OFFICE OF THE PRINCIPAL
GLENBROOK NORTH HIGH SCHOOL

To: Dr. Mike Riggle

From: Dr. Paul Pryma

Re: Fermionic Matters Trip, Minneapolis, MN.

Date: May 12, 2014

It is with pride and enthusiasm that I submit this request to you and the Board. As you know, a group of GBN students named Fermionic Matters competed this spring in the CERN International Competition. Their educational experience has been extraordinary, and their sponsor Mr. Unterman has arranged to make it even better. Attached is information describing an opportunity for our students to present at the American Association of Physics Teachers Conference in July. I fully support this endeavor, and thank you for your consideration.

PP:rp

Glenbrook North High School

2300 Shermer Rd., Northbrook, IL 60062-6700

Science Department

9-May-14

Dr. Paul Pryma:

The American Association of Physics Teachers Summer 2014 meeting has a poster session that fits our CERN student proposal. AAPT has waved the conference fee for the students. This is a wonderful opportunity for part of the team to present their work in a professional setting. The five students most central to the project have been informed of this possibility, and are eager to attend this conference. The transportation cost would be minimized by renting a vehicle that can handle 7 passengers with luggage, and housing would be in the dormitories of the University of Minnesota.

There are a number of paper sessions and posters that would interest the students. Several plenary sessions have scheduled outstanding talks. One, in particular, is by Dr. Roger Rusack discussing the past, present, and future of the Large Hadron Collider at CERN. There will be other sessions on the Standard Model, as well as astronomy, methods of teaching, demonstrations, etc. Since parts of the conference directly relate to the project that the students have proposed, this will have relevance to the students' experience.

I have attached the student proposal to CERN and a small copy of the poster they plan to present. I hope that this trip can be approved to help these students further their educational experience on this project.

Cordially,

Nathan A. Unterman

/attachments

Nathan A. Unterman
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GLENBROOK HIGH SCHOOLS
Travel Requests Requiring Board of Education Approval

I. **School** GBN ✓ GBS ~~Nathan A. Unterman~~ GBE ___ GBOC ___ **District** ___

II. **Initiator** _____ Phone 2627

Position TEACHER Date of Submission 30, APRIL 2014

III. **Dates and Times of Leave/Return**

Total Number of School Days Missed per Person ZERO

Departure Date/Time 27 JULY 6AM Return Date/Time 31 JULY

IV. **Name of Individuals Participating in Tour:** (Attach list if necessary.)

Teachers and Staff NATHAN A. UNTERMAN & Kris Frandson

Students 5 students

V. **Description, Destination, and Reason for Trip**

POSTER PRESENTATION OF CERN PROJECT AT THE NATIONAL CONFERENCE OF THE AMERICAN ASSOCIATION OF PHYSICS TEACHERS MINNEAPOLIS, MN.

VI. **Cost of Trip**

Was this trip included in your Dept. ___ Bldg. X District ___ Budget?

	Total Amount	Per Person	Account #
Registration	$ 585 TEACHER	STUDENTS WAIVED	297690
Lodging	$ 330.65	$ 47.24	297690
Meals (Advance)	$ 320.00	$ 160.00	297690
Judging	— 0 —	N/A	
Substitute Teacher	— 0 —	N/A	
Transportation			
Air	— 0 —		
Bus/Car	$ 800.00		297690
District Total	$ 2035.65	N/A	N/A
Cost to Student	—	—	N/A

VII. **Approval**

Supervisor	Principal	Superintendant
5/8/14	5/12/14	
Date	Date	Date

Reminder: No purchases or expenses prior to Board of Education approval.

Form approved by Board of Education 12/15/97.

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Nuclear Materials Testing: Use of a Charged Particle Beam as an Alternative to Neutron Bombardment to Test Cladding

Fermionic Matters, Glenbrook North High School, Northbrook, IL, USA

Graham Brunning, Ik-Jong Choi, Navid Choudhury, Ari Cotler, Yuni Dyer, Michael Dzianott, Tyler Emery, Robert Grosulescu, Benjamin Hunt, Matthew Kabelitz, Ali Khan, Shawn Killian, Emily Koss, Julia Masterman, Daniel Nibeck, Leela Pakanati, Lars Stolpe, Michael Zhang, Nathan Unterman*, Robert Froehlich*

*Advisors

Abstract

To develop more effective methods of nuclear materials testing, an experiment comparing bombardment by charged particles is proposed. Materials used in nuclear cladding (Stainless Steel-316, Zircaloy-4, and Silicon Carbide) are traditionally tested within nuclear reactors wherein the material is bombarded by neutrons. If the proposed method is successful, it will significantly shorten testing cycle times.

