003PHY-08

LSU PROPOSAL # 32689

COVER PAGE FOR TRADITIONAL AND UNDERGRADUATE ENHANCEMENT PROPOSALS
BOARD OF REGENTS SUPPORT FUND, FY 2007-08

1. This Proposal Involves: __x__One Institution ____More Than One Institution	2. Enhancement Subprogram: (check one) __x_ **TRADITIONAL** ENH Program (Includes all multidisciplinary proposals) ____**UNDERGRADUATE** ENH Program
3. This Proposal Is: (check one) _x_ Primarily an Equipment Request __ Not Primarily an Equipment Request	
4. Name(s) of Submitting Institution(s) of Higher Education (Include Branch/Campus/Other Components)	Louisiana State University/Baton Rouge
5. Address of Institution of Higher Education (Include Dept/Unit, Street Address/P.O. Box Number, City, State, Zip Code)	Louisiana State University and Agricultural and Mechanical College 330 Thomas Boyd Hall Baton Rouge, LA 70803
6. Title of Proposed Project	"Upgrade of the LSU Helium Liquefier Facility"

7. First-Year Support Fund Money Requested $236,382	8. Second-Year Support Fund Money Requested (if applicable) $	9. Proposed Duration (Circle # of Yrs.) 1x 2

10. Category In Which Proposal Is Being Submitted (check one only) __ **BUSINESS** __ **MATHEMATICS** __ **CHEMISTRY** _x_ **PHYSICS/ASTRONOMY** __ **EDUCATION** __ **Special Multidisciplinary** (See Section III.B.2.c of the RFP.) **NOTE: If you check this category, you must also check at least one other eligible discipline.)**	11. Using the Taxonomy in Appendix A of the RFP, Identify All Specific Subcategories of the General Category That Apply to This Proposal and Provide Taxonomy Numbers: Subcategory(ies): Taxonomy Number(s): 0807
12. This Proposal Is a: __x__ New Request ____ Request for Continuation of a Previously-Funded Support Fund Project (check one) Provide previous contract number:	

By signing and submitting this proposal, the signators are certifying that: (1) the proposed project has not already been funded/is not currently being funded/has not been promised funding; (2) this proposal has been reviewed and approved by an Institutional Screening Committee; and (3) the institution and the proposed project are in compliance with all applicable Federal and State laws and regulations, including, but not limited to, the required certifications set forth in: (a) Grants for Research and Education in Science and Engineering, NSF Grant Proposals Guide (GPG), NSF 03-2, effective 10/1/02, and (b) 45CFR 620, Subpart F (Requirements for a Drug-Free Workplace).

Name/Title/email (type or print) Institution (if different from Item #5 above)	Dept./Telephone No.	Degree/Year	Signature
PI/PD Philip Adams	578-6847	PhD/1986	
Co-PI/PD David Young	578-2490	PhD/1998	
Co-PI/PD John DiTusa	578-2606	PhD/1992	
Co-PI/PD			
Co-PI/PD			

Campus Head or Authorized Institutional Representative	**Dean**	**Authorized Fiscal Agent**
Name/Title/email: (type or print) James L. Bates, Director, Office of Sponsored Programs, osp@lsu.edu	Name/Title/email: (type or print) Kevin Carman, Dean, BASC 20carm@lsu.edu	Name/Title/email: (type or print) Jerry Baudin, Vice Chancellor FAS vcbaud@lsu.edu
Signature: James L. Bates	Signature: Kevin Carman	Signature: James L. Bates for
Date: 10/23/07 Telephone Number: (225)578-3386	Date: 10/23/07 Telephone Number: 578-4500	Date: 10/23/07 Telephone Number: (225)578-3386

Rev. 2007)

(Form 1-ENH,

PROJECT SUMMARY

Address (Include Department) Department of Physics and Astronomy, 202 Nicholson Hall, LSU, BR, LA

Principal Investigator(s)
Philip Adams, David Young, John DiTusa

Title of Project
"Upgrade of the LSU Helium Liquefier Facility"

Abstract (DO NOT EXCEED 250 WORDS)*

We are requesting funds to purchase a Linde Model 1410 helium liquefier system to replace our existing 28 year old installation. Our existing equipment is the only helium liquefier in the state of Louisiana. It has been used in the course of its operation to supply liquid helium to all of the universities in the southern part of the state as well as for an emergency supply for hospitals and independent MRI installations in the southeast. Old age and an increasingly problematical availability of spare parts have made replacement a necessity. Replacement will also ensure that we can continue to conserve helium gas, which is an increasingly scarce resource and will help ease the financial burden of rapidly increasing liquid helium prices.

3. Table of Contents

4. Narrative and Bibliography

We are requesting funds to purchase a helium liquefier and compressor to replace our existing 29-year old helium recovery and recycling installation in the basement of Nicholson Hall, which also houses the LSU Department of Physics and Astronomy. Our existing equipment is the only non-industrial helium liquefier in the state of Louisiana. It has been used in the course of its operation to supply liquid helium, an important cryogenic fluid used in both materials research labs and medical imaging labs, to all of the universities in the southern part of the state, as well as nearby hospitals on an emergency basis. Old age and an increasingly problematical availability of spare parts have made replacement of the current liquefier system a necessity. Replacement will also ensure that we can continue to conserve helium gas, which is an increasingly scarce resource, and help offset rapidly rising liquid helium costs.

a. The Current Situation

(*The data quoted here were taken from a technical report by Lessner, Ziegler and Ebner for Linde Kroytechnik AG and from a 1996 background paper by Dunn, Gerjuoy and Park for the American Physical Society.*)

The world helium production per annum is approximately 160 million cubic meters. While there is a small amount of helium in the atmosphere the concentration is too small to allow economic extraction. The main sources are certain helium rich natural gas reservoirs. Approximately 86% of the world's helium production is from natural gas fields in the United States. Other sources of helium are the Helios plant in Algeria and smaller plants in Poland and in Russia. Two thirds of the world's production is used in the United States. Approximately 38% of the helium produced each year is used as liquid helium. Universities and research institutes use about 1/3 of that. Thus over 10% of the world's helium is used as a cryogen in research studies in a variety of fields.

Only about half of the helium in the gas pumped from American wells is extracted to supply current demand. The rest is irretrievably lost to the atmosphere when the methane is burned. Thus, the exhaustion of our helium is determined less by helium usage than by natural gas demand, which is very high. These helium-rich fields are being rapidly depleted.

The federal government does maintain a helium reserve that could supply the current market demand for about ten years, but demand is growing at between 8% and 10% per year. Unfortunately, current legislation aimed at balancing the budget, calls for selling off even this meager reserve by the year 2015 - about the time the helium rich fields will be exhausted. The American Physical Society recognized the need for conservation of this resource ten years ago and issued a position paper and statement at that time. The text of the 1996 APS statement is as follows:

The American Physical Society is profoundly concerned about the potential loss of the nation's accumulated helium reserves. Helium is essential for achieving the extremely cold temperatures required by many current and emerging technologies, as well as for advanced scientific research. The overall demand for helium has been steadily increasing, and there is every reason to believe that this trend will continue.

Although the United States is fortunate in having a greater abundance of this critical element than any other nation, the supply has severe natural limits. Helium is economically extracted from natural gas. If not extracted, the helium is irretrievably lost to the atmosphere when the gas is burned. For this reason, the federal government prudently established a storage program for helium, but legislation now being considered would dispose of virtually this entire helium store within two decades.

In view of the importance of this unique and irreplaceable natural resource to modern science and technology, The American Physical Society urges that measures be adopted that will both conserve and enhance the nation's helium reserves. Failure to do so would not only be wasteful, but would be economically and technologically short-sighted.

a.1 Institutional Description

Since the mid 1960's LSU has been recapturing and re-liquefying helium gas. The original motive for this was convenience. Baton Rouge was a lone outpost in the south so that liquid helium was difficult and expensive to obtain. In response to the helium requirements of hospital magnetic resonance units, there now exists a relatively well organized distribution system for liquid helium from industrial suppliers such as Liquid Air. Unfortunately, however, there have been alarming increases in price. For instance, over this last summer LSU's contract price for liquid helium increased from $3.25/liter to $6.50/liter. Since our present liquefier has been out of operation, those enterprises on campus that utilize liquid helium are now paying the full cost of $650 for a 100 liter canister of liquid, with no prospect of recapturing and re-liquefying.

a.2 Rationale for Project

Cryogenic technologies are an important component of contemporary materials research. Laboratories around the world use liquid helium based refrigeration systems to study the low temperature electronic and structural properties of a wide variety of novel materials. Examples include exotic superconducting compounds, spintronic systems, high performance thermo-electrics, magneto-caloric systems, and a variety of nano-scale quantum systems. Such laboratories are housed in variety of academic departments including physics, electrical engineering, chemistry, and materials science departments. Typically, investigators these labs are trying to optimize a technologically important characteristic via structural, electronic, and/or compositional modification of a material of interest. Cryogenics plays a crucial role in this process because, in many cases, the effect that one hopes to improve upon, such as spin transport in a two-dimensional conductor, is much more readily observed at low temperatures, *i.e.* liquid helium temperatures.

The rationale for the project is twofold. First, it is important that LSU participate in the conservation of helium. It seems likely that funding agencies will eventually refuse to support research programs that do not recycle. Second, the price of liquid helium is increasing, so helium recovery makes economic sense. We are confident that once the system is running, we can recover at least 80% of the boil-off gas and re-liquefy it. This effectively reduces the price per liter by a factor of 5!

a.3 Impact on Existing Resources

There are currently a number of research groups on the LSU campus that use equipment requiring liquid helium. Equally important, however, relatively few universities have a helium recovery system in place. This proposal is only for the actual liquefier engine and associated compressors. As will be discussed in detail below, the Department of Physics and Astronomy already has made a sizable investment in gas recovery plumbing and gas storage systems that are a necessary part of the complete system. Many universities will find such an investment cost prohibitive. Therefore, LSU's helium recovery capability represents a significant recruiting

incentive for new faculty in materials research. In the following paragraphs we give a brief description of the specific research programs that the liquefier will impact.

Phil Adams's Lab: For some years now our experimental low temperature program has focused on model low dimensional systems that can provide us with insights into complex correlation effects that are known to be important in a wide variety of condensed matter systems of current interest. In particular, we have investigated the quantum properties of helium films, non-degenerate electrons on cryogenic hydrogen surfaces, thin film BCS superconductivity in high magnetic fields, and the metal-insulator transition in ultra-thin homogeneously disordered "metal" films. In each of these areas the goal has been to isolate the salient characteristics of what is an ostensibly well-controlled system with the ultimate goal of gaining a deeper understanding of quantum correlation effects in more widely studied materials. Virtually all of the work is done on an Oxford Instruments dilution refrigerator capable of cooling down to 0.05 K. This system requires 100L of helium for the initial cool-down and about 100 L a week for sustained operation.

