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The 1990 SAE Methanol Challenge:

Summary of a Successful Student Design Competition

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ABSTRACT

A follow-up to the 1989 Society of Automotive Engineers (SAE) Methanol Marathon called the Methanol Challenge was held in April 1990. One of a series of engineering student competitions using alternative fuels organized and conducted by the Center for Transportation Research at Argonne National Laboratory, the Methanol Challenge pushed the technology for dedicated M85 (85% methanol, 15% hydrocarbon fuel) methanol passenger cars to new levels. The event included complete federal exhaust emissions, cold-start and driveability, performance, and fuel economy testing. Twelve teams of student engineers from the United States and Canada competed in the Challenge using Chevrolet Corsicas donated by General Motors (GM) to the schools. The winning car, from the University of Tennessee, simultaneously demonstrated extremely low emissions, dramatically increased performance, and significantly improved fuel economy. The success of the Methanol Challenge showed that student competitions produce a valuable educational experience, develop and demonstrate advanced technology, and provide an excellent way for industry and governmental sponsors to work together to benefit engineering education and other common goals.

BACKGROUND

The 1990 Society of Automotive Engineers (SAE) Methanol Challenge was a three-day alternative fuels competition for students open only to the universities that competed in the 1989 SAE Methanol Marathon. Teams of college and university engineering students were challenged to refine the conversion of 1988 Chevrolet Corsicas to dedicated M85 (85% methanol, 15% hydrocarbon fuel) operation and test their performance against numerous benchmarks and against the similar efforts of other teams of student engineers. The events comprising the Methanol Challenge were held April 6-8, 1990, in southern Ontario, Canada, and in southeast Michigan. Table 1 shows the milestones that culminated in the Challenge.

In the 1989 SAE Methanol Marathon, the forerunner to the Methanol Challenge, teams of student engineers from 15 colleges and universities were chosen from proposals submitted in response to a solicitation sent out to all accredited engineering programs in the United States and Canada. Teams were given production 1988 Chevrolet Corsicas to convert to operate on M85. Twelve of these same teams competed in the 1990 version of this event.

TABLE 1 Milestones Culminating in the 1990 Methanol Challenge

Event	Date
Rules released	10/12/89
Schools commit to compete	10/27/89
Grants to schools	2/01/90
Cars arrive at EPA in Ann Arbor, Mich.	3/12/90
Written reports due to SAE	3/16/90
Cars transported to Esso Facility, Sarnia, Ontario	3/30/90
Methanol Challenge Event	4/6-8/90

The Methanol Challenge was designed to further challenge the student teams by establishing more stringent and controlled tests of their conversions. Full Federal Test Procedure (FTP) emissions testing was conducted, along with a -20°F cold-start test. A carefully controlled endurance event was planned to measure fuel economy and reliability at various speeds under identical conditions. Over-the-road fuel economy was measured by using a road rally format to control speed and distance. Finally, vehicle performance was measured using a 0- to 500-ft acceleration test coupled with a maneuverability course that measured transient vehicle and engine response.

An important addition to the Methanol Challenge was the inclusion of a gasoline-powered control vehicle that provided a baseline from which to judge the effectiveness of the conversions. The organizers were very fortunate to have a control vehicle similar to the converted vehicles donated to the event. One of the students from the Methanol Marathon, Martin Smith, had purchased a 1989 Corsica with equipment identical to that of the competition cars after his graduation from Concordia University. Martin most graciously offered his car as the control vehicle. Martin's car participated in all the events, including the emissions and cold-start testing.

The U.S. Department of Energy (DOE), U.S. Environmental Protection Agency (EPA), Energy, Mines and Resources of Canada (EMR), the SAE, and General Motors Corporation (GM) were the Methanol Challenge's principal sponsors. The Center for Transportation Research at Argonne National Laboratory organized and administered the competition. Argonne also recruited United Parcel Service, Goodyear Tire and Rubber Company, Air Products and Chemicals Corporation, BP Oil, Detroit Diesel Corporation, Canadian Oxygenated Fuels Association, AC Rochester, Esso Petroleum-Canada, Michigan International Speedway, and the Sports Car Club of America as associate sponsors of the event.

Schools that participated in the 1990 SAE Methanol Challenge were:

California State University - Northridge
Concordia University
Florida Institute of Technology
University of Maryland
University of Michigan
New York Institute of Technology
Pennsylvania State University
Rochester Institute of Technology
University of Tennessee
Texas Technical University
Washington University (St. Louis, MO)
University of West Virginia

These twelve schools worked on their Corsicas, donated at the end of the Methanol Marathon to each school by GM, to meet the more difficult emissions and cold-start requirements of this year's competition. Schools were responsible for providing insurance for their vehicles, their traveling and housing expenses, and for transporting their vehicles back to their campuses.

The basic rules governing the Methanol Marathon were retained for the Methanol

Challenge, although new events were added and scoring was reformulated. The changes increased the emphasis on fuel economy, emissions, and cold starting. The specific events are detailed in this paper.

STRUCTURE AND OPERATION OF THE EVENT

The schedule for the SAE Methanol Challenge is shown in Table 2. The rules for the Methanol Challenge were similar to those used for the Methanol Marathon. The scoring system (Table 3) was revised to put more emphasis on fuel economy and performance in an FTP test

TABLE 2 Schedule for the 1990 SAE Methanol Challenge

Date	Location	Events
3/12	Ann Arbor, Mich.	Emissions tests begin
3/28	Sarnia, Ontario	Cold-start tests begin
4/6	Sarnia, Ontario	Methanol Challenge begins 8:00-12:00 oral presentations/car inspections 11:00 Road rally
	Flint, Mich.	2:00 Break at Buick City
	Ann Arbor, Mich.	6:30 Arrive at EPA
4/7	Brooklyn, Mich.	7:00-10:00 45-mph endurance 10:00-10:45 Refuel 10:45-1:15 55-mph endurance 1:15-2:00 Refuel 2:00-4:00 65-mph endurance 4:00-4:45 Refuel
4/8	Milford, Mich.	7:00-8:30 Cold start 8:45-12:00 Accel. 7:30 Awards Banquet

TABLE 3 Methanol Challange Scoring Schedule

Event	Points
Fuel Economy Events	
EPA Test (from FTP; 55% city and 45% highway)	125
Endurance Event	250
Rally Fuel Economy	125
Emissions Event	500
Cold Start Event	150
Cold Driveability Event	100
Maneuverability Event	50
Rally Performance	50
Written Paper	100
Oral Presentation	50
Total	1500

that measured the emissions of the cars. This event was given a full one-third of the score (500 out of 1500 possible points). Prior to the beginning of the event, all of the competing cars were delivered to the EPA Vehicle Emissions Laboratory in Ann Arbor, Michigan, where they underwent complete FTP emissions tests. Aldehydes were also measured and scored along with HC, CO, and NO_X. The cars were required to achieve the U.S. federal exhaust emissions standards for production gasoline vehicles or face penalties. Up to 500 points could be earned by reducing the amount of pollutants in their vehicle's exhaust according to a series of brackets of reduced emissions levels. City, highway, and combined fuel economy were also measured from the FTP test.

