SURFACE VEHICLE TECHNICAL INFORMATION REPORT	J2601™-5	FEB2025
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High-Flow Prescriptive Fueling Protocols for Gaseous Hydrogen Powered Medium and Heavy-Duty Vehicles

RATIONALE

This TIR is being revised to add H35 FM60 (60 g/s maximum flow rate) fueling protocols. Previously, this TIR only included an H35 FM120 (120 g/s maximum flow rate) fueling protocol.

FOREWORD

This SAE Technical Information Report (TIR) provides prescriptive general-purpose fueling protocols which are appropriate for use in both private and publicly accessible fueling stations. This TIR supersedes SAE J2601-2 and should be used in place of SAE J2601-2, except at non-public access hydrogen stations, including mobile fueling units, using non-precooled H35 fueling protocols where the vehicles being fueled are known and appropriate administrative controls are enforced.

In this TIR, “shall” is used to express a requirement (i.e., a provision that the user is obliged to satisfy in order to comply with the TIR); “should” is used to express a recommendation or that which is advised but not required; “may” is used to express an option or that which is permissible within the limits of the TIR; and “can” is used to express either a possibility or a capability.

Notes accompanying clauses do not include requirements or alternative requirements; the purpose of a note accompanying a clause is to separate from the text explanatory or informative material. Notes to tables and figures are considered part of the table or figure and may be written as requirements. Appendices are designated normative (mandatory) or informative (non-mandatory) to define their application.

While the MC Formula fueling protocol in SAE J2601 has been used for several years for light-duty vehicle fueling, the fueling protocols in this TIR are relatively new and, at the time of publication, have had limited validation and use on stations and vehicles.

The following items are new to the MC Formula approach and have not yet been used or validated in the field:

- CHSS Volume Measurement Method (see C.3.7 and Appendix F)
- Synthetic Measured Pressure MP_{calc} (see C.3.8, C.3.12, C.3.14, and Appendix E)

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For more information on this standard, visit
https://www.sae.org/standards/content/J2601/5_202502/

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1. SCOPE

This TIR establishes high-flow fueling protocols, including their process limits for fueling of compressed gaseous hydrogen vehicles at peak flow rates from 60 to 300 g/s with compressed hydrogen storage system (CHSS) volume capacities between 248.6 and 7500 L which have been qualified to UN GTR #13. This document is initially being published as a TIR due to limited field testing of the fueling protocols. Once the fueling protocols have been field tested, the SAE Fuel Cell Standards Committee Interface Task Force intends to publish a revision to this document as an SAE Standard.

1.1 Table Summarizing Content

Table 1 - Content of this TIR

Pressure Class	H35	H35	H35	H70	H70
Protocol Name	MCF-HF-G	MCH-HF-G	Category D HF	Category D HF	MCF-HF-G
CHSS Capacity Range (liters)	248.6 to 7500	248.6 to 5000	248.6 to 5000	248.6 to 5000	248.6 to 5000
CHSS Capacity Range (kilograms)	5.97 to 180	5.97 to 120	5.97 to 120	10 to 201	10 to 201
CHSS Capacity Categories (nomenclature)	N/A	N/A	D	D	N/A
Range of Tank Sizes within the CHSS (liters)	50 to 1000	50 to 800	50 to 800	50 to 800	50 to 800
Maximum Flow Rate (grams per second)	120	60	60	60 or 90	60, 90, or 300
Fuel Delivery Temperature Categories	T40 *(-40 to -33 °C)*	T40 *(-40 to -33 °C)*	T40D *(-40 to -33 °C)*	T40D *(-40 to -33 °C)*	T40 *(-40 to -33 °C)*
	T30 *(-33 to -26 °C)*	T30 *(-33 to -26 °C)*	T30D *(-33 to -26 °C)*	T30D *(-40 to -26 °C)*	T30 *(-33 to -26 °C)*
	T20 *(-26 to -17.5 °C)*	T20 *(-26 to -17.5 °C)*	T20D *(-26 to -17.5 °C)*	T20D *(-40 to -17.5 °C)*	T20 *(-26 to -17.5 °C)*
	T10 *(-17.5 to -10 °C)*	T10 *(-17.5 to -10 °C)*			T10 *(-17.5 to -10 °C)*
	T0 *(-10 to 0 °C)*	T0 *(-10 to 0 °C)*			T0 *(-10 to 0 °C)*
	TA *(0 to 20 °C)*				

1.2 Explanatory Material

Table 1 provides an overview of the fueling protocols in this TIR. This TIR provides fueling protocols which are applicable to both the 35 MPa pressure class (H35) and the 70 MPa pressure class (H70). There are two sets of fueling protocols: (1) a high-flow version of the CHSS capacity category D protocol described in SAE J2601 named Category D HF; and (2) an MC Formula-based fueling protocol which utilizes a dynamic pressure ramp rate (PRR) continuously calculated throughout the fill. The naming convention of the MC Formula-based fueling protocol is MCF-HF-G (MC Formula - High Flow - General). The protocols allow for fueling with communications (communications fueling) or without communications (non-communications fueling) and provide end-of-fill pressure targets. For communications fueling, the fueling protocols are to be used in conjunction with SAE J2799.

These fueling protocols utilize numerous process limits on control parameters such as the maximum fuel flow rate, the rate of pressure increase, and the ending pressure. The control parameters and associated process limits are affected by factors such as ambient temperature, fuel delivery temperature, and initial pressure in the vehicle's CHSS.

An important factor in the performance of hydrogen fueling is the station's dispensing equipment cooling capability and the resultant fuel delivery temperature. The fueling protocols utilize fuel delivery temperatures in the range of -40 °C to ambient temperatures. There are six fuel delivery temperature categories denoted by a "T" rating - T40, T30, T20, T10, T0, and TA, where T40 is the coldest. Fueling times are a function of the fuel delivery temperature and CHSS volume.

The fueling protocols herein were developed based on a set of key assumptions. These assumptions are described in 7.2 and 8.2, and in Appendix A of this TIR. These assumptions should be carefully considered in the development and implementation of an on-board CHSS.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J2579 Standard for Fuel Systems in Fuel Cell and Other Hydrogen Vehicles

SAE J2600 Compressed Hydrogen Surface Vehicle Fueling Connection Devices

SAE J2601_202005 Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles

SAE J2799 Hydrogen Surface Vehicle to Station Communications Hardware and Software

2.1.2 ANSI Accredited Publications

Copies of these documents are available online at https://webstore.ansi.org/.

CSA/ANSI HGV 4.3 Test methods for hydrogen fueling parameter evaluation

2.1.3 ISO Publications

Copies of these documents are available online at https://webstore.ansi.org/.

ISO 17268 Gaseous hydrogen land vehicle refuelling connection devices

ISO 26262 Road vehicles - Functional safety

2.1.4 IEC Publications

Available from IEC Central Office, 3, rue de Varembe, P.O. Box 131, CH-1211 Geneva 20, Switzerland, Tel: +41 22 919 02 11, www.iec.ch.

IEC 61508 Functional safety of electrical/electronic/programmable electronic safety-related systems

IEC 61511 Functional safety - Safety instrumented systems for the process industry sector

2.1.5 JSAE Publications

Available from Society of Automotive Engineers of Japan, 10-2 Gobancho, Chiyoda-Ku, 102-0076 Japan, Tel: +81-3-3262-8211, https://www.jsae.or.jp/en/.

Handa, K. and Yamaguchi, S. (2018). Development of Real-time Pressure Loss Compensation Method for Hydrogen Refueling Station to Increase Refueling Amounts. *International Journal of Automotive Engineering*, *9*(4), 310-315. https://doi.org/10.20485/jsaeijae.9.4_310.

Yamaguchi, S., Fujita, Y., and Handa, K. (2018). New Tank Volume Estimation Method for Hydrogen Fueling, JSAE Technical Paper. https://tech.jsae.or.jp/paperinfo/en/content/conf2018-04.221/.

2.1.6 NIST Publications

Available from NIST, 100 Bureau Drive, Stop 1070, Gaithersburg, MD 20899-1070, Tel: 301-975-6478, www.nist.gov.

Leachman, J., Jacobson, B., Penoncello, S., and Lemmon, E. (2009). Fundamental Equations of State for Parahydrogen, Normal Hydrogen, and Orthohydrogen. *Journal of Physical and Chemical Reference Data*, *38*(3), 721-748.

2.1.7 United Nations Publications

Available from United Nations Economic Commission for Europe, Palais des Nations, CH-1211, Geneva 10, Switzerland, Tel: +41-0-22-917-12-34, www.unece.org.

UN Global Technical Regulation No. 13 Hydrogen and Fuel Cell Vehicles

2.1.8 Other Publications

Kuroki, T., Nagasawa, K., Peters, M., Leighton, D., Kurtz, J., Sakoda, N., Monde, M., and Takata, Y. (2021). Thermodynamic Modeling of Hydrogen Fueling Process from High Pressure Storage Tanks to Vehicle Tank. *International Journal of Hydrogen Energy*, *46*(42), 22004-22017.

National Renewable Energy Laboratory. (n.d.). H2FillS: Hydrogen Filling Simulation [Computer software]. U.S. Department of Energy. Retrieved from https://www.nrel.gov/hydrogen/h2fills.html.

PRHYDE (PRotocol for heavy-duty HYDrogEn refuelling) Project Consortium. (2023, April 5). PRHYDE Deliverable D6.7: PRHYDE Results as Input for Standardisation (Revision 1.2). Clean Hydrogen Energy Partnership.

2.2 Related Publications

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

2.2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J2574 Fuel Cell Vehicle Terminology

SAE J2578 Recommended Practice for General Fuel Cell Vehicle Safety

SAE J2719 Hydrogen Fuel Quality for Fuel Cell Vehicles

2.2.2 ISO Publications

Copies of these documents are available online at https://webstore.ansi.org/.

ISO 14687 Hydrogen fuel quality - Product specification

ISO 19880-1 Gaseous hydrogen - Fuelling stations - Part 1: General requirements

ISO 23273 Fuel cell road vehicles - Safety specifications - Protection against hydrogen hazards for vehicles fueled with compressed hydrogen

3. DEFINITIONS

3.1 COMPRESSED HYDROGEN STORAGE SYSTEM (CHSS)

The compressed hydrogen storage system (CHSS) (refer to SAE J2579) consists of the pressurized containment vessel(s), pressure relief devices (PRDs), shut-off device(s), and all components, fittings, and fuel lines between the containment vessel(s) and the shut-off device(s) that isolate the stored hydrogen from the remainder of the fuel system and the environment.

3.2 CHSS CAPACITY

The total water volume of all the storage vessels in the CHSS, or the total mass of hydrogen stored in all the storage vessels in the CHSS at the nominal working pressure at 15 °C.

NOTE: The total mass of hydrogen stored in the CHSS at the nominal working pressure at 15 °C is equivalent to a 100% state of charge (SOC).

3.2.1 TOTAL VOLUME (TV)

The CHSS capacity in liters is communicated as the total water volume of all the storage vessels in the CHSS using the nomenclature “TV” as one of the SAE J2799 data fields using IrDA communications.

3.2.2 TANK VOLUME LARGE (TVL)

Capacity (water volume) of the largest single tank within the CHSS, measured at the nominal working pressure and 15 °C.

NOTE 1: TVL may be communicated in the Optional Data Field.

NOTE 2: The formatting is TVL=####, where #### represents the capacity expressed in liters rounded to the nearest integer.

3.3 DISPENSER COMPONENTS

Any component of the dispenser that carries precooled hydrogen to the CHSS. In most cases, this is any component downstream of the heat exchanger up to and including the nozzle (e.g., hose break-away, dispenser hose, and nozzle).

3.3.1 HYDROGEN DISPENSING EQUIPMENT (DISPENSER)

The equipment required to condition and transfer fuel from the station to vehicle CHSS for the purpose of fueling the vehicle.

3.3.2 CONNECTOR or COUPLING

A joined assembly of a nozzle and receptacle which permits rapid coupling (or connecting) and decoupling (or disconnecting) of fuel supply nozzle to the vehicle fueling receptacle, as per SAE J2600.

3.3.3 NOZZLE

Device connected to a fuel dispensing system which engages the Hydrogen Surface Vehicle (HSV) receptacle and permits transfer of fuel (see 3.3.2).

3.3.4 RECEPTACLE

Device connected to a vehicle or storage system that receives the dispenser nozzle and permits transfer of fuel. This may also be referred to as a “fueling inlet” (see 3.3.2).

3.3.5 DISPENSER HOSE

The flexible hose assembly which transfers hydrogen between the dispenser and nozzle.

3.3.6 BREAK-AWAY

A device which allows the hose to separate from the dispenser if exposed to a sufficient mechanical stress. Typically, the hose is the only component between the nozzle and the break-away.

3.4 FUELING WITH AND WITHOUT COMMUNICATIONS

3.4.1 COMMUNICATIONS FUELING

A fueling conducted when a valid data connection is established from the vehicle to the dispenser in accordance with SAE J2799.

3.4.1.1 OPTIONAL DATA BLOCK (OD BLOCK)

A set of data in the OD data field that contains a header and data.

3.4.1.2 OPTIONAL DATA (OD DATA)

Data contained in the Optional Data Block.

3.4.1.3 OPTIONAL DATA BLOCK HEADER (OD HEADER)

A signifier at the start of the Optional Data Block (see 3.4.1.1) used to designate the data contained in the Optional Data Block.

3.4.2 NON-COMMUNICATIONS FUELING

A fueling conducted when no valid data connection from vehicle to dispenser exists, as specified in SAE J2799, or the received data is not recognized as valid by the dispenser.

3.5 FUELING TIME AND FUELING EVENTS

Figure 1 illustrates the fueling time definitions for the main and overall fueling time as described in 3.5.1 to 3.5.8.

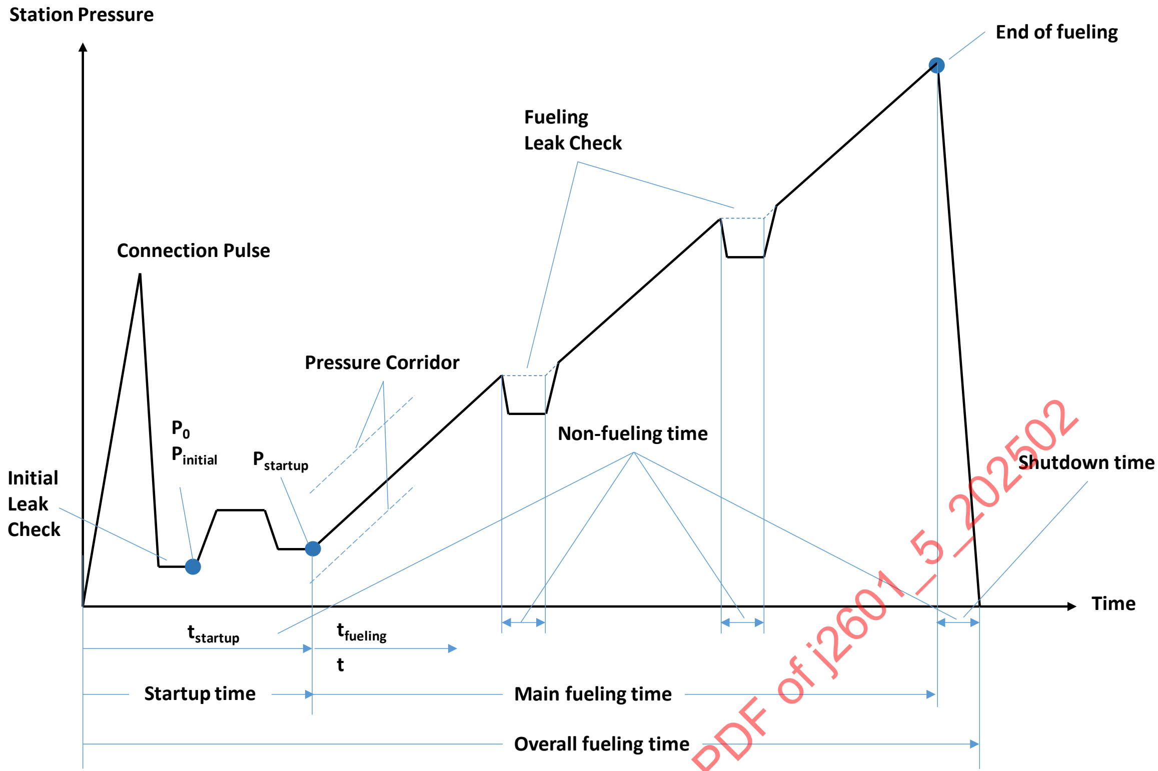


Figure 1 - Representative hydrogen fueling time diagram

3.5.1 OVERALL FUELING TIME

The total amount of time between when the user initiates the fueling at the dispenser until the nozzle can be removed. It includes the startup time, main fueling time, and shutdown time.

3.5.2 NON-FUELING TIME

The amount of time during the overall fueling time when fueling PRR is not applied. The non-fueling time includes the startup and shutdown time, plus any planned interruptions during the main fueling time. However, non-fueling events do not include stopping or pausing fuel flow due to safety issues, lack of performance, etc. See 3.5.3.1 through 3.5.3.4 for examples of events during the non-fueling time.

3.5.3 INTENDED NON-FUELING EVENTS

A planned event when gas does not flow during the overall fueling time in order to test the integrity of the system or to change the source of fuel. See 3.5.3.1 through 3.5.3.4 for examples of intended non-fueling events. Intended non-fueling events do not include stopping or pausing fuel flow due to safety issues or lack or performance.

3.5.3.1 CONNECTION PULSE

The first flow of hydrogen from the dispenser to the CHSS after connection of the nozzle, whereby the minimum amount of hydrogen necessary to open the check valve is dispensed into the CHSS. The purpose of the connection pulse is to equalize the station pressure with the CHSS pressure under static conditions so that the initial pressure can be measured.

3.5.3.2 INITIAL LEAK CHECK

The initial leak check may be implemented after the nozzle is connected and prior to the start of main fueling time. This can be accomplished by pressurizing the fueling path and measuring any decrease in pressure.

3.5.3.3 FUELING LEAK CHECK

A fueling leak check may be implemented during fueling to determine if there are any leaks in the system. This can be accomplished by pausing the fueling and measuring any decrease in pressure.

3.5.3.4 BANK SWITCHING

Bank switching occurs when the station changes the flow source from one storage bank to another.

NOTE: During bank switching, there may be variations in the mass flow rate, pressure, and temperature, or a short-term pause in fueling.

3.5.4 STARTUP TIME

The period from the moment the user initiates fueling to the moment the main fueling time begins.

NOTE 1: The startup time includes a connection pulse and initial pressure measurement and may also include a CHSS capacity measurement or determination, as well as an initial leak check.

NOTE 2: Because an accurate capacity measurement cannot be achieved within the startup time, the MCF-HF-G fueling protocol allows for a CHSS volume (capacity) measurement shortly into the main fueling time.

3.5.5 START OF FUELING

The instant immediately after the startup time when the dispenser initiates the main fueling at the prescribed ramp rate and the upper and lower tolerances on pressure are applied.

3.5.6 END OF FUELING (INTENDED)

Occurs when the dispenser stops fueling at the target pressure or SOC.

3.5.7 MAIN FUELING TIME

The period of gas flow between the start of fueling and the end of fueling. The prescribed ramp rate and the upper and lower tolerances on pressure are applied during the main fueling time. The main fueling time does not include the startup and shutdown times but can include other non-fueling times.

3.5.8 SHUTDOWN TIME

This period begins at the end of fueling (after main fueling time) and ends when the user can remove the nozzle.

3.5.9 TERMINATE FUELING

This can occur prior to the end of fueling in the event that the dispenser or vehicle has detected that a process requirement has been exceeded, the “Abort” command is issued by the vehicle, or the user terminates the fueling.

3.6 HYDROGEN SURFACE VEHICLE (HSV)

Any surface vehicle which stores and uses hydrogen as a fuel. An example of an HSV is a Fuel Cell Vehicle.

3.7 PRESSURE

3.7.1 CHSS PRESSURE ($P_{vehicle}$)

Pressure of hydrogen gas within the vehicle CHSS.

NOTE: For vehicles with multiple tanks, this TIR assumes all tanks are at equal pressure, at all times.

3.7.2 STATION PRESSURE ($P_{station}$)

The pressure of the hydrogen gas supplied to the vehicle by the dispenser, measured near the break-away (see 6.1.1.1).

3.7.3 INITIAL PRESSURE ($P_{initial}$)

The pressure in the CHSS as measured by the dispenser immediately after the connection pulse during the startup time when there is no flow. In a multi-tank CHSS, each tank is assumed to have the same initial pressure.

3.7.4 STARTUP PRESSURE ($P_{startup}$)

The pressure in the CHSS as measured by the dispenser at the end of the startup time when there is no flow.

3.7.5 TARGET PRESSURE (P_{target})

The station pressure at which the hydrogen fueling protocol targets for the end of fueling.

3.7.6 NOMINAL WORKING PRESSURE (NWP)

The NWP is the gauge pressure that characterizes typical operation of a vehicle pressure vessel, container, or system. For compressed hydrogen gas containers, NWP is the vehicle vessel pressure, as specified by the manufacturer, at a uniform gas temperature of 15 °C and 100% SOC.

3.7.7 MAXIMUM OPERATING PRESSURE (MOP)

The MOP is the highest gauge pressure of a component or system that is expected during normal operation including starts, stops, and transients (e.g., the MOP = 1.25 x NWP).

3.7.8 MAXIMUM ALLOWABLE WORKING PRESSURE (MAWP)

The MAWP is the maximum gauge pressure of the working fluid (gas or liquid) to which a piece of process equipment or system is rated with consideration for initiating fault management (e.g., the MAWP = 1.38 x NWP).

3.7.9 PRESSURE CLASS

The pressure class will be defined by the protocol's nominal working pressure. The class is denoted by the letter "H" followed by the nominal working pressure in megapascals. For example, H70 is the pressure class for a hydrogen fueling protocol with an NWP of 70 MPa.

3.8 PROCESS LIMITS

Process limits are the limits or boundaries established for various parameters which are measured and monitored by the fueling protocol. These process parameters include the station pressure, the ambient temperature, the fuel delivery temperature, the mass flow rate, and the vehicle measured temperature.

3.9 FLOW RATE

The mass flow rate in grams per second measured by the dispenser.

3.9.1 FLOW RATE MAXIMUM

The maximum flow rate that the fueling protocol allows. This is the value of the Flow Rate Maximum Class.

3.9.2 FLOW RATE MAXIMUM CLASS

Designation of the Flow Rate Maximum utilizing the term "FM" followed by the maximum flow rate value, e.g., FM90 is the designation for the Flow Rate Maximum Class of 90 g/s.

NOTE: In some cases, the Flow Rate Maximum Class is determined by the vehicle whereby the vehicle must communicate the FM value in the OD data field. In these cases, if the FM value is not communicated, or non-communications fueling is used, the fueling protocol defaults to a lower Flow Rate Maximum Class.

3.10 STATE OF CHARGE (SOC)

The ratio of the hydrogen density in the CHSS to the hydrogen density at NWP at 15 °C, expressed as a percentage.

NOTE 1: The SOC is computed using a gas density equation such as that available through the National Institute of Standards and Technology (NIST).[1]

$$SOC\ (\%) = \frac{\rho\ (P,T)}{\rho\ (NWP,\ 15\ °C)} \times 100 \qquad \text{(Eq. 1)}$$

NOTE 2: The density of the H35 Pressure Class at 35 MPa and 15 °C at 100% SOC is 24.0 g/L.

NOTE 3: The density of the H70 Pressure Class at 70 MPa and 15 °C at 100% SOC is 40.2 g/L.

3.11 TEMPERATURE

3.11.1 AMBIENT TEMPERATURE (T_{amb})

The temperature of the air measured at the fueling station where the measurement is protected from direct sunlight and other radiative and environmental effects.

3.11.2 CHSS AVERAGE VEHICLE GAS TEMPERATURE

The average temperature of the hydrogen gas in the vehicle CHSS.

3.11.3 CHSS MEASURED TEMPERATURE (MT)

The measured temperature of the gas in the vehicle CHSS.

NOTE 1: If the vehicle contains a temperature measurement device for the purpose of sending a temperature signal to the dispenser during fueling, this temperature is also assumed to be the average temperature of the gas in the vehicle. Due to the accuracy of the sensor, the vehicle manufacturer should consider the tolerances of the temperature measurement and include them as criteria for the "Abort" and "Measured Temperature" signals.

NOTE 2: For vehicles with multiple tanks in the CHSS, the measured temperature in each tank can vary. The vehicle manufacturer should consider the best approach for transmitting a single representative temperature as MT. One approach is to transmit the lowest measured temperature from the tanks in the CHSS, since the primary purpose of MT is to determine when to end the fill based on a calculated pressure or density where MT is an input. The highest measured temperature can be utilized in the criteria for sending an "Abort" signal.

[1] The ρ(P,T) function for hydrogen is available from NIST at https://www.nist.gov/publications/fundamental-equations-state-parahydrogen-normal-hydrogen-and-orthohydrogen. Refer to Leachman et al. (2009).
Note: The accuracy of the NIST equation has been quantified up to 200 MPa at the publishing of this TIR.

3.11.4 CHSS SOAK TEMPERATURE

The temperature of the CHSS after being exposed to a temperature greater or less than ambient temperature. The CHSS soak temperature may differ from the ambient temperature. In SAE J2601, Appendix A, Figure A5 shows the range of soak temperatures relative to ambient temperature due to hot or cold soak conditions.

3.11.5 FUEL DELIVERY TEMPERATURE (T_{fuel})

The temperature of the hydrogen gas supplied to the vehicle by the dispenser, measured near the break-away during fueling, and labeled as T_{fuel}. T_{fuel} is a generic term for the fuel delivery temperature and may be represented by the instantaneous fuel delivery temperature $T_{fuel\text{-}inst}$ or the mass average of the fuel delivery temperature, MAT_0, MAT_{30}, or MAT_C.

3.11.5.1 INSTANTANEOUS FUEL DELIVERY TEMPERATURE ($T_{fuel\text{-}inst}$)

The instantaneous fuel delivery temperature.

3.11.5.2 MASS AVERAGE FUEL DELIVERY TEMPERATURE (MAT_0)

The fuel delivery temperature weighted by the mass dispensed from the beginning of the main fueling time. See A.2.1.4.3 for further explanation.

3.11.5.3 EXPECTED MASS AVERAGE FUEL DELIVERY TEMPERATURE ($MAT_{expected}$)

The expected end-of-fill fuel delivery temperature weighted by the mass dispensed from the beginning of the main fueling time (MAT_0). $MAT_{expected}$ is only utilized during the first 30 seconds of mass flow from the start of the main fueling time. See A.2.1.4.1 for further explanation.

3.11.5.4 THIRTY-SECOND MASS AVERAGE FUEL DELIVERY TEMPERATURE (MAT_{30})

The fuel delivery temperature weighted by the mass dispensed after a total of 30 seconds of mass flow have elapsed from the start of the main fueling time. See A.2.1.4.2 for further explanation.

3.11.5.5 CONTROL MASS AVERAGE FUEL DELIVERY TEMPERATURE (MAT_C)

A mathematical combination of $MAT_{expected}$, MAT_0, and MAT_{30}, which is used as the control input to the t_{final} equation, which determines the PRR. See A.2.1.4 for further explanation.

3.11.6 FUEL DELIVERY TEMPERATURE CATEGORY

The fuel delivery temperature category identifies the range of allowable temperatures of the hydrogen gas. The fuel delivery temperature category is designated by the letter "T" followed by the gas fuel delivery temperature representing the category. See Table 4 for the Category D HF fueling protocol and Table 8 for the MCF-HF-G fueling protocol.

4. ABBREVIATIONS AND SYMBOLS

4.1 Abbreviations

APRR average pressure ramp rate

CHSS compressed hydrogen storage system

CFRP carbon fiber reinforced plastic

FCEV fuel cell electric vehicle

H_2 hydrogen

HSTA hydrogen station test apparatus

HSV hydrogen surface vehicle

ID protocol identifier

IrDA Infrared Data Association

MAWP maximum allowable working pressure

MOP maximum operating pressure

NIST National Institute of Standards and Technology

NWP nominal working pressure

PRR pressure ramp rate

PRV pressure relief valve

SOC state of charge

4.2 Symbols

Table 2 provides a list of the symbols used in this TIR, including a short description and the units of measurement.

Table 2 - Symbols used in this TIR

Symbol	Description	Units of Measurement
AC, BC, GC, KC, JC	Five constants utilized in the MC Equation	AC, BC, and GC are kJ/K. KC and JC are dimensionless
$APRR_{calculated}$	An average pressure ramp rate (APRR) value calculated by an equation and used to determine the maximum APRR which does not exceed the maximum flow rate	MPa/min
C_{v_cold}	Specific heat capacity of hydrogen at constant volume	kJ/kgK
FC	Fueling Command	N/A
FM	The Flow Rate Maximum Class. A value for FM can be communicated in the OD field.	g/s
FTI	Fueling Time Indicator. FTI = 1 indicates fueling is proceeding and FTI = 0 indicates fueling is paused.	Integer number of 0 or 1
h	The specific enthalpy measured at the dispenser outlet. A function of T_{fuel_inst} and $P_{station}$.	kJ/kg
h_{ave}	The mass average of the dispenser outlet specific enthalpy calculated from the start of the main fueling time (i.e., from t = 0 seconds)	kJ/kg
i	A calculation timestep counter, which advances every 1/10th of a second	Integer number
j	A calculation timestep counter, which advances every second	Integer number
K_0	A parameter which is measured during a pause in fueling, after which it is used to calculate a synthetic measured pressure MP_{calc}	MPa/gL
m	The total mass dispensed from the beginning of the main fueling time up to the current time	g
$\dot{m}$	The mass flow rate of dispensed hydrogen	g/s

Symbol	Description	Units of Measurement
$\dot{m}_{flow}$	The mass flow rate of dispensed hydrogen just before the mass flow is stopped for an intended non-fueling event, utilized in the calculation of K_0	g/s
m_0	The value of the mass dispensed at time t = 0 (i.e., the beginning of the main fueling time)	g
m_{init_cold}	The initial cold case mass in the vessel used in the MC Method ending pressure control option	kg
m_{final_cold}	The mass corresponding to 100% SOC of the vessel used in the MC Method ending pressure control option	kg
m_{add}	The mass of hydrogen required to be added to the cold case initial mass to achieve m_{final_cold}	kg
m_{tol}	The accuracy of the mass dispensed measurement, used in the CHSS volume measurement	Percent (expressed as a fraction of 100)
Δm_{VC}	The change in mass dispensed from the beginning of the main fueling time, used in the CHSS volume measurement	g
Δm_{VC_tol}	The change in mass dispensed from the beginning of the main fueling time, accounting for the accuracy of the mass measurement m_{tol}, used in the CHSS volume measurement	g
$m_{startup}$	Mass dispensed during startup time	g
$MAT_{expected}$	The expected mass average of the fuel delivery temperature at the end of the fill	°C
MAT_0	The mass average of $T_{fuel\text{-}inst}$ calculated from the start of the main fueling time (i.e., t = 0 seconds)	°C
MAT_{30}	The mass average of $T_{fuel\text{-}inst}$ calculated starting after a total of 30 seconds of mass flow have elapsed	°C
MAT_C	A mathematical combination of $MAT_{expected}$, MAT_{30}, and MAT_0 utilized as the control input for the t_{final} equation	°C
MC_{cold}	A parameter representing a lumped heat capacity of the cold case CHSS, used to calculate T_{cold} in the MC Method	kJ/K
MFR_{min}	The minimum mass flow rate allowed by the fueling protocol	g/s
MP	The CHSS measured pressure communicated via IrDA according to SAE J2799	MPa
MP_{calc}	Synthetic measured pressure calculated using the K_0 method described in C.3.8	MPa
MT	The CHSS measured temperature communicated via IrDA according to SAE J2799	K
n	A counter which advances at the same frequency as timestep counter j, but only if there is mass flow. It is utilized to determine the point in the fill at which the calculation of MAT_{30} commences.	Integer number
OD	Optional Data communicated via IrDA according to SAE J2799	N/A
ΔP	The difference between the ramp pressure P_{ramp} and vehicle pressure MP or MP_{calc}, used in the optional PRR Taper equation	MPa
P_0	A value for $P_{startup}$ adjusted for the pressure measurement accuracy P_{tol}	MPa
P_a	A parameter which provides margin for errors in the calculation of MP_{calc}	MPa
P_{final}	The final pressure used in the derivation of the t_{final} equation coefficients	MPa
$P_{initial}$	Initial pressure of hydrogen in the CHSS as per the definition in 3.7.3	MPa
P_{limit_comm}	An upper limit on pressure for communications fueling to provide protection against a fault in MT	MPa
P_{limit_high}	The upper boundary of the pressure corridor which $P_{station}$ must stay within	MPa

Symbol	Description	Units of Measurement
P_{limit_low}	The lower boundary of the pressure corridor which $P_{station}$ must stay within	MPa
P_{min}	The initial pressure used in the derivation of the t_{final} equation coefficients	MPa
P_{ramp}	The pressure upon which the PRR is based. Also used to define P_{limit_high} and P_{limit_low}.	MPa
$P_{ramp\_maximum}$	The maximum ramp pressure	MPa
$P_{station}$	Fueling pressure as measured by station at the dispenser outlet	MPa
$P_{station\_flow}$	The station pressure $P_{station}$ right before the mass flow stops for an intended non-fueling event, used in the calculation of K_0	MPa
$P_{station\_no\_flow}$	The station pressure $P_{station}$ after the mass flow has completely stopped for an intended non-fueling event, used in the calculation of K_0	MPa
$P_{station\_pause}$	The station pressure $P_{station}$ after the mass flow has completely stopped when conducting the CHSS volume measurement	MPa
$P_{startup}$	The pressure in the CHSS as measured by the station at the end of the startup time as per the definition in 3.7.4	MPa
$P_{target\_non\_comm}$	The target end-of-fill pressure for non-communications fueling	MPa
P_{target_comm}	The target end-of-fill pressure for communications fueling	MPa
$P_{target\_comm\_calc}$	A preliminarily calculated target end-of-fill pressure for communications fueling	MPa
$P_{threshold}$	A threshold pressure, which when P_{ramp} exceeds, initiates the PRR Taper method	MPa
P_{tol}	The accuracy of the station pressure measurement, used in the CHSS volume measurement	MPa
P_{trans}	A parameter which determines the weighting of MAT_0 and MAT_{30} in the MAT_C equation	MPa
ΔP_{tol_high}	A delta pressure added to P_{ramp} to define P_{limit_high}. Also used in calculating β.	MPa
PRR	The control pressure ramp rate. This represents the rate of change of P_{ramp}.	MPa/s
PRR_{Max}	A maximum pressure ramp rate	MPa/s
PRR_{MC}	The pressure ramp rate calculated by the MC Formula pressure ramp rate equation	MPa/s
PRR_{MP}	The pressure ramp rate of the measured pressure MP or MP_{calc} based on the current measured pressure and a previous measured pressure $t_{lookback}$ timesteps ago, used in PRR Taper method	MPa/s
PRR_{taper}	The pressure ramp rate calculated by the PRR Taper method	MPa/s
P_{VC}	The station pressure $P_{station}$ after the mass flow has completely stopped when conducting the CHSS volume measurement, adjusted for the pressure transducer accuracy P_{tol}	MPa
ΔP_{VC}	A formula which determines the change in pressure from $P_{startup}$ required for the CHSS volume measurement to be conducted	MPa
RR_{max}	The maximum calculated pressure ramp rate throughout the fill	MPa/s
RR_{min}	The minimum calculated pressure ramp rate throughout the fill	MPa/s
SOC_{target}	The end-of-fill target SOC, used in calculating P_{target_comm}	Percent
t	Fueling time, representing the total time elapsed since the initiation of the main fueling time, including the time elapsed during intended non-fueling events	seconds
t_{final}	The time required to fill from P_{min} to P_{final} under hot case conditions in units of seconds	seconds
t_{final_calc}	The t_{final} value calculated by the t_{final} vector, a preliminary value prior to α, β, and ε being applied	seconds
t_{final_min}	A minimum value of t_{final}, utilized to ensure the peak mass flow rate is not exceeded	seconds

Symbol	Description	Units of Measurement
$t_{lookback}$	A period of time in seconds used to look back from the current time to determine a previous value of MP or MP_{calc}, used in the PRR Taper method	seconds
t_{min_cold}	A parameter used in MC equation representing the time elapsed after which Δt_{cold} is calculated	seconds
t_{remain}	A calculated time remaining for the measured pressure MP or MP_{calc} to reach the end-of-fill target pressure, used in the PRR Taper method	seconds
Δt_{cold}	The difference between the fueling time t and t_{min_cold}	seconds
$T_{adiabatic\_cold}$	The cold case adiabatic temperature used in the MC Method ending pressure control option calculations	K
T_{amb}	Ambient temperature as measured by fueling station, not in direct sunlight	°C
ΔT_{CHSS}	A calculated change in the CHSS gas temperature from the beginning of the main fueling time, used in the CHSS volume measurement	°C
T_{cold}	The MC Method ending pressure control option cold case gas temperature, used to determine $P_{target\_non\_comm}$ and P_{limit_comm}	K
T_{fuel}	Fuel Delivery Temperature	°C
T_{fuel_inst}	Instantaneous fuel delivery temperature	°C
$T_{fuel\_inst\_A}$, $T_{fuel\_inst\_B}$	Two independent measurements of the instantaneous fuel delivery temperature for redundancy	°C
T_{init_cold}	The initial gas temperature in the cold case CHSS. T_{init_cold} is a function of T_{amb} and $P_{initial}$.	K
TT	A parameter which is a function of the ambient temperature and used in the equation for ω and ε	°C
T_{VC}	The calculated CHSS gas temperature based on T_{amb} plus ΔT_{CHSS}, used in the CHSS volume measurement	°C
TV	Total volume of the CHSS	L
TVL	Tank Volume Large - the largest tank volume of any of individual tank in the CHSS	L
$u_{adiabatic\_cold}$	The MC Method ending pressure control option cold case adiabatic specific internal energy	kJ/kg
$U_{adiabatic\_cold}$	The MC Method ending pressure control option cold case adiabatic internal energy	kJ
u_{init_cold}	The MC Method ending pressure control option cold case initial specific internal energy	kJ/kg
U_{init_cold}	The MC Method ending pressure control option cold case initial internal energy	kJ
V_{CHSS}	Volume of the CHSS measured or otherwise determined by the station (e.g., via communications)	L
V_{cold}	The volume of the 1-kg Type III vessel used in the calculation of T_{cold} in the MC Method ending pressure control option	m^3
$V_{station\_D}$	A volume parameter used to determine $APRR_{calculated}$	L
α	A parameter which is multiplied by t_{final} to compensate for non-linearity in the PRR during the fill	Dimensionless
β	A parameter which is multiplied by t_{final} to allow tolerance on pressure (i.e., the pressure corridor)	Dimensionless
ε	A parameter which is multiplied by t_{final} to increase its value when $P_{initial}$ < 5 MPa (H70) or 3 MPa (H35)	Dimensionless
ω	An intermediary parameter used in the equation for ε which is a function of the ambient temperature	Dimensionless
ρ	A calculated density of the hydrogen in the CHSS using an equation of state	g/L or kg/m^3

Symbol	Description	Units of Measurement
ρ_0	A calculated density of the hydrogen in the CHSS (using an equation of state) at the beginning of the main fueling time, used in the CHSS volume measurement	g/L or kg/m^3
ρ_{init_cold}	The MC Method ending pressure control option cold case initial density calculated based on $P_{initial}$ and T_{init_cold}	g/L or kg/m^3
ρ_{K0}	A calculated density of the hydrogen at the dispenser outlet (using an equation of state), used in the calculation of K_0	g/L or kg/m^3
ρ_{VC}	A calculated density of the hydrogen in the CHSS after the mass flow has stopped (using an equation of state), used in the CHSS volume measurement	g/L or kg/m^3
$\Delta\rho_{VC}$	The change in density from the beginning of the main fueling time, used in the CHSS volume measurement	g/L or kg/m^3

5. GENERAL FUELING PROTOCOL DESCRIPTION

Section 5 is a general description of the fueling protocols in this document and does not contain any requirements. This TIR establishes gaseous hydrogen fueling protocols for hydrogen surface vehicles with maximum flow rates from 60 to 300 g/s. There are multiple fueling protocols defined in this TIR. Each fueling protocol is distinct and is distinguished by its name, pressure class, and Flow Rate Maximum Class, as well as an associated range of CHSS sizes, range of tank sizes, and coupling type. Table 3 provides a list of the fueling protocols.

Table 3 - Fueling protocols in this TIR

Protocol Name	Section	Pressure Class	Flow Rate Maximum Class (Non-Comm)	Flow Rate Maximum Class (Comm)	Range of CHSS Capacity (liters)	Range of Tank Sizes within the CHSS (liters)	Coupling Type*
Category D HF	7	H35	FM60	FM60	248.6 to 5000	50 to 800	H35**
		H70	FM60	FM60 (w/o OD) FM90 (with OD)	248.6 to 5000	50 to 800	H70
MCF-HF-G	8	H35	FM60	FM60	248.6 to 5000	50 to 800	H35**
			FM120	FM120	248.6 to 7500	50 to 1000	H35MF or H35HF
		H70	FM60	FM60 (w/o OD) FM90 (with OD)	248.6 to 5000	50 to 800	H70
			FM300	FM300	248.6 to 5000	50 to 800	H70HF***

* Coupling types are defined in SAE J2600 and ISO 17268.
** An H35 nozzle can also connect to an H70 receptacle.
*** The H70HF coupling is not yet defined in a standard.

This TIR assumes that the dispenser will fuel the vehicle after successful nozzle and receptacle connection and completion of initial checks. The fueling station is responsible for controlling the fueling process within the operating boundaries described below. Variables that affect the fueling process include:

- Ambient temperature
- Fuel delivery temperature
- CHSS size, shape, material properties, initial temperature, and pressure
- CHSS configuration
- Dispenser to vehicle flow dynamics and thermodynamic properties

A representative fueling profile is shown in Figure 2. The profile consists of a startup time which begins after the nozzle has been connected to the vehicle and the dispenser initiates a connection pressure pulse. During the startup time, the dispenser measures the initial CHSS pressure, may optionally measure the CHSS volume, and may also check for leaks. The main fueling begins when gas starts flowing into the vehicle. During this period, the pressure rises and the gas temperature in the CHSS increases. The fueling protocol is designed so that the CHSS does not exceed the maximum operating temperature at any point during the fill. The final stage is the shutdown, which occurs after hydrogen gas has stopped flowing and ends when the nozzle can be disconnected.

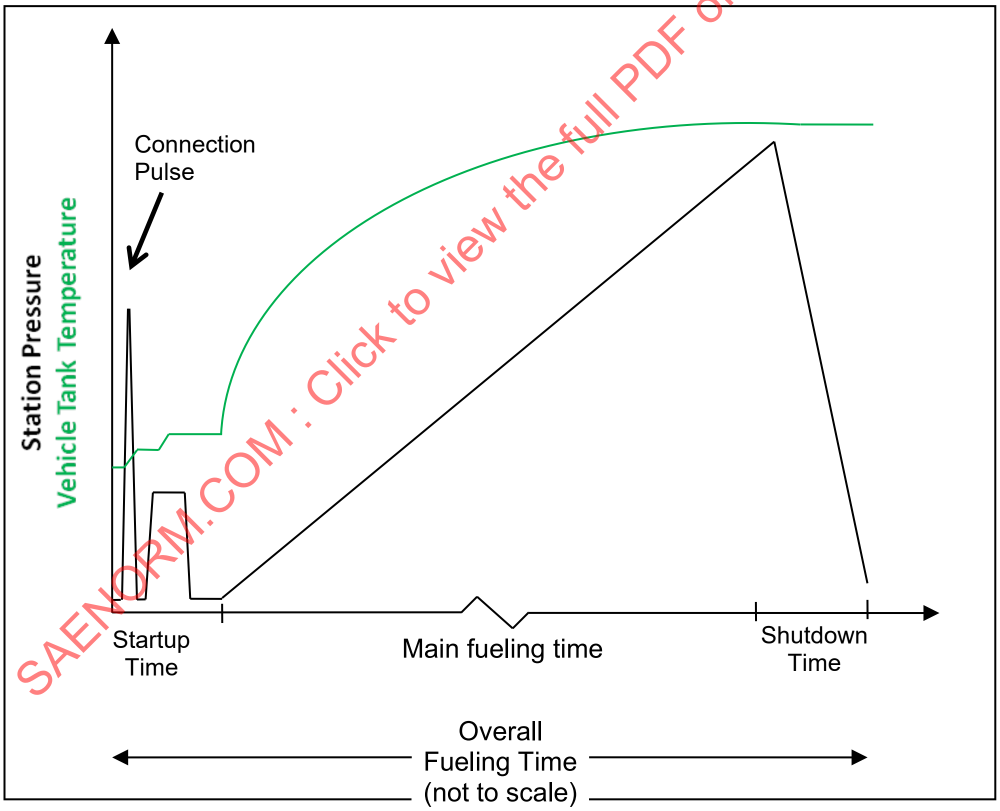


Figure 2 - Representative vehicle CHSS temperature and pressure profile during a fueling

5.1 Fueling Protocol Categories

A dispenser is designated by the fueling protocol utilized. The fueling protocol is defined by the protocol name, the pressure class, the flow rate maximum class, and the fuel delivery temperature category. For example, MCF-HF-G H70 FM300 T40 is the designation for the MCF-HF-G fueling protocol with an NWP of 70 MPa, a flow rate maximum class of 300 g/s, and a fuel delivery temperature category of T40 (-40 to -33 °C). As another example, Category D HF H70 FM90 T30D is the designation for the Category D HF fueling protocol with an NWP of 70 MPa, a Flow Rate Maximum Class of 90 g/s, and a fuel delivery temperature category of T30D (-40 to -26 °C). The fuel delivery temperature categories are defined for each fueling protocol (see 7.1 for Category D HF, and 8.1 and 8.4.1 for MCF-HF-G).

5.2 Performance Goals

The fueling protocols in this TIR define a PRR which provides the fastest fueling possible while staying within the process limits. Stations which cannot keep the pressure at the defined PRR can fuel at a slower rate and still be compliant with the fueling protocol. The state of charge target for communications fueling is 95 to 100% SOC under all normal operating conditions.

The minimum fueling time can vary widely depending on the factors discussed above. Examples of minimum fueling times are provided below. With higher fuel delivery temperature dispenser ratings or at higher ambient temperatures, fueling times will be longer.

- For a 70 MPa CHSS of 2000 L (~80 kg), with a T40D, T30D, or T20D rated dispenser and under reference conditions (ambient temperature of 20 °C and initial pressure of 10 MPa or 20% SOC), the Category D HF fueling protocol can achieve a fueling time of 20 minutes or 30 minutes, depending on whether the vehicle communicates FM=090 or not.

- For a 70 MPa CHSS of 2000 L (~80 kg), with a T30 rated dispenser (MAT_C = -28 °C) and under reference conditions (ambient temperature of 20 °C and initial pressure of 10 MPa or 20% SOC), the MCF-HF-G FM300 fueling protocol can achieve fueling times of 6-1/2 to 8 minutes (depending on the TVL size). Shorter fueling times are possible with colder fuel delivery temperatures.

- For a 35 MPa CHSS of 2000 L (48 kg), with a T10 rated dispenser (MAT_C = -14 °C) and under reference conditions (ambient temperature of 20 °C and initial pressure of 6 MPa or 20% SOC), the MCF-HF-G FM120 fueling protocol can achieve fueling times of 6 to 8 minutes (depending on the TVL size). Shorter fueling times are possible with colder fuel delivery temperatures.

5.3 Normal Operating Boundaries

The fueling protocols in this TIR are designed to ensure the hydrogen gas in the CHSS does not exceed the normal operating boundaries which are defined by the process requirements listed in Section 6. These limits include the CHSS maximum temperature and MOP.

For H35, these temperature and pressure limits are -40 to 85 °C and 0.5 to 43.5 MPa, respectively. For H70, these temperature and pressure limits are -40 to 85 °C and 0.5 to 87.5 MPa, respectively. Figure 3 shows the boundaries for an H70 fueling. The maximum CHSS gas temperature and MOP are fixed limits at the right (overheat) and top (overpressure) portions of the graph. The maximum density (100% SOC) provides an additional boundary.

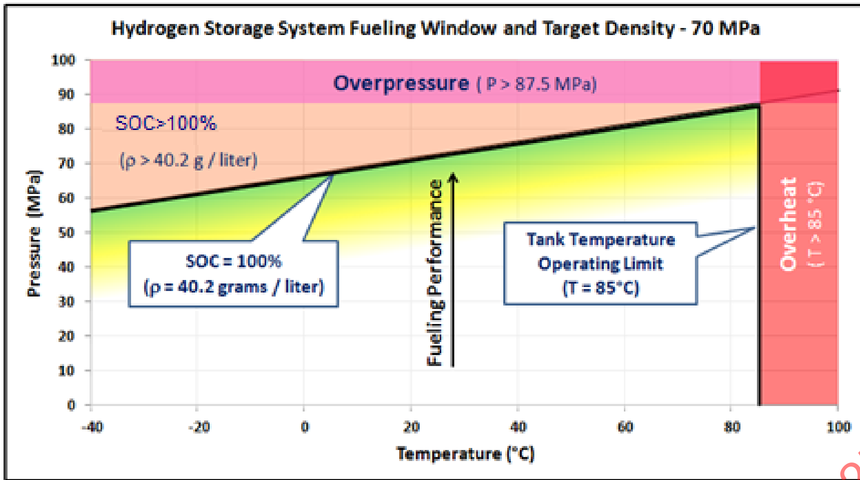


Figure 3 - Normal H70 boundary conditions

In order to keep the CHSS within its operating boundaries (i.e., Figure 3), the station will adjust the flow of the gas depending on the full set of initial conditions. For example, if a vehicle is fueled on a hot day, the initial CHSS temperature may be warmer, so the station must fuel more slowly to ensure the CHSS does not exceed the maximum vehicle CHSS operating temperature.

5.4 The Use of Communications

The fueling protocols in this TIR are designed to utilize IrDA communications as defined in SAE J2799. The IrDA communications defined in SAE J2799 have not been Automotive Safety Integrity Level (ASIL) or Safety Integrity Level (SIL) classified to any standard at the time of publishing this TIR. This means until ASIL/SIL certification is achieved, the signals are not guaranteed to be accurate, and the dispenser is responsible to ensure that process requirements are followed if it uses the communications signals.

The following are some of the guidelines that may be used to qualify components and systems for the station side SIL: IEC 61508 and IEC 61511, and for vehicle side ASIL: ISO 26262.

6. GENERAL PROCESS REQUIREMENTS FOR HYDROGEN FUELING

This section covers the general hydrogen fueling process requirements and does not contain all the detailed requirements for the dispenser and station. Each of the fueling protocols in this document may have additional requirements and process limits which are discussed in subsequent sections. The requirements in this document are minimum requirements. Manufacturers may take additional safety precautions.

NOTE: The fueling protocols in this TIR are relatively new and, at the time of publication, have had limited validation and use on stations and vehicles; therefore, users of the fueling protocols should take precautions, including conducting a risk assessment to address any possible hazards. Additionally, users of this TIR should verify that their own stations and the vehicles that can be refueled at those stations fall under the assumptions of the protocols, primarily found in Appendix A, Section A.3.

6.1 Process Requirements for Measurement and Sensors

6.1.1 Location

6.1.1.1 Station Pressure and Fuel Delivery Temperature

The sensors measuring the station pressure and fuel delivery temperature shall be located upstream of and as close as possible to the dispenser break-away or hose connection. If the dispenser uses a static break-away, the flow length between sensor and break-away shall be not more than 1 m. If the dispenser uses an inline break-away, the flow length between sensor and hose connection shall be not more than 1 m.

6.1.1.2 Ambient Temperature

The sensor used to measure the ambient air temperature at the dispenser or station shall be protected from direct sunlight and other radiative and environmental effects that may affect its accuracy.

6.1.1.3 Mass Flow Meter

The mass flow meter shall be located upstream of and as close as is practically possible to the dispenser break-away.

6.1.2 Accuracy

The station pressure, fuel delivery temperature, ambient temperature, and mass flow measurement shall account for the sensor accuracy to ensure the general process requirements in Section 6, as well as protocol specific process requirements in Sections 7 and 8, are not exceeded.[2]

6.1.3 Frequency

The station pressure shall be recorded at a frequency to ensure the general process requirements in Section 6 are not exceeded and the performance of the station can be verified.[2]

6.1.4 Reliability

As the station pressure, fuel delivery temperature, ambient temperature, and mass flow measurements are safety relevant, the dispenser manufacturer should implement means to ensure their reliability. This may include redundancy or other means such as a health signal. If redundancy is utilized, the most conservative value should be used. IEC 61508 and IEC 61511 provide guidance on risk assessment and design of safety loops.

6.2 Temperature Process Requirements

6.2.1 Fuel Delivery Temperature

The instantaneous fuel delivery temperature ($T_{fuel\text{-}inst}$) shall always be greater than or equal to -40 °C. The dispenser shall terminate fueling as soon as possible but within 5 seconds if $T_{fuel\text{-}inst}$ is less than -40 °C.

Although an upper limit on the instantaneous fuel delivery temperature is not provided as a process requirement, the standard protocols in this document were designed based on the assumption that the dispenser components are soaked at the ambient temperature. The station should implement an approach to ensure that temperature of the dispenser components does not exceed the ambient temperature (e.g., via protection from radiant heating due to exposure to sunlight).

6.2.2 Vehicle CHSS Gas Temperature

For communications fuelings, the dispenser should not fuel or should terminate fueling as soon as possible but within 5 seconds if the CHSS gas temperature signal is greater than 85 °C.

6.3 Pressure Process Requirements

6.3.1 Initial Pressure

The initial pressure is defined as $P_{initial}$. If the initial pressure is less than 0.5 MPa or greater than the NWP, then the dispenser shall terminate fueling as soon as possible but within 5 seconds.

[2] Specific sensor accuracy and frequency requirements are not specified in this TIR because it focuses on fueling protocol requirements and minimizes station requirements. The TIR does not limit sensor options as long as all general process requirements are maintained. Station providers should ensure that the worst-case accuracy scenario of all sensors is considered.

6.3.2 Maximum Operating Pressure

If the station pressure exceeds the MOP, it shall terminate fueling as soon as possible but within 5 seconds. For communications fuelings, the dispenser should not fuel or should terminate fueling as soon as possible but within 5 seconds if the CHSS pressure is greater than or equal to 125% NWP.

6.4 Other Process Requirements

6.4.1 Pressure Class

A fueling protocol is designated by its pressure class and shall only be utilized with a coupling rated for its pressure class. A dispenser shall not fuel a vehicle of a lower pressure class.

6.4.2 State of Charge

In communications fueling, the dispenser should terminate fueling as soon as possible but within 5 seconds if the SOC is greater than or equal to 100%. A pressure target is calculated based on an SOC target that the dispenser sets between a value of 95 and 100. The dispenser may choose to utilize either the station pressure ($P_{station}$) or vehicle pressure ($P_{vehicle}$) as the criteria for ending the fill when the pressure target is reached.

6.4.3 Mass Flow Rate

Each fueling protocol in this TIR has an associated minimum and maximum flow rate based on its pressure class and Flow Rate Maximum Class. The maximum flow rate for all fueling protocols in this document shall not exceed 120 g/s for H35 and 300 g/s for H70. Fueling protocols are allowed to specify a lower maximum flow rate according to the Flow Rate Maximum Class. The requirement for the minimum flow rate is protocol specific. The dispenser should continuously monitor the flow rate, and after the initial connection sequence, the dispenser shall terminate fueling as soon as possible but within 5 seconds if the measured flow rate of the hydrogen gas exceeds the protocol's minimum or maximum value.

6.4.4 Cycle Control

The dispenser shall not control hydrogen flow in a cyclic manner by repeatedly starting and stopping the fueling. The dispenser shall not decrease the flow of gas below 1% of the maximum flow rate more than 10X during the main fueling period. This requirement includes the non-fueling events (leak checks, bank switching, etc.) during the main fueling period.

6.4.5 Tolerances

Station dispensers shall consider appropriate tolerances in their protocol implementation methodology. The dispenser shall account for the measurement tolerances on the process parameters of the fueling protocol to ensure fueling is performed safely and accurately. Vehicles that communicate to the dispenser should consider appropriate tolerances for their signals.

7. CATEGORY D HF PROTOCOL

The "Category D HF" protocol is an abbreviation for "CHSS Capacity Category D HF" protocol. The CHSS Capacity Category D fueling protocol for flow rates up to 60 g/s is defined in SAE J2601_202005. In SAE J2601_202005, the CHSS Capacity Category D protocol can be implemented using either of the standardized fueling protocols, i.e., table-based or MC Formula-based. However, the Category D HF protocol in this TIR is only applicable to the table-based protocol because a HF MC Formula-based protocol (MCF-HF-G) is provided in Section 8 of this TIR.

A limited number of changes are necessary to modify the CHSS Capacity Category D protocol for higher flow rates. So, instead of repeating all of SAE J2601_202005, this section describes the changes to the appropriate sections of SAE J2601_202005. Even though in SAE J2601_202005, Category D is only defined for the H70 pressure class, in this TIR, the "Category D HF" protocol is applicable to the H35 and H70 Pressure Class. Additionally, there are some requirements for the Category D HF protocol which are not included in SAE J2601_202005 (see 7.3).

7.1 Classification

The Category D HF fueling protocol is classified based on the nominal working pressure (Pressure Class), the maximum flow rate (Flow Rate Maximum Class), and the fuel delivery temperatures (Fuel Delivery Temperature Category). It is important that the correct classifications are used for the intended application. The pressure class and Flow Rate Maximum Class are directly tied to the coupling type, as defined in the coupling standards SAE J2600 and ISO 17268. Table 4 illustrates the Category D HF fueling protocol classifications.

Table 4 - Category D HF fueling protocol classifications

Pressure Class	Flow Rate Maximum Class (Non-Comm)	Flow Rate Maximum Class (Comm)	Coupling Type	Range of CHSS Sizes (liters)	Range of Tank Sizes within the CHSS (liters)	Range of Fuel Delivery Temperatures and Fuel Delivery Temperature Categories
H35	FM60	FM60	H35	248.6 to 5000	50 to 800	T40D: -40 °C ≤ T_{fuel} ≤ -33 °C T30D: -40 °C ≤ T_{fuel} ≤ -26 °C T20D: -40 °C ≤ T_{fuel} ≤ -17.5 °C
H70	FM60	FM60 (no OD) FM90 (with FM=090 in OD)	H70	248.6 to 5000	50 to 800	T40D: -40 °C ≤ T_{fuel} ≤ -33 °C T30D: -40 °C ≤ T_{fuel} ≤ -26 °C T20D: -40 °C ≤ T_{fuel} ≤ -17.5 °C

Note 1: An H35 nozzle can also connect to an H70 receptacle.
Note 2: For the FM90 Class to be utilized, the vehicle shall request this by communicating FM=090 in the Optional Data Field (see 7.4.5). If the station is not capable of fueling at a maximum flow rate of 90 g/s, it may utilize FM=060 as the Flow Rate Maximum.

7.2 Key Assumptions

There are many assumptions embedded within the Category D HF fueling tables in Appendix G. These key modeling assumptions can be found in Appendix A of this TIR. Thermodynamic modeling was used to develop the APRR values in the fueling tables, and several assumptions were made based upon feedback from the station and vehicle manufacturers. These assumptions were used in determining the flow coefficients, reference pressure drop, internal/external diameters, lengths, and thermal mass of the fuel dispensing components on the dispenser and fuel delivery components on the vehicle, as well as the geometry and thermophysical properties of the largest individual tank volume in the CHSS. The values utilized are conservative (i.e., deemed worst case) to ensure that the Category D HF protocol is appropriate for all vehicles with CHSS falling within the assumptions and boundary conditions defined in Appendix A. If the vehicle parameters are outside these bounds, then the CHSS should be validated with respect to the Category D HF protocol to ensure that CHSS operating boundaries are not violated and that there are no performance or other concerns.

7.3 New Requirements

7.3.1 Fueling Time Indicator

The dispenser shall utilize and record a Fueling Time Indicator or FTI. FTI determines the state of fueling. When FTI is set to 1, fueling is proceeding as normal and the ramp pressure is advancing. When FTI is set to 0, fueling is paused (i.e., there is no mass flow) due to an intended non-fueling event such as a leak check or a bank switch. The dispenser shall determine when a pause is appropriate. For example, a dispenser may decide to set FTI to 0 during a bank switch, which may only take a couple of seconds to complete, or alternatively, it may decide to leave FTI set to 1 during a bank switch. FTI is utilized in 7.3.2.2 for determining when the minimum mass flow rate requirement is enforced. FTI is also utilized for the validation of the protocol function in a dispenser, for example using the protocol validation standard CSA/ANSI HGV 4.3.

FTI shall only be set to 0 for the purpose of an intended non-fueling event. Furthermore, each time that FTI is set to 0, the mass flow rate shall fall below 1% of the FM value for at least 1 timestep during the period that FTI = 0.

7.3.2 Flow Rate

7.3.2.1 Maximum Flow Rate

The Category D HF fueling protocol is designed to not exceed the Flow Rate Maximum value of the Flow Rate Maximum Class (FM###). The Category D HF protocol utilizes the FM Classes shown in Table 4. However, the dispenser should continuously monitor the flow rate, and after the initial connection sequence, the dispenser shall terminate fueling as soon as possible but within 5 seconds if the measured maximum flow rate of the hydrogen gas exceeds the FM value.

7.3.2.2 Minimum Mass Flow Rate

The Category D HF fueling protocol imposes a minimum mass flow rate which is a function of the CHSS capacity. Except during intended non-fueling time, if the mass flow rate measured by the dispenser falls below the value in Table 5 for more than 10 seconds, the dispenser shall terminate fueling as soon as possible but within 5 seconds. In the Category D HF protocol, an FTI is used to identify intended fueling time (FTI = 1) and intended non-fueling time (FTI = 0), so the minimum flow rate requirement applies when FTI = 1. See 7.3.1 for details on FTI. Interpolation shall be used to determine the appropriate minimum flow rate for CHSS capacities in between those listed in Table 5. If the CHSS capacity is indeterminate (ND), the minimum flow rate requirement shall be 1.25 g/s.

Table 5 - Minimum flow rate requirement

CHSS Capacity (liters)	Minimum Flow Rate (grams per second)
ND	1.25
250	1.25
500	2.5
750	3.75
1000	5.0
1500	7.5
≥2000	10.0

7.4 Application of the Category D HF Fueling Protocol

To apply the table-based Category D HF protocol, implement the changes below. All other requirements for the application of the table-based Category D HF are the same as defined for the CHSS Capacity Category D protocol in SAE J2601_202005. The Category D in SAE J2601_202005 is defined for H70 only; however, this TIR introduces a definition for H35, and therefore, a CHSS volume of 248.6 L and above shall be considered as Category D for both H70 and H35.

7.4.1 SAE J2601_202005, 8.7.1 - Determination of Fueling Table and Fueling Parameters

The Category D HF Fueling Tables in Appendix G of this TIR shall be substituted for the Category D fueling tables in Appendix D of SAE J2601_202005. The replacement matrix is shown in Table 6, depending on the largest tank volume (TVL) in the CHSS. TVL can only be determined via communication through the OD field, as defined in 7.4.4. If TVL is not communicated in the OD field, TVL shall be set to 800 L to ensure that the most conservative APRR is utilized.

Table 6 - Matrix correlating Category D tables from SAE J2601_202005 to Category D HF tables in SAE J2601-5

Comm/Non-Comm	Fuel Delivery Temperature Category	SAE J2601_202005 Category D Lookup Table from Appendix D	SAE J2601-5 Category D HF Lookup Table from Appendix G			
			TVL ≤ 250 L		250 L < TVL ≤ 800 L	
			H70 FM60/90	H35 FM60	H70 FM60/90	H35 FM60
Non-Communications	T40D	Table D37	Table G1	Table G13	Table G2	Table G14
	T30D	Table D38	Table G3	Table G15	Table G4	Table G16
	T20D	Table D39	Table G5	Table G17	Table G6	Table G18
Communications	T40D	Table D40	Table G7	Table G19	Table G8	Table G20
	T30D	Table D41	Table G9	Table G21	Table G10	Table G22
	T20D	Table D42	Table G11	Table G23	Table G12	Table G24

Replace the formula for $APRR_{calculated}$ in Equation 5 in 8.7.1 of SAE J2601_202005 with Equation 2:

$$APRR_{calculated} = \frac{FM}{60} \times 28.5 \times \frac{V_{station\_D}}{V_{CHSS}} \quad \text{(Eq. 2)}$$

The term “FM” in Equation 2 is the Flow Rate Maximum value associated with the Flow Rate Maximum Class. The default value for non-communications fueling and communications fueling is FM=060. For H70, if the vehicle transmits FM=090 in the OD field, as defined in 7.4.5, then FM can be set to 90. Note that if the station is not capable of fueling at FM=090, the dispenser may utilize FM=060.

7.4.2 SAE J2601_202005, 8.8 - Non-Communications Fueling

The following shall be added to the start of 8.8 of SAE J2601_202005:

Non-communications fueling shall use the CHSS Capacity Category D HF fueling protocol with an FM value of 60.

7.4.3 SAE J2601_202005, 8.9.4.2 - Data Communications Software Version Number

Replace 8.9.4.2 (“Data Communications Software Version Number”) with the following:

For the Category D HF fueling protocol, the following are the communication version numbers:

VN=01.10 and VN=02.XX are valid communications protocols. VN=01.10 is defined in SAE J2799_201912, VN=02.00 is defined in SAE J2799_202406, and VN=02.XX may be defined in subsequent revisions to SAE J2799, where X is a value between zero and nine.

The dispenser shall not fuel the vehicle if the Version Number from the vehicle does not match VN=01.10 or VN=02.XX.

7.4.4 SAE J2601_202005, 8.9.4.3 - Tank Volume

Replace 8.9.4.3 (“Tank Volume”) with the following:

Software Version Number VN=01.10, Range: 0000.0 to 5000.0.

Software Version Number VN=02.00, Range: 0000.0 to 9999.9.

The vehicle shall transmit the total water volume of the CHSS in liters at the nominal working pressure to the dispenser.

7.4.5 SAE J2601_202005, 8.9.4.8 - Optional Data

Replace 8.9.4.8 (“Optional Data”) with the following:

7.4.5.1 Flow Rate Maximum (FM) Data Requirements

In order for the dispenser to utilize a Flow Rate Maximum Class of FM90, the vehicle shall request this by communicating FM=090 in the OD field. If the vehicle does not transmit FM=090, the dispenser shall default to a Flow Rate Maximum Class of FM60 and set the Flow Rate Maximum value to FM=060.

7.4.5.2 Tank Volume Large (TVL) Data Requirements

The vehicle may optionally transmit the tank volume large or TVL, which is the size of the largest tank volume in the CHSS, in the Optional Data Field. The nomenclature for this value is TVL=####, where #### is the largest tank volume measured in liters to the nearest integer value. This value is utilized in choosing the appropriate fueling table. If TVL is not transmitted, the largest tank volume shall be set to 800 L, as this results in selecting the most conservative fueling table.

7.4.5.3 Data Formatting Requirements

The formatting of this data in the OD field shall follow the rules set forth in SAE J2799_202406, VN=02.00 or a subsequent revision of SAE J2799 using VN=02.XX. The OD Header shall be COMMON or CATDHF24. Examples are provided below.

|OD=COMMON,FM=090,TVL=0240\|

|OD=COMMON,FM=090\|

|OD=COMMON,TVL=0240\|

|OD=CATDHF24,FM=090,TVL=0240\

|OD=CATDHF24,FM=090\|

|OD=CATDHF24,TVL=0240\|

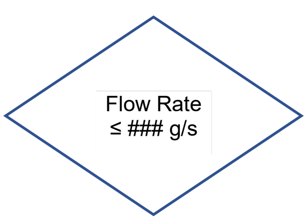
If there are data fields in the data block other than FM or TVL, they are not relevant to this fueling protocol and shall be ignored.

NOTE 1: The use of the COMMON data block with all fields provided is the preferred format since this format is the most complete and provides the least chance of misinterpretation.

NOTE 2: There is no requirement on the order of the data parameters FM and TVL. FM may precede TVL and vice versa.

7.4.6 SAE J2601_202005, Appendix B, Figure B5 - Fueling Process Check Subroutine

The decision statement for “flow rate” in the Fueling Process Check Subroutine flowchart in Figure B5 of SAE J2601_202005 shall be replaced with the following (where ### is the “FM” value):



8. MC FORMULA HIGH FLOW GENERAL PROTOCOL

The MCF-HF-G fueling protocol uses the dispenser fuel delivery temperature and pressure, ambient temperature, CHSS capacity, the largest tank volume in the CHSS, and initial pressure to calculate appropriate fueling parameters, in real-time for the duration of the fill. Modeling has been used to derive the parameters utilized by the MCF-HF-G protocol in order to optimize the fueling performance while ensuring that the process requirements of Section 6 are satisfied at all times. The key modeling assumptions are presented in Appendix A.

The dispenser selects the appropriate parameters based on the initial pressure, the CHSS capacity (V_{CHSS}), the largest tank volume (TVL), and the ambient temperature (T_{amb}). These are used to calculate the PRR and target pressure, which are both updated periodically throughout the fill.

For non-communications fueling, the dispenser will stop fueling when the calculated non-communications fueling target pressure is reached. For communications fueling, the dispenser will stop fueling at a pressure corresponding to a CHSS SOC of 95 to 100%. The dispenser may use vehicle data, including the communicated CHSS temperature, to calculate the communications fueling target pressure corresponding to the target SOC. However, the MCF-HF-G protocol also calculates a limit pressure to ensure that the CHSS stays within its operational boundaries. SAE J2799 defines the fueling messages utilized for communications fuelings. See 8.11, which defines the use of the communications signals for the MCF-HF-G protocol.

The MCF-HF-G fueling protocol flowcharts and control logic are detailed in Appendix B. The subroutines containing the equations and coefficients utilized are detailed in Appendix C. Appendices B and C are normative.

8.1 Classification

The MCF-HF-G fueling protocol is classified based on the nominal working pressure (Pressure Class), the maximum flow rate (Flow Rate Maximum Class), and the fuel delivery temperatures (Fuel Delivery Temperature Category). The fueling protocol control parameters and process limits are a function of the classification, so it is important that the correct classifications are used for the intended application. The pressure class and Flow Rate Maximum Class are directly tied to the coupling type, as defined in the coupling standards SAE J2600 and ISO 17268. Table 7 illustrates the MCF-HF-G fueling protocol classifications (note that the H70HF coupling type has not yet been defined in a standard).

Table 7 - MCF-HF-G fueling protocol classifications

<table>
<tr><th>Pressure Class</th><th>Flow Rate Maximum Class (Non-Comm)</th><th>Flow Rate Maximum Class (Comm)</th><th>Coupling Type</th><th>Range of CHSS Sizes (liters)</th><th>Range of Tank Sizes within the CHSS (liters)</th><th>Range of Fuel Delivery Temperatures (MATc)</th></tr>
<tr><td rowspan="2">H35</td><td>FM60</td><td>FM60</td><td>H35</td><td>248.6 to 5000</td><td>50 to 800</td><td>-40 °C ≤ MATC ≤ 0 °C</td></tr>
<tr><td>FM120</td><td>FM120</td><td>H35MF or H35HF</td><td>248.6 to 7500</td><td>50 to 1000</td><td>-40 °C ≤ MATC ≤ 20 °C</td></tr>
<tr><td rowspan="2">H70</td><td>FM60</td><td>FM60 (no OD) FM90 (with FM=090 in OD)</td><td>H70</td><td rowspan="2">248.6 to 5000</td><td rowspan="2">50 to 800</td><td rowspan="2">-40 °C ≤ MATC ≤ 0 °C</td></tr>
<tr><td>FM300</td><td>FM300</td><td>H70HF</td></tr>
</table>

Note 1: An H35 nozzle can also connect to an H70 receptacle.
Note 2: For the FM90 Class to be utilized, the vehicle shall request this by communicating FM=090 in the Optional Data Field (see 8.11.6.8). If the station is not capable of fueling at a maximum flow rate of 90 g/s, the dispenser may utilize FM060 as the Flow Rate Maximum.

8.1.1 Application of the H35 FM60 Fueling Protocol

The MCF-HF-G H35 FM60 fueling protocol is comprehensively defined in this TIR. An alternative application of the H35 FM60 fueling protocol is to utilize the MC Formula fueling protocol as defined in SAE J2601_202005. In this alternative application, the MC Formula CHSS Capacity Category D fueling protocol is utilized with the MC Method ending pressure control option, replacing Equation J38 with Equation J39 and utilizing the H35 pressure class for Equations J82, J83, and J84. The MCF-HF-G H35 FM60 fueling protocol is the preferred application because the assumptions and boundary conditions have been specifically designed for medium and heavy-duty vehicles and are more comprehensive than those in SAE J2601_202005. However, in cases where a dispenser manufacturer has already programmed and implemented the MC Formula CHSS Capacity Category D fueling protocol, the alternative application is acceptable.

8.2 Key Assumptions

There are many assumptions embedded within the design of the MCF-HF-G fueling protocol and utilized in the modeling for derivation of the control parameters. These key modeling assumptions can be found in Appendix A. Thermodynamic modeling was used to develop the control parameters, and several assumptions were made based upon feedback from the station and vehicle manufacturers. These assumptions were used in determining the flow coefficients, reference pressure drop, internal/external diameters, lengths, and thermal mass of the fuel dispensing components on the dispenser and fuel delivery components on the vehicle, as well as the geometry and thermophysical properties of the largest volume individual tank in the CHSS. The values utilized are conservative (i.e., deemed worst case) to ensure that the MCF-HF-G protocol is appropriate for all vehicles meeting the protocol requirements described in Section 5. If the vehicle parameters are outside these bounds, then the CHSS should be validated with respect to the MCF-HF-G protocol to ensure that CHSS operating boundaries are not violated and that there are no performance or other concerns.

8.3 Precautions

The H35 FM120 MCF-HF-G fueling protocol is designed for vehicles utilizing an H35 Pressure Class CHSS and an H35MF or H35HF coupling which is not interoperable with any other coupling geometry. At the time of publication, it has come to the attention of the SAE Interface Task Force that some HD vehicles in certain regions may install both an H35MF or H35HF receptacle and an H70 or H70HF receptacle on a vehicle utilizing an H70 Pressure Class CHSS. This is not an expected arrangement, and a vehicle using this receptacle arrangement can fuel at an H35 FM120 dispenser up to an H35 target pressure and then subsequently fuel at an H70 FM60, FM90, or FM300 dispenser up to an H70 target pressure. This subsequent fueling can potentially result in the CHSS gas temperature exceeding 85 °C. For regions where vehicles utilizing this dual receptacle arrangement are operating, hydrogen stations which provide both an H35 FM120 dispenser and an H70 FM60, FM90, or FM300 dispenser should implement countermeasure(s). One such countermeasure is to limit the non-communication pressure target of the H70 dispenser to 55 MPa. Fueling simulations show that this countermeasure prevents the CHSS gas temperature from exceeding 85 °C during a subsequent fueling without communications. Other countermeasures can also be applied.

