SAE International™

SURFACE VEHICLE INFORMATION REPORT

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70 MPa Compressed Hydrogen Surface Vehicle Fueling Connection Device and Optional Vehicle to Station Communications

RATIONALE

Not applicable.

TABLE OF CONTENTS

1. SCOPE

This technical information report specifies a guideline for the hardware requirements for fueling a Hydrogen Surface Vehicle (HSV) with compressed hydrogen storage rated at a Nominal Working Pressure of 70 MPa. It contains a description of the receptacle geometry and optional communication hardware and communications protocol to refuel the HSV. The intent of this document is to enable harmonized development and implementation of the hydrogen fueling interfaces.

It is intended to be utilized for hydrogen vehicle field evaluations until enough information is collected to enable standardization. The receptacle portion of this document is to be reevaluated utilizing international field data in approximately two (2) years and subsequently superseded by SAE J2600 in the 2009 timeframe. At that time, input would be gathered from international locations through representation in the SAE Fuel Cell Standards Committee in order to arrive at a final decision regarding the direction of the receptacle and communications standard.

The communications portion of this document is also to be reevaluated utilizing international field data and subsequently superseded by SAE J2601. It is anticipated that the communications protocol and hardware could be standardized before the above mentioned timeframe.

It is not the intent of this document to imply a position regarding the commercial fueling protocol, communication, or non-communication strategy, but simply serves as a reference for the receptacle hardware and IRDA communications if this strategy is selected. In addition, it is not intended be referenced by other Standard and/or Code organizations.

1.1 Gaseous Hydrogen Fueling System Overview

The overall hydrogen fueling system consists of a dispenser and HSV. The connector couples the hydrogen fueling system (dispenser) and the HSV, and that hydrogen fueling coupling is specified as the fueling connector interface. There are three portions of the hydrogen fueling coupling: a mechanical portion, a process portion, and a data portion. This document describes the mechanical and data portions of the fueling interface. See Figure 1.

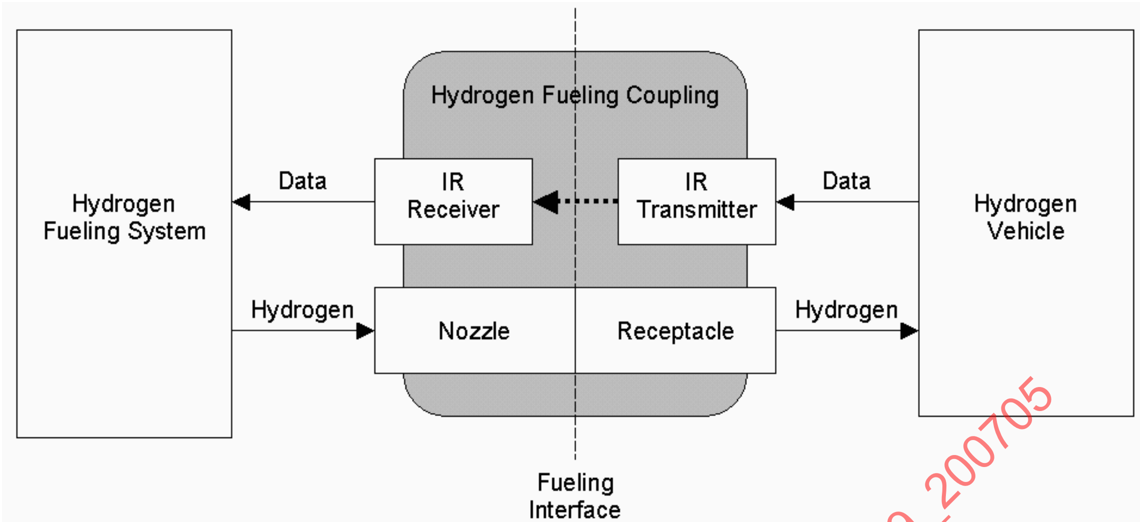

FIGURE 1 - OVERALL GASEOUS HYDROGEN FUELING SYSTEM

2. REFERENCES

2.1 Applicable Publications

The following publications are referenced in this document and will provide a meaningful understanding of the requirements specified herein. Unless otherwise specified, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J2600 Compressed Hydrogen Surface Vehicle Fueling Connection Devices

2.1.2 IrDA Publications

Available from Infrared Data Association, P.O. Box 3883, Walnut Creek, CA 94598, Tel: 925-943-6546, www.irda.org.

IrDA IrLAP 1.1 Serial Infrared Link Access Protocol

IrDA IrPHY 1.4 IrDA Serial Infrared Physical Layer Specification

IrDA Physical Layer Measurement Guidelines V1.1, 8 Sept 2000

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this document.

2.2.1 SAE Publications

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J2574 Fuel Cell Vehicle Terminology

SAE J2578 Recommended Practice for General Fuel Cell Vehicle Safety

SAE J2760 Pressure Terminology Used in Fuel Cells and Other Hydrogen Vehicle Applications

SAE AS568 Size Standard for O-Rings

3. DEFINITIONS

3.1 Ambient Temperature

The temperature in the air in the vincinity of the fueling process, and not in direct sunlight.

