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The Altitude Wind Tunnel (AWT)—A Unique Facility for Propulsion System and Adverse Weather Testing

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THE ALTITUDE WIND TUNNEL (AWT) - A UNIQUE FACILITY FOR PROPULSION SYSTEM AND ADVERSE WEATHER TESTING

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Summary

A need has arisen for a new wind tunnel facility with unique capabilities for testing propulsion systems and for conducting research in adverse weather conditions. New propulsion system concepts, new aircraft configurations with an unprecedented degree of propulsion system/aircraft integration, and requirements for aircraft operation in adverse weather dictate the need for a new test facility. Required capabilities include simulation of both altitude pressure and temperature, large size, full subsonic speed range, propulsion system operation, and weather simulation (i.e., icing, heavy rain). A cost effective rehabilitation of the NASA Lewis Research Center's Altitude Wind Tunnel (AWT) will provide a facility with all these capabilities.

Introduction

Future new aircraft and propulsion systems will require wind tunnel test facilities with unique capabilities that currently are not available in this country.[1,2] Future aircraft of all types, civil and military, will place increased emphasis on propulsion system integration, both the propulsion system with the airframe, as well as between propulsion system components. Future emphasis will also be placed on increased aircraft operational capabilities, which means operating in adverse weather conditions. These factors will require wind tunnel facilities that are large, simulate true altitude conditions (including temperature), permit the operation of a propulsion system, and can simulate adverse weather conditions. There is no large scale wind tunnel in the United States or the free world that provides these capabilities. The Altitude Wind Tunnel (AWT), located at the NASA Lewis Research Center in Cleveland, Ohio, could be modified in a cost effective manner to provide all of these necessary capabilities.

A blue-ribbon committee was formed in 1982 to review the national aeronautics research and technology policy.[3] The findings of the committee are summarized in Fig. 1. Significant gains in aircraft and aircraft propulsion system performance are yet to be made. The study concluded that numerous opportunities exist for making dramatic leaps in technology. Indeed, all currently operational military and civil aircraft could be technologically superseded by the end of the century. While advances are possible, achieving them will not be easy and advanced flight vehicles will require a considerable degree of propulsion system/airframe integration. Integration of aerodynamics, materials and structures, and propulsion will play an increasingly important role in the development of future military and civil aircraft. These new highly integrated systems will require a new type of test facility.

Operation of aircraft in adverse weather (such as heavy rain, icing conditions, etc.) is a hazardous situation for both military and civil aircraft. The only wind tunnel in this country for conducting icing research is the Icing Research Tunnel at the Lewis Research Center. This facility, while heavily used and a very valuable tool, is small and has only low-speed capabilities. This tunnel does not permit engine operation nor simulate altitude pressure.

Future Aeronautical Systems

Some of the new aircraft systems that are expected to evolve in the future are listed in Fig. 2. These new aircraft systems will incorporate new or modified types of propulsion systems, somewhat different than those currently in service. Future systems will incorporate propulsion concepts which will be more efficient, and which will not only develop thrust, but in some applications will also produce lift. In other applications the propulsion system will be used as an aid for aircraft stability and control. These new configurations will require airframe and propulsion system integration to a degree of sophistication far beyond any current systems.

There is an increasing need, for productivity, mission effectiveness, and survivability, to operate at will in all types of weather conditions (icing, snow, heavy rain). Military operations are, of course, not limited to areas or seasons of favorable climatic conditions. Civil aircraft must operate year round and in all parts of the world, and therefore frequently encounter adverse weather conditions. Current transport aircraft have some ice protective devices, but future aircraft will incorporate different features such as zero bleed engines and composite materials etc., that will not permit the use of the kinds of protective systems used on existing aircraft. New protection systems will have to be developed and this can only be done with a thorough understanding of the entire aircraft/propulsion system when operating under realistic environmental conditions.

In recent years the price of aircraft fuel has stabilized. However, it still represents a sizeable portion of the aircraft direct operating cost, approximately 50 percent, and it is probable that fuel prices will rise again at sometime in the future. Therefore energy efficiency is still extremely important to the aircraft/airline industry. One of the propulsion system concepts currently being evaluated for significantly reducing transport aircraft fuel consumption is the high-speed turboprop (Fig. 3). Through appropriate technological advancements, this concept has the potential to reduce aircraft fuel consumption by 20 to 30 percent compared to the best state-of-the-art turbofan engine. Fuel savings of this magnitude would significantly improve airline carrier profitability and possibly open up large new world markets for short/medium range aircraft. The integration of this propulsion concept with the airframe is very different from current turbofan installations. Major advancements in understanding the phenomena controlling the successful integration of this concept will be needed in order to realize these significant performance improvements.

New highly survivable military aircraft concepts (Fig. 4) will present a new and complex set of potential problems with regard to the impact of installation effects on the performance and operability of the propulsion systems. For these vehicles, less visibility to radar detection is sought by shielding or masking the "hard parts" of an engine such as the rotating machinery, the "hot parts" such as the exhaust nozzles and turbines, and the hot exhaust gases. Maneuverability is another important feature of many of these aircraft. High maneuverability is accomplished with exhaust nozzles which can be used to deflect the hot exhaust jet to aid the aerodynamic control surfaces. The design ingenuity needed to achieve this shielding and maneuverability generally results in complex and tortuous engine air inlet and exit systems such as multiturn air intakes and two-dimensional high aspect ratio nozzles. These complex and tortuous air intake systems will tend to accumulate ice making all weather operation difficult A total integrated systems approach to the analysis and evaluation of this class of aircraft is needed in order to optimize the overall performance.

The potential for developing high performance and safe vertical/short take-off and landing aircraft (V/STOL) (Fig. 5) is being explored using operating experimental vehicles and conceptual design studies. The technologies needed to capitalize on the operating flexibility advantages associated with this type of aircraft are being explored for intermediate subsonic speeds using the NASA/Army tilt rotor experimental vehicle and for high subsonic and supersonic speeds using design concepts employing deflected jets and ejector lift principles. The need to accurately understand the effect of the installation on the propulsion system which provides the vertical lift power as well as the forward flight thrust is critical to the success of these aircraft.

