles and everything, measure the separation distance. We try to get our best guess at it and then go back and see what we really did. That was all we had over there.

As far as testing at the Flight Test Center, it's pretty much the same advantages as any artificial or simulated icing conditions. It's a controlled condition, so that we can tell you pretty accurately what we are doing. Again we will be doing better as soon as we get our rangers installed and as soon as the calibrations are finished. Our cloud is fairly small. You'll notice the peak diameter we have there is about 22 feet at 400 foot separation distance. Much beyond that you really can't see the cloud, to know whether you're in it or not.

LT. CARL WOLF

That's about the largest separation distance we use and when you get in closer, like with the A-10, we can ice up just the nacelle or just the leading edge slat or just one particular part of the airplane and for our type of testing that's what we're looking for. We aren't really doing performance and handling qualities, haven't done any real performance and handling qualities. We do more of a systems analysis type testing. He can exit the cloud if there's a problem. We can get out of your condition and stop it, again getting rid of the ice by various means. For the Navy, the first part of the air program for the F-18 we sublimed the ice. It is quite a long process but they were very meticulous. They used the process of elimination to identify whether it's the engine that was causing FOD, you know, engine face ice or inlet lip ice, so they had to sublime the ice into various other configurations to determine that and the shedding which is our standard means of evaluating what happened to the engine as a system with ice coming into it and the last thing is the photography and we'll see a little bit more of that... in just a second. One last slide (Figure 15), here are the disadvantages. Hopefully these are both going to be eliminated with the finishing of this calibration. The droplet size, like I said, we're really working hard on that and we think we've got it down to a reasonable working size right at the moment. As far as airspeed, the KC-135 is limited, especially at high altitudes, where it has a very heavy weight with all that water. That minimum airspeed at 180 knots is something you really can get comfortably only after some of the water or some of the fuel is gone. The C-130, again, will make the lower end speed 100 knots and we just don't have any need for anything slower than that in the Air Force.

We've got a seven minute film. This is, like I said, is more of the history of inflight artificial icing tests at Edwards and we'll be going way back to days of this HH-53 and some of the other earlier aircraft.

FILM NARRATION

In 1971 the Flight Test Center was tasked with the responsibility for all weather and artificial inflight icing tests. The tests were conducted on every fixed wing aircraft that the Air Force has produced in the last 25 years. AFFTC capabilities are unique because of their speed range, their test time and altitude, test season, cloud droplets and photographic data. This program here is the HH-53 I was talking to you about before. You will see here the rotor mounted camera gives some pretty neat footage. You'll see in a lot of this, the old C-130 palletized icing spray system. You can see the cloud does not cover the entire helicopter. As a matter of fact, it covers barely 50% of the rotor while it's in the icing cloud. With the rotor mounted camera you will be able to observe the flexing of the rotor and shedding of the ice. This is some high speed film from the photo chase, which I found interesting in watching the rotor. Not being a rotary wing aircraft person I was fascinated by them. Now you can see the ice shed

LT. CARL WOLF

off the main rotor in a second here and come impact the tail rotor and that caused some subsequent shedding from the tail rotor. There it goes. You'll see some damage from that a little later. Again, you know, when we see this next scene on the ground you'll notice the ice, or excuse me, this is the rotor mounted camera here, but the ice on the aircraft is really a very bad large type droplet diameter type ice, its not what you'd consider representative of real world icing. You can see that big shed there on the screen, like I said, for the time it was good, but we're trying to be much better about icing now. There is the big hole in the rotor blade from the ice from the main rotor. We did some tests on the AWACS. They are primarily concerned with ice shedding off the radar dome and subsequently hitting the vertical stabilizer. Here is some of the ice shedding off there. Boeing told us that the radar was so powerful that it would melt any ice off of there and there was no need to do these tests, but we were not able to operate with the radar to prove that point. There's sort of an interesting shedding pattern here the way it just sort of unzips from the radar dome. There's rime ice there. Wayne was talking about the F-16 requiring a lot of work and these tests were done to provide a limited clearance for the F-16 to fly to Europe for adverse weather testing. The tests investigated canopy icing, the amounts of ingestible ice that form on the inlet lip and radar dome. In the future the F-16 is going to be operational and we will actually try to do handling qualities tests on the F-16, mostly as a result of the really thin wing that it's got. F-16 tests were done as a contractor specification compliance test. These were required to show that the aircraft could ingest a limited amount of ice and keep functioning and return to base safely. One of the unique features of this test was an inlet mounted camera that showed ice accretion and showed subsequent shedding when the engine and anti-ice was turned on. The power setting was fairly high so the anti-ice actually acted as a deicer. You can see some of the inlet lip ice here. Here's that scene I was telling you about. It was an inlet mounted camera. Capabilities for real time TV broadcast from the test aircraft is specifically being developed by the F-16 test force. You can see the sort of whitening up of the engine face as the ice accumulates on there and you will see some shedding or flaking off, disappearing. I apologize for the quality of this photograph. It is fairly old and we had to make a new master from an old print to make this movie, so we lost something in the translation. Ok, the A-10 is probably the most extensive inflight icing test we've done to date. Tests were done to evaluate wind screen anti-ice, the 30 mm gun, like Wayne was talking, air frame icing, engine icing. Tests were done here, that was a split screen showing ice, one of the other things we did had wing mounted cameras there. This test shows here the wind screen anti-icing was working fairly good and there is the gun all covered with ice, like Wayne was saying, that was subsequently fired and no problems with that. This was interesting. They were evaluating what would happen if an airplane was on an approach in penetration and ice, then had to do a go-around while he retracted the gear with the ice on it and just wouldn't make the uplocks. The uplocks would stay shut. This

LT. CARL WOLF (questions and answers)

is probably the most spectacular footage, unfortunately again it's a reprint. This is one inch of sort of semi-clear ice going down the inlet and it completely destroyed that engine, unfortunately.

Any questions? Yes?

Q. Why are you limited to -20°?

A. We aren't really limited to that, that's just been our standard end test point for rime ice testing. We can go to a colder temperature, but that's been a practice, not a fast rule. We've had no requirement to go to any other conditions.

Q. Now that you have identified a large variance in drop size between the old and the one you hope to recognize, what are you going to do about all of the old data from the other aircraft that were tested behind that tanker?

A. Well, let's put it this way. The old aircraft that were tested behind that old tanker that are operational, included the F-15, the F-16 and the A-10. All three of those aircraft have new icing programs coming up in the near future. The A-10, like I said, is going on right at this very minute with the new nozzle setup and it's been amazing the difference you can see on the icing formations. Especially, one of our major areas of concern on the A-10, was the leading edge slat and, you know, it's a nice round very gentle aerodynamic shape and that was identified in the early tests as a major source of engine FOD. During these past tests we've seen much reduced configurations of ice on the leading edge slat. The engine itself right now is currently being investigated and we're seeing similar changes and results. One of the things that we are seeing right now is a greater amount of ice on the engine spinner for some reason we haven't been able to explain that yet. The F-15, like I said, was a contractors specs of compliance there, there was no Air Force tests done. It just sort of swept away and was never done, but since the F-16 has had such a hard time in it's European ice, they have come back now to say, to redo the F-15. Probably in the middle of 1981 they will be back. What they are waiting for is some of the F-16 engine fixes, because they have a common engine, to go back and hope that they have that problem isolated and they can fix that before they do the air frame test, like the variable ramp may cause some shedding that is not a desirable quality of the airplane. So we're going to be looking at that and the F-16, again, the performance.

Q. What type of bleed air pressures do you get?

A. Oh, boy I'm trying to think, Kelly do you, off hand, remember what it is? It's in the area of 35 PSIA. That's right now what we're using.

LT. CARL WOLF (questions and answers)

- Q. Do you have any plans for increasing boom size?
- A. Not right at the moment. Its sort of an on-again, off-again discussion, but there has been no committment to increase the size of our boom. I guess you're implying to increase the size of the cloud coverage that we can do. We have not been tasked, or nobody had approached us with any requirements to do that, so the people that have been doing testing with us seem to be satisfied with what we're doing. Again, because, like on the A-10, we're doing specific components, we're looking at the Nacelle, the leading edge slat, the specific small component that we can test the F-16 the same way looking at canopy, looking at just the inlet and evaluating systems or small parts of the airplane. As far as that goes, I can see just the physical limitations of where would you stow that spray boom of water, you know like the helicopter boom is a really large span. I really think it would be difficult to stow something like that on a fixed wing aircraft for takeoff. I'm sure the task is not impossible but for stowing in the C-130 I could easily see them putting limitations of the size of the cargo holder as wide as the boom they'll let you put in it.
- Q. The second question I had related to your comment on the spinner. Have you done concurrent droplet trajectory analysis that would show that the smaller size droplets tend to become ingested, I'm sorry, with decreasing frequency as opposed to previous testing, where larger droplets may have gone by.
- A. No!
- Q. Harry White - Gates Lear Jet
- Sounds like you're going to be pretty busy with military projects having priority. Is it realistic to think that this airplane will be available for lease to the private sector?
- A. As far as both the KC-135 and C-130 or either?
- Q. Harry White - It's primarily the KC-135
- A. The KC-135 is fairly dedicated to the A-10 test, but that, in all likelihood will finish up within the next month or so. Its been a recurring program, but it seems like this last bout we've had with FODing the engine was all the program office could stand and they decided that they have enough data that they can work from that. The F-16 has been saying they are going to do inflight tests, but they haven't come up with any firm time frame that they want to do it. The same with the F-15. Right now all of next year's basically unbooked for committed time. One of the other problems with the KC-135 is it is also the Air Force Test Pilot School instrumented handling qualities aircraft. They take it up to do Dutch rolls and other maneuvers, so it's

LT. CARL WOLF (questions and answers)

dedicated probably 30% of the year to that type of testing, but we usually can do tests concurrent with them as far as they get the aircraft in the morning and we can have it in the afternoon, so, we've never really been impacted by them, but they are a consideration. As far as next year, it would look pretty good. I believe there is one of the Lockheed L400's coming up, Kelly do you have any idea when? Again, they have no firm commitment as far as a time frame goes. When we can get a firm commitment from somebody we'll schedule them, but, like I said, we have no firm commitments. There are known programs that they want to do but they aren't on the books as to when.

RICHARD I. ADAMS

I think that's a very interesting discussion. One of the things that we got into during the government coordination meeting back in January was the question of the availability of the existing government facilities. The government facilities cannot be prededicated to civil work. Government projects are going to take precedence. That's one of the key issues that we're having to wrestle with. I think that during the proceedings tomorrow we need to talk about the pros and cons of using existing government facilities and/or the need for developing facilities that industry can have access to. Good point.

ARTIFICIAL IN-FLIGHT ICING
AT THE
AIR FORCE FLIGHT TEST
CENTER

Carl Wolf
Kelly Adams
(805-277-2200)

Figure 1

AFFTC ICING TEST RESOURCES

- **NKC-135 ARTIFICIAL INFLIGHT ICING SPRAY TANKER**
- **C-130 PALLETIZED ICING SPRAY SYSTEM**
- **IN-FLIGHT PHOTOGRAPHY**
- **PROJECT MANAGEMENT**
- **PERSONNEL**

Figure 2

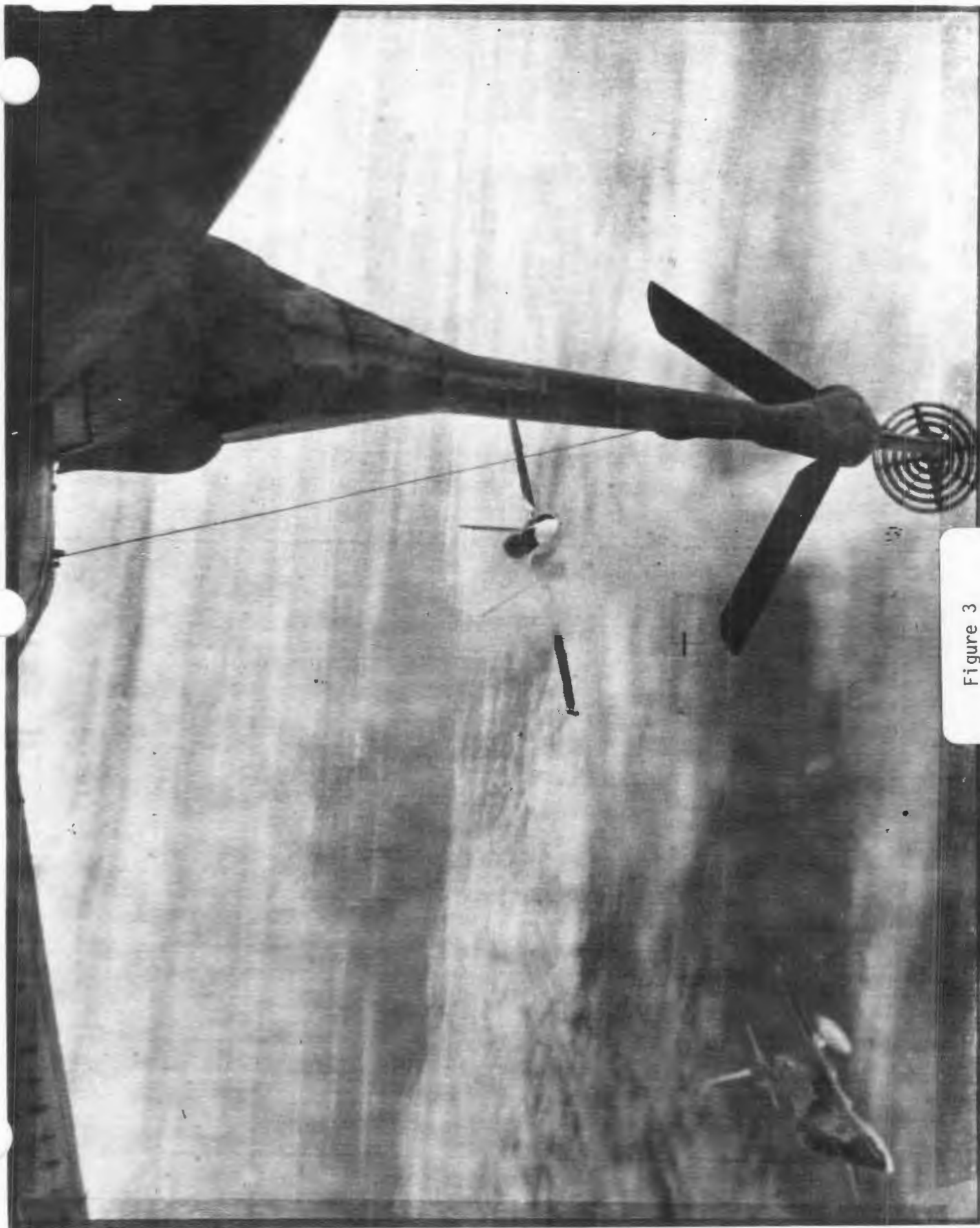


Figure 3



Figure 4

NKC-135

ARTIFICIAL IN-FLIGHT ICING AND RAIN CAPABILITY

- AIRSPEED _____ 170 TO 350 KIAS
- TEMPERATURE _____ +10 TO -20 DEGREES C
- LIQUID WATER CONTENT
 - ICING _____ 0.03 TO 2.0 GRAMS/CUBIC METER
 - RAIN _____ 2 TO 35 GRAMS/CUBIC METER
 (1.9 TO 32 IN/HR)
 (.02 TO 4.8% WATER-TO-AIR RATIO)
- TEST TIME _____ 1.5 TO 2.0 HOURS
- DROPLET SIZES

	GOAL	ACTUAL
● ICING _____	20 μ	
● RAIN _____	1000-1500 μ	

Figure 5

C-130

PALLETIZED ICING SPRAY SYSTEM DESIGN CAPABILITY

● AIRSPEED _____ 100 TO 185 KIAS

TEMPERATURE _____ +10 TO -20 DEGREES C

● LIQUID WATER CONTENT

• ICING _____ 0.05 TO 3.0 GRAMS

• RAIN _____ 2 TO 35 GRAMS PER CUBIC METER

(1.9 TO 32 IN/HR)

(0.02 TO 4.8% WATER-TO-AIR RATIO)

● TEST TIME _____ 3.0 TO 3.5 HOURS

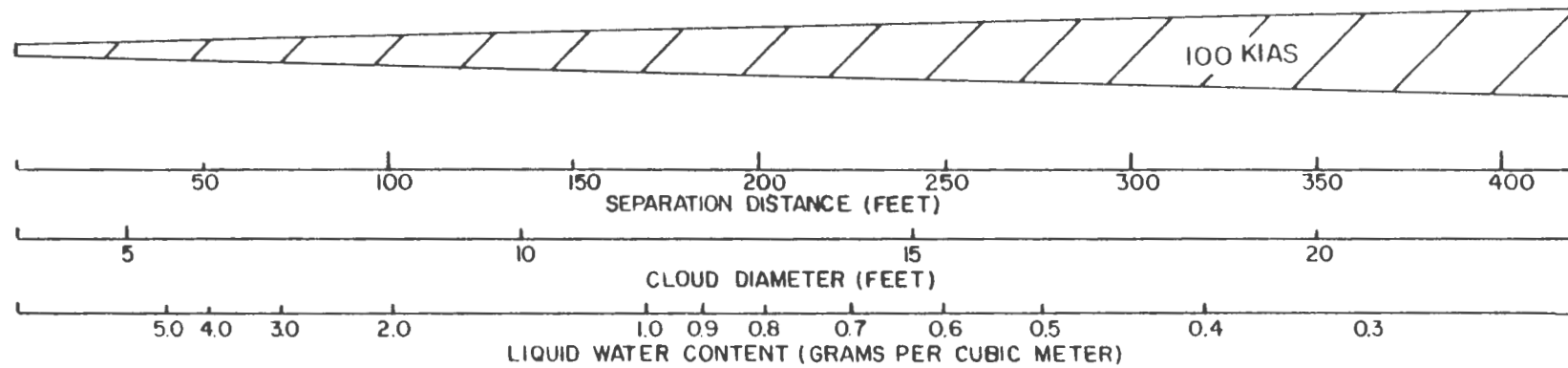
● DROPLET SIZES

	GOAL	ACTUAL
• ICING _____	20 μ	
• RAIN _____	1000-1500 μ	

Figure 7

C-130 PALLETIZED ICING-SPRAY SYSTEM DESIGN CLOUD

(MAXIMUM WATER FLOW RATE, MINIMUM AIRSPEED)



(MAXIMUM WATER FLOW RATE, MAXIMUM AIRSPEED)

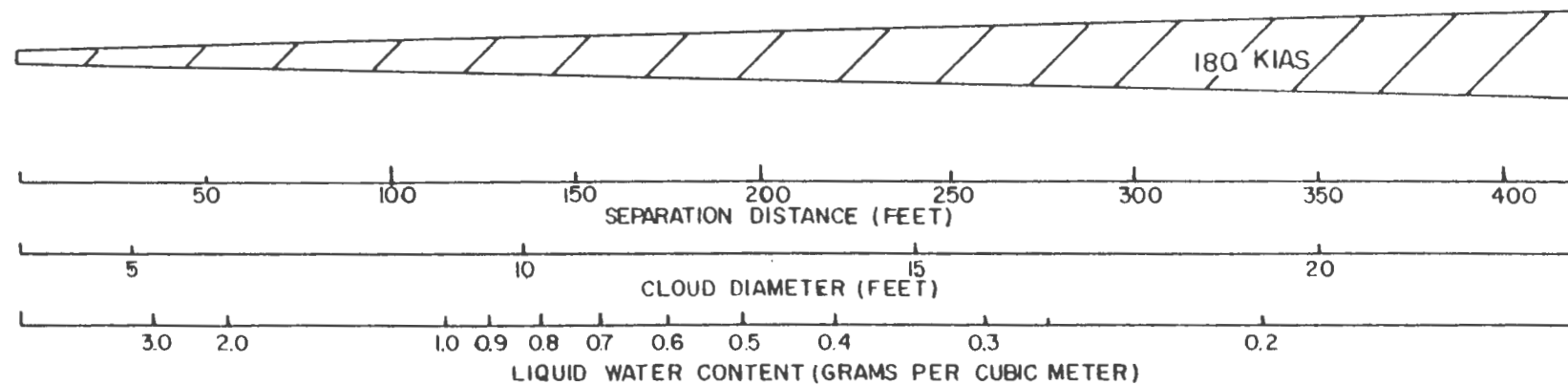
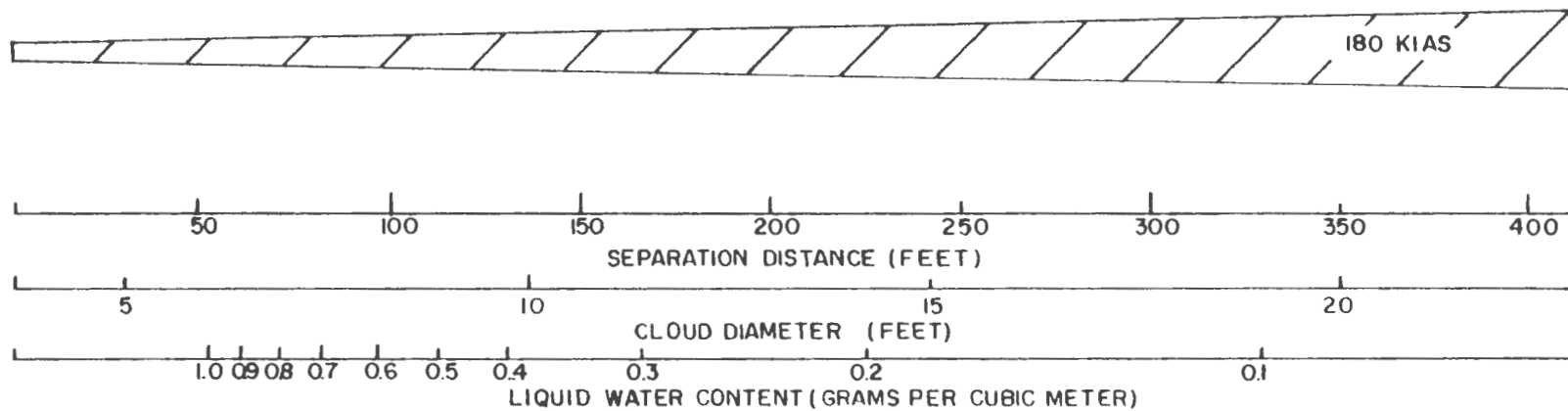


Figure 8

C-130 PALLETIZED ICING SPRAY SYSTEM DESIGN CLOUD

(MAXIMUM AIRSPEED, MINIMUM WATER FLOW RATE)



(MINIMUM AIRSPEED, MINIMUM WATER FLOW RATE)

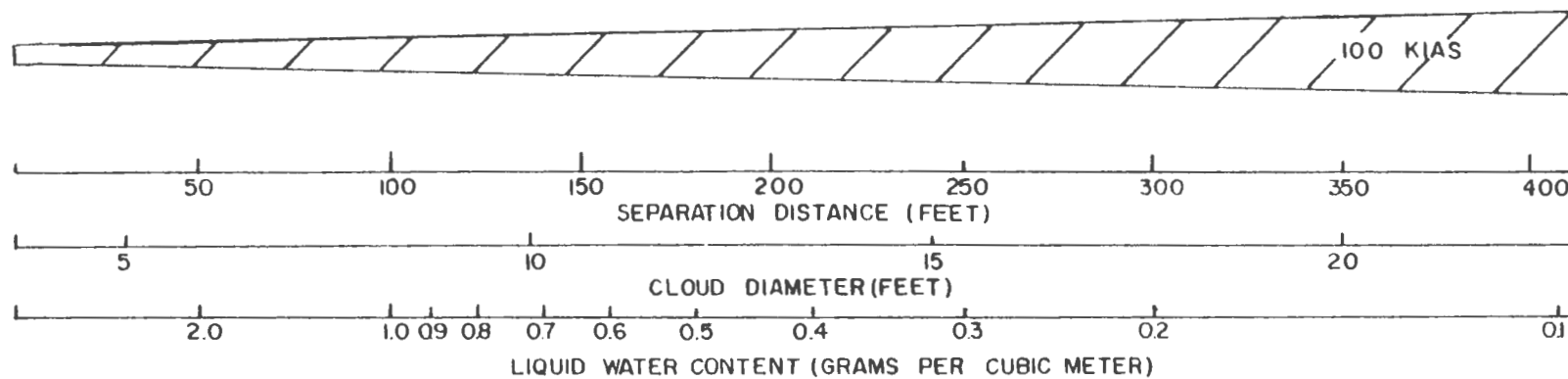


Figure 9

SPECIFICATIONS

C-5A AUXILLARY POWER UNIT (APU)

- o 128 SHAFT H.P. @ 8000 RPM
- o 107 LB/MIN BLEED AIR FLOW @ 58 PSIA
- o PROVIDES FOR A SELF-CONTAINED SYSTEM

OPERATES: T-38 GEARBOX WITH REVERSED INPUT SHAFT

- o T-38 8.0 KVA GENERATOR
- o 16 GPM VARIABLE VOLUME PRESSURE COMPENSATED HYDRAULIC PUMP

FUEL TANK

- o CRASH RESISTANT BLADDER TYPE
- o APPROX. 60 GALLONS INSTALLED (1½-2 HRS MIN.)
- o PRESSURIZED NATURALLY TO ELIMINATE HAZARDOUS VENTING

Figure 10

WATER TANKS

- o BENSON/GOODYEAR 830 GALLON CAPACITY 4 EACH MODIFIED WITH BAFFLES
- o KC-97 TANK PALLET ASSEMBLY
- o 3320 GALLONS TOTAL, GRAVITY FEED

WATER PUMP

- o ALLIS-CHALMERS 7 $\frac{1}{4}$ " CENTRIFUGAL IMPELLOR TYPE
- o 60 GPM @ 185 FT-HEAD (80 PSIA)
- o HYDRAULIC MOTOR DRIVEN, ELECTRO-HYDRAULICALLY FLOW CONTROLLED

NOZZLE ARRAY

- o 5 CONCENTRIC CIRCULAR MANIFOLDS 44" O.D.
- o 49 SPRAYING SYSTEMS $\frac{1}{4}$ J-SETUP 22 NOZZLES
 - o AIR ATOMIZATION
 - o GEOMETRICAL SHEAR AND MIXING
- o 51 BLEED AIR PARTS FOR ANTI-ICING

W

Figure 11

APU INSTRUMENTATION CONSOLE

- o KC-135 NAVIGATOR SEAT
- o SUITABLE INSTRUMENTATION FOR INFLIGHT AND GROUND OPERATION AND DIAGNOSIS
- o RADIO INSTALLATION FOR TEST MONITORING
- o OXYGEN EQUIPPED

Figure 12

BOOM SYSTEM

- o PERMITS CLOSURE AND PRESSURIZATION OF CARGO COMPARTMENT FOR TRANSIT TO TEST LOCATION AND ALTITUDE
- o MINIMUM STORAGE SPACE REQUIRED
- o NO AIRCRAFT MODIFICATIONS REQUIRED
- o HYDRAULICALLY POWERED CHAIN DRIVE TELESCOPING TUBE SYSTEM, ROLLER GUIDED
- o TRAVELING BOOM SUPPORT PALLET
 - o BLEED AIR TUBE POSITIONING
 - o LINEAR BEARING GUIDED
 - o ACTS AS WALKING TUBE SYSTEM SPACER
- o HYDRAULICALLY POSITIONED RIGID BOOM

ICING ENGINEER INSTRUMENTATION CONSOLE

- o KC-135 NAVIGATOR SEAT
- o RADIO INSTALLATION FOR TEST MONITORING
- o OXYGEN EQUIPPED
- o BOOM CONTROLS
- o TIME CODE GENERATOR AND DISPLAY
- o AN/APN-209 RADAR RANGER
- o 8-POSITION STRIP CHART RECORDER
 - o BLEED AIR CONTROLS
 - o BLEED AIR PRESSURE (TOP AND BOTTOM OF ARRAY)
 - o BLEED AIR FLOWRATE
 - o BLEED AIR TEMPERATURE (@ NOZZLE ARRAY)
 - o WATER FLOW CONTROLS
 - o WATER PRESSURE (TOP AND BOTTOM OF ARRAY)
 - o WATER TEMPERATURE (@ NOZZLE ARRAY)
 - o WATER FLOW RATE
 - o WATER QUANTITY REMAINING

Figure 14

DISADVANTAGES

- **DROPLET SIZES**
- **AIRSPEED**

U.S. AIR FORCE TULLAHOMA FACILITIES

INTRODUCTION: RICHARD I. ADAMS

The next speaker is Jay Hunt from the Tullahoma Facilities.
Jay, come on up and tell us about those tunnels.

JAY HUNT

As you see here (Figure 1) the company I work for is ARO Incorporated. We're a division of the Sverdrup Corporation. We are the prime contractors at the Arnold Engineering Development Center, AEDC, in Tullahoma and this is an Air Force Facility. That evidently is one of the world's best kept secrets. Not too many people know about this facility, but its an extremely large facility. It's divided into three working groups, the engine test facility, the pilot wind tunnel facility, and the Von Karman facility and each have a particular mission as noted by their names. The engine test facility, of which I'm a member, is dedicated to the testing of the power plants for the Air Force in the altitude test tunnel. So what I would like to do, is first of all, explain to you exactly how we test for icing at the AEDC, then give a rundown on some of the research work that I've done over the last 5 years in icing and icing instrumentation. So, if we can have the next slide we'll proceed.

This (Figure 2) is a schematic of the direct connect propulsion engine altitude tunnel. The water is injected up stream of the bell-mouth and then the photograph goes from left to right. We have shown here (Figure 3) is a hologram, a holographic phase where we use a holo-camera to determine the droplet size prior to going into the engine inlet. Now this is somewhat out dated, we've change the procedure somewhat, but I'll go along and explain it in more detail. The purpose then is to test the engine for icing, then test the anti-ice and de-ice capabilities of the inlet.

These are the military standards that we normally test to, (Figure 4) and of course we try to provide the capabilities to meet any standards that are issued by the user.

This is the air supply and exhaust capabilities (Figure 5) for the two different test cell configurations that we have at the AEDC. One is called the T cell, which are the smaller test cells, and the J cells are the largest test cells. As you can see we have pretty good capabilities, going up to around 600 kilograms per second air-flow.

In the next slide (Figure 6) we have the temperature capabilities. By-the-way, there are about 25 copies of the AGARD paper that we can go over outside here, but in the paper I state that we can meet the capabilities for testing for icing up to 400 kilograms per second, maximum sea level static airflow, but this is not quite true. This is a little bit optimistic and I need to point that out. Recently we've been testing to around 750-800 pounds per second and that's probably more accurate than the 400 kilograms per second that I said earlier.

The next two slides have the spray bar configurations (Figure 7). We're using a one quarter J-26B spraying system nozzle, and also in the next slide (Figure 8) is another configuration that we also use. The interesting thing here is that the bellmouth diameter and the duct

JAY HUNT

diameter are shown in the phantom lines. Now we placed our nozzles in between this and the reason is, that we find we get a nice even distribution of the droplets at the engine face when we do this. If we try to put the nozzles, say, on the center line and use a large number of the spray nozzles across the bellmount, we found that we end up with streaked flow and we determined that by using either a fan laser or a water mesh right at the inlet to the engine prior to testing the engine.

This shows the response of the system (Figure 9) that we have and this was done in tests on the F-101 engine for which Dick Keller was the SPO. Again, this is not exactly typical, we have changed our water spray system now and are in the process of changing the system and we do have the capabilities to equal, if not better, these response times.

This is an earlier calibration of the one-quarter J-28B spraying system nozzle (Figure 10) that was done in the large test cell itself. A holo-camera was used to find a single data point. Now, for this a number of, in the order of 200 to 400, droplets were counted per hologram. This took, on the average, four and a half hours per hologram to reduce the data so we early on recognized that this is not the way to perform an icing test.

This is a typical installation (Figure 11) in front of the helicopter inlet of the test that was run sometime in the mid-70s showing our holo-camera with the mechanical light stops that we have in it, so that we could translate these across the icing flow and determine the particle size and number density across the flow in front of the inlet.

This, of course, is the schematic of the hologram reconstruction (Figure 12). Each one of these has to be reconstructed and the holo-camera, or the hologram has to be counted, not only in the next XY planes, but also in the Z planes, through the hologram itself. This three dimensional information is nice but extracting information is almost impossible. It takes an inordinate amount of time and there is a certain amount of subjectivity to counting these droplets, so we were trying to get away from this. We instituted a research program to look at different particle sizing and systems, so that we could find an in situ measurement system to give us a realtime or nearly realtime data analyses with a direct readout. To do this, we built a subscale icing facility which simulates, in the acceleration mode, the larger test cells that we have. We use a single nozzle injection at the water injection plane and then we install our instruments at the measuring plane. Now, if you'll notice, the plenum chamber is mounted on casters and rides on rails so that we can take the interconnecting ducting and move it to the out or the inlet side of the plenum chamber and change the distance between the water injection plane and the measuring plane without moving our instrumentation system. Once we have aligned our

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instruments, we are assured that they stay aligned. Now, we wanted to use this as an icing facility. This is a full scale facility which we can very accurately, now, know our droplet size, our liquid water contents and so forth, for the inlet conditions to the water injection nozzle.

This is a range of the capabilities that we have (Figure 13) and as you see we can go up to a Mach number of about seven tenths. This is the highest Mach number that we can get and we really can't get this at the static sea level conditions. That's a little bit too optimistic, but at the higher altitudes we have no problem. We are primarily hampered by the amount of cooling that we can get and it's pressure limited. We're using a glycol cooler and the pressure limitations have us snookered here.

Now, we wanted to calibrate this time (Figure 14) so we used the hologram to determine the particle size and number density for various conditions and we also wanted to insure we were indeed getting out of the subscale tunnel what we thought we were. So we went to great lengths to calibrate this with the hologram. This is a typical histogram we got with the hologram.

And again we take the data and we do magic things with it and Nukiamo-Thamasado plot (Figure 15) or primarily what we were looking for was some type of mathematical representation for the distributions that we got so that we could use them to extrapolate or use them to correlate quite a bit of data because we were expecting to acquire quite a bit of data on this system.

In the next slide (Figure 16) we show that this is the data of the Rytan that for this particular icing cell and for our quarter J-26B we do have a fair comparison of the artificial and natural icing conditions.

The next slide we're showing (Figure 17) is a holographic distribution of the droplet going across the test cell. In this you'll notice there are variations, but we found by doing a quick taping of the hologram right after that in rapid succession that this was a temporal variation and not a spatial variation, by comparing the outputs from the holograms. In the next slide (Figure 18) this is the calculated from a computer code that was developed at AEDC. We found that in trying to determine liquid water content, to make it correspond to measured liquid water content, that we have had absolutely no success. That's been reported by others using the liquid water content meters. The problem has been that as we vary our speeds and as we change our altitude we tend to wander all over the map. So it was wondered, well can we indeed determine the liquid water content by using the holo-camera. From this you can see that the holo-camera results are all biased, they are all above the line, there's no random scatter of the

JAY HUNT

data above and below the line, so consequently, we found that we had, though, about a 10-24% variation and we decided no, that counting droplets on a single basis is not the way to arrive at the liquid water content.

In the same vein we wanted to determine the particle velocity, so we measured, very carefully, with a pitot tube, the air velocity prior to the injection of droplets and we double pulsed the holo-camera and this is the results that we get (Figure 19). You see that there is a tendency here but again we are talking about the variations of the particle speed over the pitot tube speed and I really can't answer why it appears to be going faster, but this is the results that we acquired. And we say, "yea, we can" but this is very difficult to do. The imagery from the double hologram is very hazy, and we're not at all sure what we're getting, so that's a very difficult trick to do. Then we went to different instrumentation systems.

This is a typical installation of the holo-camera (Figure 20) we used in the icing research cell. Now we had no proof, in other words, we did not know what size droplets we were producing, consequently we had to manufacture our proof, so we took the holo-camera to get our proof. So we wanted to compare all of our other devices to this and in doing this the first device we tried is a fiber optics particle sizing system (Figure 21). Now this is nothing more than a Nollenberg probe. It works on the array principle, in which, as the droplets pass through they cast shadows on the linear array. In this case, there are fiber optics that go back to photomultiplier tubes rather than diodes. Now, the beauty of this over the present configuration of the Nollenberg probe, is that it is not a probe. We expanded across a 40 foot diameter and only the laser beam interacts with the droplet field, so we do have a in situ measurement. We found that this device correlated quite well, extremely well. We got a coefficient of a fit using the least squares fit, a coefficient of about .998, which is an extremely good fit. Now, in calibrating this nozzle, we decided the thing to do was to use this device, since it's a realtime, or nearly realtime device and it's a direct readout so we can read this directly in the control room, so we've been using this device to give us all the necessary information that we want about the cloud.

We then tried a particle sizing interferometer (Figure 22) and this is the device that Wayne mentioned earlier and the current signature is down at the bottom, where the AC ripple is on top of the DC and by ratioing these through electronic means one can determine the particle size over a wide range. But, it turns out in using this device, and the high number density string that we have, we were swamping the signals. We were just getting too many signals coming through, so in the method that this is shown, which is in the on-axis forward scatter mode, we could not use this particular device. Later we went off axis by about 15° and we did get fairly good results. However, in doing so we had

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other problems, such that we could not get a direct comparison with our other devices. We're still somewhat optimistic about using this, but its not quite as much so as we were originally. Originally we thought that this would be the device of our choice and we tried to separate types, I might add, and the only difference in it was in the electronics and the method in which the visibility, the AC test, the DC ratio was formed and some of the optics were different.

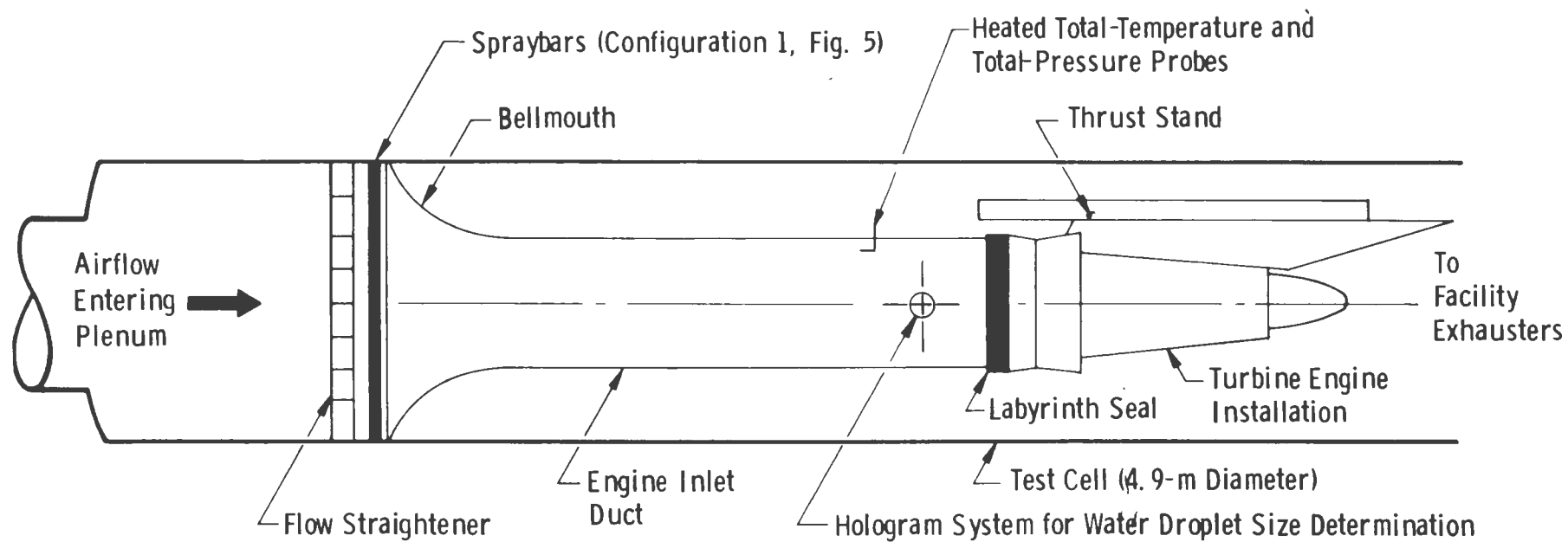
We also tried a light scattering particle sizing system (Figure 23) in which a back scatter probe was used and this used a small infrared diode laser and we had absolutely no results whatsoever with this. This was one of the probes that measured the same droplet size regardless of what you did. We even went to the trouble of putting a monodisperse generator in front of it at several different particle sizes and each particle size was always registered as 8 microns, so we had more or less deleted this from our arsenal of methods of measuring droplets. This last slide (Figure 24) pretty well summarizes the test facilities capability and the work we have done, except our future work which has involvement with NASA at Lewis. We are doing ice accretion tests, scaling law tests with the people at NASA. We are doing high speed and subscale work, they are doing the low speed, larger scaled work and we are making comparisons of the type of scaling we acquire from that. We presently at the AEDC are involved in the alpm icing in which the inlet of the alpm is being tested, much the same as Vito showed earlier. We weren't quite as lucky as they were. We had completely clobbered three fan blades with ice accretion and this was in getting engineering data, by-the-way, to determine how well the engine inlet configuration would shed ice. Well, it sheds it, but it sheds it in the wrong direction. This is one of the things that we found out. So we're still quite active in icing and we've got a pretty good research program leveled out for the next two or three years. And there is, by-the-way, a document, AEDC TR 80-33, in which all of the icing instrumentation that we have done at AEDC is summarized and all of the results were given, and if anyone has any other questions, I will be happy to answer them. Thank you!

ENGINE ICING MEASUREMENT CAPABILITIES AT THE AEDC

Jay D. Hunt

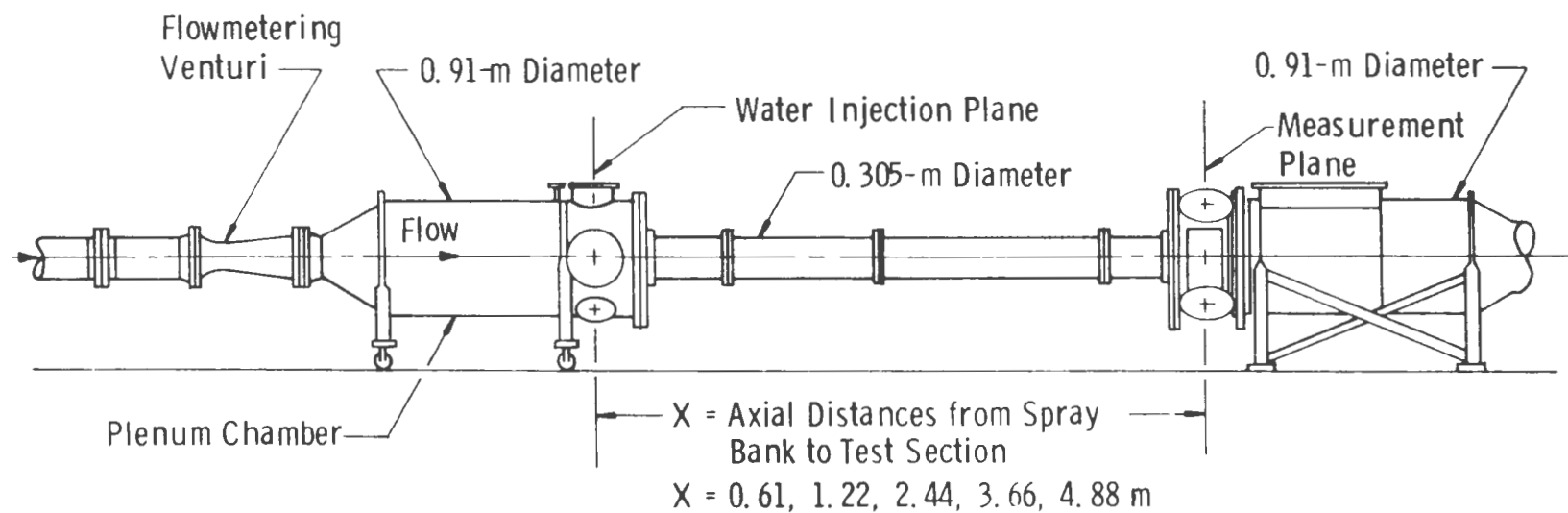
Sverdrup/ARO, Inc., AEDC Division

Arnold Air Force Station, Tennessee



DIRECT-CONNECT PROPULSION ENGINE ALTITUDE ICING TEST CELL CONFIGURATION

Figure 2



ICING RESEARCH TEST CELL

Figure 3

ICING CONDITIONS SPECIFIED IN THE MILITARY SPECIFICATIONS FOR TURBOJET AND TURBOFAN TESTING

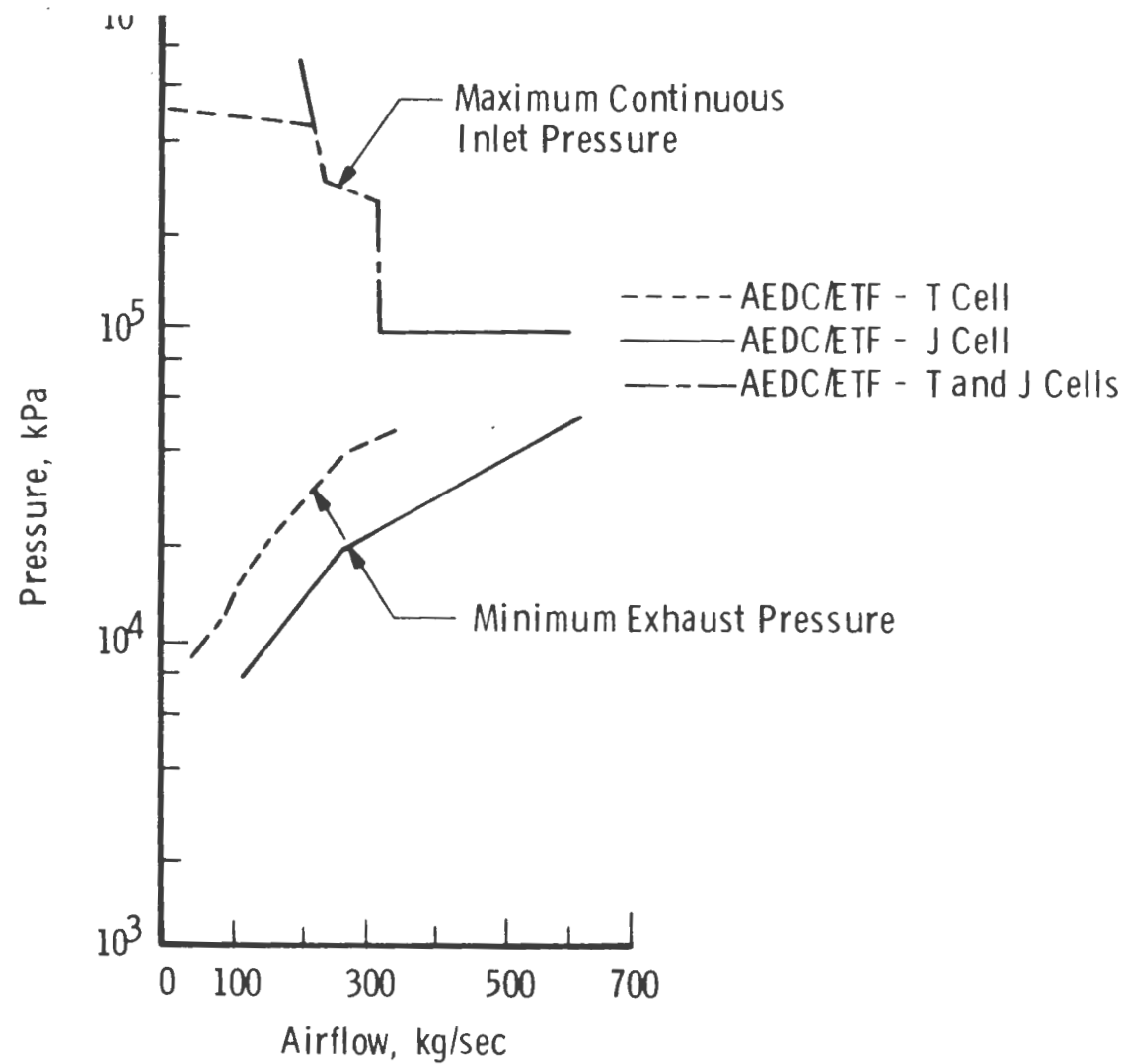
I. Sea-Level Anti-Icing Conditions

<u>Attribute</u>	<u>Condition I</u>	<u>Condition II</u>
Liquid Water Content	1 gm/m ³	2 gm/m ³
Atmospheric Air Temperature	-20°C (-4°F)	-5°C (+23°F)
Flight Velocity	Static	Static
Altitude	Sea Level	Sea Level
Mean Effective Drop Diameter	15 μm	25 μm

II. Altitude Anti-Icing Conditions

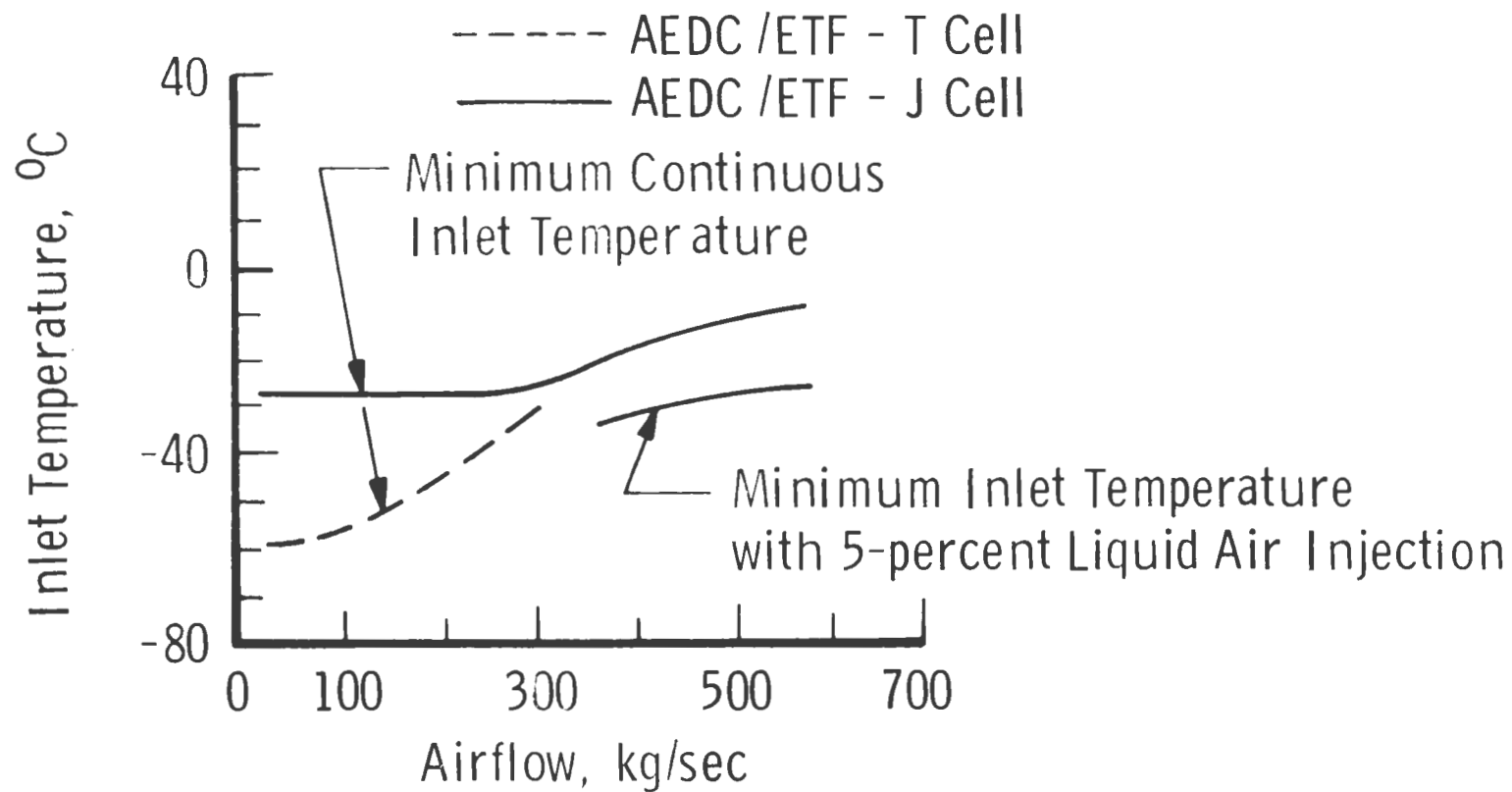
<u>Attribute</u>	<u>Condition I</u>	<u>Condition II</u>
Liquid Water Content	0.5 gm/m ³	0.5 gm/m ³
Atmospheric Air Temperature	-20°C (-4°F)	-20°C (-4°F)
Flight Velocity (Mach No.)	0.32	0.71
Altitude	6,100 m (20,000 ft)	6,100 m (20,000 ft)
Mean Effective Drop Diameter	15 μm	15 μm

Figure 4



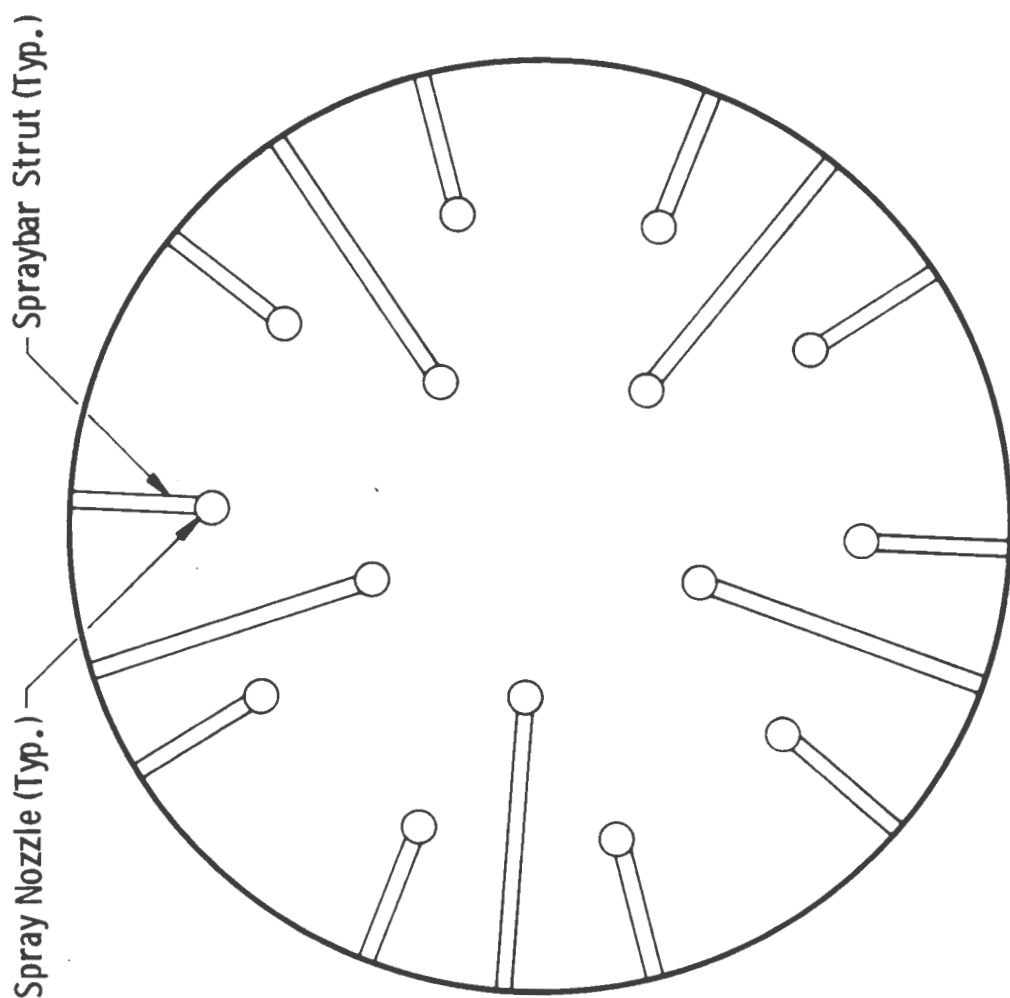
a. AIR SUPPLY AND EXHAUSTER CAPABILITY
FACILITY PERFORMANCE CAPABILITY

Figure 5



b. ESTIMATED INLET AIR TEMPERATURE CAPABILITY
FACILITY PERFORMANCE CAPABILITY

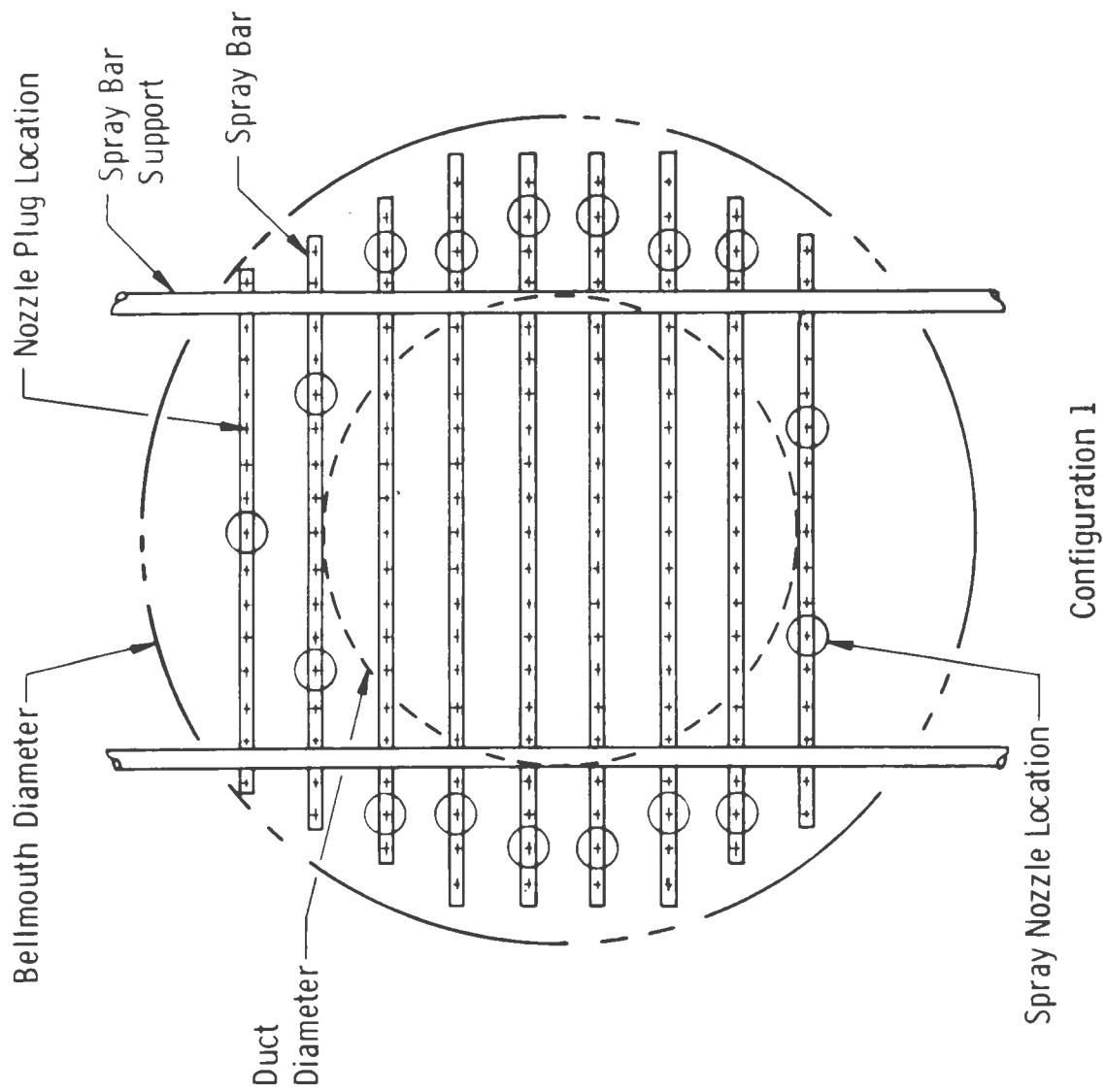
Figure 6



Configuration 2

WATER SPRAY MANIFOLD SYSTEM

Figure 7



WATER SPRAY MANIFOLD SYSTEM

Figure 8

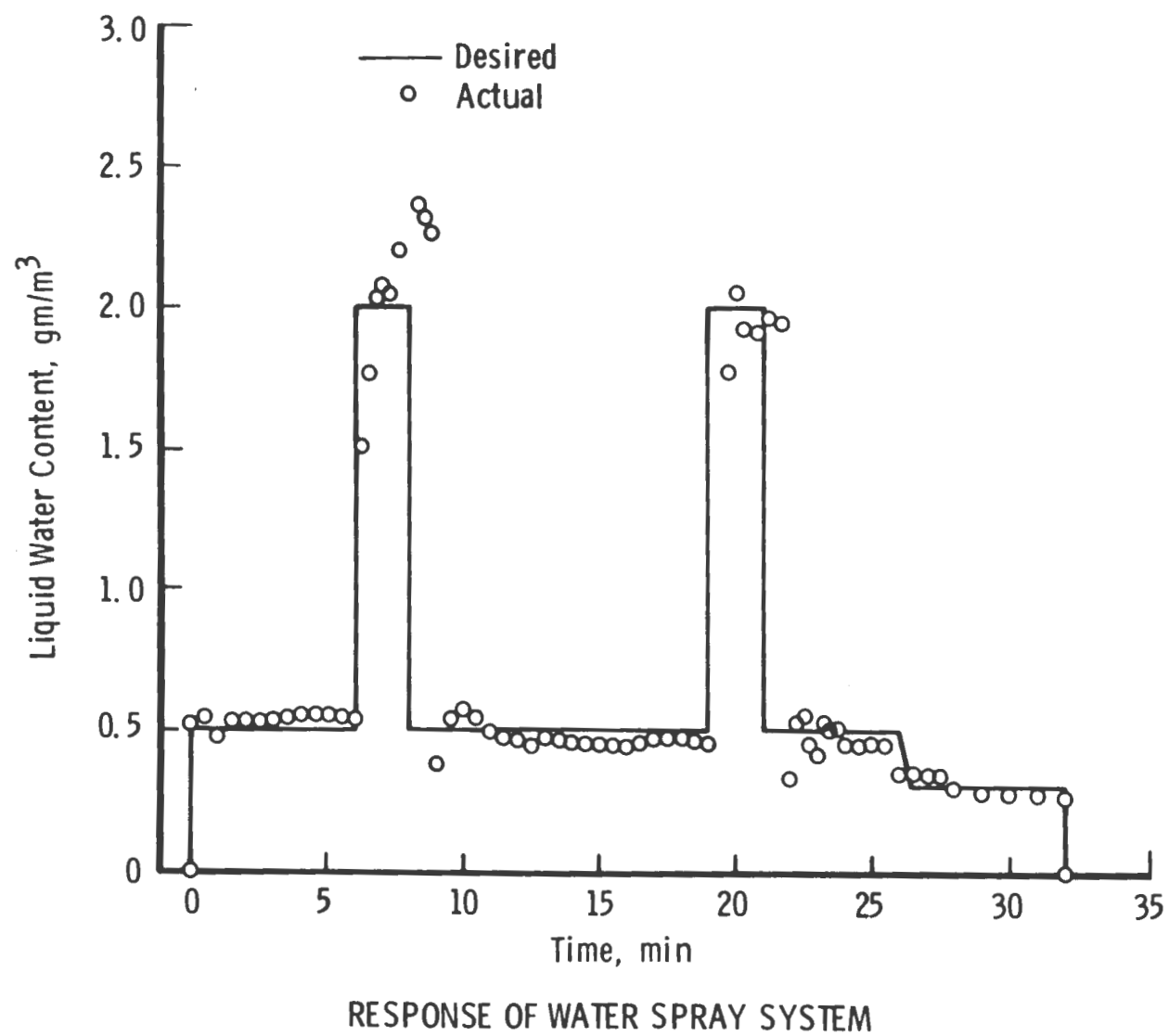
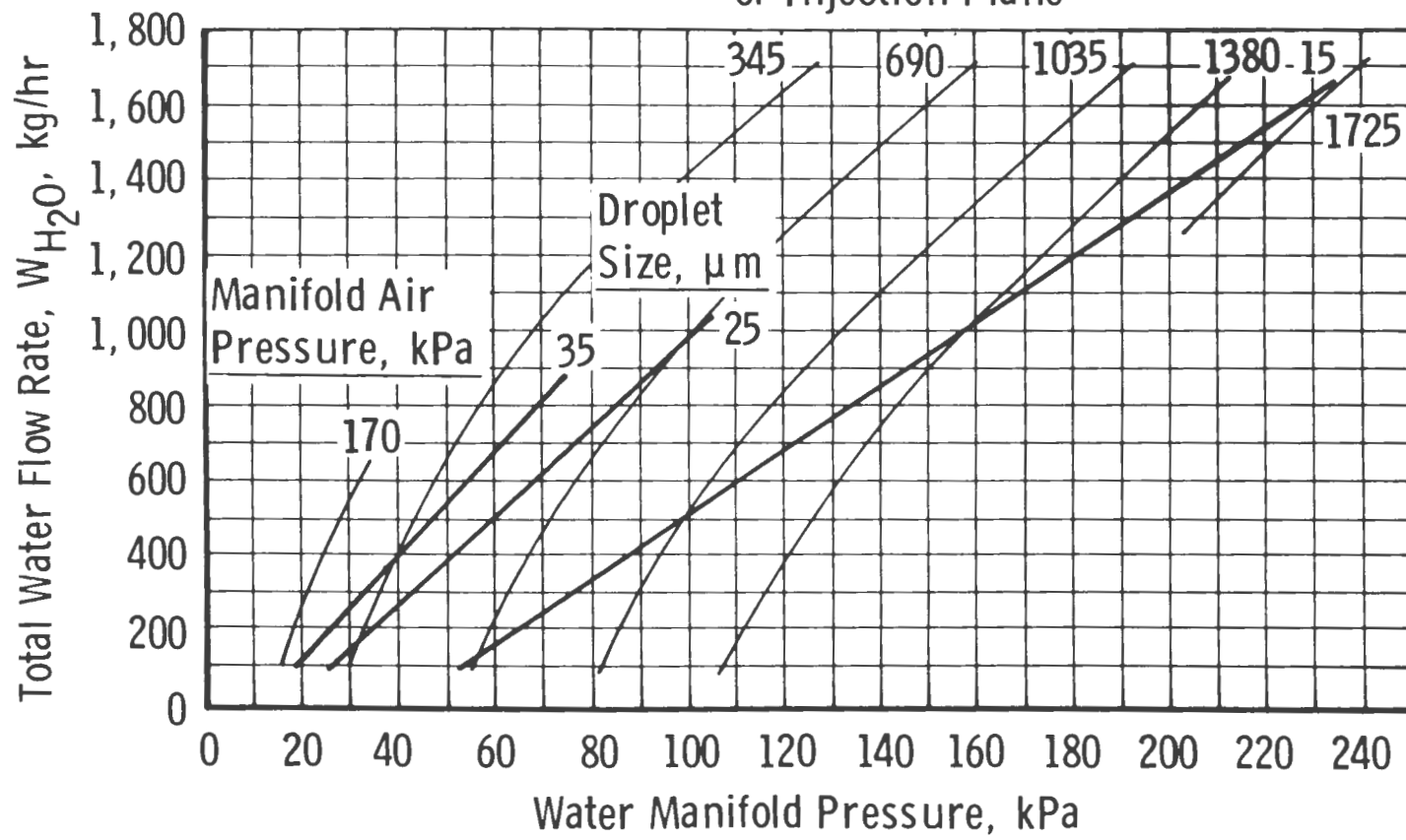


