CRYOGENIC HELIUM GAS CONVECTION RESEARCH

Official DOE Reports, Reviews and Letters from the Community
Concerning the Report with the Same Title

The Report was prepared for
The Department of Energy under Grant No. DE-FG05-94ER40878
From The Department of Physics, University of Oregon
Eugene, Oregon 97403
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The Present Compilation and Commentary was Prepared by
Russell J. Donnelly, Editor
January 1995

CRYOGENIC HELIUM GAS CONVECTION RESEARCH

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Dated October 1994

Edited by
Russell J. Donnelly

PREFACE

The cancellation of the Superconducting Supercollider Project by Congress required, among other things, an investigation into the best use of the remaining assets.

Following an Expression of Interest phase begun in March 1994, the Department of Energy funded several interested groups in June 1994 to prepare reports outlining their ideas for use of the assets at the former SSC Laboratories. These reports were due at the end of October and were subject to internal review by the Department, and to a review at the SSC Laboratories by a specially impaneled review committee for each project. The formal review took place on November 29 and 30. Our panel was chaired by Dr. Fred Koomanoff of DOE, and consisted of Dr. Hollis Wickman of NSF, Dr. Richard Nadolink of the Naval Undersea Warfare Center of Newport, Rhode Island, Dr. Oscar Manley of Basic Energy Sciences of DOE, Dr. Thomas Peterson of Fermilab and Professor Douglas Finnemore of Iowa State University.

The review consisted of presentations by our group: Professor K. Sreenivasan of Yale University, Dr. Michael McAshan and Dr. James Maddocks both formerly from the SSC Laboratories, and myself. There was ample opportunity for detailed questions and discussion and for executive session by our own panel, and by all review panels together. The panels assembled their reports in large measure before leaving the review, making it possible for the Department to assemble the review results, make some decisions and send a letter from Dr. David Nelson dated December 21 giving the texts of the individual reviews, and notice of decisions already taken by DOE on the disposition of assets. This formal letter of transmission and the anonymous reports constitute the first section of this document.

We began to collect letters from various prominent members of the turbulence and cryogenics communities both here and abroad as soon as our report was available at the end of October. We asked these scientists and engineers to allow us to use their letters in a form which could be presented to a number of agencies, since it was evident that the activities discussed in our report could be relevant to more than one Federal agency. These letters are reproduced in the second part of this document with a brief description of these writers.

The third part of this document contains the DOE summary of these actions as prepared for presentation to Congress and the Administration as one of the final measures in the termination of the SSC.

The reader will see that our report generated a great deal of support and enthusiasm from a wide cross-section of the scientific community. We are most grateful to everyone who participated in this exercise and devoted their time and energies to it. In particular Dr. Robert Diebold and his staff made every effort to ensure that our ideas had a full and fair hearing from the Department of Energy.

The results of the process described above have made us aware that our efforts to utilize helium in the attainment of very high Rayleigh and high Reynolds numbers is likely to have impact far beyond what we included in our report. Therefore we are now seeking support to implement our planned experiments and to begin the process of planning and developing flow facilities with liquid helium. For in the long run, the full utilization of the promise of cryogenic helium research in fluid mechanics will involve both flow and convection.

Russell J. Donnelly
Eugene, January 1995

Official Transmittal Letter from Dr. David Nelson, Associate Director of Energy Research at DOE, giving some decisions on property at the SSC and sending copies of the individual reports of the review panel who met at the SSCL November 29-30.

Department of Energy
Washington, DC 20585

DEC 2 1 1994

Professor Russell Donnelly
Department of Physics
University of Oregon
1371 East 13th Avenue
Eugene, Oregon 97403-1274

Dear Professor Donnelly:

I am writing to you in your capacity as Principal Investigator for the project definition study on Cryogenic Helium Convection Research. The study represents considerable thought and work on the part of many people and I hope that you will convey our appreciation to those who contributed to the project.

For your information I am enclosing a copy of the individual reports from the peer reviewers who evaluated your study at the recent review led by Dr. Robert Diebold. We have removed the names and other identifying marks in an effort to maintain the anonymity of the reviewers. A copy of the corresponding summary chapter of the DOE report will be sent to you on approximately December 28, followed by copies of the full report when published. Please let Anna Bennington, 301-903-5490, know the number of reports that you need. I hope this information will be useful to you and your colleagues as you determine how best to proceed.

