

The Brookhaven Project: Programs, achievements, show-stoppers

K.R. Sreenivasan



Trieste, Italy

**European Workshop on
Turbulence in Cryogenic Helium**

CERN

24-25 April 2007

Rough Timeline of Highlights

- ~1990 Wrote to an US Admiral and to SSC
- ~1991-92 Presentation to SSC and informal approval
- 1993 Preparatory DOE grants to Oregon and Yale; the US Congress cancels SSC
- 1994 DOE Report completed; submitted to Brookhaven
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Dynamical similarity

Reynolds number, $Re = VL/\nu$

Terrestrial applications: $O(10^9)$

Testing facilities: Huge in size (Langley: ~1 km long, ~3 m deep, ~6 m wide); expensive to operate; $Re = O(10^8)$

Extrapolation: Completely satisfactory answers for complex interactions can be obtained only by testing at full scale Reynolds numbers.

Astrophysics: $O(10^{13})$ and higher

Surface flow of ships and submarines

Dynamical similarity parameters: Re and the Froude number, Fr

$$\text{Fr} = V/(gL)^{1/2}$$

Matching Re and Fr simultaneously using water is impossible.

Possible, at least in principle, using helium II (Donnelly)

Thermal convection

The most important similarity parameter: Rayleigh number

$$Ra = \alpha g \Delta H^3 / \nu \kappa$$

For terrestrial flows up to $O(10^{20})$

Sun $O(10^{22})$

**Flows available then (using helium):
 $O(10^{12})$, in Chicago**

Why is all this interesting for Physics?

(Why SSC, Brookhaven and CERN?)

V.L. Ginzburg (2003 Nobel Prize in Physics)

(*Physics Today*, May 1990, page 9; also *Uspekhi* **42** (4), 353, 1999)

- Classified Physics into **Microphysics**, **Astrophysics** and **Macrophysics** (the small, the large and the complex)
- One of the 11 items of Macrophysics: “Strongly Nonlinear Phenomena: Turbulence”