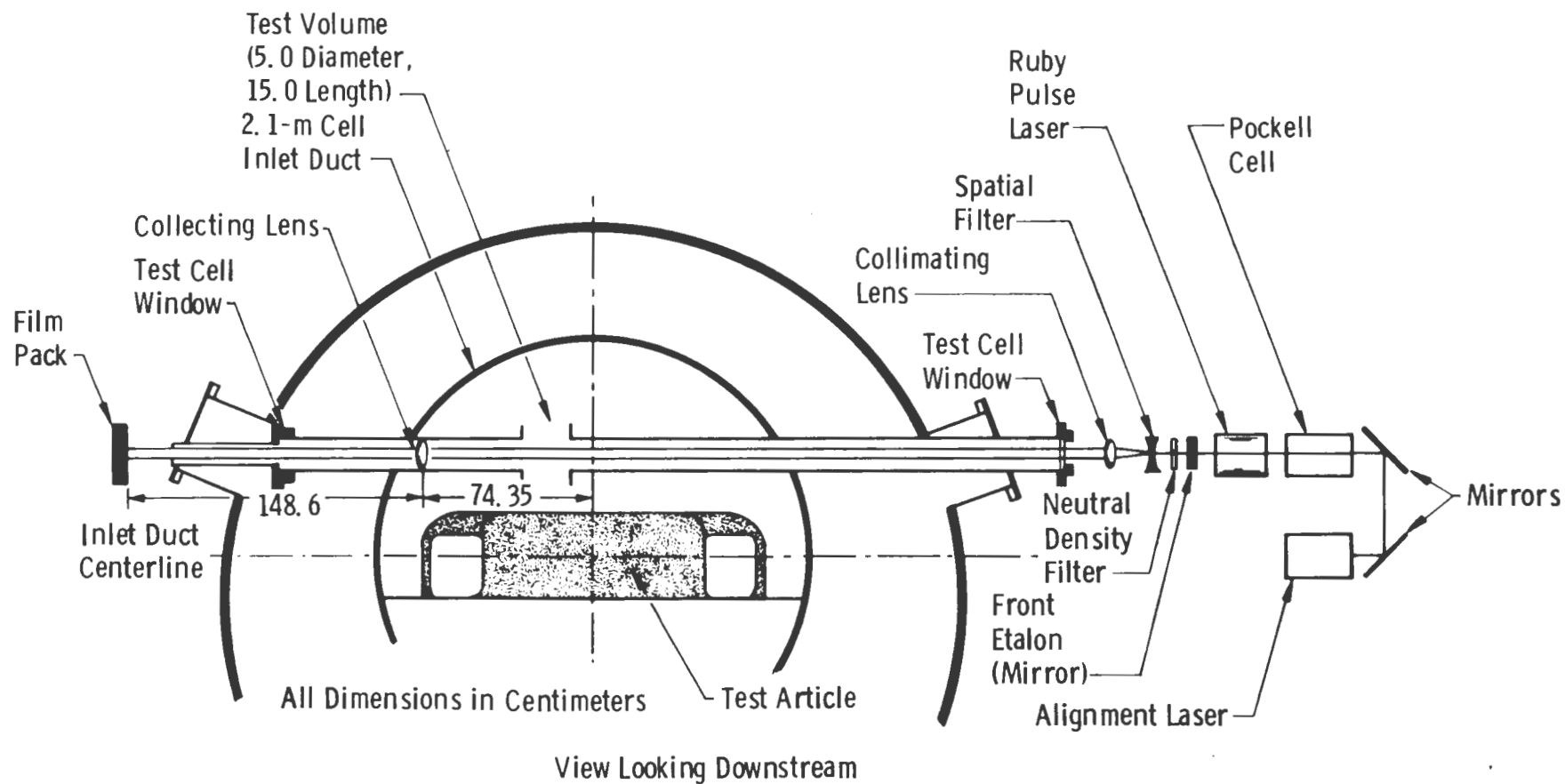
Figure 9

Nozzles = 15 Air Atomizing
 Free-Stream Vel. = 46 m/sec
 Holography Sta. = 4.6 m Downstream
 of Injection Plane



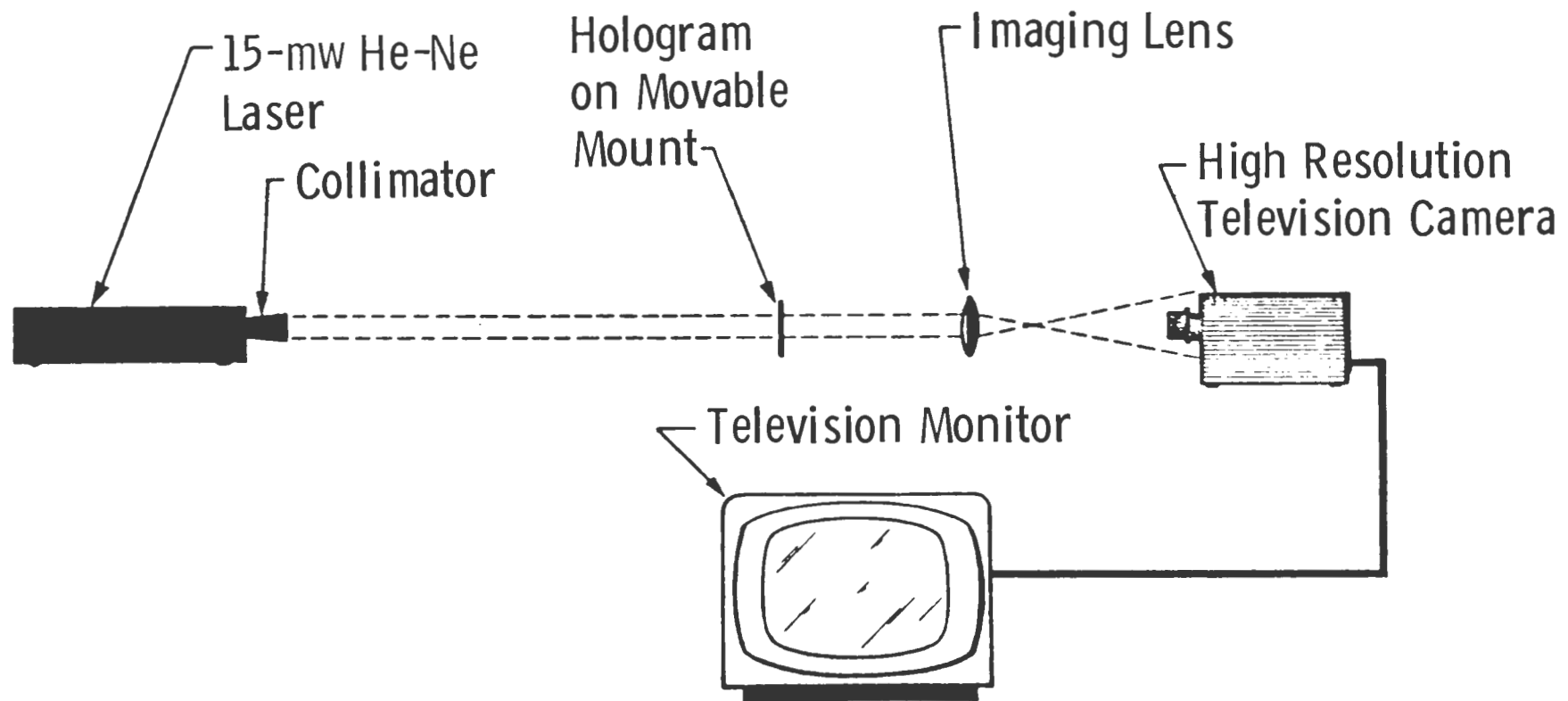
WATER SPRAY NOZZLE CALIBRATION RESULTS

Figure 10



TYPICAL HOLOGRAPHY SYSTEM INSTALLATION IN TEST CELL

Figure 11



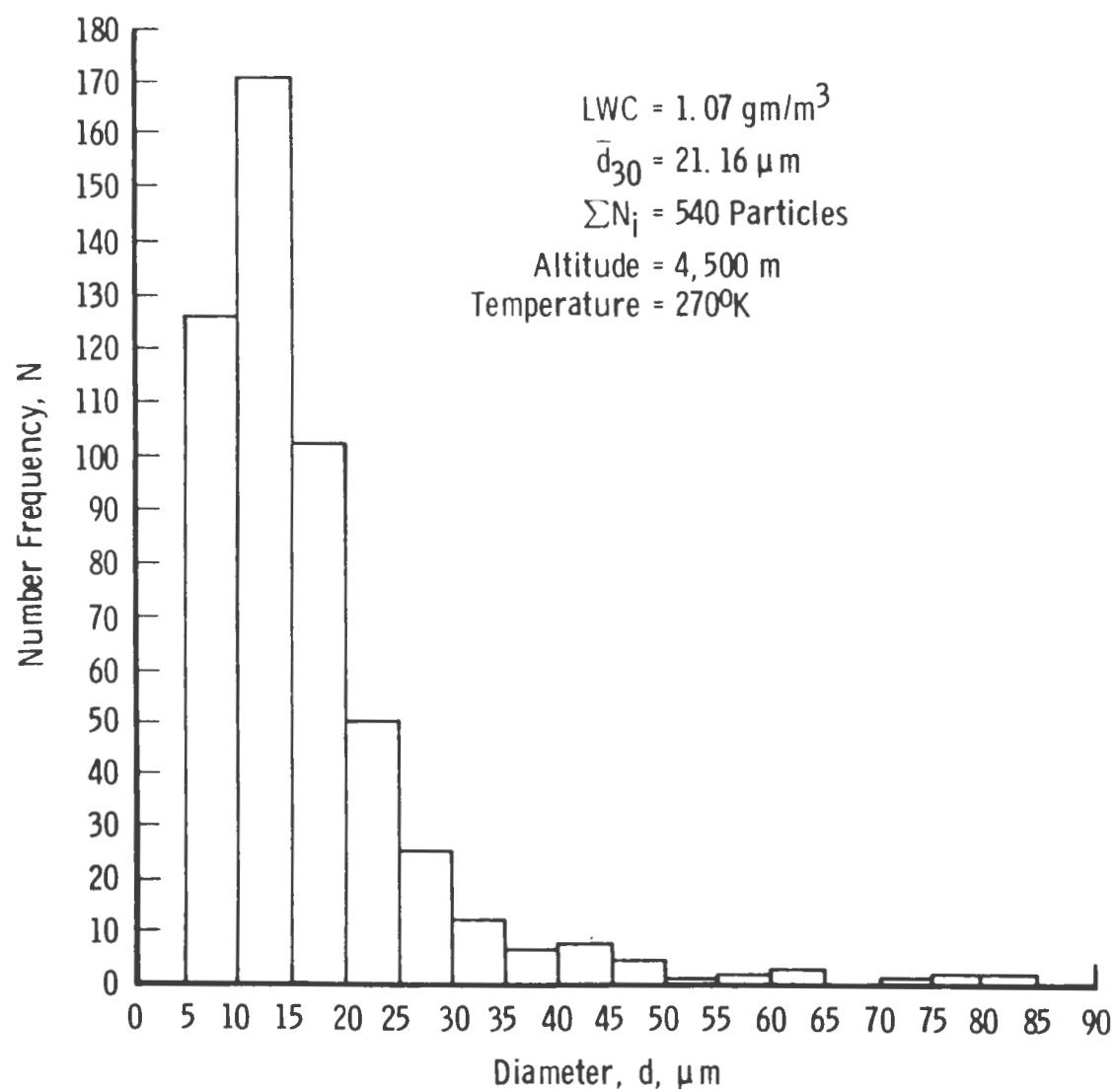
SCHEMATIC OF HOLOGRAM RECONSTRUCTION SYSTEM

Figure 12

RANGE OF OPERATING CONDITION FOR ICING RESEARCH TEST CELL

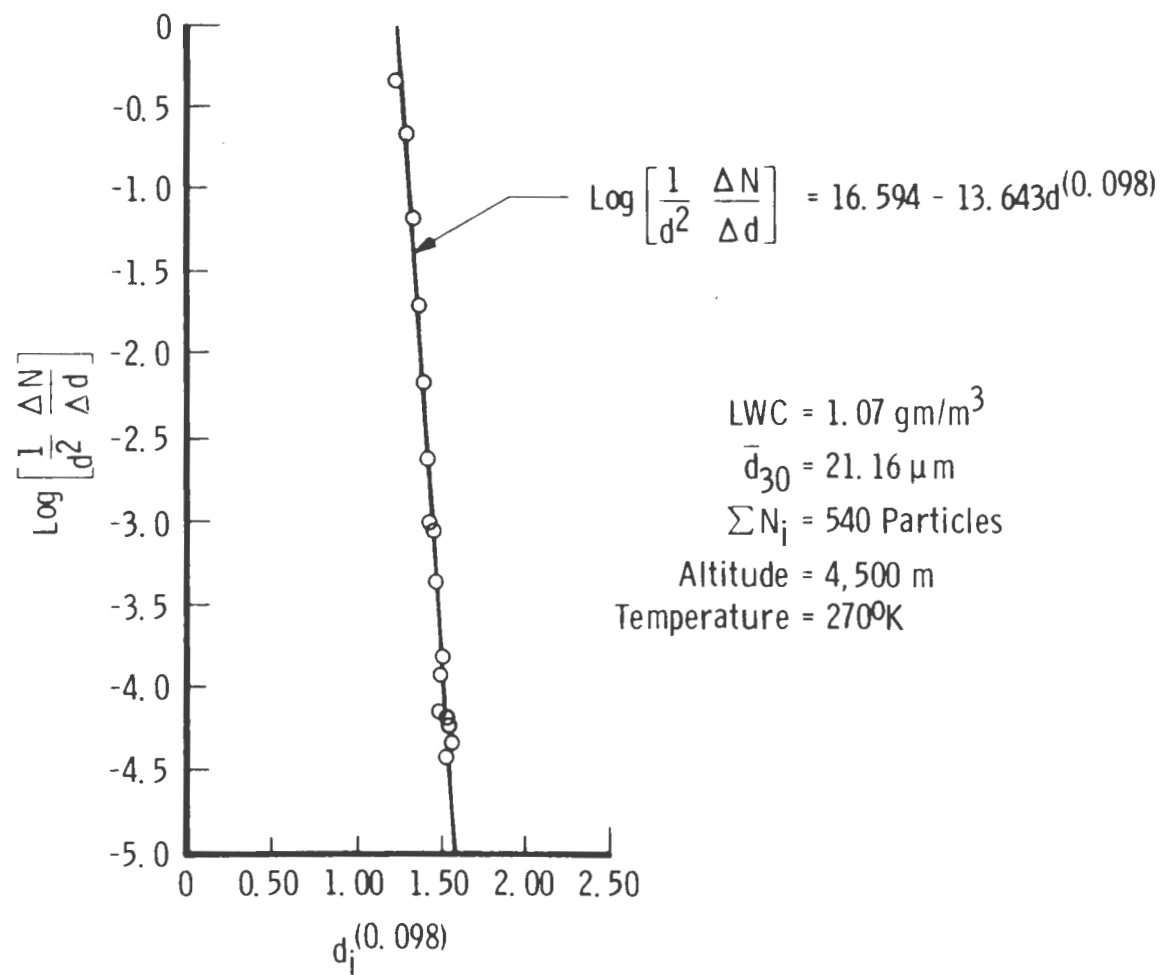
<u>Conditions</u>	<u>Level</u>	
	<u>Max</u>	<u>Min</u>
Cell Pressure	275 kPa	1 kPa
Cell Temperature	85 ⁰ C	-30 ⁰ C
Cell Mach Number	0.7	0
Airflow Rate	14 kg/sec	0
Atomizing Air Pressure	1200 kPa	140 kPa
Atomizing Air Temperature	85 ⁰ C	15 ⁰ C
Demineralized Water Pressure	2000 kPa	345 kPa
Demineralized Water Temperature	85 ⁰ C	4 ⁰ C
Demineralized Water Flow Rate	45 ℓ/hr	8 ℓ/hr

Figure 13



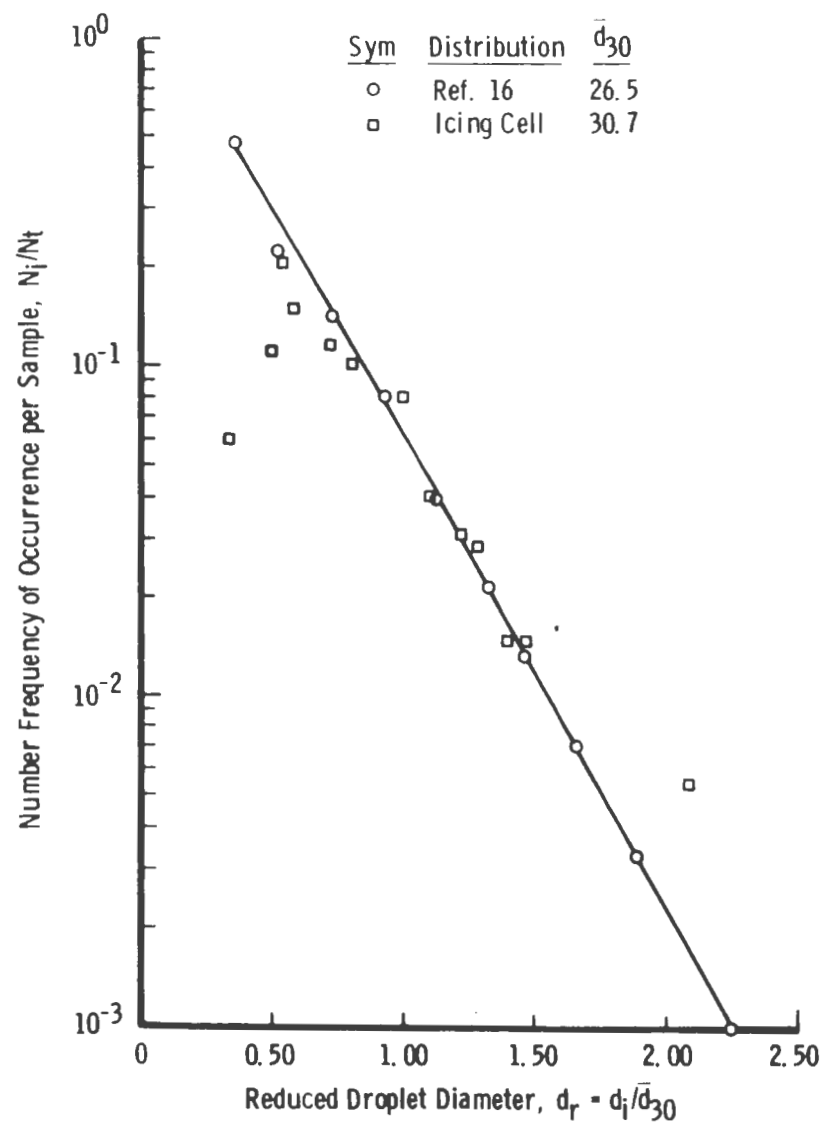
HISTOGRAM OF WATER DROPLETS

Figure 14



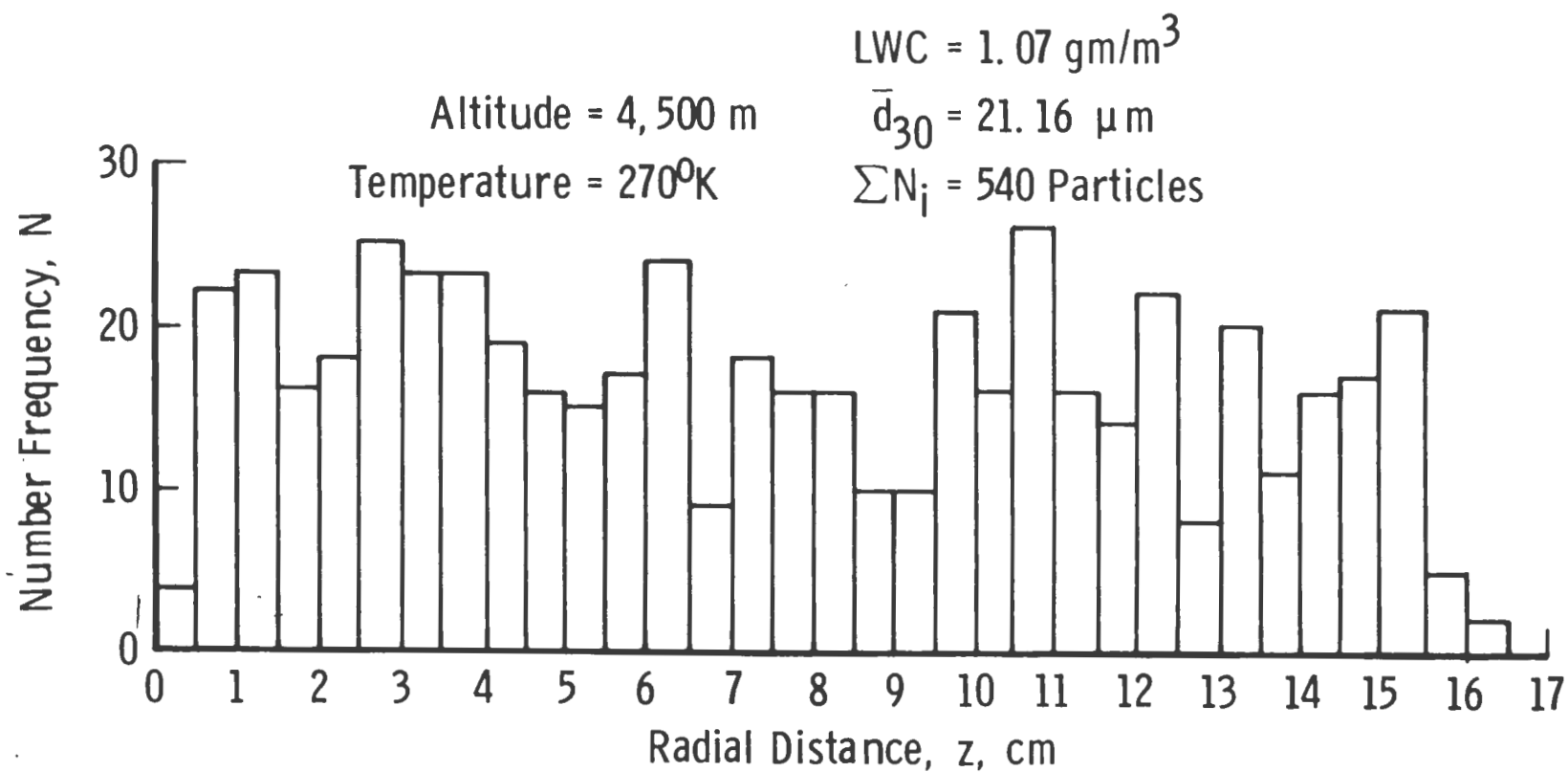
NUKIYAMA-TANASAWA CURVE FIT TO HOLOGRAPHIC DATA

Figure 15

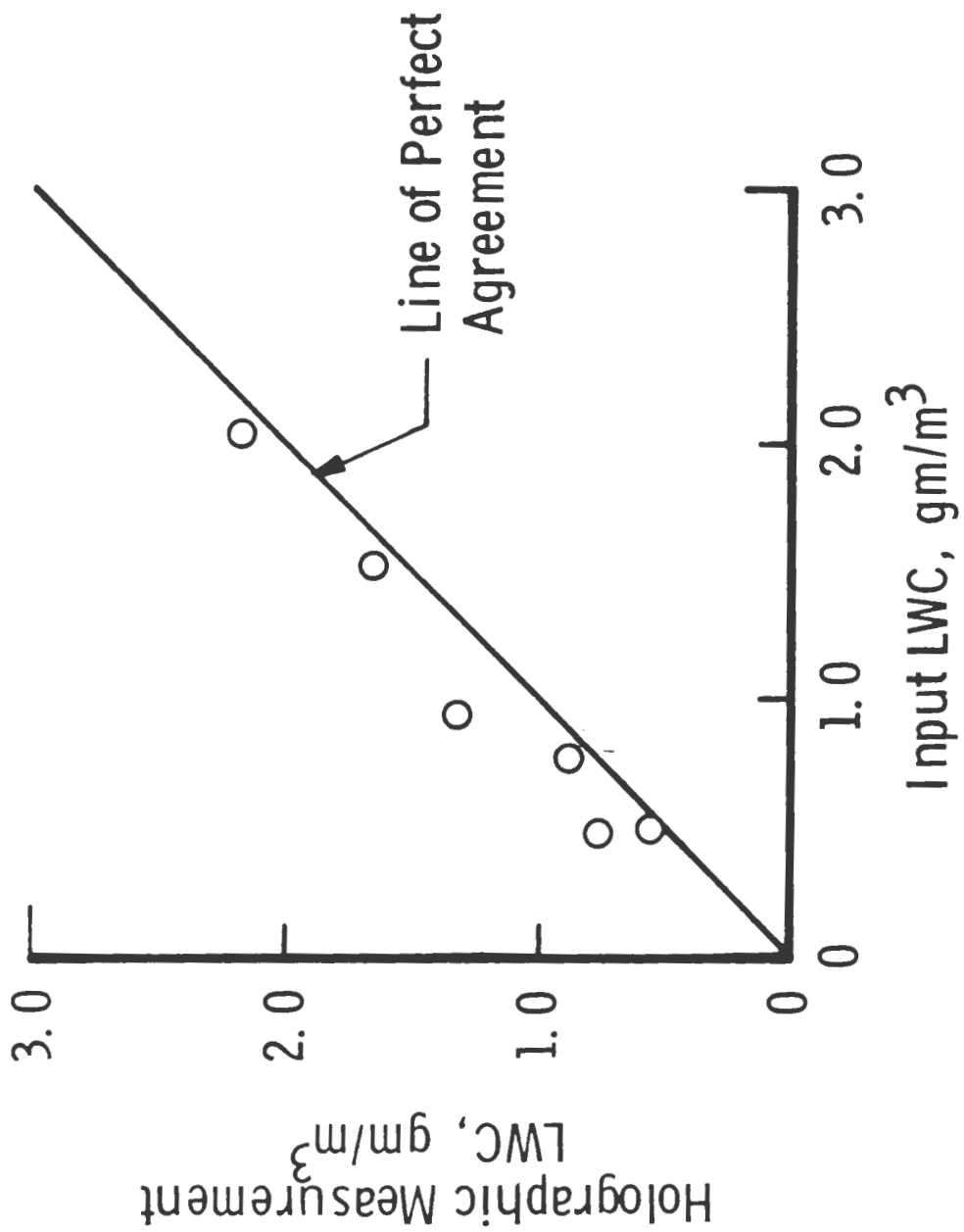


COMPARISON OF ARTIFICIAL AND NATURAL DROPLET
DISTRIBUTION FOR A CUMULIFORM CLOUD

Figure 16



DROPLET NUMBER FREQUENCY ACROSS THE TEST SECTION



CALCULATED LWC VERSUS INPUT LWC

Figure 18

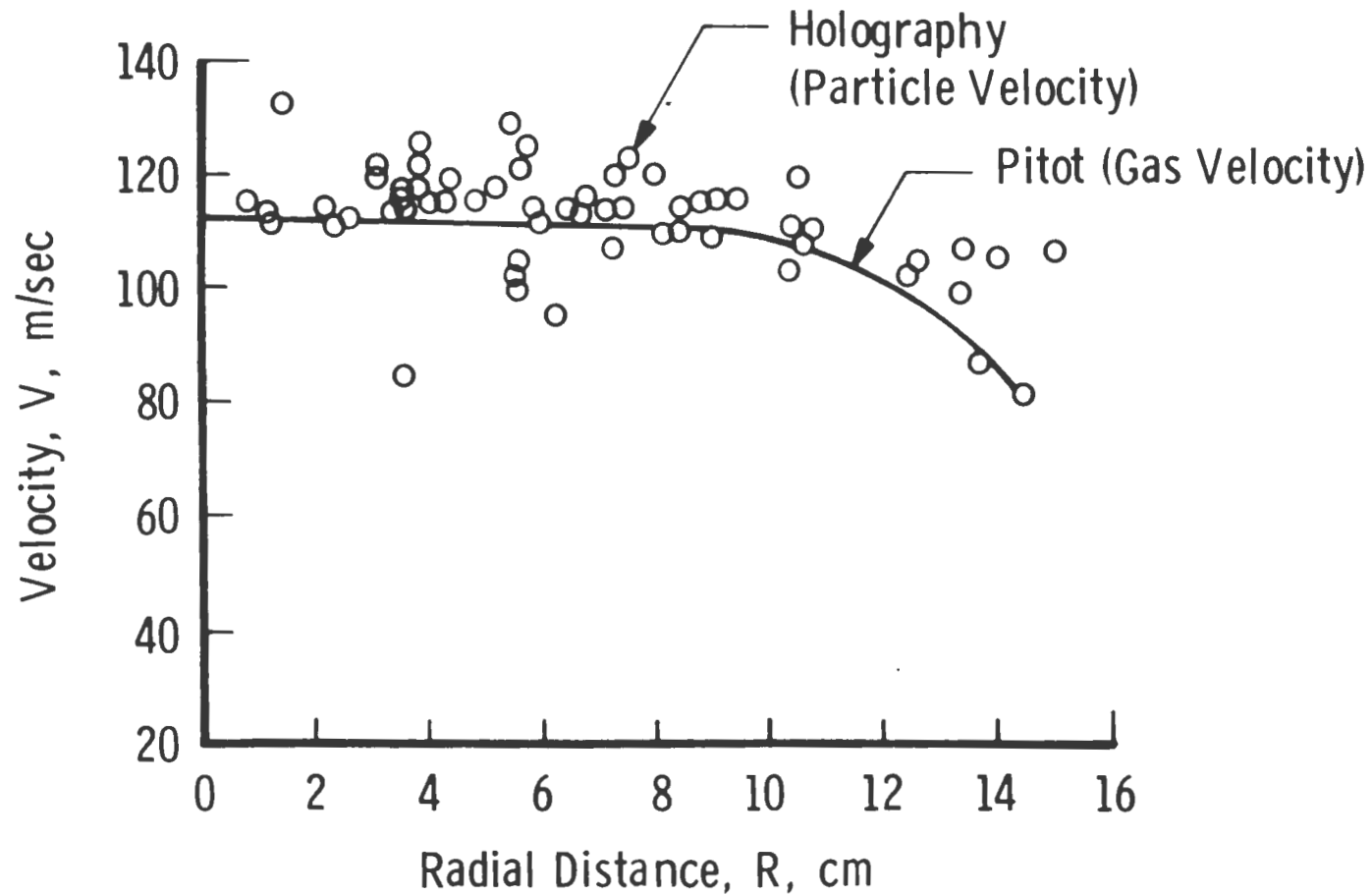
$$\text{LWC} = 0.13 \text{ gm/m}^3$$

$$\bar{d}_{30} = 39.8 \mu\text{m}$$

$$\sum N_i = 75 \text{ Particles}$$

$$\text{Altitude} = 4,500 \text{ m}$$

$$\text{Temperature} = 270^\circ\text{K}$$



COMPARISON OF GAS VELOCITY AND PARTICLE VELOCITIES

Figure 19

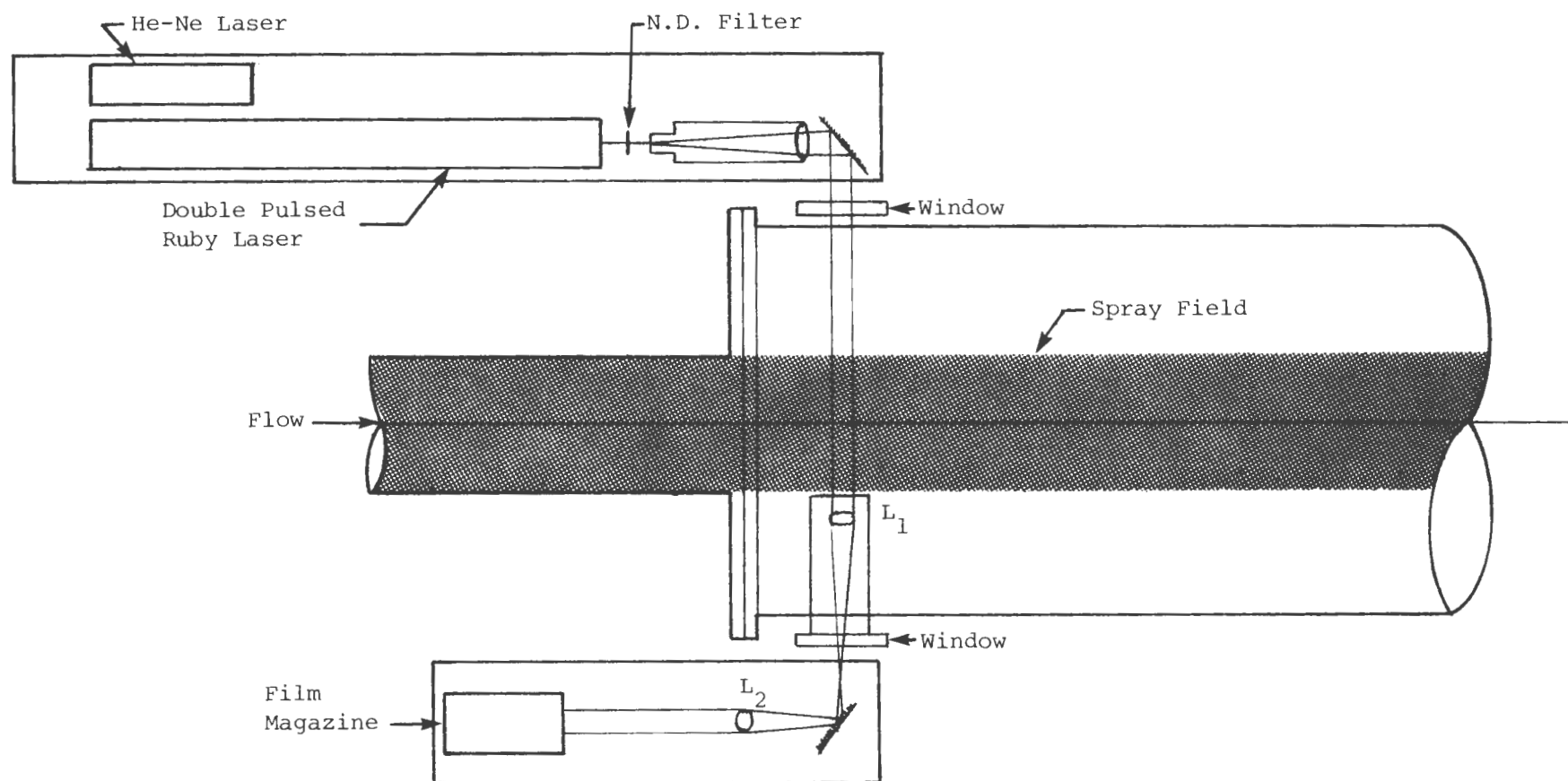


FIGURE 20 ICING RESEARCH FACILITY HOLO-CAMERA INSTALLATION

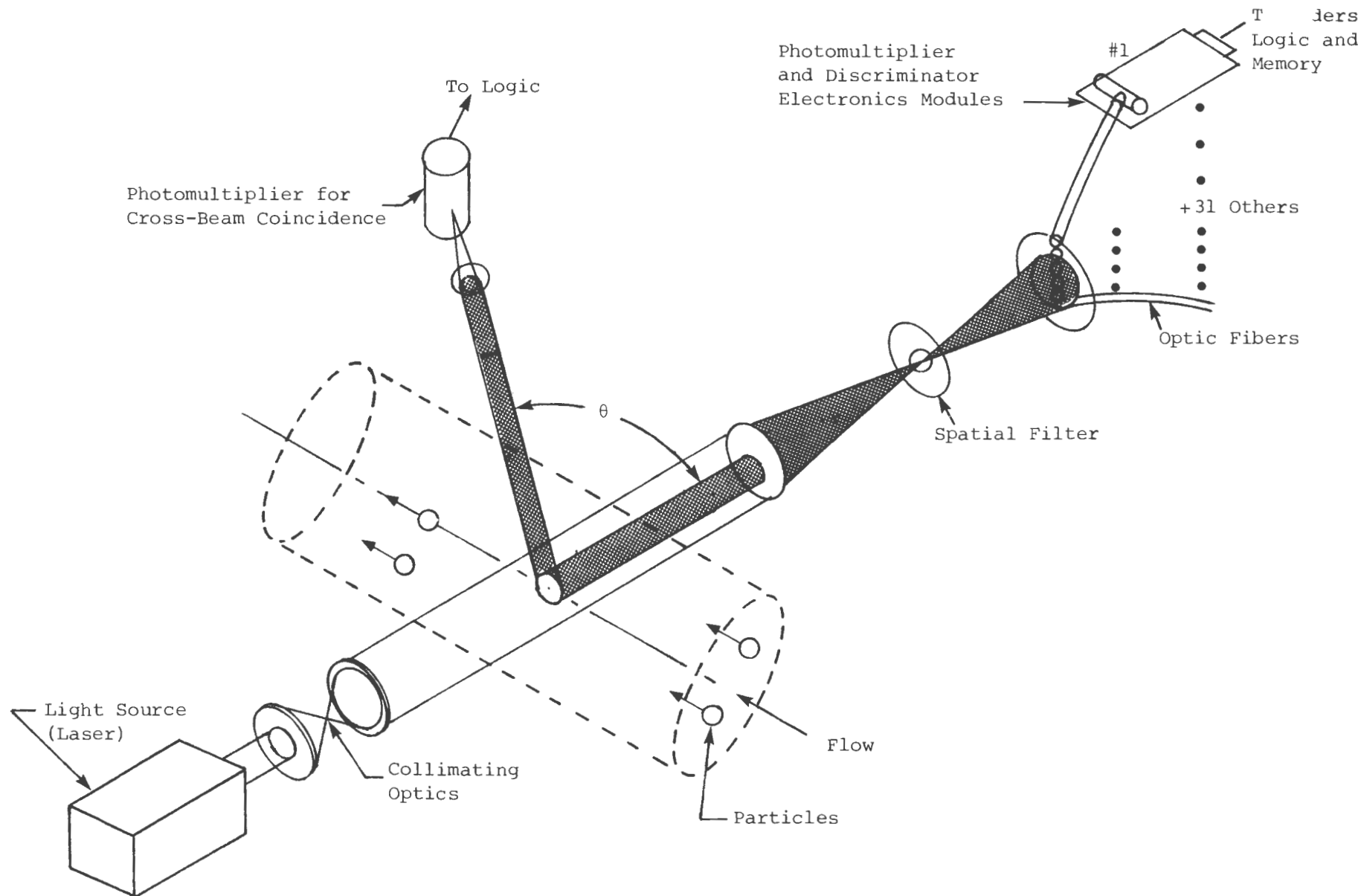


FIGURE 21 FIBER-OPTICS PARTICLE-SIZING SYSTEM

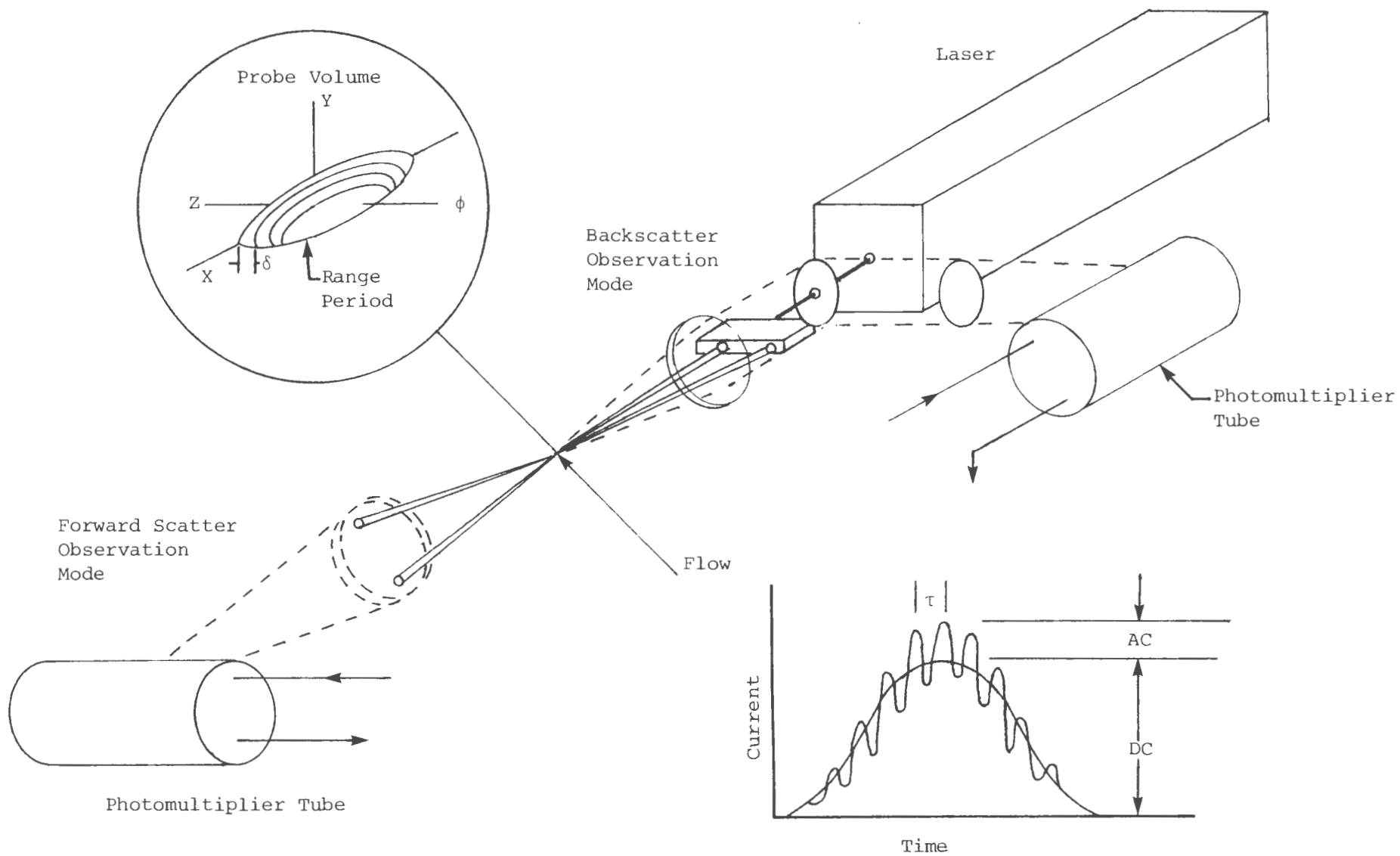


FIGURE 22 PARTICLE-SIZING INTERFEROMETER

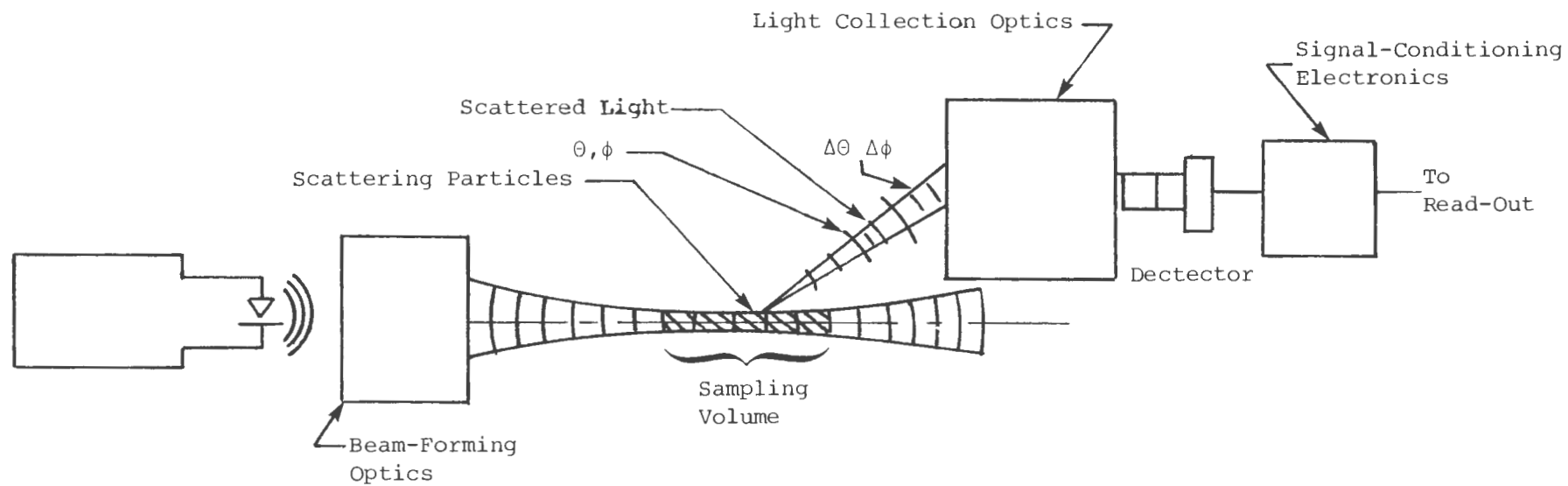


FIGURE 23 LIGHT-SCATTERING PARTICLE-SIZING SYSTEM

SUMMARY:

- 1. AEDC altitude test facilities do provide the capabilities of simulating the complete range of icing conditions.**
- 2. In the research facilities:**
 - a. The icing clouds produced closely simulate natural icing clouds.**
 - b. The water droplets are well distributed across the test section and the droplets are generally following the flow.**
 - c. Holographic determination of liquid water content is within 25% of the input liquid water content.**

Figure 24

PROPULSION DIVISION, NASA LEWIS RESEARCH LAB

INTRODUCTION: RICHARD I. ADAMS

Thank you very much, Jay. So far we've heard from first the FAA, the Army, Navy, Air Force and coming next is NASA. Milt Beheim is Chief of the Propulsion Systems Division at the NASA Lewis Research Lab in Cleveland, Ohio.

MILT BEHEIM

Since I work for NASA (Figure 1) a lot of our orientation is toward the longer term research and technology. The research facilities to do that kind of work are also applicable to near term problems. Today I hope to convey to you a longer term view of R&D opportunities for the future, and I would like to describe some facilities that we think are useful in pursuing both near term and far term objectives. We could start with both viewgraphs please.

Figure 2 is a quick overview of the kinds of things that I would like to cover today. Icing R&D requirements exist for all types of aircraft. Not only with existing ice protection equipment being used in the current development of new aircraft but for a better way to do it in future aircraft. An icing wind tunnel is an essential element in the spectrum of facilities that are needed to do that kind of work. The largest icing tunnel in this country is located at NASA in Cleveland. Although it is a productive facility, it is quite old and falls short of the potential capabilities that can be designed into wind tunnels using current technology. We are proposing a new modern facility for such work by rehabilitating an existing unused tunnel, called the Altitude Wind Tunnel (AWT). It is shown on the first figure. If activated it would offer a major enhancement in the capabilities of national icing facilities. It would be available for a variety of users. It would be useful for icing R&D but in addition has propulsion research capabilities for propeller powered aircraft and for V/STOL aircraft. The multipurpose functions that this sort of tunnel would have for icing and propulsion work is, in our judgement, a very cost effective means for meeting our R&D requirements. Just behind the altitude wind tunnel, as shown in the photograph, is the largest icing tunnel currently in operation in the country that I referred to earlier. It is called the Icing Research Tunnel (IRT) and obviously is much smaller.

A couple of years ago, some of you participated in an icing workshop that occurred in Cleveland. On the basis of that workshop NASA got back into icing research, and with the help of the people that attended that meeting and through subsequent contacts, we've assembled a list of work areas where icing R&D is of interest as shown on Figure 3. We are presently performing additional study contracts with industry to define these work areas in more depth than is possible in a workshop. There is a contract on rotorcraft, one on general aviation and small aircraft and another contract on large commercial aircraft. The results of these study contracts will be available early next year. We expect to have a review meeting that some of you may wish to attend.

The general categories shown on Figure 3 are either in generalized technology, which applies to a wide variety of aircraft, or in specific applications. Although I won't be able to go through any of these in any depth today. I'd like to indicate the principal subjects. Certainly,

MILT BEHEIM

ice accretion is one generalized subject of research, and those areas are indicated here. There's a continuing interest in better de- and anti-icing methods such as those indicated. There's a growing interest in what needs to be done when composite materials are used in large components of aircraft structures. There are new ideas in instrumentation, new work is required in both ground and flight test facilities, and new work is needed in meteorology as indicated. The application of these technologies is listed on the right side of the figure for propulsion systems and for fixed wing aircraft and rotorcraft.

The icing wind tunnel is an essential element in working those classes of problems and the role of the tunnel is summarized on the next chart (Figure 4).

If you had your druthers, you'd like to start out with studies and analysis, get into ground test facilities on component studies, as with icing tunnels and test cells, move on into flight type systems, as with a static spray rig, get on into flight tanker tests with the best of that equipment and finally proceed to the natural icing environment. In some circumstances simulated ice methods have been evolved for certain classes of aircraft. Simulated ice can be modeled with plastic or fiberglass provided that prediction methods are sufficiently accurate to determine the ice shape. If that capability is in hand, it opens up the opportunity to use conventional wind tunnels and conventional flight testing methods. That's been done rather extensively by the big airplane industry for the transport class of aircraft. It hadn't been applied, as yet to other classes of aircraft.

The functions of an icing facility are shown on Figure 5. Basically, the ground test facility has proven to be very valuable for fundamental research and to explore advanced concepts. And, when specific applications are established you need to determine whether or not protection requirements are required. We evaluate alternative methods of providing that protection doing functional checks and changes to the design to achieve compliance with regulations or contracts. Our first flight test, ideally, would provide the complete systems verification and full scale evaluations if subscale work has been required in ground test facilities. If you look at the advantages that icing wind tunnels can offer, they are listed on the same figure. First of all there is productivity. An icing wind tunnel provides its own weather. It provides flexibility in that the test hardware can be changed, in a relatively short period of time. In fact from one week to the next week an entirely different research program can be installed to study a different kind of problem or a different method of solving the problem. Since it's not a flight system there is more flexibility in making rapid changes at low cost. The ground facilities also provide easier control of variables. Some of the variables which are important are listed on Figure 6. Primary variables are flight speed, temperature, water content, drop size, the extent of the cloud, uniformity of the cloud, and

MILT BEHEIM

exposure time. The secondary variables are indicated on the right. Currently there is speculation on the effect of other unknown variables shown at the bottom of the figure. Ground test facilities generally provide more control of these variables than can be achieved with flight facilities. So I'd like to discuss their design and capabilities in a little more depth.

The circuit diagram of the Icing Research Tunnel is shown on Figure 7. Principal components include a cooler with two thousand tons of freon refrigeration and a 4000 horse power drive fan. The spray provides liquid water content from a half gram per cubic meter to two grams and drop size is varied between ten and twenty microns. The test section size is 6 X 9 feet and it has a top speed of 300 miles per hour. Typically full scale components of an aircraft are used in the test section rather than subscale models because of the difficulties in scaling the icing problems.

Operating conditions of the tunnel are compared to flight in Figure 8. Variations in pressure altitude versus speed are shown for typical flight trajectories of rotorcraft and of fixed wing aircraft. Natural icing conditions typically occur at altitudes below 20,000 feet. The icing tunnel (IRT line) is essentially a sea level tunnel that operates at a fixed pressure and speed.

It is not as limited, however, in terms of temperature as shown in Figure 9. The temperature variations of flight is shown as a function of Mach number for CTOL (Conventional Takeoff and Landing) fixed wing aircraft. Because of weather conditions they vary within the envelope. The icing tunnel (IRT) provides the proper range of temperatures, but doesn't go fast enough.

The principal shortcoming of the IRT is its small size test section of 6 X 9 feet. This problem is compounded by the current need to use full scale aircraft components (rather than subscale models) because of icing scaling problems. Current efforts in the tunnel are restricted in scope and validity of test results because of this serious constraints.

Because of these limitations of the present icing tunnel, the rehabilitation of the Altitude Wind Tunnel has been proposed. It stands right next to the present icing tunnel and it shares the same refrigeration plant. It's the only big wind tunnel in the country with a large refrigeration plant standing next to it, and it's not used for anything. It was built in the early 40's as a propulsion wind tunnel and was actively used as such up until about the mid 50's. At that point in time the tunnel was shut down and converted into space simulation tanks for the NASA space program and used as such until 1970. Since all the internal components have been removed, the tunnel is therefore not operable as a wind tunnel. The proposal to rehab the tunnel has surfaced within NASA. The Administrator has approved a preliminary study of the existing equipment by an architectural engineering firm and there are discussions with the

MILT BEHEIM

Aeronautics and Astronautics Coordinating Board (AACB) which is made up of NASA and DOD members. They are considering a variety of national facilities including this rehabilitation of AWT. In subsequent phases I'm sure there will be a more detailed consultation with the industry for their views regarding the role that a facility of this type would have in meeting their future needs.

The reasons for the interest in rehabing the altitude wind tunnel, are summarized in the Figure 10. First of all, the resurgence in icing work is very evident to all of us for the military needs and for civil needs. What is needed is an icing tunnel based on modern technology. In addition, there's a resurgence of interest in propeller propulsion systems for fuel conservation in a variety of subsonic aircraft. We don't have the facilities that provide flight simulations for propeller powered systems nor are there facilities for aeroelastic research. And there's also growing interest, in V/STOL propulsion for both Navy and Air Force missions. During the transition from horizontal to vertical flight and back again, there are important aeroelastic problems in the propulsion system. The AWT is an effective means of providing an altitude capability for research into these aeroelastic problems. Although the AWT rehabilitation is being considered for these three purposes I don't intend to talk about any of them except the icing applications to this particular audience.

We're considering two different versions of the rehabilitation as listed on Figure 11. The base rehab is achieved by using the existing drive and refrigeration systems for aircraft icing work, low speed propeller and some of the V/STOL transition work. It means putting back into the tunnel the components that were there before. The drive motor is still there, but it needs to be hooked up to the new fan as shown in Figure 12. The refrigeration plant is still there but needs to be hooked up to the new cooler. A water spray system would be provided ahead of the twenty foot test section and in the return leg an additional water spray could also be used to provide a low speed test section which is forty-five feet in diameter.

The second version is called an option which is based on a new drive and provides increased refrigeration to do a better job on high speed icing work. It also would add slots to the 20 foot test section and a free jet insert to the 45 foot test section for high speed propellers and V/STOL work. The diagram on Figure 13 illustrates this concept.

Two more coolers are added and the drive is increased to 54,000 horse power. The free jet insert is better shown on Figure 14. There is a convergent portion that creates a free jet in the returning leg which is 45 feet wide and of variable height. The variable height changes the speed that can be provided. This manner of using a free jet is not conventional design practice, and the feasibility of doing so is still under study.

MILT BEHEIM

The capabilities of the tunnel in terms of pressure, altitude, and temperature are shown on Figures 15 and 16. In Figure 15, the flight envelope encompasses the requirements of most aircraft as shown in previous figures. The base design of the tunnel will allow operation anywhere within the open portion of the test envelope. The option extends the capabilities indicated by the cross hatch. In terms of temperature (Figure 16) it extends the temperature capability that the IRT had to higher speed. The next pair of figures show some typical installations that could be accommodated in the 20 foot test section. The aircraft illustrated in Figure 17 have encountered icing problems and inquiries have been made to use the IRT. In all cases it has been too small for their purposes, but the use of the 20 foot test section would meet these needs. On Figure 18 are illustrated some typical general aviation installations for a piston engine aircraft, a jet powered aircraft and a prop powered aircraft. The next Figure 19, shows the use of the free jet in the 45 foot wide test section which a complete airplane might be used. The free jet is also a useful means to get into some large helicopter rotor work as shown on the bottom of Figure 20. Complete propulsion systems and airframes can be used also. Installations in a 20 foot test section are shown at the top of the figure.

Estimated costs of the rehabilitation of AWT is shown in Figure 21. Construction is being considered in the '84-'86 time period. The base tunnel rehabilitation is \$60M and if the option were chosen it will be around \$15M. Cost of this magnitude puts it in the class of a national facility. You may be aware of the national facilities that are presently under construction. There's a \$90M wind tunnel for transonic work being constructed now at Langley, there's a rehabilitation of the 40 X 80 tunnel underway at the Ames Center, for \$90M, and there is a new engine test facility being built at AEDC for \$47M. The rehabilitation of AWT is relatively low risk compared to the kind of technology being used in construction for some of these other facilities that I just described. It is essentially the same kind of thing that we were doing back in the early 40's. The present components that are standing unused have a very high value in terms of replacement value: the shell, the drive, the refrigeration plant, and the building. In addition, for engine work in the tunnel, the exhaust systems of the laboratory are available for exhaust scavenger and they have a replacement value of \$100M. About half of the cost of the facility is already in place. These costs for the AWT for both base and option have been escalated in terms of the increased costs of the future. In other words, they reflect the construction costs that will occur in '84 through '86. In summary then (Figure 22), NASA has become convinced with help from the industry that there are important R&D requirements for icing protection of aircraft. And so we've gotten back into the business again. The icing wind tunnel is, in our view, an essential tool in doing that kind of work. The rehabilitation of AWT is a major enhancement in our national capabilities and does so in a cost effective manner by using an existing unused facility within NASA.

