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MEMORANDUM FOR PR (In-House Contractor/In-House Publication)
FROM: PROI (TI) (STINFO) 29 February 2000

SUBJECT: Authorization for Release of Technical Information, Control Number: **AFRL-PR-ED-TP-2000-039**
Chehroudi, B. (ERC), Badakshan, A., Cohn, R., Talley, D., "Injection of Cryogenic Jets into Subcritical and Supercritical Environments"
4th International Symposium on Liquid Space Propulsion **(Statement A)**
Lampoldshausen, Germany, 13-15 Mar 2000 (Absolute Deadline: 09 Mar 2000)

1. This request has been reviewed by the Foreign Disclosure Office for: a.) appropriateness of distribution statement, b.) military/national critical technology, c.) export controls or distribution restrictions, d.) appropriateness for release to a foreign nation, and e.) technical sensitivity and/or economic sensitivity.
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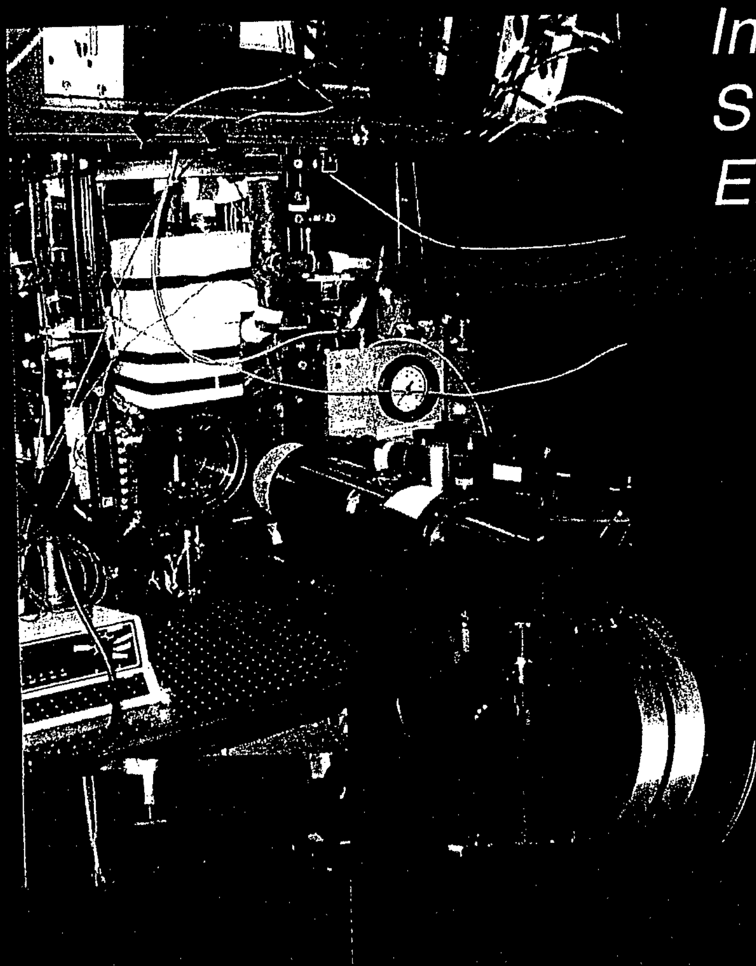
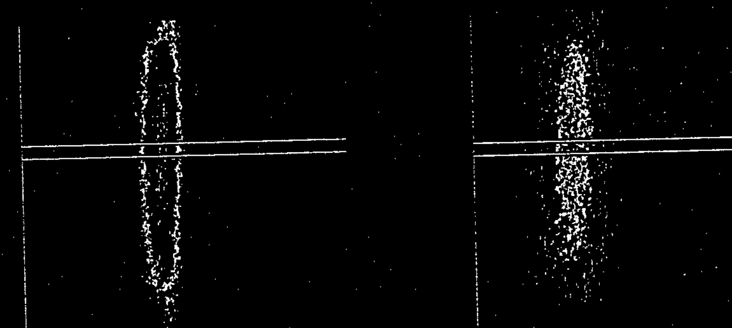
ROBERT C. CORLEY (Date)
Senior Scientist (Propulsion)
Propulsion Directorate

Fourth International Symposium on Liquid Space Propulsion
DLR – Lampoldshausen, Germany
March 13 - 15, 2000



Injection of Cryogenic Jets into Subcritical and Supercritical Environments:

B. Chehroudi, A. Badakshan, R. Cohn, and D. Talley



Subcritical N_2 Jet   Supercritical N_2 Jet

Objectives

Overall

- Determine the mechanisms which control the breakup, transport, mixing, and combustion of sub- and super-critical droplets, jets, and sprays.