3.2 Bulk Temperature

The average hydrogen gas temperature within the HSV's hydrogen storage tank.

3.3 Connector

A joined assembly of the Dispenser's nozzle and HSV's receptacle which permits quick connect and disconnect of fuel supply hose to the receptacle. The connector consists of two required and two optional components. The nozzle and receptacle are required for the connector and described by SAE J2600 and this document. An optional infrared emitter on the receptacle and infrared receiver on the nozzle may also be included as part of the connector.

3.4 Data Communications Link

The optional data communication portion of the connector consists of an infrared emitter that is mounted in the HSV in close proximity to the receptacle and infrared receivers that are located in the nozzle. These devices allow the HSV to send data to the fuel dispensing system. Figure 2 illustrates the emitter and receiver placement.

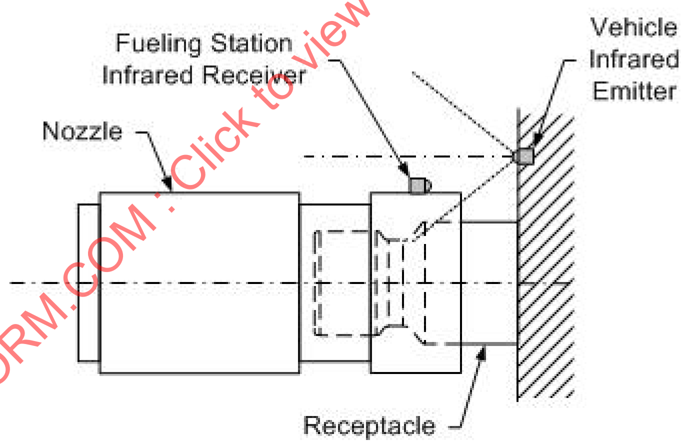

FIGURE 2 - CONNECTOR WITH INFRARED COMMUNICATIONS LINK

3.5 Hydrogen Dispensing System (Dispenser)

The dispenser consists of a supply of compressed hydrogen, a means of controlling the flow of compressed hydrogen, a means of safely venting or otherwise capturing hydrogen from the connection, an optional means of receiving communications from the HSV, and the nozzle portion of the connector.

3.6 Measured Pressure

Gas pressure measured by a sensor in the HSV's hydrogen storage tank.

3.7 Measured Temperature

Gas temperature measured by a sensor in the HSV's hydrogen storage tank.

3.8 Nozzle

A device connected to a Hydrogen Dispensing System which couples to the HSV's receptacle and permits transfer of fuel. This may also be referred to as a fueling connector (as defined in SAE J2600).

3.9 Rated Gaseous Hydrogen Density

Density of hydrogen at 70 MPa at 15 °C corresponding to a 100% State of Charge (SOC) HSV hydrogen storage tank, where the accepted standard density is 40.2 g/L.

3.10 Receptacle

A device connected to a HSV's storage system that couples to the Hydrogen Dispensing System's nozzle and permits transfer of fuel. This may also be referred to as a fueling inlet.

4. 70 MPA COMPRESSED HYDROGEN SURFACE VEHICLE FUELING CONNECTION DEVICE

4.1 Nozzle Specification, Verification Testing and Marking

The nozzle and receptacle are to conform to the SAE J2600 standard.

4.2 70 MPa Receptacle Dimensions

The receptacle geometry shall comply with the design specifications detailed in Figure 3. Note: the rear of the anti-extrusion ring is 12.4 mm from the front face. The O-Ring Standard is in section 2.1.1.