**REHABILITATION OF NASA LEWIS ALTITUDE WIND TUNNEL
FOR AIRCRAFT ICING RESEARCH, FOR PROPELLER POWERED
PROPULSION RESEARCH, AND FOR V/STOL PROPULSION
AEROELASTIC RESEARCH**



Figure 1

ICING RESEARCH NEEDS

GENERALIZED TECH

ICE ACCRETION

- ANALYSIS
- SCALING
- SHEDDING
- SIMULATION

ANTI/DEICING METHODS

- IMPULSE
- LIQUID
- ELECTROTHERMAL
- ICEPHOBICS

COMPOSITE MATERIALS

INSTRUMENTATION

- LASER
- MICROWAVE

FACILITIES

- GROUND
- FLIGHT

METEOROLOGY

- STATISTICS
- EXTENT
- DYNAMICS
- ALT. EXTREMES

APPLICATIONS

PROPULSION

- INLETS & CARBURETORS
- FANS & PROPS
- ICE INGESTION
- NACELLE STRUCTURES

CTOL & GA AIRFRAME

- ADV. AIRFOIL SENSITIVITY
- HI LIFT DEVICES
- ADV. PROTECTION CONCEPTS
- COMPOSITE STRUCTURES

ROTORCRAFT

- ROTOR ACCRETION & SENSITIVITY
- FUSELAGE ACCRETION
- ADV. PROTECTION CONCEPTS
- COMPOSITE STRUCTURES

Figure 3

DESIGN OBJECTIVES

DEVELOP AN ICING TANKER FOR USE IN CERTIFICATION
OF AIRCRAFT FOR FLIGHT IN ICING CONDITIONS

HAVE CAPABILITY TO PRODUCE AN ARTIFICIAL CLOUD
MEETING FAR REQUIREMENTS

Figure 2

STRATIFORM LWC VS MED

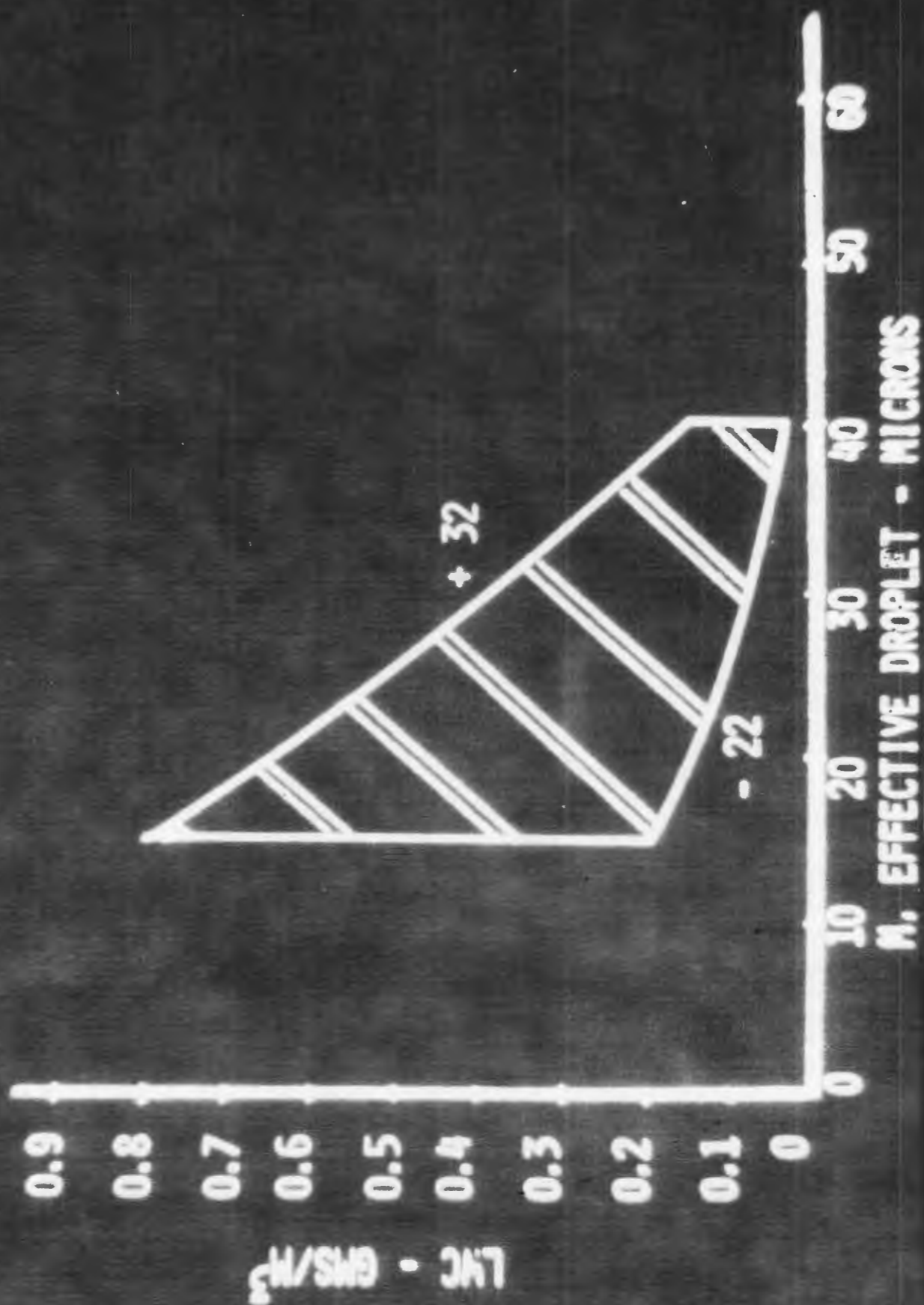


Figure 3

CUMULIFORM LWC VS MED

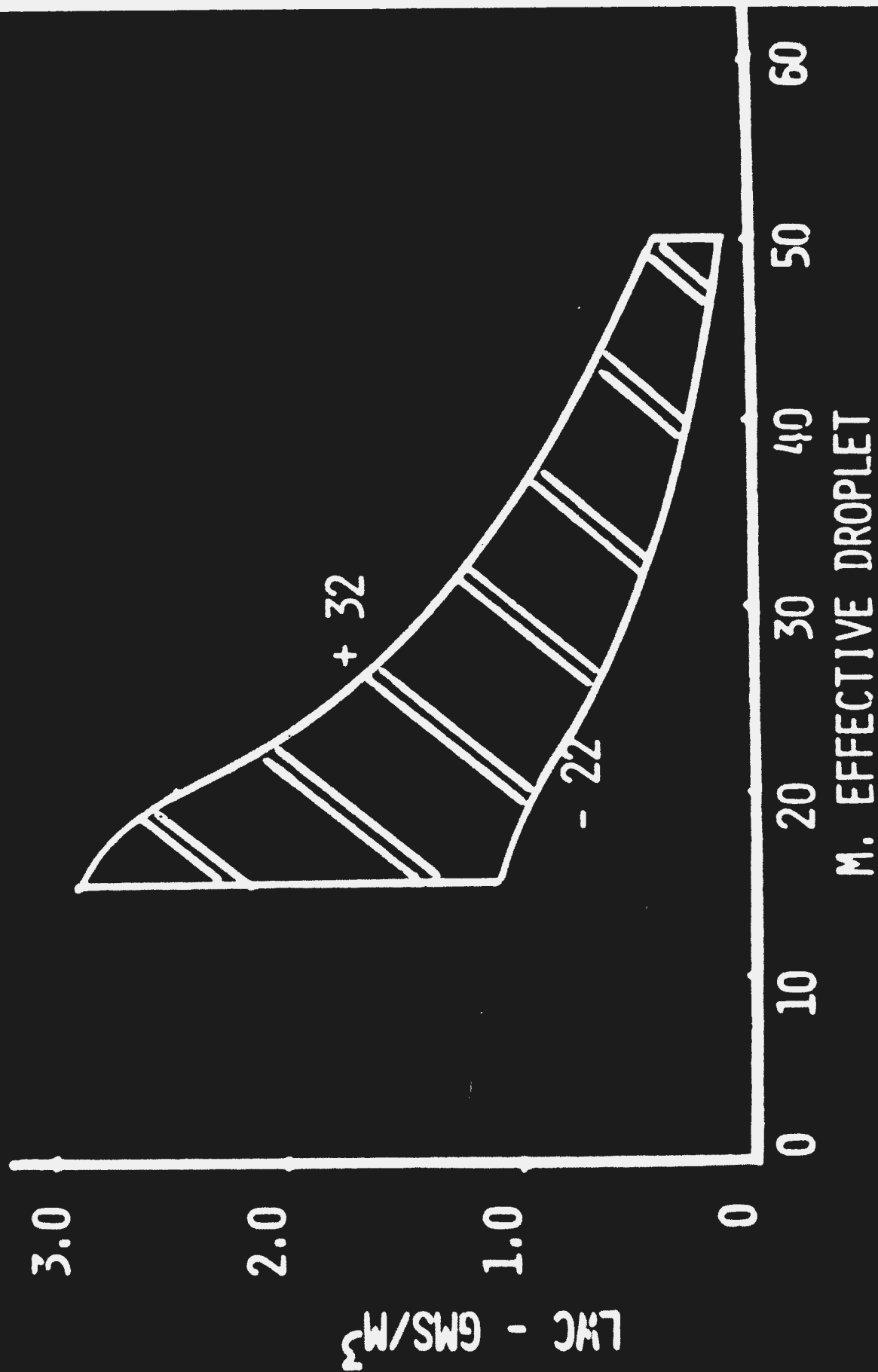


Figure 4

Figure 6

DEVELOPMENT, FLIGHT TEST AND CALIBRATION OF A T-33 ICING TANKER

Figure 7

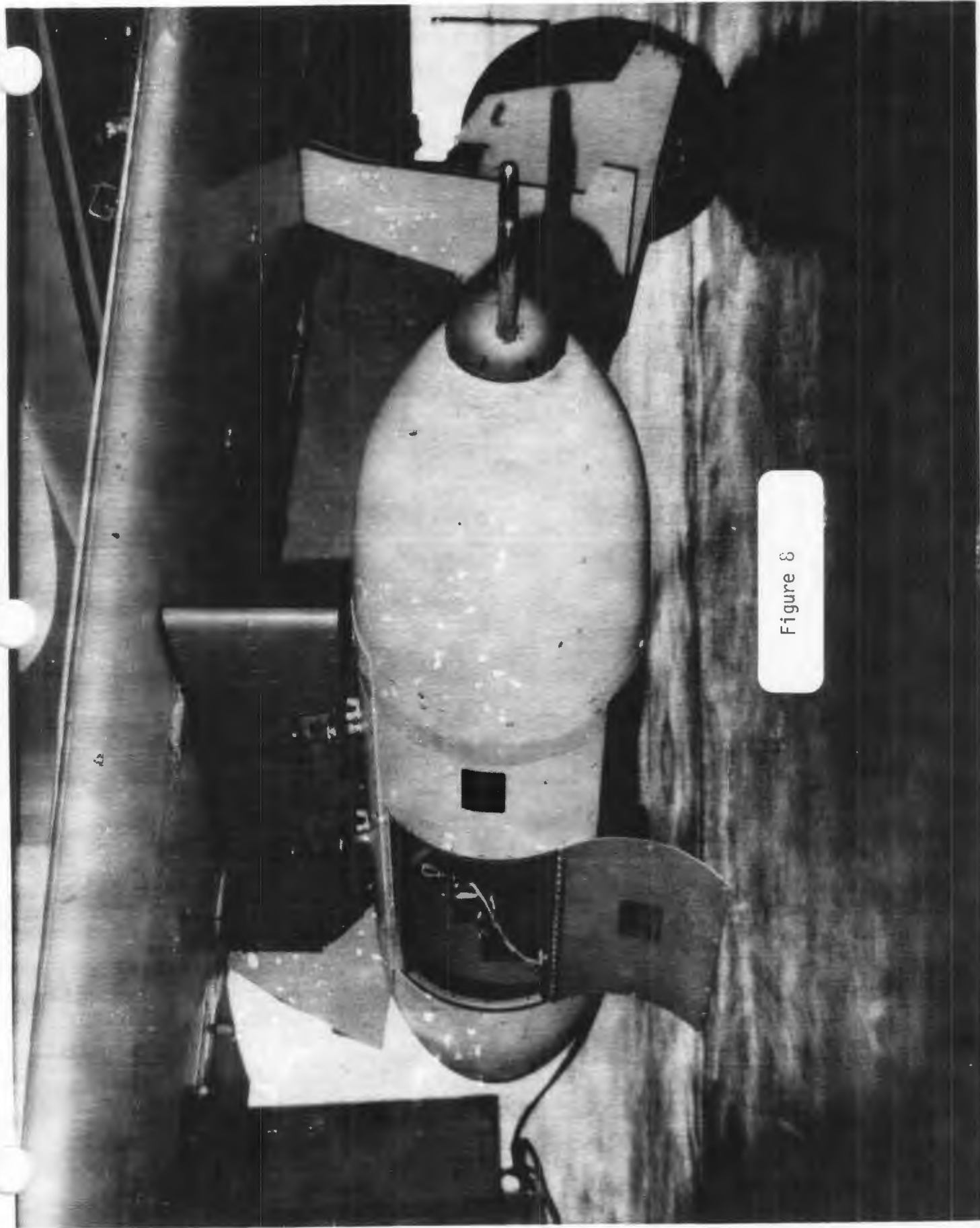


Figure 8

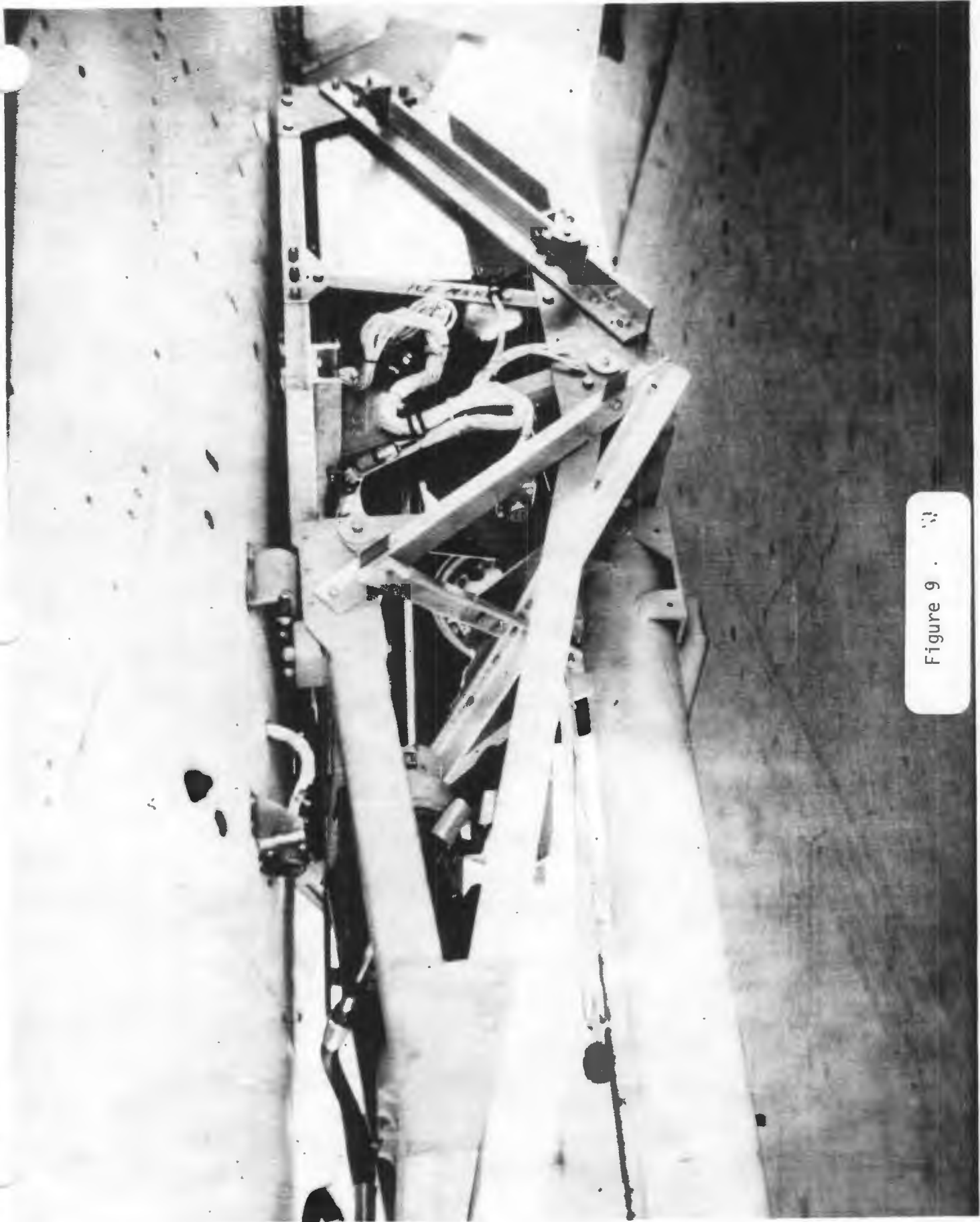
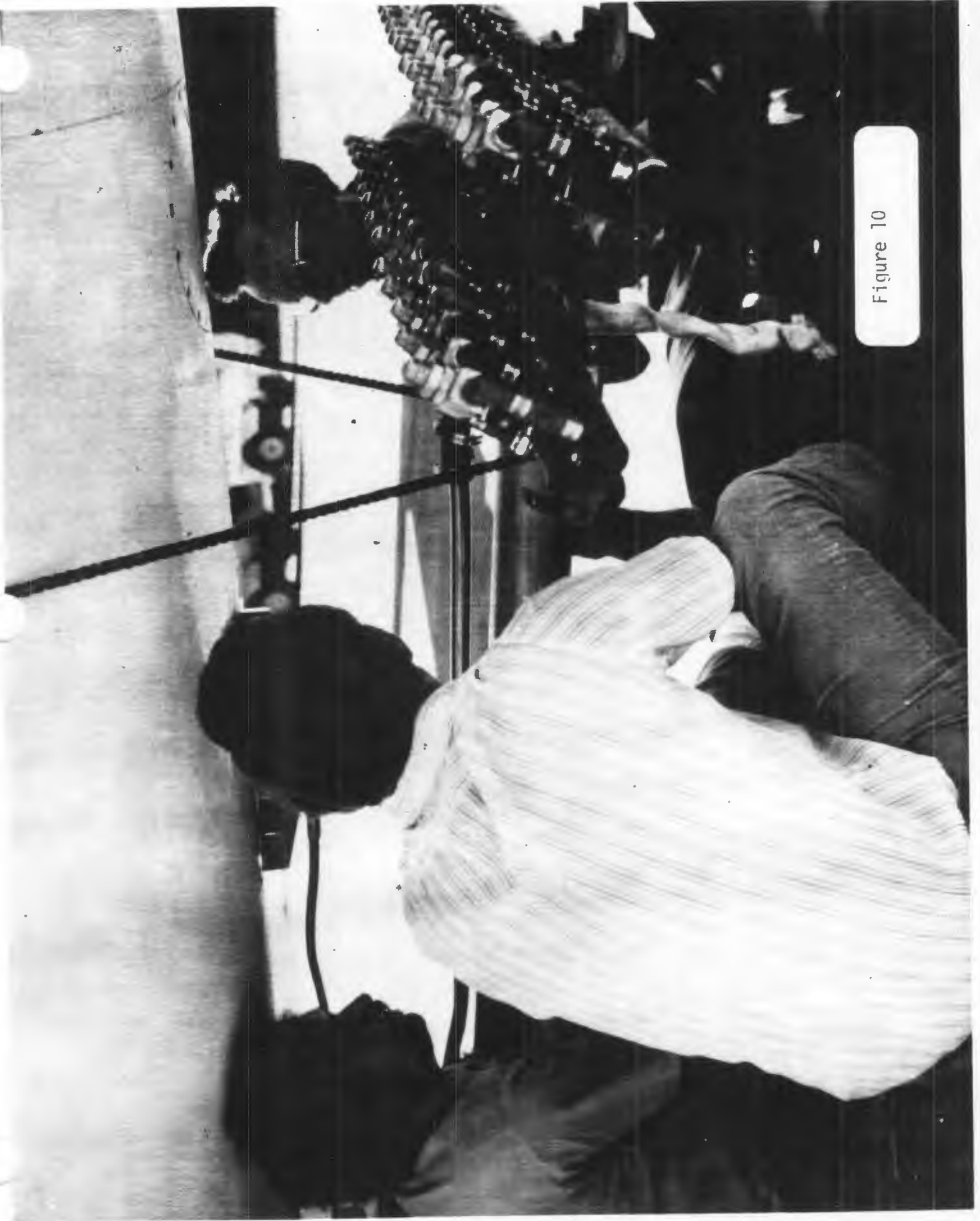


Figure 9 . 13

Figure 10



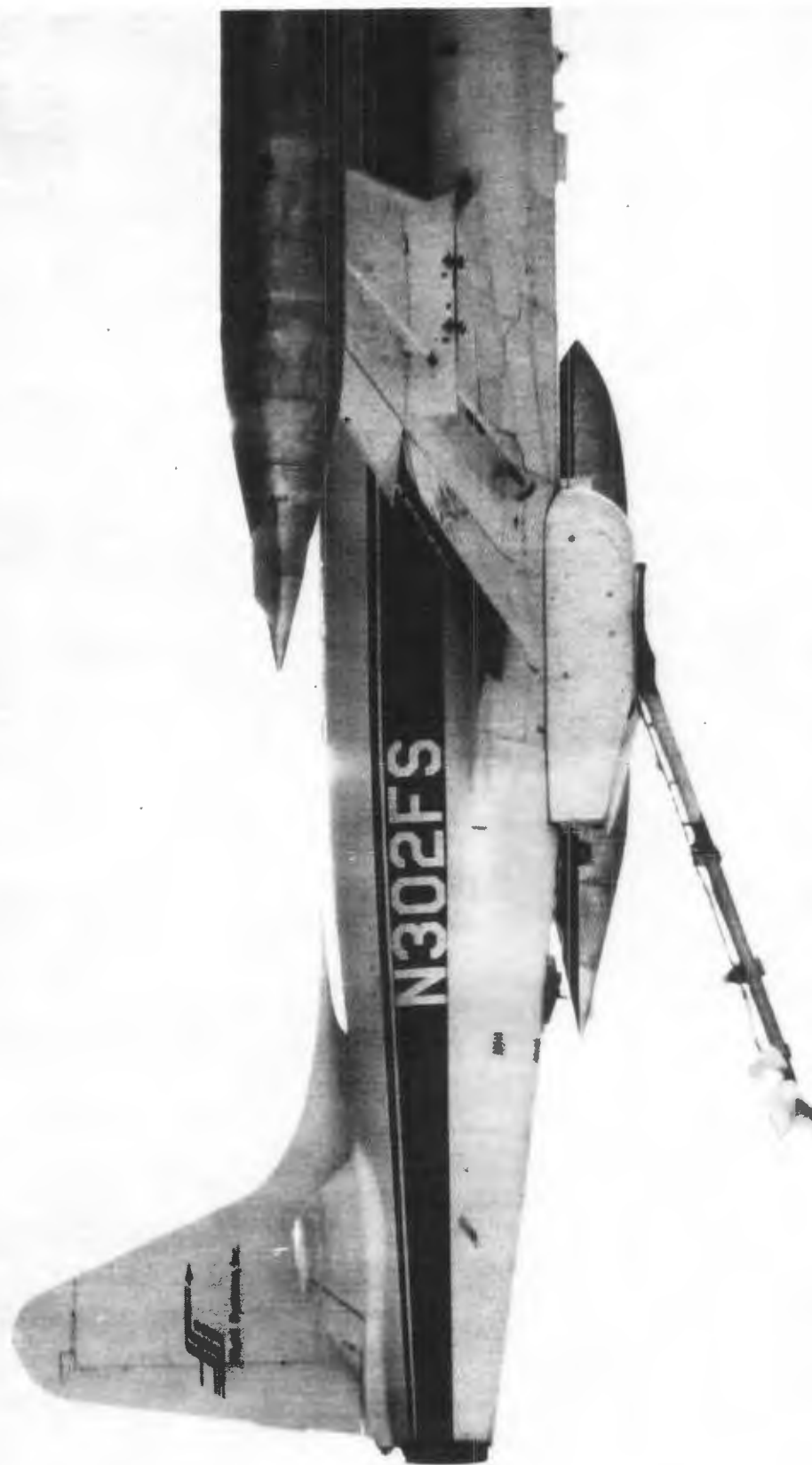


Figure 11



Figure 12



Figure 13 . 19

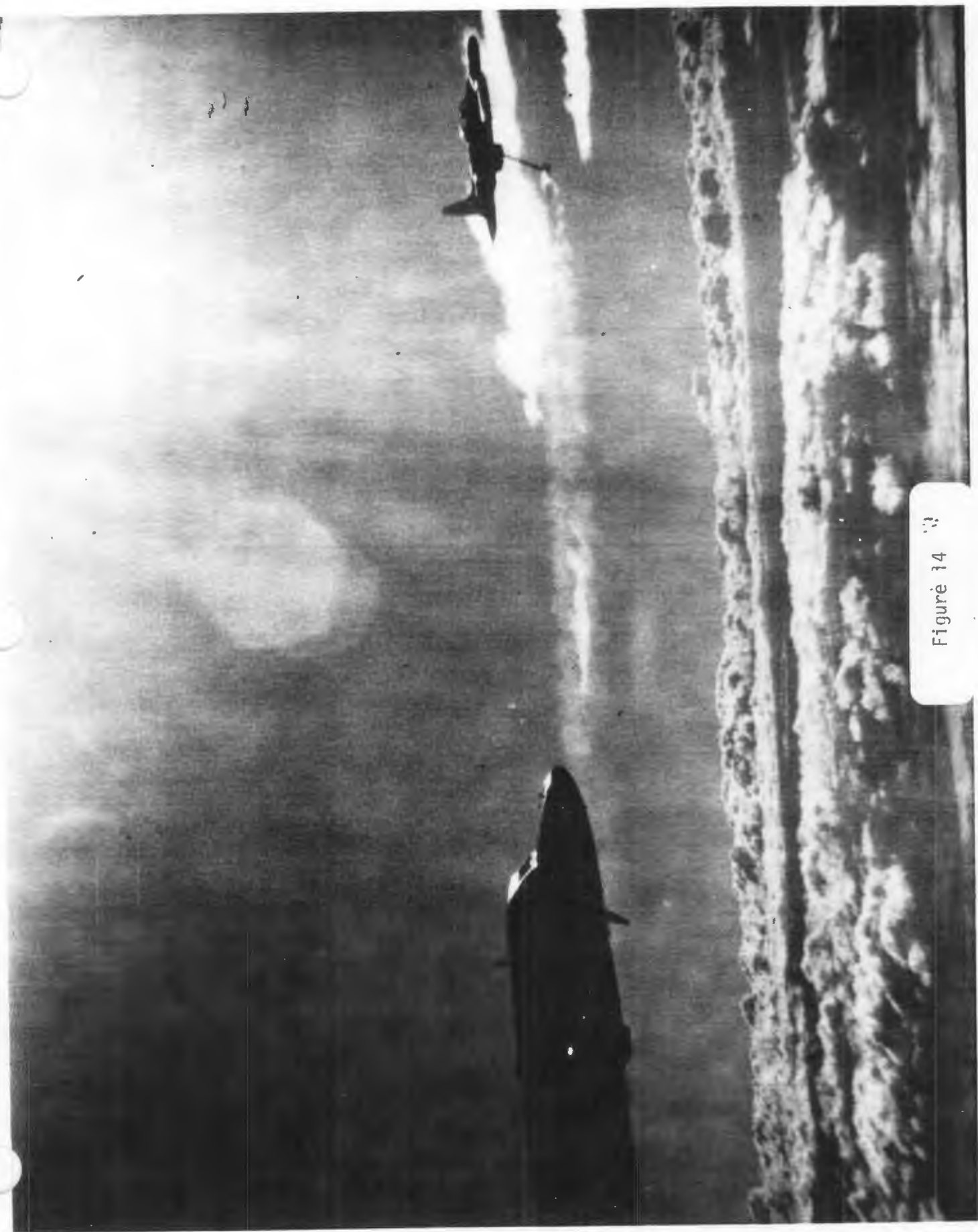


Figure 14 'W



Figure 15

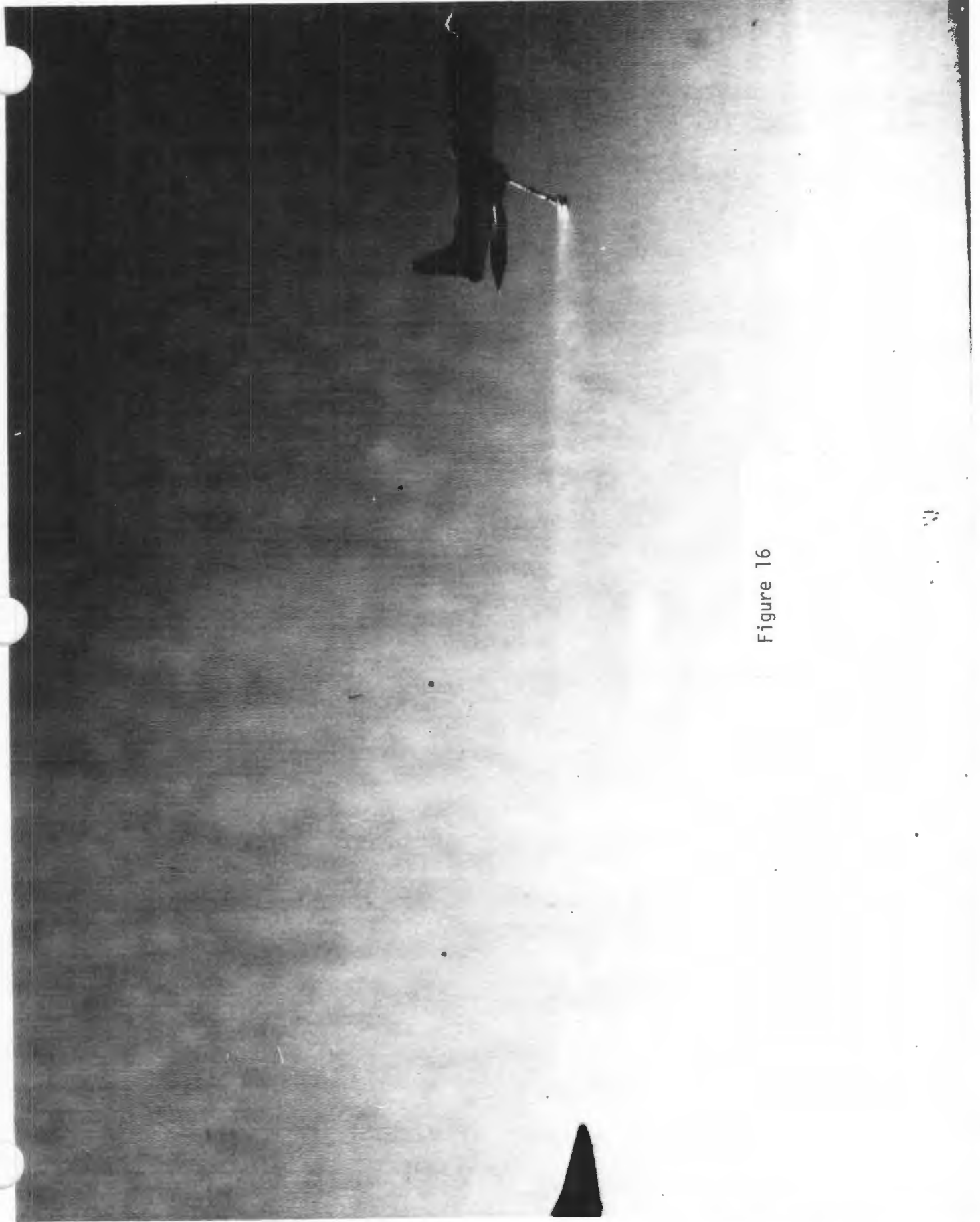


Figure 16

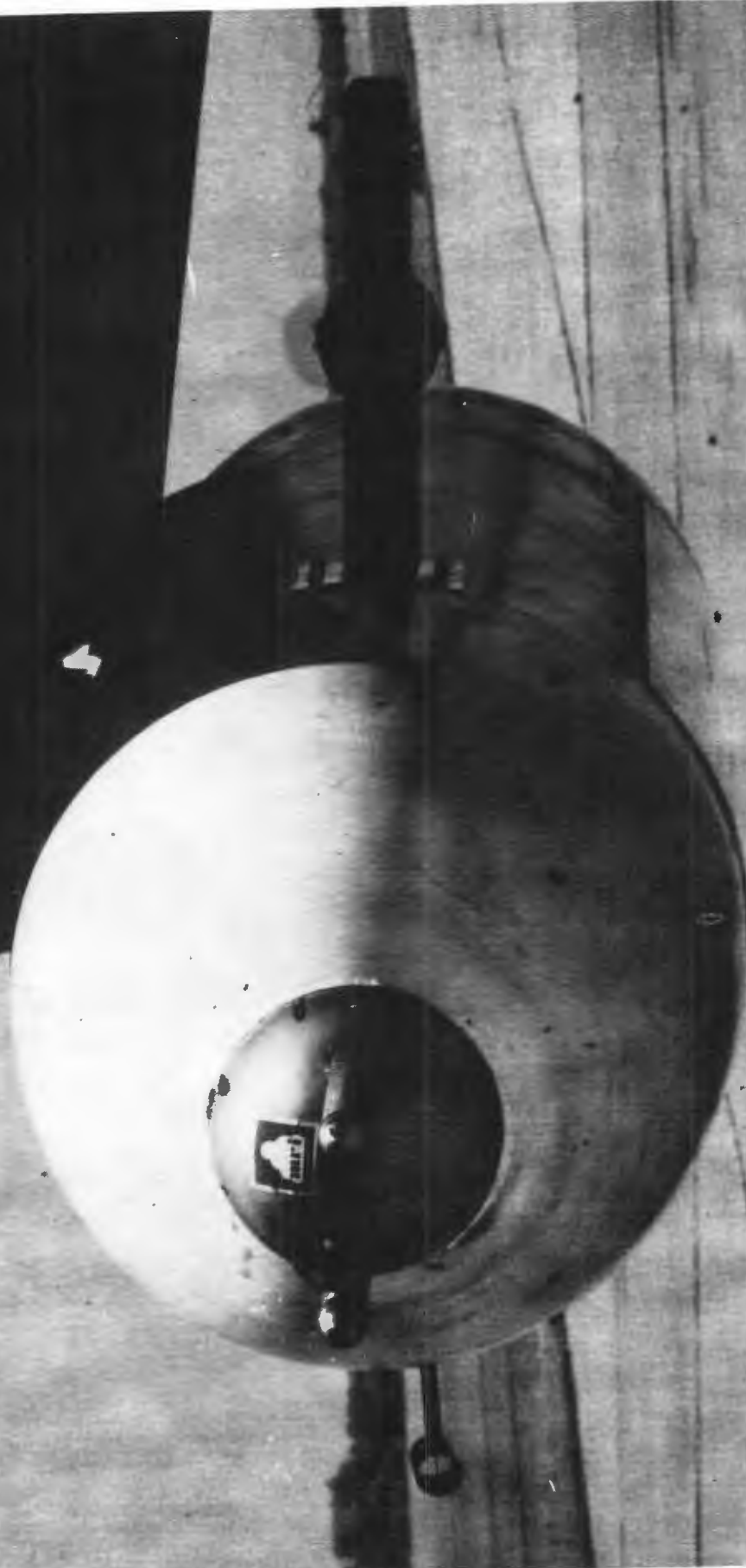


Figure 17

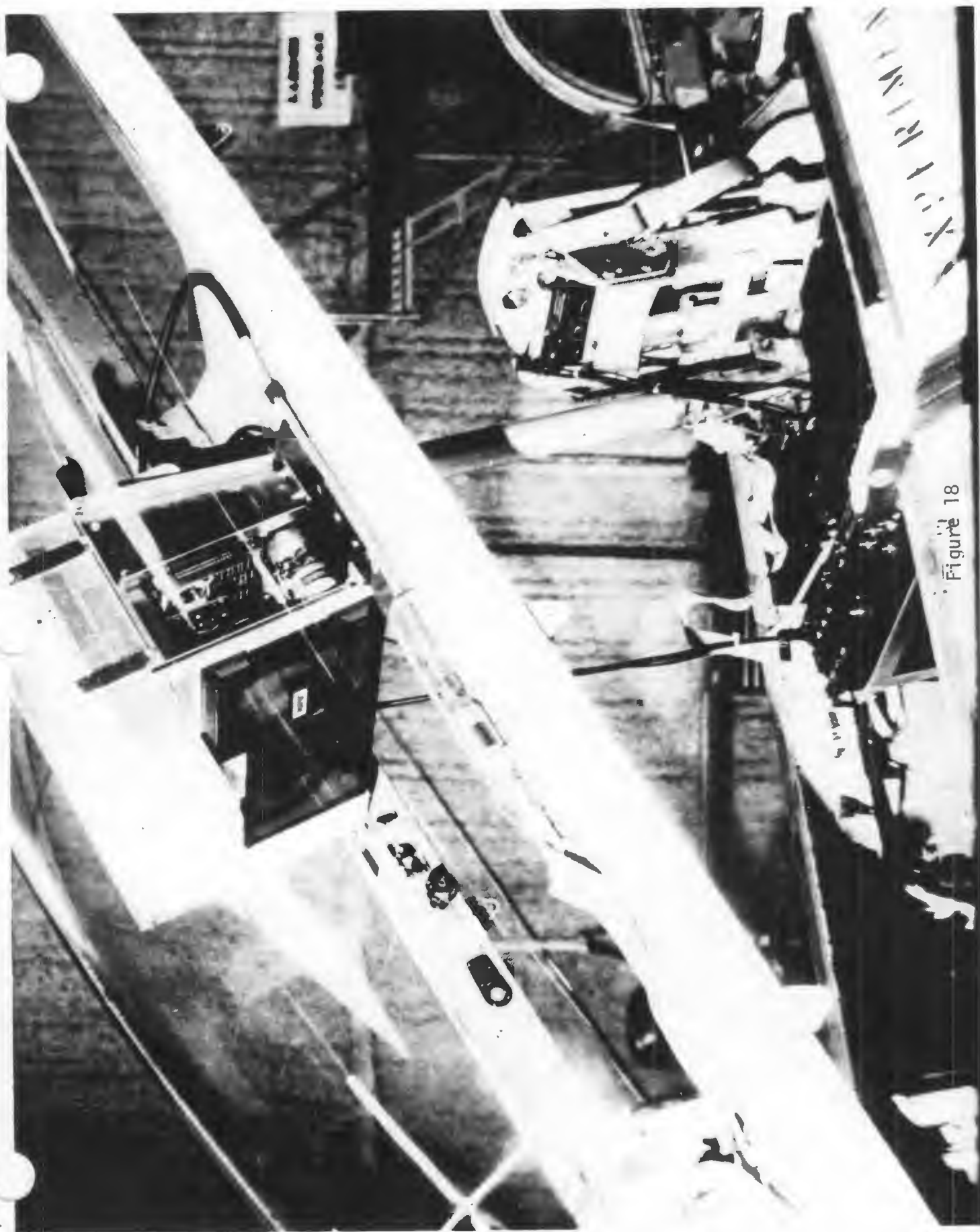


Figure 18

RICHARD I. ADAMS

The meeting that we had here on August 6th of this year was really a coordination meeting of all the various agencies in the government that were conducting meteorological surveys to acquire data that feeds into Art Hilsenrod's weather program as well as our efforts to refine the FAR 25 criteria. We are working with the Air Force Geophysics Lab and the Naval Research Lab in acquiring data. We are considering some contractual efforts, but there's no money available at the moment for that.

GENERAL DISCUSSION/QUESTIONS AND ANSWERS

MEETING CHAIRMAN: RICHARD I. ADAMS

Thanks Bob and most certainly it's going to be a great use to all of us. I might mention that there are two ice detectors that are now on the market that have the capability of directly measuring liquid water content from ice accretion rate. One of those companies is represented here today and I'm sure he'll fill you in. And if you want further information on the other company, he'll probably answer that question too.

It's now 12:00 and we have 45 minutes. The plan that I have, you see the tables lined up here with microphones, is to get into a general discussion so that we can kick around thoughts, ask questions and kick around the critical issues that we're still concerned about. Now my original intent was to have all the speakers and myself, with representatives from AIA, HAA and GAMA at the table. We don't have room for all the speakers, so I have developed a specific list that seats representatives from each of the agencies, including one from the Army, Navy and Air Force at the table. Now, let me just call out the names of those people that I would like to have up here with me. Number one, I would like to have Dave Ostrowski come up and sit with me. I haven't approached Dave on this before, but I'm sure you won't mind. I would like to have Herb Slaughter at this table, and Jim Dougherty, representing GAMA, Bob Richardson, Harry Chambers from the Army, Milt Beheim from NASA, Vito Truglio from the Navy and Carl Wolf from the Air Force. So if you will come on up now and be careful and don't trip over the cords there, the electrical cords that are laid down here, and seat yourself at the table, we'll begin the general discussion. We don't have enough microphones for everybody, so we will pass them around as necessary. Also any conversation from the audience we would like to get on tape, so we'll pass the hand mikes around.

Dave Ostrowski, while you stepped out I had asked you to come sit at the table with us here, if you don't mind.

Let me just comment, while Dave is on his way down here, that I am very pleased with the response that we've gotten from industry as presented to us by HAA, AIA and GAMA, here this morning. I think in a nut shell, it gives terrific support to what we have in mind to do and that from all of this we will be able to bring together some recommendations that we will send the FAA Headquarters and I think that we can present enough information to establish a Task Force and I think it's going to be great. I think that during the discussions that there was an expression of concern from many of you that we didn't have all the facts straight. I don't think that we can have all the facts right now or all the details that are necessary. I think, really, that what this meeting represents is a second step on a long climb up a big mountain, and that the thing that the Task Force will have to do will be to define the things that need to be done and the rationale for it and we'll have to, at the same time, take into consideration the current status of data that can possibly lead to changing the FAR 25, Appendix C criteria. But I don't think we can wait until we have changes

RICHARD I. ADAMS (General Discussion/Questions and Answers)

in those criteria to begin a national facilities effort. I think that has to be a parallel thing. If we don't start now we'll never get there. With those initial remarks, let me open it up to general discussions, question from the table and questions from the floor.

Q. KEN YOEMAN, KEY INDUSTRIES, San Antonio

I have several areas, but I would like to talk about Part 25. If you're going to review the icing criteria, the FAA now, I wish you would look at 10-93 (FAR 25.1093) and tell all of us what falling and blowing snow is. Now this is typically not a problem for pitot type inlet and inertial separator such as an helicopter can become packed and I don't think anyone is arguing the need, but just what is it? I've sent data to my region, they probably sent it off to Washington, which meant it fell off the end of the earth somewhere. The Canadians have done a great deal of work on snow. You can correlate this to visibility from the MET people and come up with something, but someone should tell industry what snow is.

The second part of 10-93 is the ground fog. Now nature's not cooperative in giving us thirty minutes of conditions that are absolutely stable. I don't know how you measure them without forward speed. That needs to be reviewed.

The other point is that your're talking about Appendix C with regard to helicopters. I think there's implications to fixed wing also, if you pick an altitude and suck the envelopes in, and before anything were to be issued, you'd better think about this.

A. RICHARD I. ADAMS

Very good, your questions are understood and let me provide a brief comment and I'm sure that others would like to comment.

The Research and Development Program that we have, to better define the criteria, does include blowing and falling snow, as well as freezing rain and as well, super cooled cloud conditions. So I think that your request didn't necessarily fall off the end of the earth. I think that it has filtered through the R&D program and something is being done about it and we're aware of what the implications are. In addition, we have on our books right now, as a matter of fact, funded in FY'81, for the initiation of an effort to define the requirements for a snow simulator that could be used for snow development testing and possibly being accreditable for snow certification. I say possibly. The ground fog issue I cannot address, but the Appendix C criteria, I referred to the August 6th meeting before, I refer to it again. During that meeting one of the basic conclusions that we reached was that if we are going to reconfigure the Appendix C criteria, that we would want to do this in terms of altitude or as a function of altitude. In other words, we would have plots of curves of liquid water content as a function of altitude, temperatures as a function of altitude. It will be the

immediate volumetric droplet diameter as a function of altitude, and droplet size distribution, with all of these things interrelated. Specifically how these curves are going to be presented we don't know yet, we haven't really started in that area. The effort that's going on right now is data gathering and NASA data that exists is a part of that. We did also conclude that this information, although its development is precipitated by the helicopter needs, can be, if it's presented properly, applicable to all kinds of aircraft. I say, if its presented properly. Let me reiterate that this is a research and development approach right now. I believe that it has the concurrence of the Washington Headquarters and also the lead regions. I think Dave Ostrowski would like to make a comment.

A. DAVE OSTROWSKI

Thank you Dick. I'm not sure all of you know me, I'm one of those fellows from the end of the earth. Which is why I'm commenting on this, I presume.

10-93 falling and blowing snow is your first point. There is a proposal, as I recall, in our Rotorcraft Regulatory Review on that particular section and I know there's been a lot of discussion and a lot of thought, consideration, given to redefining that, so forth. I, myself, am not particularly familiar with that aspect of it, but my point is, that is under consideration at the moment. I'm not sure you all are aware of the ongoing helicopter regulatory review. I know a lot of you are, but for those of you who aren't; the FAA is in the process of reconsidering all its rotorcraft rules and this pertains to certification, operation, maintenance. The total rotorcraft rule making situation is across the board. We had a public conference in New Orleans last December. We had another one just last August and we are in a regulatory mode at the moment. We do plan to issue an initial NPRM in the next month or two. So that if there are inputs, there will be further opportunity through the NPRM process to provide recommendations and comments, thoughts, whatever, as part of the process, as there has been, throughout the initial meetings in December and August.

Your point on Appendix C implication for fixed wings. Should we find some data that pertains to the envelope as it is defined now, I think that we agree, that yes, we do have to consider those implications and they certainly will be.

RICHARD I. ADAMS

I think that your question was very valid and a question that needs to be discussed. Your questions, however, are not absolutely pertinent to the subject of this meeting and that is the icing test facilities, except by reference. We do need to get the criteria situation squared away so that as we develop our facilities we're sure we're doing it in the proper manner to facilitate the different criteria. As I mentioned, this needs to be a parallel type of an effort. I would like to try, as much as possible, to constrain the discussions to the National Icing Test Facilities issues.

KEN ROSEN

I would like to amend my statement and I believe my colleagues in the rotorcraft community would agree with me. I had a subsequent conversation with Milt concerning the free jet capabilities that he's proposing in the AWT revision. We did not understand that the free jet revision was not part of his Phase I plan, but is, in fact, part of his Phase II plan. It is important that we go on record as stating that part of the Phase II plan related to the proposed revision of the AWT that related to the free jet capabilities producing that 45 foot test area and capability, I believe, up to 200 knots within that test area, will be a valuable asset to us in the rotorcraft community.

RICHARD I. ADAMS

I'm sure the tape recorder is on back there to gather that information, so we can make the amendment. Thank you.

Q. JOHN LIGON, FLIGHT SYSTEMS

Assuming a decision is made to develop a national inflight simulator, in other words, a FAA icing tanker, when do you see that occurring? When will we be competing? and What type of aircraft, what type of parameters do you think you are looking at?

A. RICHARD I. ADAMS

I think the first thing that's going to happen is to develop the justification for the tanker. That's part of what this meeting is all about. We want to consider all of the facilities needs. A national inflight tanker is a part of that need, as I see it. We at the FAA Technical Center feel that that is a valid requirement and a valid need and we feel that the best place that industry could be served by a national inflight tanker, possibly, could be to position that tanker here. It could be used in various places in the country, but that decision of where it would be located and by whom it would be owned, is still up in the air. I would like to see it here, myself. The time frame, we can only say at this point, the funding for such a facility is included in our "wish list" budget. I think that we have to be realistic when we start talking about budget and I think that the handwriting is on the wall and the FAA is not going to be able to afford that tanker on its own. I think that the FAA is going to have to have the support of NASA and DOD from a funding standpoint. The sooner we get the Task Force together, the sooner we get a national icing facilities program plan established and priorities established, and money in hand, the sooner that type of facility will be available. I guess my best guess is, at the earliest, three to four years. Now I might mention that we are working very closely in helping fund the Army's improvement of the HISS and we see that as the standby in the meantime, until we can afford the tanker that can be used by industry on a non-interference and a cost reimbursable type basis.

Q. ANDY PETERSON, BOEING VERTOL (General Discussion/Questions and Answers)

Question on the facility and certification. Is the FAA prepared today to accept the results of the HISS for certification or in the near term HISS improvement?

A. RICHARD I. ADAMS

Let me answer that from an R&D standpoint and I'm sure that somebody else would like to consider it.

Based on the experiences so far with tanker testing, the helicopter tanker testing that I've seen, I think that there is enough concern about the effects of relative humidity and solar radiation and ice crystal content, that until we know more about these issues, or the effects of parameters or conditions, on the correlation of tanker results to natural results, that it would be questionable. I think it would probably be necessary to industry at this time, or the applicants, to provide answers to those questions. Now, I'm only speaking from an R&D standpoint and my own personal opinion at the moment and maybe this is a good thing that we can open up for further discussion.

Q. ANDY PETERSON, BOEING VERTOL

Well, let me go on with that a little bit more. Today's HISS has certain limitations and there's certain questions to the FAA. If money is put into the HISS improvement program, is the FAA then going to be prepared to accept that data for certification or if not, what data will the FAA accept for certification and will the FAA define specifically what they will accept for certification? And when will they do this?

A. RICHARD I. ADAMS

One of the reasons for the research and development program, Andy, and the FAA's participation in the Army HISS improvement program is to answer questions of that type and we specifically asked the Army to look into these various effects and until that information is available, I don't think that we can make any positive statements. In the meantime, if you could show us something better, I think this is what the certification authorities would say, if you can provide more information or better light on this, you would have to Herb!

HERB SLAUGHTER

I think Andy Peterson of Boeing Vertol has asked a very, very pertinent question. Very important to us, its almost like the chicken and the egg. We're all concerned about the certification of helicopters and I think we have all brought that out, at least the people that have participated from HAA and AIA, since we're going to go through it in the time frame in the next couple of years, the first civil certification of a helicopter for icing. You're asking us to give you full support for the icing, artificial icing facilities and I think we've done that here today. But, we're all sitting now wondering what's going to come

HERB SLAUGHTER

(General Discussion/Questions and Answers)

next. When is that egg going to hatch in terms of benefits to us with regards to certification? The fixed wing people do have an advantage in the fact that they have had experience, they have had correlation between their representative tankers and the small aircraft. They have had much experience in certification with the large transport aircraft. That technique is understood by FAA, acceptable, etc. We, in the helicopter industry, are forced, and I think this should be a matter of record, it costs on the order of \$5M to start from scratch, design, go through the development test program and get FAA certification for a helicopter. Now that is a helluva lot of money and I doubt whether the fixed wing people spend that much with regard to certification.

KEN ROSEN

That's just certification in icing, Herb, not total certification.

HERB SLAUGHTER

Well, I meant, my comments are referring to certification and icing. I thought that was understood. Therefore, there should be some benefit from this and I think the closer we get to the liquid water content, the droplet size, in our artificial testing facilities, then there should be some recognition of this and that if the natural icing requirement is still there, then it should be minimal. With regard to the amount of correlation you can show with the artificial icing tests that you do, I hope we do not get into the position where we have to go through precisely the typical program that Dr. Rosen showed, where we develop in hovering, we develop more in the tanker, we test behind the tanker with FAA to show certification and then we have to show five or six points to describe the icing envelope. Now that would be disastrous to the helicopter industry in trying to get certification. I think our colleagues in France have taken four to five years in order to get to the point where they are ready for certification and after that period of time they still do not have adequate data to satisfy the FAA with regard to certification. So we feel that something should hatch out of this egg that you're giving us today that will benefit the industry in the certification process.

RICHARD I. ADAMS

I fully concur in all those things that you said. Let me give you my personal opinion and that is, in the future that the inflight tanker can be used in the certification process. Maybe not to totally eliminate the need for natural icing tests, but to reduce the amount of time that would have to be spent finding the natural conditions. I think that we are headed in the right direction with tankers. All I'm saying is, that we don't have all the facts together yet. We're in the process of trying to bring those facts together under the R&D program. I don't think that we can sit here and guarantee you or anybody else that these facts are going to fall into place and that absolutely you're going to be able to get total use of all of your

RICHARD I. ADAMS

(General Discussion/Questions and Answers)

simulation time behind a tanker being attributable to certification. That, in itself, is another parallel effort and will have to go along with the development of the facilities. These facilities are going to help you in the development process as well and I think that we have enough information at this point in time to assure us that we need to proceed with the national facilities program.

Yes Ken!

KEN ROSEN, HAA/AIA ROTORCRAFT

I think the issue really must be stated very clearly. We'll never do it! There will be no certification in the United States of a rotorcraft, unless the community, the FAA, etc., becomes convinced that simulated icing is, in fact, a very valuable and necessary tool, not only for development, but for certification. It's as simple as that, because it won't be only five points that Herb talked about, it may be, in order to hit all the combinations in natural icing, thirty to fifty points. Remember I was talking about \$20,000 a flight hour, just to operate the helicopter, let alone the tanker. The cost may be more than the \$5M that we've projected, or that Bell's projected. I can say that we don't really know what it will be and what is really unfortunate is that your very good effort, Dick, didn't get started three or four years ago. I can only say that we have to support your effort, but that the effort must be accelerated and that one of the first things that you, as the research arm, must be convinced of, or must develop, is the ability to develop confidence in the simulator, excuse me, a simulated icing environment, as a tool for certification. There is simply no way, that if we have to hit all corners of this envelope, using natural icing means, that we will succeed.

RICHARD I. ADAMS

I don't disagree whatsoever with that answer.

JIM DAUGHERTY

I hope that we're not smoking opium here but I'd like to introduce a little realism into this thing. I said this morning that we supported this and we still do. There is a possible application in the low speed regime on fixed wing aircraft. I said we favored the KC-135 tests and possibly the modifications that were addressed in relation to the C-130. But this raises an interesting spectre as to the availability thereof. My question to you would be, Do you see, or do you have in mind, considering different types of facilities for different classes of aircraft? All I've heard so far is the Chinook flying through the air and hopefully satisfying the helicopter industry's business and I'm not opposing this, I might add. But, in the broad sense from government's viewpoint, are we talking about three possible different facilities or are we really talking about prioritizing these and attempting to clarify the helicopter industry's problems first?

RICHARD I. ADAMS

(General Discussion/Questions and Answers)

The national facilities program that we have in mind includes all classes of facilities. The tankers, tunnels, icing wind tunnels, icing tests chamber and, as a matter of fact, analytical tools and techniques. And it really considers all classes of aircraft. These tankers, as a matter of fact I had a viewgraph yesterday that I wish I had right now, but, these can be used for research through development and certification, hopefully, as time goes on, to the maximum extent possible for certification, of components and the total aircraft as a system -- in any way that a particular facility is suitable for anyone of those things.

JIM DAUGHERTY

Dick, the bottom line to all of that is, and I'm happy to hear you indicate that it's a little bit more than tankers for helicopters, the bottom line really is, and it ties to your relationship with the regulatory people, when can we get rid of and under what conditions do you think we can get rid of, natural icing tests across the board?

RICHARD I. ADAMS

I can't answer that. I can only say that I do have confidence that the amount of natural icing testing that will be required for certification can be drastically reduced. Whether or not that will ever go to zero is a tremendous question. Just take one step at a time, I think.

JIM DAUGHERTY

Well, may I suggest in your preparation of your plan that you look seriously at that aspect of the thing and even think in terms of pushing this, because I agree with you. I don't think this is going to, from what I know of FAA in my previous experiences, and also the current attitude in there, it's not going to be any easy solution to this problem, no way! In fact, it seems to be going the other way in terms of the rule making process. But I would think that you need real careful consideration of this aspect with heavy emphasis on the driving force coming from you to use these ancillary tools to the maximum extent possible. Two companies have got to operate their own tankers today, and there is a third outfit that we heard from today that is willing to lease a tanker on some sort of contract basis. But it does raise a really clear spectre in my mind that in your assessment of the thing, that you not only take into account the various techniques that you alluded to just a few minutes ago, but you also relate this on some sort of time oriented basis for the different classes of aircraft. We may be talking in the real world, here, anywhere from five to ten years from what I can see.

RICHARD I. ADAMS

To reach a total end product, yes! But we've got to, I think, bite it off in small pieces and in order of priorities that are established

RICHARD I. ADAMS

(General Discussion/Questions and Answers)

and I guess I like to say the priorities that have been suggested so far as money is available. Yes Herb!

HERB SLAUGHTER

I'd like to endorse Jim Dougherty's point clearly and then add to it. In any program, such as this program to put together a national icing facility, to get the program moving forward there must be a justification and there must be a goal established. I would like to set forth for the panel a suggestion that in preparing the justification for the improvement of the artificial icing facilities that we justify it on the basis that the goals are to reduce the amount of natural icing required and that this goal be endorsed by the regulatory wing of FAA.

RICHARD I. ADAMS

I think that's a reasonable suggestion and as a matter of fact, I think our program plan that is prepared states it in a very similar manner.

Can I ask that, I've tried to address this issue from a standpoint of research and development, we have no regulatory authority here, we do have representatives from various regions. Let me just ask if one of the region's representatives would like to comment on this area. Yes? This is Tom Plumber from the Southwest Region.

TOM PLUMBER-SOUTHWEST REGION - HELICOPTER STAFF

I think you put it very well Dick, when you addressed the issue about acceptance of the simulated facilities for certification. Certainly the helicopter Certification Advisory Group, of which I'm a member, would endorse the use of this accumulative data for the purpose of reduction in natural icing tests. However, I really don't envision completely eliminating natural icing tests. If you remember Captain Lynn Hanks' presentation yesterday, he very strongly brought out the point that they would have missed some very important icing parameters if they had not conducted natural icing tests after they had done all their simulations. From an idealistic point of view, I would like to address Jim Dougherty's question about will we ever do away with natural icing tests. Idealistically, and this is only my own viewpoint at this stage, if we could ever develop a simulator that would completely test the helicopter, fixed wing or whatever, in every variable simultaneously that you would encounter, that would certainly be one of the minimum requirements to eliminate natural icing tests. I think that at this stage of the game our simulation capabilities are limited to where you can only look at a few of these parameters. For example, in the HISS we can't even fully immerse the helicopter at this point in the icing cloud. I would certainly hope that we could all work toward minimizing the cost involved, and of course this natural testing and going all over the country looking for natural icing conditions adds to the cost, and I would hope that the natural icing tests could be used to verify the analyses in the situations.

RICHARD I. ADAMS

(General Discussion/Questions and Answers)

Thank you Tom. Yes?

BOB CRAWSHAW, CESSNA AIRCRAFT

I guess my question follows along with what we have just been discussing here. We have a reasonable capability to do some simulation. I would hope that at least from, you know the poor old farmers in Kansas with the tin shed, that if you fellows come up with a tanker for use in the general aviation field, it will replace natural icing tests or I don't know what we're going to do with it. But we can use, very drastically, a lot of other data that will allow us to move more rapidly and I guess you can relate that to cost, but I'm speaking of time. I'm thinking of the kind of things that I would envision coming out of your wind tunnel type activities as far as facilities are concerned. Where, regardless of what I have, I need to write an analysis, and I'm not saying that I don't write a good one or that the FAA doesn't accept it, but I think it could be possibly better or have a better basis that we all would commonly understand and when it comes to simulated tests, I think the engine people have had excellent results certifying engines with icing in a wind tunnel. From my experience on airplanes, once they go through a wind tunnel program and get a certified engine it works great in an airplane, providing I put an inlet on it. So I don't know why it couldn't be used on an airplane.

RICHARD I. ADAMS

Very good, Bob. Its time to break for lunch.

SECOND DAY

RICHARD I. ADAMS

(General Discussion/Questions and Answers)

The crowd is beginning to thin out a little bit. People are bugging out to catch flights and etc. Vito Truglio has excused himself from the table. I would like to shoot for an objective of finishing up by 3:00. We have made arrangements for a tour of the R&D facilities at 3:00 for those of you who expressed interest in that. We attempted to make arrangements for those of you who were in caucuses yesterday and missed the tour of the ATC facilities and other points of interest in the building, this afternoon, but that could not be arranged. But we can personally show you some of these areas. So if we can finish by 3:00 then we have the tour of the R&D area and those of you who would like to take a walk around the strategic points in this building, we'll accommodate that too.

I think that the discussion that we were having before we broke for lunch was very interesting and I would like to open up the floor again to questions. Yes "JB"?

"JB" McCOLLOUGH

I haven't said anything since yesterday morning, but I have heard a lot of good presentations and I want to thank all of you who have participated in the discussions and the presentations to this point for all that you have brought to this meeting. But there is an observation that I would like to make to all of you. And that is, by the nature of the title of this meeting, National Icing Facilities, and we are holding it here in a government facility, to pick up the feeling that this is Uncle Sam's job to furnish a national facility and I hear industry saying when are you going to get these answers and how quick and will you guarantee you'll accept them when you get them, so that everything is rosy, like Uncle Sam is looked to for a handout. I also hear people here who have their own commercial facilities who say when will I be threatened in the market of competition with my facility. I hear other people who have their own private facilities that they use and that they rent out to other people and they want to know will those still be acceptable. The question that I would like to ask you, each and everyone, is this the proper role for government or is this the proper role for the competitive marketplace in the United States that we are all proud of? If we need these facilities and we need them bad enough, there's somebody clever enough to make a buck on them. And if he can do that he will respond to the customer who wants them now. And if that be the case, I think we ought to discuss whose role it should be to pursue facilities. Independently, piece-meal or in total, but don't forget that we have technology to worry about. That's my question to all of you!

RICHARD I. ADAMS

Would you like to volunteer to answer that question?

I think I mentioned this morning, "JB", that we had sort of hit around the fringe of what you have just mentioned, in the form of a survey we have underway. The results are still not completed because we have some, as I said, 38 members and the total vote isn't in and it's obvious that we're not going to release any results until we've got a fairly detailed consensus. The questions we asked were: Do you see a need for such a test facility in the future? and in this sense it was for general aviation, and that sort of bears partly on what you asked. If not, what test facility do you now use? It's obvious that if you don't see a need for it you've got to be using something, so we came around the back door. And third is: Would you favor total government funding of such installations? Coupled with user charges? We think relates to the question that you've asked. Then: if a facility is constructed, is the FAA Technical Center the logical place? The last question which isn't totally germane, although indirectly relates, was: Would separate facilities be needed for each type of aircraft, that is the class situation? So we've got a mixed bag of answers. Some people think that if the facilities existed they would be glad to use it and there's no question about it. The issue came out in a side discussion here this morning and I think yesterday, and in some of our chit-chat sessions with the industry people here, simply boils down to: if the thing does exist will we have access to it. Will we have access and that's a legitimate question, in my mind. There's no reason to engage in assumption on that point. And will the cost be reasonable? Both of those are no reason to engage in assumption. So I think that, from my point of view at least, I can't speak for the rest of them here, this is a reasoned assessment of the varied issues that you've brought out in the open here. And I think, I don't say that I recent the tone of it all, but it seemed to me that you attempted to put us on the spot as crying wolf, when in fact we're not. We came here, in our case of the general aviation people, with an open mind and an open heart and we've given you support in fourteen areas in the points that I made earlier this morning and we intend to continue to give you support, but we certainly have got to get, as we have repeatedly said here, a little better definition of where we're going and in an orderly fashion, what we expect to be doing in this program. So, I think, give us a little time at least from our segment of the industry to frame the answers to this on a statistical basis and then we will be glad to get back to you.

KEN YEOMAN

Dick, I didn't mean to cause you chest pains over Part 25, you brought it up. On the matter of the tunnel, I had a little conversation with Jack Reinmann outside as to the future of the current 6 x 9 tunnel which was not touched on in Mr. Beheim's discussion. I understand that the IRT will remain operational and will be upgraded. Three of the people this morning brought up access to this facilities. One other problem is civil access. It might be NASA's primary role to conduct research, whereas to the majority of us that are nuts and bolts engineers

KEN YEOMAN

(General Discussion/Questions and Answers)

or are interested in certification or operations, it would not be research. It would be basically commerce. Now is this going to cause a problem with access? If you're asking for a mandate from the people in the room about these facilities, someone needs to really answer that question.

RICHARD I. ADAMS

I know that Milt Beheim has answers to these questions. These issues were discussed at our government coordination back in January and it certainly is a problem. Would you like to elaborate, Milt?

MILT BEHEIM

I'm sure you're aware of the basic differences in the charters that Congress gives to the different government agencies, and NASA's charter is clearly R&D. Therefore, things that are given high priority with NASA have to be of such a character that they hit the mission of NASA which is an R&D agency. As I mentioned yesterday, in the process of creating research facilities, you do have an additional capability of also meeting more near term requirements. The icing tunnel is an example of how it has been used repeatedly even for things related to certification. I could give you a better answer to the total picture on priorities and the facilities and funding with a few of viewgraphs.

RICHARD ADAMS - "Do you have them available?"

MILT BEHEIM ("Glad you asked"!)

Something seems to be lacking here. Can you see all right? I want to point out, this (Figure 1) is the present position of NASA in terms of policies regarding using NASA facilities and it's found in the Federal Register (Vol. 43, No. 193). There are different classes of facilities shown here in Figure 1. There is the unitary group of facilities which are basically wind tunnels that were provided in a separate act of Congress in the early 1950s. There are very few of them. One group at Ames, one at Lewis, one at AEDC. Congress stipulated that these at NASA centers would be available primarily to industry for development and NASA research, as time is available.

There is a second class of facilities that has come on the scene very recently. Three facilities that I referred to yesterday are called National Facilities. One of them is the National Transonic Facility at Langley, and it has a high operational cost because of the large quantities of liquid nitrogen it consumes. All of the National Facilities are available to all users, and there is a reimburseable policy for all users of the National Transonic Facility.

In the other National Facility action under way at the present time, there is modification of the Ames 40 x 80 tunnel to also include a 60 x 120 foot test section, for some of the VTOL and rotorcraft work. There is no special policy established at this time for fees to be charged once

that facility has been modified.

The other major facility which is in the National Facilities category is the \$470M engine cell at Tullahoma and I believe it will be used in the same manner as all their other cells are used and that is, outside users pay the fee. If it's an Air Force program I'm not sure how they handle the internal bookkeeping and transfer of internal funds.

So there's very few of those facilities. I suspect if AWT is built, because of the capital investment, it would be classified as a National Facility with a user charter, but I'm not sure of that.

All other NASA wind tunnels, including the icing research tunnel in Cleveland, are primarily for NASA research and industry work when it's in the public interest. And it can be in the public interest as a joint NASA/industry research program where the results of the research are widely available and disseminated through the normal NASA distribution channels, or can be used on the basis of a fee. The fee arrangement has not been used very frequently to my knowledge. Other classes of work are indicated on Figure 1. The classes of work are; they can be a company fee project if it's beyond the scope of an existing government contract. If it's supported in a government project with a government contract, then that test time is provided on the basis of that agency's request with no fee to that agency. The consortium project may either be based on private funding (on a fee basis) or a government agency may have a legitimate interest in that work and support it, with no fee arrangement. Foreign company projects are generally not accepted. The fee is based on occupancy charges as indicated here, including energy consumption and data reduction costs. The big costs are, of course, energy and the occupancy charge, which includes an amortization of the facility. Now there is one thing that has come along very recently that could influence some of this to some extent. I think all government agencies need to be aware of it. If there is a national icing tanker, you'd better raise the same questions, because there has been established by a new act of Congress, the Office of the Inspector General. We have such an office in Cleveland. They have recently completed a study of the aeronautics program and one of their recommendations is that research cost (not facility costs, but research costs) that are applicable in the near term to industry activities, should be reimbursed to the government. And that goes way beyond user fees for using a facility. It says, "..... reimburse the government for their cost in the research program". Now what the impact will be I can't tell, but I'm sure all the government agencies are going to be faced with the same question.

Now I want the next viewgraph (Figure 2). With those fee questions in mind, would the schedule of the icing research tunnel have changed if there were user's fees involved? Here's a quick glance at the schedule of the icing tunnel and it indicates to you its accessibility to the industry. You may not be able to read it, but this shows a list against a calendar, starting in July of '79 through about July of '80. There is some work

being done in this time period using laser equipment on calibrating the cloud uniformity. Another cloud uniformity test was performed to improve the distribution of the icing spray, an internal Lewis activity. The NTSB had an entry with an aircraft component for an accident investigation. The Army HISS spray system entered the tunnel here. McDonnell Douglas was in with an advanced ice protection method study. Air Force and NASA have a joint program on ice phobics and the Army's CRREL is a part of that activity. The entry is shown. Goodrich performed studies of a boot on a helicopter rotor blade. An entry here is the Mitsubishi 300 tail. Mitsubishi owns a plant in Texas and it's a producer of a particular kind of aircraft to be certified in this country and this is a certification entry. The Army's AAH-64 inlet entry. There's a instrument entry, its a Pacer system. Here's the Army's Hell Fire missile which goes on the attack helicopter. A test here for the Air Force ice phobics program with NASA. Another instrument. Another entry of the AAH-64, the target acquisition and data systems on the nose of the helicopter. A reentry of the Mitsubishi 300 tail. Incidentally, I might comment that most entries are repeated. Its not a straightforward process to get an ice protection system to work. Next slide (Figure 3). This is a study of ice accretion on some of the new general aviation airfoils. A grant from NASA to the University of Kansas to study TAKS system which is a liquid system for deicing that has been evolved in England and it was used on a general aviation wing. Another entry of pneumatic boots for general aviation wings, a program of joint interest between industry and NASA. The AAH-64 inlet, again, to solve a problem. Now I'm getting into something that's coming up in the future. The GAW ice shapes will be continued, the F-16 inlet is coming in, the strut in the middle of the inlet requires some ice protection. The Bell Helicopter inlet entry is shown. NASA and the Army have a joint effort on helicopter rotor test rig using the OH-58 tail rotor. The Army is providing parts and some assistance on funding. There's a Lear Jet entry. There's a oscillating rotor test, taking a blade from a rotor and not whirling it but oscillating it. Some work of this type has been done in England and they indicated some success in being able to do that to simulate properly some of the worst conditions that are required for rotor protection. A Piper inlet. The Air Force is coming in with a modification of the icing spray rig for the KC-135. We've got some maintenance work coming up here but out in the 82-83 time period we don't have any firm scheduling. Would these people have been there if there were fees? Only they can answer. NASA paid the cost of these entries and it's like \$25,000 a week. Did industry have access to the facilities? I would say so. I suspect the altitude wind tunnel would be used in a similar mode. But because of costs and because of increasing pressure on NASA on cost reimbursement, there's probably going to be a fee arrangement. I don't know what it is.

HARRY WHITE, GATES LEAR JET (General Discussion/Question and Answers)

I would like to make a comment and this comment is from me and not as an Engineer at Gates Lear Jet. I was stimulated to thought by Mr. McCollough's comments and his questions and I'm sure that's what he intended rather than as any challenge to the industry.

He spoke about handouts and presented a challenge to industry accepting the challenge to go it on their own for icing. I guess I personally feel that, "yes, industry can go it on its own without government". I believe in the free enterprise system enough and I'm not waving a flag, but I believe in the system enough to believe that if there is a market and if it's practical, it will happen. As Dr. Rosen mentioned, in the case of the helicopter, if it's not practical to certify the icing of a helicopter, it just won't happen. I'm not sure that that's in the charter of the FAA to promote aviation, to allow something like that not to happen. If there are any handouts that we're talking about, I think that we all ought to remember it's not we or they paying for it, we're all taxpayers, and if the right hand is asking for monetary benefits, its because the left hand put that money into the coffers to use in the first place. So, look at it from the standpoint of it's money that we or they pay for. If industry is asking for when we can use it and how much is it going to cost, these are prudent questions to me. I guess that about does it, but I just don't like the idea of thinking in terms of: "You didn't pay for it, we paid for it!" Well, we all paid for it, and our main interest is promoting aviation and promoting our aviation so that it has a place in the world market, as I see it. Thank you!