This Presentation

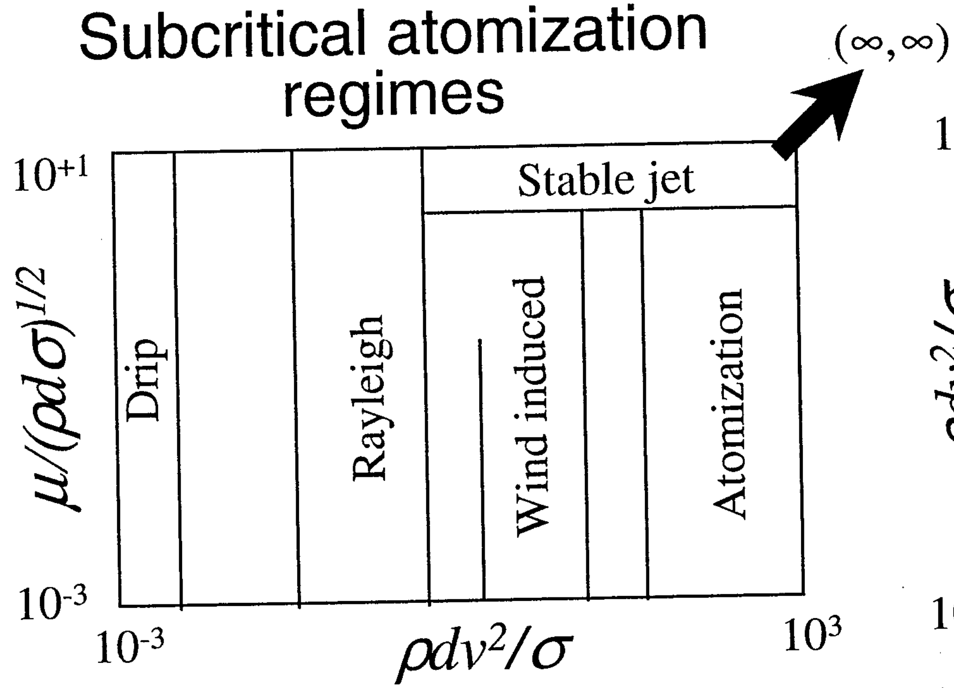
- Determine the structure of subcritical and supercritical cryogenic jets using quantitative Raman imaging.

Background

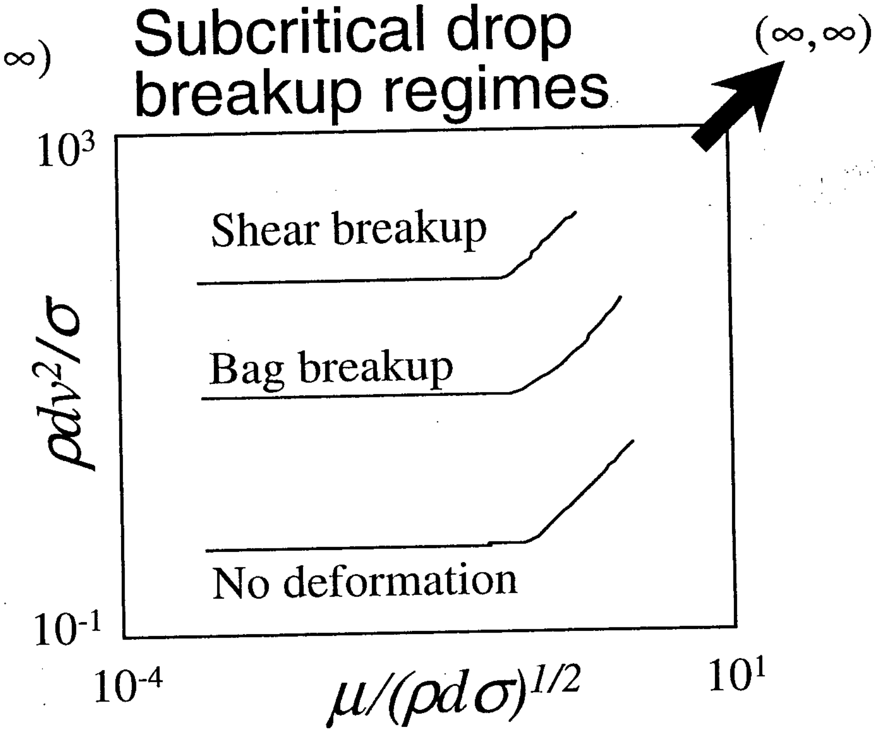
- In engines having chamber pressures exceeding the critical pressure *(SSME, Vulcain, etc.)*, the distinct difference between a "gas" and a "liquid" disappears.
- The resulting flows are influenced by factors not present in conventional sprays:
  - Vanishing surface tension and enthalpy of vaporization.
  - Equivalent gas and liquid phase densities.
  - Strongly enhanced gas / liquid solubility.
  - Liquid-like gas phase diffusivity.
  - Mixing induced critical point variations.
  - Enhanced gas phase unsteadiness.
- *Unknowns contribute to potentially large uncertainties in making design predictions.*

