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High Speed Jet Noise Research at NASA Lewis

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HIGH SPEED JET NOISE RESEARCH AT NASA LEWIS
PROGRAM CONTENT

The source noise portion of the High Speed Research Program at NASA Lewis is focused on jet noise reduction. A number of jet noise reduction concepts are being investigated. These include two concepts, the Pratt & Whitney ejector suppressor nozzle and the General Electric 2D-CD mixer ejector nozzle, that rely on ejectors to entrain significant amounts of ambient air to mix with the engine exhaust to reduce the final exhaust velocity. Another concept, the G.E. "Flade Nozzle" uses fan bypass air at takeoff to reduce the mixed exhaust velocity and to create a fluid shield around a mixer suppressor. Additional concepts are being investigated at Georgia Tech Research Institute and at NASA Lewis. These will be discussed in more detail in later figures.

Analytical methods for jet noise prediction are also being developed. Efforts in this area include upgrades to the GE MGB jet mixing noise prediction procedure, evaluation of shock noise prediction procedures, and efforts to predict jet noise directly from the unsteady Navier Stokes equation.

High Speed Jet Noise Research at NASA Lewis

Program Content

Noise reduction concept evaluation

- **P & W ejector suppressor nozzle**
- **GE 2D-CD mixer/ejector nozzle**
- **GE flade nozzle**
- **GTRI novel concepts evaluation**
- **Shear layer modification**

Analytical methods development

- **MGB model upgrade**
- **Shock noise prediction/evaluation**
- **Unsteady Navier stokes solutions**

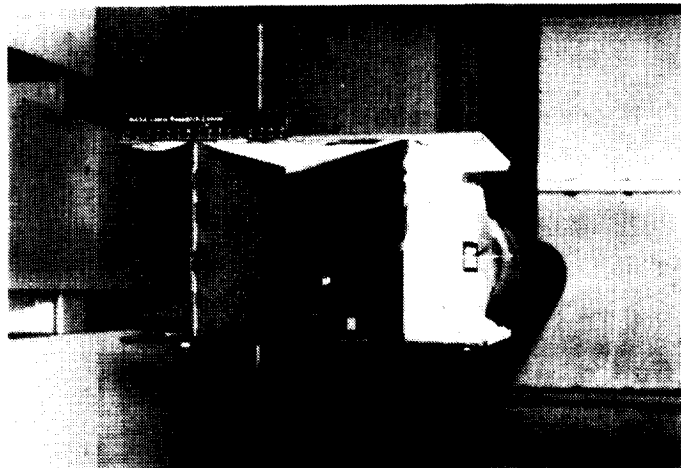
2D P&W MIXER/EJECTOR AEROACOUSTIC NOZZLE TEST IN THE NASA LEWIS 9x15 LSWT

Shown in this figure is an early version of the P&W developed mixer/ejector nozzle. This nozzle was tested in the NASA Lewis 9x15 LSWT as a proof of concept test to evaluate ejector pumping capability and noise reduction potential. Since this was the first jet noise test conducted in the 9x15 wind tunnel, the test also served as a means of evaluating the suitability of this facility for jet noise testing. Results from this test will be presented in the next two figures. Details regarding modification to the design and follow-on testing will be presented in a later paper.

2D P&W Mixer/Ejector Aeroacoustic Nozzle Test in NASA Lewis 9x15 LSWT

Objectives:

- P&W - Conduct simple 2D proof-of-concept test.
- Lewis - Obtain first jet source acoustic data in 9x15.



Results:

- Convergent nozzle noise significantly above background.
- Ejector pumping exceeded predictions ($W_s/W_p > 1.0$).
- Nozzle noise reductions observed (-6 to -8 EPNDB relative to -18 EPNDB goal).
- CFD (PARC/NASTAR) results agree with experiment.