New concepts for rotorcraft (Fig. 6) are being generated with the emphasis on achieving much higher operational speeds ($Mo \approx 0.8$). State-of-the-art rotorcraft are limited to low subsonic flight speeds due to limitations imposed by the large rotating set of blades used during both vertical and horizontal flight. As forward flight speed increases the lift to drag efficiency of current technology rotors is significantly degraded and structural concerns become serious. New approaches, such as the X-wing concept wherein the rotor becomes a stationary lifting device and the advancing blade concept wherein two counter rotating rotors are used, have the potential for alleviating the current forward flight speed limitations of rotorcraft. These concepts have the potential for expanding the forward flight envelope of future rotorcraft to the mid to high subsonic speed range. Propulsion/airframe integration technology challenges, not present in state-of-the-art rotorcraft, must be addressed with these new systems. The need to successfully accomplish the transition between shaft power operation and jet thrust is critical to the future success of these vehicles as is the need to design high performance engine intake and exhaust systems for efficient high-speed forward flight. These technology challenges must be studied and resolved through systems integration analysis and experiment.

Propulsion System Integration Facility Requirements

Many future aircraft concepts have propulsion systems highly integrated with the airframe (i.e., where the airframe/installation has a pronounced effect on the performance of the propulsion system), and in some cases involve new propulsion system concepts such as the high-speed turboprop. The propulsion unit may be buried within the airframe or closely coupled with it and be performing functions in addition to providing thrust, such as providing aircraft stability and control. Tests of the propulsion system will require portions of the airframe to correctly simulate the installed environment (Fig. 7). Tests in engine test tanks are not sufficient for these highly complex integrated systems. These new systems require a wind tunnel test configuration which can provide the actual internal flow field as well as the external flow field. For example, the rotating propeller of the turboprop system is closely coupled to the external flow field of the aircraft. The external flow must be simulated in order to investigate the operation of the total system. This differs from current turbofan or turbojet engines which have inlets to condition the flow before it reaches the engine.

Because the propulsion system and a portion of the airframe as well must be tested concurrently, requires either a large size wind tunnel or working at subscale. Subscale testing of system performance/interaction is not adequate because of the problems in simultaneously scaling aerodynamic, structural, and mechanical behavior. Also the simulation of adverse weather does not scale well (discussed in more detail in the next section). Therefore, a requirement for this new facility is that it be a wind tunnel configuration and large enough to permit full or large scale test articles

A typical subsonic flight profile is shown in Fig. 8. The dashed line represents the operating line of a typical sea level wind tunnel. As can be seen this type of facility can only simulate a very small portion of the flight envelope. In a sea level facility the tests performed at almost all speeds are at an ambient pressure significantly higher than would be encountered in actual flight. The higher pressures result in significantly greater loads on the engine components. In an atmospheric tunnel the air density can be as much as three times higher than at true altitude, which can cause significant changes in the aerodynamic performance of propellers, fans, compressors, etc. The higher air density also results in unrealistic loading patterns on these components which requires the test hardware to have a different structural characteristic or possibly a different mechanical design, thus making the test unrepresentative. Therefore, another facility requirement is simulation of the correct altitude pressure.

In actual flight, not only does the ambient pressure drop with increasing altitude, but so does the temperature. Most of the existing wind tunnels are not refrigerated and therefore operate a temperatures significantly higher than in actual flight. Figure 9 illustrates this difference and the impact caused by this difference. A typical unrefrigerated wind tunnel will generally operate at stagnation temperatures in excess of 100 °F hotter than true altitude temperatures. In order to achieve aerodynamic similarity when testing a propulsion system the corrected speed $N/\sqrt{T}$ must be the same as would occur in flight. If the air temperature T, during the test is too high, then the rotational speed N must be increased correspondingly. A temperature difference between 110 and 120 °F, as used in this example, requires that the engine be oversped by 10 to 12 percent. Overspeeding the engine has several effects which can limit or invalidate the results of the test. An overspeed of this amount would increase the centrifugal forces in the rotor, fan, or propeller blades by 25 percent. This may require using a different blade construction technique or added strength built into the blades. In either case, the blades would have a different structural response than the actual blade design. Also the increased rotational speed will cause the blades to deflect or untwist differently than designed and therefore will result in a different shape. Both the increased centrifugal loads and the blade untwist differences can significantly change the flutter characteristics. In addition to the changes in the flutter characteristics of the blades the higher rotational speed changes the forces from the engine. The engine would be running at higher than design speeds and therefore operating with a different vibrational signature than the design condition. All of these factors lead to a test situation that is mechanically very different from actual flight. Therefore, another test facility requirement is that ambient temperature be correctly simulated.

The necessary facility capabilities for conducting propulsion system integration research are summarized in Fig. 10. Currently there is no facility in existence that can provide all these capabilities

Adverse Weather Operation

To fully exploit the potential of the future energy efficient, high performance, survivable, and operationally flexible aircraft requires that they be capable of successfully operating in all weather conditions (Fig. 11). Continuing pressure to expand flight envelopes, geographic routes, and flight frequency, indicates that the effects of weather phenomena such as icing, snow, and heavy rain must continue to be explored and this can only be done under realistic environmental conditions. Successfully achieving all weather operational capability in future highly survivable military aircraft, and in current and future rotorcraft requires a more thorough understanding of the potential adverse effects of weather on these concepts. Today these conditions can only be found via costly, time consuming and risky flight testing.

Current large transport aircraft have some protection systems which are effective. However, future changes to propulsion systems and to the airframe will no longer permit the use of these existing systems and new ones will have to be developed. In order to perform adverse weather research, specialized facility capabilities are required. Icing research will be developed as an illustrative example to determine the type of facility capabilities needed for adverse weather testing

All parts of an aircraft are subject to icing, however, ice accretion on some components (i.e., propulsion system, wing) is very critical to the aircraft operation. Some of these components are listed in Fig. 12. Inlets and carburetors, of course, are critical to the operation of the engine and have been shown to be very efficient ice collectors. Fans and propellers have sharp leading edges and can collect ice easily, which could disrupt the flow over the blade and cause losses in thrust. New advanced airfoils also are thin and can accumulate ice on the leading edge and little is known about the aerodynamic penalties of these new shapes as ice accumulates. The same is true for rotorcraft.

As mentioned previously, new propulsion systems and aircraft designs will not always permit the use of ice protection systems of the type used on current transport aircraft. Figure 13 lists some of the new developments that will impact the operation of and the kind of ice protection systems that can be used. The need for improved fuel efficiency is changing current engine designs and one of those changes is the reduction of bleed air for auxiliary systems. Hot engine bleed air is used for ice protection on most civil transports. Also new materials, such as composites, are being introduced to save weight, but which may not be able to withstand the high temperatures of the engine bleed air. Advanced airfoils designed to maintain large regions of laminar flow are sensitive to the changes caused by ice buildup on the leading edge. Many new aircraft will have propulsion systems highly integrated with the airframe. This will produce engine inlet ducts with tortuous paths very susceptible to icing. Improving avionics and guidance capabilities encourage operation in adverse weather as do expanding mission requirements.