RICHARD I. ADAMS

Well said!

When we originally started planning this meeting I was aware that there were several commercial tankers that were available, two of which you heard about today and I called these companies and discussed free enterprise and things like that with them. As a matter of fact, we mentioned free enterprise in the original letter that we sent to HAA, AIA and GAMA. We, the FAA, the government doesn't want to step on the toes of industry and you certainly have the prerogative of free enterprise. But I think, realistically, when you start looking at the magnitude of the facilities that we are considering, the outlay of cash, the funds, all the technology developments that have to take place to make facilities available for everybody's use, in industry as well as government, is so tremendous that there's not a single company that would be willing to put up that amount of money. It's going to be a tremendous amount of money. One facility we are talking about here, the AWT rehabilitation, is now \$150M for completion to Phase II. So its a tremendous amount of money. We believe that with a national program, where the FAA, NASA and DOD join hands, that we can serve the interest of this great nation, the government as well as industry, and we feel that we can accelerate the research, development and the certification process to solve the unknown questions that exist and also to reduce the cost of certification. My understanding

of the FAA's charter is to foster American aviation and make American aviation competitive and I think that's a good charter and I think that the national facilities program will help to do that.

One other comment. I think what Milt Beheim has just outlined here is the fact that right now there are no national icing test tunnels. In other words, the IRT is not a national facility. It can be used to serve industry purposes under certain circumstances. The AWT would be a national facility. It would be available, but it's going to cost the user a certain amount to use it. My personal feeling is that each individual company is going to have to assess those costs and determine whether or not they want to use that facility. One thing that is very clear to me in looking at these charts and that is the IRT is booked up through about mid-1982 right now. I know that Milt has been able to work in certain high priority programs in the past year and get it done. But it's apparent to me that bigger and better icing tunnels are needed and the AWT is one step in the right direction. It's apparent to me that there are other tunnels that can bear improvement right now and the IRT is one of those, as has been very aptly pointed out here today.

Yes, Herb.

HERB SLAUGHTER

This question may have been asked while I was out of the room shortly. In the AIA and in the HAA in the helicopter area, we certainly support the AWT proposals that Milt has set before us. One of the things that appeared to me that might give us what we wanted in the time frame that we wanted is the fact that this AWT modified or put back in rehabilitated, would start operation in 1987. Now that's a long time to wait for a facility like that. Now, could I ask Milt a question? What would it take to step that up two or three years? I might recommend that when the Task Force is considering the degree of support that they might assess the financial requirements and costs to step up the availability of the AWT. Yesterday we say that this was a facility that wouldn't only help the helicopter manufacturers, but it looked like it was almost an across the board facility with regard to the civil aviation industry and military also.

MILT BEHEIM

It was originally proposed by me to be a construction project in the fiscal '83-'84 time period. In other words, start construction a year earlier and do it in two years rather than in three years. I was very disappointed when within NASA the judgement was made that they couldn't muster the resources in the concentrated form that was required to actually achieve that. Plus the fact that the advocacy of industry was not yet solidified. A decision was made within NASA to go to the present construction schedule, and that is '84 through '86 construction and '87 start-up. I think if you people have a strong interest in the facility, recognizing that many of us will still be

MILT BEHEIM

(General Discussion/Questions and Answers)

working in the business in '87, that it would be very effective if you encourage rapid construction, because then we might have it in '87. And if you didn't, you won't have it then either.

RICHARD I. ADAMS

Can we use this meeting and the consensus established in the meeting to conclude that the schedule should be accelerated? Is that a consensus of the industry representatives? Yes Ken!

KEN ROSEN, HAA/AIA

I think, to repeat, our consensus was that steps should be taken to improve the IRT and then to proceed with the AWT. Quite candidly, I'm not at all surprised by the schedule that you've put up there, which I might add has been pretty much the situation in the IRT for several years. I also have to take umbrage with you Milt, there are many people who manage to get their solution the first time. You don't always have to go back. But to answer your specific question on accelerating the schedule. With the newer generation of helicopters now entering service and with most of the major American helicopter companys seeking certification in one form or another of their new generation of helicopters, it would be to our national advantage to accelerate the schedule so that we could become competitive in the total world market place. We're no longer unique in the area of rotorcraft. Certainly the Europeans are moving very, very rapidly and I expect that many of us believe that we will see a strong threat from the Japanese when and if they decide that this will become their next technological thrust. It is clear to me that if we're going to make our helicopter market "safe" and in fact a growing presence in the world marketplace, that we must proceed with immediate certification of our new generation of helicopters for an icing environment. One way to do that would be to accelerate the work that Milton has been talking about.

HERB SLAUGHTER

I would like to underscore Ken's observations on acceleration, I hate to get into class distinctions here, but in the lighter aircraft we foresee, by '85, at least two, or maybe more, sophisticated and higher density commuter aircraft. Obviously these will be new generation aircraft taking advantage of a number of the advanced technologies and I think that from an acceleration viewpoint, this lends further to the thought.

MILT BEHEIM

I'm sure that if any of you that have worked with major facilities realize that a major facility is like a project in the sense that if you're working on a new engine system, it takes a certain number of years to get it ready, whatever it is. The unfortunate problem in selling any major facility is that the project that you know could use it will

MILT BEHEIM

(General Discussion/Questions and Answers)

probably be done by the time the facility is done, because each one has about the same time period to accomplishment. Therefore, really a major facility decision is a philosophical decision, on whether or not that capability is required in the future and you may not know in detail who is going to use it and how. The classic example is the 30 x 60 foot wind tunnel down at Langley. It goes approximately 100 MPH, it's been in operation for 50 years, it's still operating and it has had the shuttle in it and subsonic transport airplanes and everything that people never even imagined was possible when they convinced somebody to build it. Every major facility is that way. A major facility has a life of at least 50 years, except in the case of the AWT when NASA went out of aeronautics to the extent that they made a space tank out of it.

KEN ROSEN

Question! Do I hear from Milt that you wouldn't like to have support for acceleration?

MILT BEHEIM

I do, indeed, want support for acceleration because if there isn't support for acceleration, it may not be ready even in 1987. Be realistic enough to recognize that any need that you foresee at the present time, is nip and tuck in terms of getting the facility ready in time, because each one is a major undertaking. Especially within the government where there is such a long approval process. It isn't easy to get a \$150M from the Carter Administration these days.

KEN ROSEN

I see. What you're saying is: "Give your support but don't get over enthusiastic about acceleration and shortening the time period".

MILT BEHEIM

I think the technical part of it, like the construction period, could be shortened a year with overtime and that kind of thing, because the plan was originally based on that premise. I think it is too late now, though, to start construction in '83 as opposed to '84.

RICHARD I. ADAMS

I think that the important issue is that there is an identified need to shorten the schedule if possible, and I think that should be the consensus of this meeting. I agree, wholeheartedly, with the point that Milt has made here, that typically we always base our future needs on immediate requirements and we can't do that. I think that it's quite obvious that we are beginning to see the tip of the iceberg with helicopters, new helicopters, new generations of helicopters. We've got a problem right now. We need the facilities right now. We only have plans for a few helicopters right now, but there are going to be

RICHARD I. ADAMS

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more new ones in the future and we've got to have the facilities that will help certify those helicopters in the future. If we don't start now, we'll never get there.

There's a question over here that has been trying to pop-up for quite a while, Ken, excuse me.

LARRY KOEGEBOHN, DOUGLAS AIRCRAFT

And I would like to throw one more stick on the fire here. We have needs in the large airframe manufacturers too, for icing tunnels and I'd like to kind of go towards that AWT because right now the IRT is too small for some of our components. We can put a wing tip in there, but that's about it. We need the high altitude and the higher speeds because that's where our design conditions are for airframes. The high speed hold condition for 45 minutes is generally our design condition. With the big emphasis on the use of bleed air on our aircraft and the penalties that are involved in that, our next step is to design some systems, develop some systems that make less use of bleed air, lighter in weight to cut down the drag, increase the payload capability of our aircraft. So, that's where we're at, we need something to develop some new systems in. We can do some of that in the IRT, but we do need the AWT in the long run to help us refine those systems and make them more economical. So I would just like to put that on the record for where the airframe manufacturers are coming from. Thank you!

MILT BEHEIM

Our AWT would be unique in the country in that it's the only tunnel that would provide a simulation of the pressures and temperatures that occur at altitude.

Lockheed has pointed out to us that not only is it therefore applicable to icing problems, but even as a test means for composite structures under the temperatures and pressures that exist in flight and with large scale composite structures. That's the only place you would do it. There's only one tunnel in the country with a refrigeration plan standing next to it. It's in Cleveland and it's idle.

RICHARD I. ADAMS

Dr. Rosen had a question a moment ago.

KEN ROSEN

There are several opportunities that a tunnel of this type would provide and that would allow us to look at relative high tip Mach number characteristics and that has not been raised, and insofar as rotorcraft, it does have value. To add to your point Dick, Bob would reinforce this. My understanding is that we're projecting as an industry something like 20,000 helicopters by the year 1980 and perhaps double that by the turn of the century. The comment that I made before is very applicable.

KEN ROSEN

(General Discussion/Questions and Answers)

I'd like to make sure that the greater number of those helicopters are manufactured here in the United States and I believe that the acceleration of this facility would help that situation. Milt, you indicate, and I'll be very specific, you indicate we couldn't get started. Well, you know "couldn't" is a great word. What do you mean? Why couldn't we get started? Who do we have to see and how do we do it? I mean, the word "couldn't" is kind of a word that offers a challenge to us and I just wondered is there anyway that maybe we don't go through normal channels. Is there a way to accelerate this facility? I might add that many of us are looking at programs that are not the "now" programs, not the Spirit programs, not the Bell 412 type programs or the Bell 222 type programs, but the types of aircraft that we have in mind and are now beginning to conceptualize that will not be certified until late in this decade. It is those aircraft that I'm speaking to. It is those aircraft for which this tunnel will be directly applicable.

MILT BEHEIM

The overwhelming factor will be the voice of industry, because I believe that there has been sufficient discussion within government circles that the government's position is pretty well in place that there is, indeed, support for the use of AWT and particularly strong in the Army. I think it will be significant in the Navy, but I'm not sure yet and less sure of the Air Force because even though they have important cruise missile icing work underway we don't quite fit their time frame again. Therefore, most of the discussion that has occurred on AWT has occurred within government circles and with advisory groups from the industry and NASA has such a structure of advisory groups. But some of the representatives from the companies to these advisory groups don't know about these problems. You can't pick out a man who knows all about NASA. I presume the same problem exists that you can't pick out a man who knows all about Boeing and represents them in its entirety, even though they may have outstanding expertise in icing work, their representative where this is presented may know nothing about it, unfortunately. So therefore, if you in your own companies know some way to get word to your representatives, we think it could be very effective.

RICHARD I. ADAMS

Any other question or comments?

PAUL KARMACY, CENTRAL REGION

I think we are a little bit stymied right now in that in the discussion and with all the emphasis on the icing tunnel, that we've suddenly come to the conclusion that a helicopter cannot be certified for flight in icing conditions because we've placed so much emphasis on initiating or establishing the wind tunnel that is adequate, we just can't go on. And we've all gotten up and expressed our needs and I'm going to express our needs from a regional certification standpoint and that is, I was under the impression that in establishing test

facilities that, from a regulatory standpoint, the FAA, and the FAA does have an obligation to provide this, that the FAA would provide up-to-date criteria and an up-to-date definition of the icing envelope for the different classes of aircraft. The wind tunnels and the icing facilities would be a great aid in this end result for all of us. I feel that the national icing facility would provide the FAA, from a regulatory standpoint, and the applicants themselves, some good definitions of the icing envelope and a long list of equipment and means of verifying test parameters or icing parameters that would be available to industry and the government, as well, to allow anyone who wants to develop a test facility or a test rig in meeting this nationally defined criteria. Now I'm going to digress and get back to the problem that we're all faced with and that we're all sitting here hopelessly wondering how we are going to get from here to there on helicopters. Just sitting back listening to all of you talk, it sounds like no one would be able to make a move as far as certifying a helicopter for flight in icing conditions for another seven years. I think as the FAA, we have an obligation to define an acceptable means of certifying a helicopter for flight in icing conditions now. The national test facility would be just another tool available in the future for assisting industry and the FAA in reducing the time and cost in certifying.

RICHARD I. ADAMS

I think your comment is very well taken. The Technical Center R&D program is trying to focus on gathering enough facts to change the criteria if it needs to be changed. Those facts aren't available yet. The Technical Center also is trying in a supporting role to assist the southwest Region in anyway we can, in certifying the 412 helicopter, which is the first application in the United States for the certification of a civil helicopter. We have tried to take advantage of all the technology that exists and we've raised specific recommendations to the Southwest Region how to go about this. There's no question in my mind that, if the 412 helicopter is certifiable, that it can't be certified in the next two or three years. I think that if adequate facilities existed, that time frame could be reduced significantly. I think the same will be the case for the S-76 when, and if, Sikorsky applies for certification. I think the same is the case for the 234. We're departing a little bit, I think, in the case of the 234 because there, I don't know the proper terminology, but I don't think an official application has been submitted. The Eastern Region is working with Boeing Vertol in determining whether or not it's feasible to try to certify helicopters without rotor blade ice protection for a limited envelope. All this is based on work that the British have done. For example, some of you are aware that the British are currently operating the S-61 type helicopter over the North Sea, and certain corridors, under specific, definitely defined, limited conditions and the British Armed Forces are operating the Sea King and the Lynx under similar conditions. The British spent 10 years and finally are allowing themselves to do that. I don't think it's really a question of whether or not we can or cannot certify a helicopter, I think we can. The point is, it's going to cost a lot of money on the part of the company doing the certification and I think we

RICHARD I. ADAMS

(General Discussion/Questions and Answers)

need to use this as an indicator that, for the future, we need and we must improve the facilities that do exist and try to identify and develop new facilities that will be of benefit to the country, both for the industry to use and for the government to use, and military qualification testing. Yes Herb.

HERB SLAUGHTER

Seeing no other hands, I thought I might pose this question as a lead toward closing the meeting. Throughout the last couple of days we've been hearing the use of the term "Task Force", or National Icing Facilities "Task Force". Could you explain to us what the National Icing Facilities Task Force would be? What its charter would be and what its composition would be?

RICHARD I. ADAMS

In our presentation yesterday I had a viewgraph that showed the basic plan of attack and that was to use the results of the meeting that we hosted here in January, a government coordination meeting, and the results of this meeting, as a basis for the FAA Technical Center putting together specific recommendations, what the facilities needs and requirements are, and for suggesting the establishment of the Task Force. Now, as we see it, that letter would be signed by the FAA Technical Center to FAA Headquarters, that letter would also transmit a suggested letter to DOD and to NASA and ask for the development of that Task Force. Now, already the FAA has designated two people to work on this problem, Tom West and "JB" McCollough. At the January meeting one of the conclusions that we drew was that NASA and DOD needed to name specific people who are recognized experts in research and development field and in the facilities area, that can bring this whole thing to fruition. The charter of the Task Force would be to first develop a viable National Icing Facilities Program Plan. That's going to take a lot of work. It's going to take a lot of coordination with industry and all the other government agencies, but we've got to have that Task Force as a focal point to get that job done. Once the program plan is considered to be a viable plan then comes the task of securing resources. It's going to take that Task Force a tremendous amount of time and resources to do all the convincing and briefings, etc., that will be necessary to secure the funds. I think that the minutes that will come out of this meeting, and I sure am glad that we have tape recorded it so that we can accurately document the proceedings. But I think there are a lot of very valuable comments and indications of concerns that need to be included in that report. I think that we must not forget the things that have been said today.

HERB SLAUGHTER

Dick, a question. I understand the charter, if I'm reading you correctly, the composition would be FAA/DOD/NASA only without any participation from industry?

RICHARD I. ADAMS

(General Discussion/Questions and Answers)

It would be, as I envision it, a government Task Force, the government Task Force would perform the coordination of industry. But I think that this meeting sets the basic stage for that coordination.

HERB SLAUGHTER

It's really a government Task Force? That's what I wanted to get clear.

RICHARD I. ADAMS

That's my intent.

MILT BEHEIM

Dick, can I comment on what you just finished saying?

I am involved in a similar activity as this in the Aeronautics and Astronautics Coordinating Board of the DOD and NASA. The same AWT discussion, the same presentations are made, but to a government group. If you're looking ahead to the future I suggest you consider some way to marry forces, with the damn number of presentations I have to give.

KEN ROSEN, HAA/AIA

I'd like to support Milt's comment. I was about to make the same comment. It seems to me that we have had a real good meeting here and we almost have a consensus, very nearly a consensus. I might add that most of the leading researchers in the United States are here, or representatives of them are here. It seems to be that we have taken a position. It seems to me that we have had that working session and it seems to me that we ought to forward to the various administrators and appropriate government agencies with a very firm recommendation right now. Not only to form a joint working group, which I think is fine, but to step out lively in the area of specific improvements in their current facilities. I don't mean to, in anyway, indicate that I don't support the proposed formation of this joint working group, Dick. I certainly do so! But I do feel that enough has been accomplished now that you can proceed with strong positive recommendations to support Milt's efforts, the efforts of Harry and others and get them that little bit of extra support so that we can proceed in a more timely fashion.

MILT BEHEIM

I would like to underscore again the need for a timely and lively reaction of the FAA because the AACB is moving along at a quite rapid pace. It will be elevating things to high levels within the government in a short period of time and the FAA is the only major government agency that has not officially commented upon the desirabilities of the rehab of AWT. All other major government agencies have responded.

Q. Can you identify once again for us, the acronym "AACB"?

KEN ROSEN

(General Discussion/Questions and Answers)

Aeronautics and Astronautics Coordinating Board, which is an interface between the Department of Defense and NASA in regard to programs and facilities of a major nature.

"JB" McCOLLOUGH

Harry, I would like to ask you a question. Now you've been sitting right there next to Milt and he's pleaded with this audience and they responded for the past hour in helping him accelerate his program. However, you have a live bird coming at you this next icing season in behalf of industry and yet you and I know that you could also use some help in your efforts in your facility. Is there anything this group can do that you can identify to help you and this whole community get on with that program that you've got, in supporting the industry people sitting around you here?

HARRY CHAMBERS

Thanks "JB". Can you send money?

"JB" McCOLLOUGH

No! I was wondering if you could get these people to help send money. I've done all I can Harry, you've got to lay off me now for awhile.

HARRY CHAMBERS

O.K. I wish I knew how to answer that. It's an internal problem getting the HISS further developed. We've had tremendous support from the FAA. It's taken us a little while even in-house with AVRADCOM to even have a HISS improvement program recognized that's a non-funded priority. I was hoping that this next fiscal year that we would be able to start in on the large improvement program such that in two years, two icing seasons from now, we would have the improved HISS. There have been other priorities in the Department of Army though and we're unable to get the funding. So, as far as you helping us, other than having money, I don't know how at this particular point. Now we've talked about this a little earlier and we do have some things coming up and to respond to that I have to get some more information back at our headquarters, which will be this week. So I'll be in contact with you folks next week to find out what kind and if we can get any help. But in the interim, I think I covered this yesterday, we have a short range improvement program where we hope to be putting in some added air into the HISS and possibly expand on the envelope and the capability of the HISS for, not this coming icing season, but the next one.

"JB" McCOLLOUGH

I guess what generated my question was the statement of Dr. Ken Rosen, he says to Milt; "Who do we see and what can we say to help you accelerate your construction schedule", and I was hoping that he would ask you that too.

KEN ROSEN ?

(General Discussion/Questions and Answers)

Seriously, Harry in support of "JB"'s comment, would a letter to DDR&E, to the Dick Lewis', to the Dean Borgman's, to the Ballard's, would that help you get the priority that you're talking about? You indicated, "hey, I don't have that priority". Would that help?

HARRY CHAMBERS

Yes! That would help, but the thing that I feel that I have to do first is carry it in-house, and I think it would be unfair to the Command that I'm in to start crying wolf at this particular time. I think we need more of an impression in-house as to how much support we have gotten from the FAA to get as far as we have on the development of the HISS. You know, once upon a time many years ago, we started out with that thing back in 1972, you know we've come along ways and it's really been recently when we've finally have had a viable machine which will simulate, fairly well, natural icing conditions. That's really been through the FAA's help in all this. You've got to recognize too, that any future development on that HISS is going to be predicated, just like Milt was saying, on what programs can you identify that are going to be coming down the pike. Well, for the Army, what do we really have? I don't see too much unless the AAH picks up again the following season in case something happens this season. The Black Hawk, I think, is fairly well through. We have the ASH coming down the pike, but other than that I don't see too much. So... Its one of these things, you know, we have to have a lot of support from industry too and from the FAA and indications that there will be a lot of use for the HISS, because it costs the Army a lot of money to maintain it. AEFA spends a considerable amount of its time maintaining that HISS and keeping it going every year. It's a big effort and I think you're well aware of that.

KEN ROSEN

Harry, I certainly can see several other military applications which might come our way. Certainly Sea Hawk, Quick Fix, Moltuse, the Army has in its R&D plans the ever present ASH, the LHX, the AHX, that kind of thing certainly in the late 80s, early '90s. That, and by-the-way, the 43E coming the way of the Marines.

HARRY CHAMBERS

We've got to remember too, Ken, and that is that many of the aircraft that we are talking about don't require an icing capability. So a lot is going to be predicated on that. But going right back... Ken says - you're doing a lot of work for nothing. You've got icing capabilities on everyone of those aircraft, except for the ones that haven't been invented yet. Well, we have a particular user out in the Army community and of course they have the requirements in its cost effectiveness so, we're not facing requirements so we can't really say at this point in time.

HARRY CHAMBERS

(General Discussion/Questions and Answers)

This is going back to the very beginning here, OK. What is it that you can do to help us?

Let me work the problem in our Command first and I'm hoping that when I get back next week, that I'll be able to do some talking and convince the people, which I think already know about it, the total effort that the FAA has put into this and how we have to continue it on. A lot of the tests we have coming this icing season are based on FAA support and also ATL and AEFA, plus what we're doing. But, I'll get back with you as soon as I find out.

DON'T KNOW WHO IS SPEAKING

Harry, I guess it's a question of whether it's acceptable to consider the HISS as a national icing facility. If it is, then, you know even though it's under the Army cognizance, it should get consideration for this little industry use. Not only just on a basis for, if it's available, but maybe on a "first come-first served" basis at some stage.

HARRY CHAMBERS

We haven't really ironed out how we are going to do that yet. You realize the Army programs have priority. But we have essentially six different icing projects this icing season which is a big load. We're programming about 80 hours on the HISS. Now that's one aircraft and that's an awful lot of flying to get done in a short period of time, that is this winter season. With 80 hours you could do quite a bit. This season I think we are pretty well filled up. We've got the 412 in there and we feel that's sort of like a private project and we'll see how that works out and then after that time I would see the aircraft available for industry and it will be quite a bit of time there and more than likely on a "first come-first serve" basis.

RICHARD I. ADAMS

The civil need for a civil tanker of that type should be justification enough for wanting to accelerate the improvement of the HISS, and the accelerated planning for, what I call a national inflight icing simulator that could be used for industry or by the government. In the old days there was somebody that said that we should have one airplane. Let all the pilots take turns flying it, that was great. Now we've got just one tanker and we can take turns using it. I don't think that one tanker in this country is going to be enough to cover the workload of the future. It's hardly enough to cover the workload right now. And as you pointed out, the numbers of aircraft that are going to be coming back in the 1990's indicate that we need to start planning now for the facilities that will be needed then. I guess I'm going to try to sum up now. I will refer back to the viewgraph that I showed in my presentation yesterday that summarized the key conclusions of the government coordination meeting that we had back in January and those conclusions were, and this wasn't published in itself, but I think we all felt that anything that could be done to improve the icing test facilities that

exist today would be worthwhile because the facilities are in such poor shape and there's just not enough of them. We did identify specific things that we felt needed to be done right now. Number one of that list was rehabilitation of the altitude wind tunnel. Now the FAA has not yet officially responded to NASA and given direct support of that rehabilitation. And frankly, I have personally been waiting for the results of this meeting so that we can provide that response in conjunction with the letter that we will be sending to FAA Headquarters.

Secondly, we felt that there was a dire need for the development of the National Inflight Icing Simulator for use in research, development and certification with the full understanding of a combined objective and desire that simulated icing testing, using the tanker, or tunnel testing, could drastically reduce the amount of natural icing testing that would have to be performed in the future, for certification purposes.

Third, there was a considerable need to continue the flying of a test bed helicopter because there are so many unanswered questions that exist today. Gene Birocco gave us an outstanding presentation yesterday on the UH-1 and what it has accomplished, and its problem areas. I think there is a need to examine whether or not the U.S. Government should allow that aircraft to stop flying or to have a replacement for it when it's economically feasible for it to stop flying. Finally, there was a need to have a Task Force established, not only to accelerate and secure the funds for accomplishing these specific things, but also to identify the other test facilities that could be improved and how to go about doing it and to provide the resources and the justification for doing that. Now I think that what I've heard here today from the industry consensus is that industry would like this approach to take place and they would like certain efforts to be accelerated. As we have been talking here about the altitude wind tunnel rehabilitation and accelerating that, I was really trying to apply that same logic to the acceleration of the whole project, of the whole effort. Not only accelerating the altitude wind tunnel, but the HISS improvement program, the National Inflight Simulation, and the other tunnel facilities. There was one item that I failed to mention, that was the retention and the possible improvement of the Ottawa Spray Rig. I think that we have made progress there, and, as I read the consensus we are in agreement that a ground based facility of that type is needed.

The thing that the Task Force needs to wrestle with is how best to go about doing that, whether or not we can convince the Canadian government to improve that facility or whether to build a similar facility south of the border. There's a lot of considerations that have to go into a decision of that type. I, in a nut shell, think that the meeting has been very, very productive and I think that we now have enough information to go forward and recommend the establishment of this Task Force or steering committee or whatever the name of the group of people would be. I think we have enough information to make specific recommendations on things that should be done and we have some information on orders of priority.

DON'T KNOW WHO IS SPEAKING

(General Discussion/Questions and Answers)

Dick, relative to your Task Force again, I certainly agree with it and I think it's needed and I think it can help to affect the things that we need that we've discussed here in the last two days. There is a need for communication though. You've asked for help from industry and if we have to wait for other meetings like this to get communication, in order to serve as help for you, then time will disappear and there will be a lag. I would like to recommend that you, in establishing your Task Force, also establish an industry advisory group that you could communicate with when things surface, in case you should need some accelerated action from industry. I think in that way we could keep communication and keep acceleration on the program and pinpoint efforts to help the Task Force get its job done.

MILT BEHEIM

That is a very important suggestion because the AABC has decided that in the next few months we will have to start the industry survey and evaluation of responses. If we knew who to talk to it would help a great deal. Now AWT is a bit complex in that we don't view icing applications as the sole long term application for the facility. We will, indeed, be interfacing with other industry users of those additional capabilities. If we could get some way of concentrating the industry's views for icing activities I would encourage you to do so as soon as possible to help the AACB in their discussions and deliberations.

DON'T KNOW WHO IS SPEAKING

Bob, maybe you would have a suggestion. The alphabet groups might be able to focus attention relative to people that could serve as a sort of a listening post or contributing steering group, not a steering group particularly, but a communication group with the Task Force.

JIM DOUGHERTY

Mr. Chairman, we endorse the idea. GAMA endorses the concept of increased communications.

RICHARD I. ADAMS

I think that --- the recommendations that we will send forward will include the recommendation that there will be an industry advisory group established as a method of providing communication between the Task Force and industry. I see that as a very simple thing to accomplish.

Its now 3:22. The ground rules that I understand for the tour of the R&D facilities here, was if we didn't make it by 3:30 we wouldn't make it at all. Right Charlie? So we have just a few minutes to get there. For those of you who would like to attend the R&D area tour run out and jump on the tram with the tour guide and go. The others who would like look around the building here, just meet us in the lobby and we will show you what we can.

RICHARD I. ADAMS

(General Discussion/Questions and Answers)

My personal thanks to everybody for the fantastic participation and assistance in bringing this meeting together and making it a good meeting. I appreciate and I certainly enjoyed it myself.

Thank you all for coming.

THE END!

USE OF N/ WIND TUNNELS

UNITARY

- o PRIMARILY TO INDUSTRY FOR DEVELOPMENT
- o NASA RESEARCH AS TIME AVAILABLE

NATIONAL AERONAUTICAL FACILITIES

- o FOR ALL USERS
- o REIMBURSABLE POLICY FOR NTF

ALL OTHERS

- o PRIMARILY FOR NASA RESEARCH
- o INDUSTRY WORK WHEN IN PUBLIC INTEREST
JOINT NASA PROGRAM
FEE

CLASSES OF WORK

- o CO. FEE PROJECT - BEYOND SCOPE OF GOVERNMENT CONTRACT
- o GOVERNMENT PROJECT - AGENCY REQUEST, NO FEE
- o CONSORTIUM PROJECT - FEE OR AGENCY REQUEST
- o FOREIGN CO. PROJECT - GENERALLY NOT GRANTED

FEE

- o OCCUPANCY CHARGE
DIRECT MANPOWER
MAINTENANCE
DEPRECIATION
OVERHEAD
- o ENERGY/FUEL
- o DATA REDUCTION

Figure 1

408

Figure 2

[illegible]

LEGEND.

LEGEND: H = HARDWARE I = INSTALLATION T = TESTING M = MAINTENANCE O = OPEN / = SCHEDULE COMPLETED @ = NEED DATE

Figure 3

APPENDIX A

MEETING ANNOUNCEMENT

GENERAL INFORMATION

The meeting will be held in the auditorium of the new FAA Technical Center Building. Registration will be from 8:00 -9:00 a.m. on September 23, 1980 in the lobby. To facilitate registration, please complete the attached form and return by September 16.

The meeting will be hosted by the Flight Safety Research Branch and chaired by Richard I. Adams, Program Manager for Helicopter Flight Safety Research and Development. He can be reached at (609) 641-8200 extension 3735. Additional assistance can be obtained from Charles Masters at extension 2349. For general information please contact the Conferences and Visitor Affairs Section (609) 641-8200 extension 3334.

HOTEL ACCOMMODATIONS

A list of local hotels is provided on the attached sheet. Attendees will be required to make their own reservations.

DIRECTIONS TO FAA TECHNICAL CENTER



FROM NEW YORK CITY, take Garden State Parkway south to Exit 44 and follow signs to Federal Aviation Administration Technical Center.

FROM WASHINGTON, D.C./BALTIMORE, take I-95 to route 40. At junction of routes 40 and 322, follow signs to Technical Center.

FROM PHILADELPHIA/CAMDEN AREA, take Atlantic City Expressway eastbound to Exit 12W and follow signs.

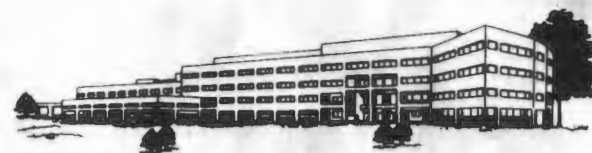
FROM ATLANTIC CITY, travel west on route 30 for about 12 miles to Pomona or take route 40/322 to route 563 and follow signs to the FAA Technical Center.

FROM ATLANTIC CITY VIA EXPRESSWAY, proceed to Exit 5 and follow signs.

FROM SOUTHERN NEW JERSEY, drive north on Garden State Parkway to Exit 36 and follow signs.

Federal Aviation Administration Technical Center

Atlantic City Airport, New Jersey 08405



ANNOUNCES

NATIONAL ICING FACILITIES COORDINATION MEETING

**FAA ★ NASA ★ DOD
INDUSTRY
HAA ★ GAMA ★ AIA**

SEPTEMBER 23 - 24, 1980

REGISTRATION	8-9 AM	SEPT 23
MEETING CLOSES	4 PM	SEPT 24

THE MEETING WILL BE HELD IN THE
AUDITORIUM of the NEW Technical Building
AT THE

**FAA TECHNICAL CENTER
ATLANTIC CITY AIRPORT, NEW JERSEY 08405**



REGISTRATION FORM

FAA/INDUSTRY NATIONAL ICING FACILITIES COORDINATION MEETING
SEPTEMBER 23 and 24, 1980

NAME: _____
TITLE: _____
COMPANY: _____
ADDRESS: _____
CITY: _____
STATE: _____
TELEPHONE: HOME _____
BUSINESS _____
ZIP: _____

MAIL TO: FLIGHT SAFETY RESEARCH BRANCH
ACT-340 (ATTN: C. MASTERS)
FAA TECHNICAL CENTER
ATLANTIC CITY AIRPORT, NEW JERSEY 08405

BACKGROUND

The FAA Technical Center (formerly NAFEC) hosted a government coordination meeting on National Icing Facilities on January 16, 1980. Key results of this meeting indicated that several actions were necessary, by the government, to assure that icing test facilities would meet future government and industry demands for aircraft icing certification, research and development. These actions included:

- Possible rehabilitation of the NASA Lewis Altitude Wind Tunnel
- Retention of and possible improvement of the Ottawa Spray Rig
- Identification of the need for a National In-Flight Icing Simulator
- The need for a National Icing Facilities Steering Group

MEETING OBJECTIVE

To obtain industry consensus on National Icing Facilities requirements to facilitate FAA recommendations regarding a National Icing Facilities Effort.

SCOPE

Discussions will address:
Icing wind tunnels, icing test chambers, snow simulation facilities, freezing rain simulators, ground based facilities, in-flight icing simulators and analytical tools for use in icing research, development and certification of military and civil helicopters, fixed-wing transport and general aviation aircraft.

NATIONAL PARTICIPATION

Agencies of the FAA, NASA and DOD will describe existing icing test facilities. Other agencies of the government are invited and encouraged to attend. All interested aircraft manufacturers and commercial testing agencies are invited. HAA, AIA and GAMA are participating in the planning and execution of the coordination meeting.

TENTATIVE AGENDA

SEPTEMBER 23

MORNING

- 8 - 9 REGISTRATION
- 9 - 12 FACILITIES OVERVIEWS

AFTERNOON

- 12 - 1 LUNCH
- 1 - 4 FACILITIES OVERVIEWS
- 4 - 5 TECHNICAL CENTER TOUR

SEPTEMBER 24

MORNING

- 9 - 12 INDUSTRY PANEL DISCUSSIONS

AFTERNOON

- 12 - 1 LUNCH
- 1 - 4 GENERAL DISCUSSIONS
& SUMMARY



During facilities overviews various government agencies will describe icing test facilities existing in North America, issues concerning industry use of these facilities and improvements planned. Panel discussions will be for the purpose of establishing an industry consensus on current and future icing facilities needs with the assistance of HAA, AIA and GAMA.

APPENDIX B

MINUTES

NATIONAL ICING FACILITIES

COORDINATION MEETING

MINUTES
NATIONAL ICING FACILITIES
COORDINATION MEETING
held at
FEDERAL AVIATION ADMINISTRATION
NATIONAL AVIATION FACILITIES
EXPERIMENTAL CENTER
ATLANTIC CITY, NEW JERSEY
on
JANUARY 16, 1980

The meeting was convened at 9 a.m., in Building 10 at the Federal Aviation Administration's (FAA), National Aviation Facilities Experimental Center (NAFEC), Atlantic City, N. J.

Mr. Michael Brandewie, Acting Chief, Engineering Management Staff, NAFEC, opened the meeting and welcomed representatives from the National Aeronautics and Space Administration (NASA) and the Department of Defense (DOD) on behalf of the Director of NAFEC.

Mr. Brandewie provided the purpose and objective of the meeting, identified Mr. Tom West of the Helicopter Program Staff, Washington, D. C., as the FAA Systems Research and Development Service representative, and introduced Mr. "JB" McCollough, Chief of the Operations Branch, Aircraft Safety Development Division, as the NAFEC Program Manager. He emphasized the FAA's interest in resolving the urgent need for improved icing facilities, the fact that the FAA is taking positive steps toward this objective, and that this is evidenced by the tasking of NAFEC to take the lead within the FAA to establish the requirements for national icing facility resource requirements.

Mr. "JB" McCollough described the mission, functions, and organizational structure of the Operations Branch, and introduced Mr. Dick Adams as the Helicopter Research and Development Program Manager, and the meeting chairman.

Mr. Adams provided an agenda (copy attached), and emphasized the meeting's objective to: 1) develop methodology for implementing national programs for developing and improving national icing facilities for research, development, and certification purposes; and 2) initiate the evolution of a national plan that would provide the basis and justification of such a national effort. He emphasized also that a primary objective was to obtain agreement of the agencies represented, that the NAFEC proposed national facilities approach is sound.

Mr. Adams provided, as introduction to the meeting, a brief description of the background leading to this meeting.

BACKGROUND.

Aircraft icing certification in the past has relied very heavily upon natural icing testing. Provisions exist in the Federal Aviation Regulations (FAR's) for use of analytical prediction techniques and simulation, but the final proof is flight test in natural icing conditions. This procedure is expensive and time consuming, especially for small, low speed aircraft such as the helicopter and single engine fixed-wing, general aviation aircraft. With these aircraft types, range and endurance are extremely limited as well as the ability to climb to higher altitudes.

These features are essential for conducting natural icing tests to allow finding the various representative conditions. Larger, high performance aircraft do not suffer in this respect because they have the necessary range and performance to fly to prevailing icing conditions for test purposes. Helicopters and small GA aircraft are restricted to a small geographical area and must await the proper test conditions moving into the operational range and altitude of the test aircraft.

Past experience of the U.S. Army, the United Kingdom (UK), Canada, France, and Germany in attempting helicopter natural icing testing for research or certification purposes indicates strongly that, with existing icing test facilities and use

of natural icing tests, 3 to 5 years are required to acquire sufficient flight test data for certification purposes. The conclusions that we must draw from this are: 1) icing simulation is essential to reduce the cost and time required for certification; and 2) existing icing test facilities are not capable of handling the requirements and traffic of today, and certainly cannot handle the traffic of tomorrow, the near future, or long-term.

These points have been identified and discussed at national and international meetings and symposiums for the past 3 years. As a result of these discussions, several individual agency and interagency cooperative programs have been initiated.

NASA has established an Icing Research Group at the Lewis Research Center in Cleveland, Ohio, and since 1978, has initiated several research projects using the Center's Icing Research Tunnel, studied the icing test facilities of North America, and devised detailed plans for rehabilitation of the Center's Altitude Wind Tunnel for use as an additional and a larger icing research facility.

The U. S. Air Force has become dedicated to improving their NKC-135 icing tanker aircraft and has plans for development of a paletized system for use in the C-130 or C-141. The U. S. Army is in the process of improving the Helicopter Icing Spray System (HISS), a CH-47 helicopter equipped with a spray boom. The FAA is providing funding and technical support of the HISS improvement program.

The U.S. Navy is continuing to improve the icing test facilities at the Naval Propulsion Test Center in Trenton, N. J.

The Arnold Engineering Development Center is enlarging engine test facilities.

A significant problem was identified during the June 1978 NASA workshop on Aircraft Icing held in Cleveland. This problem is paraphrased as follows: The present stable of icing tankers is limited to organizational and jurisdictional boundaries and, for practical purposes, are totally inaccessible to the civilian industry. The U.S. Air Force and U.S. Army have, however, since indicated that the NKC-135 tanker and HISS can be made available for commercial use at cost if there is no interference in high priority military requirements.

The civilian industry cannot afford the time and expense of developing, building, maintaining, and operating their own facilities, and if they could efforts of various manufacturers would be duplicated. This must be accomplished by the Federal Government.

The FAA has developed an -(R&D)- program to enhance the certification of civil helicopters. This program is described in draft NAFEC Report 18-8, "Engineering and Development Program Plan, Helicopter Icing Certification Research."

The FAA's efforts were initiated in 1976 by New England Region test pilot participation in the U.S. Army UH-1H icing research program at Army expense. In 1977, the Great Lakes region provided test pilot participation in the Army research program at FAA expense. In 1978, the FAA initiated an icing technology review and provided \$250,000 for financial participation in the U.S. Army's attempt to qualify the UH-1 helicopter, equipped with a partial ice protection system, for flight in icing conditions. It was this participation and the FAA's insistence that cloud parameters be more accurately measured that allowed quantification of the HISS cloud

and identification of the need for improvement. In 1979 and currently, the FAA is providing financial (\$225,000) and technical support for the Army HISS improvement program, and conduct of ice-phobic coating flight testing.

The NAFEC developed R&D program was very briefly summarized including programmed and additional funding requirements. The program chart is included in the copies of viewgraphs attached. The following key points were made:

1. FY-78 funding (\$75,000) is attributed to calibration of the HISS cloud.
2. FY-79 funding (\$125,000) is attributed as the FAA contribution for HISS improvement.
3. FY-79 funding (\$100,000) is attributed to FAA contribution for calibration of the modified HISS cloud, and conduct of simulated and natural icing tests of ice-phobic coatings for rotor blade ice protection.
4. FY-80 funding (\$150,000) is earmarked for possible participation in Phase III of the HISS Improvement Program.
5. In the out years, the preponderance of funding is allocated to "Certification Tools" or Icing Facilities.
6. FAA funding should be directed to a National Icing Facilities Program, in conjunction with funding from NASA and DOD, to assure that, in the future, icing facilities will be adequate for research, development, and certification purposes.

The types of facilities that must be considered during our discussions include:

1. Airborne/In-Flight Simulators (Tankers) for use by aviation industry as well as the military.
2. Icing Tunnel Improvements (to include quantity and quality).
3. Improvements in instrumentation for cloud parameter measurement.
4. Analytical models for prediction of the performance of ice protection systems to identify: 1) critical ice effects (such as dynamic and aerodynamic effects); and 2) aircraft performance degradation during the design phase. This will enhance flight safety during the certification process as well as reduce cost of testing.
5. An icing research helicopter to continue probing the many unanswered questions concerning icing phenomena and gather flight test data needed to correlate and establish the fidelity of analytical and simulation techniques.

The topics that need to be addressed during the meeting include:

1. Facility Needs
2. Types of Facilities
3. Projected Utilization/Justification
4. Priorities and Schedules
5. Cost Estimates
6. Management and Ownership
7. Cost Sharing

Each of the agencies of NASA and DOD represented were requested to provide comments. These comments are summarized as follows:

NASA COMMENTS.

Mr. Milton Beheim described NASA's recent establishment of a new icing research group at the NASA Lewis Research Center. He presented an extensive summary of the Research and Technology Programs using the Center's Icing Research Tunnel that have been initiated since the inception of the new group, summarized the findings of an icing test facilities study, and provided a description of NASA plans to rehabilitate the Altitude Wind Tunnel for use as an additional icing research facility. Copies of viewgraphs used by Mr. Beheim in his summary will be forwarded to each attendee by NASA.

Mr. Beheim emphasized that National support for the AWT rehabilitation program must be obtained to allow NASA to justify the expenditure. He indicated that such support had been obtained from the U.S. Air Force and the U.S. Army. A letter requesting support from the FAA has been forwarded and a letter to the U.S. Navy will be forthcoming. He emphasized that the AWT would be used for purposes other than icing research, indicating that the icing-facilities-need, alone, would be insufficient justification for the rehabilitation cost (estimated \$32.5 million). He emphasized that NASA Lewis icing tunnels were primarily used in support of NASA research objectives, however, the facilities are available for testing under any Government project. This includes civilian test projects if sanctioned by the FAA.

Mr. Beheim indicated that the NASA Lewis annual budget for aircraft icing research is \$350,000.

Mr. Beheim also presented a movie that provided a description and basis for discussion of the Ottawa Spray Rig, a ground-based icing test facility currently owned and operated by the Canadian National Research Council. This facility is currently scheduled to be closed on March 31, 1980. The AGARD Flight Mechanics Panel Working Group on Rotorcraft Icing, has recently forwarded results of a NATO survey to the Canadian Government, recommending that the facility remain in operation.

U.S. ARMY.

Mr. Harry Chambers described the history of the development of the U.S. Army HISS (tanker helicopter) and the uses since its development. He emphasized that the HISS was not developed for research purposes but actually to determine the capabilities and limitations of current Army fleet helicopters such as, the UH-1, AH-1, CH-47, and OH-58. He indicated that the HISS had been used to check out the operation of ice protection systems of the ATL research JUH-1H, UTTAS prototype helicopters, CH-47D, and Blackhawk, before allowing flight testing in natural icing conditions.

LTC Frankenberger narrated a movie describing the characteristics of the HISS improvement program. Results of icing tunnel tests indicate that efforts this year have been successful in reducing cloud droplet size however, flight testing has not yet progressed sufficiently this winter in St. Paul, Minnesota, to verify this indication. The test aircraft are, however, on site and results should be available within the next two to three weeks.

U.S. NAVY.

Mr. Tony Petruccione described the icing tunnels that exist at the Naval Aviation Propulsion Center, Trenton, N.J. He indicated that all military engine development programs utilize the facilities for engine icing and ice ingestion qualification tests, that the facilities have been kept in a continual state of improvement over the years, and they appeared to be adequate (in quantity, size, and quality) for testing of today's engines and those projected in the future. The Navy intends to continue improvement of these facilities as necessary.

Mr. Don Caldwell described several problems that exist with Navy aircraft regarding icing conditions, citing engine damage on F-14 aircraft upon carrier landings after operation in snow conditions. Snow apparently builds up in the engine inlet during flight and although while not causing problems during flight, landing impact and high power settings used during arresting gear landings cause the snow/ice formations to break loose extensively damaging (FOD) the engines. Similar problems with F-15, F-16, and F-18 were mentioned. He emphasized that attempts to find a suitable icing tunnel to investigate this problem have been futile, because of the lack of facilities and the high cost of conducting such a test.

U.S. AIR FORCE.

The U.S. Air Force was not represented at the meeting, however, informal coordination subsequent to the meeting yielded the following information.

The U.S. Air Force is currently operating the NKC-135 as an icing spray tanker. This tanker has been used on several programs other than Air Force programs including icing test of the Concord conducted in Europe and U.S. Navy aircraft icing tests conducted at Patuxent River, Maryland. The NKC-135 tanker can be made available to commercial users with FAA or other Government Agency sponsorship on an as-available basis.

Cloud droplet size has been found by the Air Force to be excessive (26 to 212 micrometers mean effective droplet diameter), corrective measures have been taken to reduce droplet size and preliminary calibration results indicate that corrective measures have been successful. Final calibration data processing will be completed approximately June 1980.

The U.S. Air Force is planning the development of a self-contained (palletized) system that can be installed in a C-130 or C-141 aircraft, however, funding limitations have delayed system development. With the spray system installed in the C-130 the following icing conditions could be provided:

Airspeed range	100-300 KIAS
LWC range	0.05-4.5 gm/m
Droplet size	20-40 micrometers
Cloud Endurance	1-4 hrs. per flight

GENERAL DISCUSSIONS.

The chairman directed the discussion toward consideration of the various FAA, NASA, and DOD comments in relation to the meeting objectives, with particular attention to the topics of concern. The following is a summary of the results of these discussions and the consensus of the meeting.

1. The meeting concluded that the need for improved and more plentiful icing test facilities is long past.

2. Facilities existing within the military complex are in existence for military use and national defense projects will always hold top priority. These facilities can be used on an as-available and noninterference basis. Available facilities are being used full time for military projects now, and availability for other (civil) projects is remote.

3. NASA has some facilities that are Unitary Facilities (available for lease by any U.S. Government Agency or commercial firms). There are no icing test facilities that fall into this category.

4. NASA's charter does not include certification testing. Some certification testing efforts are conducted in the NASA Lewis Icing Research Tunnel. Testing of this type is limited to military projects, nonproprietary civilian projects of research interest to NASA and civilian projects endorsed or requested by the FAA on a fee basis.

5. Civilian firms currently must provide their own test facilities or be able to convince either NASA or the FAA that testing being requested is relevant to NASA R&T needs or FAA certification. The IRT is currently booked through mid 1981.

6. The icing test facility needs have been discussed at many conferences in recent years. NASA has cataloged facilities having potential for icing test purposes that currently exist in North America. AGARD has summarized facilities existing in Europe, in AGARD Advisory Report No. 127 "Aircraft Icing."

7. NASA has support from the U.S. Air Force and the U.S. Army for rehabilitation of the AWT. This support could not be obtained from the Helicopter Association of America (HAA) because the results would be too far in the future. The HAA considers the problem immediate and expresses the recommendation that near term solutions should be developed.

8. Military funding for a national facilities program would be difficult to obtain.

9. National facilities have traditionally been difficult to manage. Users desire the Government to bear most of the cost burden and the Government must evolve a procedure that is fair to all. Users are seldom satisfied with the result.

10. A coordinated national program, whereby each government agency would develop, operate, and maintain their own facilities would be considered.

11. The FAA recognized a significant shortcoming in the icing facilities area and has appointed two individuals, "JB" McCollough and Tom West, to work with NASA,

DOD, and industry to resolve the problem. NASA and DOD must also appoint specific individuals to be the focal point for establishing a national plan for development of national facilities or for coordinated development of agency facilities. The FAA should request the Office of Defense Development Research and Engineering (DDR&E) and NASA headquarters to appoint similar representatives.

12. The U.S. Government does not, at this point, have a concise definition of facilities needs for forming a basis for determination of the specific facility development or improvement projects and order of priority of these projects that should be undertaken. The consensus of the meeting, however, was that the NASA proposed AWT rehabilitation should be endorsed, funded, and initiated. In addition, the consensus of the meeting concluded that in-flight simulation facilities should be developed, and that the Canadian Government should again be requested to retain the Ottawa Spray Rig. These facilities efforts are considered essential to support the immediate and near term needs for icing research, development and certification programs. Other detailed facility needs and development programs can be identified at a later date during preparation of a national facilities program plan.

13. The meeting generally endorsed establishing a national in-flight icing simulation facility at NAFEC for use by civil as well as military users. The consensus however, doubted that NASA or DOD funding could be made available for the development program. The consensus of the meeting did, however, favor establishment of a national plan to identify the national icing facilities needs and to set the stage for either a national program for facilities development or a basis for national coordination of individual agency facilities development programs.

14. The next step should be for the FAA to initiate a request to DDR&E and headquarters NASA for the establishment of a small working group to develop a national program plan. FAA representatives agreed to staff such letters and recommendations to the Associate Administrator for Research and Engineering.

RICHARD I. ADAMS
Chairman

LIST OF ATTENDEES
NATIONAL ICING FACILITIES
COORDINATION MEETING
FAA/NAFEC
ATLANTIC CITY, N.J.

JANUARY 16, 1980

<u>NAME</u>	<u>ATTENDEES ACTIVITY</u>	<u>PHONE</u>
D.C. Caldwell	NAVAIR Headquarters	(202) 692-6030 AV-222-6030
T.C. West	SRDS (ARD-330)	(202) 426-3046/4440
Tony Petruccion	NAPC, Trenton, N.J.	(609) 882-1414 X318
Milt Beheim	NASA Lewis	216-4334 X374
Vito Truglio	NAPC, Trenton, N.J.	(609) 882-1414 X305
LTC C. Frankenberger	USAAEFA (Edwards AFB)	(805) 277-2271
Harry W. Chambers	USA AVN Research and Dev. Cmd. St. Louis, Mo.	(314) 263-1703 AV-693-1703
Jack Adams	USA AVN Research and Dev. Cmd. St. Louis, Mo.	(314) 263-1694 AV-693-1694
LTC Paul G. Stringer	NAFEC/ANA-340	AV-234-1596 X3771 (609) 641-8200 X3735 FTS 346-3735
Dick Adams	NAFEC/ANA-340	AV-234-1596 X3371 (609) 641-8200 X3376 FTS 346-3735
"JB" McCollough	NAFEC/ANA-340	AV-234-1596 X3313 FTS 346-3313 (609) 641-8200 X3313

AGENDA

0900-0910	WELCOME	Director, NAFEC
0910-0930	INTRODUCTORY REMARKS BACKGROUND MEETING OBJECTIVES	JB McCollough Dick Adams
0930-1000	NASA COMMENTS	
1000-1030	ARMY COMMENTS	
1030-1050	BREAK	
1050-1120	NAVY COMMENTS	
1120-1150	AIR FORCE COMMENTS	
1150-1300	LUNCH	
1300-1500	GENERAL DISCUSSIONS & SUMMARY	

MEETING OBJECTIVES

DEVELOP METHODOLOGY

IMPLEMENTATION OF NATIONAL PROGRAMS FOR NATIONAL FACILITIES

DEVELOPMENT
MODERNIZATION

FOR

RESEARCH
DEVELOPMENT
CERTIFICATION

INITIATE EVOLUTION

NATIONAL PLAN FOR ICING FACILITIES

DEVELOPMENT
MODERNIZATION

TOPICS FOR DISCUSSION

FACILITY NEEDS & JUSTIFICATION

PROJECTED UTILIZATION

TYPES OF FACILITIES

- TUNNELS
- CHAMBERS
- GROUND BASED
- IN-FLIGHT

PRIORITIES & SCHEDULES

- DEVELOPMENT
- MODERNIZATION

COST ESTIMATES

- INITIAL INVESTMENT
- OPERATION & MAINTENANCE

MANAGEMENT & OWNERSHIP

COST SHARING

APPENDIX C

SURVEY OF AIRCRAFT ICING SIMULATION FACILITIES IN NORTH AMERICA

SURVEY OF AIRCRAFT ICING SIMULATION FACILITIES IN NORTH AMERICA*

WILLIAM OLSEN

ICING RESEARCH SECTION

NASA LEWIS RESEARCH CENTER

NASA was requested to survey the capabilities of the facilities in North America that can do aircraft icing simulation tests. The survey was requested by the Standing Committee on Icing, which is jointly sponsored by NASA, FAA and NOAA; the military services have also expressed a need for this survey. European icing facilities have already been surveyed and reported in AGARD Advisory Report 127.

The reasons for the survey are to: (1) inform the icing research community of the capabilities of existing icing facilities, (2) make it easier for a potential facility user to select and contact the icing facility that is appropriate for his test requirements, and (3) help facility managers evaluate and improve their facility.

The survey determined the location and size of each facility, its airspeed and temperature range, icing cloud parameter ranges, and the technical person to contact. The facilities surveyed and their capabilities are listed in tables A to D, one for each of the four types of simulation facilities that are described on figures A to D. The capabilities of each facility were estimated by the engineers working with that facility. The numbers in the tables are single point approximations by them of the complex operating curves of their facility. Many of the facilities have capabilities beyond that required for icing testing and these excess capabilities were not included in the tables.

* For your convenience, 2 tables listing European icing facilities are also attached.

APPENDIX D

CENTER NEWS HIGHLIGHTS

NAFEC NEWS HIGHLIGHTS

PUBLIC AFFAIRS OFFICE, ANA 5
FAA NAFEC
ATLANTIC CITY, NEW JERSEY 08405
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NATIONAL AVIATION FACILITIES EXPERIMENTAL CENTER NAFEC HEADS FAA QUEST FOR ICING TEST FACILITIES

80-6



Helicopter hovers in a super-cooled cloud created by Canadian government's Ottawa Spray Rig, which was one of the ground-based icing test facilities discussed at the meeting of aircraft icing experts.

CONSORTIUM EFFORT -- The FAA has given NAFEC the leading role in a cooperative effort with DOD and NASA to establish a consortium of ground and airborne icing test facilities. This test complex is needed for certification of helicopters to fly in icing conditions, as well as for research and development, according to NAFEC Director Joseph M. Del Balzo.

Boeing Vertol Co. has already applied to the FAA Eastern Region for certification of the first U.S. civil helicopter, its Model 234, to fly under limited icing conditions; and "we can see the others waiting in the wings," said Del Balzo. At this time the agency does not have standards for helicopter icing certification, the data needed to establish the standards, nor the facilities to obtain the data.

The icing program test effort was given to the Operations Branch of NAFEC's recently formed Aircraft Safety

Development Division, which has the responsibility for the agency's helicopter icing and certification standards program. Branch chief "JB" McCollough has named Richard I. Adams, manager of the helicopter icing and certification standards program, to head the icing facilities undertaking as well.

Adams, who is the U.S. representative on the AGARD (Advisory Group for Aeronautical Research and Development) Working Group on Rotorcraft Icing, recently joined NAFEC after working for the military for many years on helicopter research and development.

To get the national icing test facilities program under way, Adams organized and chaired a conference here on January 16, attended by aircraft icing experts from various U.S. government agencies. This initial meeting at NAFEC was concerned primarily with the question of how best to implement a national plan to establish adequate,

modern icing test facilities needed to support future research, development and certification programs for civil and military helicopters and fixed wing aircraft.

One of the specific topics addressed by the attendees concerned the types of facilities needed. They agreed that any national or international icing test facilities will have to include icing tunnel and chambers, ground-based and airborne simulation facilities, analytical prediction models and, possibly, a new, airborne, rotary wing research vehicle, according to Branch Chief McCollough.

Other topics discussed at the meeting included:

- ✕ Priorities and schedules for development or modernization of the needed facilities.
- ✕ Projected utilization of each facility.
- ✕ Cost estimates for construction and operation of the facilities.
- ✕ Funding, ownership and management arrangements.

Most of the details on these topics remain to be worked out at a later meeting, McCollough said. Some of the decisions, he added, obviously will have to be made at top government levels.

Meanwhile, Dick Adams has set himself a busy schedule visiting and evaluating existing icing facilities. He has also been assigned by Director Del Balzo as a consultant to the Eastern Region's certification team for the Vertol 234, in response to the region's request to NAFEC for a technical expert on helicopter icing.

Earlier this month, Adams traveled to Ottawa. While there, among other things, he monitored tests being conducted by the U.S. Army, which was using the Canadian government's Ottawa Spray Rig to test ice-repellant coatings on the rotor system of one of its UH-1 helicopters.

Shortly, Adams will fly to St. Paul, Minn. In St. Paul, the Army is using its specially equipped JUH-1H helicopter test bed to evaluate the most promising ice-phobic coatings under natural icing conditions. The Army is conducting these tests under an interagency agreement with the FAA.

The Army's JUH-1H rotary wing icing

test bed has electrothermal ice protection systems on its main and tail rotors and stabilizer bar and an electrically heated interlayer for keeping ice off its windshield. This research helicopter is also extensively instrumented for measuring atmospheric and flight parameters. Among other parameters, it will be able to measure liquid water content, droplet size, ambient temperature, blade pitch link and bending loads, and vibration levels. Adams will look into the availability of this vehicle for civil research or the feasibility of developing a similar flying test bed for the civil program.

In St. Paul, the Army will be pursuing two other programs of great interest to the FAA. These include the qualification of the Boeing Vertol CH-47D (the military counterpart of the civil Model 234) for flying in limited icing conditions and the test and evaluation of the Improved Helicopter Icing Spray System (HISS).

Boeing Vertol believes that the differences between its CH-47D and Model 234 are so slight when it comes to operation in icing conditions that the FAA can use the results from the Army's tests in St. Paul on the CH-47D to certify the civil 234 for restricted flying in icing conditions.

In the case of the Helicopter Icing Spray System, Adams' job will be to determine if the modifications made to the system make it acceptable to the FAA as an airborne icing test facility. The HISS is basically a spraybar carried by a CH-47 tanker. Water coming out of the nozzles on the spraybar under the proper conditions forms a cloud of super-cooled droplets. NAFEC provided funding for modifying the nozzles in the original design to produce a finer spray, after determining that the droplet-size created by the original spraybar were larger than those that would be encountered by helicopters in natural icing conditions. The job of this task force is to make sure that the government makes optimum use of the available facilities, Adams says, and then recommend the development of any additional facilities needed to do the job. The group expects to make its first recommendations within a year.



U.S. Department of
Transportation

Federal Aviation Administration Technical Center

PUBLIC AFFAIRS OFFICE
ATLANTIC CITY AIRPORT, N.J. 08405
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NEWS HIGHLIGHTS

80-38
September 29, 1980

TECHNICAL CENTER HOSTS TWO MAJOR SYMPOSIUMS



The emergence of the Tech Center as a focal point for conferences and symposiums drew plaudits from participants attending two major symposiums held in the new building. FAA Eastern Region Director Murray Smith, left, and New England Region Director Robert Whittington, right, spoke to more than 100 experts in the commuter airline field. A second symposium on helicopter and aircraft icing research was equally well attended.

In what promises to be a harbinger of things to come, the Visitors Center and auditorium in the Tech Center's new building hosted two major symposiums in the last two weeks. Both were well attended and well received.

The first, on Sept. 17-19, joined leaders of the commuter airlines industry

with the FAA. Top officials from the FAA's Eastern and New England regions used the Tech Center's modern facilities for the symposium, which drew 103 experts for a varied and comprehensive meeting.

The second symposium concerned national icing research work for heli-



icopters and aircraft. Some 75 specialists from industry and government attended that Sept. 23-24 conference.

"This initial round of major conferences is in line with our goal of using our new facilities as a focal point for aviation symposiums," said Center Director Joseph M. Del Balzo. "I'm sure that these exchanges will help those in industry, within the Technical Center and elsewhere within the agency, in jointly doing our respective jobs better."

Present at the Commuter Airlines/FAA symposium were New England Region Director Robert Whittington and Eastern Region Director Murray Smith. The symposium was coordinated at the Tech Center through a newly renamed Technology Exchange Office, formerly the Conferences and Visitor Affairs Section.

The gathering focused upon the status and future of the commuter airlines industry, and ways to maximize FAA work to make it safer. The central topics were divided into three main areas: maintenance, flight safety and air traffic control.

The FAA's criteria for mechanic licensing, commuter airline flight training and effective use of current air



"JB" McCollough, chief of the Center's Flight Safety Research Branch, ACT-340, organized the national helicopter icing research symposium. McCollough's group will head the Center's lead effort in this area for the agency.



Richard I. Adams, manager of the Center's helicopter icing program, spoke to attendees whose organizations are represented on the placard to his left. A consensus for national icing facilities was the primary goal of the Sept. 23-24 conference.

traffic control systems were focal points of panel discussions.

An open discussion period following the panel sessions concerned: FAA planning standards, surveillance and accident handling.

The panel and open discussions were led by Walter Kies, director of aeronautics for the New Jersey State Department of Transportation, and several industry and government experts.

Additional guest speakers for the affairs were Gloria Shaffer, a member of the Civil Aeronautics Board, and Lou Davis, vice president of the Airline Publishing Group, and editor of Commuter Air Magazine.

The subsequent symposium dealing with icing was designed to reach a consensus on objectives on requirements for national icing research facilities. Several facilities are being proposed to study the effects of ice on aircraft, and the FAA is seeking industry input for maximum effectiveness, with the Tech Center playing a lead role in coordinating the effort.

In addition to a description and evaluation of existing icing facilities, potential new facilities were considered at the symposium. These include: icing wind tunnels, freezing rain simulators,

(continued)

PICTORIAL HIGHLIGHTS OF CENTER SYMPOSIUMS

Deputy Director Thomas J. O'Brien, ACT-2, delivered opening remarks to attendees of the national icing research symposium. Seventy-five specialists in this field were on hand for the conference.



SCENES FROM
THE COMMUTER
AIRLINE SYMPOSIUM



Eastern Region Director Murray Smith chose the occasion of the commuter airlines symposium at the Tech Center to make some well-deserved presentations. From left, Smith presents an air carrier certificate to Paul Quackenbush, president of Empire Airlines. Smith then presented certificates of appreciation to co-pilot Wilbur Ressler and pilot Peter Kopp for their "cool-headed" wheels-up landing of an Air Virginia plane carrying three passengers. There were no injuries and damage to the plane was slight. Finally, Air Virginia President Rod Jaeger, far right, joined with Smith in expressing his gratitude to the two men. The presentations were made at a dinner in Atlantic City, which scenes are shown here.



(continued from p.2)

in-flight icing simulators and ground-based facilities.

Participants at the national icing symposium included the Department of Defense, National Aeronautics and Space Administration, the Helicopter Association of America, Inc., General Aviation Manufacturers of America, FAA and aircraft companies.

The symposium was an outgrowth of a small-scale meeting held at the Tech Center on Jan. 16. Organizing the symposium were "JB" McCollough, chief of the Flight Safety Research Branch, ACT-340, and his staff, including Richard

Adams and Charles Masters.

In an allied development related to future conferences, a detailed calendar of such events scheduled at the Technical Center through 1983, currently being updated and revised, will be available soon from the new Technology Exchange Section, ACT-64C, at (609) 641-8200, ext. 3334 or FTS 346-3334. Just named as chief of that section is former Center employee Stephanie Slavin. The section, formerly a part of the Technical Services Branch, ACT-63, is now under the Technical Information Research Branch, headed by James F. Williams.