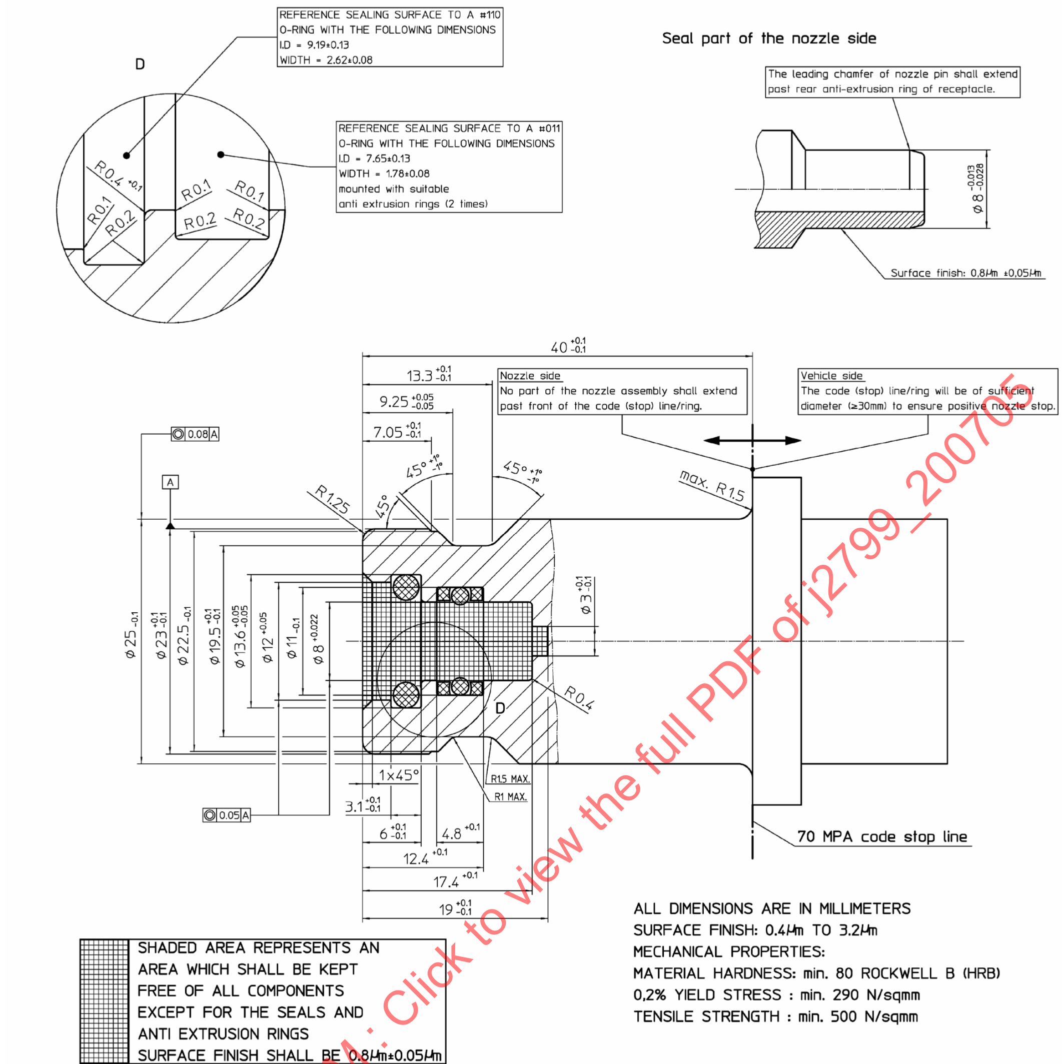

FIGURE 3 - H70 HYDROGEN RECEPTACLE

5. COMPRESSED HYDROGEN SURFACE VEHICLE TO STATION COMMUNICATION DEVICE

5.1 Physical and Functional Requirements

5.1.1 Communication Protocol

5.1.1.1 Physical Layer Protocol Specification

The infrared data link uses an optical interface based on the 38400-baud interface specified by IrDA physical layer specification, IrDA IrPHY 1.4. The physical layer implements only a portion of the IrPHY specification and it is not meant to be compatible with standard IrDA devices.

5.1.1.2 Modulation Scheme

The modulation scheme defined below is described in section 2.3 of IrPHY 1.4. A Return-To-Zero-Inverted (RZI) modulation scheme is used where a “0” is represented by a light pulse and a “1” is represented by no light pulse. The optical pulse duration is nominally 3/16 of the bit duration. The maximum pulse duration is 3/16 of the bit duration, plus a tolerance of 0.60 microseconds

5.1.1.3 Byte Framing

The signal is organized into IR frames, as shown in Figure 4, that have a direct correlation to UART frames as described in section B.3 of IrPHY 1.4. Each byte is transmitted asynchronously with a start bit, 8 data bits, and a stop bit. Data bits are transmitted in serial byte order, with the least significant bit (LSB) transmitted first and the most significant bit (MSB) transmitted last. Bits are transmitted at a rate of 38400 bits per second.

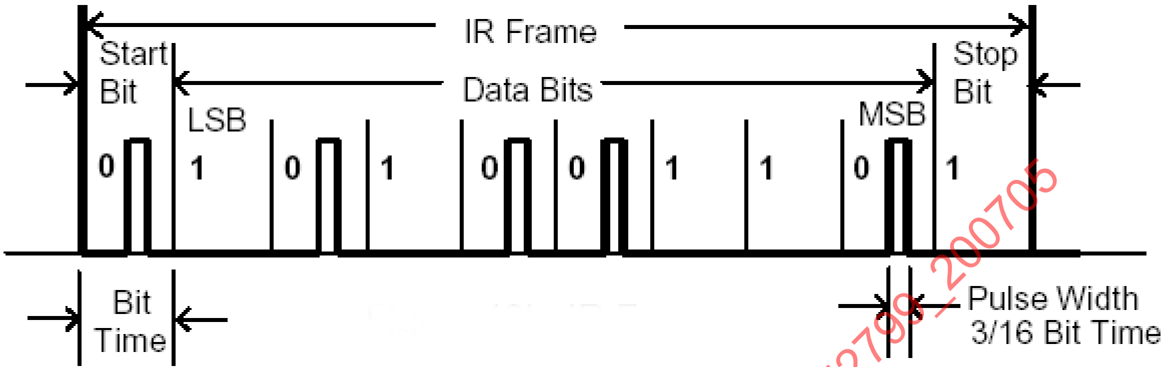

FIGURE 4 - IR FRAME

5.1.2 Data Link Layer Protocol Specification

The purpose of the data link layer is to ensure valid application data is transferred from the transmitting side to the receiving side of the data link. The data link defined below is based on the low speed asynchronous data link specified by IrDA IrLAP 1.1. The data link implements only a portion of the IrDA specification and it is not meant to be compatible with standard IrDA devices.