As you can see from the reviewers comments, your project reviewed exceedingly well. I would encourage you to work closely with the various potential funding offices as you refine your study and turn it into a formal proposal. Most of the assets and facilities needed for your project were transferred to TNRLC at a closing on December 1, although some of the equipment you requested remains DOE-owned. Given the urgent needs of other DOE laboratories and programs for this equipment, as well as the goal of finishing the SSC termination process in a timely and cost effective manner, together with the funding uncertainties associated with your project and with the future of the N15 area, it was decided to send the DOE-owned equipment to existing DOE efforts as expeditiously as possible.

Thanks again for the effort of you and your colleagues in developing the ideas for this intriguing and timely project. I wish you the best of luck with it.

Sincerely,

David B. Nelson
Associate Director
Office of Energy Research

Enclosures

cc:
R. Diebold, ER-20
F. Koomanoff, ER-10
A. Tavares, FM-50
E. Cumesty, SSCPO
G. Haas, SSCPO
E. Bingler, TNRLC
K. Screenivsan, Yale University
R. Behringer, Duke University

Topic: #2 Cryogenic Convection

Overview:

The feasibility of using the existing cryogenic facilities for exploring the highly turbulent flows has been studied. Such flows are of great scientific and engineering interest, because they occur in nature (eg atmospheric and ocean circulations) and in man made systems (eg limits on ship and aircraft dynamics).

Summary /Conclusions

There is a great opportunity to increase our understanding of highly turbulent flows with relatively small additional capital investment. Access to experimental data in the regime which is made possible by the facility under study (flow of low temperature helium) will prove extremely useful for testing the validity of numerical simulations (open to some questions because of the limitations on existing hardware and limitations on numerical methods). If possible funding should be provided, subject to the preparation of a specific, peer reviewable proposal. Such funding should be obtained from a consortium of interested Federal agencies, with a commitment to a stable multilyear research program.

1. Motivation and Benefits:

Many flows of fluids ocurring in practice are extremely turbulent. Common examples are atmospheric motion, ship-generated sea surface flows, aircraft created disturbances, etc. The scale of the observed phenomena is usually beyond the sizes normally accessible in the laboratory. Fortunately, some of the observed phenomena may be simulated on a reduced scale if one can arrange for the flow with the desired characteristics to occur in a fluid with different physical properties, notably different viscosity. That is called

Reynolds number scaling. Thus the smaller the viscosity the smaller one can take the velocity and length scale to be in order to observe a given level of turbulence. In nature the fluid with the smallest viscosity turns out to be helium at about 5K. By varying the temperature slightly in that regime, it is possible to vary the viscosity by many orders of magnitude, thus allowing, for a given fixed fluid speed, and a given fixed length scale, turbulent phenomena to be reproduced and controlled over a wide range of naturally observed length and speed scales.

In practice that means that some aspects of say atmospheric or oceanographic motions can be studied under controlled conditions. Similarly, studies related to the design of large ships can be pursued. From the point of view of the basics of fluid mechanics, it should be possible to improve our intuition concerning the behavior of turbulent flows well beyond what is currently achievable on the existing laboratory scale.

2. Feasibility:

It appears from the presentations that the flow regimes of interest are feasible and well within the reach of the limits of the physics of fluids and the proposed equipment. However, additional thought needs to be given to the instrumentation and detailed experimental procedures needed to exploit this opportunity to its technological limit.

3. Match to SSC Assets:

The available equipment, ie cryogenic facilities and physical space available are uniquely suited for the proposed range of studies. In terms of the optimal utilization of the investment made by the government in this cryogenic facility, in this reviewer's opinion, the proposed range of long-term studies may well represent the ideal utilization of these resources.

4. Similar activities

To my knowledge, activities in this area are severely limited by the available range of fluid characteristics at or near room temperature. It is simply physically impossible to reach the parameter regime without the equipment available here. While such array of facilities may exist elsewhere it is not likely that it is dedicated to fluid mechanics studies, such as those envisioned here.

5. Costs.

The estimated costs seem reasonable, save for the uncertainty in the expected overhead and no readily apparent contingency provisions.

6. Funding

The range of results obtainable her are of interest to a number of Federal agencies, and perhaps some joint funding could be arranged. Also, the results of the studies, in such areas as climate and oceanographic sciences might engage the interest of the international community. It may be possible to reduce the cost to the US Government by having some of the scientific labor carried out by foreign visitors with their own support, and hence a minimal cost to the US Govt.