John DiTusa's Lab: Our research has focused on the fundamental properties of magnetic semiconductors and the demonstration of a silicon-based materials system for spintronics applications. Spintronics is the name of a nascent technology which seeks to make use not only of charge of the electrons as is done in today's technology, but also of their spin properties in devices. We have discovered that a class of monosilicide compounds is not only intrinsically compatible with silicon, but may provide highly polarized spin currents at low temperatures. Although these particular compounds have limited applications, they will serve as motivation for the discovery of other silicide and germanide compounds with higher temperature magnetism that may serve as materials for spintronics. This work has resulted in published articles in Nature and Nature Materials as well as reviews in these journals published as `News and Views'. This research relies heavily on a Quantum Design SQUID magnetometer which remains cold unless warmed for maintenance and an Oxford 200 dilution refrigerator with an 18T superconducting magnet. The magnetometer requires about 100L of helium every two weeks. The dilution refrigerator requires 150L for the initial cool down and about 200L a week for sustained operation.

David P. Young's Lab: Our current research interests include searching for novel materials with unique magnetic and electronic properties. Many of these materials fall under the classification of strongly correlated electron systems. Most of these compounds are transition-metal and rare-earth intermetallics with pnictide and chalcogenide elements. The physical properties of many of the known ternary and quaternary compounds of this type have yet to be investigated. Materials containing magnetic transition metals and rare-earth elements can often display exotic behavior, such as: magnetic ordering, Kondo physics, superconductivity, metal-insulator transitions, enhanced electron mass (heavy Fermions), and intermediate-valence states. Often times these exotic characteristics can lead to enhanced physical properties, such as large thermopowers and giant magnetoresistance. The laboratory's main contribution in this area lies in the synthesis of high-quality single and polycrystalline materials, as well as characterization of physical properties at very low temperatures and in high magnetic fields. The latter is carried out on a Quantum Design Physical Properties Measurement System. This cryogenic system requires about 100L of helium every two week. Since our lab also screens a large number of materials across several different departments and colleges within the university, as well as across the country and around the world with domestic and international collaborators we run the Measurement System 24 hrs/day, 365 days a year.

LSU Nuclear Magnetic Resonance Facility: The NMR facility is directed by Dr. Dale Trevealan and is housed in the Department of Chemistry. It has 5 high-resolution, (solution-state) and one solid-state NMR spectrometers. These instruments consist of: one Bruker, DPX-250, one Bruker DPX-400, one Bruker AV-400 (narrow bore), one Bruker AV-400 (wide bore; solid state), one Varian Inova-500 and one Varian VS-700. Our current, on campus, user base

,stands between 136 and 140 researchers and is growing. Regular users of the facility extend over 6 departments including: chemistry, life science, chemical engineering,the sugar institute, the department of renewable resources, and the department of human ecology. Off-campus, academic researchers, using the facility, come from Southern University, South Eastern University, Our Lady of the Lake, and ULL. Additionally, following hurricane Katrina the NMR facility provided NMR support for Tulane University, the University of New Orleans, and Alcorn State University.The NMR facility also provides, on an ongoing bases, consulting services to Exxon/Mobil corporation and the McIntyre group, Ltd. (University Park, IL). All six of the magnets in the facility are super conducting magnets and therefore liquid helium is essential to the persistence of the magnetic field. Our annual helium consumption is approximately 4,100 liters and while it has always represented one of our largest operating expenses, recent (large) price increases have exacerbated this situation. To illustrate, in fiscal year 2006/2007 liquid helium, in 100 liter quantities cost of $3.25/liter. In fiscal year 2007/2008 that cost has risen to $6.50 /liter and will continue to rise. Faced with these rising costs, helium recovery therefore becomes critically important.

b. The Enhancement Plan

Three years ago Nicholson Hall, the home of Physics and Astronomy, underwent a major renovation and addition. As part of the renovation all of the major laboratories were provided with a connection to a helium recovery system. Each laboratory has a connection to a copper piping backbone. The backbone connects to a large ballast gas bag which, when it begins to fill, activates a high pressure helium compressor. The compressor empties the ballast bag. It is connected to a bank of 30 high-pressure tubes that provide 258 cubic feet of gas storage. This bank provides gas for over 1100 liters of liquid helium. Liquid nitrogen supply and all necessary electrical power are provided in the space for the actual liquefier engine. A 500 liter storage dewar is used for liquid collection from the engine. The liquid from the collection dewar is then transferred to a variety of 100 liter dewars for use in the various laboratories. The enhancement plan is to replace the old engine and associated compressors and purifiers with a new, computer-controlled system.

b.1 Project Goals and Objectives

We request funds to purchase a Linde Model 1410 helium liquefier with internal purifier and a Model RSS screw compressor. Pricing details are shown below in the budget. The 1410 is the successor to the old Model 1400 which has been inoperable for several years now. The RSS compressor is a rotary compressor as opposed to our existing reciprocating compressor.

b.2 Work Plan of Proposed Project

If the project is funded, it will take *Linde Cryogenic Plants and Services* approximately seven months to deliver the system. The system will be installed, checked, and commissioned by a *Cryogenics Plants and Services* engineer. This should take no more than about 10 days. A plastic (PVC) gas recovery line will also be installed between Nicholson Hall and Choppin Hall in order to collect helium gas from the NMR facility. This line will run through existing service tunnels and will be installed by LSU physical plant services.

b.3 Evidence of Potential to Achieve Recognized Eminence.

The LSU helium liquefier facility is considered to be a key element in the overall scientific infrastructure of the university. Not only will it help ease the financial burden on existing grants

from National Science Foundation, Department of Energy, and other funding agencies, it will serve LSU well in recruiting new faculty that require liquid helium for some aspect of their research. This is particularly important now that LSU has embarked on a Multidisciplinary Hiring Initiative in materials-related research areas.

b.4 Impact on Curriculum and Instruction

The LSU liquefier facility provides an essential resource for a wide variety of labs on campus. These labs employ and train both undergraduate and graduate students, and, in fact, provide a very important educational experience that cannot be obtained in the classroom. The recent increases in the cost of liquid helium will force investigators to shift financial resources from personnel, such as students, to cryogenic charges.

b.5 Impact on Quality of Students

With functional liquefier, current research programs that use helium will be in a better position to support students to work in the lab. Furthermore, the presence of a working helium recovery system at LSU will help attract top-flight faculty, who, in turn, will help to recruit and retain outstanding students.

b.6 Impact on Faculty Development

The helium recovery facility mostly impacts faculty research. However, research support usually has a positive influence on the quality and effectiveness of faculty teaching. For instance, without helium recovery, the increasing cost of helium will force faculty to spend more and more time looking for new funding sources to cover their cryogenics expenditures.

b.7 Performance Measures

The performance of the recovery system can be assessed by the total amount of helium liquid being produced per month and the overall efficiency of the recovery cycle.

C. Equipment

We have obtained a budgetary proposal from Linde Cyrogenic Plants and Services for a Model 1410 Helium Liquefier, RS compressor, RSS compressor, and associated maintenance kits.

c.1 Equipment Request

We request funds to purchase a Model 1410 helium liquefier with internal purifier and a Model RSS screw compressor. Pricing details are shown below. The 1410 is the successor to the old Model 1400 we now are attempting to use. The RSS compressor is a rotary compressor as opposed to our existing reciprocating compressor. Its throughput is twice that of the reciprocating compressors. The Model 1410 liquefier has also been redesigned with automatic controls. Every valve on our existing Model 1400 has to be set manually and has to be continually reset during operation as conditions change. In contrast many of the controls of the 1410 are automatic and can be monitored remotely, allowing us a much more efficient use of

personnel. The cryogenic adsorber is part of the helium purification stage. The acoustic isolation is needed for the compressor which is quite loud. The specific items are:

Model 1410 Helium Liquefier: $267,905.00
Model RSS Helium Compressor: $106,488.00
Installation, commissioning, and training: $16,000.00
Remote control and data acquisition: $11,000.00
Acoustic isolation blanket: $5,590.00
Installation Piping: $8,321.00
Cold box spare parts: $4,032.00
Purifier spare parts: $1,269.00
Compressor spare parts: $4,305.00
Cryogenic Adsorber: $11,472.00

c.2 Equipment on Hand for Project

As discussed in previous sections, Nicholson Hall has all of the necessary plumping and storage for the recovery system.

c.3 Equipment Housing and Maintenance

The system will be installed in our current helium recovery room, which is in the basement of Nicholson Hall. The system will be maintained by a full-time cryogenic technician.

d. Faculty and Staff Expertise

The Department of Physics and Astronomy has had a full-time cryo-technician line for many years now. This position was held by Ron Dupew for the last few years but he retired at the end of September 2007. We will fill this position again if the proposal is funded. In terms of the faculty, all three of the co-investigators on this proposal have extensive cryogenic experience and will be responsible for the facility's maintenance and operation.

e. Economic and/or Cultural Development and Impact

e.1 Relationships with Industrial/Institutional Sponsors.

LSU has a strong relationship with a variety of industries through the LSU NMR facility, see section **a.3**. The helium recovery system will directly benefit this facility and it associated partnerships.

e.2 Promotion of Economic Development

The helium recovery system will definitely ease budget strains on a number of research enterprises in the departments of Chemistry and Physics and Astronomy. The affected laboratories support both undergraduate and graduate students on federal grant monies. However with the increasing cost of helium the available student funds are rapidly decreasing. As Louisiana moves into a more technologically based economy, the support and training of students that one day will be a part of a new and highly educated workforce is extremely important.

We also believe that a helium recovery system will greatly aid in attracting new faculty with cutting edge materials research programs. Many materials experimentalists worldwide are

,now feeling the pinch of higher helium costs. Interestingly enough, quite a number of high profile universities have not helium recovery systems. If the helium shortage continues to deepen then it is almost a certainty that those institutions with helium recovery will benefit.

f. Additional Funding Sources

None.

5. Previous BoR Support Fund Awards

Philip W. Adams has been awarded two BoR support fund grants. The first was a grant for the study of superconductivity in the thin metal films. The proposal was entitled *Quench Condensed Thin Film Superconductors* ($175,000), and covered the period 7/1/1989 – 7/1/1992. This grant help support my laboratory in during my first years at LSU. During that time we performed a series of experiments on superconducting films, electrons on solid hydrogen, and superfluid helium films. The resulting publications played an important role in establishing myself at LSU and later winning a National Young Investigator award. Professor Roy Goodrich and I also received an equipment award in 1990 entitled "A High Magnetic Field-Ultra Low Temperature Facility" ($870,000) from BoR. This was a large grant that was used to purchase a dilution refrigerator, an 18 T superconducting magnetic, a SQUID magnetometer, and a variety of ancillary items. This equipment is still in use today and has been an important component of the success of the low temperature group at LSU.