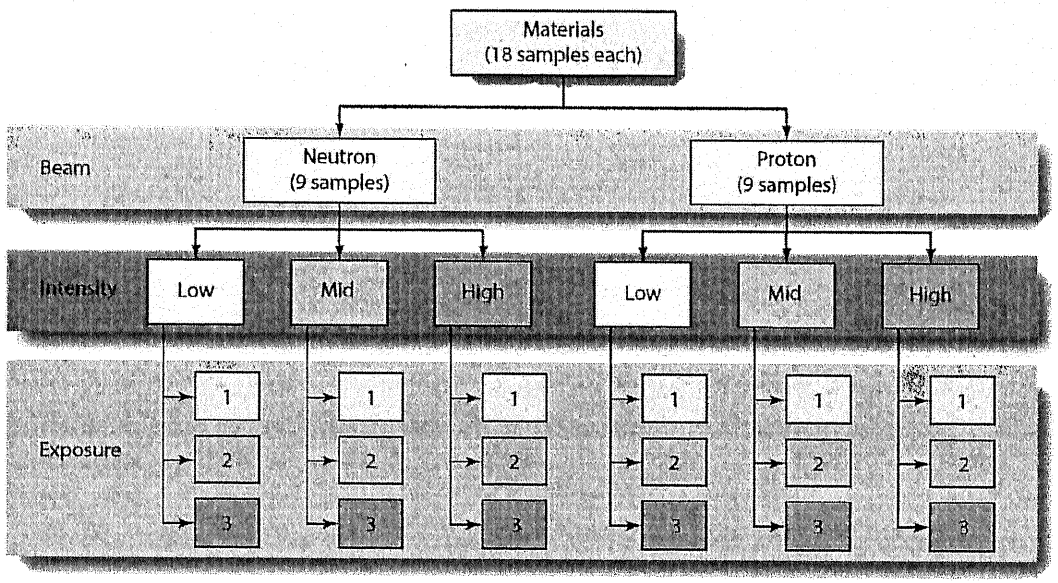
Purpose

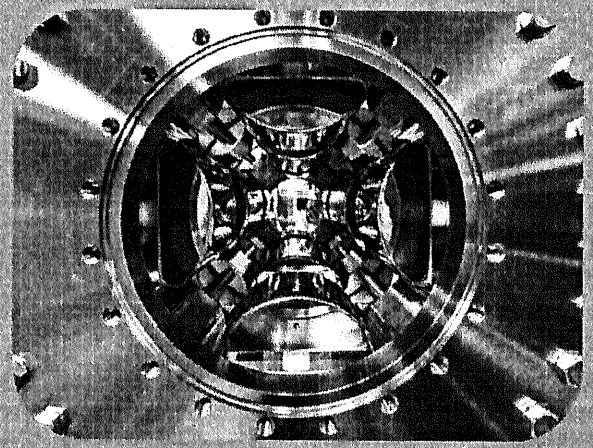
The objective of our experiment is to revolutionize the nuclear energy industry's current testing methods for nuclear reactor cladding materials. Because proton beams are more common, less expensive to operate, and allow for faster test cycles than test reactors, our method of using charged particles to simulate neutron damage will expedite testing cycles and reduce development costs. More expeditious testing allows for increased opportunities in materials innovation, and improvements in reactor safety.

Acknowledgements

Harvey Abramowitz, Mark Adams, Pat Canady, Bo Feng, Hassan Khan, Bob Peterson, Eric Prebys, Guy Savard, Hal Spinka, Di Yun, administration, faculty and staff of Glenbrook North High School.

Procedural Flowchart





Background

The Beam Line for Schools contest challenges schools all over the world to submit a tweet of intent, research proposal and video to CERN. The winning team will oversee their proposal realized through the T9 Beam Line particle accelerator. Additionally, all publishable results will carry their names as well as CERN's. In preparation for this competition we traveled to Fermilab and Argonne National Laboratories to consult nuclear and particle physicists and tour their beam line facilities.

