I. CODES & STANDARDS

I.A. 1000173.00 Green Racing Technical Support

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I.A.1. Abstract

Objectives

- Incentivize vehicle manufacturers to develop, validate, and promote advanced technologies relevant to production vehicles through motorsport participation.
- Increase the use of renewable fuels and petroleum alternatives in racing, and provide an avenue to introduce new fuels or bio-fuel blends.
- Establish a link between BioEnergies Technologies Office (BETO) and Green Racing Initiative.
- Increase the use of electric drive technologies in racing.
- Use racing as a platform to educate the public:
    - on the benefits of using renewable fuels and the concept of well-to-wheels fuel life cycles;
    - on the performance and efficiency benefits and capabilities of advanced vehicle technologies.
- Diversify the success of the Green Racing Initiative beyond the TUDOR United Sportscar Championship (TUSC) to include other racing series with the final goal of establishing advanced transportation technologies as a foundation for all motorsports.
- Gain the support of the automotive industry in the validation of "green racing" in the United States and internationally.
- Maintain collaborative partnership with the U.S. Environmental Protection Agency (EPA) and SAE International.
- Complete the revisions to SAE J2880 Green Racing Protocols and publish an updated version of this Recommended Practice for Green Racing.

Major Accomplishments

- All of the full season GTLM class cars racing with the TUSC used E85R fuel with cellulosic ethanol sourced from INEOS, a DOE grant recipient. This fuel reduced oil consumption by over 62% and provided more than 65% reduction in GHG emissions compared to conventional racing fuels with no renewable content. (For IMSA this would be a 2005 baseline.)
- Extended the partnership with IMSA through 2019 with a new MOU signed into place by DOE and IMSA leadership at the Daytona race in 2014.
- HEVs from Audi and Toyota dominated at the 24 Hours of Le Mans in 2014, and have won every World Endurance Championship (WEC) race to date in the 2014 season. Four different HEV architectures competed at Le Mans in 2014.
- Porsche returned to the LMP1 category in the WEC with an advanced HEV powered by a downsized, boosted V-4 SI engine with waste heat recovery and multiple electric drives.
- Each of the three factory HEV entries in the WEC LMP1 uses different forms of energy storage illustrating the diversity of technical solutions relevant to road cars: Audi with an electro-mechanical flywheel, Toyota with ultracapacitors, and Porsche with Li-Ion batteries.
- Nissan raced an experimental lightweight HEV at Le Mans in 2014, and was the first vehicle competing in the iconic 24 hour race to complete an entire lap of the 8.5 mile circuit at racing speeds using only electric propulsion. Nissan also announced a full factory effort in the WEC LMP1 for 2015 aiming to bring advanced HEV technology to the race track to further their development of HEV technology for road cars.

Figure 1: Formula 1 introduced new powertrains in 2014 emphasizing efficiency, energy recovery, and significantly more hybridization (photo: espn.f1.com)

- Formula 1 (F1) introduced new HEV powertrains in 2014 that specified small turbocharged V6 engines with waste heat recovery and greatly expanded electric drive capabilities. In addition, an energy allocation was established (100kg of fuel) and maximum fuel flow set to

limit potential engine power with real-time fuel flow metering for monitoring compliance to the rules. These efficiency-encouraging steps have long been a part of the Green Racing Initiative philosophy and resulted in a 30% reduction of energy consumption with competitive performance. Improvements in the first season of the new formula, show further speed potential while those teams that have been able to most efficiently use the available energy have had competitive advantages. With these changes, F1 has become elibible for a Green Challenge Award starting in the 2015 season.

