

Executive Summary

The objective was to design an Atmospheric Engine Test Cell to test an experimental Gas Turbine Engine ($\emptyset = 0.35$ m). It should be capable of performing all 'engine design' clearance tests. It would have to simulate the specific Design Point of Mach number = 0.7 at an Altitude Temperature = 219 K (35000 ft). The Design was split into 2 parts:

- The Wind Tunnel Design – The Tunnel had to achieve the Design Point Velocity ($M_{TS} = 0.7$) at the Engine Test Piece from a 'deliverable' set of Inlet conditions (P_0 , T_0 , and $\dot{m}$). These Inlet conditions served as the Design objectives for the 2nd part; the Mixing Chamber.
- The Mixing Chamber Design – The component had to cool the airflow supply prior to the Wind Tunnel Inlet. The objective was to deliver the Wind Tunnel Inlet conditions, and ultimately achieve the Design Point Test Section Temperature ($T_{TS} = 219$ K) at the Engine Test Piece.

The hypothesis for each part (Wind Tunnel and Mixing Chamber) was developed using F-Chart Engineering Equation Solver. The hypotheses were then Analytically Modelled in 3-D using Solid Edge ST6, and simulated using Numerical Methods (Meshing = ANSYS 14.5 ICEM, Solving = ANSYS 14.5 FLUENT). No scaled physical model was attempted. The Wind Tunnel was validated against the respective Analytical Model; given the simplicity of the 1-D flow path. The Mixing Chamber, which served as the research component of the Project, was validated using available published data.

The Wind Tunnel was designed as an Open Circuit Blowdown Tunnel with an Open Test Section (to house the Engine Test Piece). The Tunnel delivered the flow as a free-jet; which rammed the Test Piece. The Tunnel achieved the Velocity objective ($M_{TS} = 0.7$) in the most efficient way; using the least expensive Wind Tunnel Inlet specifications. The Project-specific purpose of the Wind Tunnel was to determine the Design objectives for the preceding Mixing Chamber. The Mixing Chamber was designed using the experimental mechanism of Underexpanded Supersonic Cooling. The cooling requirements (Absolute Temperature T_0 and Cooling Capacity $\dot{Q}$) was not possible using conventional methods (Vapor Cycle or Dry Ice sublimation). The Supersonic Cooling mechanism, however, was theoretically capable of dynamically cooling large amounts of airflow. The mechanism rapidly expanded air at ambient T_0 and high P_0 to achieve air at ambient P_0 and low T . The Mixing Chamber was fed by a single Low Pressure Centrifugal Fan (to deliver the Main flow P_0 and $\dot{m}$) and 6 High Pressure Rotary Compressors (to achieve the Supersonic Cooling contribution). The Cost per run (1 hour) amounted to $\pm$ R 1363.18 (dated 2013).

The Mixing Chamber exceeded the P_0 and $\dot{m}$ Wind Tunnel Inlet requirements, in order to achieve the Velocity objective ($M_{TS} = 0.75 > 0.7$). However, it underperformed with the Altitude Temperature objective. It only cooled the flow to $T_{TS} = 222.2$ K (> 219 K). This Altitude Temperature revised the Design Point capability of the Project to M0.75 at 222.2 K (32000 ft), instead of the 'ideal' M0.7 at 35000 ft. The reason for the shortcoming was the incomplete expansion of the latter Supersonic flows within the Mixing Chamber. This was due to the cumulative Main flow increasingly occupying the Mixing Chamber cross sectional area. It effectively suppressed the complete expansion of the latter Supersonic Jets. The Main flow inherited the higher P_0 of the Supersonic flow (hence higher M_{TS}), instead of extracting the respective Cooling potential (hence higher T_{TS}). It was proposed that additional Convective Devices be installed within the Mixing Chamber; to disrupt the flow streams and achieve further mixing.