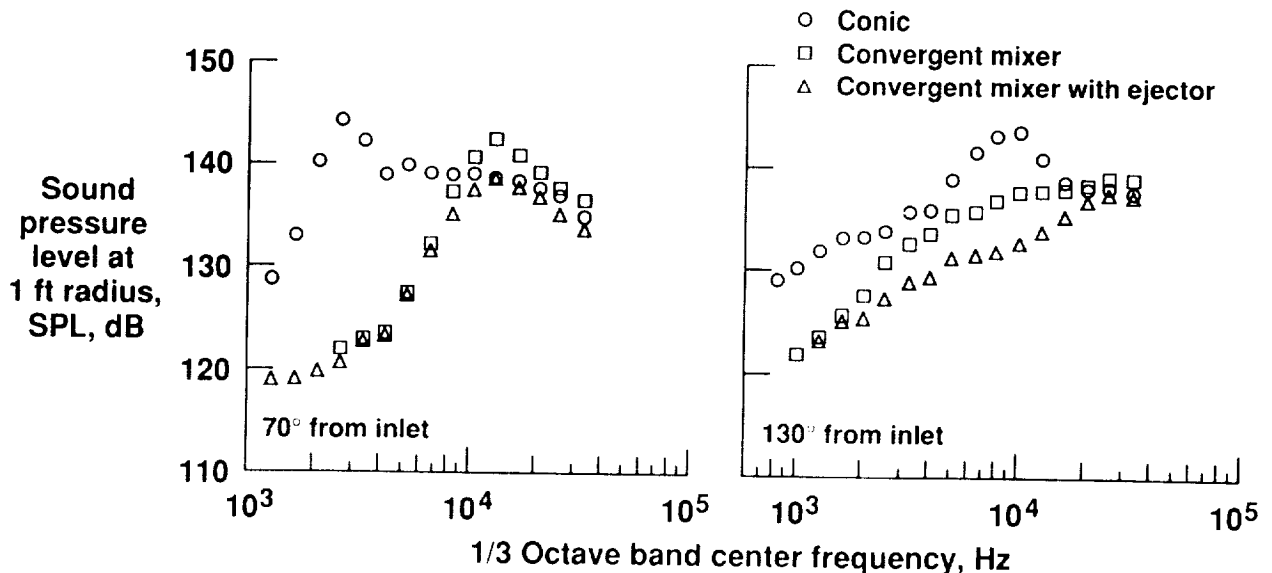
2D P&W MIXER/EJECTOR AEROACOUSTIC NOZZLE TEST
IN THE NASA LEWIS 9x15 LSWT

COMPARISON OF MIXER-EJECTOR, CONVERGENT MIXER
AND CONIC NOZZLE NOISE SPECTRA

Typical acoustic results from the test of the P&W mixer/ejector nozzle are shown in this figure. One-third octave spectra from the mixer ejector nozzle are compared with those from the mixer alone and a round conic nozzle at angles of 70 and 130 degrees from the inlet axis. These data can be used to assess the noise reduction achieved by the mixer alone and from the addition of the hardwall ejector. The addition of acoustic treatment to the ejector wall would result in additional noise reduction by absorbing noise generated within the ejector.

**2D P&W Mixer/ejector Aeroacoustic Nozzle Test in
NASA Lewis 9x15 LSWT**
Comparison of Mixer-ejector, Convergent Mixer and
Conic Nozzle Noise Spectra

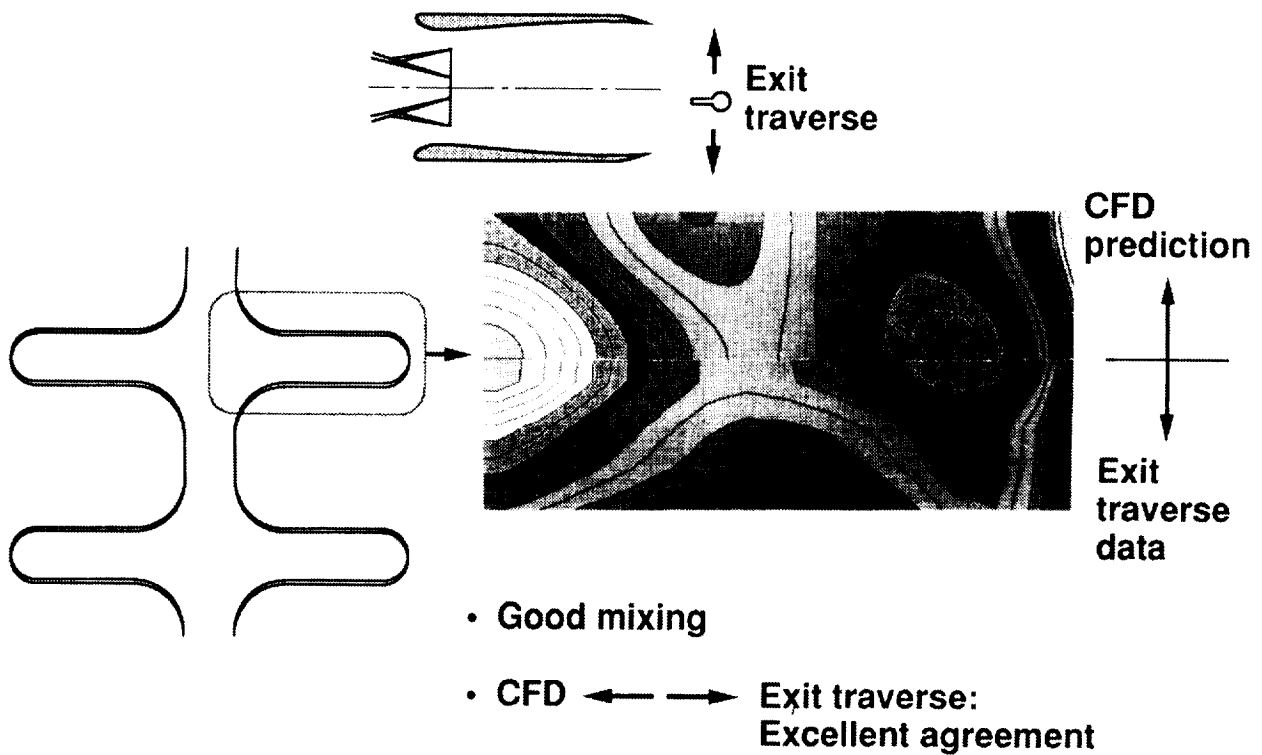
Nozzle pressure ratio = 3.5 Nominal jet temperature = 900 °R Tunnel mach number = 0.2