John F. DiTusa has been the recipient of several BoR support fund awards. Each has had a substantial effect on his research and educational programs. In 1995 he received a one year Research Competitiveness grant for \$52,000 for the project entitled 'Search for Non-Fermi Liquid Behavior in Transition Metal Compounds". In 1996 he was awarded a three year Research Competitiveness grant for the project "Transport and Magnetic Properties of Doped-Correlated Insulators" for \$189,442. These grants were highly effective in helping Dr. DiTusa's program reach the level where Federal funding was attracted as demonstrated by the NSF CAREER award and the subsequent grant renewals. In 1996 an Enhancement award from the BOR was awarded by a group headed by professor Evan Ma of LSU's Mechanical Engineering department and professor DiTusa for the "Acquisition of a High Vacuum Thin Film Deposition System". The award was for \$89,800 which was effective in helping build our film deposition and materials research infrastructure at LSU. Further BOR support for his program came by way of an Enhancement Award in 1999 entitled "Equipment for Research in Condensed Matter, and Low Temperature Physics" which provided \$138,600 for several research groups in the department of Physics and Astronomy for equipment. This grant was effective in keeping our labs equipped with modern apparatus, including an upgrade to our SQUID magnetometer, an oxygen free glove box, a thin film sputter deposition unit, an electrical discharge machine for sample preparation, and vacuum equipment for general laboratory purposes. Principle investigators on this grant included professors DiTusa, Richard Kurtz, Roger Stockbauer, Warren Johnson, Bill Hamilton, and Roy Goodrich all of the department of Physics and Astronomy at LSU. In 1996 Dr. DiTusa was part of a group of educators from Southern University and LSU who received a grant for the enhancement of "Two Upper Division Laboratory Courses in Physics" through the Undergraduate Enhancement Program at the BOR. The award was for \$77,000 and was instrumental in equipping undergraduate Modern Physics laboratories at Southern University. Principle investigators included Professors Ali Fazely, Djiola Bagayoko, and Chia H. Yang of Southern University and John F. DiTusa and Roy Goodrich of LSU. In the spring of 2005 J.F. DiTusa along with I. Vekhter of the Physics and Astronomy, E. Podlaha, E. Meletis of the Department of Mechanical Engineering, at LSU, Zhang Mao of the Physics department at Tulane University, and Yufeng Lu of the department of Mechanical Engineering at

Tulane were awarded a grant of $57,000 over two years to develop a "Materials Science and Engineering Symposium at LSU and Tulane". This grant also provided funds for the two institutions to join ICAM, the Institute for Complex Adaptive Matter, an institute dedicated to identifying new research themes in Materials Science and NanoBiology. This grant has been instrumental in providing visibility to our materials science and engineering programs and for the professional development of graduate students and faculty in MS&E programs throughout LSU and Tulane University.

D.P. Young received a grant *New materials search for novel thermoelectrics for small-scale cooling and power generation* (LEQSF 2001-04-RD-A11, $123,000). The goals of the thermoelectric project were the following: Year 1: Synthesize and screen many new materials for potential thermoelectrics and identify several good materials for optimization. Year 2: Use feedback from physical property characterization to determine the optimal processing conditions for the materials outlined in year 1 and continue to search for other new materials. Year 3: Fabricate a prototype device from the best material and test its cooling capabilities. The ultimate goal of the thermoelectric project would be a transfer of this technology to industrial users, with an emphasis on the electronic cooling of microprocessors.

This report is specific to Year 3. Near the end of the first year, we had discovered one material, Ag_8GeTe_6 (Ag816), which displayed some very unique electronic properties. The material is a mixed conductor, and thus uses both electrons and positive silver ions to conduct electricity. The thermal conductivity is extremely low, comparable to cardboard, and is much lower than the present day best thermoelectrics. Much of our effort during the past year has been focused on optimizing the electronic properties of Ag816. All of the Ag816 samples were synthesized with the RF generator that was purchased with funds from this proposal. Since this is an ionic conductor, it is not surprising that the material forms with variable silver stoichiometry. In fact, we discovered that its crystal structure is stable for $0 \leq \delta \leq 0.75$ in the formula $Ag_{8\pm\delta}GeTe_6$. For higher Ag concentrations, the resistivity is reduced, but not by an amount which makes the material an excellent thermoelectric. However, the ionic conduction along with the low thermal conductivity produces a large non-uniform Joule heating effect. Essentially this means that when a current is run through this material, a large temperature gradient can form across the sample. In some early tests, we were able to maintain a 100 °C temperature difference indefinitely across a sample only 5 mm in length! The majority of the past year was spent creating a device out of the Ag816 material. It consists of a solid bar-shaped polycrystalline sample approximately 6 mm in length with a 4-mm^2 cross-sectional area. The bar has temperature sensors and thermocouples mounted along its length, in addition to electrical leads for supplying current and measuring voltages. The thermal and electronic characteristics have been studied near room temperature, and we intend to fully characterize the temperature dependence of the device's performance during the 6-month extension of this research project. Other materials were also synthesized and measured during this funding period, including $MgCNi_3$ which is a superconducting material at low temperature, and has since been fabricated into very long and thin superconducting wire. This wire may have many applications in magnetic field creation, an area of research important to the Army, NASA, DoD, etc. Our creation of this wire has lead to funding from the Army. To date, this work has resulted in roughly 30 publications with more pending.

Subsequent to this work, the lead PI has been awarded a CAREER grant by the National Science Foundation. The level of funding is at half a million dollars for 5 years. Success of this research proposal was strongly rooted in the significant publication record produced during the BoR funding period.

6. Budget and Budget Narrative

The total cost of the proposed equipment is $420,382. Linde will charge $16,000 for installation and commissioning. In addition, another $20,000 will be needed to run a gas recovery line between Chopin Hall and Nicholson Hall in order to connect the LSU NMR facility to the liquefier facility. The budget shown below includes several sources of matching funds. The LSU Office of Research and Economic Development will contribute $120,000 in cash for the purchase of the equipment. The LSU College of Basic Sciences will contribute $70,000 in cash and the Department of Physics and Astronomy will contribute $10,000 in cash. In addtion, the Department of Physics and Astronomy will contribute a technician line at $44,000 per year. The fringe benefit rate on this salary is 34%. The overhead on the technician salary, fringe, and operational services for the installation of the gas line is 47%. The LSU Department of Chemistry will contribute the $20,000 needed to install the recovery gas line between Chopin and Nicholson Halls.

BOARD OF REGENTS SUPPORT FUND
TRADITIONAL AND UNDERGRADUATE ENHANCEMENT, FY 2007-08

Budget and Budget Justification Pages
Project Year (1) 2 Composite

Directions: Each line item under the columns "Support Fund Money Requested," "Institutional Match," and "Private Sector/Other Match" must be itemized, fully explained, and justified on **a separate budget justification page(s)**. Attach additional justification pages as needed.

Title of Proposal: Upgrade of the LSU Helium Liquefier

Project Director(s): Philip Adams, David Young, John DiTusa

Institution(s) of Higher Education: Louisiana State University and Agricultural and Mechanical College

PROPOSED BUDGET:

	Support Fund Money Requested[a]	Institutional Match[1b]	Private/Other Match[2]
A. Equipment[3]	$220,382	$200,000	
B. Software			
C. Supplies			
D. Shipping/handling			
E. Installation	$16,000		
F. Personnel training			
G. Other			
1. Technician Salary		$44,000	
2. Fringe Benefits		$14,960	
3. Gas Line (Oper. Serv)		$20,000	
4.			
5. (etc.)			
H.Indirect costs	Not Allowed	$37,111 [c]	$0 [c]
I. Maintenance	Strongly discouraged		
J. Total costs (A-I)	$236,382	$316,071	$0

[1] Stipulate whether in-cash or in-kind. The Board strongly encourages the sharing of costs for proposed projects. Applicants and institutional officials should note, however, that the employing institution will be required to honor the commitments made in the original proposal before any awards are made. Discounts for equipment purchases are not allowable as institutional match.

[2] The budget page(s) must reflect and the budget justification pages must explain any external funds that are claimed in the proposal. External funds and their expenditure must be accounted for in the same manner as Support Fund money and institutional match.

[3] Equipment.If applicable, itemize and describe briefly the proposed equipment and its intended use in the project. Include the name, model number, and manufacturer(s).

[a] Support Fund monies will not supplant state funds, and full time employees will not, under any circumstances, receive funds in excess of 100% of their regular salaries

[b] This match (In-cash) will be funded through Departmental or College operating budgets

[c] Indirect costs (F&A) at a rate of 47% of Modified Total Direct Costs (MTDC) has been applied based on current negotiated rate.

BIOGRAPHICAL SKETCH			
Provide the following information for the key personnel and consultants and collaborators. Begin with the principal investigator/program director. Photocopy this page for each person.			
Name John Feuer DiTusa		Position Title Professor	
EDUCATION (Begin with baccalaureate or other initial professional education and include postdoctoral training.			
INSTITUTION AND LOCATION	DEGREE	YEAR CONFERRED	FIELD OF STUDY
Oberlin College, Oberlin OH	B. A.	1985	Physics with Honors
Cornell University, Ithaca NY	Ph.D.	1992	Condensed Matter Physics
Cornell University, Ithaca NY	Postdoc	1992	Condensed Matter Physics
AT&T Bell Laboratories, Murray Hill NJ	Postdoc	1992-1994	Condensed Matter Phyiscs

RESEARCH AND PROFESSIONAL EXPERIENCE: Starting with present position, list, in reverse chronological order, previous relevant employment, experience, and honors. Key personnel includes the principal investigator and any other individuals who participate in the development or execution of the project. Key personnel typically will include all individuals with doctoral or other professional degrees, but in some projects will include individuals at the masters or baccalaureate level provided they contribute in a substantive way to the development or execution of the project. Include present membership on any Federal Government public advisory committee. List, in reverse chronological order, the titles, all authors, and complete references to pertinent publications during the past five years and to representative earlier publications pertinent to this application. DO NOT EXCEED TWO PAGES.

PROFESSIONAL EXPERIENCE

8/04 to present - Department of Physics and Astronomy, Louisiana State University, Professor..
8/99 to 7/04 - Department of Physics and Astronomy, Louisiana State University, Associate Professor.
8/94 t0 7/99 - Department of Physics and Astronomy, Louisiana State University, Assistant Professor
4/92 to 8/94 -AT&T Bell Laboratories, Postdoctoral Member of the Technical Staff..
1/92-4/92 - School of Applied and Engineering Physics, Cornell University, Postdoctoral Research Associate.
6/86 to 1/92 - Laboratory of Atomic and Solid State Physics, Cornell University, graduate research assistant.

Awards
2000 College of Basic Sciences Faculty Research Award, Louisiana State University.
1998 Non-tenured Faculty Award in the area of Natural & Physical Sciences, given by the Louisiana State University Chapter of the Honor Society of Phi Kappa Phi.
1997 National Science Foundation CAREER Award

Scholarly Activities

American Physical Society (1987 - present); SCES'07 Houston Local Organizing Committee member

Related Publications

Five Publications Closely Related to the Project

1.) Xu, G.Y., Broholm, C., Soh, Y.-A., Aeppli, G., DiTusa, J.F., Chen, Y., Kenzelmann, M., Frost, C.D., Ito, T., Oka, K., & Takagi, H. Mesoscopic phase coherence in a quantum spin fluid. *Science* **317**, 1049-1052 (2007).