- The light weight, downsized engine - Elan DeltaWing coupe raced in 6 rounds of the TUSC, finishing as high as fouth place in the LMP class.
- Mazda competed with their street-based diesel engine in the TUSC Prototype category in 2014. The engine uses the production block and head along with more than 50% of stock components. A 100% renewable synthetic diesel fuel with a cetane of 75 was made available to Mazda through the DOE's Green Racing program technical support. The engine was able to more than triple its output, when compared to a stock engine, to over 450 hp.
- Increased visibility for the "Clean, Fast, Effiicient" Green Challenge tagline was achieved with international television coverage, race teams and media.
- Completed the revisions to the Green Racing Protocols and published a substantially revised and updated version of SAE J2880. Conducted multiple discussions with INDYCAR about becoming a Green Challenge race series in 2015; offered to supply 2nd Generation (cellulosic) ethanol in support of the series and options to incorportate energy recovery technologies in future powertrains.
- Monitored the adoption of the HySpy fuel flow meter as the FIA-approved approach to limit power and implement fuel allocations for the 2014 Forumula 1 and LMP1 category in the World Endurance Championship. Followed the development of a second generation fuel flow sensor with greater accuracy and reliability for possible field test in TUSC in the 2015 season.
- Transported and displayed the Green Racing Simulator (E85 CORVETTE HEV race car simulator) at three TUSC races and planned for several additional events around the country next year with EPA and BETO support.

Future Achievements

- Work with TUSC to incorporate fuels with a higher percentage of renewable content into additional classes in 2015 and advanced technology into racing in 2016 and beyond.
- Continue to make advanced renewable fuel sources available to TUDOR USCC and INDYCAR for SI and CI engines.
- Develop Green Racing integration plan with INDYCAR as they qualify as a Green Racing series for the first time in 2015, and help them move towards achieving Green Challenge status and recognition from DOE, EPA, and SAE International.
- Work with the FIA to establish a Green Challenge Award in Formula 1 in 2015 or 2016. Under the revised J2880, F1 qualifies for recognition and award status starting in 2015.
- Work with the ACO to recognize the LMP1 category in WEC as a Green Racing series in 2015. Support discussions within the ACO on new formats for LMP2 and the GTE/GTLM classes to embrace Green Racing content.
- Support and incentivize the use of energy recovery technology in race cars, and identifying methods available to properly limit and/or record use of technologies to allow for performance balancing.
- Expand working relationship with BETO including additional biofuels suppliers and inclusion of BETO information on the Green Racing website update.
- Move towards a scoring system based on energy allocation, working with industry partners to develop fuel flow measurement technologies applicable in a racing vehicle.

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I.A.2. Technical Discussion

Background

Green Racing History

The Green Racing Initiative (GRI) started in 2006 with a working group of industry, government and national lab representatives. The team sought to take advantage of the efforts and opportunities in motorsports to further develop advanced transportation technologies that could be applied to street vehicles. This effort focused on providing a proving ground for petroleum displacement and technology advancements in a competitive setting. Once the working group had built the foundation for GR, a set of protocols was approved through SAE and in 2008 the J2880 'Recommended Green Racing Protocols' were established.

The American Le Mans Series (ALMS) acknowledged these protocols and awarded the first Green Challenge Award in October 2008.

The Green Challenge Award and the Michelin Green X Challenge soon became an integral part of SportsCar racing, where Michelin recognized the teams and the DOE, EPA, and SAE recognized the manufacturers who perform best when evaluated using the Green Racing formula for competition. The scoring formula takes into account measured performance and fuel consumption to determine a total score: Clean, Fast and Efficient terms are calculated in real time for each lap for each vehicle in the appropriate racing categories.

Introduction

The 2014 racing season in the US came to an end right after the end of FY2014 generating a record that showed sustainable motorsports activities advanced both technology and performance in the multiple racing series they were adopted in. The 2014 season has been extrememly competitive in the renewable fuel-powered GTLM class of the TUSC. Teams have applied new technologies and sanctioning

bodies have confirmed future rules which incorporate sustainable practices and require advanced technologies for future racing vehicles. INEOS, a cellulosic ethanol producer who has received DOE funds to develop their process, provided fuel to IMSA through a relationship with VP Racing fuels which was established through the Green Racing Initiative. The Green Racing Initiative seeks to coordinate the strategies and guide motorsports requirements to optimize efforts within motorsports to highlight advances in transportation technologies.

Approach

Motorsports are the only professional sport that can directly help attain national energy and environmental objectives. The rapid developmental cycles in racing, the focused development of advanced technologies and alternative fuels, and the search for more efficient and capable vehicles inherent in racing, all tie directly with our national transportation goals. These efforts reduce our dependence on petroleum and lower the carbon footprint of vehicles – and still provide the entertainment and drama that has made racing one of the most followed forms of sports around the world. Racing is one of the best platforms for reaching a large audience with the message that through advanced vehicle technologies and renewable fuels we can maintain the personal mobility and performance customers want while moving toward the energy security and sustainable transportation the country needs.