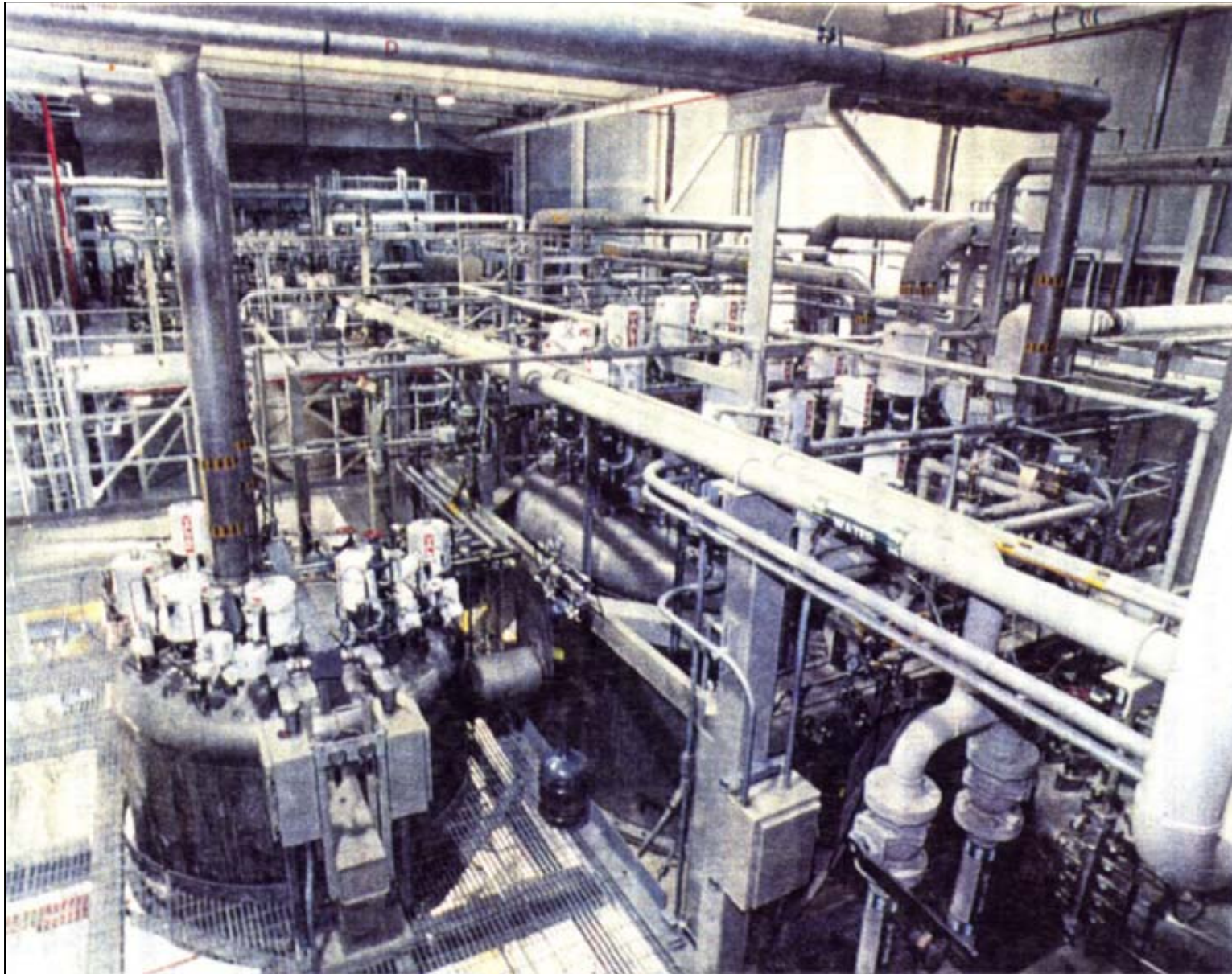
Scaling range, number of steps in the cascade, etc vary as $\log_2 \text{Re}$

Superfluid Turbulence

Helium II has a superfluid component, and produces tangles of quantized vortices.

This can coexist with classical turbulence.

Understanding the dynamics of superfluid turbulence for its own sake, and its interaction with classical turbulence are exciting problems.



The interior of the N-15 Service Building showing the cold boxes of two 4.5 kW helium temperature refrigerators. The top of one cold box with its attached turbine pod is seen in the foreground and the equipment of the second plant, N-15B, is seen in the background.

CRYOGENIC HELIUM GAS CONVECTION RESEARCH

A Discussion of Opportunities for Using the Cryogenic Facilities
of the SSC Laboratories for High Rayleigh Number and High Reynolds Number
Turbulence Research

A Report to the Department of Energy under Grant No. DE-FG05-94ER40878
From the Department of Physics, University of Oregon
Eugene, Oregon 97403

Preparation of this report was supported also by the Department of Energy
through a grant to Yale University, DE-FG05-94ER40876 and to Duke University
through grant DE-FG05-94ER40877.

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Artwork

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Editor of Report

Russell J. Donnelly

October 1994

THE CRYOGENIC HELIUM GAS CONVECTION EXPERIMENT AT THE SUPERCONDUCTING SUPERCOLLIDER LABORATORY

Participants

Principal Investigator:

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Co-Principal Investigators:

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Appendix D: Plate Thermal Issues

