TESTIMONY
of
W.P. Halperin
for
The House Committee on Science & Technology
Subcommittee on Investigations & Oversight

April 22, 2010

Mr. Chairman and members of the committee, thank you for the opportunity to testify about the negative impact on scientific research caused by the shortage of helium-three. I am a physics professor at Northwestern University, and I rely heavily on helium-three to carry out scientific research at low temperatures and have been involved in this work since 1970. Low-temperature research is essential for studying properties of materials, such as superconductivity, and magnetism, and for developing various advanced materials. Low-temperature research is also critical to future improvements in metrology and high-speed computation, including quantum information technology. Shortages of helium-three, driven by increased homeland security demands and decreased production capability, are already creating major difficulties in these areas of research.

Let me briefly review the salient points. Helium-three is a gas and a byproduct of the radioactive decay of tritium, an essential element of nuclear weapons. Following the Second World War, as the nuclear stockpile grew, stocks of helium-three grew commensurately, reaching about 230,000 liters by the year 2000. From 2001 to the present, these stocks have been drawn down at a rate far in excess of today's global production, estimated to be approximately 20,000 liters/year. The use of helium-three as a detector of radioactive materials at ports, airports and border crossings, combined with the growth of medical, commercial and scientific applications, is responsible for the extraordinary increase in demand.

Absent new production sources, it is now impossible to serve the estimated need of 70,000 liters/year. It may be possible to find alternatives to the use of helium-three for some applications, but for others the unique physical properties of helium-three are essential.

Scientific research at low temperatures is the signature example of an area in which helium-three is irreplaceable. Without adequate supplies, such research will cease entirely. To put the importance of such research in context, I note parenthetically that twelve Nobel Laureates in physics in the past 25 years owe their accomplishments in some important measure to the availability of helium-three. Cases in which substitutes might be found for helium-three include neutron detection at facilities such as at the Spallation Neutron Source (SNS) at Oak Ridge National Laboratory, oil and gas well evaluation, building construction technology and the improvement of lasers.

The issue perhaps is best illustrated by a personal experience. In October 2008 I sought information about availability and pricing from several well-known distributors of helium-three gas. I spoke with representatives of Sigma Isotec, Cambridge Isotope Labs, Icon Isotope Services, Isoflex USA, Chemgas, and Spectra gas (now Linde Electronics and Speciality Gases) and learned that only the latter two had any supply, but their prices were extraordinarily high: $800 to $2,000/liter. It was 5 to 10 times higher than I had expected and well outside of my research budget plan.

The following summer I received more bad news. Oxford Instruments, the largest supplier of low temperature refrigerators, contacted me, to say that the company could not obtain any helium-three from their supplier, Spectra Gas. Discussions among attendees at a subsequent international low-temperature physics conference revealed that the shortage was global. Although the shortage took many of us by surprise, I later learned that some government officials had been aware of the problem for some time but had not shared this information.

In the fall of 2009, Nobel Laureates Doug Osheroff and Bob Richardson, on behalf of a low-temperature working group of which I was a member, wrote to Bill Brinkman, Director of the Department of Energy's Office of Science, to express concern about the shortage of helium-three for low temperature research. Conversations with DOE ensued, but to date requests by scientists and refrigerator companies often go unanswered or unmet. Young scientists, especially, find themselves without access to this essential resource.

Many of us are also concerned that without adequate access to helium-three, instrumentation companies may soon be forced out of business. Janis Research is an example. Janis has been guaranteed an allocation, but the helium has not been delivered and the sales interruptions place the company at risk. Should Janis and other companies stop providing refrigerators, low-temperature science will end.

Dr. Brinkman requested that our working group assess the critical needs in low temperature science. The principal finding of our recently completed survey is the following: In a ten year interval, from 1999 to 2009, the purchase of helium-three for low temperature science averaged 3,500 liters/year and was growing at approximately 12%/year world-wide. (Survey details are posted at http://www.qfs2009.northwestern.edu/survey/ and attached to my written testimony.)

On a personal note, I have an immediate need in my laboratory for 20 liters of helium-three. Spectra Gas, the sole provider of helium-three released by the Department of Energy, has not responded in the five months since I made my request, and my National Science Foundation supported research is now in jeopardy.

In conclusion, we must recognize the diversity of needs for helium-three and adopt the following strategies: explore alternative technologies; establish effective communication among all stake holders; implement recycling and conservation; redesign critical-need instrumentation to be more efficient; and develop new sources of helium-three.

