WIND TUNNEL

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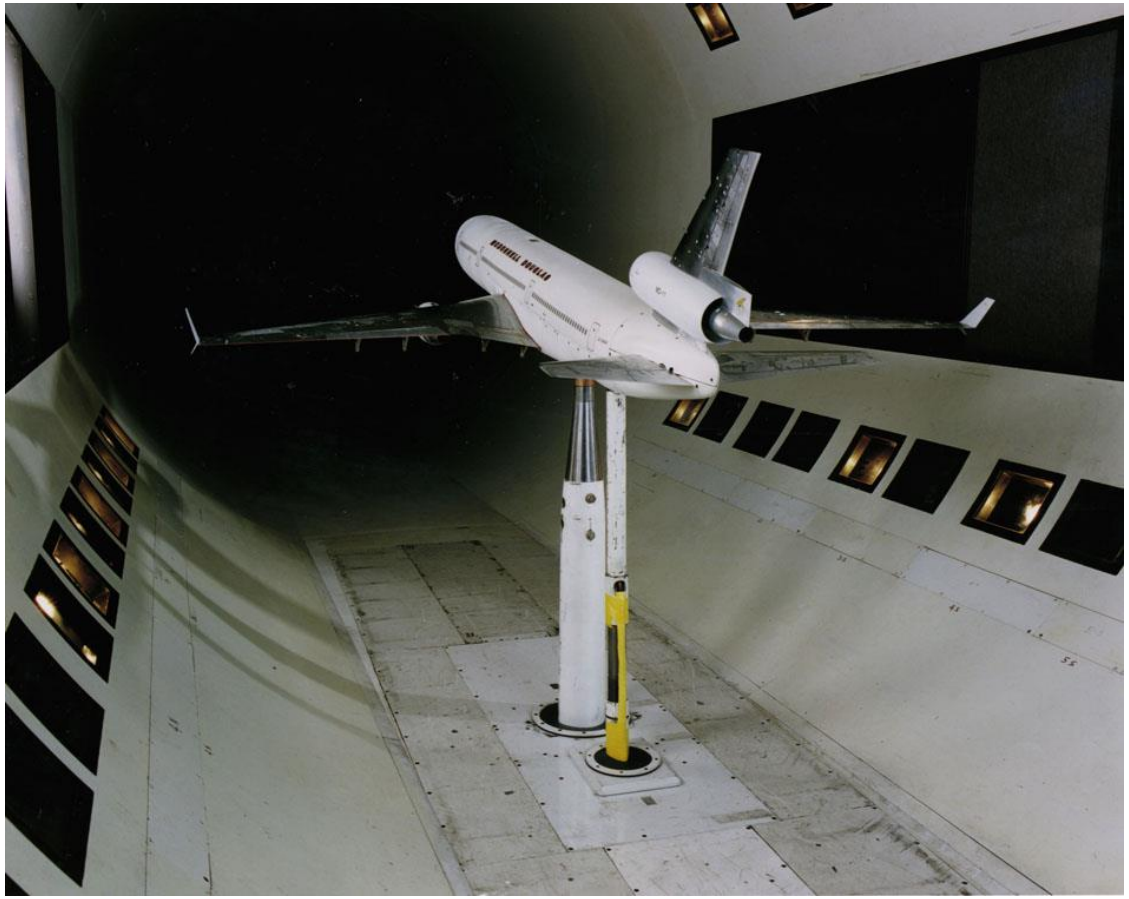
WIND TUNNELS

Wind tunnels are large tubes with air moving inside. The tunnels are used to copy the actions of an object in flight. Researchers use wind tunnels to learn more about how an aircraft will fly. **NASA** uses wind tunnels to test scale models of aircraft and spacecraft. Some wind tunnels are big enough to hold full-size versions of vehicles . The **wind tunnel** *moves air around an object, making it seem like the object is really flying*.