8.4 General Hydrogen Fueling Requirements

Stations using the MCF-HF-G fueling protocol shall meet all of the applicable requirements in Section 6.

8.4.1 Station Designators

Table 8 illustrates the fuel delivery temperature categories for the MCF-HF-G protocol. A dispenser is defined by the pressure class and its fuel delivery temperature capability. For example, the fuel delivery temperature category for the range from -40 to -33 °C is designated as T40. There are six fuel delivery temperature categories, designated by T40, T30, T20, T10, T0, and TA. Although a station may offer different fuel delivery temperature categories with multiple dispensers, it is recommended that stations utilize common fuel delivery temperature categories for all dispensers.

MAT_{30} represents the mass average of T_{fuel} calculated starting after a total of 30 seconds of mass flow have elapsed. MAT_{30} is defined in more detail in SAE J2601_202005, Appendix H, H.2.4. The fuel delivery temperature category "T" for the MCF-HF-G protocol is based on the capability of the station to achieve a value of MAT_{30} at the end of the fueling event within the range shown in Table 8. Note that the "T" designation is only a "rating" which provides an indication of the station's expected fuel delivery temperature and, thus, fueling performance. The MAT_{30} fuel delivery temperature does not have to stay within a specified "T" range as the protocol can function anywhere within the range of MAT values allowed in Table 8.

The “A” in the fuel delivery temperature category TA stands for ambient temperature. Note, however, that the H35 FM120 MCF-HF-G TA is limited to a maximum fuel delivery temperature of 20 °C.

Table 8 - Fuel delivery temperature categories

Fuel Delivery Temperature Category		$-40\ °C \le MAT_{30} \le -33\ °C$	$-33\ °C < MAT_{30} \le -26\ °C$	$-26\ °C < MAT_{30} \le -17.5\ °C$	$-17.5\ °C < MAT_{30} \le -10\ °C$	$-10\ °C < MAT_{30} \le 0\ °C$	$0\ °C < MAT_{30} \le 20\ °C$
Station Designator	H35 Pressure Class FM60	H35-T40	H35-T30	H35-T20	H35-T10	H35-T0	N/A*
Station Designator	H35 Pressure Class FM120	H35-T40	H35-T30	H35-T20	H35-T10	H35-T0	H35-TA
Station Designator	H70 Pressure Class FM60/FM90/FM300	H70-T40	H70-T30	H70-T20	H70-T10	H70-T0	N/A*

* Fuel delivery temperatures greater than 0 °C are not allowed for the H70 Pressure Class because the PRR would be less than 1 MPa/min, except for very cold ambient temperatures.

8.4.2 Fuel Delivery Temperature

See 8.4.2.1, which defines the fuel delivery temperature requirements for the MCF-HF-G fueling protocol.

8.4.2.1 Fuel Delivery Temperature Tolerance

For any fuel delivery temperature category, $T_{fuel\text{-}inst}$ shall always be ≥-40 °C, and $MAT_{expected}$ and MAT_C (the mass average fuel delivery temperature used for control - see C.3.9.2 and A.2.1.4) shall meet the requirements of Equations 3 and 4. If the requirements of Equations 3 and 4 are not met, fueling should stop as soon as possible but within 5 seconds.

$$For\ \ H35\ FM120:$$

$$-20\ °C \le MAT_{expected} \le 20\ °C \tag{Eq. 3}$$

$$MAT_C \le 20\ °C$$

$$For\ H35\ FM60\ or\ H70\ \mathrm{FM60\ /\ FM90\ /\ FM300}:$$

$$-33\ °C \le MAT_{expected} \le 0\ °C \tag{Eq. 4}$$

$$MAT_C \le 0\ °C$$

MAT_C is calculated according to Equation C65 in the Mass Average Calculation of the Fuel Delivery Temperature Subroutine under C.3.9.2. If the station cannot meet these requirements, the dispenser shall do one of the following: (a) pause (no flow) for a minimum of 90 seconds before resuming the fill with the main fueling time t and parameters n, j, and i set back to zero and $P_{startup}$ set to the most recent station pressure prior to resuming the fill; or (b) terminate the fueling as soon as possible but within 5 seconds. If option (a) is utilized, the station should ensure that the cooling system is functioning as intended and shall limit the number of occurrences to no more than two.

NOTE: During the first 30 seconds of mass flow in the main fueling time, the dispenser should monitor the rate of change of the instantaneous fuel delivery temperature $T_{fuel\text{-}inst}$ to ensure that it is decreasing at a rate which is expected. By doing so, the dispenser might be able to detect a fault condition at an earlier time than waiting until the full 30 seconds of mass flow has elapsed.

8.4.3 Startup Time

8.4.3.1 Maximum Hydrogen Mass during Startup

The total mass of hydrogen transferred to the vehicle during startup shall be less than 500 g. This amount of hydrogen is not intended to allow for an accurate measurement of the CHSS volume but is intended to provide an upper limit for the amount of mass transferred during the connection pulse.

8.4.4 Flow Rate

8.4.4.1 Maximum Flow Rate

The MCF-HF-G fueling protocol is designed to not exceed the Flow Rate Maximum Class (FM###). The MCF-HF-G utilizes the FM values shown in Table 7. However, the dispenser should continuously monitor the flow rate, and after the initial connection sequence, the dispenser shall terminate fueling as soon as possible but within 5 seconds if the measured maximum flow rate of the hydrogen gas exceeds the FM value.

8.4.4.2 Minimum Mass Flow Rate

The MCF-HF-G fueling protocol imposes a minimum mass flow rate which is a function of the CHSS capacity. Except during intended non-fueling time, if the mass flow rate measured by the dispenser falls below the value in Table 9 for more than 10 seconds, the dispenser shall terminate fueling as soon as possible but within 5 seconds. In the MCF-HF-G protocol, an FTI is used to identify intended fueling time (FTI = 1) and intended non-fueling time (FTI = 0), so the minimum flow rate requirement applies when FTI = 1. See C.3.6 for details on FTI. Interpolation shall be used to determine the appropriate minimum flow rate for CHSS capacities in between those listed in Table 9. If the CHSS capacity is indeterminate (ND), the minimum flow rate requirement shall be 1.25 g/s.

Table 9 - Minimum flow rate requirement

CHSS Capacity (liters)	Minimum Flow Rate (grams per second)
ND	1.25
250	1.25
500	2.5
750	3.75
1000	5.0
1500	7.5
≥2000	10.0

8.5 CHSS Capacity

To utilize the MCF-HF-G fueling protocol, a vehicle shall have a CHSS capacity and individual tank volumes in the range indicated in Table 7. The total CHSS volume and largest individual tank volume are utilized by the MCF-HF-G fueling protocol to select the proper t_{final} table.

The CHSS volume may be determined by a volume measurement or may be determined via communications as the data field TV. The largest tank in the CHSS shall only be determined via communications through the Optional Data Field (see 8.11.6.8). If communications fueling is not utilized, or the vehicle does not communicate the TVL, then the TVL shall be assumed to be 1000 L for H35 FM120 and 800 L for H35 FM60 or H70 FM60/FM90/FM300, respectively. The t_{final} table shall be selected based on the TVL value.

If the CHSS volume is measured, the measurement method should target an accuracy of at least ±15%. The volume measurement has two purposes: (a) to determine if the CHSS volume is within the range allowed by the MCF-HF-G fueling protocol according to Table 7; and (b) to select the correct t_{final} table. When the volume measurement is used for selecting the correct t_{final} table, the measurement method shall stack the tolerances of the measurement parameters in such a manner that the volume measurement is the largest possible because this is the most conservative approach.

The MCF-HF-G fueling protocol provides a CHSS Volume Measurement Method in Appendix C, C.3.7, and which is further explained in Appendix F. This volume measurement method provides a conservative volume measurement approach which should meet the targeted accuracy. To achieve the targeted accuracy, the volume measurement shall be conducted during the main fueling time. The main fueling begins by using the most conservative t_{final} table, and once the CHSS volume has been measured, the correct t_{final} table is determined and utilized for the remainder of the main fueling time. This methodology is new and has not been validated in the field. Users should validate the accuracy over the full range of CHSS anticipated at the station.

If the CHSS volume is not measured or determined, the corresponding conservative t_{final} table in Appendix D shall be selected. The conservative t_{final} tables in Appendix D provide the most conservative (longest) t_{final} values from all of the t_{final} tables.

NOTE: An additional confirmation of the CHSS volume for communications fueling can be implemented by utilizing the Integrity Check method described in Appendix L of SAE J2601_202005.

8.6 Pressure Requirements

8.6.1 Initial Pressure

The initial pressure is measured by the dispenser (see 3.7.3) and shall be used as $P_{initial}$ when applying the MCF-HF-G protocol. A communicated pressure from the vehicle less than the minimum allowed pressure prior to the connection pulse is acceptable provided the initial pressure measured after the connection pulse exceeds the minimum allowed value.

For the H35 FM60/FM120 MCF-HF-G protocol, if the initial pressure is less than 0.5 MPa or greater than 35 MPa, then the dispenser shall terminate fueling as soon as possible but within 5 seconds. For the H70 FM60/FM90/FM300 MCF-HF-G protocol, if the initial pressure is less than 0.5 MPa or greater than 70 MPa, then the dispenser shall terminate fueling as soon as possible but within 5 seconds.

8.6.2 Station Pressure Corridor

8.6.2.1 Station Pressure Tolerance

During the main fueling time, the MCF-HF-G protocol calculates a pressure ramp rate PRR and ramp pressure P_{ramp}, at a frequency of once every second. The ramp pressure is utilized to calculate an upper pressure limit which forms the upper boundary of a pressure corridor. An upper pressure tolerance ΔP_{tol_high} is added to the ramp pressure P_{ramp} to calculate the upper pressure limit P_{limit_high}, and the lower pressure limit is based on a PRR of 0.75 MPa/min (0.0125 MPa/s) for H35 FM120, and 1 MPa/min (0.0167 MPa/s) for H35 FM60 or H70 FM60/FM90/FM300. The upper pressure tolerance ΔP_{tol_high} is a discretionary setting within an allowed range. The dispenser shall set ΔP_{tol_high} at a value within the range of 3 to 7 MPa. Utilizing a lower value decreases the fueling time (see C.3.1.2 and Equation C24).

During the main fueling time, the dispenser shall maintain the station pressure within the upper and lower pressure limits. The objective is for the dispenser to control the station pressure in a manner which follows the ramp pressure as closely as possible. Due to the potentially wide range of the pressure corridor, the dispenser should control the pressure according to good engineering practices, avoiding rapid and large changes in pressure. During the first 15 seconds of the main fueling time, the upper pressure limit is not applied, but the lower pressure limit is. After 15 seconds of the main fueling time, both the upper and lower pressure limits are applied. If the station pressure exceeds the upper pressure limit by 5 MPa or less, it shall come back within the limit within 5 seconds of the initial excursion or shall stop fueling within 5 seconds of the initial excursion. If the magnitude of the excursion is greater than 5 MPa, the dispenser shall stop fueling within 5 seconds of the initial excursion. If the station pressure falls below the lower pressure limit, it shall come back within the limit within a total of 15 seconds of the initial excursion, not counting intended non-fueling time, and if it does not, the dispenser shall stop fueling within a total of 15 seconds of the initial excursion.

Upper pressure limit:

$$P_{station} \le P_{limit\_high} \qquad \text{(Eq. 5)}$$

where:

$P_{limit\_high} = P_{ramp} + \Delta P_{tol\_high}$

ΔP_{tol_high} = discretionary setting between 3 and 7 MPa

Lower pressure limit:

$$\text{H35 FM120} \rightarrow P_{station} \ge P_{limit\_low} \qquad \text{(Eq. 6)}$$

where:

$P_{limit\_low} = P_{startup} + 0.0125 \times t$

$$\text{H35 FM60 or H70 FM60 / FM90 / FM300} \rightarrow P_{station} \ge P_{limit\_low} \qquad \text{(Eq. 7)}$$

where:

$P_{limit\_low} = P_{startup} + 0.0167 \times t$

An illustration of the pressure corridor is shown in Figure 4 for a fueling without intended non-fueling time.

NOTE: Although the pressure limits are illustrated as straight lines, their slopes will vary with the PRR, which is tuned continuously as part of the MCF-HF-G protocol.

In the MCF-HF-G protocol, intended non-fueling time (e.g., for bank switch or leak check) is included in the main fueling period elapsed time t (i.e., t continues to advance during intended non-fueling time). During the intended non-fueling time, the ramp pressure is held constant, but the PRR continues to be calculated. Once the intended non-fueling time has passed, the fill resumes at the most recently calculated PRR.

SAE J2601_202005, Appendix H, H.2.6.2 provides a more detailed explanation of the pressure corridor and its derivation.

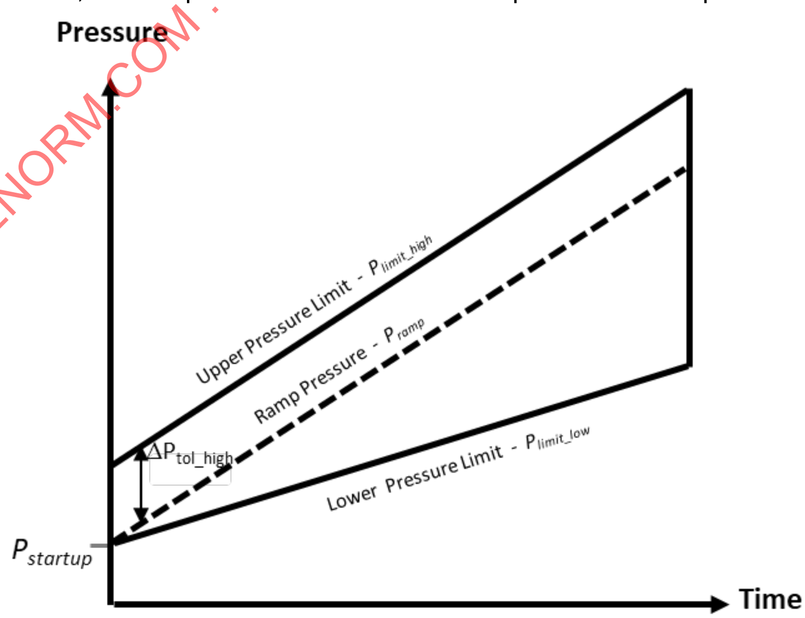


Figure 4 - Illustration of pressure corridor limits for MCF-HF-G fueling protocol

8.7 Cycle Control

The dispenser shall adhere to the cycle control requirements of 6.4.4. If the CHSS volume measurement described in 8.5 and C.3.7 is utilized, the pause in flow required for this measurement does not count against the ten-cycle limit.

8.8 "Abort" Signal from Vehicle

If the dispenser is capable of communications, whether the fueling procedure is using communications or not, the dispenser shall continue to monitor the communications interface and shall terminate fueling upon detection of an "Abort" signal from the vehicle as soon as possible but within 5 seconds. The vehicle may use the "Abort" signal to stop the fueling for any reason. This allows the vehicle to monitor the fueling process and complement the station operation with a secondary layer of control.

8.9 MCF-HF-G Fueling Flowchart

Figure 5 illustrates a general flowchart for communications and non-communications fueling. More detailed flowcharts with subroutine references are contained within Appendix B, and complete descriptions of these subroutines with all required formulas are contained within Appendix C. Appendices B and C are normative.

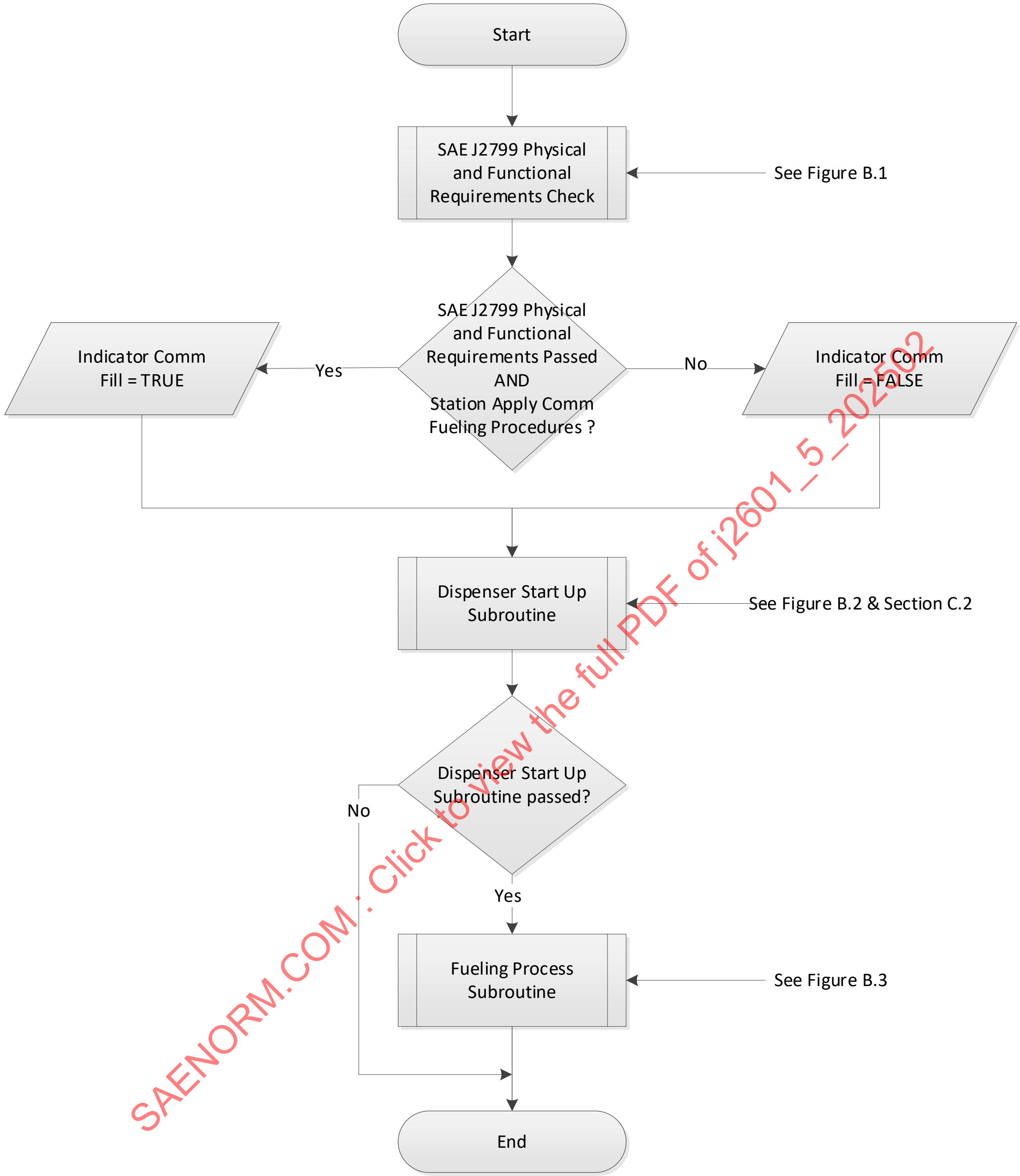


Figure 5 - General flowchart for the MCF-HF-G fueling protocol

8.9.1 Dispenser Startup

The Dispenser Startup process is illustrated by a flowchart found in Appendix B, Figure B2, and the formulas utilized are detailed in the Dispenser Startup Subroutine, found in Appendix C, Section C.2. The dispenser shall pass the Dispenser Startup Subroutine, or if it fails, shall end the fueling.

At the start of fueling, the dispenser shall monitor the communications interface for SAE J2799 signals. If no signal is present or if signals received do not pass the Physical and Functional Requirements, as defined in SAE J2799 (and Figure B1), then the dispenser shall apply the non-communications fueling procedure as described in 8.10. If a signal is present and passes the Physical and Functional Requirements, then the dispenser should apply the communications fueling procedure as described in 8.11.

NOTE: In Figure 5, the dispenser startup subroutine may begin before the SAE J2799 Physical and Functional Requirements check, based on the dispenser fueling methodology.

8.9.2 Fueling Process

Once the dispenser has passed the Dispenser Startup Subroutine, it has the information (ambient temperature, initial CHSS pressure, CHSS capacity category and largest tank volume category, expected MAT, etc.) it requires and shall then execute the fueling process as described in the Fueling Process Subroutine. The Fueling Process Subroutine flowchart is illustrated in Appendix B, Figure B3, and the formulas utilized in the Fueling Process Subroutine are detailed in Appendix C, Section C.3.

8.10 Non-Communications Fueling

All dispensers using the MCF-HF-G fueling protocol shall have the ability to fuel without communications from the vehicle.

The non-communications fueling MCF-HF-G fueling protocol assumes that no data is being passed from the vehicle to the dispenser. For a given CHSS volume, largest tank volume, ambient temperature, and fuel delivery temperature, the t_{final} and resulting PRR are the same as in the communications fueling procedure (except with non-communications fueling, the TVL is unknown and always assumed to be the largest possible). The primary difference is the end of fueling is defined by a separate target pressure.

8.10.1 Fueling Procedure

The non-communications fueling process uses the general description discussed in 8.9. The dispenser shall use the fueling process flowchart as represented in Appendix B, Figures B0 (Fueling Overview Subroutine) and B3 (Fueling Process Subroutine). For a non-communications fueling, the flag variable "Indicator Comm Fill" shall be set to FALSE. This indicates to the dispenser that the non-communications fueling pressure target shall be used to end the fill.

For non-communications fueling, the CHSS volume is unknown at the beginning of the main fueling time because it cannot be accurately measured during the startup time. The CHSS volume is measured during the main fueling time. At the beginning of the main fueling time, the conservative t_{final} table from Appendix D (see Table D36 for H35 FM120 and Table D72 for H35 FM60 or H70 FM60/FM90/FM300) is utilized and an assumption is made about the largest CHSS volume expected to fuel at the station, which is then utilized in an equation for calculating t_{final_min}. Therefore, the fueling rate at the beginning of the main fueling time is based a conservative t_{final} value from the t_{final} table and a conservative t_{final_min} value. The CHSS volume is measured according to the CHSS Volume Measurement Method in C.3.7. After the CHSS volume has been measured, the correct t_{final} table is selected and a correct t_{final_min} value is calculated, and these parameters are utilized for the remainder of the fueling. Note that the CHSS Volume Measurement Method is optional. If the CHSS volume is not measured, then t_{final_min} is based on the largest CHSS volume expected to fuel at the station for the entire main fueling period.

8.10.2 End of Fueling

For non-communication fuelings, an optional K_0 method can be used to calculate a synthetic measured pressure MP_{calc} (see C.3.8 and E.3.3 for additional information on the calculation of MP_{calc}).

If the K_0 method is not utilized, the non-communications fueling shall end when the station pressure equals the non-communications fueling target pressure $P_{target\_non\_comm}$. The station pressure shall be compared to the non-communication target pressure at least once every 100 ms, as specified in C.3.14.

If the K_0 method is utilized, the non-communications fuelings shall end when the synthetic measured pressure MP_{calc} equals the non-communications fueling target pressure $P_{target\_non\_comm}$. The synthetic measured pressure shall be compared to the non-communication target pressure at least once every 100 ms, as specified in C.3.14. Additionally, the dispenser shall take appropriate measures to ensure that under all conditions, $P_{vehicle}$ does not exceed the target pressure ($P_{target\_non\_comm}$).

NOTE: The K_0 method is new and has not been validated in the field. Users should validate the accuracy over the full range of CHSS anticipated at the station.

The MCF-HF-G protocol allows for two ending pressure control options to determine $P_{target\_non\_comm}$: (a) the MC Method, or (b) Ending Pressure Tables. Refer to Appendix H, Section H.3 of SAE J2601_202005 for a detailed explanation of these two ending pressure control options.

8.11 Communications Fueling

The communications MCF-HF-G fueling protocol shall use the IrDA signals as defined in SAE J2799 to provide information from the vehicle to the dispenser.

If applicable, the use of communications should consider 5.4, as well as local codes.

8.11.1 Fueling Procedure

The communications fueling process uses the general description discussed in 8.9. The dispenser shall use the fueling process flowchart as represented in Appendix B, Figures B0 and B3. For communications fuelings, the flag variable “Indicator Comm Fill” shall be set to TRUE.

8.11.2 Establishing Communications

The dispenser shall attempt to receive communications from the vehicle, based on SAE J2799, throughout the fueling process. To prevent communications faults while the user is connecting the fueling nozzle, the dispenser shall not consider communications as having been fully established until the nozzle is in place and the fueling startup procedure has begun. Once communications are established, the dispenser shall proceed to fuel using the communications fueling process for as long as valid signals continue to be received.

8.11.3 Loss of Communications

If the data signal from the vehicle is lost or fails the Physical and Functional Requirements as defined in SAE J2799 (see Figure B1), then the dispenser shall terminate fueling as soon as possible but within 5 seconds or shall optionally set the flag variable “Indicator Comm Fill” to FALSE and continue fueling the vehicle using the non-communication target pressure $P_{target\_non\_comm}$, assuming the dispenser determines it is appropriate to continue with fueling after the loss of the fuel command signal.

8.11.4 Communications Overfueling Density Limit

A pressure limit is determined for communications fueling, P_{limit_comm}. This pressure limit value is used as a secondary means of protection to limit the over fueling density in the event of a fault in the CHSS measured temperature MT, which causes the communications fueling pressure target to be incorrect. The determination of P_{limit_comm} depends on the ending pressure control option utilized. For the Ending Pressure Tables option, P_{limit_comm} is looked up from a set of pressure limit tables. For the MC Method ending pressure control option, P_{limit_comm} is calculated based on a cold case gas temperature T_{cold} and a maximum density corresponding to 115% SOC. Refer to Appendix H, H.3.1.4 of SAE J2601_202005 for the rationale and further detail.

8.11.5 End of Fueling

The dispenser may use vehicle data, including the communicated CHSS temperature, to calculate the communication target pressure and should end the fueling at a pressure corresponding to an SOC of 95 to 100%. All communications fuelings shall end when the vehicle pressure equals the calculated communication target pressure P_{target_comm} or when the station or synthetic measured pressure MP_{calc} equals the limit pressure P_{limit_comm}.

8.11.6 Communications Data Fields Definition

SAE J2799 defines the IrDA communications data fields. This section defines their values and use for the MCF-HF-G fueling protocol. The data fields to be sent from the vehicle to the dispenser are listed below and described in the following sections. They should be placed in the order as follows:

ID: Protocol Identifier

VN: Version Number

TV: Total Volume

RT: Receptacle Type

FC: Fueling Command

MP: Measured Pressure

MT: Measured Temperature

OD: Optional Data

8.11.6.1 Data Communication Protocol Identifier

|ID=SAE␣J2799|

The vehicle shall transmit the Protocol Identifier ID=SAE J2799. The "␣" symbol is to denote a space and used after SAE in the identifier. The dispenser shall not fuel the vehicle if the Protocol Identifier from the vehicle does not match.

8.11.6.2 Data Communications Software Version Number

For the MCF-HF-G fueling protocol, the following are the communication version numbers:

For all fueling protocols except the H35 FM120, VN=01.10 and VN=02.XX are valid communications protocols. For the H35 FM120 fueling protocol, VN=02.XX is a valid communications protocol. VN=01.10 is defined in SAE J2799_201912, VN=02.00 is defined in SAE J2799_202406, and VN=02.XX may be defined in subsequent revisions to SAE J2799, where X is a value between zero and nine.

For all fueling protocols except the H35 FM120, the dispenser shall not fuel the vehicle if the Version Number from the vehicle does not match VN=01.10 or VN=02.XX.

For the H35 FM120 fueling protocol, the dispenser shall not fuel the vehicle if the Version Number from the vehicle does not match VN=02.XX.

8.11.6.3 Total Volume

Software Version Number VN=01.10, Range: 0000.0 to 5000.0

Software Version Number VN=02.00, Range: 0000.0 to 9999.9

The vehicle shall transmit the total water volume of the CHSS in liters at the nominal working pressure to the dispenser.

8.11.6.4 Receptacle Type

|RT=H35| or |RT=H70|

The vehicle shall transmit the pressure class of its CHSS, as defined in 3.7.9. The dispenser shall not dispense fuel if the RT is less than the pressure class of the nozzle.

8.11.6.5 Fueling Command

The vehicle shall use the following fueling commands:

|FC = Dyna|

When the vehicle transmits |FC = Dyna|, the dispenser shall dispense fuel based on communications fueling as defined in 8.11.

|FC = Stat|

|FC = Stat| shall not be used. If this command is received by the dispenser, the dispenser shall terminate fueling as soon as possible but within 5 seconds.

|FC = Halt|

|FC = Halt| shall not be used. If this command is received by the dispenser, the dispenser shall terminate fueling as soon as possible but within 5 seconds.

|FC = Abort|

When the vehicle transmits |FC = Abort|, the dispenser shall terminate fueling as soon as possible but within 5 seconds.

8.11.6.6 Measured Pressure

Range: 000.0 to 100.0

The vehicle shall transmit the Measured CHSS Gas Pressure in MPa. If the dispenser monitors the Measured Pressure, it should terminate fueling as soon as possible but within 5 seconds if the Measured Pressure exceeds the MOP as defined in 6.3.2.

8.11.6.7 Measured Temperature

Range: 16.0 to 425.0

The vehicle shall transmit its CHSS Measured Gas Temperature in kelvin. The Measured Temperature should be representative of the bulk average CHSS gas temperature. If the dispenser monitors the Measured Temperature, it shall terminate fueling as soon as possible but within 5 seconds if the Measured Temperature exceeds the maximum operating Vehicle CHSS Gas Temperature as defined in 6.2.2.

8.11.6.8 Optional Data

8.11.6.8.1 Flow Rate Maximum Class FM60 or FM90

8.11.6.8.1.1 Flow Rate Maximum (FM) Data Requirements

In order for the dispenser to utilize a Flow Rate Maximum Class of FM90, the vehicle shall request this by communicating FM=090 in the OD field. If the vehicle does not transmit FM=090, the dispenser shall default to a Flow Rate Maximum Class of FM60 and set the Flow Rate Maximum value to FM=060. Note that FM=090 is only valid for the H70 FM90 fueling protocol.

8.11.6.8.1.2 Tank Volume Large (TVL) Data Requirements

The vehicle may optionally transmit the tank volume large or TVL, which is the size of the largest tank volume in the CHSS, in the Optional Data Field. The nomenclature for this value is TVL=####, where #### is the largest tank volume measured in liters to the nearest integer value. This value is utilized in choosing the appropriate t_{final} table. If TVL is not transmitted, TVL shall be set to the largest allowed for the protocol, as this results in selecting the most conservative t_{final} table.

8.11.6.8.1.3 Data Formatting Requirements

The formatting of this data in the OD Field shall follow the rules set forth in SAE J2799_202406, VN=02.00 or a subsequent revision of SAE J2799 using VN=02.XX. The OD Header shall be COMMON or MCFHFG24. Examples are provided below.

|OD=COMMON,FM=090,TVL=0300\|

|OD=COMMON,FM=090\|

|OD=COMMON,TVL=0300\|

|OD=MCFHFG24,FM=090,TVL=0300\|

|OD=MCFHFG24,FM=090\|

|OD=MCFHFG24,TVL=0300\|

If there are data fields in the data block other than FM or TVL, they are not relevant to this fueling protocol and shall be ignored.

NOTE 1: The use of the COMMON data block with all fields provided is the preferred format since this format is the most complete and provides the least chance of misinterpretation.

NOTE 2: There is no requirement on the order of the data parameters FM and TVL. FM may precede TVL and vice versa.

8.11.6.8.2 Flow Rate Maximum Class FM120 (H35) or FM300 (H70)

8.11.6.8.2.1 Tank Volume Large (TVL) Data Requirements

The vehicle may optionally transmit the tank volume large or TVL, which is the size of the largest tank volume in the CHSS, in the Optional Data Field. The nomenclature for this value is TVL=####, where #### is the largest tank volume measured in liters to the nearest integer value. This value is utilized in choosing the appropriate t_{final} table. If TVL is not transmitted, TVL shall be set to the largest allowed for the protocol, as this results in selecting the most conservative t_{final} table.

8.11.6.8.2.2 Data Formatting Requirements

The formatting of this data in the OD field shall follow the rules set forth in SAE J2799_202406, VN=02.00 or a subsequent revision of SAE J2799 using VN=02.XX. The OD Header shall be COMMON or MCFHFG24. An example is provided below.

|OD=COMMON,TVL=0300\|

|OD=MCFHFG24,TVL=0300\|

If there are data fields in the data block other than TVL, they are not relevant to this fueling protocol and shall be ignored.

NOTE 1: For the H35 FM120 and H70 FM300 fueling protocols, FM is not communicated in the data block.

NOTE 2: The use of the COMMON data block with all fields provided is the preferred format since this format is the most complete and provides the least chance of misinterpretation.

9. NOTES

9.1 Revision Indicator

A change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

PREPARED BY SAE FUEL CELL STANDARDS COMMITTEE

APPENDIX A - (INFORMATIVE) FUELING PROTOCOL RATIONALE AND DEVELOPMENT PROCESS

For the Category D HF fueling protocol described in Section 7 and normative Appendix G, and for the MCF-HF-G fueling protocol described in Section 8 and normative Appendices B and C, the SAE Interface Task Force used thermodynamic modeling and computer simulations to develop the lookup tables in Appendix G and t_{final} tables listed in Appendix D. The simulations used the boundary conditions listed in Table 3, as well as additional boundary conditions and assumptions listed in this appendix. The Category D HF and MCF-HF-G fueling protocols were developed for the fueling of Type III/IV CHSSs with the range of total volumes and individual tank volumes listed in Table 3. If other storage systems on vehicles are utilized, it is recommended that they be evaluated before implementing this protocol.

This appendix is written with the assumption that the reader is familiar with Appendices A and H from SAE J2601_202005. Because the majority of aspects of the MCF-HF-G protocol structure and derivation process are the same or very similar to those of the MC Formula fueling protocol in SAE J2601_202005, they will not be discussed here. This appendix focuses on aspects which are unique to the MCF-HF-G protocol, including the protocol structure, process limits, derivation process, and assumptions and boundary conditions.

A.1 SIMULATION MODEL

The fueling model utilized for conducting the computer simulations required for the derivation of the tables is the H2FillS model. H2FillS is a free to use and publicly available 0D/1D thermodynamic hydrogen fueling model owned by the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) (refer to National Renewable Energy Laboratory, n.d.). H2FillS can simulate the real-world fueling process from the high-pressure storage system through the vehicle tank(s).

During the fueling process simulation, the model solves for the hydrogen temperature, pressure, and density at all components. Refer to Kuroki et al. (2021), which contains the methodologies for how the model calculates those values at fueling components. This reference also contains the validation of the process and results for validating the model using LD experimental data. The applicability of the model to HD fueling is confirmed by validating the model against high-flow HD fueling data collected at the NREL HD station. Figure A1 shows the validation process. In the first step, the specifications of NREL's HD dispenser and vehicle simulator and testing conditions are set to the model (the HD vehicle simulator consists of seven type IV tanks and two type III tanks and can store over 80.0 kg of hydrogen). After those conditions are fed into the model, the model is run, and then the simulation data are compared with the corresponding testing data. At the beginning of the fueling process, there are some discrepancies between the testing and model data, but those discrepancies decrease toward the end of the fill and are almost negligible at the end. This comparison shows that the H2FillS model can predict the temperature rise of hydrogen in a large onboard storage system with good accuracy regardless of the tank type or material.

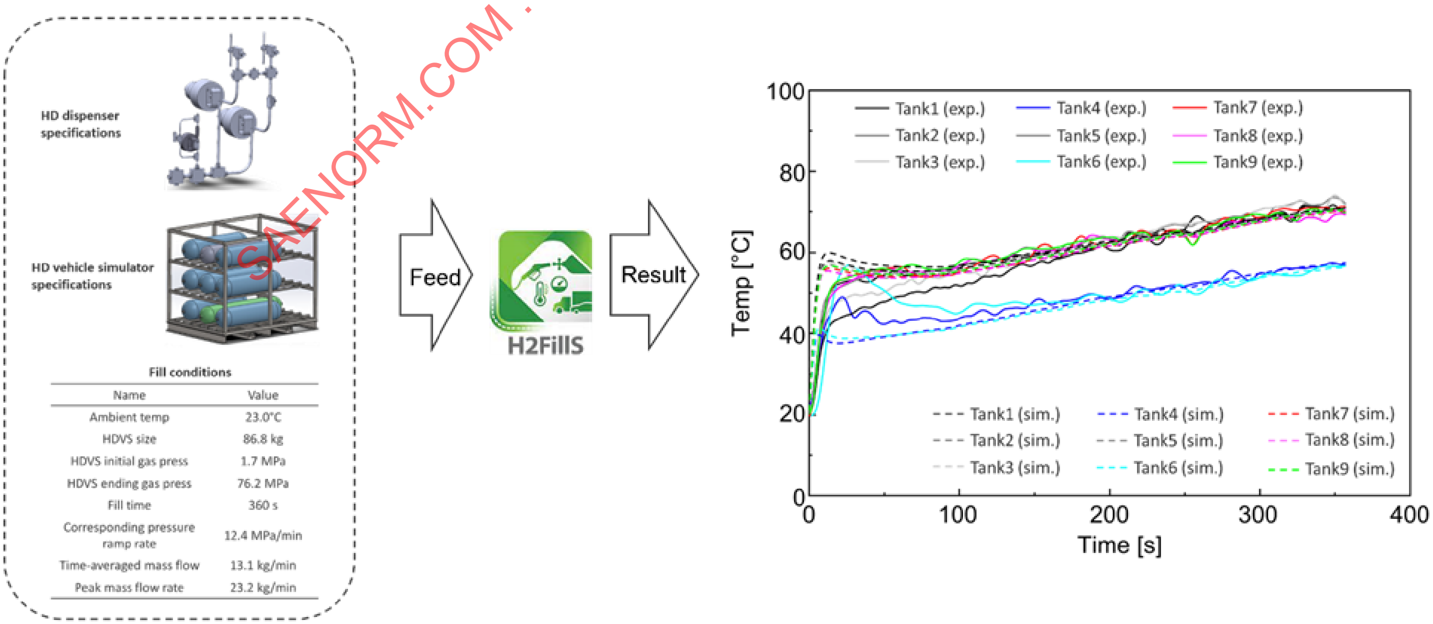


Figure A1 - H2FillS validation process and validation data

A.2 MCF-HF-G PROTOCOL STRUCTURE, PROCESS LIMITS, AND T_{FINAL} DERIVATION PROCESS

The MCF-HF-G fueling protocol is based on the MC Formula fueling protocol published in SAE J2601_202005 for light-duty (LD) vehicle fueling. For a comprehensive overview of the MC Formula fueling protocol and how it works, refer to Appendix H in SAE J2601_202005. Appendix A of SAE J2601_202005 provides a comprehensive explanation of the modeling process as well as the key assumptions and boundary conditions. The control architecture of the MCF-HF-G protocol is similar to that of the MC Formula protocol, but there are a number of changes and improvements to make the fueling protocol compatible for use with heavy-duty (HD) vehicles.

A.2.1 Protocol Structure

A.2.1.1 CHSS Capacities and Tank Sizes

HD vehicles can have a wide range of CHSS capacities and individual tank sizes within the CHSS - much more so than for LD vehicles. Furthermore, the CHSS construction can also vary substantially between different vehicle types, sizes, and applications. These variances make it more challenging to establish appropriate assumptions and boundary conditions, without being overly conservative, which would negatively impact the fueling performance.

The MCF-HF-G protocol utilizes t_{final} tables which are a function of the CHSS volume (V_{CHSS}) and the largest tank volume (TVL) within the CHSS. The MCF-HF-G can fuel HD vehicles with CHSS volumes from 248.6 to 7500 L (H35 FM120) and from 248.6 to 5000 L (H35 FM60 or H70 FM60/FM90/FM300). Furthermore, the MCF-HF-G can fuel HD vehicles with tank sizes within the CHSS ranging from 50 to 1000 L (H35 FM120) and from 50 to 800 L (H35 FM60 or H70 FM60/FM90/FM300). See A.3.2.2 for further details.

A.2.1.2 t_{final} Table Structure

The t_{final} table structure is changed from that used for the MC Formula fueling protocol in SAE J2601_202005. As explained in H.2.1 of SAE J2601_202005, for the MC Formula protocol, the t_{final} values are derived for discrete MAT values 5 °C apart and then a regression fit, or a third order polynomial equation is used to derive the coefficients a, b, c, and d of this equation. Due to the wider range of fuel delivery temperatures utilized for the MCF-HF-G protocol, and to ensure the compatibility of the MCF-HF-G protocol with an advanced MC Formula-based protocol developed under the PRHYDE project (refer to PRHYDE Project Consortium, 2023), the t_{final} tables consist of t_{final} values for discrete MAT values 2 °C apart. A regression fit equation is not used to relate these t_{final} values. Rather, t_{final} is calculated each timestep during the main fueling time by interpolating between the MAT values. Examples of this new t_{final} table structure can be found in Appendix D, which lists all of the t_{final} tables for the MCF-HF-G fueling protocol.

In SAE J2601_202005, there are two sets of t_{final} tables, one set derived by utilizing an initial pressure of 5 MPa, and another set derived by utilizing an initial pressure of 0.5 MPa. The rationale for this approach is explained in H.2.1 of SAE J2601_202005. Because for the MCF-HF-G protocol the number of CHSS configurations is relatively large, and because separate t_{final} tables are required for H35 FM120 and H35 FM60 or H70 FM60/FM90/FM300, utilizing two sets of tables with different initial pressure assumptions would double the already large number of t_{final} tables, and this was deemed impractical. Therefore, only one set of tables is utilized. This single set of t_{final} tables are derived with an initial pressure of 3 MPa for H35 FM120 and 5 MPa for H35 FM60 or H70 FM60/FM90/FM300. The two initial pressures represent an initial SOC of approximately 10% for each pressure class. This single set of t_{final} tables are appropriate for fueling conditions where the initial CHSS pressure is equal to or higher than 3 MPa and 5 MPa, respectively. When the initial CHSS pressure is less than 3 MPa and 5 MPa, respectively, the t_{final} values must be extended to ensure the maximum CHSS gas temperature does not exceed 85 °C.

To extend the t_{final} values appropriately when the initial pressure is less than 3 MPa and 5 MPa, respectively, a parameter named epsilon and represented by the symbol ε is multiplied by t_{final}. An equation for ε is provided for each fueling protocol, which is a function of the ambient temperature and the initial pressure (see Equation C20). This equation was developed by utilizing fueling simulations comparing the t_{final} value as a function of the initial pressure. The equation for ε is conservative, meaning that errors in the ε equation skew t_{final} to be longer than the true value. This was deemed to be an acceptable trade-off between the other option of doubling the number of t_{final} tables, especially since fueling events where the initial SOC is lower than 10% are statistically rare. Furthermore, the use of the two sets of t_{final} tables in the MC Formula protocol in SAE J2601_202005 is binary, meaning that if the initial pressure is equal to or above 5 MPa, one set of tables is used and if it is below 5 MPa, another set of tables is used. This means that even if the initial pressure is 4.9 MPa, the fueling rate is based on the assumption that the initial pressure is at 0.5 MPa. This can cause the fueling time to be substantially longer than if the initial pressure was 5 MPa, even though there is only 0.1 MPa difference in the initial pressure. With the ε equation approach, ε gradually increases as a function of the initial pressure. For example, if the initial pressure is 4.9 MPa, ε = 1.01, meaning the fueling time will only be 1% longer than it would be if the initial pressure was 5 MPa. Therefore, even though ε conservatively increases the t_{final} value compared with the true t_{final} value, it only adjusts t_{final} by an amount relative to the initial pressure, so overall, fueling performance should be significantly better than it would be if two sets of t_{final} tables were utilized, and they were chosen in a binary manner.

The equation for epsilon was derived by conducting two sets of fueling simulations, one with the initial pressure equal to 3 MPa and 5 MPa for H35 FM120 and H70 FM300, respectively, and another set with the initial pressure equal to 0.5 MPa for the H35 FM120 and H70 FM300, respectively. For each t_{final} table, the t_{final} values with initial pressure of 0.5 MPa are divided by the t_{final} values with initial pressure of 3 MPa or 5 MPa, which creates a table of epsilon values. Next, the maximum epsilon value from all the tables is determined for each ambient temperature. From this, an equation is derived which calculates epsilon as a function of the ambient temperature. Finally, a limited set of simulations are conducted at initial pressures in between 0.5 and 3 MPa (H35 FM120) and in between 0.5 and 5 MPa (H70 FM300) from which an equation is derived for the pressure dependency of epsilon. By combining these two equations, a final equation for epsilon is established which is a function of both ambient temperature and initial pressure (see Equation C20). The values for epsilon calculated by this equation are illustrated in the graphs shown in Figure A2.

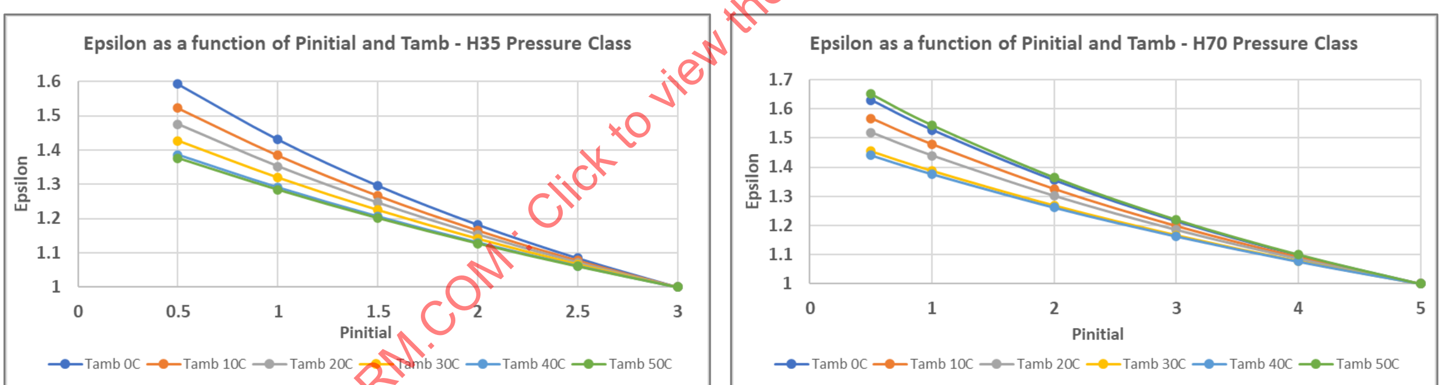


Figure A2 - Temperature and pressure dependence of epsilon for H35 FM120 and H70 FM300

A.2.1.3 Variable Pressure Ramp Rate

Consider a case where the value t_{final} is pre-determined and doesn't change during the fill. In this case, t_{final} is the denominator of the equation for APRR, as shown in Equation A1. Because t_{final} doesn't change during the fill, regardless of the starting pressure, the fill will always utilize the APRR.

$$APRR = \frac{P_{final} - P_{min}}{t_{final}} \quad \text{(Eq. A1)}$$

Now, consider the case where t_{final} changes during the fill. When t_{final} is allowed to change during the fill, an equation for the PRR must be derived that ensures that the dispenser pressure follows a rate of change path that arrives at P_{final} at the elapsed time of t_{final}. An illustration of this is shown in Figures A3 and A4. In Figure A3, the exemplary fill starts at $P_{initial}$ with a calculated t_{final} shown in black. As the fill progresses, at point P_{ramp} and t, t_{final} changes to a higher value shown in blue, causing the rate of change of the pressure to decrease such that it arrives at P_{final} at the elapsed time of the new t_{final}. In Figure A4, the exemplary fill starts at $P_{initial}$ with a calculated t_{final} shown in black. As the fill progresses, at point P_{ramp} and t, t_{final} changes to a lower value shown in blue, causing the rate of change of the pressure to increase such that it arrives at P_{final} at the elapsed time of the new t_{final}.

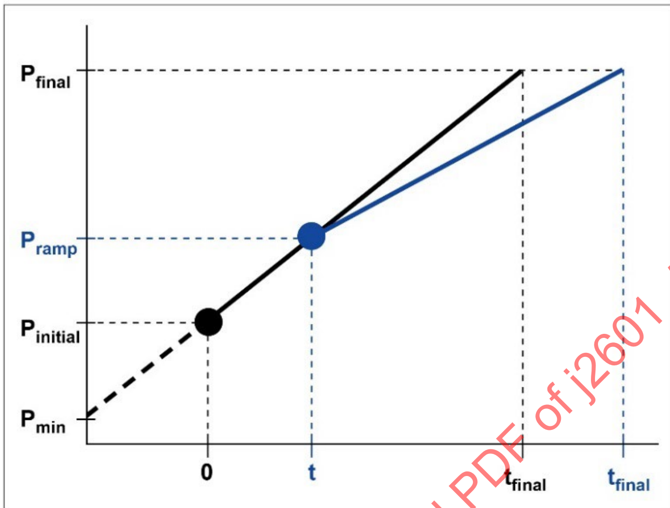


Figure A3 - Illustration of the effect on the pressure path with an increase in t_{final}

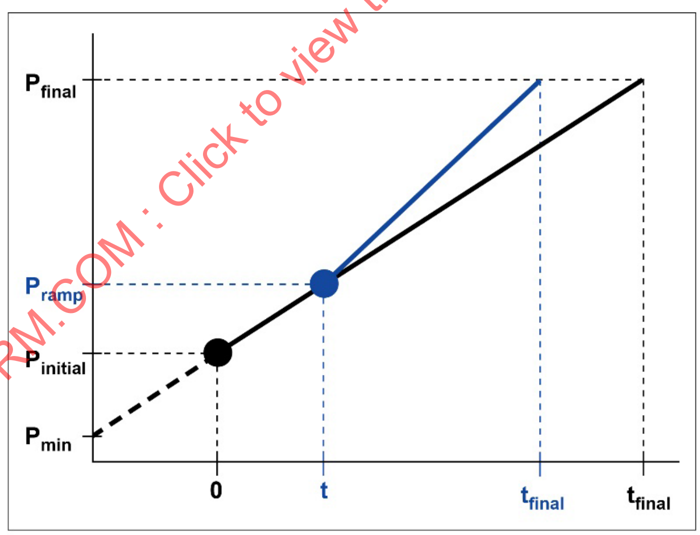


Figure A4 - Illustration of the effect on the pressure path with a decrease in t_{final}

To keep the illustration simple, the change in PRR is only shown to occur once in Figures A3 and A4, but the same approach is used whenever t_{final} changes. The equation which dictates the PRR with a changing t_{final} is Equation A2. In Equation A2, P_{ramp} represents the ramp pressure at an elapsed time of t during the fill.

$$PRR = \frac{P_{final} - P_{ramp}}{t_{final} \times \left(\frac{P_{final} - P_{initial}}{P_{final} - P_{min}} \right) - t} \quad \text{(Eq. A2)}$$

In the MCF-HF-G fueling protocol, the PRR equation substitutes $P_{startup}$ for $P_{initial}$ since $P_{startup}$ represents the starting pressure at the beginning of the main fueling time.

The equation which dictates the ramp pressure P_{ramp} as a function of the PRR is Equation A3, where j represents a timestep of 1 second.

$$P_{ramp_{j+1}} = P_{ramp} + PRR \quad \text{(Eq. A3)}$$

A.2.1.4 Mass Average Fuel Delivery Temperature

The t_{final} values in the tables are a function of the mass average fuel delivery temperature MAT based on the MAT at the end of the fill. In the fueling simulations, the fuel delivery temperature and PRR are held constant. During actual fueling, however, the fuel delivery temperature can change. At the beginning of the fill, MAT can be significantly warmer than at the end of the fill, especially if the dispenser is initially warm. If MAT were used directly in the equation for t_{final}, t_{final} would be very large at the beginning of the fill and get progressively smaller as the fuel delivery temperature cools and MAT becomes colder. This would create a PRR which is very small at the beginning of the fill and very large at the end of the fill. This is not desirable for a number of reasons. A small PRR at the beginning of the fill when the dispenser is warm causes the cool-down period to be significantly longer than it otherwise would be due to the small mass flow rate. Additionally, large changes in the PRR increase enthalpy, which if not compensated for could cause overheating, and if accounted for, will cause the overall fueling time to be longer. And finally, there must be a limit or cap placed on PRR to constrain the maximum flow rate, so if PRR is small at the beginning of the fill, PRR cannot fully compensate later in the fill due to this limit, again causing the overall fueling time to be longer than it should be.

To minimize the above detrimental effects, PRR should be as constant as possible, which in turn requires t_{final}, and thus, MAT, to be as constant as possible. The approach chosen breaks the fill into sections and establishes a set of rules for the MAT input used in the equation for t_{final}. The sectioning of the fill into Rules 1 through 3 is illustrated in Figure A5.

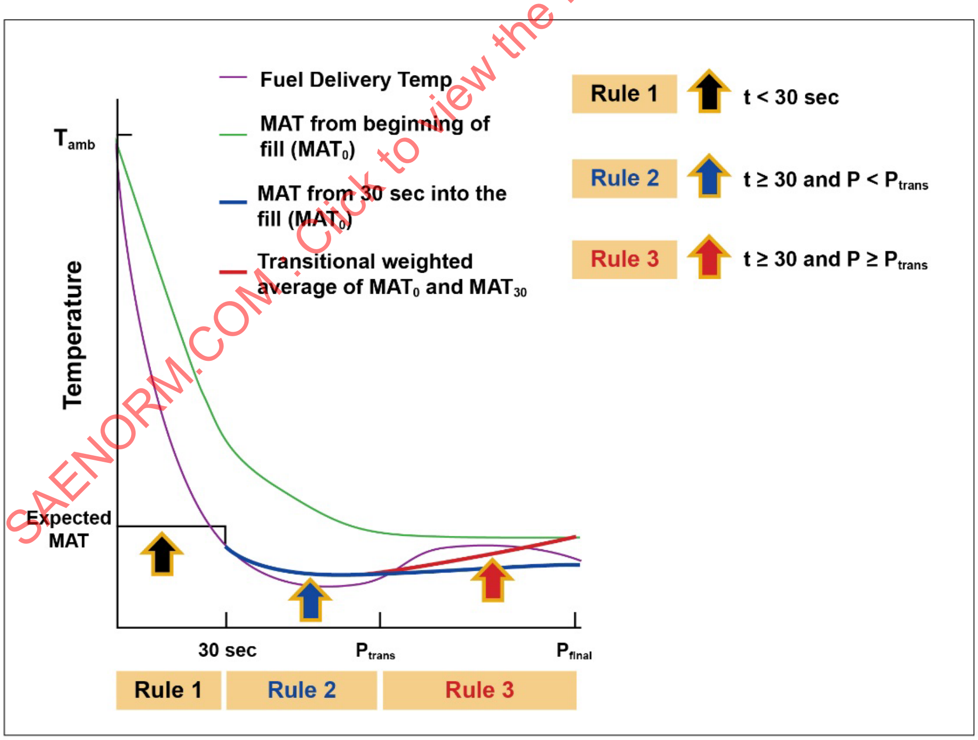


Figure A5 - Illustration of sectioning of the fill into regions where specific rules are applied for MAT

Instead of using MAT directly in the equation for t_{final}, a proxy for MAT named MAT_C ("C" stands for control input) is utilized. MAT_C is determined based on the region of the fill, where specific rules are applied, as illustrated in Figure A5.

A.2.1.4.1 Rule 1: $MAT_C = MAT_{expected}$

The first region where Rule 1 is applied is defined by the first 30 seconds of mass flow. When the fill is in this region, the Expected MAT (symbol $MAT_{expected}$) is utilized for MAT_C. Expected MAT is defined as the expected value for MAT_0 at the end of the fill. It is not important that this value be precisely correct, as its purpose is to serve as a proxy for MAT during the cool-down phase of the fill. The acceptable range for Expected MAT is -20 °C ≤ $MAT_{expected}$ ≤ 20 °C for H35 FM120 and -33 °C ≤ $MAT_{expected}$ ≤ 0 °C for H35 FM60 or H70 FM60/FM90/FM300. The upper value of 20 °C and 0 °C, respectively, is because this corresponds to the warmest MAT allowed for the fueling protocol. The lower value of -20 °C and -33 °C, respectively, is due to running worst case fueling simulations with different $MAT_{expected}$ values where the fuel delivery temperature only reached 20 °C and 0 °C, respectively, at t = 30 seconds and then held constant at this value. Under this worst-case scenario, no overheating was seen with these $MAT_{expected}$ values. There may be situations where the dispenser utilizes an $MAT_{expected}$ which is colder than what is actually expected. For example, under hot ambient temperatures, in order to achieve a sufficiently cold fuel delivery temperature within 30 seconds, it may require the dispenser to input an $MAT_{expected}$ which is colder than the Expected MAT at the end of the fill. As long as $MAT_{expected}$ is set within the ranges defined above, any value may be used.

A.2.1.4.2 Rule 2: $MAT_C = MAT_{30}$

After a total of 30 seconds of mass flow have elapsed, the fuel delivery temperature should be close to its target temperature and remain relatively stable for the remainder of the fill. Thus, the second region where Rule 2 is applied is defined by the fueling time t after 30 seconds of mass flow have elapsed and the ramp pressure (symbol P_{ramp}) being less than the transitional pressure (symbol P_{trans}). P_{trans} is defined as the midpoint between the initial pressure $P_{initial}$, and the final pressure P_{final}. For example, for an H70 Pressure Class fill with an initial pressure of 10 MPa, since P_{final} is always equal to 87.5 MPa, P_{trans} would be equal to 48.75 MPa. In this region where Rule 2 is applicable, the mass average of the fuel delivery temperature after the first 30 seconds of mass flow (symbol MAT_{30}) is utilized for MAT_C. The equation for MAT_{30} is shown in Equation A4, where j represents a timestep of 1 second and n is a counter which advances along with j, but only if there is mass flow above the minimum threshold during the timestep. If there is an intended non-fueling event during the last 10 seconds of this period (i.e., 20 ≤ n ≤ 30), then 10 is subtracted from n to allow a total of 40 seconds of mass flow. This is because during an intended non-fueling event, T_{fuel} warms, so an additional 10 seconds is provided so that T_{fuel} can cool down again after flow continues.

$$MAT_{30} = \frac{\sum_{j@n=30}^{j}\left[\left(m_{(j)} - m_{(j-1)}\right) \times 0.5\left(T_{fuel\_inst(j)} + T_{fuel\_inst(j-1)}\right)\right]}{\sum_{j@n=30}^{j}\left(m_{(j)} - m_{(j-1)}\right)} \quad \text{(Eq. A4)}$$

A.2.1.4.3 Rule 3: MAT_C = Weighted function of MAT_{30} and MAT_0

Once the ramp pressure P_{ramp} has exceeded the transitional pressure P_{trans}, it is important that the control input MAT_C gradually transition to MAT_0 by the end of the fill, as this is the value upon which t_{final} is based. MAT_0 is defined by Equation A5. Thus, the third region where Rule 3 is applied is defined by the counter n being greater than or equal to 30 seconds and the ramp pressure P_{ramp} being greater than or equal to the transitional pressure P_{trans}. This transition to MAT_0 is realized by using a weighted average of MAT_{30} and MAT_0 where the weighting factor is a function of the ramp pressure P_{ramp}. The equation for this weighted average is shown in Equation A6.

$$MAT_0 = \frac{\sum_{j@n=1}^{j}\left[\left(m_{(j)} - m_{(j-1)}\right) \times 0.5\left(T_{fuel\_inst(j)} + T_{fuel\_inst(j-1)}\right)\right]}{\sum_{j@n=1}^{j}\left(m_{(j)} - m_{(j-1)}\right)} \quad \text{(Eq. A5)}$$

$$IF\ P_{trans} < P_{ramp} \le P_{final},\ MAT_C = MAT_{30} \times \left(\frac{P_{final} - P_{ramp}}{P_{final} - P_{trans}}\right) + MAT_0 \times \left(1 - \frac{P_{final} - P_{ramp}}{P_{final} - P_{trans}}\right) \quad \text{(Eq. A6)}$$

A.2.2 Process Limits

The range of fuel delivery temperatures was also determined through the fueling simulations. The coldest fuel delivery temperature is -40 °C, just as it is for SAE J2601_202005. The criteria to establish the warmest fuel delivery temperature is that the APRR is equal to or higher than the lower pressure limit, which is based on an APRR of 0.75 MPa/min for H35 FM120 and 1.0 MPa/min for H35 FM60 or H70 FM60/FM90/FM300. These APRRs for the lower pressure limit are utilized because they are the lowest APRR which will keep the mass flow rate above the minimum value allowed (which is enforced to prevent check valve chatter). Furthermore, by utilizing these limits, the SAE J2601_202005 CHSS Capacity Category D ending pressure tables for the H70 Pressure Class can be utilized, as they are also based on a minimum APRR of 1 MPa/min. For the H35 FM120 protocol, because the lower pressure limit is based on 0.75 MPa/min, new ending pressure tables are derived. The resulting warmest fuel delivery temperatures are 20 °C for the H35 FM120 protocol and 0 °C for the H35 FM60 or H70 FM60/FM90/FM300 protocols, as indicated in Table 8.

It is important to note that at high ambient temperatures and high fuel delivery (MAT_C) temperatures, the t_{final} values in the t_{final} tables can result in a PRR which will cause the ramp pressure to fall below the lower pressure limit. The t_{final} values which will cause this to happen are shaded in red in the t_{final} tables, and the t_{final} values which may cause this to happen are shaded in yellow (these are for conditions when $P_{initial}$ is less than 3 MPa for H35 FM120 and 5 MPa for H35 FM60 or H70 FM 60/FM90/FM300. The magnitude of t_{final} depends on ε, which in turn is a function of $P_{initial}$.). If MAT_C gets sufficiently warm to utilize these yellow and red shaded t_{final} values, the fueling may not stop if it is only momentary due to the fuel delivery temperature cool-down process in the beginning of the main fueling time, or due to Joule-Thomson heating for ambient temperature fueling. However, if MAT_C is sustained at these temperatures, then the station pressure may fall below the lower pressure limit and the fueling will stop and/or the mass flow rate may fall below the minimum allowed. Therefore, the station should design the hydrogen fuel delivery precooling system with this in mind.

A.2.3 t_{final} Derivation Process

The derivation of the t_{final} is conducted in a similar manner to that described in H.2.1 of SAE J2601_202005 with some notable differences. The hot soak temperatures utilized for the derivation of t_{final} are the same as those defined in A.3.8 of SAE J2601_202005. The differences in the derivation process are explained below.

The first difference is that the target SOC for the fueling simulations is 100% for the H35 FM120 protocol and 98% for the H70 protocols. These values were chosen due to the higher pressure drops inherent in a “high-flow” fueling protocol like MCF-HF-G (a higher target SOC allows for a higher P_{limit_comm} value under low initial pressures). The second difference is that there is not a peak mass flow rate constraint imposed on the fueling simulations. The only two constraints in the fueling simulations are that the CHSS gas temperature (i.e., the highest gas temperature in any of the tanks within the CHSS) shall not exceed 85 °C and the SOC shall not exceed the target value. With these two constraints imposed, the fueling simulations calculate the highest APRR through an iterative process. This PRR is referred to as “hot case pressure ramp rate” (HPRR).

A separate set of simulations are conducted to calculate minimum t_{final} values called t_{final_min}, which are based on not exceeding the peak mass flow rate for the FM class, i.e., 120 g/s for H35 FM120, 60 g/s for H35 FM60 or H70 FM60, 90 g/s for H70 FM90, and 300 g/s for H70 FM300. These simulations are separate from the hot case simulations because they are conducted with different assumptions for the station side fuel delivery components and for the vehicle side pressure drop, and they are conducted at an ambient temperature of -40 °C and a fuel delivery temperature of -40 °C. The station side fuel delivery components are assumed to have a higher Cv value than for the hot case, and the vehicle side pressure drop is set to 5 MPa rather than 15 MPa under reference conditions. These assumptions and fueling conditions produce the highest possible mass flow rate at a constant PRR. This will result in a lower HPRR value (and higher t_{final} value) than if the hot case assumptions and fueling conditions are utilized. Fueling simulations are conducted at the conditions described and on a CHSS configured as described with capacities the same as the boundary CHSS configurations described in A.3.2.2 through A.3.2.5. These fueling simulations produce an HPRR value for each CHSS capacity. The HPRR value is converted into a t_{final_min} value, and then a regression fit equation is derived to relate t_{final_min} to the CHSS volume, as illustrated in Figure A6. This equation is then utilized to calculate t_{final_min} as a function of the CHSS volume and the minimum pressure P_{min}. This is Equation C46 in C.3.4.

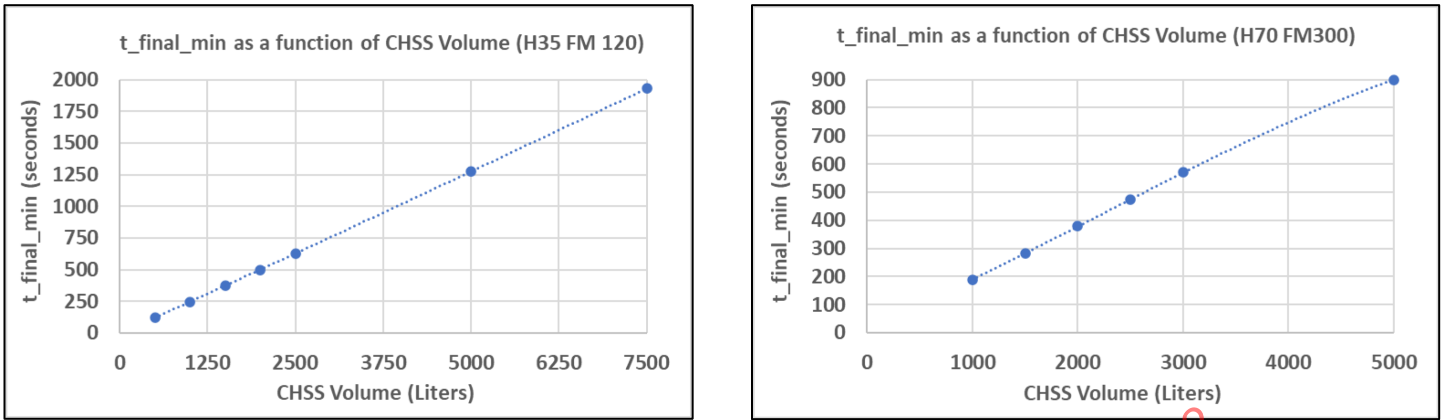


Figure A6 - HPRR as a function of CHSS volume for use in the t_{final_min} Equation C46

Another difference is in the value utilized for P_{final} and, thus, the calculation of t_{final}. In SAE J2601_202005, P_{final} is set to 83.5 MPa, which corresponds to the pressure at 97% SOC and 85 °C for the H70 Pressure Class. The MCF-HF-G fueling protocol utilizes a P_{final} value of 43.75 MPa for the H35 FM120 protocol and a P_{final} value of 87.5 MPa for the H35 FM60 or H70 FM60/FM90/FM300 protocols. t_{final} is derived by subtracting P_{min} from P_{final} and dividing by the HPRR.

A.3 ASSUMPTIONS AND BOUNDARY CONDITIONS

This section describes the assumptions and boundary conditions (BCs) utilized for the Category D HF and MCF-HF-G fueling protocol. Vehicle manufacturers should verify that their vehicle fuel system designs are within these assumptions and BCs.

A.3.1 Process for Determining Appropriate Assumptions and Boundary Conditions

The SAE Interface Task Force (ITF) formed a subgroup whose purpose was to investigate and propose appropriate assumptions and BCs, which were then reviewed and approved by the ITF. The process the subgroup utilized was to develop a set of survey questions which addressed each of the assumptions and BCs. This survey was sent to a wide swath of industry stakeholders, including vehicle manufacturers, CHSS manufacturers, and hydrogen station manufacturers and operators. The majority of the responses received were from truck and bus manufacturers, but there were also some responses from off-road vehicle manufacturers, and even a rail manufacturer. CHSS manufacturers were also well represented in the responses.

A.3.1.1 Survey

Table A1 provides an overview of the types of questions asked in the survey.

Table A1 - Overview of the questions included in the survey

Vehicle Fuel System Related	Minimum operating pressure
	Minimum flow rate
	Minimum and maximum CHSS capacities
	Minimum and maximum tank size within the CHSS
	Minimum and maximum aspect ratio of tanks used
	Tank construction - thermophysical properties of liner and CFRP*
	Tank inlet injector size and orientation
	Internal and external tubing sizes for the fuel delivery system
	Lengths of the tubing for the fuel delivery system
	Proposed reference pressure drop for vehicle
Other	Communications used
	Preferences for fuel delivery temperatures of the protocol
	Desired fueling times of the protocol
	Other

* Carbon Fiber Reinforced Plastic

A.3.2 Vehicle Side Hot Case Assumptions and Boundary Conditions

The assumptions and BCs in this section pertain to the hot case (refer to Sections A.2 and A.3 of SAE J2601_202005) and are utilized to derive the t_{final} tables in Appendix D and the lookup tables in Appendix G. These assumptions and BCs are those which result in the highest gas temperature development within the CHSS. Table A2 provides an overview of the categories of assumptions and BCs specified.

Table A2 - Categories of assumptions and boundary conditions

CHSS and Fuel Delivery System Configurations	CHSS hot soak temperatures
	Range of CHSS volumes and categories
	Range of tank volumes and categories
	Tank geometries
	Liner and CFRP thermophysical properties
	Fuel delivery system - tubing lengths and ID/OD
	Vehicle side reference pressure drop
Dispenser Component Configurations	Nozzle/receptacle ID/OD/length, thermal mass and Cv
	Break-away fitting ID/OD/length, thermal mass and Cv
	Hose ID/OD/length, thermophysical properties

A.3.2.1 CHSS Hot Soak temperatures

The CHSS hot soak temperatures utilized for hot case fueling simulations are the same as those utilized in A.3.8 of SAE J2601_202005. In the future, after operational data has been gathered for HD trucks, these hot soak temperature assumptions may be adjusted, but the information in SAE J2601_202005 is the best currently available.

A.3.2.2 Range of CHSS Volumes and Categories

Based on the industry survey, the maximum CHSS volume for the H35 FM120 protocol was determined to be 7500 L (180 kg), and the maximum CHSS volume for the H35 FM60 or H70 FM60/FM90/FM300 protocols was determined to be 5000 L (201 kg). As noted previously, some of the survey responses were from manufacturers of off-road vehicles and even rail, which can utilize larger storage capacities than on-road HD vehicles. These maximum capacities were utilized to make the fueling protocols as useful to as many applications as possible.

For the minimum CHSS volume, there were many responses in the survey indicating CHSS volume less than 500 L. To ensure a transition from LD vehicle fueling to HD vehicle fueling with no gaps in the coverage of CHSS capacities, 248.6 L was chosen as the minimum CHSS volume (248.6 L is the maximum CHSS capacity for LD vehicles in SAE J2601_202005).

To maximize performance, the range of CHSS volumes needs to be divided into categories. The finer the categories, the more optimized the fueling performance will be. However, more categories entail more t_{final} tables, so a balance needs to be reached between optimizing performance and maintaining a reasonable number of t_{final} tables. This balance resulted in eight boundary CHSS volumes and seven CHSS volume categories. Table A3 illustrates the minimum and maximum CHSS volumes as well as the CHSS volume categories utilized.

Table A3 - Minimum and maximum CHSS volumes and CHSS volume categories

Protocol	CHSS Volume (liters)							
H35 FM120	248.6	500	1000	1500	2000	2500	5000	7500
H35 FM60 or H70 FM60/FM90/FM300	248.6	500	1000	1500	2000	2500	3000	5000

A.3.2.3 Range of Tank Sizes

Based on the industry survey, the maximum tank volume for the H35 Pressure Class was determined to be 1000 L (24 kg), and the maximum tank volume for the H70 Pressure Class was determined to be 800 L (32.2 kg). The survey indicated a minimum tank volume for both pressure classes of 50 L.

To maximize performance, this range of tank volumes needs to be divided into categories. The finer the categories, the more optimized the fueling performance will be. However, more categories entail more t_{final} tables, so a balance needs to be reached between optimizing performance and maintaining a reasonable number of t_{final} tables. This balance resulted in three tank volume categories. These tank volume categories are based on the largest tank volume in the CHSS, i.e., TVL. Tables A4 and A5 illustrates the minimum and maximum tank volumes as well as the TVL tank volume categories utilized.

Table A4 - TVL tank volume categories for the MCF-HF-G protocol

Protocol	TVL Tank Volume Categories (liters)		
H35 FM120	50 to 200	200 to 350	350 to 1000
H35 FM60 or H70 FM60/FM90/FM300	50 to 200	200 to 350	350 to 800

Table A5 - TVL tank volume categories for the Category D HF protocol

Protocol	TVL Tank Volume Categories (liters)	
H35 FM60 or H70 FM60/FM90	50 to 250	250 to 800

A.3.2.4 Tank Geometries

Responses to the survey indicated a minimum aspect ratio (length divided by diameter) of 2 and a maximum aspect ratio of between 9 and 10. For the hot case assumption, a smaller aspect ratio is worst case because it has a lower surface to volume ratio than a larger aspect ratio. Therefore, the tank geometry for the hot case simulations is based on an aspect ratio of 2.

For the larger size tanks, an aspect ratio of 2 would result in a very large diameter. Therefore, one of the survey questions was about the expected largest external diameter of a tank. The survey answers ranged from 700 to 750 mm, so the maximum value of 750 mm was selected. Therefore, for the tank geometry, an aspect ratio of 2 is utilized until the external tank diameter reaches 750 mm, after which the length of the tank is extended to achieve the desired volume.

A tank geometry tool was developed which utilizes inputs of external length, external volume, and liner thickness, and from these inputs, calculates the internal diameter and length, the internal volume, the CFRP wall thickness, and the internal surface area. Tables A6 and A7 list the tanks utilized in the CHSS configurations for the hot case modeling, along with the geometric assumptions.

