

# Lecture # 3: Wind Tunnels and Water Tunnels

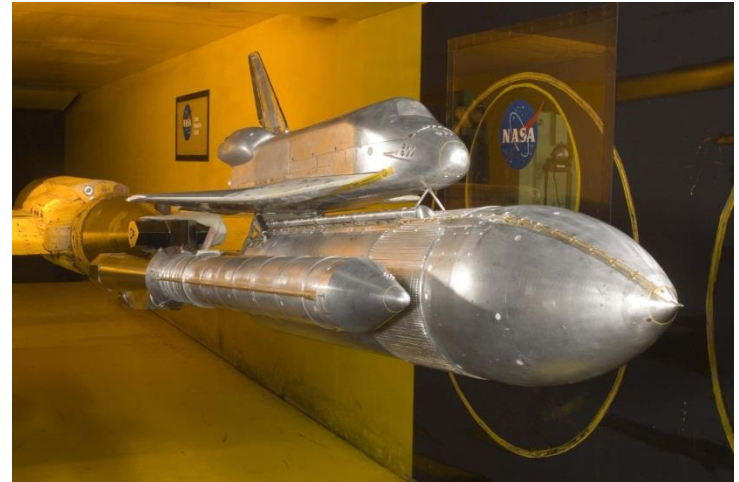
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# FUNCTION OF WIND TUNNELS AND WATER TUNNELS

- Producing the desired flow field with controlled conditions



# Relative Motion

## REST AND MOTION ARE RELATIVE

### RELATIVE MOTION



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### RELATIVE MOTION

Man is Standing at ground observing airplane or moving car man is standing hence its coordinate is not changing its position is fixed so this reference frame is stationary, but every time coordinate of airplane is changing hence airplane is moving reference frame

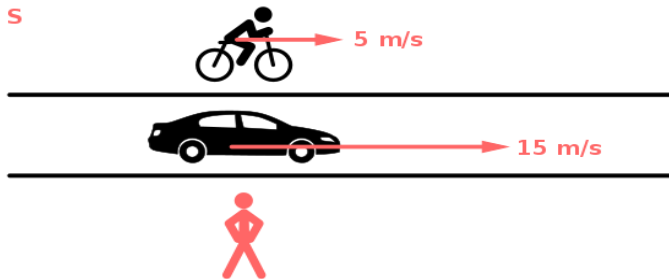


Ground

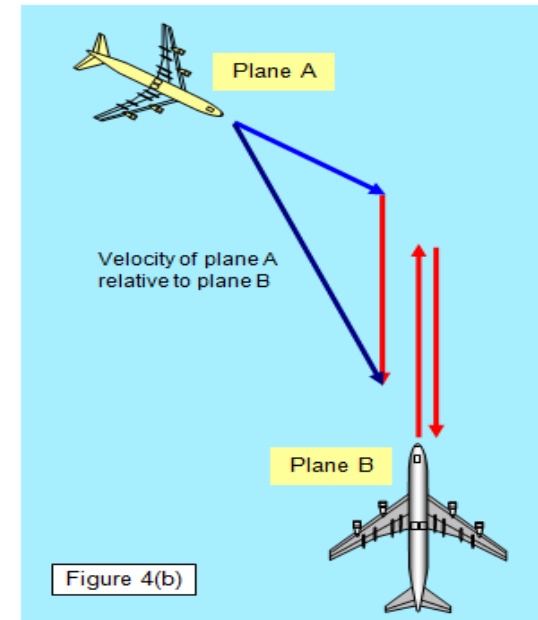
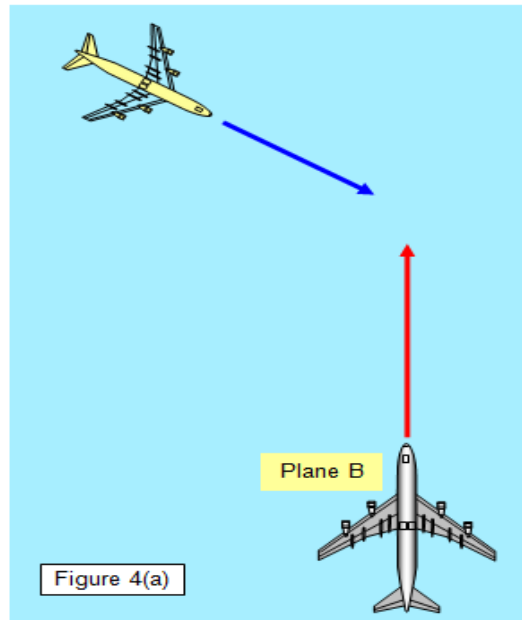
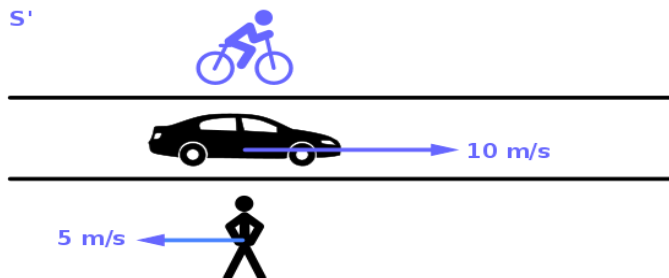
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- In classical physics and special relativity, **an inertial frame of reference** is a frame of reference that is not undergoing acceleration.

