

The AEDC 10-Deg Cone Wind Tunnel/Flight Laminar-Turbulent Correlation Program

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History Session -AEDC

AEDC 10-Deg Cone Program

A correlation between wind tunnels and flight using a standard calibration body.

- Conducted 1971 – 1982
- Basic Research and Technology - USAF and NASA
- Wind Tunnel/Flight
 - 23 major wind tunnels – US and Europe
 - Flight test on an F-15 A at NASA/DFRC Edwards AFB
- Laminar-turbulent transition Re_x
 - Flow-quality indicator for wind tunnel data correlations

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Participating Agencies.

- USAF Arnold Engineering Development Center, TN
(now Complex)
- NASA, US Naval SRDC at David Taylor Model Basin
 - NASA Langley, Ames, Dryden *(now Armstrong)* Research Centers
- Western European National Agencies
 - RAE, the UK; ONERA, France; and NLR, the Netherlands
- Industry (Calspan, US; ARA, Ltd., UK)

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NASA Dryden Flight Research Center Photo Collection
<http://www.dfrc.nasa.gov/Gallery/Photo/index.html>
NASA Photo: EC86-33524-02 Date: 1976 Photo By: NASA

F-104N #812, F-15A #287 and YF-17 #569 in formation.

Precursor and Transition Cone Flight Tests



NASA Dryden Flight Research Center Photo Collection
<http://www.dfrc.nasa.gov/gallery/photo/index.html>
NASA Photo: ECN-9554 Date: May 17, 1978 Photo by: Bob Rhine

F-15A in flight with 10 degree cone experiment and F-104N chase

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➤ *Cone in flight test (1977-1978).*

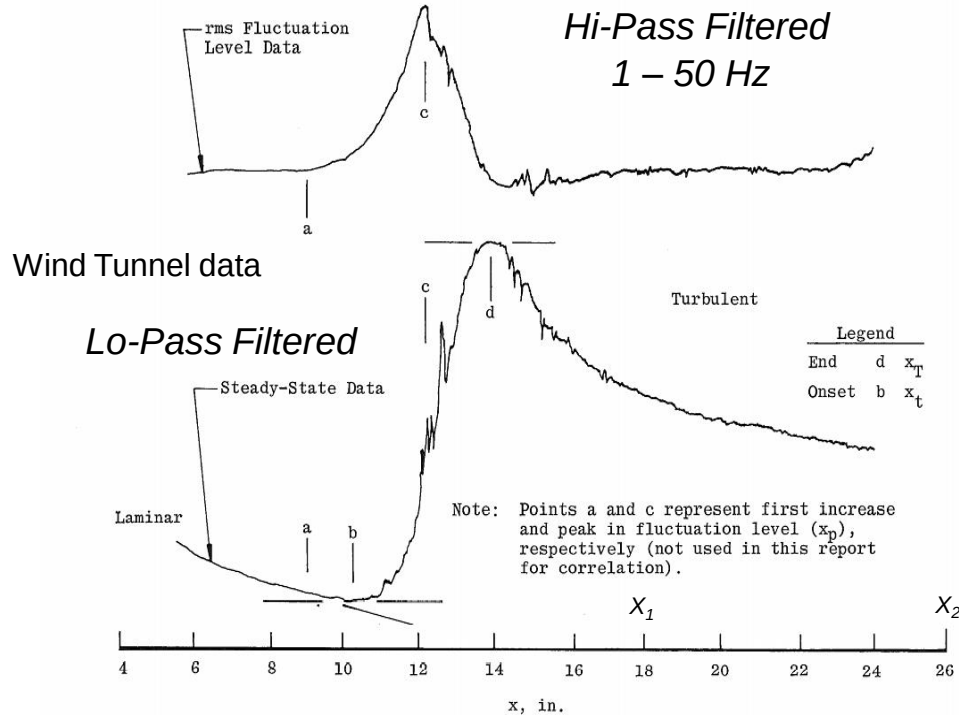
- Mach numbers (M_∞) = 0.5 – 2.0
- Traversing pitot probe in boundary Layer
- Zero incidence angle
- Adiabatic wall ($T_w/T_{aw} = 1$)
 - Cone Pre-heated before flight for $M_\infty > 1.2$
- Cone surface microphones $p_s'(2)^\wedge$
- Freestream impact $p_t'(1)$
- Accelerometers in Cone Base (2)
- Steady-state flight (~ 60 sec)
 - At near-constant Aircraft Trim Angle of Attack

[^] Ref: Linear stability theory e^N by Leslie Mack (1969) – Tollmien-Schlichting waves.



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Transition Cone Laminar – turbulent transition detection.



