The SAE Clean Snowmobile Challenge 2000 – Summary and Results

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ABSTRACT

In response to increasing concern about snowmobile noise and air pollution in environmentally sensitive areas, Teton County Wyoming Commissioner Bill Paddleford and environmental engineer Dr. Lori Fussell worked with The Society of Automotive Engineers (SAE) to form and organize a new intercollegiate design competition, the SAE Clean Snowmobile Challenge 2000 (CSC2000). Major sponsors of the CSC2000 included WestStart, Montana Department of Environmental Quality, Teton County Wyoming, SAE, United States Environmental Protection Agency, and Flagg Ranch Resort.

The goal of the CSC2000 was to develop a snowmobile with improved emission and noise characteristics that did not sacrifice performance. Modifications were expected to be cost effective and practical.

The CSC2000 was held in and around Jackson Hole, Wyoming from March 20 – 31, 2000. Participating universities competed against each other in the categories of emissions, fuel economy/range, noise, acceleration, handling, cold-start, hill climb, engineering design paper, oral presentation, and static display. Points were awarded to teams based on their performance in each of the events.

The University at Buffalo won the CSC2000 with a snowmobile featuring a four-stroke engine and catalytic aftertreatment. This first-place entry was successful at reducing noise and emissions while simultaneously improving fuel economy. However, it did experience some loss of performance capability.

The University of Waterloo took second place in the CSC2000 with a snowmobile featuring an advanced two-stroke engine and catalytic aftertreatment. The Waterloo entry significantly reduced emissions while simultaneously improving performance and fuel economy. However, noise from this entry did not meet competition standards.

INTRODUCTION

Snowmobiles provide hours of exhilarating winter fun for many outdoor enthusiasts. But these fun machines also present an ongoing environmental challenge in the form of excess exhaust emissions and high noise levels.

In an effort to find solutions to the emission and noise challenges presented by snowmobiles, Teton County Wyoming Commissioner Bill Paddleford and environmental engineer Dr. Lori Fussell worked with the SAE to form a new intercollegiate design competition, the Clean Snowmobile Challenge 2000 (CSC2000).

By bringing this new competition to engineering students in both the United States and Canada, CSC2000 organizers brought new energy, ideas, and enthusiasm to a much needed environmental/automotive engineering design problem. Students are quickly committed to making their designs succeed in ways that practicing engineers often fail, due to too many preconceived notions and opinions.

Much of the energy behind the organization of the CSC2000 came from within the community of Jackson Hole, Wyoming. A Jackson Hole-based Advisory Board made up of local land managers, businessmen, snowmobilers, and environmentalists assisted the SAE, Commissioner Paddleford, and Dr. Fussell with the development of the competition.
Major sponsors of the competition included WestStart, Montana Department of Environmental Quality, Teton County Wyoming, SAE, United States Environmental Protection Agency, and Flagg Ranch Resort. A complete list of all CSC2000 sponsors is located at the end of this paper.

The goals of the CSC2000 were:

- To give a hands-on, team-oriented experience to university students in both engine design and engine control and management systems design.
- To encourage the research and development of advanced snowmobile technology.
- To help facilitate a solution to the controversy surrounding snowmobile use in environmentally sensitive areas.
- To give snowmobilers, outfitters, land managers, government officials, and environmentalists the opportunity to work together to reach a common goal.
- To provide positive publicity opportunities for CSC2000 sponsors and the community surrounding Jackson Hole and Teton County.

COMPETITION OVERVIEW

OBJECT OF COMPETITION

The object of the CSC2000 was to develop a snowmobile that could be used to help solve the controversy surrounding snowmobile use in environmentally sensitive areas. The modified snowmobiles were expected to be quiet, emit significantly less unburned hydrocarbons (UHC) and carbon monoxide (CO) than conventional snowmobiles, and maintain or improve the performance characteristics of conventional snowmobiles. The modified snowmobiles were also expected to be cost-effective; so that snowmobile outfitters could afford to purchase them and still make a profit.

Although the modified snowmobiles competed in several performance events, the intent of the competition was to design a touring snowmobile that would primarily be ridden on groomed snowmobile trails. The use of unreliable, expensive solutions was strongly discouraged.