From the Ann Arbor, Michigan, EPA laboratory, the cars were shipped to the Esso Research Facility in Sarnia, Ontario (Figure 1). Because of the problem methanol presents in cold starting, all of the vehicles were soaked overnight at -20°F at Esso. Vehicles were then required to start within 10 s and continue to run (while stationary) without driver intervention for

FIGURE 1 The Methanol Challenge began at the Esso Research Center in Sarnia, Ontario, Canada

five minutes. No extra time was allowed beyond the initial 10 s in order to allow for special features to operate.

The teams arrived at Sarnia on April 5. On the morning of April 6, Esso hosted a ceremony to launch the event. Speakers included:

Dr. Norman Sather
Director, Energy Systems Division
Argonne National Laboratory

Dr. William Cottingham, President
GMI Engineering and Management Institute and Chair, SAE Engineering Education Board

Ray Colledge
Canadian Oxygenated Fuels Association

Stu Walker, Executive Vice President
Esso Petroleum Canada

Honorable Jake Epp, Minister of Energy, Mines and Resources, Canada

Because successful engineers also must have the ability to effectively communicate their ideas, each team was required to submit a written paper describing their conversion approach. In addition, each team had to make a 20-min oral presentation describing their conversion to a panel of automotive experts. A panel of judges also inspected and evaluated the cars.

Oral presentations and conversion judging were also done at Sarnia prior to the start of a 200-mile time-speed-distance road rally to Ann Arbor, Michigan (Figure 2). This form of competition requires the cars to maintain exact average speeds over public roads and arrive at checkpoints along the way. At checkpoints, teams were penalized for being either early or late. In this way, the route and average speeds that the cars were driven could be controlled. The rally route was designed to emulate a mix of urban and rural driving speeds and conditions. Fuel economy was measured during this event to provide data on over-the-road fuel consumption. The rally stopped for two hours in Flint, Michigan, where Buick and AC Rochester hosted lunch and toured the teams through the engineering facility.

Perhaps the most demanding fuel economy event was a nine-hour endurance run

FIGURE 2 The road rally measured fuel economy over a variety of roads and speeds.

at Michigan International Speedway (MIS) on April 7 (Figure 3). The teams were required to maintain average speeds of 45 mph for three hours, 55 mph for two and one-half hours, and 65 mph for two hours, or about 125 miles for each speed. Lap times were monitored to insure that the required speed was maintained; penalties would be assessed for any deviation from that speed. Passing was not allowed. BP Oil refueled cars between each speed run. This procedure provided a very good controlled test of fuel mileage between the vehicles and at the various speeds. Goodyear hosted lunch and opened up their pit-side hospitality suite for use by the teams, timers, and administrators. GM displayed a few engineering prototypes for the interest of the nondriving team members. GM also provided speakers who talked to the nondriving team members about GM's ongoing employee education programs. Goodyear supplied jackets as prizes for a "creeper race" that entertained nondriving and off-shift students.

On the last day of the competition, a modified GM Unified Test Standard (GMUTS) cold-start and driveability test was administered at ambient temperatures at the GM Proving Grounds in Milford, Michigan. This event not only evaluated the cold starting, but it also evaluated

FIGURE 3 The Endurance Event was held at the Michigan International Speedway.

drive-away and warm-up driveability. The temperature at Milford for this test was in the high 30°F range.

At Milford, the student teams ran a low-speed maneuverability test to insure that modifications had not interfered with vehicle handling. The first 500 ft of the maneuverability course was used as an acceleration test to determine that all vehicles were capable of covering 500 ft from a standing start in 9.5 s. The 9.5-s target was established as a minimum performance level so that an acceptable acceleration capability would be a part of the student's conversion approach. Penalties for slower acceleration and bonus points for faster acceleration were factored into the rules. GM also performed an exhaust sound test at Milford; vehicles were not allowed to exceed federal exhaust noise standards. While at Milford, GM hosted a continental breakfast at a tent erected near the maneuverability course site. Teams were treated to tours of the entire facility, after which GM hosted lunch.

United Parcel Service provided a victory banquet at the end of the event. One of the principal speakers was William Rosenberg, Assistant Administrator for Air & Radiation, U.S. Environmental Protection Agency, who spoke of the Clean Air Act issues and considerations. Mr. Rosenberg stressed the importance of reducing emissions and the part that alternative fuels can play in reducing emissions. The second principal speaker was J. Michael Davis, Assistant Secretary for Conservation & Renewable Energy, U.S. Department of Energy. Mr. Davis spoke of the need for increased energy efficiency as well as reduced environmental impacts. He expressed a need for increasing and diversifying our supplies of energy and emphasized that several alternative fuels merit consideration. The choice of an appropriate alternative fuel might differ on the basis of geography and application. Both speakers were impressed with the quality and the magnitude of the technological contributions that the students made to automotive engineering.

M85 CONVERSION APPROACHES

A number of common components facilitated the student's conversion of their vehicles. The increased chemical activity of fuel methanol was handled through the use of a GM-provided conversion kit consisting of corrosion-resistant fuel-system components and higher-capacity fuel pumps. This kit was provided at the beginning of the Methanol Marathon conversion process and included a production volume stainless-steel fuel tank. At the same time, the vehicles were equipped with an interface to the engine's computer control module that enabled changes to the look-up tables for key operational parameters, such as fuel injection pulse width, ignition timing, cold-start enrichment, EGR rates, and idle speeds.

Each of the schools took different approaches to converting their vehicles to take advantage of the properties of fuel methanol. Appendix A summarizes the conversion strategies of each of the participating schools. The rules were structured deliberately to force the teams to make difficult engineering trade-offs between decreased fuel consumption, increased performance, very low exhaust emissions, and good cold starting and driveability. The written papers of the school's conversions submitted as part of the event are summarized below.

UNIVERSITY OF MARYLAND - Maryland's students modified their engine by boring the cylinders 0.30 in. over stock and adding a turbocharger, thereby providing a boost of 7 psi as early as 2500 rpm. The surface of the intake runners were abraded to create turbulent flow. A new fifth gear was fabricated by the team, reducing the ratio from 0.72 to 0.609. A custom-ground cam shaft moved the engine torque peak down to a lower engine speed in order to take advantage of the lower fifth-gear ratio. The low position of the turbocharger and the addition of hood louvers decreased the under-hood temperatures by 40°F. A reverse flow propylene-glycol cooling system was implemented to allow more uniform, higher average cylinder head temperatures. Larger fuel injectors were used, and two parallel stock methanol compatible fuel pumps were incorporated. A heated catalytic converter was actuated prior to starting. This device achieved a temperature of 320°C in about 15 s, which enhanced emission control. A heated oxygen sensor was also used for finer mixture control, leading to reduce NO_x emissions. Compression ratio was increased to 13.25:1 despite the turbocharger. Ignition timing and fuel injector pulse width were adjusted for proper operation on methanol fuel.

