



Development and Demonstration of Using E85 in Snowmobiles

Prepared by:

A handwritten signature in black ink, appearing to read "Greg W. Davis".

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A. Management Summary:

Kettering University has a long history of developing vehicles and engines for use with alternative fuels. We have already developed both on-road and off-road vehicles that are capable of operation using high-blend ethanol (E85) fuel. In this research project, Kettering University continued to develop, document, and to increase the awareness of the viability and benefits of using ethanol blended fuels. Kettering University was able to educate both the general public and the future transportation engineers about the potential benefits of using biomass-derived fuels. This increased awareness will help to expand the markets for ethanol by stimulating interest in the fuel from the consumer, and by helping engineers to overcome reluctance to designate equipment for use with ethanol.

B. Statement of Problem:

Non-renewable sources of energy, such as oil and natural gas, supply the vast majority of Michigan's energy requirements. The demonstration of the benefits and use of ethanol blended fuels, specifically E85, can help to generate interest in the use of this fuel. Since ethanol is derived from renewable biomass resources, primarily corn, its use will help to generate more income for our farmers.

Aside from the economic benefits, the use of E85 is good for the environment. Ethanol is an oxygenated compound, which, when blended with petroleum-based fuel, will aid in combustion, significantly reducing carbon monoxide (CO), particulate matter (PM), and total unburned hydrocarbon (THC or HC) emissions, with only slight increases in emissions of oxides of nitrogen (NO_x).

Michigan alone has over 278,000 registered snowmobiles.¹ The potential impact provided by snowmobiles operating on ethanol blend fuels is tremendous. As mentioned below, the emissions level reductions on individual snowmobiles are substantial. Further, preliminary estimates of fuel usage (based upon published data^{1,2}) indicate that snowmobiles in Michigan alone use over 33 million gallons of fuel per year. If all of these machines were using E10, over 330,000 gallons of ethanol would be used, and if they were using E-85, over 2.8 million gallons would be used.

An extremely important area that would benefit from the use of ethanol fuels is the Pictured Rocks National Lakeshore. This national park has the fourth highest level of snowmobile use in the nation. Over 26,190 snowmobiles used the park during 1998-1999.² Based upon estimates made for Yellowstone N. P., this translates into over 288,000 gallons of fuel usage per year by snowmobiles in Pictured Rocks N. P.² If these machines were to use E-10, over 28,000 gallons of ethanol would be used. Even better, if they were to use E-85, over 244,000 gallons of ethanol would be used. This would provide a substantial improvement in park air quality.

¹ Michigan Snowmobile Association, Grand Rapids MI, 800/246-0260.

² "Air Quality Concerns Related to Snowmobile Usage in National Parks," U. S. Dept. of the Interior, National Park Service Air Resources Division, 2000.

Unfortunately, our experience shows that many snowmobilers are afraid to use anything other than straight gasoline (and oil) in their machines. Snowmobilers need to be made aware of the emissions benefits that can be achieved using ethanol. Further, they need to learn that they may well already use E10 in their snowmobiles with no problems! Finally, transportation engineers, too, have shown some reluctance to certify products for use with ethanol. Kettering University will educate this audience, too, in the benefits and challenges when using high-blend ethanol.

C. Accomplishments

Kettering University actively pursued the following objectives:

1. **Develop a Snowmobile Operating On E-85 For Use In The 2008 Clean Snowmobile Challenge (CSC2008).**

This event was held during March 10-15, 2008 in Houghton, Michigan and is organized by the Society of Automotive Engineers. The goal of this challenge is to design a snowmobile with reduced emissions and noise characteristics that also equals or improves upon the performance of current snowmobiles.



The students of Kettering University developed and demonstrated their E85 Clean Snowmobile At this year's competition. The team successfully completed the competition, finishing in seventh place overall. Unfortunately, the team suffered a sensor failure during the emissions event leading to a lower than expected result. After returning to Kettering University, the sensor issue was remedied and the emissions test was repeated with much better results. These results, shown below, would have placed the team in first or second place overall!



Figure 1 Competing in the Handling Event

Testing revealed that the snowmobile provided substantial emissions reductions as compared to a snowmobile operating at the 2012 standard. This data is shown in Figure 2. Emissions from other snowmobiles are shown for comparison. A typical 2001 production two-stroke

snowmobile operating on gasoline was used as the control (2001 Control). Notice that this snowmobile does not meet 2012 emissions standards. The 2004 and 2005 control snowmobiles represented early industry efforts using four-stroke engines while operating on gasoline. Kettering University 2006-2008 snowmobiles were all operated using E85 fuel.