GENERAL RULES

Each participating university was given a used, 1998 Polaris Indy Trail for modification. This model of snowmobile features a 488 cc, fan-cooled engine and is representative of the type of snowmobile rented to tourists in the Greater Yellowstone Area. Donated snowmobiles had been ridden approximately 16,000 km (10,000 miles).

Students had just six months to make modifications to the engine, suspension, fuel management system, drivetrain, track, skis, and body. Major modification restrictions included:

- The snowmobile's tunnel had to remain stock. The bulkhead had to be commercially available.
- Two-stroke engines were limited to a displacement of 500 cc and four-stroke engines were limited to a displacement of 800 cc.
- Fuel choice was limited to premium gasoline, a blend of 90% gasoline and 10% ethanol, or electricity.
- Turbochargers were not permitted.
- The snowmobile had to remain track driven and ski steered.
- The snowmobile had to be propelled with a variable ratio belt transmission.
- Traction control devices were not allowed.

A complete listing of competition rules and restrictions are available in The Clean Snowmobile Challenge 2000 Rules (1).

COMPETITION EVENTS AND SCORING

Student teams in the CSC2000 competed in seven dynamic events and three static events. Dynamic events included emissions, fuel economy/range, noise, acceleration, handling, cold-start, and hill climb. Static events included engineering design paper, oral presentation, and static display.

A breakdown of the points that were available for each event is located in Table 1.

<table>
<thead>
<tr>
<th>Event</th>
<th>Penalty for Failing Event</th>
<th>Points Available for Relative Performance in Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emissions</td>
<td>-200</td>
<td>250</td>
</tr>
<tr>
<td>Fuel Economy</td>
<td>-100</td>
<td>100</td>
</tr>
<tr>
<td>Range</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noise</td>
<td>-100</td>
<td>150</td>
</tr>
<tr>
<td>Acceleration</td>
<td>N/A</td>
<td>100</td>
</tr>
<tr>
<td>Handling</td>
<td>N/A</td>
<td>50</td>
</tr>
<tr>
<td>Cold Start</td>
<td>-100</td>
<td>0</td>
</tr>
<tr>
<td>Hill Climb</td>
<td>N/A</td>
<td>100</td>
</tr>
<tr>
<td>Engineering</td>
<td>N/A</td>
<td>100</td>
</tr>
<tr>
<td>Design Paper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oral Presentation</td>
<td>N/A</td>
<td>100</td>
</tr>
<tr>
<td>Static Display</td>
<td>N/A</td>
<td>50</td>
</tr>
<tr>
<td>Total Points</td>
<td>-500</td>
<td>1000</td>
</tr>
</tbody>
</table>

(1) Numbers in parenthesis indicate references listed at the end of the paper.
COMPETITION ENTRIES

PARTICIPATING UNIVERSITIES

All collegiate chapters of the SAE were invited to submit a proposal to compete in the CSC2000. Seven universities from the United States and Canada were selected to participate. The selected universities were:

- Colorado State University
- Ecole de Technologie Superieure
- Colorado School of Mines
- Michigan Technological University
- University of Waterloo
- Minnesota State University, Mankato
- University at Buffalo, State University of New York

TECHNICAL DESCRIPTION OF ENTRIES

Essentially, three distinct approaches to meeting competition objectives were attempted by CSC2000 participants. They were:

1. A conventional two-stroke engine with improved fuel management and the addition of exhaust aftertreatment.
2. A two-stroke engine featuring direct injection and the addition of exhaust aftertreatment.
3. A four-stroke engine featuring electronic engine management and the addition of exhaust aftertreatment.

Of these strategies, there were originally two schools interested in four stroke solutions, three schools interested in pursuing two stroke direct injection solutions, and two schools interested in competing with a more highly controlled two-stroke engine.

However, due to limited development time and other unexpected obstacles, none of the schools interested in direct injection were able to compete with a direct injected two-stroke. Additionally, one of the schools interested in a four-stroke solution abandoned its initial approach. These four teams still competed in the CSC2000, but it is important to note that their entries were essentially put together in the month before the competition took place. They are not representative of the teams’ intended design strategy.

Detailed information on each team’s intended design strategy, challenges faced, and final results are available in the individual CSC2000 participants’ Engineering Design Papers (2-8).

A summary of the snowmobiles as they actually competed in the CSC2000, not as they were intended to compete, is included in Table 2.