TOPIC: **Cyrogenic Helium Gas Convections Research.**

Overview
A national facility will be established for the study of convection and turbulence in high-Reynolds number and high-Raleigh number conditions. This opens a whole new regime of fluid flow to experiment on a laboratory scale and it will turn these problems into a real science. Results will be important in fields as varied as meteorology, naval vessel design, and air foil design.

Summary/Conclusions
The concept for the national facility is sound and the carefully designed experiments will provide an opportunity to push our understanding of turbulence into a new regime that is of great practical importance. The initial series of experiments opening the field, such as towing a grid, are difficult but straight forward extensions of known technology. Further along, there is an enormous opportunity to develop new instrumentation for multi-point velocity and temperature measurements. With this class of data, detailed mapping of the correlated motion in the form of plumes, cells, and vorticies will be possible.

1. Motivation and Benefits
Phenomena ranging from weather prediction to drag on a submarine depend on a thorough understanding of turbulence and convective flow at large Reynolds number and large Rayleigh number. At present there is no facility to experimentally develop this critical science. The central issue in this field is that the length scale needed for experiments has been too large for controlled laboratory experiment using ordinary fluids. In meteorology, for example, the scale is kilometers. To solve this problem, the national facility discussed here will use the flow of helium at low temperature to enable experiments in the laboratory that are equivalent to the large scale problem. With laboratory scaling, a whole range of variables can be changed at will to test theories and look for new phenomena. Because the viscosity of helium is so low and the range of gas density is so large in the region near the triple point of helium, the facility will enable model systems to be constructed and tested on a lab scale that would otherwise be impossible. The facility will open a whole new field of science.

2. Feasibility
There is absolutely no doubt that many new experiments can be done. The refrigeration has been developed and is available. The cell design and construction is substantial but is based on well proven methods used for large magnets already being built. Basic experiments like the towing of grids and other shapes through the fluids can certainly be done. The experiments of convective flow in which heat and temperature at the far distant ends of the tank can certainly be done and will provide valuable tests of theory. The development of single point velocity measurement is difficult but seems feasible. The development of multi-point temperature and velocity measurements will require substantial development but the projected designs appear likely to succeed. Instrumentation development is a key component in the proposal and the U.S. needs to be a world leader in the development of this instrumentation.

3. Match to SSC Assets; which assets are critical?
The dominant cost of establishing this facility, the refrigeration system, is in place and working. The secondary detailed instrumentation for basic flow measurements is easily added to the SSC assets and the match is excellent. Laboratory and office space needs to be provided.

4. Similar Activities Elsewhere

5. Costs
The costs of entering this vital and intellectually exciting field may range from 2 to 10M dollars per year. Much more could be done with additional funding but the proposed costs will produce very important new science.

6. Funding
There are many federal and industrial groups with a large stake in the development of this facility including NOAA, the Navy, and Air Force, the National Science Foundation and any agency interested in global climate. Some mix of funding sources seems feasible.

TOPIC: Cryogenic Helium Convection Research (Texas Review) Notes

Overview

Summary/Conclusions

Evaluation

1. Motivation and benefits

The extension of experimental results to higher ranges of Reynolds and Rayleigh numbers is clearly of scientific interest. The study clearly and convincingly makes that case. The question that I had before arriving here for this review was: "Who, other than people who study this, will benefit from extending the experimental results to higher Reynolds or Rayleigh numbers? Climate models? Submarine designers? Aircraft designers? Solar astronomers? Astrophysicists? That is, how big is the scientific constituency that supports this work?" This is not quite the same as who will come and do the experimental work at the facility, which is also important to define, but rather who is interested in using the results.

We heard some answers to this question, but those answers should be made as specific as possible.

2. Feasibility

In Appendix L, "support" is the weakness of the SSCL N-15 site. "Under this category is judged the expertise, both in cryogenics and in other branches of engineering, and the technical support that can be drawn on by the guest program." This problem needs to be addressed for the convection research program. This ties into the role and capabilities of the N15 support staff and the TNRLC.
Appendix L notes that other laboratories, like Fermilab and Brookhaven lab, have strong support staff while having other weaknesses as locations for this work. Perhaps ways can be found to use the support staff (e.g., engineering, purchasing departments, etc.) at one or more of these laboratories to expedite work on this convection facility even if it is located here in Texas. I would be happy to help explore the possibilities of how Fermilab can help, if and when this becomes desirable.