Ice accumulation and growth is a very complex phenomena. The two types of ice growth, Rime and Glaze, are depicted in Fig. 14. These can be very different and have very different effects on the flow over the surface the ice is accumulating on. Both types of ice growth, however, are a function of a number of different variables which are listed on the figure. Many of these are environment related and translate directly into capabilities that an icing research facility must have. Such a facility must be a wind tunnel that can simulate the speed range over which ice can accumulate. Because the ice growth is a function of the air velocity a large speed range is required. The facility must also simulate proper altitude pressure and temperature, again because the ice growth is a function of these parameters. An icing facility must also have a method of introducing moisture into the airstream in a variety of forms and amounts matching what exists in the atmosphere.

Ice accretion does not scale with the size of the surface being iced. This is demonstrated in Fig. 15. Smaller objects are more efficient ice collectors than large objects. Other factors, such as water droplet size relative to the object size and the water content in the air, also enter into the scaling phenomena. Attempts have been made to analytically account for scaling effects, but have been unsuccessful. This is due to the complexity of the problem and the scarcity of experimental data Because the scaling phenomena is complex and not well understood it is necessary to perform testing at large scale. Therefore, a requirement for an icing facility is that it be large enough to permit large scale model testing without adverse blockage effects.

Currently the largest icing research wind tunnel is the NASA Lewis Research Center Icing Research Tunnel (IRT) which has a 6 foot by 9 foot test section. The IRT is heavily used because of its very unique icing capabilities, however, it has some limitations. The IRT is a sea level tunnel and therefore does not simulate true altitude pressures. The operating line of the IRT is shown on Fig. 16. The IRT speed capability is limited to values equivalent to Mach 0.4. As can be seen from this figure there is a large portion of the flight envelope where icing conditions exist that no large test facility has the capability of simulating. Also in Fig. 16 is a sketch of a typical full scale inlet/nacelle/spinner for a turboprop propulsion system mounted in the IRT test section. Even though the IRT is the largest facility of its kind, the test hardware shown would provide high blockage levels.

The facility capabilities required for conducting adverse weather research are summarized in Fig. 17. Icing research has been used as the illustrative example to develop these criteria, but the same capabilities are what is needed for the other types of adverse weather as well. There is no facility in existence that has all these necessary capabilities for adverse weather testing.

New Test Facility Requirements Summary

The ability to correctly simulate the environmental and flight conditions needed to study and resolve the technological challenges associated with the proposed future aircraft concepts will be critical for achieving the potential they offer. In order to perform the research necessary to develop these technologies new test facility capabilities will be required (Fig. 18). The new highly integrated systems previously discussed will require a test facility that has the capability of performing tests with an actual operating propulsion system and the propulsion system must operate the same as it does in actual flight. This requires correct simulation of both altitude pressure and temperature. Such a facility must be large enough to accept a full scale propulsion system as well as a portion of the airframe. In order to properly evaluate integration effects a wind tunnel configuration is required that can simulate a broad subsonic speed range. Appropriate accommodations must be made to permit the operation of the propulsion system (i.e., an exhaust scoop). In order to perform realistic adverse weather research requires all of the above capabilities as well as a means of introducing moisture in the proper amounts and forms (clouds, mist, rain, etc.).

Altitude Wind Tunnel (AWT)

A proposal has been made to modify the existing dormant Altitude Wind Tunnel (AWT) at the NASA Lewis Research Center to provide a facility that would have all of the required capabilities for both propulsion system integration and adverse weather testing. This facility, shown in Fig. 19, was built in 1944 and was used as a refrigerated altitude wind tunnel for propulsion system testing for approximately 15 years. From 1960 to 1970 it was used as a space power chamber and has been dormant since 1970.

The proposed modifications to the existing facility would result in the design shown schematically in Fig. 20. The test section is octagonal measuring 20 ft across parallel sides. Mach numbers ranging from near 0 to more than 0.9 will be achievable with large blockage models (10 to 12 percent) including complete operating propulsion systems. The existing central Lewis altitude exhaust system will provide altitude variation from sea level to greater than 55 000 ft. The tunnel refrigeration system will allow tunnel total temperature variations from -40 to 60 °F.

The AWT standard wind tunnel components are shown in Fig. 21. The drive power for the facility will be provided by two 30 000 hp electric motors. Each can be run independently or they can be run in series depending on the operating requirements. The drive fan will be a high efficiency design with two rotor stages each containing 17 blades. The number of stator vanes (28 per stage) was selected to minimize the interactions between the vanes and rotor blades and thus minimize the noise within the tunnel. The heat exchanger will provide cooling to remove the heat added to the tunnel air by the drive fan and to simulate the desired altitude static temperatures. The flow conditioners will consist of a honeycomb section and removable screens. The screens will be removed during adverse weather testing. The flow conditioners will provide good quality (low turbulence) flow to the test section. The octagonal test section is fitted with boundary layer bleed slots running along each of the eight corners. The test section will be surrounded by a plenum chamber which can be pumped down to low pressures to bleed the boundary layer out of the test section to minimize tunnel wall interference effects.

The special features of the AWT which help provide its unique capabilities are shown in Fig. 22. The turning vanes in the two corners downstream of the test section will be heated. This feature is needed to prevent ice buildup on the vanes during adverse weather testing. The heat exchanger will be connected to a 21 000 ton capacity, Freon-22, two phase refrigeration system. This system will permit operation at static temperatures that are encountered at altitudes ranging from sea level to in excess of 55 000 ft. The water spray system will be inserted in the tunnel for adverse weather testing (i.e., icing conditions, heavy rain, snow). This system will have the capability to introduce water in various droplet sizes and water content levels. The spray bar system will be removed when not in use to preserve test section flow quality for aerodynamic tests. An engine exhaust scoop will be incorporated so that full scale engines can be operated and tested in the facility. The scoop will capture and exhaust the engine waste products so that the air circulating in the tunnel will not be contaminated. The plenum evacuation system will permit the use of large high blockage models at high subsonic speeds. The boundary layer will be drawn off by pumping down the plenum. This will minimize the wall interference effects and permits testing of larger sized models. The air drawn off will be compressed and injected back into the tunnel just downstream of the drive fan. Plans for this facility also include acoustic testing, and therefore, some acoustic features have been incorporated into the design. As mentioned before, the vane/blade ratio selected for the fan was chosen to minimize noise. A four ring silencer will be located just downstream of the heat exchanger and there will be acoustic treatment in the turning vanes and the walls of the two corners upstream of the test section. The test section will have insertable acoustic panels and several different configurations are being considered that would choke the flow at the end of the test section, to prevent downstream noise from propagating forward. With all of these features the background noise level in the test section is expected to be less than 120 dB.