Background (2)

Subcritical atomization regimes



Subcritical drop breakup regimes



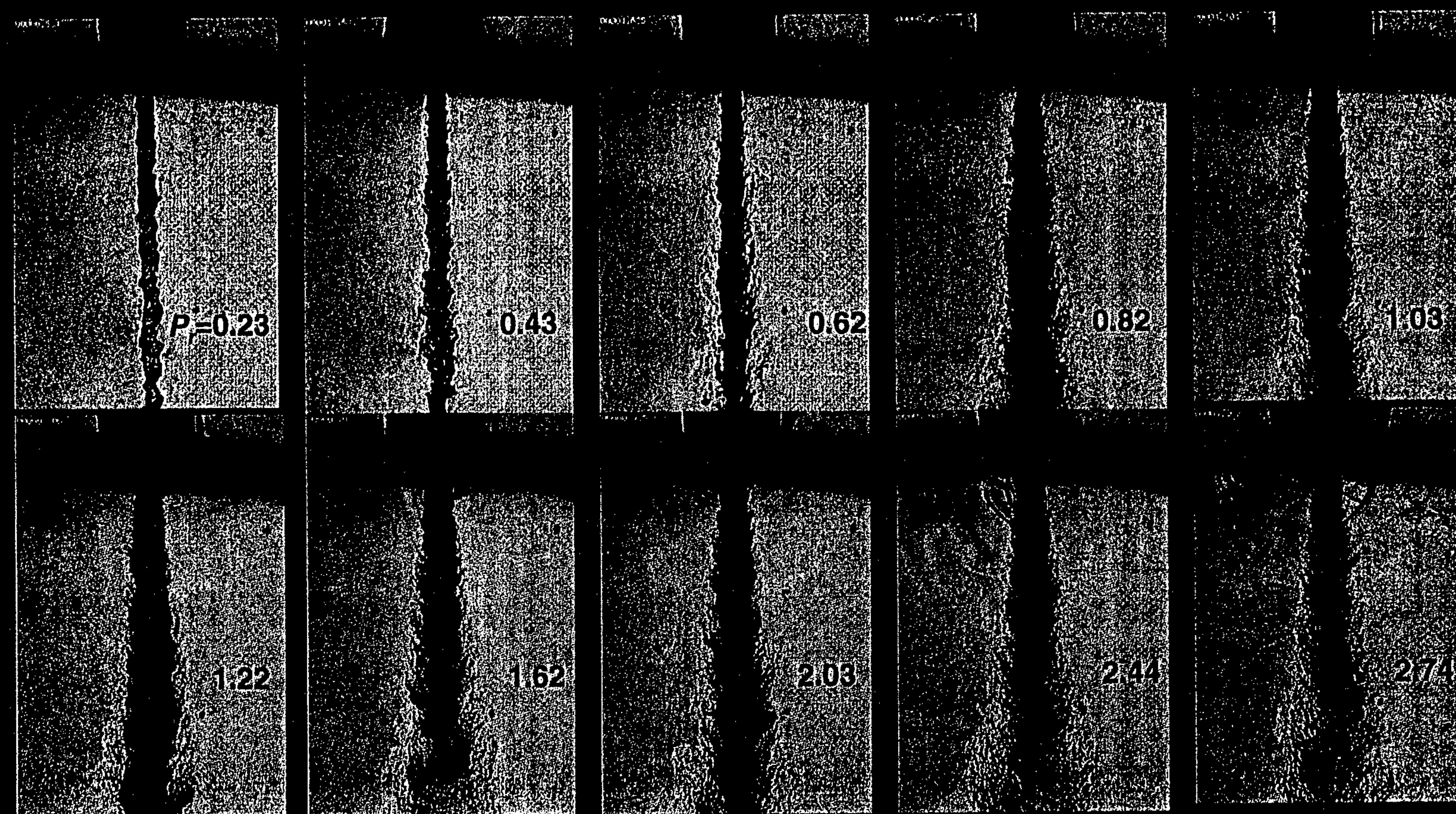
Surface tension σ vanishes at supercritical conditions. Conventional atomization and breakup parameters become *infinite*, where no data exists.