FLORIDA INSTITUTE OF TECHNOLOGY - Florida's team chose to use a lean air/fuel mixture setting coupled with an oxidizing catalytic converter. The compression ratio was increased to 12:1. A ceramic thermal coating was applied to the top of the modified bowl-designed pistons to reduce quenching effects. A single turbocharger limited to a 4 psi boost was added to restore power and efficiency to the engine for the planned three-cylinder cut-out during light-load operation. Lack of development time prevented the Florida team from perfecting that approach, and the six-cylinder mode was used for the Challenge. The exhaust system was modified by wrapping the front and rear manifold in a specially coated asbestos cloth. Florida also added an expansion flex chamber to the outlet side of the turbocharger to aid in reducing back pressure. The intake plenum used longer and larger runners to achieve a ram-tuning effect. Original fuel control and ignition parameters were changed to accommodate methanol fuel and related modifications. Cold starting was enhanced by using a small disposable ether canister operated through a temperature sensor. This sensor activated a solenoid that injected ether into the intake plenum under 35°F.

UNIVERSITY OF TENNESSEE - The University of Tennessee's cold-start strategy involved revised valve timing, zero gap piston rings, increased cranking speeds, and a separator concept. A novel cold-start assisting device separated the hydrocarbon from the methanol and injected the volatile light hydrocarbons into the air stream to enrich the cold-start mixture. The nonvaporized liquid fuel was recycled. The team used the stock compression ratio and added a turbocharger that included a bypass valve in order to reduce throttle lag. A redesigned camshaft increased cylinder cranking pressure by closing the intake valves earlier. Roller cam followers and low-tension piston rings were used to reduce engine friction and increase fuel economy. Emissions were controlled by retaining stoichiometric operation and using a three-way catalyst. The stock oxygen sensor was replaced with a heated oxygen sensor, which permitted early transition to closed-loop operation. A close-coupled metal substrate catalyst was added to further reduce emissions and to achieve more rapid catalyst light-off. Air injection, running for 100 s, was used to assist in the catalyst light-off and to control aldehydes. The team lowered fifth-gear ratio to 0.063:1 so that at 60 mph, engine speed was reduced from 2300 rpm to 2000 rpm.

WASHINGTON UNIVERSITY - ST. LOUIS - Students on the Washington team focused on a simple and reliable conversion strategy. They used a multiple-spark-discharge ignition to improve cold-starting. High-compression pistons that raised compression from 8.9:1 to 12.5:1 were fitted, which improved thermal efficiency and power density. A fuel-enrichment system, triggered by an under-hood air-temperature sensor, was devised, injecting extra fuel into the intake plenum during starting. The base fuel pulse width was adjusted slightly from previous levels, and spark plug timing was retarded by 20%.

PENNSYLVANIA STATE UNIVERSITY - Pennsylvania State used a ceramic film coating on the piston crowns and combustion chambers in an attempt to retain as much heat as possible in the engine during warm-up and to protect the exposed aluminum surfaces from methanol corrosion. The engine was dynamically balanced and used a reground cam shaft that increased valve lift approximately 18%. The compression ratio was increased to 14:1. The team preheated the fuel within the injector itself to aid in cold-starting. A nichrome resistance heating element was powered whenever the starter was engaged and ambient temperature was below 40°F. With these modifications, exhaust temperature was below 1000°F, which prompted insulation of the exhaust between the manifold and catalytic converter to promote fast light-off and maintain converter efficiency.

TEXAS TECH UNIVERSITY - Texas Tech modified the engine by increasing engine stroke from 2.99 in. to 3.31 in. in order to take advantage of the slower burning rate of methanol. A torque increase of approximately 13% was realized. Cylinders were sleeved to 3.33 in. in order to achieve a square bore/stroke ratio, and custom pistons were made. Compression ratio was increased to 11.7:1, and pistons were 200 g lighter than stock. The top piston ring was chrome in order to maximize the amount of heat retained and the oil ring was a low-tension type. Because of methanol's tendency to stick to rough surfaces, the intake ports were smoothed. Combustion chamber volumes were measured and equalized, and exhaust port runners were enlarged. Cam shaft lobe centers and duration were changed to allow for longer burn time. Roller-tip type rocker arms were used to reduce friction and valve guide wear. The diameter of the exhaust pipe was increased to 2.25 in. between the exhaust manifold and the catalytic converter, and a light-off converter was incorporated located near the exhaust manifold. The catalytic converters were specially developed for methanol and designed to control aldehydes. For cold start and driveability, heated air was obtained from the area around the exhaust manifold. This system was controlled by a thermostatically controlled valve that operated from a vacuum line on the intake manifold. A commercially available ether-injection system was also used to aid in cold-starts. The fifth-gear ratio was lowered from 0.72:1 to 0.603:1, which reduced engine speed at 60 mph to 1875 rpm.

UNIVERSITY OF MICHIGAN - The objective of the University of Michigan 1990 methanol project was to enhance the performance of the 1989 conversion. The team decided the goals on the basis of economic and time constraints as well as team interests. Three central modifications were proposed that would achieve these goals in addition to the objectives set forth in the SAE proposal.

Engine efficiency had a great influence on the desired objectives. Because of the high effective octane rating of methanol, the engine achieves maximum thermal efficiency at large spark advance and at compression ratios between 12 and 13.5:1. A ratio of 12.2:1 was implemented (which eliminated the concern of detonation), while greater spark advance reduced time losses. Platinum spark plugs were used to reduce fouling associated with high-compression ratios. In order to maximize mixing effects in the combustion chamber, the Michigan team geometrically matched the intake and exhaust ports for greater efficiency.

Team interest in a powerful engine made turbocharging essential. The turbo was selected for good low-end power with efficiency at highway speeds. The use of an IHI turbo with an integral waste gate and water cooled main bearings was cost-effective and durable. By mounting the turbo directly behind the engine, the under hood packaging of the modification was simplified.

A Webasto preheater was installed to alleviate the problem of cold-start driveability. By heating and circulating the block coolant, the Webasto increased the chamber inlet temperature of the methanol and thus increased its volatility.