I would be pleased to answer your questions.

Survey of Critical Use of ^{3}He for Cryogenic Purposes

Results of the Survey

Northwestern University
January 21 to February 5, 2010

You may also download the results as a PDF.

The rare isotope of helium, ^{3}He, has critical strategic importance. One of it's applications is to achieve low temperatures through refrigeration and measuring devices, mostly in the pursuit of fundamental knowledge, providing the essential building blocks for engineering and technology for our future. Cryogenic use of ^{3}He is critical in that there is no alternative to reaching a range of more than 4 orders of magnitude of temperature from 1 K to as low as 10-4 K. Here basic scientific investigations require ^{3}He for the study of quantum systems, including information technology, magnetism, and superconductivity. Its recent short supply and extraordinary high price has posed serious problems for the scientific community. The purpose of this survey was to document as accurately as possible world-wide use of ^{3}He in the past ten years as a framework for future cryogenic allocations and to evaluate the impact of research that uses ^{3}He.

The survey is restricted to senior or principal scientific investigators, who are representatives of their respective research groups. The survey solicitation was sent to the e-mail list serves of the International Conference on Low Temperature Physics, LT25; the International Symposium on Quantum Fluids and Solids, QFS2009; a list of principal investigators using cryogenic ^{3}He in their research grants from the National Science Foundation, the Program in Condensed Matter Physics; a list of principal investigators using cryogenic ^{3}He in their research grants from the Department of Energy, the Program in Basic Energy Sciences. These totaled approximately 2,300 including members of the communities including students, research associates, postdoctoral fellows, scientists, and finally, the principal or senior investigators who were asked, on behalf of their groups, to respond to the survey.

This survey and a copy of the results were posted at: http://www.qfs2009.northwestern.edu/survey/

Survey Results:

Number of senior investigator respondents:	206
USA respondents:	98
Total ^{3}He purchases, yearly average over ten years:	3,469 L/year
maintenance and samples gas from research groups:	1,141 L/year
new instruments (mostly refrigerators) from companies:	2,328 L/year
^{3}He for cryogenic purposes purchase last year (2009):	3,828 L
Price of ^{3}He last year, average (2009):	930 $/L

Scientific programs requiring cryogenic ^{3}He (fraction of total):

Quantum Fluids and Solids	8 %
Superconductivity	24 %
Quantum Information	7 %

Mesoscopic Physics	12 %
Magnetism	12 %
Electronic Materials	10 %
Quantum Resonators	3 %
Quantum Transport	12 %
Refrigeration Instrumentation	8 %
Detector Instrumentation	3 %
Other	2 %
Graduate student training using cryogenic ^{3}He, graduated in ten years:	3,349 students
Postdocs hired in ten years using cryogenic ^{3}He:	2,322 postdocs
Research funding in ten years requiring cryogenic ^{3}He:	2.65 billion $

Comments on growth in the cryogenic use of ^{3}He:
Sufficient information in the responses was given to determine the following growth in requirements for cryogenic use of ^{3}He. Yearly increases in purchases for cryogenic ^{3}He are 12% per year on average. The increase in cost in the past three years has been approximately a factor of 4 to 5 on average.

2005	23 %
2006	- 1 %
2007	30 %
2008	- 20 %
2009	26 %
yearly average	12 %

Comments on impact from research that uses cryogenic ^{3}He:
The significant impact of research that uses cryogenic ^{3}He includes 335 graduate student PhD's awarded per year and 232 postdoctoral fellows hired per year (numbers adjusted for response rates determined as described in b) below averaged over the past ten years). Additionally, all theoretical work related to experimental research that uses cryogenic ^{3}He would not have taken place without this range of temperature for quantum condensed systems, substantially increasing the student, staff, and funding impacts beyond that shown in this survey.

Reporting methodology:
a) The following nine companies provide cryogenic ^{3}He instrumentation and reported their sales of ^{3}He, presented above in aggregate form: Bluefors, Chase Research Cryogenics, Cryomagnetics (including Cryoconcepts), Janis Research, Lakeshore Cryotronics, Leiden Cryogenics, Oxford Instruments, Quantum Design.
b) Purchases of ^{3}He, not as a part of commercial instrumentation, made by individual research groups, reported above, were adjusted by a survey response fraction of 51%. This fraction is defined by the USA pool and was assuned to be valid elsewhere in the world. The fraction is defined as the number of USA principal investigators responding to the survey divided by the total number of funded USA principal investigators identified by program mangers from the NSF/CMP and the DOE/BES. Error in corrections for survey response rate is relatively small since 2/3 of the cryogenic ^{3}He is purchased by the instrumentation companies for which we have an accurate total response.
c) The responses were examined one-by-one to avoid duplication and improper submission and to be sure that each submission represented only one research group.