5.1.2.1 Data Link Control Characters

The following control characters are used for the data link framing as described in section 10.1 of IrLAP 1.1.

XBOF – Extra Begin of Frame character should be 0xFF hexadecimal.
BOF – Beginning of Frame character should be 0xC0 hexadecimal.
EOF – End of Frame character should be 0xC1 hexadecimal.
CE – Control Escape character should be 0x7D hexadecimal (see appendix A1.1).

5.1.2.2 Frame Check Sequence (FCS) Field

The frame check sequence field detects errors in the received frame as described in section 10.1.2 of IrLAP 1.1. The FCS field should be a 16-bit CRC-CCITT cyclic redundancy check computed on the bytes in the application data. The polynomial for the CRC should be X16 + X12 + X5 + 1. The FCS is transmitted with the least significant byte first followed by the most significant byte.

An implementation of the CRC-CCITT FCS algorithm for calculating the CRC has been provided in the FAST FRAME CHECK SEQUENCE (FCS) Implementation section of the appendix.

5.1.2.3 Data Link Frame

The application data packets are transmitted in data link frames as described in section 10 of IrLAP 1.1. The application data packets should be transmitted in data link frames. Five XBOF characters should precede the data link frame transmission. A single BOF character should be transmitted at the start of the data link frame. The application data packet should be transmitted immediately following the BOF character. A frame check sequence field should be transmitted immediately following the application data packet. The data link frame should be terminated with an EOF character as shown in Table 1.

TABLE 1 - DATA LINK FRAMING

XBOFs	BOF	Application Data	FCS	EOF

5.1.2.4 Transparency

A transparency character is defined to transform application data bytes (and FCS field bytes) which correspond to data link control characters as described in section 10.1.3 of IrLAP 1.1. The transmitting side of the data link should transform any data bytes, or FCS bytes, corresponding to control characters XBOF, BOF, EOF or CE into non-control characters prior to transmitting the data link frame.

The transformation method on the transmitting side should be:

a. Insert a control escape (CE) byte preceding the data byte.

b. Exclusive OR the data byte with 0x20 hexadecimal.

The receiving side should reverse the transformation whenever a CE byte is received in the data stream.

The receiving side should reverse the transformation using the following method:

a. Discard the control escape (CE) byte.

b. Exclusive OR the data byte with 0x20 hexadecimal.

The state machine for gaseous hydrogen fueling communication, shown in Figure 5, may be implemented by the receiver to properly decode received characters as described in section 10.1.5 of IrLAP 1.1.

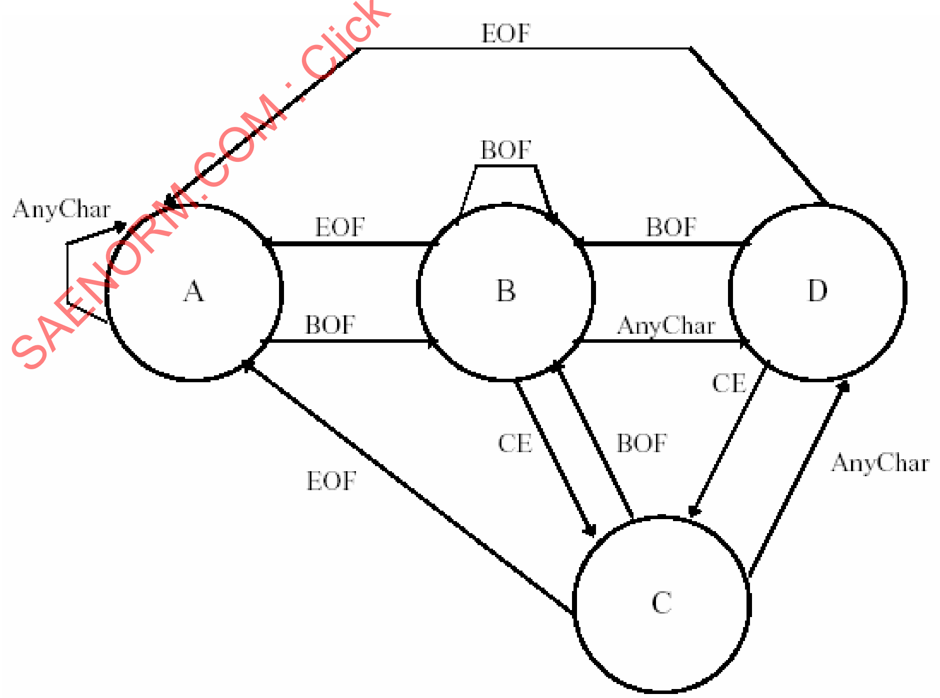

FIGURE 5 - RECEIVER TRANSPARENCY STATE MACHINE

All bytes received are discarded in state A until a BOF (or XBOF) is received. All bytes received on the AnyChar events (which cause a transition from state B to state D, or from state C to state D) are inserted into the receive data packet. A complete data packet has been decoded on the EOF event (which causes a transition from state D to state A).

