AC 2007-119: ADDRESSING AND IMPLEMENTING A SAFETY PLAN FOR INTERCOLLEGIATE DESIGN COMPETITIONS

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Addressing and Implementing a Safety Plan for Intercollegiate Design Competitions

In the Department of Engineering Technology at Middle Tennessee State University concerns have been raised about the safety of student-led engineering projects. These concerns have manifested because of the recent growth in the number of student-led projects, the number of students involved, and the space required to accommodate them. These projects have a faculty advisor to assist with arranging the use of department facilities and equipment, and handle the financial aspects related to university policy. The student teams are responsible for all other aspects of the projects, including: the designing, building, testing, and project management. The department's concern for safety is very legitimate in today's litigious society, as liability would begin with them. Neither the students nor the Engineering Technology department would want to shut down any of the projects, but that would likely be the result if there was a significant accident. This paper, therefore, is an attempt to discuss the problem of safety as related to student-led engineering projects and propose a plan that addresses the areas of concern.

The Engineering Technology department takes pride in the amount of hands-on learning its students receive as a part of the curriculum. Extensions of this hands-on learning environment are the student-led engineering projects. Student teams design, build, and race experimental vehicles to compete in nationally recognized intercollegiate design competitions. Until recently this was limited to a solar bike and a moonbuggy. This has expanded to include two solar bikes, two moonbuggies, two Baja off-road vehicles, a solar boat, and a formula style race car. When limited to a couple projects the task of supervising the student teams was relatively manageable. However, the explosion in the number of student projects has exposed an area of concern: safety. Safety is generally not at the forefront of an energetic engineering student's mind for all the usual reasons: "it will only take a second," "it will never happen to me," and an inherent sense of invulnerability common in youth. With limited space, project areas overlap. One team might be welding, and another might be using flammable substances in relatively close proximity. Materials like carbon-fiber are being used to create light weight bodies for the vehicles, but is the proper protective equipment being used? Fig. 1 shown below is a picture of a team leader's arm. White splotches are clearly evident. The student indicated the permanent splotches appeared after sanding the carbon-fiber material used on one of the vehicles.

Fig. 1 White splotches left on the skin as a result of sanding carbon-fiber

In the recent past, a team member has been taken to the emergency room to have a metal sliver removed from his eye, and during a moon buggy competition, a team member lost the tip of a finger. The eye and finger healed, but these types of incidents bring up all sorts of safety issues and questions. What are the current safety procedures, if any? Are students working alone? Are there first-aid kits readily available, and are they still accessible after normal operating hours? Who is the responsible authority in charge, and what are they responsible for? What materials are being used and are they hazardous, requiring personal protective equipment (PPE)? Are OSHA (Occupational Safety & Health Administration) standards relevant, and do they apply to student projects?

For any safety program to work, it will require a commitment from the department and the students. It must clearly define responsibilities and procedures, and to be effective long term, it must be relatively low maintenance. Students, and even faculty, are not likely to continue following any safety procedures that take significant amounts of time, i.e. filing weekly reports that take more than 15 minutes to complete. If the student engineering projects continue without a safety plan, it will only be a matter of time before someone is seriously injured.

The following is a proposed safety program that can be implemented with minimal resistance from the students and the support of an ET department and faculty. It adheres to the basic elements of a safety and health program, with specific recommendations for implementation. The safety plan is followed by a summary of relevant OSHA standards.

Department commitment and leadership

- The Engineering Technology department shall issue a written mission statement clearly defining the goals of the safety program:

  The Engineering Technology department of Middle Tennessee State University (MTSU) seeks to provide a safe environment and safety conscious culture for the continued success of all student-led engineering projects and hands-on learning experiences. The purpose of this policy is to preserve the safety and health of our students, faculty, staff, and visitors. The department recognizes the benefit to the students, the *department, and the University that the student engineering projects provide, and thereby issues this safety program in an effort to prevent and reduce incidents and accidents that may result in personal injury, property damage, and/or jeopardize the success of a project.*