Hypothesis

We hypothesize that dislocations caused by charged particle bombardment of nuclear cladding materials will be equivalent to dislocations from neutron bombardment. For samples exposed to a range of energies and durations, damage caused by each type of bombardment will be similar.

Procedure

We will choose two of the following materials for testing: Stainless Steel-316, Zircaloy-4, and Silicon Carbide. In our experiment, these samples will be bombarded by charged particles at various high energies with differing exposure times. After performing the experiment, we will compare the dislocations in each sample using available detection methods such as electron microscopy, atomic force microscopy, advanced photon sources (X-ray crystallography), or high-frequency ultrasound. An unexposed sample of each material will be used as control, and our results will be compared to that of the present state of the art.

CERN

GLENBROOK NORTH HIGH SCHOOL

Nuclear Materials Testing: Use of a Proton Beam as an Alternative to Neutron Bombardment to Test Cladding

Fermionic Matters Glenbrook North High School, Northbrook, IL

Motivation:

Even as motivated students, our typical interactions with science are limited to direct instruction, tabletop labs, and online representations. The opportunity to conduct our original experiment at CERN is incomparable to any classroom endeavor. Aside from hoping to return radioactivity-free, we want to discover new, applicable information and stoke our fascination with science.

This experience will be life-changing due to the unparalleled tools and talent found at this laboratory, which is famed for global collaboration. In addition to gaining cultural awareness, doors will be opened to broaden our scientific opportunities. Meeting even a small portion of CERN's renowned (and attractive) scientists and researchers will be inspirational.

Hypothesis:

We hypothesize that dislocations caused by proton bombardment of nuclear cladding materials will be equivalent to dislocations from neutron bombardment. For samples exposed to a range of energies and durations, damage caused by each type of bombardment will be similar.

Objective:

The objective of our experiment is to revolutionize the nuclear energy industry's

current testing methods for nuclear reactor cladding materials. Researching the integrity and lifetime of cladding material within a reactor is essential to reactor development. Because proton beams are more common, less expensive to operate, and allow for faster test cycles than test reactors, our method of using protons to simulate neutron damage will expedite testing cycles and reduce development costs. More expeditious testing allows for increased opportunities in materials innovation, and improvements in reactor safety.

Review of Literature:

The cladding material in a nuclear reactor is used to protect reactor components. The cladding becomes damaged over time due to entangled dislocations, which weaken the internal structure. Currently, the testing of cladding materials requires up to two years of exposure in a reactor.[1] The development of expedited testing processes allows for rapid innovation, leading to increased reactor safety.[2]

Stainless steel 316 (SST-316) and Zircaloy 4 (Zi-4) are materials currently used in nuclear reactor cladding. Silicon Carbide (SiC) is a largely unknown, novel material that has been proposed for reactor use.[2][3]

SST-316 is a B-grade steel with large amounts of chromium. Although SST-316 better resists oxidation from coolant interaction than Zi-4, it is no longer used in light-water reactors due to its unfavorable neutron cross section. Prior testing, however, allows insight into the material's properties.[4]

Zi-4 is the most widely used alloy in commercial nuclear reactors, due to its neutron absorption (0.26 barns), creep (0.66% at room temperature), operational lifetime (64 MWd/kg U), and high ultimate tensile strength (437 MPa).[3] The

dislocations that occur in irradiated Zi-4 are point defects, dislocation loops, and vacancy dislocations.[5]

SiC is an experimental cladding material, proposed to have both higher tensile and yield strengths than Zi-4. The neutron absorption cross section for SiC is 0.13 barns.[4] It is recognized for having a high melting point, low chemical reactivity, and no creep at high temperatures.[6] Such traits are instrumental for safety in future light-water reactors.[2]

To test materials, conditions present within nuclear reactors are simulated by neutron bombardment. At high energies, protons and neutrons act in a similar fashion. The T9 proton beam line has been proposed as a testing beam. This beam releases high-energy protons in bursts, at energies of 0.5 GeV/c - 10 GeV/c.[7] A rate of up to 10^6 particles per burst can be released at maximum energies.[8] The T9 beam spot scales with distance.[9]

Spallation uses a high-energy proton beam directed at a target to create a high-flux neutron cascade. Tungsten or tantalum targets are common due to a combination of desirable properties.[10] The energy level of the resulting neutron beam depends on the energy of the parent proton beam. Tracking determines the point of greatest particle flux on the final target.