3. Match to SSC assets: which assets are critical?

This is an excellent match to one of the cryoplants at N15. That is the critical asset here.

4. Similar activities elsewhere

Only the work of Dr. Wu at Chicago (now at NIU) was discussed. This research up to now has been on a scale several orders of magnitude smaller. It does provide important background information and experience with instrumentation, but nowhere is work of a similar scale being done.

5. Costs

Estimates for operating expenses come from people working on the project definition study for the Applied Superconductivity and Cryogenics Technology Center, and are about $2500/day "including operators". Judging from the operating costs, there are no operations of the cryogenic system in years 1 and 2, 65 days of cryo operations in years 3 and 4 and 300 days in year 5.
The cost estimates seem reasonable as far as they go. But the big uncertainty is the relationship with the "Applied Superconductivity and Cryogenics Technology Center", how overhead is paid, who pays for the system when it is not in use, etc.

6. Funding

Our group discussed funding. It sounds like there are many possibilities, and this is a facility that could be supported jointly by many organizations, dividing the burden. Other group members are better qualified to make specific recommendations than I am.

TOPIC: **Cryogenic Helium Convection Research**

Overview

(1) Very High Reynolds Number Research (VHRNR) has major technological and fundamental significance;
(2) Helium is the optimal fluid for VHRNR, but its use has not been exploited, owing to the need for cryogenic facilities;
(3) The special cryogenic infrastructure required for VHRN is fortunately available at N15.

Summary/Conclusions

This is a novel project that can lead to a productive facility that would be unique in the world. Initial experiments will establish a knowledge base leading to additional, focused experiments of a more technological nature that would be of major utility in the field of naval architecture.

The PI and co-PIs should be encouraged to prepare a full proposal for multi-agency submission.

1. Motivation and Benefits

Establishment of a VHRNR facility would provide opportunities to carry out fundamental experiments in fluid dynamics (particularly in the area of turbulence) that are not currently possible in conventional (water) facilities. The results of the experiments, if definitive, would extend scaling ranges to unprecedented Renolds number values. The information obtained would be of great interest in basic science and of equally great importance to technological fields where high Reynolds numbers are encountered, viz., astrophysics, atmospheric science, global weather modeling, naval architecture, and so forth. At present*, there are no viable alternatives to the proposed project for obtaining high Reynolds number data for a real system. (* Update: Subsequent discussion has suggested that alternate facilities may exist at BNL. This point requires clarification.)

2. Feasibility

Proposed macroscopic construction details of the helium and associated gas/liquid handling of the helium handling apparatus largely use existing technology. A previous experiment of Wu and Libchaber (WL) provides in many respects proof-of-concept for certain microscopic aspects of the project. However, significant instrument development beyond the WL experiment is involved because of the physical scale of the proposed experiment and the needed turbulence detection methods. The PI and associates are expert in bolometry, but will need to develop laser doppler velocimetry (LDV) and visualization techniques (employing suspended particles) if the project is to be successful. Thus, substantial development work in these areas in planned at Oregon, Duke, and possibly other locations. This will be critical to the success of the project.

Direct visualization of characteristic regions of turbulence via optical study of suspended particle motion, light scattering from density fluctuations, etc. would have major impact on the engineering community and interested but non-expert scientists. Reasonable, but not definitive, arguments are presented that such data can be obtained. It will be most exciting if these ideas can be further refined so that they can be successfully implemented on the large scale of the proposal convection chamber. The need to develop adequate instrumentation for the project represents the major risk factor for the proposal. However, the potential payoff gretly justifies this risk. The knowledge gained in developing new turbulence visualiztion methods will be valuable as a standalone activity -- especially since the observational length scale for some of this phenomena is argured to decrease with increasing Reynolds number and hence not overlap with existing measuement methods.

3. Match to SSC Assets; which assets are critical?

Qualitatively, the match is excellent. The refrigeration capabilities at N15 are unique. They provide an established facility that makes the proposed convection project economically viable. Without N15, it is unlikely that a helium convection project could be proposed in the context of current Federal budget constraints.

It is crucial that a stable commitment of N15 resources for a period of at least 5 years be established at the outset. It seems likely that the project could entirely utilize one of the two refrigeration plants full time.