CFD/TRANSLATING PROBE COMPARISON AND MIXING

Shown in this figure are results from a temperature traverse at the ejector exhaust. The results indicate that good mixing between the primary and the induced flows was achieved. Also shown is a corresponding predicted temperature field at the same location. Good agreement between measured and predicted temperatures was achieved.

CFD/Translating Probe Comparison and Mixing



GE NOISE REDUCTION CONCEPTS

The main characteristics of two noise reductions concepts developed by General Electric are given in this figure. Details regarding these concepts will be given in a later paper. The first concept, like that of Pratt & Whitney, is mixer ejector nozzle. The mixer nozzle is designed with convergent-divergent chutes to minimize shock noise. The ejector, designed to achieve 60% pumping, will be acoustically treated to absorb noise generated within the ejector.

The second GE concept, the Flade Nozzle, is designed for an engine cycle with reduced mixed exhaust velocity. The fan flow from this cycle will be used to produce a fluid shield around a mixer nozzle.

GE Noise Reduction Concepts

2DCD mixer ejector nozzle

- **Mixer nozzle with C-D chutes**
- **Acoustically treated ejector - 60 percent pumping**

Flade nozzle

- **Increased by-pass ratio (lower core velocity)**
- **Mixer on primary nozzle (no ejector)**
- **By-pass flow used for fluid shield**