CONCORDIA UNIVERSITY - The Concordia team added a Garrett T3 variable nozzle turbocharger (VNT) that was modulated by a diaphragm located immediately behind the turbo to maintain a constant intake pressure of 15 psi. A heavily insulated oxidation catalytic converter was added, and the exhaust pipe was insulated and heat shielded from the turbo exit up to the second under-car converter. A 2200-W NGK air preheater was mounted directly onto a modified tunnel plenum from the turbocharger compressor outlet. The compressed air was routed through a 2.5-in. stainless-steel tube that contained two auxiliary fuel injectors. These fuel injectors provided additional fuel during high-power conditions and also served to cool the compressed air, thereby acting as an intercooler. The original plenum volume was tripled. The manifold air temperature sensor was relocated to the plenum to take into account the actual charge temperature due to the turbo fuel vaporization and under hood heating effects. The fuel system was modified by replacing the 3.8 G/S injectors with 4.5 G/S injectors and adding a dual fuel-pump configuration. Concordia modified the cam timing to provide greater lift and reduced overlap; roller hydraulic lifters were used to reduce friction. Cylinder heads were changed to incorporate titanium valves and appropriately lighter springs, allowing higher engine rpm. Spark plugs were custom made with a split gap using V-grove electrodes. The team incorporated a manual cut-off switch to eliminate fuel injection to three of the cylinders when in cruising conditions. This modification was intended to enhance fuel economy. However, its use was not allowed because all such features must be incorporated into the electronic engine-control system. Compression ratio was increased to 10.5:1. Greater fuel economy and improved emissions reduction was the aim of employing a lean air/fuel ratio under light-load operating conditions.

ROCHESTER INSTITUTE OF TECHNOLOGY - The students at Rochester increased their engine's compression ratio to 15:1 and installed a roller hydraulic camshaft featuring reduced duration and valve overlap. The team used a multiple-spark-discharge system to increase spark duration and improve cold starting. Modified Champion spark plugs incorporated a split side electrode, which resulted in a reduction of hydrocarbons and CO at the expense of a small increase in NO_x. New flat-top pistons were used, eliminating the valve reliefs. The distance from the piston top to the first ring was reduced, the top molybdenum ring was plasma thermal-barrier coated, and a low-tension oil ring was selected. A ceramic thermal barrier coating was applied to the tops of the pistons and cylinder head combustion surfaces. Increased exhaust-gas recirculation was achieved by adding a large EGR valve, thereby reducing NO_x emissions but increasing carbon monoxide and hydrocarbon levels. Tubular exhaust manifolds were used in conjunction with a new catalytic converter, which had a larger inlet and outlet. Manifolds were covered by a ceramic thermal barrier coating and ceramic cloth insulation tape. Engine management was optimized to allow a closed-loop operation at a stoichiometric air-to-fuel ratio.

NEW YORK INSTITUTE OF TECHNOLOGY - To enhance cold starting and greatly reduce cold-run emissions, NYIT used an injection scheme in which dimethyl ether (DME) was catalytically cracked from the methanol fuel using otherwise wasted exhaust heat and a fluorinated gamma-alumina catalyst. The production process occurred during hot-run conditions, and then the DME was stored in an on-board tank that was precharged with nitrogen for adequate pressure at low temperatures. This modification made the starting fuel available immediately for quick cold starts. Pistons with a stock-like dish were used with a longer stroke crankshaft for increased compression without the efficiency losses associated with flat-top pistons. The increased stroke crankshaft also increased low-rpm torque, which allowed use of lower (numerically) fifth gear for greater fuel economy. Additionally, the shift points are lowered because of the shifted torque curve for additional fuel efficiency. The combustion chamber, exhaust ports, and exhaust manifold interior were coated with a ceramic thermal-barrier coating for reduced exhaust catalyst light-off time. The combustion chamber coating also proved to enhance cold driveability. A close-coupled three-way catalyst was used to further reduce catalyst light-off time.

WEST VIRGINIA UNIVERSITY - The West Virginia team added a higher-amperage battery located in the trunk to aid in cold-starting. In addition, the team placed six CH80 glow plugs in line with the fuel injector's spray pattern. These plugs operated at part power for a short period when the door was opened, anticipating a start, at full power during cranking, and at part power until a coolant set-point temperature was reached. These plugs were intended to vaporize the fuel just before it entered the cylinder. The spark plugs used were a cooler heat range than standard plugs and were modified to have a V-shaped electrode to expose more spark to the fuel mixture. These plugs were fired by six Accel Super Coils. Custom-made forged, flat-top pistons provided a 11.6:1 compression. Although one was tested, a turbocharger was not used in the final design. To improve emissions, West Virginia utilized a slightly lean-of-stoichiometric air/fuel ratio and a small prototype catalytic converter (located ahead of the main catalytic converter) that was designed to control aldehydes. The main converter remained a three-way catalyst design. Both catalytic converters as well as the down pipe were wrapped with thermotech insulation. Spark timing was advanced 5° from default settings.

CALIFORNIA STATE UNIVERSITY - NORTHRIDGE - The team from California-Northridge increased the compression ratio to 12:1 using forged aluminum pistons. The team used an active displacement system, which was a mechanism allowing the engine to operate on three cylinders at cruising speeds. The heads and manifold were modified to accept the electromechanical mechanism deactivating the intake valves. A custom cam was used that provided more duration and lift to accommodate the increased power demands during three-cylinder operation. The intake valves were opened sooner and for longer duration to accommodate the incoming methanol and air charge. The tops of the pistons, the bottoms of the valves, the combustion chamber, and the exhaust ports were all coated with a metallic ceramic composite to retain more heat in the engine. A dry film lubricant was used on all wearing surfaces. A second catalytic converter employing a Corderite EX-20 substrate washed with increased noble metal was installed ahead of the original converter to decrease exhaust emissions. Two batteries were used, connected in a series, to allow 24 V to operate a high-torque starter. To enhance cold starting, a boiler chamber incorporating a nichrome wire heater brought the fuel to a quick boil. The vaporized fuel was drawn into the engine by use of engine vacuum. Somewhat smoother cold running was achieved by increasing the amount of fuel delivered during cold operation by 5%. To ensure good acceleration during cold running, the acceleration enrichment multipliers were increased by 50%. Crank fuel pulse width was enriched by 50% during cold start, and stumbling during sudden acceleration was reduced by increasing the idle speed by 50 to 150 rpm. Propylene glycol was used as an engine coolant to take advantage of its high boiling point. The team used platinum spark plugs to provide a hotter burn and facilitate easier starting.

RESULTS OF THE COMPETITION

The results from each of the competitive events is described briefly below. Concordia University suffered a major engine problem several weeks before the event and could not get their car repaired and in proper operating condition in time for emissions testing or the beginning of the competition. However, through a great amount of effort, they did have their car ready for the final day's competition on April 8. Thus, their scores on the earlier events are listed as zeros.

EMISSIONS - The emissions performance of the eight schools that did better than the existing federal standards illustrates the potential of fuel methanol to reduce levels of some of the regulated emissions. However, the results also demonstrate the difficulty of lowering all the levels simultaneously while striving for improved performance, fuel economy, and driveability. Only the University of Tennessee demonstrated that it could achieve control over all of the regulated emissions plus aldehydes at levels that surpass the proposed California Ultra Low Emission Vehicle (ULEV) levels. The proposed California ULEV emission standards are 0.04 g HC, 1.7 g CO, 0.2 g NO_x, and 15 mg/mi aldehydes. It should be noted that these tests were performed when the vehicles were essentially new from an emission-control-system perspective; therefore, the deterioration rates from these levels are unknown. Table 4 lists the EPA emissions results.