EVENT DESCRIPTIONS AND RESULTS

EMISSION TEST

Carbon monoxide (CO) and unburned hydrocarbon (UHC) emissions were measured from all CSC2000 snowmobiles. Emission measurements were taken utilizing the Fuel Efficiency Automobile Test (FEAT) equipment developed at the University of Denver.

The FEAT is an infrared (IR) remote monitoring system for automobile CO and UHC exhaust emissions (9). Figure 1 shows a schematic diagram of the instrument.

Figure 1 Schematic Diagram of the FEAT

The instrument and techniques employed have been fully described in the literature and only a brief overview will be provided here (10,11). The FEAT instrument was designed to emulate the results one would obtain using a conventional non-dispersive infrared (NDIR) exhaust gas analyzer. Thus, FEAT is also based on NDIR principles. An IR source sends a horizontal beam of radiation across a single traffic lane, approximately 10 inches above the road surface. This beam is directed into the detector on the opposite side and divided between four individual detectors: CO, carbon dioxide, UHC, and reference. An optical filter that transmits infrared light of a wavelength known to be uniquely absorbed by the molecule of interest is placed in front of each detector, determining its specificity. Reduction in the signal caused by absorption of light by the molecules of interest reduces the voltage output. One way of conceptualizing the instrument is to imagine a typical garage-type NDIR instrument in which the separation of the IR source and detector is increased from 8 centimeters to 6-12 meters. Instead of pumping exhaust gas through a flow cell, a car now drives between the source and the detector.

The FEAT has been shown to give accurate readings for CO and UHC in double-blind studies of vehicles both on the road and on dynamoseters (12-14). Ashbaugh et al. (15) used a fully instrumented vehicle with tailpipe emissions controllable by the driver/passenger in a series of drive-by experiments with the vehicles emissions set for CO between 0-10% and between 0-
Table 2 Summary of CSC2000 Modification Strategies

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorado State University</td>
<td>Suzuki Spirit ZRT 600, sleeved to 500cc</td>
<td>Two stroke</td>
<td>Mechanical, lean setting</td>
<td>Carburetors</td>
<td>Liquid</td>
<td>Blend of 10% ethanol and 90% gasoline</td>
<td>Lean burn</td>
<td>Foam, ducting changes</td>
</tr>
<tr>
<td>Ecole de Technologie Superieure</td>
<td>Polaris 500 cc</td>
<td>Two stroke</td>
<td>Mechanical, lean setting</td>
<td>Carburetors</td>
<td>Liquid</td>
<td>Blend of 10% ethanol and 90% gasoline</td>
<td>Lean burn</td>
<td>Student built 3-expansion chamber exhaust system, non-sequential</td>
</tr>
<tr>
<td>Colorado School of Mines</td>
<td>Polaris 488 cc</td>
<td>Two stroke</td>
<td>DTA Engine control unit</td>
<td>Electronic fuel injection</td>
<td>Air</td>
<td>Blend of 10% ethanol and 90% gasoline</td>
<td>Catalyst, student designed electrostatic precipitator</td>
<td>Foam insulation, sound dampening devices</td>
</tr>
<tr>
<td>Michigan Technological University</td>
<td>Polaris 500cc Fuji (Note: finished competition with Polaris 440cc Fuji due to breakdown)</td>
<td>Two stroke</td>
<td>Mechanical</td>
<td>Carburetors</td>
<td>Liquid</td>
<td>Blend of 10% ethanol and 90% gasoline</td>
<td>Partial flow-through catalyst with secondary air injection</td>
<td>Modification to stock muffler, tunnel lined with sound barrier material, hood lined with Dynomat liner and sound absorbing foam, exhaust directed into track</td>
</tr>
<tr>
<td>University of Waterloo</td>
<td>Modified Polaris 500 cc</td>
<td>Two stroke</td>
<td>Mechanical, slightly lean setting</td>
<td>Carburetors</td>
<td>Liquid</td>
<td>Blend of 10% ethanol and 90% gasoline</td>
<td>Two way monolithic oxidation catalyst</td>
<td>Student designed silencer, insulation, standard air box design</td>
</tr>
<tr>
<td>Minnesota State University</td>
<td>Polaris 500 cc</td>
<td>Two stroke</td>
<td>MoTeC M48 electronic control unit</td>
<td>Electronic fuel injection</td>
<td>Liquid</td>
<td>Blend of 10% ethanol and 90% gasoline</td>
<td>Two-way monolithic oxidation catalyst with secondary air injection</td>
<td>Addition of a silencer, Polaris Edge air box, hood and side panel redesign, Dynomat hood liner</td>
</tr>
<tr>
<td>University at Buffalo</td>
<td>Polaris Sportsman 500 cc</td>
<td>Four stroke</td>
<td>Magneti Marelli electronic engine management system</td>
<td>Electronic fuel injection</td>
<td>Liquid</td>
<td>Premium gasoline</td>
<td>Close-coupled palladium only catalyst</td>
<td>Muffler, air box, reduction of metal to metal contacts, header wrap, sealed cowl lined with open cell foam</td>
</tr>
</tbody>
</table>