Table A6 - Tank geometric assumptions for H35 FM120

Dimensions	Tank Size (liters)										
	50	100	200	248.6	300	350	500	600	700	950	1000
Aspect Ratio	2	2	2	2	2	2	2.4	2.8	3.4	4.1	4.3
External Length (meters)	0.7444	0.9396	1.1854	1.2722	1.3578	1.4298	1.7825	2.0768	2.5181	3.1065	3.2528
External Diameter (meters)	0.3722	0.4698	0.5927	0.6361	0.6789	0.7149	0.7500	0.7500	0.7500	0.7500	0.7500
Internal Length (meters)	0.7004	0.8831	1.1133	1.1961	1.2747	1.3421	1.6904	1.9847	2.4260	3.0144	3.1617
Internal Diameter (meters)	0.3282	0.4133	0.5205	0.5600	0.5958	0.6272	0.6579	0.6579	0.6579	0.6579	0.6579
Liner Thickness (meters)	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
CFRP Wall Thickness (meters)	0.0180	0.0242	0.0321	0.0348	0.0375	0.0398	0.0421	0.0421	0.0421	0.0421	0.0421
Internal Surface Area (square meters)	0.7222	1.1468	1.8208	2.1041	2.3860	2.6442	3.4934	4.1017	5.0137	6.2297	6.5342

Table A7 - Tank geometric assumptions for H35 FM60 or H70 FM60/FM90/FM300

Dimensions	Tank Size (liters)										
	50	100	200	248.6*	300	350	450	500	600	700	800
Aspect Ratio	2	2	2	2	2	2	2.3	2.5	2.9	3.3	3.7
External Length (meters)	0.7655	0.9606	1.2064	1.2960	1.3788	1.4508	1.6912	1.8437	2.1485	2.4533	2.7584
External Diameter (meters)	0.3828	0.4803	0.6032	0.6480	0.6894	0.7254	0.7500	0.7500	0.7500	0.7500	0.7500
Internal Length (meters)	0.7085	0.8912	1.1214	1.2052	1.2828	1.3502	1.5875	1.7400	2.0448	2.3496	2.6547
Internal Diameter (meters)	0.3258	0.4109	0.5182	0.6480	0.5934	0.6248	0.6463	0.6463	0.6463	0.6463	0.6463
Liner Thickness (meters)	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
CFRP Wall Thickness (meters)	0.0245	0.0307	0.0385	0.0414	0.0440	0.0463	0.0479	0.0479	0.0479	0.0479	0.0479
Internal Surface Area (square meters)	0.7252	1.1505	1.8254	2.1099	2.3912	2.6502	3.2229	3.5327	4.1514	4.7702	5.3896

* These tank dimensions are also used as the 250-L tank for the TVL in the Category D HF fueling protocol.

A.3.2.5 CHSS Configurations

In SAE J2601_202005 for LD fueling, for the hot case, which determines the t_{final} values, the boundaries of the CHSS capacity categories are defined by a worst-case design single tank. Refer to Section A.3 of SAE J2601_202005. For HD vehicles, the CHSS will almost always consist of multiple tanks. Furthermore, there may be different tank sizes within the CHSS. As noted previously, the range of possible tank sizes is quite large. Therefore, different tank size categories are utilized based on the TVL within the category. To construct the hot case CHSS configuration for a given CHSS capacity, a range of tank sizes are utilized, from the smallest possible to the largest possible within the TVL range. This approach is illustrated in Figure A7 for a CHSS capacity of 1500 L and a TVL of 350 L.

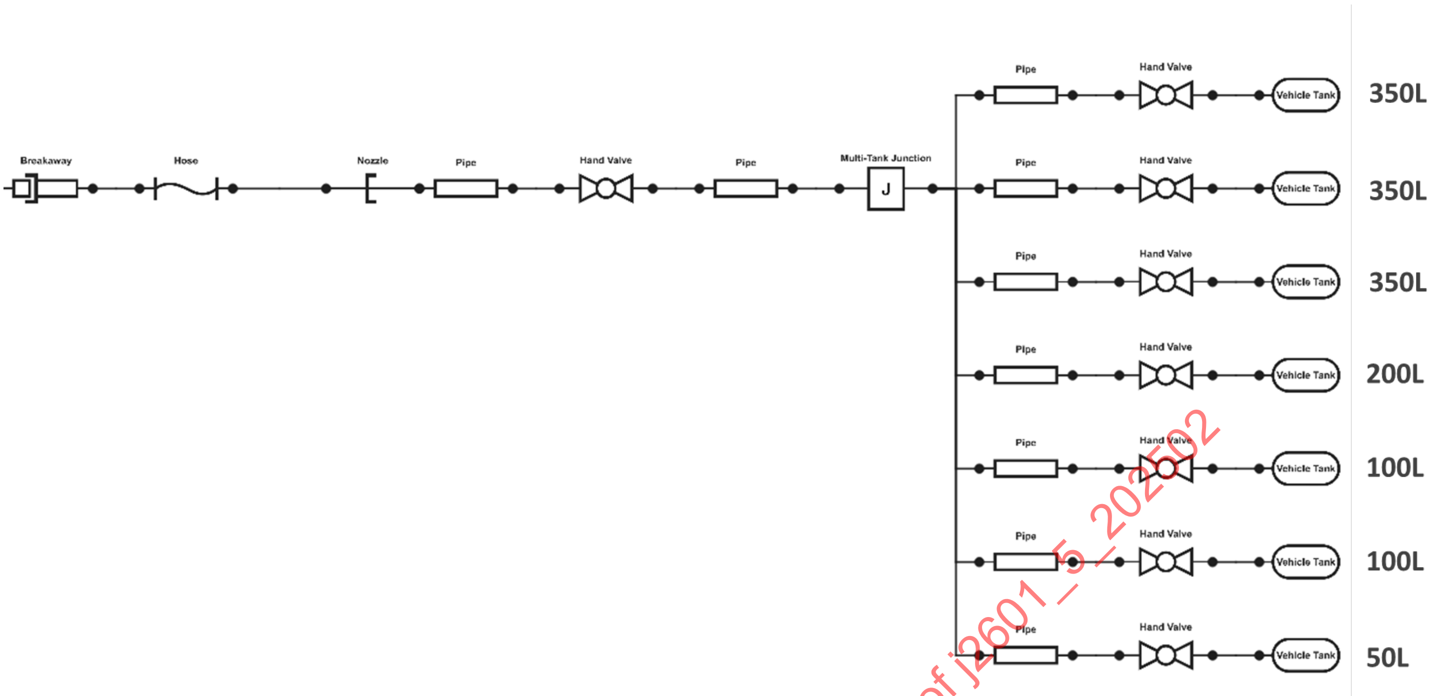


Figure A7 - Example hot case CHSS configuration with capacity of 1500 L and TVL of 350 L

In the hot case CHSS configurations, it is important that both the largest and smallest tank volumes are included, as the fueling simulations show that these are the tanks that develop the highest temperature during fueling. For the majority of fueling conditions, the largest tank will develop the highest temperature because the ratio of the internal surface area to the volume decreases with increasing tank size. Because the internal surface area strongly influences the heat transfer, a lower surface to volume ratio means there is less surface area for heat dissipation. However, the largest tank volume does not develop the highest temperature under all fueling conditions. This is because the temperature development is also influenced by the temperature of the hydrogen entering the tank, and the heat transfer from the fuel delivery components can warm the hydrogen. This heat transfer is influenced primarily by the thermal mass of these components. The smaller the tank, the smaller the amount of hydrogen flowing through the fuel delivery components routed to that tank, which means the ratio of the heat capacity of the fueling components to the heat capacity of the hydrogen for small tanks is higher, causing the inlet gas temperature to also be higher. In some conditions (typically at cold fuel delivery temperatures), the higher inlet gas temperature for the small tank has a higher influence than the more favorable surface to volume ratio, causing the small tank to develop a higher temperature than the large tank. The fueling simulations typically show that the tank size with the highest temperature development is always either the largest tank or the smallest tank. However, just to make sure that all potentialities are captured, a range of tank sizes between the smallest and largest are included in the CHSS configuration.

In A.3.2.2 and A.3.2.3, the range of CHSS volumes and TVL volumes are defined. For each boundary of these categories, a hot case CHSS is configured based on the assumptions and BCs. Tables A8, A9, and A10 list the number of tanks and their sizes utilized for each of these boundary CHSS configurations.

Table A8 - Tank sizes used in each CHSS configuration for hot case modeling - MCF-HF-G H35 FM120

TVL (liters)	CHSS Volume (liters)							
	248.6	500	1000	1500	2000	2500	5000	7500
1000	N/A	1 x 450 1 x 50	1 x 950 1 x 50	1 x 1000 1 x 300 1 x 100 2 x 50	1 x 1000 1 x 500 1 x 300 1 x 100 2 x 50	1 x 1000 1 x 700 1 x 600 1 x 100 2 x 50	2 x 1000 1 x 700 1 x 600 2 x 500 1 x 300 1 x 200 1 x 100 2 x 50	4 x 1000 1 x 700 1 x 600 3 x 500 1 x 300 1 x 200 1 x 100 2 x 50
350	1 x 248.6	1 x 350 1 x 100 1 x 50	2 x 350 2 x 100 2 x 50	3 x 350 1 x 200 2 x 100 1 x 50	4 x 350 2 x 200 1 x 100 2 x 50	6 x 350 1 x 200 1 x 100 2 x 50	13 x 350 1 x 200 2 x 100 1 x 50	Same as above
200	1 x 200 1 x 50	1 x 200 2 x 100 2 x 50	4 x 200 1 x 100 2 x 50	6 x 200 2 x 100 2 x 50	9 x 200 1 x 100 2 x 50	11 x 200 2 x 100 2 x 50	24 x 200 1 x 100 2 x 50	Same as above

Table A9 - Tank sizes used in each CHSS configuration for hot case modeling - MCF-HF-G H35 FM60 or H70 FM60/FM90/FM300

TVL (liters)	CHSS Volume (liters)							
	248.6	500	1000	1500	2000	2500	3000	5000
800	N/A	1 x 450 1 x 50	1 x 800 1 x 100 2 x 50	1 x 800 1 x 300 1 x 200 1 x 100 2 x 50	1 x 800 1 x 500 1 x 300 1 x 200 1 x 100 2 x 50	1 x 800 1 x 700 1 x 600 1 x 200 1 x 100 2 x 50	1 x 800 1 x 700 1 x 600 1 x 450 1 x 300 1 x 100 1 x 50	2 x 800 1 x 700 1 x 600 2 x 500 1 x 450 1 x 300 1 x 200 1 x 100 1 x 50
350	1 x 248.6	1 x 350 1 x 100 1 x 50	2 x 350 2 x 100 2 x 50	3 x 350 1 x 200 2 x 100 1 x 50	4 x 350 2 x 200 1 x 100 2 x 50	6 x 350 1 x 200 1 x 100 2 x 50	7 x 350 2 x 200 1 x 100 1 x 50	13 x 350 1 x 200 2 x 100 1 x 50
200	1 x 200 1 x 50	1 x 200 2 x 100 2 x 50	4 x 200 1 x 100 2 x 50	6 x 200 2 x 100 2 x 50	9 x 200 1 x 100 2 x 50	11 x 200 2 x 100 2 x 50	14 x 200 1 x 100 2 x 50	24 x 200 1 x 100 2 x 50

Table A10 - Tank sizes used in each CHSS configuration for hot case modeling - Category D HF H70 Press Class

TVL (liters)	CHSS Volume (liters)							
	248.6	500	1000	1500	2000	2500	3000	5000
800	N/A	1 x 450 1 x 50	1 x 800 1 x 100 2 x 50	1 x 800 1 x 300 1 x 200 1 x 100 2 x 50	1 x 800 1 x 500 1 x 300 1 x 200 1 x 100 2 x 50	1 x 800 1 x 700 1 x 600 1 x 200 1 x 100 2 x 50	1 x 800 1 x 700 1 x 600 1 x 450 1 x 300 1 x 100 1 x 50	2 x 800 1 x 700 1 x 600 2 x 500 1 x 450 1 x 300 1 x 200 1 x 100 1 x 50
250	1 x 248.6	1 x 250 2 x 100 2 x 50	3 x 250 2 x 100 2 x 50	5 x 250 2 x 100 2 x 50	7 x 250 2 x 100 1 x 50	9 x 250 2 x 100 1 x 50	11 x 250 2 x 100 1 x 50	19 x 250 2 x 100 1 x 50

A.3.2.6 Liner and CFRP Thermophysical Properties

From the survey, there are two primary liner materials utilized in hydrogen storage tanks - high density polyethylene (HDPE) and polyamide (PA). Proprietary compositions of these material types can result in slight variances in thermophysical properties. The PA material has properties which result in less heat transfer and, thus, a higher temperature development in the tank. Therefore, thermophysical properties based on a PA liner material are utilized. The CFRP tank wall thermophysical properties are the same as those used in SAE J2601_202005. Table A11 lists the thermophysical properties utilized for the hot case modeling.

Table A11 - Tank and CFRP thermophysical properties

Properties	Liner	CFRP
Thermal Conductivity (W/m*K)	0.26	0.5
Specific Heat (J/kg*K)	2500	1120
Density (kg/m^3)	1070	1494

A.3.2.7 Vehicle Fuel Delivery System - Tubing Lengths and ID/OD

In the survey, the diagram in Figure A8 was utilized. This figure illustrates the main fueling line L1 and branch lines L2 after a junction or manifold in a multi-tank CHSS (the number of tanks can be larger than the three illustrated). Respondents were asked to provide the longest length used or expected to be used for L1 and L2. Additionally, the respondents were asked to provide the largest internal and external diameters used or expected to be used for L1 and L2.

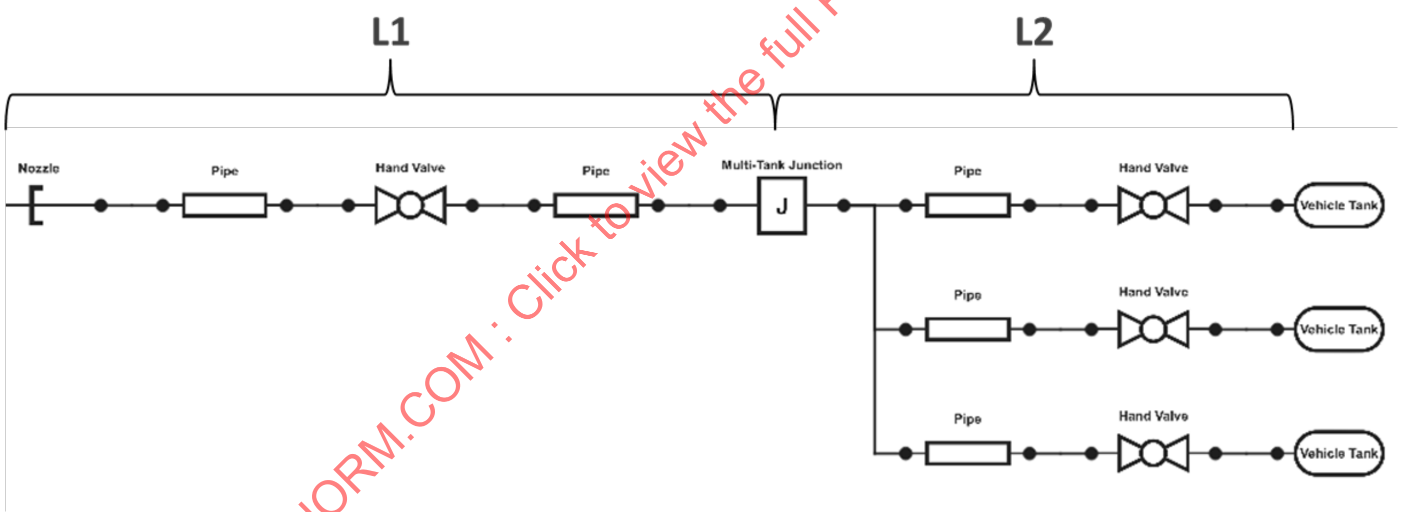


Figure A8 - Illustration of the fuel delivery system and representative lines L1 and L2

A.3.2.7.1 Tubing ID/OD

Table A12 lists the internal and external diameters utilized for the fuel delivery system lines L1 and L2 utilized in the CHSS configurations for hot case modeling. These values were derived from the survey responses. The diameters used for line L1 are a function of the CHSS volume. For CHSS volumes equal to or greater than 1500 L, these diameters represent the largest from the survey. The survey answers were correlated to commercially available tubing. For CHSS volumes less than 1500 L, the diameter for the L1 line is one tubing size smaller since this size is more than adequate for the mass flow.

Table A12 - Internal and external diameters utilized for the fuel delivery system lines L1 and L2

CHSS Volume	Pressure Class	L1		L2		Notes
		ID (millimeters)	OD (millimeters)	ID (millimeters)	OD (millimeters)	
≥1500 L	H35	13.1	19.1	9.1	14.3	L1 based on 3/4-inch cone & thread tubing rated @ 12500 psi L2 based on 9/16-inch cone & thread tubing rated @ 12500 psi
	H70	11.1	19.1	7.9	14.3	L1 based on 3/4-inch cone & thread tubing rated @ 20000 psi L2 based on 9/16-inch cone & thread tubing rated @ 20000 psi
<1500 L	H35	9.1	14.3	9.1	14.3	L1 & L2 based on 9/16-inch cone & thread tubing rated @ 12500 psi
	H70	7.9	14.3	7.9	14.3	L1 & L2 based on 9/16-inch cone & thread tubing rated @ 20000 psi

A.3.2.7.2 Tubing Lengths

Tables A13 and A14 list the tubing lengths utilized for the fuel delivery system lines L1 and L2 utilized in the CHSS configurations for hot case modeling. These values were derived from the survey responses. The longest values for L1 and L2 were derived from the survey, and it was noted these lengths were based on the largest CHSS capacities. The survey responses for smaller CHSS capacities were shorter. The ITF used the rationale that the tubing lengths will scale with vehicle size - larger vehicles will necessitate longer fuel delivery lines. Furthermore, the CHSS capacity was deemed to also scale with vehicle size (larger size vehicles require higher capacity CHSS). Therefore, the tubing lengths for L1 and L2 are a function of the CHSS volume. Because the tubing diameter for L1 changes when the CHSS volume is less than 1500 L, L1 also increases when the CHSS volume is less than 1500 L to provide an equivalent heat capacity to a larger diameter L1 with shorter length (displayed in gray text and parentheses in the tables).

Table A13 - Tubing lengths utilized for the fuel delivery system lines L1 and L2 - H35 FM120

CHSS Volume (liters)	L1 Length (meters) (ID = 13.1 mm & OD = 19.1 mm)	L1 Length (meters) (ID = 9.1 mm & OD = 14.3 mm)	L2 Length (meters) (ID = 9.1 mm & OD = 14.3 mm)	Total Length - L1 & L2
≥5000	23	N/A	7	30
2500	14	N/A	7	21
2000	12	N/A	7	19
1500	10	N/A	7	17
1000	(8)	11	6	17
500	(6)	10	4	14
248.6	(4)	7	3	10

Table A14 - Tubing lengths utilized for the fuel delivery system lines L1 and L2 - H35 FM60 or H70 FM60/FM90/FM300

CHSS Volume (liters)	L1 Length (meters) (ID = 11.1 mm & OD = 19.1 mm)	L1 Length (meters) (ID = 7.9 mm & OD = 14.3 mm)	L2 Length (meters) (ID = 7.9 mm & OD = 14.3 mm)	Total Length - L1 & L2
≥2500	14	N/A	7	21
2000	12	N/A	7	19
1500	10	N/A	7	17
1000	(8)	13.5	6	19.5
500	(6)	10.2	4	14.2
248.6	(4)	6.8	3	9.8

A.3.2.8 Vehicle Side Reference Pressure Drop

In SAE J2601_202005, the reference pressure drop is defined between the nozzle and receptacle interface and the internal CHSS pressure. This is a difficult if not impossible measurement to make because the nozzle and receptacle are coupled during fueling and operate as a single component. It is possible to measure the pressure just downstream of the receptacle, so the reference pressure drop is defined as the difference in pressure from the exit of the receptacle to the internal CHSS pressure. By defining the pressure drop in this manner, a vehicle manufacturer can readily test their CHSS and fuel delivery system design for compliance with the defined reference pressure drop.

Another issue with the definition of the reference pressure drop in SAE J2601_202005 is that the mass flow rate in the definition scales linearly with the CHSS capacity. For larger CHSS capacities, the reference pressure drop can be defined at a mass flow rate higher than the maximum peak mass flow rate. This is unrealistic and presents a problem when trying to measure the pressure drop on a CHSS and fuel delivery system design for compliance. Additionally, because the mass flow rate scales with the CHSS capacity, the SAE J2601 reference pressure drop definition overestimates the pressure drop for small CHSS capacities and underestimates the pressure drop for large CHSS capacities.

The objective of the reference pressure drop is to ensure good performance of the fueling protocol for all CHSS capacities. This means that the pressure drop under conditions where the fueling protocol reaches its maximum value should be approximately the same for all CHSS capacities. The ratio of the flow condition specified for the reference pressure drop to the peak flow rate should be the same for all CHSS capacities. If these objectives are met, all CHSS capacities will perform equally well.

The reference pressure drop is defined as follows. The reference pressure drop is measured from the exit of the receptacle to the CHSS internal pressure (it is assumed that all tanks in the CHSS develop pressure equally during fueling).

The reference pressure drop is 15 MPa under the following conditions:

- Vehicle CHSS pressure = 10 MPa
- H2 temperature at break-away (T_{fuel}) = -15 °C
- Mass Flow Rate (H35):
  - For a CHSS volume ≥670 L, the flow rate shall be 2/3rds of the peak flow rate allowed by the fueling protocol, i.e., 80 g/s
  - For a CHSS volume <670 L, the flow rate shall be 2/3rds the value of 1.5 x capacity (grams) divided by 200 seconds (which is the t_{final_min} value)

- Mass Flow Rate (H70):
    - For a CHSS volume ≥1000 L, the flow rate shall be 2/3rds of the peak flow rate allowed by the fueling protocol, i.e., 200 g/s
    - For a CHSS volume <1000 L, the flow rate shall be 2/3rds the value of 1.5 x capacity (grams) divided by 200 seconds (which is the t_{final_min} value)

Tables A15 and A16 list the reference flow rate for the reference pressure drop as a function of the CHSS capacity as well as the ratio of the reference flow rate to the peak flow rate.

Table A15 - Reference flow conditions for reference pressure drop - H35 FM120

CHSS Volume (liters)	CHSS Capacity (kilograms)	Reference Flow Rate (grams per second)	Ratio of the Reference Flow Rate to the Peak Flow Rate of the Protocol
248.6	5.97	30	~2/3*
500	12	60	~2/3*
750	18	80	2/3
1000	24	80	2/3
1250	30	80	2/3
1500	36	80	2/3
1750	42	80	2/3
2250	54	80	2/3
2500	60	80	2/3
3000	72	80	2/3
3500	84	80	2/3
4000	96	80	2/3
5000	120	80	2/3
7500	180	80	2/3

* Peak flow rate is based on t_{final_min} and is lower than the maximum flow rate of the fueling protocol.

Table A16 - Reference flow conditions for reference pressure drop - H70 FM300

CHSS Volume (liters)	CHSS Capacity (kilograms)	Reference Flow Rate (grams per second)	Ratio of the Reference Flow Rate to the Peak Flow Rate of the Protocol
248.6	10	50	~2/3*
500	20	100	~2/3*
750	30	150	~2/3*
1000	40	200	2/3
1250	50	200	2/3
1500	60	200	2/3
1750	70	200	2/3
2000	80	200	2/3
2250	90	200	2/3
2500	100	200	2/3
3000	120	200	2/3
3500	140	200	2/3
4000	160	200	2/3
4500	180	200	2/3
5000	200	200	2/3

* Peak flow rate is based on t_{final_min} and is lower than the maximum flow rate of the fueling protocol.

A.3.2.8.1 Reference Pressure Drop for Hot Case Modeling

The reference pressure drop in the H2FillS fueling model is illustrated in Figure A9. A valve in the middle of the L1 fueling line is utilized to tune the pressure drop to match the reference pressure drop definition. This is done for each CHSS configuration in Tables A8, A9, and A10. These CHSS configurations can have a wide range of tank volumes, especially for the largest TVL configurations. To ensure that the pressure develops equally in each of the tanks, the Cv of the multi-tank junction and of the valve in the L2 fueling line is set to a value of 5. By doing this, the tuning valve in the L1 fueling line is the primary source of the pressure loss in the system, and the pressure develops nearly equally in each tank. To ensure that this approach is equal to a fuel delivery system where the pressure loss is contributed by each of the components, fueling simulations were conducted comparing the temperature development using the same reference pressure drop but with the pressure loss contributed primarily by the valve in L1 and with the pressure loss distributed through the multi-tank junction and the valve in L2. The fueling simulations showed no discernable difference in the temperature development, confirming that the approach used in the fueling model is equivalent to what would be expected in a real-world design.

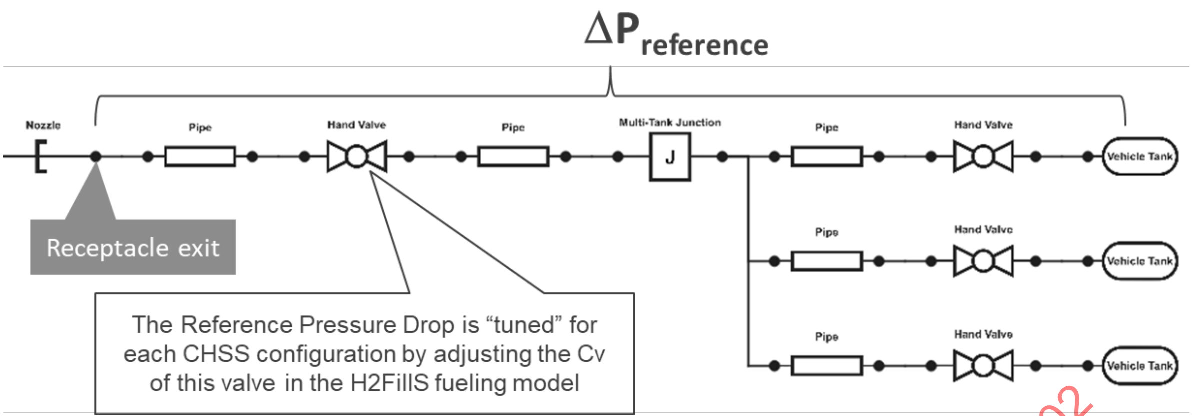


Figure A9 - Illustration of the reference pressure drop in the H2FillS fueling model

A.3.3 Station Side Hot Case Assumptions and Boundary Conditions

The station side fuel delivery components consist of the break-away, hose, and nozzle/receptacle coupling. The H2FillS fueling model accepts thermophysical inputs for each of these components. Assumptions are made for each of these components and are discussed in A.3.3.1 and A.3.3.2.

A.3.3.1 Assumptions for the Nozzle/Receptacle Coupling and Breakaway Coupling

Figure A10 shows the inputs required in H2FillS for the nozzle element and break-away element. The nozzle element is a representation of the nozzle/receptacle coupling.

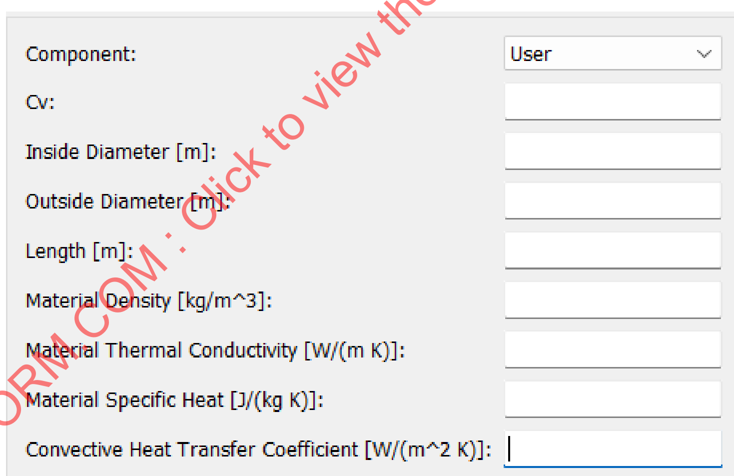


Figure A10 - H2FillS inputs for the nozzle and break-away element

To obtain the required inputs for the nozzle/receptacle and break-away, manufacturers of these components were surveyed. For both sets of components, they were asked to provide the Cv or Kv, internal diameter, overall length, material, and wetted mass. The wetted mass is defined as the mass of the nozzle and receptacle which is exposed to hydrogen - this is the mass which can contribute heat to the hydrogen as it flows through the coupling (the thermal mass or heat capacity would be the wetted mass multiplied by the specific heat capacity of the material). In H2FillS, the wetted mass is calculated as the total volume of the wetted material multiplied by its density. Therefore, the outside diameter dimension in the H2FillS input is adjusted so it matches the wetted mass assumption.

For the H35 FM120 protocol, high-flow commercial components are available in the market. However, at the time of publication, H70 FM300 high-flow commercial components are still under development and have not yet been standardized. There are multiple proposals for the H70HF receptacle geometry, and H70HF component prototypes have been developed. These prototypes are currently undergoing testing. The information available for these H70HF prototype nozzles, receptacles, and break-aways is limited and is also considered confidential. Based on the information received through the survey of the manufacturers, a worst-case combination of all the responses is utilized in H2FillS for the nozzle and break-away inputs. This should ensure that the assumptions utilized are conservative. In the future, after the H70HF geometry has been standardized and testing has been conducted, SAE J2601-5 may be revised with more accurate assumptions for the nozzle/receptacle and break-away.

For the nozzle/receptacle coupling, a Cv or Kv was not provided by the component manufacturers. Instead, a Cv or Kv of the nozzle and of the receptacle were received. Because the Cv or Kv across the coupled nozzle/receptacle is not known, the Cv of the coupling is established by adding the Cv values of each component in series according to Equation A7.

$$\frac{1}{(Cv_{coupling})^2} = \frac{1}{(Cv_{nozzle})^2} + \frac{1}{(Cv_{receptacle})^2} \quad \text{(Eq. A7)}$$

Table A17 lists the assumptions for the nozzle/receptacle which are utilized as inputs for the nozzle element in the H2FillS fueling model. Table A18 lists the assumptions for the break-away which are utilized as inputs for the break-away element in the H2FillS fueling model.

Table A17 - Assumptions for the nozzle/receptacle which are utilized for the nozzle element in H2FillS

Thermophysical Properties	Assumption (H35 FM120)	Assumption (H70 FM300)
Cv	0.383	1.2529
Internal Diameter (meters)	0.008	0.008
Outside Diameter (meters)	0.04	0.0588
Length (meters)	0.31	0.2344
Material	316 Stainless Steel	316 Stainless Steel
Material Density (kg/m^3)	8000	8000
Wetted Mass (kilograms)	3	5
Material Thermal Conductivity [W/(m K)]	15	15
Material Specific Heat Capacity [J/(kg K)]	500	500
Convective Heat Transfer Coefficient [W/(m^2 K)]	20	20

Table A18 - Assumptions for the break-away which are utilized for the break-away element in H2FillS

Thermophysical Properties	Assumption (H35 FM120)	Assumption (H70 FM300)
Cv	1.852	1.852
Internal Diameter (meters)	0.012	0.008
Outside Diameter (meters)	0.043	0.0588
Length (meters)	0.284	0.2344
Material	316 Stainless Steel	316 Stainless Steel
Material Density (kg/m^3)	8000	8000
Wetted Mass (kilograms)	3	5
Material Thermal Conductivity [W/(m K)]	15	15
Material Specific Heat Capacity [J/(kg K)]	500	500
Convective Heat Transfer Coefficient [$W/(m^2 K)$]	20	20

A.3.3.2 Assumptions for the Hose

Figure A11 shows the inputs required in H2FillS for the hose element.

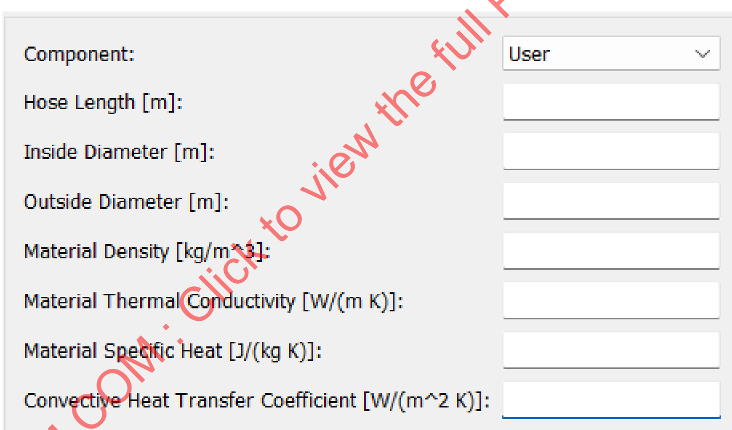


Figure A11 - H2FillS inputs for the hose element

To obtain the required inputs for the hose, manufacturers of these components were surveyed. Information was received for a commercially available 6-mm ID hose as well as a still-under-development prototype 10-mm ID hose. The 10-mm ID hose is intended for H70 high-flow (300 g/s) fueling. Once it is available, it may also be used for H35 high-flow fueling, but for H35 high-flow, the 6-mm ID hose is the most conservative (will create a higher pressure drop), so it is utilized for the H35 hose inputs.

The hose consists of an inner layer (Layer 1), a middle layer (Layer 2), and an outer layer (Layer 3). Layer 1 is made of a polymer material, and its purpose is to contain or prevent permeation of hydrogen. Layer 2 is made of steel wires, and its purpose is for structural strength. Layer 3 is a polymer material for protection from external elements. This layered construction is illustrated in Figure A12. Table A19 provides the information received on these two hoses.

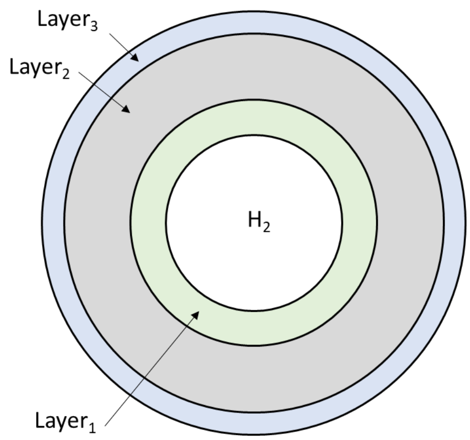


Figure A12 - Cross section of a three-layer hose

Table A19 - Hose thermophysical properties received from manufacturers

Thermophysical Properties	Hose Properties for H35 FM120			Hose Properties for H70 FM300		
	Layer 1	Layer 2	Layer 3	Layer 1	Layer 2	Layer 3
Material	Polymer	Steel Wire	Polymer	Polymer	Steel Wire	Polymer
Thickness (millimeters)	~1.0	~1.3	~0.9	~1.2	~2.0	~1.2
Density (kg/m³)	1400	7850	1050	1400	7850	1140
Specific Heat Capacity [J/(kg K)]	1500	450	1250	1500	450	500
Thermal Conductivity [W/(m K)]	0.3	50.0	0.23	0.3	50.0	1.7
ID (millimeters)	6.3			9.9		

As shown in Figure A11, the hose element inputs in H2FillS are for a single layer. The public version of H2FillS cannot handle such a hose consisting of multiple layers, so the three-layer hose is treated as a single-layer hose that has similar characteristics in terms of heat transfer from the hose to the precooled hydrogen. First, changes are made to the public version of H2FillS to make it possible for the modified version to handle the three-layer hose. The modified H2FillS model is run with the fueling system configuration in Figure A13 under slow- and fast-fill conditions detailed in Table A20. The used fueling system configuration consists of a break-away, hose, nozzle, piping, a flow junction, hand valves, and eight 10.0-kg type IV vehicle tanks. The fueling conditions are shown in Table A20. After the fast- and slow-filling simulations are performed, a conversion approach from the three-layer hose to a single-layer hose is evaluated; more specifically, the single layer hose's outer diameter, density, specific heat, thermal conductivity, and heat transfer coefficient on the outer surface are treated as variables. The best combination of those variables is selected. The evaluation criterion is whether the hose outlet temperature profiles with the single- and three-layer hoses match. This is because the complete overlap of the two profiles means the two hoses have the same heat transfer characteristics in terms of the convective heat transfer from the hoses to precooled hydrogen.

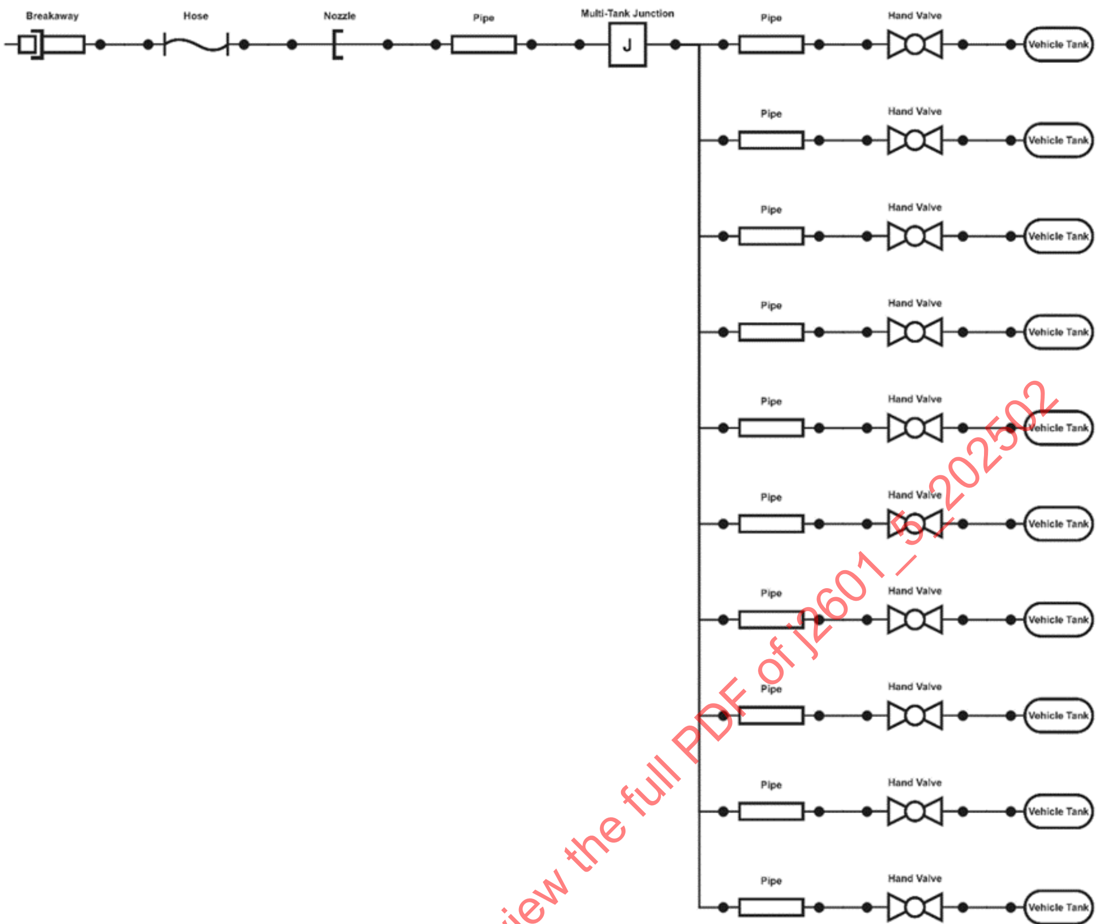


Figure A13 - Fueling system configuration for converting three-layer hose properties to those for single layer

Table A20 - Fueling conditions for converting three-layer hose properties to those for single layer

	Fast Filling	Slow Filling
APRR (MPa/min)	12.5	1.0
Precooling temp (°C)	-40.0	-40.0
Initial gas press. (MPa)	2.0	2.0
Ambient & soak gas temp (°C)	50.0	50.0
Total fueling time (seconds)	400.0	4971.0

Table A21 shows the best-found combinations of the variables by which the simulated hose outlet temperature agrees with that of the three-layer hose. The Table A21 properties are utilized in H2FillS for the hose element inputs. Figure A14 shows comparisons of the hose outlet temperatures simulated with the single- and three-layer hoses under the fast- and slow-filling conditions. In the comparison of the fast-filling simulations, the two hose outlet temperatures almost overlap; the maximum error between the simulations with the single- and three-layer hoses is only 0.9 °C, and the average error is 0.025 °C. The comparison of the slow-filling simulations also shows that the hose outlet temperature profiles match; the maximum and average errors are 2.9 °C and 0.06 °C, respectively. These two comparisons provide confidence that the three-layer hose can be treated as a single-layer hose with the properties listed in Table A21.

Table A21 - Three-layer equivalent single-layer hose geometry and thermophysical properties

Thermophysical Properties	H35 FM120	H70 FM300
Length (meters)	6	6
ID (millimeters)	6.3	9.9
OD (millimeters)	10	15
Density (kg/m^3)	1000.0	1000.0
Thermal Conductivity [W/(m K)]	0.3	0.3
Specific Heat Capacity [J/(kg K)]	1500.00	1500.0
External Convective Heat Transfer Coefficient [W/(m^2 K)]	2.5	2.5

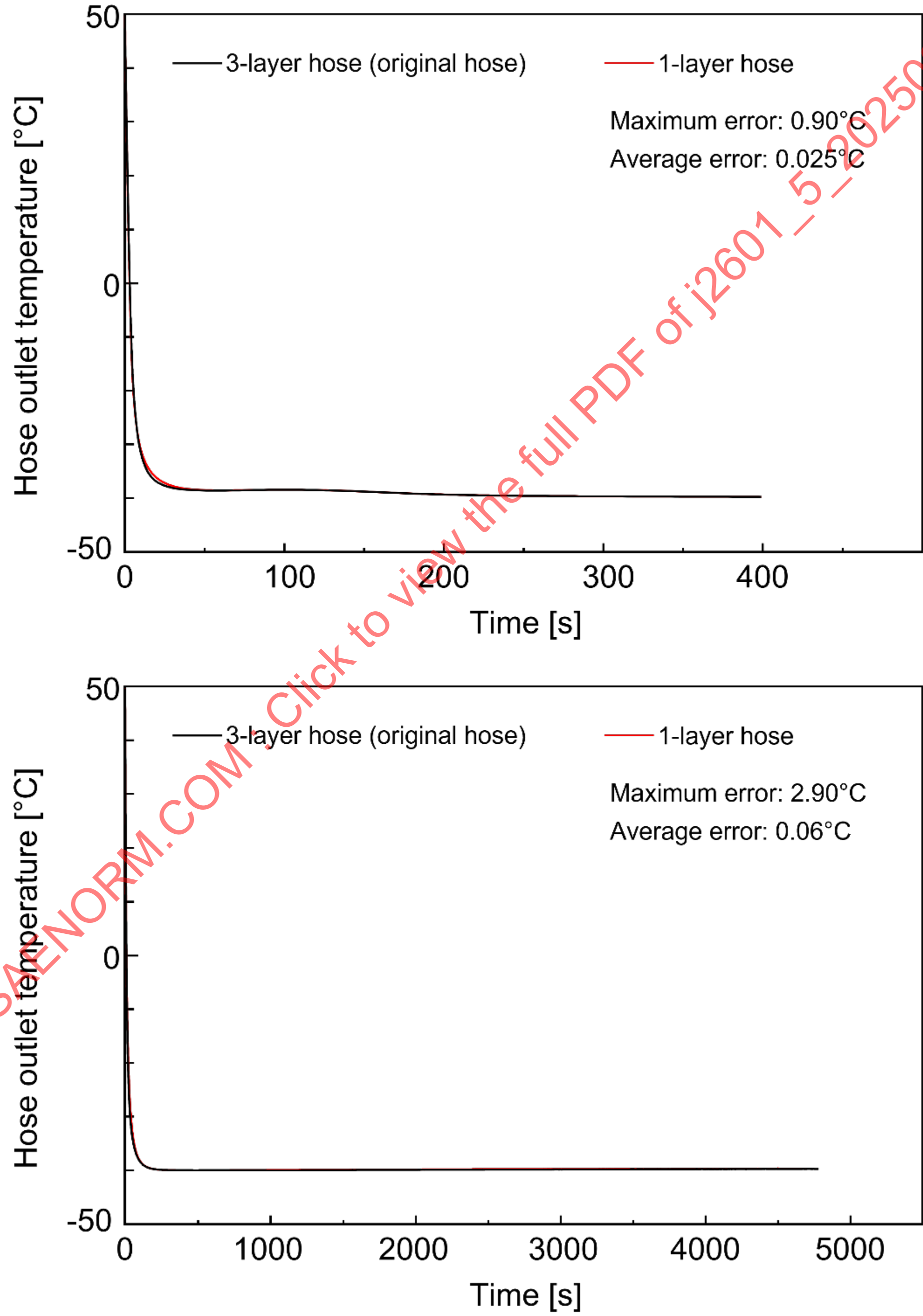


Figure A14 - Comparison of hose outlet temperatures: three-layer versus equivalent single-layer hose

A.3.4 Cold Case Assumptions and Boundary Conditions

The cold case assumptions and boundary conditions utilized are identical to those in Section A.3 of SAE J2601_202005. The MC Method ending pressure control option is the same as that for MC Formula in SAE J2601_202005, except that the equation for T_{init_cold} (see Equation C31) has been revised for better accuracy. For the ending pressure tables control option, the H70 pressure targets and limits are mostly the same as those for the MC Formula CHSS Capacity Category D fueling protocol in SAE J2601_202005. The only change made was to adjust the communications fueling pressure limits for pressures of 5 MPa and below based on an SOC of 98% instead of 97%. For the ending pressure tables control option, the H35 pressure targets and limits were derived in the same manner as the CHSS Capacity Category D fueling protocol in SAE J2601_202005, except that the target pressures were based on 100% density for H35 of 24.0 g/L.

APPENDIX B - (NORMATIVE) MCF-HF-G FUELING PROTOCOL FLOWCHARTS

B.1 INTRODUCTION

As per 8.9, this appendix details the flowcharts for the application of the MCF-HF-G fueling protocol. These flowcharts provide an explanation of the control logic and order of operation. These flowcharts are to be used in conjunction with the subroutines detailed in Appendix C. Where appropriate, a reference to the applicable section and/or equation of Appendix C is called out in the flowcharts.

An overview to the subroutines flowcharts is as follows:

Figure B0 - MCF-HF-G fueling overview

Figure B1 - SAE J2799 Physical and Functional Requirements Subroutine

Figure B2 - MCF-HF-G Dispenser Startup Subroutine

Figure B3 - MCF-HF-G Fueling Process Subroutine

Figure B4 - MCF-HF-G Parameter Initialization Subroutine (see C.3.1)

Figure B5 - MCF-HF-G Ending Pressure Initialization Subroutine for ending pressure tables (see C.3.2.1)

Figure B6 - MCF-HF-G Ending Pressure Initialization Subroutine for MC Method (see C.3.2.2)

Figure B7 - MCF-HF-G Selection of t_{final} Table Subroutine (see C.3.3)

Figure B8 - MCF-HF-G Calculation of t_{final_min} Subroutine (see C.3.4)

Figure B9 - MCF-HF-G t_{final} Vector Interpolation Subroutine (see C.3.5)

Figure B10 - MCF-HF-G Fueling Time Indicator Subroutine (see C.3.6)

Figure B11 - MCF-HF-G CHSS Volume Measurement Subroutine (see C.3.7)

Figure B12 - MCF-HF-G Calculation of K_0 Subroutine (see C.3.8)

Figure B13 - MCF-HF-G Mass Average Calculation of the Fuel Delivery Temperature Subroutine (see C.3.9.2)

Figure B14 - MCF-HF-G Mass Average Calculation of Enthalpy Subroutine (see C.3.9.3)

Figure B15 - MCF-HF-G Calculation of T_{cold} Subroutine (see C.3.10)

Figure B16 - MCF-HF-G Calculation of t_{final} Subroutine (see C.3.11)

Figure B17 - MCF-HF-G Calculation of PRR and P_{ramp} Subroutine (see C.3.12)

Figure B18 - MCF-HF-G Determination of Pressure Targets and Limits Subroutine (see C.3.13)

Figure B19 - MCF-HF-G Evaluate End-of-Fill Criteria Subroutine (see C.3.14)

Figure B20 - MCF-HF-G Process Check Subroutine (see C.3.15)

Figure B21 - MCF-HF-G Advance Counters Subroutine (see C.3.16)

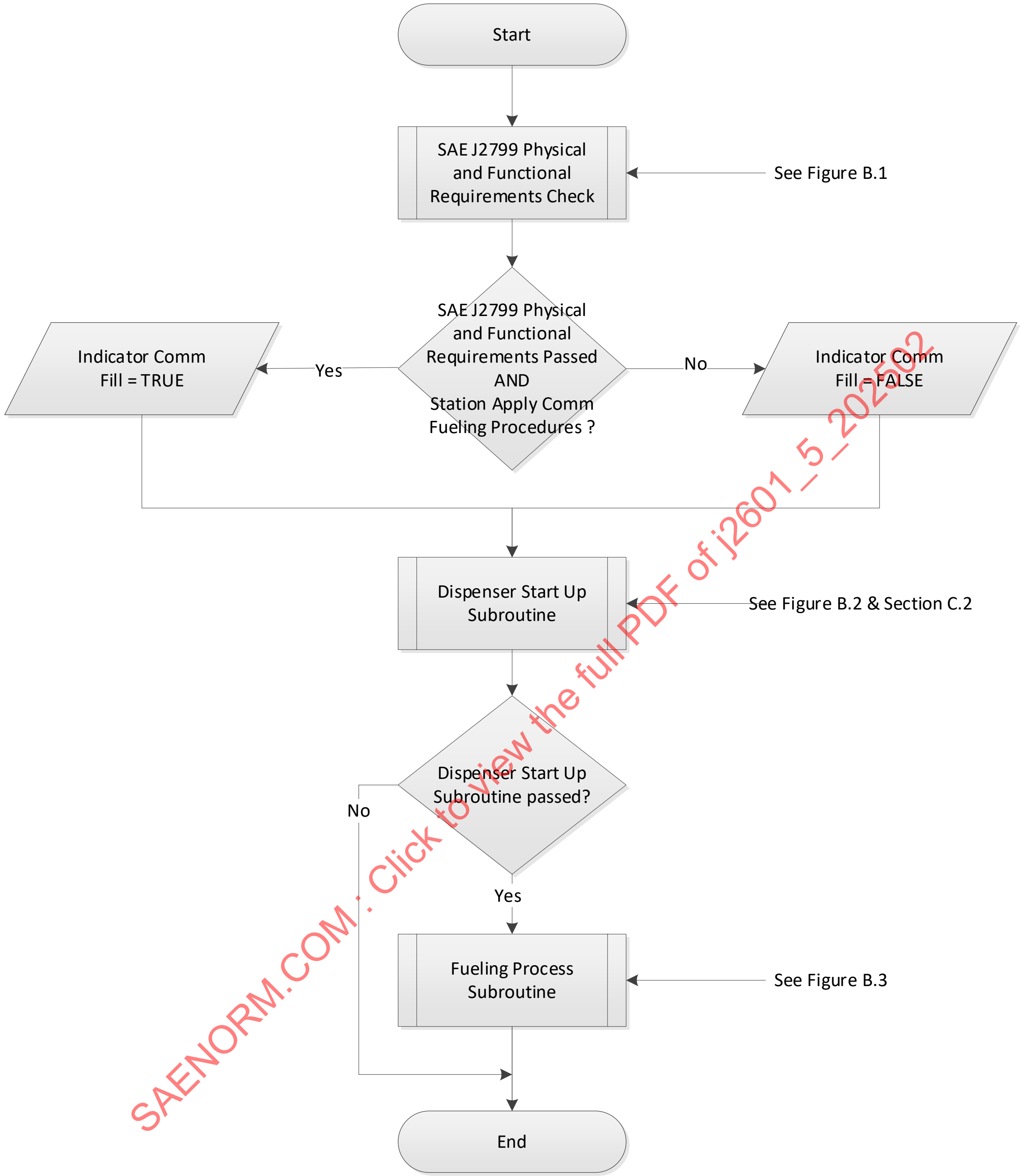


Figure B0 - MCF-HF-G fueling overview

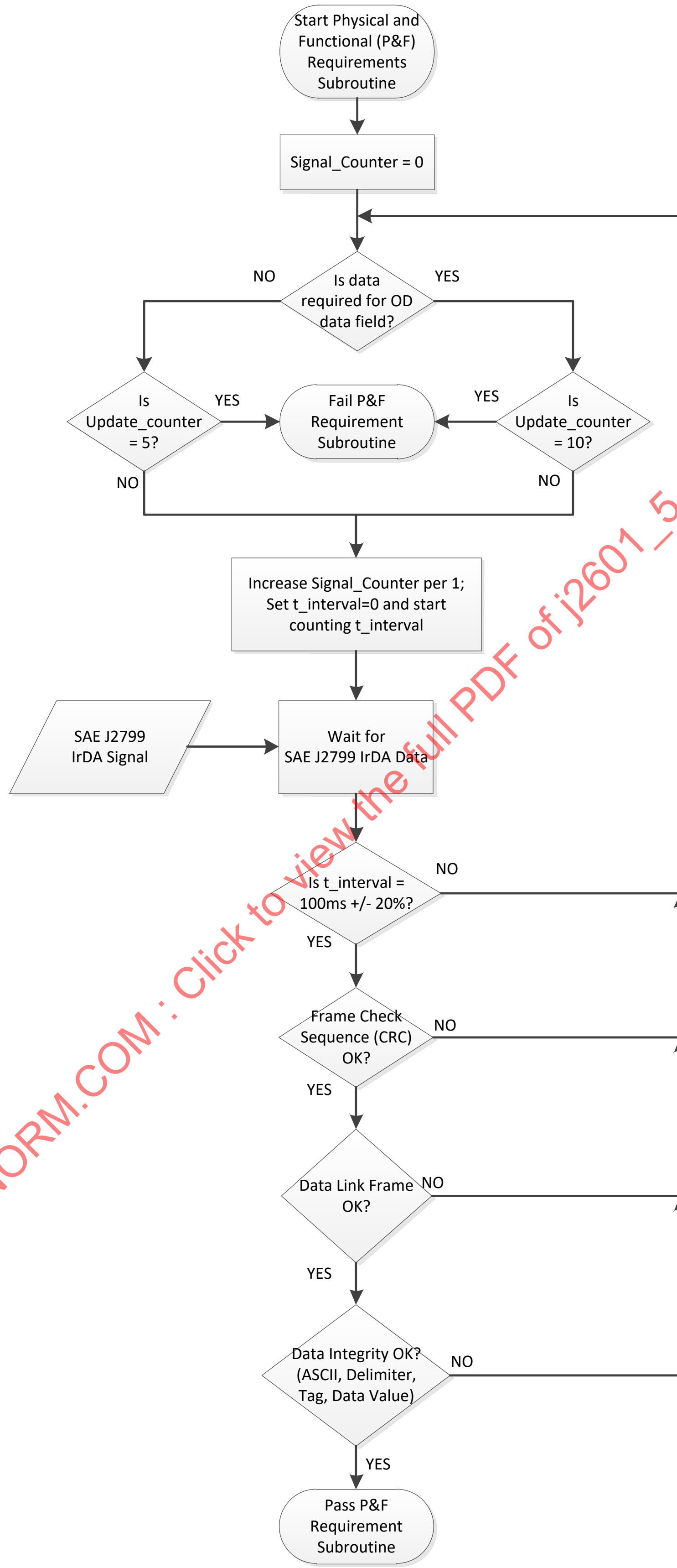


Figure B1 - Physical and Functional Requirements Subroutine

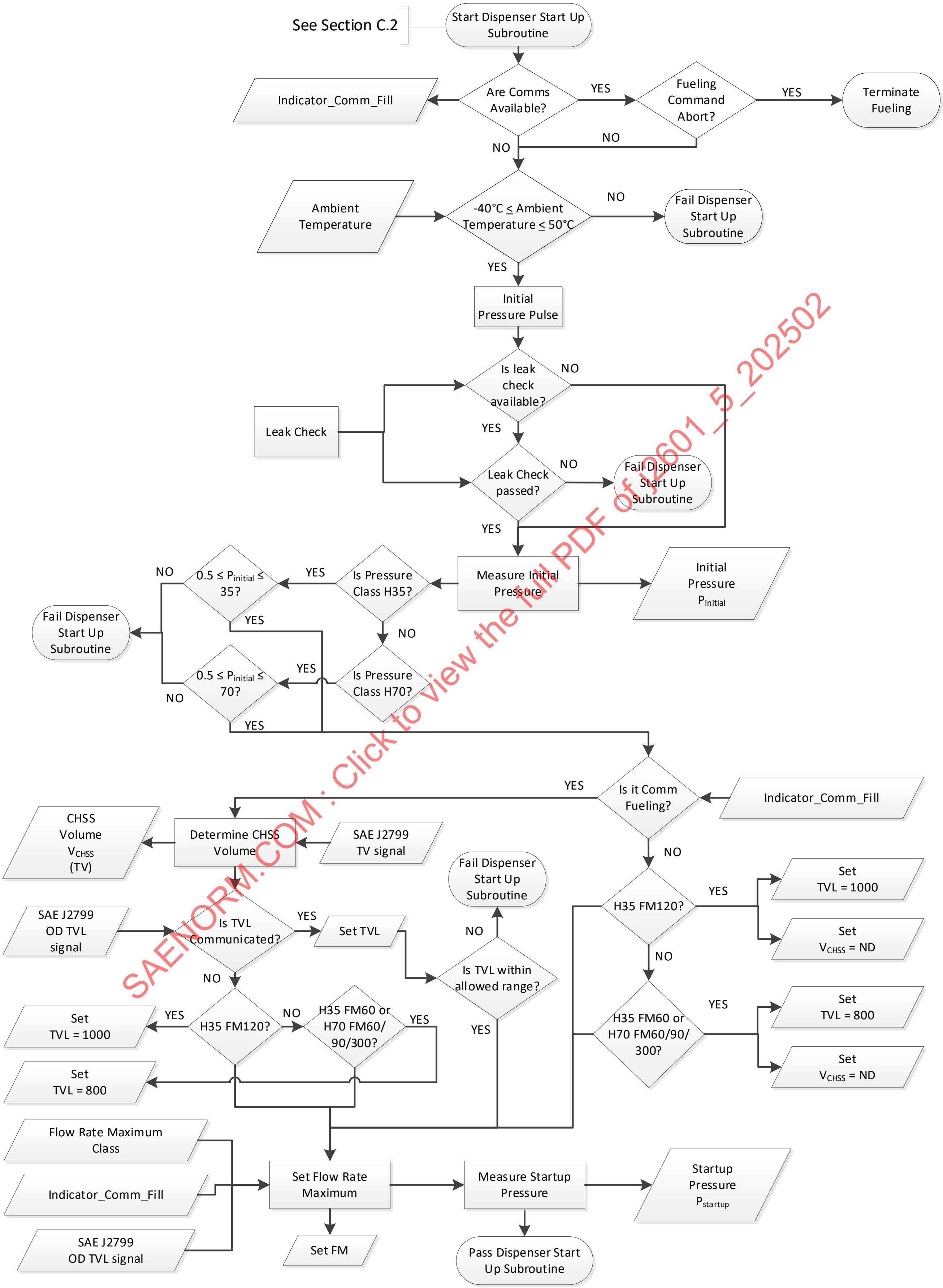


Figure B2 - MCF-HF-G Dispenser Startup Subroutine

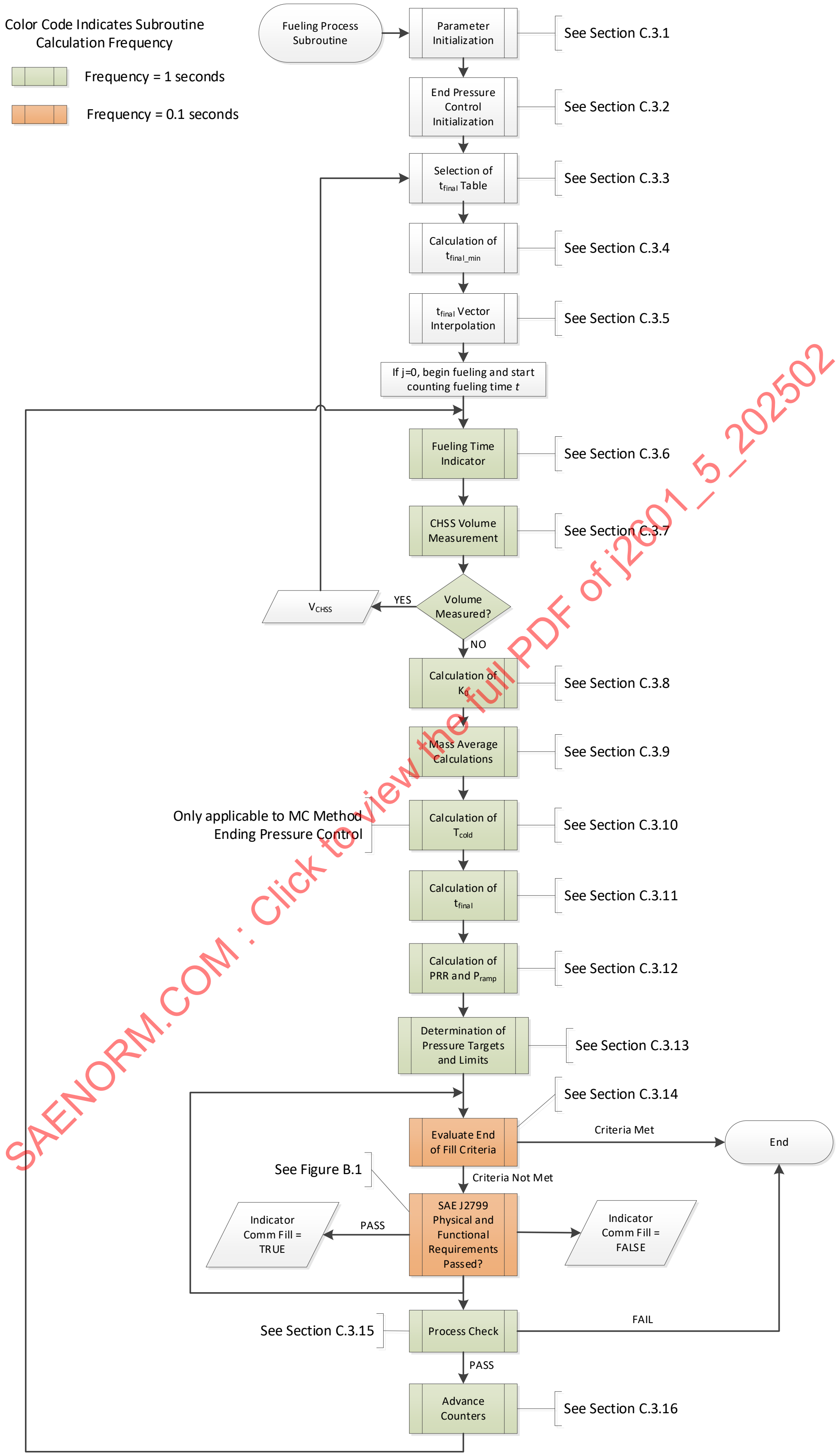


Figure B3 - MCF-HF-G Fueling Process Subroutine

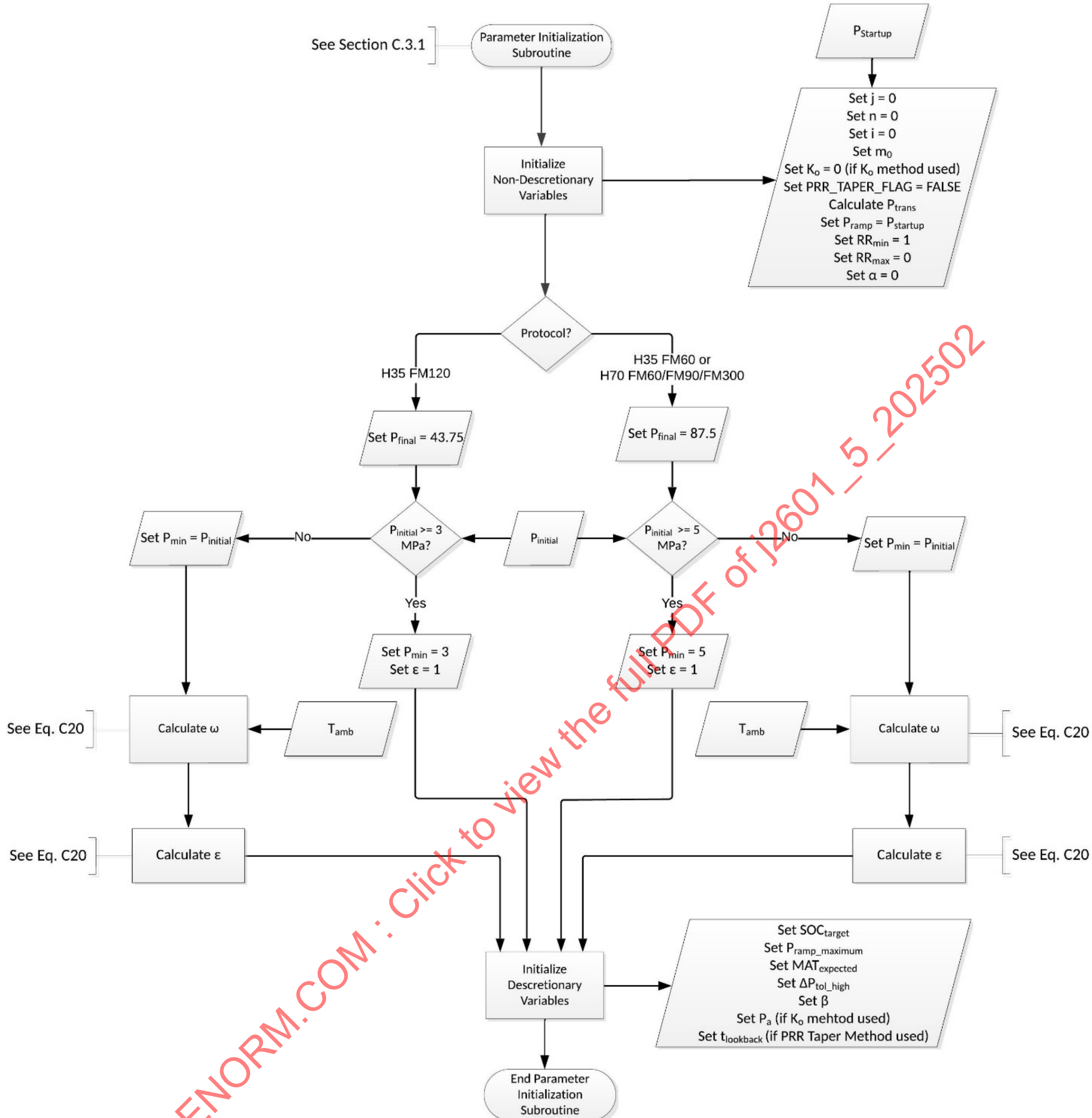


Figure B4 - MCF-HF-G Parameter Initialization Subroutine (see C.3.1)

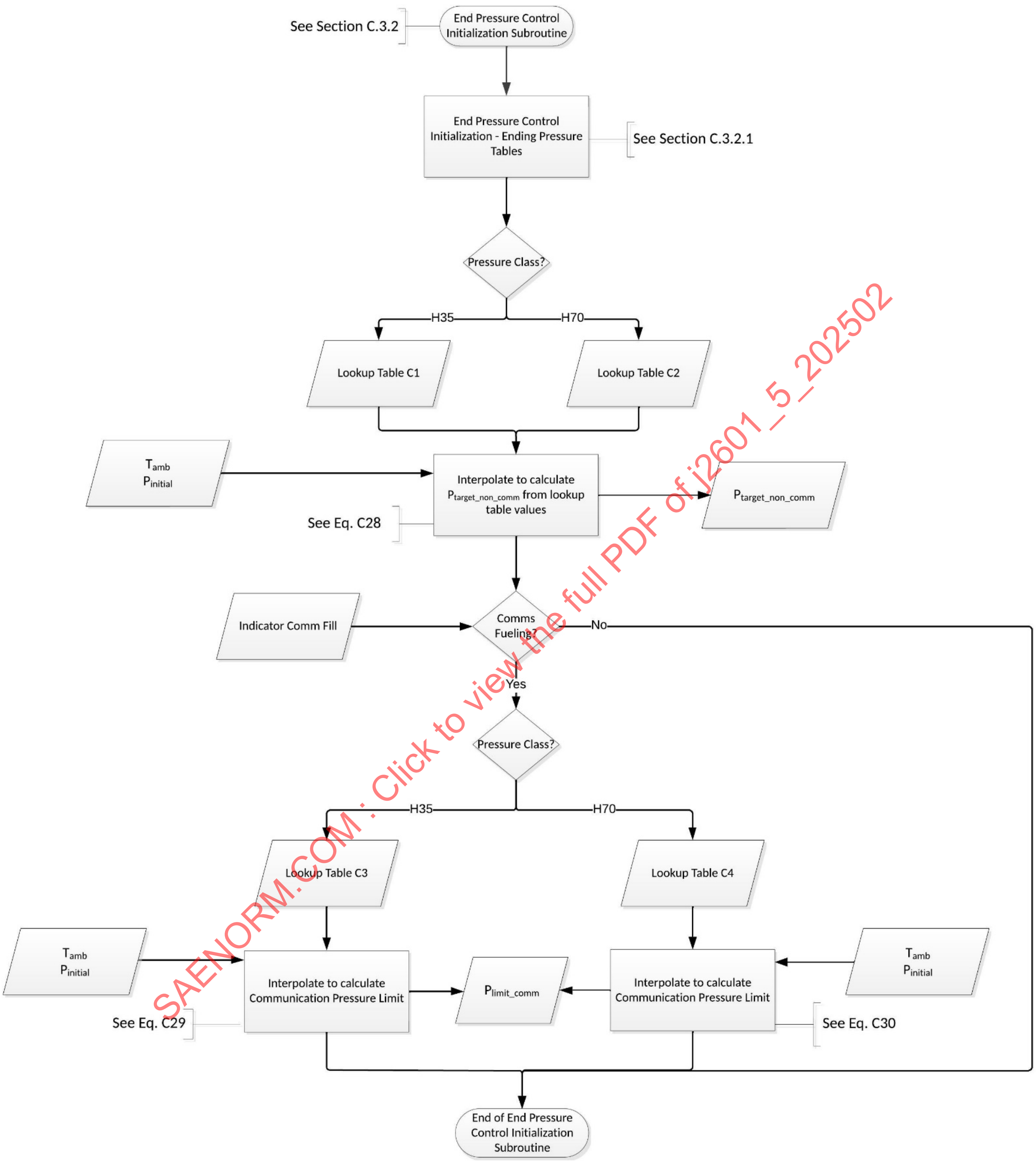


Figure B5 - MCF-HF-G Ending Pressure Initialization Subroutine for ending pressure tables (see C.3.2.1)

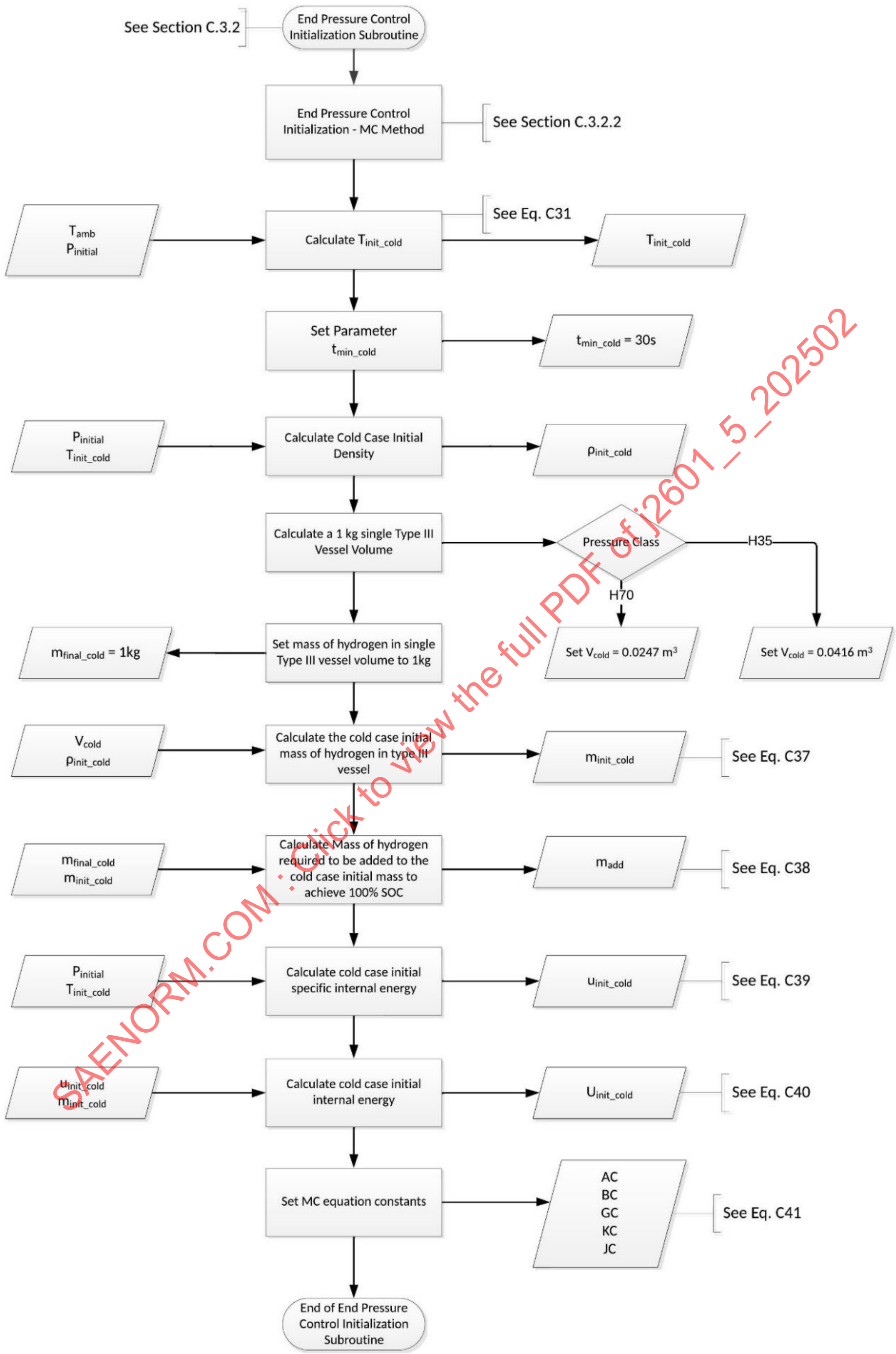


Figure B6 - MCF-HF-G Ending Pressure Initialization Subroutine for MC Method (see C.3.2.2)