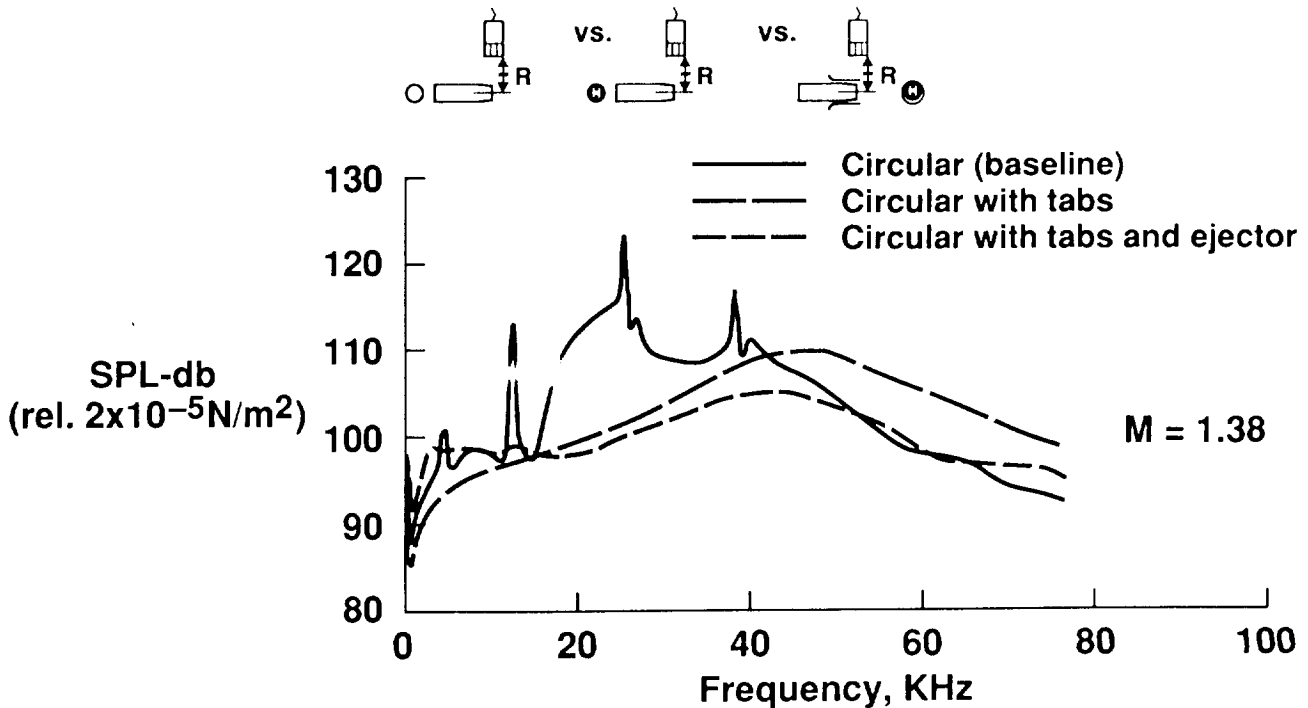
NOVEL JET NOISE REDUCTION CONCEPTS

CIRCULAR NOZZLE WITH TABS AND EJECTOR

In this figure, acoustic results from tests conducted by Georgia Tech Research Institute of a circular nozzle with tabs and an ejector are shown. Previous results with tabs and a circular nozzle have shown that the tabs can significantly enhance the mixing of the nozzle flow with ambient air. By combining the rapid mixing of the tabbed nozzle with the noise suppression potential of a treated ejector, it is hoped that significant jet noise reduction can be achieved with simple nozzle geometries and a short ejectors.

