

## **2006-294: A CHEMICAL ENGINEERING COMPETITION FOR MIDDLE AND HIGH SCHOOL STUDENTS**

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## A Chemical Engineering Competition for Middle and High School Students

Groups of engineering societies host many K-12 engineering competitions around the country. Typical contests are Rube-Goldberg tasks, robots, toothpick bridges, rubber band-powered cars, paper airplanes, and the Future City Competition<sup>1</sup>. These competitions rarely include an explicitly chemical engineering event. This lack is a missed chance at interesting students in careers in chemical engineering. A chemical engineering event for middle and high school students has been developed and implemented at the Tulsa Engineering Challenge<sup>2</sup> (TECh) in Spring 2005. This Chemical Switch Competition was inspired by the chemical stop switches used by many teams in the Chem-E-Car Competition run by the American Institute of Chemical Engineers.

The goal of the Chemical Switch Competition is to use a chemical reaction to break an electrical circuit 20 seconds after setup. Breaking the circuit before 20 seconds disqualifies the run. This forces the students to use reaction kinetics to find a reaction that is not instantaneous but also is not too slow. The electric circuit contains an LED that turns off when the circuit is broken to provide a visual cue to stop timing. Students attach their equipment to the circuit with alligator clips, and power for the LED is provided by a 9-volt battery. Entries that do not break the circuit within 5 minutes are given a second chance, and the judges break ties by deciding which team had the most fun during the competition. Prizes for 2005 were \$50, \$30, and \$20 for 1st, 2nd, and 3rd places, respectively, with middle school and high school students competing in separate divisions. Prizes in TECh are split 50/50 between the students and their classroom. The Tulsa local section of AIChE provided the prize money. These prizes were lower than the prizes in the other competitions at TECh and were raised to \$100, \$75, and \$50 for 2006. The students may compete either individually or as a team, with no upper limit on the size of the team.

The test circuit was designed and built by two University of Tulsa electrical engineering students as a project for one of their classes. Their circuit diagram is given in Figure 1, and a picture of the unit is given in Figure 2. The test circuit has an on/off switch and a green LED that indicates that the unit is on. This simple feature is very useful for determining that the unit is working correctly. The students attach their equipment to the circuit with the alligator clips. The test circuit contains a blue LED that is on when the circuit is completed through the alligator clips and the contest entry. When the student entry breaks the circuit, the blue LED turns off. A 9-volt battery powers the LEDs. A different colored LED could replace the blue LED to reduce power consumption. The materials for this test circuit can be purchased for less than \$25.

Safety is an important consideration. The contest rules included the following restrictions and instructions for safety:

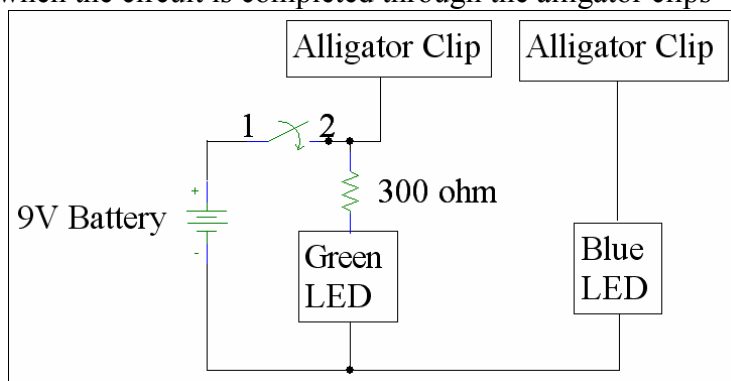


Figure 1. Circuit diagram of the testing unit.