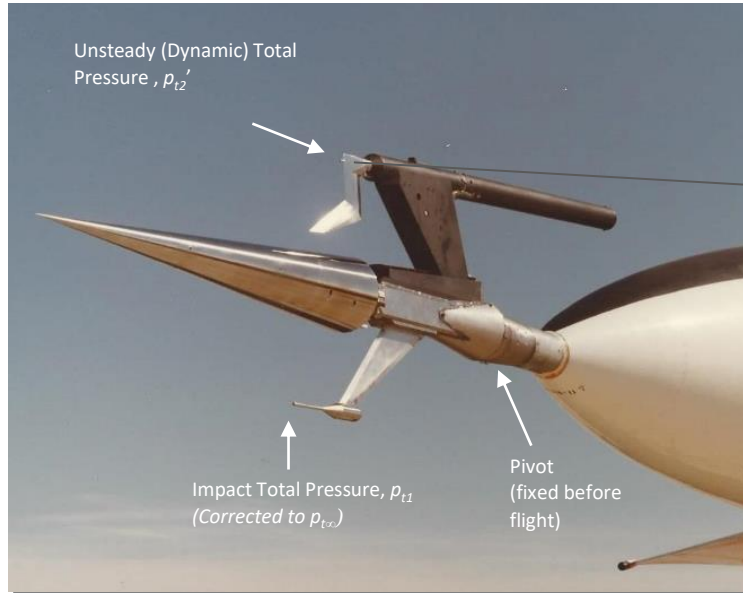
NASA T-38 photo/chase aircraft in background



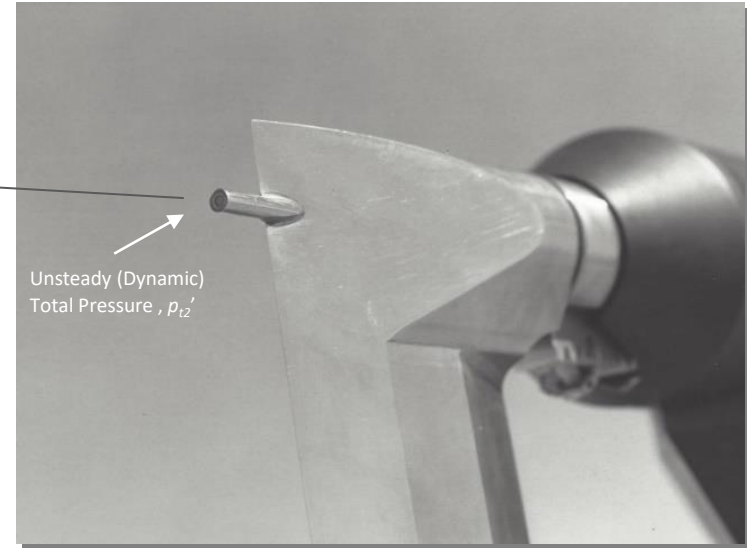
“Preston tube”

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Airspeed-Altimeter-Alpha-Beta and p_t' fixed probes.



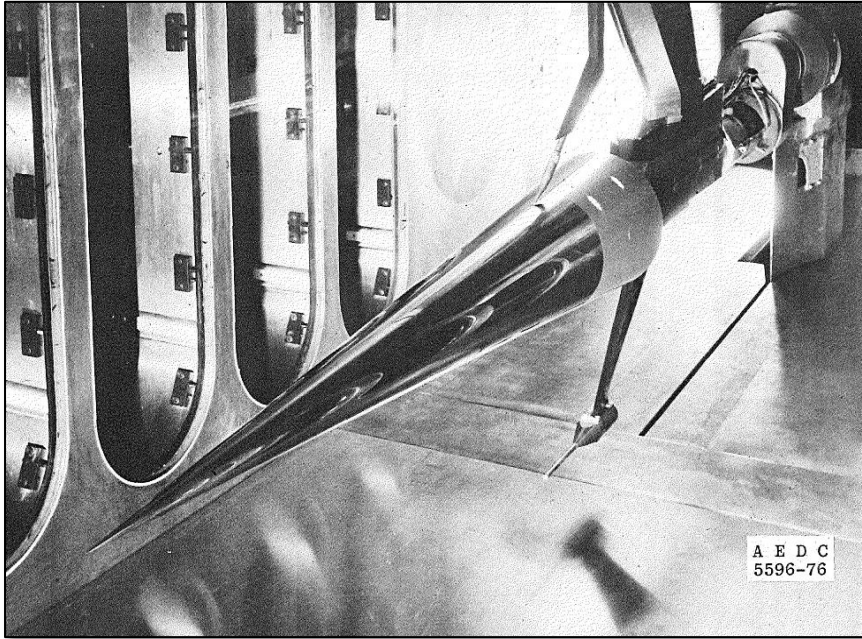
*Hemispherical-head 9-Hole pitot-static probe
(pivot sting mount for trim AOA)*



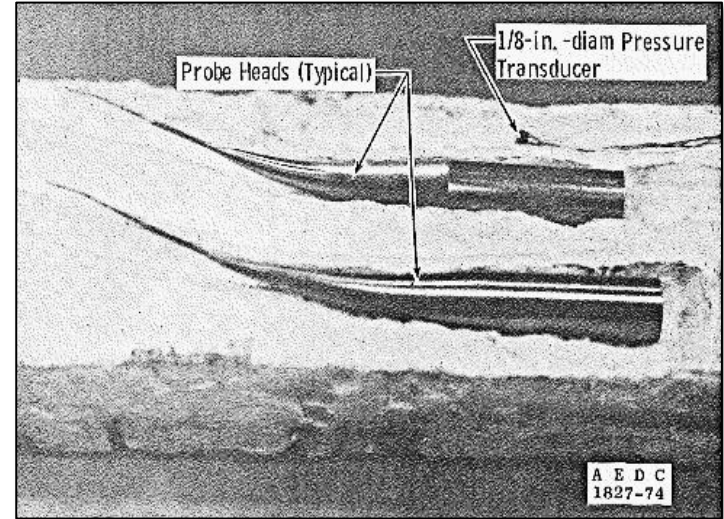
p_t' probe (0 Hz –
20 kHz)

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Correlated with Pate-Schueler (Ref.) Supersonic-Hypersonic.