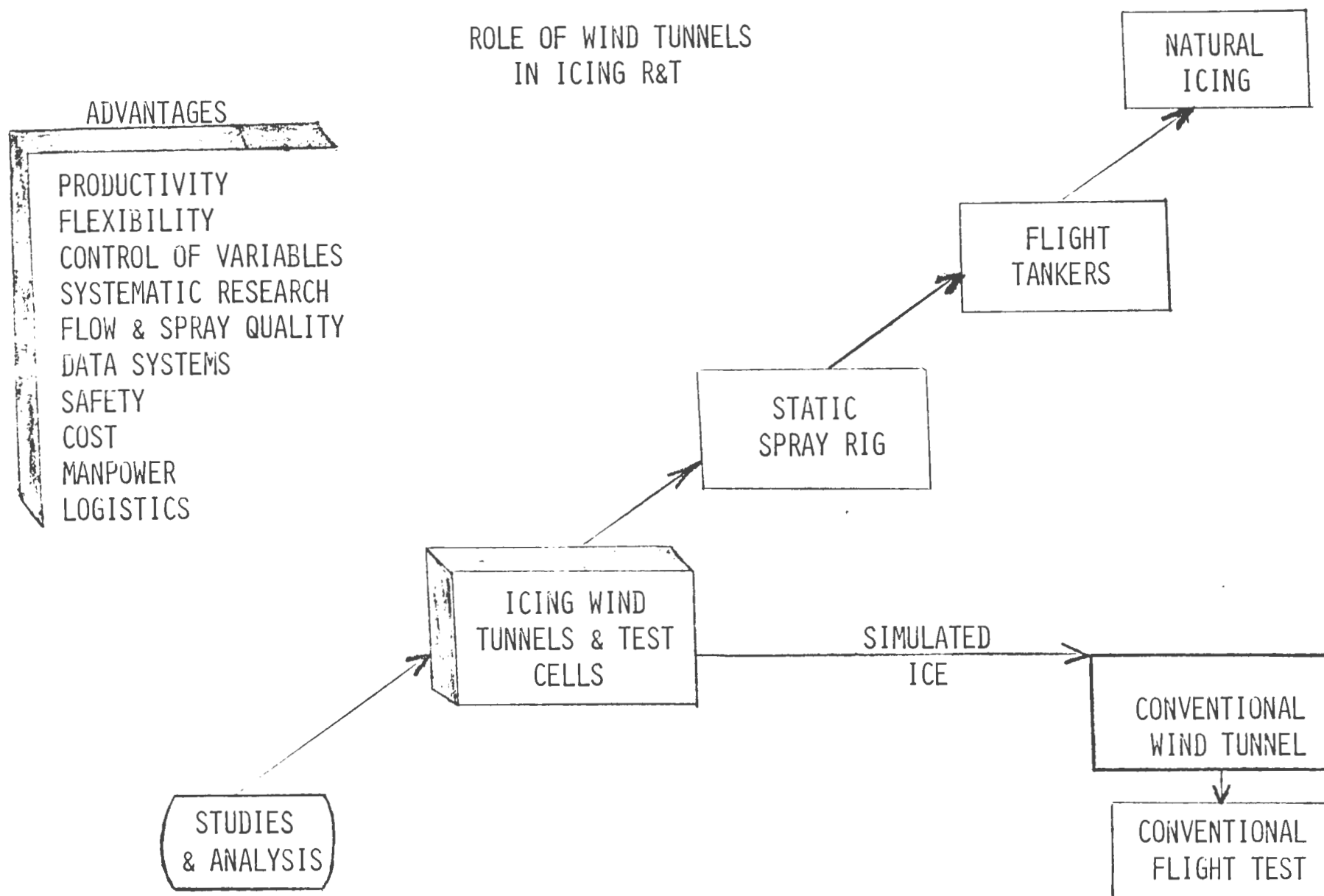


Figure 4

ICING FACILITY FUNCTIONS

APPLICATION	GROUND TEST	FLIGHT TEST
GENERAL	FUNDAMENTAL RESEARCH ADVANCED CONCEPTS	
SPECIFIC	PROTECTION REQUIREMENTS EVALUATE ALTERNATIVES FUNCTIONAL CHECKS & CHANGES REGULATORY OR CONTRACT COMPLIANCE	COMPLETE SYSTEM VERIFICATION FULL SCALE EVALUATION

Figure 5

ICING TEST VARIABLES

PRIMARY

FLIGHT SPEED (MACH NUMBER)

TEMPERATURE

WATER CONTENT

MEAN DROP SIZE

CLOUD EXTENT & UNIFORMITY

EXPOSURE TIME

SECONDARY

PRESSURE

TURBULENCE

DROP SIZE STATISTICS

UNKNOWN

HUMIDITY

SUPERCOOLING

MIXED CONDITIONS

SOLAR HEAT

Figure 6

LEV RESEARCH CENTER
ICING RESEARCH TUNNEL, SHOP AND OFFICE

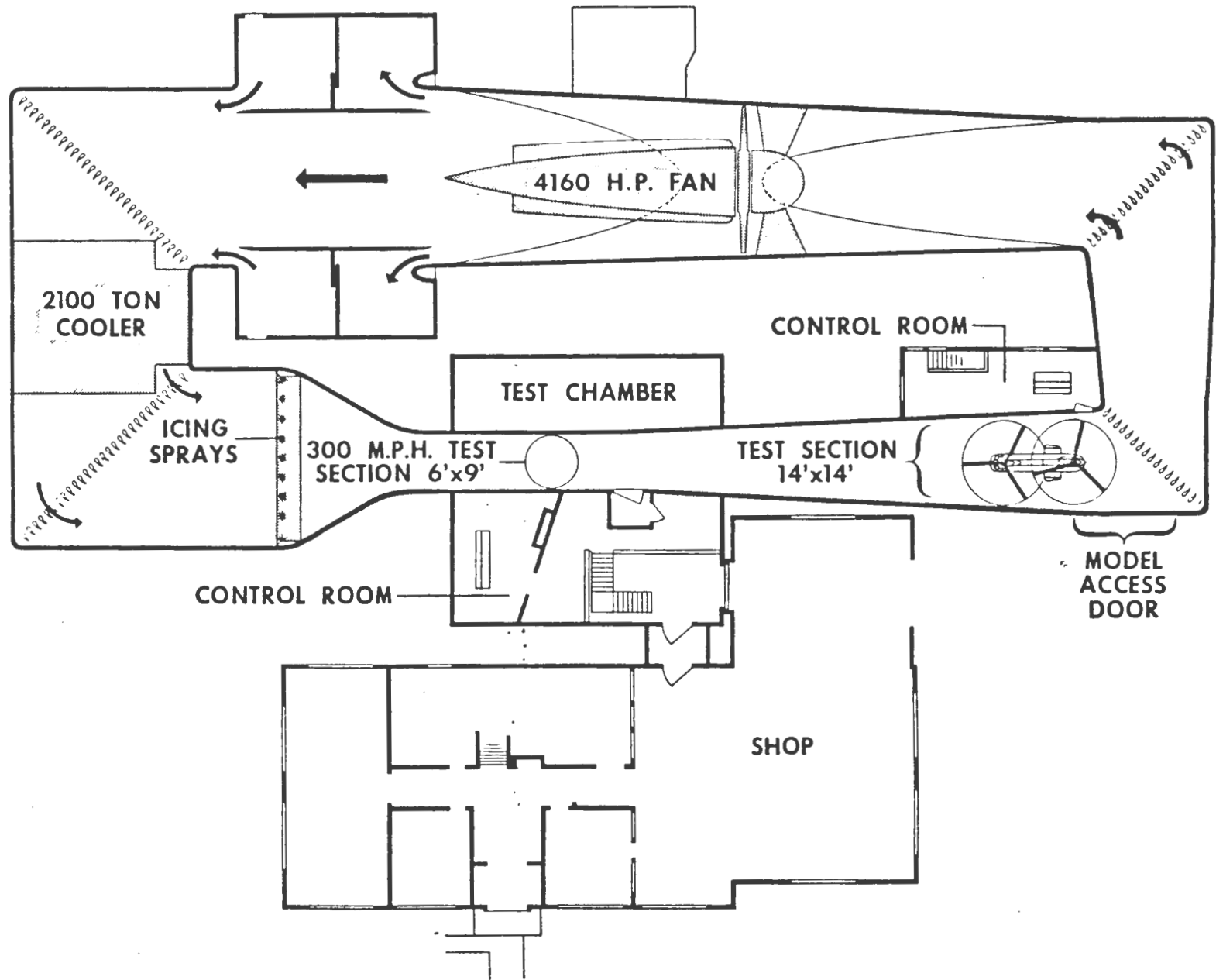


Figure 7

PRESSURE REQUIREMENTS
ICING TUNNEL

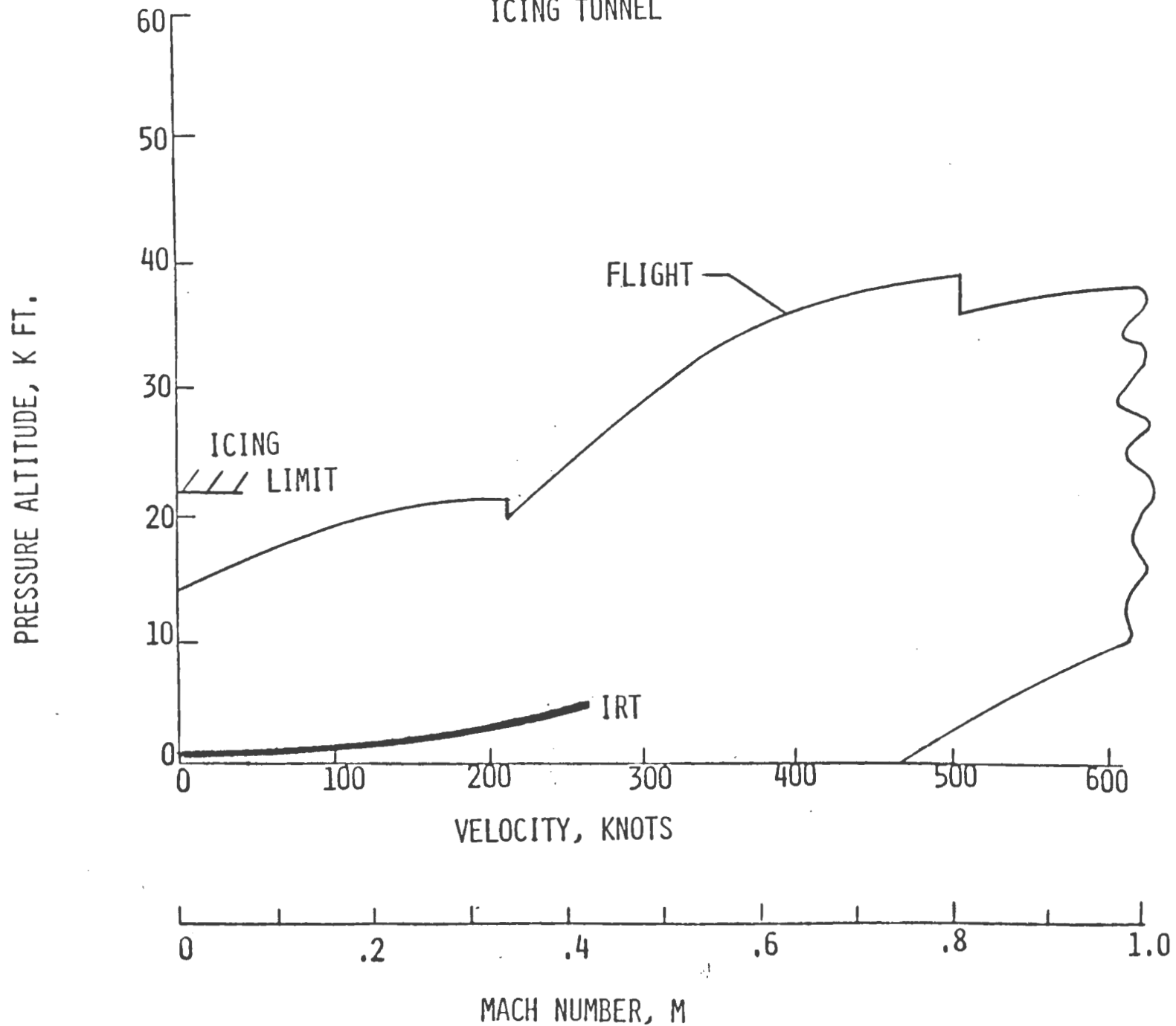


Figure 8

TEMPERATURE REQUIREMENTS
ICING TUNNEL

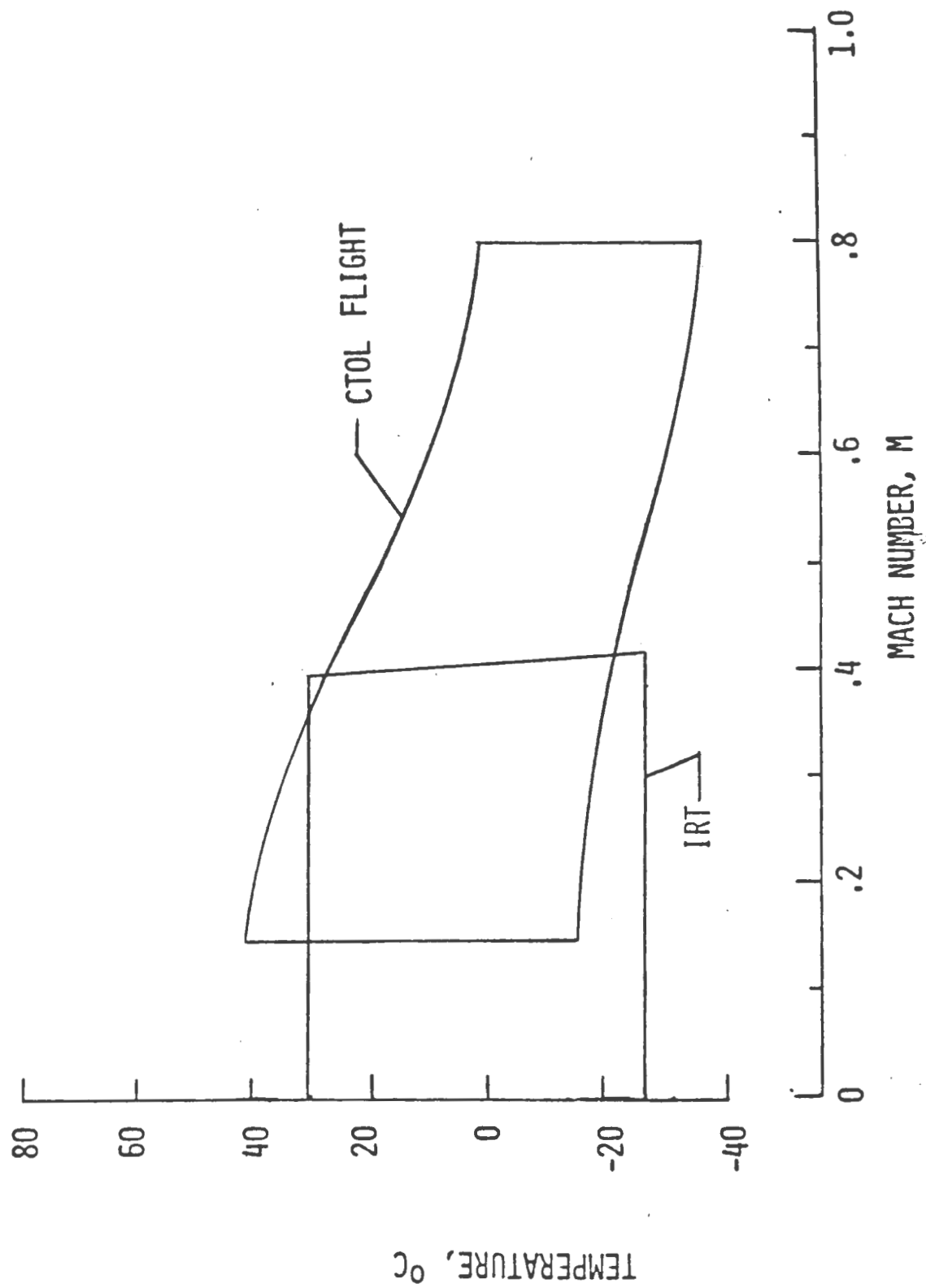


Figure 9

WHY AN ALTITUDE WIND TUNNEL

<u>NATIONAL TREND</u>	<u>APPLICATIONS</u>	<u>FACILITY NEEDS</u>
o RESURGENCE OF <u>ICING R&T</u> FOR ALL WEATHER CAPABILITY	- o MILITARY NEEDS - ARMY ROTORCRAFT - AF TACTICAL AIRCRAFT - AF CRUISE MISSILES - o CIVIL NEEDS - ROTORCRAFT CERTIFICATION - GEN AV GROWTH - ADVANCED CTOL	o ICING WIND TUNNEL MODERNIZATION
o RESURGENCE OF <u>PROPELLER</u> FOR FUEL CONSERVATION	- o HIGH SPEED CTOL TRANSPORT - o GEN AV & COMMUTER - PROPELLER TECHNOLOGY - ADVANCED ENGINES	- o FLIGHT SIMULATION - o AEROELASTIC RESEARCH
o GROWING NEED OF <u>V/STOL R&T</u> FOR MILITARY	- o NAVY VTOL - o AF V/STOL	o TRANSITION AEROELASTICS

Figure 10

AWT REHAB

	APPLICATION	FACILITY DESIGN
<u>BASE</u>	- o AIRCRAFT ICING - o LOW SPEED PROPELLER - o V/STOL TRANSITION	o EXISTING DRIVE & REFRIGERATION
<u>OPTION</u>	- o HIGH SPEED ICING - o HIGH SPEED PROPELLER - o IMPROVED V/STOL	- o NEW DRIVE & INCREASED REFRIGERATION - o SLOTTED TEST SECTION - o FREE JET INSERT

Figure 11

AWT FLOW CIRCUIT

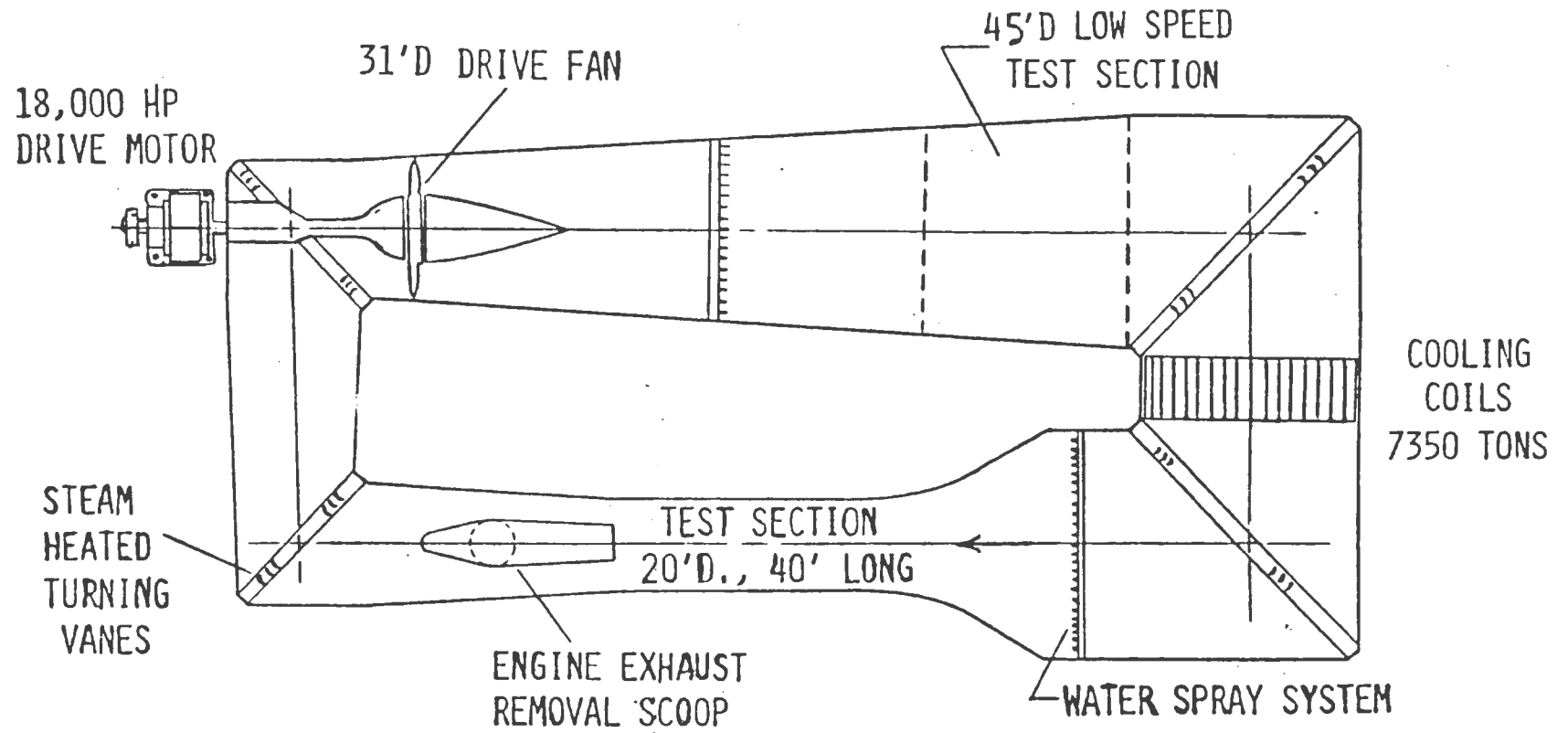


Figure 12

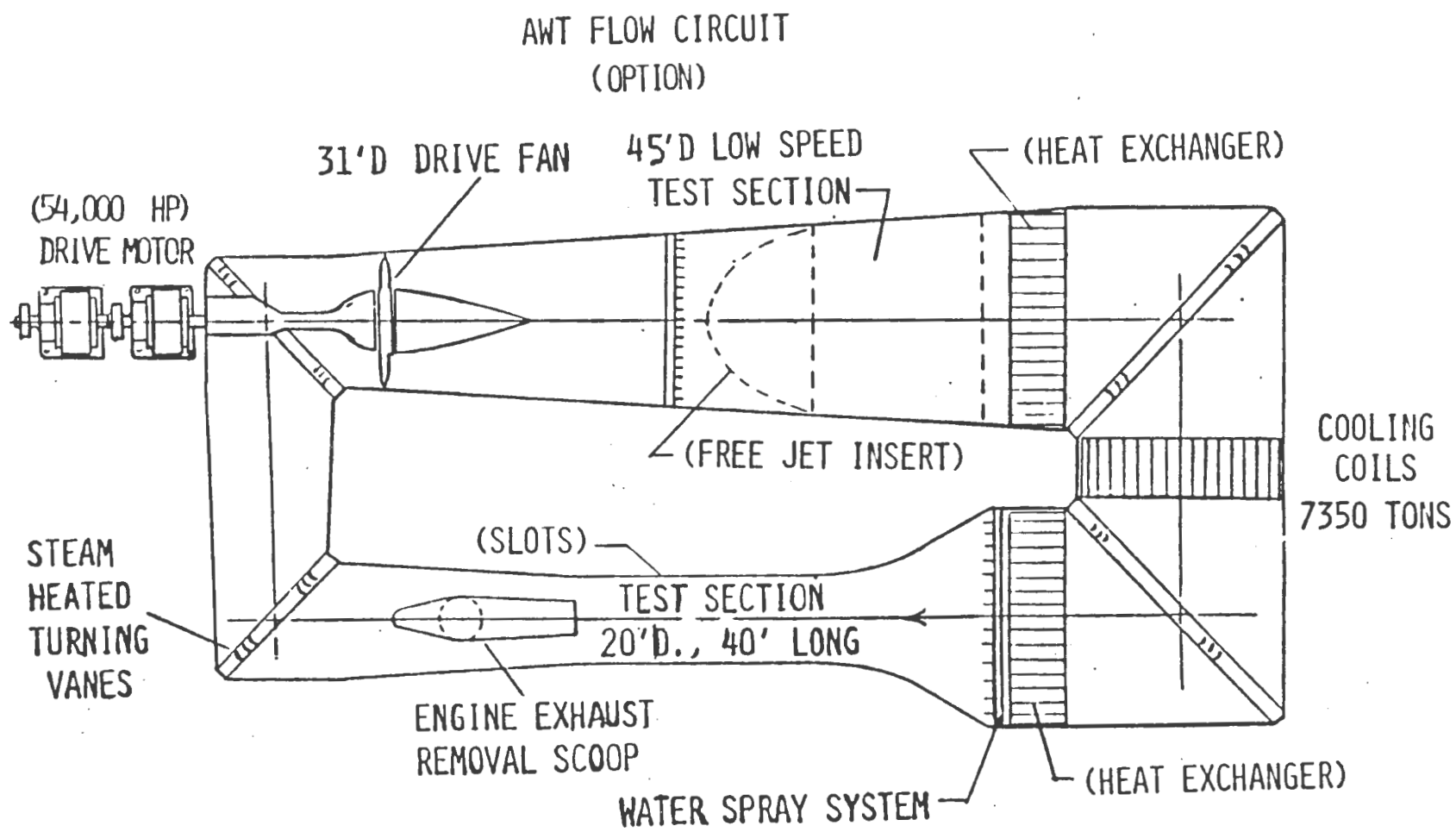


Figure 13

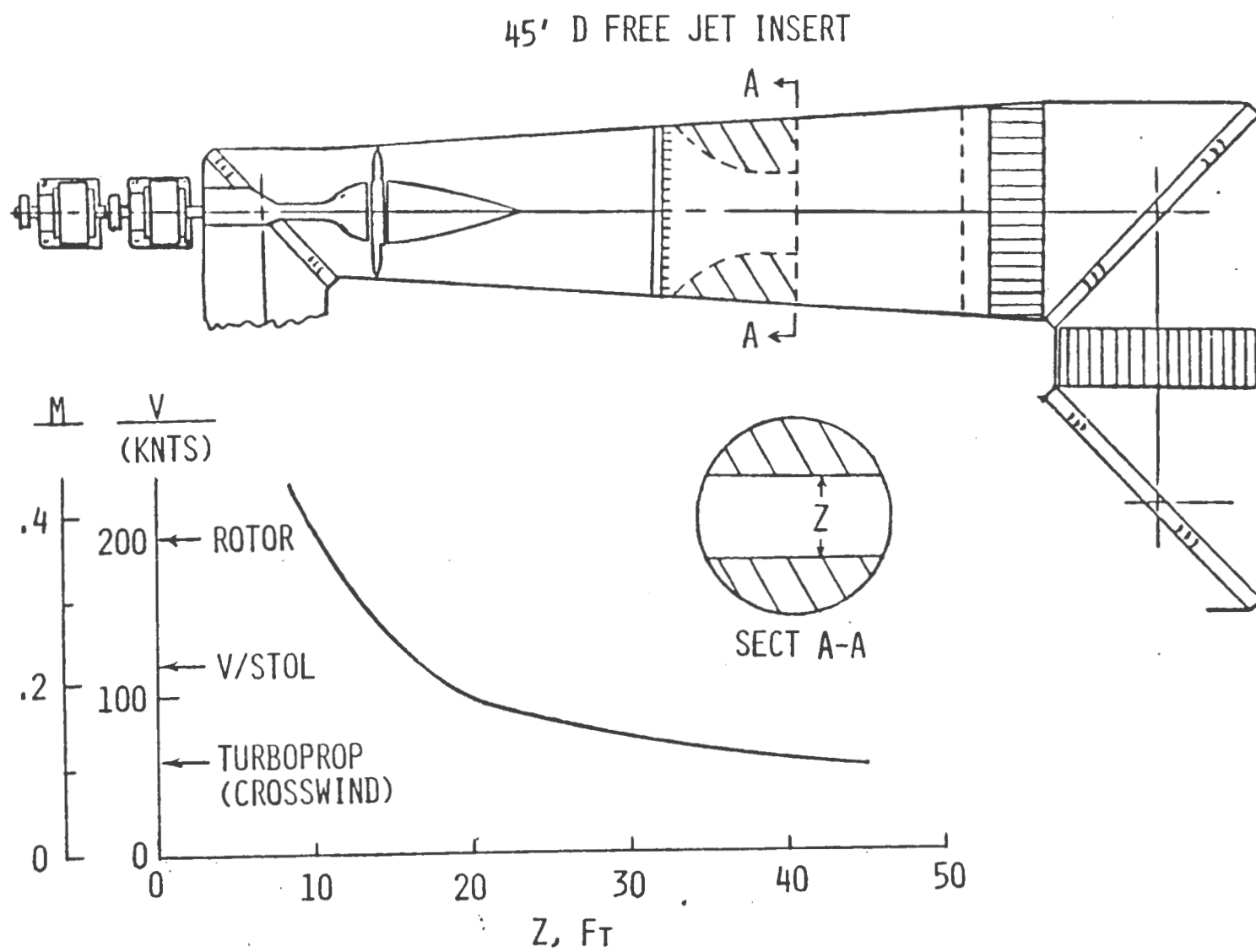


Figure 14

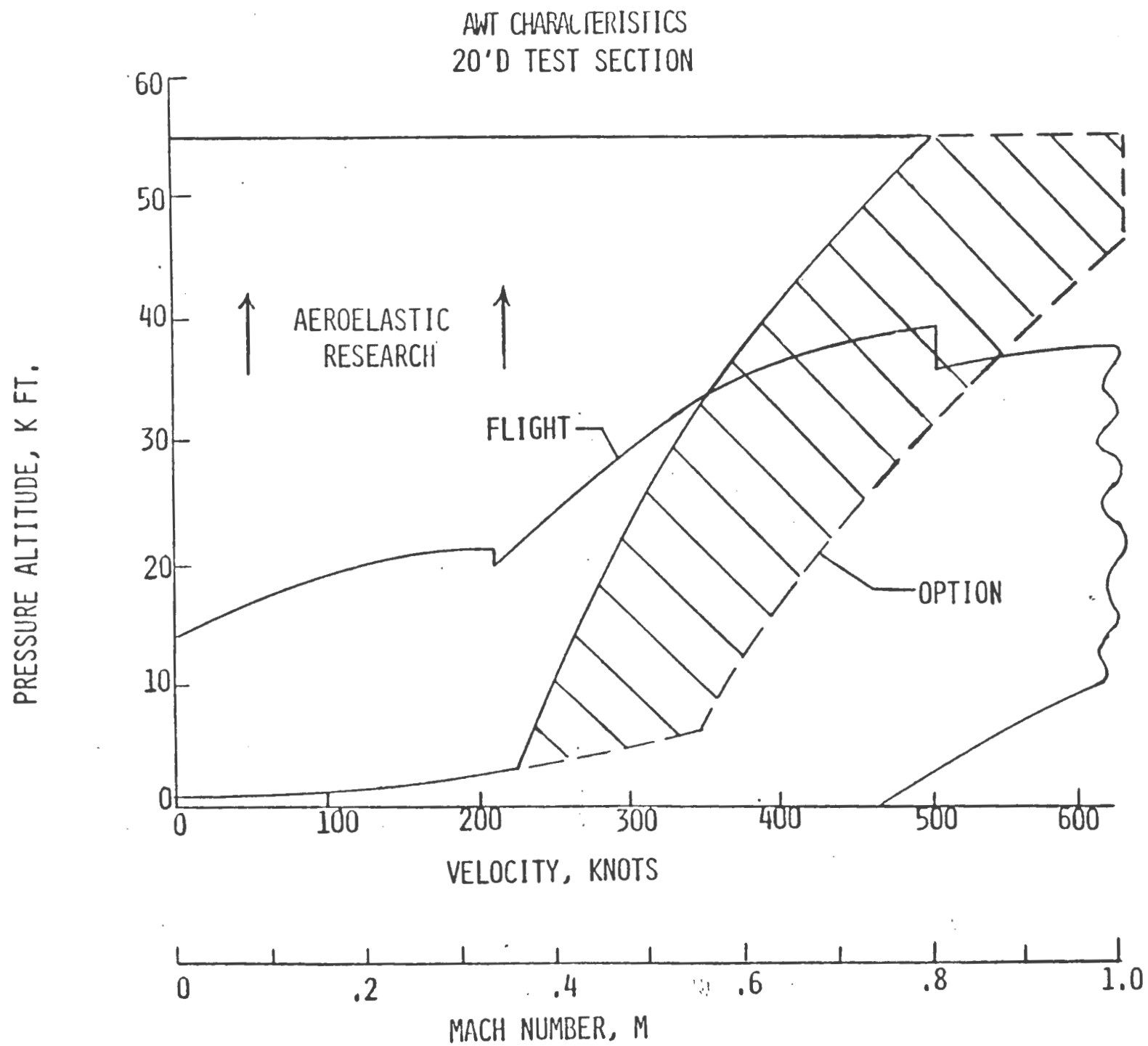


Figure 15

CHARACTERISTICS
TEMPERATURE LIMITATIONS

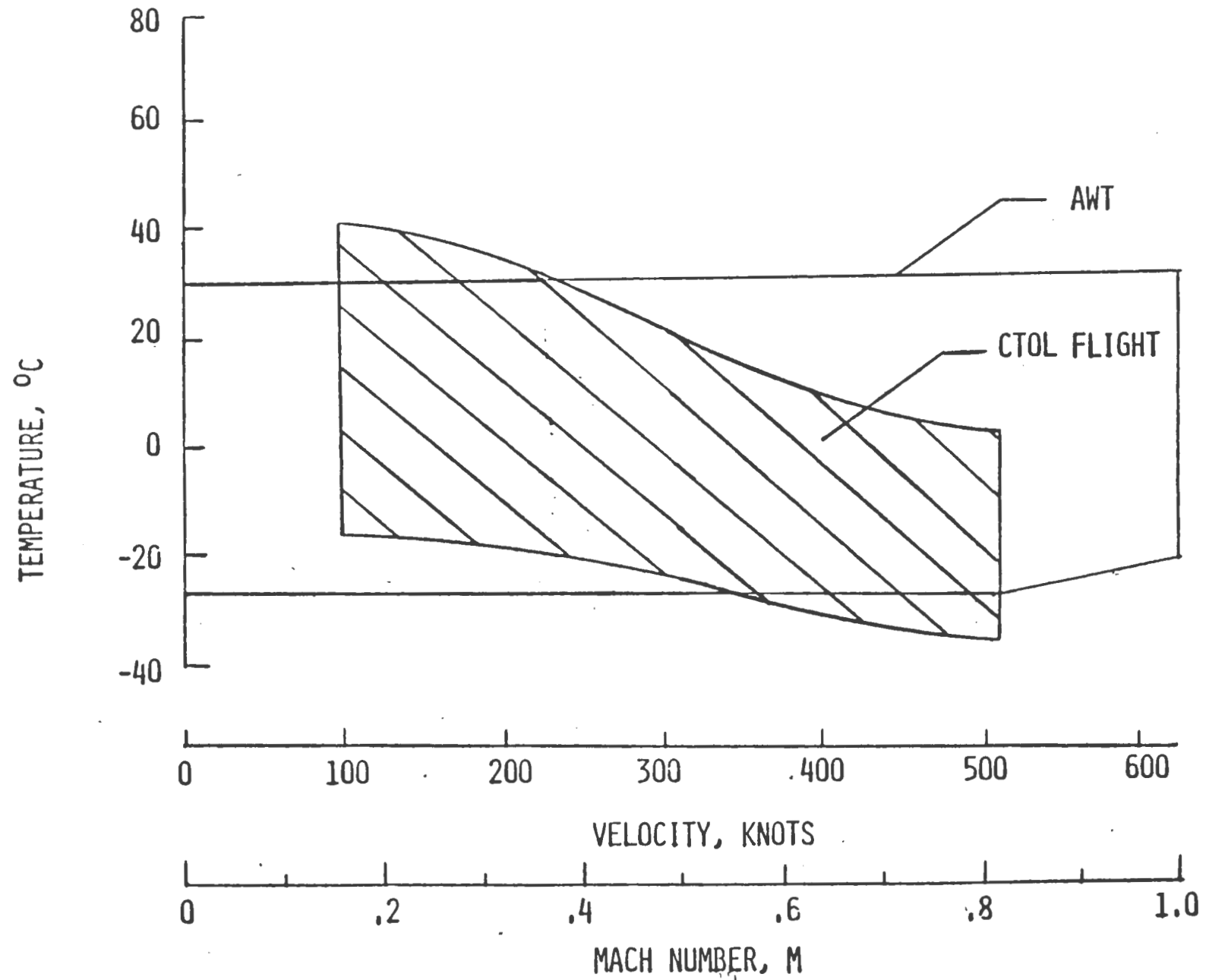
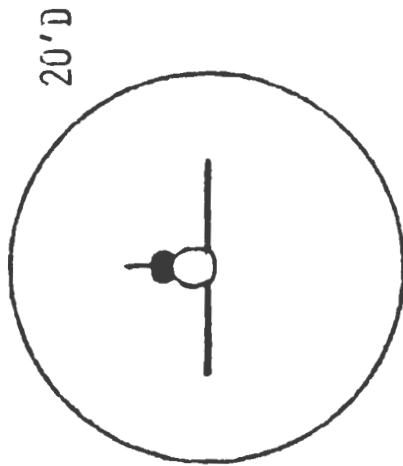
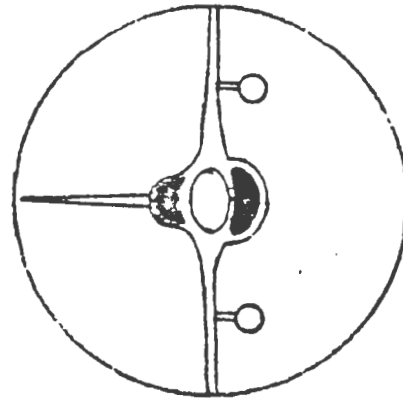


Figure 16

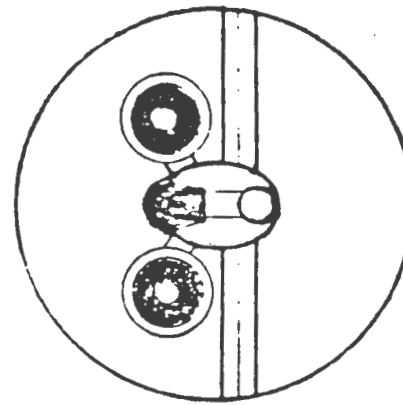
HIGH PERFORMANCE MILITARY



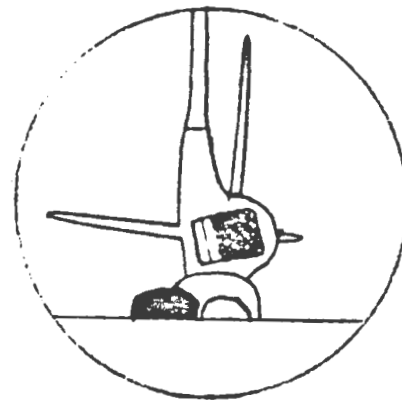
ALCM



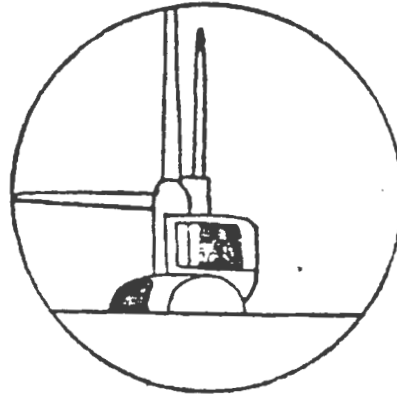
F-16



A-10



F-14



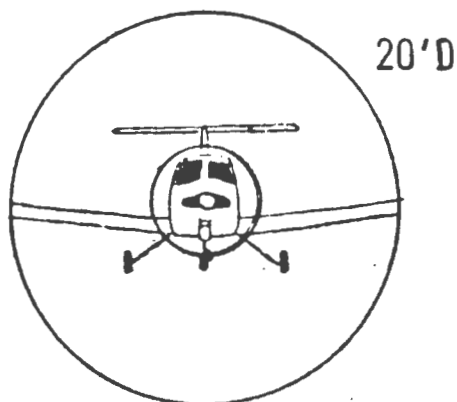
F-15

AWT EMPHASIS

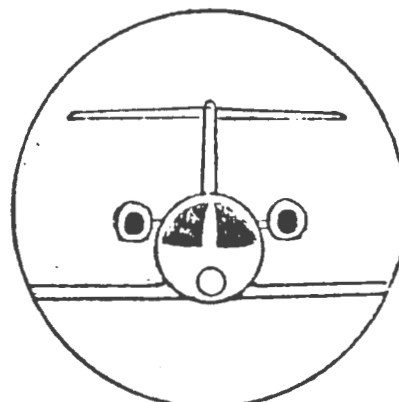
ICING

Figure 17

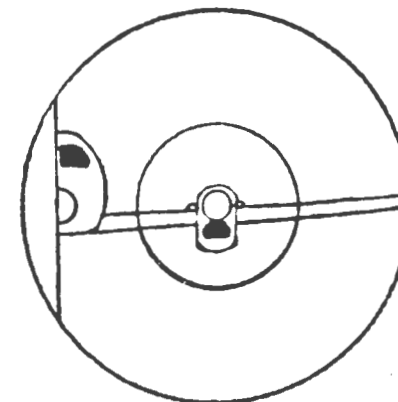
GENERAL AVIATION



PISTON ENGINE



TURBOFAN



TURBOPROP

NASA PROGRAMS

INTERMITTENT
COMBUSTION

QCGAT

GAP
GATE
STAT

AWT EMPHASIS

COOLING
PERFORMANCE
ICINGPERFORMANCE
ACOUSTICS
ICINGAEROELASTICS
PERFORMANCE
ICING

Figure 18

G.A. AIRCRAFT IN 45'D LOW SPEED TEST SECTION OF AWT

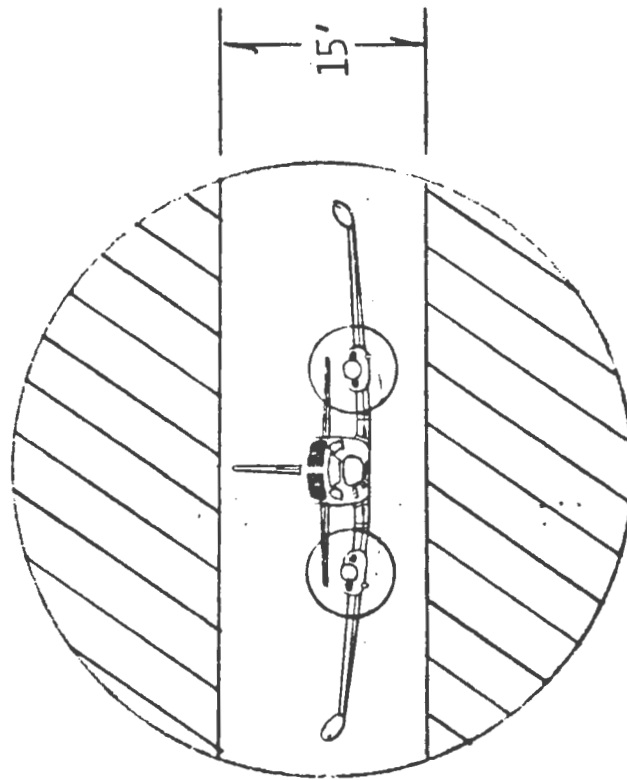
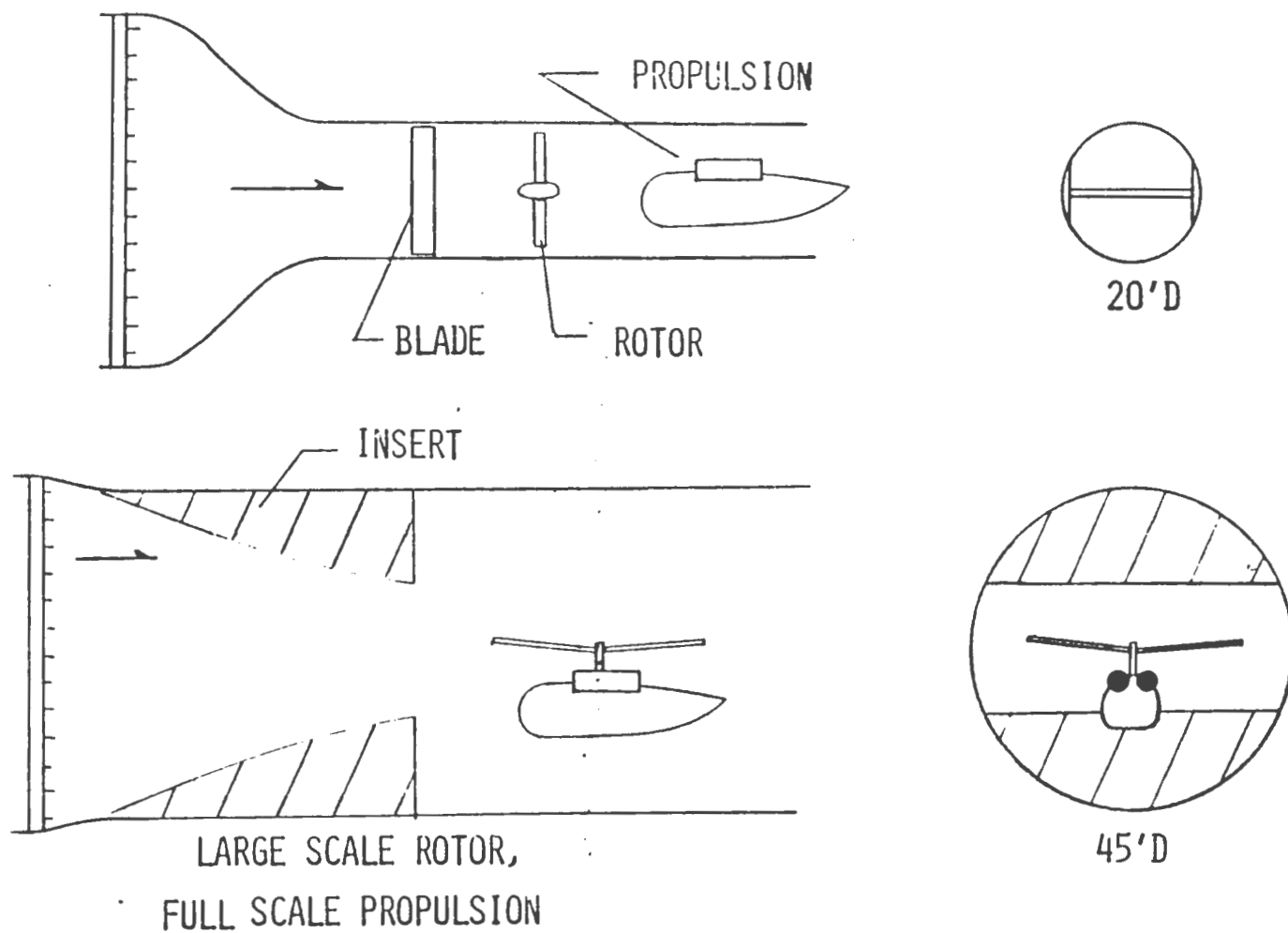


Figure 19

ROTORCRAFT



AWT EMPHASIS
ICING
PERFORMANCE

Figure 20

AWT REHAB COSTS

- CONSTRUCTION IN FY '84-86

BASE \$60M

OPTION \$151M

- LOW RISK

ROUTINE TECHNOLOGY

WE DID IT BEFORE - 1942

- HIGH VALUE OF PRESENT COMPONENTS

SHELL

DRIVE

REFRIGERATION

BUILDING

\$ 75 M ('85 EST.)

PSL EXHAUST

\$ 100 M ('85 EST.)

SUMMARY

IMPORTANT R&D REQUIREMENTS FOR ICING PROTECTION OF AIRCRAFT

ICING WIND TUNNEL ESSENTIAL TOOL IN SUCH WORK

REHAB OF AWT OFFERS MAJOR ENHANCEMENT IN NATURAL CAPABILITY
IN COST EFFECTIVE MANNER

Figure 22

RICHARD I. ADAMS

Thank you Milt, thank you very much.

Well, gentlemen, you have heard discussions, descriptions of the vast majority of the icing testing facilities that exists in the United States and a little bit of information on one facility that exists in Canada that is an exception to the United States agencies. The rest of the meeting really I guess, is up to the representatives from industry, HAA, GAMA, AIA, to really help us decide the types of recommendations that we, the FAA Technical Center, needs to forward to FAA headquarters and the NASA and DOD for the establishment of a national facility effort to help you, industry, as well as the government agencies. The agenda for tomorrow starts at 9:00 and starts off, almost immediately, with presentations from representatives of the three associations who will attempt to summarize the industry consensus. I realize that as we were going through the presentations that we were rushing, we did discourage some questions. The question that I have at the moment is, "Are there questions that any of you have in mind about the presentations or facilities that exist that you would like to cover now or possibly first thing in the morning". Yes Ken!

Q. KEN ROSEN

I have one that I would like to cover now. I would like to address Milt. I think his proposal of the AWT rehabilitation and that is, in the low speed section of the proposed AWT obviously is going to be applicable to helicopters, looks like at least small helicopters, as the case with some of our products. How low a speed are you going to be able to attain in that section? Here you get up to 200 knots for a very small cross section cloud up to 45 foot in diameter. But how low a speed will be your capabilities?

A. MILT BEHEIM

I believe we'll find out when we determine what the recirculation problems are. As you operate the rotor in downwash conditions, there is a recirculation phenomena that results. The faster you go, the easier it is to wipe out its effects. The other thought that accompanies this is that recirculation may not be an overriding influence if you're looking at an icing problem. It may be if you're looking at a performance problem. But if you're trying to find out if it's shedding correctly, in the proper sequence, why recirculation may not hamper us. I was hoping we could certainly get down to almost 100 knots, maybe even lower.

KEN ROSEN

I was guessing 80 to 85 knots, thinking about the types of velocities we get, that might be about it.

MILT BEHEIM

Yes, maybe there are other views here too from people that are familiar with aerodynamic testing, performance testing and the recirculation problem.

Q. KEN ROSEN

Also, do you have a plan or is there a facility within that specific section for an exhaust? In other words, say you do have an exhaust in the present tunnel, it proved to be very useful in the last 10 years. Do you have that included in the facility so that may not be an add-on?

A. MILT BEHEIM

That's right! There will be exhaust systems provided in both test sections. In the high speed test section we have an engine exhaust scavenge and in the low speed test section we have also. It may be used to simulate an engine or it may be used to scavenge the engine exhaust.

Q. KEN ROSEN

The next question that I have is on the availability. As you know many of us have been power limited during our various tests in Cleveland. My concern is would the advent of one more large device cause power supply problems with the utility or with your own power plant? Do people within NASA have the availability of that amount of power and will that become a problem to potential users?

A. MILT BEHEIM

The power is available for a much larger facility than this. In fact our 10 X 10 foot tunnel runs at twice the power level that the high option AWT runs at. AWT high option is like 110,000 horse power. Our 10 X 10 runs at 250,000 horse power. It's not a question of power available in that area. It's primarily a question of cost and the desire of our headquarters staff to reduce consumption to meet national objectives.

Q. KEN ROSEN

When would you envision availability for what time area?

A. MILT BEHEIM

I believe that it would be used on the same basis that our icing research tunnel is used at the present time. There are around 15 entries per year into the icing tunnel. At the present time almost all of those entries are either Government contract supported, or

MILT BEHEIM

else are being requested by the FAA. There are relatively few entries of a NASA research type, because the research program has only been in place for two years. I would expect a growth in the number of entries that occur for NASA research. I believe that we have accommodated every request for the use of the icing tunnel from industry within the constraints that I can accept them within NASA. Now there are some things that NASA can't do for you for free. But I think that things have worked reasonably well in that regard using the icing tunnel and I would expect that the AWT would be used in the same way except that there would be user charges, as there will be for all national facilities.

Q. KEN ROSEN

Would you envision availability by '86, '85, what do you think?

A. MILT BEHEIM

Construction in the '84, '85, '86 time period, and operation in '87. Yes.

Q. I have a question for you? Some of the previous speakers have mentioned projects are going on in coordination with NASA Lewis. One was icing scaling and the other was numerical analysis. Can you talk about those briefly or give us references?

A. MILT BEHEIM

The thrust of the meeting was primarily facilities but I'm glad you brought this up. The question could be answered best by Jack Reinmann. Jack is head of icing research activities at Lewis.

JACK REINMANN

We have an initial effort in icing scaling and it was mentioned by Jay Hunt from AEDC. We are planning to try to verify the existing scaling laws. These have been on the books for, I don't know, for at least ten or fifteen years. I think Lockheed published some of the first scaling laws and we will be putting certain models in the tunnel controlling the conditions, measuring the ice shapes and then by using the scaling laws change the model size, change the icing conditions and see if we can get the same icing shapes. We don't know what we can do in the area of the energy equations, which is a lot more complicated and we're not even sure that there is a decent scaling law available. In addition, we have a contract with the University of Tennessee to reanalyze the scaling problem from a true similarity analysis, using methods

that have been developed by people like Simon Ostrach. That's a separate program that's going simultaneously and we'll see what comes out of that as far as new scaling relations go. With AEDC they will be running the high speed tests and the altitude part of the scaling analyses and we'll be running the larger model sizes and the lower speed end of the scaling. To do this properly if you wanted to do all the scaling in NASA's IRT would require that you get down to five micron drop size. We do not have nozzles that will go down that far and Jay Hunt will also be looking at nozzles and to develop the smaller drop sizes, so that scaling might be possible once we find a nozzle. The other problem is that the reliability of making a drop size measurements of five microns is really in question. So even if we think we can make five micron drops, we don't know whether we can measure them or reproduce them in every body's tunnels. The other area is icing scaling analysis. We have a number of both grants and contracts in the area of water droplet trajectories. We have water droplet trajectory codes for 3D bodies using Hess paneling techniques, both for lifting and nonlifting. The nonlifting portion is finished and it's available in a published report. If you'll give me your name, we'll see that you get a copy of that report. The contract for the lifting code will be let shortly. We have another code being developed by FWG Associates in Tennessee on 2D lifting bodies and axisymmetric inlets or angle of attack. That code is being developed, and it will be about 6 months or 8 months before it's available. We have a program with Ohio State on flows around 2D lifting bodies to look at ice accretion shapes and also to look at the performance penalties due to icing on the airfoil. We have a code being developed also with Ohio State for water droplet trajectory around rotating flows, both for propellers and for helicopter blades. Its very new and again we are looking at that from the standpoint of performance penalties. We'll try to develop some ice shapes and put them on the blades and see what the performance penalties will be like. Eventually we would like to do that in conjunction with some kind of an experimental program. We also have a code being developed for ice accretion modeling, including an energy balance, and developing the actual shape following initially the Stallabrass-Lasowshi technique that were developed in Canada. That's being done by the University of Dayton Research Institute which also is doing frost modeling for another NASA Center. There will also be some work being done by Langley at our request, at separated flows, again to look at the performance penalties of these complicated ice shapes on 2D lifting bodies. I think that covers the analysis pretty well.

- Q. I have heard that NASA was looking at the basic data that was accumulated years ago to establish the icing envelope and that they were specifically looking at the data that has been accumulated for lower altitudes which is more representative of helicopter operations. The initial indication is that the icing

MILT BEHEIM

envelope will not be as stringent as that specified presently.

- A. I could talk about that. We brought to the attention, at this last meeting that Dick Adams called here on the problem of cloud physics, a report by Porter Perkins that was not taken into account in any of these studies which had about 1000 data points below 10,000 feet. We have been analyzing that data statistically to see what the water, or what the liquid water content looks like as a function of altitude. We have also gone back and looked at other old NASA data which amounts to about 400 to 600 data points and that result is that we do not find, this is preliminary statistical analysis, we do not find any correlation of liquid water content with altitude, and the liquid water contents have been below 1 gram per cubic meter except for a couple of points.

Q. PORTER PERKINS

Is this information being shared with the FAA regulatory people?

- A. Yes it is. We're in contact with both Dick Adams and with, who's the other fellow in from headquarters?

A. RICHARD I ADAMS

Information right now is being shared with the R&D people. The R&D people have not gotten to the point to have confidence that anything is going to change that. Dave Ostrowski is here and he's our contact in Washington.

- Q. The reason that's important, Dick, or the reason it's important to discuss it, obviously, is that there are certain rules that are currently being considered in Washington. And, I believe, certainly important, that this latest piece of technical information be filtered in immediately before any precipitous action is taken with those rules that might result in significant expense.

A. RICHARD I. ADAMS

Yes. Most certainly, once we have confidence that the information is technically correct and some sound recommendations or inference can be made. I think, really, it's a little too early for that. This issue was just surfaced two or three months ago and it's going to take a little while to make sure that there is enough data and we are working very closely with NASA in this regard. Are there any other questions. Go ahead.

MILT BEHEIM (Questions and Answers)

Let me say one thing more because I forgot to talk about this earlier. I really (would like) to finish a list over here regarding the advantages of ground test facilities. I talked about the control of variables in ground test facilities. To perform systematic research by sorting through all kinds of variables in a relatively short period of time. Flow quality is something that is more closely scrutinized in the ground test facility than is done in the flight work. I think data systems at our ground test facilities are obviously more extensive than ever can be achieved in a flight system. Safety is hardly an issue in ground test facilities. The cost of carrying every advanced concept into a flight test is out of the question. I believe, also, that the manpower can be utilized year round in a systematic way that minimizes the logistic problems attendant with most flight programs. The only point of this story is, everyone of these has an unique and important role to play and they all look alike, and each one has a very important function. I think it's value, though, is a value to recognize through its contribution to the wind tunnel. Thank you.

CLOSING REMARKS - SEPTEMBER 23, 1981

RICHARD I. ADAMS

We're running 13 minutes overtime at the moment, so I would like to make sure that if there are any additional questions that you have, that will bear on your deliberations this evening, that are necessary for tomorrow morning's presentation, then let's ask those questions or make a determination to have some more general discussions first thing in the morning before you come up with your final conclusions. Anyone have a comment or suggestion in that regard? We have a tour that was scheduled at 4:00. We'll let you take a look at some of the facilities here in the building. Also, I have been asked to remind the members of the AIA and the HAA to meet with Bob Richardson and Herb Slaughter. Herb is really representing Jack Reese of the AIA who is not here. We have two conference rooms available. Specifically, Jack has named Dr. Rosen, Andy Peterson and Herb Coffman as the people that he would like to meet with in addition to the many other members of the HAA or companies that are represented by the HAA. Herb Slaughter would like very much to have Darwin Hawkins and Harry White, Richard Keller from GE, George Franchenni from Allison, R.A. MacWhittier, Ken Smith from Lockheed and Mr., I'm sorry I can't read your writing here, Herb, the McDonnell Douglas representative. Those people please meet with Herb and Bob in the lobby out here and Charlie Masters and I will get you to the proper conference rooms. All the others who would like to take a little tour of the facilities meet us out here. Yes! Would those two gentlemen stand up so that we know who they are? Yes! Herb and Bob. Very good.

Let me just, very, very briefly, throw something out or something else out for your consideration. This will take just one second.

What we've been hearing about all day today are the various types of facilities that are needed for various purposes and are outlined here (Figure 1) or summarized here (Figure 2) and one of the things that we've been trying to get a handle on is really the specific requirements of these different types of facilities. And this gets to be a pretty sizable matrix. A pretty sizeable matrix of information that would have to appear, combining all these facilities types for the various purposes with the specific detailed requirements for each of them, such as the airspeed range and many of these things we've talked about today. Many questions have been asked, specifically about the test endurance. How much time you need. I would only like to encourage that during your deliberations to make sure that you give some thought to this and give us what help you can in this area. It would seem to me that these requirements from industry would basically be set by the future aircraft types. Now one point that has been brought up here is that it could also be set by any future changes to the FAR 25, Appendix C criteria. We have currently parallel efforts going on in both these areas. Possibly there could be some changes in the FAR criteria, but we can't say what those changes are going to be right now. But we've got to start someplace and we've got to start planning right now. Unless anyone else

RICHARD I. ADAMS (questions and answers)

has some questions or comments that are needed to get us ready to go in the morning. Yes, Bob?

Q. Bob Richardson

Are those laundry lists going to be available to us as we have our little meeting? Can you make a copy of it?

A. Richard Adams

I think we can find a Xerox machine someplace! If not, then I will give you these.

Q. Bob Richardson

We also need a viewgraph in our conference room. Could you make that available to us please?

A. Richard Adams

Yes, you can take one of these. I think right now we are not over committing ourselves, am I, back there? I think we're alright? How long will you need these conference rooms? 10, 11, 12 o'clock tonight?

A. Bob Richardson

Better leave them available to use until, at least, 10 or 11 o'clock.

O.K. If there's no other -- Yes?

Q. Will a list of attendees be published with the minutes?

A. Yes. As a matter of fact, if there is anyone here who did not register at the desk, please do so because we will develop an attendance list from the registration list. I would like to stress once again that all the speakers that spoke already really put these presentations together as a result of a verbal request from me within thirty days and I sure appreciate that. I think they did a fantastic job both from the standpoint of responding and really telling us what the facilities were all about today and I certainly appreciate it. I would like before they leave; that arrangements are made to either have a hard copy of information that we can use to publish with these proceedings or make arrangements to send us a hard copy in the very near future within the next few days. Any other matters before we adjourn? Thank you very much and don't work too hard. Hope to see everybody over at the Clubhouse at 6:00 or so.

HELICOPTER ICING CERTIFICATION TOOLS

PROBLEM STATEMENT

- **NATURAL ICING TESTS**
 - **EXPENSIVE**
 - **TIME CONSUMING**
 - **LIMITED CONDITIONS**
- **IN-FLIGHT SIMULATION**
 - **LIMITED CAPABILITIES**
- **OTTAWA SPRAY RIG**
 - **LIMITED CAPABILITIES**
 - **THREAT OF CLOSURE**
- **ICING TUNNELS/CHAMBERS**
- **ANALYTICAL TECHNIQUES**

Figure 1

HELICOPTER ICING CERTIFICATION TOOLS

OBJECTIVES

- ASSURE
 - ADEQUATE FACILITIES
 - RESEARCH
 - DEVELOPMENT
 - CERTIFICATION
 - SAFE
 - COST EFFECTIVE
 - TIMELY
 - ADEQUATE ANALYTICAL TECHNIQUES
 - CERTIFICATION CREDIT
 - ANALYSIS
 - DEVELOPMENT TEST
 - SIMULATION
- REDUCE
 - CERTIFICATION — TIME — COST
- ENHANCE SAFETY
 - CERTIFICATION PROCESS
 - OPERATIONS

Figure 2

NATIONAL ICING FACILITIES
COORDINATION MEETING

MINUTES

SECOND DAY - SEPTEMBER 24, 1980

INDUSTRY PANEL DISCUSSIONS

FAA TECHNICAL CENTER

ATLANTIC CITY AIRPORT, NEW JERSEY 08405

INDUSTRY PANEL DISCUSSIONS

MEETING CHAIRMAN: RICHARD I. ADAMS

Good morning, gentlemen. If you will take your seats we will try to get started. I think we have everybody here now. Looks like the crowd is a little thinner today, maybe it's spread out, it appears that way.

First, I would like to announce a couple of changes in the agenda for today. We're having some viewgraphs prepared for the HAA presentation and so therefore, we will have the GAMA consensus first with Jim Dougherty being the spokesman, followed by really a joint HAA/AIA consensus. At the first break this morning we are going to reconfigure. We're going to set up some tables here on the apron and we're going to have the speakers from yesterday and representatives from HAA, GAMA and the AIA at that table, along with myself and we'll get into some general discussion. Now, I would like very much, to make it flow as smoothly as possible to reserve all questions until the general discussion session. That will be after the break so that we can get the consensus presentations over with in an orderly, precise manner. Then we can bring any questions and any other general discussions that really we got into yesterday. I thought that some of those discussions were becoming quite interesting and I would really like to see those issues pursued further today because we will have the time. I think that the way we're progressing, that possibly, after lunch, we may be through. I would like to play that by ear. At the same time a few people mentioned yesterday the desire to have a tour of our R&D facilities here on the Center, in addition to the brief tour that you had of the building yesterday. Now, we can make arrangements if there is significant interest, so could I have an indication by a show of hands of interest? So there is about 12-14? O.K.! Charlie, can you pass that over to Jennifer, because she needs that now. Also Charlie, the pointer that we had yesterday, I think that's your personal property. Did you bring that back by chance?

Another point that I would like to bring at this time is the fact that we are aware that certain companies have their own small tankers. Cessna has one, Piper has one and also Flight Systems Incorporated out of Mojave has a tanker. I would like, when we start the general discussions this afternoon, to start off those discussions with a very brief overview from John Ligon from Flight Systems, Inc. If there are representatives from Cessna and Piper, who can briefly describe their tankers, I would like to hear that. You can think about that and let me know.

John Ligon is prepared and we've talked about it so far, but I have not coordinated this with the Cessna or Piper representatives. So with those introductory remarks and announcements, we'll start by hearing from the GAMA representative, Mr. Jim Dougherty.

GAMA REMARKS ON NATIONAL ICING FACILITIES

JAMES E. DOUGHERTY

Mr. Chairman, GAMA is pleased to be present and participate in the FAA/Industry Coordination Meeting on National Icing Facilities held here at the FAA Technical Center at Atlantic City, New Jersey, on September 23 and 24, 1980. I am pleased to indicate we have representation from several of our member companies. These are: Ted Blaser and Norm Weisend, BF Goodrich; Robert Crawshaw, Cessna Aircraft Company; George Drake, AVCO Lycoming; Darwin Hawkins and Harry White, Gates Learjet; and James Pyne, Garrett AiResearch.

We are of the view that yesterday's proceedings wherein outstanding experts from the various government facilities outlined work in progress and future possibilities, were very informative and useful in terms of trying to establish a new national direction in this technical area. We commend the FAA for its leadership in this respect.

Perhaps a few words on GAMA's relationship to the aircraft system would be helpful. As you may know, there are over 200,000 general aviation aircraft currently operating with certificates of airworthiness in the United States in the field of general aviation. Within these ranks there are several hundred various type certificate aircraft, many of which are still in production. Based on rather recent production figures, United States general aviation industry is producing approximately 13,000 new aircraft per year. There have been years when even this figure was exceeded. Approximately 22% are being exported. These aircraft range in speeds from 120 mph to 600 or more mph. The upper altitude limit on some of them is as high as 51,000 feet. These fleets are comprised of single and twin engine aircraft with a variety of powerplant installations ranging from reciprocating engine through turboprop installations to jet powered aircraft. The de-icing and/or anti-icing systems range from thermal to mechanical to electrical. To date the primary source of certification standards for the Part 23 aircraft is FAR 25, adopted in the early 1950 era.

Turning to the question before us today, GAMA constituency has a number of reactions to yesterday's proceedings. These are not arranged in a prioritized manner but in a broad sense all would have to be considered in the formulation of a proposed national policy. The sessions, as we said earlier, have proved to be highly favorable and informative and established, once again, that communication of this type is a necessary adjunct to problem solution.