2.) Singh, S., Capan, C., Nicklas, M., Rams, M., Gladun, A., Lee, H., DiTusa, J.F., Fisk, Z., Steglich, F., Wirth, S. Probing the quantum critical behavior of $CeCoIn_5$ via Hall effect measurements. *Phys. Rev. Lett.* **98** 057001 (2007).

3.) Mena, F.P., DiTusa, J.F., van der Marel, D., Aeppli, G., Young, D.P., Presura, C., Damascelli, A., & Mydosh, J.A. Ferromagnetism lowers the optical conductivity of the magnetic semiconductor $Fe_{1-x}Co_xSi$. *Phys. Rev. B* **73**, 085205 (2006).

4.) Manyala, N., Sidis, Y., DiTusa, J.F., Aeppli, G., Young, D.P., & Fisk, Z. Large anomalous Hall effect in a silicon-based magnetic semiconductor. *Nature Materials* **3**, 255-262 (2004).

5.) Manyala, N., Sidis, Y., DiTusa, J.F., Aeppli, G., Young, D., & Fisk Z., Magnetoresistance from quantum interference effects in ferromagnets. *Nature* **404**, 581-584 (2000).

Five Other Significant Publications of the Principal Investigator

1.) Goodrich, R.G., Browne, D., Kurtz, R., Young, D.P., DiTusa, J.F., Adams, P.W., & Hall, D. De Haas - van Alphen measurements of the electronic structure of $LaSb_2$. *Phys. Rev. B* **69**, 125114 (2004).

2.) Kenzelmann, M., Xu, G., Zaliznyak, I.A., Broholm, C., DiTusa, J.F., Aeppli, G., Ito, T., Oka, K., & Takagi, H. Structure of end states for a Haldane spin chain. *Phys. Rev. Lett.* **90**, 087202 1-4 (2003).

3.) Young, D.P., Goodrich, R.G., DiTusa, J.F., Guo, S., & Adams, P.W. High magnetic field sensor using $LaSb_2$. *Appl. Phys. Lett.* **82**, 3713-1715 (2003).

4.) Xu, G., Aeppli, G., Bisher, M.E., Broholm, C., DiTusa, J.F., Frost, C.D., Ito, T., Oka, K., Paul, R.L., Takagi, H., & Treacy, M.M.J. Holes in a Quantum Spin Liquid. *Science* **289**, 419-422 (2000).

5.) DiTusa, J.F., Friemelt, K., Bucher, E., Aeppli, G., & Ramirez A.P. Metal--insulator transitions in the
Kondo insulator FeSi and classic semiconductors are similar. *Phys. Rev. Lett.* **78**, 2831-2834 (1997) and **78**, 4309(E) (1997).

Thesis Advisor and Post Graduate-Scholar Sponsor

John Anderson, University of Texas Medical School, Vladimir Butko Los Alamos National Laboratory, Cigdem Capan, University of California, Irvine, Song Guo Janis Research, Ncholu I. Manyala, Lesotho National University, Rajan Rai LSU, Drew Rebar, LSU, Yvon Sidis Laboratoire Leon Brillouin, Mohan Chaka Vera University of Texas San Antonio.
Total Number of Postdoctoral Scholars Sponsored 4, Total number of graduate students advised 5.

CURRENT AND PENDING SUPPORT

(From ALL sources, including Board of Regents Support Fund)

The following information MUST be provided for each investigator and other key personnel. Use additional sheets as necessary.

NAME OF INVESTIGATOR: John DiTusa

Status of Support: _x__Current ___Pending ___Submission Planned in Near Future

Contract Number/Proposal Title: : ICAM Postdoctoral Fellowship for the Support of Cigdem Capan for Collaborative Research with Zachary Fisk

Source of Support: The Institute for Complex and Adaptive Matter

Award Amount (or Annual Rate): $____40,000 _____ Period Covered: 06/01/06-06/01/08_____

Location of Activity: LSU

Person-Months or % of Effort Committed to the Project: _____Cal Yr _____Acad _____Summ

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Status of Support: _x__Current ___Pending ___Submission Planned in Near Future

Contract Number/Proposal Title: Materials Science and Engineering Symposium at LSU and Tulane University

Source of Support: State Of Louisiana Board Of Regents

Award Amount (or Annual Rate): $___57,000_____ Period Covered: 8/1/05-7/31/08_____

Location of Activity:

Person-Months or % of Effort Committed to the Project: _____Cal Yr _____Acad _____Summ

---

Status of Support: ___Current __x_Pending ___Submission Planned in Near Future

Contract Number/Proposal Title: A Neutron Scattering Investigation of the Dynamics of Magnetic Semiconductors

Source of Support: Division of Science Department of Energy

Award Amount (or Annual Rate): $_548,111_____ Period Covered:_6/01/08 - 5/30/11 _

Location of Activity: LSU

Person-Months or % of Effort Committed to the Project: _____Cal Yr _____Acad _1___Summ

---

Status of Support: ___Current _x__Pending ___Submission Planned in Near Future

Contract Number/Proposal Title: Magnetic Semiconductors: From Fundamental Investigations to Spintronics Demonstrations.

Source of Support: National Science Foundation

Award Amount (or Annual Rate): $__489,112_____ Period Covered:_09/01/08 - 08/31/11_

Location of Activity: LSU

Person-Months or % of Effort Committed to the Project: _____Cal Yr _____Acad __2__Summ

BIOGRAPHICAL SKETCH
Provide the following information for the key personnel and consultants and collaborators. Begin with the Principal investigator/program director. Photocopy this page for each person.

NAME **David P. Young**	POSITION TITLE **Associate Professor**

EDUCATION (Begin with baccalaureate or other initial professional education and include postdoctoral training.)

INSTITUTION AND LOCATION	DEGREE	YEAR CONFERRED	FIELD OF STUDY
Truman State University	**BS**	**1993**	**Physics**
Florida State University	**MS**	**1995**	**Condensed Matter Physics**
Florida State University	**Ph.D.**	**1998**	**Condensed Matter Physics**
Princeton University	**postdoc**	**-**	**Novel Materials**

RESEARCH AND PROFESSIONAL EXPERIENCE: Starting with present position, list, in reverse chronological order, previous relevant employment, experience, and honors. Key personnel includes the principal investigator and any other individuals who participate in the development or execution of the project. Key personnel typically will include all individuals with doctoral or other professional degrees, but in some projects will include individuals at the masters or baccalaureate level provided they contribute in a substantive way to the development or execution of the project. Include present membership on any Federal Government public advisory committee. List, in reverse chronological order, the titles, all authors, and complete references to pertinent publications during the past five years and to representative earlier publications pertinent to this application.
DO NOT EXCEED TWO PAGES.

August 2005 – Present	**Associate Professor of Physics**	**Department of Physics and Astronomy, Louisiana State University**
August 2000 – August 2005 **Louisiana State University**	**Assistant Professor of Physics**	**Department of Physics and Astronomy,**
September 1998 – August 2000	**Postdoctoral Researcher**	**Department of Chemistry Princeton University**
May 1994 – September 1998	**Research Assistant**	**National High Magnetic Field Lab**

Florida State University

May 1993 – August 1993	**Research Assistant**	**Nuclear Research Building Florida State University**

Publications

1. "de Haas an Alphen Masurements of the electronic structure of $LaSb_2$", R.G. Goodrich, D. Browne, R. Kurtz, D.P. Young, J.F.Ditusa, P.W. Adams, and D. Hall, *Phys. Rev. B* **69**, 125114 (2004).
2. "Electronic Transport in EuB_6", G.A. Wigger, R. Monnier, H.R. Ott, D.P. Young, and Z. Fisk, *Phys. Rev. B* **69**, 125118 (2004).
3. "Weak ferromagnetism in CaB_6", M. C. Bennett, J. van Lierop, E. M. Berkeley, J. F. Mansfield, C. Henderson,M. C. Aronson, D P. Young, A. Bianchi, Z. Fisk, F. Balakirev,and A. Lacerda, *Phys. Rev. B* **69**, 132407 (2004).
4. "New aspects of the temperature – magnetic field phase diagram of CeB_6", R.G. Goodrich, D.P. Young, D. Hall, Z. Fisk, N. Harrison, J. Betts, A. Migliori, F.M. Woodward, and J.W. Lynn, *Physical Review B* **69**, 054415 (2004).
5. "Large anomalous Hall effect in a silicon-based magnetic semiconductor", Ncholu Manyala, Yvan Sidis, John F. DiTusa, Gabriel Aeppli, David P. Young, Zachary Fisk, *Nature Materials* **3**, 255-262 (2004).