Supercritical atomization and breakup regimes are largely <u>unknown</u>

Shadowgraph Results - N_2 into N_2

$P_{cr} = 3.39$ MPa $T_{amb} = 300$ K Re = 25,000- 75,000

$T_{cr} = 126$ K $T_{inj} = 99\text{-}120$ K $V_{inj} = 10\text{-}15$ m/s



Mixing Layer Structure - N_2 into N_2

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P_{cr} = 3.39 Mpa, T_{cr} = 126 K, T_{inj} = 128 K, T_{amb} = 300 K

Low Pres. Subcritical
Droplets

Mod. Pres. Supercritical
Transition

High Pres. Supercritical
Gas layers

Jet Spreading Angles

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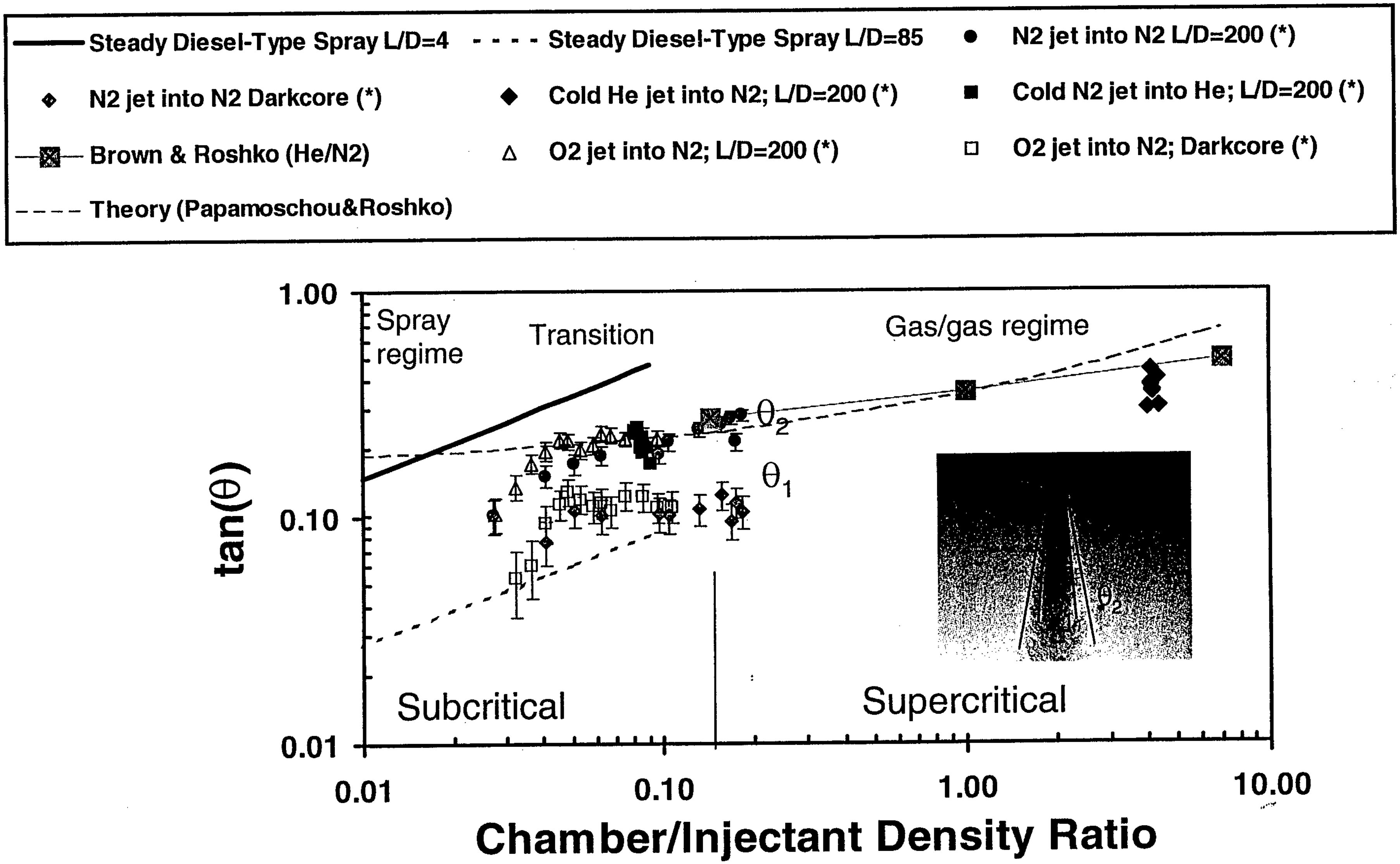
Chehroudi et. al., AIAA 99-0206, AIAA 99-2489