TABLE 4 Results of EPA Emissions Test

METHANOL CHALLENGE	EPA EMISSIONS RESULTS					
Team	HC (g/mi)	NMHC (g/mi)	CO (g/mi)	NO_x (g/mi)	Aldehydes (mg/mi)	Points
Cal State - Northridge	0.15	0.10	2.4	0.37	19	225
Concordia						-300
Florida Tech.	0.17	0.13	2.3	0.71	38	225
Maryland	0.09	0.05	2.0	0.30	18	225
Univ. of Michigan	0.44	0.37	4.1	0.43	47	-300
New York Tech.	0.05	0.02	0.6	0.70	10	225
Penn. State	0.24	0.19	1.4	0.50	32	225
Rochester Tech.	0.31	0.22	8.4	0.16	37	-300
Tennessee	0.10	0.01	1.2	0.18	9	500
Tenn. (w/shift lite)	0.09	0.06	1.8	0.37	19	225
Texas Tech	0.04	0.03	0.06	0.71	4	225
Wash.-St. Louis	0.10	0.06	2.1	0.63	14	225
West Virginia	0.04	0.03	0.5	2.02	3	-300
89 Corsica - Gas Baseline	0.27	—	1.6	0.34	---	
EPA Certification Data '88 Corsica	0.35	0.28	3.1	1.53	2	-300

COLD START - The organizers wanted a realistic test of cold-starting performance. Because fuel volatility is vitally important for good cold starting, it was decided that a fuel RVP typical of what could be expected to be seen in the field as a winter-blended M85 fuel should be used. BP Oil Company supplied all the fuel for the event and selected a hydrocarbon primer consisting of light isocrackate with an RVP of 11.2 lb. When the vehicles arrived at the Esso Petroleum - Canada research facilities, the vehicles were warmed-up on a chassis dynamometer, their batteries fully charged, and the oil changed to a BP-provided 5W30 methanol-formulated mineral oil. The remaining 9 lb RVP fuel used for the emissions tests was pumped out of the vehicles and the winter-grade M85 installed. The vehicles were then put in the cold chamber overnight and allowed to stabilize at -20°F.

The next morning, none of the methanol-powered cars started. The organizers were criticized by some of the teams for changing their oil, because several schools used special synthetic blends that improved cold-cranking rpm. The organizers felt that the vehicles were in danger of having their oil diluted because of the short duration of the engine operation in the process of transporting and moving prior to the cold-start test. A secondary rationale was the use of a common oil among all of the competitors would make the evaluation of their cold start approaches more fair and valid. With no starts, the amount of useful data gathered was minimal.

The gasoline-powered control vehicle started within three seconds under the identical temperature. It used a production winter-blended premium gasoline fuel with an RVP of 13 lb taken from the Esso pumps. To make a truly valid comparison, it too should have received a 11.2 lb custom-blended fuel. It was the oversight of the organizers in controlling this parameter that limited the validity of this event. BP has subsequently opened their cold-start testing facility to any of the Challenge competitors to attempt a start using 13 lb RVP M85 fuel. To date, none of the schools have had the resources to travel to BP's Cleveland facilities to attempt the retest.

WRITTEN PAPERS, ORAL PRESENTATIONS, AND CONVERSION INSPECTIONS - Teams were required to submit written papers describing their proposals for judging in advance of the competition. They presented 20-min oral presentations covering their conversion approach the first day of the event. Two panels of experts were assembled to perform the judging. The first panel reviewed the written papers and physically inspected the vehicles, judging the conversions on their innovativeness, how they handled the required performance trade-offs, and their cost-effectiveness.

A second panel of judges heard the oral presentations and rated them according to both their technical content and the effectiveness of their presentations. Samples of the judging sheets for both sets of judges appear as App. B. Table 5 shows the results of the oral presentation, and Table 6 shows the results of the written paper.

TABLE 5 Results of the Oral Presentation

METHANOL CHALLENGE — **ORAL PRESENTATION**

Team	Average Score
Cal State - Northridge	40
Concordia	—
Florida Tech.	53
Maryland	48
Univ. of Michigan	21
New York Tech.	42
Penn. State	48
Rochester Tech.	40
Tennessee	64
Tenn. (w/shift lite)	—
Texas Tech	46
Wash.-St. Louis	51
West Virginia	51
89 Corsica - Gas Baseline	
EPA Certification Data '88 Corsica	

Author Name

TABLE 6 Results of the Written Conversion Papers

METHANOL CHALLENGE	**CONVERSION PAPER**
Team	Average Score
Cal State - Northridge	62
Concordia	—
Florida Tech.	62
Maryland	66
Univ. of Michigan	53
New York Tech.	59
Penn. State	60
Rochester Tech.	54
Tennessee	73
Tenn. (w/shift lite)	—
Texas Tech	62
Wash.-St. Louis	58
West Virginia	66
89 Corsica - Gas Baseline	
EPA Certification Data '88 Corsica	

TABLE 7 Road Rally Performance

METHANOL CHALLENGE	**ROAD RALLY PERFORMANCE**	
Team	Rally Time	Score
Cal State - Northridge	2040	13
Concordia	——	—
Florida Tech.	1612	16
Maryland	526	50
Univ. of Michigan	729	36
New York Tech.	3136	8
Penn. State	4620	6
Rochester Tech.	1607	16
Tennessee	3009	9
Tenn. (w/shift lite)	——	—
Texas Tech	2552	10
Wash.-St. Louis	2963	9
West Virginia	1226	21
89 Corsica - Gas Baseline		
EPA Certification Data '88 Corsica		

ROAD RALLY PERFORMANCE - Over-the-road fuel economy was the primary motivation for conducting a time-speed-distance road rally during the Challenge (see Figure 2). Its format was such that the organizers controlled average speed and driving cycle to emulate suburban driving. The fuel economy results from this event are included in the following section. As a part of the event, however, teams could earn points for how closely they kept to the schedule dictated by the rally route and instructions. Rallying is a fun and safe form of motor sport and requires skill, discipline, and a team effort. Points were awarded in proportion to how well each team did in comparison to the best team. The wide range of scores that resulted are listed in Table 7.

FUEL ECONOMY RESULTS: FTP, RALLY, AND ENDURANCE EVENTS - One of methanol's limiting factors is its low-energy density, compared with gasoline or diesel fuel. At the same time, its high octane and latent heat of evaporation provide the potential for increased engine efficiency. The organizers felt that improvements in fuel economy were important for the students to develop and demonstrate. To gain the most accurate measurement of fuel economy, several events were held to insure an accurate measurement. All of the fuel economy results are expressed both in terms of actual gallons of M85 consumed and the gasoline-equivalent gallons. The conversion from M85 to gasoline-equivalent gallons was done using the actual measured Btu in the M85 and the Btu in a typical unleaded gasoline.

Over-the-road fuel economy was measured on the road rally, as described above. The rally covered about 200 miles in two legs with refueling at the finish; the resulting fuel economy is shown in Table 8.