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# Types of Wind Tunnels

**Based on Flow Speed:**

- **Subsonic or low-speed wind tunnels ( $M \ll 1.0$ )**
- **Transonic wind tunnels ( $M \approx 1.0$ )**
- **Supersonic wing tunnels ( $1.0 < M < 5.0$ )**
- **Hypersonic wind tunnels ( $M > 5.0$ )**

$$\text{ratio} = \frac{\text{Object Speed}}{\text{Speed of Sound}} = \text{Mach Number}$$



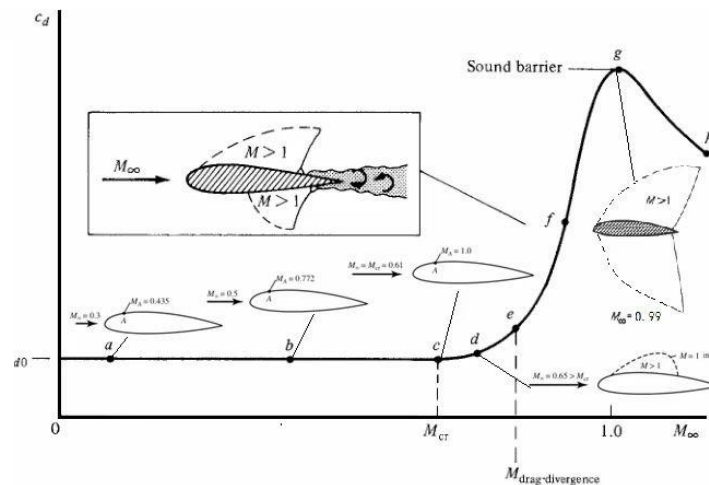
**Transonic**  
Mach = 1.0



**Supersonic**  
Mach > 1.0



**Hypersonic**  
Mach > 5.0



Sketch of the variation of profile drag coefficient with freestream Mach number, illustrating the critical and drag-divergence Mach numbers and showing the large drag rise near Mach 1.



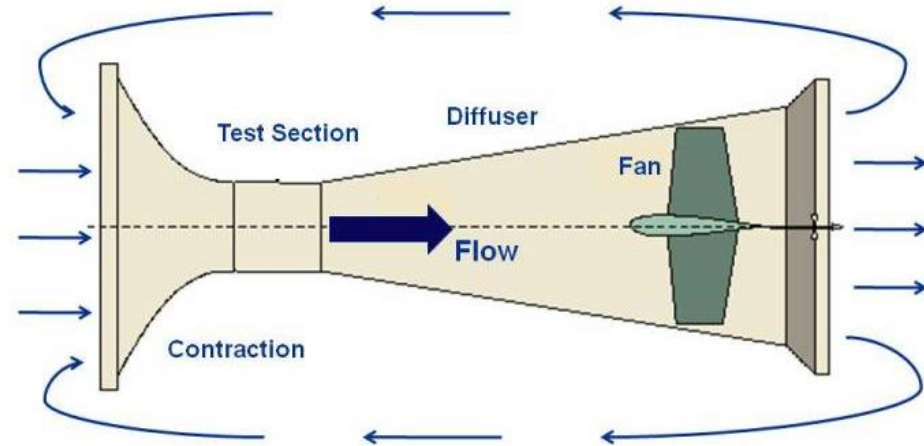
# Types of Wind Tunnels

## Based on Shape:

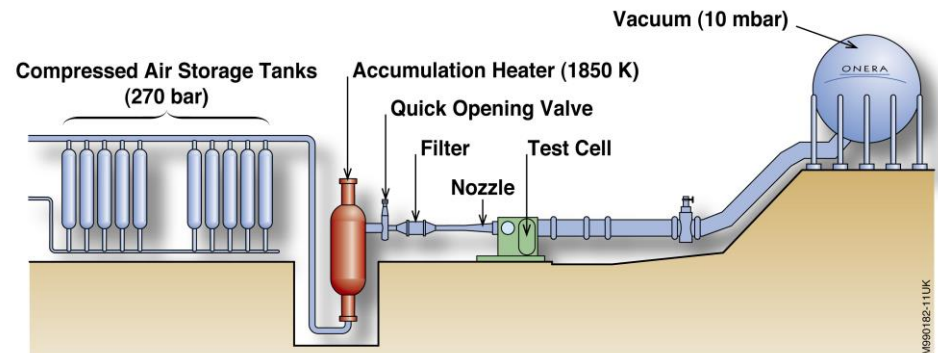
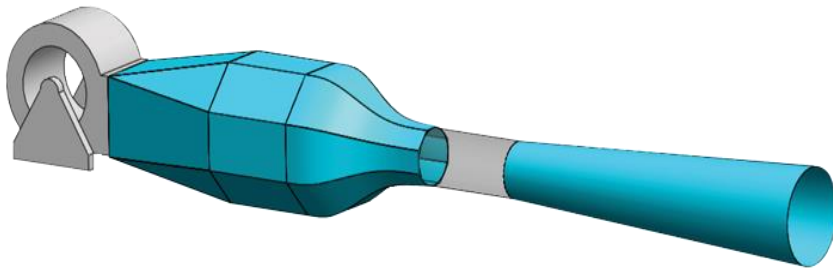
- **Open circuit wind tunnel:**



## Open Return Wind Tunnel



- **Suction wind tunnel:** With the inlet open to atmosphere, axial fan or centrifugal blower is installed after test section.