Empirical Correlation

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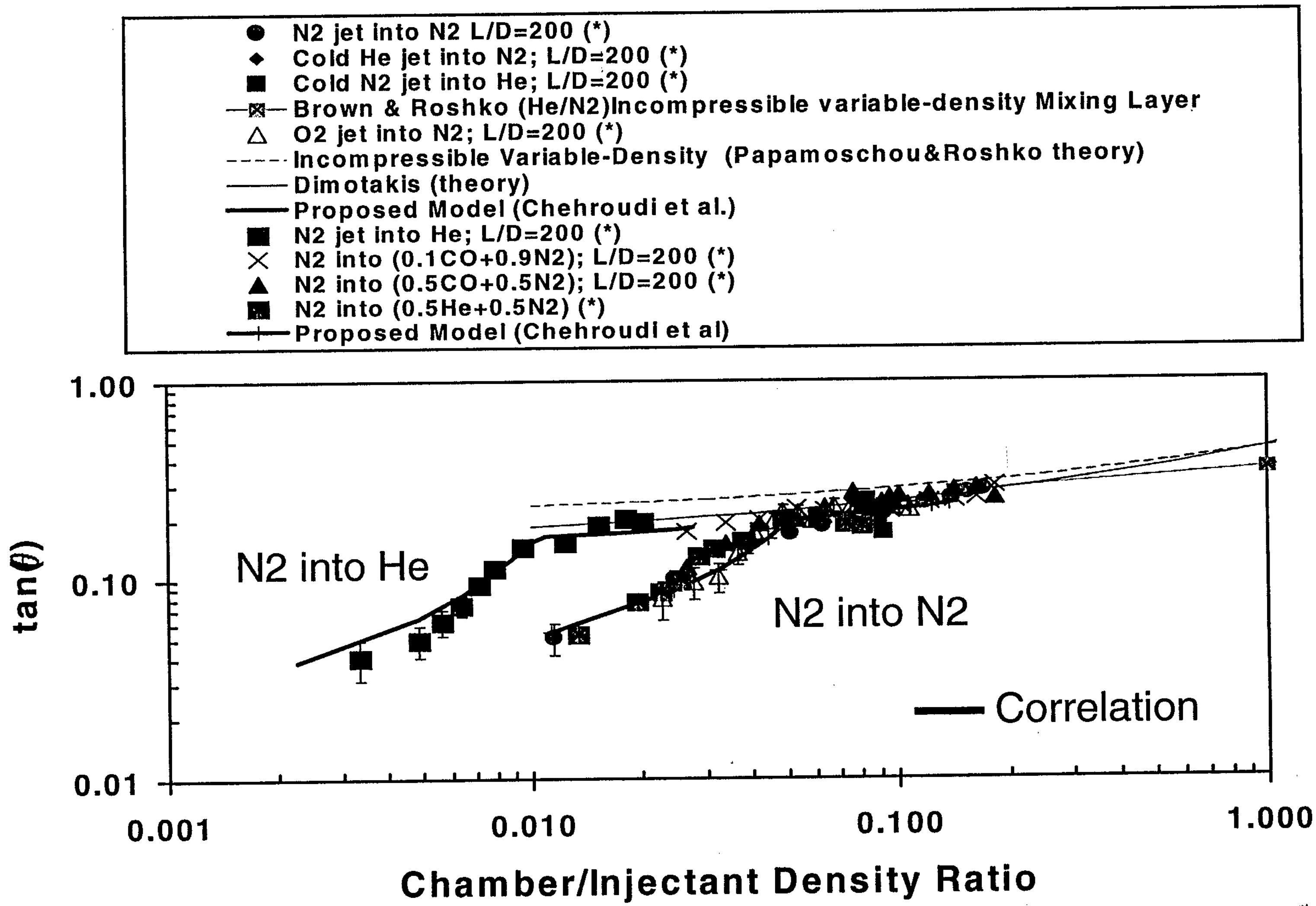

