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Recommendations Regarding Future Tractor-Trailer Coupling Technology

Developed by the Technology & Maintenance Council's (TMC)
Future Chassis & Brake Systems Task Force

ABSTRACT

TMC's Future Chassis & Brake Systems Task Force conducted a review of the potential benefits of automated tractor-trailer coupling technologies. The Task Force found that when compared to current processes, an automated coupler system would improve the safety and comfort for drivers of articulated vehicle combinations through the reduction of operational accidents and injuries, improve productivity through efficiency of the coupling/uncoupling process, and as a result, reduce costs to the end user. TMC recommends that equipment manufacturers and suppliers develop a tractor-trailer coupling system that reduces the numerous driver physical demands associated with coupling and uncoupling the trailer to and from the tractor, and increases the overall reliability of the tractor-trailer interconnection coupling system.

INTRODUCTION

Evolving requirements from emerging automated tractor technologies and emerging trailer technologies are prompting manufacturers to take another look at the tractor-to-trailer interface to improve overall vehicle compatibility, safety, maintenance, and efficiency. The current tractor-trailer coupling system is a very manual, driver-dependent process that has been around for many decades. The Future Chassis & Brake Task Force of TMC's Future Truck Committee has been exploring the potential for developing automation technologies for coupling and uncoupling of the trailer to and from the tractor. TMC's position is that the future tractor-to-trailer interface will need to utilize advanced automated technologies to improve upon driver retention, safety, and efficiency.

It is anticipated that automated coupling will provide status, warnings and diagnostics to the driver during the coupling process regarding fifth wheel jaws locked and engaged to

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trailer kingpin, trailer landing gear position, and the engagement of electrical and pneumatic connections. TMC believes automated coupling will help reduce equipment damage, maintenance, and health care costs, as well as increase operational efficiencies and driver retention. TMC believes these items can be achieved through advancements in automated coupling technologies, which employ sensors to monitor engagement of the fifth wheel jaws to the trailer's kingpin, a motorized landing gear for raising and lowering, and a coupler module that combines pneumatic and electrical connections into a single interface. In fact, most of the technology needed to automate the tractor-trailer coupling process is already available in the industry today.

The purpose of this position paper is three-fold:

- Provide recommendations for a possible future, automated tractor-to-trailer interface to facilitate increased awareness of developing technology.
- Offer goals for an automated tractor-to-trailer coupling design, performance, operation, security, and reliability.
- Provide a baseline for automated coupling from which to demonstrate the operational capabilities, benefits, and challenges.

This paper is organized into the following sections:

- Operational Description
- Performance Requirements
- Safety Considerations
- Security
- Environmental
- Compatibility
- Maintenance Considerations
- Application Considerations
- Efficiency Benefits
- Concerns
- Conclusions

OPERATIONAL DESCRIPTION

Today, there are several new advancements that are adding to the complexity of the tractor-trailer coupling system, such as electric and highly automated vehicles, telematics, two-way power (tractor-to-trailer and trailer-to-tractor), regenerative trailer braking and electromechanical braking. As a result, tractor-to-trailer connectivity options are becoming more complex. The tractor-trailer combination is advancing to an integrated vehicle. Multi-voltage systems are likely to become common place in less than a decade. Today, 12 volts is common, but future needs may require accommodating 12 volts, 24 volts, 48 volts, and higher. The automated coupler needs to provide for expansion to accommodate future technology advancements.

Today's separate electrical conductors for stop lights, side markers, turn signals, etc., can also be eliminated. Multiplexing of the trailer light emitting diode (LED) lights will be turned on and off by sending Controlled Area Network (CAN) messages over the SAE J1939 data-bus. The e-trailer equipped with a generator and battery will be able to provide additional power to the electrified tractor through the tractor-trailer interconnection.

Multiplexing allows for multiple signals to be carried on a single electrical circuit, allowing for better utilization of the electrical circuit and greater tractor-trailer electrical communications. Multiplexing will also have multiple distinct functions for different criticality, safety domain and security that also impacts the tractor-trailer interconnect. The privilege to read and to separately modify each of these distinct functions needs to be considered and logically segmented for automated coupling. The tractor-trailer control and communication activity are critical to identifying standardization opportunities across all the options, and the ability to interface both forward and backward.

Multiplexing is anticipated to meet the needs for future trailer systems for several decades to come.

With “Smart Trailers” now on the roadways, automated vehicle technologies and electromechanical braking on the horizon, there is a growing demand for the interchange of digital information between towing and towed vehicles. At a minimum, the automated coupler electrical connections will need to support two network buses. One bus will be dedicated for brakes and running gear, and a second bus for items other than brakes and running gear.