At the same time as the FTP emissions tests, EPA technicians performed both city and highway fuel economy driving cycle tests. The tests lead to the composite fuel economy number used to calculate CAFE performance and the numbers used for the federally required new car Fuel Economy Label. The results were are listed in Table 9.

TABLE 8 Road Rally Fuel Economy

METHANOL CHALLENGE — ROAD RALLY FUEL ECONOMY				
Team	Total Gallons	MPG	Gas Eq. MPG	Points
Cal State - Northridge	14.6	13.43	24.01	70
Concordia	----	----	----	----
Florida Tech.	13.43	14.55	26.0	94
Maryland	12.83	14.18	25.35	87
Univ. of Michigan	13.24	14.81	26.48	98
New York Tech.	12.38	15.84	28.31	112
Penn. State	13.56	14.46	25.85	92
Rochester Tech.	11.56	16.96	30.32	123
Tennessee	11.39	17.22	30.78	125
Tenn. (w/shift lite)	----	----	----	----
Texas Tech	13.39	14.64	26.18	95
Wash.-St. Louis	14.5	13.52	24.17	72
West Virginia	14.28	13.73	24.55	77
89 Corsica - Gas Baseline	----	----	----	----
EPA Certification Data '88 Corsica				

TABLE 9 Results of FTP Composite Fuel Economy

METHANOL CHALLENGE — FTP COMPOSITE FUEL ECONOMY						
Team	City MPG	Highway MPG	Combined MPG	Rank	MPG/ Gas Eq.	Points
Cal State - Northridge	11.57	20.74	15.70	8	28.06	106
Concordia			0.00	12	0.00	0
Florida Tech.	12.66	19.53	15.75	7	28.16	107
Maryland	11.57	22.11	16.31	6	29.16	113
Univ. of Michigan	12.66	23.71	17.63	1	31.52	125
New York Tech.	11	19.36	14.76	11	26.39	91
Penn. State	11.91	21.88	16.40	5	29.31	114
Rochester Tech.	12.26	22.34	16.80	3	30.02	118
Tennessee	11.97	22.22	16.58	4	29.64	116
Tenn. (w/shift lite)	15.34	23.20	18.10	—*	32.35	—*
Texas Tech	12.37	23.48	17.37	2	31.05	123
Wash.-St. Louis	11.51	19.65	15.17	9	27.12	98
West Virginia	10.94	19.53	14.81	10	26.47	92
89 Corsica - Gas Baseline	19.9	35.8	24.9	—	24.9	—
EPA Certification Data '88 Corsica	21.1	37.3	26.2	—	26.2	—

*Results not used for scoring because of inferior emissions results.

Finally, the all-day endurance event held at MIS (see Figure 3) gave comparative fuel economy at 45, 55, and 65 mph under identical conditions. At least 130 miles were traveled for each of the three speeds under closely monitored conditions. The teams performed in an exemplary manner at MIS; there were no on-track incidents. The weather was cold and windy; snow covered the track at the beginning of the event. The results of this endurance event are shown in Table 10.

COLD DRIVEABILITY EVENT - Early on the morning of April 8, the cold driveability event was held at the Milford Proving Grounds. During the evening of April 7, the competing cars were driven from MIS to Milford to sit out overnight in

TABLE 10 Endurance Fuel Economy

METHANOL CHALLENGE — ENDURANCE FUEL ECONOMY	45 MPH		55 MPH		65 MPH		
Team	MPG	Gas Eq. MPG	MPG	Gas Eq. MPG	MPG	Gas Eq. MPG	Total MPG
Cal State - Northridge	23.33	41.71	20.52	36.69	18.66	33.35	20.69
Concordia	—	—	—	—	—	—	—
Florida Tech.	20.01	35.77	19.06	34.07	17.59	31.44	18.85
Maryland	20.80	37.19	19.92	35.61	18.45	32.98	19.69
Univ. of Michigan	21.26	38.0	19.78	35.36	18.07	32.30	19.63
New York Tech.	19.09	34.12	20.13	35.98	17.04	30.47	18.68
Penn. State	21.26	38.0	19.3	34.50	18.29	32.70	19.56
Rochester Tech.	22.23	39.74	20.13	35.98	18.34	32.79	20.13
Tennessee	23.58	42.15	19.95	35.67	17.59	31.44	20.11
Tenn. (w/shift lite)	—	—	—	—	—	—	—
Texas Tech	22.67	40.53	21.73	38.85	18.73	33.49	20.93
Wash.-St. Louis	19.55	34.95	18.80	33.60	16.83	30.08	18.33
West Virginia	19.69	35.20	18.0	32.18	16.47	29.44	17.98
89 Corsica - Gas Baseline	40.08	40.08	32.45	32.45	29.20	29.20	33.37
EPA Certification Data '88 Corsica	—	—	—	—	—	—	—

preparation for this event. An ambient tempera ture of 38-40°F awaited the trained GM evaluators, who began this event at 7:00 a.m. A modified GMUTS test was performed that ranked the performance of the M85 conversions using a demerit system for faults in starting, cold drive-away, and warm up performance. A perfect score was 100; cars deemed acceptable for production must have a score of 97 and above. Good driveability performance requires significant efforts in calibration and tailoring of the engine-control strategies. This type of tailoring is difficult to perform for student teams, which had only limited access to the engine controller. Nevertheless, half of the schools scores in the 80s; West Virginia University and the University of Tennessee tied with a score of 87, the highest score in this event. The baseline gasoline Corsica turned in a score of 98; the complete results are listed in Table 11.

ACCELERATION EVENT - A 0- to 500-ft acceleration event was held at GM's Milford Proving Grounds (Figure 4). The track was laid out as the beginning of the maneuverability event course held on the asphalt-covered "Black Lake." Two drivers made two runs each, with the best of each run averaged for the final score. The rules set a 9.5-s minimum performance level so that teams could not neglect engine output to favor minimum fuel consumption. There were bonus points available for better performance and penalty points for performance under the target. Three teams did not meet the target time and were penalized. Eight out of the nine remaining

TABLE 11 Results of Cold Driveability Performance

METHANOL CHALLENGE — COLD DRIVEABILITY	
Team	Points
Cal State - Northridge	82
Concordia	
Florida Tech.	84
Maryland	0
Univ. of Michigan	64
New York Tech.	80
Penn. State	47
Rochester Tech.	79
Tennessee	87
Tenn. (w/shift lite)	
Texas Tech	72
Wash.-St. Louis	80
West Virginia	87
89 Corsica - Gas Baseline	98
EPA Certification Data '88 Corsica	