0.35% (propane) for UHC to confirm the accuracy of the on-road readings. The results are an accuracy of \( \pm 5\% \) for CO and \( \pm 15\% \) for UHC. Recently, the abilities to measure nitric oxide and exhaust opacity have been added (16).

The FEAT has been easily adapted for measurements of snowmobile exhaust emissions and has been successfully used to make two in-use surveys of snowmobile emissions in Yellowstone National Park in the winter of 1998 and 1999 (17, 18). The FEAT source and detector were placed on insulating pads on top of the snow. Snowmobile exhaust exits at the front of the sleds toward the ground, so the beam height was lowered to approximately 15 cm (6 in) above the snow. Sampling time was extended from 1/2 second for cars to a full second for snowmobiles. This allows additional time for the rear of the sled to clear the beam. To reduce snow spray a plastic artificial snow matte, approximately 1.2 m x 2.4 m (4 ft x 8 ft) in size, was laid on top of the snow directly under the path of the sensing beam. The video camera photographed the front cowling of each sled as it was measured for a permanent video record of the event. The support equipment was housed nearby in the University’s mobile home. The instrument was calibrated before and after each measurement period using a certified gas cylinder (Praxair, Danbury, CT.). Temperature, humidity and pressure were recorded for all of the measurement sessions.
In the CSC2000, the FEAT was used to measure CO and UHC emissions during two different modes of operation:

1. A gentle acceleration from 0 to 24 km/h (15 mph), to simulate a snowmobile pulling away from an entrance gate - This mode of testing took place at an altitude of approximately 2000 meters (6,600 feet) above sea level. Temperatures ranged from 4-9°C (40-49 °F). Relative humidity ranged from 47% and 55%. Wind speed was less than 1 m/s.

2. A climb up a gentle hill (3 to 4 percent grade) at a constant speed of 32 km/h (20 mph) - This mode of testing took place at an altitude of approximately 2,260 meters (7,400 feet) above sea level. Temperatures ranged from 4-7°C (39-44 °F). Relative humidity ranged from 48% and 57%. Wind speed was less than 1 m/s.

Professional drivers drove the snowmobiles during the emission tests. Ten measurements of each mode were taken for each snowmobile. The highest and lowest measurements for each mode were thrown out. The remaining sixteen measurements were averaged together to generate each snowmobile’s average CO and UHC emission in parts per million (ppm).

CSC2000 participants were expected to reduce the CO emissions of their original snowmobile by at least 25% and the UHC emissions of their original snowmobile by at least 50% to pass the event. Teams that did not meet these minimum reductions received 200 penalty points. Emission reductions were measured relative to a control snowmobile of the same make, model, and usage as the snowmobiles given to CSC2000 participants.

Up to 250 points were available to teams based upon their ability to simultaneously reduce CO and UHC emissions beyond competition minimums. Test results are summarized in Table 3.

The University at Buffalo achieved significant reductions in emissions with its four-stroke design. As indicated in Table 3, UHC emissions were below the limit of detectability of the CS2000 emission test procedure, a greater than 99.5% reduction. CO emissions were reduced by 46%.

Also achieving impressive results was the University of Waterloo. A 95% reduction in UHC emissions was achieved using an advanced two stroke engine with catalytic aftertreatment. CO emissions were reduced by 47%.