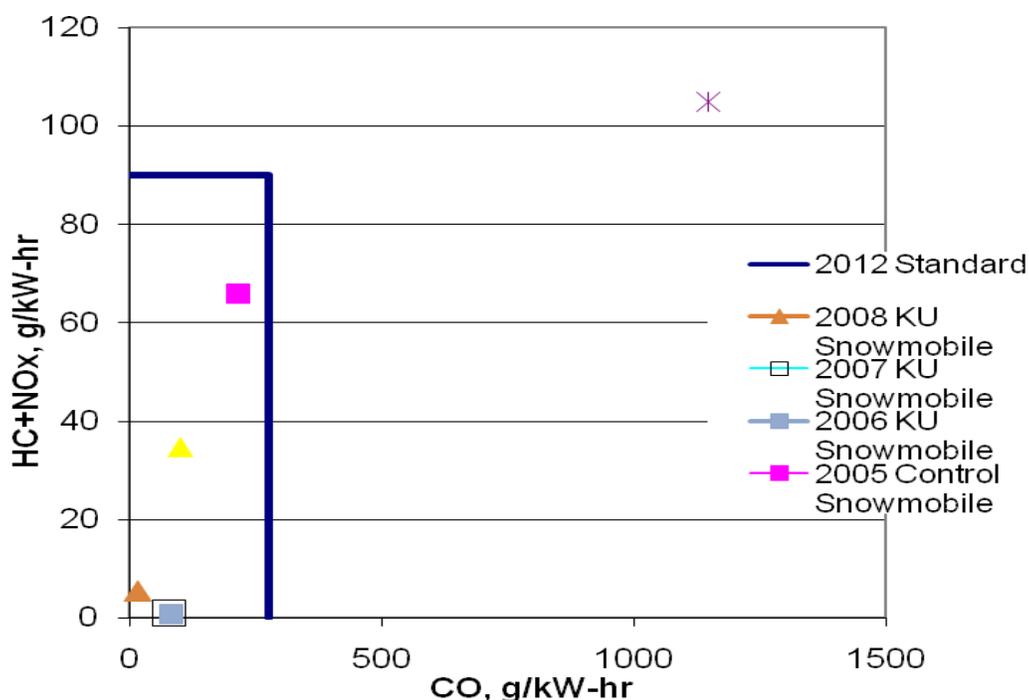


Figure 2 Emissions Results of Various Snowmobiles

Specifically, the 2008 Kettering University snowmobile emissions are shown in Table 1. The snowmobile achieved a reduction of approximately 94% when compared to snowmobiles operating at the 2012 standard.

Table 1 Comparison of 2008 Snowmobile with 2012 Standard

Snowmobile/Std	CO, g/kW-hr	HC+NOx, g/kW-hr
2012 Standard	275	90
2008 KU Snowmobile	17	5
% Reduction	94%	94%

Impact

The impact of the Clean Snowmobile Challenge on the industry and society is large. For example, during the earlier days of the competition, there was very little industry support-in fact, much criticism. Further, there were NO commercially available four-stroke snowmobiles. A four-stroke snowmobile is typically at least 75% cleaner and much quieter than its two-stroke counterpart. Today, representatives from each of the major snowmobile manufacturers and the International Snowmobile Manufacturers Association attend, and in many cases, help with the competition in design judging, etc. Further, other industry partners have also taken note including Horiba Instruments (the largest maker of emissions testing equipment), and Lotus Engineering (a major automotive design and engineering firm), and Caterpillar Corporation (a major off-road equipment manufacturer). These partners, too, support the competition and many

of the teams. Today, all major manufacturers have at least one four-stroke engine model in their snowmobile lineup.

Back in 2002, we were selected by the competition to undergo additional emissions testing at Southwest Research Institute (SwRI), the premier private testing laboratory for emissions testing, located in San Antonio, TX. This testing resulted in an SAE publication on emissions potential that is widely regarded as having helped the snowmobile manufacturers to move forward with cleaner designs.

The organizer of the clean snowmobile competition has worked directly with members of SwRI to develop the SAE Noise testing standard for snowmobiles, which has been adopted and is now part of the EPA requirements. Data used in developing this standard came from the results of the clean snowmobile challenges.

Finally, during 1999, Kettering University began development of our first clean snowmobile using a small automobile engine with a turbocharger. This was the first demonstrated use of a turbocharger for a trail sled using a four-stroke engine. This was widely promoted and documented, resulting in a closer working relationship between Yamaha and Kettering University. Turbochargers are now available for most of the four-stroke snowmobiles.

Today, there are still no commercially available snowmobiles operating on E85. Kettering University through its many displays and in conjunction with the clean snowmobile challenge hopes to, once again, lead the way by demonstrating the benefits of using this fuel, and demonstrating the technical requirements necessary to make this happen.

Deliverable

This task resulted in the completion of the clean snowmobile for use in the competition while operating on E85. The team will also competed and displayed the snowmobile at the competition and the community of Houghton, MI.

2. Display the Snowmobile at the 2007 Snowmobile Expo

The 2007-08 Clean Snowmobile Challenge team secured a booth and displayed this vehicle at the 2008 Snowmobile Expo held in Novi Michigan, Nov. 2-4, 2007. This event is held in the Rock Financial Showplace, a 220,000 sq. ft. indoor exhibit space. This is the largest snowmobile show in the world! Crowds were large and many people had questions about the snowmobile and the use of ethanol. Over 15,000 people attended the show and our booth workers estimate that between 1,000 to 2,000 people visited our booth.