6. "Electronic properties of novel 4d metallic oxide $SrRhO_3$", K. Yamaura, Q. Huang, D.P. Young, M. Arai, E. Takayama-Muromachi, *Physica B* **329-333**, 820 (2003).
7. "Angle-resolved photoemission study and first principles calculation of the electronic structure of $LaSb_2$", Alice. I. Acatrinei, D. Browne, Y. Losovyj, D.P. Young, M. Moldovan, JuliaY. Chan, P. T. Sprunger, and Richard L. Kurtz, *J. Phys.: Condens. Matter* **15**, L511-L517 (2003).
8. "Magnetoresistance of electrodeposited FeCoNiCu/Cu multilayers",Q. Huang, D.P. Young, and E.J. Podlaha, *Journal of Appliea Physics* **94**, 1864 (2003).
9. "Synthesis, structure, and magnetism of a new heavy fermion – $CePdGa_6$", R.T. Macaluso, S. Nakatsuji, H. Lee, Z. Fisk, M. Moldovan, D.P. Young, and J.Y. Chan, *Journal of Solid State Chemistry* **174**, 296 (2003).
10. "Superconducting properties of $MgCNi_3$ films", D.P. Young, M. Moldovan, D. Craig, J.Y. Chan, and P.W. Adams, *Phys. Rev. B* **68**, 020501(R) (2003).
11. "High magnetic field sensor using $LaSb_2$", D.P. Young, R.G. Goodrich, J.F. DiTusa, S. Guo, and P.W. Adams, *Applied Physics Letters* **82**, 3713 (2003).
12. "Magnetic properties – parasitic ferromagnetism in the hexaborides? Reply", D.P. Young, Z. Fisk, J.D. Thompson, H.R. Ott, S.B. Oseroff, and R.G. Goodrich, *Nature* **420**, 144 (2002).
13. "Crystal structure and electronic and magnetic properties of the bilayered rhodium oxide $Sr_3Rh_2O_7$", K. Yamaura, Q. Huang, D.P Young, Y. Noguchi, and E. Takayama-Muromachi, *Physical Review B* **66**, 134431 (2002).
14. "High-Pressure and High-Temperature Synthesis of a Novel Perovskite Compound: Magnetic and Electric Properties of the Rhodium Oxide $SrRhO_3$", K. Yamaura, D. P. Young, and E. Takayama-Muromachi, *Mat. Res. Soc. Symp. Proc.* **718** (2002) Material Research Society.
15. "^{11}B-NMR in CaB_6", J. L. Gavilano, Sh. Mushkolaj, D. Rau, H. R. Ott, A. Bianchi, D. P. Young and Z. Fisk, *Physica B* **312-313**, 813-814 (2002)
16. Electrodeposition of FeCoNiCu/Cu Compositionally Modulated Multilayers", Q. Huang, D. P. Young, J. Y. Chan, J. Jiang, and E J. Podlaha, *Journal of The Electrochemical Society* **149** (6) C349-C354 (2002).
17. "Superconducting properties of BeB2.75", D. P. Young, R. G. Goodrich, and P. W. Adams, *Physical Review B* **65**, 180518(R) (2002).
18. "Elastic properties of ferromagnetic EuB_6", S. Zherlitsyn, B. Wolf, B. Luthi, M. Lang, P. Hinze, E. Uhrig, W. Assmus, H.R. Ott, D.P.Young, and Z. Fisk, *Euro. Phys. J. B* **22**, 327-333 (2001).
19. "Magnetic polarons and the metal-semiconductor transition in (Eu, La)B_6 and EuO: Raman Scattering Studies, C. S. Snow, S. L. Cooper, D. P. Young, Z. Fisk, Arnaud Comment, and Jean-Philippe Ansermet, *Physical Review B* **64**, (17) 4412 (2001).
20. "Fermi surface measurements on the low-carrier density ferromagnet $Ca_{1-x}La_xB_6$ and SrB_6", Donavan Hall, D. P. Young, Z. Fisk, T. P. Murphy, E. C. Palm, A. Teklu, and R. G. Goodrich, *Physical Review B* **64**, (23) 3105 (2001).
21. "Synthesis, structure, and superconducting in $BeB_{1.09}$", J. Y. Chan, F. R. Fronzcek, D. P. Young, and P. W. Adams, *Journal of Solid State Chemistry* **163**, 385-389 (2001).
22. "Fermi-surface measurements on the low-carrier density ferromagnet $Ca_{1-x}La_xB_6$ and SrB_6", D.P. Young, Z. Fisk, T.P. Murphy, E.C. Palm, A. Teklu, and R. G. Goodrich, *Physical Review B* **64**, 233105 (2001).
23. "Synthesis, crystal structure, magnetic, and electric properties of the cross-linked chain cobalt oxychloride Ba5Co5ClO13", K. Yamaura, D. P. Young, T. Siegrist, C. Besnard, C. Svensson, Y. Liu, and R. J. Cava, *Journal of Solid State Chemistry* **158** (2), 175-179 (2001).
24. Thermally induced variable-range-hopping crossover and ferromagnetism in the layered cobalt oxide $Sr_2Y_{0.5}Ca_{0.5}Co_2O_7$", K. Yamaura, D. P. Young, and R. J. Cava, *Physical Review B* **63** (2001).
25. "Enhancement of metallic behavior in bismuth cobaltates through lead doping", S. M. Loureiro, D. P. Young, R. J. Cava, R. Jin, Y. Liu, P. Bordet, Y. Qin, H. Zandbergen, M. Godinho, M. Núñez-Regueiro, and B. Batlogg, *Physical Review B* **63** (2001).
26. "Anomalous NMR spin-lattice relaxation in SrB_6 and $Ca_{1-x}La_xB_6$", J. L. Gavilano, Sh. Mushkolaj, D. Rau, H. R. Ott, A. Bianchi, D. P. Young, and Z. Fisk, *Physical Review B* **63**, 140410-1 – 3 (2001).
27. "Magnetic polarons and the metal-semiconductor transitions in (Eu,La)B[sub 6] and EuO: Raman scattering studies C. S. Snow, S. L. Cooper, D. P. Young, Z. Fisk, Arnaud Comment, and Jean-Philippe Ansermet, *Physical Review B* **64**, 174412 (2001).
28. "Band structure and thermoelectric properties of pure and doped Ag_3AuTe_2-a very low thermal conductivity material", D.P. Young, C.L. Brown, P. Khalifah, and R.J. Cava, *Journal of Applied Physics* **88**, (10) (2000).
29. "Electronic transport in $Eu_{1-x}Ca_xB_6$, S. Paschen, D. Pushin, M. Schlatter, P. Vonlanthen, H. R. Ott, D. P. Young, and Z. Fisk, *Physical Review B* **61**, 4174-4180 (2000).
30. "Unusual magnetism of hexaborides", H. R. Ott, J. L. Gavilano, B. Ambrosini, P. Vonlanthen, E. Felder, L. Degiorgi, D. P. Young, Z. Fisk, and R. Zysler, *Physica B* **281-282**, 423-7 (2000).
31. "Low-temperature NMR studies of SrB_6", J. L. Gavilano, B. Ambrosini, H. R. Ott, D. P. Young, and Z. Fisk, *Physica B* **281-282**, 428-9 (2000).
32. "A new mechanism for magnetoresistance in ferromagnets", N. Manyala, Y. Sidis, J.F. DiTusa, G. Aeppli, D.P. Young, and Z. Fisk, *Nature* **404**, 581-584 (2000).
33. "Development of the high-field heavy-Fermion ground state in $Ce_xLa_{1-x}B_6$", R.G. Goodrich, N. Harrison, A. Teklu, D.P. Young, and Z. Fisk, *Physical Review Letters* **82**, 3669-72 (1999).
34. "High-temperature weak ferromagnetism in a low-carrier free electron gas", D.P. Young, D.W. Hall, M.E. Torelli, Z. Fisk, J.L. Sarrao, J.D. Thompson, H.R. Ott, S.B. Oseroff, R.G. Goodrich, R. Zysler, *Nature* **397**, 412-14 (1999).

CURRENT AND PENDING SUPPORT

(From ALL sources, including Board of Regents Support Fund)

NAME OF INVESTIGATOR: David Young

Status of Support: _X__Current ___Pending ___Submission Planned in Near Future

Contract Number/Proposal Title: **DMR-0449022 - CAREER: The synthesis and characterization of transition metal and lanthanide intermetallic strongly correlated electron systems**

Source of Support: **National Science Foundation**

Award Amount (or Annual Rate): $ 500,000 Period Covered: 06/2005 - 06/2010

Location of Activity: **Louisiana State University**

Person-Months or % of Effort Committed to the Project: _____Cal Yr __1.0___Acad __1.0___Summ

---

Status of Support: _X__Current ___Pending ___Submission Planned in Near Future

Contract Number/Proposal Title: **#32442 - FRG3: Energy Conversion and Storage Materials**

Source of Support: Louisiana Board of Regents: PKSFI

Award Amount (or Annual Rate): $ 171,875 Period Covered: 09/2007 - 09/2012

Location of Activity: Louisiana State University

Person-Months or % of Effort Committed to the Project: _____Cal Yr ___1.0__Acad __0.5___Summ

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Status of Support: ___Current ___Pending ___Submission Planned in Near Future

Contract Number/Proposal Title:

Source of Support:

Award Amount (or Annual Rate): $_____ Period Covered:_____

Location of Activity:

Person-Months or % of Effort Committed to the Project: _____Cal Yr _____Acad _____Summ

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Status of Support: ___Current ___Pending ___Submission Planned in Near Future

Contract Number/Proposal Title:

Source of Support:

Award Amount (or Annual Rate): $_____ Period Covered:_____

Location of Activity:

Person-Months or % of Effort Committed to the Project: _____Cal Yr _____Acad _____Summ

BIOGRAPHICAL SKETCH			
Provide the following information for the key personnel and consultants and collaborators. Begin with the principal investigator/program director. Photocopy this page for each person.			
Name: Philip W. Adams		Position Title: Professor	
EDUCATION (Begin with baccalaureate or other initial professional education and include postdoctoral training.			
INSTITUTION AND LOCATION	DEGREE	YEAR CONFERRED	FIELD OF STUDY
LSU Rutgers University AT&T Bell Labs	B.S. Ph.D. Postdoc	1980 1986 1988	Physics Physics Physics

RESEARCH AND PROFESSIONAL EXPERIENCE: Starting with present position, list, in reverse chronological order, previous relevant employment, experience, and honors. Key personnel includes the principal investigator and any other individuals who participate in the development or execution of the project. Key personnel typically will include all individuals with doctoral or other professional degrees, but in some projects will include individuals at the masters or baccalaureate level provided they contribute in a substantive way to the development or execution of the project. Include present membership on any Federal Government public advisory committee. List, in reverse chronological order, the titles, all authors, and complete references to pertinent publications during the past five years and to representative earlier publications pertinent to this application. DO NOT EXCEED TWO PAGES.

Philip W. Adams
born: July 28, 1958
e-mail: adams@phys.lsu.edu

Louisiana State University
Department of Physics and Astronomy
Baton Rouge, LA 70803
(225) 578-6847

(a) Professional Preparation:

- 10/86 Ph.D., Physics, Rutgers University, New Brunswick, NJ
- 12/80 B.S., Physics, Louisiana State University, Baton Rouge, LA

(b) Appointments:

- Full Professor of Physics, LSU, Baton Rouge, LA, 1999 – present.
- Associate Professor of Physics, LSU, Baton Rouge, LA, 1993 - 1999.
- Assistant Professor of Physics, LSU, Baton Rouge, LA, 1988 -1993.
- Postdoc in Physical Research Laboratory, AT&T Bell Labs, Murray Hill, NJ, 1986 -1988.

(c) Awards:

- Fellow of the American Physical Society, 2006
- Alumni Association Faculty Excellence Award, 2001
- Tiger Athletic Foundation Undergraduate Teaching Award, 2000
- College of Basic Sciences Research Award, LSU, 1993
- Phi Kappa Phi Non-Tenured Faculty Award, LSU, 1993
- NSF National Young Investigator Award, 1992
- University Fellow, Rutgers University, 1981-1985

(d) Publications:

(Five publications closely related to grant activity)

1. "Coulomb Gap: How a Metal Film Becomes an Insulator", V. Yu. Butko, J.F. DiTusa, and **P.W. Adams**, *Phys. Rev. Lett.* **84**, 1543 (2000).
2. "State Memory and Reentrance in a Paramagnetically Limited Superconductor", V. Yu. Butko, E.I. Meletis and **P.W. Adams**, *Phys. Rev. Lett.* **83**, 3725 (1999). (Featured in *Physical Review Focus* **4**, story 23 (1999).)
3. "Quantum Metallicity in a Two-Dimensional Insulator", V.Yu. Butko and **P.W. Adams**, *Nature* **409**, 161 (2001).
4. "Tenfold Magnetoconductance in a Non-Magnetic Metal Film", V. Yu. Butko, J.F. DiTusa, and **P.W. Adams**, *Phys. Rev. Lett.* **85**, 162 (2000).
5. "Spin Proximity Effect in Ultrathin Superconducting Be-Au Bilayers", X.S. Wu, **P.W. Adams**, Y. Yang, and R.L. McCarley, *Phys. Rev. Lett.* **96**, 127002 (2006) (Featured in *Physical Review Focus* **17**, story 12 (2006)).