Wind tunnel is a device used to investigate an interaction between solid body flows in wind tunnel can be performed in term of:

- Monitoring physical flow phenomenon such as laminar, turbulent and separation flows, vortex and shock wave.
- Measuring aerodynamic quantities such as pressure, skin friction, lift, drag and moments. In order to monitor the flow phenomenon and measure aerodynamic quantities, engineers require measuring equipment and measurement techniques. One experimental aerodynamic problem can be solved by some different measurement techniques. In addition, for a special problem of experimental aerodynamic sometimes requires a specific wind tunnel construction.

WIND TUNNELS (NASA)



WIND TUNNELS

The wind tunnel provides great benefits for aerodynamic tests compared to free flight testing, that is:

- Specified flow condition such as Mach number and incidence can be achieved

sustained much easier in a wind tunnel.

- Dangerous, uncontrollable flight condition may safely investigate in wind tunnel.
- Data acquisition and processing is simpler with direct connection to ground based equipment.

The main disadvantage of wind tunnel is that it is seldom possible to reproduce the condition of full scale motion exactly. This is mainly due to the use of scaled models for reason of tunnel cost and power consumption.

WIND TUNNELS (NASA)

How Can Wind Tunnels Help Spacecraft?

NASA also uses wind tunnels to test **spacecraft** (космический аппарат, КА) and **rockets**. These vehicles are made to operate in space. Space has **no atmosphere**. Spacecraft and rockets have to travel through the atmosphere to get to space. Vehicles that take humans into space also must come back through the atmosphere to Earth.

Wind tunnels are important in making the new Ares rockets and Orion spacecraft. Ares and Orion are new vehicles that will take astronauts into space. NASA engineers tested ideas for the design of Ares in wind tunnels. They needed to see how well Ares would fly. Engineers tested Orion models. They needed to know what would happen to different designs when the spacecraft came back through the atmosphere.

Long after the first design work is finished, NASA can still use wind tunnels. Wind tunnel tests have helped NASA change the space shuttle to make it safer. Wind tunnels will keep helping make all spacecraft and rockets better.

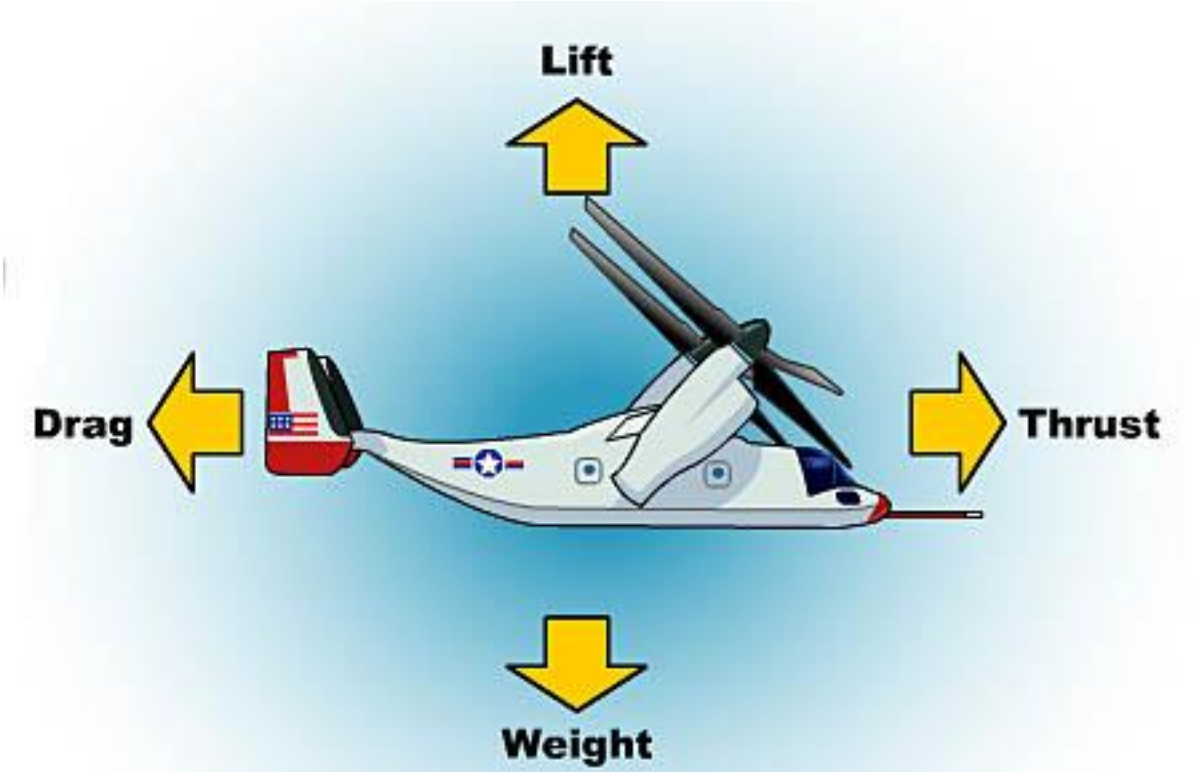
WIND TUNNELS (NASA)