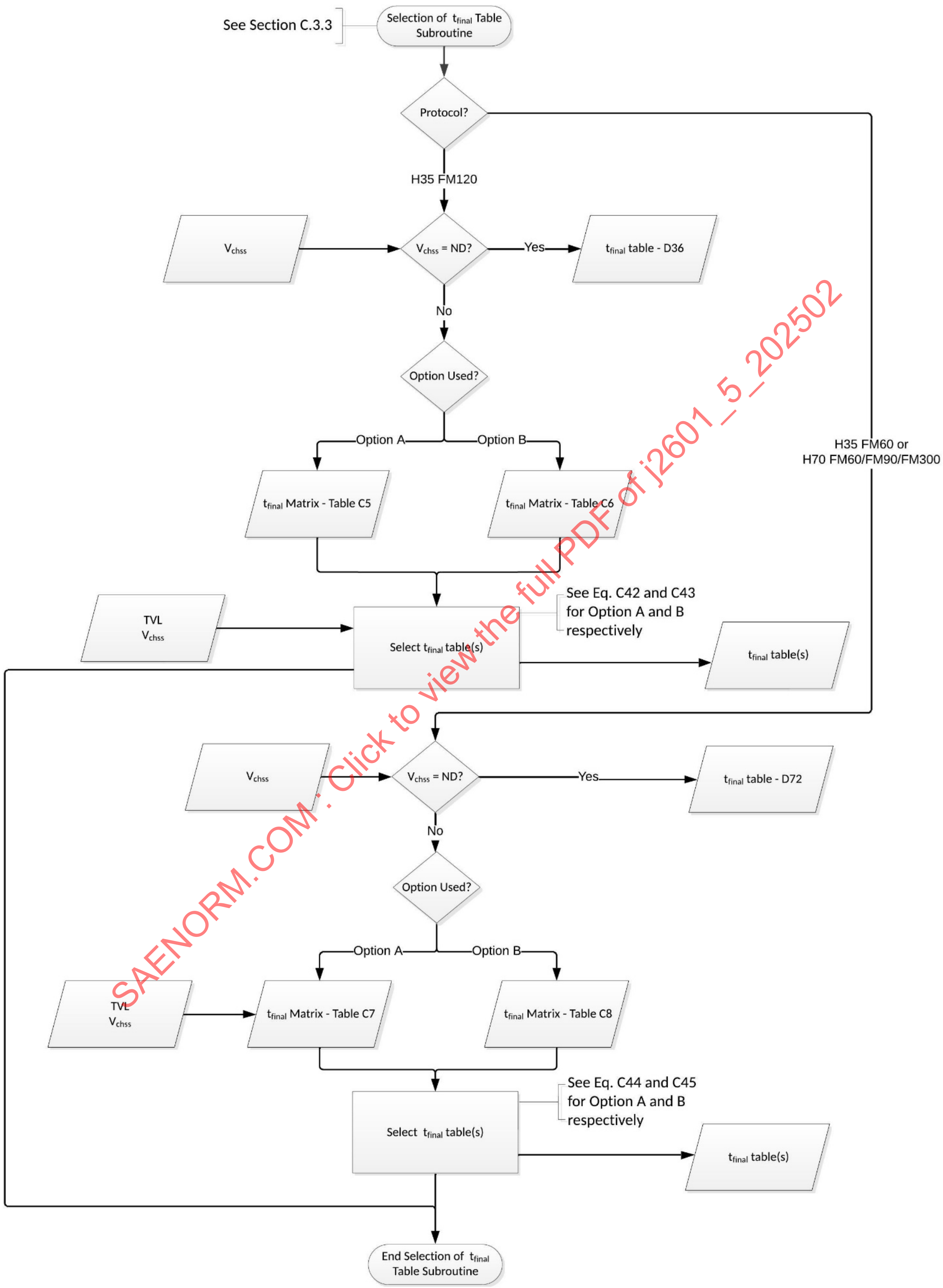


Figure B7 - MCF-HF-G Selection of t_{final} Table Subroutine (see C.3.3)

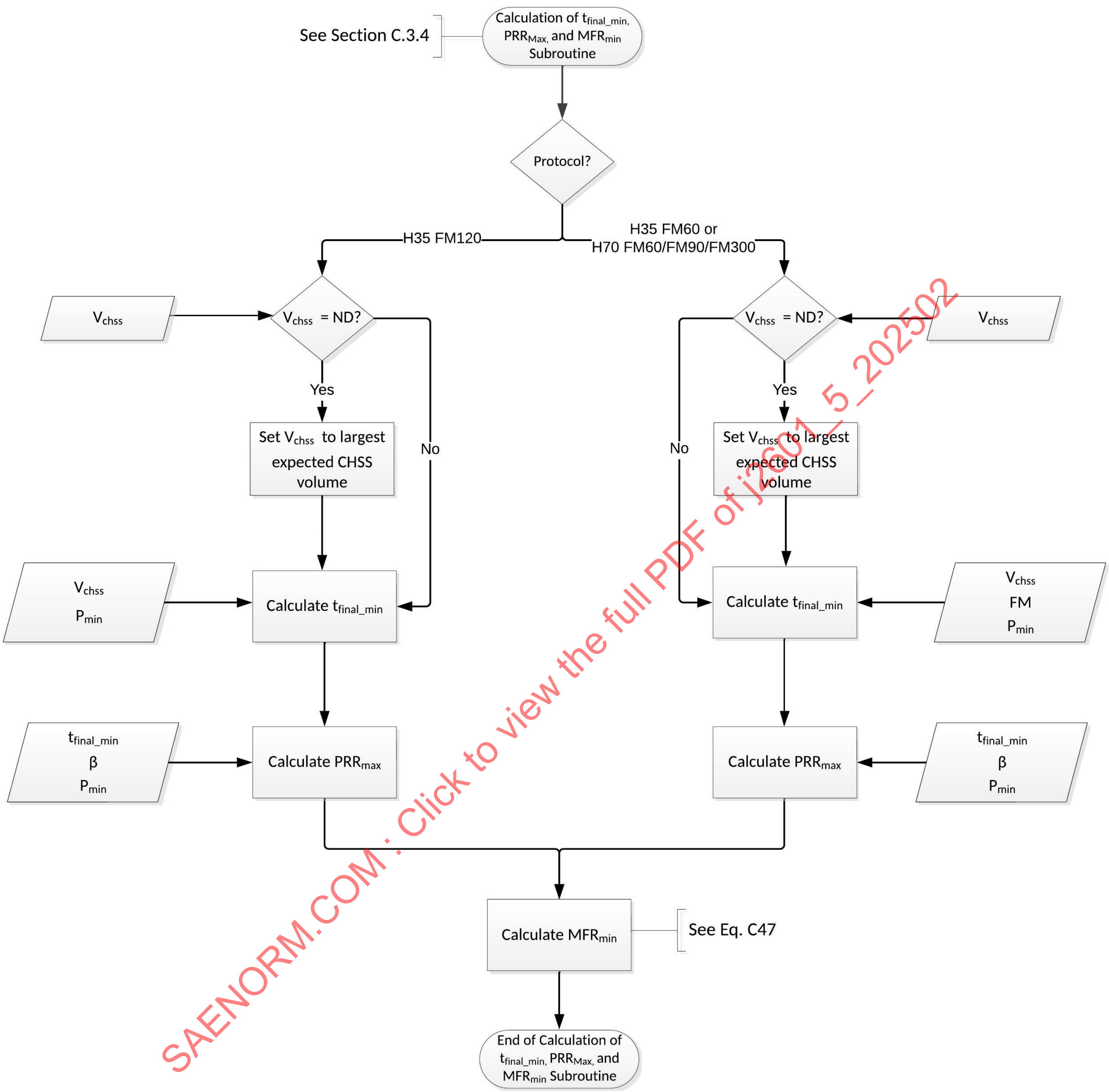


Figure B8 - MCF-HF-G Calculation of t_{final_min} Subroutine (see C.3.4)

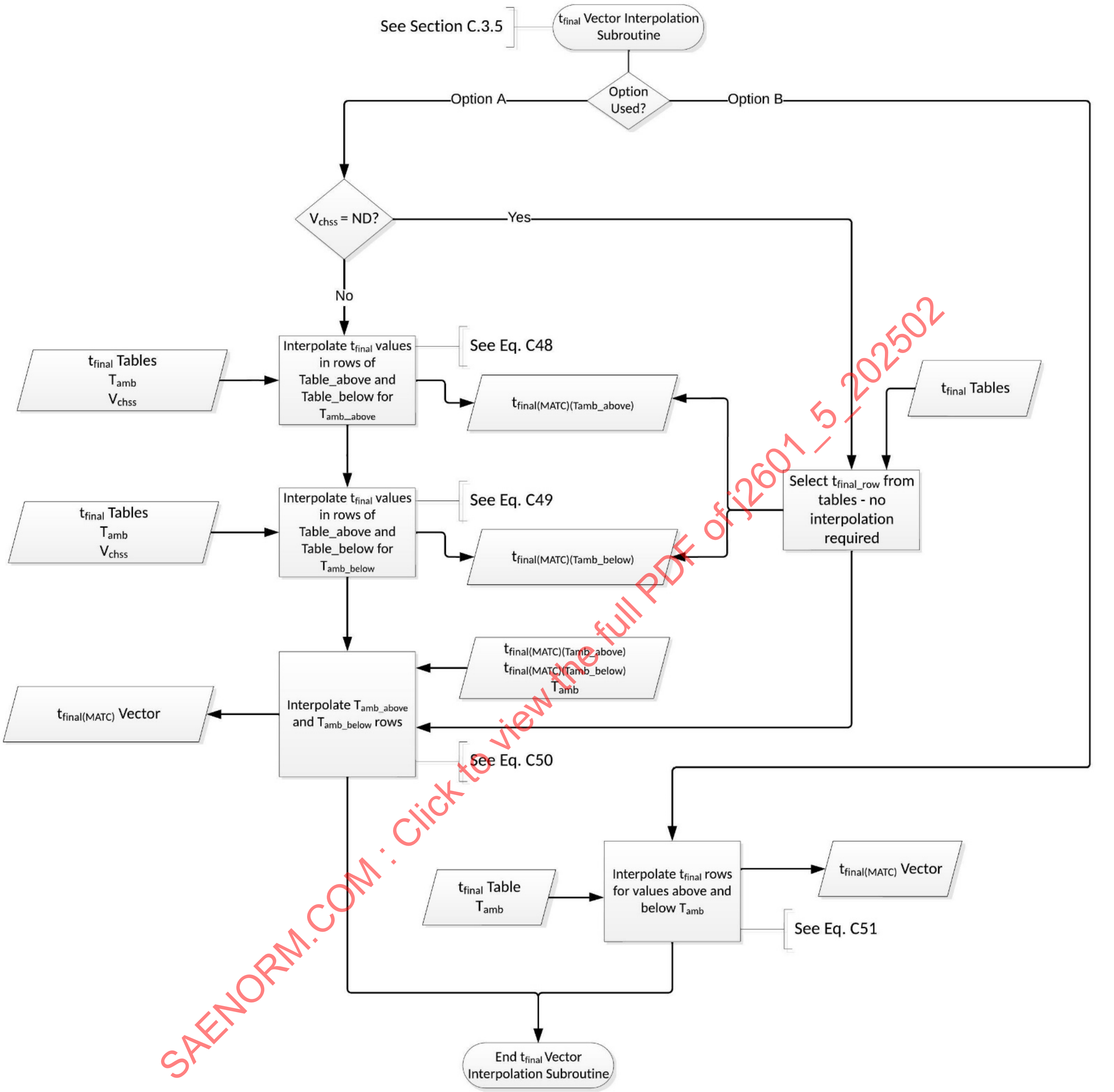


Figure B9 - MCF-HF-G t_{final} Vector Interpolation Subroutine (see C.3.5)

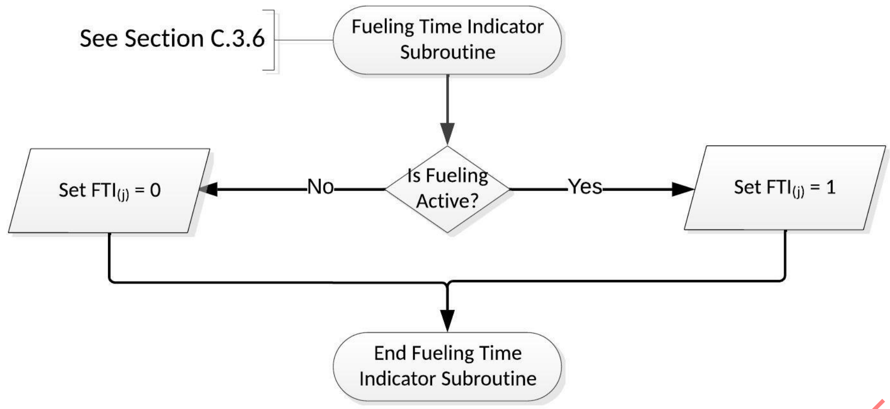


Figure B10 - MCF-HF-G Fueling Time Indicator Subroutine (see C.3.6)

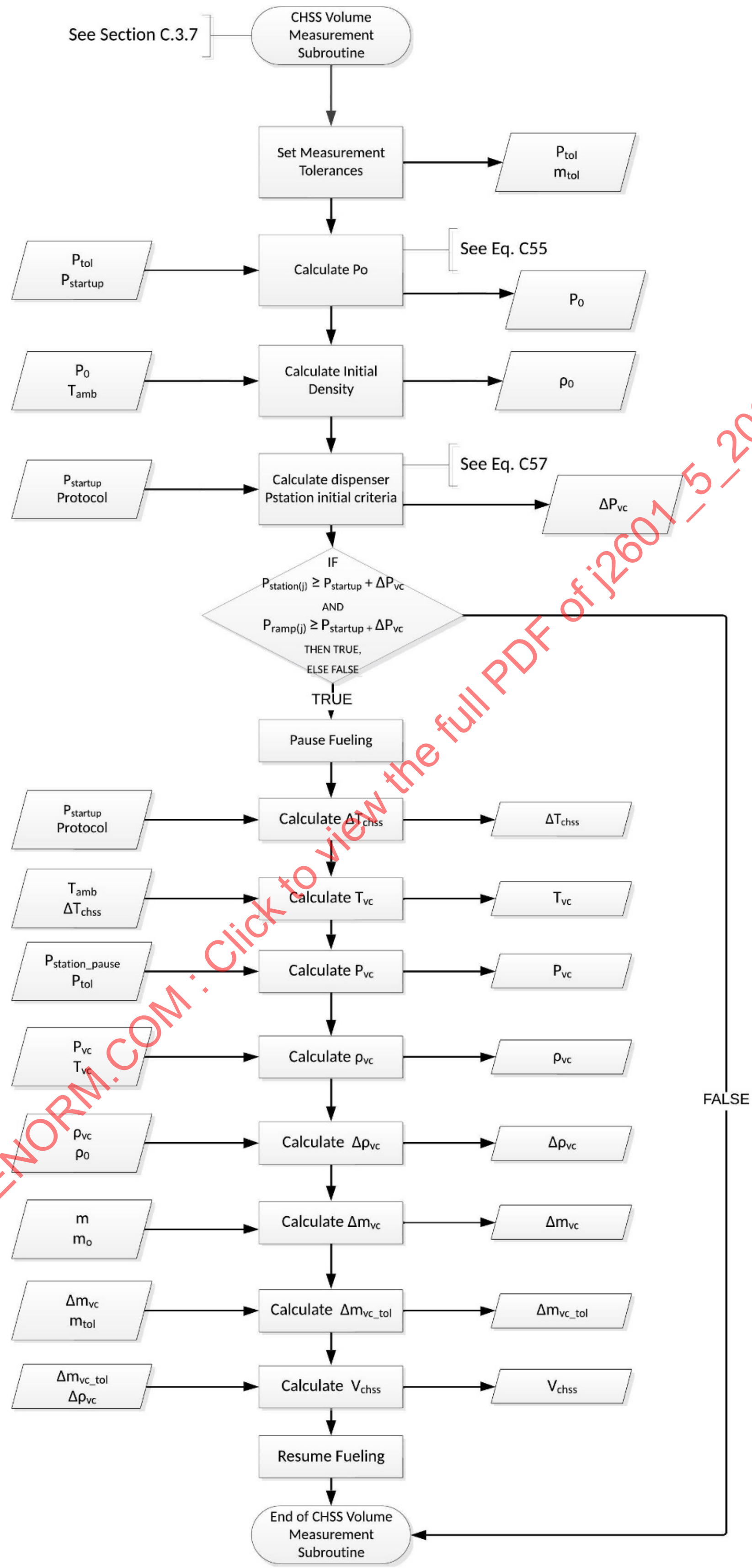


Figure B11 - MCF-HF-G CHSS Volume Measurement Subroutine (see C.3.7)

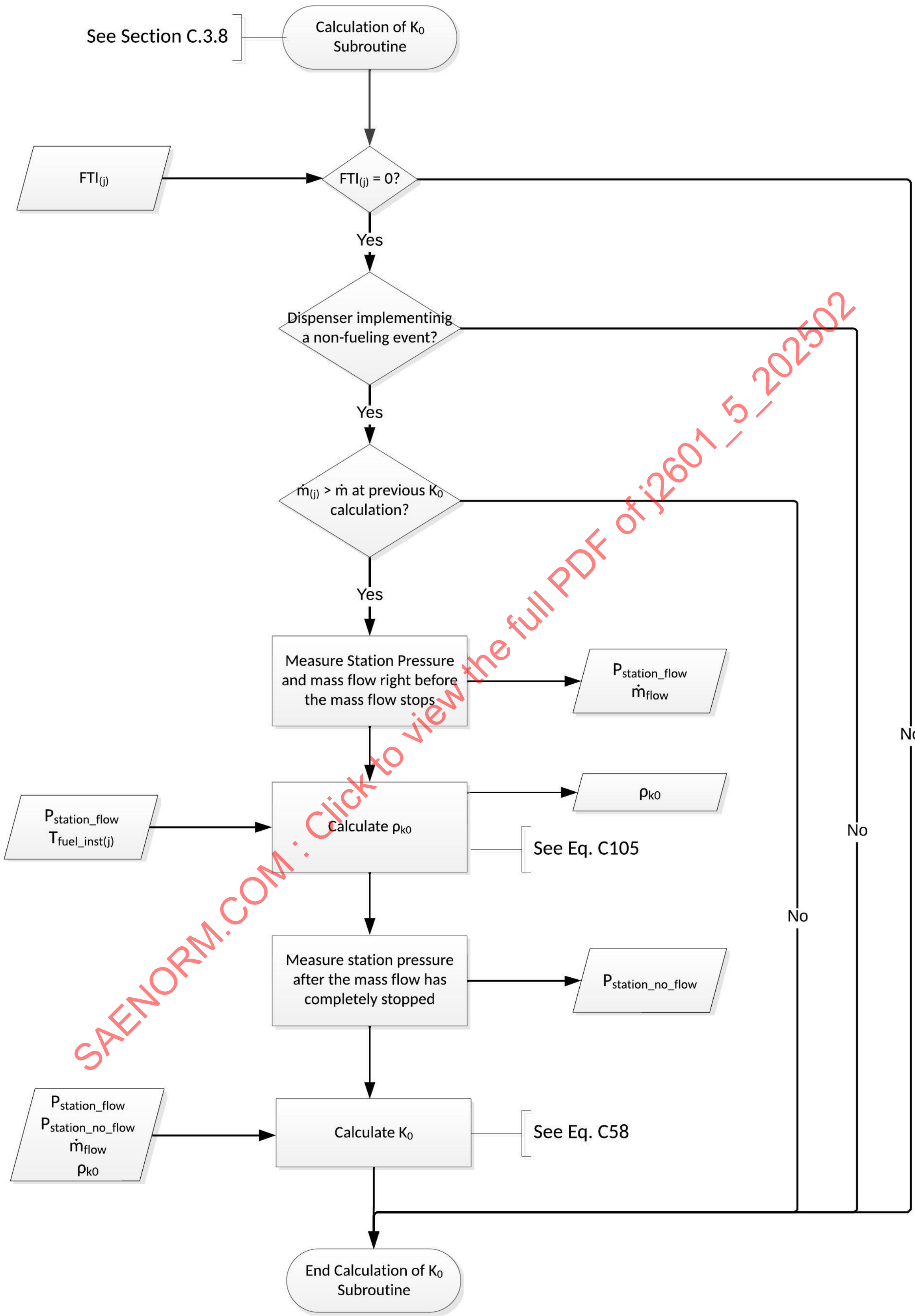


Figure B12 - MCF-HF-G Calculation of K_0 Subroutine (see C.3.8)

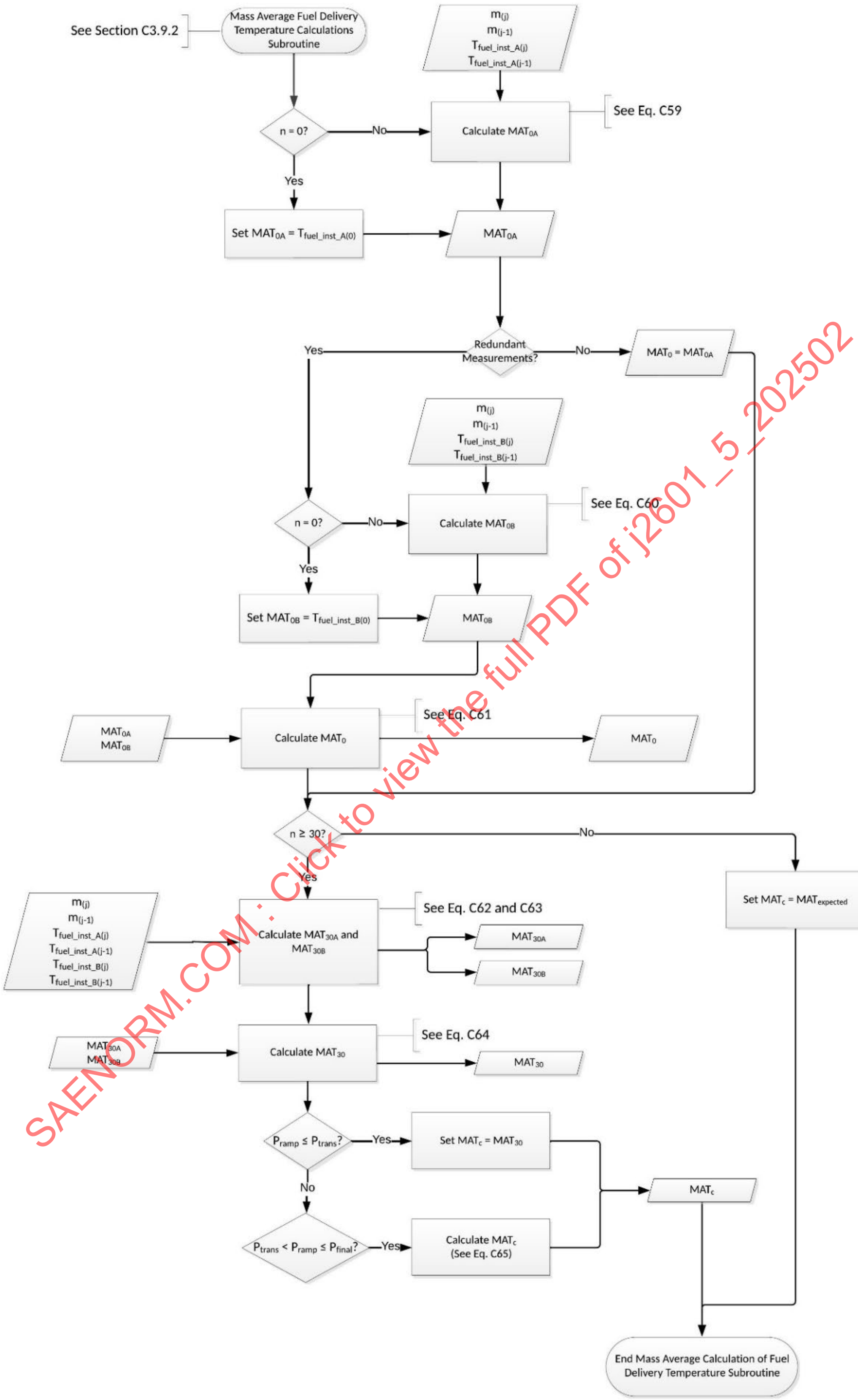


Figure B13 - MCF-HF-G Mass Average Calculation of the Fuel Delivery Temperature Subroutine (see C.3.9.2)

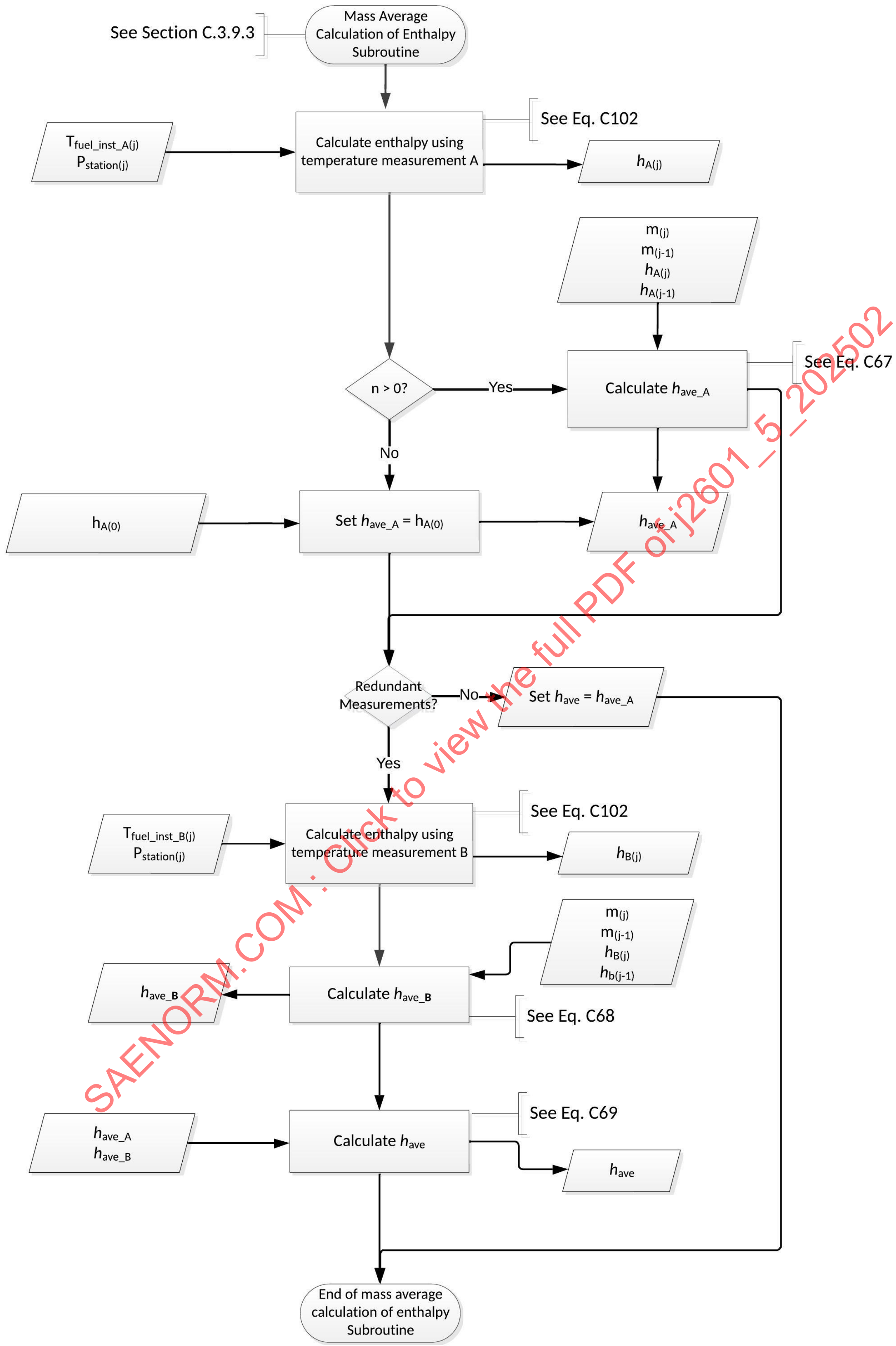


Figure B14 - MCF-HF-G Mass Average Calculation of Enthalpy Subroutine (see C.3.9.3)

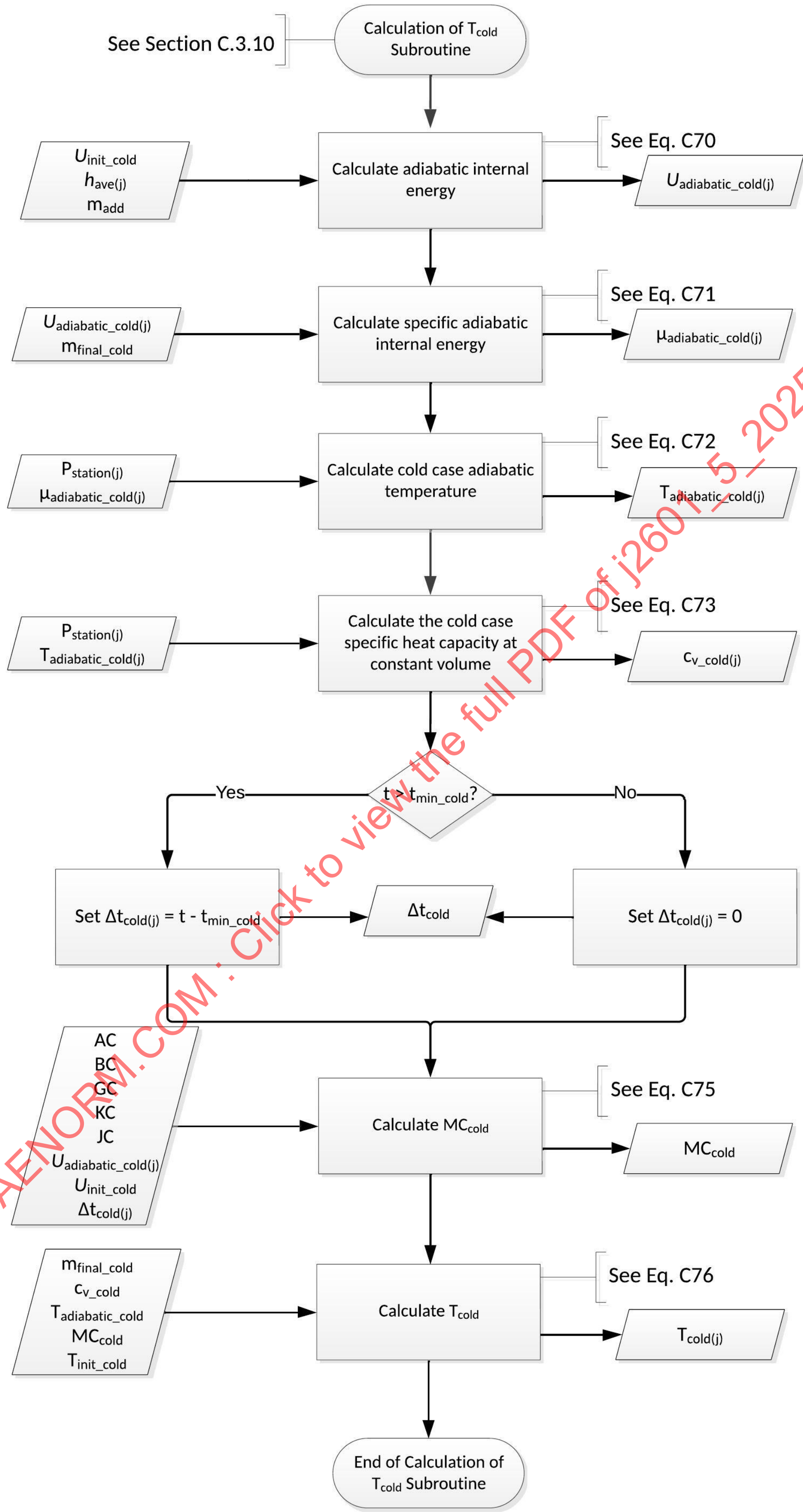


Figure B15 - MCF-HF-G Calculation of T_{cold} Subroutine (see C.3.10)

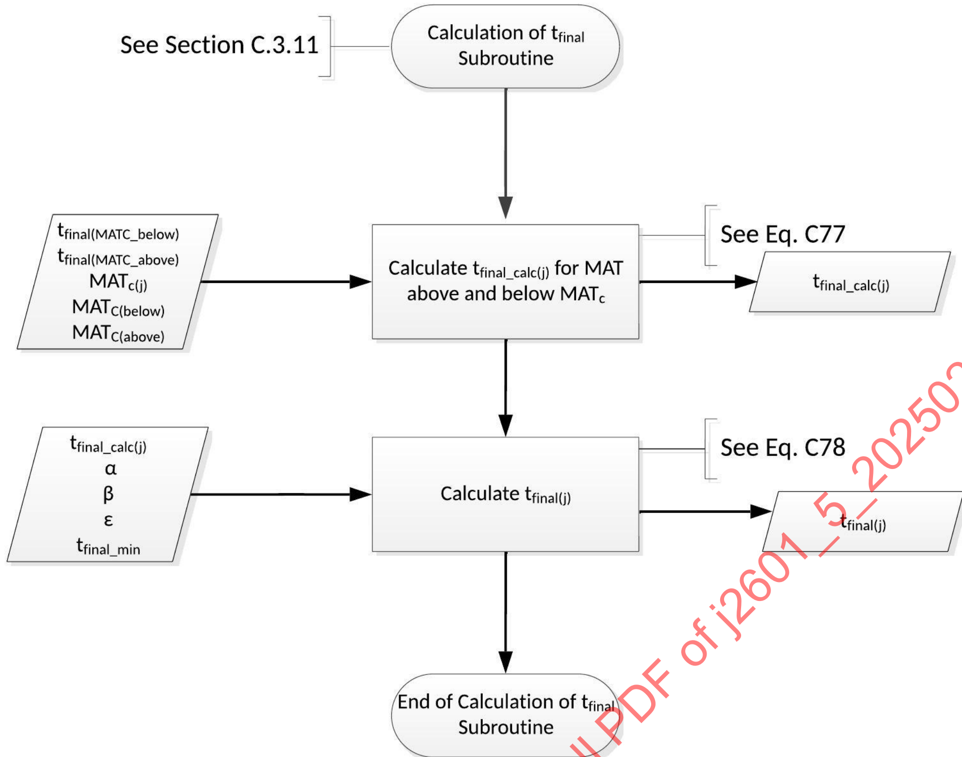


Figure B16 - MCF-HF-G Calculation of t_{final} Subroutine (see C.3.11)

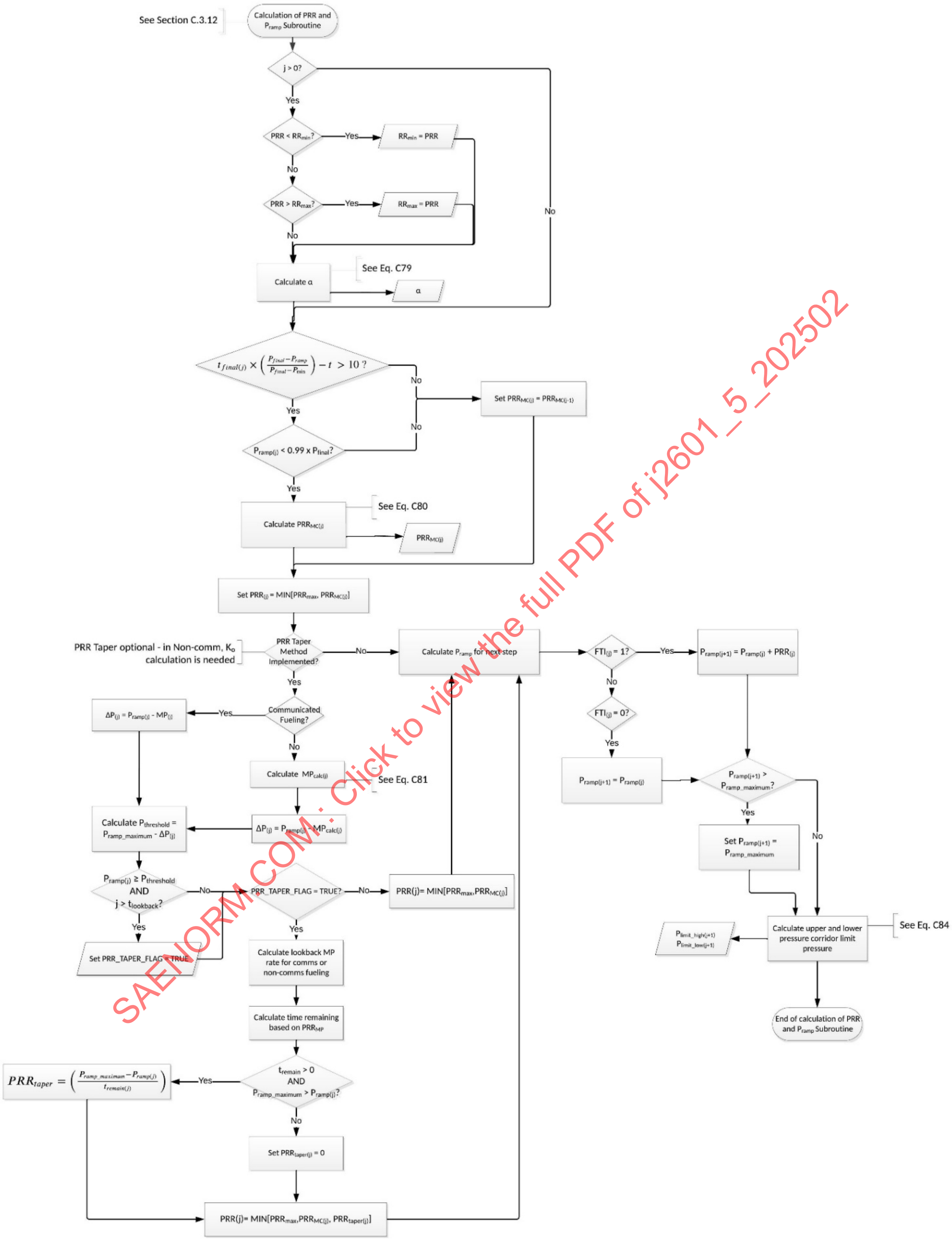


Figure B17 - MCF-HF-G Calculation of PRR and P_{ramp} Subroutine (see C.3.12)

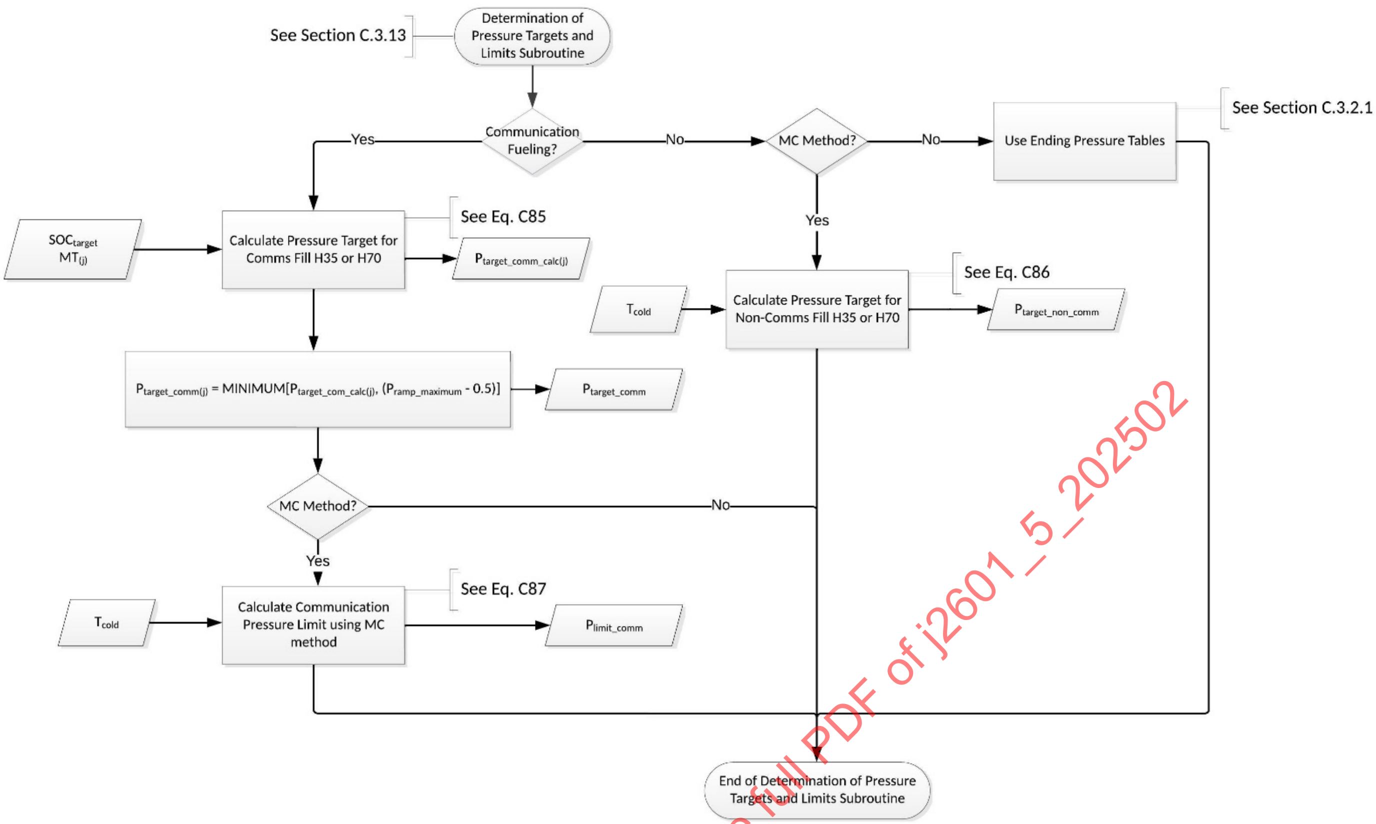


Figure B18 - MCF-HF-G Determination of Pressure Targets and Limits Subroutine (see C.3.13)

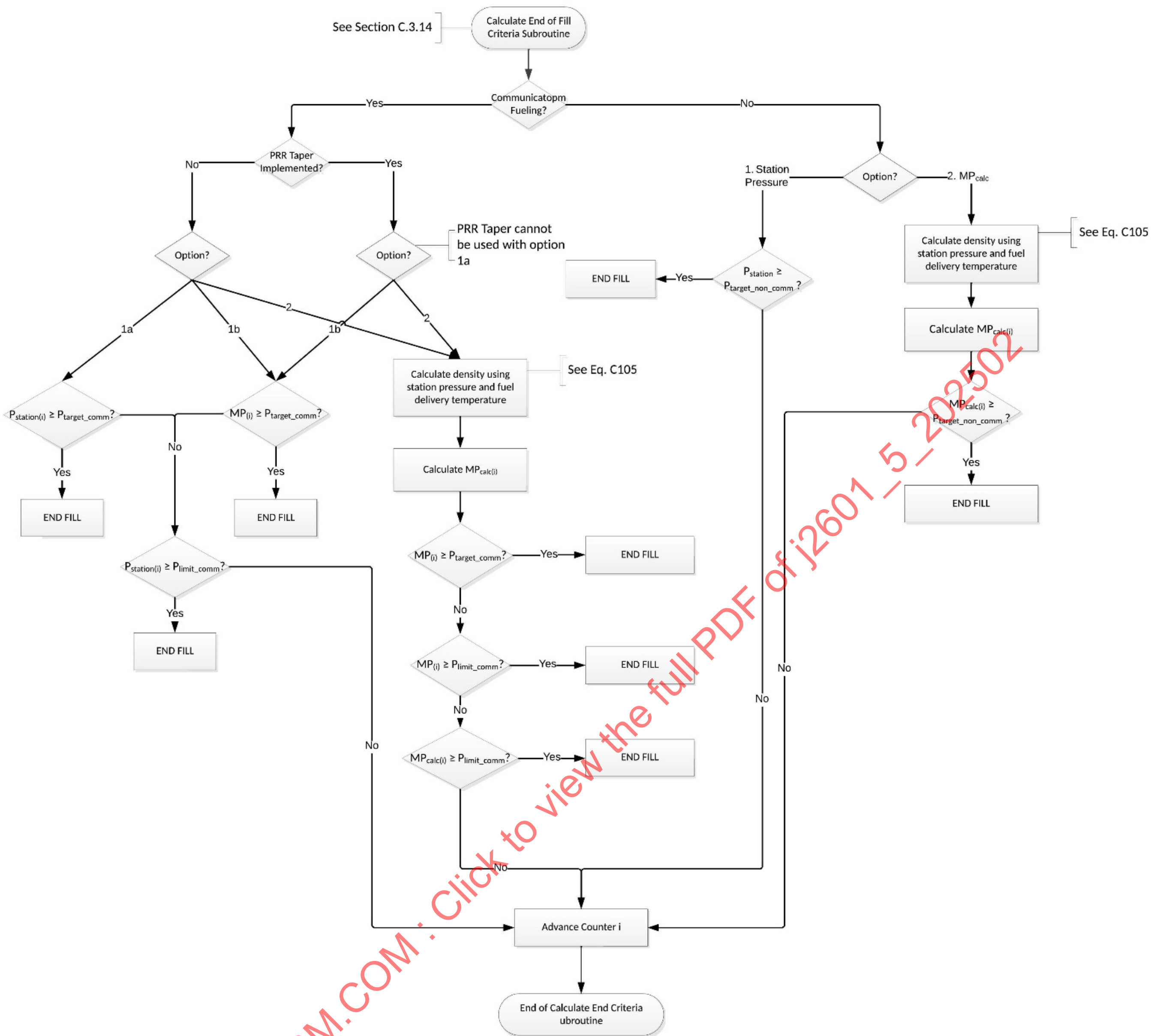


Figure B19 - MCF-HF-G Evaluate End-of-Fill Criteria Subroutine (see C.3.14)

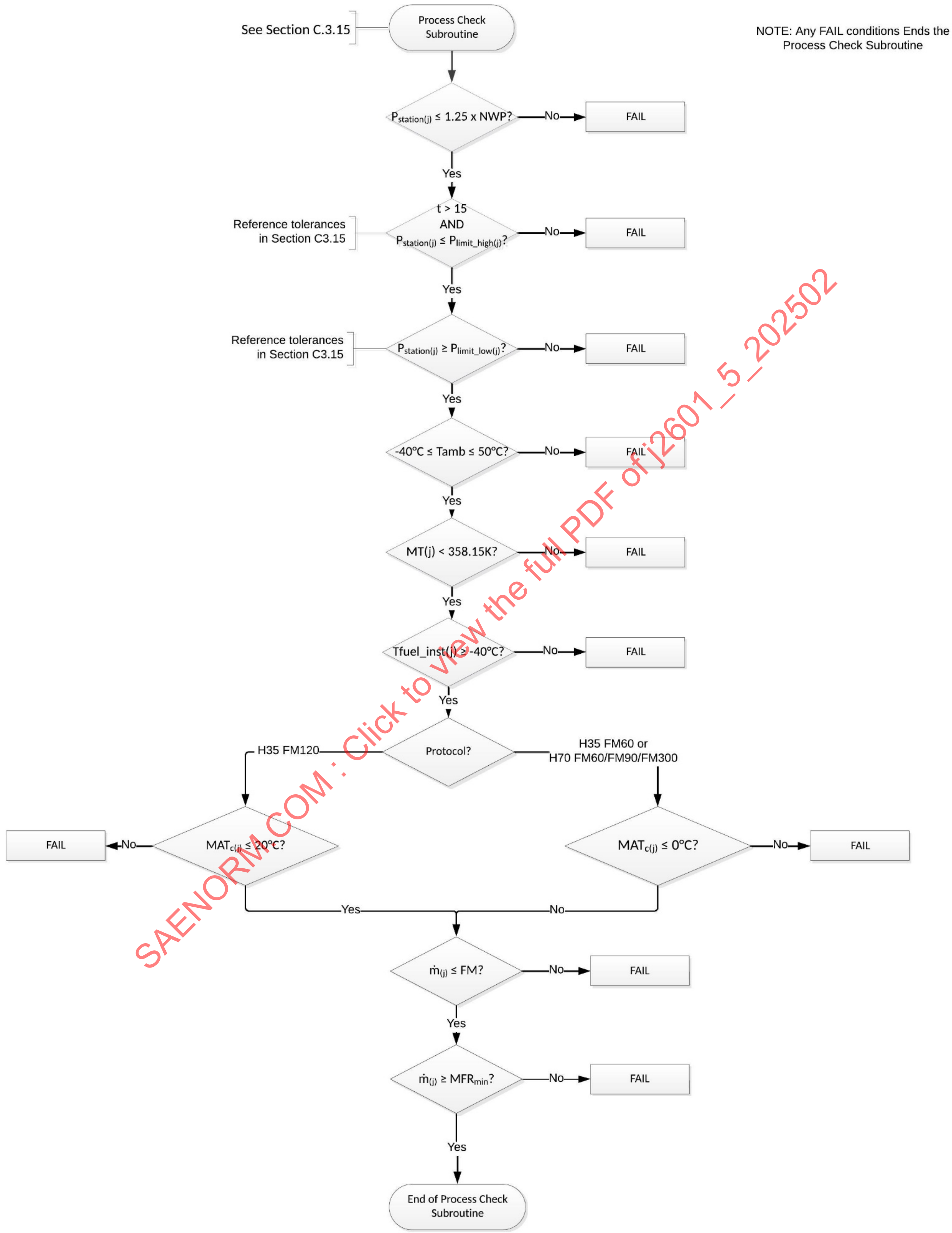


Figure B20 - MCF-HF-G Process Check Subroutine (see C.3.15)

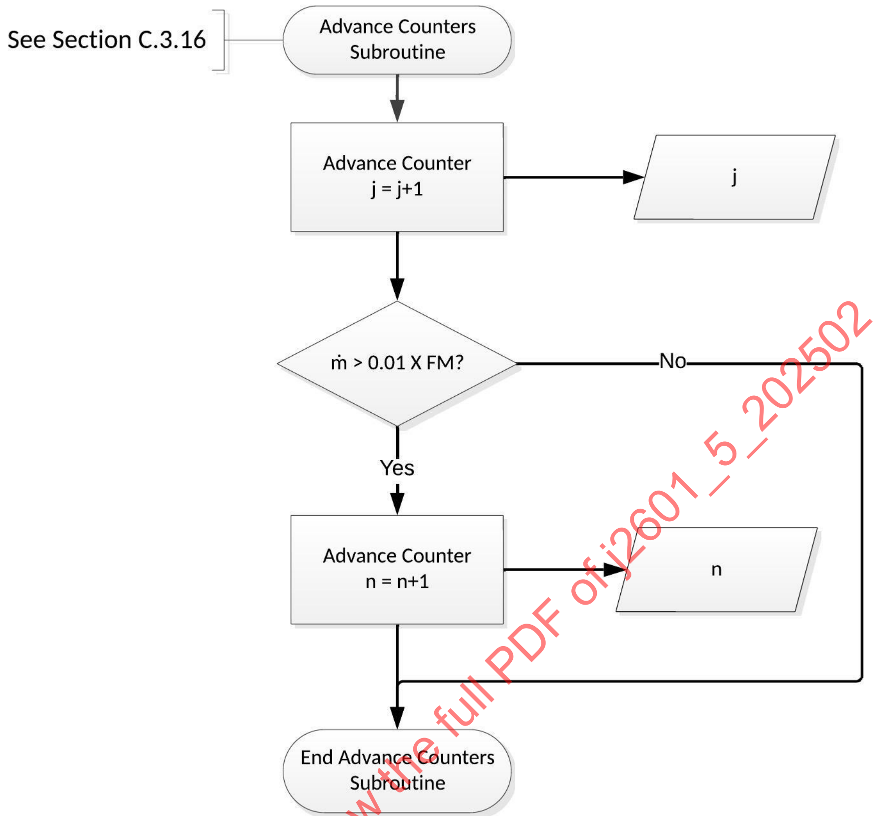


Figure B21 - MCF-HF-G Advance Counters Subroutine (see C.3.16)

APPENDIX C - (NORMATIVE) MCF-HF-G FUELING PROTOCOL CONTROL SUBROUTINES

C.1 INTRODUCTION

The fueling control is based on an advanced version of the MC Formula protocol found in SAE J2601_202005. The control is structured by utilizing subroutines which describe a certain function within the overall control structure. These subroutines are labeled based on their function and are ordered by their sequence within the control structure. Although these subroutines are described below generally in the order they are executed, see Appendix B for the flow diagrams, which definitively describe the order of operation of these subroutines.

All equations in Appendix C shall be implemented as stated and shall follow the order of calculation as defined in the flowcharts in Appendix B. There are some parameters which allow for discretionary settings (see C.3.1.2), and some subroutines and some functions/equations are optional. These are noted in the appropriate sections of Appendix C.

Although an explanation for each parameter and equation, as well as guidance for their use, is provided, Section 3 should also be utilized as a reference for definitions, and Section 4 as a reference for abbreviations and symbols utilized in the subroutines.

C.2 DISPENSER STARTUP SUBROUTINE

The Dispenser Startup Subroutine is used to determine essential initial conditions. The flowchart for the Dispenser Startup Subroutine is shown in Figure B2.

C.2.1 Check for Communications and Fueling Command Abort

The dispenser first checks if there are communications available, and if so, if an “Abort” from the IR communication data field named “FC” is present. If there is an “Abort,” the dispenser shall terminate the startup process. If there is not an “Abort” command, the startup procedure continues.

(Eq. C1)

$$IF\ Communications\ are\ available$$

$$Set\ Indicator\_Comm\_Fill = TRUE$$

$$ELSE$$

$$Set\ Indicator\_Comm\_Fill = FALSE$$

$$END\ IF$$

$$IF\ FC = Dyna$$

$$Continue\ Startup$$

$$ELSE\ IF\ FC = Abort$$

$$Abort\ Startup$$

$$END\ IF$$

C.2.2 Measure Ambient Temperature

The dispenser next checks that the ambient temperature is within the defined limits. If it is within the defined limits, the ambient temperature is recorded as T_{amb}.

(Eq. C2)

$$IF\ -40\ °C \leq T_{amb} \leq 50\ °C$$

$$Record\ T_{amb}\ and\ continue\ Startup$$

$$ELSE\ Abort\ Startup$$

$$END\ IF$$

C.2.3 Initial Pressure Pulse, Leak Check, and Determine Initial CHSS Pressure

An initial pressure pulse equilibrates the station pressure and CHSS pressure. If utilized, a leak check routine is implemented right after the initial pressure pulse. If the leak check fails, the dispenser shall terminate the startup process. If the leak check passes, or if the leak check routine is not utilized, the dispenser shall then measure the initial CHSS pressure. If it is within the defined limits, the initial CHSS pressure is recorded as $P_{initial}$.

(Eq. C3)

$$IF\ 0.5\ MPa \leq P_{initial} \leq NWP\ AND\ Leak\ Check\ Passed$$

$$Record\ P_{initial}\ and\ continue\ Startup$$

$$ELSE\ Abort\ Startup$$

$$END\ IF$$

C.2.4 Determination of CHSS Volume and Largest Tank Volume

The dispenser next determines the CHSS volume, V_{CHSS}, and the largest tank volume, TVL. During the dispenser startup, the CHSS volume may only be determined through communications via the TV value. If communications are not available, then the CHSS volume is considered indeterminate. The CHSS volume can be measured during the main fueling time using the CHSS Volume Measurement Subroutine in C.3.7.

(Eq. C4)

$$If\ Indicator\_Comm\_Fill = TRUE, \quad Set\ V_{CHSS} = TV$$

$$If\ Indicator\_Comm\_Fill = FALSE, \quad Set\ V_{CHSS} = ND$$

$$\text{For H35 FM60 or H70 FM60 / FM90 / FM300}$$

$$IF\ 248.6 \leq V_{CHSS} \leq 5000\ OR\ V_{CHSS} = ND$$

$$Continue\ Startup$$

$$ELSE\ Abort\ Startup$$

$$END\ IF$$

For H35 FM120

$$IF\ 248.6 \leq V_{CHSS} \leq 7500\ OR\ V_{CHSS} = ND$$

$$Continue\ Startup$$

$$ELSE\ Abort\ Startup$$

$$END\ IF$$

The largest tank volume, TVL, can only be determined via communications (see 8.11.6.8 for a complete formatting description of optional data parameters). The dispenser stores this value as TVL. If communications are not utilized, or this TVL is not communicated in the Optional Data Field, the dispenser shall set TVL to 800 L for the FM60 or H70 FM60/FM90/FM300 protocols and set TVL to 1000 L for the H35 FM120 protocol.

(Eq. C5)

For H35 FM60 or H70 FM60/FM90/FM300

$$If\ Indicator\_Comm\_Fill = TRUE,\quad Set\ TVL\ to\ value\ communicated\ in\ OD\ field$$

$$If\ Indicator\_Comm\_Fill = FALSE, or\ TVL\ is\ not\ communicated\ in\ the\ OD\ field,\quad Set\ TVL = 800$$

$$IF\ 50 \leq TVL \leq 800$$

$$Continue\ Startup$$

$$ELSE\ Abort\ Startup$$

$$END\ IF$$

For H35 FM120

$$If\ Indicator\_Comm\_Fill = TRUE,\quad Set\ TVL\ to\ value\ communicated\ in\ OD\ field$$

$$If\ Indicator\_Comm\_Fill = FALSE, or\ TVL\ is\ not\ communicated\ in\ the\ OD\ field,\quad Set\ TVL = 1000$$

$$IF\ 50 \leq TVL \leq 1000$$

$$Continue\ Startup$$

$$ELSE\ Abort\ Startup$$

$$END\ IF$$

C.2.5 Setting the Flow Rate Maximum Value FM

The dispenser shall set the Flow Rate Maximum Value FM based on the Flow Rate Maximum Class FM. See 8.1 for guidance.

(Eq. C6)

For the H70 Pressure Class

$$If\ the\ Flow\ Rate\ Maximum\ Class\ is\ FM60\ or\ FM90$$

$$THEN$$

$$If\ Indicator\_Comm\_Fill = TRUE\ and\ FM = 090\ is\ received\ in\ the\ OD\ block, Set\ FM = 90$$

$$ELSE$$

$$If\ Indicator\_Comm\_Fill = FALSE\ \ or\ FM = 090\ is\ not\ received\ in\ the\ OD\ block$$

$$or\ Dispenser\ is\ not\ capable\ of\ FM90, Set\ FM = 60$$

$$END\ IF$$

$$If\ the\ Flow\ Rate\ Maximum\ Class\ is\ FM300$$

$$Set\ FM = 300$$

$$END\ IF$$

For H35 FM60

$$Set\ FM = 60$$

For H35 FM120

$$Set\ FM = 120$$

C.3 FUELING PROCESS SUBROUTINE

The subroutines in Section C.3 describe the fueling process.

C.3.1 Subroutine - Parameter Initialization

C.3.1.1 Initialization of Parameters with Non-Discretionary Settings

The settings of the parameters in this subsection do not allow for discretion. The parameters shall be set and/or calculated as indicated.

The initial step is to set the timestep counters to zero. The timestep *j* is used to calculate all control parameters, as defined in Subroutines "Fueling Time Indicator," "Mass Average Calculations," "Calculation of T_{cold}," "Calculation of t_{final}," "Calculation of PRR and P_{ramp}," "Determination of Pressure Targets and Limits," and "Process Check." The timestep *j* shall be set to 1 second, meaning that the calculations are performed once every second.

$$Initialize\ \ j = 0 \quad \text{(Eq. C7)}$$

The counter *n* is used to determine the point in the fill when mass flow begins and when a total of 30 seconds of mass flow have elapsed. The counter *n* advances at the same frequency as timestep counter *j* but only advances if there is mass flow. It is utilized to determine the point in the fill at which the calculation of MAT_{30} commences.

$$Initialize\ \ n = 0 \tag{Eq. C8}$$

The counter *i* is used to determine when the end-of-fill criteria has been met in the Evaluate End-of-Fill Criteria Subroutine in C.3.14. The timestep *i* shall be set to 0.1 second, meaning that the calculations are performed once every 1/10th of a second.

$$Initialize\ \ i = 0 \tag{Eq. C9}$$

The mass is initialized at the beginning of the main fueling time, i.e., when t = 0. This mass initialization is utilized in the CHSS Volume Measurement Subroutine in C.3.7. Note that m_0 is the value of the mass dispensed at time t = 0. It is not necessarily a zero value, as the mass dispensed during startup may have accumulated in the mass measurement. The unit of measure for m_0 is grams.

$$Set\ \ m_0\ as\ the\ mass\ reading\ at\ time\ t = 0 \tag{Eq. C10}$$

The parameter K_0 is initialized to zero using Equation C11. K_0 is calculated in the Calculation of K_0 Subroutine in C.3.8.

$$If\ K_0\ Method\ and\ MP_{calc}\ is\ utilized,\ \ Initialize\ \ K_0 = 0 \tag{Eq. C11}$$

The flag variable PRR_TAPER_FLAG is initially set to FALSE. PRR_TAPER_FLAG is used in the PRR Taper method in Equation C82. The PRR Taper method is optional, so if PRR Taper is not used, then PRR_TAPER_FLAG remains set to FALSE throughout the fueling event. IF PRR Taper is utilized, PRR_TAPER_FLAG is changed to TRUE when certain conditions are met in Equation C82.

$$PRR\_TAPER\_FLAG = FALSE \tag{Eq. C12}$$

P_{final} is a parameter utilized in the variable PRR equation. It represents the maximum pressure used in the derivation of the t_{final} values. The unit of measure for P_{final} is megapascals.

(Eq. C13)

$$If\ the\ protocol\ is\ H35\ FM60\ or\ H70\ FM60, FM90, FM300, Set\ \ P_{final} = 87.5$$

$$If\ the\ protocol\ is\ H35\ FM120, Set\ \ P_{final} = 43.75$$

P_{trans} is a parameter used in the mass average fuel delivery temperature control (MAT_C) equation. The unit of measure for P_{trans} is megapascals.

$$Set\ \ P_{trans} = \frac{P_{final} + P_{initial}}{2} \tag{Eq. C14}$$

$P_{startup}$ is used to set the initial ramp pressure P_{ramp}. $P_{startup}$ is the station pressure measured at the end of the startup time/beginning of the main fueling time. The unit of measure for P_{ramp} is megapascals.

$$Set\ P_{ramp} = P_{startup} \tag{Eq. C15}$$

P_{min} is the minimum initial pressure and is utilized in the PRR equation (see Equation C80) as well as the equation for β (see Equation C25). The unit of measure for P_{min} is megapascals.

(Eq. C16)

For H35 FM60 and H70 FM60/FM90/FM300

$$IF\ P_{initial}\ \geq 5\ MPa,$$

$$THEN\ Set\ P_{min} = 5$$

$$ELSE$$

$$Set\ P_{min} = P_{initial}$$

$$END\ IF$$

For H35 FM120

$$IF\ P_{initial}\ \geq 3\ MPa,$$

$$THEN\ Set\ P_{min} = 3$$

$$ELSE$$

$$Set\ P_{min} = P_{initial}$$

$$END\ IF$$

RR_{min} is the minimum calculated PRR throughout the fill. It is utilized in the equation for α (see Equation C79). The unit of measure for RR_{min} is MPa/s.

$$Set\ \ RR_{min} = 1 \quad \text{(Eq. C17)}$$

RR_{max} is the maximum calculated PRR throughout the fill. It is utilized in the equation for α (see Equation C79). The unit of measure for RR_{max} is MPa/s.

$$Set\ \ RR_{max} = 0 \quad \text{(Eq. C18)}$$

α is a parameter which is multiplied by t_{final} to compensate for non-linearity in the PRR during the fill (see Equations C78 and C79). Refer to H.2.6.1 of SAE J2601_202005 for a detailed explanation of α. The higher the difference between RR_{max} and RR_{min}, the higher α becomes. α is calculated for each timestep j. The unit of measure for α is dimensionless.

$$Set\ \alpha = 1 \quad \text{(Eq. C19)}$$

ε is a parameter which is multiplied by t_{final} to increase t_{final} when $P_{initial}$ is less than 5 MPa for the H35 FM60 or H70 FM60/FM90/FM300 protocols, and when $P_{initial}$ is less than 3 MPa for the H35 FM120 protocol (see Equation C78). This is because the t_{final} values were derived with an initial pressure of 5 MPa and 3 MPa, respectively, so when the initial pressure is lower than these values, the fueling time must be increased. For more details on the ε parameter, see A.2.1.2. The unit of measure for ε is dimensionless. ε is set using Equation C20. In Equation C20, the unit of measure for T_{amb} is degrees Celsius (°C).

(Eq. C20)

For H35 FM60 or H70 FM60 / FM90 / FM300

$$IF\ P_{initial} \geq 5\ MPa,$$

$$THEN\ Set\ \varepsilon = 1$$

$$ELSE$$

$$IF\ T_{amb} \geq 0, TT = T_{amb}$$

$$ELSE$$

$$TT = 0$$

$$END\ IF$$

$$\omega = 0.07837762 - 0.0009585859 \times TT + 0.00006455478 \times TT^2 - 0.00000297125 \times TT^3 + 0.0000000415851 \times TT^4$$

$$Set\ \varepsilon = \frac{(P_{final} - P_{initial})}{(P_{final} - 5) \times [1 - \omega \times (5 - P_{initial})]}$$

$$END\ IF$$

For H35 FM120

$$IF\ P_{initial} \geq 3\ MPa,$$

$$THEN\ Set\ \varepsilon = 1$$

$$ELSE$$

$$IF\ T_{amb} \geq 0, TT = T_{amb}$$

$$ELSE$$

$$TT = 0$$

$$END\ IF$$

$$\omega = 0.1333077 - 0.00163512 \times TT + 0.00005851981 \times TT^2 - 0.00000190054 \times TT^3 + 0.0000000209790 \times TT^4$$

$$Set\ \varepsilon = \frac{(P_{final} - P_{initial})}{(P_{final} - 3) \times [1 - \omega \times (3 - P_{initial})]}$$

$$END\ IF$$

C.3.1.2 Initialization of Parameters with Discretionary Settings

The settings for the parameters in this subsection shall be determined by the discretion of the dispenser manufacturer within the acceptable range provided.

A communications-fill pressure target is calculated continuously during fueling. The pressure target is calculated based on an end-of-fill target density of 40.2 g/L for the H70 Pressure Class and an end-of-fill target density of 24.0 g/L for the H35 Pressure Class. However, the pressure target may be reduced to account for sensor tolerance. The amount the SOC target is reduced for sensor tolerance is determined by the dispenser manufacturer. A parameter SOC_{target} is used to define the target SOC, where SOC_{target} = 100 represents a target density of 40.2 g/L for the H70 Pressure Class, and a target density of 24.0 g/L for the H35 Pressure Class. Communications fueling should achieve a final SOC in the CHSS of ≥95% and ≤100%. Thus, SOC_{target} shall be set between 95 and 100, where the value 95 represents 95% SOC and the value 100 represents 100% SOC. The unit of measure for SOC_{target} is percent (%).

$$Set\ SOC_{target} \quad \text{(Eq. C21)}$$

The dispenser must set the maximum ramp pressure, $P_{ramp\_maximum}$. The ramp pressure (P_{ramp}) is the pressure that the dispenser targets for each timestep throughout the fill. The maximum ramp pressure should be set at some value below P_{final} which gives the dispenser sufficient margin for controlling the station pressure without exceeding P_{final}. For example, for a pressure class of H70, given that P_{final} is equal to 87.5 MPa, a dispenser may set the maximum ramp pressure to 85 MPa or 86 MPa, and for a pressure class of H35, a dispenser may set the maximum ramp pressure to 42 MPa or 42.5 MPa (note that the H35 FM60 protocol uses a P_{final} value of 87.5 so that the pressure ramp rates are the same as the H70 FM60 protocol; therefore, in this case, $P_{ramp\_maximum}$ should be set at some value below 43.75 MPa). If the station pressure falls behind the ramp pressure, the ramp pressure may reach the maximum ramp pressure before the station pressure reaches the target pressure. When this occurs, the ramp pressure is held constant at the maximum ramp pressure value until the station pressure or vehicle pressure reaches the target pressure. The unit of measure for $P_{ramp\_maximum}$ is megapascals.

$$Set\ P_{ramp\_maximum} \quad \text{(Eq. C22)}$$

The dispenser shall determine the expected mass average fuel delivery temperature, $MAT_{expected}$. This should be based on the fuel delivery temperature control setpoint, i.e., the fuel delivery temperature that the cooling system is targeting during the fill. $MAT_{expected}$ shall be set to a value within the range specified in Equation C23. The unit of measure for $MAT_{expected}$ is degrees Celsius (°C).

$$Set\ MAT_{expected} \quad \text{(Eq. C23)}$$

$$For\ H35\ FM60\ or\ H70\ FM60, FM90, FM300, -33\ °C\ \leq\ MAT_{expected} \leq 0\ °C$$

$$For\ H35\ FM120, -20\ °C\ \leq\ MAT_{expected} \leq 20\ °C$$

ΔP_{tol_high} is an upper tolerance on the ramp pressure P_{ramp}. ΔP_{tol_high} is a value which is added to P_{ramp} to provide an upper limit pressure P_{limit_high} which the station pressure $P_{station}$ shall not exceed (see Process Check Subroutine in C.3.15). The unit of measure for ΔP_{tol_high} is megapascals. The range of acceptable values for ΔP_{tol_high} is 3 to 7 MPa. Setting ΔP_{tol_high} to a higher value in this range provides more margin for station pressure excursions above the ramp pressure, but it also causes β in Equations C25 and C78 to be larger, which increases the fueling time. Setting ΔP_{tol_high} to a lower value in the range decreases the fueling time but provides less margin for station pressure excursions.

$$Set\ \Delta P_{tol\_high}\ \ to\ a\ value\ between\ 3\ and\ 7 \quad \text{(Eq. C24)}$$

β is a parameter which is multiplied by t_{final} to allow for the pressure tolerance ΔP_{tol_high}. Refer to H.2.6.2 of SAE J2601_202005 for a detailed explanation of β. The unit of measure for β is dimensionless. ΔP_{tol_high} is set using Equation C24.

$$Set\ \beta = \frac{P_{final} - P_{min}}{P_{final} - P_{min} - \Delta P_{tol\_high}} \quad \text{(Eq. C25)}$$

The parameter P_a is factor used in the calculation of the synthetic measured pressure MP_{calc}, which is a function of K_0, $\dot{m}$, and ρ (see Equations C81, C88, and C89). K_0 is measured in the Calculation of K_0 Subroutine in C.3.8 (which is optional). The parameter P_a provides margin for the uncertainty in the calculation of MP_{calc}, i.e., P_a is added to the calculation, which gives a higher value for MP_{calc}. The value used for P_a is discretionary and can range from zero to a positive number (a higher value is more conservative). As an example, P_a may be set to 1 MPa. The unit of measure for MP_{calc} is megapascals.

$$If\ K_0\ Method\ and\ MP_{calc}\ is\ utilized,\ \ Set\ \ P_a \qquad \text{(Eq. C26)}$$

The parameter $t_{lookback}$ is used in the PRR Taper method in Equation C82. $t_{lookback}$ defines the lookback period of time for which a previous value of the measured pressure MP is utilized. The unit of measure for $t_{lookback}$ is seconds. The PRR Taper method and its attributes are explained in Appendix E. The use of the PRR Taper method and Equation C82 is optional.

$$If\ PRR\ Taper\ Method\ is\ utilized,\ \ Set\ \ t_{lookback} = 30 \qquad \text{(Eq. C27)}$$

C.3.2 Subroutine - Ending Pressure Control Initialization

This subroutine is divided into two sections, C.3.2.1 and C.3.2.2, based on the ending pressure control method chosen. C.3.2.1 is only applicable to the use of Ending Pressure Tables for ending pressure control. C.3.2.2 is only applicable to the use of the MC Method for ending pressure control.

C.3.2.1 Ending Pressure Control Initialization - Ending Pressure Tables

C.3.2.1.1 Calculation of Non-Communications Fueling Pressure Target

Tables C1 and C2 provide the non-communications fueling pressure targets as a function of the ambient temperature and initial pressure for Pressure Classes H35 and H70, respectively. Equation C28 is utilized to conduct the interpolation required to calculate the non-communications fueling pressure target using inputs of ambient temperature T_{amb}, and initial pressure $P_{initial}$. In Equation C28, $P_{initial\_below}$ represents the $P_{initial}$ value in the table directly below the actual initial pressure $P_{initial}$, and $P_{initial\_above}$ represents the $P_{initial}$ value in the table directly above the initial pressure $P_{initial}$. In Equation C28, T_{amb_below} represents the T_{amb} value in the table directly below the actual ambient temperature T_{amb}, and T_{amb_above} represents the T_{amb} value in the table directly above the actual ambient temperature T_{amb}. P_{table} represents the actual table pressure target value at $P_{initial\_above}$ or $P_{initial\_below}$ and at T_{amb_above} or T_{amb_below}.

As an example, in Table C2, P_{table} (20,30) = 69.9 MPa, where 20 represents $P_{initial\_above}$ or $P_{initial\_below}$, and 30 represents T_{amb_above} or T_{amb_below}. In Equation C28, P_{below} is an intermediate calculation representing the below pressure target value after interpolating on T_{amb}, and P_{above} is an intermediate calculation representing the above pressure target value after interpolating on T_{amb}. The final $P_{target\_non\_comm}$ value is a result of interpolating P_{below} and P_{above} on $P_{initial}$.