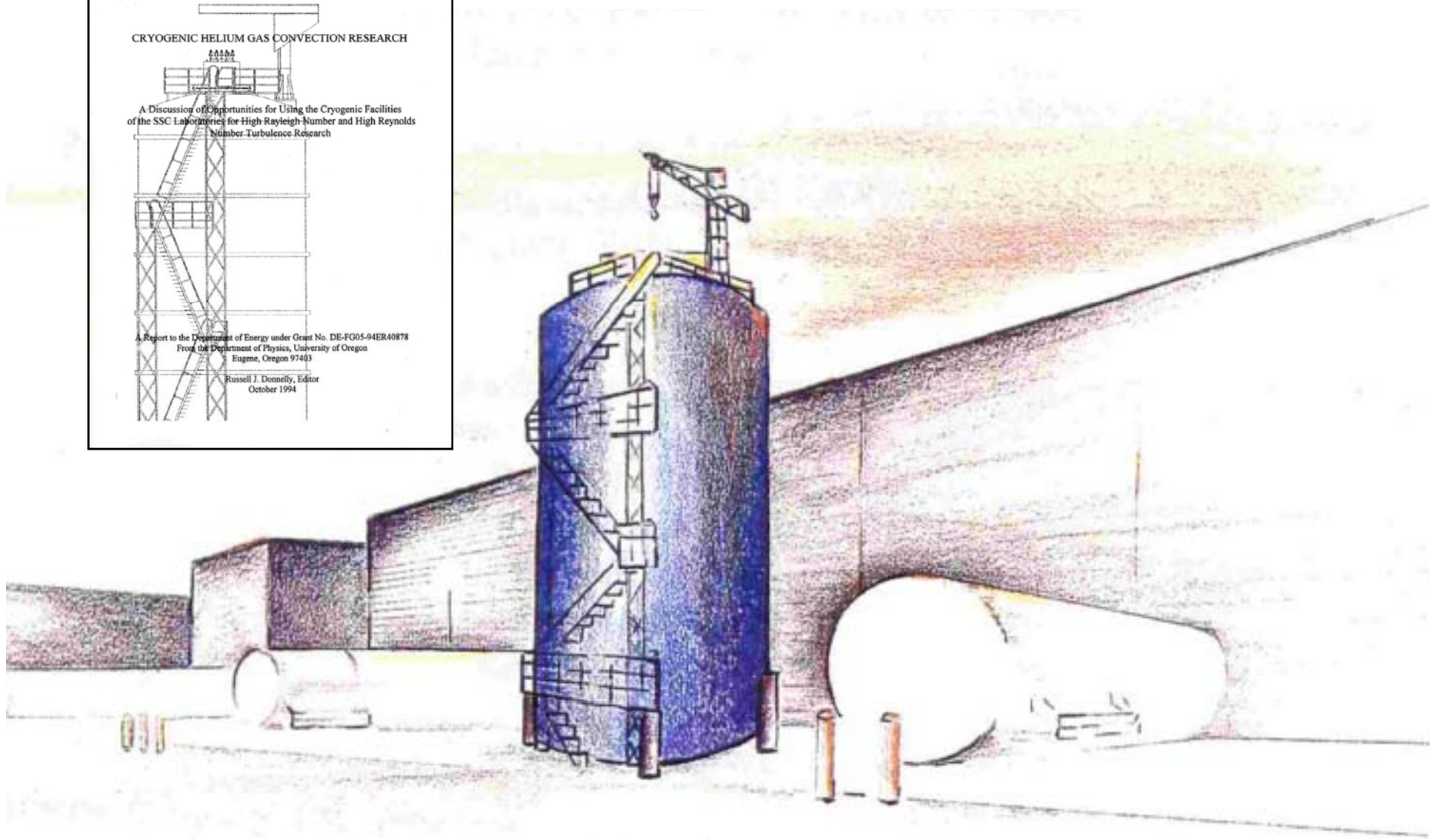
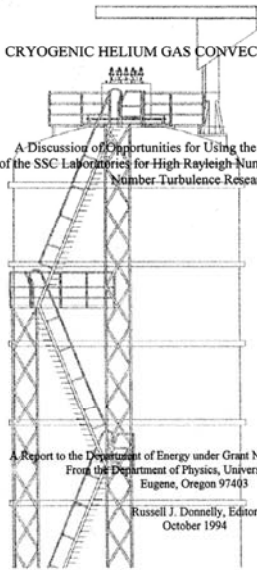
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- Extrapolation by scaling
- Bottom plate temperature distribution
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- Effective thermal resistance between the plate and the helium sink
- Heaters
- Contact resistance
- Minimizing temperature variations on the plate surface
- Results and conclusions