Novel Jet Noise Reduction Concepts Georgia Tech Research Institute

Circular nozzle with tabs and ejector



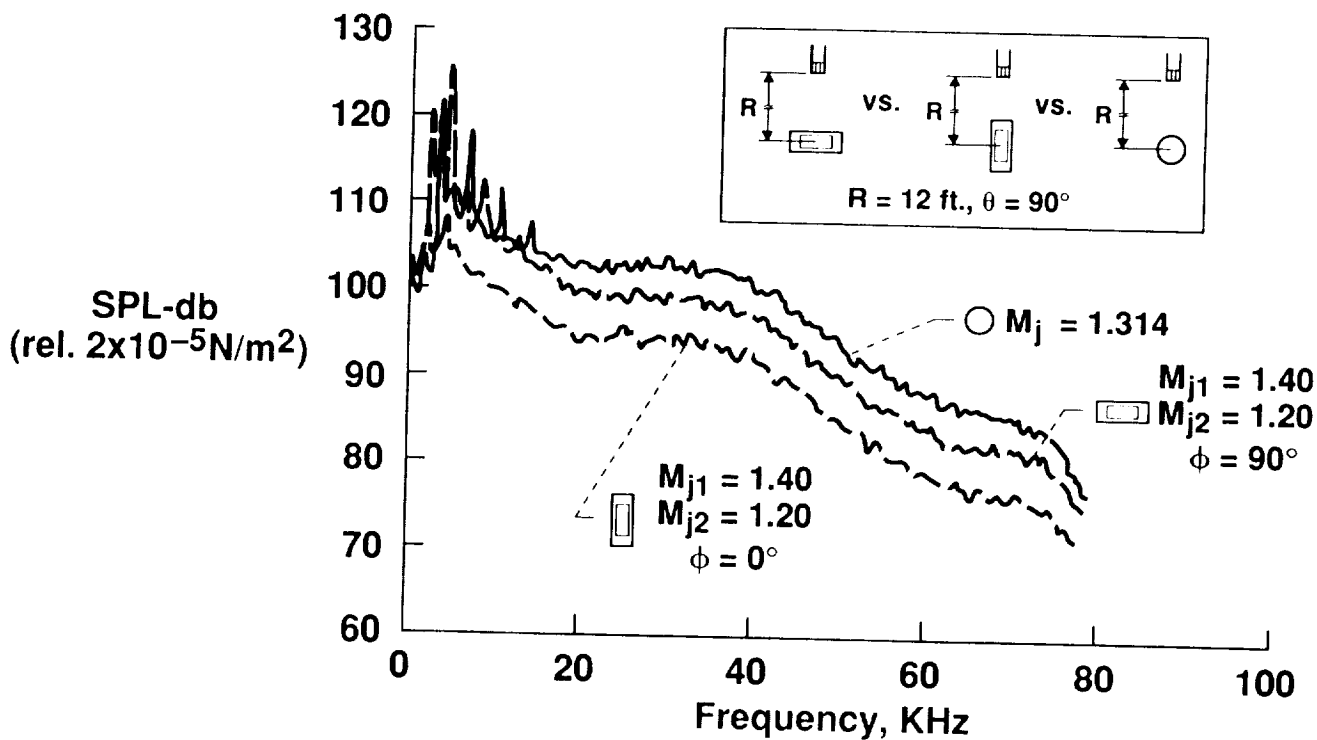
NOVEL JET NOISE REDUCTION CONCEPTS

COAXIAL RECTANGULAR NOZZLE

Another concept being investigated at Georgia Tech Research Institute is the coaxial rectangular nozzle. In this figure, test results show the noise reduction, relative to a conic nozzle, achieved by using a dual flow rectangular nozzle. The concept's success at supersonic flow conditions may indicate that it is most effective in reducing shock noise.

Novel Jet Noise Reduction Concepts Georgia Tech Research Institute

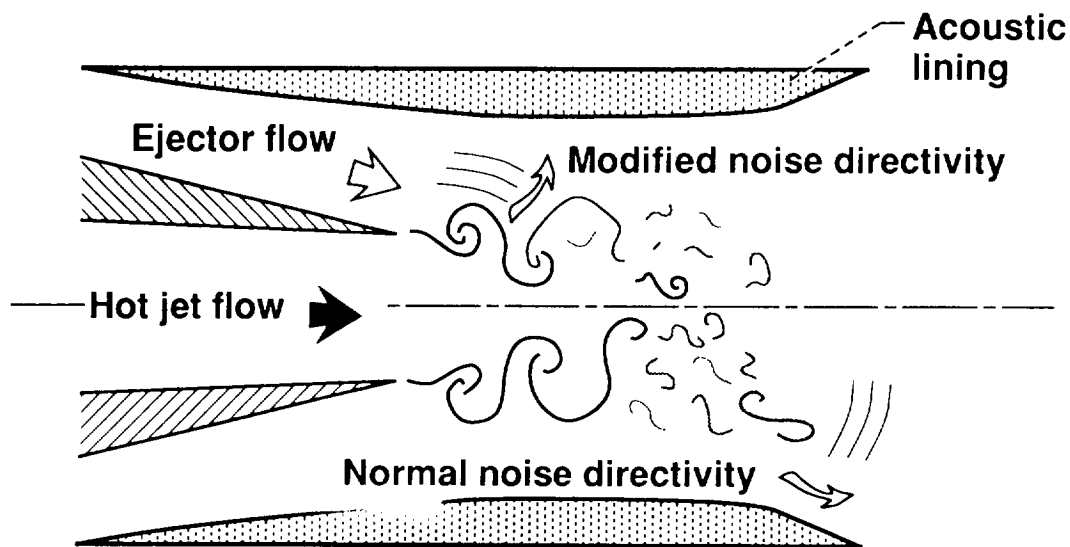
Coaxial rectangular nozzle



NOISE REDUCTION BY SHEAR LAYER MODIFICATION

At Lewis, jet screech is being investigated as a means of exciting the jet shear layer and enhancing the mixing within an ejector. Enhanced mixing can significantly shorten the ejector or provide more treatment length to suppress internally generated noise. The effect of excitation on the directivity of the internally generated noise is also being studied. The effectiveness of wall treatment within an ejector could be enhanced if the internally generated noise can be made to propagate toward the side walls.