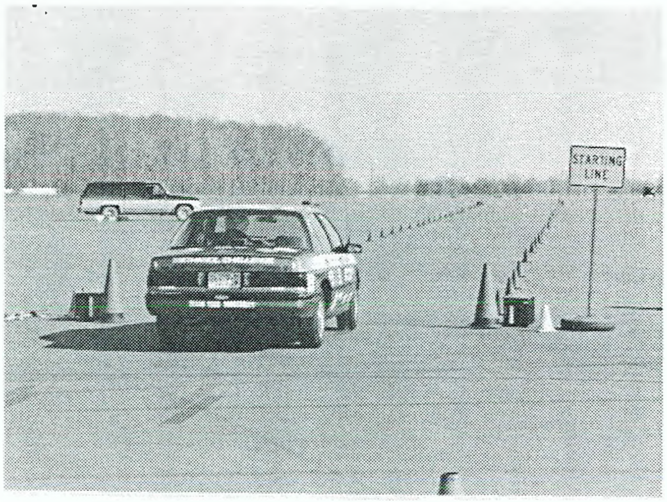

FIGURE 4 The General Motors Proving Grounds in Milford, Mich., was the site for the acceleration and maneuverability events.

teams had acceleration times superior to that of the baseline control Corsica. Several teams experienced mechanical problems during this event. Because all-out acceleration produced the most strain on the vehicles, the organizers held this event last so that any mechanical problems would not eliminate the vehicles from other events. California-Northridge, New York Institute of Technology, the University of Maryland, and Concordia developed problems that limited their ability to compete. We took their best times recorded prior to their problem and used them as the basis for scoring. Team malfunctions were reflected in penalties for breakdowns and repairs described below. The results of the acceleration event are listed in Table 12.

MANEUVERABILITY EVENT - To test the transient response of the conversions and their ability to perform under maximum performance conditions, a maneuverability event was conducted in the form of a low-speed solo handling event. Volunteers from GM's Advanced Engineering Staff spent Saturday morning setting-up the course on the Black Lake at Milford. The course had a variety of corners, 11 in all, that included sweeping, constant, and reduced-radius configurations. A production

TABLE 12 Results of Acceleration Tests

METHANOL CHALLENGE	ACCELERATION	
Team	Time	Bonus Points
Cal State - Northridge	9.276	20
Concordia	8.811	59
Florida Tech.	8.457	86
Maryland	9.74	-92
Univ. of Michigan	8.907	51
New York Tech.	9.654	-58
Penn. State	8.67	70
Rochester Tech.	8.57	78
Tennessee	8.042	116
Tenn. (w/shift lite)		
Texas Tech	8.294	98
Wash.-St. Louis	9.649	-56
West Virginia	8.802	59
89 Corsica - Gas Baseline	8.937	48
EPA Certification Data '88 Corsica		

Corsica similar to the vehicles in the event was used to set-up and test the course. Safety was the primary consideration, and speeds were kept below 50 mph. As stated above, the course also included the distance required for the acceleration event as its first leg. The results of this event appear in Table 13. Although 12 s separated the fastest and slowest cars, the scoring formula used by the organizers did not provide enough discrimination between the times, allowing only an 8-point spread between the field for a 18% difference in performance.

EXHAUST NOISE EVENT AND OTHER PENALTIES - The exhaust noise event was done in conjunction with the cold driveability event; a sound meter was set-up as part of the driving loop at the end of the test cycle. Competitors were required to meet federal exhaust noise limits as measured by SAE J-986b. Vehicles with exhaust noise in excess of 80 decibels were penalized by a sliding formula listed in the rules.

In order to maintain our testing schedule, all of the competing vehicles had to arrive at the EPA test laboratory by March 12 or face penalties. Because a number of vehicles were

TABLE 13 Results of Maneuverability Tests

METHANOL CHALLENGE	MANEUVERABILITY			
Team	Time 1	Time 2	Average Time	Score
Cal State - Northridge	70.26	74.86	72.56	45
Concordia	68.721	71.503	70.112	47
Florida Tech.	66.722	65.187	65.9545	50
Maryland	66.676	88.535	77.6055	42
Univ. of Michigan	71.477	67.526	69.5015	47
New York Tech.	75.917	71.098	73.5075	45
Penn. State	73.81	69.211	71.5105	46
Rochester Tech.	67.125	67.39	67.2575	49
Tennessee	67.84	72.66	70.25	47
Tenn. (w/shift lite)				
Texas Tech	66.423	69.992	68.2075	48
Wash.-St. Louis	70.952	68.517	69.7345	47
West Virginia	68.453	78.781	73.617	45
89 Corsica - Gas Baseline			0	0
EPA Certification Data '88 Corsica				

late, penalties were assessed. Additional penalties could be earned by repairs needed during the event, variance in required speeds, excess exhaust noise, and unsafe behavior. Several teams needed to make minor repairs and adjustments and were penalized 25 points per occurrence. No penalties for other reasons needed to be imposed. All of the penalties assessed during the event appear in Table 14.

OVERALL RESULTS - The University of Tennessee scored an impressive victory, garnering 1336 out of 1500 possible points. In doing so, the Tennessee conversion showed that it is possible to build a methanol-powered vehicle that delivers impressive performance (70% more horsepower), improved fuel economy (at least 10% better on a Btu basis), and dramatically lower exhaust emissions (lower than California's ULEV standards) at the same time. Tennessee's victory was nearly complete, capturing the best conversion award and the best overall design and concept. Only the cold-start difficulty kept Tennessee from claiming a total victory in the competition to produce the best alternative-fueled vehicle yet made.

The second and third place finishes of Texas Tech and Penn State were noteworthy. Each team had taken a more conservative conversion approach, but both teams had executed their naturally aspirated engine concepts very well. Florida Tech finished fourth, with good performances in every event, in spite of 120 penalty points for being late for emission testing. In fifth place, California-Northridge proved to have good fuel economy and emissions. The University of Michigan won the best FTP fuel economy award. Table 15 summarizes the final scores for the competition.

CONCLUSION

The 1990 SAE Methanol Challenge was an even greater technical success than the more publicized Methanol Marathon. The Challenge was intended to have a heavier emphasis on the remaining engineering issues of dedicated fuel methanol operation and to be less of a public relations event. The level of engineering competence displayed by the participating student teams was both outstanding and remarkable. Given the limited resources available in terms of finances and equipment, and the fact that this project was an extracurricular activity, each team's performance in these demanding events was truly noteworthy.