**FUEL ECONOMY/RANGE TEST**

All CSC2000 snowmobiles completed a trip in Yellowstone National Park that was 143 kilometers (89.5 miles) in length. Participants were required to maintain a speed equal to the legal speed limit. The required speed was occasionally reduced for safety in poor driving conditions.

Trail conditions were hard packed, groomed snow. The temperature during testing was approximately -4°C (25°F).

Snowmobiles began the trip full tanks. The amount of fuel required to fill the tank upon return was used to award points for this event.

A maximum of 100 points was available for the fuel economy/range event. Teams not completing the event were penalized 100 points. Individual team results for fuel economy/range event are listed Table 4.

<table>
<thead>
<tr>
<th>Participant</th>
<th>CO (ppm Propane)</th>
<th>CO (% Reduction)</th>
<th>UHC (ppm Propane)</th>
<th>UHC (% Reduction)</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorado State University</td>
<td>59,900</td>
<td>42%</td>
<td>22,800</td>
<td>-10%</td>
<td>-200</td>
</tr>
<tr>
<td>Ecole de Technologie Superiure</td>
<td>57,600</td>
<td>44%</td>
<td>23,500</td>
<td>-13%</td>
<td>-200</td>
</tr>
<tr>
<td>Colorado School of Mines</td>
<td>78,100</td>
<td>24%</td>
<td>4,600</td>
<td>78%</td>
<td>-200</td>
</tr>
<tr>
<td>Michigan Technological University</td>
<td>66,800</td>
<td>35%</td>
<td>24,500</td>
<td>-18%</td>
<td>-200</td>
</tr>
<tr>
<td>University of Waterloo</td>
<td>54,500</td>
<td>47%</td>
<td>1,000</td>
<td>95%</td>
<td>50</td>
</tr>
<tr>
<td>Minnesota State University</td>
<td>103,800</td>
<td>-1%</td>
<td>19,600</td>
<td>6%</td>
<td>-200</td>
</tr>
<tr>
<td>University at Buffalo</td>
<td>55,700</td>
<td>46%</td>
<td>-200*</td>
<td>&gt;99.5%</td>
<td>50</td>
</tr>
<tr>
<td>Control Snowmobile</td>
<td>103,100</td>
<td>N/A</td>
<td>20,800</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

* The negative hydrocarbon value indicates that University at Buffalo’s hydrocarbons are below the limit of detectability of this test procedure (approximately 100 ppm propane).
Results of particular interest were seen in both the University of Waterloo and University at Buffalo snowmobiles. The University of Waterloo increased fuel economy to 17.2 mpg and the University at Buffalo increased fuel economy to 27.6 mpg, when compared to the control snowmobile’s 12.2 mpg fuel economy. Therefore, the increased cost associated with these advanced snowmobile designs would be somewhat offset by their reduced fuel costs.

**NOISE TEST**

All CSC2000 snowmobiles were subjected to noise measurements intended to determine the maximum exterior sound level possible from the competing snowmobiles. Noise measuring equipment was located on the exhaust side of the snowmobile, 15 m (50 ft) from the road. The test layout was as specified in SAE J192 (19).

The noise level measurements were taken in conjunction with the acceleration event. This ensured that snowmobiles were operating at wide-open throttle and were making the maximum amount of noise. Two acceleration runs were made by each snowmobile. Each team’s noise level was recorded as the highest of the two noise measurements.

The instrument used for the testing was a Quest Technologies M2400, #JN4070101. The instrument was allowed to equilibrate to ambient temperature for the hour it took to set up the speed trap for the acceleration event. The instrument was calibrated using the calibrator supplied with the instrument, with appropriate corrections for ambient conditions.

The instrument was oriented vertically, with the microphone set 1.5 m (60 inches) above the hard snow surface. A windscreen was in place. Background noise was between 40 to 45 dBA.

The test track was set up near the Cathedral Group turnout in Grand Teton National Park. The snow surrounding the track was about three feet deep of hard pack, covered with ½ inches of light fluff. The elevation of the test site was 1920 meters (6295 feet) above sea level. The temperature during testing was approximately -4°C (25°F). The relative humidity was 62%. Wind speed ranged from 2.2-3.5 m/s (5-8 mph).

Snowmobiles louder than 74 dB measured on the A-weighted scale, 50 feet from the road failed the noise event and received 100 penalty points. Snowmobiles quieter than 74 dB were awarded up to 150 points, based upon their relative improvement. Results are presented in Table 4.