Noise Reduction by Shear Layer Modification

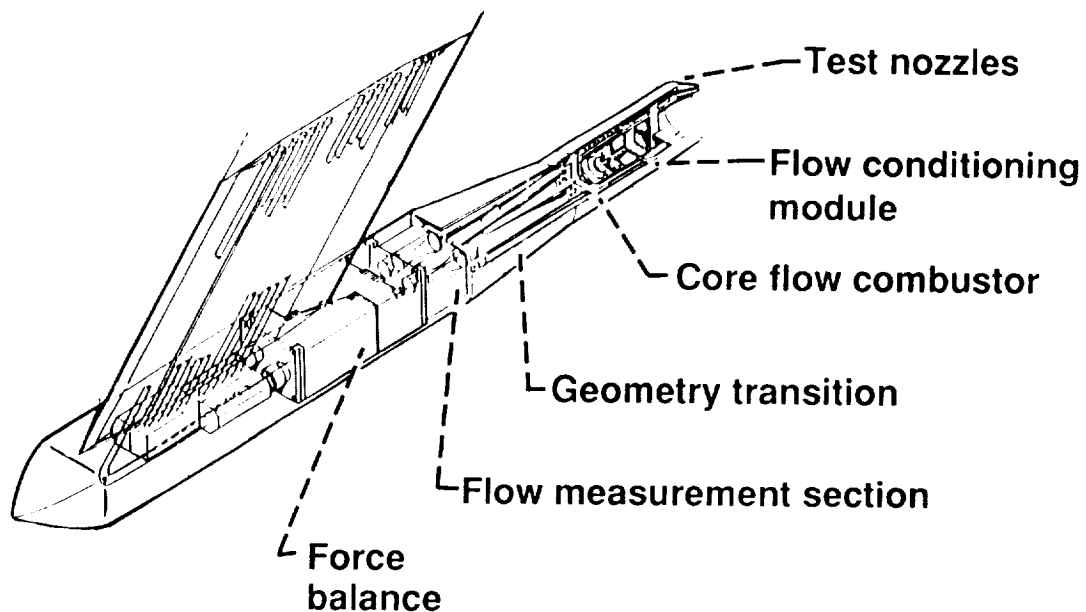


- Apply aerodynamic excitation principles to enhance mixing and minimize performance penalty.
- Apply aerodynamic excitation principles to alter directivity of internal shear layer noise to maximize liner effectiveness.

JET EXIT RIG WITH TRANSITION FOR
AXISYMMETRIC NOZZLES

Shown in this figure is a schematic of the NASA Lewis Research Center jet exit rig. This rig is designed for testing of both NASP and HSR nozzles and is compatible with the NASA Lewis 8x6 and 10x10 supersonic wind tunnels and the 9x15 low speed wind tunnel, the NASA Ames 40x80 wind tunnel, and the new Lewis nozzle acoustic test rig.