(Five other significant publications)

6. "Low Temperature Susceptibility of the Noncentrosymmetric Superconductor $CePt_3Si$", D.P. Young, M. Moldovan, X.S. Wu, Julia Y. Chan, and **P.W. Adams**, *Phys. Rev. Lett.* **94**, 107001 (2005).
7. "Field-Induced Spin Mixing in Ultra-Thin Superconducting Al and Be Films in High Parallel Magnetic Fields", **P.W. Adams**, *Phys. Rev. Lett.* **92**, 067003 (2004)., X.S. Wu, **P.W. Adams**, and G. Catelani, accepted in PRB,
8. "Scaling Behavior of the Critical Current Density in $MgCNi_3$ Microfibers", D.P. Young, M. Moldovan, and P.W. Adams, *Phys. Rev.* B **70**, 064508 (2004) (Featured in *Physical Review Focus* **14**, story 9 (2004)).
9. "Avalanches and Slow Relaxation: Dynamics of Thin-Film Granular Superconductors in Parallel Magnetic Field", Wenhao Wu and **P.W. Adams**, *Phys. Rev. Lett.* **74**, 610 (1995).
10. "Orbital Response of Evanescent Cooper Pairs in Paramagnetically Limited Al Films", X.S. Wu, G. Catelani, and **P.W. Adams**, *Phys. Rev. Lett.* **95**, 167001 (2005).

(e) Synergistic Activities:

- *Teach For America* Summer Intern sponsor
- Developed new electronic instrumentation lab for undergrad physics majors

(f) Collaborators: Julia Chan, Dept. of Chemistry, LSU
R.L. McCarley, Dept. of Chemistry, LSU
D. Hall, Physical Review Letters
L.L. Henry, Dept. of Physics, Southern U.
Milind Kunchur, Dept. of Physics, U. of South Carolina
Ruslan Prozorov, Dept. of Physics, U. of South Carolina
Gianluigi Catelani, Dept. of Physics, Cornell U.

Advisors:

Graduate: William Glaberson, The Hebrew U.
Postdoctoral: Prof. Mikko Paalanen, Helsinki U. Tech.

Postdocs:

Wenhao Wu (1992-1995)
Vladimir Butko (1998-2001)
Xiao-Song Wu (2004-2005)

CURRENT AND PENDING SUPPORT

(From ALL sources, including Board of Regents Support Fund)

The following information MUST be provided for each investigator and other key personnel. Use additional sheets as necessary.

NAME OF INVESTIGATOR: Philip Adams

Status of Support: __x_Current __ _Pending ___Submission Planned in Near Future

Contract Number/Proposal Title: Quantum Transport in Thin Film Correlated Insulators

Source of Support: Department of Energy

Award Amount (or Annual Rate): $509,084. Period Covered:_8/1/2007 - 8/1/2010

Location of Activity: LSU-Baton Rouge

Person-Months or % of Effort Committed to the Project: _____Cal Yr 2 Acad 2 Summ

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Status of Support: ___Current ___Pending ___Submission Planned in Near Future

Contract Number/Proposal Title:

Source of Support: DOE

Award Amount (or Annual Rate): Period Covered:

Location of Activity: LSU-Baton Rouge

Person-Months or % of Effort Committed to the Project: _____Cal Yr Acad Summ

---

Status of Support: ___Current ___Pending ___Submission Planned in Near Future

Contract Number/Proposal Title:

Source of Support:

Award Amount (or Annual Rate): $_____ Period Covered:_____

Location of Activity:

Person-Months or % of Effort Committed to the Project: _____Cal Yr _____Acad _____Summ

---

Status of Support: ___Current ___Pending ___Submission Planned in Near Future

Contract Number/Proposal Title:

Source of Support:

Award Amount (or Annual Rate): $_____ Period Covered:_____

Location of Activity:

Person-Months or % of Effort Committed to the Project: _____Cal Yr _____Acad _____Summ

LOUISIANA STATE UNIVERSITY
AND AGRICULTURAL AND MECHANICAL COLLEGE
Department of Physics & Astronomy

October 22, 2007

Mr. John Wallin
Associate Commissioner for Sponsored Programs Administration
Louisiana Board of Regents
PO Box 3677
Baton Rouge, LA 70821-3677

Dear Mr. Wallin,

The LSU Department of Physics and Astronomy enthusiastically supports the purchase of a helium liquefier to be housed in Nicholson Hall. The department will provide $10,000 in cash as matching funds for the purchase of the liquefier engine and its associated components as described in the proposal "Upgrade of the LSU Liquefier Facility". In addition, the department will commit a full time technician line to the project in the amount of $44,000 per year, plus fringe (34%).

Sincerely,

Michael L. Cherry, Professor and Chair
Department of Physics and Astronomy

LSU
LOUISIANA STATE UNIVERSITY
College of Basic Sciences

5 October, 2005

To: Phil Adams
Professor, Physics & Astronomy

From: Kevin Carman
Dean, College of Basic Sciences

Re: Matching funds for helium condenser

The College of Basic Sciences is pleased to provide $70,000 in matching funds toward the purchase of a helium condenser. LSU is making major investments toward the development of a world-class program in materials science. Low-temperature, condensed-matter physics will be a core component of that effort, and reliable availability of liquid helium is an absolute necessity in this field. The helium condenser will also provide a vitally important source of helium for our nuclear magnetic resonance (NMR) facility. I am particularly pleased that the departments of chemistry and physics & astronomy, as well as the Office of Research, are also making substantial contributions toward this effort. This broad buy-in illustrates the substantial impact that the new He condenser will have on our programs.

Office of the Dean • 338 Choppin Hall • Baton Rouge, Louisiana • 70803 • Business Office (225) 578-8859 •
Student Services (225) 578-4200 • Fax (225) 578-8826 • http://science.lsu.edu • bascdean@lsu.edu

LOUISIANA STATE UNIVERSITY

College of Basic Sciences

Department of Chemistry

Louisiana State University
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23 October 2007

Professor Philip W. Adams
Department of Physics and Astronomy
LSU

Dear Dr. Adams,

This is to confirm that the LSU Chemistry Department will contribute $20,000 toward the proposal that you are preparing for submission to the LSU Board of Regents. Numerous researchers in the Chemistry Department will benefit substantially from this helium liquefier and associated equipment if the proposal is funded, and we are delighted to make this contribution.

We very much hope that your proposal is successful.

Sincerely yours,

Andrew W. Maverick
Professor and Chair, Department of Chemistry
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maverick@lsu.edu

LOUISIANA STATE UNIVERSITY

Research & Economic Development

Louisiana State University
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October 22, 2007

Board of Regents
P. O. Box 3677
Baton Rouge, LA 70821-3677

To Whom It May Concern:

I am writing this strong letter of support for the proposal "*Upgrade of the LSU Helium Liquefier Facility*", submitted to the Board of Regents by Professor David Young and others here at LSU. The LSU Office of Research and Economic Development strongly supports the purchase of a helium liquefier proposed by Dr. Young and his colleagues to be housed in Nicholson Hall. LSU is one of a very few research universities that has the infrastructure in place for the recovery and reliquefication of helium gas. Liquid helium is a used in a wide variety of materials characterization and measurements technologies. Indeed, we believe that a plentiful and cheap source of this non-renewable resource is absolutely crucial to LSU's Materials Initiative and to the state's long term goals for developing a technology-based economy.

We are investing a great deal of resources towards developing a strong materials science and engineering program at LSU. Part of this investment will take the form of 7 new faculty positions aimed at materials research through our Multidisciplinary Hiring Initiative. The instrument that is being requested through this proposal will fill a critical need within LSU's existing materials research program and will allow for emerging research in the design and characterization of new materials. Furthermore, the instrument will allow our existing faculty, as well as our new materials research faculty, to explore new and exciting areas of research that have tremendous potential for the future.

This proposal has the highest priority in The Office of Research and Economic Development and we are committing $120,000 to help underwrite the cost of the proposed instrument.

We look forward to learning the outcome of the review of this proposal, and we appreciate your support.

Sincerely yours,

Brooks A. Keel, Ph.D.
Vice Chancellor

Linde
Cryogenic Plants and Services
A Division of Linde BOC Process Plants LLC

BUDGETARY PROPOSAL

COMMERCIAL PART

LOUISIANA STATE UNIVERSITY

MODEL 1410 HELIUM LIQUEFIER

RS COMPRESSOR
RSS COMPRESSOR

Commercial Part, Issue 01, dated February 28, 2006

Table of Contents

1 General

The pricing in this Proposal is **budgetary**, delivery time is estimated.

2 Estimated Price – Prices are given in U. S. Dollars

2.1 The estimated price for the Scope of Supply as specified in section 2 of the Technical Part amounts to:

	Price
One Model 1410 Helium Liquefier	**$267,905.00**
One RS Helium Compressor	**$134,503.00**
One RSS Helium Compressor	**$106,488.00**

Two (2) copies of Operation and Maintenance Manual and Installation Interface drawings are included with system purchase.

Installation Check, commissioning and training **$16,000.00**
To be done by Cryogenic Plants and Services service engineer.
Assumed time requirement is 10 days.

3 Accessories and Spare Parts

a. One (1) Data Acquisition System including laptop PC and software. Remote control included.

PRICE **$11,000.00**

b. One (1) Acoustic Blanket for an RS Helium Compressor Modules

PRICE - per compressor..... **$5,590.00**

c. One (1) Installation Piping Kit

PRICE **$8,321.00**

d. **Recommended Spare Parts Kits**

e. One (1) Spare Parts Kit for basic M1410 cold box module.

PRICE $4,032.00

f. One (1) Spare Parts Kit for M1410 automatic purifier.

PRICE $1,269.00

One (1) Spare Parts Kit for Model RS/RSS Compressor.

PRICE $4,305.00

h. **Recommended Maintenance Kits**

Maintenance kits offered below should only be purchased for the applicable compressor modules related to the customer purchase.

1) One (1) Expansion Engine Maintenance Kit for 2" engine

PRICE $888.00

2) One (1) Expansion Engine Maintenance Kit for 3" engine

PRICE..... $888.00

3) One (1) Adsorber Maintenance Kit for Model RS/RSS Compressor Module

PRICE - per compressor $716.00

i. One (1) Cryogenic Adsorber

PRICE $11,472.00

4. The price per Article 2.1 is budgetary.

The terms of sale are EX WORKS shop. The term "EX WORKS" shall be understood in accordance with Incoterms 2000.

The above price is subject to payment terms acceptable to Seller.

5. **Payment Terms**

60% of the "EX-WORKS" contract value with placement of the order.

40% of the "EX-WORKS" contract value at the time of shipment from Cryogenic Plants and Services.