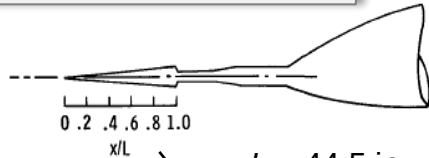
Cone in AEDC von Karman Facility Tunnel A
(zero incidence – adiabatic wall)



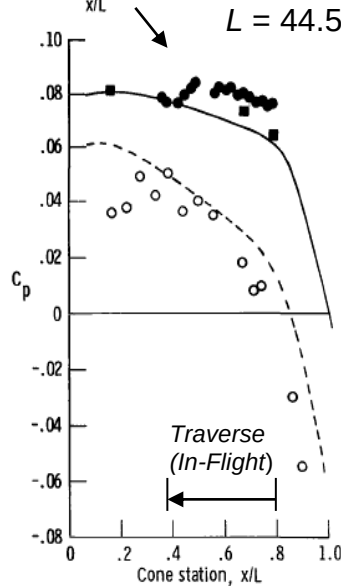
0.020-in.-inner-diameter hypodermic needle
(tip opening height of 0.006 in.)

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Facsimile Cone (Pate's Cone) In-Flight



Geometry used for flight computations



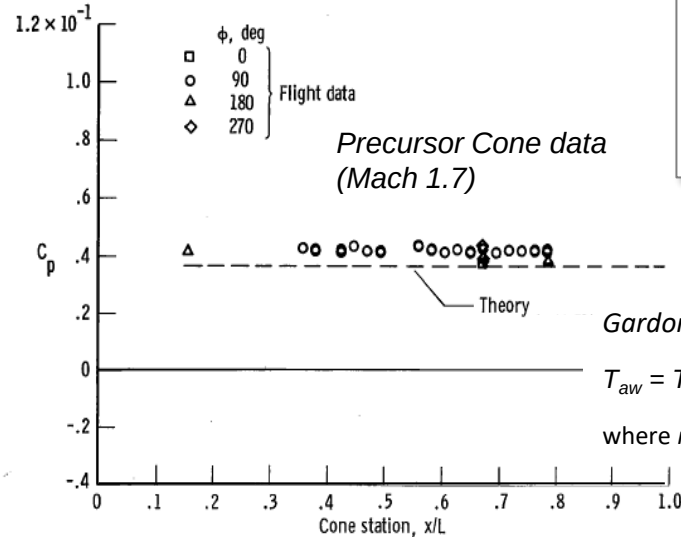
Precursor Cone Flow Field.

Ref. "Conical Flow," NACA 1135 (1953), and computations by J. C. Adams, AEDC (1974)

ϕ , deg
 $\circ$ 0
 $\square$ 180
 — Euler equations for cone plus fuselage
 - - Theory (ref. 24) for cone alone

Open symbols denote wind tunnel data (cone alone)
 Closed symbols denote flight data (cone plus aircraft)

Pre-cursor Cone data and subscale cone-alone wind tunnel data (Mach 0.6)



Under auspices of AIAA Fluid Mechanics Panel
Transition Study Group:
 Eli Reshotko, Chair
 Mark Morkovin
 Phil Klebanoff
 Les Mack
 Jim Kendall
 Leith Potter
 Ken Stetson