Details of the test section are shown in Fig. 23. The octagonal shape provides a convenient geometry for the use of boundary layer control bleed slots which permits good transonic performance with large blockage models. The octagonal shape also facilitates use of flat high quality optical windows for icing research and for the use of laser measurement systems. This shape provides a convenient sidewall design for easily installing and interchanging acoustic panels. Model entry will be from the bottom of the test section. The tunnel floor will be mounted on screw-jacks which will allow it to be raised and lowered. The models will be brought onto the tunnel floor at the surrounding shop level and then will be raised into place. Models can be mounted from either the sidewall trunnions or a floor plate in the center of the test section. These features will allow for rapid model installation and removal from the test section thereby providing high experimental productivity. A force balance will be attached to the tunnel floor plate to allow thrust measurements of propulsion system performance. A considerable analytical and physical modeling effort is underway to assure this design will provide the required test environment and performance.[4,5]

Concluding Remarks

The modified Altitude Wind Tunnel design will provide all the necessary facility capabilities for conducting propulsion system integration and adverse weather research. The capabilities of the rehabilitated AWT relative to those needed for propulsion system integration research, are summarized in Fig. 24. This facility would simulate both true altitude pressure and temperature concurrently over the flight range of interest. It is a wind tunnel configuration and therefore would provide the proper flow field over the entire test article. It has a large test section (20 ft across parallel sides), which with the plenum evacuation system to reduce wall interference effects, will permit testing of full size hardware including actual propulsion systems along with a sizeable portion of the aircraft. It includes an exhaust scoop to remove engine waste products.

The capabilities of the rehabilitated AWT relative to those needed for adverse weather research, as illustrated for icing research, are summarized in Fig. 25 and also in Ref. 6. As stated above, this facility would correctly simulate both altitude pressure and temperature. The proposed AWT configuration also includes a method for introducing moisture into the test section in various forms and amounts. Comparisons are also made with the Lewis Icing Research Tunnel which is the largest and most heavily used icing facility in this country. As can be seen from the plot the IRT is limited to operation along a line from Mach 0 to 0.4 at sea level pressures. The AWT configuration, on the other hand, would cover a very large speed/altitude envelope. Figure 25 also includes sketches showing the size of the proposed AWT relative to the Lewis IRT. The sketches show the same inlet/nacelle model mounted in both tunnels. As can be seen the blockage in the IRT facility would be quite high, however, that would not be the case in AWT, in fact, a full size propeller (14 ft diameter) could also be included and operated.

The ability to correctly simulate the environmental and flight conditions needed to study and resolve the technological challenges associated with the proposed future aircraft concepts will be critical for achieving the potential that they offer. Unique ground test facilities are used to simulate the needed flight environment and thereby significantly reduce the time, cost, and risk that would be associated with flight testing. Ground test facilities also provide the more accurate measurement systems and more flexible test conditions that are needed to fully understand complex technical phenomena and resolve technological questions.

An evaluation of existing U.S. ground test facilities has revealed a critical void in the capability to provide the appropriate conditions for conducting accurate evaluations of the integrated technologies associated with propulsion/airframe integration and all weather operation. To fill this void Lewis has proposed to rehabilitate and modify the existing dormant Altitude Wind Tunnel facility that will simultaneously satisfy the test requirements needed to successfully evaluate and resolve the technological challenges associated with future high potential aeronautical vehicles.

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FUTURE OF AERONAUTICS

- MAJOR ADVANCEMENTS STILL ACHIEVABLE
- SIGNIFICANT TECHNICAL CHALLENGES EXIST
- UNPRECEDENTED DEGREE OF INTEGRATION
  - INTERACTION OF PROPULSION SYSTEM COMPONENTS
  - EFFECTS OF INSTALLATION ON PROPULSION SYSTEM

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Figure 1.

FUTURE AERONAUTICAL SYSTEMS

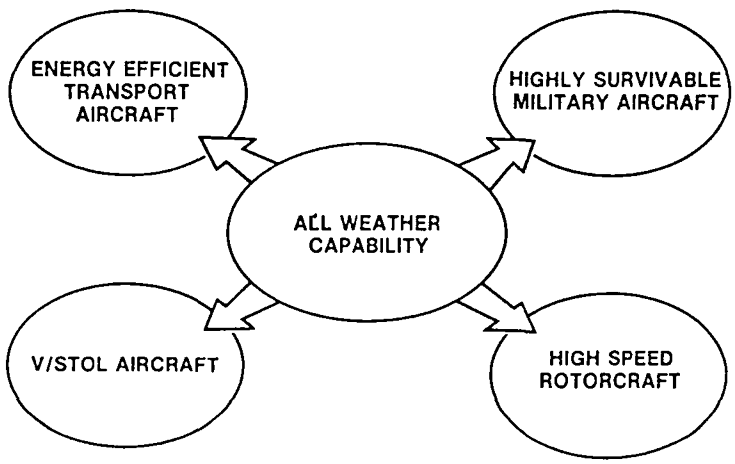

Figure 2.

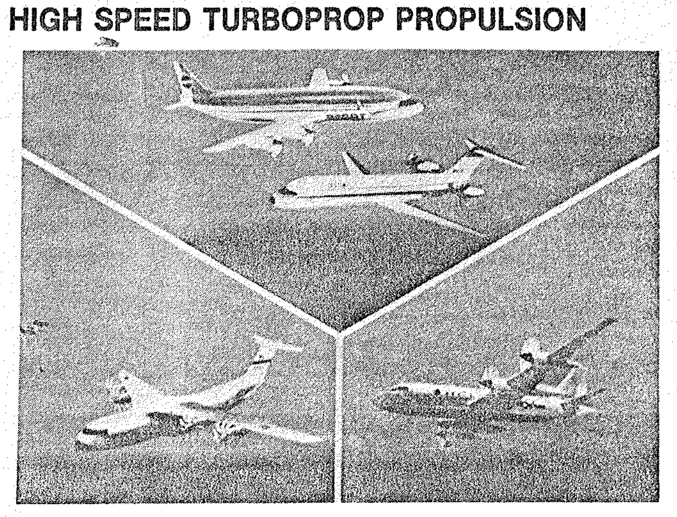

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Figure 3.