5.1.3 Presentation Layer Protocol Specification

The dispenser should attempt to support the highest-level fueling process for which it has received all the required data that meet the required data integrity checks.

5.1.3.1 Data Integrity Checks

5.1.3.1.1 Data Type

All data should be transmitted in ASCII format.

5.1.3.1.2 Proper Delimiter Check

A single pipe character ("|" ASCII, $7C hexadecimal) should be used to delimit all pieces of data. All valid data should be contained between two pipe characters, as shown in Table 2.

TABLE 2 - DELIMITER PERMUTATIONS AND INTERPRETATIONS

|MP=010.0|VN=02.99|	Proper format, both valid
MP=010.0|VN=02.99|	MP not valid due to no leading delimiter
|MP=010.0|VN=02.99	VN not valid due to no trailing delimiter
|MP=010.0||VN=02.99|	All data valid, redundant delimiter is not required

5.1.3.1.3 Proper Tag Check

The first two characters after the data delimiter should contain a defined data tag. All tags comparisons should be case sensitive. The third character after the delimiter should be the “=” character (hexadecimal $3D). Any deviations from this format should result in all data between the delimiters being discarded.

5.1.3.1.4 Properly Defined Value Check for Required Character Data

All character data for a required data field should be an exact match for a defined value. All defined data comparisons should be case sensitive. Extra spaces and/or characters should invalidate the data.

5.1.3.1.5 Properly Defined Value Check for Required Numerical Data

All defined numerical data positions should be filled using leading and following zeros as required to fill the defined format. Extra spaces and or characters should invalidate the data. All defined numerical data should be greater than or equal to the minimum defined value and less than or equal to the maximum defined value, as shown in Table 3.

TABLE 3 - VALUE CHECK PERMUTATIONS AND INTERPRETATIONS

|MP=035.0|	Proper format
|MP=35.0|	Not valid due to lack of leading zero
|MP=035|	Not valid due to lack of decimal point and trailing zero
|MP= 035.0|	Not valid due to extra space before numerical data.
|MP=3.5E1|	Not valid, scientific notation not supported
|MP=035.0|	Proper range
|MP=100.1|	Not valid, data outside of defined data range (000.0 – 100.0)

5.1.3.1.6 Data Interval Check

All required data fields for a given fueling process should have been updated with properly formatted message data within 5 times the nominal transmission interval to be considered valid. The only exception to this requirement is that dispenser should respond to any properly formatted abort command (FC=Abort) from the vehicle regardless of whether the data has been received within its nominal transmission interval.

5.1.4 Communication Hardware for Gaseous Fueling

5.1.4.1 Infrared Transmitter/Receiver Placement

5.1.4.1.1 Vehicle Transmitter

The vehicle should have at least 1 infrared transmitter as shown in Figure 7. The infrared transmitter(s) on the vehicle should have a minimum half angle of a=55°, see Figure 9. The vehicle transmitter(s) should be located on the mounting surface at a radius of rv=22 ± 4 millimeters from the axis of the receptacle, see Figure 7. The vehicle transmitter(s) should be at least dv,min=0 millimeters from reference plane z=0 which is 50 millimeters from the plane defined by the leading edge of the receptacle, see Figure 9. The vehicle transmitter(s) should be at most dv,max=20 millimeters from reference plane z=0 which is 50 millimeters from the plane defined by the leading edge of the receptacle, see Figure 9.

The minimum intensity of the vehicle infrared emitter should be 40 mW/sr within the range of the half angle. The maximum intensity of the vehicle infrared emitter should be 100 mW/sr within the range of the half angle.

5.1.4.1.2 Nozzle Receiver

The nozzle should have at least 3 infrared receivers. The infrared receivers on the nozzle should have a minimum half angle of b=55°, see Figure 9.The angle between adjacent nozzle infrared receivers should be no more than c=120°, see Figure 8.The nozzle receivers should be located rn=22 ± 4 millimeters from the axis of the nozzle, see Figure 8. When the nozzle is fully engaged with the receptacle, the receivers on the nozzle should be at least dn,min=15 millimeters from the reference plane z=0, see Figure 9. When the nozzle is fully engaged with the receptacle, the receivers on the nozzle should be no more than dn,max=35 millimeters from the reference plane z=0, see Figure 9.

As a guideline, for the above specified geometry the minimum irradiance that the nozzle receiver will be required to detect will be 100 μW/cm2 and the maximum irradiance that the nozzle receiver will be required to detect will be 50 mW/cm2.