Table C1 - Non-communications fueling pressure targets - H35 Pressure Class

H35 MCF-HF-G Non-Comm		Target Pressure, $P_{target\_non\_comm}$ [MPa]								
		Initial Tank Pressure, $P_{initial}$ [MPa]								
		0.5	2	5	10	15	20	30	35	>35
Ambient Temperature, T_{amb} [°C]	>50	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling
	50	37.6	37.4	37.3	37.0	36.8	36.7	36.6	36.4	no fueling
	45	37.2	37.1	37.0	36.7	36.6	36.5	36.6	36.4	no fueling
	40	36.9	36.8	36.7	36.5	36.4	36.4	36.5	36.4	no fueling
	35	36.6	36.5	36.4	36.3	36.2	36.2	36.4	36.3	no fueling
	30	36.2	36.1	35.9	35.7	35.7	35.7	35.8	35.7	no fueling
	25	35.7	35.6	35.4	35.2	35.1	35.1	35.2	no fueling	no fueling
	20	35.3	35.2	35.0	34.7	34.6	34.5	34.6	no fueling	no fueling
	10	34.4	34.2	34.0	33.7	33.5	33.4	33.3	no fueling	no fueling
	0	33.7	33.4	33.0	32.7	32.4	32.3	32.0	no fueling	no fueling
	-10	33.3	33.0	32.5	31.7	31.3	31.1	30.6	no fueling	no fueling
	-20	33.0	32.7	32.2	31.4	30.7	30.0	no fueling	no fueling	no fueling
	-30	32.4	32.2	31.8	31.1	30.4	29.6	no fueling	no fueling	no fueling
	-40	32.2	32.0	31.6	30.9	30.2	29.5	no fueling	no fueling	no fueling
	<-40	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling

Table C2 - Non-communications fueling pressure targets - H70 Pressure Class

H70 MCF-HF-G Non-Comm	Target Pressure, $P_{target\_non\_comm}$ [MPa]											
	Initial Tank Pressure, $P_{initial}$ [MPa]											
Ambient Temperature, T_{amb} [°C]	0.5	2	5	10	15	20	30	40	50	60	70	>70
>50	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling
50	73.6	72.6	72.6	72.2	71.9	71.9	71.5	71.2	71.0	71.2	71.9	no fueling
45	73.1	72.2	72.6	71.8	71.6	71.5	71.2	71.0	70.9	71.1	71.9	no fueling
40	71.3	71.8	72.2	71.4	71.2	71.2	70.9	70.8	70.8	71.1	71.9	no fueling
35	71.4	71.3	71.3	71.1	70.9	70.8	70.6	70.6	70.7	71.0	71.9	no fueling
30	70.5	71.0	71.0	70.2	70	69.9	69.6	69.5	69.6	69.9	70.8	no fueling
25	68.6	69.7	69.6	69.3	69.0	68.9	68.6	68.4	68.5	68.8	no fueling	no fueling
20	67.1	68.9	68.8	68.4	68.1	67.9	67.5	67.4	67.4	67.7	no fueling	no fueling
10	64.7	67.8	67.3	66.3	65.9	65.6	65.1	64.7	64.5	64.6	no fueling	no fueling
0	60.4	67.3	66.8	65.9	64.9	64.0	63.4	63.0	62.9	63.2	no fueling	no fueling
-10	60.4	66.8	66.3	65.4	64.5	63.5	61.5	60.8	60.6	60.9	no fueling	no fueling
-20	60.0	66.3	65.8	65.0	64.1	63.0	61.2	59.4	57.5	no fueling	no fueling	no fueling
-30	60.2	65.8	65.3	64.5	63.7	62.7	61.0	59.3	57.5	no fueling	no fueling	no fueling
-40	60.2	65.3	64.8	64.1	63.3	62.4	60.7	59.1	57.5	no fueling	no fueling	no fueling
<-40	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling

Calculation of Non-Communications Fueling Pressure Target (Eq. C28)

$$P_{below} = P_{table}(P_{initial\_below}, T_{amb\_below}) + \frac{[P_{table}(P_{initial\_below}, T_{amb\_above}) - P_{table}(P_{initial\_below}, T_{amb\_below})] \times [T_{amb} - T_{amb\_below}]}{[T_{amb\_above} - T_{amb\_below}]}$$

$$P_{above} = P_{table}(P_{initial\_above}, T_{amb\_below}) + \frac{[P_{table}(P_{initial\_above}, T_{amb\_above}) - P_{table}(P_{initial\_above}, T_{amb\_below})] \times [T_{amb} - T_{amb\_below}]}{[T_{amb\_above} - T_{amb\_below}]}$$

$$P_{target\_non\_comm} = P_{below} + \frac{[P_{above} - P_{below}] \times [P_{intial} - P_{initial\_below}]}{[P_{initial\_above} - P_{initial\_below}]}$$

As an example of using Equation C28, consider Table C2, with $P_{initial}$ = 23 MPa and T_{amb} = 32 °C. In this case, $P_{initial\_below}$ = 20, $P_{initial\_above}$ = 30, T_{amb_below} = 30, and T_{amb_above} = 35. $P_{target\_non\_comm}$ is calculated as follows:

$$P_{below} = 69.9 + \frac{[70.8 - 69.9] \times [32 - 30]}{[35 - 30]} = 70.3$$

$$P_{above} = 69.6 + \frac{[70.6 - 69.6] \times [32 - 30]}{[35 - 30]} = 70$$

$$P_{target\_non\_comm} = 70.3 + \frac{[70 - 70.3] \times [23 - 20]}{[30 - 20]} = 70.2$$

C.3.2.1.2 Calculation of Communications Fueling Pressure Limit

A pressure limit, P_{limit_comm}, is calculated for communications fueling. This pressure limit value is used as a secondary means of protection to limit over filling in the event of a fault in the CHSS measured temperature MT, which causes the communications fueling pressure target to be incorrect.

Tables C3 and C4 provide the communications fueling pressure limits as a function of the ambient temperature and initial pressure for Pressure Classes H35 and H70, respectively. Equations C29 (H35 Pressure Class) and C30 (H70 Pressure Class) are utilized to conduct the interpolation required to calculate the communications fueling pressure limit using inputs of ambient temperature T_{amb}, and initial pressure, $P_{initial}$. In Equations C29 and C30, $P_{initial\_below}$ represents the $P_{initial}$ value in the table directly below the actual initial pressure $P_{initial}$, and $P_{initial\_above}$ represents the $P_{initial}$ value in the table directly above the initial pressure $P_{initial}$. In Equations C29 and C30, T_{amb_below} represents the T_{amb} value in the table directly below the actual ambient temperature T_{amb}, and T_{amb_above} represents the T_{amb} value in the table directly above the actual ambient temperature T_{amb}. P_{table} represents the actual table pressure target value at $P_{initial\_above}$ or $P_{initial\_below}$ and at T_{amb_above} or T_{amb_below}. Note that if $P_{initial} \leq 3$ MPa for the H35 Pressure Class and if $P_{initial} \leq 5$ MPa for the H70 Pressure Class, interpolation is conducted only on ambient temperature using the table value for $P \leq 3$ and $P \leq 5$, respectively (i.e., P_{below} and P_{above} are not calculated).

As an example, in Table C4, P_{table} (20,30) = 85.6 MPa, where 20 represents $P_{initial\_above}$ or $P_{initial\_below}$, and 30 represents T_{amb_above} or T_{amb_below}. In Equations C29 and C30, P_{below} is an intermediate calculation representing the below pressure target value after interpolating on T_{amb}, and P_{above} is an intermediate calculation representing the above pressure target value after interpolating on T_{amb}. The final P_{limit_comm} value is a result of interpolating P_{below} and P_{above} on $P_{initial}$.

Table C3 - Communications fueling pressure limits - H35 Pressure Class

H35 MCF-HF-G		**Communications Fueling Pressure Limit, P_{limit_comm} [MPa]**							
		Initial Tank Pressure, $P_{initial}$ [MPa]							
		≤3	**5**	**10**	**15**	**20**	**30**	**35**	**>35**
Ambient Temperature, T_{amb} [°C]	**>50**	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling
	50	**43.75**	**42.6**	**42.4**	**42.2**	**41.9**	**41.1**	**40.5**	no fueling
	45	**43.75**	**42.7**	**42.4**	**42.1**	**41.7**	**40.7**	**39.8**	no fueling
	40	**43.75**	**42.6**	**42.2**	**41.8**	**41.3**	**40.1**	**39.1**	no fueling
	35	**43.75**	**42.6**	**42.2**	**41.8**	**41.2**	**40.0**	**39.1**	no fueling
	30	**43.75**	**42.5**	**42.1**	**41.5**	**40.9**	**39.6**	**38.6**	no fueling
	25	**43.75**	**42.4**	**41.9**	**41.3**	**40.6**	**39.2**	no fueling	no fueling
	20	**43.75**	**42.2**	**41.6**	**40.9**	**40.2**	**38.7**	no fueling	no fueling
	10	**43.75**	**41.9**	**41.2**	**40.4**	**39.6**	**37.9**	no fueling	no fueling
	0	**43.75**	**41.3**	**40.4**	**39.5**	**38.5**	**36.5**	no fueling	no fueling
	-10	**43.75**	**41.1**	**40.3**	**39.3**	**38.4**	**36.3**	no fueling	no fueling
	-20	**43.75**	**41.0**	**40.1**	**39.2**	**38.3**	no fueling	no fueling	no fueling
	-30	**43.75**	**40.9**	**40.0**	**39.1**	**38.1**	no fueling	no fueling	no fueling
	-40	**43.75**	**40.7**	**39.8**	**38.9**	**38.0**	no fueling	no fueling	no fueling
	<-40	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling

Table C4 - Communications fueling pressure limits - H70 Pressure Class

H70 MCF-HF-G Comm	Communications Fueling Pressure Limit, P_{limit_comm} [MPa]									
	Initial Tank Pressure, $P_{initial}$ [MPa]									
Ambient Temperature, T_{amb} [°C]	≤5	10	15	20	30	40	50	60	70	>70
>50	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling
50	84.8	86.9	86.6	86.2	85.4	84.5	83.4	82.2	80.9	no fueling
45	84.8	87.0	86.7	86.2	85.2	84.1	82.8	81.4	79.6	no fueling
40	84.8	87.0	86.4	85.9	84.6	83.3	81.8	80.2	78.1	no fueling
35	84.8	87.0	86.4	85.9	84.6	83.2	81.7	80.1	78.1	no fueling
30	84.8	86.9	86.3	85.6	84.2	82.6	81.0	79.2	77.1	no fueling
25	84.8	86.8	86.0	85.3	83.7	82.0	80.2	78.3	76.0	no fueling
20	84.8	86.4	85.5	84.7	83.0	81.2	79.3	77.4	75.0	no fueling
10	84.8	85.7	84.8	83.9	82.0	80.0	78.0	75.9	73.4	no fueling
0	84.8	84.6	83.4	82.3	80.0	77.7	75.4	72.9	no fueling	no fueling
-10	84.8	84.4	83.2	82.1	79.8	77.5	75.2	72.8	no fueling	no fueling
-20	84.8	84.2	83.0	81.9	79.6	77.3	75.0	72.6	no fueling	no fueling
-30	84.8	83.9	82.8	81.7	79.4	77.1	74.8	72.4	no fueling	no fueling
-40	84.8	83.7	82.6	81.4	79.2	76.9	74.6	72.3	no fueling	no fueling
<-40	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling	no fueling

Calculation of Communications Fueling Pressure Limit - H35 Pressure Class (Eq. C29)

$$IF\ P_{initial} > 3\ MPa$$

$$THEN$$

$$P_{below} = P_{table}(P_{initial\_below}, T_{amb\_below}) + \frac{[P_{table}(P_{initial\_below}, T_{amb\_above}) - P_{table}(P_{initial\_below}, T_{amb\_below})] \times [T_{amb} - T_{amb\_below}]}{[T_{amb\_above} - T_{amb\_below}]}$$

$$P_{above} = P_{table}(P_{initial\_above}, T_{amb\_below}) + \frac{[P_{table}(P_{initial\_above}, T_{amb\_above}) - P_{table}(P_{initial\_above}, T_{amb\_below})] \times [T_{amb} - T_{amb\_below}]}{[T_{amb\_above} - T_{amb\_below}]}$$

$$P_{limit\_comm} = P_{below} + \frac{[P_{above} - P_{below}] \times [P_{intial} - P_{initial\_below}]}{[P_{initial\_above} - P_{initial\_below}]}$$

$$ELSE\ IF\ P_{initial} \leq 3\ MPa$$

$$THEN$$

$$P_{limit\_comm} = P_{table}(P \leq 3, T_{amb\_below}) + \frac{[P_{table}(P \leq 3, T_{amb\_above}) - P_{table}(P \leq 3, T_{amb\_below})] \times [T_{amb} - T_{amb\_below}]}{[T_{amb\_above} - T_{amb\_below}]}$$

$$END\ IF$$

Calculation of Communications Fueling Pressure Limit - H70 Pressure Class (Eq. C30)

$$IF\ P_{initial} > 5\ MPa$$

$$THEN$$

$$P_{below} = P_{table}(P_{initial\_below}, T_{amb\_below}) + \frac{[P_{table}(P_{initial\_below}, T_{amb\_above}) - P_{table}(P_{initial\_below}, T_{amb\_below})] \times [T_{amb} - T_{amb\_below}]}{[T_{amb\_above} - T_{amb\_below}]}$$

$$P_{above} = P_{table}(P_{initial\_above}, T_{amb\_below}) + \frac{[P_{table}(P_{initial\_above}, T_{amb\_above}) - P_{table}(P_{initial\_above}, T_{amb\_below})] \times [T_{amb} - T_{amb\_below}]}{[T_{amb\_above} - T_{amb\_below}]}$$

$$P_{limit\_comm} = P_{below} + \frac{[P_{above} - P_{below}] \times [P_{intial} - P_{initial\_below}]}{[P_{initial\_above} - P_{initial\_below}]}$$

$$ELSE\ IF\ P_{initial} \leq 5\ MPa$$

$$THEN$$

$$P_{limit\_comm} = P_{table}(P \leq 5, T_{amb\_below}) + \frac{[P_{table}(P \leq 5, T_{amb\_above}) - P_{table}(P \leq 5, T_{amb\_below})] \times [T_{amb} - T_{amb\_below}]}{[T_{amb\_above} - T_{amb\_below}]}$$

$$END\ IF$$

C.3.2.2 Ending Pressure Control Initialization - MC Method

Equation C31 is used to calculate the initial CHSS temperature T_{init_cold} with cold case assumptions, meaning the CHSS began at the cold soak temperature and 100% SOC, and then was defueled at the maximum flow rate, as explained in SAE J2601_202005, Appendix A, A.3.8 and A.3.9. In Equation C31, the unit of measure for T_{amb} is degrees Celsius (°C) and the unit for T_{init_cold} is kelvin (K).

(Eq. C31)

For the H70 Pressure Class:

$$T_{init\_cold} = \frac{48457.85}{\left\{\left[1 + \left(\frac{(T_{amb} + 273.15 - 318.33)}{35.15}\right)^2\right] \times \left[1 + \left(\frac{(P_{initial} - 513.54)}{16.03}\right)^2\right]\right\}} + 226$$

For the H35 Pressure Class:

$$T_{init\_cold} = \frac{-112.12}{\left\{\left[1 + \left(\frac{(T_{amb} + 273.15 - 238.55)}{-78.26}\right)^2\right] \times \left[1 + \left(\frac{(P_{initial} - 10.42)}{53.93}\right)^2\right]\right\}} + 346.47$$

As an example, with T_{amb} = 32 °C and $P_{initial}$ = 12 MPa, for the H70 Pressure Class, T_{init_cold} = 269.4 K, and for the H35 Pressure Class, T_{init_cold} = 281.5 K.

Equation C32 is used to set the parameter t_{min_cold} to 30 seconds. This parameter is used in the MC equation and represents the time elapsed after which the parameter Δt_{cold} is calculated. Δt_{cold} is the difference between the fueling time t and t_{min_cold}. The unit of measure for t and t_{min_cold} is seconds.

$$Set\ t_{\min\_cold} = 30 \qquad \text{(Eq. C32)}$$

The cold case initial density ρ_{init_cold} is calculated based on $P_{initial}$ and T_{init_cold}. The equation to calculate density is not given here, as the dispenser should have this capability. If desired, a reference equation for density is given in C.4.4, Equation C105. The unit of measure for ρ_{init_cold} is kilograms per cubic meter.

$$Set\ \rho_{init\_cold} = \rho\left(P_{initial}, T_{init\_cold}\right) \qquad \text{(Eq. C33)}$$

A 1-kg Type III vessel is used in the calculation of the ending pressure, as detailed in SAE J2601_202005 Appendix A, A.3.7. The volume of this vessel is set for either the H70 or H35 Pressure Class. Units are in cubic meters.

$$IF\ Pressure\ Class = H70,\ \ THEN\ Set\ V_{cold} = 0.0247 \qquad \text{(Eq. C34)}$$

$$IF\ Pressure\ Class = H35,\ THEN\ Set\ V_{cold} = 0.0416 \qquad \text{(Eq. C35)}$$

The mass of hydrogen in the Type III vessel at 100% SOC is 1 kg. The unit of measure for m_{final_cold} is kilograms.

$$Set\ m_{final\_cold} = 1 \qquad \text{(Eq. C36)}$$

The cold case initial mass of hydrogen in this single Type III vessel is calculated based on the initial density ρ_{init_cold} and the volume V_{cold}. The unit of measure for m_{init_cold} is kilograms.

$$Set\ m_{init\_cold} = V_{cold} \times \rho_{init\_cold} \qquad \text{(Eq. C37)}$$

The mass of hydrogen required to be added to the cold case initial mass to achieve 100% SOC is calculated. The unit of measure for m_{add} is kilograms.

$$Set\ m_{add} = m_{final\_cold} - m_{init\_cold} \qquad \text{(Eq. C38)}$$

The cold case initial specific internal energy is calculated based on the initial pressure $P_{initial}$ and the cold case initial temperature T_{init_cold}. The equation to calculate specific internal energy is not given here, but guidance for the calculation of specific internal energy is given in C.4.2, and if desired, a reference equation for specific internal energy is also provided, Equation C103. The unit of measure for u_{init_cold} is kilojoules per kilogram.

$$Set\ u_{init\_cold} = u\left(P_{initial}, T_{init\_cold}\right) \qquad \text{(Eq. C39)}$$

The cold case initial internal energy U_{init_cold} is calculated based on the cold case initial specific internal energy u_{init_cold} and the cold case initial mass m_{init_cold}. The unit of measure for U_{init_cold} is kilojoules.

$$Set\ U_{init\_cold} = u_{init\_cold} \times m_{init\_cold} \qquad \text{(Eq. C40)}$$

There are five constants utilized in the MC Equation. Refer to H.3.1 of SAE J2601_202005 for a detailed explanation of the MC Equation and how it is used in calculating the end-of-fill pressure target and limit. The five constants utilized in the MC Equation are set. The unit of measure for AC, BC, and GC is kilojoule per kelvin. KC and JC are dimensionless.

$$AC = 1.10487E + 00 \quad \text{(Eq. C41)}$$

$$BC = 2.20466E + 00$$

$$GC = 2.22198E + 01$$

$$KC = 1.63097E - 03$$

$$JC = 8.23284E - 01$$

C.3.3 Subroutine - Selection of t_{final} Table

C.3.3.1 Introduction

t_{final} tables store t_{final} values which are a function of the ambient temperature T_{amb} and the mass average fuel delivery temperature used for control, MAT_C. The t_{final} table contains discrete values of T_{amb} and MAT_C. The t_{final} value is stored as an integer value in units of seconds. The appropriate t_{final} table is chosen based on the total CHSS volume V_{CHSS} and the largest tank volume TVL. The t_{final} tables are displayed in Appendix D.

C.3.3.1.1 Color Shading in the Tables

The lower pressure limit for the MCF-HF-G protocol is 0.75 MPa/min for the H35 FM120 protocol and 1 MPa/min for the H35 FM60 or H70 FM60/FM90/FM300 protocols. Some t_{final} values in the tables in Appendix D will cause the PRR to be less than this lower limit. A sustained PRR of less than 0.75 MPa/min and 1 MPa/min, respectively, will likely result in one of the process limits to be exceeded, causing the fueling to stop prematurely. These process limits include the lower pressure limit and the minimum flow rate requirement.

t_{final} values which are longer than 2700 to 3035 seconds for the H35 FM120 protocol and 4500 to 4770 seconds for the H35 FM60 or H70 FM60/FM90/FM300 protocols will cause the PRR to be lower than 0.75 MPa/min and1 MPa/min, respectively, when utilizing a P_{min} value equal to 3 MPa and 5 MPa, respectively, depending on the value of ΔP_{tol_high} utilized (see Equation C24). ΔP_{tol_high} has a discretionary setting between 3 and 7 MPa. The lower value of the range (i.e., 2700 seconds for H35 FM120 and 4500 seconds for H35 FM60 or H70 FM60/FM90/FM300) corresponds to a ΔP_{tol_high} of 7 MPa, whereas the higher value of the range (i.e., 3035 seconds for H35 FM120 and 4770 seconds for H35 FM60 or H70 FM60/FM90/FM300) corresponds to a ΔP_{tol_high} of 3 MPa. In the t_{final} tables, t_{final} values which are greater than the lower value of the range, i.e., 2700 seconds for H35 FM120 and 4500 seconds for H35 FM60 or H70 FM60/FM90/FM300, are shaded red as a precautionary indicator to the user.

If $P_{initial}$ and P_{min} is less than 3 MPa for the H35 FM120 protocol and 5 MPa for the H35 FM60 or H70 FM60/FM90/FM300 protocols, t_{final} is multiplied by ε, causing t_{final} to be even larger and the PRR to be even slower. The lower the initial pressure, the larger the ε value and resultant t_{final} value. The t_{final} values shaded in yellow in the t_{final} tables indicate conditions where the calculated PRR may be slower than 0.75 MPa/min for the H35 FM120 protocol and 1.0 MPa/min for the H35 FM60 or H70 FM60/FM90/FM300 protocols, depending on the value of $P_{initial}$.

To ensure fuelings are not stopped prematurely, it is recommended that the fuel delivery temperature be kept sufficiently cold so that MAT_C is colder than the values shaded in yellow and red.

C.3.3.1.2 Options for Utilizing the t_{final} Tables

There are two options for utilizing the t_{final} tables: Option A (Advanced t_{final} tables) and Option B (Basic t_{final} tables). With Advanced Option A, t_{final} is determined depending on the TVL category and interpolated over T_{amb} and V_{CHSS}. Option A utilizes 23 t_{final} tables. With Basic Option B, t_{final} is determined depending the on TVL category and V_{CHSS} categories and interpolated over T_{amb}. Option B utilizes 12 t_{final} tables. Advanced Option A is more precise and results in lower t_{final} values, which reduces the fueling time. However, Option A also requires an additional interpolation step, so it is a bit more complex than Option B. Basic Option B results in slightly longer t_{final} values but is simpler to implement. The difference in t_{final} values between the two options will vary and can be determined by studying the t_{final} tables in Appendix D. As an example, for the H35 FM120 protocol at an ambient temperature of 40 °C and an MAT_C of -10 °C, and for a V_{CHSS} of 2100 L and TVL of 200 L, the t_{final} value for Option A is 682 seconds versus 828 seconds for Option B. As an example, for the H70 FM300 protocol at an ambient temperature of 40 °C and an MAT_C of -26 °C, and for a V_{CHSS} of 2100 L and TVL of 200 L, the t_{final} value for Option A is 690 seconds versus 789 seconds for Option B.

Table C5 provides a matrix of the H35 FM120 t_{final} tables for Advanced Option A, and Table C6 provides a matrix of the H35 FM120 t_{final} tables for Basic Option B. Table C7 provides a matrix of the H35 FM60 or H70 FM60/FM90/FM300 t_{final} tables for Advanced Option A, and Table C8 provides a matrix of the H35 FM60 or H70 FM60/FM90/FM300 t_{final} tables for Basic Option B.

In the last column in these matrices, there is an additional t_{final} table for the case where V_{CHSS} is indeterminate (i.e., ND). This table is a conservative t_{final} table consisting of the largest t_{final} value from all the t_{final} tables.

Table C5 - Matrix of t_{final} tables for Advanced Option A - H35 FM120

TVL (liters)	V_{CHSS} (liters)								
	248.6	500	1000	1500	2000	2500	5000	7500	ND
50 ≤ TVL ≤ 200	Table D1	Table D2	Table D3	Table D4	Table D5	Table D6	Table D7	Table D8	
200 < TVL ≤ 350	Table D9	Table D10	Table D11	Table D12	Table D13	Table D14	Table D15	Table D16	Table D36
350 < TVL ≤ 1000	Table D9	Table D17	Table D18	Table D19	Table D20	Table D21	Table D22	Table D23	

Table C6 - Matrix of t_{final} tables for Basic Option B - H35 FM120

TVL (liters)	V_{CHSS} (liters)				
	248.6 ≤ V_{CHSS} ≤ 1000	1000 < V_{CHSS} ≤ 2000	2000 < V_{CHSS} ≤ 5000	5000 < V_{CHSS} ≤ 7500	ND
50 ≤ TVL ≤ 200	Table D24	Table D25	Table D26	Table D27	
200 < TVL ≤ 350	Table D28	Table D29	Table D30	Table D31	Table D36
350 < TVL ≤ 1000	Table D32	Table D33	Table D34	Table D35	

Table C7 - Matrix of t_{final} tables for Advanced Option A - H35 FM60 or H70 FM60/FM90/FM300

TVL (liters)	V_{CHSS} (liters)								
	248.6	500	1000	1500	2000	2500	3000	5000	ND
50 ≤ TVL ≤ 200	Table D37	Table D38	Table D39	Table D40	Table D41	Table D42	Table D43	Table D44	
200 < TVL ≤ 350	Table D45	Table D46	Table D47	Table D48	Table D49	Table D50	Table D51	Table D52	Table D72
350 < TVL ≤ 800	Table D45	Table D53	Table D54	Table D55	Table D56	Table D57	Table D58	Table D59	

Table C8 - Matrix of t_{final} tables for Basic Option B - H35 FM60 or H70 FM60/FM90/FM300

TVL (liters)	V_{CHSS} (liters)				
	248.6 ≤ V_{CHSS} ≤ 1000	1000 < V_{CHSS} ≤ 2000	2000 < V_{CHSS} ≤ 3000	3000 < V_{CHSS} ≤ 5000	ND
50 ≤ TVL ≤ 200	Table D60	Table D61	Table D62	Table D63	
200 < TVL ≤ 350	Table D64	Table D65	Table D66	Table D67	Table D72
350 < TVL ≤ 800	Table D68	Table D69	Table D70	Table D71	

C.3.3.2 H35 FM120 t_{final} Table Selection

C.3.3.2.1 Advanced Option A

Equation C42 provides the t_{final} table selection formulas for the H35 FM120 protocol using Advanced Option A. Using Advanced Option A, two tables are selected, one labeled $Table_{below}$, and the other labeled $Table_{above}$.

(Eq. C42)

If 248.6 ≤ V_{CHSS} ≤ 500 L, and 50 ≤ TVL ≤ 200 L, select Table D1 as $Table_{below}$ and select Table D2 as $Table_{above}$
If 500 < V_{CHSS} ≤ 1000 L, and 50 ≤ TVL ≤ 200 L, select Table D2 as $Table_{below}$ and select Table D3 as $Table_{above}$
If 1000 < V_{CHSS} ≤ 1500 L, and 50 ≤ TVL ≤ 200 L, select Table D3 as $Table_{below}$ and select Table D4 as $Table_{above}$
If 1500 < V_{CHSS} ≤ 2000 L, and 50 ≤ TVL ≤ 200 L, select Table D4 as $Table_{below}$ and select Table D5 as $Table_{above}$
If 2000 < V_{CHSS} ≤ 2500 L, and 50 ≤ TVL ≤ 200 L, select Table D5 as $Table_{below}$ and select Table D6 as $Table_{above}$
If 2500 < V_{CHSS} ≤ 5000 L, and 50 ≤ TVL ≤ 200 L, select Table D6 as $Table_{below}$ and select Table D7 as $Table_{above}$
If 5000 < V_{CHSS} ≤ 7500 L, and 50 ≤ TVL ≤ 200 L, select Table D7 as $Table_{below}$ and select Table D8 as $Table_{above}$

If 248.6 ≤ V_{CHSS} ≤ 500 L, and 200 < TVL ≤ 350 L, select Table D9 as $Table_{below}$ and select Table D10 as $Table_{above}$
If 500 < V_{CHSS} ≤ 1000 L, and 200 < TVL ≤ 350 L, select Table D10 as $Table_{below}$ and select Table D11 as $Table_{above}$
If 1000 < V_{CHSS} ≤ 1500 L, and 200 < TVL ≤ 350 L, select Table D11 as $Table_{below}$ and select Table D12 as $Table_{above}$
If 1500 < V_{CHSS} ≤ 2000 L, and 200 < TVL ≤ 350 L, select Table D12 as $Table_{below}$ and select Table D13 as $Table_{above}$
If 2000 < V_{CHSS} ≤ 2500 L, and 200 < TVL ≤ 350 L, select Table D13 as $Table_{below}$ and select Table D14 as $Table_{above}$
If 2500 < V_{CHSS} ≤ 5000 L, and 200 < TVL ≤ 350 L, select Table D14 as $Table_{below}$ and select Table D15 as $Table_{above}$
If 5000 < V_{CHSS} ≤ 7500 L, and 200 < TVL ≤ 350 L, select Table D15 as $Table_{below}$ and select Table D16 as $Table_{above}$

If 248.6 ≤ V_{CHSS} ≤ 500 L, and 350 < TVL ≤ 1000 L, select Table D9 as $Table_{below}$ and select Table D17 as $Table_{above}$
If 500 < V_{CHSS} ≤ 1000 L, and 350 < TVL ≤ 1000 L, select Table D17 as $Table_{below}$ and select Table D18 as $Table_{above}$
If 1000 < V_{CHSS} ≤ 1500 L, and 350 < TVL ≤ 1000 L, select Table D18 as $Table_{below}$ and select Table D19 as $Table_{above}$
If 1500 < V_{CHSS} ≤ 2000 L, and 350 < TVL ≤ 1000 L, select Table D19 as $Table_{below}$ and select Table D20 as $Table_{above}$
If 2000 < V_{CHSS} ≤ 2500 L, and 350 < TVL ≤ 1000 L, select Table D20 as $Table_{below}$ and select Table D21 as $Table_{above}$
If 2500 < V_{CHSS} ≤ 5000 L, and 350 < TVL ≤ 1000 L, select Table D21 as $Table_{below}$ and select Table D22 as $Table_{above}$
If 5000 < V_{CHSS} ≤ 7500 L, and 350 < TVL ≤ 1000 L, select Table D22 as $Table_{below}$ and select Table D23 as $Table_{above}$

If V_{CHSS} = ND, select Table D36 as $Table_{below}$ and select Table D36 as $Table_{above}$

C.3.3.2.2 Basic Option B

Equation C43 provides the t_{final} table selection formulas for the H35 FM120 protocol using Basic Option B. Using Basic Option B, only one table is selected.

(Eq. C43)

If 248.6 ≤ V_{CHSS} ≤ 1000 L, and 50 ≤ TVL ≤ 200 L, select Table D24
If 1000 < V_{CHSS} ≤ 2000 L, and 50 ≤ TVL ≤ 200 L, select Table D25
If 2000 < V_{CHSS} ≤ 5000 L, and 50 ≤ TVL ≤ 200 L, select Table D26
If 5000 < V_{CHSS} ≤ 7500 L, and 50 ≤ TVL ≤ 200 L, select Table D27

If 248.6 ≤ V_{CHSS} ≤ 1000 L, and 200 < TVL ≤ 350 L, select Table D28
If 1000 < V_{CHSS} ≤ 2000 L, and 200 < TVL ≤ 350 L, select Table D29
If 2000 < V_{CHSS} ≤ 5000 L, and 200 < TVL ≤ 350 L, select Table D30
If 5000 < V_{CHSS} ≤ 7500 L, and 200 < TVL ≤ 350 L, select Table D31

If 248.6 ≤ V_{CHSS} ≤ 1000 L, and 350 < TVL ≤ 1000 L, select Table D32
If 1000 < V_{CHSS} ≤ 2000 L, and 350 < TVL ≤ 1000 L, select Table D33
If 2000 < V_{CHSS} ≤ 5000 L, and 350 < TVL ≤ 1000 L, select Table D34
If 5000 < V_{CHSS} ≤ 7500 L, and 350 < TVL ≤ 1000 L, select Table D35

If V_{CHSS} = ND, select Table D36

C.3.3.3 H35 FM60 or H70 FM60/FM90/FM300 t_{final} Table Selection

C.3.3.3.1 Advanced Option A

Equation C44 provides the t_{final} table selection formulas for the H35 FM60 or H70 FM60/FM90/FM300 protocols using Advanced Option A. Using Advanced Option A, two tables are selected, one labeled $Table_{below}$, and the other labeled $Table_{above}$.

(Eq. C44)

If 248.6 ≤ V_{CHSS} ≤ 500 L, and 50 ≤ TVL ≤ 200 L, select Table D37 as $Table_{below}$ and select Table D38 as $Table_{above}$
If 500 < V_{CHSS} ≤ 1000 L, and 50 ≤ TVL ≤ 200 L, select Table D38 as $Table_{below}$ and select Table D39 as $Table_{above}$
If 1000 < V_{CHSS} ≤ 1500 L, and 50 ≤ TVL ≤ 200 L, select Table D39 as $Table_{below}$ and select Table D40 as $Table_{above}$
If 1500 < V_{CHSS} ≤ 2000 L, and 50 ≤ TVL ≤ 200 L, select Table D40 as $Table_{below}$ and select Table D41 as $Table_{above}$
If 2000 < V_{CHSS} ≤ 2500 L, and 50 ≤ TVL ≤ 200 L, select Table D41 as $Table_{below}$ and select Table D42 as $Table_{above}$
If 2500 < V_{CHSS} ≤ 3000 L, and 50 ≤ TVL ≤ 200 L, select Table D42 as $Table_{below}$ and select Table D43 as $Table_{above}$
If 3000 < V_{CHSS} ≤ 5000 L, and 50 ≤ TVL ≤ 200 L, select Table D43 as $Table_{below}$ and select Table D44 as $Table_{above}$

If 248.6 ≤ V_{CHSS} ≤ 500 L, and 200 < TVL ≤ 350 L, select Table D45 as $Table_{below}$ and select Table D46 as $Table_{above}$
If 500 < V_{CHSS} ≤ 1000 L, and 200 < TVL ≤ 350 L, select Table D46 as $Table_{below}$ and select Table D47 as $Table_{above}$
If 1000 < V_{CHSS} ≤ 1500 L, and 200 < TVL ≤ 350 L, select Table D47 as $Table_{below}$ and select Table D48 as $Table_{above}$
If 1500 < V_{CHSS} ≤ 2000 L, and 200 < TVL ≤ 350 L, select Table D48 as $Table_{below}$ and select Table D49 as $Table_{above}$
If 2000 < V_{CHSS} ≤ 2500 L, and 200 < TVL ≤ 350 L, select Table D49 as $Table_{below}$ and select Table D50 as $Table_{above}$
If 2500 < V_{CHSS} ≤ 3000 L, and 200 < TVL ≤ 350 L, select Table D50 as $Table_{below}$ and select Table D51 as $Table_{above}$
If 3000 < V_{CHSS} ≤ 5000 L, and 200 < TVL ≤ 350 L, select Table D51 as $Table_{below}$ and select Table D52 as $Table_{above}$

If 248.6 ≤ V_{CHSS} ≤ 500 L, and 350 < TVL ≤ 800 L, select Table D45 as $Table_{below}$ and select Table D53 as $Table_{above}$
If 500 < V_{CHSS} ≤ 1000 L, and 350 < TVL ≤ 800 L, select Table D53 as $Table_{below}$ and select Table D54 as $Table_{above}$
If 1000 < V_{CHSS} ≤ 1500 L, and 350 < TVL ≤ 800 L, select Table D54 as $Table_{below}$ and select Table D55 as $Table_{above}$
If 1500 < V_{CHSS} ≤ 2000 L, and 350 < TVL ≤ 800 L, select Table D55 as $Table_{below}$ and select Table D56 as $Table_{above}$
If 2000 < V_{CHSS} ≤ 2500 L, and 350 < TVL ≤ 800 L, select Table D56 as $Table_{below}$ and select Table D57 as $Table_{above}$
If 2500 < V_{CHSS} ≤ 3000 L, and 350 < TVL ≤ 800 L, select Table D57 as $Table_{below}$ and select Table D58 as $Table_{above}$
If 3000 < V_{CHSS} ≤ 5000 L, and 350 < TVL ≤ 800 L, select Table D58 as $Table_{below}$ and select Table D59 as $Table_{above}$

If V_{CHSS} = ND, select Table D72 as $Table_{below}$ and select Table D72 as $Table_{above}$

C.3.3.3.2 Basic Option B

Equation C45 provides the t_{final} table selection formulas for the H35 FM60 or H70 FM60/FM90/FM300 protocols using Basic Option B. Using Basic Option B, only one table is selected.

(Eq. C45)

If 248.6 ≤ V_{CHSS} ≤ 1000 L, and 50 ≤ TVL ≤ 200 L, select Table D60
If 1000 < V_{CHSS} ≤ 2000 L, and 50 ≤ TVL ≤ 200 L, select Table D61
If 2000 < V_{CHSS} ≤ 3000 L, and 50 ≤ TVL ≤ 200 L, select Table D62
If 3000 < V_{CHSS} ≤ 5000 L, and 50 ≤ TVL ≤ 200 L, select Table D63

If 248.6 ≤ V_{CHSS} ≤ 1000 L, and 200 < TVL ≤ 350 L, select Table D64
If 1000 < V_{CHSS} ≤ 2000 L, and 200 < TVL ≤ 350 L, select Table D65
If 2000 < V_{CHSS} ≤ 3000 L, and 200 < TVL ≤ 350 L, select Table D66
If 3000 < V_{CHSS} ≤ 5000 L, and 200 < TVL ≤ 350 L, select Table D67

If 248.6 ≤ V_{CHSS} ≤ 1000 L, and 350 < TVL ≤ 800 L, select Table D68
If 1000 < V_{CHSS} ≤ 2000 L, and 350 < TVL ≤ 800 L, select Table D69
If 2000 < V_{CHSS} ≤ 3000 L, and 350 < TVL ≤ 800 L, select Table D70
If 3000 < V_{CHSS} ≤ 5000 L, and 350 < TVL ≤ 800 L, select Table D71

If V_{CHSS} = ND, select Table D72

C.3.4 Subroutine - Calculation of t_{final_min}, PRR_{max}, and MFR_{min}

t_{final_min} is a t_{final} minimum value utilized to ensure that the peak mass flow rate does not exceed the limit value for the Flow Rate Maximum Class and pressure class. t_{final_min} is used in Equation C78. t_{final_min} is also used to calculate PRR_{max}, which is used in Equations C80 and C82. The unit of measure for t_{final_min} is seconds.

In Equation C46, if V_{CHSS} is indeterminate, it should be set to a value representing the largest CHSS expected to fuel at the station. For a publicly accessible station, this may be based on the vehicle with the largest known CHSS volume, or for a controlled access station, the vehicle with the largest CHSS volume with access to the station. If there is uncertainty regarding the vehicle with the largest know CHSS volume, then V_{CHSS} can be set to the largest value allowed for the pressure class. The unit of measure for t_{final_min} is seconds, and the unit of measure for PRR_{max} is MPa/s.

(Eq. C46)

For H35 FM60 or H70 FM60/FM90/FM300

$$IF\ V_{CHSS} = ND$$

$$THEN$$

$$Utilize\ V_{CHSS} = the\ largest\ expected\ CHSS\ volume\ in\ Equation\ C46\ only$$

$$End\ IF$$

$$t_{final\_min} = \left(\frac{87.5 - P_{min}}{82.5}\right) \times \left(\frac{300}{FM}\right) \times (0.2107041 \times V_{CHSS} - 0.00000538442 \times V_{CHSS}^2 - 18.2)$$

$$IF\ t_{final\_min} < 200$$

$$THEN$$

$$t_{final\_min} = 200$$

$$END\ IF$$

$$PRR_{max} = \left(\frac{87.5 - P_{min}}{\beta \times t_{final\_min}}\right)$$

For H35 FM120

$$IF\ V_{CHSS} = ND$$

$$THEN$$

$$Utilize\ V_{CHSS} = the\ largest\ expected\ CHSS\ volume\ in\ Equation\ C46\ only$$

$$END\ IF$$

$$t_{final\_min} = \left(\frac{43.75 - P_{min}}{40.75}\right) \times (0.259 \times V_{CHSS} - 13.6)$$

$$IF\ t_{final\_min} < 200$$

$$THEN$$

$$t_{final\_min} = 200$$

$$END\ IF$$

$$PRR_{max} = \left(\frac{43.75 - P_{min}}{\beta \times t_{final\_min}}\right)$$

MFR_{min} represents the minimum mass flow rate allowed (see 8.4.4.2). MFR_{min} is a function of V_{CHSS}. MFR_{min} is set by interpolating on V_{CHSS} according to the values in Table C9 using Equation C47. If V_{CHSS} = ND, no interpolation is used, and MRF_{min} is set to 1.25. The unit for MFR_{min} is grams per second.

Table C9 - Table of MFR_{min} values as a function of V_{CHSS}

V_{CHSS} (liters)	MFR_{min} (g/s)
ND	1.25
250	1.25
500	2.5
750	3.75
1000	5.0
1500	7.5
≥2000	10.0

$$MFR_{min} = MFR_{min(Table_{below})} + \frac{[MFR_{min(Table_{above})} - MFR_{min(Table_{below})}] \times [V_{CHSS} - V_{CHSS(Table_{below})}]}{[V_{CHSSS(Table_{above})} - V_{CHSS(Table_{below})}]} \quad \text{(Eq. C47)}$$

As an example, if V_{CHSS} = 1200 L, MFR_{min} is calculated as follows:

$$MFR_{min} = 7.5 + \frac{[5.0 - 7.5] \times [1200 - 1500]}{[1000 - 1500]} = 6.0$$

C.3.5 Subroutine - t_{final} Vector Interpolation

C.3.5.1 Introduction

This subroutine uses interpolation to calculate a t_{final} vector, which is then used in the Calculation of t_{final} Subroutine (see C.3.11) to calculate the t_{final} value used for control in the PRR equation. The t_{final} table(s) from the Selection of t_{final} Tables Subroutine are used. If Advanced Option A is utilized in the Selection of t_{final} Tables, there is an additional interpolation step.

C.3.5.2 Interpolation for Advanced Option A

This subsection only applies if Advanced Option A is used in the Selection of t_{final} Tables Subroutine. If Basic Option B is used, then this subsection does not apply and C.3.5.3 shall be used.

For the $Table_{below}$ and $Table_{above}$, select the row of t_{final} values for the ambient temperature directly above T_{amb}. For example, if T_{amb} = 32 °C, select the row of t_{final} values for an ambient temperature of 35 °C. Interpolate these two rows of t_{final} values on V_{CHSS} using Equation C48. If V_{CHSS} is indeterminate, then interpolation is not necessary because the $Table_{below}$ and $Table_{above}$ are the same table. Therefore, if V_{CHSS} is indeterminate, Equations C48 and C49 are not applicable.

(Eq. C48)

For each t_{final} value in the row, calculate an interpolated t_{final} value as follows:

$$t_{final(MAT_C)(T_{amb\_above})} = t_{final(MAT_C)(T_{amb\_above})(Table_{below})} + \frac{[t_{final(MAT_C)(T_{amb\_above})(Table_{above})} - t_{final(MAT_C)(T_{amb\_above})(Table_{below})}] \times [V_{CHSS} - V_{table\_below}]}{[V_{table\_above} - V_{table\_below}]}$$

Next, for the $Table_{below}$ and $Table_{above}$, select the row of t_{final} values for the ambient temperature directly below T_{amb}. For example, if T_{amb} = 32 °C, select the row of t_{final} values for an ambient temperature of 30 °C. Interpolate these two rows of t_{final} values on V_{CHSS} using Equation C49. If V_{CHSS} is indeterminate, then interpolation is not necessary because the $Table_{below}$ and $Table_{above}$ are the same table.

(Eq. C49)

For each t_{final} value in the row, calculate an interpolated t_{final} value as follows:

$$t_{final(MAT_C)(T_{amb\_below})} = t_{final(MAT_C)(T_{amb\_below})(Table_{below})} + \frac{[t_{final(MAT_C)(T_{amb\_below})(Table_{above})} - t_{final(MAT_C)(T_{amb\_below})(Table_{below})}] \times [V_{CHSS} - V_{table\_below}]}{[V_{table\_above} - V_{table\_below}]}$$

See the example in Table C10 for the application of Equations C48 and C49 for a T_{amb} of 32 °C and V_{CHSS} of 1200 L. The output is an interpolated row of values for an ambient temperature of 35 °C and 30 °C. Note that this example is truncated to save space.

Table C10 - Example of the application of Equations C48 and C49

	Row Temperature	Volume	MAT$_C$ (°C)										
			-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20
Table$_{above}$	35 °C	1500 L	400	450	500	550	600	650	700	750	800	850	900
Table$_{below}$	35 °C	1000 L	350	400	450	500	550	600	650	700	750	800	850
Interpolated T_{amb_above}	**35 °C**	**1200 L**	**370**	**420**	**470**	**520**	**570**	**620**	**670**	**720**	**770**	**820**	**870**
Table$_{above}$	30 °C	1500 L	350	400	450	500	550	600	650	700	750	800	850
Table$_{below}$	30 °C	1000 L	300	350	400	450	500	550	600	650	700	750	800
Interpolated T_{amb_below}	**30 °C**	**1200 L**	**320**	**370**	**420**	**470**	**520**	**570**	**620**	**670**	**720**	**770**	**820**

The next step is to interpolate the two rows on the ambient temperature T_{amb} using Equation C50.

(Eq. C50)

For each t_{final} value in the row, calculate an interpolated t_{final} value as follows:

$$t_{final(MAT_C)} = t_{final(MAT_C)(T_{amb\_below})} + \frac{[t_{final(MAT_C)(T_{amb\_above})} - t_{final(MAT_C)(T_{amb\_below})}] \times [T_{amb} - T_{amb\_below}]}{[T_{amb\_above} - T_{amb\_below}]}$$

See the example in Table C11 for the application of Equation C50 for a T_{amb} of 32 °C and V_{CHSS} of 1200 L. The output is an interpolated row of values for an ambient temperature of 32 °C. This is the t_{final} vector.

Table C11 - Example of the application of Equation C50

	Row Temperature	Volume	MATC (°C)										
			-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20
Eq. C48 T_{amb_above}	35 °C	1200 L	370	420	470	520	570	620	670	720	770	820	870
Eq. C49 T_{amb_below}	30 °C	1200 L	320	370	420	470	520	570	620	670	720	770	820
Interpolated t_{final} vector Eq. C50	**32 °C**	**1200 L**	**340**	**390**	**440**	**490**	**540**	**590**	**640**	**690**	**740**	**790**	**840**

After interpolation, a t_{final} vector is stored, i.e., a t_{final} value for each MAT_C value in the table. Using the example in Table C11, the vector would be as follows:

t_{final} vector → $t_{final(-40)}$ = 340, $t_{final(-38)}$ = 390, $t_{final(-36)}$ = 440, $t_{final(-34)}$ = 490, $t_{final(-32)}$ = 540, $t_{final(-30)}$ = 590, $t_{final(-28)}$ = 640, $t_{final(-26)}$ = 690, $t_{final(-24)}$ = 740, $t_{final(-22)}$ = 790, $t_{final(-20)}$ = 840, etc. (Example is truncated.)

C.3.5.3 Interpolation for Basic Option B

This subsection only applies if Basic Option B is used in the Selection of t_{final} Tables Subroutine. If Advanced Option A is used, then this subsection does not apply and C.3.5.2 shall be used.

Using the t_{final} Table selected in the Selection of t_{final} Tables Subroutine, select the row of t_{final} values for the ambient temperature directly above and directly below T_{amb}. For example, if T_{amb} = 32 °C, select the row of t_{final} values for an ambient temperature of 35 °C (T_{amb_above}) and an ambient temperature of 30 °C (T_{amb_below}). Interpolate these two rows of t_{final} values on T_{amb} using Equation C51.

(Eq. C51)

For each t_{final} value in the row, calculate an interpolated t_{final} value as follows:

$$t_{final(MAT_C)} = t_{final(MAT_C)(T_{amb\_below})} + \frac{\left[t_{final(MAT_C)(T_{amb\_above})} - t_{final(MAT_C)(T_{amb\_below})}\right] \times \left[T_{amb} - T_{amb\_below}\right]}{\left[T_{amb\_above} - T_{amb\_below}\right]}$$

See the example in Table C12 for the application of Equation C51 for a T_{amb} of 32 °C and V_{CHSS} of 1200 L. The output is an interpolated row of values for an ambient temperature of 32 °C. This is the t_{final} vector.

Note that this example is truncated to save space.

Table C12 - Example of the application of Equation C51

	Row Temperature	MATC (°C)										
		-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20
T_{amb_above}	35 °C	370	420	470	520	570	620	670	720	770	820	870
T_{amb_below}	30 °C	320	370	420	470	520	570	620	670	720	770	820
Interpolated t_{final} vector Eq. C51	**32 °C**	**340**	**390**	**440**	**490**	**540**	**590**	**640**	**690**	**740**	**790**	**840**

After interpolation, a t_{final} vector is stored, i.e., a t_{final} value for each MAT_C value in the table. Using the example in Table C12, the vector would be as follows for the H70 Pressure Class:

t_{final} vector → $t_{final(-40)}$ = 340, $t_{final(-38)}$ = 390, $t_{final(-36)}$ = 440, $t_{final(-34)}$ = 490, $t_{final(-32)}$ = 540, $t_{final(-30)}$ = 590, $t_{final(-28)}$ = 640, $t_{final(-26)}$ = 690, $t_{final(-24)}$ = 740, $t_{final(-22)}$ = 790, $t_{final(-20)}$ = 840, etc. (Example is truncated.)

C.3.6 Subroutine - Fueling Time Indicator

This subroutine is used to set the Fueling Time Indicator or FTI. FTI determines the state of fueling. When FTI is set to 1, fueling is proceeding as normal, and the ramp pressure P_{ramp} is advancing. When FTI is set to 0, fueling is paused (i.e., there is no mass flow) due to an intended non-fueling event such as a leak check or a bank switch. The dispenser shall determine when a pause is appropriate. For example, a dispenser may decide to set FTI to 0 during a bank switch, which may only take a couple of seconds to complete, or, alternatively, it may decide to leave FTI set to 1 during a bank switch. FTI shall be set at each timestep j, which means FTI is determined and set once every second. The value of FTI at timestep j determines whether P_{ramp} advances during timestep j=1 (see Equation C83).

FTI shall only be set to 0 for the purpose of an intended non-fueling event. Furthermore, each time that FTI is set to 0, the mass flow rate shall fall below 1% of the FM value for at least 1 timestep during the period that FTI=0.

(Eq. C52)

$$IF\ Fueling\ is\ Active$$

$$Set\ FTI_{(j)} = 1$$

$$ELSE\ IF\ Fueling\ is\ Paused$$

$$Set\ FTI_{(j)} = 0$$

C.3.7 Subroutine - CHSS Volume Measurement

This subroutine is optional. If the CHSS volume is indeterminate (i.e., cannot be determined via communications), this subroutine provides a methodology for calculating the CHSS volume with an accuracy better than ±15%, depending on the accuracy of the mass and station pressure measurements. See Appendix F for additional information on the development and implementation of the volume measurement method prescribed in this subroutine.

NOTE: This methodology is new and has not been validated in the field. Users should validate the accuracy over the full range of CHSS anticipated at the station.

Because the range of CHSS volumes for the MCF-HF-G fueling protocol is very wide, the 500 g of mass dispensed allowed during startup is insufficient to measure the CHSS volume with an accuracy of ±15%. Therefore, the CHSS volume must be measured during the main fueling time. Once the CHSS volume has been measured using the approach in this subroutine, the t_{final} vector is then recalculated using the determined V_{CHSS}.

The CHSS volume measurement requires knowledge of the dispenser’s pressure transducer accuracy and the accuracy of the mass dispensed. The dispenser pressure transducer accuracy can be obtained from the manufacturer. The accuracy of the mass dispensed can be obtained from the dispenser’s metrology certification, or, alternatively, an accuracy value from the mass flow meter manufacturer can be used. Equations C53 and C54 are used to set the tolerance of the dispenser pressure and mass flow measurements, respectively. Tolerance is the deviation above/below the true value. For example, if the pressure transducer has an accuracy of ±0.2 MPa, then the tolerance P_{tol} is 0.2. Likewise, if the mass flow measurement has an accuracy of ±2.5%, then the tolerance m_{tol} is 0.025.

The CHSS volume measurement criteria in Equation C57 is evaluated based on a timestep j, which is advanced every 1 second. However, the CHSS volume measurement is only conducted one time and shall be initiated within 10 timesteps of the criteria in Equation C57 being satisfied. Note that the volume measurement will take several timesteps to complete to allow sufficient time for the mass flow to stop completely.

Set the dispenser pressure tolerance using Equation C53.

$$Set\ P_{tol}\ (units\ of\ MPa) \tag{Eq. C53}$$

Set the mass flow measurement tolerance using Equation C54.

$$Set\ m_{tol}\ (units\ of\ percent, expressed\ as\ a\ fraction\ of\ 100) \tag{Eq. C54}$$

Calculate P_0 using Equation C55.

$$P_0 = P_{startup} + P_{tol} \tag{Eq. C55}$$

Calculate the initial density as function of P_0 and T_{amb} using an appropriate equation of state. An equation for density is provided in C.4.4 (see Equation C105), although an alternative equation of state may be used. The unit for ρ_0 is kilograms per cubic meter or grams per liter.

$$\rho_0 = f(P_0, T_{amb}) \tag{Eq. C56}$$

Equation C57 provides the formula for calculating the CHSS volume. This calculation shall only be done one time during the fueling event. The dispenser shall pause the fueling within 10 timesteps after the initial criteria for $P_{station(j)}$ and $P_{ramp(j)}$ in Equation C57 has been met. The pause should be sufficiently long to ensure that the mass flow has stopped completely. The calculations are conducted during this pause period.

(Eq. C57)

$$For\ H35\ FM120:$$

$$\Delta P_{VC} \geq 11.38 - 0.5476P_{startup} + 0.02159P_{startup}^2 - 0.0003148P_{startup}^3$$

$$For\ H35\ FM60\ or\ H70\ FM60, FM90, FM300:$$

$$\Delta P_{VC} \geq 13.03 - 0.3642P_{startup} + 0.007208P_{startup}^2 - 0.0000542P_{startup}^3$$

$$IF\ P_{station(j)} \geq P_{startup} + \Delta P_{VC}\ AND\ P_{ramp(j)} \geq P_{startup} + \Delta P_{VC}$$

$$THEN$$

$$Pause\ fueling\ (stop\ the\ mass\ flow\ completely)\ within\ 10\ timesteps\ of\ the\ IF\ condition\ first\ being\ satisfied$$

$$and\ then\ conduct\ the\ following\ calculations\ after\ a\ sufficient\ settlement\ time\ (e.g., 5\ seconds)$$

$$For\ H35\ FM120:$$

$$\Delta T_{CHSS} = 26.59 - 1.4955P_{startup} + 0.04832P_{startup}^2 - 0.0006182P_{startup}^3$$

$$For\ H35\ FM60\ or\ H70\ FM60, FM90, FM300:$$

$$\Delta T_{CHSS} = 27.79 - 1.4867P_{startup} + 0.03834P_{startup}^2 - 0.0003513P_{startup}^3$$

$$T_{VC} = T_{amb} + \Delta T_{CHSS}$$

$$P_{VC} = P_{station\_pause} - P_{tol}$$

$$NOTE:\ P_{station_{pause}}\ is\ the\ P_{station}\ value\ after\ mass\ flow\ has\ stopped\ completely$$

$$\rho_{VC} = f(P_{VC}, T_{VC})$$

$$NOTE: this\ density\ \rho_{VC}\ is\ calculated\ using\ the\ same\ equation\ of\ state\ used\ in\ Equation\ \ C56$$

$$\Delta\rho_{VC} = \rho_{VC} - \rho_0$$

$$\Delta m_{VC} = m - m_0\ (where\ m\ represents\ the\ accumulated\ mass\ in\ grams\ after\ flow\ has\ stopped\ completely)$$

$$\Delta m_{VC\_tol} = \Delta m_{VC}(1 + m_{tol})$$

$$V_{CHSS} = \left(\frac{\Delta m_{VC\_tol}}{\Delta\rho_{VC}}\right)$$

For H35 FM60 or H70 FM60/FM90/FM300

$$IF\ 248.6\ \leq\ V_{CHSS}\ \leq 5000$$

$$Continue$$

$$ELSE\ Stop\ Fueling$$

$$END\ IF$$

For H35 FM120

$$IF\ 248.6\ \leq\ V_{CHSS}\ \leq 7500$$

$$Continue$$

$$ELSE\ Stop\ Fueling$$

$$END\ IF$$

$$Go\ to\ the\ Selection\ of\ t_{final}\ Table\ Subroutine, Section\ C.3.3$$

$$END\ IF$$

After V_{CHSS} has been calculated using Equation C57, go to the Selection of t_{final} Table Subroutine and select the correct t_{final} table(s) based on V_{CHSS}, then go to the Calculation of t_{final_min} and calculate the correct t_{final_min} value based on V_{CHSS}, and then go to the t_{final} Vector Interpolation Subroutine and recalculate the t_{final} vector. Then, proceed through the subsequent subroutines as normal.

C.3.8 Subroutine - Calculation of K_0

C.3.8.1 Introduction

This subroutine is optional. This subroutine is used to calculate a parameter K_0. For further information on the development and application of the K_0 approach, refer to Handa and Yamaguchi (2018). K_0 is used to calculate a “synthetic” measured pressure named MP_{calc}. MP_{calc} may be used for both non-communications fueling and for communications fueling.

For non-communications fueling, MP_{calc} is used in the Pressure Ramp Rate Taper equation (see Equation C82) and in the Evaluate End-of-Fill Criteria for Non-Communications Fueling, Equation C88, Option 2. The attributes of the PRR Taper method are described in Appendix E. The attribute of using MP_{calc} for end-of-fill determination with non-communications fueling in Equation C88 is a higher end-of-fill SOC.

For communications fueling, MP_{calc} is used in the Evaluate End-of-Fill Criteria for Communications Fueling, Equation C89, Option 2. In Option 2, MP_{calc} is compared to P_{limit_comm} instead of $P_{station}$ being compared to P_{limit_comm}. This allows the station pressure to exceed P_{limit_comm}, which in some instances, will result in a higher-ending SOC, especially for fills that end with a relatively high measured temperature MT.

The Calculation of K_0 is only conducted during intended non-fueling time. The accuracy of K_0 depends on the pressure drop between the station pressure $P_{station}$ and the CHSS pressure, which is a function of the mass flow rate. The higher the mass flow rate, the more accurate K_0 should be. Therefore, K_0 should only be calculated when the mass flow rate at the time of calculation is higher than the previous time at which K_0 was measured.

The criteria for measuring K_0 in Equation C58 is evaluated based on a timestep j, which is advanced every 1 second. However, K_0 is actually measured only during the timesteps where the criteria in Equation C58 are satisfied, and it will take several timesteps to conduct the measurement.

NOTE: The K_0 method is new and has not been validated in the field. Users should validate the accuracy over the full range of CHSS anticipated at the station.

C.3.8.2 Calculation of K_0

Equation C58 shall only be conducted during an intended non-fueling event.

(Eq. C58)

$$IF\ FTI_{(j)} = 0$$

$$AND$$

$$If\ dispenser\ is\ implementing\ an\ intended\ non-fueling\ event\ where\ the\ mass\ flow\ will\ stop\ completely$$

$$AND$$

$$IF\ \dot{m}_{(j)}\ just\ prior\ to\ FTI\ changing\ from\ 1\ to\ 0\ is\ greater\ than\ \dot{m}\ at\ the\ previous\ time\ K_0\ was\ measured$$

$$THEN$$

$$Measure\ P_{station}\ and\ \dot{m}\ just\ prior\ to\ FTI\ changing\ from\ 1\ to\ 0$$

$$P_{station\_flow} = P_{station}\ just\ prior\ to\ FTI\ changing\ from\ 1\ to\ 0$$

$$\dot{m}_{flow} = \dot{m}\ just\ prior\ to\ FTI\ changing\ from\ 1\ to\ 0$$

$$\rho_{K0} = f\left(P_{station\_flow}, T_{fuel\_inst(j)}\right)\ using\ an\ appropriate\ equation\ of\ state\ for\ density\ such\ as\ Eq.C105$$

$$Measure\ P_{station}\ \ after\ the\ mass\ flow\ has\ completely\ stopped$$

$$P_{station\_no\_flow} = P_{station}\ \ after\ the\ mass\ flow\ has\ completely\ stopped$$

$$K_0 = \frac{\rho_{K0}\left(P_{station\_flow} - P_{station\_no\_flow}\right)}{\dot{m}_{flow}^2}$$

$$END\ IF$$

C.3.9 Subroutine - Mass Average Calculations

C.3.9.1 Introduction

This subroutine is used to calculate the mass average of the fuel delivery temperature measured at the dispenser outlet and the mass average of enthalpy measured at the dispenser outlet. The mass average of enthalpy is only calculated if the MC Method is used as the ending pressure control option. These mass average calculations shall be conducted using the timestep j, which means they are calculated once every second.

The mass average calculations in this subroutine utilize inputs from the dispenser pressure sensor and the fuel delivery temperature sensor. The location, accuracy, and reliability requirements for these sensors are listed in 6.1.

A method of fault detection (sensor drift or failure) of the fuel delivery temperature measurement should be utilized. Although this subroutine does not prescribe a methodology for ensuring the integrity of this measurement, the requirements of 6.1.4 should be adhered to. As an example of a potential methodology, redundancy may be applied so that the mass average of two temperature measurements is compared, and if the absolute value of their difference is greater than a limit criterion, the dispenser faults and stops the fill. The limit criterion should be determined by the dispenser manufacturer based on sensor type used and its standard error. An example of a limit criterion is the standard error of the sensor or some multiple thereof. It should be noted that the mass average calculation is inherently more accurate the more mass that is dispensed. Thus, the dispenser manufacturer may decide to implement the limit criterion after a certain amount of time has passed or mass has been dispensed. Alternatively, the limit criterion can be progressive in nature, such that it decreases with increasing elapsed time or mass dispensed.

In addition to implementing a fault detection methodology, the error of the temperature measurement should also be considered and the requirements of 6.1.2 adhered to. Typically, a temperature sensor will employ a standard measurement error of ±X, where X is expressed in the units of measurement. In this case, to ensure that the most conservative measurement is utilized as the control input, for the fuel delivery temperature utilized in the mass average fuel delivery temperature calculation, the + measurement error should be added to the measured value, and for the fuel delivery temperature utilized in the mass average enthalpy calculation, the + measurement error should be subtracted from the measured value. Alternatively, if the sensor has been calibrated by an accredited laboratory, the measured value can be corrected by the calibrated error for both the mass average temperature and enthalpy calculations.

If redundancy is employed and two fuel delivery temperatures are measured, then two mass average values (represented as A and B) should be calculated and the most conservative value utilized as the control input.

C.3.9.2 Mass Average Calculation of the Fuel Delivery Temperature Subroutine

A key control input for determining the PRR is the mass average of the fuel delivery temperature measured at the dispenser outlet. There are two mass average calculations, MAT_0 and MAT_{30}. MAT_0 begins the calculation at the beginning of the main fueling time from t = 0 seconds (once mass flow has begun). MAT_{30} begins the calculation after a total of 30 seconds of mass flow have elapsed. See A.2.1.4 for a detailed explanation of how the mass average of the fuel delivery temperature is used in the PRR control. The unit of measure for MAT_0 and MAT_{30} is degrees Celsius (°C).

In the equations in this subroutine, T_{fuel_inst} is the fuel delivery temperature measured at the dispenser outlet, and m represents the total mass dispensed from the beginning of the main fueling time. $T_{fuel\_inst(j)}$ represents the temperature measured at the current timestep j. $T_{fuel\_inst(j-1)}$ represents the temperature measured at the previous timestep j-1. $T_{fuel\_inst\_A}$ and $T_{fuel\_inst\_B}$ represent two separate measurements when redundancy is employed. $m_{(j)}$ represents the total mass dispensed up to the current timestep j. $m_{(j-1)}$ represents the total mass dispensed up to the previous timestep j-1. Thus, $m_{(j)}$ - $m_{(j-1)}$ represents the change in mass over the last timestep j. The unit of measure for T_{fuel_inst} is degrees Celsius (°C). The unit of measure for m is grams.

In Equations C59 and C60 for MAT_0 and Equations C62 and C63 for MAT_{30}, and Equation C65, which utilizes MAT_{30}, a parameter named n (a counter) is utilized for determining the point in the fill at which these calculations shall commence. The calculation of MAT_0 begins after mass flow commences and the calculation of MAT_{30} begins after a total of 30 seconds of mass flow have elapsed. Because the timestep counter j advances every second, regardless of whether there is mass flow or not, a separate counter n, which updates at the same frequency as j, is utilized. The difference between n and j is that n only updates when there is mass flow during the calculation cycle, which means that n does not advance during an intended non-fueling event such as a leak check or bank switch. Since, by definition, the calculation of MAT_0 begins after mass flow has initiated, and the calculation of MAT_{30} begins after a total of 30 seconds of mass flow, the calculation of MAT_0 begins when n=1 and the calculation of MAT_{30} begins when n=30. Since the summation terms in the numerator and denominator of Equations C59, C60, C62, and C63 utilize the timestep j, the time at which the calculation begins in Equations C59 and C60 is denoted by j at n=1, and the time at which the calculations begins in Equations C62 and C63 is denoted by j at n=30, which represents the value of j when the counter n reaches 30. If there are no intended non-fueling events during the first 30 seconds of the fill, then j and n will reach 30 at the same time (assuming that n=1 when j=1).

If an intended non-fueling event occurs when $20 \le n \le 30$, then subtract 10 seconds from n. In this case, a total of 40 seconds of mass flow are allowed prior to the MAT_{30} calculation beginning. The purpose of subtracting 10 seconds is to allow the fuel delivery temperature T_{fuel_inst} to get cold again after the warming which occurs during the intended non-fueling event.

It is important that the denominator in Equations C59, C60, C62, and C63 be calculated as the sum of $m_{(j)} - m_{(j-1)}$, rather than just using the value $m - m_{(j@n=1)}$ (see Equations C59 and C60), or $m - m_{(j@n=30)}$ (see Equations C62 and C63). This is because the mass average is a weighting function, and thus, the change in mass for the numerator and denominator must be summed in the same way.

$$IF\ n = 0,\ THEN\ MAT_{0\_A} = T_{fuel\_inst\_A(0)},\ ELSE\ \ MAT_{0\_A} = \frac{\sum_{j@n=1}^{j}\left[\left(m_{(j)} - m_{(j-1)}\right) \times 0.5\left(T_{fuel\_inst\_A(j)} + T_{fuel\_inst\_A(j-1)}\right)\right]}{\sum_{j@n=1}^{j}\left(m_{(j)} - m_{(j-1)}\right)} \quad \text{(Eq. C59)}$$

$$IF\ n = 0,\ THEN\ MAT_{0\_B} = T_{fuel\_inst\_B(0)},\ ELSE\ \ MAT_{0\_B} = \frac{\sum_{j@n=1}^{j}\left[\left(m_{(j)} - m_{(j-1)}\right) \times 0.5\left(T_{fuel\_inst\_B(j)} + T_{fuel\_inst\_B(j-1)}\right)\right]}{\sum_{j@n=1}^{j}\left(m_{(j)} - m_{(j-1)}\right)} \quad \text{(Eq. C60)}$$

$$MAT_0 = MAXIMUM\left[MAT_{0\_A}, MAT_{0\_B}\right] \quad \text{(Eq. C61)}$$

$$IF\ n \ge 30,\ THEN\ MAT_{30\_A} = \frac{\sum_{j@n=30}^{j}\left[\left(m_{(j)} - m_{(j-1)}\right) \times 0.5\left(T_{fuel\_inst\_A(j)} + T_{fuel\_inst\_A(j-1)}\right)\right]}{\sum_{j@n=30}^{j}\left(m_{(j)} - m_{(j-1)}\right)} \quad \text{(Eq. C62)}$$

$$IF\ n \ge 30,\ THEN\ MAT_{30\_B} = \frac{\sum_{j@n=30}^{j}\left[\left(m_{(j)} - m_{(j-1)}\right) \times 0.5\left(T_{fuel\_inst\_B(j)} + T_{fuel\_inst\_B(j-1)}\right)\right]}{\sum_{j@n=30}^{j}\left(m_{(j)} - m_{(j-1)}\right)} \quad \text{(Eq. C63)}$$

$$MAT_{30} = MAXIMUM\left[MAT_{30\_A}, MAT_{30\_B}\right] \quad \text{(Eq. C64)}$$

The mass average of the fuel delivery temperature which is utilized as the control input for the t_{final} equation is labeled as MAT_C. MAT_C is calculated from either $MAT_{expected}$, MAT_{30}, or a combination of MAT_{30} and MAT_0. The logic for making this determination is explained in A.2.1.4. Equation C65 is utilized to calculate MAT_C.

(Eq. C65)

$$IF$$

$$n \leq 30$$

$$THEN$$

$$MAT_C = MAT_{expected}$$

$$ELSE$$

$$IF\ P_{ramp} \leq P_{trans}$$

$$THEN$$

$$MAT_C = MAT_{30}$$

$$ELSE$$

$$IF\ P_{trans} < P_{ramp} \leq P_{final}$$

$$THEN$$

$$MAT_C = MAT_{30} \times \left(\frac{P_{final} - P_{ramp}}{P_{final} - P_{trans}}\right) + MAT_0 \times \left(1 - \frac{P_{final} - P_{ramp}}{P_{final} - P_{trans}}\right)$$

$$END\ IF$$

C.3.9.3 Mass Average Calculation of Enthalpy Subroutine

This subroutine is only applicable if the MC Method is utilized as the ending pressure control option. If Ending Pressure Tables are the ending pressure control option, this subroutine is not applicable.

In the equations in this subroutine, T_{fuel_inst} is the temperature measured at the dispenser outlet, $P_{station}$ is the station pressure measured at the dispenser outlet, h represents the specific enthalpy calculated at the dispenser outlet, and m represents the total mass dispensed from the beginning of the main fueling time. $h_{(j)}$ represents the specific enthalpy calculated at the current timestep j. $h_{(j-1)}$ represents the specific enthalpy calculated at the previous timestep j-1. $T_{fuel\_inst\_A}$ and $T_{fuel\_inst\_B}$, and h_A and h_B represent two separate measurements when redundancy is employed. $m_{(j)}$ represents the total mass dispensed up to the current timestep j. $m_{(j-1)}$ represents the total mass dispensed up to the previous timestep j-1. Thus, $m_{(j)} - m_{(j-1)}$ represents the change in mass over the last timestep j. The unit of measure for T_{fuel_inst} is degrees Celsius (°C), and the unit of measure for m is grams.

Equations C66 through C69 are used to calculate the mass average of the dispenser outlet enthalpy h_{ave}. The equation for specific enthalpy as a function of temperature and pressure is not given here, but guidance for the calculation of specific enthalpy is given in C.4.1, and if desired, a reference equation for specific enthalpy is provided by Equation C102. When using Equation C102, the unit of measure for temperature is kelvin (K), and the unit of measure for pressure is megapascals. The unit of measure for h and h_{ave} is kilojoules per kilogram.

It is important that the denominator in Equations C67 and C68 be calculated as the sum of $m_{(j)} - m_{(j-1)}$, rather than just using the value $m - m_{(j@n=1)}$. This is because the mass average is a weighting function, and, thus, the change in mass for the numerator and denominator must be summed in the same way.

$$h_{A(j)} = h\left[\left(T_{fuel\_inst\_A(j)} + 273.15\right), P_{station(j)}\right], \;\; h_{B(j)} = h\left[\left(T_{fuel\_inst\_B(j)} + 273.15\right), P_{station(j)}\right] \quad \text{(Eq. C66)}$$

$$IF\ n = 0,\ h_{ave\_A} = h_{A(0)}\ \ ELSE\ \ h_{ave\_A} = \frac{\sum_{j@n=1}^{j}\left[\left(m_{(j)} - m_{(j-1)}\right) \times 0.5\left(h_{A(j)} + h_{A(j-1)}\right)\right]}{\sum_{j@n=1}^{j}\left(m_{(j)} - m_{(j-1)}\right)} \quad \text{(Eq. C67)}$$

$$IF\ n = 0,\ h_{ave\_B} = h_{B(0)}\ \ ELSE\ \ h_{ave\_B} = \frac{\sum_{j@n=1}^{j}\left[\left(m_{(j)} - m_{(j-1)}\right) \times 0.5\left(h_{B(j)} + h_{B(j-1)}\right)\right]}{\sum_{j@n=1}^{j}\left(m_{(j)} - m_{(j-1)}\right)} \quad \text{(Eq. C68)}$$

$$h_{ave} = MINIMUM\left[h_{ave\_A}, h_{ave\_B}\right] \quad \text{(Eq. C69)}$$

C.3.10 Subroutine - Calculation of T_{cold}

This subroutine is only applicable if the MC Method is utilized as the ending pressure control option. If Ending Pressure Tables are the ending pressure control option, this subroutine is not applicable.

This subroutine is used to calculate the cold case CHSS gas temperature using the MC Method equations. Refer to H.3.1 of SAE J2601_202005 for a detailed explanation of the MC Method and how it is used to calculate the end-of-fill pressure target. T_{cold} represents the cold case gas temperature and is used to calculate the pressure target for non-communications fueling and the pressure limit for communications fueling.

The calculations in this subroutine shall be conducted using the timestep *j*, which means they are calculated once every second.

Equation C70 calculates the adiabatic internal energy. The unit of measure for $U_{adiabatic\_cold}$ is kilojoules.

$$U_{adiabatic\_cold(j)} = U_{init\_cold} + m_{add} \times h_{ave(j)} \quad \text{(Eq. C70)}$$

Equation C71 calculates the specific adiabatic internal energy. The unit of measure for $u_{adiabatic\_cold}$ is kilojoules per kilogram.

$$u_{adiabatic\_cold(j)} = \frac{U_{adiabatic\_cold(j)}}{m_{final\_cold}} \quad \text{(Eq. C71)}$$

Equation C72 calculates the cold case adiabatic temperature $T_{adiabatic\_cold}$. The equation for temperature as a function of pressure and specific internal energy is not given here, but guidance for this calculation is given in C.4.3, and if desired, a reference equation for temperature is provided by Equation C104. The unit of measure for $T_{adiabatic\_cold}$ is kelvin (K).

$$T_{adiabatic\_cold(j)} = f\left(P_{station(j)}, u_{adiabatic\_cold(j)}\right) \quad \text{(Eq. C72)}$$

Equation C73 calculates the cold case specific heat capacity at constant volume c_{v_cold}. The equation for specific heat capacity as a function of pressure and temperature is not given here, but guidance for this calculation is given in C.4.5, and if desired, a reference equation for specific heat capacity is provided by Equation C106. The unit of measure for c_{v_cold} is kilojoules per kilogram.

$$c_{v\_cold(j)} = f\left(P_{station(j)}, T_{adiabatic\_cold(j)}\right) \quad \text{(Eq. C73)}$$

Equations C74 and C75 are used to calculate MC_{cold}. For a detailed explanation of MC_{cold} and how it is used, refer to H.3.1 of SAE J2601_202005. The unit of measure for MC_{cold} is kilojoules per kilogram.

$$IF\ \ t > t_{\min\_cold},\ \ \Delta t_{cold(j)} = t - t_{\min\_cold},\ \ ELSE\ \ \Delta t_{cold} = 0 \tag{Eq. C74}$$

$$MC_{cold(j)} = AC + BC \times \ln\sqrt{\frac{U_{adiabatic\_cold(j)}}{U_{init\_cold}}} + GC \times \left(1 - e^{-KC\times\Delta t_{cold(j)}}\right)^{JC} \tag{Eq. C75}$$

The final step in this subroutine is to calculate T_{cold}. T_{cold} represents the cold case gas temperature in the cold case CHSS and is used in the Determine Non-Communications Fueling Pressure Target and Communications Fueling Pressure Limit using MC Method Subroutine in C.3.13.2 to calculate the pressure target for non-communications fueling and the pressure limit for communications fueling. The unit of measure for T_{cold} is kelvin (K).

$$T_{cold(j)} = \frac{m_{final\_cold}\times c_{v\_cold(j)}\times T_{adiabatic\_cold(j)} + MC_{cold(j)}\times T_{init\_cold}}{MC_{cold(j)} + m_{final\_cold}\times c_{v\_cold(j)}} \tag{Eq. C76}$$

As an example, for T_{amb} = 32 °C, $P_{initial}$ = 12 MPa, h_{ave} = 3200 kJ/kg, and t = 600 seconds, for the H70 Pressure Class, MC_{cold} = 17.6 kJ/K and T_{cold} = 294.0 K, and for the H35 Pressure Class, MC_{cold} = 17.0 kJ/K and T_{cold} = 298.3 K. These values are calculated using the reference equations in Section C.4.