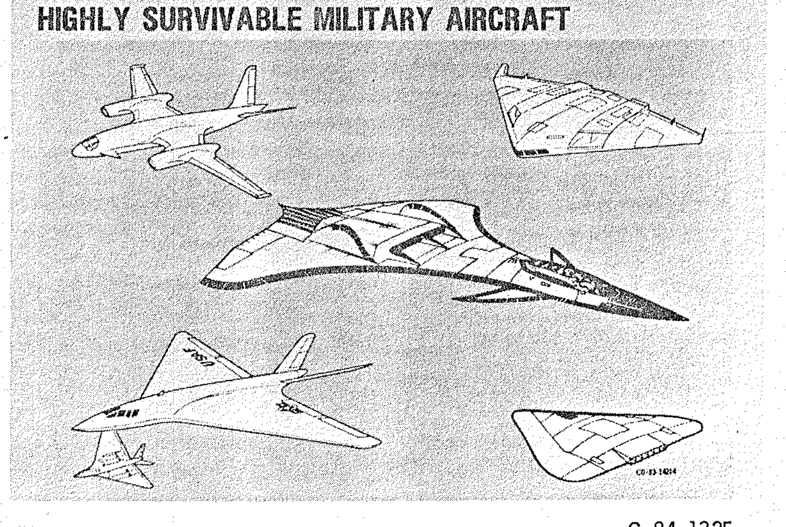

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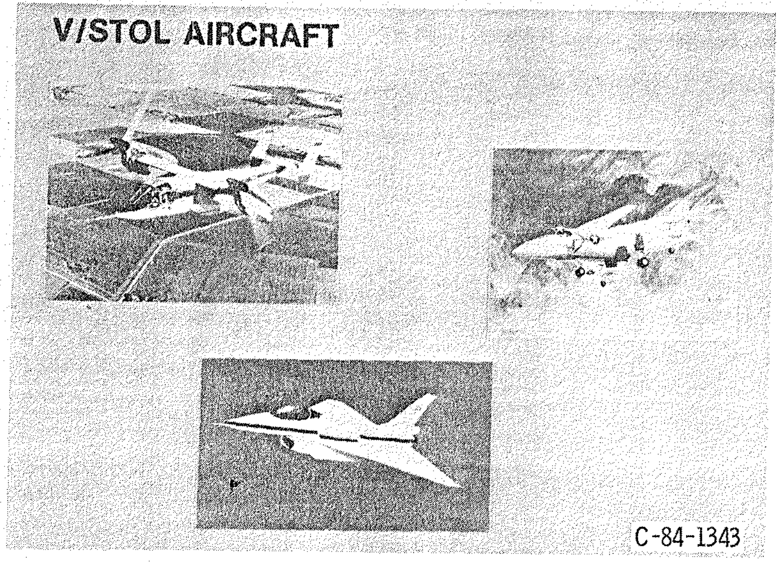
Figure 4.



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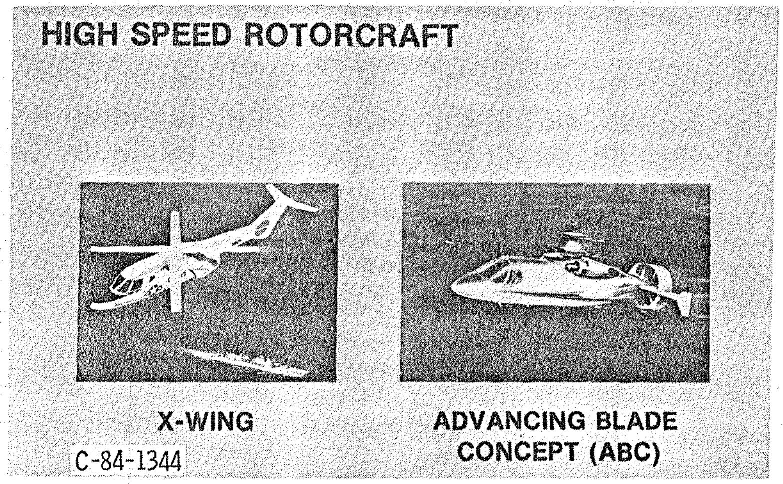

Figure 6.

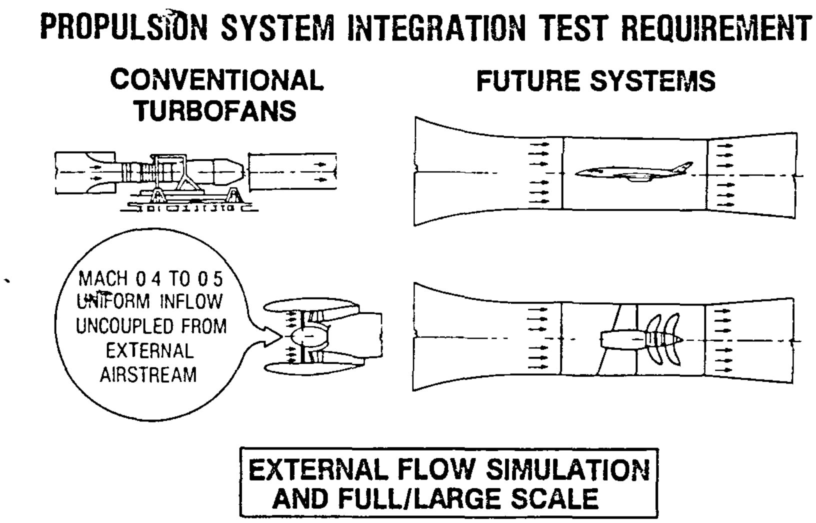

Figure 7.

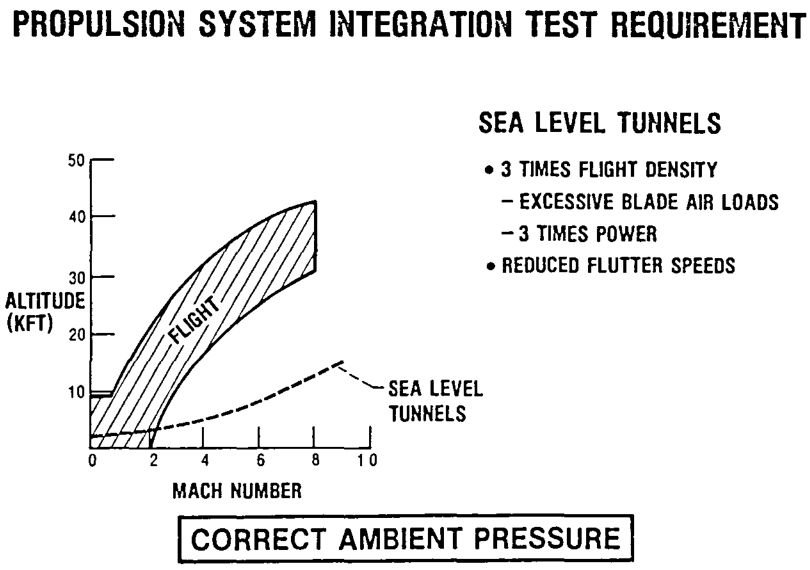

Figure 8.