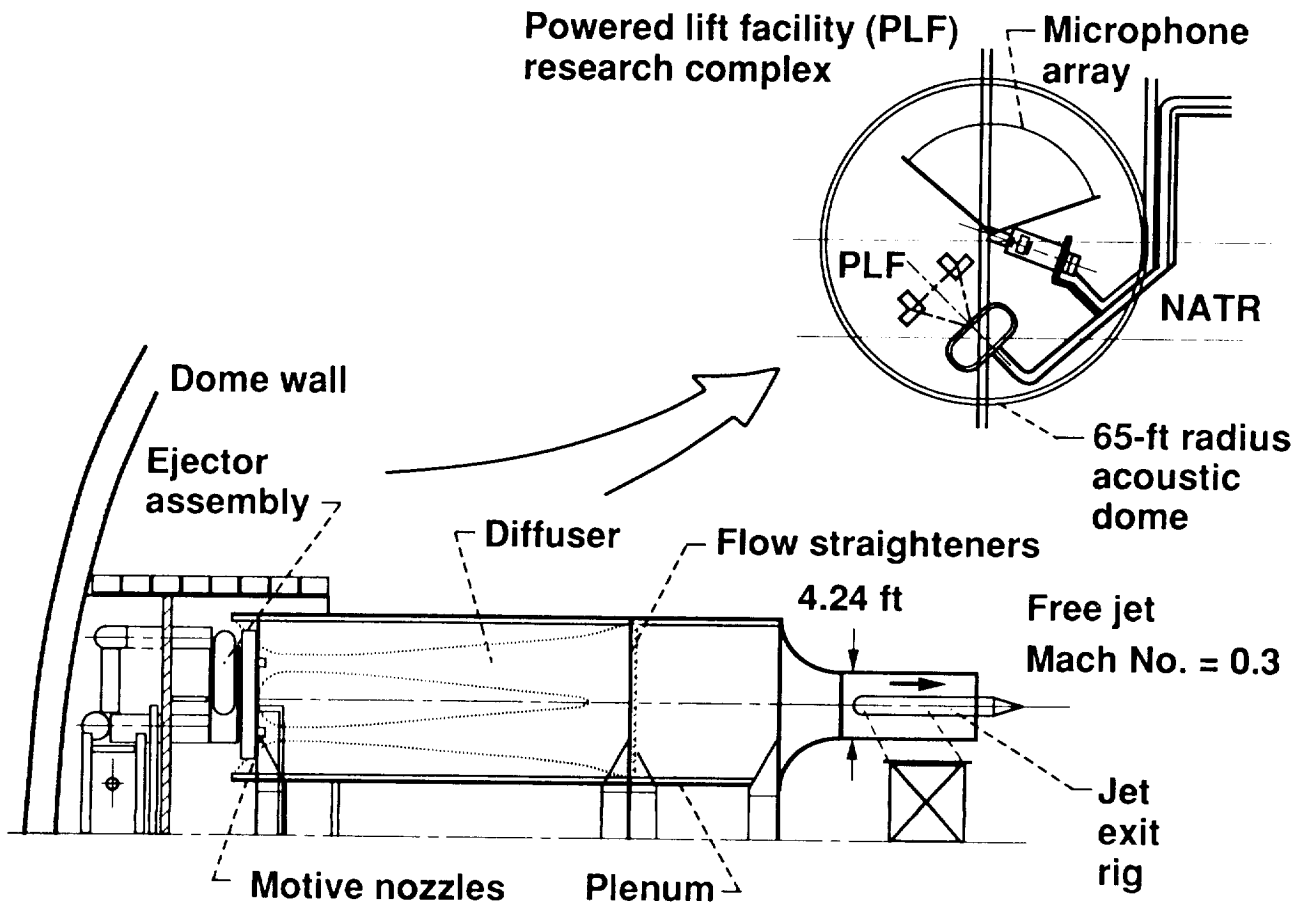
Jet Exit Rig With Transition for Axisymmetric Nozzles



NOZZLE ACOUSTIC TEST RIG (NATR)

A schematic of a new nozzle acoustic test rig is shown in this figure. The rig will be located within a 65 foot radius geodesic dome. The dome is designed to minimize community noise problems from the nozzle acoustic test rig and the adjacent Powered Lift Facility. Acoustic treatment will be installed on the inside of the dome to provide an anechoic environment for acoustic testing. Forward flight effects will be simulated by means of a free jet. Heated air will be provided to test nozzles by the jet exit rig discussed previously.

Nozzle Acoustic Test Rig (NATR)



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JET NOISE PREDICTION EFFORTS

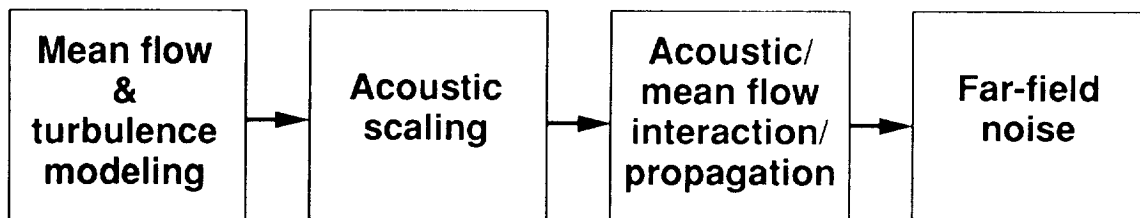
Efforts at Lewis to improve the state-of-the-art of jet noise prediction include the evaluation and improvement of existing jet mixing and shock noise prediction procedures and the development of new prediction procedures. Planned improvements to the existing, GE developed, MGB procedure include replacing Reichardt's mean flow prediction method with the Parc code and adding non-axisymmetric effects to the acoustic/mean flow interaction radiation model. Shock noise prediction methods are currently being evaluated over a range of jet Mach numbers and temperatures both with and without forward flight effects.