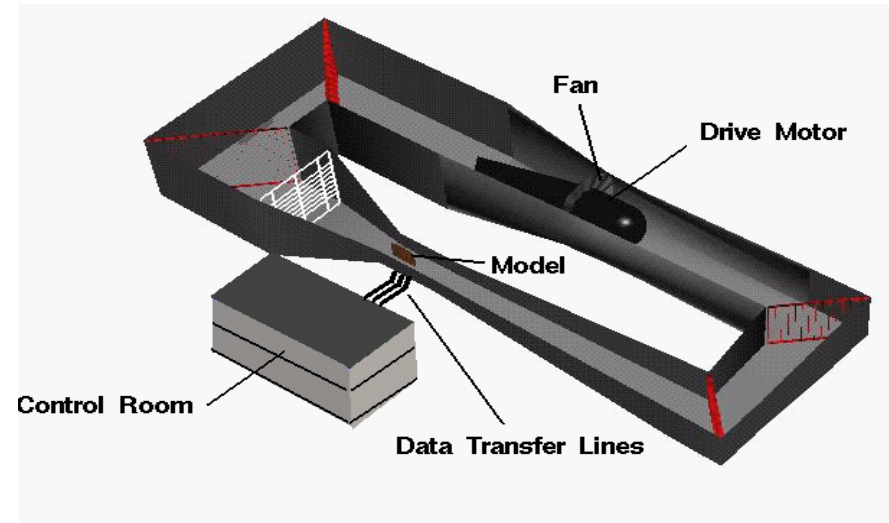
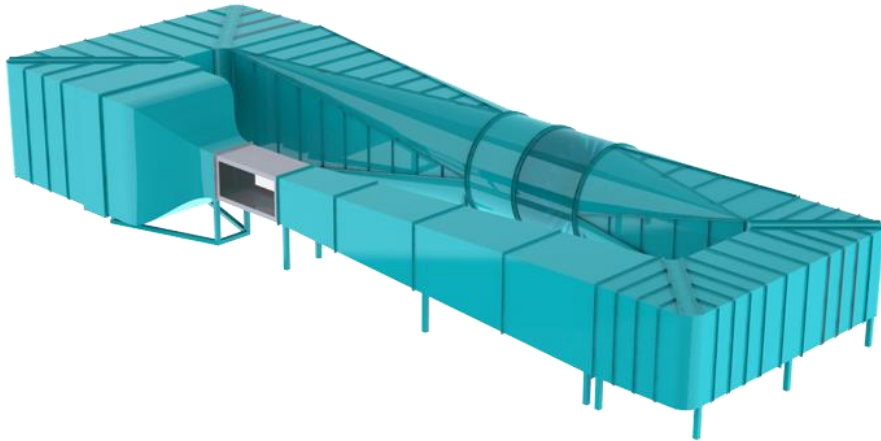


- **Blow down wind tunnel:** A blower is installed at the inlet of wind tunnel which throws the air into wind tunnel.

# □ TYPES OF WIND TUNNELS

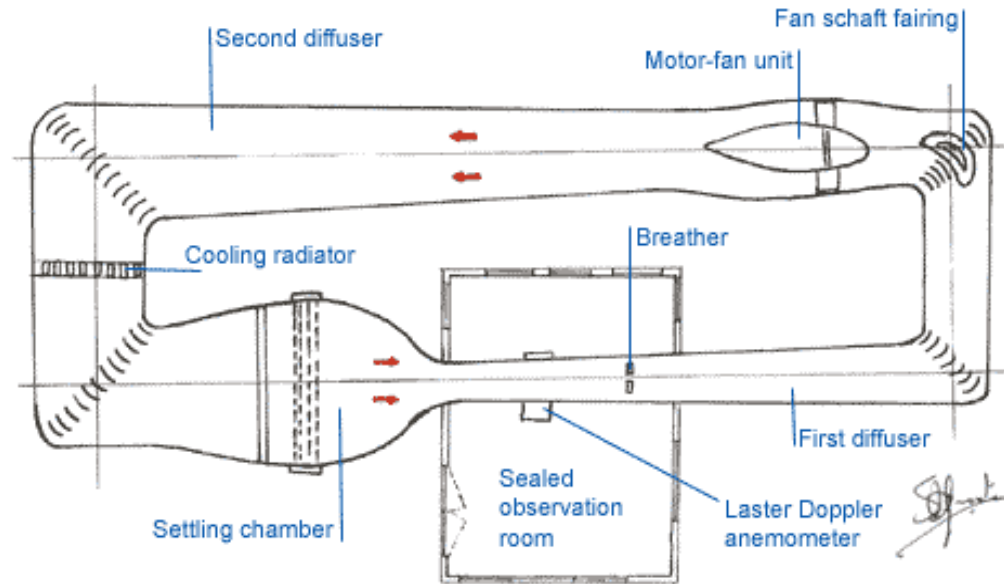
*Based on Shape:*

- *Close-circuit wind tunnel:*



# Components of a Closed-Looped Wind Tunnel

- *Test section*
- *Contraction section*
- *Diffuser section*
- *Setting chamber*
- *Screens and similar structures*
- *Cooling system / radiators*
- *Motors / fans*