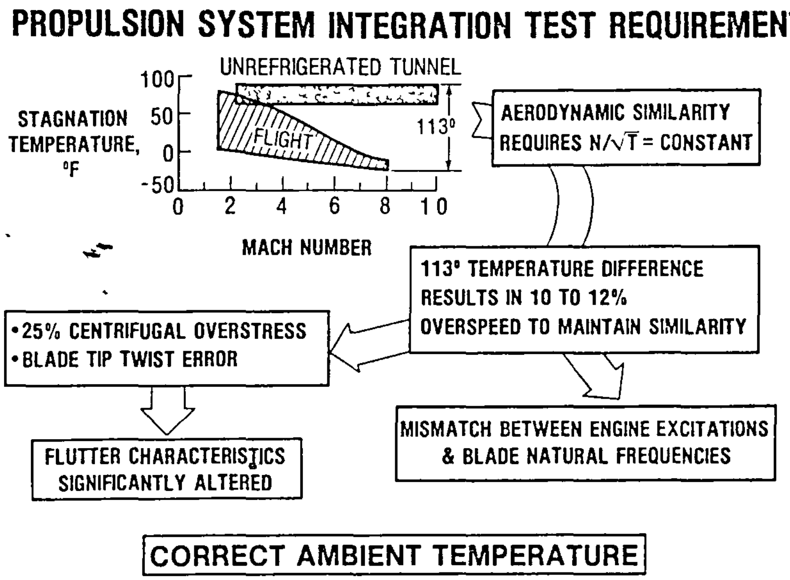

Figure 9.

PROPULSION SYSTEM INTEGRATION TEST REQUIREMENTS SUMMARY

- EXTERNAL FLOW SIMULATION
- CORRECT PRESSURE AND TEMPERATURE
- FULL/LARGE SCALE

SUITABLE FACILITY
NON EXISTENT

Figure 10.

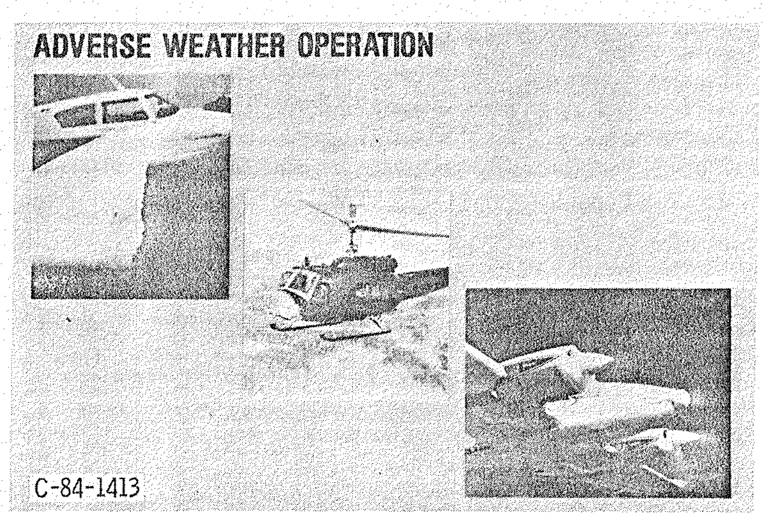

Figure 11.

ICING R&D APPLICATIONS

- **PROPULSION SYSTEMS**
  - INLETS
  - CARBURETORS
  - FAN
  - PROPELLERS
- **FIXED AND ROTARY WING AIRCRAFT**
  - ADVANCED AIRFOILS
  - HIGH LIFT DEVICES

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Figure 12.

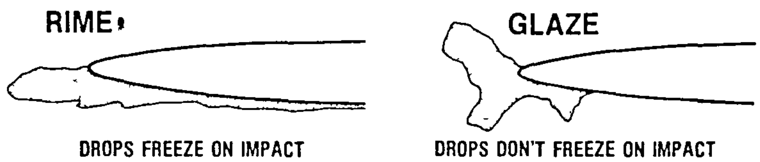
NEW DEVELOPMENTS IMPACTING FUTURE ICING R&D

- ZERO BLEED ENGINES
- COMPOSITE MATERIALS
- ADVANCED AIRFOILS
- HIGHLY INTEGRATED VEHICLE CONFIGURATIONS
- ADVANCED AVIONICS/ELECTRONICS
- NEW MISSION REQUIREMENTS

Figure 13.

ICING R & D TEST REQUIREMENTS

- TYPES OF ICE GROWTH



- ICE GROWTH IS A FUNCTION OF
  - VELOCITY
  - AMBIENT TEMPERATURE
  - AMBIENT PRESSURE
  - LIQUID WATER CONTENT
  - WATER DROP SIZE
  - AIRFOIL SIZE, SHAPE
  - ANGLE-OF ATTACK

MANY COMPLEX VARIABLES CORRECTLY SIMULATED

Figure 14.

EFFECT OF SIZE OF OBJECT ON ICE ACCRETION

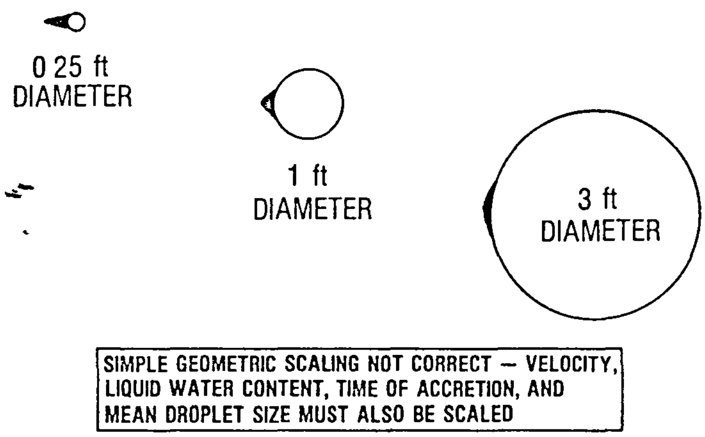


Figure 15.