C.3.11 Subroutine - Calculation of t_{final}

This subroutine is used to calculate t_{final}, which is defined as the total time required to fill from P_{min} to P_{final}. t_{final} is the key control input to the PRR equation (see Equation C80). The unit of measure for t_{final} is seconds.

The calculations in this subroutine shall be conducted using the timestep *j*, which means they are calculated once every second.

To calculate t_{final} for each timestep, the t_{final} vector calculated in the t_{final} Vector Interpolation Subroutine (see C.3.5) is utilized, along with the $MAT_{C(j)}$ from the Mass Average Calculation of the Fuel Delivery Temperature Subroutine (see C.3.9.2). From the t_{final} vector, the t_{final} value associated wth the MAT_C value directly below (colder than) $MAT_{C(j)}$ and the t_{final} value associated with the MAT_C value directly above (warmer than) $MAT_{C(j)}$ are utilized. These values are referred to as $t_{final(MATC\_below)}$ and MAT_{C_below} and $t_{final(MATC\_above)}$ and MAT_{C_above}, respectively. As an example, a shortened t_{final} vector is defined as follows: $t_{final(-40)}$ = 340, $t_{final(-38)}$ = 390, $t_{final(-36)}$ = 440, $t_{final(-34)}$ = 490, $t_{final(-32)}$ = 540, etc. In this example, if $MAT_{C(j)}$ for the current timestep is -33.1 °C, then $t_{final(MATc\_below)}$ is $t_{final(-34)}$ = 490, $MAT_{C(below)}$ is -34 °C, $t_{final(MATc\_above)}$ is $t_{final(-32)}$ = 540, and $MAT_{C(above)}$ is -32 °C.

Equation C77 derives a calculated value for t_{final} named t_{final_calc} for each timestep j. This is a preliminary value of t_{final} prior to the factors α, β, and ε being applied in Equation C78.

$$t_{final\_calc(j)} = t_{final(MAT_{C\_below})} + \frac{\left[t_{final(MAT_{C\_above})} - t_{final(MAT_{C\_below})}\right] \times \left[MAT_{C(j)} - MAT_{C(below)}\right]}{\left[MAT_{C(above)} - MAT_{C(below)}\right]} \tag{Eq. C77}$$

Finally, t_{final} for each timestep j is calculated by multiplying t_{final_calc} by α, β, and ε using Equation C78. For more details on the α and β parameters, refer to H.2.6 of SAE J2601_202005. For more details on the ε parameter, see C.3.1.1 and A.2.1.2.

$$t_{final(j)} = \alpha \times \beta \times\ \varepsilon\ \times t_{final\_calc(j)} \tag{Eq. C.78}$$

$$IF\ t_{final(j)} <\ \beta \times t_{final\_min}$$

$$THEN$$

$$t_{final(j)} =\ \beta \times t_{final\_min}$$

$$END\ IF$$

C.3.12 Subroutine - Calculation of PRR and P_{ramp}

This subroutine is used to calculate the pressure ramp rate PRR, the ramp pressure P_{ramp}, the limit pressures P_{limit_high} and P_{limit_low}, and the factor α, used in the t_{final} equation. The ramp pressure is the pressure targeted by the dispenser control at any time during the fill. The upper and lower limit pressures define a boundary or limit on the station pressure that is not to be exceeded. See A.2.3 for a detailed explanation of the variable pressure ramp rate PRR and refer to H.2.6 of SAE J2601_202005 for a detailed explanation of α, P_{limit_high}, and P_{limit_low}.

The calculations in this subroutine shall be conducted based on a timestep j, which is advanced every 1 second. Thus, each calculation in this subroutine is conducted once every second.

Equation C79 is used to calculate α. α is a factor which accounts for variability in the PRR during the fill. α is multiplied by the t_{final} equation to extend the fueling time based on the amount of variability in the PRR. The unit of measure for α is dimensionless. The unit of measure for RR_{min} and RR_{max} is MPa/s.

Note that in Equation C79, for the first calculation cycle when j = 0, α is not calculated, and the initialization value of 1 is utilized.

(Eq. C79)

$$IF\ j > 0$$

$$THEN$$

$$IF\ \ PRR < RR_{min},\ THEN\ RR_{min} = PRR$$

$$IF\ \ PRR > RR_{max},\ THEN\ RR_{max} = PRR$$

$$\alpha\ = \left[\frac{100+18.5(RR_{max}-RR_{min})}{100}\right]$$

$$END\ IF$$

Equation C80 is used to calculate the pressure ramp rate PRR_{MC} and PRR. The unit of measure for PRR is MPa/s.

(Eq. C80)

$$IF\quad t_{final(j)} \times \left(\frac{P_{final} - P_{startup}}{P_{final} - P_{min}}\right) - t > 10\quad AND\ P_{ramp(j)} < 0.99 \times P_{final}$$

$$THEN$$

$$PRR_{MC(j)} = \frac{P_{final} - P_{ramp(j)}}{t_{final(j)} \times \left(\frac{P_{final} - P_{startup}}{P_{final} - P_{min}}\right) - t}$$

$$ELSE$$

$$PRR_{MC(j)} = PRR_{MC(j-1)}$$

$$END\ IF$$

$$PRR_{(j)} = MINIMUM[PRR_{max}, PRR_{MC(j)}]$$

Equation C81 calculates the synthetic measured pressure $MP_{calc(j)}$. $MP_{calc(j)}$ is used in the PRR Taper method for non-communications fueling using Equation C82. The application of Equation C81 is optional.

(Eq. C81)

$$\rho_{(j)} = f\left(P_{station(j)}, T_{fuel\_inst(j)}\right) \; using\ an\ appropriate\ equation\ of\ station\ for\ density\ such\ as\ Eq. C105$$

$$MP_{\text{calc}(j)} = P_{station(j)} - K_0 \left[\frac{\dot{m}_{(j)}^2}{\rho_{(j)}}\right] + P_a \text{ , } where\ P_a\ is\ defined\ and\ set\ in\ Equation\ C26$$

Equation C82 calculates a reduced pressure ramp rate PRR_{taper}. An explanation of the PRR Taper method and its attributes can be found in Appendix E. The application of Equation C82 is optional.

(Eq. C82)

$$\Delta P_{(j)} = P_{ramp(j)} - MP_{(j)} \text{ (communications fueling)}$$

OR

$$\Delta P_{(j)} = P_{ramp(j)} - MP_{\text{calc}(j)} \text{ (non-communications fueling)}$$

$$P_{threshold} = P_{ramp\_maximum} - \Delta P_{(j)}$$

$$IF\ P_{ramp(j)} \geq P_{threshold}\ AND\ j > t_{lookback}$$

$$THEN$$

$$PRR\_TAPER\_FLAG = TRUE$$

$$END\ IF$$

$$IF\ PRR\_TAPER\_FLAG = TRUE$$

$$THEN$$

Calculate lookback MP ramp rate:

$$PRR_{MP(j)} = \frac{\left(MP_{(j)} - MP_{(j-t_{lookback})}\right)}{t_{lookback}} \text{ (communications fueling)}$$

OR

$$PRR_{MP(j)} = \frac{\left(MP_{calc(j)} - MP_{calc(j-t_{lookback})}\right)}{t_{lookback}} \text{ (non-communications fueling)}$$

Calculate time remaining based on PRR_{MP}:

$$t_{remain(j)} = \frac{\left(P_{target\_comm} - MP_{(j)}\right)}{PRR_{MP}(j)} \text{ OR } t_{remain(j)} = \frac{\left(P_{target\_non\_comm} - MP_{calc(j)}\right)}{PRR_{MP}(j)}$$

Calculate PRR_{taper}:

$$IF \ \ t_{remain(j)} > 0 \quad AND \quad P_{ramp\_maximum} > P_{ramp(j)}$$

$$THEN$$

$$PRR_{taper(j)} = \frac{\left(P_{ramp\_maximum} - P_{ramp(j)}\right)}{t_{remain(j)}}$$

$$ELSE$$

$$PRR_{taper(j)} = 0$$

$$END\ IF$$

$$PRR_{(j)} = MINIMUM[PRR_{max}, PRR_{MC(j)}, PRR_{taper(j)}]$$

$$ELSE$$

$$PRR_{(j)} = MINIMUM[PRR_{max}, PRR_{MC(j)}]$$

$$END\ IF$$

Equation C83 calculates the ramp pressure P_{ramp} for the next timestep j+1.

(Eq. C83)

$$IF\ FTI_{(j)} = 1$$

$$THEN$$

$$P_{ramp(j+1)} = P_{ramp(j)} + PRR_{(j)}$$

$$ELSE\ IF\ FTI_{(j)} = 0$$

$$THEN$$

$$P_{ramp(j+1)} = P_{ramp(j)}$$

$$END\ IF$$

$$IF\ P_{ramp(j+1)} > P_{ramp\_maximum}$$

$$THEN$$

$$P_{ramp(j+1)} = P_{ramp\_maximum}$$

$$END\ IF$$

Equation C84 calculates the upper and lower pressure corridor limit pressure P_{limit_high} P_{limit_low}.

(Eq. C84)

$$P_{limit\_high(j+1)} = P_{ramp(j+1)} + \Delta P_{tol\_high}$$

$$IF\ P_{limit\_high(j+1)} > P_{final}, THEN\ P_{limit\_high(j+1)} = P_{final}$$

$$IF\ protocol\ is\ H35\ FM60\ or\ H70\ FM60, FM90, FM300$$

$$THEN$$

$$P_{limit\_low(j+1)} = P_{startup} + 0.0167 \times (t+1)$$

$$END\ IF$$

$$IF\ protocol\ is\ H35\ FM120$$

$$THEN$$

$$P_{limit\_low(j+1)} = P_{startup} + 0.0125 \times (t+1)$$

$$END\ IF$$

C.3.13 Subroutine - Determination of Pressure Targets and Limits

The calculations in this subroutine shall be conducted based on a timestep j, which is advanced every 1 second. Thus, each calculation in this subroutine is conducted once every second.

This subroutine has two subsections. The first subsection, C.3.13.1, calculates the communications fueling pressure target for both ending pressure control options. The second subsection, C.3.13.2, calculates the non-communications fueling pressure target and communications fueling pressure limit for the MC Method ending pressure control option. If ending pressure tables are utilized, C.3.13.2 is not applicable. Note that when ending pressure tables are utilized, the non-communications fueling pressure target and communications fueling pressure limit are calculated in the Ending Pressure Control Initialization Subroutine (see C.3.2.1).

C.3.13.1 Determine Communications Fueling Pressure Target

A pressure target is calculated for communications fueling based the SOC_{target} value set in the Parameter Initialization Subroutine (see C.3.1, Equation C21). The unit of measure for $P_{target\_comm\_cal}$ and P_{target_comm} is megapascal, the unit of measure for MT is kelvin (K), and the unit of measure for SOC_{target} is % (i.e., 100% is expressed as 100). The equation for $P_{target\_comm\_calc}$ has an accuracy of + 0/-0.08 MPa over the range of temperatures 233.15 K ≤ MT ≤ 358.15 K and range of target SOC 95 ≤ SOC_{target} ≤ 100, referencing data from NIST.

(Eq. C85)

$$IF\ Pressure\ Class = H70$$

$$P_{target\_comm\_calc(j)} = (0.0144 \times SOC_{target} - 0.439) \times (0.2782 \times MT_{(j)} - 4.7145E-05 \times MT_{(j)}^2 - 6.18) - 0.1$$

$$IF\ Pressure\ Class = H35$$

$$P_{target\_comm\_calc(j)} = (0.0123 \times SOC_{target} - 0.227) \times (0.1346 \times MT_{(j)} - 1.3637E-05 \times MT_{(j)}^2 - 2.65) - 0.12$$

$$P_{target\_comm(j)} = MINIMUM[P_{target\_comm\_calc(j)}, (P_{ramp\_maximum} - 0.5)]$$

C.3.13.2 Determine Non-Communications Fueling Pressure Target and Communications Fueling Pressure Limit Using MC Method

This section is only applicable when the MC Method is used for ending pressure control. If ending pressure tables are utilized for ending pressure control, this section is not applicable.

This section provides the equations for calculating a non-communications fueling pressure target and a communications fueling pressure limit. The non-communications fueling pressure target is calculated in C.3.13.2.1, and the communications fueling pressure limit is calculated in C.3.13.2.2.

C.3.13.2.1 Determine Non-Communications Fueling Pressure Target Using MC Method

A pressure target is calculated for non-communications fueling based on an end-of-fill target density of 40.2 g/L for the H70 Pressure Class and 24.0 g/L for the H35 Pressure Class. The unit of measure for $P_{target\_non\_comm}$ is megapascal, and the unit of measure for T_{cold} is kelvin (K). Equation C86 has an accuracy of ±0.01 MPa over the range of temperatures 233.15 K ≤ T_{cold} ≤ 358.15 K, referencing data from NIST.

Calculate Non-Communications Fueling Pressure Target (Eq. C86)

$$IF\ \ Pressure\ Class = H70,\ P_{target\_non\_comm} = 0.2782 \times T_{cold(j)} - 4.7145E-05 \times {T_{cold(j)}}^2 - 6.18$$

$$IF\ \ Pressure\ Class = H35,\ P_{target\_non\_comm} = 0.1346 \times T_{cold(j)} - 1.3637E-05 \times {T_{cold(j)}}^2 - 2.65$$

C.3.13.2.2 Determine Communications Fueling Pressure Limit Using MC Method

A pressure limit is calculated for communications fueling based on a limit of 115% SOC, which corresponds to maximum density of 46.23 g/L for the H70 Pressure Class and 27.6 g/L for the H35 Pressure Class. Refer to H.3.1.4 of SAE J2601_202005 for an explanation and rationale for this density limit. The pressure limit P_{limit_comm} is used as secondary protection in case of a fault condition in the MT signal. The unit of measure for P_{limit_comm} is megapascals, and the unit of measure for T_{cold} is kelvin (K). Equation C87 has an accuracy of ±0.01 MPa over the range of temperatures 233.15 K ≤ T_{cold} ≤ 358.15 K, referencing data from NIST.

Calculate Communications Fueling Pressure Limit (Eq. C87)

$$IF\ \ Pressure\ Class = H70,\ P_{limit\_comm} = MINIMUM\left[84.8,\ \left(0.3457 \times T_{cold(j)} - 6.6942E-05 \times {T_{cold(j)}}^2 - 7.29\right)\right]$$

$$IF\ \ Pressure\ Class = H35,\ P_{limit\_comm} = MINIMUM\left[43.75,\ \left(0.1622 \times T_{cold(j)} - 1.8904E-05 \times {T_{cold(j)}}^2 - 3.40\right)\right]$$

C.3.14 Subroutine - Evaluate End-of-Fill Criteria

This subroutine is utilized to determine if the end-of-fill criteria is met, which will then end the fill. The calculations in this subroutine shall be conducted based on a timestep *i*, which is advanced every 0.1 second. Thus, each calculation in this subroutine is conducted once every 1/10th of a second.

C.3.14.1 Evaluate End-of-Fill Criteria for Non-Communications Fueling

The condition for the end-of-fill criteria to be met for non-communications fueling is for the either the station pressure or for MP_{calc} (if the K_0 method in C.3.8 is utilized) to be greater than or equal to the non-communications fueling pressure target. The dispenser shall end the fill immediately when this criterion is satisfied. In Equation C88, the station pressure measurement shall account for the sensor error.

(Eq. C88)

Option 1: The use of Station Pressure

$$IF\ \ Indicator\_Comm\_Fill\ =\ FALSE\ \ \ AND\ \ P_{station(i)} \geq P_{target\_non\_comm},\ \ THEN\ \ \ END\ FILL$$

$$i = i + 1$$

Option 2: The use of MP_{calc}

$$\rho_{(i)} = f\left(P_{station(i)}, T_{fuel\_inst(i)}\right)\ using\ an\ appropriate\ equation\ of\ station\ for\ density\ such\ as\ Equation\ C105$$

$$MP_{\mathrm{calc}(i)} = P_{station(i)} - K_0 \left[\frac{\dot{m}_{(i)}^2}{\rho_{(i)}}\right] + P_a\ , where\ P_a\ is\ defined\ and\ set\ in\ Equation\ C26$$

$$IF\ \ Indicator\_Comm\_Fill\ =\ FALSE\ \ \ AND\ \ MP_{calc(i)} \geq P_{target\_non\_comm},\ \ THEN\ \ \ END\ FILL$$

$$i = i + 1$$

C.3.14.2 Evaluate End-of-Fill Criteria for Communications Fueling

There are two options provided for evaluating the end-of-fill criteria for communications fueling. The first option is used if the synthetic measured pressure MP_{calc} using the K_0 method in C.3.8 is not utilized. With Option 1, there are two sub-options, 1a and 1b. In Option 1a, the condition for the end-of-fill criteria to be met for communications fueling is for the station pressure $P_{station}$ to be greater than or equal to the communications fueling pressure target, or for the station pressure $P_{station}$ to be greater than or equal to the communications fueling pressure limit, whichever occurs first. In Option 1b, the condition for the end-of-fill criteria to be met for communications fueling is for the measured pressure MP to be greater than or equal to the communications fueling pressure target, or for the station pressure $P_{station}$ to be greater than or equal to the communications fueling pressure limit, whichever occurs first. With either option, the dispenser shall end the fill immediately when either of these criterion is satisfied.

The second option is used if the synthetic measured pressure MP_{calc} using the K_0 method in C.3.8 is utilized. With Option 2, the condition for the end-of-fill criteria to be met for communications fueling is for the measured pressure MP to be greater than or equal to the communications fueling pressure target, or for the either the measured pressure MP or the synthetic measured pressure MP_{calc} to be greater than or equal to the communications fueling pressure limit. The dispenser shall end the fill immediately when any of these criteria are satisfied.

The use of Option 1a is the most conservative and will result in the lowest ending SOC. Option 1b is less conservative but may still result in some fills not achieving the desired target pressure, especially for fills that start from a low initial pressure. This is because the station pressure may reach the communications fueling pressure limit before the measured pressure MP reaches the communications fueling pressure target. Option 2 will consistently provide the highest ending SOC but relies on MP and MP_{calc} to ensure that the pressure limit is not exceeded.

(Eq. C89)

Option 1a: The Use of Station Pressure

NOTE: Option 1a cannot be used with the PRR Taper method. If PRR Taper is used, choose Option 1b or Option 2.

$$IF\ \ Indicator\_Comm\_Fill\ =\ TRUE$$

$$THEN$$

$$IF\ \ P_{station(i)} \geq P_{target\_comm}\ , THEN\ END\ FILL$$

$$IF\ \ P_{station(i)} \geq P_{limit\_comm}\ , THEN\ END\ FILL$$

$$i = i + 1$$

$$END\ IF$$

Option 1b: The Use of Measured Pressure MP and Station Pressure

$$IF\ \ Indicator\_Comm\_Fill\ =\ TRUE$$

$$THEN$$

$$IF\ \ MP_{(i)} \geq P_{target\_comm}\ , THEN\ END\ FILL$$

$$IF\ \ P_{station(i)} \geq P_{limit\_comm}\ , THEN\ END\ FILL$$

$$i = i + 1$$

$$END\ IF$$

Option 2: The Use of Measured Pressure MP and Synthetic Measured Pressure MP_{calc}

$$IF\ \ Indicator\_Comm\_Fill\ =\ TRUE$$

$$THEN$$

$$\rho_{(i)} = f\left(P_{station(i)}, T_{fuel\_inst(i)}\right)\ using\ an\ appropriate\ equation\ of\ station\ for\ density\ such\ as\ Equation\ C105$$

$$MP_{calc(i)} = P_{station(i)} - K_0 \left[\frac{\dot{m}_{(i)}^2}{\rho_{(i)}}\right] + P_a\ , where\ P_a\ is\ defined\ and\ set\ in\ Equation\ C26$$

$$IF\ \ MP_{(i)} \geq P_{target\_comm(j)}\ , THEN\ END\ FILL$$

$$IF\ \ MP_{(i)} \geq P_{limit\_comm}\ , THEN\ END\ FILL$$

$$IF\ \ MP_{calc(i)} \geq P_{limit\_comm}\ , THEN\ END\ FILL$$

$$i = i + 1$$

$$END\ IF$$

C.3.15 Subroutine - Process Check

This subroutine is used to check if temperature, pressure, and mass flow rate are within the process limits. If any of the process condition checks are not satisfied, the Process Check Subroutine fails, and the fill shall terminate as soon as possible but within 5 seconds.

The unit of measure for $P_{station}$, and P_{limit_high} is megapascal. The unit of measure of T_{amb}, T_{fuel}, and MAT_C is degrees Celsius (°C). The unit of measure for MT is kelvin (K). The unit of measure for t is seconds, and the unit of measure for $\dot{m}$ is grams per second.

The calculations in this subroutine shall be conducted based on a timestep *j*, which is advanced every 1 second. Thus, each calculation in this subroutine is conducted once every second.

$$IF\ P_{station(j)} \leq P_{final},\ THEN\ PASS,\quad ELSE\ FAIL \qquad \text{(Eq. C90)}$$

$$When\ t > 15, IF\ P_{station(j)} \leq P_{limit\_high(j)},\ THEN\ PASS,\quad ELSE\ FAIL^{\dagger} \qquad \text{(Eq. C91)}$$

$$IF\ P_{station(j)} \geq P_{limit\_low(j)},\ THEN\ PASS,\quad ELSE\ FAIL^{\dagger\dagger} \qquad \text{(Eq. C92)}$$

$$IF\ \text{-}40 \leq T_{amb} \leq 50,\ THEN\ PASS,\quad ELSE\ FAIL \qquad \text{(Eq. C93)}$$

$$IF\ MT_{(j)} < 358.15,\ THEN\ PASS,\quad ELSE\ FAIL \qquad \text{(Eq. C94)}$$

$$IF\ T_{fuel\_inst(j)} \geq -40,\ THEN\ PASS,\quad ELSE\ FAIL \qquad \text{(Eq. C95)}$$

$$For\ the\ H35\ \text{FM120 protocol:}$$

$$IF\ MAT_{C(j)}\ \leq 20\ THEN\ PASS,\quad ELSE\ FAIL^{\dagger\dagger\dagger} \qquad \text{(Eq. C96)}$$

$$For\ the\ H35\ FM60\ or\ H70\ \text{FM60, FM90, FM300 protocols:}$$

$$IF\ MAT_{C(j)} \leq 0\quad THEN\ PASS,\quad ELSE\ FAIL^{\dagger\dagger\dagger} \qquad \text{(Eq. C97)}$$

$$IF\ \dot{m}_{(j)} \leq FM,\ THEN\ PASS,\quad ELSE\ FAIL \qquad \text{(Eq. C98)}$$

$$IF\ \dot{m}_{(j)} \geq MFR_{min},\ THEN\ PASS,\quad ELSE\ FAIL^{\ddagger} \qquad \text{(Eq. C99)}$$

† Note to Equation C91: If the station pressure exceeds the upper pressure limit by 5 MPa or less, it shall come back within the limit within 5 seconds of the initial excursion or shall stop fueling within 5 seconds of the initial excursion. If the magnitude of the excursion is greater than 5 MPa, the dispenser shall stop fueling within 5 seconds of the initial excursion.

†† Note to Equation C92: The station pressure shall stay above the lower limit pressure of the pressure corridor only when mass is flowing, which excludes intended non-fueling events such as a leak check or bank switch (i.e., when FTI = 0). Also, if the station pressure falls below the lower pressure limit, it shall come back within the limit within 15 seconds of the initial excursion, not counting intended non-fueling time, and if it does not, the dispenser shall stop fueling within 15 seconds of the initial excursion.

††† Note to Equations C96 and C97: If this process limits fails, the dispenser shall do one of the following: (a) pause (no flow) for a minimum of 90 seconds before resuming the fill with the main fueling time t and parameters n, j, and i set back to zero and $P_{startup}$ set to the most recent station pressure prior to resuming the fill; or (b) terminate the fueling as soon as possible but within 5 seconds. If option (a) is utilized, the station should ensure that the cooling system is functioning as intended and shall limit the number of occurrences to no more than two.

‡ Note to Equation C99: For this process limit to fail, the mass flow rate must be less than MFR_{min} for 10 consecutive seconds during intended fueling time (i.e., when FTI = 1).

C.3.16 Subroutine - Advance Counters

Advance the counter j by 1.

$$j = j + 1 \qquad \text{(Eq. C100)}$$

The counter n is only advanced if the mass flow rate over the timestep is greater than 1% of the Flow Rate Maximum value (FM), as determined in Equation C6.

$$IF\ \dot{m} > 0.01\ \times FM,\ \ n = n + 1 \qquad \text{(Eq. C101)}$$

$$ELSE\ \ n = n$$

$$END\ IF$$

If an intended non-fueling event occurs between 20 ≤ n ≤ 30, then subtract 10 from n. The purpose of subtracting 10 seconds is to allow the fuel delivery temperature T_{fuel_inst} to get cold again after the warming which occurs during the intended non-fueling event.

C.4 REFERENCE EQUATIONS

Application of the MCF-HF-G protocol, especially when utilizing the MC Method for the ending pressure control option, requires calculation of hydrogen thermophysical properties. The thermophysical properties used in the application of the MCF-HF-G protocol should be referenced to NIST data. The programmer should ensure that the equations chosen for calculating the thermophysical properties of hydrogen are as accurate as possible compared to the NIST Standard Reference Database.

Equations C102 through C106 are given as a reference for calculating thermophysical properties of hydrogen which are required in the MC Method and other formulas within the MCF-HF-G control. These equations are generally accurate to within 0.5 to 1%. The programmer may utilize these reference equations or another set of reference equations provided they have documented and comparable accuracy.

C.4.1 Specific Enthalpy (kJ/kg)

(Eq. C102)

$$h = (4.92522\text{E} - 15 \times P^5 - 0.0000000000016076 \times P^4 + 0.000000000214858 \times P^3 - 0.0000000146189 \times P^2 + 0.000000454324 \times P - 0.00000987705) \times T^3 + (0.00000000055184 \times P^4 - 0.000000141472 \times P^3 + 0.0000132881 \times P^2 - 0.000497343 \times P + 0.0108438) \times T^2 + (0.00000000202796 \times P^5 - 0.000000664561 \times P^4 + 0.0000901478 \times P^3 - 0.00639724 \times P^2 + 0.225139 \times P + 10.4372) \times T + (-0.000000255167 \times P^5 + 0.0000852825 \times P^4 - 0.0119306 \times P^3 + 0.894471 \times P^2 - 27.6592 \times P + 112.034)$$

where:

P = absolute pressure in units of megapascals

T = absolute temperature in units of kelvin

Example input/output:

Inputs		Output	
P (MPa)	***T*** (K)	***h*** (kJ/kg) - NIST	***h*** (kJ/kg) - Equation C102
70.1	288.15	4232.1	4232.0

C.4.2 Specific Internal Energy (kJ/kg)

(Eq. C103)

$$u = 496.1 \times [(-0.000000251102 \times P^2 + 0.00003270544 \times P + 0.020635744157) \times T + (0.000110237178 \times P^2 - 0.014948338423 \times P - 0.706955972653)]$$

where:

P = absolute pressure in units of megapascals

T = absolute temperature in units of kelvin

Example input/output:

Inputs		Output	
P (MPa)	***T*** (K)	***u*** (kJ/kg) - NIST	***u*** (kJ/kg) - Equation C103
70.1	288.15	2488.8	2499.4

C.4.3 Temperature (K)

(Eq. C104)

$$T = (0.000001148 \times P^2 - 0.000148149 \times P + 0.0976624642) \times u + (-0.0047605417 \times P^2 + 0.6412591317 \times P + 34.3729762461)$$

where:

P = absolute pressure in units of megapascals

u = specific internal energy in units of kilojoules per kilogram

Example input/output:

Inputs		Output	
P (MPa)	***u*** (kJ/kg)	***T*** (K) - NIST	***T*** (K) - Equation C104
70.1	2488.8	288.15	287.19

C.4.4 Density (kg/m³)

(Eq. C105)

$$\rho = (-1.1671\text{E}-16 \times P^4 + 0.0000000000000035429 \times P^3 - 0.00000000000380467 \times P^2 + 0.000000000151947 \times P - 0.00000000000376254) \times T^4 + (0.000000000000159364 \times P^4 - 0.0000000000491286 \times P^3 + 0.00000000538378 \times P^2 - 0.000000222007 \times P + 0.00000000512189) \times T^3 + (-0.0000000000826768 \times P^4 + 0.000000026014 \times P^3 - 0.00000293356 \times P^2 + 0.00012714 \times P - 0.00000263185) \times T^2 + (0.0000000195877 \times P^4 - 0.00000634261 \times P^3 + 0.0007478 \times P^2 - 0.0354828 \times P + 0.000608078) \times T + (-0.0000018437 \times P^4 + 0.000623884 \times P^3 - 0.0798237 \times P^2 + 4.77618 \times P - 0.0536549)$$

where:

P = absolute pressure in units of megapascals

T = absolute temperature in units of kelvin

Example input/output:

Inputs		Output	
P (MPa)	***T*** (K)	***ρ*** (kg/m³) - NIST	***ρ*** (kg/m³) - Equation C105
70.1	288.15	40.21	40.21

C.4.5 Specific Heat Capacity at Constant Volume (kJ/kgK)

(Eq. C106)

$$c_v = 0.49608 \times [(-2.6305218\text{E}-13 \times T^3 + 2.9504059885\text{E}-10 \times T^2 + -0.000000114316 \times T + 0.000015724461) \times \times P^3 + (2.239406732\text{E}-11 \times T^3 + -0.000000026242 \times T^2 + 0.000010846506 \times T + -0.001653192666) \times P^2 + (-0.000000000909584 \times T^3 + 0.000001163147 \times T^2 + -0.000549326926 \times T + 0.106819055) \times \text{P} + (0.000000183407 \times T^3 + -0.000222580465 \times T^2 + 0.091271823485 \times T + 8.231398432926)]$$

where:

P = absolute pressure in units of megapascals

T = absolute temperature in units of kelvin

Example input/output:

Inputs		Output	
P (MPa)	***T*** (K)	c_v (kJ/kgK) - NIST	c_v (kJ/kgK) - Equation C106
70.1	288.15	10.703	10.678

APPENDIX D - (NORMATIVE) MCF-HF-G t_{final} TABLES

D.1 INTRODUCTION

The following t_{final} tables provide t_{final} values in units of seconds as a function of T_{amb} and MAT_C.

D.1.1 Color Shading in the Tables

The lower pressure limit for the MCF-HF-G protocol is 0.75 MPa/min for the H35 FM120 protocol and 1 MPa/min for the H35 FM60 or H70 FM60/FM90/FM300 protocols. Some t_{final} values in the tables in this appendix will cause the PRR to be less than this lower limit. A sustained PRR of less than 0.75 MPa/min and 1 MPa/min, respectively, will likely result in one of the process limits to be exceeded, causing the fueling to stop prematurely. These process limits include the lower pressure limit and the minimum flow rate requirement.

t_{final} values which are longer than 2700 to 3035 seconds for the H35 FM120 protocol and 4500 to 4770 seconds for the H35 FM60 or H70 FM60/FM90/FM300 protocols will cause the PRR to be lower than 0.75 MPa/min and 1 MPa/min, respectively, when utilizing a P_{min} value equal to 3 MPa and 5 MPa, respectively, depending on the value of ΔP_{tol_high} utilized (see Equation C24). ΔP_{tol_high} has a discretionary setting between 3 and 7 MPa. The lower value of the range (i.e., 2700 seconds for H35 FM120 and 4500 seconds for H35 FM60 or H70 FM60/FM90/FM300) corresponds to a ΔP_{tol_high} of 7 MPa, whereas the higher value of the range (i.e., 3035 seconds for H35 FM120 and 4770 seconds for H35 FM60 or H70 FM60/FM90/FM300) corresponds to a ΔP_{tol_high} of 3 MPa. In the t_{final} tables below, t_{final} values which are greater than the lower value of the range, i.e., 2700 seconds for H35 FM120 and 4500 seconds for H35 FM60 or H70 FM60/FM90/FM300 are shaded red as a precautionary indicator to the user.

If $P_{initial}$ and P_{min} is less than 3 MPa for H35 FM120 and 5 MPa for H35 FM60 or H70 FM60/FM90/FM300, t_{final} is multiplied by ε, causing t_{final} to be even larger and the PRR to be even slower. The lower the initial pressure, the larger the ε value and resultant t_{final} value. The t_{final} values shaded in yellow in the t_{final} tables indicate conditions where the calculated PRR may be slower than 0.75 MPa/min for the H35 FM120 protocol and 1.0 MPa/min for the H35 FM60 or H70 FM60/FM90/FM300 protocols, depending on the value of $P_{initial}$.

To ensure fuelings are not stopped prematurely, it is recommended that the fuel delivery temperature be kept sufficiently cold so that MAT_C is colder than the values shaded in yellow and red.

D.1.2 H35 FM120 t_{final} Tables - Option A

Tables D1 through D23 are the H35 FM120 t_{final} tables for the application of Advanced Option A in Equation C42.

Table D1 - H35 FM120 t_{final} - V_{CHSS} 248.6 L and 50 L ≤ TVL ≤ 200 L

T_{amb} (°C)	MATc (°C)																	
	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	163	163	163	163	163	163	189	238	296	365	449	549	669	808	966	1144	1342	1562
45	163	163	163	163	163	163	163	181	223	272	327	390	464	548	643	749	865	993
40	163	163	163	163	163	163	163	163	174	211	253	300	351	409	474	545	624	710
35	163	163	163	163	163	163	163	163	166	202	242	288	337	392	454	522	596	678
30	163	163	163	163	163	163	163	163	163	171	204	243	285	331	380	434	494	559
25	163	163	163	163	163	163	163	163	163	163	174	207	243	283	325	370	418	472
20	163	163	163	163	163	163	163	163	163	163	163	177	209	243	280	319	361	405
15	163	163	163	163	163	163	163	163	163	163	163	163	185	216	250	285	323	362
10	163	163	163	163	163	163	163	163	163	163	163	163	165	192	223	255	290	325
5	163	163	163	163	163	163	163	163	163	163	163	163	163	163	185	212	242	273
0	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	177	203	230
-5	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	172	197	224
-10	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	166	191	217
-15	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	185	210
-20	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	179	204
-25	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	174	198
-30	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	168	192
-35	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	186
-40	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	181

T_{amb} (°C)	MATc (°C)												
	-4	-2	0	2	4	6	8	10	12	14	16	18	20
50	1806	2074	2365	2681	3020	3379	3747	4118	4490	4856	5215	5559	5890
45	1131	1278	1434	1601	1778	1965	2161	2365	2579	2801	3030	3263	3498
40	804	903	1008	1119	1237	1360	1488	1621	1760	1903	2053	2206	2362
35	766	860	958	1062	1171	1284	1401	1521	1646	1774	1906	2041	2178
30	630	705	784	867	955	1047	1141	1239	1339	1442	1549	1657	1767
25	529	591	656	725	798	874	952	1033	1117	1203	1292	1382	1474
20	453	505	559	617	678	742	809	878	949	1022	1098	1175	1253
15	404	449	497	548	601	658	717	777	840	905	973	1041	1111
10	363	403	445	490	538	588	640	694	750	808	869	930	992
5	306	339	374	411	450	491	534	579	626	674	725	777	829
0	259	289	319	350	383	418	454	491	530	571	614	658	703
-5	252	281	311	342	374	408	443	479	518	558	599	642	686
-10	245	274	303	333	365	398	432	468	505	544	585	627	670
-15	238	266	295	325	356	388	422	457	494	532	571	612	654
-20	231	259	288	317	347	379	412	446	482	519	558	598	639
-25	225	252	280	309	339	370	402	436	471	507	545	584	624
-30	218	245	273	302	331	362	393	426	460	496	533	571	610
-35	212	239	266	294	323	353	384	416	450	485	521	558	597
-40	206	232	259	287	315	345	375	407	439	474	509	546	583

Table D2 - H35 FM120 t_{final} - V_{CHSS} 500 L and 50 L ≤ TVL ≤ 200 L

T_{amb} (°C)	MAT$_C$ (°C) -40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	163	163	163	163	163	163	166	201	251	311	381	463	562	679	813	964	1133	1321
45	163	163	163	163	163	163	163	163	195	239	289	346	412	486	571	666	771	888
40	163	163	163	163	163	163	163	163	163	189	228	272	322	376	435	501	575	656
35	163	163	163	163	163	163	163	163	163	183	220	264	312	364	422	486	556	634
30	163	163	163	163	163	163	163	163	163	163	189	225	267	312	360	412	469	532
25	163	163	163	163	163	163	163	163	163	163	163	194	230	269	311	356	404	456
20	163	163	163	163	163	163	163	163	163	163	163	169	199	234	271	310	352	397
15	163	163	163	163	163	163	163	163	163	163	163	163	178	209	243	279	318	358
10	163	163	163	163	163	163	163	163	163	163	163	163	163	188	219	252	287	324
5	163	163	163	163	163	163	163	163	163	163	163	163	163	163	182	211	241	274
0	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	177	203	232
-5	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	173	199	227
-10	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	169	194	221
-15	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	165	189	216
-20	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	185	212
-25	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	181	207
-30	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	176	202
-35	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	172	197
-40	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	168	193

T_{amb} (°C)	MAT$_C$ (°C) -4	-2	0	2	4	6	8	10	12	14	16	18	20
50	1529	1755	2001	2270	2562	2877	3210	3556	3914	4279	4647	5010	5365
45	1015	1151	1296	1452	1618	1794	1980	2174	2379	2594	2818	3050	3286
40	744	838	939	1046	1160	1280	1405	1535	1672	1814	1963	2116	2274
35	718	808	903	1004	1111	1223	1339	1458	1583	1712	1846	1983	2122
30	600	673	751	833	920	1011	1106	1203	1304	1409	1518	1628	1741
25	512	573	637	706	778	854	933	1015	1100	1188	1278	1371	1465
20	444	495	550	608	669	734	801	871	943	1018	1096	1175	1255
15	401	446	494	545	599	656	716	778	842	909	978	1048	1121
10	363	404	447	492	540	591	645	700	758	818	880	943	1008
5	308	343	379	417	457	499	543	589	637	688	740	793	848
0	262	293	325	358	392	428	465	504	544	587	631	677	724
-5	256	287	319	351	385	420	457	495	534	576	619	664	710
-10	251	281	312	344	378	412	448	486	525	566	608	652	697
-15	245	276	306	338	371	405	440	477	515	555	597	640	684
-20	240	270	300	332	364	398	432	468	506	545	586	628	671
-25	235	264	294	325	357	390	425	460	497	536	576	617	659
-30	230	259	289	319	351	384	417	452	488	526	566	606	648
-35	225	253	283	313	344	377	410	444	480	517	556	596	636
-40	220	248	277	307	338	370	403	436	472	508	546	585	625

Table D3 - H35 FM120 t_{final} - V_{CHSS} 1000 L and 50 L ≤ TVL ≤ 200 L

T_{amb} (°C)	MAT$_C$ (°C)																	
	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	163	163	163	163	177	206	241	282	329	379	432	513	607	714	836	974	1130	1304
45	163	163	163	163	163	163	175	202	233	275	329	392	461	536	618	707	806	915
40	163	163	163	163	163	163	163	163	187	220	261	308	362	422	486	552	624	701
35	163	163	163	163	163	163	163	163	182	215	254	300	353	411	473	538	607	682
30	163	163	163	163	163	163	163	163	163	187	219	257	301	352	406	463	522	585
25	163	163	163	163	163	163	163	163	163	164	191	223	260	303	350	400	454	509
20	163	163	163	163	163	163	163	163	163	163	169	195	227	263	303	348	396	446
15	163	163	163	163	163	163	163	163	163	163	163	177	204	236	272	312	356	402
10	163	163	163	163	163	163	163	163	163	163	163	163	185	213	245	281	321	363
5	163	163	163	163	163	163	163	163	163	163	163	163	163	180	206	235	268	304
0	163	163	163	163	163	163	163	163	163	163	163	163	163	163	175	198	225	256
-5	163	163	163	163	163	163	163	163	163	163	163	163	163	163	171	195	221	250
-10	163	163	163	163	163	163	163	163	163	163	163	163	163	163	168	191	217	245
-15	163	163	163	163	163	163	163	163	163	163	163	163	163	163	165	187	212	241
-20	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	183	208	236
-25	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	180	204	231
-30	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	176	200	227
-35	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	173	196	222
-40	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	170	192	218

T_{amb} (°C)	MAT$_C$ (°C)												
	-4	-2	0	2	4	6	8	10	12	14	16	18	20
50	1496	1707	1935	2186	2459	2755	3069	3398	3743	4098	4460	4821	5178
45	1035	1164	1302	1450	1609	1778	1956	2144	2343	2552	2772	2999	3232
40	785	875	971	1074	1183	1299	1421	1547	1680	1820	1966	2117	2273
35	762	848	940	1037	1140	1248	1361	1478	1600	1726	1858	1993	2132
30	652	722	797	876	960	1049	1140	1236	1335	1438	1544	1654	1766
25	566	626	689	755	826	900	977	1056	1139	1225	1315	1406	1499
20	497	550	604	661	721	785	850	918	989	1063	1139	1217	1297
15	450	499	549	600	654	710	769	829	892	958	1026	1095	1166
10	408	454	500	548	597	648	700	754	811	870	931	993	1057
5	342	383	425	467	511	555	600	646	694	743	795	848	902
0	289	324	361	400	439	479	520	560	602	644	689	734	780
-5	283	318	354	392	432	471	511	551	592	634	678	722	767
-10	277	312	348	385	424	464	503	543	583	624	667	711	755
-15	272	306	341	379	417	456	495	534	574	615	657	700	743
-20	267	300	335	372	410	448	487	526	565	606	647	689	732
-25	261	294	329	365	403	441	480	518	557	597	637	679	721
-30	256	288	323	358	396	434	472	510	549	588	628	668	710
-35	251	283	317	352	389	427	464	502	540	579	618	659	699
-40	247	277	311	346	382	419	457	495	532	571	609	649	689

Table D4 - H35 FM120 t_{final} - V_{CHSS} 1500 L and 50 L ≤ TVL ≤ 200 L

Tamb (°C)	MATC (°C)																	
	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	173	173	180	206	237	273	315	364	419	480	544	612	712	824	947	1083	1235	1405
45	172	172	173	174	174	196	222	252	287	331	389	458	536	622	712	806	905	1013
40	171	171	172	173	173	174	175	198	228	265	308	358	417	483	555	631	710	792
35	170	171	172	172	173	174	175	193	223	258	300	349	405	469	539	613	690	770
30	170	170	171	172	173	174	175	175	196	225	259	299	346	399	458	522	590	661
25	169	170	171	172	172	173	174	175	176	199	227	260	298	343	392	447	507	570
20	169	169	170	171	172	173	174	175	175	177	201	228	260	297	339	386	438	493
15	168	169	170	171	172	173	173	174	175	176	183	207	235	268	304	346	391	441
10	168	169	170	171	171	172	173	174	175	176	177	189	214	242	275	311	351	396
5	167	168	169	170	171	172	173	173	174	175	176	177	183	205	231	260	293	330
0	167	168	169	169	170	171	172	173	174	175	175	176	177	178	197	221	248	277
-5	167	168	169	169	170	171	172	173	174	175	175	176	177	178	194	217	243	272
-10	167	168	169	169	170	171	172	173	174	175	175	176	177	178	190	213	238	267
-15	167	168	169	169	170	171	172	173	174	174	175	176	177	178	187	209	234	262
-20	167	168	168	169	170	171	172	173	174	174	175	176	177	178	184	205	229	257
-25	167	168	168	169	170	171	172	173	174	174	175	176	177	178	180	201	225	252
-30	167	168	168	169	170	171	172	173	173	174	175	176	177	178	179	198	221	247
-35	167	167	168	169	170	171	172	173	173	174	175	176	177	178	179	194	217	242
-40	167	167	168	169	170	171	172	173	173	174	175	176	177	178	178	191	213	238

Tamb (°C)	MATC (°C)												
	-4	-2	0	2	4	6	8	10	12	14	16	18	20
50	1593	1799	2024	2271	2540	2831	3140	3466	3805	4156	4514	4870	5222
45	1130	1256	1390	1535	1690	1855	2030	2214	2409	2615	2831	3054	3284
40	877	966	1060	1161	1267	1380	1498	1622	1752	1888	2031	2179	2332
35	852	937	1027	1121	1221	1327	1436	1550	1668	1792	1920	2053	2188
30	733	807	882	960	1042	1128	1218	1310	1406	1506	1610	1717	1826
25	635	701	768	836	907	980	1055	1132	1213	1297	1383	1472	1563
20	552	612	674	736	799	863	928	995	1064	1136	1210	1286	1363
15	495	551	608	666	725	785	844	905	967	1031	1098	1165	1234
10	445	496	549	604	660	716	772	828	885	943	1003	1064	1126
5	370	413	459	507	557	608	660	711	762	814	866	919	972
0	311	347	386	427	471	517	564	611	658	706	754	801	849
-5	304	340	378	419	462	507	553	600	647	694	741	788	835
-10	298	333	370	411	453	498	543	589	636	682	729	775	822
-15	293	326	363	403	444	488	533	579	625	671	717	763	809
-20	287	320	356	395	436	479	523	568	614	660	705	751	796
-25	281	314	349	387	428	470	514	558	603	649	694	739	783
-30	276	308	342	380	419	461	504	548	593	638	683	727	771
-35	271	302	336	372	411	453	495	539	583	627	672	716	759
-40	266	296	329	365	404	444	486	529	573	617	661	704	748

Table D5 - H35 FM120 t_{final} - V_{CHSS} 2000 L and 50 L ≤ TVL ≤ 200 L

	MAT$_C$ (°C)																	
T_{amb} (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	230	231	231	232	262	299	341	391	448	511	581	664	777	899	1027	1162	1310	1472
45	228	229	230	231	232	233	242	275	318	369	429	499	581	672	770	873	980	1090
40	227	228	229	230	231	232	233	234	259	297	340	392	451	519	594	675	762	853
35	227	228	228	229	230	232	233	234	254	290	332	381	439	504	577	656	740	828
30	226	227	228	229	230	231	232	233	235	254	288	329	375	429	489	555	627	704
25	225	226	227	228	229	231	232	233	234	235	253	287	325	369	419	475	536	603
20	224	226	227	228	229	230	231	232	233	235	236	253	285	322	364	410	462	519
15	224	225	226	227	229	230	231	232	233	234	235	236	259	291	327	368	414	464
10	224	225	226	227	228	229	230	231	233	234	235	236	237	264	296	332	372	417
5	223	224	225	226	227	228	230	231	232	233	234	235	236	237	251	280	312	347
0	222	223	224	225	227	228	229	230	231	232	233	234	235	237	238	239	265	294
-5	222	223	224	225	227	228	229	230	231	232	233	234	235	237	238	239	260	289
-10	222	223	224	225	226	228	229	230	231	232	233	234	235	236	238	239	256	283
-15	222	223	224	225	226	228	229	230	231	232	233	234	235	236	237	239	251	278
-20	222	223	224	225	226	227	229	230	231	232	233	234	235	236	237	239	247	273
-25	222	223	224	225	226	227	228	230	231	232	233	234	235	236	237	238	243	269
-30	222	223	224	225	226	227	228	230	231	232	233	234	235	236	237	238	239	264
-35	222	223	224	225	226	227	228	229	231	232	233	234	235	236	237	238	239	259
-40	222	223	224	225	226	227	228	229	231	232	233	234	235	236	237	238	239	255

	MAT$_C$ (°C)												
T_{amb} (°C)	-4	-2	0	2	4	6	8	10	12	14	16	18	20
50	1652	1848	2063	2298	2555	2835	3133	3447	3779	4121	4474	4827	5177
45	1207	1329	1460	1600	1750	1910	2079	2258	2447	2648	2859	3078	3304
40	946	1040	1136	1236	1340	1451	1566	1687	1814	1947	2087	2231	2382
35	918	1009	1101	1195	1294	1398	1505	1616	1731	1852	1978	2108	2241
30	784	866	948	1031	1115	1202	1290	1381	1476	1574	1676	1780	1887
25	673	747	821	897	973	1050	1127	1205	1285	1368	1454	1541	1630
20	581	646	713	782	853	924	994	1065	1135	1208	1282	1357	1434
15	519	578	639	703	769	836	902	968	1035	1101	1169	1237	1306
10	466	518	574	633	694	757	820	882	945	1008	1071	1134	1197
5	387	430	477	527	580	635	691	749	806	865	923	981	1038
0	326	361	400	442	487	534	584	635	687	741	795	849	902
-5	320	355	392	433	477	524	572	623	674	727	780	834	886
-10	314	348	385	425	468	514	561	611	662	714	766	819	871
-15	308	342	378	417	459	504	551	599	649	701	753	804	856
-20	303	335	371	409	450	494	540	588	637	688	739	790	841
-25	298	329	364	401	442	485	530	577	626	675	726	776	827
-30	292	323	357	394	433	476	520	566	614	663	713	763	813
-35	287	317	350	387	425	467	511	556	603	651	701	750	799
-40	282	312	344	379	418	458	501	546	592	640	688	737	786

Table D6 - H35 FM120 t_{final} - V_{CHSS} 2500 L and 50 L ≤ TVL ≤ 200 L

T_{amb} (°C)	MAT$_C$ (°C) -40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	287	288	289	290	291	323	366	416	474	539	611	714	832	963	1101	1244	1394	1555
45	285	286	287	288	289	291	292	306	351	403	464	536	619	713	816	927	1042	1162
40	284	285	286	287	288	289	291	292	294	325	370	421	481	549	626	710	802	899
35	283	284	285	287	288	289	291	292	294	318	361	411	468	534	608	689	776	870
30	282	283	285	286	287	289	290	292	293	294	314	355	401	455	515	582	655	735
25	281	282	284	285	287	288	289	291	292	294	295	310	349	393	443	498	559	627
20	280	282	283	285	286	287	289	290	292	293	294	296	307	344	385	431	482	539
15	280	281	283	284	286	287	288	290	291	293	294	295	297	311	347	387	432	482
10	279	281	282	284	285	286	288	289	291	292	293	295	296	298	315	350	390	433
5	279	280	281	283	284	285	287	288	290	291	292	294	295	296	298	299	328	363
0	278	279	280	282	283	284	286	287	289	290	291	293	294	295	297	298	300	308
-5	277	279	280	282	283	284	286	287	289	290	291	293	294	295	297	298	299	303
-10	277	279	280	282	283	284	286	287	288	290	291	293	294	295	297	298	299	301
-15	277	279	280	282	283	284	286	287	288	290	291	292	294	295	297	298	299	301
-20	277	279	280	281	283	284	286	287	288	290	291	292	294	295	297	298	299	301
-25	277	279	280	281	283	284	285	287	288	290	291	292	294	295	296	298	299	301
-30	277	279	280	281	283	284	285	287	288	290	291	292	294	295	296	298	299	300
-35	277	278	280	281	283	284	285	287	288	289	291	292	294	295	296	298	299	300
-40	277	278	280	281	283	284	285	287	288	289	291	292	293	295	296	298	299	300

T_{amb} (°C)	MAT$_C$ (°C) -4	-2	0	2	4	6	8	10	12	14	16	18	20
50	1731	1921	2128	2356	2604	2874	3163	3469	3792	4129	4476	4824	5172
45	1285	1409	1540	1678	1825	1981	2146	2321	2506	2701	2908	3123	3345
40	1000	1102	1206	1311	1418	1529	1643	1762	1887	2018	2156	2298	2445
35	967	1066	1166	1267	1369	1473	1580	1690	1804	1923	2047	2174	2305
30	820	907	997	1088	1179	1271	1363	1455	1550	1648	1749	1852	1958
25	699	776	856	938	1021	1105	1189	1273	1356	1440	1527	1614	1703
20	601	668	738	811	887	964	1042	1119	1196	1274	1351	1428	1506
15	537	596	659	725	795	866	939	1011	1084	1157	1230	1303	1374
10	482	534	590	650	713	779	847	915	984	1053	1123	1191	1259
5	402	444	490	539	592	649	707	768	830	893	957	1021	1084
0	339	374	411	452	496	544	594	646	700	757	815	873	932
-5	333	367	404	444	487	533	582	633	686	742	799	856	914
-10	328	361	396	435	477	523	570	621	673	727	783	839	896
-15	322	354	389	427	468	513	559	608	660	713	768	823	879
-20	316	348	382	419	460	503	549	597	647	699	753	807	862
-25	311	342	375	412	451	493	538	585	634	686	739	792	846
-30	306	336	369	404	443	484	528	574	622	673	725	777	830
-35	302	330	362	397	435	475	518	563	611	660	711	763	815
-40	302	325	356	390	427	467	509	553	599	648	698	749	800

Table D7 - H35 FM120 t_{final} - V_{CHSS} 5000 L and 50 L ≤ TVL ≤ 200 L

	MATC (°C)																	
Tamb (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	574	576	578	580	582	584	586	588	614	697	794	906	1036	1184	1348	1528	1721	1923
45	570	572	574	576	578	580	583	586	589	591	607	681	767	864	973	1094	1228	1373
40	567	569	571	573	576	578	581	584	586	589	592	595	599	668	744	828	923	1027
35	565	567	570	573	575	578	581	584	586	589	592	594	597	647	719	799	888	985
30	563	566	569	571	574	577	579	582	585	588	590	593	596	598	613	677	748	826
25	562	564	567	570	573	575	578	581	583	586	589	591	594	597	599	602	640	704
20	560	563	566	568	571	574	577	579	582	585	587	590	593	595	598	601	603	608
15	559	562	565	567	570	573	575	578	581	583	586	589	591	594	597	599	602	605
10	558	561	564	566	569	572	574	577	580	582	585	588	590	593	595	598	601	603
5	556	559	562	564	567	569	572	575	577	580	583	585	588	591	593	596	598	601
0	554	557	559	562	565	567	570	573	575	578	581	583	586	588	591	594	596	599
-5	554	557	559	562	565	567	570	572	575	578	580	583	586	588	591	593	596	599
-10	554	557	559	562	564	567	570	572	575	578	580	583	585	588	591	593	596	598
-15	554	556	559	562	564	567	570	572	575	577	580	583	585	588	590	593	596	598
-20	554	556	559	561	564	567	569	572	575	577	580	582	585	588	590	593	595	598
-25	553	556	559	561	564	567	569	572	574	577	580	582	585	587	590	593	595	598
-30	553	556	559	561	564	566	569	572	574	577	579	582	585	587	590	592	595	598
-35	553	556	558	561	564	566	569	571	574	577	579	582	585	587	590	592	595	597
-40	553	556	558	561	563	566	569	571	574	577	579	582	584	587	590	592	595	597

	MATC (°C)												
Tamb (°C)	-4	-2	0	2	4	6	8	10	12	14	16	18	20
50	2133	2346	2562	2783	3015	3262	3523	3798	4090	4396	4715	5040	5369
45	1529	1691	1858	2028	2201	2376	2551	2726	2906	3092	3286	3486	3692
40	1140	1261	1390	1525	1665	1809	1954	2100	2246	2393	2541	2688	2836
35	1091	1205	1325	1451	1582	1716	1852	1989	2126	2263	2400	2536	2672
30	911	1003	1102	1207	1317	1432	1551	1671	1793	1917	2041	2164	2285
25	774	849	930	1017	1110	1208	1309	1414	1522	1633	1744	1856	1968
20	666	728	796	868	946	1029	1116	1206	1301	1398	1498	1599	1701
15	607	651	709	772	840	912	988	1068	1152	1239	1329	1421	1514
10	606	609	636	691	750	814	881	951	1026	1104	1185	1268	1353
5	604	606	609	611	624	675	730	787	848	913	981	1051	1124
0	601	604	607	609	612	614	617	660	710	764	820	879	940
-5	601	604	606	609	612	614	617	646	694	746	800	857	917
-10	601	604	606	609	611	614	616	632	679	729	782	837	894
-15	601	603	606	609	611	614	616	619	664	713	764	817	872
-20	601	603	606	608	611	614	616	619	650	697	747	798	852
-25	600	603	606	608	611	613	616	618	637	682	730	781	833
-30	600	603	605	608	611	613	616	618	624	668	715	763	814
-35	600	603	605	608	610	613	616	618	621	655	700	747	796
-40	600	602	605	608	610	613	615	618	620	642	686	731	779

Table D8 - H35 FM120 t_{final} - V_{CHSS} 7500 L and 50 L ≤ TVL ≤ 200 L

	MATC (°C)																	
Tamb (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	860	862	865	867	869	872	875	879	884	965	1096	1249	1426	1632	1865	2124	2409	2715
45	853	856	858	860	864	868	872	877	881	885	889	993	1121	1267	1433	1618	1826	2055
40	847	849	853	857	861	865	870	874	878	882	886	891	913	1021	1143	1280	1434	1605
35	844	849	853	857	861	865	869	874	878	882	886	891	900	1005	1122	1254	1402	1565
30	842	847	851	855	859	863	868	872	876	880	885	889	893	897	980	1089	1210	1346
25	840	845	849	853	857	862	866	870	874	878	883	887	891	895	899	956	1058	1171
20	839	843	847	851	856	860	864	868	872	877	881	885	889	893	897	902	935	1030
15	837	842	846	850	854	858	863	867	871	875	879	883	888	892	896	900	904	939
10	836	840	844	849	853	857	861	865	869	874	878	882	886	890	894	898	903	907
5	833	838	842	846	850	854	858	862	867	871	875	879	883	887	891	895	900	904
0	831	835	839	843	847	851	856	860	864	868	872	876	880	884	888	892	896	901
-5	831	835	839	843	847	851	855	860	864	868	872	876	880	884	888	892	896	901
-10	831	835	839	843	847	851	855	860	864	868	872	876	880	884	888	892	896	900
-15	831	835	839	843	847	851	855	860	864	868	872	876	880	884	888	892	896	900
-20	831	835	839	843	847	851	855	859	864	868	872	876	880	884	888	892	896	900
-25	831	835	839	843	847	851	855	859	864	868	872	876	880	884	888	892	896	900
-30	831	835	839	843	847	851	855	859	864	868	872	876	880	884	888	892	896	900
-35	831	835	839	843	847	851	855	859	863	868	872	876	880	884	888	892	896	900
-40	830	835	839	843	847	851	855	859	863	868	872	876	880	884	888	892	896	900

	MATC (°C)												
Tamb (°C)	-4	-2	0	2	4	6	8	10	12	14	16	18	20
50	3038	3370	3712	4064	4435	4832	5254	5705	6189	6705	7249	7812	8389
45	2303	2565	2837	3118	3407	3702	4000	4306	4626	4963	5320	5692	6082
40	1794	1997	2214	2443	2682	2929	3179	3431	3687	3947	4212	4483	4763
35	1745	1938	2143	2360	2587	2820	3055	3292	3532	3774	4018	4264	4514
30	1495	1656	1830	2015	2211	2416	2625	2838	3054	3272	3492	3711	3930
25	1296	1432	1579	1737	1906	2084	2269	2459	2654	2853	3054	3254	3454
20	1136	1251	1376	1511	1656	1811	1973	2142	2316	2496	2680	2864	3049
15	1032	1133	1243	1363	1492	1629	1775	1927	2085	2250	2419	2590	2762
10	942	1032	1130	1236	1350	1474	1604	1740	1884	2034	2190	2348	2508
5	908	912	958	1045	1139	1240	1348	1463	1585	1713	1847	1986	2128
0	905	909	913	917	972	1056	1146	1242	1344	1452	1567	1687	1811
-5	905	909	913	917	961	1043	1130	1224	1323	1429	1541	1657	1777
-10	905	909	913	917	949	1030	1115	1207	1304	1407	1515	1628	1745
-15	904	909	913	917	939	1017	1101	1190	1285	1385	1491	1601	1715
-20	904	909	913	917	928	1005	1087	1174	1267	1364	1468	1575	1685
-25	904	908	913	917	921	993	1074	1159	1249	1345	1445	1550	1657
-30	904	908	912	917	921	982	1060	1144	1232	1325	1424	1525	1631
-35	904	908	912	916	921	971	1048	1129	1216	1307	1403	1502	1605
-40	904	908	912	916	920	960	1035	1115	1200	1289	1383	1480	1580

Table D9 - H35 FM120 t_{final} - V_{CHSS} 248.6 L and 200 L < TVL ≤ 350 L

	MATC (°C)																	
T_{amb} (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	163	163	163	163	163	163	199	252	318	397	496	617	762	933	1128	1346	1592	1865
45	163	163	163	163	163	163	163	192	238	293	355	428	515	616	730	856	996	1149
40	163	163	163	163	163	163	163	163	185	226	273	325	384	452	528	612	706	808
35	163	163	163	163	163	163	163	163	177	216	261	312	368	432	504	584	672	769
30	163	163	163	163	163	163	163	163	163	183	220	263	310	362	419	482	552	628
25	163	163	163	163	163	163	163	163	163	163	188	224	264	308	355	407	463	526
20	163	163	163	163	163	163	163	163	163	163	163	192	227	265	306	350	397	448
15	163	163	163	163	163	163	163	163	163	163	163	170	201	236	273	312	354	399
10	163	163	163	163	163	163	163	163	163	163	163	163	179	210	244	280	317	357
5	163	163	163	163	163	163	163	163	163	163	163	163	163	174	202	233	266	300
0	163	163	163	163	163	163	163	163	163	163	163	163	163	163	169	195	223	253
-5	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	188	216	246
-10	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	182	210	239
-15	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	177	203	232
-20	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	171	197	225
-25	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	166	191	218
-30	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	185	212
-35	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	179	205
-40	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	174	199

	MAT_C (°C)												
T_{amb} (°C)	-4	-2	0	2	4	6	8	10	12	14	16	18	20
50	2169	2502	2862	3250	3662	4089	4519	4945	5363	5769	6161	6535	6890
45	1314	1491	1678	1877	2088	2310	2542	2782	3032	3289	3553	3819	4086
40	918	1036	1160	1292	1430	1575	1725	1880	2042	2209	2382	2558	2738
35	873	983	1099	1220	1348	1480	1617	1756	1900	2049	2201	2355	2511
30	711	799	892	989	1092	1199	1309	1421	1537	1656	1779	1903	2029
25	593	665	741	822	906	995	1086	1180	1276	1376	1478	1581	1686
20	504	564	627	695	766	841	918	997	1080	1164	1251	1339	1429
15	448	500	555	614	676	742	810	880	953	1028	1105	1184	1264
10	400	446	495	547	602	660	721	783	848	915	984	1055	1127
5	336	374	413	456	501	549	598	650	704	760	818	878	938
0	285	317	351	386	424	464	505	548	594	641	690	741	792
-5	277	309	342	377	413	452	492	535	579	625	673	722	773
-10	269	301	333	367	403	441	480	521	565	610	656	704	754
-15	262	293	325	358	393	430	468	509	551	595	640	687	735
-20	255	285	316	349	383	419	457	496	537	580	625	671	718
-25	247	277	308	340	374	409	446	484	524	566	610	655	701
-30	240	270	300	332	365	399	435	472	512	553	596	639	684
-35	233	263	293	324	356	389	425	461	500	540	582	624	668
-40	227	255	285	315	347	380	414	450	488	527	568	610	653

Table D10 - H35 FM120 t_{final} - V_{CHSS} 500 L and 200 L < TVL ≤ 350 L

	MAT$_C$ (°C)																	
T_{amb} (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	163	163	163	163	163	163	175	223	285	362	457	577	726	904	1111	1346	1612	1907
45	163	163	163	163	163	163	163	177	221	276	341	418	511	620	747	889	1049	1226
40	163	163	163	163	163	163	163	163	178	219	269	326	391	466	552	649	758	878
35	163	163	163	163	163	163	163	163	173	212	260	316	379	451	534	627	731	846
30	163	163	163	163	163	163	163	163	163	183	223	270	323	383	449	524	607	699
25	163	163	163	163	163	163	163	163	163	163	193	233	279	330	386	447	515	590
20	163	163	163	163	163	163	163	163	163	163	169	203	243	287	335	387	444	507
15	163	163	163	163	163	163	163	163	163	163	163	182	218	258	302	349	399	455
10	163	163	163	163	163	163	163	163	163	163	163	165	196	232	272	315	361	410
5	163	163	163	163	163	163	163	163	163	163	163	163	165	195	228	265	305	347
0	163	163	163	163	163	163	163	163	163	163	163	163	163	165	193	224	259	295
-5	163	163	163	163	163	163	163	163	163	163	163	163	163	163	188	219	253	289
-10	163	163	163	163	163	163	163	163	163	163	163	163	163	163	184	214	248	283
-15	163	163	163	163	163	163	163	163	163	163	163	163	163	163	180	210	242	278
-20	163	163	163	163	163	163	163	163	163	163	163	163	163	163	176	205	237	272
-25	163	163	163	163	163	163	163	163	163	163	163	163	163	163	172	200	232	266
-30	163	163	163	163	163	163	163	163	163	163	163	163	163	163	168	196	227	261
-35	163	163	163	163	163	163	163	163	163	163	163	163	163	163	164	191	222	255
-40	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	187	217	250

	MAT$_C$ (°C)												
T_{amb} (°C)	-4	-2	0	2	4	6	8	10	12	14	16	18	20
50	2234	2592	2980	3402	3854	4333	4827	5328	5833	6334	6827	7301	7759
45	1419	1626	1846	2081	2330	2594	2870	3157	3457	3769	4090	4417	4747
40	1010	1151	1301	1460	1629	1807	1991	2182	2382	2589	2804	3024	3250
35	971	1105	1246	1396	1553	1717	1886	2060	2240	2425	2616	2810	3007
30	800	907	1021	1142	1270	1403	1541	1683	1829	1979	2134	2292	2451
25	673	762	856	956	1062	1173	1288	1407	1529	1656	1786	1917	2051
20	576	651	730	814	904	998	1096	1197	1301	1409	1521	1634	1749
15	515	580	650	724	803	886	973	1062	1155	1252	1351	1452	1554
10	464	521	583	649	719	793	870	950	1034	1120	1209	1300	1392
5	391	438	488	542	600	661	725	792	861	934	1009	1085	1164
0	334	374	416	461	509	560	614	670	729	790	854	919	986
-5	327	367	408	453	500	550	602	657	715	775	837	901	967
-10	321	360	401	444	490	539	591	645	701	760	821	883	948
-15	315	353	393	436	481	529	580	633	688	745	805	867	930
-20	308	346	386	428	472	520	569	621	675	732	790	850	912
-25	302	340	379	420	464	510	559	609	663	718	776	835	895
-30	296	333	372	412	455	501	549	598	651	705	762	819	879
-35	291	327	365	405	447	492	539	588	639	692	748	805	863
-40	285	321	358	397	439	483	529	577	627	680	734	790	847

Table D11 - H35 FM120 t_{final} - V_{CHSS} 1000 L and 200 L < TVL ≤ 350 L

T_{amb} (°C)	MATc (°C) -40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	163	163	163	163	176	206	241	282	328	392	482	586	711	859	1032	1230	1454	1706
45	163	163	163	163	163	163	174	207	252	307	374	451	538	636	747	873	1015	1173
40	163	163	163	163	163	163	163	173	207	248	299	358	427	502	583	672	772	882
35	163	163	163	163	163	163	163	170	203	243	292	350	417	491	570	657	753	859
30	163	163	163	163	163	163	163	163	179	213	254	303	360	423	492	565	644	731
25	163	163	163	163	163	163	163	163	163	189	223	264	312	368	428	493	561	634
20	163	163	163	163	163	163	163	163	163	168	197	232	273	321	375	432	493	557
15	163	163	163	163	163	163	163	163	163	163	180	211	248	290	338	391	447	506
10	163	163	163	163	163	163	163	163	163	163	166	193	225	263	306	354	406	461
5	163	163	163	163	163	163	163	163	163	163	163	166	192	222	258	298	342	390
0	163	163	163	163	163	163	163	163	163	163	163	163	165	190	220	253	290	331
-5	163	163	163	163	163	163	163	163	163	163	163	163	163	187	216	248	285	326
-10	163	163	163	163	163	163	163	163	163	163	163	163	163	184	212	244	281	321
-15	163	163	163	163	163	163	163	163	163	163	163	163	163	182	209	240	276	315
-20	163	163	163	163	163	163	163	163	163	163	163	163	163	179	206	236	271	310
-25	163	163	163	163	163	163	163	163	163	163	163	163	163	176	202	233	267	305
-30	163	163	163	163	163	163	163	163	163	163	163	163	163	173	199	229	263	300
-35	163	163	163	163	163	163	163	163	163	163	163	163	163	171	196	225	258	296
-40	163	163	163	163	163	163	163	163	163	163	163	163	163	168	193	222	254	291

T_{amb} (°C)	MATc (°C) -4	-2	0	2	4	6	8	10	12	14	16	18	20
50	1984	2289	2620	2981	3372	3793	4237	4699	5177	5666	6160	6648	7128
45	1347	1534	1735	1950	2181	2427	2685	2956	3242	3541	3853	4173	4502
40	1003	1134	1274	1424	1583	1752	1929	2113	2307	2509	2720	2938	3163
35	975	1100	1233	1375	1525	1684	1848	2017	2194	2378	2567	2762	2960
30	826	927	1036	1151	1274	1403	1537	1676	1821	1970	2125	2283	2444
25	713	797	887	984	1086	1195	1307	1423	1545	1670	1800	1933	2068
20	624	696	773	855	942	1034	1129	1229	1332	1440	1551	1665	1781
15	567	632	700	772	850	931	1016	1105	1197	1293	1392	1493	1597
10	518	576	638	703	772	845	921	1000	1083	1169	1258	1349	1443
5	440	492	545	600	658	719	782	848	918	990	1065	1142	1221
0	376	422	470	518	568	621	675	731	790	851	915	981	1048
-5	370	416	463	511	561	612	665	721	778	839	901	966	1032
-10	364	409	456	504	553	604	656	711	767	827	888	951	1016
-15	358	403	449	497	545	596	647	701	757	815	875	937	1001
-20	353	397	443	490	538	588	639	691	746	804	863	924	986
-25	347	391	436	483	531	580	630	682	736	792	851	911	972
-30	342	385	430	476	524	572	622	673	726	782	839	898	958
-35	336	379	424	470	517	565	614	664	717	771	828	886	945
-40	331	373	418	463	510	557	606	655	707	761	817	874	932

Table D12 - H35 FM120 t_{final} - V_{CHSS} 1500 L and 200 L < TVL ≤ 350 L

	MAT$_C$ (°C)																	
T_{amb} (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	172	173	179	206	237	273	315	364	419	480	568	683	811	956	1121	1309	1522	1762
45	171	172	173	173	174	195	222	259	308	368	440	525	621	727	840	963	1100	1251
40	170	171	172	172	173	174	187	217	254	298	352	416	490	574	664	759	859	967
35	170	171	171	172	173	174	184	213	249	293	345	407	479	561	649	742	840	944
30	169	170	171	172	173	174	175	191	221	257	300	352	412	482	558	640	725	815
25	169	170	171	172	172	173	174	175	198	229	265	308	358	417	483	555	631	711
20	168	169	170	171	172	173	174	175	179	205	235	272	315	365	421	484	552	624
15	168	169	170	171	172	173	174	174	175	189	216	248	286	330	380	436	497	564
10	168	169	170	171	172	172	173	174	175	176	199	227	261	300	344	394	450	510
5	168	168	169	170	171	172	173	174	175	175	176	196	223	255	291	331	377	428
0	167	168	169	170	171	171	172	173	174	175	176	177	194	219	249	282	320	362
-5	167	168	169	170	170	171	172	173	174	175	176	177	191	216	245	278	315	357
-10	167	168	169	170	170	171	172	173	174	175	176	177	188	213	241	273	310	351
-15	167	168	169	170	170	171	172	173	174	175	176	177	186	210	238	269	305	345
-20	167	168	169	170	170	171	172	173	174	175	176	177	183	207	234	265	300	340
-25	167	168	169	169	170	171	172	173	174	175	176	176	181	204	231	261	296	335
-30	167	168	169	169	170	171	172	173	174	175	176	176	178	201	227	257	291	330
-35	167	168	169	169	170	171	172	173	174	175	176	176	177	199	224	254	287	325
-40	167	168	169	169	170	171	172	173	174	175	176	176	177	196	221	250	283	320

	MAT$_C$ (°C)												
T_{amb} (°C)	-4	-2	0	2	4	6	8	10	12	14	16	18	20
50	2029	2320	2638	2985	3363	3769	4200	4650	5118	5599	6087	6572	7050
45	1418	1598	1792	2000	2224	2463	2714	2978	3258	3551	3858	4175	4500
40	1085	1211	1346	1491	1646	1810	1982	2162	2351	2549	2757	2971	3192
35	1057	1178	1306	1443	1589	1742	1902	2068	2241	2421	2608	2799	2995
30	909	1008	1114	1226	1344	1470	1600	1736	1877	2023	2175	2330	2489
25	794	879	968	1062	1161	1266	1376	1489	1607	1730	1857	1987	2120
20	698	775	852	934	1019	1109	1202	1299	1400	1505	1614	1725	1839
15	633	704	776	850	927	1008	1091	1177	1267	1361	1457	1557	1658
10	575	641	709	778	848	921	997	1074	1155	1239	1326	1416	1507
5	484	542	603	665	728	792	857	923	992	1063	1137	1212	1290
0	409	460	513	569	626	685	744	803	863	924	988	1053	1120
-5	403	452	505	560	617	675	734	792	851	912	974	1038	1103
-10	396	445	497	552	608	666	723	781	840	900	961	1024	1088
-15	390	438	490	544	600	656	714	771	829	888	948	1010	1072
-20	384	432	482	536	591	647	704	761	818	876	936	996	1058
-25	378	425	475	528	582	638	694	751	807	865	923	983	1043
-30	372	418	468	520	574	629	685	741	797	854	911	970	1030
-35	366	412	461	512	566	621	676	731	787	843	900	958	1016
-40	361	406	454	505	558	612	667	722	777	832	888	945	1003