The University at Buffalo’s snowmobile achieved particularly impressive reductions in noise levels (66 dBA, at wide-open-throttle, 50 feet from the road). The noise emissions from this winning entry are comparable to the noise levels measured during a normal conversation over a banquet table. This shows that it is possible to achieve large reductions in the maximum exterior sound level of snowmobiles.

**ACCELERATION TEST**

The acceleration event was scored on the basis of elapsed time to 500 feet from a standing start. Student participants drove their own snowmobiles in this event. The event comprised the better of two runs.

CSC2000 acceleration testing took place at the Cathedral Group Turnout in Grand Teton National Park. Conditions were as described in the Noise Test Description.

### Table 4 Results of the Fuel Economy/Range Event, Noise Test, and Acceleration Test

<table>
<thead>
<tr>
<th>Participant</th>
<th>Fuel Economy (MPG)</th>
<th>Fuel Economy Points</th>
<th>Maximum Sound Level dBA</th>
<th>Noise Test Points</th>
<th>Best Acceleration (seconds)</th>
<th>Acceleration Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorado State University</td>
<td>9.7</td>
<td>3</td>
<td>83.4</td>
<td>-100</td>
<td>7.615</td>
<td>80</td>
</tr>
<tr>
<td>Ecole de Technologie Superieure</td>
<td>Did not finish (DNF)</td>
<td>-100</td>
<td>DNF</td>
<td>-100</td>
<td>27.971</td>
<td>0</td>
</tr>
<tr>
<td>Colorado School of Mines</td>
<td>DNF</td>
<td>-100</td>
<td>75.5</td>
<td>-100</td>
<td>8.277</td>
<td>51</td>
</tr>
<tr>
<td>Michigan Technological University</td>
<td>8.4</td>
<td>0</td>
<td>75.4</td>
<td>-100</td>
<td>7.286</td>
<td>97</td>
</tr>
<tr>
<td>University of Waterloo</td>
<td>17.2</td>
<td>32</td>
<td>78.3</td>
<td>-100</td>
<td>7.241</td>
<td>100</td>
</tr>
<tr>
<td>Minnesota State University</td>
<td>DNF</td>
<td>-100</td>
<td>73.0</td>
<td>18</td>
<td>8.594</td>
<td>39</td>
</tr>
<tr>
<td>University at Buffalo</td>
<td>27.6</td>
<td>100</td>
<td>66.8</td>
<td>150</td>
<td>10.025</td>
<td>0</td>
</tr>
<tr>
<td>Control Snowmobile</td>
<td>12.2</td>
<td>N/A</td>
<td>75</td>
<td>N/A</td>
<td>7.841</td>
<td>N/A</td>
</tr>
</tbody>
</table>
JACircuits timing equipment was used to measure the elapsed time from 0 to 500 feet for this event. This equipment measures elapsed time between two points using a pulsed infrared light beam at the start and finish line. The timing circuit was calibrated by Performance Timing Systems, to 0.001 seconds. The limit of resolution of the timing equipment was 0.001 seconds.

A maximum of 100 points was available for the acceleration event. Individual team results for the acceleration event are listed in Table 4.

The University of Waterloo won the acceleration event, improving the elapsed time to 500 feet from a standing start by almost 0.6 seconds (over the control). This is notable because this sled also reduced UHC emissions by 95% and CO emissions by 47%. Therefore, reduced emissions do not necessarily produce a reduction in performance.

HANDLING TEST

The handling capabilities of each modified snowmobile were evaluated by professional snow cross drivers. Drivers based their evaluation on the snowmobiles’ cornering, ride, engine response, braking, clutching, and overall performance.

A maximum of 50 points was available for the handling event. Individual team results for handling event are listed in Table 5.

COLD START TEST

Because cold starting is essential in a snowmobile, the CSC2000 cold start event was a penalty only event. CS2000 snowmobiles were cold-soaked overnight. Teams had exactly one minute to start their snowmobile. Snowmobiles that did not start within 60 seconds failed the cold start event and received 100 penalty points.

Snowmobiles that started within 60 seconds passed the event received zero points. Cold start testing took place at -6°C (22 °F).

Individual team results for the cold start event are listed in Table 5.