- Representatives of the department shall be assigned to hold and participate in safety meetings and inspections with team members. Meetings shall be held on a scheduled basis and as needed to address safety concerns that may arise as a project progresses.
- The department shall clearly define what resources, if any, it is willing to commit to meet the safety needs of each project. This shall be issued in response to a formal request from each team listing the needs of each project. Resources may include, but not be limited to: personal protective equipment, training, equipment, access to work areas and general facilities, first-aid supplies, first-aid training, and environmental monitoring.
- A faculty member shall be designated for each project. A faculty member may not be assigned more than two projects.
- Safety rules and procedures shall be drafted with student input for each specific work area, and each team project. These rules and procedures shall establish protocols for construction of vehicles and specific work areas, i.e. are all flammables removed from the welding area and proper personal protective equipment is utilized and specifically protects against the hazard, i.e. carbon-fiber, or any chemical used in the construction of a vehicle. Any activity that may endanger the safety of a person or property must cease immediately until it has been judged by a competent person of authority to be safe to continue. The rules and procedures must stipulate for all projects that no team member may work alone on any aspect of physical vehicle construction.
- The safety plan shall be reviewed and revised on an annual or semi-annual basis. The reviewing committee shall consist of members of each team, faculty advisors assigned to the project, the department head, and relevant staff.

Assignment of responsibilities

- The faculty advisor shall at a minimum be responsible for ensuring that the team members are adhering to the established safety policies and procedures. The faculty advisor is also responsible for reviewing the weekly safety reports submitted by the team.
- A competent person shall be defined as one who has been trained or has demonstrated competency to use any piece of equipment. A competent person shall be defined as one who is familiarized with the Material Safety Data Sheet (MSDS) and the required use, if any, of the proper personal protective equipment for any material used in the construction of a project.
- It is the duty of every team member to think about his/her safety and the safety of his/her teammates.

Fig. 2 Safety hazard: No welding gloves and only one welder's helmet.

- Any team member, faculty, or staff has the duty and authority to stop work on the project at anytime if that member identifies a safety issue. Work may not continue until the safety issue in question is eliminated, protected against, or determined not to exist by a competent person.
- Team leaders shall be responsible for all access to work areas after normal hours of operation. Work after normal hours of operation are not permitted without the presence of a team leader. Team leaders shall record dates and times of all work done after hours.
- Teams shall be responsible for maintaining a list of materials and corresponding MSDS pages both in the work area and in the department office. If work areas overlap, the other teams must also be informed.
- Potentially hazardous equipment may not be used by unaccompanied team members or without the supervision of a competent person.

Identification and control of hazards

- A Job Safety Analysis (JSA) shall be required of each project prior to physical construction. What materials are to be used? How will assembly of the project occur? What are the hazards? What are the risks? How will the team protect against the hazards? What PPE is needed?
- Periodic review and review after an accident is required for the JSA.
- Worksite safety inspections shall be performed periodically and involve the team members, faculty advisor, and a faculty member from the Environmental Health and Safety concentration.

Fig. 3 Gas tanks for welders are not locked into the proper restraints.

- Any identified hazard shall be eliminated or controlled against by any of the following means: changing the way the job is performed, changing the physical conditions, changing the job procedures, reducing the frequency, or use of personal protective equipment.
- Access to safety equipment, i.e. eye washes, fire extinguishers, first-aid kits, and PPE shall be unobstructed.

Training and education

- A mandatory safety training meeting shall be conducted at the beginning of a project with all team members.
- Team leaders and the faculty advisor must attend an additional safety training session with regards to their leadership responsibilities.
- Team leaders shall be required to receive first-aid training.
- Team members may not use equipment they have not been trained to use by a competent person.
- All team members must be familiar with the MSDS and their location for any material found or used in the work area.
- Equipment training committed to by the department shall be available upon request at the earliest convenience of the designated trainer.

Record keeping and hazard analysis

- Weekly safety updates will be submitted to the assigned faculty advisor. The report will list any safety concerns, injuries, or near misses that occurred that week.
- Reports shall be written in a uniform manner.
- Accidents and near misses must be reported immediately to the faculty advisor. After any accident an accident investigation must occur to determine root causes and propose the appropriate corrective action.

- Records must be maintained in the work area and in the department office.