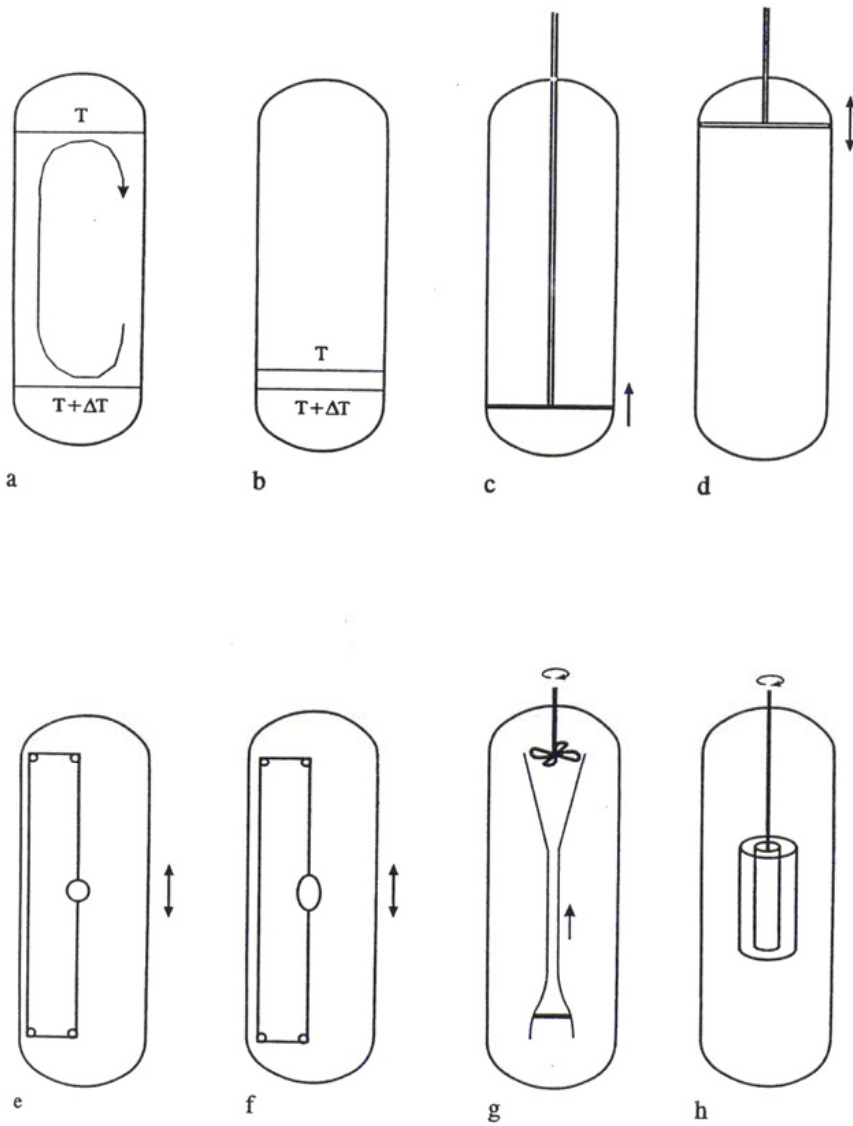
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The BNL cryostat and its potential uses

- (a) ultra-high-Rayleigh-number convection
- (b) convection with variable aspect ratio
- (c) towed grid
- (d) oscillating grid
- (e) towed sphere
- (f) towed ellipsoid
- (g) a tunnel insert
- (h) a Taylor-Couette insert

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Concerning the Report with the Same Title

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The Present Compilation and Commentary was Prepared by
Russell J. Donnelly, Editor
January 1995

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Russell J. Donnelly
Katepalli R. Sreenivasan

Editors

**Flow at Ultra-High
Reynolds and Rayleigh
Numbers**

A Status Report



Springer

What did we do right?