Click here to view an archived copy of the survey.

BIOGRAPHICAL SKETCH

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a) Professional Preparation

Bachelor of Science,	B.Sc.,1967	Queen's University, Kingston, Ontario
Master of Science,	M.Sc., 1968	University of Toronto, Ontario
Doctor of Philosophy,	Ph.D.,1975	Cornell University, Ithaca, NY
Postdoctoral Fellow	(1974-75)	Cornell University, Ithaca, NY

b) Appointments and Honors:

Science Advisory Board, Center of Excellence, Low Temp. and Quantum Devices, Helsinki Univ. of Tech. 2009-
International Advisory Committee, High Magnetic Field Laboratory, Chinese Academy of Sciences, Hefei 2009-
Fellow, The Institute of Physics, (2004-)
Editorial Board, Journal of Low Temperature Physics, Springer, (2004-)
Chair, External Advisory Committee, National High Magnetic Field Laboratory (2004-)
Regional Editor for North America, New Journal of Physics, Inst. of Phys. (2002-)
John Evans Professor of Physics (2001-)
Director, Interdisciplinary Science Program, Northwestern University (1999-)
Chairman, Department of Physics and Astronomy (1990-1995)
Fellow, American Physical Society (1995)
Editor, Progress in Low Temperature Physics, Elsevier (1995-)
Professor, Northwestern University (1986-present)
Associate Professor, Northwestern University (1981-86)
Alfred P. Sloan Fellow (1977-81)
Assistant Professor, Northwestern University (1975-81)
Resident Associate, Argonne National Laboratory (1979-85)

c) Publications (10 selected from 201):

Spatially Resolved Electronic Structure Inside and Outside the Vortex Core of a High Temperature Superconductor, V. F. Mitrovic, E. E. Sigmund, M. Eschrig, H. N. Bachman, W.P. Halperin, A.P. Reyes, P. Kuhns, W.G. Moulton, Nature **413**, 501 (2001).
Two-dimensional Superconductivity, B. Chen, W.P. Halperin, P. Guptasarma, D.G. Hinks, V.F. Mitrovic, A.P. Reyes, and P. Kuhns, Nature Physics **3**, 239 (2007).
Discovery of an Excited Cooper Pair State in Superfluid ^{3}He, J.P. Davis. J. Pollanen, H. Choi, J.A. Sauls, and W.P. Halperin, Nature Physics, **4**, 571 (2008).
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Magnetic Impurities in the Pnictide Superconductor $Ba_{1-x}K_xFe_2As_2$, S. Mukhopadhyay, S. Oh, A.M. Mounce, M. Lee, W.P. Halperin, N. Ni, S.L. Bud'ko, P.C. Canfield, A.P. Reyes, and P.L. Kuhns, New J. Phys. **11**, 055002 (2009).
Quantum Size Effects in Metallic Powders, W.P. Halperin, Rev. Mod. Phys. **58**, 533 (1986).
Discovery of the Acoustic Faraday Effect in Superfluid ^{3}He-B, Y.Lee, T. Haard, W. P. Halperin, and J.A. Sauls, Nature, **400**, 431 (1999).
Antiferromagnetism in the Vortex Cores of $YBa_2Cu_3O_{7-d}$, V. F. Mitrovic, E. E. Sigmund, W.P. Halperin, A.P. Reyes, P. Kuhns, W.G. Moulton, Phys. Rev B. Rapid **67**, 220503 (2003).
Surface Specific Heat and Andreev Bound States, H. Choi, J.P. Davis, J. Pollanen, and W.P. Halperin, Phys. Rev. Lett. **96**, 125301 (2006).
Intrinsic Impurity in the High Temperature Superconductor $Bi_2Sr_2CaCu_2O_{8+d}$, Bo Chen, Sutirtha Mukhopadhyay, W.P. Halperin, Prasenjit Guptasarma, and D.G. Hinks, Phys. Rev. B **77**, 052508 (2008).