5.2 Communication Description

5.2.1 Gaseous Fueling Communications

5.2.1.1 Data Definitions

5.2.1.2 Protocol Identifier

Tag:	ID=
Units:	Not Applicable
Range:	SAE J2799
Example:	|ID=SAE J2799|
Interval:	100 ms
Direction:	Vehicle to Dispenser

The vehicle should transmit the protocol identifier to the dispenser to aid in the decoding of the transmitted data. For this revision of this document the ID shall be “SAE J2799”.

5.2.1.3 Data Communications Software Version Number

Tag: VN=
Units: Not Applicable
Format: ##.##
Range: 00.00 – 99.99
Example: |VN=10.02|
Interval: 100 ms
Direction: Vehicle to Dispenser

The vehicle should transmit its version number to the dispenser to aid in the decoding of the transmitted data. The major revision should be defined as the whole number portion of the version number. The minor revision should be defined as the decimal portion of the version number.

Example: For version number 10.02, the major revision is 10 and the minor revision is 02.

For this revision of this document the Version Number shall be 01.00.

5.2.1.4 Tank Volume

Tag: TV=
Units: Liters
Format: ####.#
Range: 0000.0 – 5000.0
Example: |TV=0200.0|
Interval: 100 ms
Direction: Vehicle to Dispenser

The vehicle should transmit the storage volume of the hydrogen tank in liters at the nominal working pressure to the dispenser.

5.2.1.5 Receptacle Type

Tag: RT=
Units: Not Applicable
Range: H25, H35, H50, H70 (As defined by the SAEJ2600 standard)
Example: |RT=H35|
Interval: 100 ms
Direction: Vehicle to Dispenser

The vehicle should transmit the SAE J2600 receptacle code for the vehicle's original fuel receptacle that should correspond to the rated pressure of the vehicle's fueling system.

5.2.1.6 Fueling Command

Tag: FC=
Units: Not Applicable
Range: Dyna(dynamic), Stat (static), Halt, Abort
Example: |FC=Dyna |
Interval: 100 ms
Direction: Vehicle to Dispenser

The vehicle should transmit the fueling command signal to tell the dispenser the vehicle is ready to receive fuel:

FC=Dyna – Dynamic Fueling- Dispenser may dispense fuel with real time vehicle data.
FC=Stat – Static Fueling – Dispenser may dispense fuel based on last available data from vehicle.
FC=Halt – Dispenser should pause the fueling process.
FC=Abort – Dispenser should terminate the fueling process and may not dispense fuel until the dispenser fueling process is restarted by the operator.

5.2.1.7 Measured Pressure

Tag: MP=
Units: MPa
Format: ###.#
Range: 000.0 – 100.0
Example: |MP=043.7|
Interval: 100 ms
Direction: Vehicle to Dispenser

The vehicle should transmit the measured pressure of hydrogen gas in the vehicle's storage tank in MPa.

5.2.1.8 Measured Temperature

Tag: MT=
Units: Kelvin
Format: ###.#
Range: 16.0 – 425.0
Example: |MT=353.0|
Interval: 100 ms
Direction: Vehicle to Dispenser

The vehicle should transmit the measured gas temperature of the hydrogen gas in the vehicle's storage tank in Kelvin.

5.2.1.9 Optional Data

Tag: OD=
Units: None
Range: Any 0 to 16 Characters not including "|"
Example: |OD=Parameter(s)|
Interval: 100 ms minimum
Direction: Vehicle to Dispenser

The vehicle may transmit this optional data set to the dispenser. The data may contain any character except the delimiter character ("|" ASCII, $7C hexadecimal). As the data set is optional and its content not defined by this document, vehicle and dispenser programmers must have first agreed upon the data and its format. The dispenser may ignore the data set if it does not recognize it.

Multiple parameters may be transmitted using the OD tag. For example, the vehicle and dispenser programmers may have agreed to transmit three numerical variables A, B, and C. If A=0.5, B=725.5, and C=2345, one transmit format they might agree upon is:

|OD=A0.5B725.5C2345|

Alternatively, the data could be passed one or two at a time in different OD data sets, at the appropriate transmission interval:

|OD=A=0.5;B=725.5|
|OD=C=2345|

5.2.2 Communications Process

5.2.2.1 Establishing Communications

The dispenser should attempt to receive communications throughout the communications fueling process. To prevent inadvertent loss of communications while the operator is connecting the fueling nozzle, the dispenser should not consider communications as having been lost until communications has been established and the flow of fuel has begun.

5.2.2.2 Required Data – Communications Fueling

The dispenser may execute a dynamic communications fueling if the vehicle sets the Fueling Command to "Dynamic" and if the following data fields for the vehicle have met their respective data integrity and fueling strategy checks: Maximum number of 8 signals can be transmitted – seven are required signals and one optional signal (which can incorporate multiple data points) to be defined.

ID: Protocol Identifier
VN: Version Number
RT: Receptacle Type
TV: Tank Volume
FC: Fueling Command
MT: Measured Temperature
MP: Measured Pressure

The dispenser may execute a Static communication fill if the vehicle sets the Fueling Command to "Static" and the above listed data fields have met their respective data integrity and fueling strategy checks. Then, the vehicle may have the option to switch off communication and the filling station should start or continue the fueling process using the data provided once the fueling command was set to "Static".