Procedure:

To conduct this experiment, we will choose two of the following materials for testing: SST-316, Zi-4, and SiC. This will limit the testing matrix to 36 trials. The samples will be bombarded by energetic protons and neutrons respectively. Multiple beam energies ranging from 10 MeV to 10 GeV will be selected (Figure 1). The 14 MeV

energy level is of interest because it is the fast neutron energy from nuclear fission.[11] The lower range of energies may result from spallation or another method. However, higher energy levels may expedite testing and are still useful if the 14 MeV energy level is unavailable.

Three different exposure times at each beam energy and material will be employed. All samples will be cut from the same section of material to minimize differences in their internal structure. Due to the low energy flux within a test reactor, we can only simulate the particle flux inside of a nuclear reactor using this procedure. After performing the experiment, we will compare the dislocations in each sample using available detection methods. An untouched sample of each material will be used as a control.

We will need detectors to track the location, cross section, intensity, and flux of the beams. For all trials, a tracker will determine the beam spot location while a scintillator will count the number of hits to determine the flux.

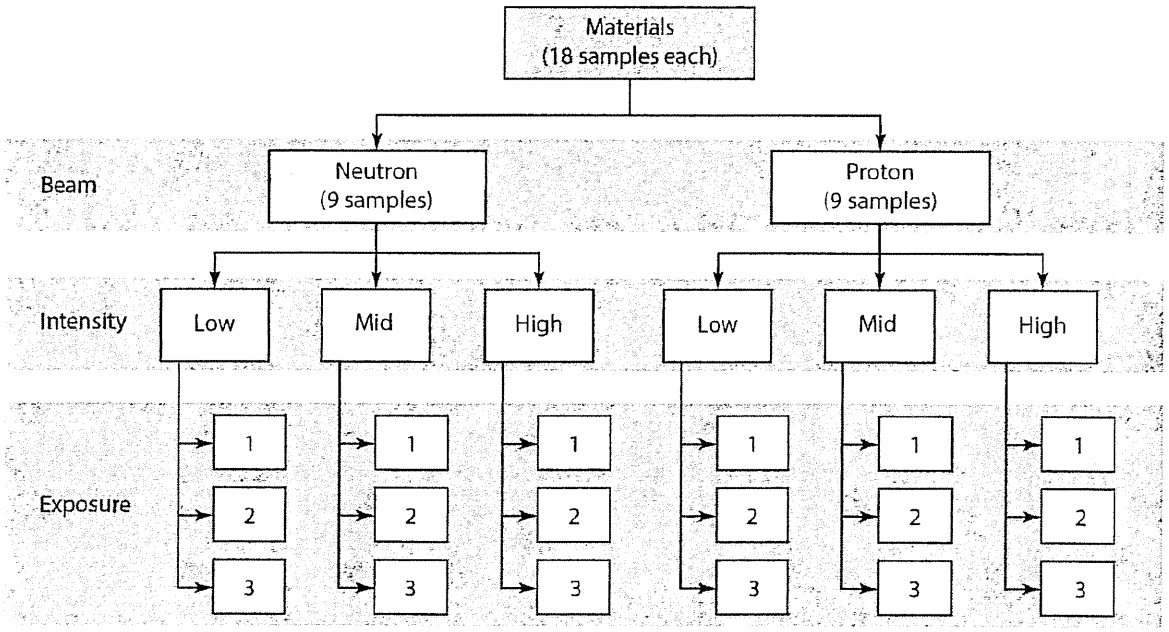


Figure 1 Experiment Procedure Design for 38 samples, including controls.