TABLE 14 Penalty Points for Each of the Participants

METHANOL CHALLENGE — PENALTY POINTS				
Team	Sound Test	EPA Lateness	Mech. Repairs	Penalty Total
Cal State - Northridge	12	60	25	97
Concordia	0			
Florida Tech.	0	120		120
Maryland	0		25	25
Univ. of Michigan	10			10
New York Tech.	15	90	25	130
Penn. State	34			34
Rochester Tech.	24			24
Tennessee	0	15	25	40
Tenn. (w/shift lite)	—	—	—	
Texas Tech	25	30		55
Wash.-St. Louis	0	75		75
West Virginia	0			
89 Corsica - Gas Baseline	0			
EPA Certification Data '88 Corsica				

TABLE 15 Summary of Final Results

METHANOL CHALLENGE — FINAL TOTALS														
Team	*Final Total	Rank	Accel	Fuel Econ	Emiss	Cold Start	Cold Drive	Endur Penalty	Fuel Econ Rally	Maneuv	Convers Paper	Oral Presen	Sound	Penalty Points
Cal State - Northridge	812	5	20	423	225	0	82	0	13	45	62	40	12	85
Concordia	106	12	59	0	0	0	0	0	0	47	0	0	0	0
Florida Tech.	873	4	86	416	225	0	84	0	16	50	62	53	0	120
Maryland	747	6	-92	432	225	0	0	0	50	42	66	48	0	25
Univ. of Michigan	416	10	51	454	-300	0	64	0	36	47	53	21	10	0
New York Tech.	688	8	-58	416	225	0	90	0	8	45	59	42	15	115
Penn. State	904	3	70	436	225	0	47	0	6	46	60	48	34	0
Rochester Tech.	472	9	78	480	-300	0	79	0	16	49	54	40	24	0
Tennessee	1336	1	116	480	500	0	87	0	9	47	73	64	0	40
Tenn. (w/shift lite)														
Texas Tech	976	2	98	468	225	0	72	0	10	48	62	46	25	30
Wash.-St. Louis	714	7	-56	375	225	0	60	0	9	47	58	51	0	75
West Virginia	389	11	59	365	-300	0	87	0	21	45	66	45	0	0
89 Corsica - Gas Baseline	146		48	0	0	0	98	0	0	0	0	0	0	0
EPA Certification Data '88 Corsica														

The results of this competition illustrate the many benefits that student-design competitions create among all the people and organizations touched by the event. The students benefit from an excellent hands-on learning experience and the chance to prove themselves in front of potential employers. The sponsoring organizations benefit by having some of the most creative minds in North America working to solve engineering problems of alternative fuels at a very modest direct cost. The universities and colleges benefit from the exposure that they receive, which could improve new-student recruiting potential. The automobile industry benefits from the positive exposure and image created by the event, the new hires that result from it, and the experience of their personnel, some of whom will go on to become the industry's new leaders. The public benefits by a demonstration of an alternative-fuel technology that is shown to be nearly ready for widespread use. Because several hundred new engineers and professors are experienced with a future transportation-fuel technology (the result of a partnership of public and private organizations), a more energy-secure and environmentally safe future is possible.

ACKNOWLEDGMENTS

The organizers would like to extend their thanks to the many individuals and organizations that worked together to make the Methanol Challenge a success. The organizers would also like to thank the 15 judges from all parts of the automotive industry who donated their time and expertise to evaluate and rank each team's conversions, technical reports, and oral presentations. Gratitude is also extended to the dozens of GM volunteer timers and event workers who gave up a Saturday to work with this event. Goodyear, who opened its suite at MIS and provided a good continental breakfast, snacks, and an excellent midday meal for all participants, also deserves recognition. In particular, we would like to acknowledge the help and inspiration of our sponsors:

Office of Transportation Technology, U.S. Department of Energy
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Appendix A: Conversion Approach Summary

Team	Compression Ratio	Engine Size	Turbocharger	Combustion Chamber Modifications	Transmission Modifications	Air -Fuel Ratio	Ignition Modifications	Cam Modifications	Exhaust Modifications	Additional Features
Tennessee	stock	stock	yes (with bypass valve)	no	lower 5th gear	stoich.	no	yes	yes	fuel separator for cold start
Washington-St. Louis	12.5:1	stock	no	no	no	stoich.	multiple spark retarded 20%	no	no	-
Penn. State	14.1	stock	no	ceramic coating	no	stoich.	-	yes	insulated	fuel preheated
Texas Tech.	11.7:1	170 in.^{3} (longer stroke)	no	-	lower 5th gear	stoich.	-	yes	light-off converter added	ether injection for cold start
Michigan	12.2:1	stock	yes (with bypass valve - 8 psi)	-	no	lean	advanced spark platinum plugs	yes	additional converter	preheater for cold start
Concordia	10.5:1	195 in.^{3}	yes - 15 psi	smoothed polished	no	lean	split gap plugs	yes	additional converter	air preheater, larger injectors
Maryland	13.25:1	bored 0.30 over stock	yes - 7 psi	-	lower 5th gear	stoich.	adjusted timing	yes	preheated converter	larger injectors
Florida Tech.	12.1	stock	yes - 4 psi	ceramic coating	no	lean	changed timing	-		ether injection for cold start
Rochester	15.1	stock	no	ceramic coating, flat-top pistons	no	stoich.	multiple spark split side electrode plugs	yes		-
New York Inst. of Tech.	raised	stock (longer stroke)	longer stroke	ceramic coating	lower 5th gear	stock	-	-	added converter	ether separated & injected for cold start, fuel preheated during warm-up
West Virginia	11.6:1	stock	no	flat top pistons	no	lean	V-shaped electrode plugs fired by separate coils; 5° advanced spark	-	added converter	glow plugs before injectors
California State - Northridge	12.1	stock	no	ceramic coating, aluminum pistons	no	stock	platinum plugs	yes	added converter	3-cylinder operation at cruising speeds; vaporized fuel for cold start

- teams did not supply information.

Appendix B: Sample Scoring Sheets

METHANOL CHALLENGE DESIGN JUDGING SCORING SHEET

School:______________________________________

JUDGES: Circle the score which you feel best represents the team's design score from their written report for each of the following categories:

METHANOL CONVERSION (20 points total)	Bad	Poor	Average	Good	Better	Excellent
Design Concept	0	1	2	3	4	5
Degree Takes Advantage of Methanol's Properties	0	1	2	3	4	5
Degree of Innovation	0	1	2	3	4	5
Cost/Performance Tradeoff	0	1	2	3	4	5
EMISSIONS CONTROL SYSTEM (15 points total)						
System Design	0	1	2	3	4	5
Comprehensiveness of Design	0	1	2	3	4	5
Degree of Innovation	0	1	2	3	4	5
COLD START/DRIVEABILITY (15 points)						
Cold Start Approach	0	1	2	3	4	5
Modification to Improve Driveability	0	1	2	3	4	5
Degree of Innovation	0	1	2	3	4	5

____
Author Name

____
Page No.

METHANOL CHALLENGE ORAL PRESENTATION SCORING SHEET

School:____

JUDGES: Circle the score which you feel best represents the presentation's merit for each of the following categories:

ORAL PRESENTATION (45 points total)

	Bad	Poor	Average	Good	Better	Excellent
Organization	0	1	2	3	4	5
Delivery	0	1	2	3	4	5
Visuals/Graphics	0	1	2	3	4	5
Overall Effectiveness	0	1	2	3	4	5

QUALITY OF INFORMATION PRESENTED SUPPORTING (30 points total)

	Bad	Poor	Average	Good	Better	Excellent
Conversion Concept	0	1	2	3	4	5
Degree of Innovation	0	1	2	3	4	5
Cost/Performance Trade-off	0	1	2	3	4	5

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Author Name

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Page No.