HILL CLIMB EVENT

All participants in the CSC2000 were required to compete in the World Championship Snowmobile Hill Climb. The hill climb event was scored based on elapsed time to climb a course up Snow King Mountain. The course was approximately 3000 feet long, had an average grade of 19 degrees (39%), and a maximum grade of 30 degrees (60%). Each team made two attempts at the climb. Professional snowmobile drivers rode the snowmobiles in this event.

The snow conditions at the World Championship Hill Climb were particularly challenging on the day CSC2000 teams participated. In fact, only a small percentage of the professional hill climb entries (which featured special hill climb tracks and traction control devices) reached the top of the course on the day CSC2000 teams competed.

All CSC2000 snowmobiles (except for Ecole de Technologie Superieure’s...which had broken down) made it just as far as the professionals that were bogging down. Additionally, Michigan Technological University’s snowmobile made it all the way to the top of the course. Individual team results for the hill climb event are listed in Table 5.

ENGINEERING DESIGN PAPER

This event required CSC2000 teams to write an engineering design paper describing their snowmobile modifications. Students were expected to explain why modifications were performed and document the results

<table>
<thead>
<tr>
<th>Participant</th>
<th>Handling Results</th>
<th>Cold Start Results</th>
<th>Hill Climb Results</th>
<th>Engineering Design Paper Results</th>
<th>Oral Design Presentation Results</th>
<th>Static Display Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorado State University</td>
<td>50</td>
<td>0, Pass</td>
<td>0, DNF</td>
<td>81</td>
<td>64</td>
<td>42</td>
</tr>
<tr>
<td>Ecole de Technologie Superieure</td>
<td>0, Did Not Finish (DNF)</td>
<td>-100, Fail</td>
<td>0, DNF</td>
<td>72</td>
<td>59</td>
<td>28</td>
</tr>
<tr>
<td>Colorado School of Mines</td>
<td>0</td>
<td>0, Pass</td>
<td>0, DNF</td>
<td>67</td>
<td>61</td>
<td>29</td>
</tr>
<tr>
<td>Michigan Technological University</td>
<td>0, DNF</td>
<td>0, Pass</td>
<td>100</td>
<td>45</td>
<td>44</td>
<td>30</td>
</tr>
<tr>
<td>University of Waterloo</td>
<td>32</td>
<td>0, Pass</td>
<td>0, DNF</td>
<td>84</td>
<td>66</td>
<td>38</td>
</tr>
<tr>
<td>Minnesota State University</td>
<td>42</td>
<td>-100, Fail</td>
<td>0, DNF</td>
<td>77</td>
<td>60</td>
<td>34</td>
</tr>
<tr>
<td>University at Buffalo</td>
<td>29</td>
<td>0, Pass</td>
<td>0, DNF</td>
<td>63</td>
<td>74</td>
<td>41</td>
</tr>
</tbody>
</table>
of their snowmobile development and testing. Students were also expected to include a detailed cost analysis of their modifications (including justification for any increased cost of the snowmobile). Finally, teams were expected to address the durability and practicality of any modifications.

CSC2000 engineering design papers were judged on content, organization, use of graphics, and references. A maximum of 100 points was available for the engineering design paper event. Individual team results for the engineering design paper event are listed in Table 5.

NOTE: University at Buffalo's paper was received two days late. Their engineering design paper score reflects a 20 point late penalty

ORAL PRESENTATION

Each CSC2000 team made a ten-minute oral presentation on the rationale and approach to their snowmobile modifications. A five-minute question and answer period followed each presentation.

In their presentation, teams were expected state clearly how their modified snowmobile addresses the needs of snowmobilers (performance), environmentalists/land managers (noise and emissions), and snowmobile tour operators (cost, durability/re-sale value).

CSC2000 oral presentations were judged on content, format, delivery, effectiveness of visual aids, and ability to answer judges' questions.

A maximum of 100 points was available for the oral presentation event. Individual team results for the oral presentation event are listed in Table 5.

STATIC DISPLAY

As part of the CSC2000, each team placed their snowmobile on display at the World Championship Hill Climb, held March 30th through April 2nd in Jackson Hole, Wyoming. Static displays were expected to focus on encouraging snowmobile outfitters to use the modified snowmobiles as part of their rental fleet and educating snowmobilers about the need to reduce noise and emissions from snowmobiles. Teams were encouraged to put up signs, hand out flyers, and use any other marketing techniques to attract attention to their prototype snowmobile.