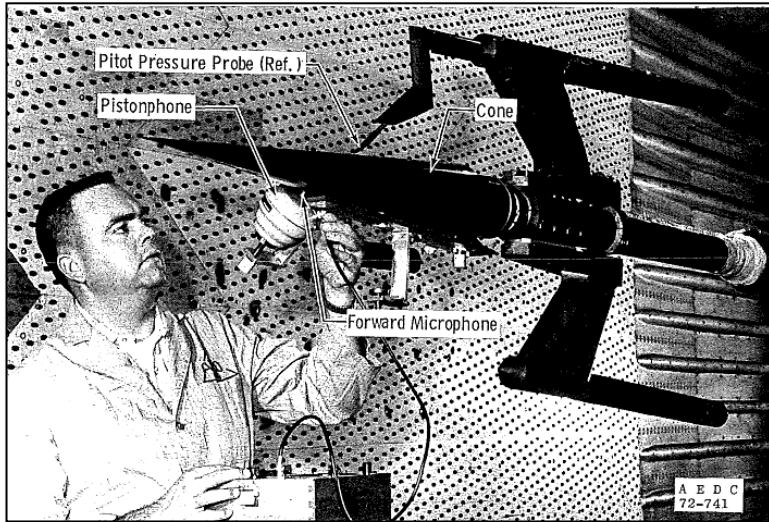
Gardon gages (alt.) by C.T. Kidd

$$T_{aw} = T_{se} [1 + r ((\gamma - 1)/2) M_e^2]$$

where $r = 0.88$ turbulent

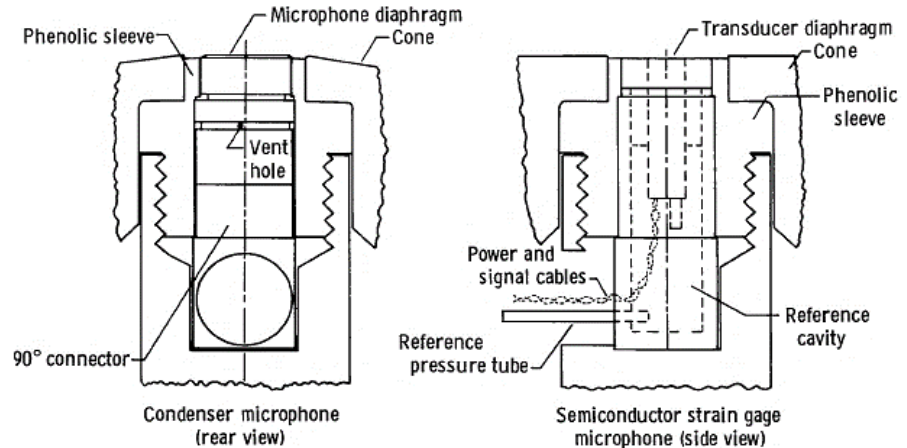
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Cone in AEDC 16-FT Transonic Propulsion Wind Tunnel.



*In-place calibration of Cone surface microphone
(using pistonphone 1.0 kHz sine wave at
140 dB SPL - Ref. 0.0002 dynes/cm²)*

(Temperature - limited to 585° R)



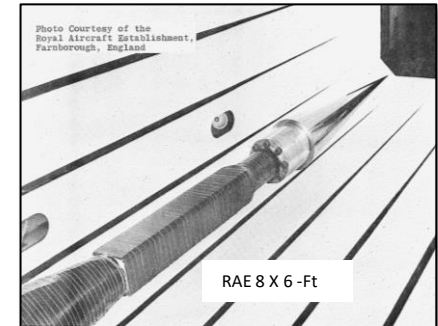
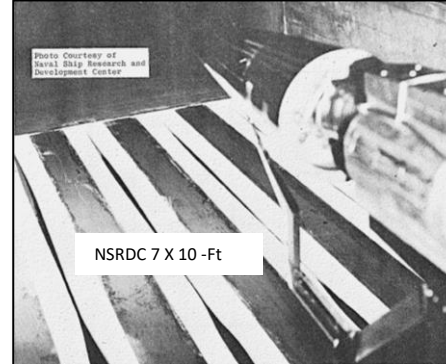
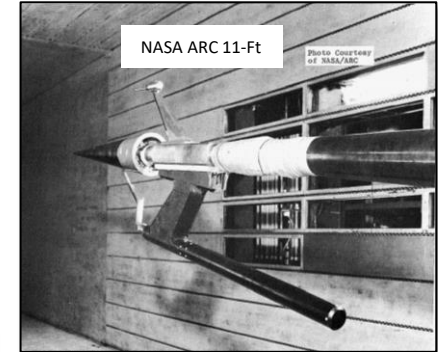
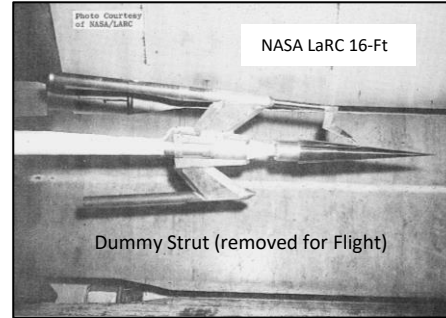
*1/4- in. condenser microphones or 0.094-
in. strain-gage microphones (0 – 20 kHz)*

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➤ *Cone in wind tunnels.*

- Mach numbers (M_∞) 0.2 – 5.5
- Traversing pitot probe in boundary Layer
- Zero incidence angle
- Adiabatic wall ($T_w/T_{aw} = 1$)
- Cone surface microphones p_s' (2)
- Freestream impact p_t' (1)
- Steady-state flight (60 sec)