The digital interchange demand of information between tractor and trailer is requiring even higher transmission speeds. There is growing interest to support higher speeds for the use of cameras for surround view and backup on trailers. Interconnected by a bus affords for higher bandwidths and media access features that can improve the safety and security posture of the tractor-trailer combination.

Automated vehicle technology is bringing new demands to the tractor-trailer coupling process. Developers of automated technology are awakening to the fact that the driver is still a key component to the coupling of the tractor-trailer. An automated coupler will allow for the coupling and uncoupling of the trailer from the tractor to be performed automatically. An automated coupler will allow mechanical, electrical, pneumatic, and applicable auxiliary functions of the trailer to be coupled and uncoupled from the tractor without the direct manual intervention of the driver from outside of the tractor cab.

PERFORMANCE REQUIREMENTS

The automated tractor-trailer coupling process may be performed as a continuous single operation or in a sequence of steps commanded by the driver by pressing a series of buttons/ icons consisting of:

- Tractor suspension lowers,
- Tractor fifth wheel is positioned under trailer’s upper coupler,
- Tractor suspension is raised,
- Tractor backs into trailer bringing kingpin into fifth wheel throat,
- Fifth wheel jaws engaged and locked to trailer kingpin,
- Raise trailer landing gear

The automated tractor-trailer uncoupling process may be performed as a continuous single operation or in a sequence of steps commanded by the driver by pressing a series of buttons or icons consisting of:

- Lower trailer landing gear
- Fifth wheel jaws unlocked and disengaged from trailer kingpin
- Tractor suspension lowers to move fifth wheel jaws away from trailer kingpin
- Tractor moves forward and away from trailer

A standard set of icons will be required for eliminating confusion among various coupling systems when performing the process of coupling and uncoupling the trailer to and from the tractor.

The automated tractor-trailer coupler eliminates the need for coil air line tubing, which will improve the air application and release timing at the tractor’s gladhand coupler and the trailer brakes.

Endurance

Eliminating coil cables and coil air lines will eliminate strain that occurs between connectors, coil cable, gladhand couplers, and coil air tubing. Eliminating strain will improve the overall endurance compared to today’s tractor-trailer electrical and pneumatic manual interconnections.

The coupler will need to survive a minimum of 10,000 mechanical cycles. A cycle is defined as follows:

a. Opening of the cover,
b. Insertion of the plug into the socket,
c. Latching and unlatching of the fifth wheel jaws or locking device,
d. Withdrawal of the plug,

e. Closing of the socket cover.

Parameter defined by:

- 2,500 cycles (cycle = couple & uncouple) per SAE J318, *Gladhand Couplers*
- 5,000 cycles (cycle = couple & uncouple) per SAE J560, *seven-pin Plug & Receptacle*
- 20 cycles/day, five days/week, 52 weeks/year = one year results in approximately 5,000 cycles

SAFETY CONSIDERATIONS

The coupling and uncoupling of the trailer to and from the tractor puts numerous physical demands upon the driver. In an environment where there is a shortage of drivers, steps need to be taken to improve the working environment for the purpose of driver retention.

The current process of coupling and uncoupling the trailer to and from the tractor is very archaic. In today's working environment, with the use of aero dynamic tractor fairings and trailer skirts, drivers are at risk of slipping off equipment, straining muscles and spraining their backs. Drivers are at risk of injury from having to squeeze into tight places to connect and disconnect coil air lines and electrical cables; and checking fifth wheel jaws for being engaged and locked around the kingpin.

According to OSHA and data from the Bureau of Labor Statistics 13 fatalities in truck transportation occurred in Midwestern states from 2015 to 2017 related to coupling (attaching) and uncoupling (detaching) trucks from the rig. An automated tractor trailer coupling process that eliminates human intervention will eliminate mistakes that can be made by the driver during the tractor-trailer coupling process. See *https://www.osha.gov/news/newsreleases/trade/04172018*.

When the driver is outside the tractor cab and in the yard between the tractor and trailer there is a risk of the driver being hit, caught, pinched, and crushed by moving equipment due to human error such as not properly setting the parking brakes. Having the driver remain in the tractor cab when making air and electric connections will help improve the yard safety.

SECURITY

Automated coupling will need to preserve the present reliability of operation of the tractor-trailer coupling for drivers; even though the connectivity of tractor-trailer networks will increase cybersecurity risks. The automatic coupler must provide cybersecurity resilience, so tractor-trailer networks are not compromised. Diagnostic systems for the automated coupler need to be segmented from the tractor and the trailer vehicle networks with some form of separation, either access controls or wholly separate systems. Automated coupling that allows for tractor-trailer network interconnect, where telematic connections are present, will increase the cybersecurity risks that come with telematics.