ICING R&D TEST REQUIREMENTS

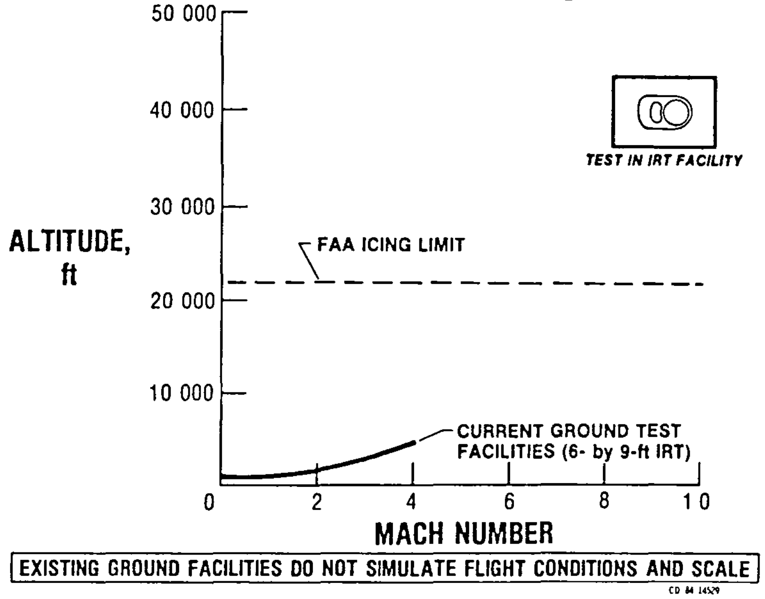


Figure 16.

ICING R&D TEST REQUIREMENTS SUMMARY

- FLIGHT ALTITUDE SIMULATION
- CORRECT FLIGHT SPEEDS
- CORRECT MOISTURE CONTENT AND FORM
- FULL/LARGE SCALE

SUITABLE FACILITY NON-EXISTENT

CD 84 14545

Figure 17.

NEW TEST FACILITY REQUIREMENTS

- CONCURRENT PRESSURE AND TEMPERATURE SIMULATION OF ALTITUDE
- LARGE SCALE TEST ARTICLES
- FULL SUBSONIC SPEED RANGE
- WIND TUNNEL CONFIGURATION-AERODYNAMICS/ACOUSTICS
- PROPULSION SYSTEM OPERATION/SIMULATION
- ICING, HEAVY RAIN CAPABILITY

NO EXISTING NOR PLANNED FACILITY MEETS THESE NEEDS

Figure 18.

ALTITUDE WIND TUNNEL

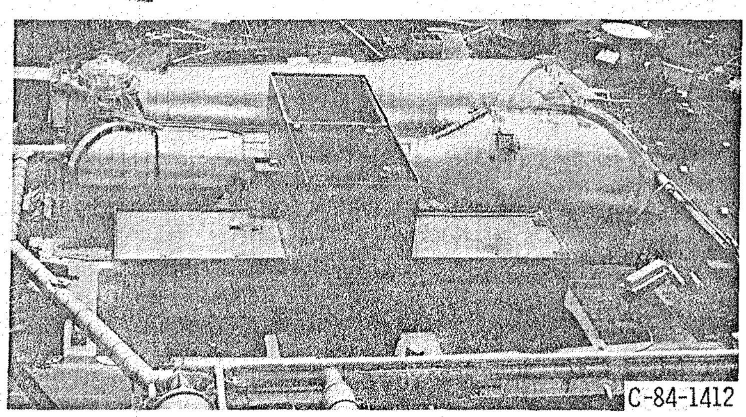
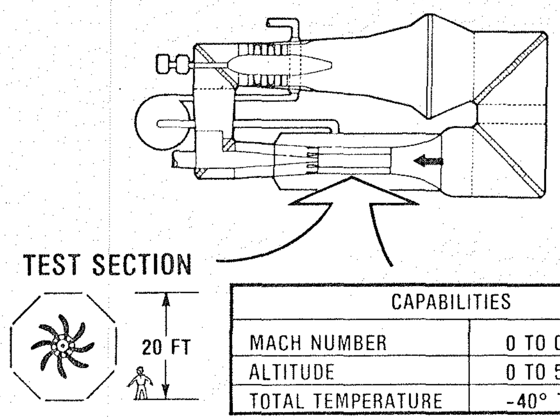


Figure 19.

ALTITUDE WIND TUNNEL



CAPABILITIES	
MACH NUMBER	0 TO 0.9 +
ALTITUDE	0 TO 55 000 FT +
TOTAL TEMPERATURE	-40° TO 60° F

CD-84-14869

Figure 20.

STANDARD WIND TUNNEL COMPONENTS

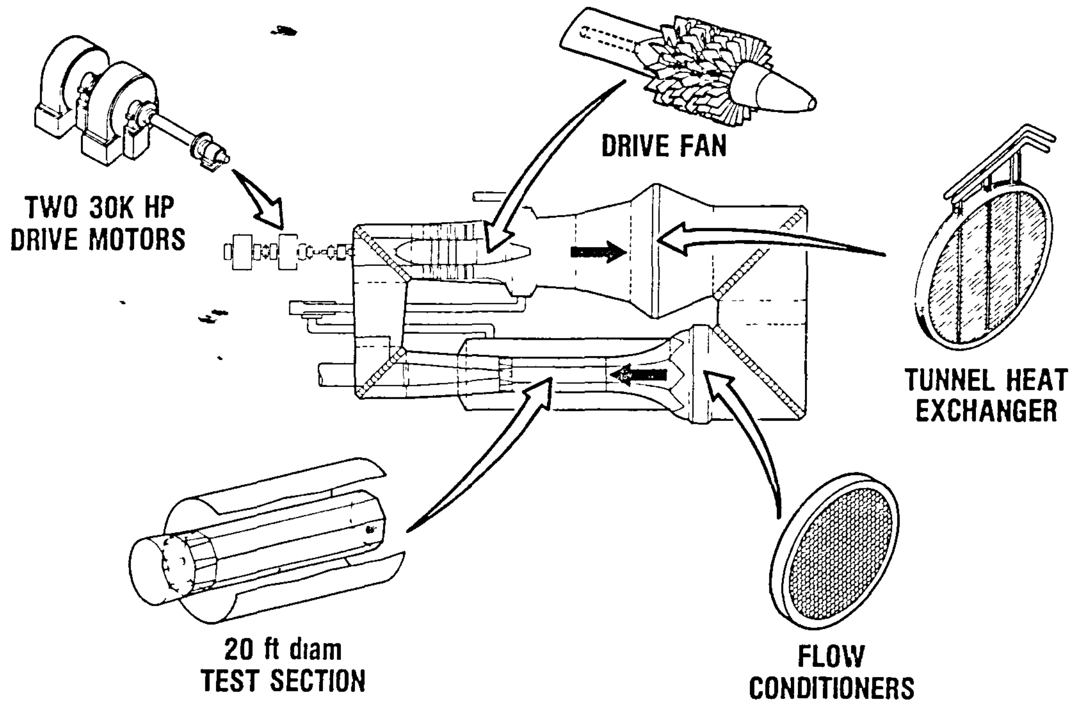


Figure 21.