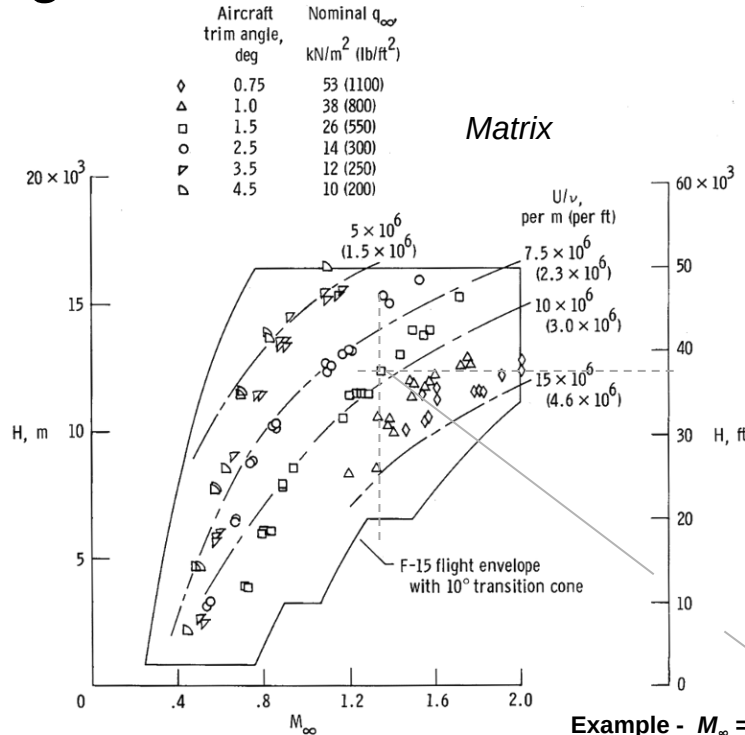
Emphasis: Same instrumentation, same procedures, same Cone (1971-1977)



Cone in different transonic wind tunnels (zero incidence – adiabatic wall)

AEDC 10-Deg Cone Program

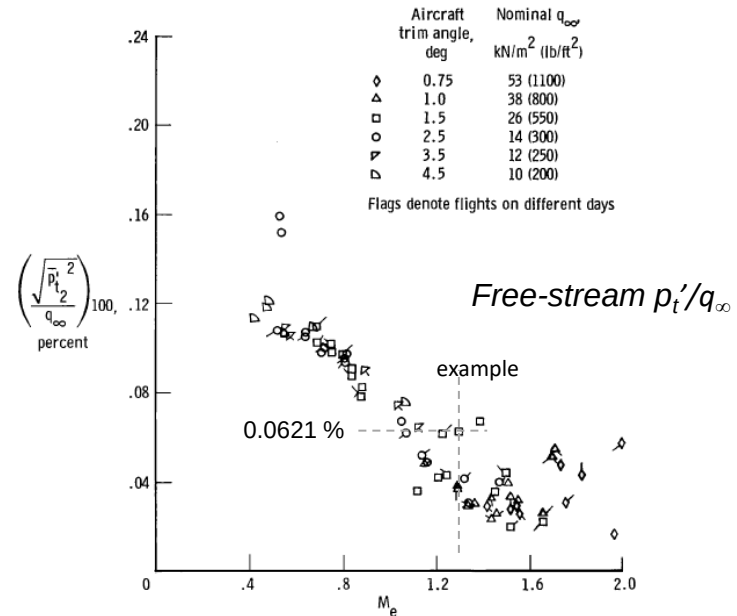
Flight Test Matrix of Test Points.



Example - $M_\infty = 1.35$ $H = 37,800$ ft, $T_{s_\infty} = -66^\circ$ F, $p_s = 422$ psf, $q_\infty \approx 550$ psf
(Flight 330 on 8-23-78)

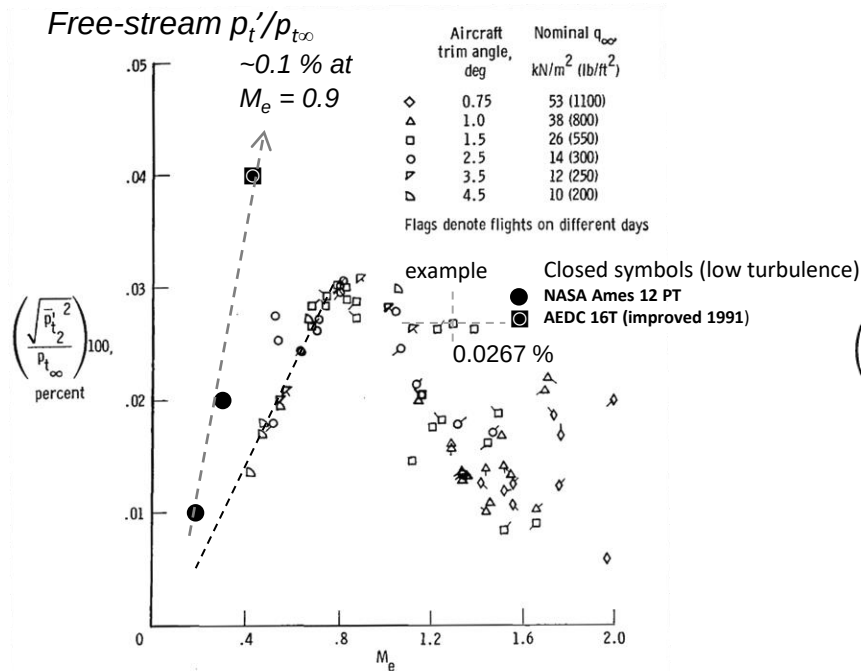
Measured Unsteadiness

(Wind Tunnel Ref. $\sim 1.1\%$ at $M_\infty = 1.5$)