Table D13 - H35 FM120 t_{final} - V_{CHSS} 2000 L and 200 L < TVL ≤ 350 L

T_{amb} (°C)	MAT$_C$ (°C)																	
	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	229	230	231	232	262	299	341	391	448	524	628	750	887	1036	1198	1378	1581	1808
45	228	229	230	230	231	232	258	299	351	413	487	575	677	791	913	1040	1176	1324
40	227	227	228	229	231	232	233	252	290	337	392	457	533	621	717	821	929	1042
35	226	227	228	229	231	232	233	248	286	331	384	448	522	607	702	802	909	1019
30	225	227	228	229	230	231	232	234	254	292	336	389	450	521	601	688	782	879
25	225	226	227	228	230	231	232	233	234	260	297	341	393	452	519	594	676	763
20	224	226	227	228	229	230	232	233	234	235	266	303	346	396	453	517	588	665
15	224	225	226	228	229	230	231	232	234	235	244	277	315	360	410	466	530	599
10	224	225	226	227	228	230	231	232	233	234	235	255	289	328	372	423	479	541
5	223	224	225	227	228	229	230	231	232	234	235	236	249	280	316	357	403	454
0	222	224	225	226	227	228	229	231	232	233	234	235	236	243	272	305	343	385
-5	222	224	225	226	227	228	229	230	232	233	234	235	236	239	268	301	338	379
-10	222	224	225	226	227	228	229	230	232	233	234	235	236	237	265	297	333	374
-15	222	224	225	226	227	228	229	230	232	233	234	235	236	237	261	293	328	368
-20	222	223	225	226	227	228	229	230	232	233	234	235	236	237	258	289	324	363
-25	222	223	225	226	227	228	229	230	232	233	234	235	236	237	254	285	319	358
-30	222	223	225	226	227	228	229	230	231	233	234	235	236	237	251	281	315	353
-35	222	223	225	226	227	228	229	230	231	233	234	235	236	237	248	277	311	348
-40	222	223	224	226	227	228	229	230	231	233	234	235	236	237	245	274	306	343

T_{amb} (°C)	MAT$_C$ (°C)												
	-4	-2	0	2	4	6	8	10	12	14	16	18	20
50	2060	2337	2639	2971	3331	3721	4135	4572	5029	5501	5983	6465	6943
45	1484	1658	1844	2045	2260	2491	2735	2993	3265	3552	3853	4164	4486
40	1160	1285	1417	1557	1708	1867	2035	2210	2395	2589	2793	3004	3222
35	1133	1252	1378	1511	1653	1802	1958	2120	2289	2465	2649	2838	3031
30	980	1083	1189	1299	1416	1539	1666	1798	1936	2080	2229	2382	2539
25	854	947	1040	1136	1236	1340	1447	1558	1674	1795	1920	2048	2179
20	747	831	917	1004	1092	1183	1276	1372	1472	1575	1682	1792	1904
15	674	752	832	914	996	1080	1165	1251	1341	1433	1529	1627	1727
10	609	681	756	832	910	989	1068	1148	1229	1313	1400	1488	1578
5	510	571	636	704	774	846	918	990	1063	1136	1210	1286	1364
0	432	483	538	597	659	724	790	856	923	990	1057	1125	1193
-5	425	476	530	588	649	713	778	844	910	976	1043	1109	1176
-10	419	468	522	579	640	703	767	832	897	963	1029	1095	1160
-15	413	461	514	571	630	693	756	820	885	950	1015	1080	1145
-20	407	455	507	562	621	683	746	809	873	937	1002	1066	1130
-25	401	448	499	554	612	673	735	798	861	925	989	1052	1115
-30	395	442	492	546	603	663	725	787	850	913	976	1039	1101
-35	389	435	485	538	594	654	715	776	838	901	963	1025	1087
-40	384	429	478	530	586	644	705	765	827	889	951	1013	1073

Table D14 - H35 FM120 t_{final} - V_{CHSS} 2500 L and 200 L < TVL ≤ 350 L

	MATC (°C)																	
Tamb (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	286	287	288	289	290	323	366	416	485	575	682	809	954	1113	1282	1461	1659	1879
45	285	286	287	288	289	290	292	336	390	454	530	620	725	844	974	1111	1254	1403
40	283	284	285	286	288	289	291	292	323	371	427	494	571	661	761	870	986	1108
35	282	283	285	286	288	289	291	292	318	365	419	484	559	646	743	849	963	1082
30	281	283	284	286	287	289	290	292	293	323	368	421	483	555	636	726	824	928
25	281	282	284	285	287	288	290	291	292	294	326	371	423	482	550	626	710	801
20	280	282	283	285	286	287	289	290	292	293	295	330	373	424	481	545	617	696
15	280	281	283	284	286	287	288	290	291	293	294	303	341	385	435	492	555	626
10	279	281	282	284	285	287	288	289	291	292	294	295	313	352	396	446	503	565
5	278	280	281	283	284	286	287	288	290	291	293	294	296	302	338	378	423	474
0	278	279	280	282	283	285	286	288	289	290	292	293	295	296	297	325	362	403
-5	278	279	280	282	283	285	286	287	289	290	292	293	295	296	297	320	357	398
-10	278	279	280	282	283	285	286	287	289	290	292	293	294	296	297	316	352	392
-15	277	279	280	282	283	285	286	287	289	290	292	293	294	296	297	312	347	387
-20	277	279	280	282	283	284	286	287	289	290	292	293	294	296	297	308	343	382
-25	277	279	280	282	283	284	286	287	289	290	291	293	294	296	297	304	338	376
-30	277	279	280	282	283	284	286	287	289	290	291	293	294	296	297	301	334	371
-35	277	279	280	282	283	284	286	287	289	290	291	293	294	296	297	298	330	367
-40	277	279	280	281	283	284	286	287	289	290	291	293	294	296	297	298	326	362

	MATC (°C)												
Tamb (°C)	-4	-2	0	2	4	6	8	10	12	14	16	18	20
50	2122	2389	2681	3000	3349	3727	4130	4555	5001	5467	5943	6421	6898
45	1563	1733	1914	2110	2320	2545	2783	3034	3301	3582	3879	4186	4503
40	1234	1361	1494	1633	1781	1938	2102	2274	2455	2646	2846	3054	3269
35	1204	1327	1454	1587	1726	1873	2026	2184	2350	2524	2704	2890	3081
30	1037	1148	1260	1373	1491	1613	1739	1869	2005	2146	2293	2444	2598
25	898	998	1099	1202	1307	1413	1521	1632	1747	1866	1989	2115	2245
20	781	870	963	1057	1153	1250	1347	1444	1545	1648	1754	1863	1974
15	702	784	869	957	1047	1138	1229	1320	1412	1505	1601	1699	1798
10	634	708	786	868	952	1038	1124	1210	1296	1383	1471	1560	1650
5	531	592	658	728	802	879	957	1036	1115	1195	1275	1354	1433
0	449	500	555	615	679	746	816	887	960	1034	1108	1181	1255
-5	443	493	547	606	668	735	804	874	946	1019	1092	1164	1236
-10	437	486	539	597	658	724	791	861	932	1004	1076	1148	1219
-15	431	479	531	588	649	713	780	848	918	989	1061	1131	1202
-20	425	472	523	579	639	702	768	836	905	975	1046	1116	1185
-25	419	465	516	571	629	692	757	823	892	961	1031	1100	1169
-30	413	459	508	562	620	682	746	812	879	947	1016	1085	1153
-35	407	452	501	554	611	672	735	800	866	934	1002	1070	1137
-40	402	446	494	546	603	662	724	788	854	921	989	1056	1122

Table D15 - H35 FM120 t_{final} - V_{CHSS} 5000 L and 200 L < TVL ≤ 350 L

	MATC (°C)																	
Tamb (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	573	575	577	579	581	582	585	599	685	786	905	1046	1209	1396	1602	1825	2060	2305
45	569	571	573	575	578	580	583	586	589	622	705	801	913	1041	1185	1344	1519	1707
40	565	567	570	573	576	578	581	584	587	590	592	641	721	813	917	1033	1162	1303
35	564	567	570	573	576	578	581	584	587	590	592	628	706	794	894	1004	1127	1263
30	563	566	569	572	574	577	580	583	585	588	591	594	613	685	766	856	956	1067
25	562	565	567	570	573	576	578	581	584	587	590	592	595	599	666	740	823	915
20	561	563	566	569	572	574	577	580	583	585	588	591	594	596	599	648	717	794
15	560	562	565	568	571	573	576	579	582	584	587	590	593	595	598	601	648	715
10	559	561	564	567	570	572	575	578	581	583	586	589	591	594	597	600	602	648
5	557	559	562	565	568	570	573	576	579	581	584	587	589	592	595	598	600	603
0	555	557	560	563	566	568	571	574	576	579	582	585	587	590	593	595	598	601
-5	555	557	560	563	566	568	571	574	576	579	582	584	587	590	593	595	598	601
-10	555	557	560	563	565	568	571	574	576	579	582	584	587	590	592	595	598	600
-15	554	557	560	563	565	568	571	573	576	579	582	584	587	590	592	595	598	600
-20	554	557	560	562	565	568	571	573	576	579	581	584	587	589	592	595	598	600
-25	554	557	560	562	565	568	570	573	576	579	581	584	587	589	592	595	597	600
-30	554	557	560	562	565	568	570	573	576	578	581	584	587	589	592	595	597	600
-35	554	557	559	562	565	568	570	573	576	578	581	584	586	589	592	594	597	600
-40	554	557	559	562	565	567	570	573	576	578	581	584	586	589	592	594	597	600

	MATC (°C)												
Tamb (°C)	-4	-2	0	2	4	6	8	10	12	14	16	18	20
50	2558	2817	3091	3386	3704	4048	4415	4804	5217	5651	6100	6556	7015
45	1903	2105	2309	2516	2727	2946	3172	3409	3658	3920	4196	4484	4782
40	1456	1617	1785	1957	2132	2310	2487	2665	2845	3031	3224	3422	3627
35	1408	1562	1721	1885	2052	2220	2388	2555	2723	2894	3069	3247	3429
30	1188	1318	1454	1597	1745	1896	2047	2199	2350	2502	2654	2805	2957
25	1016	1124	1241	1364	1494	1628	1764	1902	2041	2180	2319	2457	2594
20	878	970	1069	1175	1287	1405	1527	1651	1778	1907	2036	2164	2291
15	789	870	956	1050	1150	1256	1366	1480	1596	1716	1836	1957	2077
10	713	784	861	944	1033	1127	1227	1330	1437	1547	1660	1773	1886
5	606	659	721	788	861	939	1021	1108	1200	1295	1394	1495	1597
0	603	606	612	667	726	791	859	932	1009	1091	1176	1264	1355
-5	603	606	609	657	715	778	844	915	991	1070	1153	1239	1327
-10	603	606	609	647	703	765	830	899	972	1050	1131	1214	1300
-15	603	606	608	637	692	752	816	883	955	1030	1110	1191	1275
-20	603	606	608	627	682	740	803	868	938	1012	1089	1169	1251
-25	603	605	608	618	671	729	789	854	922	994	1069	1147	1227
-30	603	605	608	611	661	717	777	840	906	977	1050	1126	1204
-35	603	605	608	611	652	706	765	826	891	960	1032	1106	1182
-40	602	605	608	610	642	696	753	813	877	944	1014	1087	1161

Table D16 - H35 FM120 t_{final} - V_{CHSS} 7500 L and 200 L < TVL ≤ 350 L

T_{amb} (°C)	MATC (°C) -40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	860	862	865	867	869	872	875	879	884	965	1096	1249	1426	1632	1865	2124	2409	2715
45	853	856	858	860	864	868	872	877	881	885	889	993	1121	1267	1433	1618	1826	2055
40	847	849	853	857	861	865	870	874	878	882	886	891	913	1021	1143	1280	1434	1605
35	844	849	853	857	861	865	869	874	878	882	886	891	900	1005	1122	1254	1402	1565
30	842	847	851	855	859	863	868	872	876	880	885	889	893	897	980	1089	1210	1346
25	840	845	849	853	857	862	866	870	874	878	883	887	891	895	899	956	1058	1171
20	839	843	847	851	856	860	864	868	872	877	881	885	889	893	897	902	935	1030
15	837	842	846	850	854	858	863	867	871	875	879	883	888	892	896	900	904	939
10	836	840	844	849	853	857	861	865	869	874	878	882	886	890	894	898	903	907
5	833	838	842	846	850	854	858	862	867	871	875	879	883	887	891	895	900	904
0	831	835	839	843	847	851	856	860	864	868	872	876	880	884	888	892	896	901
-5	831	835	839	843	847	851	855	860	864	868	872	876	880	884	888	892	896	901
-10	831	835	839	843	847	851	855	860	864	868	872	876	880	884	888	892	896	900
-15	831	835	839	843	847	851	855	860	864	868	872	876	880	884	888	892	896	900
-20	831	835	839	843	847	851	855	859	864	868	872	876	880	884	888	892	896	900
-25	831	835	839	843	847	851	855	859	864	868	872	876	880	884	888	892	896	900
-30	831	835	839	843	847	851	855	859	864	868	872	876	880	884	888	892	896	900
-35	831	835	839	843	847	851	855	859	863	868	872	876	880	884	888	892	896	900
-40	830	835	839	843	847	851	855	859	863	868	872	876	880	884	888	892	896	900

T_{amb} (°C)	MATC (°C) -4	-2	0	2	4	6	8	10	12	14	16	18	20
50	3038	3370	3712	4064	4435	4832	5254	5705	6189	6705	7249	7812	8389
45	2303	2565	2837	3118	3407	3702	4000	4306	4626	4963	5320	5692	6082
40	1794	1997	2214	2443	2682	2929	3179	3431	3687	3947	4212	4483	4763
35	1745	1938	2143	2360	2587	2820	3055	3292	3532	3774	4018	4264	4514
30	1495	1656	1830	2015	2211	2416	2625	2838	3054	3272	3492	3711	3930
25	1296	1432	1579	1737	1906	2084	2269	2459	2654	2853	3054	3254	3454
20	1136	1251	1376	1511	1656	1811	1973	2142	2316	2496	2680	2864	3049
15	1032	1133	1243	1363	1492	1629	1775	1927	2085	2250	2419	2590	2762
10	942	1032	1130	1236	1350	1474	1604	1740	1884	2034	2190	2348	2508
5	908	912	958	1045	1139	1240	1348	1463	1585	1713	1847	1986	2128
0	905	909	913	917	972	1056	1146	1242	1344	1452	1567	1687	1811
-5	905	909	913	917	961	1043	1130	1224	1323	1429	1541	1657	1777
-10	905	909	913	917	949	1030	1115	1207	1304	1407	1515	1628	1745
-15	904	909	913	917	939	1017	1101	1190	1285	1385	1491	1601	1715
-20	904	909	913	917	928	1005	1087	1174	1267	1364	1468	1575	1685
-25	904	908	913	917	921	993	1074	1159	1249	1345	1445	1550	1657
-30	904	908	912	917	921	982	1060	1144	1232	1325	1424	1525	1631
-35	904	908	912	916	921	971	1048	1129	1216	1307	1403	1502	1605
-40	904	908	912	916	920	960	1035	1115	1200	1289	1383	1480	1580

Table D17 - H35 FM120 t_{final} - V_{CHSS} 500 L and 350 L < TVL ≤ 1000 L

	MATC (°C)																	
Tamb (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	163	163	163	163	163	163	179	230	297	381	488	626	798	1005	1247	1523	1834	2182
45	163	163	163	163	163	163	163	182	230	290	361	448	553	678	824	989	1174	1378
40	163	163	163	163	163	163	163	163	185	230	284	346	419	504	602	713	838	977
35	163	163	163	163	163	163	163	163	180	223	275	336	406	488	582	688	808	939
30	163	163	163	163	163	163	163	163	163	192	236	287	345	411	486	571	666	772
25	163	163	163	163	163	163	163	163	163	167	204	248	298	354	415	485	562	648
20	163	163	163	163	163	163	163	163	163	163	178	215	259	307	360	418	483	554
15	163	163	163	163	163	163	163	163	163	163	163	194	232	276	324	376	432	495
10	163	163	163	163	163	163	163	163	163	163	163	175	209	249	293	339	390	445
5	163	163	163	163	163	163	163	163	163	163	163	163	176	209	246	286	329	375
0	163	163	163	163	163	163	163	163	163	163	163	163	163	176	207	242	280	320
-5	163	163	163	163	163	163	163	163	163	163	163	163	163	172	203	237	274	313
-10	163	163	163	163	163	163	163	163	163	163	163	163	163	168	198	231	268	307
-15	163	163	163	163	163	163	163	163	163	163	163	163	163	165	194	226	262	301
-20	163	163	163	163	163	163	163	163	163	163	163	163	163	163	189	221	257	294
-25	163	163	163	163	163	163	163	163	163	163	163	163	163	163	185	216	251	289
-30	163	163	163	163	163	163	163	163	163	163	163	163	163	163	181	212	246	283
-35	163	163	163	163	163	163	163	163	163	163	163	163	163	163	177	207	241	277
-40	163	163	163	163	163	163	163	163	163	163	163	163	163	163	173	202	236	271

	MATC (°C)												
Tamb (°C)	-4	-2	0	2	4	6	8	10	12	14	16	18	20
50	2570	2994	3455	3954	4488	5048	5619	6191	6758	7315	7855	8373	8867
45	1602	1841	2096	2367	2656	2961	3280	3612	3957	4314	4681	5052	5424
40	1128	1290	1462	1645	1838	2042	2253	2472	2700	2937	3182	3433	3689
35	1083	1236	1398	1568	1747	1934	2127	2324	2529	2739	2955	3174	3396
30	887	1009	1140	1278	1423	1575	1731	1891	2057	2227	2402	2580	2760
25	742	843	951	1065	1186	1312	1443	1577	1715	1858	2004	2153	2304
20	633	717	808	904	1005	1113	1223	1338	1456	1578	1704	1831	1960
15	564	638	717	801	891	986	1084	1185	1290	1399	1511	1624	1740
10	506	571	641	716	796	880	967	1058	1152	1250	1350	1452	1556
5	424	478	535	596	661	731	803	878	957	1039	1124	1210	1299
0	362	406	454	504	559	617	677	741	807	877	949	1022	1098
-5	355	398	445	495	548	605	664	726	791	859	930	1002	1076
-10	348	391	436	485	538	593	651	712	776	842	911	982	1054
-15	341	383	428	476	527	582	639	699	761	826	894	963	1034
-20	334	376	420	467	517	571	627	685	747	811	877	945	1014
-25	328	369	412	458	508	560	615	673	733	795	860	927	994
-30	322	362	405	450	498	550	604	660	719	781	844	909	976
-35	315	355	397	442	489	540	593	648	706	766	829	893	958
-40	309	348	390	434	480	530	582	636	693	752	814	876	941

Table D18 - H35 FM120 t_{final} - V_{CHSS} 1000 L and 350 L < TVL ≤ 1000 L

T_{amb} (°C)	MATC (°C) -40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	163	163	163	163	176	206	241	281	328	397	497	617	763	941	1150	1392	1666	1975
45	163	163	163	163	163	163	175	208	256	316	390	478	579	698	834	991	1170	1369
40	163	163	163	163	163	163	163	177	213	258	315	383	462	551	650	761	887	1028
35	163	163	163	163	163	163	163	174	209	254	309	377	454	541	638	746	869	1005
30	163	163	163	163	163	163	163	163	187	224	271	327	394	470	552	641	742	853
25	163	163	163	163	163	163	163	163	168	200	239	287	344	410	482	560	644	737
20	163	163	163	163	163	163	163	163	163	180	213	254	303	361	424	493	567	646
15	163	163	163	163	163	163	163	163	163	166	196	232	276	327	385	449	516	588
10	163	163	163	163	163	163	163	163	163	163	180	212	251	298	350	409	471	537
5	163	163	163	163	163	163	163	163	163	163	163	183	215	252	296	346	400	458
0	163	163	163	163	163	163	163	163	163	163	163	163	185	216	253	294	341	392
-5	163	163	163	163	163	163	163	163	163	163	163	163	183	214	249	290	336	387
-10	163	163	163	163	163	163	163	163	163	163	163	163	181	211	246	287	332	382
-15	163	163	163	163	163	163	163	163	163	163	163	163	179	208	243	283	328	377
-20	163	163	163	163	163	163	163	163	163	163	163	163	177	206	240	279	324	373
-25	163	163	163	163	163	163	163	163	163	163	163	163	175	203	237	276	320	368
-30	163	163	163	163	163	163	163	163	163	163	163	163	173	201	234	272	316	364
-35	163	163	163	163	163	163	163	163	163	163	163	163	171	198	231	269	312	359
-40	163	163	163	163	163	163	163	163	163	163	163	163	169	196	228	265	308	355

T_{amb} (°C)	MATC (°C) -4	-2	0	2	4	6	8	10	12	14	16	18	20
50	2321	2700	3117	3575	4076	4619	5193	5793	6415	7050	7689	8319	8937
45	1589	1828	2085	2363	2663	2985	3326	3686	4069	4472	4894	5328	5771
40	1184	1352	1533	1728	1936	2158	2391	2636	2895	3167	3453	3750	4058
35	1155	1317	1490	1674	1870	2076	2292	2516	2751	2995	3250	3511	3779
30	976	1108	1250	1401	1562	1732	1908	2092	2283	2482	2688	2900	3117
25	840	950	1069	1196	1331	1473	1622	1776	1936	2103	2276	2453	2635
20	733	827	928	1036	1151	1273	1400	1532	1669	1812	1960	2112	2268
15	666	749	838	934	1036	1145	1258	1376	1498	1626	1758	1894	2032
10	608	682	762	848	940	1037	1139	1244	1355	1470	1589	1711	1835
5	519	582	649	720	796	877	962	1050	1143	1240	1340	1444	1550
0	446	502	560	620	685	753	825	899	978	1060	1146	1235	1326
-5	441	496	553	614	677	744	815	888	966	1047	1131	1218	1307
-10	436	491	547	607	669	736	805	878	954	1034	1117	1202	1289
-15	430	485	541	600	662	727	796	867	942	1021	1102	1186	1272
-20	425	479	535	593	655	719	787	857	931	1008	1088	1171	1255
-25	420	474	529	587	647	711	778	847	920	996	1075	1156	1238
-30	415	469	524	581	640	703	769	838	909	984	1062	1141	1223
-35	410	463	518	574	633	696	761	828	899	973	1049	1127	1207
-40	405	458	512	568	627	688	752	819	889	961	1037	1114	1192

Table D19 - H35 FM120 t_{final} - V_{CHSS} 1500 L and 350 L < TVL ≤ 1000 L

T_{amb} (°C)	MAT																	
	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	172	173	179	205	235	271	313	361	416	476	577	702	846	1012	1204	1424	1676	1960
45	171	172	172	173	174	195	221	260	312	376	455	551	660	781	913	1062	1229	1416
40	170	171	171	172	173	174	190	222	262	311	371	443	529	626	730	842	964	1099
35	170	170	171	172	173	174	188	219	258	306	365	437	521	616	719	829	948	1079
30	169	170	171	172	173	174	174	199	232	272	322	381	453	535	625	722	824	934
25	169	170	171	171	172	173	174	181	210	244	286	336	397	468	547	633	724	819
20	168	169	170	171	172	173	174	175	191	220	256	299	351	412	481	557	639	725
15	168	169	170	171	172	173	174	175	178	205	237	275	321	375	437	506	581	662
10	168	169	170	171	172	172	173	174	175	191	219	253	294	342	398	461	530	605
5	168	168	169	170	171	172	173	174	175	176	192	220	253	292	338	389	448	512
0	167	168	169	170	171	172	172	173	174	175	176	193	220	253	290	333	382	436
-5	167	168	169	170	171	172	172	173	174	175	176	191	218	250	287	329	377	432
-10	167	168	169	170	171	171	172	173	174	175	176	189	216	248	284	326	373	427
-15	167	168	169	170	171	171	172	173	174	175	176	188	214	245	281	322	369	422
-20	167	168	169	170	171	171	172	173	174	175	176	186	212	243	278	319	365	418
-25	167	168	169	170	171	171	172	173	174	175	176	184	210	240	275	315	361	413
-30	167	168	169	170	171	171	172	173	174	175	176	183	208	238	273	312	358	409
-35	167	168	169	170	171	171	172	173	174	175	176	181	206	236	270	309	354	404
-40	167	168	169	170	171	171	172	173	174	175	176	180	204	233	267	306	350	400

T_{amb} (°C)	MAT_C (°C)												
	-4	-2	0	2	4	6	8	10	12	14	16	18	20
50	2279	2629	3013	3437	3903	4410	4951	5522	6120	6739	7370	8000	8625
45	1623	1849	2092	2357	2643	2951	3279	3628	3999	4392	4807	5236	5678
40	1247	1408	1582	1769	1970	2184	2411	2650	2903	3171	3454	3748	4055
35	1223	1377	1543	1721	1911	2112	2323	2543	2774	3015	3269	3529	3798
30	1053	1181	1317	1464	1620	1786	1959	2139	2328	2525	2730	2942	3159
25	921	1029	1145	1268	1400	1539	1685	1836	1995	2160	2333	2509	2692
20	815	909	1009	1114	1227	1346	1471	1601	1737	1879	2026	2178	2333
15	746	831	921	1016	1117	1223	1335	1451	1572	1698	1830	1965	2103
10	683	763	845	932	1023	1119	1219	1323	1433	1546	1665	1786	1911
5	581	653	726	802	879	961	1045	1133	1225	1321	1421	1524	1630
0	496	560	626	694	764	835	908	984	1062	1145	1230	1319	1409
-5	491	554	620	687	756	827	899	974	1051	1132	1216	1303	1392
-10	486	548	613	680	749	819	890	964	1040	1120	1203	1288	1375
-15	480	542	607	674	742	811	882	954	1030	1108	1190	1273	1359
-20	475	537	601	667	735	803	873	945	1020	1097	1177	1259	1343
-25	470	531	595	660	727	796	865	936	1009	1086	1165	1245	1328
-30	465	526	589	654	720	788	857	927	1000	1075	1152	1232	1313
-35	460	520	583	647	714	781	849	918	990	1064	1141	1219	1299
-40	455	515	577	641	707	774	841	910	980	1054	1129	1206	1285

Table D20 - H35 FM120 t_{final} - V_{CHSS} 2000 L and 350 L < TVL ≤ 1000 L

T_{amb} (°C)	MAT_C (°C) -40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	229	230	231	232	260	296	339	388	446	538	649	779	925	1091	1276	1485	1723	1991
45	228	228	229	230	231	232	263	307	362	428	508	607	722	851	990	1138	1301	1480
40	226	227	228	229	230	231	233	260	302	354	416	490	579	681	793	913	1040	1175
35	226	227	228	229	230	231	233	258	299	350	411	484	571	671	782	900	1024	1156
30	225	226	227	229	230	231	232	234	269	312	363	425	498	583	678	782	893	1008
25	225	226	227	228	230	231	232	233	244	281	324	376	438	510	592	683	782	886
20	224	225	227	228	229	230	231	233	234	254	292	336	389	450	521	600	688	782
15	224	225	226	228	229	230	231	232	234	237	270	310	356	411	474	545	625	711
10	224	225	226	227	228	230	231	232	233	234	251	286	328	377	433	497	569	648
5	223	224	225	227	228	229	230	231	233	234	235	250	284	324	369	422	481	547
0	222	224	225	226	227	228	230	231	232	233	234	235	248	281	319	362	411	466
-5	222	224	225	226	227	228	230	231	232	233	234	235	246	279	316	358	407	462
-10	222	224	225	226	227	228	229	231	232	233	234	235	244	276	313	355	403	457
-15	222	224	225	226	227	228	229	231	232	233	234	235	242	274	310	352	399	453
-20	222	224	225	226	227	228	229	231	232	233	234	235	240	272	308	349	395	448
-25	222	224	225	226	227	228	229	231	232	233	234	235	238	269	305	345	392	444
-30	222	224	225	226	227	228	229	231	232	233	234	235	237	267	302	342	388	440
-35	222	224	225	226	227	228	229	231	232	233	234	235	237	265	300	339	384	435
-40	222	224	225	226	227	228	229	231	232	233	234	235	236	263	297	336	381	431

T_{amb} (°C)	MAT_C (°C) -4	-2	0	2	4	6	8	10	12	14	16	18	20
50	2292	2623	2988	3391	3833	4317	4836	5387	5969	6575	7197	7823	8447
45	1679	1895	2129	2383	2659	2957	3275	3613	3973	4358	4765	5187	5625
40	1320	1476	1643	1824	2019	2228	2448	2681	2929	3191	3469	3760	4062
35	1297	1447	1608	1780	1964	2160	2365	2580	2807	3045	3294	3552	3818
30	1129	1256	1390	1532	1685	1846	2015	2191	2376	2570	2773	2982	3198
25	994	1105	1220	1342	1471	1607	1750	1898	2054	2217	2386	2561	2741
20	880	981	1083	1190	1302	1420	1542	1670	1803	1943	2088	2238	2392
15	802	897	993	1091	1193	1299	1409	1523	1642	1767	1897	2030	2167
10	733	821	911	1003	1097	1195	1295	1398	1506	1618	1735	1855	1979
5	620	697	778	861	946	1033	1120	1209	1301	1397	1496	1598	1703
0	528	594	665	740	817	896	976	1056	1137	1220	1306	1394	1485
-5	523	588	659	733	809	888	966	1046	1126	1208	1293	1379	1468
-10	517	583	652	725	801	879	957	1036	1115	1196	1279	1364	1452
-15	512	577	646	718	794	871	948	1026	1104	1184	1266	1350	1436
-20	507	571	639	711	786	863	939	1016	1094	1173	1254	1336	1420
-25	502	565	633	704	778	854	930	1007	1084	1162	1242	1323	1406
-30	497	560	627	698	771	846	922	998	1074	1151	1230	1310	1391
-35	492	554	621	691	764	838	913	988	1064	1140	1218	1297	1377
-40	488	549	615	684	756	831	905	980	1055	1130	1207	1285	1364

Table D21 - H35 FM120 t_{final} - V_{CHSS} 2500 L and 350 L < TVL ≤ 1000 L

T_{amb} (°C)	MAT$_C$ (°C) -40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	286	287	288	289	290	321	363	417	495	590	705	841	997	1171	1359	1565	1795	2053
45	284	285	286	287	288	290	300	346	404	473	556	658	776	912	1059	1215	1380	1559
40	282	283	285	286	288	289	291	295	340	393	457	533	623	728	845	972	1108	1250
35	282	283	285	286	288	289	291	292	336	389	452	526	615	718	833	958	1091	1229
30	281	283	284	285	287	289	290	292	303	348	400	463	537	624	721	830	947	1071
25	281	282	283	285	287	288	290	291	292	313	358	411	474	547	630	724	827	937
20	280	282	283	285	286	287	289	290	292	293	323	368	422	484	555	636	726	824
15	280	281	283	284	286	287	289	290	291	293	300	340	388	443	506	578	659	748
10	279	281	282	284	285	287	288	290	291	293	294	315	358	407	463	528	600	680
5	279	280	281	283	284	286	287	289	290	292	293	295	311	351	397	449	508	575
0	278	279	281	282	284	285	286	288	289	291	292	294	295	306	344	387	435	490
-5	278	279	281	282	283	285	286	288	289	291	292	294	295	303	341	383	432	486
-10	278	279	281	282	283	285	286	288	289	291	292	294	295	301	338	380	428	481
-15	278	279	281	282	283	285	286	288	289	291	292	294	295	299	335	377	424	477
-20	278	279	281	282	283	285	286	288	289	291	292	294	295	296	333	374	420	473
-25	278	279	280	282	283	285	286	288	289	291	292	294	295	296	330	370	417	468
-30	278	279	280	282	283	285	286	288	289	291	292	293	295	296	327	367	413	464
-35	278	279	280	282	283	285	286	288	289	291	292	293	295	296	325	364	409	460
-40	278	279	280	282	283	285	286	288	289	291	292	293	295	296	322	361	406	456

T_{amb} (°C)	MAT$_C$ (°C) -4	-2	0	2	4	6	8	10	12	14	16	18	20
50	2341	2660	3011	3399	3827	4295	4798	5335	5904	6499	7114	7734	8356
45	1753	1962	2190	2437	2705	2995	3305	3635	3989	4366	4766	5182	5615
40	1397	1553	1718	1895	2086	2289	2505	2734	2977	3234	3508	3794	4093
35	1373	1524	1682	1851	2032	2223	2424	2635	2858	3092	3337	3592	3856
30	1200	1330	1466	1608	1758	1916	2082	2255	2438	2628	2828	3035	3248
25	1054	1172	1293	1417	1546	1681	1822	1968	2122	2282	2449	2622	2800
20	929	1037	1148	1260	1375	1494	1617	1743	1875	2013	2156	2304	2456
15	844	944	1048	1154	1262	1371	1483	1597	1716	1839	1968	2099	2235
10	768	861	958	1058	1160	1263	1366	1471	1580	1692	1808	1927	2049
5	648	728	813	902	994	1087	1182	1276	1372	1469	1569	1671	1776
0	552	619	692	770	852	937	1024	1111	1198	1287	1376	1466	1558
-5	547	613	685	762	843	928	1013	1099	1186	1274	1362	1450	1540
-10	542	607	678	755	835	918	1003	1088	1174	1261	1348	1435	1524
-15	537	602	672	747	827	909	993	1078	1163	1248	1335	1420	1507
-20	532	596	665	740	818	900	983	1067	1151	1236	1321	1406	1492
-25	527	590	659	732	810	891	974	1057	1140	1224	1309	1392	1476
-30	522	584	652	725	802	883	964	1047	1129	1213	1296	1379	1461
-35	517	579	646	718	795	874	955	1036	1119	1201	1283	1365	1447
-40	512	574	640	711	787	866	946	1027	1108	1190	1271	1352	1433

Table D22 - H35 FM120 t_{final} - V_{CHSS} 5000 L and 350 L < TVL ≤ 1000 L

T_{amb} (°C)	MATc (°C)																	
	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	573	575	577	578	580	582	585	616	706	814	941	1093	1269	1473	1699	1944	2203	2475
45	569	571	572	575	577	580	583	586	589	659	752	861	988	1135	1301	1486	1687	1903
40	565	567	570	573	575	578	581	584	587	590	621	703	798	907	1031	1170	1325	1495
35	564	567	570	573	576	578	581	584	587	590	614	694	787	893	1013	1148	1298	1462
30	563	566	569	572	574	577	580	583	586	589	592	614	691	780	879	991	1117	1256
25	562	565	567	570	573	576	579	582	585	588	591	593	614	688	772	866	972	1089
20	561	563	566	569	572	575	578	581	584	586	589	592	595	613	684	764	854	953
15	560	563	566	568	571	574	577	580	583	586	588	591	594	597	627	698	777	865
10	559	562	565	567	570	573	576	579	582	585	587	590	593	596	599	640	711	789
5	557	560	563	566	569	571	574	577	580	583	586	588	591	594	597	600	608	672
0	556	558	561	564	567	570	572	575	578	581	584	587	589	592	595	598	601	603
-5	555	558	561	564	567	570	572	575	578	581	584	586	589	592	595	598	601	603
-10	555	558	561	564	567	570	572	575	578	581	584	586	589	592	595	598	601	603
-15	555	558	561	564	567	570	572	575	578	581	584	586	589	592	595	598	600	603
-20	555	558	561	564	567	570	572	575	578	581	584	586	589	592	595	598	600	603
-25	555	558	561	564	567	569	572	575	578	581	584	586	589	592	595	598	600	603
-30	555	558	561	564	567	569	572	575	578	581	584	586	589	592	595	598	600	603
-35	555	558	561	564	567	569	572	575	578	581	584	586	589	592	595	598	600	603
-40	555	558	561	564	567	569	572	575	578	581	583	586	589	592	595	598	600	603

T_{amb} (°C)	MATc (°C)												
	-4	-2	0	2	4	6	8	10	12	14	16	18	20
50	2759	3060	3384	3738	4127	4553	5013	5507	6036	6596	7180	7776	8380
45	2128	2358	2593	2836	3093	3367	3656	3964	4293	4646	5021	5415	5826
40	1678	1869	2065	2266	2471	2680	2894	3116	3348	3593	3852	4123	4407
35	1639	1822	2011	2204	2400	2599	2800	3006	3219	3442	3675	3917	4167
30	1406	1566	1733	1906	2083	2263	2442	2623	2805	2993	3186	3385	3589
25	1218	1356	1503	1657	1816	1980	2145	2309	2475	2642	2811	2982	3156
20	1064	1183	1311	1447	1590	1738	1889	2041	2195	2349	2504	2658	2812
15	963	1069	1184	1306	1437	1573	1713	1855	1999	2144	2290	2435	2579
10	876	971	1073	1184	1302	1427	1556	1688	1823	1960	2099	2236	2373
5	743	820	904	996	1095	1201	1312	1428	1548	1672	1798	1925	2052
0	638	701	771	847	929	1019	1113	1213	1318	1428	1541	1656	1773
-5	632	694	763	838	919	1006	1099	1197	1300	1407	1518	1631	1746
-10	626	688	755	828	908	994	1085	1181	1282	1387	1496	1607	1719
-15	620	681	747	820	898	982	1072	1166	1265	1368	1475	1584	1694
-20	615	675	740	811	888	971	1059	1151	1248	1350	1455	1561	1669
-25	609	668	733	803	878	960	1046	1137	1232	1332	1435	1539	1645
-30	606	662	725	794	869	949	1034	1123	1217	1314	1415	1518	1622
-35	606	656	718	786	860	939	1022	1110	1202	1297	1397	1498	1600
-40	606	650	712	778	851	928	1010	1096	1187	1281	1379	1478	1578

Table D23 - H35 FM120 t_{final} - V_{CHSS} 7500 L and 350 L < TVL ≤ 1000 L

T_{amb} (°C)	MATc (°C)																	
	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	860	862	865	867	869	872	875	879	884	965	1096	1249	1426	1632	1865	2124	2409	2715
45	853	856	858	860	864	868	872	877	881	885	889	993	1121	1267	1433	1618	1826	2055
40	847	849	853	857	861	865	870	874	878	882	886	891	913	1021	1143	1280	1434	1605
35	844	849	853	857	861	865	869	874	878	882	886	891	900	1005	1122	1254	1402	1565
30	842	847	851	855	859	863	868	872	876	880	885	889	893	897	980	1089	1210	1346
25	840	845	849	853	857	862	866	870	874	878	883	887	891	895	899	956	1058	1171
20	839	843	847	851	856	860	864	868	872	877	881	885	889	893	897	902	935	1030
15	837	842	846	850	854	858	863	867	871	875	879	883	888	892	896	900	904	939
10	836	840	844	849	853	857	861	865	869	874	878	882	886	890	894	898	903	907
5	833	838	842	846	850	854	858	862	867	871	875	879	883	887	891	895	900	904
0	831	835	839	843	847	851	856	860	864	868	872	876	880	884	888	892	896	901
-5	831	835	839	843	847	851	855	860	864	868	872	876	880	884	888	892	896	901
-10	831	835	839	843	847	851	855	860	864	868	872	876	880	884	888	892	896	900
-15	831	835	839	843	847	851	855	860	864	868	872	876	880	884	888	892	896	900
-20	831	835	839	843	847	851	855	859	864	868	872	876	880	884	888	892	896	900
-25	831	835	839	843	847	851	855	859	864	868	872	876	880	884	888	892	896	900
-30	831	835	839	843	847	851	855	859	864	868	872	876	880	884	888	892	896	900
-35	831	835	839	843	847	851	855	859	863	868	872	876	880	884	888	892	896	900
-40	830	835	839	843	847	851	855	859	863	868	872	876	880	884	888	892	896	900

T_{amb} (°C)	MATc (°C)												
	-4	-2	0	2	4	6	8	10	12	14	16	18	20
50	3038	3370	3712	4064	4435	4832	5254	5705	6189	6705	7249	7812	8389
45	2303	2565	2837	3118	3407	3702	4000	4306	4626	4963	5320	5692	6082
40	1794	1997	2214	2443	2682	2929	3179	3431	3687	3947	4212	4483	4763
35	1745	1938	2143	2360	2587	2820	3055	3292	3532	3774	4018	4264	4514
30	1495	1656	1830	2015	2211	2416	2625	2838	3054	3272	3492	3711	3930
25	1296	1432	1579	1737	1906	2084	2269	2459	2654	2853	3054	3254	3454
20	1136	1251	1376	1511	1656	1811	1973	2142	2316	2496	2680	2864	3049
15	1032	1133	1243	1363	1492	1629	1775	1927	2085	2250	2419	2590	2762
10	942	1032	1130	1236	1350	1474	1604	1740	1884	2034	2190	2348	2508
5	908	912	958	1045	1139	1240	1348	1463	1585	1713	1847	1986	2128
0	905	909	913	917	972	1056	1146	1242	1344	1452	1567	1687	1811
-5	905	909	913	917	961	1043	1130	1224	1323	1429	1541	1657	1777
-10	905	909	913	917	949	1030	1115	1207	1304	1407	1515	1628	1745
-15	904	909	913	917	939	1017	1101	1190	1285	1385	1491	1601	1715
-20	904	909	913	917	928	1005	1087	1174	1267	1364	1468	1575	1685
-25	904	908	913	917	921	993	1074	1159	1249	1345	1445	1550	1657
-30	904	908	912	917	921	982	1060	1144	1232	1325	1424	1525	1631
-35	904	908	912	916	921	971	1048	1129	1216	1307	1403	1502	1605
-40	904	908	912	916	920	960	1035	1115	1200	1289	1383	1480	1580

D.1.3 H35 FM120 t_{final} Tables - Option B

Tables D24 through D35 are the H35 FM120 t_{final} tables for the application of Basic Option B in Equation C43.

Table D24 - H35 FM120 t_{final} - 248.6 L ≤ V_{CHSS} ≤ 1000 L and 50 L ≤ TVL ≤ 200 L

	MATC (°C)																	
Tamb (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	163	163	163	163	177	206	241	282	329	379	449	549	669	808	966	1144	1342	1562
45	163	163	163	163	163	163	175	202	233	275	329	392	464	548	643	749	865	993
40	163	163	163	163	163	163	163	163	187	220	261	308	362	422	486	552	624	710
35	163	163	163	163	163	163	163	163	182	215	254	300	353	411	473	538	607	682
30	163	163	163	163	163	163	163	163	163	187	219	257	301	352	406	463	522	585
25	163	163	163	163	163	163	163	163	163	164	191	223	260	303	350	400	454	509
20	163	163	163	163	163	163	163	163	163	163	169	195	227	263	303	348	396	446
15	163	163	163	163	163	163	163	163	163	163	163	177	204	236	272	312	356	402
10	163	163	163	163	163	163	163	163	163	163	163	163	185	213	245	281	321	363
5	163	163	163	163	163	163	163	163	163	163	163	163	163	180	206	235	268	304
0	163	163	163	163	163	163	163	163	163	163	163	163	163	163	175	198	225	256
-5	163	163	163	163	163	163	163	163	163	163	163	163	163	163	171	195	221	250
-10	163	163	163	163	163	163	163	163	163	163	163	163	163	163	168	191	217	245
-15	163	163	163	163	163	163	163	163	163	163	163	163	163	163	165	187	212	241
-20	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	183	208	236
-25	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	180	204	231
-30	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	176	200	227
-35	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	173	196	222
-40	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	170	192	218

	MATC (°C)												
Tamb (°C)	-4	-2	0	2	4	6	8	10	12	14	16	18	20
50	1806	2074	2365	2681	3020	3379	3747	4118	4490	4856	5215	5559	5890
45	1131	1278	1434	1601	1778	1965	2161	2365	2579	2801	3030	3263	3498
40	804	903	1008	1119	1237	1360	1488	1621	1760	1903	2053	2206	2362
35	766	860	958	1062	1171	1284	1401	1521	1646	1774	1906	2041	2178
30	652	722	797	876	960	1049	1141	1239	1339	1442	1549	1657	1767
25	566	626	689	755	826	900	977	1056	1139	1225	1315	1406	1499
20	497	550	604	661	721	785	850	918	989	1063	1139	1217	1297
15	450	499	549	600	654	710	769	829	892	958	1026	1095	1166
10	408	454	500	548	597	648	700	754	811	870	931	993	1057
5	342	383	425	467	511	555	600	646	694	743	795	848	902
0	289	324	361	400	439	479	520	560	602	644	689	734	780
-5	283	318	354	392	432	471	511	551	592	634	678	722	767
-10	277	312	348	385	424	464	503	543	583	624	667	711	755
-15	272	306	341	379	417	456	495	534	574	615	657	700	743
-20	267	300	335	372	410	448	487	526	565	606	647	689	732
-25	261	294	329	365	403	441	480	518	557	597	637	679	721
-30	256	288	323	358	396	434	472	510	549	588	628	668	710
-35	251	283	317	352	389	427	464	502	540	579	618	659	699
-40	247	277	311	346	382	419	457	495	532	571	609	649	689

Table D25 - H35 FM120 t_{final} - 1000 L < V_{CHSS} ≤ 2000 L and 50 L ≤ TVL ≤ 200 L

	MATC (°C)																	
Tamb (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	230	231	231	232	262	299	341	391	448	511	581	664	777	899	1027	1162	1310	1472
45	228	229	230	231	232	233	242	275	318	369	429	499	581	672	770	873	980	1090
40	227	228	229	230	231	232	233	234	259	297	340	392	451	519	594	675	762	853
35	227	228	228	229	230	232	233	234	254	290	332	381	439	504	577	656	740	828
30	226	227	228	229	230	231	232	233	235	254	288	329	375	429	489	555	627	704
25	225	226	227	228	229	231	232	233	234	235	253	287	325	369	419	475	536	603
20	224	226	227	228	229	230	231	232	233	235	236	253	285	322	364	410	462	519
15	224	225	226	227	229	230	231	232	233	234	235	236	259	291	327	368	414	464
10	224	225	226	227	228	229	230	231	233	234	235	236	237	264	296	332	372	417
5	223	224	225	226	227	228	230	231	232	233	234	235	236	237	251	280	312	347
0	222	223	224	225	227	228	229	230	231	232	233	234	235	237	238	239	265	294
-5	222	223	224	225	227	228	229	230	231	232	233	234	235	237	238	239	260	289
-10	222	223	224	225	226	228	229	230	231	232	233	234	235	236	238	239	256	283
-15	222	223	224	225	226	228	229	230	231	232	233	234	235	236	237	239	251	278
-20	222	223	224	225	226	227	229	230	231	232	233	234	235	236	237	239	247	273
-25	222	223	224	225	226	227	228	230	231	232	233	234	235	236	237	238	243	269
-30	222	223	224	225	226	227	228	230	231	232	233	234	235	236	237	238	239	264
-35	222	223	224	225	226	227	228	229	231	232	233	234	235	236	237	238	239	259
-40	222	223	224	225	226	227	228	229	231	232	233	234	235	236	237	238	239	255

	MATC (°C)												
Tamb (°C)	-4	-2	0	2	4	6	8	10	12	14	16	18	20
50	1652	1848	2063	2298	2555	2835	3140	3466	3805	4156	4514	4870	5222
45	1207	1329	1460	1600	1750	1910	2079	2258	2447	2648	2859	3078	3304
40	946	1040	1136	1236	1340	1451	1566	1687	1814	1947	2087	2231	2382
35	918	1009	1101	1195	1294	1398	1505	1616	1731	1852	1978	2108	2241
30	784	866	948	1031	1115	1202	1290	1381	1476	1574	1676	1780	1887
25	673	747	821	897	973	1050	1127	1205	1285	1368	1454	1541	1630
20	581	646	713	782	853	924	994	1065	1135	1208	1282	1357	1434
15	519	578	639	703	769	836	902	968	1035	1101	1169	1237	1306
10	466	518	574	633	694	757	820	882	945	1008	1071	1134	1197
5	387	430	477	527	580	635	691	749	806	865	923	981	1038
0	326	361	400	442	487	534	584	635	687	741	795	849	902
-5	320	355	392	433	477	524	572	623	674	727	780	834	886
-10	314	348	385	425	468	514	561	611	662	714	766	819	871
-15	308	342	378	417	459	504	551	599	649	701	753	804	856
-20	303	335	371	409	450	494	540	588	637	688	739	790	841
-25	298	329	364	401	442	485	530	577	626	675	726	776	827
-30	292	323	357	394	433	476	520	566	614	663	713	763	813
-35	287	317	350	387	425	467	511	556	603	651	701	750	799
-40	282	312	344	379	418	458	501	546	592	640	688	737	786

Table D26 - H35 FM120 t_{final} - 2000 L < V_{CHSS} ≤ 5000 L and 50 L ≤ TVL ≤ 200 L

	MAT$_C$ (°C)																	
T_{amb} (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	574	576	578	580	582	584	586	588	614	697	794	906	1036	1184	1348	1528	1721	1923
45	570	572	574	576	578	580	583	586	589	591	607	681	767	864	973	1094	1228	1373
40	567	569	571	573	576	578	581	584	586	589	592	595	599	668	744	828	923	1027
35	565	567	570	573	575	578	581	584	586	589	592	594	597	647	719	799	888	985
30	563	566	569	571	574	577	579	582	585	588	590	593	596	598	613	677	748	826
25	562	564	567	570	573	575	578	581	583	586	589	591	594	597	599	602	640	704
20	560	563	566	568	571	574	577	579	582	585	587	590	593	595	598	601	603	608
15	559	562	565	567	570	573	575	578	581	583	586	589	591	594	597	599	602	605
10	558	561	564	566	569	572	574	577	580	582	585	588	590	593	595	598	601	603
5	556	559	562	564	567	569	572	575	577	580	583	585	588	591	593	596	598	601
0	554	557	559	562	565	567	570	573	575	578	581	583	586	588	591	594	596	599
-5	554	557	559	562	565	567	570	572	575	578	580	583	586	588	591	593	596	599
-10	554	557	559	562	564	567	570	572	575	578	580	583	585	588	591	593	596	598
-15	554	556	559	562	564	567	570	572	575	577	580	583	585	588	590	593	596	598
-20	554	556	559	561	564	567	569	572	575	577	580	582	585	588	590	593	595	598
-25	553	556	559	561	564	567	569	572	574	577	580	582	585	587	590	593	595	598
-30	553	556	559	561	564	566	569	572	574	577	579	582	585	587	590	592	595	598
-35	553	556	558	561	564	566	569	571	574	577	579	582	585	587	590	592	595	597
-40	553	556	558	561	563	566	569	571	574	577	579	582	584	587	590	592	595	597

	MAT$_C$ (°C)												
T_{amb} (°C)	-4	-2	0	2	4	6	8	10	12	14	16	18	20
50	2133	2346	2562	2783	3015	3262	3523	3798	4090	4396	4715	5040	5369
45	1529	1691	1858	2028	2201	2376	2551	2726	2906	3092	3286	3486	3692
40	1140	1261	1390	1525	1665	1809	1954	2100	2246	2393	2541	2688	2836
35	1091	1205	1325	1451	1582	1716	1852	1989	2126	2263	2400	2536	2672
30	911	1003	1102	1207	1317	1432	1551	1671	1793	1917	2041	2164	2285
25	774	849	930	1017	1110	1208	1309	1414	1522	1633	1744	1856	1968
20	666	728	796	868	946	1029	1116	1206	1301	1398	1498	1599	1701
15	607	651	709	772	840	912	988	1068	1152	1239	1329	1421	1514
10	606	609	636	691	750	814	881	951	1026	1104	1185	1268	1353
5	604	606	609	611	624	675	730	787	848	913	981	1051	1124
0	601	604	607	609	612	614	617	660	710	764	820	879	940
-5	601	604	606	609	612	614	617	646	694	746	800	857	917
-10	601	604	606	609	611	614	616	632	679	729	783	839	896
-15	601	603	606	609	611	614	616	619	664	713	768	823	879
-20	601	603	606	608	611	614	616	619	650	699	753	807	862
-25	600	603	606	608	611	613	616	618	637	686	739	792	846
-30	600	603	605	608	611	613	616	618	624	673	725	777	830
-35	600	603	605	608	610	613	616	618	621	660	711	763	815
-40	600	602	605	608	610	613	615	618	620	648	698	749	800

Table D27 - H35 FM120 t_{final} - 5000 L < V_{CHSS} ≤ 7500 L and 50 L ≤ TVL ≤ 200 L

	MAT$_C$ (°C)																	
T_{amb} (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	860	862	865	867	869	872	875	879	884	965	1096	1249	1426	1632	1865	2124	2409	2715
45	853	856	858	860	864	868	872	877	881	885	889	993	1121	1267	1433	1618	1826	2055
40	847	849	853	857	861	865	870	874	878	882	886	891	913	1021	1143	1280	1434	1605
35	844	849	853	857	861	865	869	874	878	882	886	891	900	1005	1122	1254	1402	1565
30	842	847	851	855	859	863	868	872	876	880	885	889	893	897	980	1089	1210	1346
25	840	845	849	853	857	862	866	870	874	878	883	887	891	895	899	956	1058	1171
20	839	843	847	851	856	860	864	868	872	877	881	885	889	893	897	902	935	1030
15	837	842	846	850	854	858	863	867	871	875	879	883	888	892	896	900	904	939
10	836	840	844	849	853	857	861	865	869	874	878	882	886	890	894	898	903	907
5	833	838	842	846	850	854	858	862	867	871	875	879	883	887	891	895	900	904
0	831	835	839	843	847	851	856	860	864	868	872	876	880	884	888	892	896	901
-5	831	835	839	843	847	851	855	860	864	868	872	876	880	884	888	892	896	901
-10	831	835	839	843	847	851	855	860	864	868	872	876	880	884	888	892	896	900
-15	831	835	839	843	847	851	855	860	864	868	872	876	880	884	888	892	896	900
-20	831	835	839	843	847	851	855	859	864	868	872	876	880	884	888	892	896	900
-25	831	835	839	843	847	851	855	859	864	868	872	876	880	884	888	892	896	900
-30	831	835	839	843	847	851	855	859	864	868	872	876	880	884	888	892	896	900
-35	831	835	839	843	847	851	855	859	863	868	872	876	880	884	888	892	896	900
-40	830	835	839	843	847	851	855	859	863	868	872	876	880	884	888	892	896	900

	MAT$_C$ (°C)												
T_{amb} (°C)	-4	-2	0	2	4	6	8	10	12	14	16	18	20
50	3038	3370	3712	4064	4435	4832	5254	5705	6189	6705	7249	7812	8389
45	2303	2565	2837	3118	3407	3702	4000	4306	4626	4963	5320	5692	6082
40	1794	1997	2214	2443	2682	2929	3179	3431	3687	3947	4212	4483	4763
35	1745	1938	2143	2360	2587	2820	3055	3292	3532	3774	4018	4264	4514
30	1495	1656	1830	2015	2211	2416	2625	2838	3054	3272	3492	3711	3930
25	1296	1432	1579	1737	1906	2084	2269	2459	2654	2853	3054	3254	3454
20	1136	1251	1376	1511	1656	1811	1973	2142	2316	2496	2680	2864	3049
15	1032	1133	1243	1363	1492	1629	1775	1927	2085	2250	2419	2590	2762
10	942	1032	1130	1236	1350	1474	1604	1740	1884	2034	2190	2348	2508
5	908	912	958	1045	1139	1240	1348	1463	1585	1713	1847	1986	2128
0	905	909	913	917	972	1056	1146	1242	1344	1452	1567	1687	1811
-5	905	909	913	917	961	1043	1130	1224	1323	1429	1541	1657	1777
-10	905	909	913	917	949	1030	1115	1207	1304	1407	1515	1628	1745
-15	904	909	913	917	939	1017	1101	1190	1285	1385	1491	1601	1715
-20	904	909	913	917	928	1005	1087	1174	1267	1364	1468	1575	1685
-25	904	908	913	917	921	993	1074	1159	1249	1345	1445	1550	1657
-30	904	908	912	917	921	982	1060	1144	1232	1325	1424	1525	1631
-35	904	908	912	916	921	971	1048	1129	1216	1307	1403	1502	1605
-40	904	908	912	916	920	960	1035	1115	1200	1289	1383	1480	1580

Table D28 - H35 FM120 t_{final} - 248.6 L ≤ V_{CHSS} ≤ 1000 L and 200 L < TVL ≤ 350 L

	MATc (°C)																	
Tamb (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	163	163	163	163	176	206	241	282	328	397	496	617	762	933	1128	1346	1612	1907
45	163	163	163	163	163	163	174	207	252	307	374	451	538	636	747	889	1049	1226
40	163	163	163	163	163	163	163	173	207	248	299	358	427	502	583	672	772	882
35	163	163	163	163	163	163	163	170	203	243	292	350	417	491	570	657	753	859
30	163	163	163	163	163	163	163	163	179	213	254	303	360	423	492	565	644	731
25	163	163	163	163	163	163	163	163	163	189	223	264	312	368	428	493	561	634
20	163	163	163	163	163	163	163	163	163	168	197	232	273	321	375	432	493	557
15	163	163	163	163	163	163	163	163	163	163	180	211	248	290	338	391	447	506
10	163	163	163	163	163	163	163	163	163	163	166	193	225	263	306	354	406	461
5	163	163	163	163	163	163	163	163	163	163	163	166	192	222	258	298	342	390
0	163	163	163	163	163	163	163	163	163	163	163	163	165	190	220	253	290	331
-5	163	163	163	163	163	163	163	163	163	163	163	163	163	187	216	248	285	326
-10	163	163	163	163	163	163	163	163	163	163	163	163	163	184	212	244	281	321
-15	163	163	163	163	163	163	163	163	163	163	163	163	163	182	209	240	276	315
-20	163	163	163	163	163	163	163	163	163	163	163	163	163	179	206	236	271	310
-25	163	163	163	163	163	163	163	163	163	163	163	163	163	176	202	233	267	305
-30	163	163	163	163	163	163	163	163	163	163	163	163	163	173	199	229	263	300
-35	163	163	163	163	163	163	163	163	163	163	163	163	163	171	196	225	258	296
-40	163	163	163	163	163	163	163	163	163	163	163	163	163	168	193	222	254	291

	MATc (°C)												
Tamb (°C)	-4	-2	0	2	4	6	8	10	12	14	16	18	20
50	2234	2592	2980	3402	3854	4333	4827	5328	5833	6334	6827	7301	7759
45	1419	1626	1846	2081	2330	2594	2870	3157	3457	3769	4090	4417	4747
40	1010	1151	1301	1460	1629	1807	1991	2182	2382	2589	2804	3024	3250
35	975	1105	1246	1396	1553	1717	1886	2060	2240	2425	2616	2810	3007
30	826	927	1036	1151	1274	1403	1541	1683	1829	1979	2134	2292	2451
25	713	797	887	984	1086	1195	1307	1423	1545	1670	1800	1933	2068
20	624	696	773	855	942	1034	1129	1229	1332	1440	1551	1665	1781
15	567	632	700	772	850	931	1016	1105	1197	1293	1392	1493	1597
10	518	576	638	703	772	845	921	1000	1083	1169	1258	1349	1443
5	440	492	545	600	658	719	782	848	918	990	1065	1142	1221
0	376	422	470	518	568	621	675	731	790	851	915	981	1048
-5	370	416	463	511	561	612	665	721	778	839	901	966	1032
-10	364	409	456	504	553	604	656	711	767	827	888	951	1016
-15	358	403	449	497	545	596	647	701	757	815	875	937	1001
-20	353	397	443	490	538	588	639	691	746	804	863	924	986
-25	347	391	436	483	531	580	630	682	736	792	851	911	972
-30	342	385	430	476	524	572	622	673	726	782	839	898	958
-35	336	379	424	470	517	565	614	664	717	771	828	886	945
-40	331	373	418	463	510	557	606	655	707	761	817	874	932

Table D29 - H35 FM120 t_{final} - 1000 L < V_{CHSS} ≤ 2000 L and 200 L < TVL ≤ 350 L

T_{amb} (°C)	MATc (°C) -40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	229	230	231	232	262	299	341	391	448	524	628	750	887	1036	1198	1378	1581	1808
45	228	229	230	230	231	232	258	299	351	413	487	575	677	791	913	1040	1176	1324
40	227	227	228	229	231	232	233	252	290	337	392	457	533	621	717	821	929	1042
35	226	227	228	229	231	232	233	248	286	331	384	448	522	607	702	802	909	1019
30	225	227	228	229	230	231	232	234	254	292	336	389	450	521	601	688	782	879
25	225	226	227	228	230	231	232	233	234	260	297	341	393	452	519	594	676	763
20	224	226	227	228	229	230	232	233	234	235	266	303	346	396	453	517	588	665
15	224	225	226	228	229	230	231	232	234	235	244	277	315	360	410	466	530	599
10	224	225	226	227	228	230	231	232	233	234	235	255	289	328	372	423	479	541
5	223	224	225	227	228	229	230	231	232	234	235	236	249	280	316	357	403	454
0	222	224	225	226	227	228	229	231	232	233	234	235	236	243	272	305	343	385
-5	222	224	225	226	227	228	229	230	232	233	234	235	236	239	268	301	338	379
-10	222	224	225	226	227	228	229	230	232	233	234	235	236	237	265	297	333	374
-15	222	224	225	226	227	228	229	230	232	233	234	235	236	237	261	293	328	368
-20	222	223	225	226	227	228	229	230	232	233	234	235	236	237	258	289	324	363
-25	222	223	225	226	227	228	229	230	232	233	234	235	236	237	254	285	319	358
-30	222	223	225	226	227	228	229	230	231	233	234	235	236	237	251	281	315	353
-35	222	223	225	226	227	228	229	230	231	233	234	235	236	237	248	277	311	348
-40	222	223	224	226	227	228	229	230	231	233	234	235	236	237	245	274	306	343

T_{amb} (°C)	MATc (°C) -4	-2	0	2	4	6	8	10	12	14	16	18	20
50	2060	2337	2639	2985	3372	3793	4237	4699	5177	5666	6160	6648	7128
45	1484	1658	1844	2045	2260	2491	2735	2993	3265	3552	3858	4175	4502
40	1160	1285	1417	1557	1708	1867	2035	2210	2395	2589	2793	3004	3222
35	1133	1252	1378	1511	1653	1802	1958	2120	2289	2465	2649	2838	3031
30	980	1083	1189	1299	1416	1539	1666	1798	1936	2080	2229	2382	2539
25	854	947	1040	1136	1236	1340	1447	1558	1674	1795	1920	2048	2179
20	747	831	917	1004	1092	1183	1276	1372	1472	1575	1682	1792	1904
15	674	752	832	914	996	1080	1165	1251	1341	1433	1529	1627	1727
10	609	681	756	832	910	989	1068	1148	1229	1313	1400	1488	1578
5	510	571	636	704	774	846	918	990	1063	1136	1210	1286	1364
0	432	483	538	597	659	724	790	856	923	990	1057	1125	1193
-5	425	476	530	588	649	713	778	844	910	976	1043	1109	1176
-10	419	468	522	579	640	703	767	832	897	963	1029	1095	1160
-15	413	461	514	571	630	693	756	820	885	950	1015	1080	1145
-20	407	455	507	562	621	683	746	809	873	937	1002	1066	1130
-25	401	448	499	554	612	673	735	798	861	925	989	1052	1115
-30	395	442	492	546	603	663	725	787	850	913	976	1039	1101
-35	389	435	485	538	594	654	715	776	838	901	963	1025	1087
-40	384	429	478	530	586	644	705	765	827	889	951	1013	1073

Table D30 - H35 FM120 t_{final} - 2000 L < V_{CHSS} ≤ 5000 L and 200 L < TVL ≤ 350 L

T_{amb} (°C)	MAT$_C$ (°C) -40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	573	575	577	579	581	582	585	599	685	786	905	1046	1209	1396	1602	1825	2060	2305
45	569	571	573	575	578	580	583	586	589	622	705	801	913	1041	1185	1344	1519	1707
40	565	567	570	573	576	578	581	584	587	590	592	641	721	813	917	1033	1162	1303
35	564	567	570	573	576	578	581	584	587	590	592	628	706	794	894	1004	1127	1263
30	563	566	569	572	574	577	580	583	585	588	591	594	613	685	766	856	956	1067
25	562	565	567	570	573	576	578	581	584	587	590	592	595	599	666	740	823	915
20	561	563	566	569	572	574	577	580	583	585	588	591	594	596	599	648	717	794
15	560	562	565	568	571	573	576	579	582	584	587	590	593	595	598	601	648	715
10	559	561	564	567	570	572	575	578	581	583	586	589	591	594	597	600	602	648
5	557	559	562	565	568	570	573	576	579	581	584	587	589	592	595	598	600	603
0	555	557	560	563	566	568	571	574	576	579	582	585	587	590	593	595	598	601
-5	555	557	560	563	566	568	571	574	576	579	582	584	587	590	593	595	598	601
-10	555	557	560	563	565	568	571	574	576	579	582	584	587	590	592	595	598	600
-15	554	557	560	563	565	568	571	573	576	579	582	584	587	590	592	595	598	600
-20	554	557	560	562	565	568	571	573	576	579	581	584	587	589	592	595	598	600
-25	554	557	560	562	565	568	570	573	576	579	581	584	587	589	592	595	597	600
-30	554	557	560	562	565	568	570	573	576	578	581	584	587	589	592	595	597	600
-35	554	557	559	562	565	568	570	573	576	578	581	584	586	589	592	594	597	600
-40	554	557	559	562	565	567	570	573	576	578	581	584	586	589	592	594	597	600

T_{amb} (°C)	MAT$_C$ (°C) -4	-2	0	2	4	6	8	10	12	14	16	18	20
50	2558	2817	3091	3386	3704	4048	4415	4804	5217	5651	6100	6556	7015
45	1903	2105	2309	2516	2727	2946	3172	3409	3658	3920	4196	4484	4782
40	1456	1617	1785	1957	2132	2310	2487	2665	2845	3031	3224	3422	3627
35	1408	1562	1721	1885	2052	2220	2388	2555	2723	2894	3069	3247	3429
30	1188	1318	1454	1597	1745	1896	2047	2199	2350	2502	2654	2805	2957
25	1016	1124	1241	1364	1494	1628	1764	1902	2041	2180	2319	2457	2594
20	878	970	1069	1175	1287	1405	1527	1651	1778	1907	2036	2164	2291
15	789	870	956	1050	1150	1256	1366	1480	1596	1716	1836	1957	2077
10	713	784	861	944	1033	1127	1227	1330	1437	1547	1660	1773	1886
5	606	659	721	788	861	939	1021	1108	1200	1295	1394	1495	1597
0	603	606	612	667	726	791	859	932	1009	1091	1176	1264	1355
-5	603	606	609	657	715	778	844	915	991	1070	1153	1239	1327
-10	603	606	609	647	703	765	830	899	972	1050	1131	1214	1300
-15	603	606	608	637	692	752	816	883	955	1030	1110	1191	1275
-20	603	606	608	627	682	740	803	868	938	1012	1089	1169	1251
-25	603	605	608	618	671	729	789	854	922	994	1069	1147	1227
-30	603	605	608	611	661	717	777	840	906	977	1050	1126	1204
-35	603	605	608	611	652	706	765	826	891	960	1032	1106	1182
-40	602	605	608	610	642	696	753	813	877	944	1014	1087	1161

Table D31 - H35 FM120 t_{final} - 5000 L < V_{CHSS} ≤ 7500 L and 200 L < TVL ≤ 350 L

	MATC (°C)																	
Tamb (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	860	862	865	867	869	872	875	879	884	965	1096	1249	1426	1632	1865	2124	2409	2715
45	853	856	858	860	864	868	872	877	881	885	889	993	1121	1267	1433	1618	1826	2055
40	847	849	853	857	861	865	870	874	878	882	886	891	913	1021	1143	1280	1434	1605
35	844	849	853	857	861	865	869	874	878	882	886	891	900	1005	1122	1254	1402	1565
30	842	847	851	855	859	863	868	872	876	880	885	889	893	897	980	1089	1210	1346
25	840	845	849	853	857	862	866	870	874	878	883	887	891	895	899	956	1058	1171
20	839	843	847	851	856	860	864	868	872	877	881	885	889	893	897	902	935	1030
15	837	842	846	850	854	858	863	867	871	875	879	883	888	892	896	900	904	939
10	836	840	844	849	853	857	861	865	869	874	878	882	886	890	894	898	903	907
5	833	838	842	846	850	854	858	862	867	871	875	879	883	887	891	895	900	904
0	831	835	839	843	847	851	856	860	864	868	872	876	880	884	888	892	896	901
-5	831	835	839	843	847	851	855	860	864	868	872	876	880	884	888	892	896	901
-10	831	835	839	843	847	851	855	860	864	868	872	876	880	884	888	892	896	900
-15	831	835	839	843	847	851	855	860	864	868	872	876	880	884	888	892	896	900
-20	831	835	839	843	847	851	855	859	864	868	872	876	880	884	888	892	896	900
-25	831	835	839	843	847	851	855	859	864	868	872	876	880	884	888	892	896	900
-30	831	835	839	843	847	851	855	859	864	868	872	876	880	884	888	892	896	900
-35	831	835	839	843	847	851	855	859	863	868	872	876	880	884	888	892	896	900
-40	830	835	839	843	847	851	855	859	863	868	872	876	880	884	888	892	896	900

	MATC (°C)												
Tamb (°C)	-4	-2	0	2	4	6	8	10	12	14	16	18	20
50	3038	3370	3712	4064	4435	4832	5254	5705	6189	6705	7249	7812	8389
45	2303	2565	2837	3118	3407	3702	4000	4306	4626	4963	5320	5692	6082
40	1794	1997	2214	2443	2682	2929	3179	3431	3687	3947	4212	4483	4763
35	1745	1938	2143	2360	2587	2820	3055	3292	3532	3774	4018	4264	4514
30	1495	1656	1830	2015	2211	2416	2625	2838	3054	3272	3492	3711	3930
25	1296	1432	1579	1737	1906	2084	2269	2459	2654	2853	3054	3254	3454
20	1136	1251	1376	1511	1656	1811	1973	2142	2316	2496	2680	2864	3049
15	1032	1133	1243	1363	1492	1629	1775	1927	2085	2250	2419	2590	2762
10	942	1032	1130	1236	1350	1474	1604	1740	1884	2034	2190	2348	2508
5	908	912	958	1045	1139	1240	1348	1463	1585	1713	1847	1986	2128
0	905	909	913	917	972	1056	1146	1242	1344	1452	1567	1687	1811
-5	905	909	913	917	961	1043	1130	1224	1323	1429	1541	1657	1777
-10	905	909	913	917	949	1030	1115	1207	1304	1407	1515	1628	1745
-15	904	909	913	917	939	1017	1101	1190	1285	1385	1491	1601	1715
-20	904	909	913	917	928	1005	1087	1174	1267	1364	1468	1575	1685
-25	904	908	913	917	921	993	1074	1159	1249	1345	1445	1550	1657
-30	904	908	912	917	921	982	1060	1144	1232	1325	1424	1525	1631
-35	904	908	912	916	921	971	1048	1129	1216	1307	1403	1502	1605
-40	904	908	912	916	920	960	1035	1115	1200	1289	1383	1480	1580

Table D32 - H35 FM120 t_{final} - 248.6 L ≤ V_{CHSS} ≤ 1000 L and 350 L < TVL ≤ 1000 L

Tamb (°C)	MATc (°C) -40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	163	163	163	163	176	206	241	281	328	397	497	626	798	1005	1247	1523	1834	2182
45	163	163	163	163	163	163	175	208	256	316	390	478	579	698	834	991	1174	1378
40	163	163	163	163	163	163	163	177	213	258	315	383	462	551	650	761	887	1028
35	163	163	163	163	163	163	163	174	209	254	309	377	454	541	638	746	869	1005
30	163	163	163	163	163	163	163	163	187	224	271	327	394	470	552	641	742	853
25	163	163	163	163	163	163	163	163	168	200	239	287	344	410	482	560	644	737
20	163	163	163	163	163	163	163	163	163	180	213	254	303	361	424	493	567	646
15	163	163	163	163	163	163	163	163	163	166	196	232	276	327	385	449	516	588
10	163	163	163	163	163	163	163	163	163	163	180	212	251	298	350	409	471	537
5	163	163	163	163	163	163	163	163	163	163	163	183	215	252	296	346	400	458
0	163	163	163	163	163	163	163	163	163	163	163	163	185	216	253	294	341	392
-5	163	163	163	163	163	163	163	163	163	163	163	163	183	214	249	290	336	387
-10	163	163	163	163	163	163	163	163	163	163	163	163	181	211	246	287	332	382
-15	163	163	163	163	163	163	163	163	163	163	163	163	179	208	243	283	328	377
-20	163	163	163	163	163	163	163	163	163	163	163	163	177	206	240	279	324	373
-25	163	163	163	163	163	163	163	163	163	163	163	163	175	203	237	276	320	368
-30	163	163	163	163	163	163	163	163	163	163	163	163	173	201	234	272	316	364
-35	163	163	163	163	163	163	163	163	163	163	163	163	171	198	231	269	312	359
-40	163	163	163	163	163	163	163	163	163	163	163	163	169	196	228	265	308	355

Tamb (°C)	MATc (°C) -4	-2	0	2	4	6	8	10	12	14	16	18	20
50	2570	2994	3455	3954	4488	5048	5619	6191	6758	7315	7855	8373	8937
45	1602	1841	2096	2367	2663	2985	3326	3686	4069	4472	4894	5328	5771
40	1184	1352	1533	1728	1936	2158	2391	2636	2895	3167	3453	3750	4058
35	1155	1317	1490	1674	1870	2076	2292	2516	2751	2995	3250	3511	3779
30	976	1108	1250	1401	1562	1732	1908	2092	2283	2482	2688	2900	3117
25	840	950	1069	1196	1331	1473	1622	1776	1936	2103	2276	2453	2635
20	733	827	928	1036	1151	1273	1400	1532	1669	1812	1960	2112	2268
15	666	749	838	934	1036	1145	1258	1376	1498	1626	1758	1894	2032
10	608	682	762	848	940	1037	1139	1244	1355	1470	1589	1711	1835
5	519	582	649	720	796	877	962	1050	1143	1240	1340	1444	1550
0	446	502	560	620	685	753	825	899	978	1060	1146	1235	1326
-5	441	496	553	614	677	744	815	888	966	1047	1131	1218	1307
-10	436	491	547	607	669	736	805	878	954	1034	1117	1202	1289
-15	430	485	541	600	662	727	796	867	942	1021	1102	1186	1272
-20	425	479	535	593	655	719	787	857	931	1008	1088	1171	1255
-25	420	474	529	587	647	711	778	847	920	996	1075	1156	1238
-30	415	469	524	581	640	703	769	838	909	984	1062	1141	1223
-35	410	463	518	574	633	696	761	828	899	973	1049	1127	1207
-40	405	458	512	568	627	688	752	819	889	961	1037	1114	1192