Electron microscopy, atomic force microscopy, high frequency ultrasound, or advanced photon sources (synchrotron X-ray crystallography) can analyze dislocations. However, sample preparation for electron microscopy may be destructive.[12][13][14]

Sources

1. Interview with Dr. Bo Feng, Argonne National Laboratory, Argonne, IL.
2. http://web.mit.edu/newsoffice/2013/better-cladding-for-nuclear-reactors-0726.html.
3. http://energy.gov/sites/prod/files/M3LW-12IN0502028_Tradeoff_study_report.pdf
4. http://link.springer.com/article/10.1007%2FBF02418736#page-1
5. https://www.antinternational.com/fileadmin/Products_and_handbooks/Zirat/ZIRAT14_IZNA9_STR_In-Reactor_Creep_sample.pdf
6. http://www.ans.org/pubs/journals/nt/a_16989
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9. http://ps-div.web.cern.ch/ps-div/Reports/PA9321/Figures/Fig17.gif
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11. http://journals.aps.org/pr/abstract/10.1103/PhysRev.137.B929
12. http://journals.aps.org/prb/abstract/10.1103/PhysRevB.31.805
13. http://etylab.ece.utexas.edu/pdfpubs/jap_aug03.pdf
14. http://www.ndt- ed.org/EducationResources/CommunityCollege/Ultrasonics/Introduction/

Glenbrook High School District #225

BOARD POLICY: STUDENT TRIPS **7230**

Section A - Introduction

The Board of Education believes that structured learning should not be limited to the classroom. Valuable experiences for Glenbrook students exist within and outside the boundaries of District #225. The Board also realizes that additional responsibilities arise whenever students are taken from the school premises. Staff, parents, and students should be aware of these responsibilities and the necessity for reasonable administrative procedures. The physical welfare of our students and staff must always be paramount in our considerations. It shall be the policy of this Board of Education to maintain insurance for the liability of the district, its board members, its employees, and authorized volunteers as a result of student injury, property loss and general liability coverage on student trips. It shall also be the Board's policy to encourage the maintenance of adequate personal automobile liability and medical insurance by our staff members.

Section B – Definition of Student Trips

A student trip shall be considered to be a school-sponsored activity away from the school premises usually falling within two major areas.

1. Instructional Field Trips and Extended Classroom:

   Instructional field trips provide experiences out of the classroom that are normally carried on during regular class hours and are related to the planned curriculum. In some instances pre- and post-school hours may be utilized.

   a. A field trip implements and/or augments group classroom instruction. Transportation for field trips is restricted by The School Code to Illinois or adjacent states.

   b. An "extended classroom" allows individual students to pursue their studies in various work-related, volunteer, or observation activities outside the classroom.

2. Student Activity Trips:

   Student activity trips are connected with regularly sponsored in school or post-school programs and may include but not be limited to the following:

   a. An activity trip as part of an extracurricular activity

   b. A contest (or practice for a contest) between students representing Glenbrook and another secondary school, or between participants in intramural sports (contestants, cheerleaders, marching band, etc.)

   c A performance or exhibition displaying special talent by an individual or group of students (e.g., band, chorus, etc.)

   d. A convention or workshop in which an individual or group of students representing Glenbrook participate (e.g., student council convention or workshop)

Section C – General Parameters

1. All student trips must be approved by and will be subject to the procedures set forth by the school principal or the designated representative.

2. Recommendation of the principal and approval of the superintendent shall be required for all overnight student trips. Recommendation of the principal and the superintendent and approval of the Board shall be required for all student trips conducted outside the State of Illinois or adjacent states.

3. Funding for student trips shall be in accordance with the guidelines adopted by the Board.

4. No student shall be penalized for non-participation in a class field trip. No student shall be penalized for participation in a class field trip or student activity trip.

5. Reasonable administrative care should be taken to ensure safety and orderly behavior on all student trips. Staff members shall accompany all field trips except "extended classroom" trips.

6. All Board and school policies, procedures and regulations regarding student conduct apply for students on student trips.

7. Transportation on all student trips should be by district-owned vehicles or by commercial vehicles, whenever practical. Occasionally, because of a limited number of participating students, private transportation is permissible when approved by the principal or the designated representative. In these instances, travel may be by private automobile, if the driver is a Glenbrook staff member, parent, or student.

8. Students participating in student trips must travel to and from the trip's destination in the school-sponsored mode of transportation unless an exception for good cause is made by the trip's sponsor for the student to be transported by the student, his/her parent or guardian.

9. The Parental Permission Slip and Field Trip Request Application, as specified in the procedures to this policy, shall be used in complying with this policy.

Source: School Code; Section 10-20.19
10-22.22,
10-22.29b
29-3.1

Revised: February 6, 1978
Revised: September 10, 1984
Revised: October 28, 1996
Revised: May 29, 2001
Revised: July 10, 2006