Racing brings out the best in automotive technology and places it in a demanding competitive environment allowing a technology showcase that resonates with the public. Racing also inherently values efficiency as successful teams operate in alignment with sanctioning body rules to optimize fuel use with other racing parameters, like distance between required tire changes. Efficiency and petroleum displacement are attributes that underpin our national energy and environmental objectives. Building on core values in racing and adding renewable fuels and advanced transportation technologies as ways to improve sustainability, we have developed the Green Racing Initiative with our partners.

Results

The 2014 racing season had a number of highlights in advancing transportation technologies through motorsports. Of particular interest was the domination of hybridized racing vehicles in the world's most important sporting event, the 24 Hours of Le Mans. Audi, Porsche and Toyota each brought hybridized Le Mans Prototype (LMP1) vehicles to the event, with the Audi's diesel HEVs taking the pole and finishing in first and second place.

Figure 2: An Audi R18 e-tron quattro diesel HEV took first and second place in the 2014 24 Hours of Le Mans in (photo: Audi Sport)

Toytota's ultra-capacitor and Porsche's Li-Ion battery SI HEVs often matched the pace of the Audis but ultimately finished in third and eleventh places repectively at the world's most famous endurance race. At the end of FY2014 with three races to go, Toyota holds a small lead in the driver's and manufacturer's championships in the 2014 World Endurance Championship (WEC), illustrating the close competiton within this elite category of the most technologically-advanced racing vehicles in the world. The Automobile Club de l'Ouest (ACO) refined their 2014 rule package for the LMP1 premiere category vehicles in the WEC expanding the size and type of energy recovery and hybrid technologies by a factor of 4 as well as allowing a limited amount of energy (fuel) per lap depending on the level of hybrid technologies applied to each car. These ACO rules were developed to enhance efficiency and not performance in consultation with the Green Racing Initiative. The rules are remarkably open with regards to technologies allowing the factory teams to be innovative in creating and applying advanced technologies. This shift of motorsports to using energy allocations, rather than purely speed, as a way to structure future competition represents a substantial change in the perspective of sanctioning bodies, and places a renewed relevance in the sport, as energy efficiency is something the manufacturers deal with in every vehicle they produce. WEC also moved to E20 cellulosic as the base fuel for all its categories, lowering its WTW GHG emissions by 18.5% and boosting its oil displacement to 19.5%.

The Green Racing Initiative has become an integral part of the TUSC in its first year of operation. TUSC was formed from the merger of the American Le Mans Series and the GRAND AM sportcar racing series into a major new unified Sportscar racing series for North America. Green Racing content will spread to other classes in TUSC over the next several years. Working in close collaboration with TUSC and the ACO from which a significant amount of the sporting regulations are drawn, the Green Racing Initiative continues to explore ways where advanced technologies can be showcased and renewable fuels utilized for racing in the future.

Figure 3: DeltaWing Coupe continues its development in 2014 (photo: deltawingracing.com)

The experimental DeltaWing from the innovative Garage 56 at the 2012 Le Mans race returned in updated form in the TUSC in 2014. A completely new chassis and ongoing developments made the car competitive by the end of the 2014 season. The DeltaWing led the Petit Le Mans race and placed fourth in the LMP class in 2014 after an early shot at winning the race. It remains a fan favorite due to its innovative, light weight design and tiny front wheels.

The 2014 TUSC season continued to offer advanced renewable fuels for use by its competing teams. In the GTLM class, E85R dominated as the fuel of choice in this ultra-competitive category. All the top three finishers in all the races used E85R fuel. The GT class is based on cars that are on the road today and puts rival teams in door-to-door competition that may be the most competitive class in racing anywhere in the world. All the BMW, Corvette, Dodge, Ferrari, and Porsche factory cars and most of the privately entered cars used this renewable fuel with great success. The wholesale movement to E85R was primarily motivated by the performance potential of this excellent fuel, but the message with respects to its upstream impact and its energy security and environmental advantages have provided an excellent outreach opportunity for DOE goals. The Green Challenge scoring system accurately reflects each fuel's characteristics in terms of its greenhouse gas and oil replacement attributes without rewarding a team's selection of bio-fuels over conventional fuels. That makes this switch to renewable fuels at this level of motorsports all the more impressive and significant. This noteworthy accomplishment demonstrates that these fuels are capable of outstanding performance, reliability, and capable of widespread use in street vehicles.