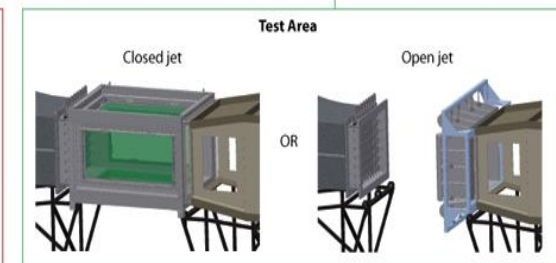
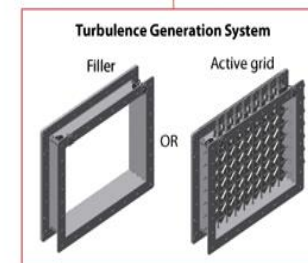
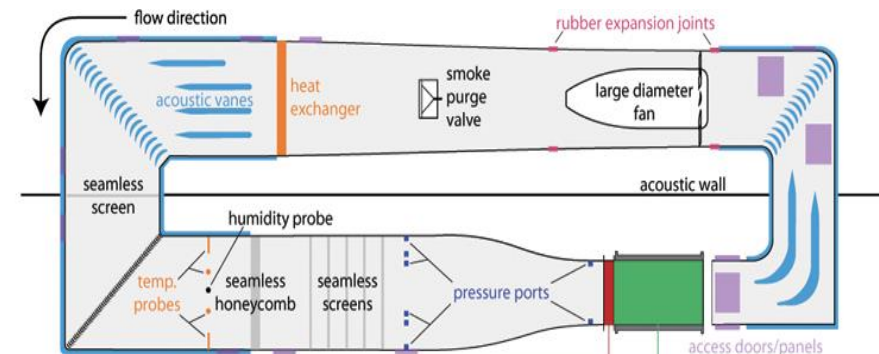
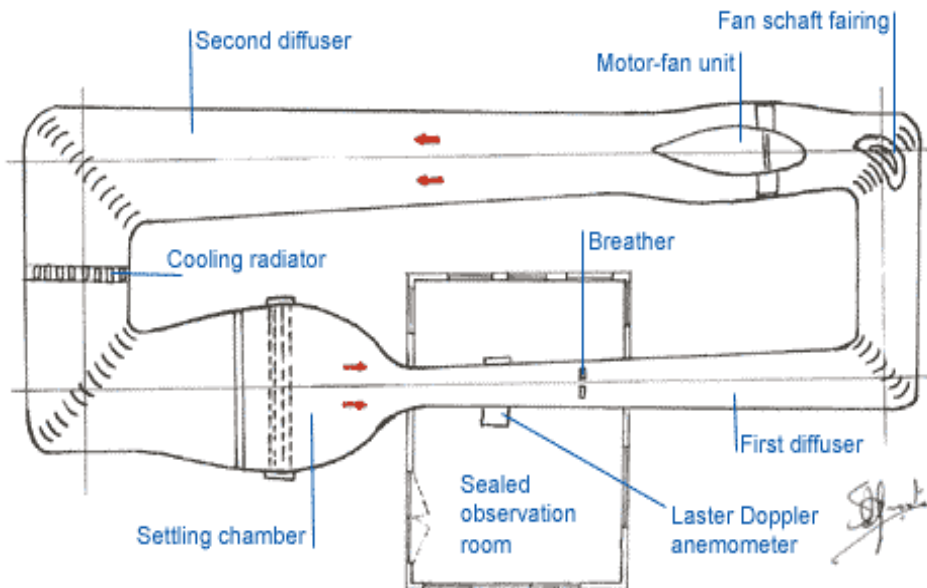
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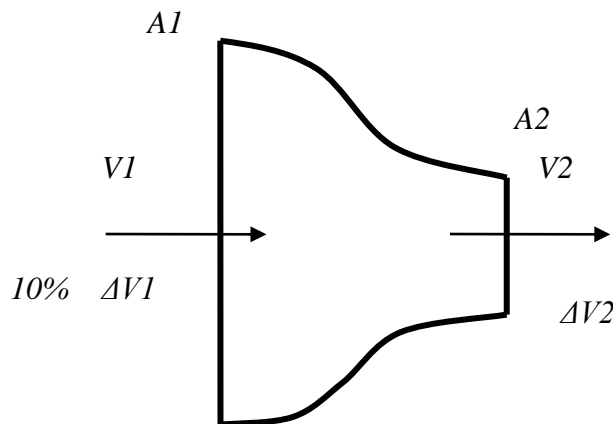
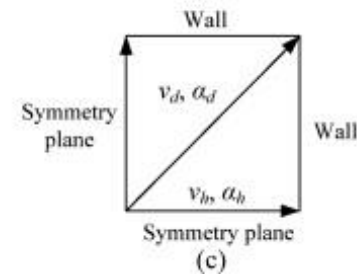
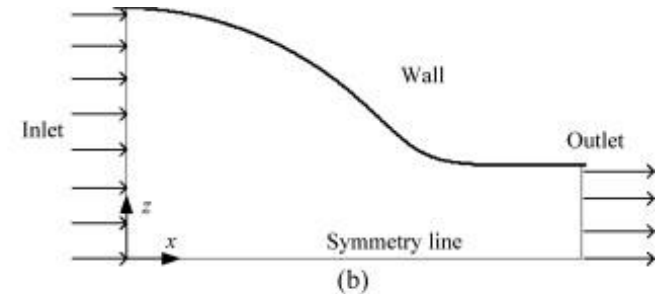
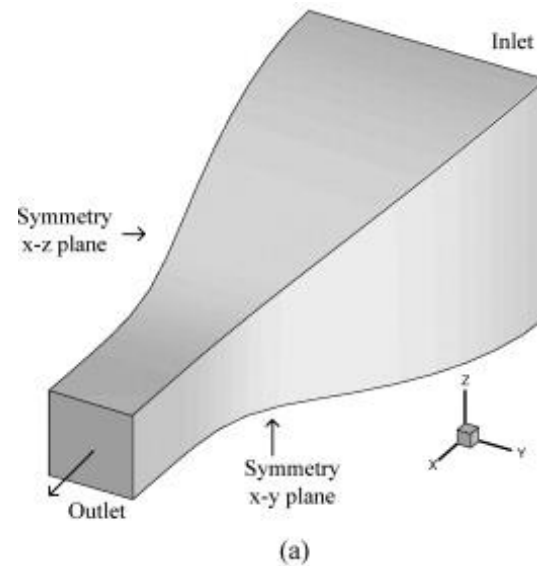
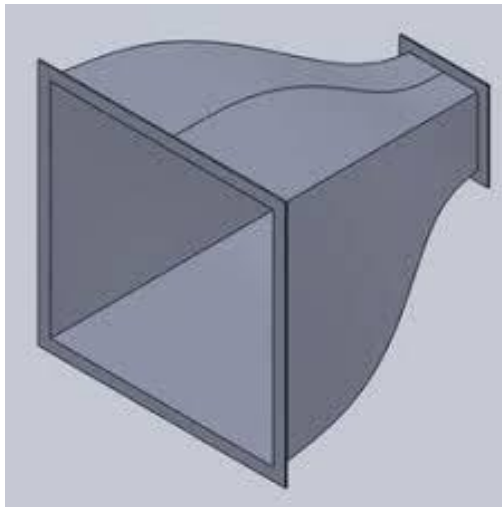
# COMPONENTS OF A WIND TUNNEL