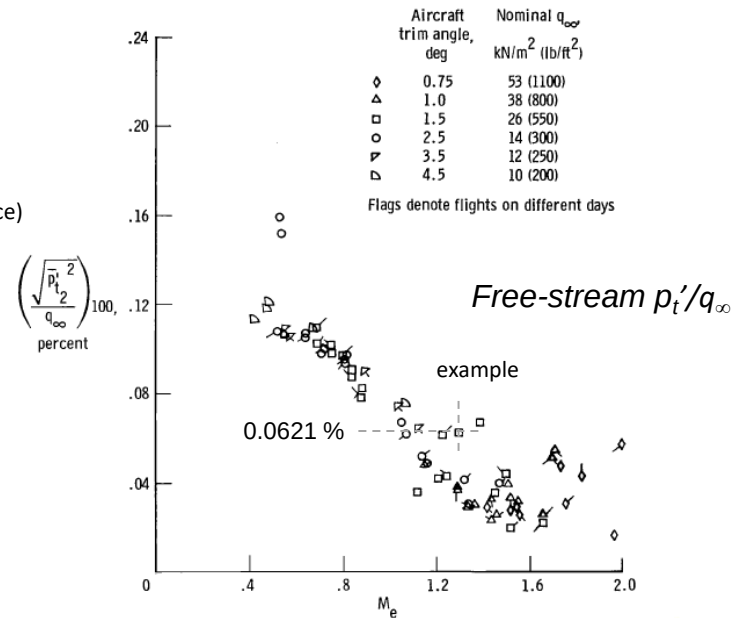


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Free-stream Unsteadiness measured In Flight.



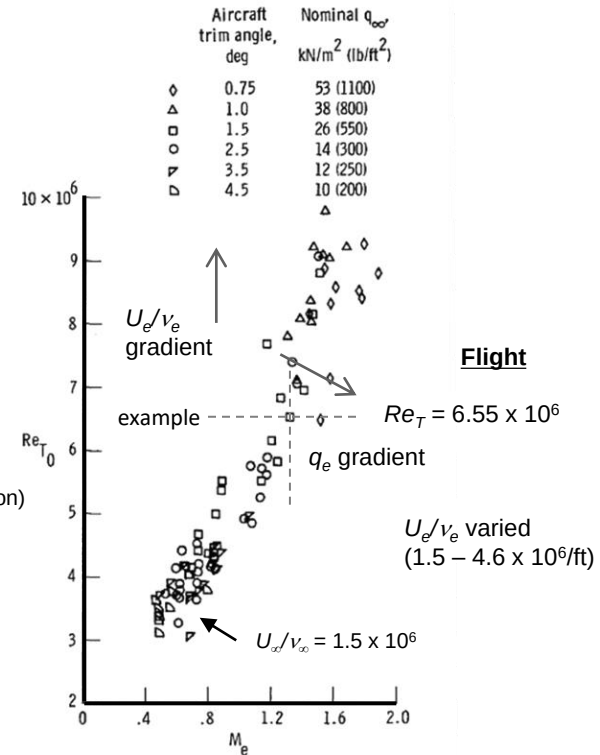
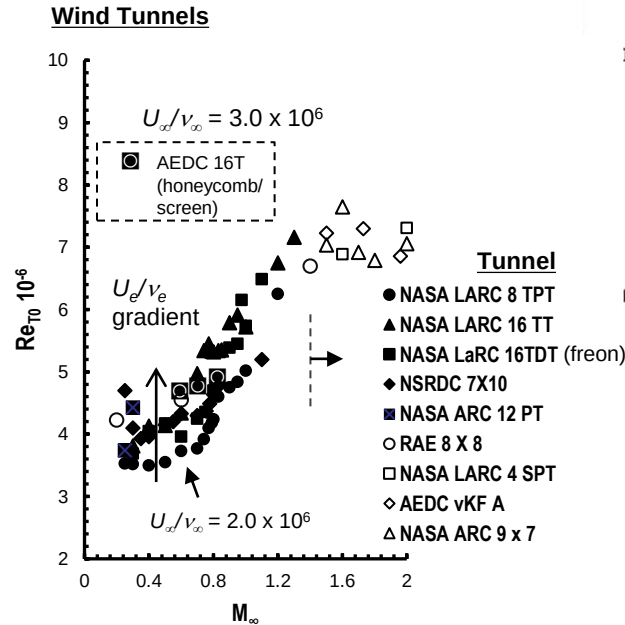
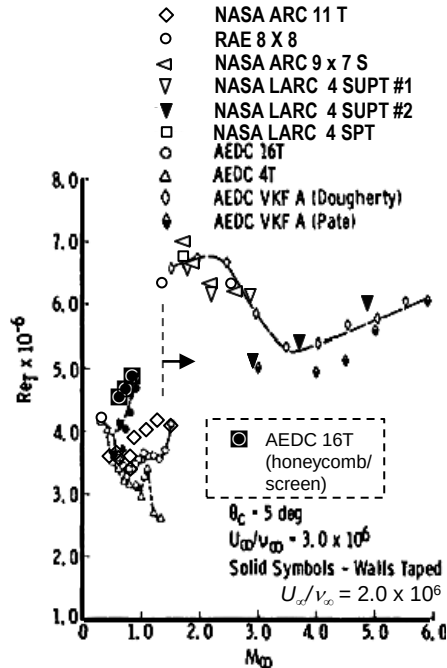
(Wind Tunnel Ref. $\sim 1.1\%$ at $M_\infty = 1.5$)



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Cone Re_T in Wind Tunnels and Flight.