Figure 4: Green Challenge Awards were given in all ten TUSC races in 2014 (photo: press.porsche.com)

In the LMP class in TUSC, Mazda's commitment to their diesel-powered prototype race car was a major story. The remarkable performance from a production-based diesel engine was highlighted by its use of 100% synthetic renewable diesel fuel made from waste vegitable oil thanks to the Green Racing program. Its high cetane, zero sulfur content allowed impressive power density – achieving more than three times the production engine's power - and virtually no PM emissions. This engine's performance became better and better as the season unfolded, now producing in excess of 450 hp. Mazda also made a major contribution to STEM education by bringing a race car to local high schools near the race tracks to show how important STEM education was to open exciting futures for high school students. Using their commitment to racing as their model, they explained how practical and specific applications of science and technology will shape the future and offered real-life examples of how that knowledge can be put to work.

Figure 5: Mazda Skyactiv-Diesel production-based race engine competed in all ten TUDOR United Sportscar Championship races using 100% renewable synthetic diesel fuel (photo by mazdamotorsports.com).

Figure 6: Fans and professional racing drivers alike try their hand at the GRS. Tommy Milner of Corvette Racing puts the simulated E85/Hybrid Corvette to the test.

Due to the success of last years Green Racing Simulator (GRS), the mobile outreach simulator was deployed again this season for the Green Racing program. The GRS, developed by Argonne National Laboratory, incorporates a program that calculates the amount of regenerative braking energy captured and fuel used during two laps of simulated racing.

This simulator was set up at three IMSA races in 2014. It served as a notable means of disseminating the DOE's Green Racing key message that the use of renewable fuels and hybrids can displace a substantial amount of imported petroleum to over 1000 racing fans.

Conclusions

Motorsports in FY2014 was a year that showed significant world-wide acceptance of Green Racing content in the premier racing series around the world: WEC LMP1, F1, TUSC, and INDYCAR. Significant petroleum reduction was recorded in the GTLM class in TUSC of 62.5% with a 65.5% reduction in GHG emissions when compared to a baseline of the 2005 series. All vehicles in GTLM class are running on E85 racing fuel, while the Mazda LMP team has successfully employed an advanced synthetic renewable diesel fuel to power their two-car team in the TUSC. Green Racing continues to expand in the elite levels of racing, illustrating how advanced transportation technologies and renewable fuels are leading the way to sustainable transportation through motorsports.

Important accomplishments regarding the incorporatation of energy recovery systems into world class racing were showcased multiple times during the year. The adoption in F1 of both exhaust and kinetic energy recovery was an important part of reducing energy consumption in that series by 30%. The domination of HEVs in the WEC LMP1 class with competitive vehicles fielded by three major OEMs shows that recovering energy is an essential element in the future of racing at the highest levels. Making advanced renewable fuels available to TUSC and INDYCAR shows that using these fuels is the easiest and most cost-effective way to reduce the carbon emissions and oil consumption of race series.

The adoption and publications of the updates to SAE J2880, the Green Racing Protocols, provides a flexible set of guidelines for racing series around the world to adopt elements of Green Racing that fit their situation. In addition, the new J2880 contains a set of recognitions and rewards that incentivize series' progressing to greater levels of Green Racing content and sustainability. The Protocols form a solid foundation for advancing the development of technologies and fuels used in future road vehicles.

The relationship between DOE, IMSA and partners at EPA and SAE International is strong and there are many opportunities for building acceptance of Green Racing principles contained in the Green Racing Protocols. The Green Racing Initiative continues to impact the future of motorsports in alignment with DOE's transportation goals.

I.A.3. Products

Publications

1. SAE J2880 Protocols for Green Racing (http://standards.sae.org/j2880_201406)

Tools and Data

During FY2014, proprietary data and opportunities to be included in test/development were made available to the Green Racing Working Group representatives. As these are projects in process reports will be generated in FY2015.

1. Flowsonic fuel flow measuring systems ability to enable enforcement of energy allocation regulations.
2. Advanced energy storage device (flywheel simulink model) was obtained from a Green Racing partner and will be used in HEV analysis in FY2015.