- Test section
- Contraction section
- Diffuser section
- Setting chamber
- Screens and similar structures
- Cooling system / radiators
- Motors /fans





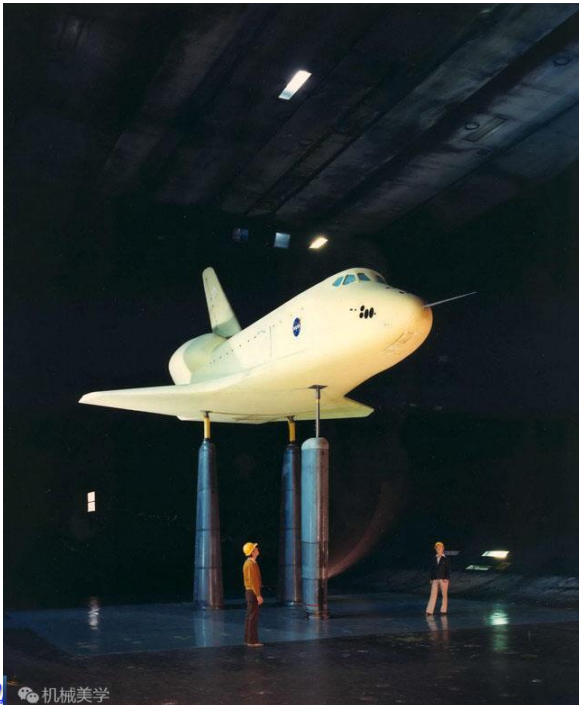
# FUNCTION OF CONTRACTION SECTION



$$c_1 = \frac{A_1}{A_2} \quad \text{if} \quad \frac{\Delta V_1}{V_1} = 0.1$$

$$\frac{\Delta V_2}{V_2} = \frac{1}{c^2} \frac{\Delta V_1}{V_1} = \frac{0.1}{100} = 0.001$$