What Types of Wind Tunnels Does NASA Use?

NASA has many different types of wind tunnels. They are located at NASA centers all around the country. The wind tunnels come **in a lot of sizes**. Some are **only a few inches square**, and **some are large enough to test a full-size airplane**. Some wind tunnels test aircraft at very slow speeds. But some wind tunnels are made to test at hypersonic speeds. That is more than *4,000 miles per hour*!

Aerodynamics .
What Are the Four Forces of Flight? (NASA)

The **four forces** of flight are lift, weight, thrust and drag. These forces make an object move up and down, and faster or slower. How much of each force there is changes how the object moves through the air.



Aerodynamics .
What Are the Four Forces of Flight?

- **What Is Drag?**
  Drag is a force that *tries to slow something down*. It makes it hard for an object to move. It is harder to walk or run through water than through air. That is because water causes more drag than air. The shape of an object also changes the amount of drag. Most round surfaces have less drag than flat ones. Narrow surfaces usually have less drag than wide ones. The more air that hits a surface, the more drag it makes.

- **What Is Thrust?**
  Thrust (сила тяги) is the force that is the opposite of drag. Thrust is the push that moves something forward. For an aircraft to keep moving forward, it must have more thrust than drag. A small airplane might get its thrust from a propeller. A larger airplane might get its thrust from jet engines. A glider (планер) does not have thrust. It can only fly until the drag causes it to slow down and land.

Aerodynamics .
What Are the Four Forces of Flight?

- **How Do an Airplane's Wings Provide Lift?**
  The shape of an airplane's wings is what makes it able to fly. Airplanes' wings are curved on top and flatter on the bottom. That shape makes air flow over the top faster than under the bottom. So, less air pressure is on top of the wing. This condition makes the wing, and the airplane it's attached to, move up. Using curves to change air pressure is a trick used on many aircraft. Helicopter rotor blades use this trick. Lift for kites also comes from a curved shape. Even sailboats use this concept. A boat's sail is like a wing. That's what makes the sailboat move.

CLASSIFICATION OF WIND TUNNEL

- Aeronautical Wind Tunnels
- Automobile Tunnels
- Aeroacoustic Tunnels

CLASSIFICATION OF WIND TUNNEL.
Aeronautical Wind Tunnels.

- High Reynold's Number Tunnels
- Pressurized Tunnels
- Heavy Gas TunnelsCryogenic Tunnels
- High-altitude Tunnels
- V/STOL Tunnels
- Spin Tunnels

CLASSIFICATION OF WIND TUNNEL

- Based on speed range
- Based on flow circulation

CLASSIFICATION OF WIND TUNNEL

BASED ON SPEED RANGE

The most appropriate classification of wind tunnels is by the speed range they cover. The classification of wind tunnels based on the speed range includes:

- **Low speed wind tunnel (Subsonic).** The flow velocity in low subsonic wind tunnel is of the Mach number range of zero till 0.3. Viscous and inertial forces are dominant while compressibility effects are negligible.
- **High speed wind tunnel (Transonic).** The designation high speed usually includes high subsonic, transonic and low supersonic regimes, so that the range of the flow velocity for high speed wind tunnel is of Mach number between 0.3 and 1.4. Here, in principle, compressibility effects are of dominant importance. However, viscous effects also play an important part in particular when shock boundary layer intersection leads to flow separation.
- **Supersonic wind tunnel.** The flow velocity in supersonic wind tunnel is the range of Mach number of 1.4 till 5.0. Compressibility effects are dominant. The pressure disturbance raises in the flow field propagating downstream.