4. Similar Activities Elsewhere

To the best of my knowledge, there are no competing facilities elsewhere. This is certainly a strength of the proposal and could lead to international collaborations or possibly cost-sharing. Options and opportunities here have not yet been explored in great detail,

5. Costs

The cost of the project as given in the report seems reasonable — even economical at this point. However, much will depend upon realities of cost-sharing provided by the TNRLC. I am not an expert in the area of engineering development costs and my comments have are qualitative, at best. I am nevertheless impressed by the details provided in the report concerning construction details and probable costs. Where overlapping, they agree with my past experience with low temperature projects.

In current budget climates, much care should be taken so that any full proposal resulting from this report provide conservative and responsible estimates for project expenses.

6. Funding

Several options exist and were discussed during the first day of the project presentation. Opportunity for multi-agency collaboration was identified. The list of potentially interested agencies is impressive; DOE, NSF, ONR, AFOSR, NOAA, NASA, etc. A mechanism for establishing such a multi-agency proposal and activity is yet to be defined. Memoranda of agreement have recently been established between NSF and ONR, and NSF and DOE/Argonne. These may be useful. Programs within NSF that may be relevant include the STC Program and the National Facilities Program in the Division of Materials Research. There is general consensus that a multi-agency funding mode would reduce outlays by specific agencies and enhance likelihood for participation in the project. The many and impressive letters of support from academia suggest the project would fare well under peer review.

Interaction and outreach to industry need to be further explored, since this aspect can be a required component of potential funding modes.

TOPIC: Cryogenic Helium Convection Research

Overview

The proposed convection research proposal overall is an excellent first step in establishing the Texas site as a world-class center-of-excellence in High Reynolds Number Flow research. A unique and possible one-time opportunity exists to capitalize on the SSC cryogenic facilities to facilitate a research program which has appeal to:

- Navy	- DOE
- Air Force	- Texas Commission
- ARPA	- US and foreign universities
- NSF	- US commercial interests

Summary/Conclusions

In order to proceed with the implementation of the proposed work, a consortia of potential sponsors is recommended to share the fiscal burden and the results of the research.

The technical feasibility of the proposed research is judged to be excellent and at the leading edge of very high Reynolds Number Flows of geophysical and Naval interest.

The following important points need to be articulated in any high-level presentation:

- Emphasis on major technological/applicational implications
- Helium is an "ultimate" fluid
- Unique opportunity exists to capitalize on a national resource (SSC-cryogenics N15 plant)

Evaluation

1. The scientific technical, educational, and/or economic motivation and benefits

The proposed convection experiment provides a unique opportunity to extend the Reynolds and Rayleigh number range by several decades, thereby being of great interest to researchers worldwide. The implications of the positive outcome of such experiments cannot now be calculated in the world of turbulence theory and the practical applications to aerodynamics and hydrodynamics. The educational benefits are direct, in that a number of graduate students and post-docs will be participating for a number of years as well as a number of universities. One of the economic benefits which may be derived in the eventual interest and support by the US Navy in replacing the present arsenals of water tunnels with one or two liquid helium facilities which could be shared by universities and the Navy for both basic research and advanced design work for submersibles. Some additional comments that may lead to a more successful and accepted proposal are:

- The turbulence data collected must be first class in order to be accepted by the community.

- Basic fluid mechanics measurements on 3-D objects, i.e., drag, etc., need to be made to convince the Navy.

- Involving a Texas university would be politically useful and expand the educational benefits.

2. The overall feasibility and the availability of funding

The proposed convection experiment appears to be without major flaws, yet the scale and costing of the pressure vessel are worrisome. The technical team assembled are first class, and certainly the cryogenic expertise at the N15 site of the SSC is unique and completely eliminates the risk of a major element of such experiments. Some other short comments are:

- The proposed research and follow-ons must interest a consortia of funding sources, i.e., DOE, NSF, Navy, NASA, AFOSR, etc., provide something for everybody.

- Laser Doppler Velocimetry (LDV) is crucial instrumentation but very difficult in this environment. Obtain specific expertise on the team.

3. The match of SSC assets to needs

This is clearly the strongest part of the proposal because the N15 site facilities are a perfect match for the proposed experiments. There remains a question of what is the actual costs of the N15 site operation if this experiment is the only user? It if is a 10-workyear operation, then five million dollars is needed for five-year support. Is this included in the cost proposal?

4. Comparisons to similar activities elsewhere

There was no discussion or concern about competitive proposals in this subject area. There does appear to be other cryogenic facilities at national labs that could also support these proposed experiments.