# □ NASA AMES WIND TUNNEL - (25M × 37M TEST SECTION, 756W POWER)





# □ NASA AMES WIND TUNNEL - (25M × 37M TEST SECTION, 75GW POWER)

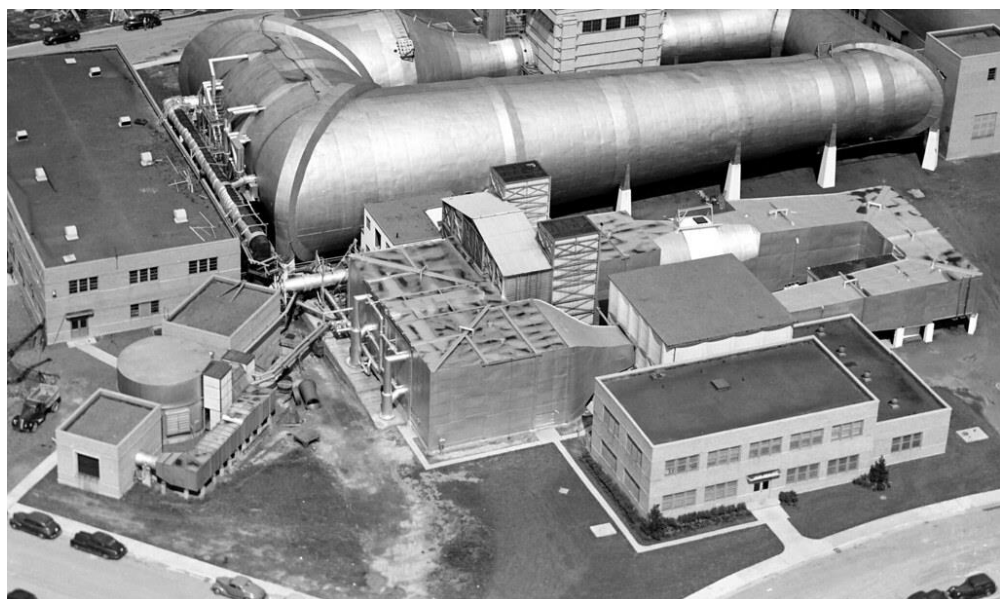
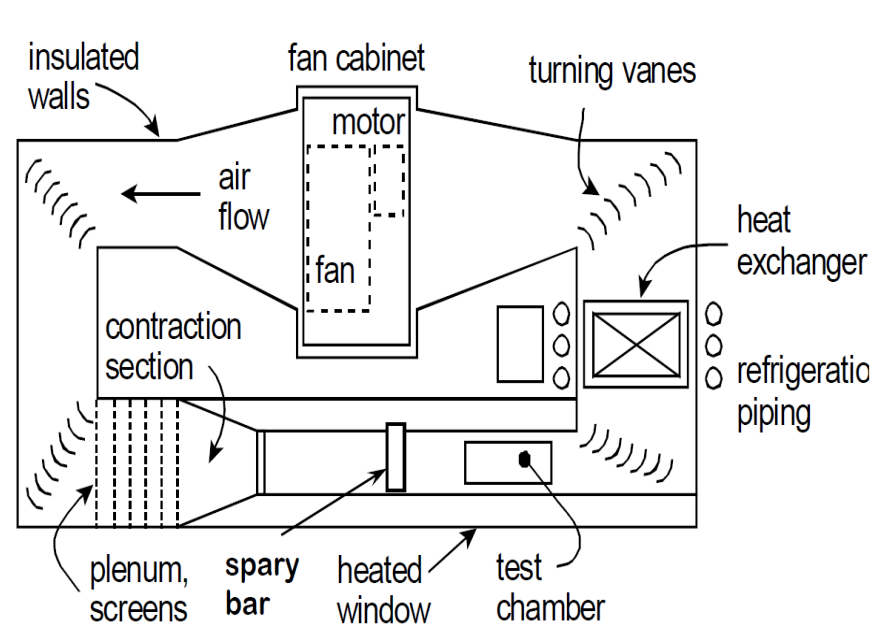
**NASA Ames Wind Tunnel**



**Testing in NASA Ames Wind Tunnel**



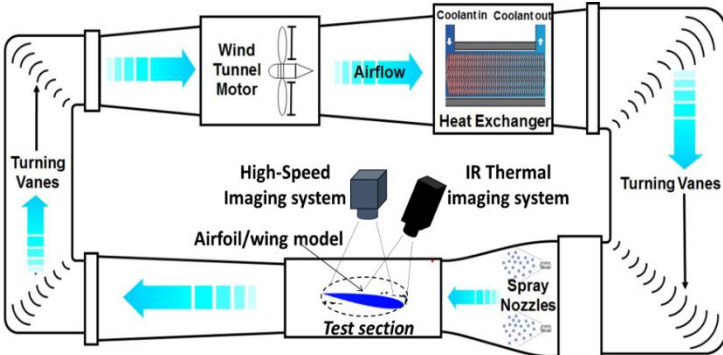
# ❏ Icing Wind Tunnels



• **ICING RESEARCH TUNNEL @ NASA GLENN CENTER**



# ❏ Icing Research Tunnel @ Iowa State University (ISU-IRT)



• **ISU Icing Research Tunnel (ISU-IRT)**, donated by Collins Aerospace System, is a new refurbished, research-grade multi-functional icing research tunnel.