Normalized Intensity Defect Plot: Supercritical Regime (3)

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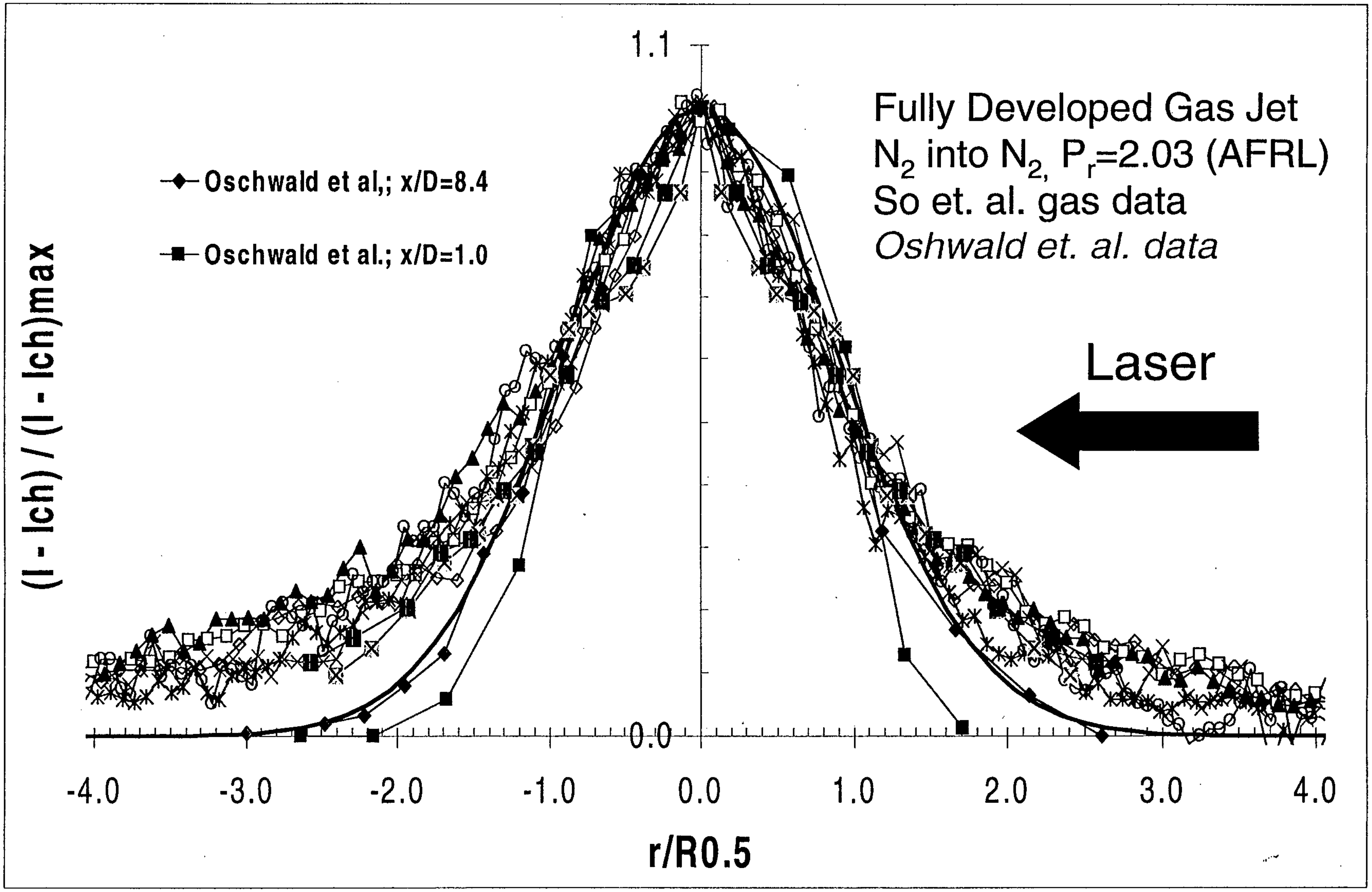

Normalized Intensity Defect Plot: Supercritical Regime (4)