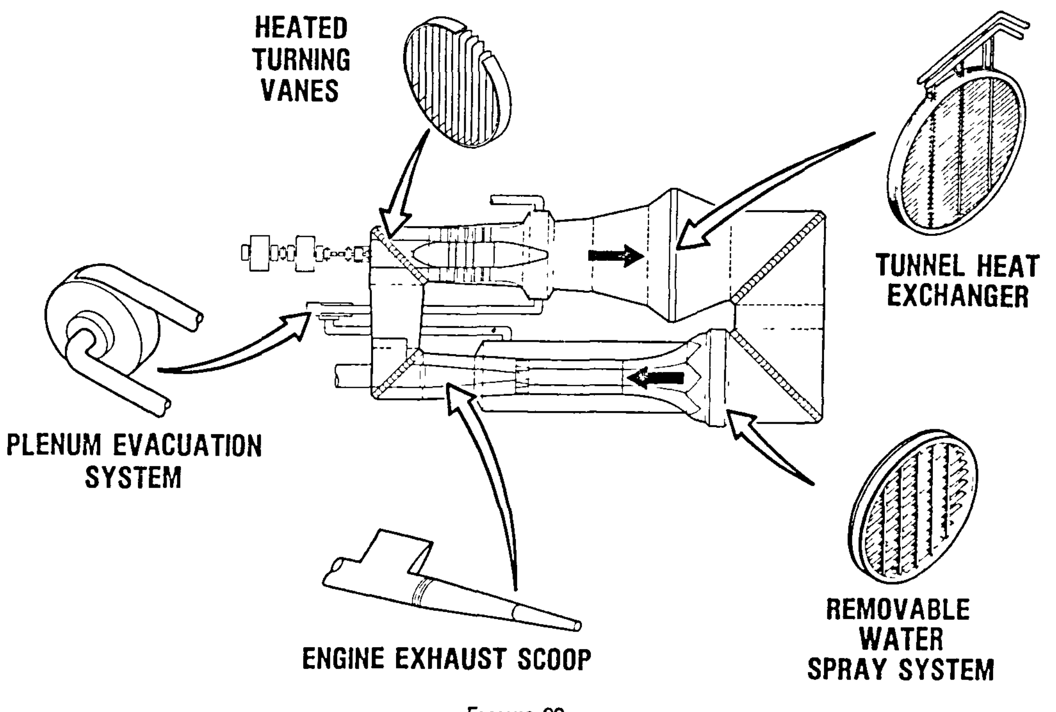
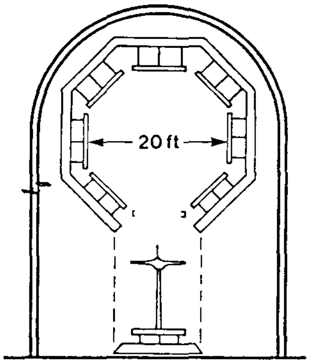


Figure 22.

TEST SECTION FEATURES



- OCTAGONAL CROSS SECTION
- SLOTTED WALL WITH PLENUM
- FLAT WINDOWS
- FORCE BALANCE
- REMOVABLE ACOUSTICAL WALLS
- BOTTOM MODEL ENTRY
- RAPID MODEL ACCESS

Figure 23.

AWT SATISFIES PROPULSION SYSTEM INTEGRATION TEST REQUIREMENTS

CONCURRENT PRESSURE & TEMPERATURE

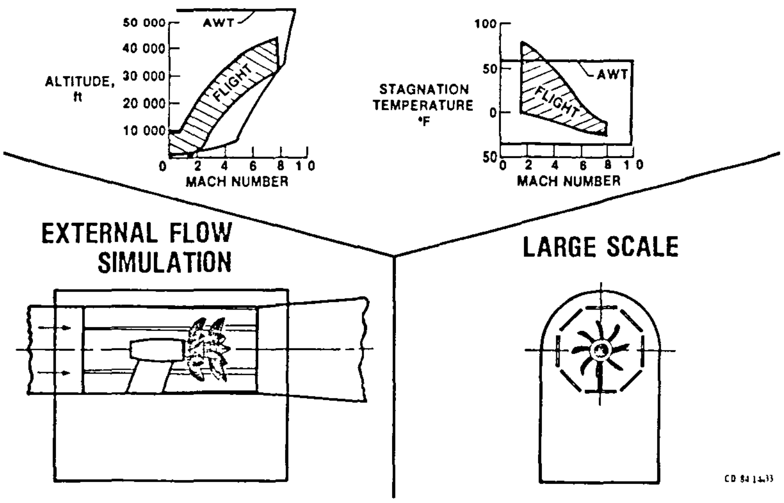


Figure 24.

AWT SATISFIES ICING TEST REQUIREMENTS

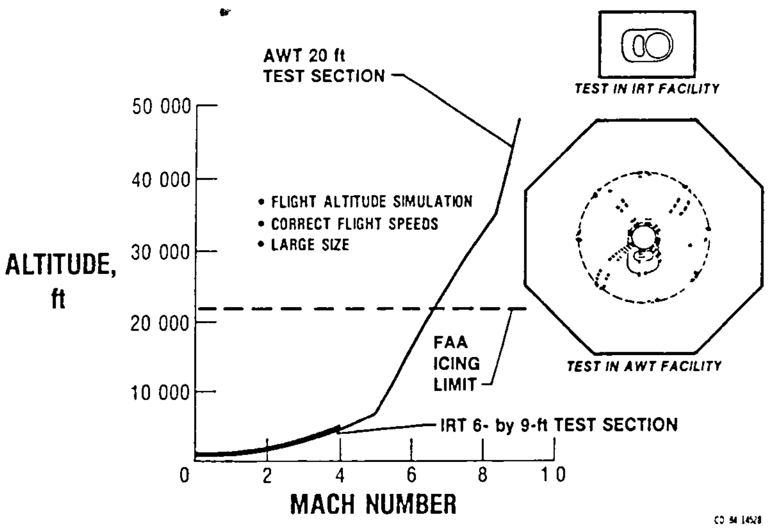


Figure 25.

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15 Supplementary Notes

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16 Abstract

A need has arisen for a new wind tunnel facility with unique capabilities for testing propulsion systems and for conducting research in adverse weather conditions. New propulsion system concepts, new aircraft configurations with an unprecedented degree of propulsion system/aircraft integration, and requirements for aircraft operation in adverse weather dictate the need for a new test facility. Required capabilities include simulation of both altitude pressure and temperature, large size, full subsonic speed range, propulsion system operation, and weather simulation (i.e., icing, heavy rain). A cost effective rehabilitation of the NASA Lewis Research Center's Altitude Wind Tunnel (AWT) will provide a facility with all these capabilities.

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