CSC2000 static displays were judged on aesthetics, student knowledge, handouts/posters, and overall impression.

A maximum of 50 points was available for the static display event. Individual team results for the static display event are listed in Table 5.

PENALTIES ASSESSED DURING THE CSC2000

In addition to receiving penalties for failing individual events, CSC2000 participants received penalty points for arriving late at the competition, performing unscheduled maintenance on their snowmobile, and/or violating competition safety rules. The penalty points assessed during the CSC2000 are listed below:

- Colorado School of Mines, -50 points, late arrival
- Colorado School of Mines, -25 points, unscheduled maintenance
- Ecole de Technologie Superieure, -25 points, unscheduled maintenance
- Michigan Technological University, -25 points, unscheduled maintenance
- Minnesota State University, -25 points, unscheduled maintenance
- University at Buffalo, -25 points, unscheduled maintenance

SUMMARY OF COMPETITION WINNERS

The final standings of the participants in the CSC2000 are listed in Table 6.

Table 6 Final CSC2000 Standings

<table>
<thead>
<tr>
<th>Participant</th>
<th>Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>University at Buffalo</td>
<td>1st Place</td>
</tr>
<tr>
<td>University of Waterloo</td>
<td>2nd Place</td>
</tr>
<tr>
<td>Colorado State University</td>
<td>3rd Place</td>
</tr>
<tr>
<td>Michigan Technological University</td>
<td>4th Place</td>
</tr>
<tr>
<td>Minnesota State University</td>
<td>5th Place</td>
</tr>
<tr>
<td>Colorado School of Mines</td>
<td>6th Place</td>
</tr>
<tr>
<td>Ecole de Technologie Superieure</td>
<td>7th Place</td>
</tr>
</tbody>
</table>

In addition to awards for final overall standing, several category awards were presented to CSC2000 competitors. They are listed below.

- Best Emissions: University at Buffalo, SUNY
- Best Fuel Economy: University at Buffalo, SUNY
- Quietest Snowmobile: University at Buffalo, SUNY
- Best Design: University at Buffalo, SUNY
- Best Performance: Michigan Technological University
- Best Wreck: Colorado State University
- Phoenix Rising Award: Colorado School of Mines
CONCLUSION

Through the CSC2000, a first step has been taken to solve the noise and emission challenges presented by snowmobiles. Although many CSC2000 participants would have benefited from additional development time, the results from the first year of the Clean Snowmobile Challenge Collegiate Design Series clearly demonstrate that the noise and emission problems associated with traditional snowmobiles can be solved through advances in engine, noise control, and emission control technology.

Using a four-stroke engine and catalytic aftertreatment, the University at Buffalo (UB) was successful at reducing CO emissions by 46% and UHC emissions by more than 99.5%. The UB snowmobile’s maximum exterior sound level was reduced to conversational levels (66 dBA), 50 feet from the road. Additionally, the fuel economy of the UB snowmobile was increased to 27.6 miles per gallon. The only weakness in the UB snowmobile was its acceleration performance, which was decreased by approximately 25%.

The University of Waterloo (UW) entry proved that advanced two-stroke engines show promise as well. The UW snowmobile featured an advanced two-stroke engine with catalytic aftertreatment. The UW snowmobile’s CO emissions were reduced by 47% and UHC emissions were reduced by 95%. The fuel economy of the UW snowmobile was increased by 41%, to 17.2 miles per gallon. Additionally, its acceleration performance was 0.6 seconds faster than the control snowmobile. This design, however, was unsuccessful at meeting the stringent CSC2000 noise requirements. Therefore, noise reduction from advanced two-stroke engines remains an issue requiring further research.

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The authors would like to acknowledge the following individuals for their dedication to the development of the CSC2000: Teton County Commissioner Bill Paddleford, Mrs. Lisa Paddleford, Dr. Jerry Fussell, Mr. Robert Sechler, the CSC2000 Rules Committee, and the CSC2000 Advisory Board.

Finally, we express our appreciation to the faculty and students of our participating universities. You accomplished so much in such a short amount of time. We are grateful for your dedication and innovation.

REFERENCES


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