Pretty much everything until the last step

What could we have done better?

1. Emphasis could have been solely on physics
2. Didn't involve sufficient number of physicists outside of nonlinear physics; astrophysicists, geophysicists
3. Instrumentation didn't make as much progress as hoped
4. Dynamics of the community
5. Didn't pursue the resubmission for personal reasons

What thoughts for this enterprise?

- Build on what has happened already
- Get the long-term commitment of the CERN management
- Commit an articulate and respected leader, and build an international team
- Build a genuine community with a broad base and high standards (core + second rung)
- Prepare a proposal for instrumentation first and make it succeed (~a few M Euro)
- Prepare the final proposal after many discussions

THE END

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- Estimate of heat transport from known measurements
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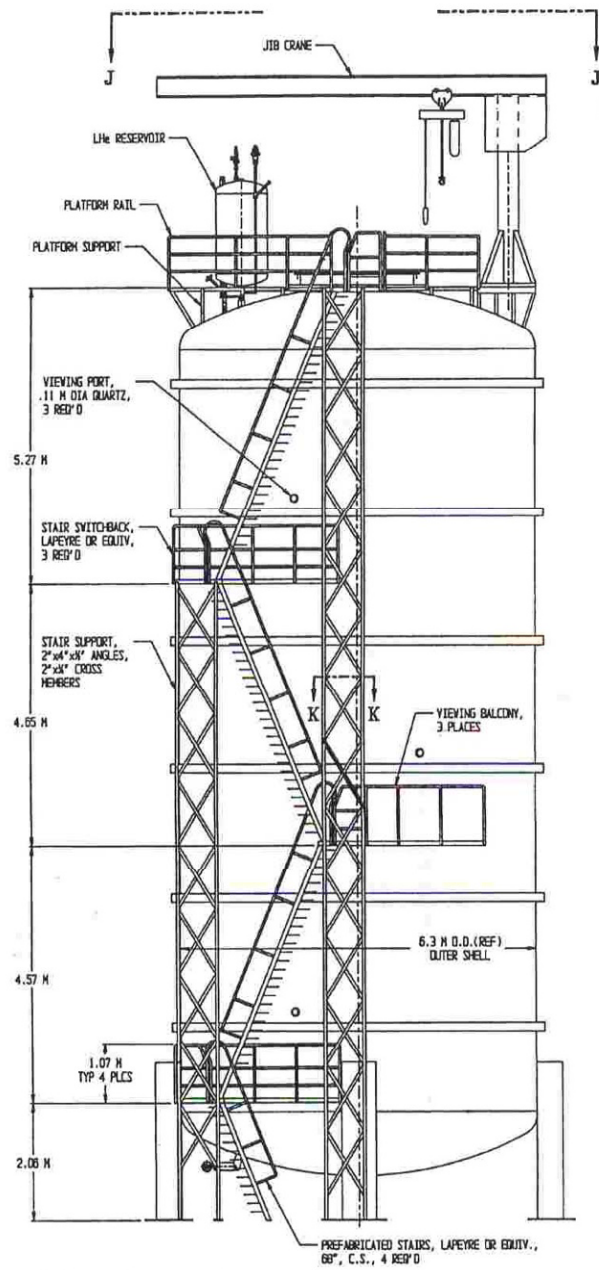
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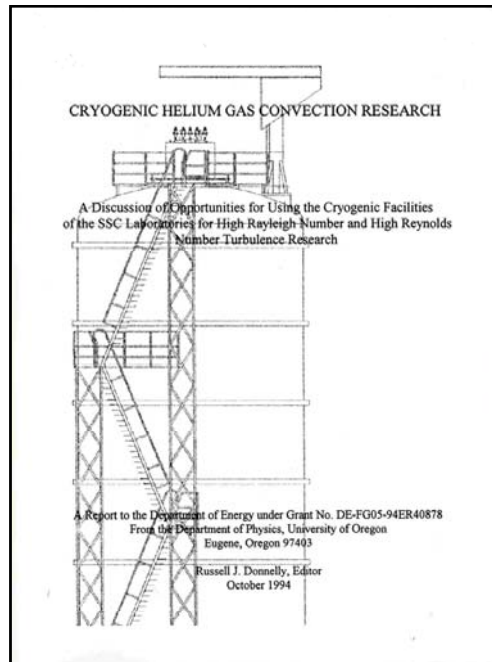
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PLATFORM AND STAIR SYSTEM DETAIL