6. **Estimated Time of Delivery**

The estimated EX WORKS shop delivery time of the system will be seven (7) months.

Timely delivery is subject to timely fulfillment of Buyer's contractual obligations.

Seller is not liable for damages caused by late delivery.

7. **Performance**

Seller will guarantee certain performance parameters set forth in Section 2 of the Technical Part. They shall be exclusively demonstrated in a Performance Test to be stipulated in the final contract document.

8. **General Terms and conditions of Sale**

Above price is further based on LBPP's General Terms and Conditions of Sale, Form No. ADM-F006, attached hereto. Changes hereto might have a price impact.

9. **Validity**

Linde will offer a firm fixed price upon receipt of a detailed specification from the Buyer.

10. **Attachments**

LBPP Terms and Conditions

Respectfully,

John B. Urbin
Business Unit Manager
Cryogenic Plants and Services
A Division of Linde BOC Process Plants LLC

JBU/jr
Attachment: LBPP Terms and Conditions of Sale

Attachment 1

1. DEFINITIONS: "Seller" shall be defined as Linde BOC Process Plants LLC ("LBPP"), or Hydro-Chem, a division of LBPP, or Cryogenic Plants and Services, a division of LBPP, as specified in the Proposal. "Purchaser" shall be defined as the person or company for whom this Proposal has been prepared and submitted. "Equipment" shall be defined as the materials, equipment, supplies, or parts to be provided to Purchaser as specifically referenced in this Proposal. "Proposal" means the technical/commercial proposal prepared by Seller for supply of services and/or Equipment, to which these General Terms and Conditions of Sale are made a part thereof and incorporated therein. "Contract Price" shall mean the total purchase price set forth in Seller's Proposal for the services and/or Equipment outlined therein.

2. ACCEPTANCE, INTEGRATION: This Proposal shall constitute an offer which is valid for and must be accepted by Purchaser within thirty (30) days from the date hereof, unless otherwise set forth in the Proposal. Upon acceptance, this Proposal shall constitute a contract of sale for the Equipment referenced herein. This Proposal contains the entire agreement between the parties and supercedes all prior agreements and understandings. This Proposal may not be modified or amended except by written agreement signed by both Seller and Purchaser. **THIS OFFER IS EXPRESSLY CONDITIONED ON PURCHASER'S ACCEPTANCE OF ALL OF THE TERMS SET FORTH HEREIN. UNLESS SPECIFICALLY AGREED TO IN A WRITING SIGNED BY SELLER, THE TERMS AND CONDITIONS OF THIS PROPOSAL REPRESENT THE ONLY TERMS AND CONDITIONS APPLICABLE TO THIS CONTRACT, NOTWITHSTANDING ANY STATEMENTS TO THE CONTRARY WHICH MAY BE CONTAINED IN PURCHASE ORDER DOCUMENTATION ISSUED BY PURCHASER OR ANY OTHER DOCUMENT SUPPLIED BY PURCHASER RELATING TO THIS TRANSACTION, WHICH ADDITIONAL OR INCONSISTENT TERMS ARE OBJECTED TO BY SELLER.**

3. SHIPPING TERMS AND RISK OF LOSS: Unless otherwise set forth in the Proposal, all shipments of Equipment shall be made Ex Works as defined in INCOTERMS 2000. Transportation and insurance charges, if required, will be prepaid by Seller, to be invoiced at actual cost to the Purchaser in addition to the Contract Price.. The Contract Price includes standard packing for normal shipment. Costs of export or special packing shall be considered a cost extra. All transportation and transit insurance costs shall be borne by Purchaser, and Purchaser shall bear all risk of loss at the time the Equipment is ready to be delivered to Purchaser's carrier at point of shipment. Purchaser shall insure the Equipment against all risks of loss for the benefit of Seller at least to the extent of any payment balance due. Claims for shortages in shipment shall be deemed waived unless made in writing to Seller within ten (10) days after delivery.

4. PAYMENT TERMS: Payments for domestic sales will be made in accordance with the specified payment schedule. All payments are due net thirty (30) days. Payments for export sales will be made in accordance with the specified payment schedule by way of a confirmed irrevocable letter of credit established in favor of Seller on a USA bank acceptable to Seller. The letter of credit is to be established at the time of award. Delivery schedules are based on receipt of letter of credit within thirty (30) days of award. Seller shall have the right to suspend performance if the letter of credit is not provided as outlined above. All expenses connected with opening, amending, confirming, negotiating and maintaining the letter of credit shall be borne by Purchaser. All payments shall be deemed to have been effected when credited in US Dollars to Seller's U.S.A. bank account for Seller's free disposal. Any payments due upon shipment shall be considered due upon readiness for shipment, and Seller shall be compensated for any storage or other costs associated with any delays in shipment requested by Purchaser. Seller reserves the right to make early shipment or partial shipments and invoice Purchaser accordingly. All payments in arrears are subject to finance charges of 1½% per month on outstanding balances, which shall be applicable as pre-judgment and post-judgment interest. If Seller is required to file suit to collect outstanding balances, Purchaser agrees to reimburse Seller for all costs incurred in the collection thereof, including reasonable attorneys' fees. Seller may accept a lesser payment on an invoiced amount without prejudice to Seller's right to collect the balance.

5. TAXES AND DUTIES: All taxes normally imposed upon and assessed against Purchaser, including but not limited to, Federal, state, local, or value added sales and/or use taxes measured on the price of Equipment and/or services, and any applicable duties, are not included in the Contract Price. Unless Purchaser provides an exemption certificate as required by law, Purchaser shall pay all local, state and federal sales, use, excise, manufacturers, privilege, occupation, transfer, import and export, or other taxes or duties arising out of this transaction directly to the taxing authorities or reimburse Seller as may be appropriate

6. PERFORMANCE GUARANTEES, TESTING, AND ACCEPTANCE: Except as otherwise set forth below, Seller warrants that the Equipment shall comply with the specifications as specifically stated in Seller's Proposal or accepted by Seller in a writing signed by an authorized representative of Seller and Purchaser. Performance specifications referenced in Seller's Proposal are generally considered typical or expected values and are not guaranteed, except only for such performance specifications designated in Seller's written proposal as guaranteed values. Said guarantees, if any, shall be demonstrated in a performance test to be conducted at Seller's facilities prior to shipment of the Equipment to Purchaser. Said performance test shall be witnessed by Purchaser and said Equipment shall be deemed accepted as in compliance with all specifications and performance guarantees, if any, at the successful completion of said performance test prior to shipment to Purchaser, which test shall be in lieu of a performance test at Purchaser's or user's plant facilities. In the event that the Proposal and/or contract provides for performance testing at Purchaser's or user's plant facilities, the following shall be applicable: Seller's guarantees are subject to compliance by Purchaser with specified performance test parameters and design/operating conditions. Performance test procedures shall be as set forth in the Proposal or otherwise agreed between the parties. Purchaser shall conduct performance tests using qualified personnel and provide feedstock and utilities in sufficient quantity and quality. Within thirty (30) days after start-up, or six (6) months after date of shipment, whichever first occurs, Purchaser must inspect, operate, and test the Equipment and either accept it or provide to Seller in writing any reasons for non-acceptance, including test results evidencing the failure

of the Equipment to achieve contract specifications or performance guarantees. Purchaser must retest the Equipment in accordance with the above procedures within ten (10) days after Seller notifies Purchaser that the Equipment is ready for inspection and retesting. Any retest shall repeat only such part or parts of the previous test which was not successful, unless applicable government permits or regulations require otherwise. Seller assumes no liability for Purchaser's costs of testing or retesting the Equipment. If the plant is shut down for any reason during the performance test except due to the fault of Seller, the portion of the performance test completed prior to such shut down may be used by Seller as the basis for calculating the performance test results. Failure to comply with the above procedures will result in a deemed acceptance of the Equipment as in compliance with performance guarantees and specifications. After acceptance or deemed acceptance, Seller assumes liability only for a Material/Mechanical Warranty as set forth below.

7. MATERIAL/MECHANICAL WARRANTY: Seller warrants to Purchaser that the Equipment will be free from defects in workmanship and material, under normal use and service as herein specified, for a period of twelve (12) months after start-up of the Equipment or eighteen (18) months from completion of shipment, whichever occurs first, except that parts sold as a spare or for replacement are warranted for one (1) year from date of shipment or until the expiration of the recommended service period, whichever occurs first. Resale products shall pass through the warranty offered by the original manufacturer. This warranty does not cover Purchaser furnished designs, equipment, and/or materials. In the event that Purchaser requests that shipment be delayed, said warranty period shall commence as if the Equipment had been shipped as originally scheduled by Seller. This warranty shall not apply to Equipment supplied by Seller which has been repaired or altered, except under Seller's approval or supervision, or to Equipment that has been subject to misuse, negligence, accident, corrosion, erosion, normal wear, improper maintenance or operation beyond design specifications or parameters. Unless Seller has herein assumed responsibility for field erection, this warranty shall not apply to defects arising out of faulty or improper field erection of Equipment. No warranties are offered or liabilities accepted unless (1) Seller has received written notification of the defect during said warranty period within ten (10) days after discovery thereof and (2) Seller has been provided a reasonable opportunity to remedy any defects in performance All warranties on repaired or replaced parts or components of the Equipment shall expire on the date of expiration of the original warranty period as stated herein.

8. DISCLAIMER: EXCEPT FOR THE EXPRESS WARRANTY STATED HEREIN, SELLER DISCLAIMS ALL WARRANTIES, EXPRESS OR IMPLIED, WITH RESPECT TO THE EQUIPMENT AND/OR SERVICES, INCLUDING ANY AND ALL IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE.

9. EXCLUSIVE REMEDY: The sole and exclusive remedy of the Purchaser for any liability of Seller of any kind, including (a) warranty, (b) contract, (c) negligence, or (d) otherwise, contained in the terms and conditions hereof or in any terms additional or supplemental hereto, is limited to, at Seller's option, (1) the repair or replacement of defective Equipment, or (2) refund to Purchaser the money paid to Seller for defective components of the Equipment, or (3) the payment of liquidated damages if so provided in the Proposal. Purchaser's remedy and Seller's liability for defective engineering/design services shall be limited to the supply of corrective engineering/design services. Seller's liability to repair or replace is limited to the direct cost of the repaired or replaced component.. Site labor costs associated with removal or reinstallation, and all transportation costs to and from Seller's location or designated supplier shall be to the account of the Purchaser. In the event that Seller elects to conduct field repairs at the job site, the direct costs to make such repairs shall be to the account of Seller. Purchaser shall be responsible for assistance in identifying the defect and cause, access to, and decontamination of the Equipment, as required, to allow Seller to perform its obligations hereunder. Purchaser will provide Seller with continuous and unobstructed access to the Equipment to perform its obligations hereunder within a reasonable time after the defect is discovered. Field repairs as provided for above will not be paid or allowed by Seller unless Seller is notified of the defect and given ten (10) days to inspect the defect prior to corrective action. Field repair charges must be approved in writing by an authorized representative of SELLER before parts are repaired, replaced, or altered in any manner. Any repair or alteration without such approval shall act to void any existing warranty, along with any obligation on the part of Seller to pay for such unauthorized modifications.