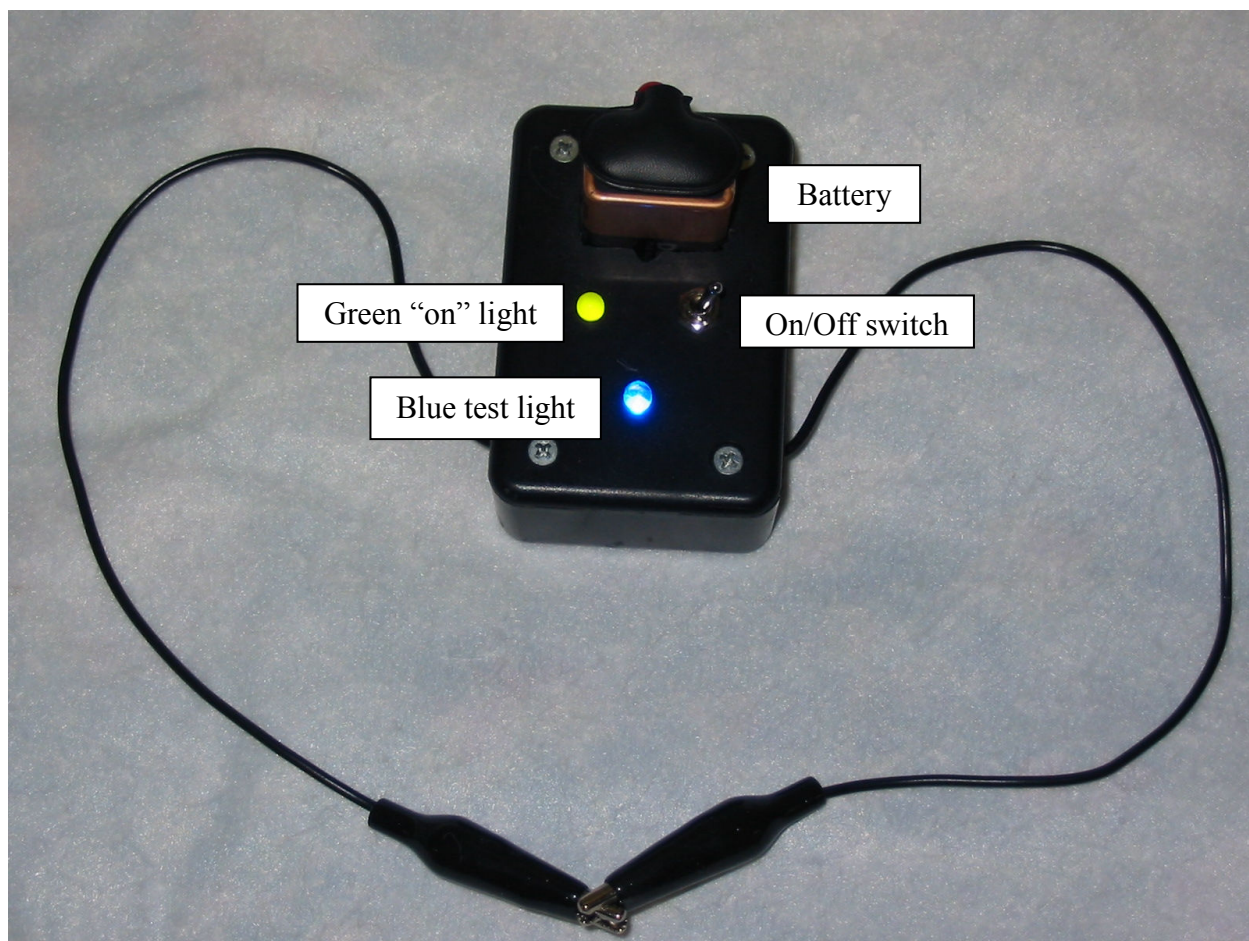


Figure 2. Picture of the test circuit

- The design must operate safely indoors: Open flames, smoke, and sprays are not allowed.
- Dilutions must be done before bringing chemicals to the site, since we had no fume hood available.
- Entrants must arrange for safe disposal of waste chemicals, although we did provide for collection and disposal of waste acids.
- The entry must leave no residue on the table or surrounding area.
- The light bulb may not be turned off by destroying it.
- The entry must fit on a table 2' by 6'.
- Students may bring no more than 250 mL of each chemical, which must be transported safely to the competition site.
- Chemical containers must be properly labeled with the name of the chemical, the concentration, the student's name, the school name, the teacher's name, and a phone number.
- Chemicals must be brought to the competition table immediately upon arrival and stored there until the team leaves.
- Appropriate gloves and safety goggles must be worn during the setup, operation, and takedown of the entry.

The judges have the final decision on whether the safety precautions have been followed. Designs that are deemed unsafe are disqualified from the competition.

The students are required to submit Design Documentation, as shown in Figure 3, with their entry. The design documentation is partly for the judges to assess the safety of the design but also for the team to let the judges know when to start timing.

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| <p style="text-align: center;"><b>2006 TULSA ENGINEERING CHALLENGE</b></p> <p style="text-align: center;"><b>DESIGN DOCUMENTATION</b></p> <p style="text-align: center;"><b>CHEMICAL SWITCH COMPETITION</b></p> <p><b>PLEASE TYPE OR PRINT CLEARLY AND LEGIBLY</b></p> <p>Name of school: _____</p> <p>School address, city, zip: _____</p> <p>_____</p> <p>Sponsoring teacher: _____</p> <p>Phone number: _____</p> <p>Name(s) of entrant(s): (1) _____</p> <p style="padding-left: 100px;">(2) _____</p> <p>Chemicals used (name, concentration, and amounts)</p> <p>_____</p> <p>_____</p> <p>Chemical switch mechanism: describe how the chemicals above are used to turn off the light bulb: _____</p> <p>_____</p> <p>Timing start point: The competition officials will start timing your entry at this designated point. This should be something like when you have shaken up your chemicals and set the entry down to react, or when you drop a wire into an acid bath, or start dripping a second reactant into the first.</p> <p>_____</p> <p>_____</p> |
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Figure 3. Design Documentation to be submitted with each entry.