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	X/D	Pch	Pr	Inj. Temp	Inj. Vel	Re	Inj/Cham
		MPa		K	m/s		density ratio
Oschwald et al.	1.0	4.0	1.2	140	5.0	115000	3.3
Oschwald et al.	8.4	4.0	1.2	118	5.0	126000	12.5
Chehroudi et al.	4.8 to 24.4	6.9	2.0	95	8.0	35000	7.1
Chehroudi et al.	4.8 to 24.4	1.5	0.4	110	8.0	12000	40.6
So et. al.	5.1	0.1	--	275	11.6	5000	0.6
So et. al.	6.4	0.1	--	275	11.6	5000	0.6

Normalized Intensity Defect Plot: Subcritical Regime

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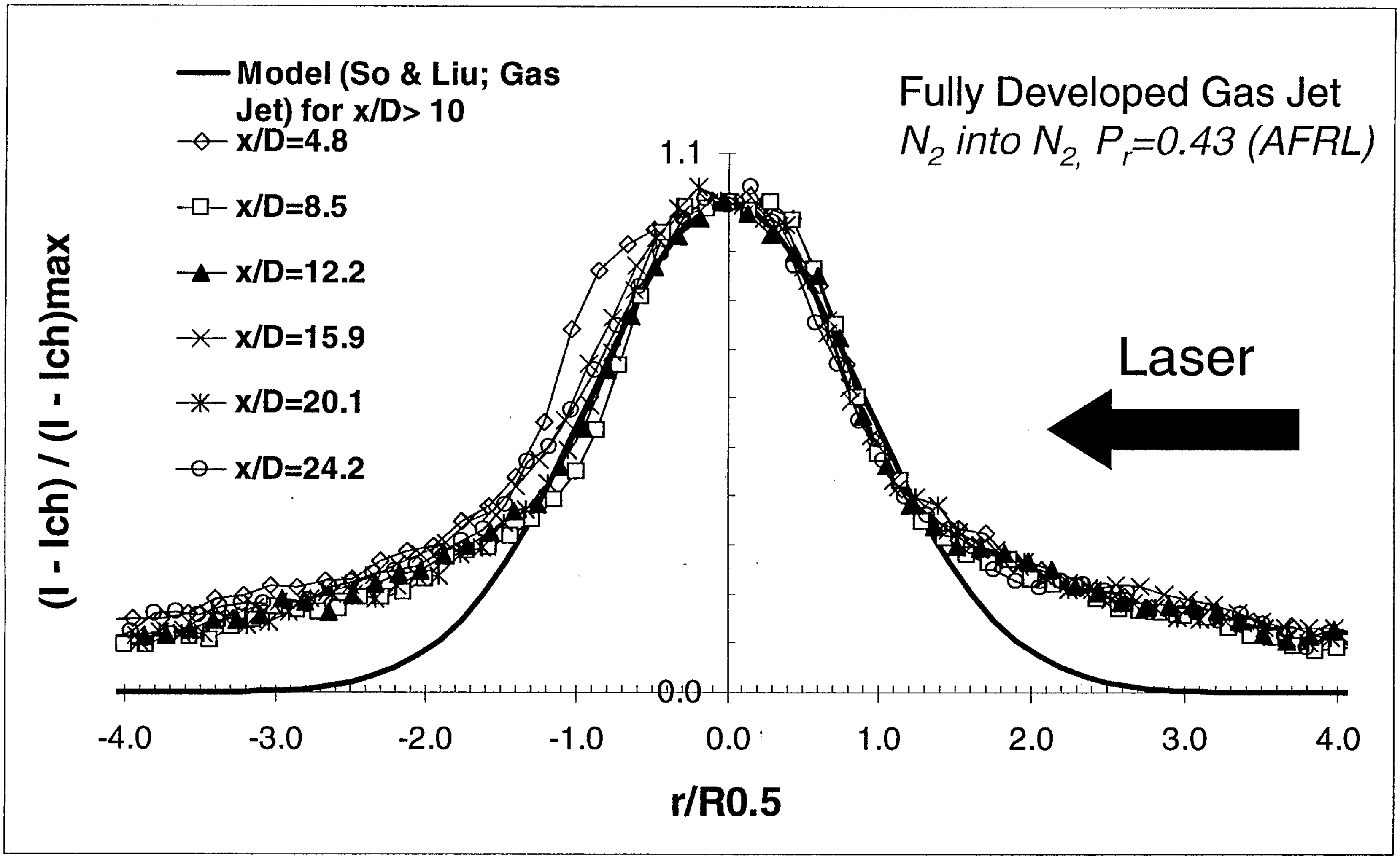
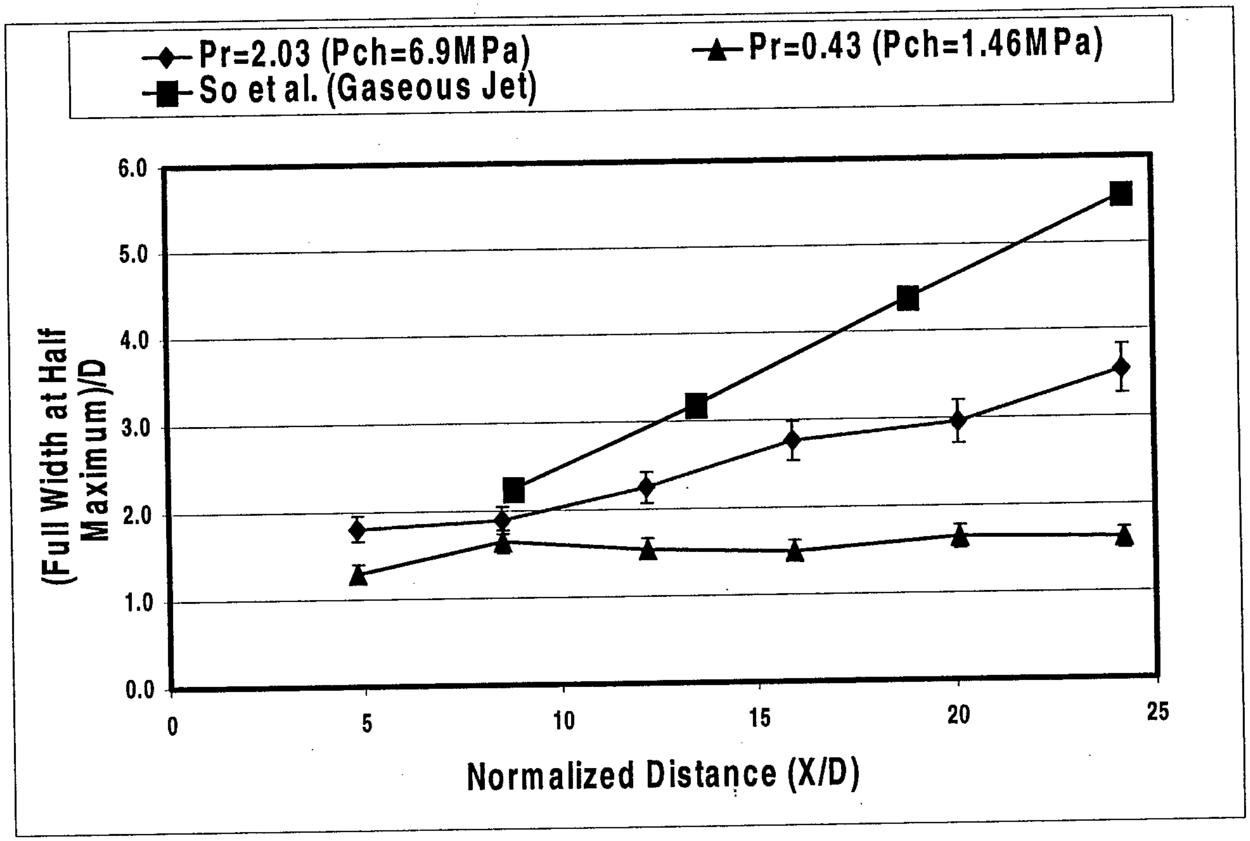


Growth Rates



Summary & Conclusions

- Measurement system integrity has been established by performing Raman measurements of isothermal N_2 at different pressures.
- Measurements were constrained to the near-field in order to maintain large Froude numbers (minimize buoyancy).
- Growth rates measured from Raman profiles measured at 2 x FWHM point agree well with shadowgraph measurements.
  - The equivalency of visual and density growth rates has also been reported in the literature (Brown & Roshko, 1974).
- To within experimental error, the near-field plots appear to reduce to self-similar shapes for both the supercritical and subcritical cases.
  - Not the same profile as for fully developed turbulent gas jets.
- The near-field supercritical profile more closely approaches that of fully developed turbulent gas jets than the near-field subcritical profile.

Future

- Complete N_2-into-N_2 analysis.
- Reduce and analyzise N_2-into-N_2/He data.