5.2.2.3 Required Data – Non-Communications Fueling

The dispenser may execute a non-communications fueling at 70 MPa dispensers without any data fields present.

5.2.2.4 Loss of Communications

The dispenser should attempt to support the highest-level fueling process for which it has received all the required data that meet the required data integrity checks. If there is a break in communications and the last signal is halt, the controller shall abort the fueling process. The dispenser should default to an appropriate fallback fueling strategy, if one or more of the required data fields fails to pass its data integrity check.

5.2.2.5 Communications Re-established

The dispenser may optionally resume a dynamic or static communications fueling after a communications loss at any time during the fueling if all of the required data fields meet the requirements of their data integrity check. The dispenser manufacturer may choose the appropriate strategy switching intervals and number of attempts to re-establish communications to accommodate their dispenser design and fueling strategy. As per 5.1.4.5, the dispenser should however allow a non-communication fueling based on a dispenser option to the user or if communication is not established after an appropriate period of time.

5.2.3 Vehicle Behavior

5.2.3.1 Data Transmission

The vehicle shall transmit the required data sets for the desired fueling type at the nominal interval throughout the fueling process.

5.2.3.2 Temperature Range Check

The vehicle shall be responsible for ensuring that its tank temperature is within the manufacturer's specification limits.

5.2.3.3 Pressure Range Check

The vehicle shall be responsible for ensuring that its tank pressure is within the manufacturer's specification limits.

5.2.3.4 Fueling Command for Communications Equipped Vehicles

The vehicle should only send the fueling command as fueling (FC=Dyna or Stat) if the requirements of the temperature range check, pressure range check, and all other vehicle specific fueling criteria have been satisfied.

The vehicle may request one fueling halt, which may consist of up to 60 seconds worth of repeated fueling halt (FC=Halt) commands. The vehicle should transmit the fueling halt command for at least 2 seconds before resuming the fueling.

The vehicle may send the fueling abort command (FC=Abort) to terminate the fueling process. All SAE J2799 communication equipped dispensers should support a properly formatted fueling abort command for all fueling types (dynamic communications, static communications, and non-communications fuelings) regardless of whether it meets the data interval check. The fueling abort command can be sent at any time and will require the operator restart the dispenser's fueling process to resume fueling.

5.2.4 Dispenser Behavior

5.2.4.1 Protocol Identifier Check

The dispenser should confirm that the protocol identifier received from the vehicle is compatible with a known data definition.

5.2.4.2 Version Number Check

The dispenser should confirm that the major revision of the version number received from the vehicle is compatible with a known data definition. If the major revision of the version number is known, the dispenser may execute a communications fueling based on the data received. If the major revision of the version number is not known, dispenser should execute a non-communications fueling.

5.2.4.3 Receptacle Type Pressure Rating Check

The dispenser should not dispense fuel if the SAE J2600 pressure rating for the received receptacle type data field is less than the pressure rating of the nozzle being used to fuel the vehicle.

5.2.4.4 Fueling Command Check

The dispenser should terminate the fueling process at any time if it receives a properly formatted abort fueling command (FC=Abort). The abort fueling command should be supported for all fueling types on any dispenser equipped with SAE J2799 compliant communications hardware, and is not subject to the data interval, protocol ID, or version number checks.

The dispenser may dispense fuel when it receives fueling command signal set to fueling (FC=Dyna or Stat) if all other fueling criteria are also met.

The dispenser should not dispense fuel when it receives the fueling command signal set to halt (FC=Halt). The dispenser should support one fueling halt request from the vehicle, which may consist of up to 60 seconds worth of repeated "FC=Halt" commands. The dispenser should remain in the halt state for at least 2 seconds before resuming the fueling.

5.2.4.5 Fueling Limit Check

The dispenser should use the vehicle's measured hydrogen gas temperature signal and the dispenser-measured vehicle gas pressure to calculate the actual density (or State of Charge) of Hydrogen gas in the tank.

The dispenser may use the vehicle's measured pressure as part of its fueling limit check.

5.3 Compliance Tests

5.3.1 Qualification of a Gaseous Hydrogen Communication System

5.3.1.1 Qualification Test Setup

To qualify a SAE J2799 communication device, whether vehicle or station side, it shall be independently tested using a qualification test setup. The qualification test setup should consist of electronics capable of testing the full range of receiver/transmitter locations, powers, and sensitivities as specified in sections 5.1.3.1.1 and 5.1.3.1.2. The qualification test setup should have the transmitter and receiver positioned around a simulated receptacle, consisting of a shaft of stainless steel with a diameter of 30 mm. Simulated light sources should be positioned at the distance specified by IrDA Physical Layer Measurement Guidelines (refer to sections 2.1.5, 2.1.6 and 2.1.7). The simulated light sources should be directed toward and be positioned within line of sight of the receivers. The apparatus should be located in an environment with no ambient light.