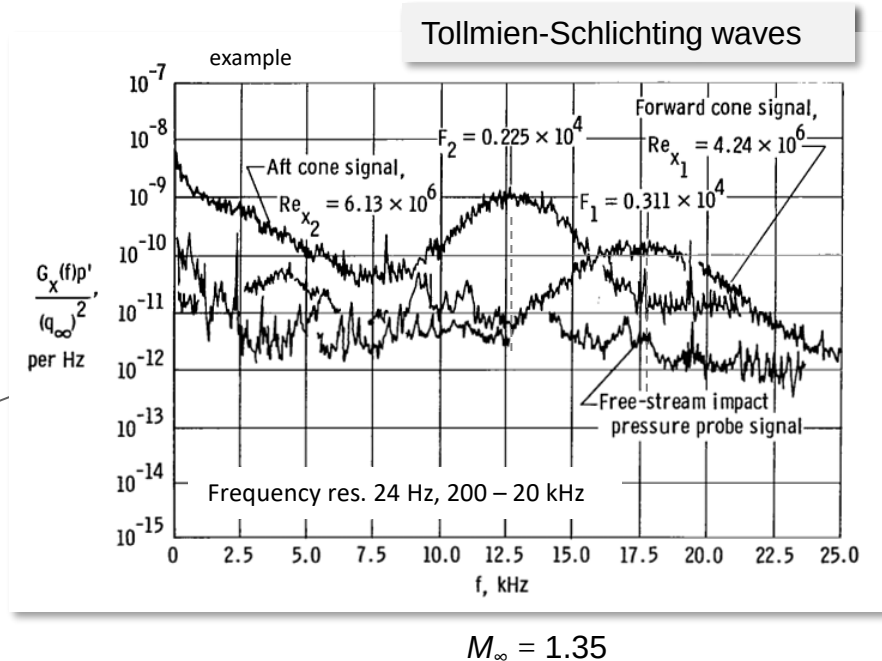
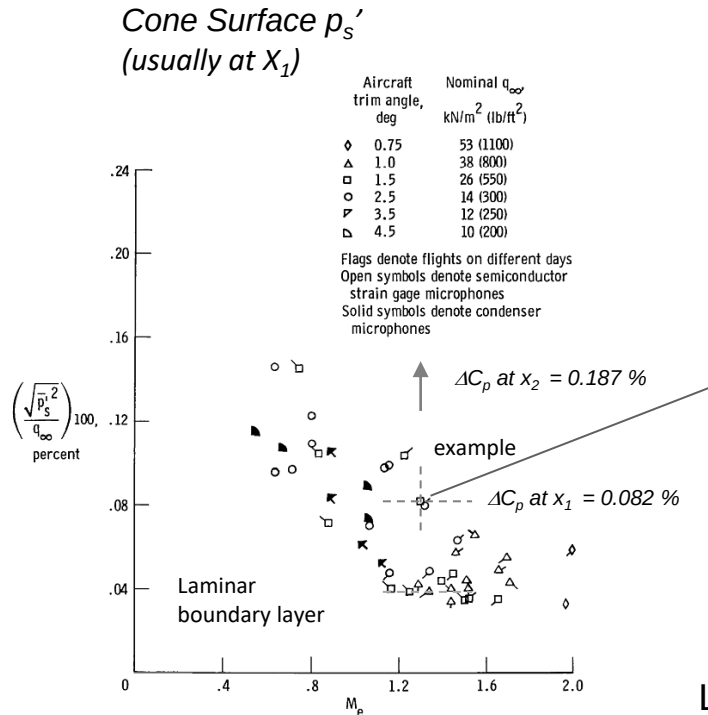
(Zero incidence – adiabatic wall)



Note: AEDC 16T with honeycomb/screen - improved (D. Sinclair, 1991)

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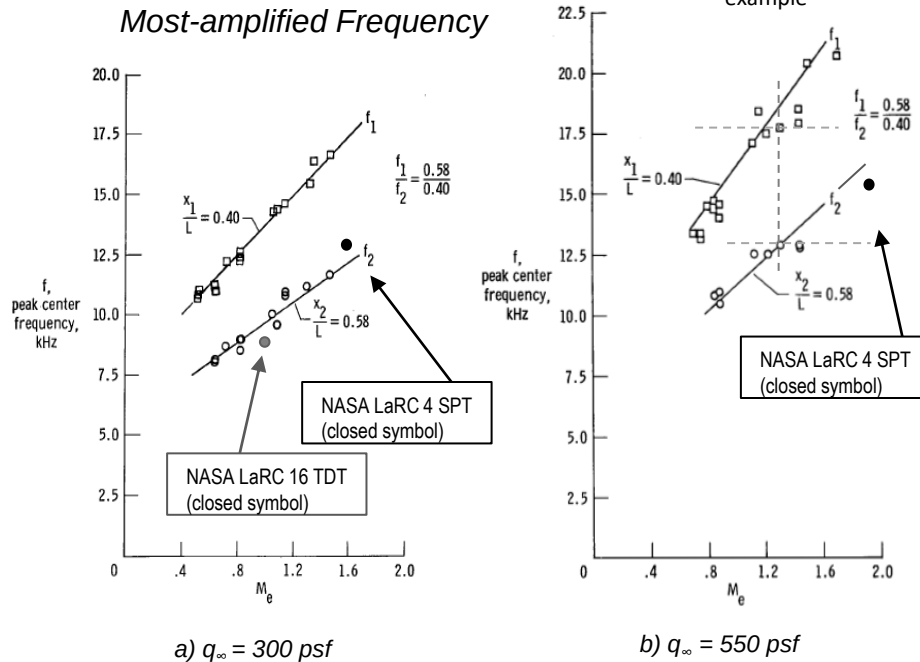
Unsteadiness measured In-Flight on Cone surface.