Those areas discussed yesterday and considered to have been of help in policy formulation include:

1. Modifying of the HISS Test Bed by the Army as we believe this would be of use in the low speed regime, and therefore beneficial to certain general aviation type aircraft.

JAMES E. DOUGHERTY

2. Availability of the KC-135, either in its present or modified sense, to the private sector is welcomed. Conceivably, it could be used in evaluating higher speed twin engine general aviation aircraft.
3. Reopening of the NASA Altitude Wind Tunnel (AWT) is supported. The question of whether or not it be Phase One or Phase Two is not settled in our view, but the basic interest in general aviation would be the ability to test an airplane full scale in the sizes we produce. Unfortunately, you never get a test facility of that type big enough for all classes of aircraft, but conceivably larger components could fit. The time table on this proposition should be accelerated if at all possible. But at this stage it seems as if such a facility probably would not come on line much before 1985. GAMA has several commuter designs which hopefully will be in the final engineering or early production stages by that time.
4. The continued use of tankers within the general aviation field is envisioned. Two of our manufacturers, Cessna and Piper, own and operate same, and both intend to continue doing so. The question of the extent of recognition given by the FAA certificating authorities to icing evaluation using tankers needs further discussion.
5. Research on the nature and extent of use of icing shapes is needed. This is one of the tools currently employed by industry today, but again the question is raised of the extent of consideration given to such testing in the certification program for aircraft.
6. How good is the FAR 25 icing map? Some of our manufacturers are required to fly the corners at excessive cost and delay - yet tools such as analytical techniques, wind tunnel results and tanker tests are available.
7. Perhaps a better definition of availability to simulate cloud physics tailored to icing tunnel tests for each class of aircraft is needed. In this respect we wish to underscore that there may very well be a marked difference in the evaluation of different aircraft types, i.e., helicopters vs. light aircraft vs. large transports. Entwined also in this may be a need to find a basis for a new methodology that recognizes the lower altitude regime and the higher altitude regime without the need for such extensive natural icing test as are now required.
8. GAMA believes continued support should be given to the OTTAWA Tests Rig, hopefully in its present site, but elsewhere if Canadian support for this activity is not forthcoming.

JAMES E. DOUGHERTY

9. GAMA believes that more communicative opinions and technical discussions of this type are needed. We would endorse the development of the National Task Force to this end.
10. GAMA has a survey of this problem in process, but the total results are not yet available. Hopefully these can be summarized and made available to you at a later date. In the process of conducting our survey, the NASA questionnaire of 7-2-80, surfaced the views of several companies. The nature of these questions and the answers thereto greatly overshadow the few issues GAMA has raised in its survey. We believe that the results of this NASA study should be summarized rapidly and made available to the interested groups such as GAMA, HAA, and AIA. We understand that these are being evaluated by type of aircraft, which should prove very useful in pointing out possible differences in approach by these three industry segments.

I would like to share with you a few of the comments received to date in response to our questionnaire:

One manufacturer indicates that the increased use of general aviation aircraft for business purposes makes it imperative that the aircraft be capable of operating in all weather conditions. Since operations in icing conditions can be extremely hazardous, it is imperative that aircraft ice protection equipment and instrumentation be improved as well as improving and simplifying methods of certification.

There is an on-going need for improvement in icing simulation facilities. However, the type of facilities improvements needed to satisfy FAA certification requirements will be entirely dependent on the extent of icing simulation that the FAA would accept in lieu of natural icing tests.

In the past this manufacturer has used the Air Force C-130 icing spray tanker; however, these tests could only be used for discrete portions of the aircraft due to the limitations of the size of the icing cloud. In addition, it was found that the icing cloud generated by the tanker was more severe than natural icing conditions. Since it is not possible to totally immerse the test vehicle in the tanker ice cloud, the cost effectiveness of this type of test is questionable.

Most of that manufacturer's icing certification programs have been conducted under natural icing condition without any preliminary tanker tests. These programs were time consuming and expensive, looking for the appropriate climative conditions that would satisfy FAA certification requirements in addition to assuring that the aircraft could be operated safely in icing conditions.

Improvements or additions to icing test facilities should be government funded coupled with user fees when used by non-government customers.

Another manufacturer advises:

Our experience indicates that airborne simulators have offered an attractive alternative to fixed facilities for transport category airplanes. Consequently, increased government funding of efforts to fully develop airborne spray system capabilities seems in order.

A third manufacturer, in response to the NASA questionnaire, set forth final recommendations as follows:

The aspects of the icing problem which need the most attention are the design envelopes, water catch characteristics as a function of shape, improved spectrometers, drop supercooling characteristics and ice phobic coatings. NASA could make significant contributions in all of these areas.

A principal airframe manufacturer submitted extensive support for the use of his company's tankers and advocates that consideration should be given to eliminating icing tests in evaluating flight in actual icing conditions.

Another manufacturer has given strong support for some of the points as mentioned earlier, i.e., airborne/in-flight simulators, icing tunnels, and updating and modernizing ice certification criteria to reflect the performance differences between the various types of aircraft and the improved ATC.

Mr. Chairman, we thrust these views will be of use in formulating a reasonable consensus, not only in terms of GAMA, but in terms of the entire industry. We will be pleased to continue our support for this activity as the program evolves.

MEETING CHAIRMAN: RICHARD I. ADAMS

That's a very good rundown Jim, I sure appreciate it. As I mentioned before, the HAA and AIA consensus is going to be sort of combined, so I would like to introudce Bob Richardson. Bob will call upon various speakers to provide this overall summary, including Dr. Ken Rosen and various others. So, I'll just turn this session over to Bob and let him introduce all the others that he needs.

HAA CONSENSUS

BOB RICHARDSON, DIRECTOR

Thank you, Mr. Chairman. Gentlemen. My name is Bob Richardson and I'm Executive Director of the Helicopter Association of America. I bring a message from our President, Delford Smith, who's Chairman of Evergreen Helicopters and Evergreen International Airlines and President, this year, of the Helicopter Association of America. He would like you to know that we are very pleased to have been invited to this conference and we hope that we can make a substantial contribution to the subject. The Helicopter Association of America is an international, independent, non-profit organization and the purpose of the HAA gang is to represent and promote helicopter interests of its member companies. HAA international, as we have become to call it because of its world-wide, unified nature, also provides its members with many services and benefits that can help companies operate more safely and effectively. HAA members are companies that own and operate for hire, and/or use helicopters for private and corporate business. The HAA acts vigorously to present its members with views in a united manner, to many audiences such as government bodies, business and industry, the news media and the public. Now in addition to the operators who are the founders and backbone of the HAA, we have some 200 companies known as associate members and they are the airframe and engine manufacturers in our industry. Many of us are flyers and vendor companies, electronic firms and large overhaul facilities, insurance companies and the like. We have three common members with AIA who are present today, representatives of Sikorsky Aircraft Division of United Technologies, Bell Helicopter Textron and Boeing Vertol Company. The HAA consensus will be presented by Dr. Ken Rosen of Sikorsky Division of United Technologies and I would like to acknowledge working with Dr. Rosen and myself yesterday, Herb Kauffman, Model 412 De-ice Project Engineer from Bell Helicopter Textron and Andy Peterson, Senior Propulsion Technology Engineer from Boeing Vertol. We caucused yesterday afternoon and were fortunate to be able to come to an agreement in a relatively short period of time. Now after Dr. Rosen articulates the details of our consensus on behalf of the HAA, Herb Slaughter from Sikorsky Aircraft will speak on behalf of the AIA consensus and he will make it clear, as I will right now, that the HAA position is endorsed by the AIA Rotorcraft people. Dr. Rosen's presentation is quite detailed and technical in nature and I don't want to take up any more time with the preliminaries. I would like to pass the baton to Dr. Rosen and he will give you our position. Thank you very much.

DR. KEN ROSEN

Good morning gentlemen (Figure 1)! Its always a pleasure to be at an icing conclave and I'm very pleased this morning to represent the HAA and the AIA rotorcraft community to state our recommendations for improvements in the national icing facilities. As Bob indicated, Herb and Andy and I and Bob gathered yesterday, we deliberated on our position on icing facilities and we decided, because of the very nature of this presentation, to refrain from comments on general aspects of icing research. I'd like to begin by saying that I agree with many of Jim's comments concerning the need for additional research in the areas of droplet trajectory in the area of model similitude and in modeling icing and the area of icing criteria. We decided not to present that information here because we felt that the purpose of this specific conference was related to icing facilities. As such I will address only that subject in this presentation.

Indicated in this viewgraph (Figure 2) is what we believe to be an orderly progression of events that would lead to the certification of a helicopter in an icing environment. You would begin with laboratory development work, using icing tunnels or facilities of that type, proceed to hover in a simulated icing cloud, which we believe would be of the developmental nature, and then proceed to forward flight in an artificial or simulated icing environment, which we believe should become a certification tool and then again a limited amount of natural icing. This we believe to be an orderly progression of events. I might add that the first three bullets in this chart, that is laboratory testing, hover testing and forward flight testing are what we are talking about here, because they all relate to the specific facility improvement that we believe are necessary. So up again with the discussion on laboratory facilities.

The icing laboratory facilities are indicated here (Figure 3) for helicopter airframe inlet work. The two facilities that we have found most useful are the NASA Lewis Facility and the Arnold Facility and most of our work has been done in the NASA Lewis Facility. However, the Arnold Facility also offers opportunities to that end. I might add that three engine facilities, which we have also discussed in this conference, have indicated to those of us in the rotorcraft propulsion community that they have adequate airflow capability and liquid water content and droplet capability and altitude capability to satisfy the engine requirements of the rotorcraft community. We see no need for improvements in the engine facilities. I might add that this position has also been discussed with both General Electric and Detroit Diesel of Allison. Not indicated on this chart are two other facilities which I believe also could be an aid in development of the helicopter. Certainly the cold weather capabilities, described at the Army Cold Weather Regions Laboratory (CRREL), could play a part in the development of specific components and the cold soak capability of the Eglin Hanger offer additional opportunities. I will address the Lewis facility at this time, which we believe to be the focal point for the potential improvements.

Indicated here (Figure 4) is a cross section of the test area of the Lewis Tunnel. You can see that this tunnel test area a 6 x 9 foot area. As indicated, the tunnel was built in the early 1940's and indicated here

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is an S-76 inlet test rig. As you can see, what we have done for this particular test, is we have taken a section of the S-76 and literally cut it out, and put in the tunnel. The reason that we do is obviously not only to get inlet characteristics, but to simulate the approach aerodynamics into the inlet. It's very important, in inlet icing work, that one simulate the external aerodynamics, so that the droplet trajectories are representative of the realities of the real world on helicopters. As such we're trying to get as much of the inlet and related external airframe into the model. You can see that you don't have much room and the prudent observer would note that the subject of end wall effects has to come to mind. I might add that we have tested many inlets, Sikorsky designs, in my own relative experience, in the tunnel, something like 10, and we have not had a problem with the end walls, but we have gotten pretty close on some occasions. So it's clear to us that, I might add that this particular engine you're dealing with about a 6 pound per second situation here and some of the helicopter engines that we have dealt with have been up to 50 pounds per second. In the case of the Sky Crane and in the case of the CH-53 and CH-47 class aircraft, you're dealing in the 25 to 30 pound per second range. So that facility would even, test rig would even, be bigger. It's clear to us that the facility is marginal in cross section and should be increased in size.

I would like to address a limitation in the tunnel which did not surface in yesterday's presentation by the NASA Lewis people, which I believe supports some of their thoughts on the tunnel improvements. As Jim indicated earlier, there is a lively discussion under way with the FAA concerning the validity of the Part 25 curves and specifically how those curves would be applied to Part 29. Some of the recent work at NASA would tend to indicate, although this has not yet been confirmed, I want to stress that point, that some of the aspects of those curves are now questionable, specifically, below 10,000 feet. The present Lewis tunnel has a limitation. Indicated here (Figure 5) at a speed of 110 knots is the minimum liquid water content that one can achieve in the Lewis tunnel. It cannot get less than 1 gram per cubic meter in the Lewis tunnel right now. The blue area is approximately what we believe is achievable in that tunnel. This entire area, below 1 gram per cubic meter, across the entire spectrum, which is indeed representative of the continuous icing curve of the FARs, cannot be achieved with the present Lewis facility. So it is clear that the range of liquid water content must be improved within the present facility and certainly must be provided for in any eventual refurbishment of the AWT. I expect, and many of my colleagues expect, that new requirements will surface this decade which will result in testing demands in this entire region and it is very important that we be able to do so within any new national tunnel facility.

Illustrated in this chart (Figure 6) is the relationship of the minimum liquid water content that can be obtained in the Lewis tunnel. You can see that in the helicopter region of interest, in this region, that you really cannot operate much below .8, or .9 gram per cubic meters. This is another way of looking at my point on previous charts. This entire region, which is really indicative of the real world helicopter operation, can not currently be tested for in the Lewis tunnel. You can test about this region, you cannot test below this region, below this line.

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In summary, we do agree that several laboratory actions are required. Those actions are indicated here (Figure 7). We believe that the tunnel must improve its ability as an icing simulation tool. The tunnel has another limitation in that it loses its calibration somewhere below 90 knots and in fact, somewhere even below that it loses its ability to provide adequate refrigeration. Certainly the engineering studies that would take place on either refurbishing this tunnel, or in going to an AWT, should consider low speed operation and the ability to provide adequate refrigeration and temperature capabilities to -22° Fahrenheit at all speeds certainly down to at least 60 or 70 knots. So what we are saying here is we need a lower speed capability, we need an increased range of liquid water content and of course, we do need to have a modernization of the droplet size instrumentation that's used in the tunnel. Certainly spectrometer devices, laser nephelometer devices, and formvar drop devices, would be suitable. In any decision related to a large cross section, we believe that two studies ought to be conducted. One, NASA should look very carefully at the use of their secondary test section. A cursory look would indicate that we cannot obtain the speed characteristic required for helicopter work in their current cross section of the NASA tunnel. That section is very infrequently used and I am not even sure it has been used in recent years. The AWT conversion to an icing facility is one that we did support, I might add that we do support the modernization of the IRT, as having priority over that conversion, but we certainly believe that conversion is very feasible. Our review indicates that the Phase One plan, that is to get up to speeds of approximately 200 knots, would satisfy the needs of our community. I believe that was approximately the \$60M plan as opposed to the more expensive Phase Two plan. We believe that NASA, within their charter, should collate and extensively distribute the work that has been done by the French, and has been done by Lockheed and others related to model testing. We think that there is --- here and I might add that if any provisioning of the AWT or improvements for the IRT are contemplated, that the capability to do model testing should be provided. That means that specifically, so far as the facility is concerned, that we must have capabilities to go to rather small droplet size. Probably down as low as 5 microns in order to do any kind of model work. (Next chart, please).

We began this discussion by summarizing our position on the laboratory testing. As you recall, the second phase of certification, of development and certification, is, we believe, hovering testing. The reason that I believe that the Ottawa Spray Rig is a valuable tool, is simply because of the enormous expense that one must bear in any kind of tanker simulation in helicopter work. The current costs for fielding a helicopter of the size of an S-76 or a Blackhawk, now approaches the staggering sum of \$20,000 per hour. That is an enormous amount of money for us. I might add that in a recent snow certification program on the Spirit, and I'm not embarrassed to say this because it is a matter of public record, we spent nearly \$600,000 and flew over 6,000 miles in order to satisfy that criteria. That specific investment would be nothing compared to what we would have to spend in order to fill out all corners of the icing envelope in natural icing. Even tanker

testing by itself is an enormously costly undertaking. To field the tanker requires an enormous team of people from AEFA, and also a significant support effort from Sikorsky or any helicopter manufacturer. What I feel would be practical and economic would be to go to Ottawa first, to do your development work out of Ottawa, to get that 90% confidence or 80% confidence, so that the number of icing seasons for which you would have to seek solutions behind a tanker or natural icing, would be minimized. Ottawa offers that kind of opportunity for us.

Indicated here Figure 8 is the extent of the Ottawa cloud. The Canadians are recommending approximately a 65 foot diameter. You can see on this side of the chart approximately a 10,000 pound gross weight machine, on this side of the chart about a 70,000 - 72,000 pound gross weight machine. The CH-53E barely fits. As a matter of fact, it doesn't quite fit. When you think of the problems of station-keeping it's clear that a problem does exist with the size of the cloud. One of our recommendations in any refurbishment of the Ottawa facility would be to increase its size approximately 25%.

In summary, we believe that an investment in the Ottawa Spray Rig would be very valuable (Figure 9) and that it is, in fact, a valuable tool for economical development of a helicopter ice protection system. We believe that the facility should be retained and that it should be nurtured. One of the key problems with the facility, quite candidly, is the age of the personnel that are associated in the management and operation of the facility. Many of these folks are about to retire. Many of them have a tremendous amount of knowledge. Our discussions with the Canadians indicate that the National Research Council feels that they have done their bit and that their charter has just about been played out. One of the clear recommendations of our working group was that personnel should be trained in the use of that facility and, I might add, that it might even be feasible for NASA to support the facility insofar as placing, on station, younger engineers who might have a chance to serve a very brief apprenticeship over these very few precious years that are left to them before 1985, so that our options remain open in 1985. We might jointly decide to move the facility to the United States or to continue operation at Ottawa. It seems to me to be a very reasonable investment on the part of our nation to place personnel or support training of personnel and not to lose the capability that has been developed at Ottawa over the last 35 years. As I indicated we do feel that cloud size should be increased slightly, up 25%, and that a very fundamental piece of research ought to be developed leading to the extrapolation of the Ottawa data to forward flight. We believe that is at least theoretically feasible, it might be an appropriate program for NASA investigation to determine how a helicopter might be developed and possibly, and even eventually, certified at the Ottawa Spray Rig, if one were able to prove conclusively, adequate extrapolation to forward flight from a hover facility.

Perhaps the most expensive form of icing certification is natural icing. This is particularly difficult for a helicopter, which has a very limited range of operation, both from the area of altitude and the area

DR. KEN ROSEN

of range. Clearly, we do not have the continental scope that is available to many of our fixed wing brethren and we must operate in a very, very small area and as such are subject to the vagaries of the weather that might exist in that area. In that sense, natural icing becomes a very, very difficult situation for us. The natural predecessor to natural icing would be use of the tanker facility (Figure 10) and that offers us opportunities to operate out of a fixed base, to provide the controllable icing conditions which we cannot depend upon in natural icing and certainly an enormous increase in the number of icing encounters per season. This does remain at the present time, and I say it for the record, our best school for development and certification. (Next please).

Here (Figure 11) you can see the cloud size of the HISS. I believe I even have this cloud somewhat larger than it really is. I have indicated 8 x 36, I believe at, 150 or 200 foot range. I'm not sure that's quite right. I believe that one of the things that Captain Hanks mentioned yesterday was the cloud was only 32 feet. In any case it's clear that a 10,000 pound gross weight machine indicated to the left, in itself, cannot be completely immersed and certainly a 70 plus thousand pound machine cannot begin to be immersed. So it is clear that a larger cloud is required, certainly when you take that coupled with station keeping problems.

Indicated here (Figure 12) is our summary position concerning tankers. We're saying, fundamentally, that the tanker cloud is too small for complete rotor evaluation, certainly for all classes of rotor. We do believe that turbulence and downwash effects from the tanker are probably slightly larger and probably ought to be improved. The tanker does have a water capacity limitation which could become significant, certainly in relationship to the larger size cloud we feel we want. One of the limitations of the current tanker is that it does not provide droplet diameter control. We believe that any refurbishment of the tanker or updating to the 47-D model should include a droplet diameter control. In addition, the tanker speed range should be increased on both sides of its current operating speed, I guess around 90 to 100 knots. Although the tanker can go up to speeds beyond that, for various weight reasons, they have decided that 90 to 100 knots would, in fact, be the area of operation that was preferred. We would like to see that speed increase up towards 150 knots. Certainly that's the representative speed that we want to go to. All of those thoughts ought to go into the tanker refurbishment plan that Harry Chambers and Captain Hanks were talking about. We certainly support that plan, we want to see it happen. We think it's practical. We think it should be given, as a matter of fact, the top priority billing of this entire conference. I won't address the Air Force tankers at the present time, fundamentally because I believe their clouds are too small. The discussion yesterday indicated that it would be very difficult to increase the size of those clouds. However, the matter could be pursued. I think it's premature right now to comment on what we would like to see happen with those Air Force tankers until a little bit more design studies are done.

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In summary (Figure 13), we believe that as far as the tankers are concerned a larger cloud is required and that a tradeoff study should be done comparing the potential of the C-130 versus the higher capacity helicopter tanker. At present it would appear that the higher capacity tanker is the way to go, but certainly someone ought to look at this. This is something that perhaps Dick could do within his charter. Whatever is done, that tanker must be available for civil use and certainly, additional correlation is required between the HISS and natural icing.

I would like to pause for a moment and talk a little bit about the NASA tunnel refurbishment. One important point is that whatever is done in that tunnel, that tunnel must be available for certification use. Not only for research, but for certification. It's a very difficult situation and I think it is necessary to make overtly clear that our support for the tunnel refurbishment is clearly related to a commitment on the part of NASA that the facility be used not only for basic research, but for certification. Because of the applied nature of icing engineering, virtually any kind of test that you do in that tunnel is, in reality, research and I believe that this is both a NASA and an FAA charter.

You know it's very nice for us all to sit up here and talk about all these good things. They all cost a lot of money and it's nice to say we ought to do this and we ought to do that, but as we all know we all have a limited pocketbook. So what our committee did was, we sat down and we prioritized our recommendations (Figure 14), because we believe you will be faced with some very real problems with your various administrations in obtaining the required funding in a timely manner. We believe that first priority should go to the tanker, I use the word HISS/C-130, but I mean tanker. Certainly the improvements discussed aiming towards the CH-47D or another airborne tanker, should at the present time, receive top priority. The present facility at Cleveland must be improved. I grouped these two together, but the most important thing right now is that we get increased liquid water content range in that tunnel. That's very important. The Ottawa Spray Rig must be maintained, personnel must be trained, a cadre of trained people must be developed who are familiar with the icing facility at Ottawa and know its nuances, its vagaries, know how to baby it along and in fact, run it when the present generation of researchers retire, which I suspect will happen in the very next few years. The AWT conversion at Lewis is one that must be explored very carefully. We support it. The rotorcraft community can only support Phase I of the conversion. And our position right now, is that, that would be all that would be required for us and that would be adequate for our needs at least until the mid or the late '90s. One other item that I did not mention, which I believe requires some effort, would be to review the potential of the Eglin climatic hangar insofar as its rotorcraft development testing capability is concerned. I believe a design study should be undertaken to determine what potential that hangar has to rotorcraft icing research.

Well, gentlemen, that concludes my presentation. Thank you very much.

HAA/AIA ROTORCRAFT
POSITION ON ICING FACILITIES

Figure 1

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HAA/AIA ROTORCRAFT

STEPS IN DEVELOPMENT, CERTIFICATION

- LABORATORY-DEVELOPMENT
- HOVER IN ARTIFICIAL ICING-DEVELOPMENT
- FORWARD FLIGHT IN ARTIFICIAL ICING-DEVELOPMENT/
CERTIFICATION
- FLIGHT IN NATURAL ICING-CERTIFICATION

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Figure 2

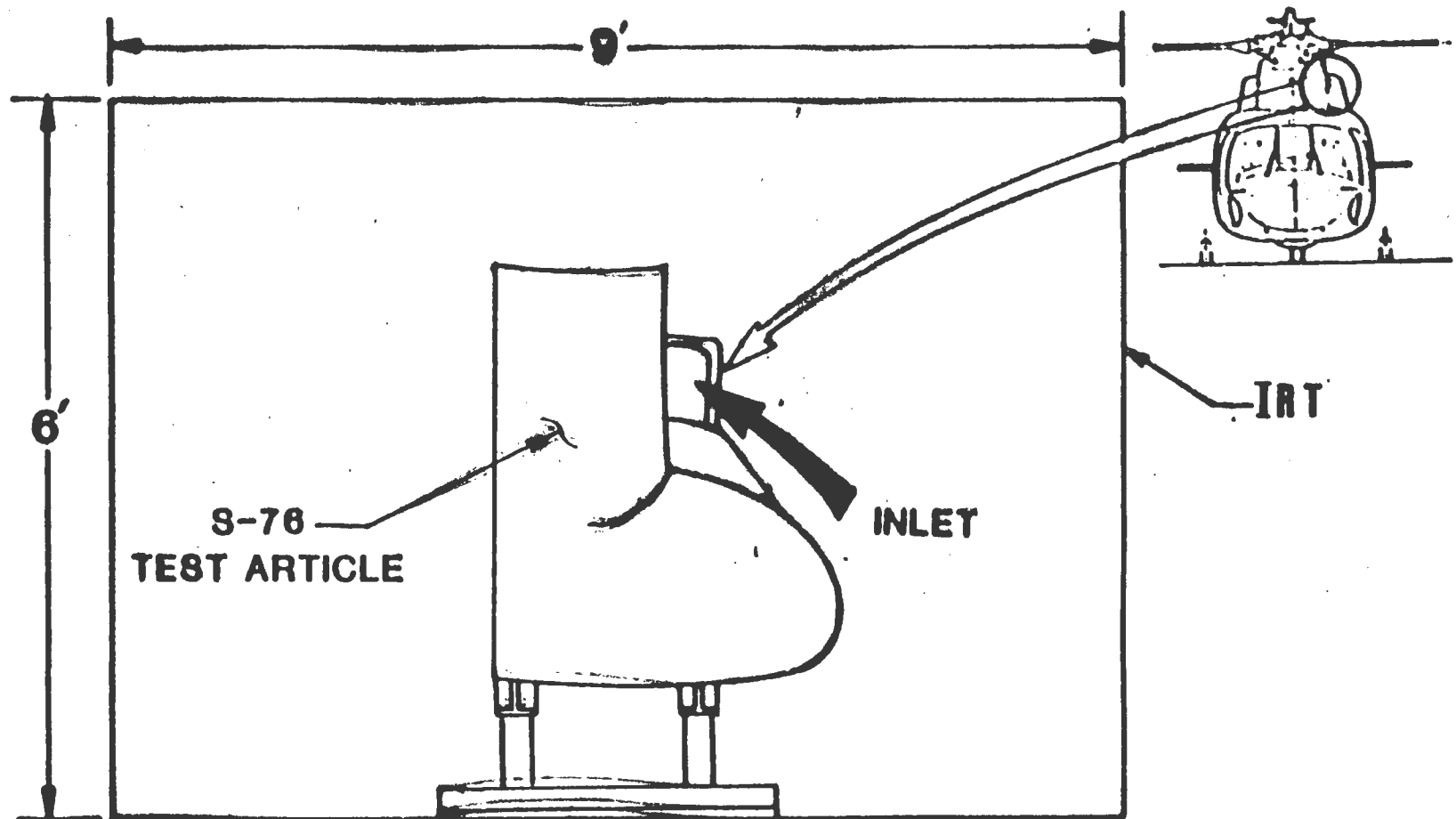
HAA / AIA ROTORCRAFT

ICING LAB FACILITIES

- NASA LEWIS ICING RESEARCH TUNNEL
 - USAF ARNOLD RESEARCH CELL (TUNNEL)
 - NRC ENGINE TEST FACILITY
 - USN NAPTC ENGINE TEST FACILITY
 - USAF ARNOLD ENGINE TEST FACILITY
- } INSTALLATION, DEVELOPMENT/
CERTIFICATION

LABORATORY SIZE RESTRICTIONS

- IRT IS LARGEST FACILITY IN OPERATION

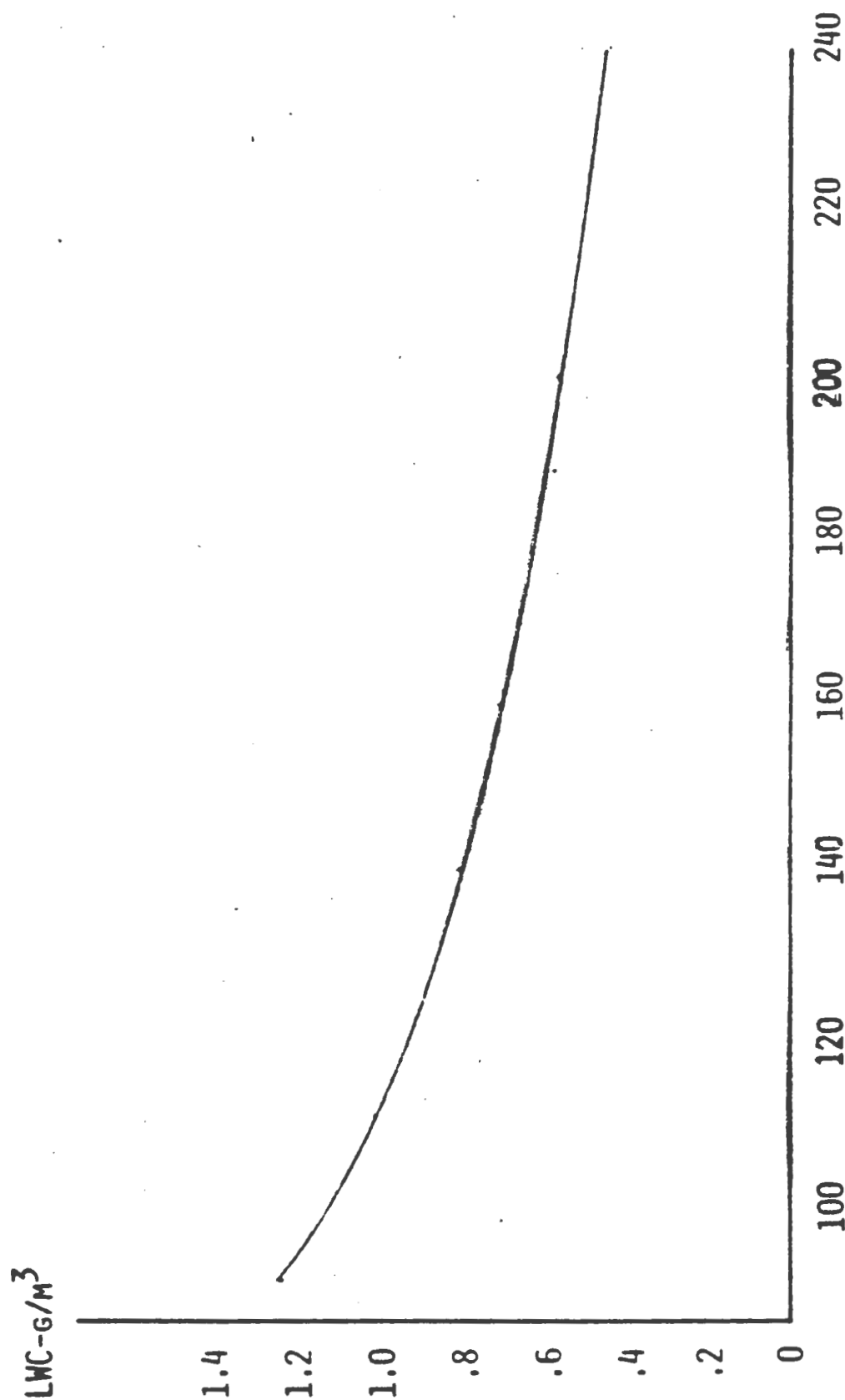


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Figure 4

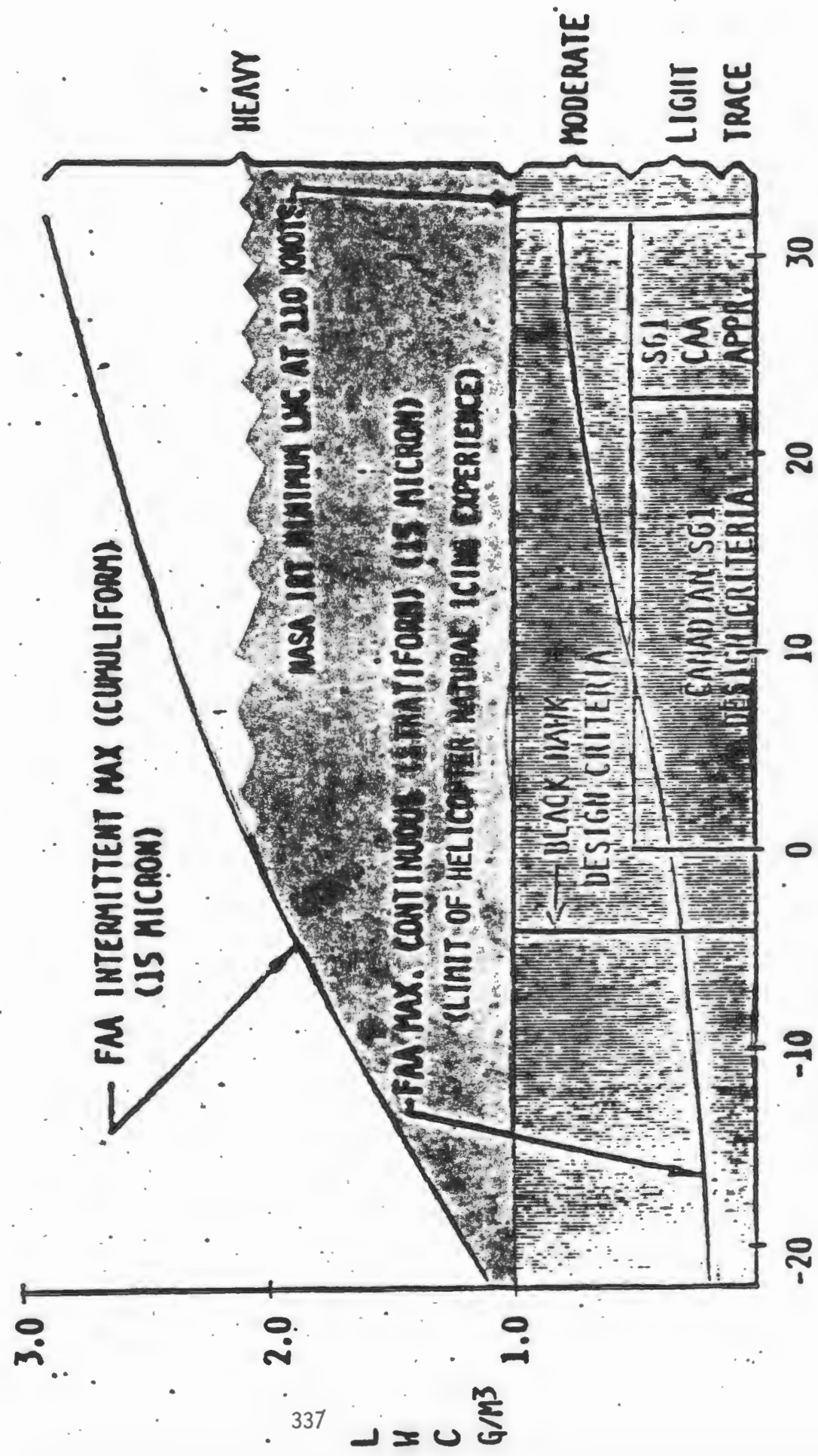
HAA / AIA ROTORCRAFT

NASA ICING RESEARCH TUNNEL
MINIMUM LWC VS AIRSPEED



IIAA / AIA ROTORCRAFT
AIRSPEED - KNOTS
Figure 5

NEED FOR IMPROVED IRI "RANGE"



TEMPERATURE OF Figure 6

SEPT. 24, 1980

L
H
C
G/M³

ICING LABORATORY ACTIONS REQUIRED

- IMPROVE ICING SIMULATION

- LOWER SPEED CAPABILITY
- INCREASED RANGE OF LWC
- MODERN LWC AND DROPLET SIZE INSTRUMENTATION



FOR IRT

- LARGER TEST SECTION

- IRT - USE OF SECONDARY TEST SECTION ?
- AWT CONVERSION TO ICING FACILITY
- PROVISIONS FOR MODEL TESTING?

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Figure 7

HAA / AIA ROTORCRAFT

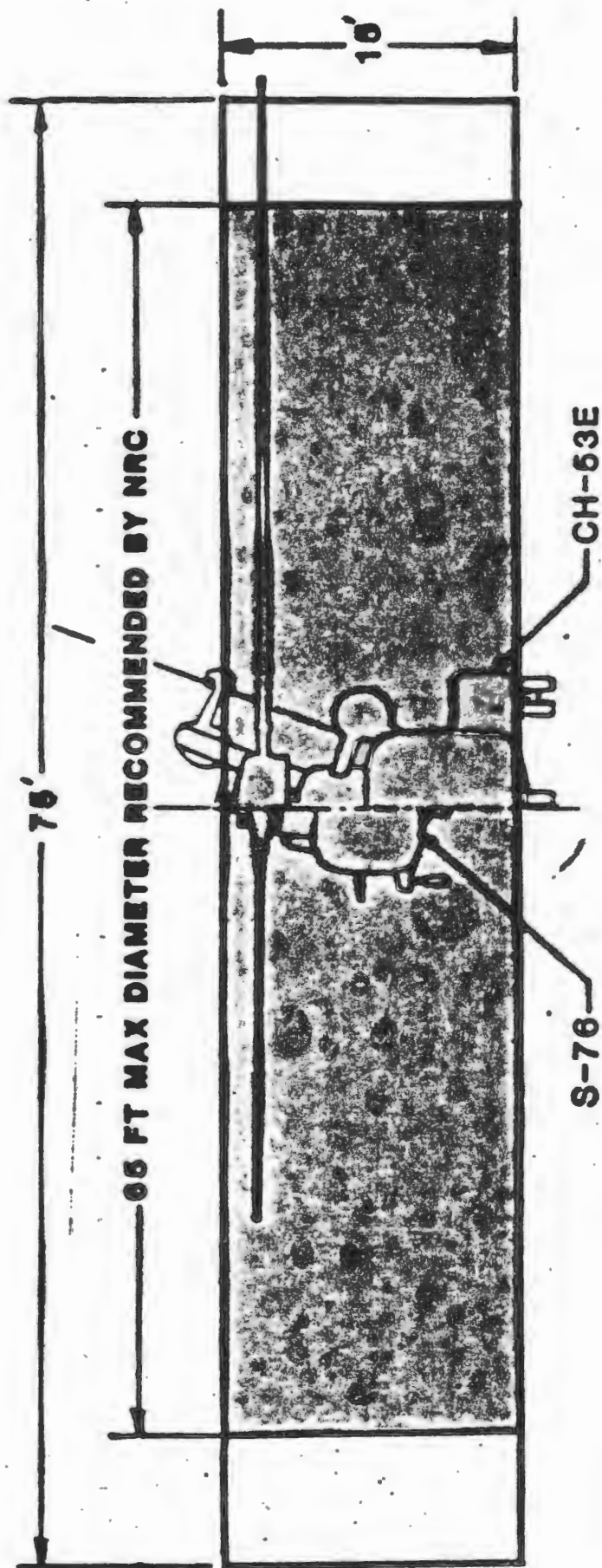


Figure 8

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HOVER ARTIFICIAL ICING

- . NRC OTTAWA SPRAY RIG IS ONLY FACILITY AVAILABLE
- . HOVER TESTING REQUIRED FOR ECONOMICAL DEVELOPMENT
- . ACTIONS REQUIRED
 - RETAIN FACILITY
 - TRAIN PERSONNEL
 - INCREASE CLOUD SIZE. (25%)
 - DEVELOP TECHNOLOGY TO EXTRAPOLATE TO FORWARD FLIGHT

- **FIXED BASE OPERATION**
- **CONTROLLABLE ICING CONDITIONS**
- **MORE ENCOUNTERS PER ICING SEASON**

HISS HAS LARGEST INFLIGHT CLOUD

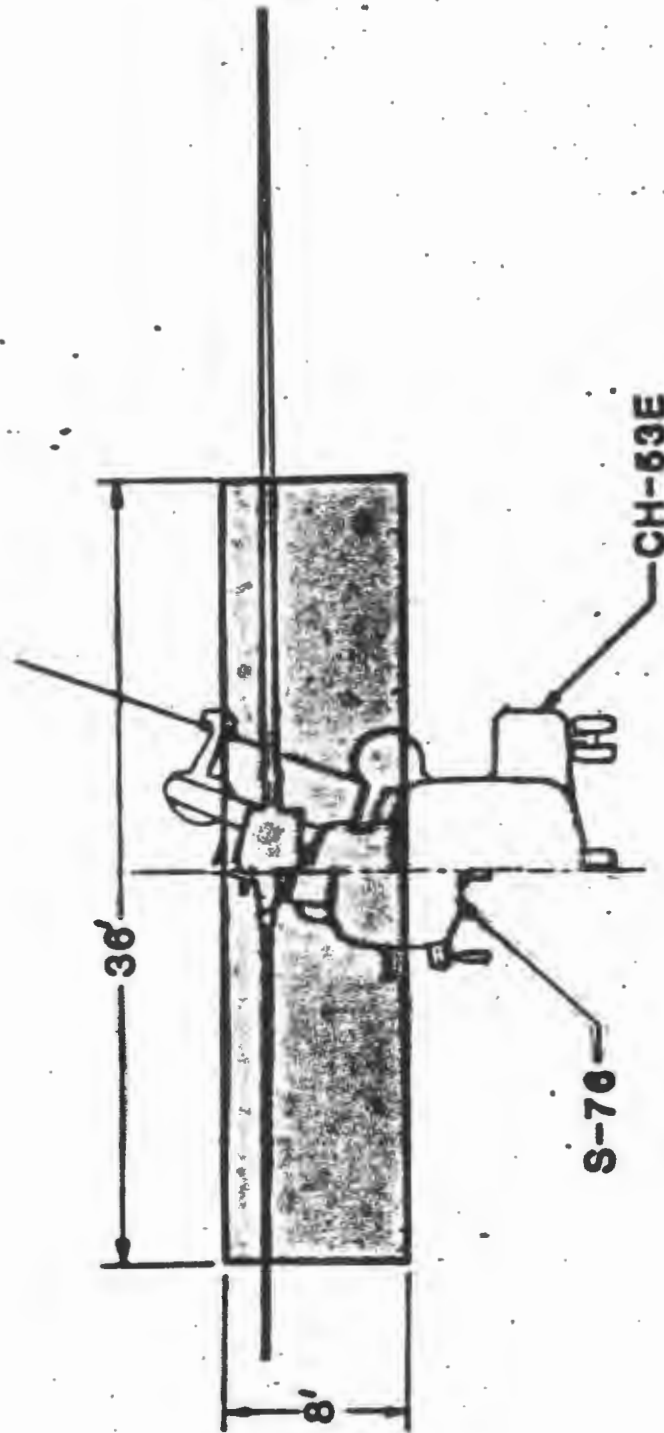


Figure 11

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• **HISS TANKER**

CLOUD TOO SMALL (36' x 8') FOR ROTOR EVALUATION
TURBULENCE AND DOWNWASH EFFECTS FROM TANKER TOO LARGE
WATER CAPACITY LIMITATION

• **USAF KC 135 TANKER**

MINIMUM FLIGHT SPEED TOO HIGH FOR MOST HELICOPTERS (165 KNOTS)
CLOUD TOO SMALL (11 FT DIAMETER) FOR ROTOR EVALUATION

• **USAF C130 TANKER**

CLOUD TOO SMALL (15 FT DIAMETER) FOR ROTOR EVALUATION

TANKER FACILITY ACTIONS REQUIRED

- LARGER CLOUD REQUIRED

TRADEOFF STUDY FOR NEW SPRAY RIG FOR C130 VS
HIGHER CAPACITY HELICOPTER TANKER

- AVAILABILITY FOR CIVIL USE

- FURTHER CORRELATION OF HISS AND NATURAL ICING

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Figure 13

HAA / AIA ROTORCRAFT

HAA/ AIA ROTORCRAFT SUMMARY

FACILITY PRIORITIES

- . HISS / C-130
- . IRT IMPROVEMENT
- . OTTAWA SPRAY RIG
- . AWT CONVERSION --- PHASE I
- . REVIEW POTENTIAL OF EGLIN CLIMATIC HANGAR

Figure 14

MEETING CHAIRMAN: RICHARD I. ADAMS

At this time I would like to introduce Mr. Herb Slaughter. Mr. Slaughter is Manager of Product Integrity for Sikorsky Aircraft and he is representing the AIA today. Mr. Jack Reese could not be with us. Herb.

AIA CONSENSUS

HERB SLAUGHTER

The AIA is pleased to be invited to participate in the proceedings of the National Icing Facilities Symposium. I am here to represent Jack Reese, who has extended his apologies direct to Dick Adams in a telegram today, saying that he was not able to attend but has given support to the efforts of discussing the National Icing Facilities. The AIA represents a large broad segment of the aviation industry all the way from large transport aircraft to the smaller transport aircraft, to certain equipment and engine manufacturers, as well as the helicopter manufacturers. We have within AIA a diverse view with regard to supporting of R&D activities and the use of certain facilities relative to artificial icing certification. In order to bring out these differences of views, I had brought together the representatives that are here for the symposium to bring out a consensus and that consensus has been developed in two parts, one for the fixed wing group of AIA and the other for the rotorcraft group of AIA, and we will present those in two parts today. The representatives from AIA who are here today, I would like to recognize those people that did participate in our AIA consensus meeting and I would like them to stand as I read their names. Darwin Hawkins from Gates Lear Jet; Harry White from Gates Lear Jet; Dick Keller from GE; Bill Stiefel from Allison, General Motors; R.E. McWhirter from Lockheed, Georgia; R.N. Stevens from Boeing Vertol - Ross Stevens; W.E. Huey from Lockheed, Georgia; Larry Koegeboehn from Douglas Aircraft; Bill Gurley from Bell and Craig Sutton from Grumman. Now these members met yesterday and we came up with what we feel is a good consensus statement for the fixed wing aircraft side of AIA and Harry White, Project Engineer for Propulsion and Icing at Gates Lear Jet will make that statement.

GATES LEAR JET

HARRY WHITE

Thank you Herb and I would like to thank the rest of the members of the caucus for giving me the honor of presenting their position for them. I would say that this was a general consensus and because of that I'll just read this and minimize the potential of editorializing.

Basically we have four points and one question which need not be answered at this time, but should be pondered by the FAA in conjunction with any facilities that are going to be developed.

Point number one is that airborne inflight simulators should be developed on a high priority basis though with the understanding that civil aviation can benefit from the technological spinoff rather than the product itself. If research was conducted on equipment to accurately simulate natural clouds, industry can benefit from that technology and either lease less sophisticated airborne simulators or adapt their own aircraft to use the equipment. Parallel development must be made to improvements to instrumentation for cloud parameter measurements with emphasis on onboard data reduction of cloud content.

Item two. Wind tunnel size limits tests to de-ice and anti-ice components rather than the entire system, for example, the entire aircraft. To put a scaled aircraft in the system, or put a scaled aircraft in an icing tunnel will require research into scaling of icing parameters. The ability to test an entire aircraft with protected and unprotected surfaces in a controlled environment of an icing tunnel will insure that the entire design is adequate for all icing conditions. Research conducted on scale will also be valuable in the development of analytical models to project anti-icing or de-icing system performance. To mathematically model water impingement, evaporation and runback will impact the system optimization of the most severe icing and aircraft performance conditions. A large scale facility is needed in order to test full scale aircraft up to and including the size of small business jets and large components of large transports. Icing tunnels are valuable tools providing that they be used for test certification and not just as a development tool. The point has been iterated several times in this meeting and I am sure the FAA will take due consideration of this.

Item three. Thoroughly investigate correlation of icing tunnel tests or inflight tanker tests and actual icing encounters, leading to a most cost effective system for certification.

Item number four. The certification requirements must be reviewed in light of these national icing facilities discussions. These requirements will affect the capabilities required of these facilities, an example being the holding pattern exposure time of 45 minutes proposed in Advisory Circular 20-73. If you have to hold in ice for 45 minutes, obviously you need an icing tanker that has enough water to give you that 45 minute count.

HARRY WHITE

And our last item which is a question to the FAA and something for them to consider, is that due to the competitive nature of our industry, and that airframers many times have programs for similar models going on at the same time, how will the national icing facility establish a criteria by which people will be allowed to use that facility? Will it be a first come, first served, this type of a question.

That presents the four items and the question that the AIA caucus developed in last night's meeting. And I would say while the time was available to us until 11:00 for the meeting room, the uniform opinion and the cooperation among the members allowed us to get out of the meeting somewhat before that time.

HERB SLAUGHTER

Thank you very much, Harry. I would like to close our presentation from industry with a few remarks from the helicopter group of AIA.

As stated by Bob Richardson, the technical presentation as presented by Dr. Rosen has the full support of the AIA helicopter group. However, in providing that support, I would like to bring out and emphasize the fact that here we stand in 1980 with all the technology available to us, through the years of advancements in R&D and advancements in the development of aircraft and helicopters and we do not have in this country today a helicopter certified for operation in icing conditions. Now this disturbs me and I think it disturbs generally the helicopter manufacturers. There are various reasons for this. Regulations, cost, high power requirements, lack of testing facilities. We feel strongly that the operation and environment for the helicopter in the future will depend upon the approval and certification of the helicopter for dispatching in known icing conditions. The helicopter industries met with the FAA last year in a helicopter workshop. In the area of icing I recall three strong recommendations from that industry group, namely review the icing facilities, define the icing envelope, and conduct an innovative approach to icing certification. The FAA in the area of the R&D group, has moved rapidly with regard to, as I understand, only one of those recommendations. That is the assessment of icing facilities. We are very discouraged in the helicopter industry with the progress made by the FAA in defining the icing envelope and in taking an innovative approach to the icing certification of helicopters. However, I have been enheartened by the new prospectives that have come forth in our discussions here in the last two days and I have a few general observations to reinstall in the minds of those present, of those that are going to make the decisions for helicopters as a result of this meeting and as a result of the carrying out of the recommendations of industry from that workshop.

The helicopter is different from airplanes. It is constructed differently. It has different operating characteristics. It has a unique operator base and where commonality exists may require, and I'm talking about commonality with fixed wing, may require different techniques of substantiation. The helicopter is primarily a short range vehicle. It is a competitor to the airplane where it can take advantage of its ability to land and take off from small spaces. This uniqueness, however, works to its disadvantage when it comes to demonstrating its ability to operate in icing conditions. First, yesterday's presentation confirmed the lack of an icing tunnel large enough to test the complete helicopter in a manner which will permit the demonstration of blade ice elimination in somewhere near its natural state. This is our first shortcoming of the airplane icing test facilities. Also the helicopter does not have the liberty to use a substantiation technique which requires us to range over long distances and large areas seeking natural ice. Also there is some doubt as to whether the helicopter environment produces the same degree of icing established for subsonic jet airplanes. We are heartened by the recent NASA efforts to define the icing environment for helicopters that was mentioned in discussion yesterday. We are discouraged by the action taken by the regulatory side of the FAA in

HERB SLAUGHTER

proceeding with rulemaking on the icing envelope for helicopters without fully considering this new effort on the part of NASA. Whatever the defined icing environment, if you cannot find it in a reasonable period of time, alternate methods of substantiation must be considered. The FAA has not been receptive to the problem, which will give recognition to a satisfactory demonstration of capabilities for those natural icing conditions which can be experienced in a reasonable period of time. Therefore, the next viable solution lies in the use of artificial or simulated ice. The explanation provided yesterday rouses my enthusiasm for successful use of the present and improved simulation facilities in providing reasonable, adequate substantiation compliance with the FAA criteria. The technical presentation by Dr. Rosen representing HAA, which the AIA helicopter group supports, has brought out some of the shortcomings of the present facilities. Elimination of these shortcomings will provide an economic and efficient system for the very difficult task of helicopter icing certification. The ability of the helicopter to operate in icing conditions is essential to its continued use in searching out and supporting the production of energy sources, particularly those related to petroleum. I believe the initial solution is present, particularly if a more representative helicopter icing envelope can be established. We must look to make certification more effective for the industry through the use and support of artificial icing facilities. In closing, I would like to reemphasize the point that the AIA helicopter group fully supports the HAA technical position presented by Dr. Rosen, then led by the Executive Director of HAA, Bob Richardson. And I would like to provide this opportunity to direct our thanks to Dick Adams, who has moved ahead very rapidly and effectively in working on the industry recommendation for assessment of icing facilities. I would like to acknowledge the help in this direction with regard to Charlie Masters, "JB" McCollough and the support given to this effort by Tom West of the FAA R&D office. I think we can now look for a culmination of this meeting, taking into effect improvements which will encourage the certification of the helicopter under icing conditions. I look forward to further action on the FAA in solving the problems that the helicopter has in this area of icing, particularly with regard to the certification procedures. I hope that this forum will communicate that to the regulatory side of the FAA. Thank you very much.

RICHARD I. ADAMS

Thank you very much, Bob and Harry. Those were fantastic comments. I would like to just, very briefly, remark, Herb, on the areas of concern that you've expressed. They were expressed at the HAA/FAA workshop in Washington.

Work within the FAA is progressing in the area of trying to better define the icing criteria. The fact that NASA has recently uncovered this old set of data that, I guess has been ignored, was partially, regardless of the FAA's efforts to look into this problem area, because of their unique program element in that specific area. We held a meeting here on the 6th of August. Before that meeting I personally talked to Porter Perkins, who, as many of you know, is one of the old researchers who was working for NACA back in the 1940's and the early 50's, when the overall surveys were being conducted and I think it was through that chain any efforts on the part of NASA to look into this that has led to identifying these old data. We at the Technical Center right now are in the process of setting up another meeting with NASA Langley to assist them in justifying continued flying. As a matter of fact they are planning to fly a Twin Otter and this really was a result of the August 6th meeting that we had. Primarily for the purpose of validating that old data we're going to fly old instrumentation versus new instrumentation in natural icing conditions. In addition, NASA Lewis has planned to do some back to back comparisons of that instrumentation in the IRT. Some of those tests may have already started. I don't think it's valid to get into detail at the moment. For the record I want everybody to know that we are actively pursuing that area. As a matter of fact, I don't know if you recall the viewgraph that gave a schedule of our overall icing R&D program, I've set a deadline of 1983 to make sure that we had final criteria from an R&D standpoint. I think at this point and I don't want to defend the regulatory people and the certification authorities, but I have not been in that area, I want to support them to the extent that I can, but these findings of NASA are brand new findings. The regulatory process, or the regulatory review process, has been in process for quite some time. This new data is just emerging so I really don't think that they've had time to respond. This subject really is not a primary subject of this meeting, but it is a natural side issue. In the area of innovative approaches, from an R&D standpoint I have fully endorsed, myself, and encouraged that the Eastern Region use or make known, the innovative approach that Boeing Vertol has suggested in the certification of their model 234. I think that you are all aware of the fact that Boeing Vertol has asked the Eastern Region to monitor tests that were conducted last winter on the CH-47D for applicability to their 234 and as a matter of fact the 234 certification attempt was to be with a partial ice protection system, possibly without rotor protection. To me that was an innovative approach. I think that the Eastern Region is willing to go along with whatever the companies can develop and present to them and they are willing, I think, to monitor those efforts from any strategic point that it appears to be beneficial. They've had representatives on test site this past winter. I think that's a step in the right direction. I'm not trying to apologize, I just want, as a matter of fact, I think that the FAA is really attempting to do as much as possible in these areas to respond

RICHARD I. ADAMS

to the recommendations that were made at the workshop. I also want you to know that I personally am going to do everything that I can to implement the recommendations that come out of this meeting too. At least the ones that are meaningful and I believe from what I've heard so far, it is meaningful. I certainly appreciate the effort that everyone has put into it. I think coffee is ready outside, so I suggest we take a break. We'll set up for the general discussion and proceed then.

Bob Ligon, of Flight Systems, Inc. has volunteered to give us a slide presentation. Bob are you here yet?

Bob - Yes.

Richard Adams - And we can record this portion. The next portion, I've been requested by Bob Crawshaw, since he does not have an official clearance from his company, that we not tape record that portion. So we will turn that off. We've made the arrangements to do that, Bob. Well, John if you will come forward I think after these two presentations, we will assemble a few people at these tables and start the general discussion.

FLIGHT SYSTEMS, INC.

JOHN LIGON

Could I have the first slide please (Figure 1)?

I would like to thank Dick Adams and all of you all very much for giving Flight Systems and myself an opportunity to describe our tanker. I don't have a prepared briefing by any means, so just bear with me. I'm just going to sort of wing it through.

I'm going to go through and basically describe our tanker to you, discuss the calibration that we have done and some of the test programs that we have done to date, some of the improvements that we still have to do on the tanker and then comment on your national simulator.

We, at Flight Systems, looked at the icing field, I guess you could say, and thought that there was a lucrative market for it, namely an independent flight test organization with an icing tanker, so we've made decisions to develop, as we say, an icing tanker for use in certification of aircraft for flight in known icing conditions (Figure 2). Our specific objective was to have the capability to produce an artificial cloud exceeding the FAR Part 25, Appendix C requirements. What our tanker is capable of is the following: for altitude, we can go from 0 to 25,000 feet, for airspeed we can go from 120 knots indicated to 225 knots indicated and then 300 knots true on up to 25,000 feet. We have been to -26° centigrade, we have a time on station that's variable and seasonal related, if you can imagine, in Mojave. In the winter time we can stay on station for approximately 35 minutes and this is our fuel limit, not a water limit, at 10,000 feet. As an example when Gates Lear Jet was out this summer, and we went to 25,000 feet, we had a 15 minute limit on station for fuel reasons. Our cloud size is 8 to 9 feet nominal diameter. Liquid water content, which I'll go through shortly again, is 0 to 1 gram per cubic meter and droplet size, we were aiming for twenty to fifty microns. It appears we are at 30 to 40 microns, we're not really sure where we are. We have several calibrations and that is sort of confused at the present time. We had planned our system to be year round since it is capable up to 25,000 feet, but it appears from MRI that our system is very seasonally related in terms of temperature and relative humidity and that humidity just destroys our small droplet size.

We have aimed our tanker to fulfill the right half of the FAR Part 25 C envelope (Figure 3) the next slide (Figure 4) is the cumuliform. Once again we were aiming for the right side of the envelope.

Our T33 system is schematically depicted on this slide (Figure 5). We have a built in water supply, two tip tanks capable of carrying up to 200 gallons per tip 400 gallons total. We take the water from the tip tanks, bring it inboard to a subtank of 8 gallons on the centerline. It then goes down a boom, through a boost pump, down to the boom and out a series of nozzles. Our nozzle array, which in the next slide (Figure 6), is 13 nozzles on two arrays. The two spray bars are 3 feet wide and they

JOHN LIGON

are one foot apart. At the same time we have air venting off of the engine and taking down to the center line. The air is routed through our subtank to assist in heating the water and then it's taken down through the boom. The water is run through the boom to keep it from freezing. It's taken down to the boom and we have air pressure with one-half J. as well, we have our instrumentation being bleed air pressure, water pressure and bleed air temperature and OAT (outside air temperature) probes right on the boom so we know what the parameters are at the nozzle itself, not up in the sump or up higher.

The next series of slides (Figures 7 and 8) give you a rough detail of what the T33 tanker looks like. This (Figure 8) just briefly shows how we get the water out of the tip tank. We have the capability of putting fuel tanks on for ferrying it to a remote site and then putting the water tanks on, so we preserve the fuel tank capability.

We run our water, which is what we were concerned about, the possible freezing, we run our water below the wings to the inboard, to the fuselage and then up into the fuseage.

This is a slide (Figure 9) of our system without the shroud around it. It's essentially attached through the centerline of the aircraft through the tow hooks, which we have modified for carriage.

This (Figure 10) shows our nozzles on the nozzle array, thirteen, one half J per spray bar.

This (Figure 11) is a shot of the boom partially down. It is hydraulically controlled for extension and retraction. The boom was initially 5 feet long. We found that there was quite a bit of turbulence at that distance down so we put an extension down four more feet. As with other programs, we had quite a bit of growing pains and horror stories, I guess you could say, in that our first two landings were made with the boom down and we had an electric flight motor that failed twice. We then went to an air assist and now we have gone to a hydraulic motor which has been reliable since that time.

Just an overall shot of the boom (Figure 12), well, essentially down, and the picture of our spray cloud (Figure 13) as it exists at the present time, below the aircraft.

We have done three programs so far to date. The first program was with Rockwell International (Figure 14). This shows their model 65 behind our aircraft in January of this year. I don't have a slide available for our program with Canadair. But anyway, we have put the CL 600 behind our tanker in February of this year. Next slide will show the Gates Lear Jet (Figure 15).

You will notice the second T33, it was instrumented for the Gates Lear Jet program. Show the next slide (Figure 16) and it will show the Lear behind our aircraft.

JOHN LIGON

You can see that, what I mentioned awhile ago, remember the other T33 aircraft, we had, I'll go back to the Canadair program just to briefly discuss. Canadair flew behind our aircraft in February of this year. The calibration technique was an icing sphere. Now an icing sphere is a very crude method to ballpark liquid water content droplet size. Admittedly, it's nothing compared to the MRI or Nolenberg approach, but it does let you know if you are in the ball park. The icing sphere data was submitted to the Canadian DOT and it was rejected. At that time Canadair elected to go ahead and contract with MRI to put their equipment on our aircraft and we calibrated, they then flew this T33 with the Nolenberg probes behind our aircraft in June of this year. The atmospheric conditions in June are quite a bit different than February in the Mojave Desert. In February we were flying at 12,000 feet at -10° centigrade. In June of this year we were flying the same air speed and altitude, but of course, the humidity was 15% and the temperature was above freezing. So we had different distances during that flight and they have backed out the humidity effect and temperature effects and had concluded, and it's been submitted to DOT, that in February our icing cloud has $-.24$ grams per cubic meter and a 35 micron in effective droplet size. That was backing the data backwards to February. Like I said, it's quite a bit of difference, so there was a bit of, I guess, theoretical analysis of data and distance effects and relative humidity and temperature effects.

Next slide shows the instrumentation (Figure 17), again, how we had set it up. We also had a Johnson-Williams Probe, which is not shown here with the equipment. But it was mounted before the plate was on the side there for the Canadair test.

This (Figure 18) is the set of the instrumentation in the rear cockpit. I would like to now discuss the Gates Lear Jet Program briefly. The MRI instrumentation flight was on for the Gates Lear Jet Program, as well. The intent being that Gates Lear Jet was looking for a particular droplet size and liquid water content. With the humidity effects that MRI was talking about, it is very difficult to predict what that would have been. So MRI, again, put their instrumentation on our T33 aircraft and they attempted to call our conditions at 100 feet back behind the aircraft. The cold condition or the desired condition was an FAR droplet size, $.1$ grams per cubic meter and once those conditions were called, and stabilized, then the T33 would move out and the Lear would move in. As it turns out, I guess relative humidity sort of ate our cloud up, because we had $.07$ grams per cubic meter and their computations said $.07$ grams at 75 microns. It's apparent that our drops have been eaten up with that type of information because just considering how many grams per second we were flowing, the speed and the size of the cloud, told me that we should have been $.25$. So somewhere we lost from $.25$ to $.07$ in the first 100 feet behind the tanker.

Now I was going to give you some of the improvements that we are considering. We do feel that our tanker is, at the present time, based on the sphere data in particular and the MRI statements to Canadair, that we do produce an FAR cloud. But as you can see, we also have quite

JOHN LIGON

a few yellow popsicles on our boom as well. That's kind of embarrassing at the present time and we have ordered a red round heater to put on the entire nozzle array and so the next person that flies behind us is going to have a warm glow on his face. We're putting 200 amps down through the nozzle array. I've been very impressed with Edwards Air Force Base and other people that talked about the quarter J problem. Apparently, the quarter J nozzle is superior to the half J. We had looked at the quarter J nozzle in depth when we first were considering it, but I didn't think it would give me the liquid water content that we were looking for. So I'm very interested in this data if, in fact, the liquid water content can be obtained with the quarter J, then we will be looking seriously into changing the half J into the quarter J. In addition, as I've said earlier, we only have so much time on station. We have additional capability of improving our time on station. We have 45 minutes worth of water and depending on the altitude, 15 to 35 minutes worth of fuel. We have a design available at the present time to put fuel tanks on our pylons and extend our total pylon station, since that is the reason we are limited.

Now, I think the National Simulator, from Flight Systems' standpoint is an excellent idea. We would like to be involved to help develop the system. We have invested quite a bit of money and we have quite a bit of experience at the present time. We think that our T33 can be a significant asset in the interim until the National Simulator would be flying. It's also been pointed out that there's quite a bit of research data acquired in the low altitude region, for example, on what really is there. I think that if the data is fully researched you'll find that there is quite a bit of data. For example, the Navy has a lot of data flying out of San Diego and in fact, they were flying over in Hawaii with us last year. They were gathering a significant amount of cloud data over the Island of Hawaii and there's a company in Tulsa, Airomat, that has a government contract, I understand, to gather data. I think that the Air Force Geophysics Lab has gathered quite a bit of cloud physics data and the University of Wyoming has gathered quite a bit of data. These are all with the Nolenberg type probes. If the desire, after redoing all the data, is to gather more data, Flight Systems would be more than happy to put the equipment on our T33. In fact, we do have an operational design at the present time to do that.

That concludes my briefing discussion of the T33 icing tanker. I don't have a handout on the icing tanker, I do have quite a few copies of the test report back at Mojave. If anybody is interested give me your name later and I will see that you get a copy of that.

2ND DAY

FLIGHT SYSTEMS, INC.