10. CONSEQUENTIAL DAMAGES: In no event, whether through breach of contract, breach of warranty, delays in performance, negligence, gross negligence, strict liability, or other tort liability, shall Seller be liable for consequential, incidental, or delay damages of any nature, including, but not limited to, loss of product or profit, loss of customers, business injury or interruption, plant downtime, additional labor or overhead expenses, inefficiencies, construction delays, etc.

11. LIMITATION OF LIABILITY: The total cumulative liability of Seller arising hereunder, whether such liability arises through breach of contract, breach of express or implied warranties, breach of performance or material guarantees, negligence, gross negligence, strict liability, misrepresentation or other tort liability, contractual indemnities assumed by Seller, liquidated damages, or otherwise, shall in no event exceed the Contract Price, except only for personal or bodily injury, including death, or property damage, for which Seller's liability shall be limited to the extent and limits of, and proceeds recovered from, Seller's insurance carriers, with liability not to exceed aggregate limits of $2 Million U.S. Dollars.

12. CONFIDENTIAL INFORMATION: All information, data, designs, and drawings furnished by Seller in connection with this Proposal, or provided or developed during execution of the contract, represent confidential and proprietary information of Seller, which information shall remain the exclusive property of Seller. Purchaser agrees that such information shall be kept confidential and not disclosed to third parties, or used for any purpose, other than for repairs or maintenance of the Equipment, without the prior written permission of Seller. No rights or licenses with respect to said information, trademarks, patents, or any other intellectual property rights, are intended to be granted to Purchaser, other than the right to use said Equipment at Purchaser's or user's plant location.

13. FOREIGN SUPPLY: SELLER reserves the right to furnish at its discretion, material and components from qualified foreign suppliers on a world-wide basis, subject to the limitations of any applicable laws, regulations, codes or standards.

14. FORCE MAJEURE: If the performance of Seller of all or any part of the contract for sale of Equipment is prevented, hindered or delayed or otherwise made impracticable by conditions beyond the control of Seller, including but not limited to, inability of Seller, its subcontractors or suppliers to obtain parts, skilled labor, fabricating materials or supplies, or in the event of interruption or shortage of or delays in transportation, strikes, labor troubles, floods, fires, accidents, earthquakes, riots, explosions, war, acts of government, customs barriers or taxes, export/import control regulations, import surcharges, the bankruptcy or other insolvency of suppliers to Seller, etc. Seller shall be excused from performance hereunder for the period the force majeure condition is in effect.

15. DELIVERY: The delivery dates set forth in this Proposal are approximate based upon available information. Seller shall exercise its best efforts to achieve or better the delivery schedule set forth herein. If Purchaser delays shipment, payments are to be made as though shipment had been made as specified and Equipment shall be held at Purchaser's risk and subject to reasonable storage and handing charges. The delivery date will also be directly affected by delays due to awaiting drawing approval or receipt of necessary information from Purchaser and temporary work suspension or engineering changes requested by Purchaser. The time period for delivery shall not commence until the contract is awarded and all contract documents fully accepted and executed by Purchaser and Seller.

16. LAWS, CODES AND STANDARDS: Seller shall comply with applicable laws, regulations, or codes in effect on the date of the Proposal as specifically set forth in Seller's proposal or agreed upon written contract specifications. Compliance with new or amended laws or regulations, or other laws, regulations, or codes not specifically referenced in the Proposal or agreed upon written contract specifications which operate to modify or increase the scope of work, shall entitle Seller to a contract extra based upon demonstrated costs.

17. FIELD ERECTION SERVICES: Installation and/or field erection shall be provided by Purchaser unless otherwise set forth in this Proposal. In the event that this Proposal provides for the supply of field erection/installation services, or if Purchaser later requests Seller to provide such services, additional terms and conditions entitled Field Erection Supplemental Terms and Conditions Form ADM-F007 Rev 000 shall be incorporated herein as part of this contract..

18. FIELD CONSULTING SERVICES: If requested by Purchaser, in addition to the Contract Price, Seller will provide a Service Representative in accordance with quoted per diem rates and terms and conditions as provided in Form ADM-F008 Rev 000. Services provided by the Service Representative are only advisory in nature. Purchaser is solely responsible for the field erection, installation, testing, start-up, operation and maintenance of the Equipment at all times, including all supervision thereof. All required labor and labor supervision shall be supplied by Purchaser. Service Representative is not authorized or licensed to operate any equipment or controls, is not responsible for acts and/workmanship of employees, subcontractors, or agents of Purchaser or any other party, and does not have the right or authority to control details of the work during field erection, installation, testing, start-up or maintenance of the Equipment. Any visual inspection or supervision performed by Service Representative is on a best efforts basis and is not guaranteed to discover any and all defects and/or deficiencies. Purchaser shall maintain an all risk property fire and extended coverage policy on the Equipment to insure said Equipment against loss or damage, which coverage shall be primary with waivers of rights of subrogation against Seller. Seller's liability in contract or tort arising from the supply of Service Representative shall be limited to the total charges billed to Purchaser for said services. In no event shall Seller be liable, whether in contract or tort, for consequential or incidental damages arising from the supply of Service Representative.

19. CHANGES AND TERMINATION: Any contract or order resulting from this Proposal shall be binding on the parties, and termination, rescission, suspension, or modifications to the specifications, scope of work, or any other changes will be accepted by Seller only upon terms that will reimburse Seller for all costs, expenses, and/or losses and provide a pro rata increment of profit.

20. PATENT INFRINGEMENT: Seller shall defend any suit or proceeding brought against Purchaser based upon a claim that any of the apparatus of Seller's design furnished hereunder constitutes an infringement of any United States Patent, provided that Seller is notified promptly in writing, but no later than thirty (30) days after Purchaser's receipt of notification, and given authority, information and assistance for the defense of same. Seller's liability for infringement of patents is limited to apparatus or mechanical claims related to the Equipment supplied, but does not extend to patent infringement arising out of mechanical or process designs or other information supplied by Purchaser, or to the use of the Equipment in connection with Purchaser's process, or use in combination with other equipment not supplied by Seller. In the event of a patent or intellectual property right infringement action covered under this indemnity, Seller will, to the exclusion of any further claims, assume control of such litigation and defend Purchaser with counsel selected by Seller and, at Seller's option, modify the Equipment as necessary to make the Equipment non-infringing, replace the infringing portion of the Equipment, or obtain a royalty free license to use the Equipment for the benefit of Purchaser. In no event shall Seller be liable for consequential damages of any nature.

21. FOUNDATIONS: Unless otherwise set forth in this Proposal, Purchaser will furnish any and all necessary foundations, foundation designs, foundation bolts, and templates for Equipment. Seller shall not be responsible for the depth of footings, size or accuracy of foundation, or the character of the materials selected for their construction, nor shall Seller be responsible for any damages, or necessary repair, to Equipment caused by, or resulting from, defects in or settlement of the foundation.

22. SECURITY INTEREST: Purchaser hereby grants to Seller, its successors and assigns, a security interest in Equipment sold to Purchaser hereunder to secure payment of the Contract Price. Default in the payment of the full price or any payment when due shall permit Seller to declare all obligations of Purchaser immediately due and payable, and in such event, Seller shall have all the rights and remedies of a secured party under applicable law. Purchaser agrees to join with Seller in the execution of financing statements necessary to perfect the security interest herein granted, and Seller is expressly authorized, as attorney-in-fact for Purchaser, to file one or more financing statements or a copy or original of the contract of sale in the appropriate filling office as may be required, naming Purchaser as debtor and Seller as secured party.

23. WEATHER PROTECTION: Damage may occur to critical components of the Equipment if proper weather protection is not followed during periods of field construction or storage by Purchaser. Purchaser assumes responsibility to take necessary protective measures. Seller's guarantees are based upon "as new" condition of the Equipment, and, in the event of damage during periods of storage or field erection, Purchaser shall bear all costs of repair/replacement of damaged components of the Equipment.

24. PERMITS: Purchaser assumes responsibility for securing all approvals and/or permits required by any governmental regulations, laws, or ordinances, necessary for the installation, field erection, use, and operation of Equipment, and Purchaser shall pay all required fees. If any modifications are required in the Equipment to meet such approvals and/or permits, Purchaser shall reimburse Seller as a contract extra based upon demonstrated costs.

25. WAIVER AND ASSIGNMENT: Failure of Seller to enforce any of its rights hereunder shall not constitute a waiver of such rights. This agreement may not be transferred or assigned by operation of law or otherwise, without the prior express written consent of Seller. Any transfer or assignment of any rights, duties or obligations hereunder without such consent shall be void.

26. UNITED STATES GOVERNMENT CONTRACT: If this agreement is placed under a U.S. Government Contract (prime or subcontract), then this contract is also subject to the applicable U.S. Government contract clause(s) as are required by public law which are hereby incorporated into this contract by reference.

27. EXPORT SALES: No provision of this contract shall be construed to require Seller to export or deliver any technical information, data and/or equipment if such export or delivery is then prohibited or restricted by any law or regulation of the U.S. Government.

28. NUCLEAR LIABILITY: When any Equipment furnished hereunder are to be used in or in connection with any nuclear installation or activity, Seller, its employees and suppliers of any tier shall have no liability for any nuclear damage, injury or contamination, and Purchaser will indemnify Seller, its employees and suppliers against any such liability, whether as a result of breach of contract, indemnity, warranty, tort (including Seller's or its supplier's negligence), strict liability or otherwise. In addition, Purchaser shall furnish upon request from Seller financial protection, including but not limited to, an agreement of indemnification as contemplated by Section 170, of the Atomic Energy Act of 1954, as amended, and also nuclear liability insurance from ANI and MAELU, or both, pursuant to Section 170 of said act. Any decontamination necessary for Seller's performance hereunder (including warranty obligations) shall be performed by others without cost to Seller.

29. GOVERNING LAW AND DISPUTE RESOLUTION: All claims, disputes and other matters in question arising out of, or relating to, this contract or the breach thereof, shall be decided by binding arbitration in accordance with the Construction Industry Arbitration Rules of the American Arbitration Association, to be held in Tulsa, Oklahoma, U.S.A. In no event shall the arbitration be made after the date when institution of legal or equitable proceedings based on such claim, dispute or other matter in question would be barred by the applicable statute of limitations. The parties hereby stipulate and agree that the maximum monetary limit of judgment or award, if any, authorized to be entered by said arbitrator(s) in favor of either party shall in no event exceed the Contract Price. Any decision or award rendered by at least a majority of the arbitrators shall be final and judgment may be entered upon it under the United States Arbitration Act or laws of the State of Oklahoma, as may be applicable. The Contract shall be governed by and construed in accordance with the laws of the State of Oklahoma, excluding the law of conflict. The United Nations Convention on Contracts for the International Sale of Goods does not apply to this contract.