CLASSIFICATION OF WIND TUNNEL

BASED ON SPEED RANGE

- **Hypersonic wind tunnel.** The flow velocity in hypersonic wind tunnel is of Mach number above 5.0. It is desired to allow real gas effects to occur. This requires that besides the high Mach number in test section also high total temperatures are provided. The high temperatures, which are linked with high pressures, yield vibration of the gas molecules, possibly causing dissociation and ionization. These are dominant features of hypersonic flows where the gas can no longer be treated as an ideal gas.

CLASSIFICATION OF WIND TUNNEL

BASED ON FLOW CIRCULATION

The other wind tunnel classification based on **flow circulation** is divided into **open circuit wind tunnel** and **closed circuit wind tunnel.**

- **Open circuit wind tunnel.** Open circuit wind tunnel is *first type of wind tunnel* built. The tunnel is usually referred to as an Eiffel type. Such a wind tunnel **consists of a nozzle**, at test section, **a diffuser** and **a driving unit**. **The principle work** of this wind tunnel is a *direct sucking of the atmospheric air lying outside of the wind tunnel brought into the tunnel settling chamber and continued to the end of the wind tunnel using a driving unit then the air is threw away to atmosphere*. The position of driving units can be at the downstream end where the tunnel is operated as suction tunnel while otherwise it would be termed a blow down tunnel. The suction tunnel is more preferred in a design by a reason of airflow quality.

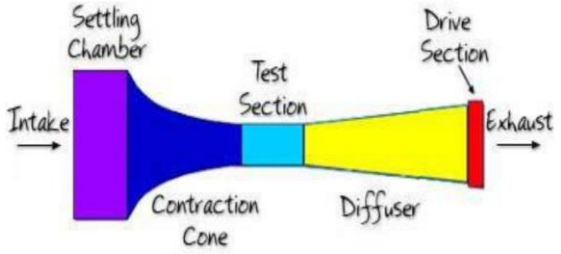


Figure 2.3: Open circuit wind tunnel

CLASSIFICATION OF WIND TUNNEL
Open circuit tunnel

Advantages of the Open Return Tunnel

- Low construction cost. Cheaper to build
- Superior design for propulsion and smoke visualization. There is no accumulation of exhaust products in an open tunnel. Pollutants are purged (e.g. smoke flow visualization or tests on internal combustion engines)

Disadvantages of the Open Return Tunnel

- Poor flow quality possible in the test section. The size of the tunnel must be compatible to the size of the room: the room is the return path for the air
- High operating costs. More expensive to run than closed type. The fan (вентилятор) must continually accelerate flow through the tunnel.
- Noisy operation. Loud noise from the fan may limit times of operation.

CLASSIFICATION OF WIND TUNNEL

BASED ON FLOW CIRCULATION

- **Closed circuit tunnel.** Closed circuit tunnel has been developed to reduce the amount of used energy. This tunnel is also called as *Gottingen type*. **The principle work** of this tunnel is by circulating the used airflow passing by the diffuser to the settling chamber using the connecting channel. The closed circuit tunnel consists of three types including single and double return. Of these, only the first is in general acceptance at present. *In the double return arrangement*, the particular air that scrapes along the wall of the return passages forms wakes in the centre of the jet and hence passes directly over the model. Unless the contraction ratio is large, this air is extremely tuberlent and tends to make the interpretation of the test data difficult. The fans are preferred attach on the connecting channel by reason of a protection from the model failure and of good from standpoint of fan efficiency.