Relevant OSHA regulations

A list of tasks utilized by the students for the construction of their project vehicles was gathered from the project charters as submitted by the students, and are listed in Table 1. The tasks performed by the students clearly have some similarities with tasks performed in a typical manufacturing facility: drilling, milling, cutting, grinding, welding, painting, cleaning, mechanical assembly, electrical, and so forth. These activities are regulated in industry by some of the following OSHA standards.

• Sanding – Plastic – Metal – Wood • Shaping – Plastic – Metal – Wood • Drilling • Lathe • Milling • Cutting • Pressing • Grinding	• Metal forming • Casting – Plastic – Metal • Welding • Mechanical assembly • Hydraulics • Compressed gas/fluid • Electrical Wiring • Electrical Testing • Soldering	• Bondo • Painting • Caulking • Fiberglass • Gel coat • Epoxy • Laminating • Cleaning • Metal • Plastic • specific cleaning solution

Table 1 List of Construction Tasks

1910.106 - Flammable and combustible liquids & 1910.101 - compressed gases

Several of the projects employ gasoline powered engines and required gasoline on hand for vehicle testing purposes. Projects may also require the use of other flammable or combustible liquids. Welding, grinding, and cutting generate a lot of sparks. This is a potentially deadly safety hazard. All potentially flammable or combustible liquids should be kept in a "fire resistant storage cabinet well away from any potential ignition source. Currently this is not the case, as there are no fire cabinets available for student use. 1910.101 Compressed Gases was included here because of the welder. There are two welders available to the students and until recently the compressed Argon cylinders where not stored properly.

1910.38 - Employee emergency plans & 1910.151 - medical services and first aid

Continuing with the fire prevention topic, 1910.38 contain the following section: "Fire prevention housekeeping." "The standard calls for the control of accumulations of flammable and combustible waste materials." "It is the intent of this standard to assure that hazardous accumulations of combustible waste materials are controlled so that a fast developing fire, rapid spread of toxic smoke, or an explosion will not occur." The student projects generate a lot of waste materials, and some students are not particularly tidy. With the amount of cutting, grinding, and welding taking place, this is another potential fire hazard.

1910.38 also includes "Emergency action plan elements." This addresses "emergencies that the employer may reasonably expect in the workplace." "Examples are: fire; toxic chemical releases; hurricanes; tornadoes; blizzards; floods; and others." This section also calls for the detailing of what "rescue and medical first aid duties are to be performed and by whom." "All employees are to be told what actions they are to take in these emergency situations that the employer anticipates may occur in the workplace." It is essential that the students and faculty know ahead of time, should any emergency occur, what course of action should be followed. It could mean the difference between life and death.

Section 1910.151, medical services and first aid, is another important section. "Adequate first aid supplies shall be readily available." Currently there are no first aid kits in the student work areas. Work on the projects often takes place after normal school hours when the only available kits are locked up in the department office and at the end of the machine shop. This is an unacceptable situation that must be remedied immediately. It was recommended in the safety plan submitted to the department that project leaders receive first aid training. This course of action is supported by 1910.151: "a person or persons shall be adequately trained to render first aid."

General machining and equipment

All of the grinding, cutting, milling, drilling, welding, and lathing of various metal, wood, and plastic materials presents a lot of similar potential hazards that can be covered by several OSHA regulations. This includes, for example: 1910.212 - General requirements for all machines, 1910.213 - Woodworking machinery requirements, 1910 Subpart Q - Welding, Cutting, and Brazing, and 1910.215 - Abrasive wheel machinery. Also, as the vehicles are assembled they become more cumbersome to move and therefore require the use of more portable hand tools. The relevant OSHA regulation covering these tools is: 1910 Subpart P - Hand and Portable Powered Tools and Other Hand-Held Equipment. Students should also be familiar with 1910 Subpart O - Machinery and Machine Guarding.

Equipment used frequently often becomes worn-out, fatigued, or broken. Students should be familiar with the practice of lockout/tagout as covered by 1910.147 - The control of hazardous energy (lockout/tagout). If a piece of equipment is broken, or presents a hazard it should be de-energized and locked out to prevent possible injury to others who may attempt to use the equipment.

1910.132 - Personal protective equipment - general requirements.