• **The working parameters of the ISU-IRT include:**

- **Test section:**  $0.4\text{m} \times 0.4\text{m} \times 2.0\text{m}$
- **Airflow velocity:**  $V_{\infty} = 5 \sim 100 \text{ m/s}$ ;
- **Temperature:**  $T_{\infty} = -25^{\circ}\text{C} \sim 20^{\circ}\text{C}$ ;
- **Droplet size:**  $D_{\text{droplet}} = 10 \sim 100 \mu\text{m}$ ;
- **Liquid Water Content:**  $\text{LWC} = 0.1 \sim 10 \text{ g/m}^3$

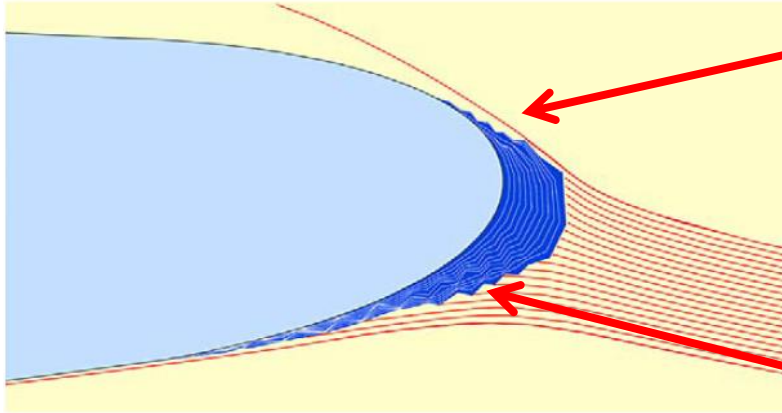
- **The large LWC range allows ISU-IRT to be run over a wide range of conditions (i.e., from dry rime to wet glaze icing).**
- **Received ~\$10M in funded research for ~30 projects since 2008 from NASA, NSF, FAA, NAVY, GE, P&W, UTAS, DuPont...**





# ❏ ICING RESEARCH TUNNEL @ IOWA STATE UNIVERSITY (ISU-IRT)

- Icing is a very complex, multiphase flow problem coupled with heat transfer & phase changing.



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Upper surface

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Lower surface

AoA<sub>iced</sub> = 0 deg

AoA<sub>iced</sub> = 5 deg

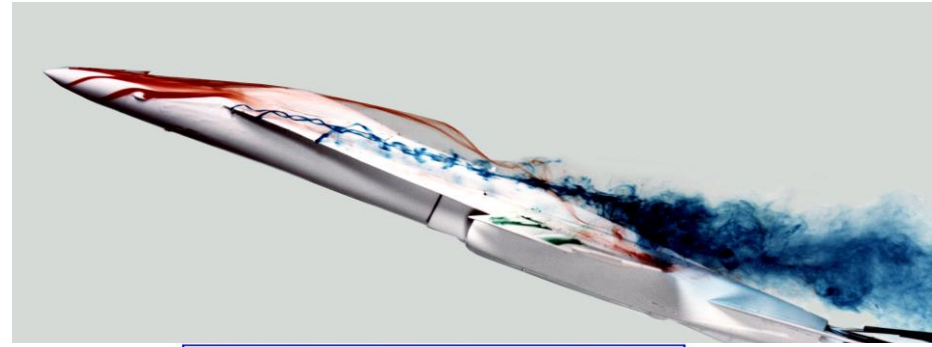
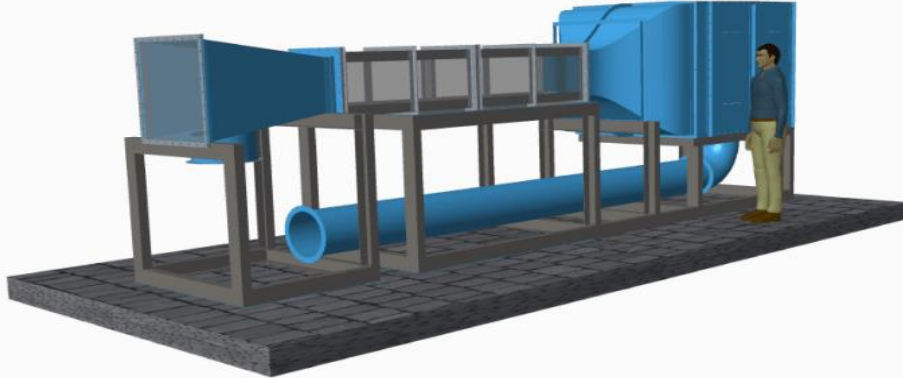
AoA<sub>iced</sub> = 10 deg