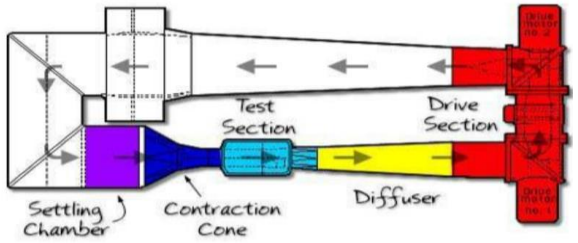


Figure 2.4: Closed circuit wind tunnel

Pictures of wind tunnels

The NASA Langley Transonic Dynamics Tunnel

The NRC's 9mx9m tunnel

CLASSIFICATION OF WIND TUNNEL
Closed circuit tunnel

Advantages of the Closed Return Tunnel

- Cheaper to run: energy is required only to overcome losses.
- Less noisy than open type.
- The quality of the flow can be easily controlled.

Disadvantages of the Closed Return Tunnel

- More expensive to build
- Not easy to purge
- Continuous losses of energy in the tunnel heat up the air, so the air may need cooling, especially in the summer

CLASSIFICATION OF WIND TUNNEL

Wind tunnels may also be classified according to their air pressure:

- atmospheric
- variable- densityor their size:
- ordinary
- full-scale

CLASSIFICATION OF WIND TUNNEL

- The criterion for classification is the purpose for which the wind tunnel is designed: research or education. If the wind tunnel is for research it is called a research wind tunnel. If however, it is designed to be used for education, then, it is called an educational wind tunnel.

- The criterion for classification is the **nature of the flow**: laminar vs. turbulent flow. Boundary layer wind tunnels are used to simulate turbulent flow near and around engineering and manmade structures.

Uses of wind tunnels

There are many uses of wind tunnels. They vary from ordinary to special: these include uses

- for Subsonic, supersonic and hypersonic studies of flight;
- for propulsion and icing research;
- for the testing of models and full-scale structures, etc.

Some common uses are presented below. Wind tunnels are used for the following:

To determine aerodynamic loads

Wind tunnels are used to determine aerodynamic loads on the immersed structure. The loads could be static forces and moments or dynamic forces and moments. Examples are forces and moments on airplane wings, airfoils, and tall buildings.

Uses of wind tunnels

- **To study how to improve energy consumption by automobiles**

They can also be used on automobiles to measure drag forces with a view to reducing the power required to move the vehicle on roads and highways.

- **To study flow patterns**

To understand and visualize flow patterns near, and around, engineering structures. For example, how the wind affects flow around tall structures such as sky scrapers, factory chimneys, bridges, fences, groups of buildings, etc. How exhaust gases ejected by factories, laboratories, and hospitals get dispersed in their environments.

- **Other uses include**

To teach applied fluid mechanics, demonstrate how mathematical models compare to experimental results, demonstrate flow patterns, and learn and practice the use of instruments in measuring flow characteristics such as velocity, pressures, and torques.

Air Properties Definitions

Glenn Research Center

Air is a Gas. 78% Nitrogen, 21% Oxygen, traces H_2O, CO_2, Ar, ..

Property	Dimensions	Value (SLS*)	
Mass, Volume		Metric	Imperial
Density (r)	mass/volume	1.229 kg/m^3	.00237 $slug/ft^3$
Specific Volume (v)	volume/mass	.814 m^3/kg	422 $ft^3/slug$
Pressure (p)	force/area	101.3 kN/m^2	14.7 lb/in^2
Temperature (T)	degrees	15 ^oC	59 ^oF
Viscosity (mu)	force–time/area	1.73×10^{-5} $N\text{-}s/m^2$	3.62×10^{-7} $lb\text{-}s/ft^2$

* Sea Level Static (Standard Day)

WIND TUNNEL TESTING VIDEOS

- Videos\Mercedes-Benz SLS AMG Developement and Testing Wind tunnel.mp4
- Videos\Pro Stock Snowmobile Wind Tunnel.mp4
- Videos\3T Wind Tunnel Testing with BMC Racing Team.mp4
- Videos\AeroDyn .mp4

- http://ru.scribd.com/doc/150035406/Wind-Tunnel-ppt#scribd
- http://futureflight.arc.nasa.gov/
- http://www.nasa.gov/audience/forstudents/k-4/stories/homework-topics-index.html
- http://www.a2wt.com/index.html