In House Jet Noise Prediction Efforts

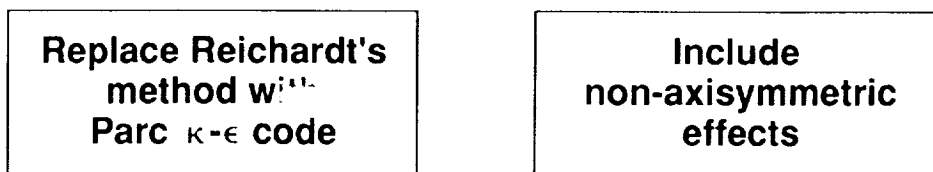
Improve jet mixing noise prediction

- Improve 'MGB' procedure

Prediction Procedure Elements



Planned improvements



Evaluate/improve shock noise prediction

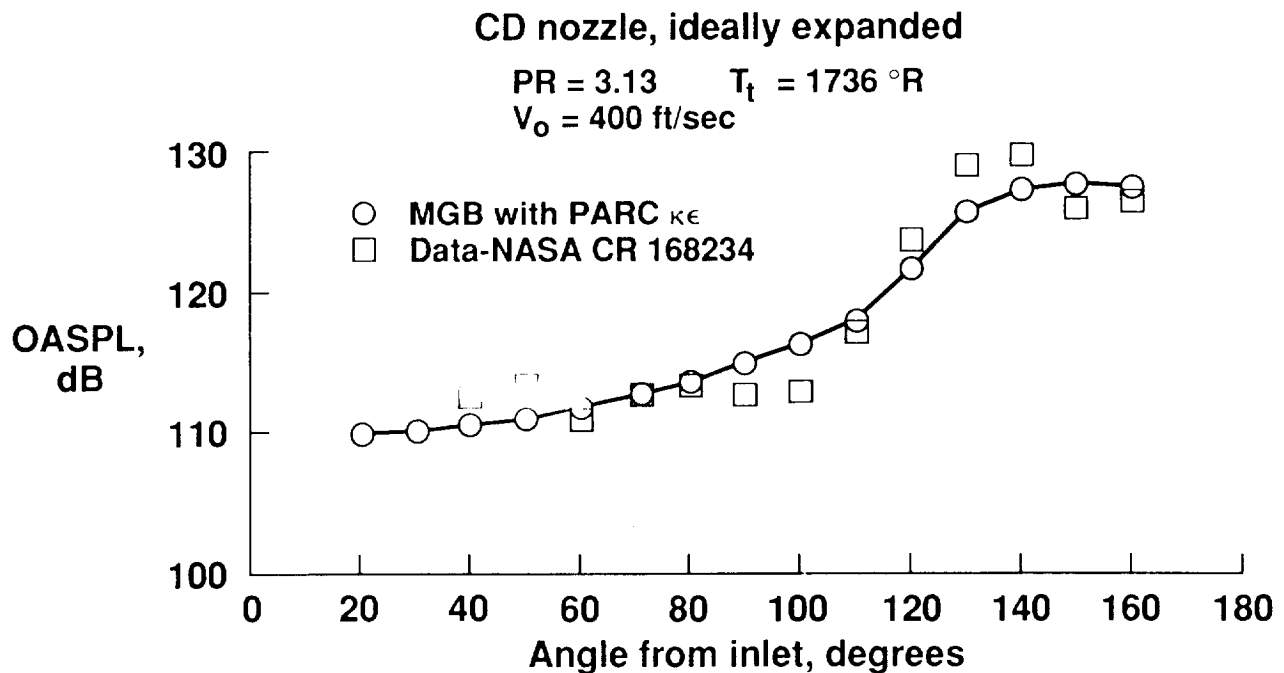
- Evaluate current shock noise prediction procedures
- Incorporate CFD predicted shock characteristics into current shock noise prediction procedures

MGB JET NOISE PREDICTION MODEL
WITH PARC AERO INPUT

Shown in this figure are typical results comparing predicted and measured jet noise directivities for a convergent-divergent nozzle at the nozzle design pressure ratio. The prediction was made using the GE MGB method with aerodynamic inputs from the Parc code.

MGB Jet Noise Prediction Model with PARC- $\kappa\epsilon$ Aero Input

Comparison of Measured and Predicted Jet Noise Directivity



HIGH SPEED JET NOISE RESEARCH
AT NASA LEWIS

SUMMARY

Significant progress has been made. High ejector pumping, necessary for the success of ejector suppressor concepts, has been demonstrated. Detailed designs have been completed for several promising noise reduction concepts that are to be tested this year. Other more novel concepts are being investigated. Initial steps have been taken to upgrade jet noise prediction procedures.

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Summary

- **High ejector pumping demonstrated**
- **Two acoustically treated ejector/suppressor designs plus fluid shield/mixer concept to be evaluated this year**
- **Other novel concepts being investigated**
- **Aeroacoustic prediction procedures being upgraded**