AoA<sub>iced</sub> = 15 deg

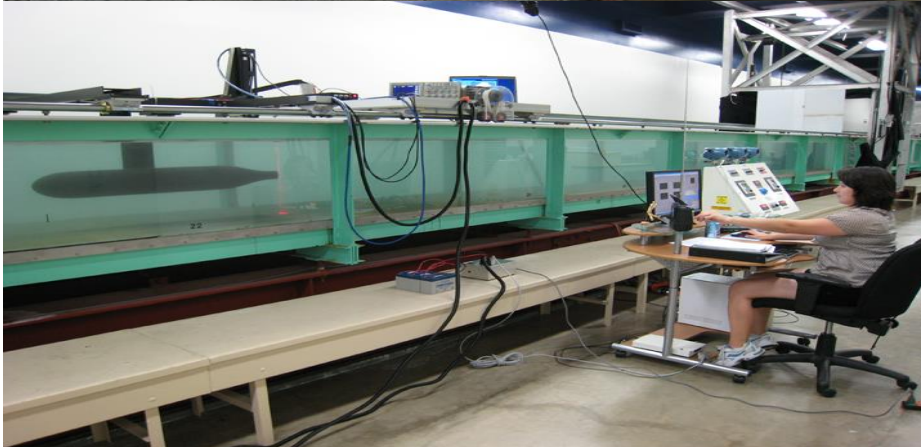
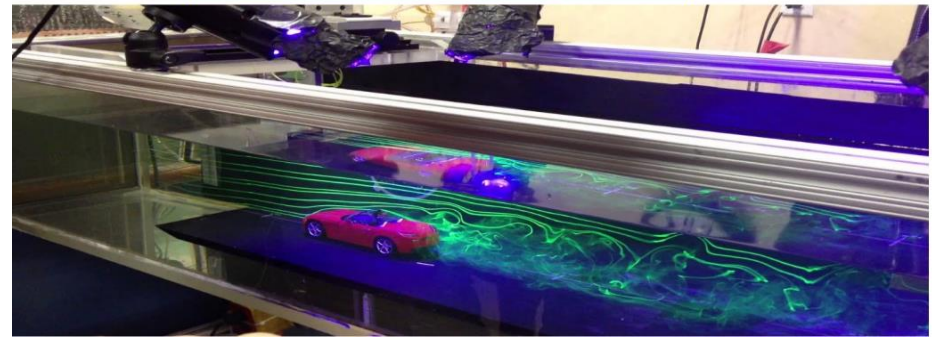




# □ WATER TUNNELS



Water Tunnel for Testing of Car

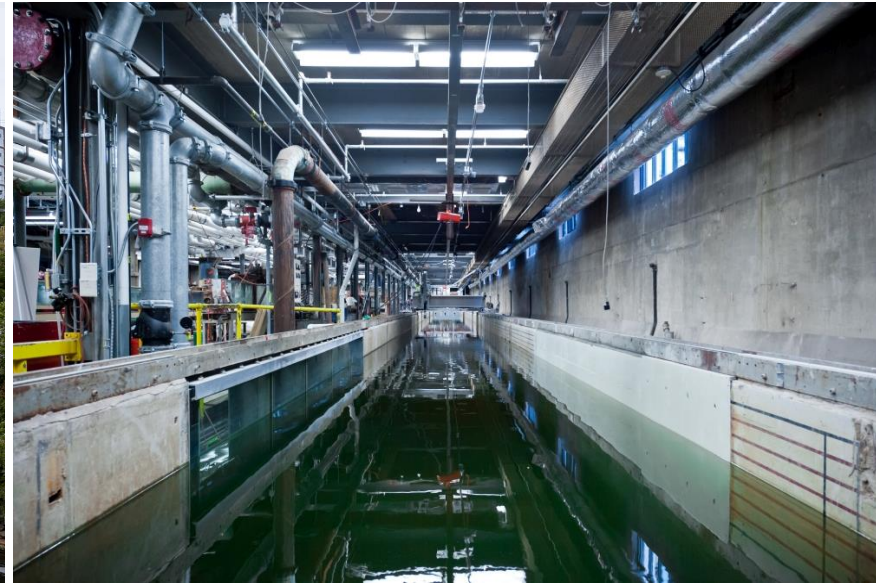


<https://www.youtube.com/watch?v=ufQj9irKQdU>

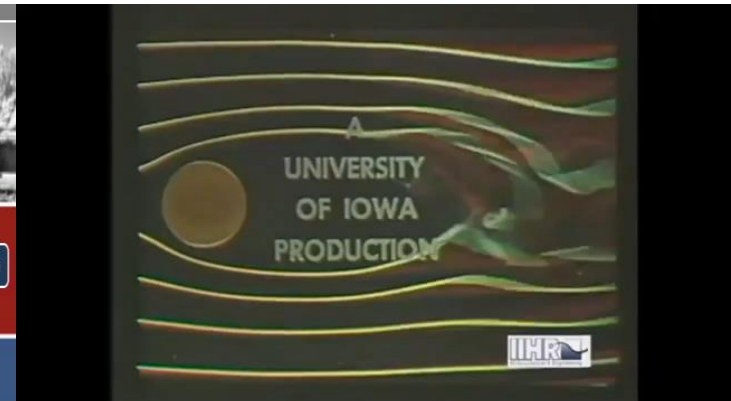


# ❑ Water Tunnels

- *Saint Anthony Falls Laboratory; University of Minnesota*



- *Hydrosience research laboratory at the University of Iowa*





# ❑ TOWING TANK



- **TOWING TANK**