"JOHN LIGON"

Figure 1

DESIGN OBJECTIVES

DEVELOP AN ICING TANKER FOR USE IN CERTIFICATION
OF AIRCRAFT FOR FLIGHT IN ICING CONDITIONS

HAVE CAPABILITY TO PRODUCE AN ARTIFICIAL CLOUD
MEETING FAR REQUIREMENTS

Figure 2

STRATIFORM LWC VS MED

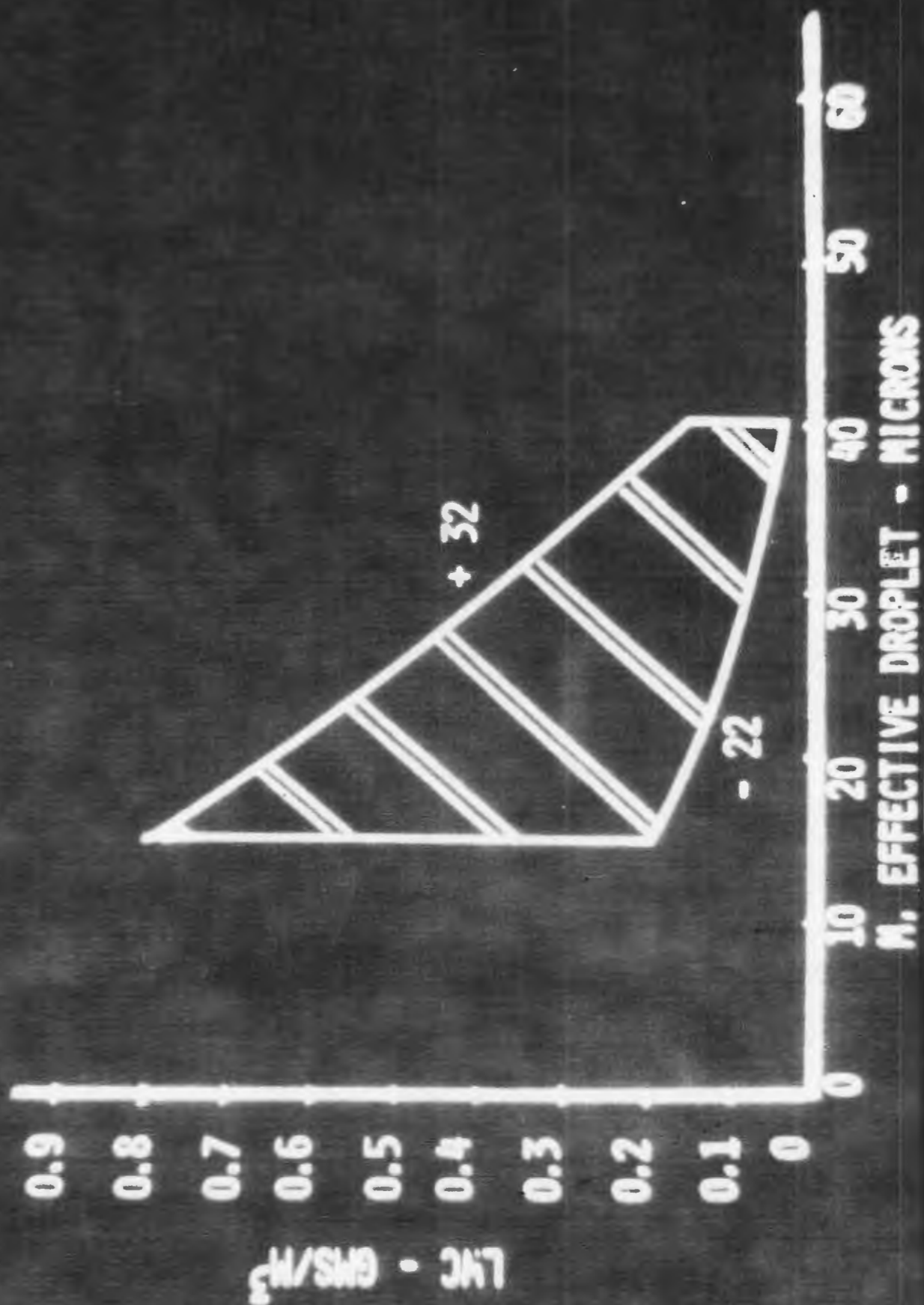


Figure 3

CUMULIFORM LWC VS MED

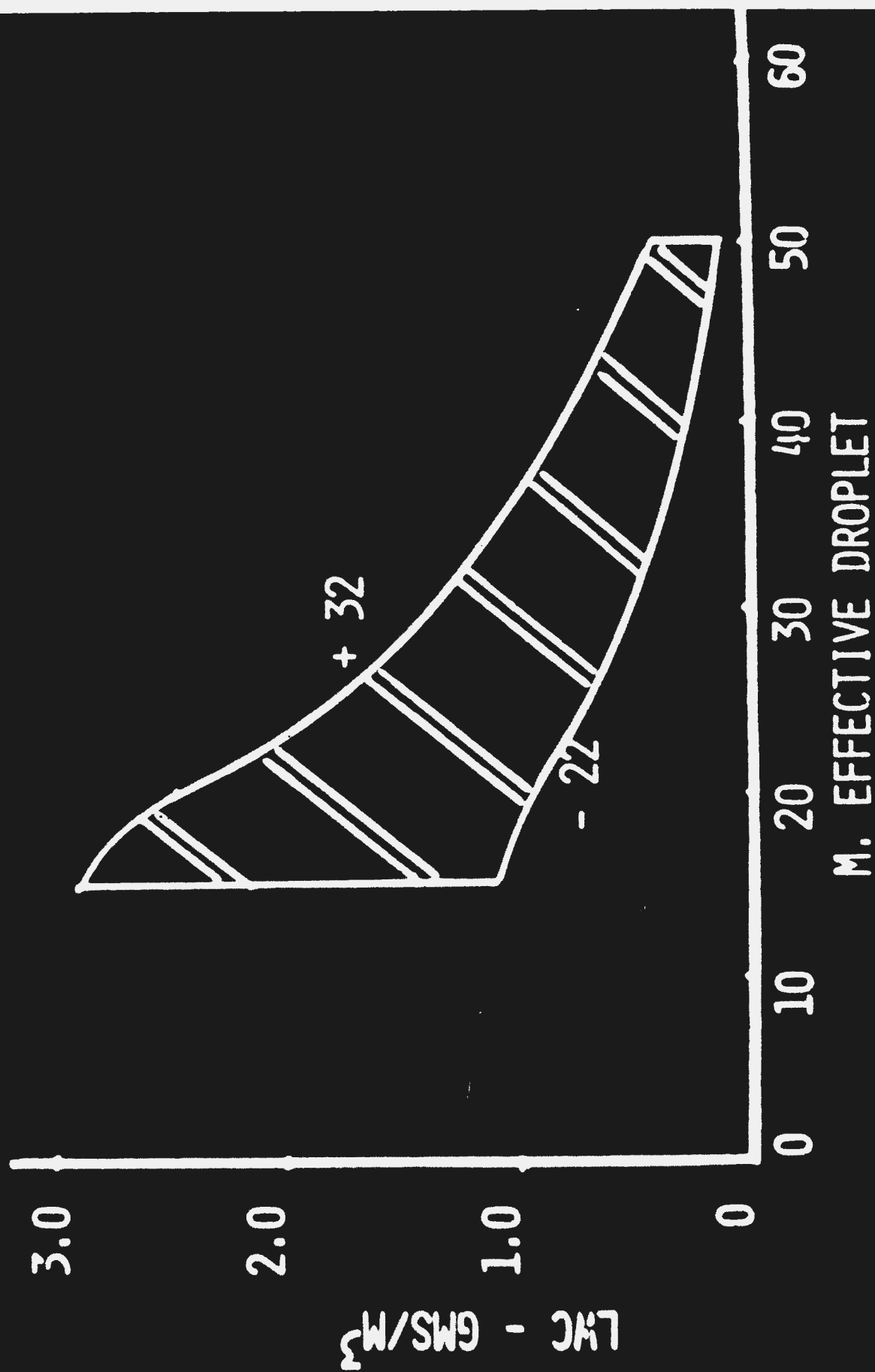
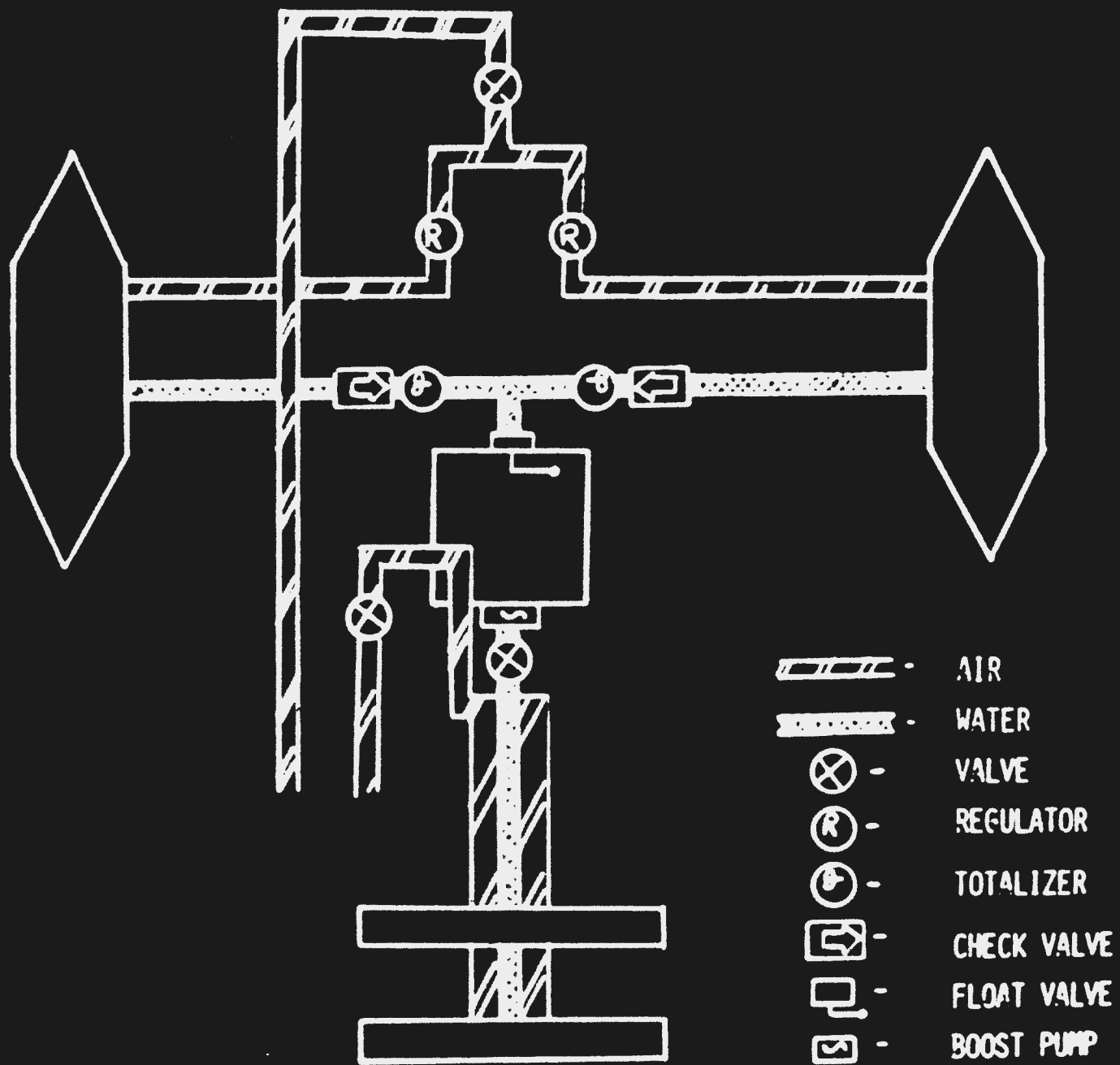


Figure 4



FUNCTIONAL SCHEMATIC

Figure 5

Figure 6

DEVELOPMENT, FLIGHT TEST AND CALIBRATION OF A T-33 ICING TANKER

Figure 7

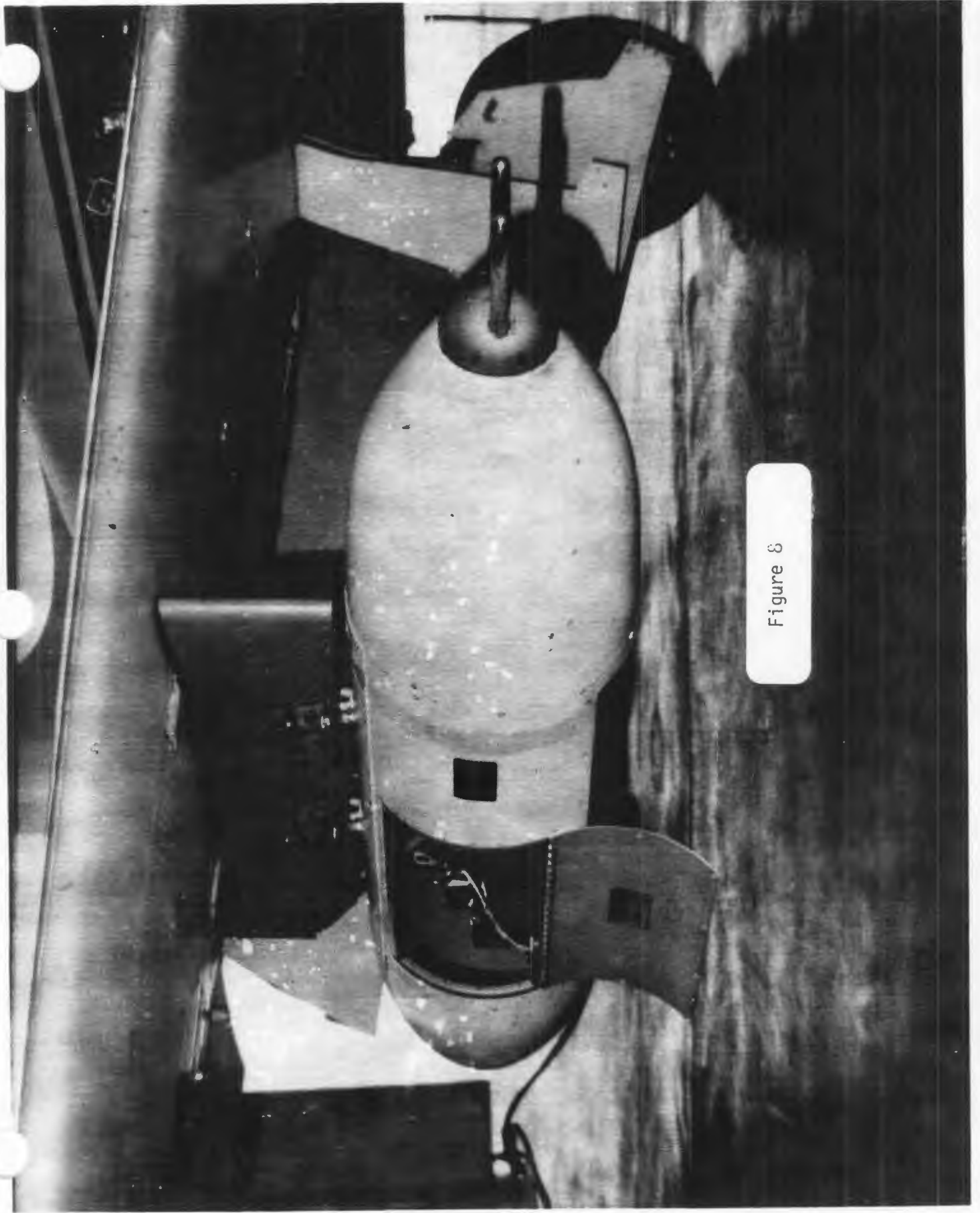


Figure 6

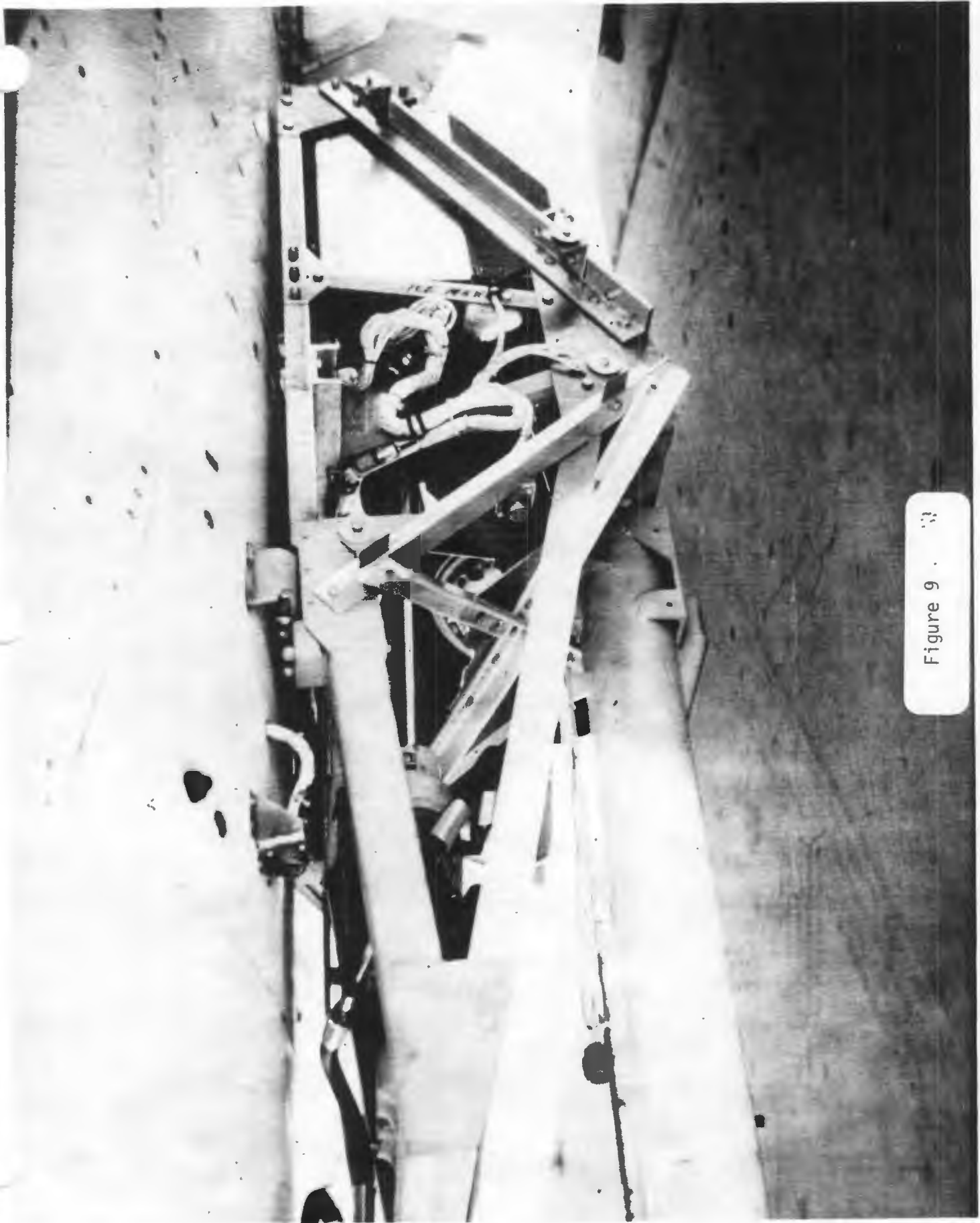


Figure 9 . 13

Figure 10



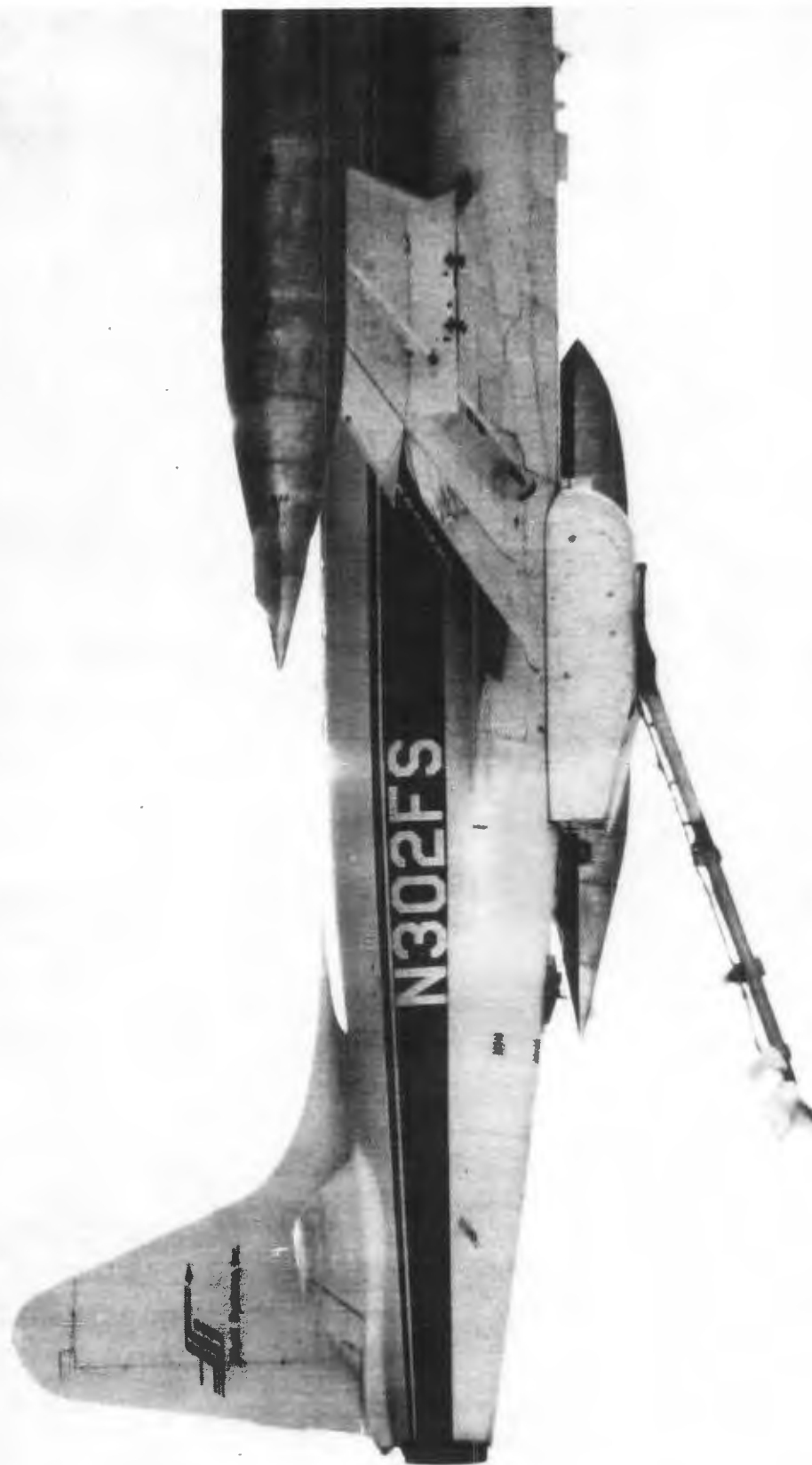


Figure 11



Figure 12



Figure 13 . '8



Figure 14



Figure 15

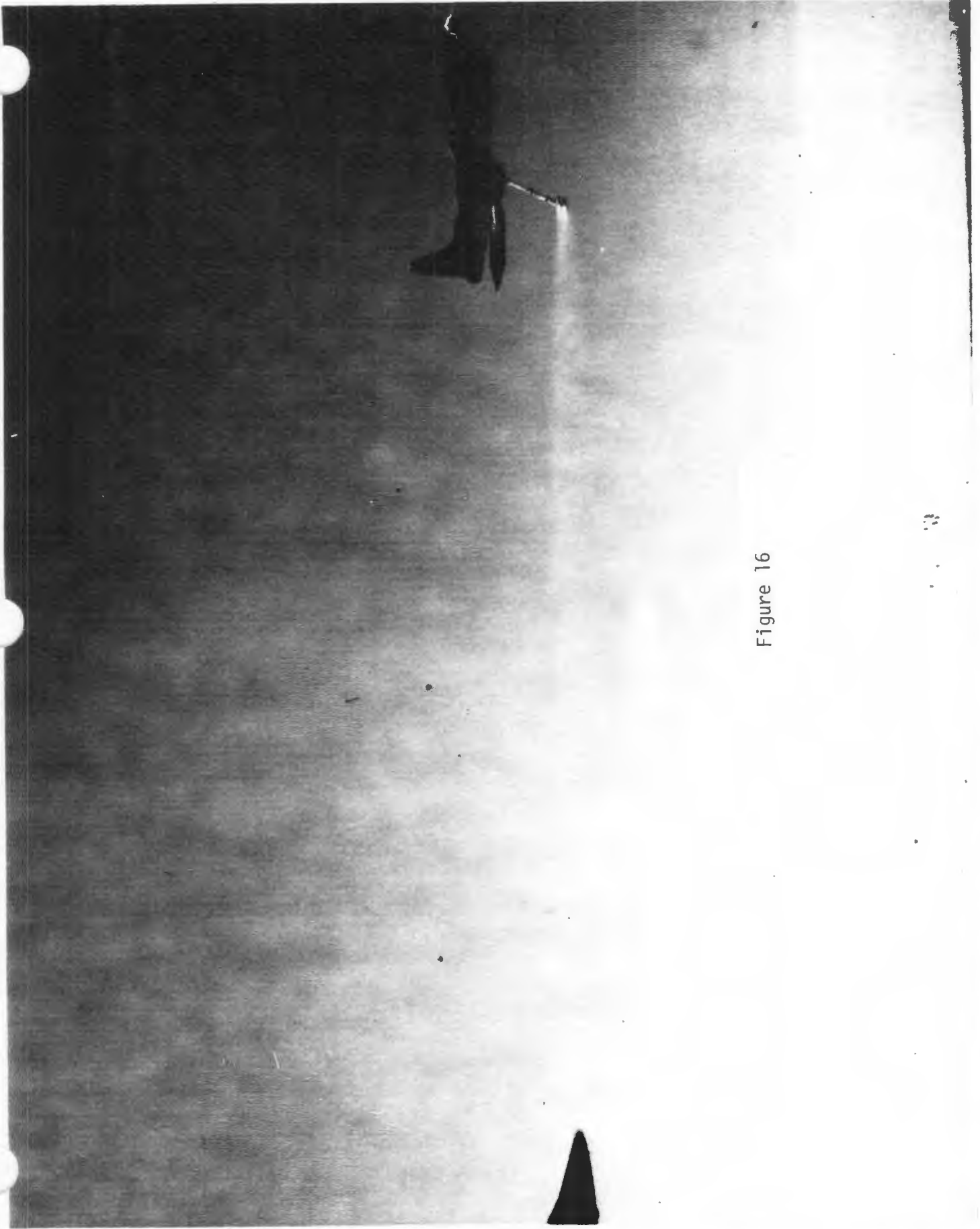


Figure 16

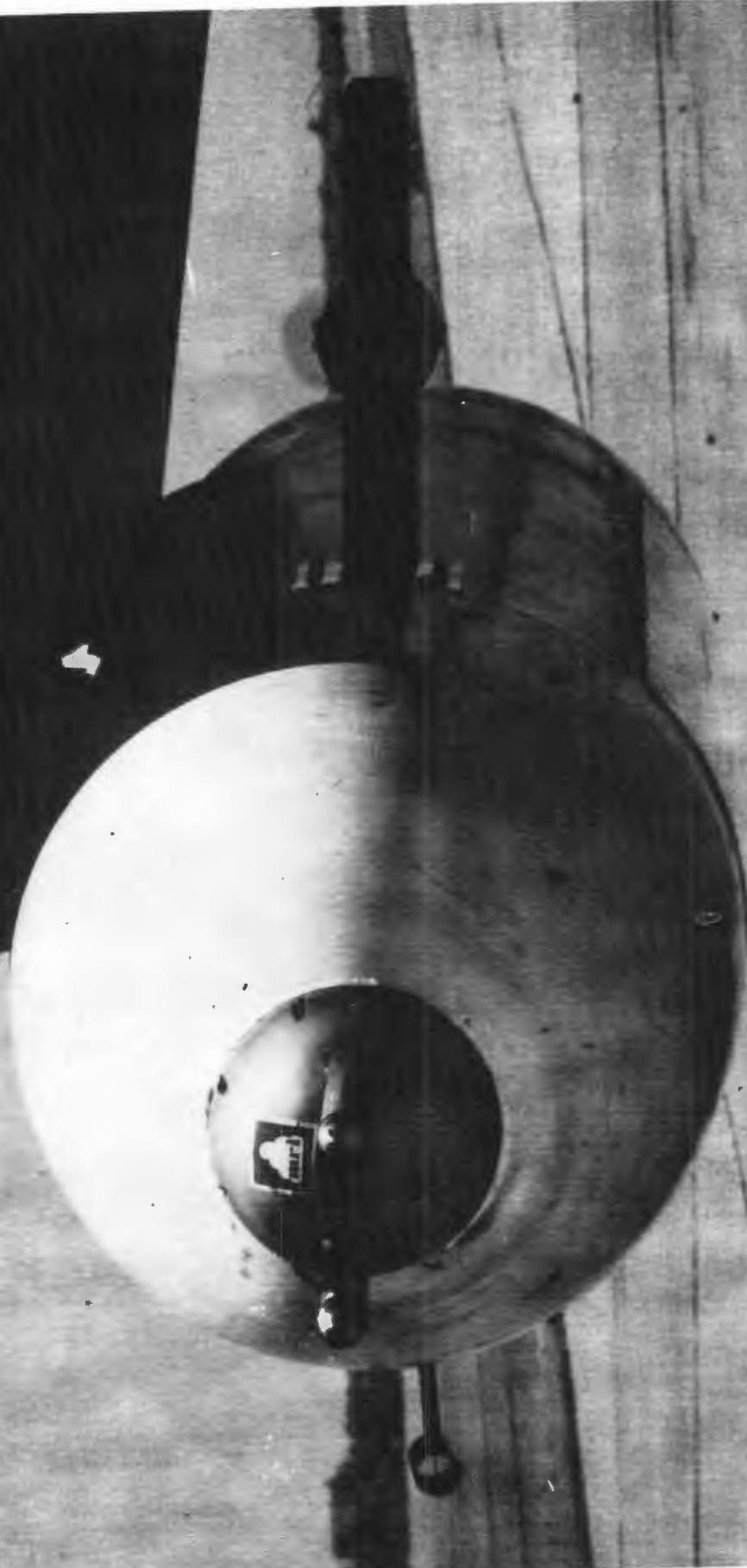


Figure 17

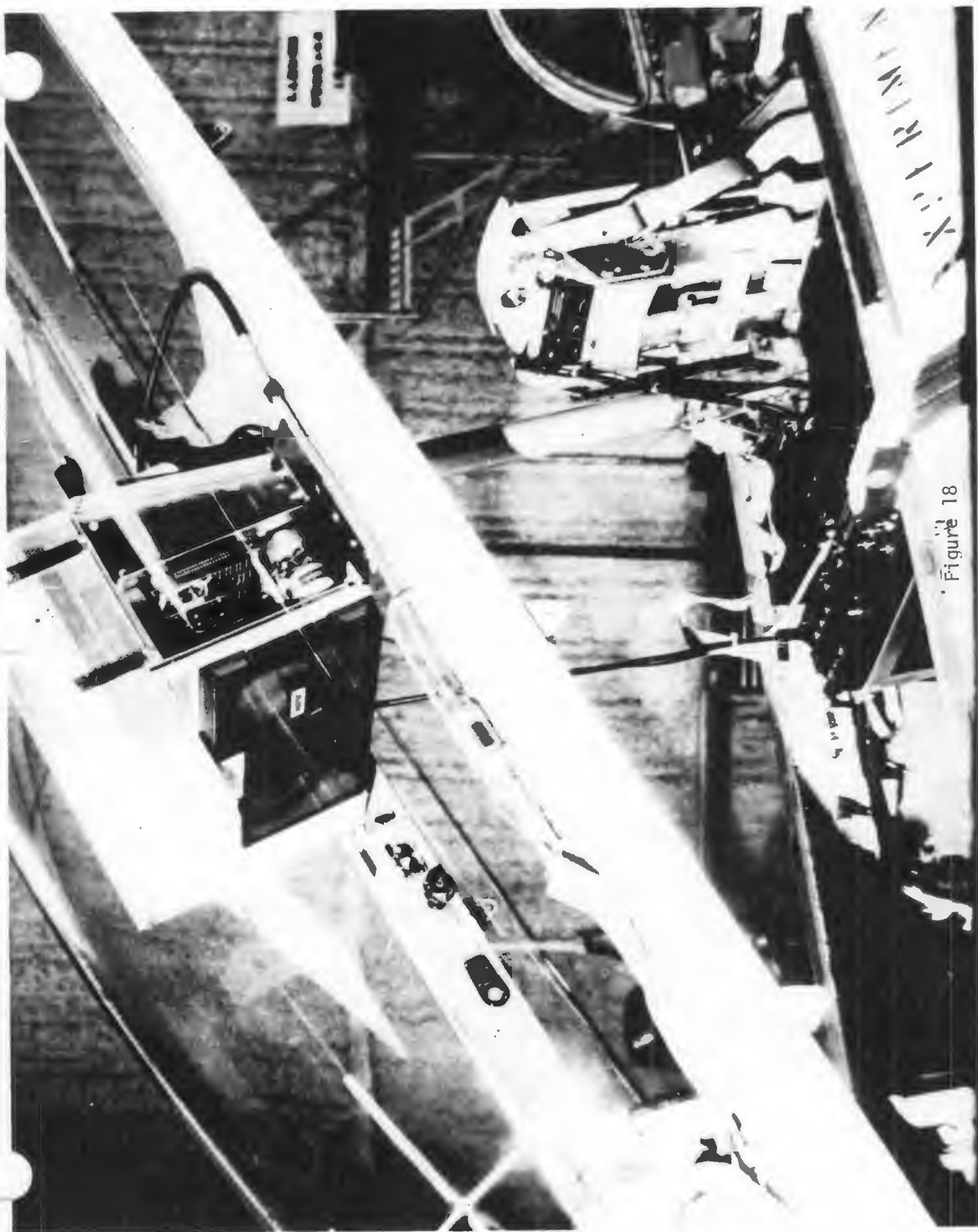


Figure 18

RICHARD I. ADAMS

The meeting that we had here on August '6th of this year was really a coordination meeting of all the various agencies in the government that were conducting meteorological surveys to acquire data that feeds into Art Hilsenrod's weather program as well as our efforts to refine the FAR 25 criteria. We are working with the Air Force Geophysics Lab and the Naval Research Lab in acquiring data. We are considering some contractual efforts, but there's no money available at the moment for that.

GENERAL DISCUSSION/QUESTIONS AND ANSWERS

MEETING CHAIRMAN: RICHARD I. ADAMS

Thanks Bob and most certainly it's going to be a great use to all of us. I might mention that there are two ice detectors that are now on the market that have the capability of directly measuring liquid water content from ice accretion rate. One of those companies is represented here today and I'm sure he'll fill you in. And if you want further information on the other company, he'll probably answer that question too.

It's now 12:00 and we have 45 minutes. The plan that I have, you see the tables lined up here with microphones, is to get into a general discussion so that we can kick around thoughts, ask questions and kick around the critical issues that we're still concerned about. Now my original intent was to have all the speakers and myself, with representatives from AIA, HAA and GAMA at the table. We don't have room for all the speakers, so I have developed a specific list that seats representatives from each of the agencies, including one from the Army, Navy and Air Force at the table. Now, let me just call out the names of those people that I would like to have up here with me. Number one, I would like to have Dave Ostrowski come up and sit with me. I haven't approached Dave on this before, but I'm sure you won't mind. I would like to have Herb Slaughter at this table, and Jim Dougherty, representing GAMA, Bob Richardson, Harry Chambers from the Army, Milt Beheim from NASA, Vito Truglio from the Navy and Carl Wolf from the Air Force. So if you will come on up now and be careful and don't trip over the cords there, the electrical cords that are laid down here, and seat yourself at the table, we'll begin the general discussion. We don't have enough microphones for everybody, so we will pass them around as necessary. Also any conversation from the audience we would like to get on tape, so we'll pass the hand mikes around.

Dave Ostrowski, while you stepped out I had asked you to come sit at the table with us here, if you don't mind.

Let me just comment, while Dave is on his way down here, that I am very pleased with the response that we've gotten from industry as presented to us by HAA, AIA and GAMA, here this morning. I think in a nut shell, it gives terrific support to what we have in mind to do and that from all of this we will be able to bring together some recommendations that we will send the FAA Headquarters and I think that we can present enough information to establish a Task Force and I think it's going to be great. I think that during the discussions that there was an expression of concern from many of you that we didn't have all the facts straight. I don't think that we can have all the facts right now or all the details that are necessary. I think, really, that what this meeting represents is a second step on a long climb up a big mountain, and that the thing that the Task Force will have to do will be to define the things that need to be done and the rationale for it and we'll have to, at the same time, take into consideration the current status of data that can possibly lead to changing the FAR 25, Appendix C criteria. But I don't think we can wait until we have changes

RICHARD I. ADAMS (General Discussion/Questions and Answers)

in those criteria to begin a national facilities effort. I think that has to be a parallel thing. If we don't start now we'll never get there. With those initial remarks, let me open it up to general discussions, question from the table and questions from the floor.

Q. KEN YOEMAN, KEY INDUSTRIES, San Antonio

I have several areas, but I would like to talk about Part 25. If you're going to review the icing criteria, the FAA now, I wish you would look at 10-93 (FAR 25.1093) and tell all of us what falling and blowing snow is. Now this is typically not a problem for pitot type inlet and inertial separator such as an helicopter can become packed and I don't think anyone is arguing the need, but just what is it? I've sent data to my region, they probably sent it off to Washington, which meant it fell off the end of the earth somewhere. The Canadians have done a great deal of work on snow. You can correlate this to visibility from the MET people and come up with something, but someone should tell industry what snow is.

The second part of 10-93 is the ground fog. Now nature's not cooperative in giving us thirty minutes of conditions that are absolutely stable. I don't know how you measure them without forward speed. That needs to be reviewed.

The other point is that your're talking about Appendix C with regard to helicopters. I think there's implications to fixed wing also, if you pick an altitude and suck the envelopes in, and before anything were to be issued, you'd better think about this.

A. RICHARD I. ADAMS

Very good, your questions are understood and let me provide a brief comment and I'm sure that others would like to comment.

The Research and Development Program that we have, to better define the criteria, does include blowing and falling snow, as well as freezing rain and as well, super cooled cloud conditions. So I think that your request didn't necessarily fall off the end of the earth. I think that it has filtered through the R&D program and something is being done about it and we're aware of what the implications are. In addition, we have on our books right now, as a matter of fact, funded in FY'81, for the initiation of an effort to define the requirements for a snow simulator that could be used for snow development testing and possibly being accreditable for snow certification. I say possibly. The ground fog issue I cannot address, but the Appendix C criteria, I referred to the August 6th meeting before, I refer to it again. During that meeting one of the basic conclusions that we reached was that if we are going to reconfigure the Appendix C criteria, that we would want to do this in terms of altitude or as a function of altitude. In other words, we would have plots of curves of liquid water content as a function of altitude, temperatures as a function of altitude. It will be the

immediate volumetric droplet diameter as a function of altitude, and droplet size distribution, with all of these things interrelated. Specifically how these curves are going to be presented we don't know yet, we haven't really started in that area. The effort that's going on right now is data gathering and NASA data that exists is a part of that. We did also conclude that this information, although its development is precipitated by the helicopter needs, can be, if it's presented properly, applicable to all kinds of aircraft. I say, if its presented properly. Let me reiterate that this is a research and development approach right now. I believe that it has the concurrence of the Washington Headquarters and also the lead regions. I think Dave Ostrowski would like to make a comment.

A. DAVE OSTROWSKI

Thank you Dick. I'm not sure all of you know me, I'm one of those fellows from the end of the earth. Which is why I'm commenting on this, I presume.

10-93 falling and blowing snow is your first point. There is a proposal, as I recall, in our Rotorcraft Regulatory Review on that particular section and I know there's been a lot of discussion and a lot of thought, consideration, given to redefining that, so forth. I, myself, am not particularly familiar with that aspect of it, but my point is, that is under consideration at the moment. I'm not sure you all are aware of the ongoing helicopter regulatory review. I know a lot of you are, but for those of you who aren't; the FAA is in the process of reconsidering all its rotorcraft rules and this pertains to certification, operation, maintenance. The total rotorcraft rule making situation is across the board. We had a public conference in New Orleans last December. We had another one just last August and we are in a regulatory mode at the moment. We do plan to issue an initial NPRM in the next month or two. So that if there are inputs, there will be further opportunity through the NPRM process to provide recommendations and comments, thoughts, whatever, as part of the process, as there has been, throughout the initial meetings in December and August.

Your point on Appendix C implication for fixed wings. Should we find some data that pertains to the envelope as it is defined now, I think that we agree, that yes, we do have to consider those implications and they certainly will be.

RICHARD I. ADAMS

I think that your question was very valid and a question that needs to be discussed. Your questions, however, are not absolutely pertinent to the subject of this meeting and that is the icing test facilities, except by reference. We do need to get the criteria situation squared away so that as we develop our facilities we're sure we're doing it in the proper manner to facilitate the different criteria. As I mentioned, this needs to be a parallel type of an effort. I would like to try, as much as possible, to constrain the discussions to the National Icing Test Facilities issues.

KEN ROSEN

I would like to amend my statement and I believe my colleagues in the rotorcraft community would agree with me. I had a subsequent conversation with Milt concerning the free jet capabilities that he's proposing in the AWT revision. We did not understand that the free jet revision was not part of his Phase I plan, but is, in fact, part of his Phase II plan. It is important that we go on record as stating that part of the Phase II plan related to the proposed revision of the AWT that related to the free jet capabilities producing that 45 foot test area and capability, I believe, up to 200 knots within that test area, will be a valuable asset to us in the rotorcraft community.

RICHARD I. ADAMS

I'm sure the tape recorder is on back there to gather that information, so we can make the amendment. Thank you.

Q. JOHN LIGON, FLIGHT SYSTEMS

Assuming a decision is made to develop a national inflight simulator, in other words, a FAA icing tanker, when do you see that occurring? When will we be competing? and What type of aircraft, what type of parameters do you think you are looking at?

A. RICHARD I. ADAMS

I think the first thing that's going to happen is to develop the justification for the tanker. That's part of what this meeting is all about. We want to consider all of the facilities needs. A national inflight tanker is a part of that need, as I see it. We at the FAA Technical Center feel that that is a valid requirement and a valid need and we feel that the best place that industry could be served by a national inflight tanker, possibly, could be to position that tanker here. It could be used in various places in the country, but that decision of where it would be located and by whom it would be owned, is still up in the air. I would like to see it here, myself. The time frame, we can only say at this point, the funding for such a facility is included in our "wish list" budget. I think that we have to be realistic when we start talking about budget and I think that the handwriting is on the wall and the FAA is not going to be able to afford that tanker on its own. I think that the FAA is going to have to have the support of NASA and DOD from a funding standpoint. The sooner we get the Task Force together, the sooner we get a national icing facilities program plan established and priorities established, and money in hand, the sooner that type of facility will be available. I guess my best guess is, at the earliest, three to four years. Now I might mention that we are working very closely in helping fund the Army's improvement of the HISS and we see that as the standby in the meantime, until we can afford the tanker that can be used by industry on a non-interference and a cost reimbursable type basis.

Q. ANDY PETERSON, BOEING VERTOL (General Discussion/Questions and Answers)

Question on the facility and certification. Is the FAA prepared today to accept the results of the HISS for certification or in the near term HISS improvement?

A. RICHARD I. ADAMS

Let me answer that from an R&D standpoint and I'm sure that somebody else would like to consider it.

Based on the experiences so far with tanker testing, the helicopter tanker testing that I've seen, I think that there is enough concern about the effects of relative humidity and solar radiation and ice crystal content, that until we know more about these issues, or the effects of parameters or conditions, on the correlation of tanker results to natural results, that it would be questionable. I think it would probably be necessary to industry at this time, or the applicants, to provide answers to those questions. Now, I'm only speaking from an R&D standpoint and my own personal opinion at the moment and maybe this is a good thing that we can open up for further discussion.

Q. ANDY PETERSON, BOEING VERTOL

Well, let me go on with that a little bit more. Today's HISS has certain limitations and there's certain questions to the FAA. If money is put into the HISS improvement program, is the FAA then going to be prepared to accept that data for certification or if not, what data will the FAA accept for certification and will the FAA define specifically what they will accept for certification? And when will they do this?

A. RICHARD I. ADAMS

One of the reasons for the research and development program, Andy, and the FAA's participation in the Army HISS improvement program is to answer questions of that type and we specifically asked the Army to look into these various effects and until that information is available, I don't think that we can make any positive statements. In the meantime, if you could show us something better, I think this is what the certification authorities would say, if you can provide more information or better light on this, you would have to Herb!

HERB SLAUGHTER

I think Andy Peterson of Boeing Vertol has asked a very, very pertinent question. Very important to us, its almost like the chicken and the egg. We're all concerned about the certification of helicopters and I think we have all brought that out, at least the people that have participated from HAA and AIA, since we're going to go through it in the time frame in the next couple of years, the first civil certification of a helicopter for icing. You're asking us to give you full support for the icing, artificial icing facilities and I think we've done that here today. But, we're all sitting now wondering what's going to come

HERB SLAUGHTER

(General Discussion/Questions and Answers)

next. When is that egg going to hatch in terms of benefits to us with regards to certification? The fixed wing people do have an advantage in the fact that they have had experience, they have had correlation between their representative tankers and the small aircraft. They have had much experience in certification with the large transport aircraft. That technique is understood by FAA, acceptable, etc. We, in the helicopter industry, are forced, and I think this should be a matter of record, it costs on the order of \$5M to start from scratch, design, go through the development test program and get FAA certification for a helicopter. Now that is a helluva lot of money and I doubt whether the fixed wing people spend that much with regard to certification.

KEN ROSEN

That's just certification in icing, Herb, not total certification.

HERB SLAUGHTER

Well, I meant, my comments are referring to certification and icing. I thought that was understood. Therefore, there should be some benefit from this and I think the closer we get to the liquid water content, the droplet size, in our artificial testing facilities, then there should be some recognition of this and that if the natural icing requirement is still there, then it should be minimal. With regard to the amount of correlation you can show with the artificial icing tests that you do, I hope we do not get into the position where we have to go through precisely the typical program that Dr. Rosen showed, where we develop in hovering, we develop more in the tanker, we test behind the tanker with FAA to show certification and then we have to show five or six points to describe the icing envelope. Now that would be disastrous to the helicopter industry in trying to get certification. I think our colleagues in France have taken four to five years in order to get to the point where they are ready for certification and after that period of time they still do not have adequate data to satisfy the FAA with regard to certification. So we feel that something should hatch out of this egg that you're giving us today that will benefit the industry in the certification process.

RICHARD I. ADAMS

I fully concur in all those things that you said. Let me give you my personal opinion and that is, in the future that the inflight tanker can be used in the certification process. Maybe not to totally eliminate the need for natural icing tests, but to reduce the amount of time that would have to be spent finding the natural conditions. I think that we are headed in the right direction with tankers. All I'm saying is, that we don't have all the facts together yet. We're in the process of trying to bring those facts together under the R&D program. I don't think that we can sit here and guarantee you or anybody else that these facts are going to fall into place and that absolutely you're going to be able to get total use of all of your

RICHARD I. ADAMS

(General Discussion/Questions and Answers)

simulation time behind a tanker being attributable to certification. That, in itself, is another parallel effort and will have to go along with the development of the facilities. These facilities are going to help you in the development process as well and I think that we have enough information at this point in time to assure us that we need to proceed with the national facilities program.

Yes Ken!

KEN ROSEN, HAA/AIA ROTORCRAFT

I think the issue really must be stated very clearly. We'll never do it! There will be no certification in the United States of a rotorcraft, unless the community, the FAA, etc., becomes convinced that simulated icing is, in fact, a very valuable and necessary tool, not only for development, but for certification. It's as simple as that, because it won't be only five points that Herb talked about, it may be, in order to hit all the combinations in natural icing, thirty to fifty points. Remember I was talking about \$20,000 a flight hour, just to operate the helicopter, let alone the tanker. The cost may be more than the \$5M that we've projected, or that Bell's projected. I can say that we don't really know what it will be and what is really unfortunate is that your very good effort, Dick, didn't get started three or four years ago. I can only say that we have to support your effort, but that the effort must be accelerated and that one of the first things that you, as the research arm, must be convinced of, or must develop, is the ability to develop confidence in the simulator, excuse me, a simulated icing environment, as a tool for certification. There is simply no way, that if we have to hit all corners of this envelope, using natural icing means, that we will succeed.

RICHARD I. ADAMS

I don't disagree whatsoever with that answer.

JIM DAUGHERTY

I hope that we're not smoking opium here but I'd like to introduce a little realism into this thing. I said this morning that we supported this and we still do. There is a possible application in the low speed regime on fixed wing aircraft. I said we favored the KC-135 tests and possibly the modifications that were addressed in relation to the C-130. But this raises an interesting spectre as to the availability thereof. My question to you would be, Do you see, or do you have in mind, considering different types of facilities for different classes of aircraft? All I've heard so far is the Chinook flying through the air and hopefully satisfying the helicopter industry's business and I'm not opposing this, I might add. But, in the broad sense from government's viewpoint, are we talking about three possible different facilities or are we really talking about prioritizing these and attempting to clarify the helicopter industry's problems first?

RICHARD I. ADAMS

(General Discussion/Questions and Answers)

The national facilities program that we have in mind includes all classes of facilities. The tankers, tunnels, icing wind tunnels, icing tests chamber and, as a matter of fact, analytical tools and techniques. And it really considers all classes of aircraft. These tankers, as a matter of fact I had a viewgraph yesterday that I wish I had right now, but, these can be used for research through development and certification, hopefully, as time goes on, to the maximum extent possible for certification, of components and the total aircraft as a system -- in any way that a particular facility is suitable for anyone of those things.

JIM DAUGHERTY

Dick, the bottom line to all of that is, and I'm happy to hear you indicate that it's a little bit more than tankers for helicopters, the bottom line really is, and it ties to your relationship with the regulatory people, when can we get rid of and under what conditions do you think we can get rid of, natural icing tests across the board?

RICHARD I. ADAMS

I can't answer that. I can only say that I do have confidence that the amount of natural icing testing that will be required for certification can be drastically reduced. Whether or not that will ever go to zero is a tremendous question. Just take one step at a time, I think.

JIM DAUGHERTY

Well, may I suggest in your preparation of your plan that you look seriously at that aspect of the thing and even think in terms of pushing this, because I agree with you. I don't think this is going to, from what I know of FAA in my previous experiences, and also the current attitude in there, it's not going to be any easy solution to this problem, no way! In fact, it seems to be going the other way in terms of the rule making process. But I would think that you need real careful consideration of this aspect with heavy emphasis on the driving force coming from you to use these ancillary tools to the maximum extent possible. Two companies have got to operate their own tankers today, and there is a third outfit that we heard from today that is willing to lease a tanker on some sort of contract basis. But it does raise a really clear spectre in my mind that in your assessment of the thing, that you not only take into account the various techniques that you alluded to just a few minutes ago, but you also relate this on some sort of time oriented basis for the different classes of aircraft. We may be talking in the real world, here, anywhere from five to ten years from what I can see.

RICHARD I. ADAMS

To reach a total end product, yes! But we've got to, I think, bite it off in small pieces and in order of priorities that are established

RICHARD I. ADAMS

(General Discussion/Questions and Answers)

and I guess I like to say the priorities that have been suggested so far as money is available. Yes Herb!

HERB SLAUGHTER

I'd like to endorse Jim Dougherty's point clearly and then add to it. In any program, such as this program to put together a national icing facility, to get the program moving forward there must be a justification and there must be a goal established. I would like to set forth for the panel a suggestion that in preparing the justification for the improvement of the artificial icing facilities that we justify it on the basis that the goals are to reduce the amount of natural icing required and that this goal be endorsed by the regulatory wing of FAA.

RICHARD I. ADAMS

I think that's a reasonable suggestion and as a matter of fact, I think our program plan that is prepared states it in a very similar manner.

Can I ask that, I've tried to address this issue from a standpoint of research and development, we have no regulatory authority here, we do have representatives from various regions. Let me just ask if one of the region's representatives would like to comment on this area. Yes? This is Tom Plumber from the Southwest Region.

TOM PLUMBER-SOUTHWEST REGION - HELICOPTER STAFF

I think you put it very well Dick, when you addressed the issue about acceptance of the simulated facilities for certification. Certainly the helicopter Certification Advisory Group, of which I'm a member, would endorse the use of this accumulative data for the purpose of reduction in natural icing tests. However, I really don't envision completely eliminating natural icing tests. If you remember Captain Lynn Hanks' presentation yesterday, he very strongly brought out the point that they would have missed some very important icing parameters if they had not conducted natural icing tests after they had done all their simulations. From an idealistic point of view, I would like to address Jim Dougherty's question about will we ever do away with natural icing tests. Idealistically, and this is only my own viewpoint at this stage, if we could ever develop a simulator that would completely test the helicopter, fixed wing or whatever, in every variable simultaneously that you would encounter, that would certainly be one of the minimum requirements to eliminate natural icing tests. I think that at this stage of the game our simulation capabilities are limited to where you can only look at a few of these parameters. For example, in the HISS we can't even fully immerse the helicopter at this point in the icing cloud. I would certainly hope that we could all work toward minimizing the cost involved, and of course this natural testing and going all over the country looking for natural icing conditions adds to the cost, and I would hope that the natural icing tests could be used to verify the analyses in the situations.

RICHARD I. ADAMS

(General Discussion/Questions and Answers)

Thank you Tom. Yes?

BOB CRAWSHAW, CESSNA AIRCRAFT

I guess my question follows along with what we have just been discussing here. We have a reasonable capability to do some simulation. I would hope that at least from, you know the poor old farmers in Kansas with the tin shed, that if you fellows come up with a tanker for use in the general aviation field, it will replace natural icing tests or I don't know what we're going to do with it. But we can use, very drastically, a lot of other data that will allow us to move more rapidly and I guess you can relate that to cost, but I'm speaking of time. I'm thinking of the kind of things that I would envision coming out of your wind tunnel type activities as far as facilities are concerned. Where, regardless of what I have, I need to write an analysis, and I'm not saying that I don't write a good one or that the FAA doesn't accept it, but I think it could be possibly better or have a better basis that we all would commonly understand and when it comes to simulated tests, I think the engine people have had excellent results certifying engines with icing in a wind tunnel. From my experience on airplanes, once they go through a wind tunnel program and get a certified engine it works great in an airplane, providing I put an inlet on it. So I don't know why it couldn't be used on an airplane.

RICHARD I. ADAMS

Very good, Bob. Its time to break for lunch.

SECOND DAY

RICHARD I. ADAMS

(General Discussion/Questions and Answers)

The crowd is beginning to thin out a little bit. People are bugging out to catch flights and etc. Vito Truglio has excused himself from the table. I would like to shoot for an objective of finishing up by 3:00. We have made arrangements for a tour of the R&D facilities at 3:00 for those of you who expressed interest in that. We attempted to make arrangements for those of you who were in caucuses yesterday and missed the tour of the ATC facilities and other points of interest in the building, this afternoon, but that could not be arranged. But we can personally show you some of these areas. So if we can finish by 3:00 then we have the tour of the R&D area and those of you who would like to take a walk around the strategic points in this building, we'll accommodate that too.

I think that the discussion that we were having before we broke for lunch was very interesting and I would like to open up the floor again to questions. Yes "JB"?

"JB" McCOLLOUGH

I haven't said anything since yesterday morning, but I have heard a lot of good presentations and I want to thank all of you who have participated in the discussions and the presentations to this point for all that you have brought to this meeting. But there is an observation that I would like to make to all of you. And that is, by the nature of the title of this meeting, National Icing Facilities, and we are holding it here in a government facility, to pick up the feeling that this is Uncle Sam's job to furnish a national facility and I hear industry saying when are you going to get these answers and how quick and will you guarantee you'll accept them when you get them, so that everything is rosy, like Uncle Sam is looked to for a handout. I also hear people here who have their own commercial facilities who say when will I be threatened in the market of competition with my facility. I hear other people who have their own private facilities that they use and that they rent out to other people and they want to know will those still be acceptable. The question that I would like to ask you, each and everyone, is this the proper role for government or is this the proper role for the competitive marketplace in the United States that we are all proud of? If we need these facilities and we need them bad enough, there's somebody clever enough to make a buck on them. And if he can do that he will respond to the customer who wants them now. And if that be the case, I think we ought to discuss whose role it should be to pursue facilities. Independently, piece-meal or in total, but don't forget that we have technology to worry about. That's my question to all of you!

RICHARD I. ADAMS

Would you like to volunteer to answer that question?

I think I mentioned this morning, "JB", that we had sort of hit around the fringe of what you have just mentioned, in the form of a survey we have underway. The results are still not completed because we have some, as I said, 38 members and the total vote isn't in and it's obvious that we're not going to release any results until we've got a fairly detailed consensus. The questions we asked were: Do you see a need for such a test facility in the future? and in this sense it was for general aviation, and that sort of bears partly on what you asked. If not, what test facility do you now use? It's obvious that if you don't see a need for it you've got to be using something, so we came around the back door. And third is: Would you favor total government funding of such installations? Coupled with user charges? We think relates to the question that you've asked. Then: if a facility is constructed, is the FAA Technical Center the logical place? The last question which isn't totally germane, although indirectly relates, was: Would separate facilities be needed for each type of aircraft, that is the class situation? So we've got a mixed bag of answers. Some people think that if the facilities existed they would be glad to use it and there's no question about it. The issue came out in a side discussion here this morning and I think yesterday, and in some of our chit-chat sessions with the industry people here, simply boils down to: if the thing does exist will we have access to it. Will we have access and that's a legitimate question, in my mind. There's no reason to engage in assumption on that point. And will the cost be reasonable? Both of those are no reason to engage in assumption. So I think that, from my point of view at least, I can't speak for the rest of them here, this is a reasoned assessment of the varied issues that you've brought out in the open here. And I think, I don't say that I recent the tone of it all, but it seemed to me that you attempted to put us on the spot as crying wolf, when in fact we're not. We came here, in our case of the general aviation people, with an open mind and an open heart and we've given you support in fourteen areas in the points that I made earlier this morning and we intend to continue to give you support, but we certainly have got to get, as we have repeatedly said here, a little better definition of where we're going and in an orderly fashion, what we expect to be doing in this program. So, I think, give us a little time at least from our segment of the industry to frame the answers to this on a statistical basis and then we will be glad to get back to you.

KEN YEOMAN

Dick, I didn't mean to cause you chest pains over Part 25, you brought it up. On the matter of the tunnel, I had a little conversation with Jack Reinmann outside as to the future of the current 6 x 9 tunnel which was not touched on in Mr. Beheim's discussion. I understand that the IRT will remain operational and will be upgraded. Three of the people this morning brought up access to this facilities. One other problem is civil access. It might be NASA's primary role to conduct research, whereas to the majority of us that are nuts and bolts engineers

KEN YEOMAN

(General Discussion/Questions and Answers)

or are interested in certification or operations, it would not be research. It would be basically commerce. Now is this going to cause a problem with access? If you're asking for a mandate from the people in the room about these facilities, someone needs to really answer that question.

RICHARD I. ADAMS

I know that Milt Beheim has answers to these questions. These issues were discussed at our government coordination back in January and it certainly is a problem. Would you like to elaborate, Milt?

MILT BEHEIM

I'm sure you're aware of the basic differences in the charters that Congress gives to the different government agencies, and NASA's charter is clearly R&D. Therefore, things that are given high priority with NASA have to be of such a character that they hit the mission of NASA which is an R&D agency. As I mentioned yesterday, in the process of creating research facilities, you do have an additional capability of also meeting more near term requirements. The icing tunnel is an example of how it has been used repeatedly even for things related to certification. I could give you a better answer to the total picture on priorities and the facilities and funding with a few of viewgraphs.

RICHARD ADAMS - "Do you have them available?"

MILT BEHEIM ("Glad you asked"!)

Something seems to be lacking here. Can you see all right? I want to point out, this (Figure 1) is the present position of NASA in terms of policies regarding using NASA facilities and it's found in the Federal Register (Vol. 43, No. 193). There are different classes of facilities shown here in Figure 1. There is the unitary group of facilities which are basically wind tunnels that were provided in a separate act of Congress in the early 1950s. There are very few of them. One group at Ames, one at Lewis, one at AEDC. Congress stipulated that these at NASA centers would be available primarily to industry for development and NASA research, as time is available.

There is a second class of facilities that has come on the scene very recently. Three facilities that I referred to yesterday are called National Facilities. One of them is the National Transonic Facility at Langley, and it has a high operational cost because of the large quantities of liquid nitrogen it consumes. All of the National Facilities are available to all users, and there is a reimburseable policy for all users of the National Transonic Facility.

In the other National Facility action under way at the present time, there is modification of the Ames 40 x 80 tunnel to also include a 60 x 120 foot test section, for some of the VTOL and rotorcraft work. There is no special policy established at this time for fees to be charged once

that facility has been modified.

The other major facility which is in the National Facilities category is the \$470M engine cell at Tullahoma and I believe it will be used in the same manner as all their other cells are used and that is, outside users pay the fee. If it's an Air Force program I'm not sure how they handle the internal bookkeeping and transfer of internal funds.

So there's very few of those facilities. I suspect if AWT is built, because of the capital investment, it would be classified as a National Facility with a user charter, but I'm not sure of that.

All other NASA wind tunnels, including the icing research tunnel in Cleveland, are primarily for NASA research and industry work when it's in the public interest. And it can be in the public interest as a joint NASA/industry research program where the results of the research are widely available and disseminated through the normal NASA distribution channels, or can be used on the basis of a fee. The fee arrangement has not been used very frequently to my knowledge. Other classes of work are indicated on Figure 1. The classes of work are; they can be a company fee project if it's beyond the scope of an existing government contract. If it's supported in a government project with a government contract, then that test time is provided on the basis of that agency's request with no fee to that agency. The consortium project may either be based on private funding (on a fee basis) or a government agency may have a legitimate interest in that work and support it, with no fee arrangement. Foreign company projects are generally not accepted. The fee is based on occupancy charges as indicated here, including energy consumption and data reduction costs. The big costs are, of course, energy and the occupancy charge, which includes an amortization of the facility. Now there is one thing that has come along very recently that could influence some of this to some extent. I think all government agencies need to be aware of it. If there is a national icing tanker, you'd better raise the same questions, because there has been established by a new act of Congress, the Office of the Inspector General. We have such an office in Cleveland. They have recently completed a study of the aeronautics program and one of their recommendations is that research cost (not facility costs, but research costs) that are applicable in the near term to industry activities, should be reimbursed to the government. And that goes way beyond user fees for using a facility. It says, "..... reimburse the government for their cost in the research program". Now what the impact will be I can't tell, but I'm sure all the government agencies are going to be faced with the same question.

Now I want the next viewgraph (Figure 2). With those fee questions in mind, would the schedule of the icing research tunnel have changed if there were user's fees involved? Here's a quick glance at the schedule of the icing tunnel and it indicates to you its accessibility to the industry. You may not be able to read it, but this shows a list against a calendar, starting in July of '79 through about July of '80. There is some work

being done in this time period using laser equipment on calibrating the cloud uniformity. Another cloud uniformity test was performed to improve the distribution of the icing spray, an internal Lewis activity. The NTSB had an entry with an aircraft component for an accident investigation. The Army HISS spray system entered the tunnel here. McDonnell Douglas was in with an advanced ice protection method study. Air Force and NASA have a joint program on ice phobics and the Army's CRREL is a part of that activity. The entry is shown. Goodrich performed studies of a boot on a helicopter rotor blade. An entry here is the Mitsubishi 300 tail. Mitsubishi owns a plant in Texas and it's a producer of a particular kind of aircraft to be certified in this country and this is a certification entry. The Army's AAH-64 inlet entry. There's a instrument entry, its a Pacer system. Here's the Army's Hell Fire missile which goes on the attack helicopter. A test here for the Air Force ice phobics program with NASA. Another instrument. Another entry of the AAH-64, the target acquisition and data systems on the nose of the helicopter. A reentry of the Mitsubishi 300 tail. Incidentally, I might comment that most entries are repeated. Its not a straightforward process to get an ice protection system to work. Next slide (Figure 3). This is a study of ice accretion on some of the new general aviation airfoils. A grant from NASA to the University of Kansas to study TAKS system which is a liquid system for deicing that has been evolved in England and it was used on a general aviation wing. Another entry of pneumatic boots for general aviation wings, a program of joint interest between industry and NASA. The AAH-64 inlet, again, to solve a problem. Now I'm getting into something that's coming up in the future. The GAW ice shapes will be continued, the F-16 inlet is coming in, the strut in the middle of the inlet requires some ice protection. The Bell Helicopter inlet entry is shown. NASA and the Army have a joint effort on helicopter rotor test rig using the OH-58 tail rotor. The Army is providing parts and some assistance on funding. There's a Lear Jet entry. There's a oscillating rotor test, taking a blade from a rotor and not whirling it but oscillating it. Some work of this type has been done in England and they indicated some success in being able to do that to simulate properly some of the worst conditions that are required for rotor protection. A Piper inlet. The Air Force is coming in with a modification of the icing spray rig for the KC-135. We've got some maintenance work coming up here but out in the 82-83 time period we don't have any firm scheduling. Would these people have been there if there were fees? Only they can answer. NASA paid the cost of these entries and it's like \$25,000 a week. Did industry have access to the facilities? I would say so. I suspect the altitude wind tunnel would be used in a similar mode. But because of costs and because of increasing pressure on NASA on cost reimbursement, there's probably going to be a fee arrangement. I don't know what it is.

I would like to make a comment and this comment is from me and not as an Engineer at Gates Lear Jet. I was stimulated to thought by Mr. McCollough's comments and his questions and I'm sure that's what he intended rather than as any challenge to the industry.