SCALE: 1/48 = 1



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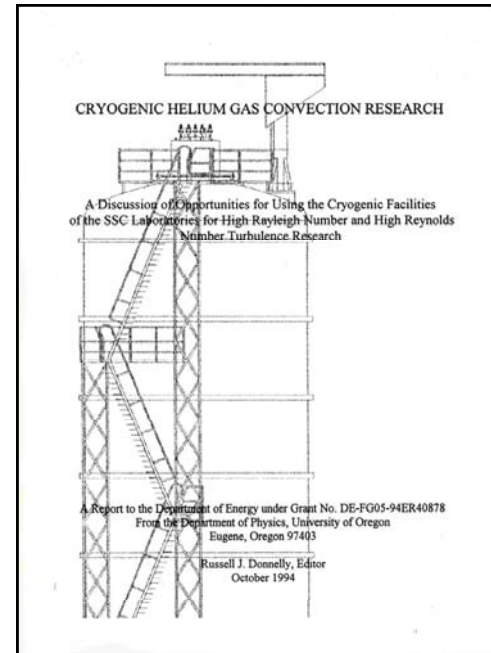
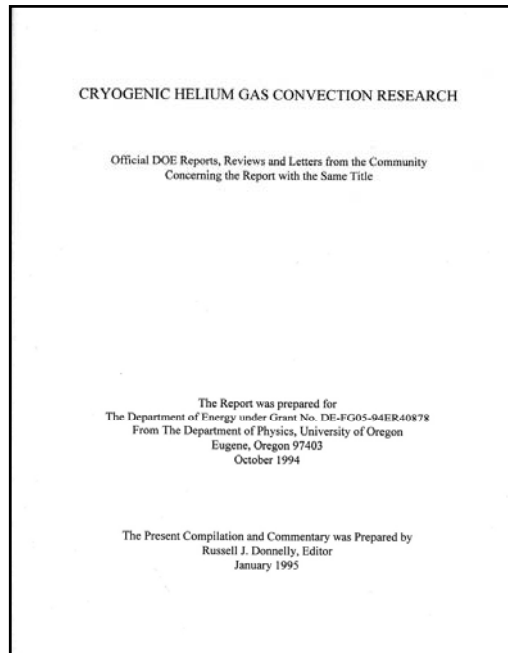
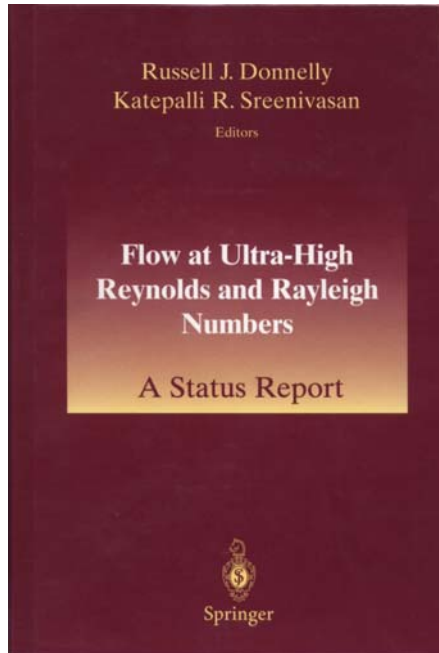
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