This Proceedings paper is due before the 2006 Competition on March 16, so results from 2006 will be presented at the conference. As of one week before the competition, five teams are registered to compete. Only one team competed in 2005<sup>3</sup> because rules for the entire TECh were

published late, and the Chemical Switch Competition rules were later than the rest. To generate interest for future competitions, we brought chemicals for students to try on-site. The students had two choices of mechanisms. The first was to dip a wire completing the circuit into an acid, which would eat through the wire to break the circuit. The second was to use a gas-generating reaction to inflate a balloon, which would move a wire to break the circuit. After the students chose a mechanism, they chose their chemicals. We brought sulfuric, hydrochloric, and acetic acids in concentrations of 1 – 6 M. Copper, zinc, magnesium, and aluminum strips or wires were available, as well as magnesium and zinc turnings and baking soda. We provided gloves and safety glasses for the students, and they were allowed to do at least some of the pouring and assembly. Many students tried the reactions throughout the day, but not very many turned the circuit off after about 20 seconds. We intentionally supplied reaction combinations that would not work and let the students try them. Then we could talk with them about reaction kinetics and how they could choose a better reaction.

The University of Tulsa freshman chemical engineering class completed a similar project in Spring 2006. The freshman class had two rules different from those of the Chemical Switch Competition: they had to mechanically flip a switch to turn off the light and their goal was to flip the switch between 20 and 60 seconds, with the target time announced the day of the competition. The students produced six different designs:

1. A weight was tied to a string attached to a tethered magnesium strip. The magnesium strip was placed in hydrochloric acid. When enough magnesium reacted, the strip broke and the weight dropped and flipped the switch.
2. The second group used the same design as #1 but replaced the hydrochloric acid with sulfuric acid.
3. Another group used a design similar to #1 but replaced the string with a rubber band. They also dripped the acid onto the magnesium strip with a burette. They taped a protractor to the stopcock so they could repeat their valve positions.
4. The fourth group attached a syringe and a tube to the top of an Erlenmeyer flask. They used the syringe to inject hydrochloric acid into the flask, which already had magnesium turnings. The tube led to another syringe. The gas produced from the reaction pushed out the plunger on the second syringe and flipped the switch.
5. The next group replaced the second syringe of #4 with a solenoid valve.
6. The last group also used a weight mechanism. They supported the weight on a block of polystyrene foam held on nails in a beaker. They poured acetone in the beaker. When the polystyrene dissolved in the acetone, the weight dropped and flipped the switch.

The target time was 46 seconds. All of the teams eventually flipped the switch within two minutes. Design #1 won first place with 47.30 seconds, #4 was second at 47.90 seconds, and #3 was third at 50.59 seconds.

The freshman competition brought up potential problems. Will a team get a second chance if there is a technical problem? One team's switch was sticking, so their design worked but the switch did not move. We allowed them an extra run (and they greased the switch). For another team, the switch flipped but the light did not go out. We stopped the time when the switch was moved. Will a team with a design that does not include a chemical reaction (acetone and polystyrene) be allowed to compete? We allowed it for the freshman competition, and we would for the middle school division of the Chemical Switch Competition. We would not allow a high

school team to use a similar “reaction” unless they were able to convince us that they truly thought it was a chemical reaction.

The Chemical Switch Competition is a simple way for students who are being introduced to chemistry to extend those lessons to engineering. It requires the students to develop a way of using a chemical reaction to break a circuit, to choose an appropriate chemical reaction, and time the reaction's functioning. Very few engineering fairs include these chemical aspects in their competitions, and it is hoped that other locales will introduce this or a similar competition to their engineering fairs. Visit [www.tulsaengineer.org](http://www.tulsaengineer.org) for information on the Tulsa Engineering Challenge and the 2006 rules for the Chemical Switch Competition.

Acknowledgements: Chris Carpenter and Justin Smalling are the University of Tulsa electrical engineering majors who designed and built the test circuit.

#### Bibliography

1. Future City Competition: [www.futurecity.org](http://www.futurecity.org) (accessed March 8, 2006)
2. Tulsa Engineering Challenge: [www.tulsaengineer.org](http://www.tulsaengineer.org) (accessed March 8, 2006)
3. University of Tulsa Department of Chemical Engineering news article: [www.che.utulsa.edu/PhotoAlbum/TulsaEngineeringChallenge/TulsaEngineeringChallenge.htm](http://www.che.utulsa.edu/PhotoAlbum/TulsaEngineeringChallenge/TulsaEngineeringChallenge.htm) (accessed March 8, 2006)