"Protective equipment, including personal protective equipment for eyes, face, head, and extremities, protective clothing, respiratory devices, and protective shields and barriers, shall be provided, used, and maintained in a sanitary and reliable condition wherever it is necessary by reason of hazards of processes or environment, chemical hazards, radiological hazards, or mechanical irritants encountered in a manner capable of causing injury or impairment in the function of any part of the body through absorption, inhalation or physical contact."

1910.1200 - Hazard communication

This may be the most important and relevant OSHA regulation as pertains to the student engineering projects. Students and faculty need to be aware of the hazards. According to OSHA, "The purpose of this section is to ensure that the hazards of all chemicals produced or imported are evaluated, and that information concerning their hazards is transmitted to employers and employees. This transmittal of information is to be accomplished by means of comprehensive hazard communication programs, which are to include container labeling and other forms of warning, material safety data sheets and employee training." Work on the student projects sometimes involves solvents, paints, epoxies, hardeners, resins, and other potentially hazardous chemicals and materials. As was recommended in the project safety plan, MSDS sheets should be maintained in the student work areas and in the department office. Project members and faculty advisors should be made aware of any hazards associated with any chemicals or materials used. If something is a know hazard, people are more likely to take the steps necessary to protect themselves.

Conclusion

To the Department of Engineering Technology at Middle Tennessee State University the value of the student engineering projects is immeasurable. It provides an opportunity for hands-on learning and the application of classroom knowledge. They are also a great resource for positive public relations and student recruitment and retention. To shut down any or all projects due to a preventable accident would be a great loss. Safety must be an integral part of the student engineering projects.

The need for a safety program is obvious. The above outlined elements of a safety and health program are not perfect, and will not prevent every accident. Nothing can. It is, however, a good start to a process that should never stop improving. Safety is everyone's concern. No one wants a team member to get hurt, or worse. Having a written safety and health program will have many benefits. It will prevent and reduce incidents and accidents. It will give the teams an additional sense of team unity when they can count on their team members to be thinking about everyone's safety. Part of the safety plan may also be included in the design report that is required of each project at competition. The inclusion of safety considerations will likely lead to more points being awarded for the report. The most important benefit of all will be the safe and successful completion of every project.

This paper has also examined a few of the OSHA regulations relevant to the tasks undertaken by the students during the construction of their projects, but a question now arises. Are the OSHA regulations legally applicable to the student engineering projects? The answer is no. OSHA only covers workplaces, and the students are not employees. The OSHA regulations would be more applicable to providing a safe work environment for the faculty and staff. Does that mean the OSHA regulations are of no value to the student engineering projects? No. The relevant

OSHA regulations can be an excellent resource and tool for both the student engineers and faculty advisors, as an addition to a comprehensive safety plan. This will also benefit the students by introducing them to safety standards that they will likely encounter in industry. Safety is not a perfect science, accidents will still happen. But, the more tools and knowledge available, the easier it is to proactively prevent possible safety hazards. OSHA regulations should be incorporated into the safety program as a "best practices" resource for the student engineering projects at a university. For any university with student-led projects, the old adage, "safety first," should always apply.

Fig. 4 Team Leader John Winker with the 2005 MTSU Mini Baja.

Elements of an Effective Safety and Health Program. OSHA Voluntary Safety and Health Program Management Guidelines, 1989. <http://www.osha.gov/SLTC/safetyhealth/s-hprograms.ppt>

Foroudastan, S. & Anderton M., "Implementing a National Competition Design Project as a Capstone Course at MTSU" 2006 Proceeding of ASEE-SE conference.

Foroudastan, S. & Anderton M., "Undergraduate Research and Creative Activity at Middle Tennessee State University" ASEE Conference, 2006.

NIOSH Safety Checklist Program for Schools. Chapter 2: How to Establish an Effective Occupational Safety and Health and Environmental Safety Program. October 2003. < http://www.cdc.gov/niosh/docs/2004-101/chap2.html>

Occupational Safety & Health Administration. Regulations (Standards - 29 CFR). <http://www.osha.gov/pls/oshaweb/owasrch.search_form?p_doc_type=STANDARDS&p_toc_level=0&p_keyvalue=>

Pictures taken by Michael Anderton. November 2005.