Adding encryption is not going to be a silver bullet. Layered defenses are needed from systems architecture down through to firmware in both the 'things that roll' and the 'cloud' backends. Similar to the requirements formulated for telematics in the National Motor Freight Traffic Association (NMFTA) *Cybersecurity Requirements for Telematics Systems*, comprehensive sets of security requirements will need to be developed and fleets will need to review these requirements as part of the evaluation and validation process when they consider purchasing equipment.

The defenses needed will be realized by equipment manufacturers and builders with strong cybersecurity processes. Organizations need to:

a. identify and manage cybersecurity risks,
b. protect the vehicle ecosystem,
c. detect, monitor, and respond to cybersecurity events, and
d. recover from cybersecurity events safely.

Security is a manifestation of systems properties where the responsibility for next generation trailer technology no longer falls only to the component manufacturer, but also the responsibility of the trailer builders too. This involves integrating several processes into the product lifecycle, including a Vulnerability Disclosure Program (VDP), incident response, and threat modelling, to name a few. For more details on a VDP, consider Cybersecuirty and Infrastructure Security Administration (CISA) Binding Operational Directive BOD 20-01 and for security objectives see SAE J3061, *Cybersecurity Guidebook for Cyber-Physical Vehicle Systems, Appendix A*, UN-ECE-WP.29, *Cybersecurity Management Sytem Requirements*, and ISO/SAE DIS 21434, *Road Vehicles - Cybersecurity Engineering*. The documents recommend threat modelling of components and systems in early designs and throughout the product lifecycle.

ENVIRONMENTAL

The automated coupler will need to comply with SAE J1455, *Recommended Environmental Practices is Electronic Equipment Design In Heavy-Duty Vehicle Applications*, requirements for chassis mounted components.

Weather

The automated coupler will be exposed and will need to operate and perform without degradation in extreme weather conditions, from frigid winters in Alaska (-40°F), to hot dry summers in Arizona (150°F), and hot humid conditions in Florida.

Fluid Resistance

The automated coupler will be exposed to shop fluids when servicing the vehicle, so there shall be no cracks, splits, or other damage to the coupler. A list of potential shop fluids includes engine oils, additives, transmission oil, rear axle oil, power steering fluid, axle grease, window washer solvent, diesel fuel, diesel exhaust fluid, alcohol, degreasers, soap and detergents, steam, battery acid, spray paint, ether, etc. The automated coupler will also need to withstand high temperature and pressure wash (IP69K) when having to degrease the coupler.

Corrosion

The automated coupler will show no evidence of corrosion from common deicing agents such as potassium chloride (KCl), sodium chloride (NaCl), calcium chloride ($CaCl_2$), and magnesium chloride ($MgCl_2$), which is detrimental to the normal operation of the coupler.

Thermal Shock

The automated coupler will show no evidence of cracking, chipping, or other damage detrimental to normal operation of the coupler.

Dust and Sand

The exposure of the automated coupler to fine dust and sand will not cause problems to moving parts, form conductive bridges, or act as an absorbent material for collecting water vapors.

Mechanical Vibration and Shock

The automated coupler, when subjected to mechanical vibration or shock, will have no performance degradations such as:

- Loss of wiring harness electrical connection from improper connector design, assembly, fretting corrosion,
- Coupler metal fatigue failure,
- Coupler seal leakage.

The automated coupler, when subjected to mechanical shocks encountered during the operational life of the vehicle caused by curbs and potholes, or from shipping, handling and installation, will have no performance degradation or visible damage.

COMPATIBILITY

After the many years it took to achieve current standardization, TMC strongly encourages that new and evolving electrical systems pursue approaches that avoid creation of new barriers to connectivity, as may result from proprietary

designs. With the continual buying and selling of equipment, fleet mergers and consolidations, and the long service life now expected of all capital equipment, most notably the countless numbers of trailers and dollies with well over a decade of useful life, compatible electrical connections is a critical factor in utility, productivity and economic value in the fleets. To prevent incompatibilities and proprietary interfaces, the trucking industry needs to have standards to facilitate interoperability and connectivity across fleets and various OEMs equipment. There is a danger that “proprietary” solutions will work against the current interchangeability among tractors and trailers.

At the same time, the advent of high voltage electric trucks, hybrids, solar power, trailer drive axles with regenerative power and supplemental propulsion, electric Trailer Refrigeration Units, every increasing telematics power needs are introducing multi-voltage electric power systems across the medium- and heavy-duty spectrum. Automation is already seeing driverless yard and port terminal to warehouse applications wherein automatic coupling is no longer future concept, but a here-and-now reality. Design solutions that are being pushed by demand and need, must be tempered to avoid "siloization" resulting from new and innovative designs.

The automated coupler needs to be compatible when interfacing with the existing tractor’s and trailer’s wire gages and pneumatic lines and fittings. The automated coupler must not degrade brake application and release times and must comply with regulatory requirements regarding air system integrity.