The qualification test setup should be capable of including a 38% transmittance filter in the 850 to 900 nm IR range placed 2 ± 0.5 mm in front of the transmitter. The setup should not allow any transmitted or reflected IR light to pass around the filter.

The test setup is shown in Figure 6.

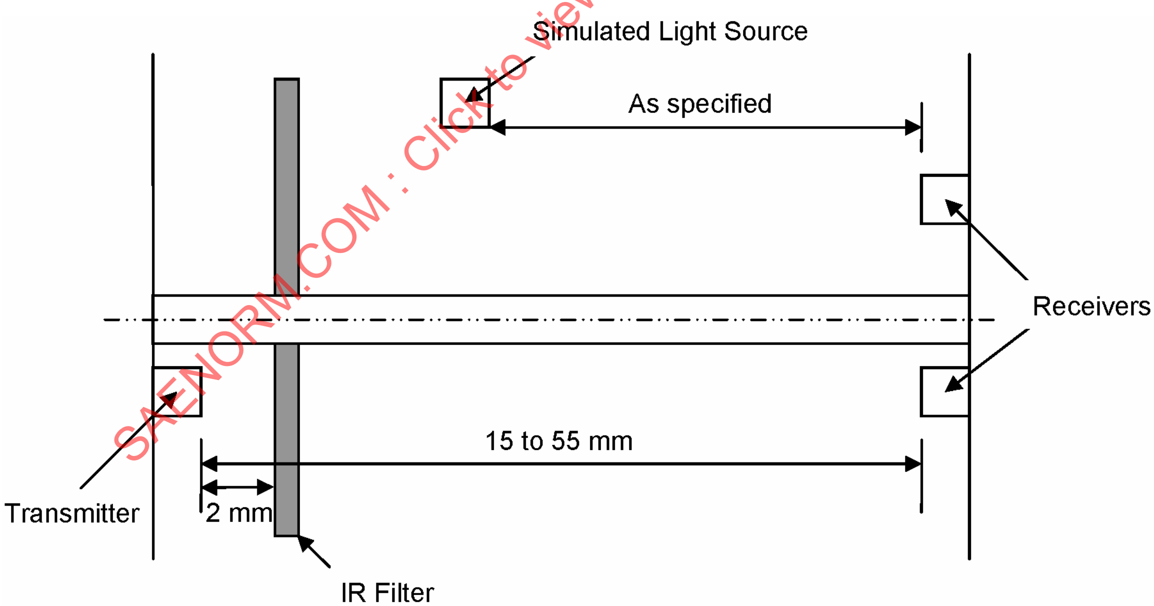

FIGURE 6 - QUALIFICATION TEST SETUP

5.3.1.2 Test Scenario Definition

The scenarios listed in Table 4 shall be tested:

TABLE 4 - TEST SCENARIOS

Scenario	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
IR Filter	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	Y	Y	Y	Y
Simulated Sunlight	Y	N	N	Y	N	N	Y	N	N	Y	N	N	N	N	N	N
Simulated Florescent Light	N	Y	N	N	Y	N	N	Y	N	N	Y	N	N	N	N	N
Simulated Incandescent Light	N	N	Y	N	N	Y	N	N	Y	N	N	Y	N	N	N	N
Transmitter – Receiver Separation (mm)	55	55	55	55	55	55	15	15	15	15	15	15	55	55	15	15
Orientation (degrees)	30	30	30	30	30	30	0	0	0	0	0	0	30	30	30	30
Transmitter or receiver radial dimension (mm)	24	24	24	18	18	18	24	24	24	18	18	18	18	24	18	24

The orientation is determined by setting the 0 degree reference to be where the transmitter directly aligns with any receiver. Scenarios 1 to 6 test the low signal to noise condition; scenarios 7 to 12 test the highest received power scenarios; and scenarios 13 to 16 test a dark ambient light.

5.3.2 Transient Lighting Test

In addition to the above scenarios the transient effects of lighting should be tested by repeating the poorest performing scenario in which a simulated light source is used. However, during transmission, the simulated light source is turned on for 10 ± 5 seconds and then off for 10 ± 5 seconds. This is repeated throughout the duration of the test.

5.3.2.1 Transmission Definition

For each scenario specified above the transmitting side should send 65,536 messages, each containing 9 unsigned word length numbers (1,179,648 bytes total). The algorithm to generate the data to be transmitted is included as follows.

```
For Message_Number = 0 to 65535 step 1
      For Word = 0 to 8 step 1
            Data(2*Word) = Low_Byte(Message_Number)
            Data(2*Word+1) = High_Byte(Message_Number)
      Next
      Call Transmit_Data
Next
```

Each message may contain the pre- and post-signal data as required for communication synchronization. The messages should not contain a data length filed, as the messages for this test are of fixed length. The messages should not contain error-checking fields. The transmit controller should maintain a message frequency of 10 Hz.

5.3.2.2 Test Criteria

When the transmission is complete the data will be checked bit-for-bit. The number of incorrect bits will be recorded to determine the Bit Error Ratio (BER) for the test as shown in Table 5.