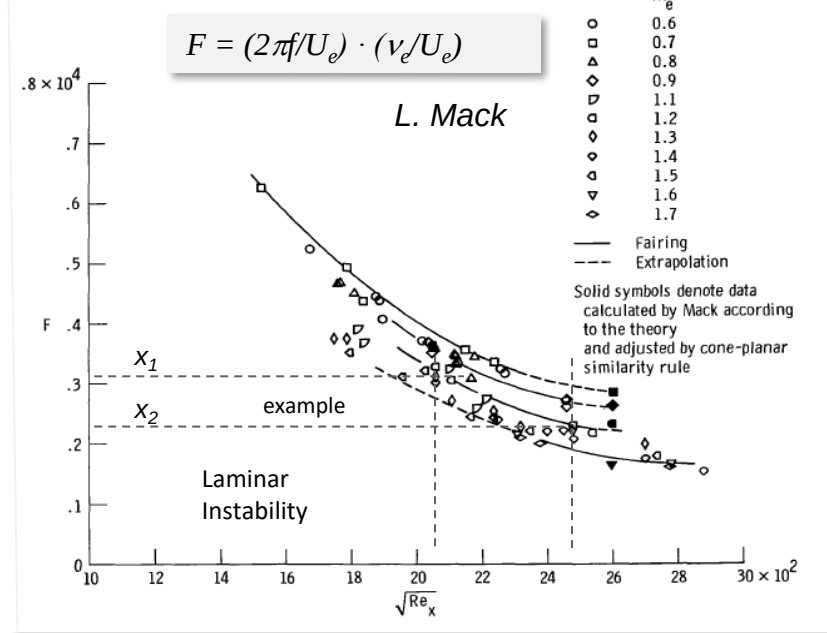
Laminar Instability and Transition

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Tollmien – Schlichting Waves measured In-Flight.



Strouhal Number/ Re_x/ft



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➤ *Concluding Remarks about the Program.*

- Produced comprehensive empirical data base.
 - Also NASA ARC Sep. Flow Tunnel/Flight $M_\infty=1.5$ & 1.8 and Relative Incidence 2.2 deg
- Data have seen extensive use as benchmark data for advanced analytical methods.
 - CFD, “Quiet Tunnels” design parameters, LFC/NLF
- Participating Facilities have used the data, along with other standard calibration data, to:
 - Correlate User test data among Facilities
 - Make Facility upgrades for improved flow quality
- Designer decisions for new Facilities
 - in part using the Cone data

Ref. D.J. Peake, D.F. Fisher, D.C. McRae



NASA Dryden Flight Research Center Photo Collection
<http://www.dfrc.nasa.gov/Gallery/Photo/index.html>
NASA Photo: EC80-12547 Date: March 20, 1980 Photo By: NASA

F-15A #287 in flight



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Back-up

AEDC 10-Deg Cone Program

➤ *Procedure in wind tunnels*

- Set sting angle $\alpha \approx 0$ and $\beta \approx 0$.
- Hold tunnel T_t near constant and wait for Cone to obtain $T_w/T_{aw} \approx 1.0$.
- Set p_t at lowest operating point and sweep Re/ft from lowest to highest p_t at a given M_∞ .
- Repeat p_t sweeps at each higher M_∞ in succession measuring Re_T and p_s' on Cone.
- Record high-speed data - pitot probe retracted.
- Perform pitot probe traverse and determine Re_T .
- Rotate Cone 90 and 180 deg on sting and perform off-nominal $\pm \beta$ variations to confirm flow angularity.

Note: Conduct calibrations of Cone's fixed probe versus test section M_∞ , $p_{t\infty}$, $p_{s\infty}$, α , and β .

➤ *Procedure in flight test*

- Set the sting angle fixed pivot for trim AOA.
- Pre-launch a radiosonde weather balloon and determine $T_{s\infty}$ and $T_{t\infty}$ lapse, compute T_{aw} .
- Pre-heat the Cone before flt up to 220-240 °F.
 - for $M_\infty > 1.2$
- Fly a progression of highest M_∞ first, then lower Mach numbers until end for the day.
- Select M_∞ and H for each successive test point.
- Adjust H to obtain $T_w/T_{aw} \approx 1.0$.
- Fly straight and level to $\alpha \approx 0$ and $\beta \approx 0$.
- Record high-speed data - pitot probe retracted.
- Perform pitot probe traverse and determine Re_T .
- Perform off-nominal β sweeps with aircraft trim tabs in 0.25-deg increments.