5. Reasonableness of cost estimates, completeness of infrastructure need

The capital cost projection for the helium cryostat is the biggest potential cost growth item in this project. Assuming the Texas Commission will fully cooperate in the MOU to dedicate one-half of the plant for the project duration, a major obstacle will be eliminated. Infracture costs appear to be medium to low estimates based on burdened DOD FY95 rates.

6. Realism of business plans and funding expectations

The points covered in criteria #2 and #5 apply to the realism of business plans and funding expectations. In short, a consortium of sponsors is needed in order to share the five-year expense and each should be convinced of a "compelling reason" that is supportable at the individual agency leadership levels.

List of Persons Writing DOE in Support of the Cryogenic Gas Convection Experiment

Title(s)	First Name	Last Name	Institution	Other ID
Professor	Guenter	Ahlers	UCSB	National Academy of Sciences
Professor, Academician	Grigory	Barenblatt	Minnesota	G. I. Taylor Chair, Cambridge UK
Dean of Engineering	Allan	Bromley	Yale	Former Presidential Science Advisor
Dr.	Dennis	Bushnell	NASA Langley	Assoc. Chief, Gas Dynamics Division
Professor	Alexandre	Chorin	Berkeley	National Academy of Sciences
Professor	Nigel	Goldenfeld	Illinois	University Scholar
Dr.	Jackson	Herring	NCAR	Mesoscale & Microscale Meteorology
Dr.	Pierre	Hohenberg	AT&T Bell Labs	National Academy of Sciences
Professor	Masahide	Murakami	Tsukuba	Pioneer in liquid helium hydrodynamics
Professor	Alan	Newell	Arizona	Head, Dept. Of Mathematics
Dean	Itamar	Procaccia	Weizmann Institute	Levinson Chair
Professor	Larry	Redekopp	USC	Chairman, Mechanical Engineering and Chairman of the Executive Committee, Division of Fluid Dynamics, APS
Professor	Larry	Sirovich	Rockefeller	
Professor	Edward	Spiegel	Columbia	Rutherfurd Professor of Astronomy
Poynting Professor	W. F.	Vinen	Birmingham	Fellow Royal Society of London
Professor, Academician	Vladimir	Zakharov	Arizona	Director, Landau Institute, Moscow

UNIVERSITY OF CALIFORNIA, SANTA BARBARA

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DEPARTMENT OF PHYSICS

SANTA BARBARA, CALIFORNIA 93106

November 25, 1994

Dr. Robert Diebold, ER-20
U.S. Department of Energy
19901 Germantown Road
Germantown, MD 20874

Dear Dr. Diebold:

I am writing in support of the Report entitled "Cryogenic Helium Gas Convection Research" which was edited by Russell J. Donnelly. In this document it is proposed that the cryogenic facilities of the SSC Laboratories be used to establish a facility for high Rayleigh and Reynolds number turbulence research.

The existing cryogenic facility offers a unique opportunity to operate a very large convection chamber (10 m high, 5 m in diameter), using helium gas. Such a chamber can be used to extend presently existing studies of turbulence as a function of the Rayleigh number by several decades, thereby exploring a new regime in which it should become clear what the relevant asymptotic scaling laws may be. In addition to the primary use for the study of thermally driven turbulent flows, the chamber will be useful for a variety of other studies involving grid turbulence etc. A long-term productive scientific program is likely to evolve with significant practical implications in areas where turbulence plays a role. Thus I strongly support the use of the existing cryogenic capabilities for the establishment of this facility.

Sincerely yours,

Guenter Ahlers
Professor of Physics
Director, Center for Nonlinear Sciences

GRIGORY ISAAKOVICH BARENBLATT, Hill Visiting Professor
Department of Aerospace Engineering & Mechanics
107 Akerman Hall, 110 Union Street S.E.
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Dr. R. Diebold, ER-20,
US Department of Energy,
19901 Germantown Road,
Germantown, MD 20874

19 November, 1994

Dear Dr. Diebold:

I received the proposal of Professor R. J. Donnelly and his colleagues under the general title 'Criogenic helium gas convection research'.