He spoke about handouts and presented a challenge to industry accepting the challenge to go it on their own for icing. I guess I personally feel that, "yes, industry can go it on its own without government". I believe in the free enterprise system enough and I'm not waving a flag, but I believe in the system enough to believe that if there is a market and if it's practical, it will happen. As Dr. Rosen mentioned, in the case of the helicopter, if it's not practical to certify the icing of a helicopter, it just won't happen. I'm not sure that that's in the charter of the FAA to promote aviation, to allow something like that not to happen. If there are any handouts that we're talking about, I think that we all ought to remember it's not we or they paying for it, we're all taxpayers, and if the right hand is asking for monetary benefits, its because the left hand put that money into the coffers to use in the first place. So, look at it from the standpoint of it's money that we or they pay for. If industry is asking for when we can use it and how much is it going to cost, these are prudent questions to me. I guess that about does it, but I just don't like the idea of thinking in terms of: "You didn't pay for it, we paid for it!" Well, we all paid for it, and our main interest is promoting aviation and promoting our aviation so that it has a place in the world market, as I see it. Thank you!

RICHARD I. ADAMS

Well said!

When we originally started planning this meeting I was aware that there were several commercial tankers that were available, two of which you heard about today and I called these companies and discussed free enterprise and things like that with them. As a matter of fact, we mentioned free enterprise in the original letter that we sent to HAA, AIA and GAMA. We, the FAA, the government doesn't want to step on the toes of industry and you certainly have the prerogative of free enterprise. But I think, realistically, when you start looking at the magnitude of the facilities that we are considering, the outlay of cash, the funds, all the technology developments that have to take place to make facilities available for everybody's use, in industry as well as government, is so tremendous that there's not a single company that would be willing to put up that amount of money. It's going to be a tremendous amount of money. One facility we are talking about here, the AWT rehabilitation, is now \$150M for completion to Phase II. So its a tremendous amount of money. We believe that with a national program, where the FAA, NASA and DOD join hands, that we can serve the interest of this great nation, the government as well as industry, and we feel that we can accelerate the research, development and the certification process to solve the unknown questions that exist and also to reduce the cost of certification. My understanding

of the FAA's charter is to foster American aviation and make American aviation competitive and I think that's a good charter and I think that the national facilities program will help to do that.

One other comment. I think what Milt Beheim has just outlined here is the fact that right now there are no national icing test tunnels. In other words, the IRT is not a national facility. It can be used to serve industry purposes under certain circumstances. The AWT would be a national facility. It would be available, but it's going to cost the user a certain amount to use it. My personal feeling is that each individual company is going to have to assess those costs and determine whether or not they want to use that facility. One thing that is very clear to me in looking at these charts and that is the IRT is booked up through about mid-1982 right now. I know that Milt has been able to work in certain high priority programs in the past year and get it done. But it's apparent to me that bigger and better icing tunnels are needed and the AWT is one step in the right direction. It's apparent to me that there are other tunnels that can bear improvement right now and the IRT is one of those, as has been very aptly pointed out here today.

Yes, Herb.

HERB SLAUGHTER

This question may have been asked while I was out of the room shortly. In the AIA and in the HAA in the helicopter area, we certainly support the AWT proposals that Milt has set before us. One of the things that appeared to me that might give us what we wanted in the time frame that we wanted is the fact that this AWT modified or put back in rehabilitated, would start operation in 1987. Now that's a long time to wait for a facility like that. Now, could I ask Milt a question? What would it take to step that up two or three years? I might recommend that when the Task Force is considering the degree of support that they might assess the financial requirements and costs to step up the availability of the AWT. Yesterday we say that this was a facility that wouldn't only help the helicopter manufacturers, but it looked like it was almost an across the board facility with regard to the civil aviation industry and military also.

MILT BEHEIM

It was originally proposed by me to be a construction project in the fiscal '83-'84 time period. In other words, start construction a year earlier and do it in two years rather than in three years. I was very disappointed when within NASA the judgement was made that they couldn't muster the resources in the concentrated form that was required to actually achieve that. Plus the fact that the advocacy of industry was not yet solidified. A decision was made within NASA to go to the present construction schedule, and that is '84 through '86 construction and '87 start-up. I think if you people have a strong interest in the facility, recognizing that many of us will still be

MILT BEHEIM

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working in the business in '87, that it would be very effective if you encourage rapid construction, because then we might have it in '87. And if you didn't, you won't have it then either.

RICHARD I. ADAMS

Can we use this meeting and the consensus established in the meeting to conclude that the schedule should be accelerated? Is that a consensus of the industry representatives? Yes Ken!

KEN ROSEN, HAA/AIA

I think, to repeat, our consensus was that steps should be taken to improve the IRT and then to proceed with the AWT. Quite candidly, I'm not at all surprised by the schedule that you've put up there, which I might add has been pretty much the situation in the IRT for several years. I also have to take umbrage with you Milt, there are many people who manage to get their solution the first time. You don't always have to go back. But to answer your specific question on accelerating the schedule. With the newer generation of helicopters now entering service and with most of the major American helicopter companies seeking certification in one form or another of their new generation of helicopters, it would be to our national advantage to accelerate the schedule so that we could become competitive in the total world market place. We're no longer unique in the area of rotorcraft. Certainly the Europeans are moving very, very rapidly and I expect that many of us believe that we will see a strong threat from the Japanese when and if they decide that this will become their next technological thrust. It is clear to me that if we're going to make our helicopter market "safe" and in fact a growing presence in the world marketplace, that we must proceed with immediate certification of our new generation of helicopters for an icing environment. One way to do that would be to accelerate the work that Milton has been talking about.

HERB SLAUGHTER

I would like to underscore Ken's observations on acceleration, I hate to get into class distinctions here, but in the lighter aircraft we foresee, by '85, at least two, or maybe more, sophisticated and higher density commuter aircraft. Obviously these will be new generation aircraft taking advantage of a number of the advanced technologies and I think that from an acceleration viewpoint, this lends further to the thought.

MILT BEHEIM

I'm sure that if any of you that have worked with major facilities realize that a major facility is like a project in the sense that if you're working on a new engine system, it takes a certain number of years to get it ready, whatever it is. The unfortunate problem in selling any major facility is that the project that you know could use it will

MILT BEHEIM

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probably be done by the time the facility is done, because each one has about the same time period to accomplishment. Therefore, really a major facility decision is a philosophical decision, on whether or not that capability is required in the future and you may not know in detail who is going to use it and how. The classic example is the 30 x 60 foot wind tunnel down at Langley. It goes approximately 100 MPH, it's been in operation for 50 years, it's still operating and it has had the shuttle in it and subsonic transport airplanes and everything that people never even imagined was possible when they convinced somebody to build it. Every major facility is that way. A major facility has a life of at least 50 years, except in the case of the AWT when NASA went out of aeronautics to the extent that they made a space tank out of it.

KEN ROSEN

Question! Do I hear from Milt that you wouldn't like to have support for acceleration?

MILT BEHEIM

I do, indeed, want support for acceleration because if there isn't support for acceleration, it may not be ready even in 1987. Be realistic enough to recognize that any need that you foresee at the present time, is nip and tuck in terms of getting the facility ready in time, because each one is a major undertaking. Especially within the government where there is such a long approval process. It isn't easy to get a \$150M from the Carter Administration these days.

KEN ROSEN

I see. What you're saying is: "Give your support but don't get over enthusiastic about acceleration and shortening the time period".

MILT BEHEIM

I think the technical part of it, like the construction period, could be shortened a year with overtime and that kind of thing, because the plan was originally based on that premise. I think it is too late now, though, to start construction in '83 as opposed to '84.

RICHARD I. ADAMS

I think that the important issue is that there is an identified need to shorten the schedule if possible, and I think that should be the consensus of this meeting. I agree, wholeheartedly, with the point that Milt has made here, that typically we always base our future needs on immediate requirements and we can't do that. I think that its quite obvious that we are beginning to see the tip of the iceberg with helicopters, new helicopters, new generations of helicopters. We've got a problem right now. We need the facilities right now. We only have plans for a few helicopters right now, but there are going to be

RICHARD I. ADAMS

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more new ones in the future and we've got to have the facilities that will help certify those helicopters in the future. If we don't start now, we'll never get there.

There's a question over here that has been trying to pop-up for quite a while, Ken, excuse me.

LARRY KOEGEBOEHN, DOUGLAS AIRCRAFT

And I would like to throw one more stick on the fire here. We have needs in the large airframe manufacturers too, for icing tunnels and I'd like to kind of go towards that AWT because right now the IRT is too small for some of our components. We can put a wing tip in there, but that's about it. We need the high altitude and the higher speeds because that's where our design conditions are for airframes. The high speed hold condition for 45 minutes is generally our design condition. With the big emphasis on the use of bleed air on our aircraft and the penalties that are involved in that, our next step is to design some systems, develop some systems that make less use of bleed air, lighter in weight to cut down the drag, increase the payload capability of our aircraft. So, that's where we're at, we need something to develop some new systems in. We can do some of that in the IRT, but we do need the AWT in the long run to help us refine those systems and make them more economical. So I would just like to put that on the record for where the airframe manufacturers are coming from. Thank you!

MILT BEHEIM

Our AWT would be unique in the country in that it's the only tunnel that would provide a simulation of the pressures and temperatures that occur at altitude.

Lockheed has pointed out to us that not only is it therefore applicable to icing problems, but even as a test means for composite structures under the temperatures and pressures that exist in flight and with large scale composite structures. That's the only place you would do it. There's only one tunnel in the country with a refrigeration plan standing next to it. It's in Cleveland and it's idle.

RICHARD I. ADAMS

Dr. Rosen had a question a moment ago.

KEN ROSEN

There are several opportunities that a tunnel of this type would provide and that would allow us to look at relative high tip Mach number characteristics and that has not been raised, and insofar as rotorcraft, it does have value. To add to your point Dick, Bob would reinforce this. My understanding is that we're projecting as an industry something like 20,000 helicopters by the year 1980 and perhaps double that by the turn of the century. The comment that I made before is very applicable.

KEN ROSEN

(General Discussion/Questions and Answers)

I'd like to make sure that the greater number of those helicopters are manufactured here in the United States and I believe that the acceleration of this facility would help that situation. Milt, you indicate, and I'll be very specific, you indicate we couldn't get started. Well, you know "couldn't" is a great word. What do you mean? Why couldn't we get started? Who do we have to see and how do we do it? I mean, the word "couldn't" is kind of a word that offers a challenge to us and I just wondered is there anyway that maybe we don't go through normal channels. Is there a way to accelerate this facility? I might add that many of us are looking at programs that are not the "now" programs, not the Spirit programs, not the Bell 412 type programs or the Bell 222 type programs, but the types of aircraft that we have in mind and are now beginning to conceptualize that will not be certified until late in this decade. It is those aircraft that I'm speaking to. It is those aircraft for which this tunnel will be directly applicable.

MILT BEHEIM

The overwhelming factor will be the voice of industry, because I believe that there has been sufficient discussion within government circles that the government's position is pretty well in place that there is, indeed, support for the use of AWT and particularly strong in the Army. I think it will be significant in the Navy, but I'm not sure yet and less sure of the Air Force because even though they have important cruise missile icing work underway we don't quite fit their time frame again. Therefore, most of the discussion that has occurred on AWT has occurred within government circles and with advisory groups from the industry and NASA has such a structure of advisory groups. But some of the representatives from the companies to these advisory groups don't know about these problems. You can't pick out a man who knows all about NASA. I presume the same problem exists that you can't pick out a man who knows all about Boeing and represents them in its entirety, even though they may have outstanding expertise in icing work, their representative where this is presented may know nothing about it, unfortunately. So therefore, if you in your own companies know some way to get word to your representatives, we think it could be very effective.

RICHARD I. ADAMS

Any other question or comments?

PAUL KARMACY, CENTRAL REGION

I think we are a little bit stymied right now in that in the discussion and with all the emphasis on the icing tunnel, that we've suddenly come to the conclusion that a helicopter cannot be certified for flight in icing conditions because we've placed so much emphasis on initiating or establishing the wind tunnel that is adequate, we just can't go on. And we've all gotten up and expressed our needs and I'm going to express our needs from a regional certification standpoint and that is, I was under the impression that in establishing test

facilities that, from a regulatory standpoint, the FAA, and the FAA does have an obligation to provide this, that the FAA would provide up-to-date criteria and an up-to-date definition of the icing envelope for the different classes of aircraft. The wind tunnels and the icing facilities would be a great aid in this end result for all of us. I feel that the national icing facility would provide the FAA, from a regulatory standpoint, and the applicants themselves, some good definitions of the icing envelope and a long list of equipment and means of verifying test parameters or icing parameters that would be available to industry and the government, as well, to allow anyone who wants to develop a test facility or a test rig in meeting this nationally defined criteria. Now I'm going to digress and get back to the problem that we're all faced with and that we're all sitting here hopelessly wondering how we are going to get from here to there on helicopters. Just sitting back listening to all of you talk, it sounds like no one would be able to make a move as far as certifying a helicopter for flight in icing conditions for another seven years. I think as the FAA, we have an obligation to define an acceptable means of certifying a helicopter for flight in icing conditions now. The national test facility would be just another tool available in the future for assisting industry and the FAA in reducing the time and cost in certifying.

RICHARD I. ADAMS

I think your comment is very well taken. The Technical Center R&D program is trying to focus on gathering enough facts to change the criteria if it needs to be changed. Those facts aren't available yet. The Technical Center also is trying in a supporting role to assist the southwest Region in anyway we can, in certifying the 412 helicopter, which is the first application in the United States for the certification of a civil helicopter. We have tried to take advantage of all the technology that exists and we've raised specific recommendations to the Southwest Region how to go about this. There's no question in my mind that, if the 412 helicopter is certifiable, that it can't be certified in the next two or three years. I think that if adequate facilities existed, that time frame could be reduced significantly. I think the same will be the case for the S-76 when, and if, Sikorsky applies for certification. I think the same is the case for the 234. We're departing a little bit, I think, in the case of the 234 because there, I don't know the proper terminology, but I don't think an official application has been submitted. The Eastern Region is working with Boeing Vertol in determining whether or not it's feasible to try to certify helicopters without rotor blade ice protection for a limited envelope. All this is based on work that the British have done. For example, some of you are aware that the British are currently operating the S-61 type helicopter over the North Sea, and certain corridors, under specific, definitely defined, limited conditions and the British Armed Forces are operating the Sea King and the Lynx under similar conditions. The British spent 10 years and finally are allowing themselves to do that. I don't think it's really a question of whether or not we can or cannot certify a helicopter, I think we can. The point is, it's going to cost a lot of money on the part of the company doing the certification and I think we

RICHARD I. ADAMS

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need to use this as an indicator that, for the future, we need and we must improve the facilities that do exist and try to identify and develop new facilities that will be of benefit to the country, both for the industry to use and for the government to use, and military qualification testing. Yes Herb.

HERB SLAUGHTER

Seeing no other hands, I thought I might pose this question as a lead toward closing the meeting. Throughout the last couple of days we've been hearing the use of the term "Task Force", or National Icing Facilities "Task Force". Could you explain to us what the National Icing Facilities Task Force would be? What its charter would be and what its composition would be?

RICHARD I. ADAMS

In our presentation yesterday I had a viewgraph that showed the basic plan of attack and that was to use the results of the meeting that we hosted here in January, a government coordination meeting, and the results of this meeting, as a basis for the FAA Technical Center putting together specific recommendations, what the facilities needs and requirements are, and for suggesting the establishment of the Task Force. Now, as we see it, that letter would be signed by the FAA Technical Center to FAA Headquarters, that letter would also transmit a suggested letter to DOD and to NASA and ask for the development of that Task Force. Now, already the FAA has designated two people to work on this problem, Tom West and "JB" McCollough. At the January meeting one of the conclusions that we drew was that NASA and DOD needed to name specific people who are recognized experts in research and development field and in the facilities area, that can bring this whole thing to fruition. The charter of the Task Force would be to first develop a viable National Icing Facilities Program Plan. That's going to take a lot of work. It's going to take a lot of coordination with industry and all the other government agencies, but we've got to have that Task Force as a focal point to get that job done. Once the program plan is considered to be a viable plan then comes the task of securing resources. It's going to take that Task Force a tremendous amount of time and resources to do all the convincing and briefings, etc., that will be necessary to secure the funds. I think that the minutes that will come out of this meeting, and I sure am glad that we have tape recorded it so that we can accurately document the proceedings. But I think there are a lot of very valuable comments and indications of concerns that need to be included in that report. I think that we must not forget the things that have been said today.

HERB SLAUGHTER

Dick, a question. I understand the charter, if I'm reading you correctly, the composition would be FAA/DOD/NASA only without any participation from industry?

RICHARD I. ADAMS

(General Discussion/Questions and Answers)

It would be, as I envision it, a government Task Force, the government Task Force would perform the coordination of industry. But I think that this meeting sets the basic stage for that coordination.

HERB SLAUGHTER

It's really a government Task Force? That's what I wanted to get clear.

RICHARD I. ADAMS

That's my intent.

MILT BEHEIM

Dick, can I comment on what you just finished saying?

I am involved in a similar activity as this in the Aeronautics and Astronautics Coordinating Board of the DOD and NASA. The same AWT discussion, the same presentations are made, but to a government group. If you're looking ahead to the future I suggest you consider some way to marry forces, with the damn number of presentations I have to give.

KEN ROSEN, HAA/AIA

I'd like to support Milt's comment. I was about to make the same comment. It seems to me that we have had a real good meeting here and we almost have a consensus, very nearly a consensus. I might add that most of the leading researchers in the United States are here, or representatives of them are here. It seems to be that we have taken a position. It seems to me that we have had that working session and it seems to me that we ought to forward to the various administrators and appropriate government agencies with a very firm recommendation right now. Not only to form a joint working group, which I think is fine, but to step out lively in the area of specific improvements in their current facilities. I don't mean to, in anyway, indicate that I don't support the proposed formation of this joint working group, Dick. I certainly do so! But I do feel that enough has been accomplished now that you can proceed with strong positive recommendations to support Milt's efforts, the efforts of Harry and others and get them that little bit of extra support so that we can proceed in a more timely fashion.

MILT BEHEIM

I would like to underscore again the need for a timely and lively reaction of the FAA because the AACB is moving along at a quite rapid pace. It will be elevating things to high levels within the government in a short period of time and the FAA is the only major government agency that has not officially commented upon the desirabilities of the rehab of AWT. All other major government agencies have responded.

Q. Can you identify once again for us, the acronym "AACB"?

KEN ROSEN

(General Discussion/Questions and Answers)

Aeronautics and Astronautics Coordinating Board, which is an interface between the Department of Defense and NASA in regard to programs and facilities of a major nature.

"JB" McCOLLOUGH

Harry, I would like to ask you a question. Now you've been sitting right there next to Milt and he's pleaded with this audience and they responded for the past hour in helping him accelerate his program. However, you have a live bird coming at you this next icing season in behalf of industry and yet you and I know that you could also use some help in your efforts in your facility. Is there anything this group can do that you can identify to help you and this whole community get on with that program that you've got, in supporting the industry people sitting around you here?

HARRY CHAMBERS

Thanks "JB". Can you send money?

"JB" McCOLLOUGH

No! I was wondering if you could get these people to help send money. I've done all I can Harry, you've got to lay off me now for awhile.

HARRY CHAMBERS

O.K. I wish I knew how to answer that. It's an internal problem getting the HISS further developed. We've had tremendous support from the FAA. It's taken us a little while even in-house with AVRADCOM to even have a HISS improvement program recognized that's a non-funded priority. I was hoping that this next fiscal year that we would be able to start in on the large improvement program such that in two years, two icing seasons from now, we would have the improved HISS. There have been other priorities in the Department of Army though and we're unable to get the funding. So, as far as you helping us, other than having money, I don't know how at this particular point. Now we've talked about this a little earlier and we do have some things coming up and to respond to that I have to get some more information back at our headquarters, which will be this week. So I'll be in contact with you folks next week to find out what kind and if we can get any help. But in the interim, I think I covered this yesterday, we have a short range improvement program where we hope to be putting in some added air into the HISS and possibly expand on the envelope and the capability of the HISS for, not this coming icing season, but the next one.

"JB" McCOLLOUGH

I guess what generated my question was the statement of Dr. Ken Rosen, he says to Milt; "Who do we see and what can we say to help you accelerate your construction schedule", and I was hoping that he would ask you that too.

KEN ROSEN ?

(General Discussion/Questions and Answers)

Seriously, Harry in support of "JB"'s comment, would a letter to DDR&E, to the Dick Lewis', to the Dean Borgman's, to the Ballard's, would that help you get the priority that you're talking about? You indicated, "hey, I don't have that priority". Would that help?

HARRY CHAMBERS

Yes! That would help, but the thing that I feel that I have to do first is carry it in-house, and I think it would be unfair to the Command that I'm in to start crying wolf at this particular time. I think we need more of an impression in-house as to how much support we have gotten from the FAA to get as far as we have on the development of the HISS. You know, once upon a time many years ago, we started out with that thing back in 1972, you know we've come along ways and it's really been recently when we've finally have had a viable machine which will simulate, fairly well, natural icing conditions. That's really been through the FAA's help in all this. You've got to recognize too, that any future development on that HISS is going to be predicated, just like Milt was saying, on what programs can you identify that are going to be coming down the pike. Well, for the Army, what do we really have? I don't see too much unless the AAH picks up again the following season in case something happens this season. The Black Hawk, I think, is fairly well through. We have the ASH coming down the pike, but other than that I don't see too much. So... Its one of these things, you know, we have to have a lot of support from industry too and from the FAA and indications that there will be a lot of use for the HISS, because it costs the Army a lot of money to maintain it. AEFA spends a considerable amount of its time maintaining that HISS and keeping it going every year. It's a big effort and I think you're well aware of that.

KEN ROSEN

Harry, I certainly can see several other military applications which might come our way. Certainly Sea Hawk, Quick Fix, Moltuse, the Army has in its R&D plans the ever present ASH, the LHX, the AHX, that kind of thing certainly in the late 80s, early '90s. That, and by-the-way, the 43E coming the way of the Marines.

HARRY CHAMBERS

We've got to remember too, Ken, and that is that many of the aircraft that we are talking about don't require an icing capability. So a lot is going to be predicated on that. But going right back... Ken says - you're doing a lot of work for nothing. You've got icing capabilities on everyone of those aircraft, except for the ones that haven't been invented yet. Well, we have a particular user out in the Army community and of course they have the requirements in its cost effectiveness so, we're not facing requirements so we can't really say at this point in time.

HARRY CHAMBERS

(General Discussion/Questions and Answers)

This is going back to the very beginning here, OK. What is it that you can do to help us?

Let me work the problem in our Command first and I'm hoping that when I get back next week, that I'll be able to do some talking and convince the people, which I think already know about it, the total effort that the FAA has put into this and how we have to continue it on. A lot of the tests we have coming this icing season are based on FAA support and also ATL and AEFA, plus what we're doing. But, I'll get back with you as soon as I find out.

DON'T KNOW WHO IS SPEAKING

Harry, I guess it's a question of whether it's acceptable to consider the HISS as a national icing facility. If it is, then, you know even though it's under the Army cognizance, it should get consideration for this little industry use. Not only just on a basis for, if it's available, but maybe on a "first come-first served" basis at some stage.

HARRY CHAMBERS

We haven't really ironed out how we are going to do that yet. You realize the Army programs have priority. But we have essentially six different icing projects this icing season which is a big load. We're programming about 80 hours on the HISS. Now that's one aircraft and that's an awful lot of flying to get done in a short period of time, that is this winter season. With 80 hours you could do quite a bit. This season I think we are pretty well filled up. We've got the 412 in there and we feel that's sort of like a private project and we'll see how that works out and then after that time I would see the aircraft available for industry and it will be quite a bit of time there and more than likely on a "first come-first serve" basis.

RICHARD I. ADAMS

The civil need for a civil tanker of that type should be justification enough for wanting to accelerate the improvement of the HISS, and the accelerated planning for, what I call a national inflight icing simulator that could be used for industry or by the government. In the old days there was somebody that said that we should have one airplane. Let all the pilots take turns flying it, that was great. Now we've got just one tanker and we can take turns using it. I don't think that one tanker in this country is going to be enough to cover the workload of the future. It's hardly enough to cover the workload right now. And as you pointed out, the numbers of aircraft that are going to be coming back in the 1990's indicate that we need to start planning now for the facilities that will be needed then. I guess I'm going to try to sum up now. I will refer back to the viewgraph that I showed in my presentation yesterday that summarized the key conclusions of the government coordination meeting that we had back in January and those conclusions were, and this wasn't published in itself, but I think we all felt that anything that could be done to improve the icing test facilities that

exist today would be worthwhile because the facilities are in such poor shape and there's just not enough of them. We did identify specific things that we felt needed to be done right now. Number one of that list was rehabilitation of the altitude wind tunnel. Now the FAA has not yet officially responded to NASA and given direct support of that rehabilitation. And frankly, I have personally been waiting for the results of this meeting so that we can provide that response in conjunction with the letter that we will be sending to FAA Headquarters.

Secondly, we felt that there was a dire need for the development of the National Inflight Icing Simulator for use in research, development and certification with the full understanding of a combined objective and desire that simulated icing testing, using the tanker, or tunnel testing, could drastically reduce the amount of natural icing testing that would have to be performed in the future, for certification purposes.

Third, there was a considerable need to continue the flying of a test bed helicopter because there are so many unanswered questions that exist today. Gene Birocco gave us an outstanding presentation yesterday on the UH-1 and what it has accomplished, and its problem areas. I think there is a need to examine whether or not the U.S. Government should allow that aircraft to stop flying or to have a replacement for it when it's economically feasible for it to stop flying. Finally, there was a need to have a Task Force established, not only to accelerate and secure the funds for accomplishing these specific things, but also to identify the other test facilities that could be improved and how to go about doing it and to provide the resources and the justification for doing that. Now I think that what I've heard here today from the industry consensus is that industry would like this approach to take place and they would like certain efforts to be accelerated. As we have been talking here about the altitude wind tunnel rehabilitation and accelerating that, I was really trying to apply that same logic to the acceleration of the whole project, of the whole effort. Not only accelerating the altitude wind tunnel, but the HISS improvement program, the National Inflight Simulation, and the other tunnel facilities. There was one item that I failed to mention, that was the retention and the possible improvement of the Ottawa Spray Rig. I think that we have made progress there, and, as I read the consensus we are in agreement that a ground based facility of that type is needed.

The thing that the Task Force needs to wrestle with is how best to go about doing that, whether or not we can convince the Canadian government to improve that facility or whether to build a similar facility south of the border. There's a lot of considerations that have to go into a decision of that type. I, in a nut shell, think that the meeting has been very, very productive and I think that we now have enough information to go forward and recommend the establishment of this Task Force or steering committee or whatever the name of the group of people would be. I think we have enough information to make specific recommendations on things that should be done and we have some information on orders of priority.

DON'T KNOW WHO IS SPEAKING

(General Discussion/Questions and Answers)

Dick, relative to your Task Force again, I certainly agree with it and I think it's needed and I think it can help to affect the things that we need that we've discussed here in the last two days. There is a need for communication though. You've asked for help from industry and if we have to wait for other meetings like this to get communication, in order to serve as help for you, then time will disappear and there will be a lag. I would like to recommend that you, in establishing your Task Force, also establish an industry advisory group that you could communicate with when things surface, in case you should need some accelerated action from industry. I think in that way we could keep communication and keep acceleration on the program and pinpoint efforts to help the Task Force get its job done.

MILT BEHEIM

That is a very important suggestion because the AABC has decided that in the next few months we will have to start the industry survey and evaluation of responses. If we knew who to talk to it would help a great deal. Now AWT is a bit complex in that we don't view icing applications as the sole long term application for the facility. We will, indeed, be interfacing with other industry users of those additional capabilities. If we could get some way of concentrating the industry's views for icing activities I would encourage you to do so as soon as possible to help the AACB in their discussions and deliberations.

DON'T KNOW WHO IS SPEAKING

Bob, maybe you would have a suggestion. The alphabet groups might be able to focus attention relative to people that could serve as a sort of a listening post or contributing steering group, not a steering group particularly, but a communication group with the Task Force.

JIM DOUGHERTY

Mr. Chairman, we endorse the idea. GAMA endorses the concept of increased communications.

RICHARD I. ADAMS

I think that --- the recommendations that we will send forward will include the recommendation that there will be an industry advisory group established as a method of providing communication between the Task Force and industry. I see that as a very simple thing to accomplish.

Its now 3:22. The ground rules that I understand for the tour of the R&D facilities here, was if we didn't make it by 3:30 we wouldn't make it at all. Right Charlie? So we have just a few minutes to get there. For those of you who would like to attend the R&D area tour run out and jump on the tram with the tour guide and go. The others who would like look around the building here, just meet us in the lobby and we will show you what we can.

RICHARD I. ADAMS

(General Discussion/Questions and Answers)

My personal thanks to everybody for the fantastic participation and assistance in bringing this meeting together and making it a good meeting. I appreciate and I certainly enjoyed it myself.

Thank you all for coming.

THE END!

USE OF N/ WIND TUNNELS

UNITARY

- o PRIMARILY TO INDUSTRY FOR DEVELOPMENT
- o NASA RESEARCH AS TIME AVAILABLE

NATIONAL AERONAUTICAL FACILITIES

- o FOR ALL USERS
- o REIMBURSABLE POLICY FOR NTF

ALL OTHERS

- o PRIMARILY FOR NASA RESEARCH
- o INDUSTRY WORK WHEN IN PUBLIC INTEREST
JOINT NASA PROGRAM
FEE

CLASSES OF WORK

- o CO. FEE PROJECT - BEYOND SCOPE OF GOVERNMENT CONTRACT
- o GOVERNMENT PROJECT - AGENCY REQUEST, NO FEE
- o CONSORTIUM PROJECT - FEE OR AGENCY REQUEST
- o FOREIGN CO. PROJECT - GENERALLY NOT GRANTED

FEE

- o OCCUPANCY CHARGE
DIRECT MANPOWER
MAINTENANCE
DEPRECIATION
OVERHEAD
- o ENERGY/FUEL
- o DATA REDUCTION

Figure 1

[illegible]

LEGEND.

..... H = HARDWARE I = INSTALLATION T = TESTING M = MAINTENANCE O = OPEN / = SCHEDULE COMPLETED @ = NEED DATE

Figure 2

[illegible]

LEGEND.

..... H = HARDWARE I = INSTALLATION T = TESTING M = MAINTENANCE O = OPEN / = SCHEDULE COMPLETED @ = NEED DATE

Figure 3

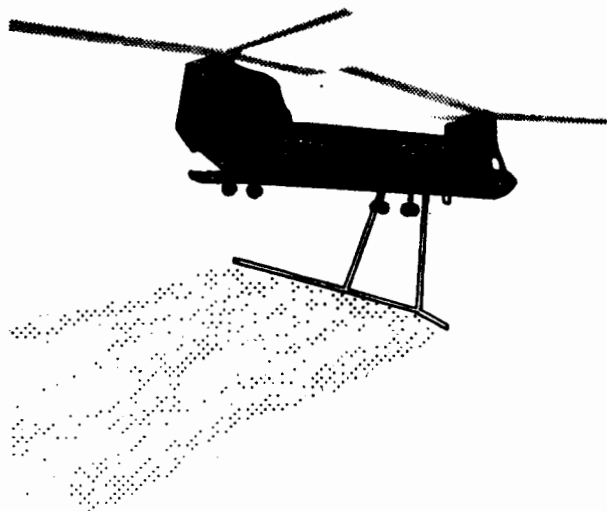
APPENDIX A

MEETING ANNOUNCEMENT

The meeting will be held in the auditorium of the new FAA Technical Center Building. Registration will be from 8:00 -9:00 a.m. on September 23, 1980 in the lobby. To facilitate registration, please complete the attached form and return by September 16.

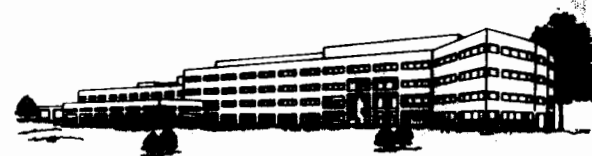
HOTEL ACCOMMODATIONS

A-7

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FROM SOUTHERN NEW JERSEY, drive north on Garden State Parkway to Exit 36 and follow signs.

Atlantic City Airport, New Jersey 08405



ANNOUNCES

NATIONAL ICING FACILITIES COORDINATION MEETING

FAA * NASA * DOD
INDUSTRY
HAA * GAMA * AIA

SEPTEMBER 23 - 24, 1980

REGISTRATION	8-9 AM	SEPT 23
MEETING CLOSES	4 PM	SEPT 24

THE MEETING WILL BE HELD IN THE
AUDITORIUM of the NEW Technical Building
AT THE

**FAA TECHNICAL CENTER
ATLANTIC CITY AIRPORT, NEW JERSEY 08405**

REGISTRATION FORM

FAA/INDUSTRY NATIONAL ICING FACILITIES COORDINATION MEETING
SEPTEMBER 23 and 24, 1980

NAME: _____
TITLE: _____
COMPANY: _____
ADDRESS: _____
CITY: _____
STATE: _____
TELEPHONE: HOME _____
BUSINESS _____
ZIP: _____

MAIL TO: FLIGHT SAFETY RESEARCH BRANCH
ACT-340 (ATTN: C. MASTERS)
FAA TECHNICAL CENTER
ATLANTIC CITY AIRPORT, NEW JERSEY 08405

BACKGROUND

The FAA Technical Center (formerly NAFEC) hosted a government coordination meeting on National Icing Facilities on January 16, 1980. Key results of this meeting indicated that several actions were necessary, by the government, to assure that icing test facilities would meet future government and industry demands for aircraft icing certification, research and development. These actions included:

- Possible rehabilitation of the NASA Lewis Altitude Wind Tunnel
- Retention of and possible improvement of the Ottawa Spray Rig
- Identification of the need for a National In-Flight Icing Simulator
- The need for a National Icing Facilities Steering Group

MEETING OBJECTIVE

To obtain industry consensus on National Icing Facilities requirements to facilitate FAA recommendations regarding a National Icing Facilities Effort.

SCOPE

Discussions will address:
Icing wind tunnels, icing test chambers, snow simulation facilities, freezing rain simulators, ground based facilities, in-flight icing simulators and analytical tools for use in icing research, development and certification of military and civil helicopters, fixed-wing transport and general aviation aircraft.

NATIONAL PARTICIPATION

Agencies of the FAA, NASA and DOD will describe existing icing test facilities. Other agencies of the government are invited and encouraged to attend. All interested aircraft manufacturers and commercial testing agencies are invited. HAA, AIA and GAMA are participating in the planning and execution of the coordination meeting.

TENTATIVE AGENDA

SEPTEMBER 23

MORNING

- 8 - 9 REGISTRATION
- 9 - 12 FACILITIES OVERVIEWS

AFTERNOON

- 12 - 1 LUNCH
- 1 - 4 FACILITIES OVERVIEWS
- 4 - 5 TECHNICAL CENTER TOUR

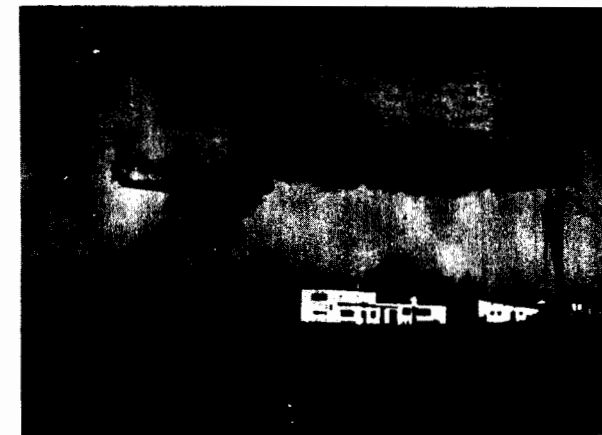
SEPTEMBER 24

MORNING

- 9 - 12 INDUSTRY PANEL DISCUSSIONS

AFTERNOON

- 12 - 1 LUNCH
- 1 - 4 GENERAL DISCUSSIONS
& SUMMARY



During facilities overviews various government agencies will describe icing test facilities existing in North America, issues concerning industry use of these facilities and improvements planned. Panel discussions will be for the purpose of establishing an industry consensus on current and future icing facilities needs with the assistance of HAA, AIA and GAMA.

APPENDIX B

MINUTES

NATIONAL ICING FACILITIES

COORDINATION MEETING

MINUTES
NATIONAL ICING FACILITIES
COORDINATION MEETING
held at
FEDERAL AVIATION ADMINISTRATION
NATIONAL AVIATION FACILITIES
EXPERIMENTAL CENTER
ATLANTIC CITY, NEW JERSEY
on
JANUARY 16, 1980

The meeting was convened at 9 a.m., in Building 10 at the Federal Aviation Administration's (FAA), National Aviation Facilities Experimental Center (NAFEC), Atlantic City, N. J.

Mr. Michael Brandewie, Acting Chief, Engineering Management Staff, NAFEC, opened the meeting and welcomed representatives from the National Aeronautics and Space Administration (NASA) and the Department of Defense (DOD) on behalf of the Director of NAFEC.

Mr. Brandewie provided the purpose and objective of the meeting, identified Mr. Tom West of the Helicopter Program Staff, Washington, D. C., as the FAA Systems Research and Development Service representative, and introduced Mr. "JB" McCollough, Chief of the Operations Branch, Aircraft Safety Development Division, as the NAFEC Program Manager. He emphasized the FAA's interest in resolving the urgent need for improved icing facilities, the fact that the FAA is taking positive steps toward this objective, and that this is evidenced by the tasking of NAFEC to take the lead within the FAA to establish the requirements for national icing facility resource requirements.

Mr. "JB" McCollough described the mission, functions, and organizational structure of the Operations Branch, and introduced Mr. Dick Adams as the Helicopter Research and Development Program Manager, and the meeting chairman.

Mr. Adams provided an agenda (copy attached), and emphasized the meeting's objective to: 1) develop methodology for implementing national programs for developing and improving national icing facilities for research, development, and certification purposes; and 2) initiate the evolution of a national plan that would provide the basis and justification of such a national effort. He emphasized also that a primary objective was to obtain agreement of the agencies represented, that the NAFEC proposed national facilities approach is sound.

Mr. Adams provided, as introduction to the meeting, a brief description of the background leading to this meeting.

BACKGROUND.

Aircraft icing certification in the past has relied very heavily upon natural icing testing. Provisions exist in the Federal Aviation Regulations (FAR's) for use of analytical prediction techniques and simulation, but the final proof is flight test in natural icing conditions. This procedure is expensive and time consuming, especially for small, low speed aircraft such as the helicopter and single engine fixed-wing, general aviation aircraft. With these aircraft types, range and endurance are extremely limited as well as the ability to climb to higher altitudes.

These features are essential for conducting natural icing tests to allow finding the various representative conditions. Larger, high performance aircraft do not suffer in this respect because they have the necessary range and performance to fly to prevailing icing conditions for test purposes. Helicopters and small GA aircraft are restricted to a small geographical area and must await the proper test conditions moving into the operational range and altitude of the test aircraft.

Past experience of the U.S. Army, the United Kingdom (UK), Canada, France, and Germany in attempting helicopter natural icing testing for research or certification purposes indicates strongly that, with existing icing test facilities and use

of natural icing tests, 3 to 5 years are required to acquire sufficient flight test data for certification purposes. The conclusions that we must draw from this are: 1) icing simulation is essential to reduce the cost and time required for certification; and 2) existing icing test facilities are not capable of handling the requirements and traffic of today, and certainly cannot handle the traffic of tomorrow, the near future, or long-term.

These points have been identified and discussed at national and international meetings and symposiums for the past 3 years. As a result of these discussions, several individual agency and interagency cooperative programs have been initiated.

NASA has established an Icing Research Group at the Lewis Research Center in Cleveland, Ohio, and since 1978, has initiated several research projects using the Center's Icing Research Tunnel, studied the icing test facilities of North America, and devised detailed plans for rehabilitation of the Center's Altitude Wind Tunnel for use as an additional and a larger icing research facility.

The U. S. Air Force has become dedicated to improving their NKC-135 icing tanker aircraft and has plans for development of a paletized system for use in the C-130 or C-141. The U. S. Army is in the process of improving the Helicopter Icing Spray System (HISS), a CH-47 helicopter equipped with a spray boom. The FAA is providing funding and technical support of the HISS improvement program.

The U.S. Navy is continuing to improve the icing test facilities at the Naval Propulsion Test Center in Trenton, N. J.

The Arnold Engineering Development Center is enlarging engine test facilities.

A significant problem was identified during the June 1978 NASA workshop on Aircraft Icing held in Cleveland. This problem is paraphrased as follows: The present stable of icing tankers is limited to organizational and jurisdictional boundaries and, for practical purposes, are totally inaccessible to the civilian industry. The U.S. Air Force and U.S. Army have, however, since indicated that the NKC-135 tanker and HISS can be made available for commercial use at cost if there is no interference in high priority military requirements.

The civilian industry cannot afford the time and expense of developing, building, maintaining, and operating their own facilities, and if they could efforts of various manufacturers would be duplicated. This must be accomplished by the Federal Government.

The FAA has developed an -(R&D)- program to enhance the certification of civil helicopters. This program is described in draft NAFEC Report 18-8, "Engineering and Development Program Plan, Helicopter Icing Certification Research."

The FAA's efforts were initiated in 1976 by New England Region test pilot participation in the U.S. Army UH-1H icing research program at Army expense. In 1977, the Great Lakes region provided test pilot participation in the Army research program at FAA expense. In 1978, the FAA initiated an icing technology review and provided \$250,000 for financial participation in the U.S. Army's attempt to qualify the UH-1 helicopter, equipped with a partial ice protection system, for flight in icing conditions. It was this participation and the FAA's insistence that cloud parameters be more accurately measured that allowed quantification of the HISS cloud

and identification of the need for improvement. In 1979 and currently, the FAA is providing financial (\$225,000) and technical support for the Army HISS improvement program, and conduct of ice-phobic coating flight testing.

The NAFEC developed R&D program was very briefly summarized including programmed and additional funding requirements. The program chart is included in the copies of viewgraphs attached. The following key points were made:

1. FY-78 funding (\$75,000) is attributed to calibration of the HISS cloud.
2. FY-79 funding (\$125,000) is attributed as the FAA contribution for HISS improvement.
3. FY-79 funding (\$100,000) is attributed to FAA contribution for calibration of the modified HISS cloud, and conduct of simulated and natural icing tests of ice-phobic coatings for rotor blade ice protection.
4. FY-80 funding (\$150,000) is earmarked for possible participation in Phase III of the HISS Improvement Program.
5. In the out years, the preponderance of funding is allocated to "Certification Tools" or Icing Facilities.
6. FAA funding should be directed to a National Icing Facilities Program, in conjunction with funding from NASA and DOD, to assure that, in the future, icing facilities will be adequate for research, development, and certification purposes.

The types of facilities that must be considered during our discussions include:

1. Airborne/In-Flight Simulators (Tankers) for use by aviation industry as well as the military.
2. Icing Tunnel Improvements (to include quantity and quality).
3. Improvements in instrumentation for cloud parameter measurement.
4. Analytical models for prediction of the performance of ice protection systems to identify: 1) critical ice effects (such as dynamic and aerodynamic effects); and 2) aircraft performance degradation during the design phase. This will enhance flight safety during the certification process as well as reduce cost of testing.
5. An icing research helicopter to continue probing the many unanswered questions concerning icing phenomena and gather flight test data needed to correlate and establish the fidelity of analytical and simulation techniques.

The topics that need to be addressed during the meeting include:

1. Facility Needs
2. Types of Facilities
3. Projected Utilization/Justification
4. Priorities and Schedules
5. Cost Estimates
6. Management and Ownership
7. Cost Sharing

Each of the agencies of NASA and DOD represented were requested to provide comments. These comments are summarized as follows:

NASA COMMENTS.

Mr. Milton Beheim described NASA's recent establishment of a new icing research group at the NASA Lewis Research Center. He presented an extensive summary of the Research and Technology Programs using the Center's Icing Research Tunnel that have been initiated since the inception of the new group, summarized the findings of an icing test facilities study, and provided a description of NASA plans to rehabilitate the Altitude Wind Tunnel for use as an additional icing research facility. Copies of viewgraphs used by Mr. Beheim in his summary will be forwarded to each attendee by NASA.

Mr. Beheim emphasized that National support for the AWT rehabilitation program must be obtained to allow NASA to justify the expenditure. He indicated that such support had been obtained from the U.S. Air Force and the U.S. Army. A letter requesting support from the FAA has been forwarded and a letter to the U.S. Navy will be forthcoming. He emphasized that the AWT would be used for purposes other than icing research, indicating that the icing-facilities-need, alone, would be insufficient justification for the rehabilitation cost (estimated \$32.5 million). He emphasized that NASA Lewis icing tunnels were primarily used in support of NASA research objectives, however, the facilities are available for testing under any Government project. This includes civilian test projects if sanctioned by the FAA.

Mr. Beheim indicated that the NASA Lewis annual budget for aircraft icing research is \$350,000.

Mr. Beheim also presented a movie that provided a description and basis for discussion of the Ottawa Spray Rig, a ground-based icing test facility currently owned and operated by the Canadian National Research Council. This facility is currently scheduled to be closed on March 31, 1980. The AGARD Flight Mechanics Panel Working Group on Rotorcraft Icing, has recently forwarded results of a NATO survey to the Canadian Government, recommending that the facility remain in operation.

U.S. ARMY.

Mr. Harry Chambers described the history of the development of the U.S. Army HISS (tanker helicopter) and the uses since its development. He emphasized that the HISS was not developed for research purposes but actually to determine the capabilities and limitations of current Army fleet helicopters such as, the UH-1, AH-1, CH-47, and OH-58. He indicated that the HISS had been used to check out the operation of ice protection systems of the ATL research JUH-1H, UTTAS prototype helicopters, CH-47D, and Blackhawk, before allowing flight testing in natural icing conditions.

LTC Frankenberger narrated a movie describing the characteristics of the HISS improvement program. Results of icing tunnel tests indicate that efforts this year have been successful in reducing cloud droplet size however, flight testing has not yet progressed sufficiently this winter in St. Paul, Minnesota, to verify this indication. The test aircraft are, however, on site and results should be available within the next two to three weeks.

U.S. NAVY.

Mr. Tony Petruccione described the icing tunnels that exist at the Naval Aviation Propulsion Center, Trenton, N.J. He indicated that all military engine development programs utilize the facilities for engine icing and ice ingestion qualification tests, that the facilities have been kept in a continual state of improvement over the years, and they appeared to be adequate (in quantity, size, and quality) for testing of today's engines and those projected in the future. The Navy intends to continue improvement of these facilities as necessary.

Mr. Don Caldwell described several problems that exist with Navy aircraft regarding icing conditions, citing engine damage on F-14 aircraft upon carrier landings after operation in snow conditions. Snow apparently builds up in the engine inlet during flight and although while not causing problems during flight, landing impact and high power settings used during arresting gear landings cause the snow/ice formations to break loose extensively damaging (FOD) the engines. Similar problems with F-15, F-16, and F-18 were mentioned. He emphasized that attempts to find a suitable icing tunnel to investigate this problem have been futile, because of the lack of facilities and the high cost of conducting such a test.

U.S. AIR FORCE.

The U.S. Air Force was not represented at the meeting, however, informal coordination subsequent to the meeting yielded the following information.

The U.S. Air Force is currently operating the NKC-135 as an icing spray tanker. This tanker has been used on several programs other than Air Force programs including icing test of the Concord conducted in Europe and U.S. Navy aircraft icing tests conducted at Patuxent River, Maryland. The NKC-135 tanker can be made available to commercial users with FAA or other Government Agency sponsorship on an as-available basis.

Cloud droplet size has been found by the Air Force to be excessive (26 to 212 micrometers mean effective droplet diameter), corrective measures have been taken to reduce droplet size and preliminary calibration results indicate that corrective measures have been successful. Final calibration data processing will be completed approximately June 1980.

The U.S. Air Force is planning the development of a self-contained (palletized) system that can be installed in a C-130 or C-141 aircraft, however, funding limitations have delayed system development. With the spray system installed in the C-130 the following icing conditions could be provided:

Airspeed range	100-300 KIAS
LWC range	0.05-4.5 gm/m
Droplet size	20-40 micrometers
Cloud Endurance	1-4 hrs. per flight

GENERAL DISCUSSIONS.

The chairman directed the discussion toward consideration of the various FAA, NASA, and DOD comments in relation to the meeting objectives, with particular attention to the topics of concern. The following is a summary of the results of these discussions and the consensus of the meeting.

1. The meeting concluded that the need for improved and more plentiful icing test facilities is long past.

2. Facilities existing within the military complex are in existence for military use and national defense projects will always hold top priority. These facilities can be used on an as-available and noninterference basis. Available facilities are being used full time for military projects now, and availability for other (civil) projects is remote.

3. NASA has some facilities that are Unitary Facilities (available for lease by any U.S. Government Agency or commercial firms). There are no icing test facilities that fall into this category.

4. NASA's charter does not include certification testing. Some certification testing efforts are conducted in the NASA Lewis Icing Research Tunnel. Testing of this type is limited to military projects, nonproprietary civilian projects of research interest to NASA and civilian projects endorsed or requested by the FAA on a fee basis.

5. Civilian firms currently must provide their own test facilities or be able to convince either NASA or the FAA that testing being requested is relevant to NASA R&T needs or FAA certification. The IRT is currently booked through mid 1981.

6. The icing test facility needs have been discussed at many conferences in recent years. NASA has cataloged facilities having potential for icing test purposes that currently exist in North America. AGARD has summarized facilities existing in Europe, in AGARD Advisory Report No. 127 "Aircraft Icing."

7. NASA has support from the U.S. Air Force and the U.S. Army for rehabilitation of the AWT. This support could not be obtained from the Helicopter Association of America (HAA) because the results would be too far in the future. The HAA considers the problem immediate and expresses the recommendation that near term solutions should be developed.

8. Military funding for a national facilities program would be difficult to obtain.

9. National facilities have traditionally been difficult to manage. Users desire the Government to bear most of the cost burden and the Government must evolve a procedure that is fair to all. Users are seldom satisfied with the result.

10. A coordinated national program, whereby each government agency would develop, operate, and maintain their own facilities would be considered.

11. The FAA recognized a significant shortcoming in the icing facilities area and has appointed two individuals, "JB" McCollough and Tom West, to work with NASA,

DOD, and industry to resolve the problem. NASA and DOD must also appoint specific individuals to be the focal point for establishing a national plan for development of national facilities or for coordinated development of agency facilities. The FAA should request the Office of Defense Development Research and Engineering (DDR&E) and NASA headquarters to appoint similar representatives.

12. The U.S. Government does not, at this point, have a concise definition of facilities needs for forming a basis for determination of the specific facility development or improvement projects and order of priority of these projects that should be undertaken. The consensus of the meeting, however, was that the NASA proposed AWT rehabilitation should be endorsed, funded, and initiated. In addition, the consensus of the meeting concluded that in-flight simulation facilities should be developed, and that the Canadian Government should again be requested to retain the Ottawa Spray Rig. These facilities efforts are considered essential to support the immediate and near term needs for icing research, development and certification programs. Other detailed facility needs and development programs can be identified at a later date during preparation of a national facilities program plan.

13. The meeting generally endorsed establishing a national in-flight icing simulation facility at NAFEC for use by civil as well as military users. The consensus however, doubted that NASA or DOD funding could be made available for the development program. The consensus of the meeting did, however, favor establishment of a national plan to identify the national icing facilities needs and to set the stage for either a national program for facilities development or a basis for national coordination of individual agency facilities development programs.

14. The next step should be for the FAA to initiate a request to DDR&E and headquarters NASA for the establishment of a small working group to develop a national program plan. FAA representatives agreed to staff such letters and recommendations to the Associate Administrator for Research and Engineering.

RICHARD I. ADAMS
Chairman

LIST OF ATTENDEES
NATIONAL ICING FACILITIES
COORDINATION MEETING
FAA/NAFEC
ATLANTIC CITY, N.J.

JANUARY 16, 1980

<u>NAME</u>	<u>ATTENDEES ACTIVITY</u>	<u>PHONE</u>
D.C. Caldwell	NAVAIR Headquarters	(202) 692-6030 AV-222-6030
T.C. West	SRDS (ARD-330)	(202) 426-3046/4440
Tony Petruccion	NAPC, Trenton, N.J.	(609) 882-1414 X318
Milt Beheim	NASA Lewis	216-4334 X374
Vito Truglio	NAPC, Trenton, N.J.	(609) 882-1414 X305
LTC C. Frankenberger	USAAEFA (Edwards AFB)	(805) 277-2271
Harry W. Chambers	USA AVN Research and Dev. Cmd. St. Louis, Mo.	(314) 263-1703 AV-693-1703
Jack Adams	USA AVN Research and Dev. Cmd. St. Louis, Mo.	(314) 263-1694 AV-693-1694
LTC Paul G. Stringer	NAFEC/ANA-340	AV-234-1596 X3771 (609) 641-8200 X3735 FTS 346-3735
Dick Adams	NAFEC/ANA-340	AV-234-1596 X3371 (609) 641-8200 X3376 FTS 346-3735
"JB" McCollough	NAFEC/ANA-340	AV-234-1596 X3313 FTS 346-3313 (609) 641-8200 X3313

AGENDA

0900-0910	WELCOME	Director, NAFEC
0910-0930	INTRODUCTORY REMARKS BACKGROUND MEETING OBJECTIVES	JB McCollough Dick Adams
0930-1000	NASA COMMENTS	
1000-1030	ARMY COMMENTS	
1030-1050	BREAK	
1050-1120	NAVY COMMENTS	
1120-1150	AIR FORCE COMMENTS	
1150-1300	LUNCH	
1300-1500	GENERAL DISCUSSIONS & SUMMARY	

MEETING OBJECTIVES

DEVELOP METHODOLOGY

IMPLEMENTATION OF NATIONAL PROGRAMS FOR NATIONAL FACILITIES

DEVELOPMENT
MODERNIZATION

FOR

RESEARCH
DEVELOPMENT
CERTIFICATION

INITIATE EVOLUTION

NATIONAL PLAN FOR ICING FACILITIES

DEVELOPMENT
MODERNIZATION

TOPICS FOR DISCUSSION

FACILITY NEEDS & JUSTIFICATION

PROJECTED UTILIZATION

TYPES OF FACILITIES

- TUNNELS
- CHAMBERS
- GROUND BASED
- IN-FLIGHT

PRIORITIES & SCHEDULES

- DEVELOPMENT
- MODERNIZATION

COST ESTIMATES

- INITIAL INVESTMENT
- OPERATION & MAINTENANCE

MANAGEMENT & OWNERSHIP

COST SHARING

APPENDIX C

SURVEY OF AIRCRAFT ICING SIMULATION FACILITIES IN NORTH AMERICA

SURVEY OF AIRCRAFT ICING SIMULATION FACILITIES IN NORTH AMERICA *

WILLIAM OLSEN

ICING RESEARCH SECTION

NASA LEWIS RESEARCH CENTER

NASA was requested to survey the capabilities of the facilities in North America that can do aircraft icing simulation tests. The survey was requested by the Standing Committee on Icing, which is jointly sponsored by NASA, FAA and NOAA; the military services have also expressed a need for this survey. European icing facilities have already been surveyed and reported in AGARD Advisory Report 127.

The reasons for the survey are to: (1) inform the icing research community of the capabilities of existing icing facilities, (2) make it easier for a potential facility user to select and contact the icing facility that is appropriate for his test requirements, and (3) help facility managers evaluate and improve their facility.

The survey determined the location and size of each facility, its airspeed and temperature range, icing cloud parameter ranges, and the technical person to contact. The facilities surveyed and their capabilities are listed in tables A to D, one for each of the four types of simulation facilities that are described on figures A to D. The capabilities of each facility were estimated by the engineers working with that facility. The numbers in the tables are single point approximations by them of the complex operating curves of their facility. Many of the facilities have capabilities beyond that required for icing testing and these excess capabilities were not included in the tables.

* For your convenience, 2 tables listing European icing facilities are also attached.

APPENDIX D

CENTER NEWS HIGHLIGHTS

NAFEC NEWS HIGHLIGHTS

PUBLIC AFFAIRS OFFICE, ANA 5
FAA NAFEC
ATLANTIC CITY, NEW JERSEY 08405
(609) 641 8200

NATIONAL AVIATION FACILITIES EXPERIMENTAL CENTER NAFEC HEADS FAA QUEST FOR ICING TEST FACILITIES

80-6



Helicopter hovers in a super-cooled cloud created by Canadian government's Ottawa Spray Rig, which was one of the ground-based icing test facilities discussed at the meeting of aircraft icing experts.

CONSORTIUM EFFORT -- The FAA has given NAFEC the leading role in a cooperative effort with DOD and NASA to establish a consortium of ground and airborne icing test facilities. This test complex is needed for certification of helicopters to fly in icing conditions, as well as for research and development, according to NAFEC Director Joseph M. Del Balzo.

Boeing Vertol Co. has already applied to the FAA Eastern Region for certification of the first U.S. civil helicopter, its Model 234, to fly under limited icing conditions; and "we can see the others waiting in the wings," said Del Balzo. At this time the agency does not have standards for helicopter icing certification, the data needed to establish the standards, nor the facilities to obtain the data.

The icing program test effort was given to the Operations Branch of NAFEC's recently formed Aircraft Safety

Development Division, which has the responsibility for the agency's helicopter icing and certification standards program. Branch chief "JB" McCollough has named Richard I. Adams, manager of the helicopter icing and certification standards program, to head the icing facilities undertaking as well.

Adams, who is the U.S. representative on the AGARD (Advisory Group for Aeronautical Research and Development) Working Group on Rotorcraft Icing, recently joined NAFEC after working for the military for many years on helicopter research and development.

To get the national icing test facilities program under way, Adams organized and chaired a conference here on January 16, attended by aircraft icing experts from various U.S. government agencies. This initial meeting at NAFEC was concerned primarily with the question of how best to implement a national plan to establish adequate,

modern icing test facilities needed to support future research, development and certification programs for civil and military helicopters and fixed wing aircraft.

One of the specific topics addressed by the attendees concerned the types of facilities needed. They agreed that any national or international icing test facilities will have to include icing tunnel and chambers, ground-based and airborne simulation facilities, analytical prediction models and, possibly, a new, airborne, rotary wing research vehicle, according to Branch Chief McCollough.

Other topics discussed at the meeting included:

- ✕ Priorities and schedules for development or modernization of the needed facilities.
- ✕ Projected utilization of each facility.
- ✕ Cost estimates for construction and operation of the facilities.
- ✕ Funding, ownership and management arrangements.

Most of the details on these topics remain to be worked out at a later meeting, McCollough said. Some of the decisions, he added, obviously will have to be made at top government levels.

Meanwhile, Dick Adams has set himself a busy schedule visiting and evaluating existing icing facilities. He has also been assigned by Director Del Balzo as a consultant to the Eastern Region's certification team for the Vertol 234, in response to the region's request to NAFEC for a technical expert on helicopter icing.

Earlier this month, Adams traveled to Ottawa. While there, among other things, he monitored tests being conducted by the U.S. Army, which was using the Canadian government's Ottawa Spray Rig to test ice-repellant coatings on the rotor system of one of its UH-1 helicopters.

Shortly, Adams will fly to St. Paul, Minn. In St. Paul, the Army is using its specially equipped JUH-1H helicopter test bed to evaluate the most promising ice-phobic coatings under natural icing conditions. The Army is conducting these tests under an interagency agreement with the FAA.

The Army's JUH-1H rotary wing icing

test bed has electrothermal ice protection systems on its main and tail rotors and stabilizer bar and an electrically heated interlayer for keeping ice off its windshield. This research helicopter is also extensively instrumented for measuring atmospheric and flight parameters. Among other parameters, it will be able to measure liquid water content, droplet size, ambient temperature, blade pitch link and bending loads, and vibration levels. Adams will look into the availability of this vehicle for civil research or the feasibility of developing a similar flying test bed for the civil program.

In St. Paul, the Army will be pursuing two other programs of great interest to the FAA. These include the qualification of the Boeing Vertol CH-47D (the military counterpart of the civil Model 234) for flying in limited icing conditions and the test and evaluation of the improved Helicopter Icing Spray System (HISS).

Boeing Vertol believes that the differences between its CH-47D and Model 234 are so slight when it comes to operation in icing conditions that the FAA can use the results from the Army's tests in St. Paul on the CH-47D to certify the civil 234 for restricted flying in icing conditions.

In the case of the Helicopter Icing Spray System, Adams' job will be to determine if the modifications made to the system make it acceptable to the FAA as an airborne icing test facility. The HISS is basically a spraybar carried by a CH-47 tanker. Water coming out of the nozzles on the spraybar under the proper conditions forms a cloud of super-cooled droplets. NAFEC provided funding for modifying the nozzles in the original design to produce a finer spray, after determining that the droplet-size created by the original spraybar were larger than those that would be encountered by helicopters in natural icing conditions. The job of this task force is to make sure that the government makes optimum use of the available facilities, Adams says, and then recommend the development of any additional facilities needed to do the job. The group expects to make its first recommendations within a year.

icopters and aircraft. Some 75 specialists from industry and government attended that Sept. 23-24 conference.

"This initial round of major conferences is in line with our goal of using our new facilities as a focal point for aviation symposiums," said Center Director Joseph M. Del Balzo. "I'm sure that these exchanges will help those in industry, within the Technical Center and elsewhere within the agency, in jointly doing our respective jobs better."

Present at the Commuter Airlines/FAA symposium were New England Region Director Robert Whittington and Eastern Region Director Murray Smith. The symposium was coordinated at the Tech Center through a newly renamed Technology Exchange Office, formerly the Conferences and Visitor Affairs Section.

The gathering focused upon the status and future of the commuter airlines industry, and ways to maximize FAA work to make it safer. The central topics were divided into three main areas: maintenance, flight safety and air traffic control.

The FAA's criteria for mechanic licensing, commuter airline flight training and effective use of current air



Richard I. Adams, manager of the Center's helicopter icing program, spoke to attendees whose organizations are represented on the placard to his left. A consensus for national icing facilities was the primary goal of the Sept. 23-24 conference.

traffic control systems were focal points of panel discussions.

An open discussion period following the panel sessions concerned: FAA planning standards, surveillance and accident handling.

The panel and open discussions were led by Walter Kies, director of aeronautics for the New Jersey State Department of Transportation, and several industry and government experts.

Additional guest speakers for the affairs were Gloria Shaffer, a member of the Civil Aeronautics Board, and Lou Davis, vice president of the Airline Publishing Group, and editor of Commuter Air Magazine.

The subsequent symposium dealing with icing was designed to reach a consensus on objectives on requirements for national icing research facilities. Several facilities are being proposed to study the effects of ice on aircraft, and the FAA is seeking industry input for maximum effectiveness, with the Tech Center playing a lead role in coordinating the effort.

In addition to a description and evaluation of existing icing facilities, potential new facilities were considered at the symposium. These include: icing wind tunnels, freezing rain simulators,

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"JB" McCollough, chief of the Center's Flight Safety Research Branch, ACT-340, organized the national helicopter icing research symposium. McCollough's group will head the Center's lead effort in this area for the agency.



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NEWS HIGHLIGHTS

80-38
September 29, 1980

TECHNICAL CENTER HOSTS TWO MAJOR SYMPOSIUMS



The emergence of the Tech Center as a focal point for conferences and symposiums drew plaudits from participants attending two major symposiums held in the new building. FAA Eastern Region Director Murray Smith, left, and New England Region Director Robert Whittington, right, spoke to more than 100 experts in the commuter airline field. A second symposium on helicopter and aircraft icing research was equally well attended.

In what promises to be a harbinger of things to come, the Visitors Center and auditorium in the Tech Center's new building hosted two major symposiums in the last two weeks. Both were well attended and well received.

The first, on Sept. 17-19, joined leaders of the commuter airlines industry

with the FAA. Top officials from the FAA's Eastern and New England regions used the Tech Center's modern facilities for the symposium, which drew 103 experts for a varied and comprehensive meeting.

The second symposium concerned national icing research work for heli-





Eastern Region Director Murray Smith chose the occasion of the commuter airlines symposium at the Tech Center to make some well-deserved presentations. From left, Smith presents an air carrier certificate to Paul Quackenbush, president of Empire Airlines. Smith then presented certificates of appreciation to co-pilot Wilbur Ressler and pilot Peter Kopp for their "cool-headed" wheels-up landing of an Air Virginia plane carrying three passengers. There were no injuries and damage to the plane was slight. Finally, Air Virginia President Rod Jaeger, far right, joined with Smith in expressing his gratitude to the two men. The presentations were made at a dinner in Atlantic City, which scenes are shown here.



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in-flight icing simulators and ground-based facilities.

Participants at the national icing symposium included the Department of Defense, National Aeronautics and Space Administration, the Helicopter Association of America, Inc., General Aviation Manufacturers of America, FAA and aircraft companies.

The symposium was an outgrowth of a small-scale meeting held at the Tech Center on Jan. 16. Organizing the symposium were "JB" McCollough, chief of the Flight Safety Research Branch, ACT-340, and his staff, including Richard

Adams and Charles Masters.

In an allied development related to future conferences, a detailed calendar of such events scheduled at the Technical Center through 1983, currently being updated and revised, will be available soon from the new Technology Exchange Section, ACT-64C, at (609) 641-8200, ext. 3334 or FTS 346-3334. Just named as chief of that section is former Center employee Stephanie Slavin. The section, formerly a part of the Technical Services Branch, ACT-63, is now under the Technical Information Research Branch, headed by James F. Williams.

PICTORIAL HIGHLIGHTS OF CENTER SYMPOSIUMS

Deputy Director Thomas J. O'Brien, ACT-2, delivered opening remarks to attendees of the national icing research symposium. Seventy-five specialists in this field were on hand for the conference.



SCENES FROM
THE COMMUTER
AIRLINE SYMPOSIUM