Many operators were unaware that they, most likely, had already used E10 in their snowmobiles with no ill effects! It seems that many snowmobilers are concerned about trying new fuels! Many were glad to know that ethanol does not hurt their machines. Further, many people were aware of the benefits of ethanol regarding emissions and, especially, the nation's reliance on foreign oil.



Figure 3 Kettering University Booth at the 2007 Snowmobile USA Show

Deliverable

This task resulted in the successful display of the clean snowmobile at the Expo. Additionally, we educated attendees through posters and handouts, and direct communication.

3. Other Vehicle Displays and Presentations

Finally, Kettering University continued to display the snowmobile and provide promotional literature at community events, such as the AgExpo, in order to attract attention to ethanol and to educate the public about the real benefits of using ethanol in transportation.

Kettering University displayed the snowmobile and provided promotional literature at many other community events, such as the Earth Day in Ann Arbor, Michigan Technological University Community Displays, Society of Engineers (SAE) & Engineering Society of Detroit Foundation Banquet held at the GM Wintergarden, Detroit, SAE World Congress and Exposition, Detroit, and Ethanol Night at Dixie Speedway. Additionally, the team was featured on many local television news broadcasts and is a regular stop on all University tours.



Figure 4 Team Display at the Keewanaw Mall in Houghton/Hancock MI



Figure 5 Team Leader Jason Sanger, Giving a Talk to Keewanaw Area Elementary and Middle School Children



Figure 6 Team Display at Ethanol Night, Dixie Speedway



Figure 7 Captain Cornelius Trying Out the E85 Clean Snowmobile



Figure 8 Kettering University Display SAE Foundation Banquet Held in GMs World Headquarters, Detroit, MI.



Figure 9 Kettering University Students Promoting the Clean Snowmobile and E85.

Deliverable

Kettering University prepared, setup and displayed the clean snowmobile at various community events.

4. Disseminate project results in Technical papers and presentations.

The results of this project were documented in a technical paper for SAE. The paper, entitled “Development of Clean Snowmobile Technology for Operation on High-Blend Ethanol for the 2008 Clean Snowmobile Challenge,” is published as paper number 2008-32-0053. Further this

paper was presented at the SAE Small Engine Technology Conference held in Milwaukee WI, from Sep, 9-11, 2008.

SAE is the world's largest professional organization dedicated to transportation. As stated on the website: "SAE members design, manufacture, test, market, and maintain self-propelled land, sea, air, and space vehicles, their components and systems. Engineers from every technical discipline and the professionals who work closely with them improve vehicle efficiency, performance, reliability, and safety. Many SAE members are leaders in the field who serve as key resources for the engineering community." Further, SAE has a total membership of nearly 90,000 engineers, business executives, educators, and students from more than 97 countries. These members share information and exchange ideas for advancing the engineering of mobility systems.



Figure 10 Kettering University Presentation at the SAE Small Engine Technology Conference.

Additionally, many Universities have subscriptions receiving either electronic access, Microfiche, or hard copies of all SAE Technical papers. This means that an additional audience of future engineers will be able to reference this material at no charge through their respective Universities. These Universities include schools such as Kettering University, U. of Michigan, Michigan State University, Michigan Technological University, Lawrence Technological University, West Virginia University, University of Maryland, Rochester Institute of Technology, U. of Wisconsin, etc.

Deliverable

This task resulted in the completion of an SAE Technical publication. Further, this work was presented at an SAE technical meeting.

D. Acknowledgements

This project could not have been completed without the dedicated efforts of many people, some of these are acknowledged below:

Mr. Ray Rust and Mr. Clint Lee, Senior Mechanical Engineering Technicians,

Kettering University Clean Snowmobile Team. The CSC team, consisting of approximately 20-30 students.

Attachments

Kettering University Clean Snowmobile Challenge Team History of Success



First Place Finish in Static Display
Second Place Finish in Emissions Event
Third Place Finish in Noise Event

2002 First Place Finish Overall (tie)
Demonstrated Operation Using E85 at Southwest Research Institute
Most Practical
Best Value
Quietest Snowmobile

2001 Second Place Finish Overall
Best Design
Quietest Snowmobile

2008 Seventh Place Overall

2007 Second Place Finish Overall (tie)
Third Place Finish in Performance Events
Third Place Finish in Design
Third Place Finish in Best Value

2006 Second Place Finish Overall (tie)
Only Team Using E85 Fuel
Third Place Finish in Performance Events
Second Place in Design
Third Place in the Emissions Event

2005 Fifth Place Finish Overall
Second Place Finish in Fuel Economy
Second Place Finish in the Design Paper

2004 Seventh Place Finish Overall
Second Place Finish in Noise Event
Second Place Finish in Acceleration Event

2003 Third Place Finish Overall
Most Practical