I found this proposal to be very important and promising. Moreover, it seems to be a beginning of a completely new stage in experimental fluid mechanics. Indeed, the possibilites of reaching high Reynolds and Rayleigh numbers at proposed facilites are incomparable with previous ones. And reaching high Reynolds numbers is now the problem of crucial importance. Indeed, apparently the small parameter in turbulence is not $1/Re$, but

$$\varepsilon = \frac{1}{\ln Re},$$

so, to be really small, enormously large Reynolds numbers should be achieved, at least of the order of 10^{12}. Meanwhile the Reynolds numbers achieved at the beginning of thirties by Nikuradze are 6 orders of magnitude less, and until now nobody was able even to repeat these experiments. The best attempts of J. Laufer (1954) correspond to $Re = 5 \cdot 10^4$ and $Re = 5 \cdot 10^5$.

It is strange to recognize that now we do not know the simplest turbulent flow, the flow in circular cylindrical pipe at large Reynolds numbers! And it is good, that instead of spending money for achieving particles of high energy, we will achieve a progress in practically very important fascinating fundamental problem: turbulence at high Reynolds and Rayleigh numbers.

I am speaking about the turbulence in the pipes and channels, although these problems, being mentioned in the proposal, are not the first to be solved: it will be a natural next step. But the problems proposed for the first turn are also interesting and important. Perhaps they are even the best for the first stage. Among them I am mostly interested in the problem of turbulent burst (by the way, in the future experiments in the towing tank the wake behind a self-propelled body gives an exactly equivalent problem, so it may be very interesting to compare the results). As far as the decay rate in the grid turbulence is considered, I anticipate here more complicated investigation: not only the Reynolds number dependence of the exponent n in the law:

$$\overline{u'^2} \sim t^{-n},$$

but also the dependence of n on the type of grid (passive grid, active grids of various types etc.)

I can foresee some other complications, in particular one related to the constitutive equation of liquid helium. But all that is of secondary importance.

Summing up, I am sure that fluid mechanics will be benefited by this entirely new approach. I am sure that Professor Sreenivasan will advise properly new groups of interested fluid mechanicists. I am sure that the flow of money from the interested customers will increase with achieving new results: practical applications are evident. I think that the project should be supported.

G. Barenblatt

Foreign member, American Academy of Arts and Sciences,
Foreign Associate, US National Academy of Engineering,
Member, Academia Europaea

cy- Diebold
Koomanoff

November 17, 1994
2:10 p.m.

TELEPHONE MESSAGE

To: Robert Diebold

From: Dean Alan Bromley, Engineering Department, Yale University (former Presidential Science Advisor)

Subject: SSC Project Definition Study from Dr. K.R. Sreenivasan, Yale U., "Cryogenic Helium Gas Convection Research"

Dr. Bromley called to advise Dr. Diebold of his support of the above-referenced study, proposed by one of his faculty members. Stated that the study is for a very worthwhile and important project and hopes that, somehow, funding is found and made available for it.

A.Bennington

(4)

National Aeronautics and
Space Administration
Langley Research Center
Hampton, VA 23681-0001

NASA

NOV 18 1994

Reply to Attn of:

Dr. Robert Diebold,ER-20
U.S. Dept. Of Energy
19901 Germantown Road
Germantown,MD 29874

Subject: Support Of "Cryogenic Helium Gas Convection Research",A Report And Proposal By R.J.Donnelly to DOE Dtd. October,1994,[prepared under grant DE-FG05-94ER40878]

The undersigned has conducted turbulent shear flow research for air vehicles for many years and has consulted extensively for the Navy in the area of submarine hydrodynamics.As an introduction,the current state-of-the-art in turbulence is wholly unsatisfactory.Laboratory studies are universally conducted,by current necessity,at low-to-moderate Reynolds Number while most technological systems/applications,as well as geophysical flows,are typified by very large Reynolds Number.This situation has led to inate conservatism in design and serious shortfalls in detailed understanding and prediction.

The subject liquid helium facility would,uniquely,provide a major new capability to bridge the present serious gap between current laboratory capabilities and actual applications in terms of Reynolds Number.What is particularly important is that this new capability is inherently affordable,both as to initial and life cycle costs.Previous suggestions for high Reynolds Number facilities required far greater expenditures and their operation would have been exceedingly difficult and cumbersome.

If the subject concept is such a good idea one may reasonably ask why it has not been previously adopted/exploited.The short answer is that liquid helium is so far outside the experience base of aero and hydro-dynamicists that these communities are essentially afraid of the development risks involved.There are many such risks which include requisite model smoothness,instrumentation issues,model optical access and facility productivity.On the aeronautical side the lack of a compressibility simulation capability relegates the helium facility to a basic turbulence physics as opposed to a development role.For the Navy this capability would significiently