MAINTENANCE CONSIDERATIONS

An automated coupler can reduce the maintenance issues found with today’s manual tractor-trailer interconnection system by eliminating coil electrical cables and coil plastic airline tubing. The electrical and pneumatic connection is made in the surrounding area of the tractor fifth wheel and the trailer kingpin. Electrical connectors and airline couplers are no longer mounted on the back of the tractor’s cab and the nose of the trailer with the automated coupler. Today’s tractor-trailer interconnection system can create strains at the end of the electrical cable creating fatigue of conductors that leads to open circuit failures. Today’s tractor-trailer interconnection system also has strains at the end of the plastic airline tubing causing material fatigue that can lead to air leakage.

The automated coupler must provide a moisture tight cover to protect the automated coupler’s electrical and pneumatic connections from road spray and foreign debris such as sand and dust. The current manual tractor-trailer interconnect system has open electrical and pneumatic connections. The current seven-pin SAE J560 plug and receptacle can be exposed to moisture creating corrosion of the electrical terminals inside the connector, which can lead to electrical failures. Today’s gladhand couplers, mounted on the nose of trailers, can be exposed to foreign debris such as sand and dust while parked in the yard. The debris then enters the air brake system causing premature failure of tractor and trailer pneumatic braking components.

The seven-pin SAE J560 connector and gladhand couplers can become dislodged from the holder while the tractor is traveling bobtail. The coil electrical cable and airline tubing may find itself wrapped around the tractor’s drive shaft. The automated coupler eliminates the use of the seven-pin SAE J560 connector, coiled electrical cables, gladhands and coil airline tubing as components of the tractor-trailer interconnection system, thus eliminating the risk of coil electrical cables and airline tubing getting damaged and failing.

APPLICATION CONSIDERATIONS

An automated coupler can have different levels of automation that may limit the procedures regarding electrical and pneumatic connections.

The automated coupler connector module will be mounted in the location of the tractor's fifth wheel and the trailer's kingpin, which is the connection and pivot point of the articulated vehicles. The automated coupler is intended for the interconnection between a tractor and a semi-trailer, with the potential for future applications on a dolly and a second semi-trailer.

The automated coupler must be capable of coupling in an angular range along the longitudinal axis of the tractor-trailer to, at least, a maximum of ±45° from the longitudinal axis of the tractor to the trailer. The automated coupler will also need to be adaptable to various trailer upper coupler configurations such as flatbeds, box trailers, tank trailers, and livestock trailers. The trailer's upper coupler must be adequately designed for housing the automated coupling system components without affecting strength and durability of the trailer's structure.

Trailers intended for intermodal on Trailer on Flatcar (TOFC) applications should avoid automated couplers until such time as another design solution for the flat rail car drop plate is identified that will not damage the trailer's automated coupler. The flat rail cars are equipped with drop plates on each end of the flatcar. The trailer is secured to the flat rail car through the drop plate at the trailer's kingpin. The current flat rail car drop plate would crush and destroy the trailer's portion of the automated coupler.

EFFICIENCY BENEFITS

The automated coupler will improve the overall productivity of the yard and the convenience to the driver through eliminating the need for the driver to get out of the cab to connect and disconnect electrical and pneumatic connections and raise and lower the landing gear.

CONCERNS

TMC acknowledges that every technical innovation presents its own set of issues or concerns. These include:

- Voltage/power requirements,
- Backwards compatibility with current systems,
- Corrosion of electrical/electronic components caused by deicing chemicals,
- Obstruction of the flat rail car drop plate with the trailer's automated coupler for intermodal,
- Mechanical vibration concerns from having a stiffer connection point between tractor and trailer versus today's coiled electrical cable and air tubing where the connections at the tractor and the trailer move independently.

CONCLUSIONS

TMC recommends that automated tractor-trailer coupling technology be developed for the purposes of:

- Enhancing driver safety,
- Reducing the numerous driver physical demands when coupling and uncoupling the trailer to and from the tractor,
- Improving productivity and convenience by having driver stay in the cab,
- Meeting the changing functional needs of the trucking industry,
- Improving the overall efficiency of the future truck,
- Improved pneumatic trailer brake timing from elimination of coil air lines on tractors,
- Eliminating the strain of coil electrical cables and air lines through elimination of them,
- Preventing foreign debris from entering air brake system from a moisture tight cover eliminating premature failure of pneumatic braking components,
- Eliminating corrosion through a moisture tight cover to protect electrical connections,
- Providing a cost reduction to the end users through less 'down time' by eliminating maintenance of coil electrical cables and air brake tubing,\
- Having secured layered defenses from systems architecture down through to

firmware in both the ‘things that roll’ and the ‘cloud’ backends for cybersecurity resilience,

- Increasing the overall reliability of the tractor-trailer interconnection coupling system.