Table D33 - H35 FM120 t_{final} - 1000 L < V_{CHSS} ≤ 2000 L and 350 L < TVL ≤ 1000 L

	MATc (°C)																	
Tamb (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	229	230	231	232	260	296	339	388	446	538	649	779	925	1091	1276	1485	1723	1991
45	228	228	229	230	231	232	263	307	362	428	508	607	722	851	990	1138	1301	1480
40	226	227	228	229	230	231	233	260	302	354	416	490	579	681	793	913	1040	1175
35	226	227	228	229	230	231	233	258	299	350	411	484	571	671	782	900	1024	1156
30	225	226	227	229	230	231	232	234	269	312	363	425	498	583	678	782	893	1008
25	225	226	227	228	230	231	232	233	244	281	324	376	438	510	592	683	782	886
20	224	225	227	228	229	230	231	233	234	254	292	336	389	450	521	600	688	782
15	224	225	226	228	229	230	231	232	234	237	270	310	356	411	474	545	625	711
10	224	225	226	227	228	230	231	232	233	234	251	286	328	377	433	497	569	648
5	223	224	225	227	228	229	230	231	233	234	235	250	284	324	369	422	481	547
0	222	224	225	226	227	228	230	231	232	233	234	235	248	281	319	362	411	466
-5	222	224	225	226	227	228	230	231	232	233	234	235	246	279	316	358	407	462
-10	222	224	225	226	227	228	229	231	232	233	234	235	244	276	313	355	403	457
-15	222	224	225	226	227	228	229	231	232	233	234	235	242	274	310	352	399	453
-20	222	224	225	226	227	228	229	231	232	233	234	235	240	272	308	349	395	448
-25	222	224	225	226	227	228	229	231	232	233	234	235	238	269	305	345	392	444
-30	222	224	225	226	227	228	229	231	232	233	234	235	237	267	302	342	388	440
-35	222	224	225	226	227	228	229	231	232	233	234	235	237	265	300	339	384	435
-40	222	224	225	226	227	228	229	231	232	233	234	235	236	263	297	336	381	431

	MATc (°C)												
Tamb (°C)	-4	-2	0	2	4	6	8	10	12	14	16	18	20
50	2321	2700	3117	3575	4076	4619	5193	5793	6415	7050	7689	8319	8937
45	1679	1895	2129	2383	2663	2985	3326	3686	4069	4472	4894	5328	5771
40	1320	1476	1643	1824	2019	2228	2448	2681	2929	3191	3469	3760	4062
35	1297	1447	1608	1780	1964	2160	2365	2580	2807	3045	3294	3552	3818
30	1129	1256	1390	1532	1685	1846	2015	2191	2376	2570	2773	2982	3198
25	994	1105	1220	1342	1471	1607	1750	1898	2054	2217	2386	2561	2741
20	880	981	1083	1190	1302	1420	1542	1670	1803	1943	2088	2238	2392
15	802	897	993	1091	1193	1299	1409	1523	1642	1767	1897	2030	2167
10	733	821	911	1003	1097	1195	1295	1398	1506	1618	1735	1855	1979
5	620	697	778	861	946	1033	1120	1209	1301	1397	1496	1598	1703
0	528	594	665	740	817	896	976	1056	1137	1220	1306	1394	1485
-5	523	588	659	733	809	888	966	1046	1126	1208	1293	1379	1468
-10	517	583	652	725	801	879	957	1036	1115	1196	1279	1364	1452
-15	512	577	646	718	794	871	948	1026	1104	1184	1266	1350	1436
-20	507	571	639	711	786	863	939	1016	1094	1173	1254	1336	1420
-25	502	565	633	704	778	854	930	1007	1084	1162	1242	1323	1406
-30	497	560	627	698	771	846	922	998	1074	1151	1230	1310	1391
-35	492	554	621	691	764	838	913	988	1064	1140	1218	1297	1377
-40	488	549	615	684	756	831	905	980	1055	1130	1207	1285	1364

Table D34 - H35 FM120 t_{final} - 2000 L < V_{CHSS} ≤ 5000 L and 350 L < TVL ≤ 1000 L

	MATc (°C)																	
Tamb (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	573	575	577	578	580	582	585	616	706	814	941	1093	1269	1473	1699	1944	2203	2475
45	569	571	572	575	577	580	583	586	589	659	752	861	988	1135	1301	1486	1687	1903
40	565	567	570	573	575	578	581	584	587	590	621	703	798	907	1031	1170	1325	1495
35	564	567	570	573	576	578	581	584	587	590	614	694	787	893	1013	1148	1298	1462
30	563	566	569	572	574	577	580	583	586	589	592	614	691	780	879	991	1117	1256
25	562	565	567	570	573	576	579	582	585	588	591	593	614	688	772	866	972	1089
20	561	563	566	569	572	575	578	581	584	586	589	592	595	613	684	764	854	953
15	560	563	566	568	571	574	577	580	583	586	588	591	594	597	627	698	777	865
10	559	562	565	567	570	573	576	579	582	585	587	590	593	596	599	640	711	789
5	557	560	563	566	569	571	574	577	580	583	586	588	591	594	597	600	608	672
0	556	558	561	564	567	570	572	575	578	581	584	587	589	592	595	598	601	603
-5	555	558	561	564	567	570	572	575	578	581	584	586	589	592	595	598	601	603
-10	555	558	561	564	567	570	572	575	578	581	584	586	589	592	595	598	601	603
-15	555	558	561	564	567	570	572	575	578	581	584	586	589	592	595	598	600	603
-20	555	558	561	564	567	570	572	575	578	581	584	586	589	592	595	598	600	603
-25	555	558	561	564	567	569	572	575	578	581	584	586	589	592	595	598	600	603
-30	555	558	561	564	567	569	572	575	578	581	584	586	589	592	595	598	600	603
-35	555	558	561	564	567	569	572	575	578	581	584	586	589	592	595	598	600	603
-40	555	558	561	564	567	569	572	575	578	581	583	586	589	592	595	598	600	603

	MATc (°C)												
Tamb (°C)	-4	-2	0	2	4	6	8	10	12	14	16	18	20
50	2759	3060	3384	3738	4127	4553	5013	5507	6036	6596	7197	7823	8447
45	2128	2358	2593	2836	3093	3367	3656	3964	4293	4646	5021	5415	5826
40	1678	1869	2065	2266	2471	2680	2894	3116	3348	3593	3852	4123	4407
35	1639	1822	2011	2204	2400	2599	2800	3006	3219	3442	3675	3917	4167
30	1406	1566	1733	1906	2083	2263	2442	2623	2805	2993	3186	3385	3589
25	1218	1356	1503	1657	1816	1980	2145	2309	2475	2642	2811	2982	3156
20	1064	1183	1311	1447	1590	1738	1889	2041	2195	2349	2504	2658	2812
15	963	1069	1184	1306	1437	1573	1713	1855	1999	2144	2290	2435	2579
10	876	971	1073	1184	1302	1427	1556	1688	1823	1960	2099	2236	2373
5	743	820	904	996	1095	1201	1312	1428	1548	1672	1798	1925	2052
0	638	701	771	847	929	1019	1113	1213	1318	1428	1541	1656	1773
-5	632	694	763	838	919	1006	1099	1197	1300	1407	1518	1631	1746
-10	626	688	755	828	908	994	1085	1181	1282	1387	1496	1607	1719
-15	620	681	747	820	898	982	1072	1166	1265	1368	1475	1584	1694
-20	615	675	740	811	888	971	1059	1151	1248	1350	1455	1561	1669
-25	609	668	733	803	878	960	1046	1137	1232	1332	1435	1539	1645
-30	606	662	725	794	869	949	1034	1123	1217	1314	1415	1518	1622
-35	606	656	718	786	860	939	1022	1110	1202	1297	1397	1498	1600
-40	606	650	712	778	851	928	1010	1096	1187	1281	1379	1478	1578

Table D35 - H35 FM120 t_{final} - 5000 L < V_{CHSS} ≤ 7500 L and 350 L < TVL ≤ 1000 L

	MAT$_C$ (°C)																	
T_{amb} (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	860	862	865	867	869	872	875	879	884	965	1096	1249	1426	1632	1865	2124	2409	2715
45	853	856	858	860	864	868	872	877	881	885	889	993	1121	1267	1433	1618	1826	2055
40	847	849	853	857	861	865	870	874	878	882	886	891	913	1021	1143	1280	1434	1605
35	844	849	853	857	861	865	869	874	878	882	886	891	900	1005	1122	1254	1402	1565
30	842	847	851	855	859	863	868	872	876	880	885	889	893	897	980	1089	1210	1346
25	840	845	849	853	857	862	866	870	874	878	883	887	891	895	899	956	1058	1171
20	839	843	847	851	856	860	864	868	872	877	881	885	889	893	897	902	935	1030
15	837	842	846	850	854	858	863	867	871	875	879	883	888	892	896	900	904	939
10	836	840	844	849	853	857	861	865	869	874	878	882	886	890	894	898	903	907
5	833	838	842	846	850	854	858	862	867	871	875	879	883	887	891	895	900	904
0	831	835	839	843	847	851	856	860	864	868	872	876	880	884	888	892	896	901
-5	831	835	839	843	847	851	855	860	864	868	872	876	880	884	888	892	896	901
-10	831	835	839	843	847	851	855	860	864	868	872	876	880	884	888	892	896	900
-15	831	835	839	843	847	851	855	860	864	868	872	876	880	884	888	892	896	900
-20	831	835	839	843	847	851	855	859	864	868	872	876	880	884	888	892	896	900
-25	831	835	839	843	847	851	855	859	864	868	872	876	880	884	888	892	896	900
-30	831	835	839	843	847	851	855	859	864	868	872	876	880	884	888	892	896	900
-35	831	835	839	843	847	851	855	859	863	868	872	876	880	884	888	892	896	900
-40	830	835	839	843	847	851	855	859	863	868	872	876	880	884	888	892	896	900

	MAT$_C$ (°C)												
T_{amb} (°C)	-4	-2	0	2	4	6	8	10	12	14	16	18	20
50	3038	3370	3712	4064	4435	4832	5254	5705	6189	6705	7249	7812	8389
45	2303	2565	2837	3118	3407	3702	4000	4306	4626	4963	5320	5692	6082
40	1794	1997	2214	2443	2682	2929	3179	3431	3687	3947	4212	4483	4763
35	1745	1938	2143	2360	2587	2820	3055	3292	3532	3774	4018	4264	4514
30	1495	1656	1830	2015	2211	2416	2625	2838	3054	3272	3492	3711	3930
25	1296	1432	1579	1737	1906	2084	2269	2459	2654	2853	3054	3254	3454
20	1136	1251	1376	1511	1656	1811	1973	2142	2316	2496	2680	2864	3049
15	1032	1133	1243	1363	1492	1629	1775	1927	2085	2250	2419	2590	2762
10	942	1032	1130	1236	1350	1474	1604	1740	1884	2034	2190	2348	2508
5	908	912	958	1045	1139	1240	1348	1463	1585	1713	1847	1986	2128
0	905	909	913	917	972	1056	1146	1242	1344	1452	1567	1687	1811
-5	905	909	913	917	961	1043	1130	1224	1323	1429	1541	1657	1777
-10	905	909	913	917	949	1030	1115	1207	1304	1407	1515	1628	1745
-15	904	909	913	917	939	1017	1101	1190	1285	1385	1491	1601	1715
-20	904	909	913	917	928	1005	1087	1174	1267	1364	1468	1575	1685
-25	904	908	913	917	921	993	1074	1159	1249	1345	1445	1550	1657
-30	904	908	912	917	921	982	1060	1144	1232	1325	1424	1525	1631
-35	904	908	912	916	921	971	1048	1129	1216	1307	1403	1502	1605
-40	904	908	912	916	920	960	1035	1115	1200	1289	1383	1480	1580

D.1.4 H35 FM120 t_{final} Tables - Conservative

Table D36 is the conservative t_{final} table to be used when the CHSS volume is indeterminate in Equation C42 or C43.

NOTE: The t_{final} values in this table are the most conservative t_{final} values from Tables D1 through D23, accounting for t_{final_min}. In other words, if $t_{final\_min} > t_{final}$ for the V_{CHSS} of the table, this t_{final} value is not considered because it would not be utilized.

Table D36 - H35 FM120 t_{final} - Conservative

	MAT$_C$ (°C)																	
T_{amb} (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	163	163	163	163	163	163	199	282	419	538	705	841	997	1473	1699	2124	2409	2715
45	163	163	163	163	163	163	163	192	256	376	508	658	776	912	1301	1486	1687	2055
40	163	163	163	163	163	163	163	163	185	258	315	443	579	728	845	972	1325	1495
35	163	163	163	163	163	163	163	163	180	254	309	437	571	718	833	958	1298	1462
30	163	163	163	163	163	163	163	163	163	192	271	381	453	583	721	830	947	1071
25	163	163	163	163	163	163	163	163	163	167	204	287	397	510	592	724	827	937
20	163	163	163	163	163	163	163	163	163	163	178	254	303	412	521	636	726	824
15	163	163	163	163	163	163	163	163	163	163	163	194	276	327	437	545	659	748
10	163	163	163	163	163	163	163	163	163	163	163	175	251	298	398	461	569	680
5	163	163	163	163	163	163	163	163	163	163	163	163	176	252	296	389	448	547
0	163	163	163	163	163	163	163	163	163	163	163	163	163	176	253	294	382	436
-5	163	163	163	163	163	163	163	163	163	163	163	163	163	172	249	290	377	432
-10	163	163	163	163	163	163	163	163	163	163	163	163	163	168	246	287	332	427
-15	163	163	163	163	163	163	163	163	163	163	163	163	163	165	194	283	328	422
-20	163	163	163	163	163	163	163	163	163	163	163	163	163	163	189	279	324	418
-25	163	163	163	163	163	163	163	163	163	163	163	163	163	163	185	276	320	413
-30	163	163	163	163	163	163	163	163	163	163	163	163	163	163	181	272	316	409
-35	163	163	163	163	163	163	163	163	163	163	163	163	163	163	177	269	312	404
-40	163	163	163	163	163	163	163	163	163	163	163	163	163	163	173	265	308	400

	MAT$_C$ (°C)												
T_{amb} (°C)	-4	-2	0	2	4	6	8	10	12	14	16	18	20
50	3038	3370	3712	4064	4488	5048	5619	6191	6758	7315	7855	8373	8937
45	2303	2565	2837	3118	3407	3702	4000	4306	4626	4963	5320	5692	6082
40	1678	1997	2214	2443	2682	2929	3179	3431	3687	3947	4212	4483	4763
35	1639	1938	2143	2360	2587	2820	3055	3292	3532	3774	4018	4264	4514
30	1406	1566	1733	2015	2211	2416	2625	2838	3054	3272	3492	3711	3930
25	1054	1356	1503	1657	1816	2084	2269	2459	2654	2853	3054	3254	3454
20	929	1037	1311	1447	1590	1738	1973	2142	2316	2496	2680	2864	3049
15	844	944	1048	1306	1437	1573	1713	1855	2085	2250	2419	2590	2762
10	768	861	958	1058	1302	1427	1556	1688	1823	2034	2190	2348	2508
5	648	728	813	902	994	1087	1312	1428	1548	1672	1798	1986	2128
0	528	594	692	770	852	937	1024	1111	1318	1428	1541	1656	1773
-5	523	588	685	762	843	928	1013	1099	1300	1407	1518	1631	1746
-10	517	583	678	755	835	918	1003	1088	1282	1387	1496	1607	1719
-15	512	577	672	747	827	909	993	1078	1163	1368	1475	1584	1694
-20	507	571	665	740	818	900	983	1067	1151	1350	1455	1561	1669
-25	470	565	659	732	810	891	974	1057	1140	1332	1435	1539	1645
-30	465	560	652	725	802	883	964	1047	1129	1314	1415	1518	1622
-35	460	554	646	718	795	874	955	1036	1119	1297	1397	1498	1600
-40	455	549	640	711	787	866	946	1027	1108	1190	1379	1478	1578

D.1.5 H35 FM60 or H70 FM60/FM90/FM300 t_{final} Tables - Option A

Tables D37 through D59 are the H35 FM60 or H70 FM60/FM90/FM300 t_{final} tables for the application of Advanced Option A in Equation C44.

Table D37 - H35 FM60 or H70 FM60/FM90/FM300 t_{final} - V_{CHSS} 248.6 L and 50 L ≤ TVL ≤ 200 L

	MAT$_C$ (°C)																	
T_{amb} (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	188	246	350	520	773	1122	1596	2245	3190	4672	6805	8712	10212	11395	12380	13227	13971	14640
45	177	192	248	336	465	638	859	1131	1457	1838	2283	2804	3415	4116	4892	5720	6561	7383
40	177	177	197	250	325	428	561	723	915	1134	1381	1655	1960	2297	2663	3059	3488	3951
35	177	177	189	238	307	402	525	677	855	1057	1281	1529	1799	2089	2399	2726	3072	3436
30	177	177	177	204	254	323	413	526	659	812	982	1170	1374	1593	1824	2067	2322	2590
25	177	177	177	179	218	269	337	422	526	645	778	926	1088	1262	1445	1637	1839	2050
20	177	177	177	177	191	231	283	349	430	524	632	751	882	1024	1174	1332	1498	1671
15	177	177	177	177	177	207	250	304	371	450	541	643	755	877	1007	1143	1287	1437
10	177	177	177	177	177	188	224	269	325	391	468	556	652	758	871	990	1116	1248
5	177	177	177	177	177	177	191	225	267	317	375	443	519	603	693	789	892	1000
0	177	177	177	177	177	177	177	193	225	264	309	362	422	489	562	641	725	814
-5	177	177	177	177	177	177	177	187	218	255	299	350	408	472	543	619	701	788
-10	177	177	177	177	177	177	177	182	212	248	289	338	394	456	525	599	678	762
-15	177	177	177	177	177	177	177	178	206	240	280	327	381	441	507	579	656	738
-20	177	177	177	177	177	177	177	177	200	233	271	316	368	427	491	560	635	715
-25	177	177	177	177	177	177	177	177	195	226	263	307	356	413	475	542	615	692
-30	177	177	177	177	177	177	177	177	190	220	255	297	345	400	460	525	596	671
-35	177	177	177	177	177	177	177	177	185	214	248	288	334	387	445	508	577	650
-40	177	177	177	177	177	177	177	177	181	208	241	279	324	375	431	493	559	630

	MAT$_C$ (°C)		
T_{amb} (°C)	-4	-2	0
50	15269	15846	16357
45	8161	8889	9567
40	4438	4941	5456
35	3817	4206	4602
30	2867	3156	3451
25	2269	2495	2726
20	1851	2036	2226
15	1593	1753	1917
10	1386	1527	1671
5	1113	1230	1350
0	908	1006	1107
-5	879	974	1072
-10	851	943	1038
-15	824	914	1006
-20	799	886	976
-25	774	859	947
-30	751	833	919
-35	728	808	892
-40	706	785	866

Table D38 - H35 FM60 or H70 FM60/FM90/FM300 t_{final} - V_{CHSS} 500 L and 50 L ≤ TVL ≤ 200 L

T_{amb} (°C)	MAT$_C$ (°C) -40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6	-4	-2	0
50	191	232	287	364	518	741	1042	1433	1932	2565	3391	4481	5855	7356	8763	9993	11066	12028	12890	13659	14373
45	177	183	217	270	357	479	644	853	1107	1403	1746	2140	2592	3112	3697	4349	5064	5819	6596	7363	8103
40	177	177	177	218	273	350	453	584	744	930	1142	1380	1645	1938	2257	2602	2979	3388	3828	4292	4777
35	177	177	177	211	264	336	434	557	709	885	1084	1305	1549	1813	2096	2397	2718	3058	3418	3791	4176
30	177	177	177	188	229	283	357	450	566	701	855	1027	1217	1422	1640	1871	2115	2373	2644	2924	3214
25	177	177	177	177	202	245	302	375	465	571	693	832	984	1149	1325	1512	1708	1915	2131	2354	2585
20	177	177	177	177	182	216	262	319	391	476	575	687	812	949	1094	1249	1412	1584	1763	1948	2139
15	177	177	177	177	177	198	236	285	345	417	501	598	705	824	950	1085	1228	1378	1535	1696	1862
10	177	177	177	177	177	183	216	257	308	370	442	525	618	721	833	951	1077	1209	1348	1491	1639
5	177	177	177	177	177	177	187	219	259	306	362	426	500	582	671	767	870	979	1094	1213	1335
0	177	177	177	177	177	177	177	191	222	259	303	354	413	479	551	630	715	805	901	1001	1104
-5	177	177	177	177	177	177	177	187	218	254	296	346	403	467	538	614	697	785	878	976	1077
-10	177	177	177	177	177	177	177	184	213	248	289	337	393	456	524	599	680	766	857	952	1050
-15	177	177	177	177	177	177	177	180	209	243	283	329	383	444	511	584	663	747	836	929	1025
-20	177	177	177	177	177	177	177	177	205	237	276	322	374	434	499	570	647	729	816	907	1001
-25	177	177	177	177	177	177	177	177	201	232	270	314	365	423	487	556	632	712	797	886	978
-30	177	177	177	177	177	177	177	177	197	228	264	307	357	413	475	543	617	695	779	865	955
-35	177	177	177	177	177	177	177	177	193	223	258	300	348	403	464	530	602	679	761	846	933
-40	177	177	177	177	177	177	177	177	189	219	253	293	340	394	453	518	588	663	743	827	912

Table D39 - H35 FM60 or H70 FM60/FM90/FM300 t_{final} - V_{CHSS} 1000 L and 50 L ≤ TVL ≤ 200 L

	MAT$_C$ (°C)																				
T_{amb} (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6	-4	-2	0
50	268	325	401	500	627	784	981	1311	1758	2317	3024	3939	5107	6464	7830	9079	10216	11226	12144	12971	13723
45	211	246	289	343	410	490	624	813	1048	1327	1650	2021	2447	2932	3479	4091	4768	5494	6250	7004	7744
40	177	200	230	265	306	364	458	577	725	900	1102	1331	1586	1870	2178	2512	2877	3274	3701	4154	4630
35	177	191	219	252	290	353	442	556	697	862	1053	1266	1503	1760	2037	2331	2645	2980	3333	3702	4083
30	177	177	190	217	253	305	373	460	568	695	842	1008	1192	1393	1607	1834	2076	2330	2598	2876	3164
25	177	177	177	193	227	269	323	391	476	576	693	826	973	1135	1308	1492	1686	1891	2106	2328	2558
20	177	177	177	177	206	241	285	340	408	489	583	691	812	945	1088	1241	1402	1573	1751	1936	2126
15	177	177	177	177	192	223	260	307	365	434	515	607	712	827	951	1084	1225	1374	1530	1691	1857
10	177	177	177	177	179	207	240	281	330	390	459	539	630	730	839	956	1080	1212	1350	1493	1640
5	177	177	177	177	177	184	211	244	282	328	383	445	517	597	684	778	880	988	1102	1220	1342
0	177	177	177	177	177	177	188	215	246	283	326	376	433	498	569	646	729	819	913	1013	1116
-5	177	177	177	177	177	177	185	211	242	278	320	368	424	487	557	632	713	801	893	990	1091
-10	177	177	177	177	177	177	182	208	238	273	314	361	416	477	545	618	698	783	874	968	1067
-15	177	177	177	177	177	177	179	205	234	268	308	354	407	467	533	605	683	767	855	948	1043
-20	177	177	177	177	177	177	177	201	230	263	302	347	399	458	522	593	669	751	837	927	1021
-25	177	177	177	177	177	177	177	198	227	259	296	341	391	448	512	581	655	735	820	908	1000
-30	177	177	177	177	177	177	177	195	223	254	291	334	384	440	501	569	642	720	803	889	979
-35	177	177	177	177	177	177	177	192	219	250	286	328	376	431	491	557	629	705	787	871	959
-40	177	177	177	177	177	177	177	189	216	246	281	322	369	422	481	546	616	691	771	854	940

Table D40 - H35 FM60 or H70 FM60/FM90/FM300 t_{final} - V_{CHSS} 1500 L and 50 L ≤ TVL ≤ 200 L

	MAT$_C$ (°C)																	
T$_{amb}$ (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	366	433	521	634	777	958	1188	1487	1889	2430	3101	3808	4673	5859	7114	8330	9457	10481
45	286	328	377	436	508	593	694	848	1068	1329	1634	1986	2390	2849	3366	3943	4581	5270
40	234	265	300	340	384	436	514	626	765	930	1121	1339	1585	1857	2155	2479	2832	3216
35	223	253	286	323	365	414	499	606	738	895	1075	1280	1507	1756	2024	2311	2617	2944
30	195	220	248	279	313	366	431	514	616	736	876	1034	1211	1405	1613	1835	2070	2320
25	177	194	217	245	283	328	381	447	527	623	733	860	1002	1158	1326	1504	1695	1895
20	177	177	197	225	258	297	342	396	461	538	628	731	847	975	1114	1262	1419	1586
15	177	177	185	211	241	276	316	364	419	485	562	651	750	861	982	1111	1248	1394
10	177	177	177	199	226	258	294	336	385	442	508	585	672	768	873	986	1108	1236
5	177	177	177	179	203	230	261	296	336	381	433	493	562	639	723	814	913	1018
0	177	177	177	177	183	206	233	263	297	335	377	425	480	542	611	685	766	853
-5	177	177	177	177	180	203	230	259	293	330	371	418	472	532	599	672	751	836
-10	177	177	177	177	178	200	226	256	288	325	365	411	463	523	588	659	736	819
-15	177	177	177	177	177	198	223	252	284	320	360	404	455	513	577	647	722	803
-20	177	177	177	177	177	195	220	248	280	315	354	398	448	504	567	635	709	788
-25	177	177	177	177	177	192	217	245	276	310	348	391	440	496	557	623	696	773
-30	177	177	177	177	177	190	214	241	272	306	343	385	433	487	547	612	683	759
-35	177	177	177	177	177	187	211	238	268	301	338	379	426	479	537	601	670	745
-40	177	177	177	177	177	185	208	234	264	297	333	373	419	471	528	591	658	731

	MAT$_C$ (°C)		
T$_{amb}$ (°C)	-4	-2	0
50	11429	12286	13076
45	5992	6723	7446
40	3631	4071	4535
35	3291	3653	4028
30	2584	2858	3143
25	2107	2326	2554
20	1762	1944	2132
15	1547	1705	1870
10	1372	1512	1657
5	1129	1245	1366
0	945	1043	1144
-5	926	1021	1120
-10	908	1000	1097
-15	890	980	1074
-20	872	961	1053
-25	856	942	1032
-30	840	924	1012
-35	824	907	993
-40	809	890	975

Table D41 - H35 FM60 or H70 FM60/FM90/FM300 t_{final} - V_{CHSS} 2000 L and 50 L ≤ TVL ≤ 200 L

	MATC (°C)																				
Tamb (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6	-4	-2	0
50	426	493	577	683	817	985	1198	1473	1837	2325	2943	3628	4376	5466	6659	7857	8991	10044	11012	11890	12708
45	337	382	433	491	559	641	736	890	1094	1340	1628	1961	2345	2782	3275	3826	4437	5103	5807	6527	7246
40	276	310	348	391	437	488	573	679	811	966	1147	1356	1591	1853	2140	2454	2797	3170	3575	4007	4462
35	264	296	333	373	417	478	559	661	786	934	1106	1301	1519	1759	2019	2298	2597	2917	3258	3614	3985
30	232	259	289	323	371	427	492	572	669	784	916	1068	1238	1425	1626	1842	2072	2317	2576	2847	3128
25	205	229	259	295	337	385	441	506	583	675	781	901	1037	1188	1351	1525	1710	1907	2115	2331	2556
20	189	212	240	272	309	351	399	454	518	592	679	778	889	1012	1146	1290	1444	1608	1780	1959	2145
15	180	201	226	255	289	327	371	420	477	541	615	700	796	903	1019	1144	1279	1421	1571	1727	1889
10	177	191	213	240	271	306	346	391	441	498	562	636	720	813	915	1025	1143	1268	1401	1539	1682
5	177	177	194	217	243	273	308	346	389	436	488	546	612	687	769	857	953	1055	1164	1278	1397
0	177	177	177	197	220	246	276	309	346	386	430	479	532	592	659	731	810	895	985	1080	1180
-5	177	177	177	195	217	243	272	305	341	381	424	472	524	583	648	719	796	878	967	1059	1156
-10	177	177	177	193	215	240	268	301	337	376	418	465	517	574	638	707	782	863	949	1040	1134
-15	177	177	177	190	212	237	265	297	332	371	413	459	509	565	627	695	769	848	932	1021	1113
-20	177	177	177	188	209	234	261	293	328	366	407	452	502	557	618	684	756	833	916	1002	1093
-25	177	177	177	186	207	231	258	289	323	361	402	446	495	549	608	673	744	819	900	985	1073
-30	177	177	177	184	204	228	255	285	319	356	396	440	488	541	599	662	732	806	885	968	1054
-35	177	177	177	182	202	225	252	281	315	351	391	434	481	533	590	652	720	793	870	951	1036
-40	177	177	177	180	200	222	248	278	311	347	386	428	475	525	581	642	708	780	856	935	1018

Table D42 - H35 FM60 or H70 FM60/FM90/FM300 t_{final} - V_{CHSS} 2500 L and 50 L ≤ TVL ≤ 200 L

T_{amb} (°C)	MAT$_C$ (°C)																				
	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6	-4	-2	0
50	483	553	635	738	867	1028	1231	1492	1835	2289	2869	3531	4228	5256	6403	7577	8717	9781	10760	11658	12489
45	382	431	485	546	614	692	784	941	1137	1372	1647	1968	2338	2760	3236	3770	4364	5013	5705	6415	7129
40	313	350	391	437	486	547	632	736	862	1012	1187	1387	1615	1869	2149	2455	2790	3156	3553	3977	4426
35	300	335	374	417	468	537	619	718	839	982	1147	1335	1546	1780	2033	2306	2599	2914	3249	3600	3967
30	263	292	326	371	423	482	550	630	724	835	963	1110	1274	1456	1653	1863	2089	2330	2585	2851	3130
25	237	266	300	340	385	437	496	562	639	728	830	948	1080	1226	1384	1554	1736	1930	2134	2347	2569
20	222	248	278	313	353	399	450	508	573	646	730	826	934	1055	1185	1326	1476	1637	1806	1983	2166
15	211	234	262	294	331	372	419	472	530	595	667	750	844	948	1061	1183	1314	1454	1602	1756	1915
10	200	222	248	277	310	348	391	439	493	551	615	687	769	860	959	1066	1181	1304	1435	1570	1711
5	184	203	225	250	279	312	348	390	435	485	539	598	663	735	815	901	995	1095	1202	1314	1431
0	177	186	206	228	252	280	312	348	388	431	478	528	582	642	706	777	854	937	1026	1119	1217
-5	177	184	203	225	250	277	308	344	383	426	471	521	575	633	696	765	840	922	1008	1099	1195
-10	177	182	201	223	247	274	305	339	378	420	465	514	567	624	686	754	827	907	991	1080	1173
-15	177	180	199	220	244	271	301	335	373	415	459	508	559	616	676	742	814	892	975	1062	1152
-20	177	179	197	218	241	268	297	331	369	409	454	501	552	608	667	731	802	878	959	1044	1132
-25	177	177	195	215	238	264	294	327	364	404	448	495	545	599	658	721	790	864	944	1027	1113
-30	177	177	193	213	236	261	290	323	359	399	442	488	538	592	649	711	778	851	929	1010	1095
-35	177	177	191	211	233	258	287	319	355	394	437	482	531	584	640	701	767	838	914	994	1077
-40	177	177	189	209	231	255	283	315	351	389	431	476	524	576	632	691	756	826	900	979	1060

Table D43 - H35 FM60 or H70 FM60/FM90/FM300 t_{final} - V_{CHSS} 3000 L and 50 L ≤ TVL ≤ 200 L

	MATC (°C)																	
Tamb (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	535	608	692	792	916	1069	1262	1507	1825	2243	2776	3401	4037	4980	6051	7180	8300	9366
45	423	475	532	596	665	743	838	989	1176	1400	1662	1969	2321	2724	3180	3691	4261	4887
40	346	385	429	478	530	602	688	789	911	1056	1224	1417	1636	1882	2153	2450	2775	3131
35	332	369	411	457	519	592	675	773	889	1027	1186	1368	1572	1798	2044	2310	2596	2903
30	292	325	367	415	470	533	604	684	777	884	1009	1151	1310	1486	1677	1883	2104	2340
25	270	301	338	380	429	484	545	615	692	779	879	993	1121	1263	1418	1584	1762	1952
20	252	280	313	350	393	442	496	557	625	699	781	874	980	1097	1224	1361	1509	1666
15	239	265	295	330	369	413	463	518	579	646	719	800	891	992	1103	1223	1351	1488
10	228	252	279	311	346	387	433	483	539	600	666	738	817	906	1003	1108	1221	1342
5	209	230	254	281	312	346	385	429	477	530	586	647	712	784	861	946	1038	1136
0	192	211	232	255	282	312	346	384	426	471	521	573	629	690	755	823	899	980
-5	190	209	229	253	279	309	342	379	420	466	514	566	622	681	745	812	885	965
-10	188	207	227	250	276	305	338	375	415	460	508	559	614	672	735	801	873	951
-15	186	205	225	248	273	302	334	370	411	454	502	552	606	664	725	790	861	937
-20	185	203	223	245	270	298	330	366	406	449	496	546	599	656	716	780	849	923
-25	183	201	220	243	267	295	327	362	401	444	490	539	592	648	707	770	837	910
-30	181	199	218	240	265	292	323	358	396	438	484	533	585	640	698	760	826	897
-35	180	197	216	238	262	289	319	353	391	433	478	526	578	632	690	751	815	885
-40	178	195	214	235	259	286	316	349	387	428	472	520	571	625	681	741	805	873

	MATC (°C)		
Tamb (°C)	-4	-2	0
50	10360	11278	12127
45	5557	6252	6957
40	3519	3933	4373
35	3232	3577	3939
30	2590	2853	3127
25	2153	2363	2582
20	1833	2007	2188
15	1633	1785	1942
10	1470	1603	1743
5	1242	1352	1467
0	1068	1160	1256
-5	1051	1140	1235
-10	1034	1122	1214
-15	1018	1104	1194
-20	1003	1087	1174
-25	988	1070	1156
-30	974	1054	1138
-35	960	1038	1120
-40	946	1023	1104

Table D44 - H35 FM60 or H70 FM60/FM90/FM300 t_{final} - V_{CHSS} 5000 L and 50 L ≤ TVL ≤ 200 L

	MATc (°C)																	
Tamb (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	727	817	916	1026	1149	1290	1464	1684	1960	2311	2754	3283	3855	4614	5526	6527	7571	8606
45	569	632	702	779	861	948	1070	1214	1383	1585	1821	2095	2411	2773	3182	3641	4156	4728
40	463	510	566	634	713	801	899	1007	1128	1264	1416	1593	1794	2020	2269	2543	2844	3176
35	449	499	558	626	702	788	884	989	1106	1236	1381	1547	1734	1942	2169	2415	2683	2971
30	415	460	511	570	637	711	794	886	986	1094	1213	1343	1489	1652	1830	2021	2228	2450
25	385	426	471	523	581	646	719	800	888	982	1083	1192	1311	1442	1585	1741	1908	2087
20	359	395	436	482	533	591	656	727	805	889	978	1073	1174	1285	1402	1530	1669	1817
15	341	374	411	453	500	553	612	677	748	825	907	993	1085	1183	1288	1398	1518	1647
10	324	354	389	428	471	519	572	632	697	768	844	923	1008	1097	1190	1289	1394	1507
5	296	323	353	386	424	465	511	561	618	679	744	814	888	966	1046	1130	1219	1312
0	271	295	322	351	383	419	459	503	551	604	661	723	788	857	929	1002	1079	1159
-5	269	292	319	348	380	415	454	497	545	597	654	714	779	847	918	990	1066	1144
-10	266	290	316	345	376	411	450	492	539	591	646	706	770	837	907	978	1053	1130
-15	264	287	313	342	373	407	445	487	534	584	639	698	761	828	896	967	1040	1116
-20	262	285	310	338	369	403	441	482	528	578	632	690	752	818	886	956	1028	1102
-25	260	283	308	335	366	399	436	477	522	572	625	683	744	809	876	945	1016	1089
-30	258	280	305	332	363	396	432	472	517	566	618	675	736	799	866	934	1004	1076
-35	255	278	302	329	359	392	428	468	512	559	611	667	727	790	856	923	993	1064
-40	253	275	300	327	356	388	424	463	506	554	605	660	719	782	846	913	981	1052

	MATc (°C)		
Tamb (°C)	-4	-2	0
50	9603	10540	11414
45	5348	6002	6676
40	3537	3925	4340
35	3281	3608	3953
30	2687	2937	3200
25	2277	2477	2687
20	1975	2140	2314
15	1785	1929	2080
10	1629	1756	1889
5	1410	1514	1624
0	1243	1331	1421
-5	1227	1312	1401
-10	1211	1294	1381
-15	1195	1277	1362
-20	1180	1260	1344
-25	1166	1244	1326
-30	1151	1229	1309
-35	1138	1214	1292
-40	1124	1199	1276

Table D45 - H35 FM60 or H70 FM60/FM90/FM300 t_{final} - V_{CHSS} 248.6 L and 200 L < TVL ≤ 350 L

	MAT_C (°C)																	
T_{amb} (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	189	256	377	585	903	1360	2013	3001	4770	7977	10501	12166	13436	14481	15363	16154	16858	17511
45	177	198	262	364	518	730	1003	1343	1756	2247	2828	3523	4342	5284	6305	7331	8302	9204
40	177	177	205	265	354	476	635	832	1065	1332	1633	1970	2345	2761	3214	3703	4232	4790
35	177	177	197	252	333	445	592	774	989	1233	1504	1803	2129	2480	2852	3245	3660	4094
30	177	177	177	214	272	353	459	593	752	935	1138	1362	1605	1865	2139	2427	2729	3044
25	177	177	177	187	230	290	370	471	593	734	892	1068	1259	1464	1680	1905	2142	2388
20	177	177	177	177	201	246	307	385	480	592	718	859	1014	1180	1356	1541	1734	1936
15	177	177	177	177	182	220	269	333	411	505	611	731	863	1005	1157	1316	1483	1657
10	177	177	177	177	177	198	239	292	357	435	526	628	742	865	997	1136	1283	1435
5	177	177	177	177	177	177	202	241	290	348	417	496	585	683	789	901	1020	1145
0	177	177	177	177	177	177	177	205	242	287	340	402	472	551	636	727	825	929
-5	177	177	177	177	177	177	177	199	235	277	328	388	455	531	613	702	797	897
-10	177	177	177	177	177	177	177	193	227	268	317	374	439	512	592	678	770	867
-15	177	177	177	177	177	177	177	188	220	260	306	361	424	494	571	655	744	838
-20	177	177	177	177	177	177	177	183	214	251	296	349	409	477	552	633	719	811
-25	177	177	177	177	177	177	177	178	208	244	287	337	395	461	533	611	695	785
-30	177	177	177	177	177	177	177	177	202	237	278	326	382	446	515	591	673	760
-35	177	177	177	177	177	177	177	177	197	230	269	316	369	431	498	572	651	736
-40	177	177	177	177	177	177	177	177	191	223	261	305	357	417	482	553	630	712

	MAT_C (°C)		
T_{amb} (°C)	-4	-2	0
50	18110	18662	19181
45	10039	10813	11524
40	5381	5978	6579
35	4541	4995	5454
30	3372	3707	4051
25	2644	2907	3175
20	2145	2359	2578
15	1838	2023	2212
10	1594	1757	1923
5	1276	1411	1549
0	1038	1151	1267
-5	1003	1112	1225
-10	970	1076	1185
-15	938	1041	1148
-20	908	1008	1111
-25	879	977	1077
-30	851	946	1044
-35	825	917	1013
-40	799	889	982

Table D46 - H35 FM60 or H70 FM60/FM90/FM300 t_{final} - V_{CHSS} 500 L and 200 L < TVL ≤ 350 L

	MATC (°C)																				
T_{amb} (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6	-4	-2	0
50	190	230	286	419	645	991	1486	2167	3111	4448	6438	9012	11407	13294	14838	16145	17282	18291	19214	20074	20835
45	177	182	226	302	422	603	853	1177	1580	2060	2627	3294	4074	4977	5993	7085	8224	9346	10427	11427	12372
40	177	177	189	240	314	423	574	771	1013	1299	1626	1997	2412	2873	3377	3926	4521	5161	5844	6548	7268
35	177	177	185	232	303	405	547	733	962	1229	1532	1871	2243	2648	3080	3538	4024	4536	5070	5617	6173
30	177	177	177	205	258	334	440	578	751	954	1185	1444	1729	2036	2362	2707	3070	3451	3849	4259	4679
25	177	177	177	184	226	284	365	471	604	763	946	1151	1377	1623	1883	2158	2447	2749	3065	3389	3722
20	177	177	177	177	201	248	311	394	499	626	772	939	1123	1325	1539	1766	2004	2254	2514	2781	3055
15	177	177	177	177	185	225	277	347	435	541	666	809	967	1141	1327	1524	1731	1948	2174	2406	2644
10	177	177	177	177	177	206	251	309	383	474	580	703	841	992	1155	1328	1511	1702	1902	2106	2316
5	177	177	177	177	177	180	214	259	315	384	466	561	670	791	921	1061	1210	1368	1533	1704	1880
0	177	177	177	177	177	177	188	222	266	319	383	459	545	642	749	863	986	1117	1256	1399	1548
-5	177	177	177	177	177	177	184	218	260	311	373	447	531	625	729	841	961	1088	1223	1363	1507
-10	177	177	177	177	177	177	181	213	254	304	364	435	517	609	710	819	936	1061	1192	1328	1468
-15	177	177	177	177	177	177	177	209	248	297	355	424	504	593	692	799	913	1034	1162	1295	1431
-20	177	177	177	177	177	177	177	205	243	290	346	413	491	578	674	778	890	1009	1134	1263	1396
-25	177	177	177	177	177	177	177	201	238	283	338	403	478	564	657	759	868	984	1106	1232	1362
-30	177	177	177	177	177	177	177	197	233	277	330	393	466	549	641	740	847	960	1080	1203	1330
-35	177	177	177	177	177	177	177	193	228	271	322	384	455	536	625	722	826	937	1054	1175	1299
-40	177	177	177	177	177	177	177	190	224	265	315	374	444	523	610	705	807	915	1029	1148	1269

Table D47 - H35 FM60 or H70 FM60/FM90/FM300 t_{final} - V_{CHSS} 1000 L and 200 L < TVL ≤ 350 L

T_{amb} (°C)	MAT$_C$ (°C)																				
	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6	-4	-2	0
50	268	324	400	499	625	806	1174	1675	2328	3165	4252	5693	7509	9480	11314	12944	14380	15660	16810	17850	18804
45	211	246	288	343	409	543	744	1011	1348	1752	2225	2774	3408	4136	4960	5876	6869	7907	8964	9993	10975
40	177	200	229	264	318	409	535	702	913	1165	1458	1792	2166	2581	3035	3530	4068	4653	5281	5941	6627
35	177	191	219	251	311	398	518	678	879	1118	1394	1705	2049	2425	2827	3256	3713	4197	4707	5235	5778
30	177	177	190	225	274	341	433	554	707	891	1104	1346	1613	1905	2217	2546	2896	3264	3650	4051	4464
25	177	177	177	205	245	299	371	466	586	731	900	1093	1308	1543	1795	2061	2343	2638	2948	3269	3599
20	177	177	177	188	223	267	325	400	496	613	750	907	1083	1277	1486	1707	1941	2187	2445	2710	2984
15	177	177	177	177	208	246	296	360	441	541	657	792	945	1113	1294	1487	1692	1907	2132	2364	2603
10	177	177	177	177	195	229	272	327	396	481	582	699	832	979	1138	1308	1488	1679	1879	2084	2295
5	177	177	177	177	177	203	238	280	334	400	478	569	674	791	919	1057	1205	1362	1527	1699	1876
0	177	177	177	177	177	182	211	246	288	340	402	474	558	653	757	870	992	1123	1261	1405	1555
-5	177	177	177	177	177	180	208	242	283	334	394	465	547	640	742	852	972	1099	1234	1375	1521
-10	177	177	177	177	177	177	205	239	279	328	387	456	537	627	727	835	952	1077	1209	1346	1488
-15	177	177	177	177	177	177	202	235	274	323	380	448	526	615	713	819	933	1055	1184	1318	1457
-20	177	177	177	177	177	177	200	232	270	317	373	440	516	603	699	803	915	1034	1161	1292	1427
-25	177	177	177	177	177	177	197	229	266	312	367	431	506	591	685	787	897	1014	1138	1266	1399
-30	177	177	177	177	177	177	194	225	262	307	360	424	497	580	672	772	880	994	1116	1242	1371
-35	177	177	177	177	177	177	192	222	258	302	354	416	488	569	659	757	863	975	1094	1218	1345
-40	177	177	177	177	177	177	189	219	255	297	348	409	479	559	647	743	847	957	1074	1195	1319

Table D48 - H35 FM60 or H70 FM60/FM90/FM300 t_{final} - V_{CHSS} 1500 L and 200 L < TVL ≤ 350 L

	MAT$_C$ (°C)																	
T_{amb} (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	366	433	520	633	777	957	1187	1551	2102	2789	3642	4711	6038	7592	9252	10859	12359	13739
45	286	327	376	436	507	592	765	1002	1303	1665	2091	2584	3150	3795	4520	5326	6208	7157
40	233	265	300	339	384	465	580	731	922	1153	1423	1733	2082	2471	2896	3358	3864	4412
35	222	252	285	323	372	455	566	711	894	1114	1370	1662	1986	2342	2725	3134	3571	4036
30	195	219	247	283	334	400	486	598	739	909	1109	1336	1590	1869	2168	2486	2824	3183
25	177	193	223	260	304	358	427	516	628	763	921	1103	1308	1533	1776	2034	2309	2599
20	177	181	207	240	279	325	382	454	544	654	782	931	1099	1285	1486	1701	1930	2171
15	177	177	196	226	261	303	353	415	493	586	696	824	969	1131	1306	1494	1694	1906
10	177	177	186	213	246	283	329	383	449	530	626	737	863	1004	1158	1324	1501	1688
5	177	177	177	194	221	254	291	336	388	451	526	613	713	826	949	1083	1228	1382
0	177	177	177	177	201	229	261	299	342	392	452	522	602	693	793	903	1022	1150
-5	177	177	177	177	198	226	258	295	338	387	445	514	592	682	780	887	1004	1129
-10	177	177	177	177	196	224	255	291	334	382	439	506	583	670	767	872	986	1109
-15	177	177	177	177	194	221	252	288	329	377	433	498	574	660	754	857	969	1089
-20	177	177	177	177	192	219	249	285	325	372	427	491	565	649	742	843	953	1071
-25	177	177	177	177	190	216	246	281	321	367	421	484	556	639	730	829	937	1052
-30	177	177	177	177	188	214	244	278	317	363	415	477	548	629	718	815	921	1035
-35	177	177	177	177	186	212	241	275	314	358	409	470	539	619	707	802	906	1017
-40	177	177	177	177	184	209	238	272	310	354	404	463	531	609	695	789	891	1001

	MAT$_C$ (°C)		
T_{amb} (°C)	-4	-2	0
50	14996	16144	17202
45	8143	9134	10105
40	5004	5628	6280
35	4527	5038	5567
30	3559	3951	4357
25	2903	3218	3544
20	2425	2688	2959
15	2128	2357	2595
10	1885	2089	2299
5	1545	1714	1890
0	1286	1429	1577
-5	1262	1401	1546
-10	1239	1375	1516
-15	1217	1350	1488
-20	1196	1326	1461
-25	1175	1302	1434
-30	1155	1280	1409
-35	1135	1258	1385
-40	1116	1237	1361

Table D49 - H35 FM60 or H70 FM60/FM90/FM300 t_{final} - V_{CHSS} 2000 L and 200 L < TVL ≤ 350 L

T_{amb} (°C)	MAT$_C$ (°C) -40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6	-4	-2	0
50	426	493	576	683	817	985	1199	1529	2030	2656	3428	4383	5562	6968	8513	10077	11580	12981	14280	15471	16569
45	336	381	432	491	559	650	815	1034	1312	1651	2051	2516	3051	3661	4346	5110	5953	6864	7819	8794	9760
40	276	310	348	390	446	530	640	782	961	1178	1433	1728	2062	2435	2844	3292	3781	4313	4888	5497	6139
35	264	296	332	374	439	520	627	764	936	1143	1386	1664	1976	2319	2690	3088	3515	3970	4452	4955	5476
30	231	258	295	342	398	465	549	657	790	951	1140	1357	1601	1871	2161	2472	2803	3154	3526	3912	4314
25	210	239	274	315	364	421	491	577	684	812	963	1137	1333	1551	1787	2039	2308	2592	2892	3204	3528
20	198	224	255	291	335	385	445	516	603	707	830	972	1134	1314	1509	1719	1942	2180	2430	2690	2959
15	189	213	241	275	315	360	414	477	552	642	748	871	1010	1166	1336	1519	1715	1923	2142	2369	2604
10	181	203	229	260	296	338	387	444	510	588	680	787	908	1045	1194	1355	1528	1712	1906	2107	2315
5	177	187	210	236	268	304	345	393	447	510	582	666	763	872	992	1122	1263	1414	1574	1741	1915
0	177	177	193	216	243	274	311	352	398	450	509	576	654	743	840	947	1063	1188	1321	1462	1608
-5	177	177	191	214	241	272	307	348	394	445	503	569	646	732	828	932	1046	1168	1299	1436	1579
-10	177	177	189	212	239	269	304	344	389	440	497	562	637	722	816	918	1030	1150	1277	1411	1551
-15	177	177	188	210	236	266	301	341	385	435	491	555	629	712	804	905	1014	1131	1257	1388	1524
-20	177	177	186	208	234	264	298	337	381	430	486	548	620	702	793	891	999	1114	1237	1365	1498
-25	177	177	184	207	232	261	295	334	377	426	480	541	612	693	782	879	984	1097	1217	1343	1473
-30	177	177	183	205	230	259	292	330	373	421	475	535	605	684	771	866	969	1080	1198	1322	1450
-35	177	177	181	203	228	256	289	327	369	416	469	529	597	675	760	854	955	1064	1180	1301	1426
-40	177	177	180	201	226	254	286	324	365	412	464	522	590	666	750	842	942	1049	1162	1281	1404

Table D50 - H35 FM60 or H70 FM60/FM90/FM300 t_{final} - V_{CHSS} 2500 L and 200 L < TVL ≤ 350 L

T_{amb} (°C)	MAT$_C$ (°C) -40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6	-4	-2	0
50	483	552	635	738	867	1028	1231	1549	2020	2608	3333	4227	5324	6639	8110	9637	11131	12545	13851	15069	16186
45	382	430	484	545	613	714	874	1082	1347	1669	2052	2498	3012	3600	4261	4998	5815	6701	7639	8598	9558
40	312	349	391	436	507	593	701	839	1011	1218	1463	1747	2070	2432	2831	3267	3745	4266	4829	5429	6061
35	299	334	374	431	500	584	688	822	987	1186	1419	1687	1990	2324	2686	3076	3494	3942	4417	4914	5430
30	265	301	344	395	455	526	611	716	845	1001	1182	1392	1629	1891	2175	2479	2804	3151	3517	3899	4297
25	248	281	319	364	417	479	551	636	740	865	1011	1179	1369	1582	1812	2059	2323	2603	2899	3207	3528
20	234	263	297	337	384	439	502	574	660	762	881	1019	1176	1351	1541	1746	1966	2200	2447	2703	2970
15	223	250	281	319	362	411	468	534	610	697	801	920	1056	1207	1373	1552	1744	1949	2165	2389	2621
10	213	238	267	302	341	387	439	498	566	644	733	838	956	1089	1235	1392	1562	1742	1934	2133	2339
5	197	219	245	274	308	348	393	443	501	565	636	719	813	919	1036	1164	1302	1450	1607	1772	1944
0	182	202	225	251	280	314	353	398	447	502	562	629	705	792	887	992	1105	1228	1359	1497	1642
-5	181	201	223	249	278	312	350	394	443	497	556	622	697	782	875	978	1089	1209	1338	1472	1614
-10	180	199	221	246	275	309	347	390	438	492	550	616	689	772	864	964	1074	1191	1317	1449	1586
-15	178	197	219	244	273	306	343	386	434	487	544	609	681	762	853	951	1059	1174	1297	1426	1561
-20	177	196	218	242	271	303	340	382	430	482	539	602	673	753	842	939	1044	1157	1278	1404	1536
-25	177	195	216	240	268	300	337	379	425	477	533	596	665	744	831	926	1030	1141	1259	1383	1512
-30	177	193	214	238	266	298	334	375	421	472	528	590	658	735	821	914	1016	1125	1241	1362	1488
-35	177	192	212	236	264	295	331	371	417	467	522	583	651	727	811	903	1002	1110	1223	1342	1466
-40	177	190	211	234	261	292	328	368	413	463	517	577	644	718	801	891	989	1094	1206	1323	1444

Table D51 - H35 FM60 or H70 FM60/FM90/FM300 t_{final} - V_{CHSS} 3000 L and 200 L < TVL ≤ 350 L

	MAT$_C$ (°C)																				
T_{amb} (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6	-4	-2	0
50	534	607	691	791	916	1065	1258	1560	1996	2539	3205	4020	5014	6203	7553	8995	10450	11859	13186	14422	15568
45	422	474	532	595	664	773	927	1126	1376	1680	2042	2466	2954	3512	4140	4841	5619	6468	7375	8309	9253
40	346	385	429	488	563	651	758	891	1056	1255	1489	1761	2072	2421	2805	3227	3690	4195	4743	5328	5946
35	331	369	420	482	556	643	747	875	1035	1225	1449	1707	1998	2321	2673	3051	3460	3897	4363	4851	5360
30	302	342	388	443	507	581	668	772	897	1047	1223	1425	1653	1908	2184	2481	2799	3139	3499	3876	4269
25	284	319	360	409	465	531	606	693	794	915	1057	1220	1404	1610	1834	2076	2335	2610	2901	3206	3523
20	267	299	336	379	430	487	553	629	715	814	931	1065	1217	1387	1573	1773	1989	2219	2462	2716	2979
15	255	284	318	358	405	458	518	586	664	751	852	968	1100	1248	1410	1585	1774	1975	2188	2410	2640
10	243	271	303	340	382	431	486	549	619	698	786	887	1003	1133	1276	1430	1596	1774	1962	2159	2363
5	225	249	277	309	346	388	435	489	550	616	689	770	862	967	1081	1206	1342	1487	1642	1805	1975
0	208	230	254	283	315	351	393	439	492	549	612	681	756	840	934	1037	1149	1269	1399	1535	1678
-5	207	228	253	280	312	348	389	436	487	544	606	674	749	831	923	1024	1133	1252	1378	1511	1651
-10	205	227	251	278	310	345	386	432	483	539	600	667	741	822	912	1011	1119	1235	1359	1489	1625
-15	204	225	249	276	307	342	382	428	479	534	594	661	733	813	902	999	1105	1218	1340	1467	1600
-20	203	223	247	274	305	339	379	424	474	529	589	654	726	804	891	987	1091	1202	1321	1446	1576
-25	201	222	245	272	302	337	376	420	470	524	583	648	719	796	882	975	1077	1187	1304	1426	1554
-30	200	220	244	270	300	334	373	416	466	519	578	642	711	788	872	964	1064	1172	1286	1406	1531
-35	198	219	242	268	297	331	369	413	461	515	573	635	704	780	862	953	1051	1157	1270	1387	1510
-40	197	217	240	266	295	328	366	409	457	510	567	629	697	772	853	942	1039	1143	1254	1369	1489

Table D52 - H35 FM60 or H70 FM60/FM90/FM300 t_{final} - V_{CHSS} 5000 L and 200 L < TVL ≤ 350 L

T_{amb} (°C)	MAT$_C$ (°C) -40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	725	815	914	1024	1147	1288	1462	1740	2110	2567	3124	3800	4615	5588	6709	7952	9270	10606
45	568	630	700	777	884	1013	1164	1346	1570	1840	2159	2532	2964	3460	4018	4642	5340	6110
40	473	530	597	675	765	868	985	1118	1272	1453	1666	1912	2192	2510	2861	3249	3676	4144
35	469	526	592	669	757	858	973	1103	1253	1427	1630	1864	2128	2424	2747	3099	3480	3891
30	438	489	547	615	692	781	880	992	1118	1259	1419	1605	1815	2049	2304	2580	2879	3200
25	410	456	508	568	637	715	803	901	1010	1129	1262	1412	1583	1774	1982	2207	2451	2711
20	385	427	473	527	588	658	736	823	920	1025	1139	1266	1406	1565	1738	1926	2129	2346
15	368	406	449	499	555	619	690	771	859	955	1058	1172	1296	1433	1585	1749	1927	2117
10	351	387	427	473	525	583	649	723	805	893	988	1091	1202	1324	1457	1602	1759	1928
5	323	355	390	430	475	526	582	646	717	793	876	965	1060	1162	1271	1387	1516	1654
0	298	327	358	394	433	477	526	581	642	710	782	860	944	1032	1125	1224	1330	1444
-5	297	325	356	391	430	473	522	577	637	704	776	853	935	1023	1115	1212	1316	1428
-10	295	323	354	388	427	470	518	572	632	698	769	846	927	1014	1105	1201	1303	1412
-15	293	321	352	386	424	467	515	568	627	692	763	839	920	1005	1095	1189	1290	1397
-20	292	319	349	383	421	464	511	564	623	687	757	832	912	996	1085	1178	1278	1383
-25	290	317	347	381	419	460	507	559	618	681	751	825	904	988	1075	1167	1266	1369
-30	288	315	345	379	416	457	503	555	613	676	745	818	897	979	1066	1157	1253	1355
-35	287	313	343	376	413	454	500	551	608	671	739	811	889	971	1057	1146	1242	1342
-40	285	311	341	374	410	451	496	547	604	665	733	805	882	963	1048	1136	1230	1329

T_{amb} (°C)	MAT$_C$ (°C) -4	-2	0
50	11916	13163	14347
45	6942	7816	8715
40	4655	5202	5786
35	4330	4794	5282
30	3542	3902	4280
25	2989	3280	3585
20	2578	2820	3075
15	2320	2532	2754
10	2107	2295	2491
5	1802	1958	2121
0	1567	1698	1835
-5	1548	1676	1810
-10	1530	1655	1786
-15	1513	1635	1763
-20	1496	1615	1741
-25	1480	1597	1719
-30	1464	1579	1699
-35	1448	1561	1679
-40	1433	1544	1659

Table D53 - H35 FM60 or H70 FM60/FM90/FM300 t_{final} - V_{CHSS} 500 L and 350 L < TVL ≤ 800 L

	MAT$_C$ (°C)																				
T_{amb} (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6	-4	-2	0
50	190	231	291	435	686	1079	1652	2462	3627	5398	8142	11228	13600	15496	16998	18289	19436	20458	21398	22257	23047
45	177	182	229	311	443	644	927	1296	1758	2314	2976	3763	4692	5779	6980	8258	9542	10771	11931	12995	13985
40	177	177	192	245	326	447	616	838	1112	1436	1808	2231	2707	3237	3818	4452	5141	5881	6663	7457	8265
35	177	177	187	238	314	427	587	796	1054	1356	1699	2083	2505	2964	3454	3974	4525	5104	5705	6321	6940
30	177	177	177	209	267	351	468	623	818	1046	1307	1598	1919	2265	2633	3020	3428	3857	4304	4763	5233
25	177	177	177	188	233	297	386	505	655	833	1038	1269	1523	1799	2091	2398	2721	3060	3412	3774	4146
20	177	177	177	177	207	258	327	420	538	680	845	1031	1238	1464	1704	1957	2223	2502	2791	3089	3394
15	177	177	177	177	191	233	291	368	466	586	726	886	1064	1259	1466	1686	1917	2159	2410	2668	2931
10	177	177	177	177	177	213	262	326	409	511	631	769	923	1093	1274	1467	1670	1883	2104	2332	2564
5	177	177	177	177	177	186	223	272	334	411	503	611	732	868	1014	1170	1336	1512	1695	1885	2079
0	177	177	177	177	177	177	194	232	280	340	412	496	593	702	821	950	1087	1233	1387	1546	1711
-5	177	177	177	177	177	177	191	227	274	331	401	483	578	684	800	924	1058	1200	1350	1505	1665
-10	177	177	177	177	177	177	187	223	268	323	391	471	562	666	779	901	1031	1170	1315	1466	1622
-15	177	177	177	177	177	177	184	218	262	316	381	458	548	648	759	878	1005	1140	1282	1429	1580
-20	177	177	177	177	177	177	180	214	256	308	371	446	533	632	739	855	980	1112	1250	1394	1541
-25	177	177	177	177	177	177	177	209	250	301	362	435	520	616	720	834	955	1084	1220	1359	1503
-30	177	177	177	177	177	177	177	205	245	294	353	424	507	600	702	813	932	1058	1190	1327	1467
-35	177	177	177	177	177	177	177	202	240	287	345	414	494	585	685	793	909	1033	1162	1295	1432
-40	177	177	177	177	177	177	177	198	235	281	337	404	482	570	668	774	887	1008	1135	1265	1399

Table D54 - H35 FM60 or H70 FM60/FM90/FM300 t_{final} - V_{CHSS} 1000 L and 350 L < TVL ≤ 800 L

T_{amb} (°C)	MAT$_C$ (°C) -40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6	-4	-2	0
50	267	323	397	495	620	817	1216	1759	2463	3356	4500	5988	7849	9953	12032	13937	15645	17186	18589	19858	21027
45	210	245	287	341	407	559	785	1090	1478	1944	2489	3126	3867	4724	5698	6783	7961	9187	10436	11646	12808
40	177	199	228	263	323	424	567	762	1010	1309	1657	2055	2502	3002	3553	4157	4822	5547	6327	7148	7992
35	177	190	218	251	317	414	552	739	978	1263	1593	1965	2378	2830	3317	3838	4398	4993	5624	6275	6947
30	177	177	190	227	280	355	461	604	788	1010	1268	1561	1885	2239	2618	3021	3450	3904	4383	4881	5397
25	177	177	177	208	252	312	395	507	652	829	1036	1272	1535	1823	2131	2458	2804	3169	3553	3951	4364
20	177	177	177	192	229	278	346	435	552	694	863	1057	1274	1514	1771	2043	2332	2637	2956	3286	3628
15	177	177	177	181	214	257	315	391	490	612	757	924	1113	1322	1547	1786	2039	2306	2585	2873	3170
10	177	177	177	177	201	239	289	354	439	544	669	815	981	1164	1363	1574	1799	2035	2283	2538	2801
5	177	177	177	177	181	212	252	302	368	449	546	661	792	939	1100	1273	1458	1655	1861	2075	2296
0	177	177	177	177	177	191	223	264	315	379	456	547	653	772	904	1046	1200	1365	1539	1720	1908
-5	177	177	177	177	177	188	221	260	311	373	448	538	641	759	888	1028	1179	1339	1510	1686	1869
-10	177	177	177	177	177	186	218	257	306	367	441	529	631	746	873	1010	1158	1315	1481	1654	1832
-15	177	177	177	177	177	185	216	254	302	362	434	520	620	733	858	992	1137	1292	1454	1623	1797
-20	177	177	177	177	177	183	213	251	298	356	427	512	610	721	843	975	1118	1269	1428	1593	1763
-25	177	177	177	177	177	181	211	248	294	351	421	503	600	709	829	959	1099	1247	1403	1565	1731
-30	177	177	177	177	177	179	209	245	290	346	414	495	590	697	815	943	1080	1226	1379	1537	1700
-35	177	177	177	177	177	177	206	242	286	341	408	487	580	685	801	927	1062	1205	1356	1511	1670
-40	177	177	177	177	177	177	204	239	283	336	402	480	571	674	788	912	1045	1185	1333	1485	1641

Table D55 - H35 FM60 or H70 FM60/FM90/FM300 t_{final} - V_{CHSS} 1500 L and 350 L < TVL ≤ 800 L

	MATC (°C)																	
Tamb (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	364	430	517	629	770	948	1177	1552	2110	2795	3626	4640	5873	7335	8963	10665	12359	13974
45	285	326	375	433	504	590	782	1041	1373	1772	2242	2784	3407	4119	4919	5815	6804	7871
40	233	264	299	338	382	473	600	770	988	1254	1565	1923	2328	2779	3275	3819	4416	5069
35	222	252	285	321	375	465	588	754	965	1221	1520	1860	2240	2657	3108	3592	4113	4670
30	194	219	247	284	339	411	508	637	802	1004	1240	1511	1813	2146	2504	2887	3295	3729
25	177	193	224	262	310	369	448	551	683	844	1035	1255	1503	1776	2070	2384	2718	3072
20	177	182	210	244	285	336	401	485	593	724	880	1062	1268	1496	1742	2006	2287	2584
15	177	177	199	231	269	315	371	444	537	650	785	942	1122	1322	1538	1770	2017	2279
10	177	177	190	219	254	295	346	409	490	588	705	843	1000	1177	1368	1574	1794	2027
5	177	177	177	200	229	265	307	359	421	498	591	699	824	966	1121	1290	1471	1664
0	177	177	177	183	209	240	276	319	370	431	505	592	693	808	935	1074	1225	1386
-5	177	177	177	182	207	238	274	316	366	426	499	585	684	797	922	1059	1207	1366
-10	177	177	177	180	206	236	271	313	363	422	493	578	675	787	910	1044	1190	1346
-15	177	177	177	179	204	234	269	310	359	417	488	571	667	776	898	1030	1173	1326
-20	177	177	177	178	203	232	267	307	356	413	482	564	659	766	886	1016	1157	1308
-25	177	177	177	177	201	230	264	305	352	409	477	557	651	757	874	1003	1141	1289
-30	177	177	177	177	200	228	262	302	349	404	471	551	643	747	863	989	1126	1272
-35	177	177	177	177	198	227	260	299	346	400	466	544	635	738	852	976	1111	1254
-40	177	177	177	177	197	225	258	297	342	396	461	538	627	729	841	964	1096	1238

	MATC (°C)		
Tamb (°C)	-4	-2	0
50	15503	16921	18244
45	8993	10134	11268
40	5777	6530	7319
35	5262	5881	6524
30	4190	4671	5171
25	3446	3836	4241
20	2898	3224	3562
15	2555	2840	3136
10	2272	2527	2789
5	1869	2082	2303
0	1559	1739	1927
-5	1534	1711	1894
-10	1511	1684	1862
-15	1489	1657	1832
-20	1467	1632	1804
-25	1446	1608	1776
-30	1426	1585	1749
-35	1406	1562	1724
-40	1387	1540	1699

Table D56 - H35 FM60 or H70 FM60/FM90/FM300 t_{final} - V_{CHSS} 2000 L and 350 L < TVL ≤ 800 L

	MATc (°C)																	
Tamb (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	422	488	570	675	808	976	1188	1563	2086	2735	3529	4505	5697	7119	8705	10358	11988	13536
45	334	378	429	487	554	660	836	1071	1377	1750	2190	2701	3288	3959	4714	5557	6493	7512
40	274	308	346	388	451	540	661	820	1023	1272	1566	1906	2293	2726	3203	3726	4302	4933
35	262	294	330	377	445	532	651	806	1004	1244	1527	1852	2216	2619	3055	3526	4033	4576
30	230	258	298	346	405	478	573	696	852	1041	1265	1524	1815	2137	2485	2858	3257	3683
25	212	241	277	320	372	435	513	613	738	891	1072	1283	1521	1785	2071	2377	2705	3054
20	200	226	259	298	344	399	466	548	651	777	926	1100	1297	1518	1758	2015	2291	2583
15	192	216	246	282	325	375	435	507	597	706	835	986	1158	1352	1562	1789	2031	2289
10	184	207	235	268	307	354	408	473	551	646	759	891	1043	1213	1399	1600	1816	2046
5	177	192	216	245	279	319	365	419	483	558	647	752	873	1009	1160	1324	1502	1692
0	177	178	199	225	254	289	329	376	429	491	563	647	745	856	980	1115	1262	1421
-5	177	177	198	223	253	287	327	373	426	487	557	641	737	847	968	1101	1246	1402
-10	177	177	197	222	251	285	325	370	423	483	552	635	730	838	957	1088	1231	1384
-15	177	177	196	221	249	283	322	367	419	479	547	628	722	829	947	1076	1216	1366
-20	177	177	195	219	248	281	320	365	416	475	542	622	715	820	936	1063	1201	1349
-25	177	177	194	218	246	279	317	362	413	471	537	616	707	811	926	1051	1187	1333
-30	177	177	192	216	244	277	315	359	409	467	533	610	700	803	916	1039	1173	1316
-35	177	177	191	215	243	275	313	356	406	463	528	605	693	794	906	1027	1159	1300
-40	177	177	190	214	241	273	311	354	403	459	524	599	687	786	896	1016	1146	1285

	MATc (°C)		
Tamb (°C)	-4	-2	0
50	14984	16326	17565
45	8594	9705	10820
40	5618	6349	7121
35	5156	5763	6397
30	4136	4610	5106
25	3422	3807	4209
20	2893	3215	3551
15	2561	2844	3138
10	2287	2539	2800
5	1894	2104	2323
0	1590	1768	1954
-5	1568	1743	1924
-10	1547	1717	1895
-15	1526	1693	1867
-20	1506	1670	1840
-25	1487	1648	1814
-30	1468	1626	1789
-35	1450	1605	1765
-40	1432	1585	1742

Table D57 - H35 FM60 or H70 FM60/FM90/FM300 t_{final} - V_{CHSS} 2500 L and 350 L < TVL ≤ 800 L

T_{amb} (°C)	MATC (°C)																				
	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6	-4	-2	0
50	478	547	628	729	856	1017	1219	1567	2053	2654	3387	4277	5356	6640	8099	9667	11267	12837	14335	15742	17052
45	379	427	481	541	608	723	894	1119	1408	1763	2183	2674	3238	3883	4609	5421	6325	7312	8367	9457	10559
40	310	347	388	439	513	605	723	877	1072	1309	1591	1919	2293	2713	3176	3686	4248	4864	5534	6251	7010
35	298	332	374	435	508	598	714	864	1054	1284	1555	1869	2222	2614	3040	3500	3997	4531	5102	5702	6328
30	266	303	347	400	464	542	636	756	907	1089	1305	1554	1837	2150	2490	2855	3248	3668	4114	4584	5074
25	251	284	323	371	428	495	576	674	796	944	1119	1322	1552	1810	2090	2390	2712	3055	3420	3801	4199
20	237	267	303	346	397	456	526	609	710	832	977	1145	1336	1551	1785	2038	2309	2597	2903	3222	3555
15	227	255	289	328	375	429	493	568	656	762	888	1035	1202	1390	1595	1817	2056	2310	2579	2859	3150
10	218	244	275	312	355	405	464	531	610	703	814	942	1089	1255	1437	1634	1846	2072	2311	2560	2819
5	202	226	253	285	323	366	416	474	540	615	702	805	923	1056	1203	1364	1538	1725	1924	2132	2350
0	188	210	234	262	295	333	376	426	483	546	618	701	797	906	1026	1159	1303	1459	1626	1801	1985
-5	188	208	233	261	293	330	374	423	479	542	614	695	790	897	1016	1146	1288	1441	1605	1777	1956
-10	187	207	231	259	291	328	371	420	476	538	609	689	782	888	1006	1134	1273	1424	1584	1753	1928
-15	186	206	230	258	289	326	369	417	473	534	604	683	775	880	995	1122	1259	1407	1565	1730	1902
-20	185	205	229	256	288	324	366	415	469	530	599	678	768	872	985	1110	1245	1391	1546	1708	1876
-25	184	204	228	255	286	322	364	412	466	527	595	672	762	863	976	1099	1232	1375	1527	1686	1851
-30	183	203	226	253	284	320	361	409	463	523	590	667	755	855	966	1087	1219	1360	1510	1666	1827
-35	182	202	225	252	283	318	359	406	459	519	586	661	749	847	957	1076	1206	1345	1492	1645	1804
-40	181	201	224	250	281	316	357	403	456	515	581	656	742	840	948	1066	1193	1330	1475	1626	1782

Table D58 - H35 FM60 or H70 FM60/FM90/FM300 t_{final} - V_{CHSS} 3000 L and 350 L < TVL ≤ 800 L

	MAT$_C$ (°C)																	
T_{amb} (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	529	601	685	784	907	1058	1247	1597	2053	2622	3316	4161	5184	6405	7795	9296	10833	12340
45	418	470	527	590	662	786	948	1160	1433	1767	2165	2629	3164	3776	4463	5233	6090	7031
40	343	382	428	493	571	664	780	929	1116	1342	1611	1924	2283	2687	3133	3625	4167	4763
35	329	370	424	488	565	658	772	918	1100	1320	1579	1879	2219	2598	3011	3458	3942	4463
30	305	345	393	450	518	599	695	812	958	1134	1341	1581	1854	2157	2488	2845	3228	3640
25	287	323	367	418	479	550	633	731	850	994	1163	1359	1582	1832	2104	2398	2714	3051
20	271	304	344	390	444	508	581	666	766	885	1025	1188	1374	1583	1811	2058	2324	2608
15	260	291	328	371	421	479	546	623	712	816	939	1081	1244	1427	1628	1845	2079	2329
10	250	279	313	353	399	452	514	585	666	758	866	991	1135	1297	1474	1667	1875	2098
5	232	258	288	322	363	409	463	524	592	669	756	856	972	1102	1246	1404	1575	1759
0	216	239	266	296	332	372	419	472	532	598	671	754	847	954	1073	1203	1345	1498
-5	215	238	264	295	330	370	416	469	528	594	667	749	841	946	1063	1191	1331	1482
-10	214	237	263	293	328	368	414	466	525	590	662	743	834	938	1054	1180	1317	1466
-15	213	236	262	292	326	366	411	463	522	586	658	738	828	931	1044	1169	1304	1450
-20	212	235	261	290	325	364	409	460	518	582	653	733	822	923	1035	1158	1292	1435
-25	211	234	259	289	323	362	407	458	515	579	649	728	815	915	1027	1147	1279	1421
-30	210	232	258	287	321	360	404	455	512	575	645	723	809	908	1018	1137	1267	1406
-35	209	231	257	286	319	358	402	452	509	571	640	718	803	901	1009	1127	1255	1392
-40	208	230	256	285	318	356	400	449	506	568	636	713	798	894	1001	1117	1244	1379

	MAT$_C$ (°C)		
T_{amb} (°C)	-4	-2	0
50	13778	15127	16388
45	8042	9097	10176
40	5413	6109	6849
35	5021	5609	6225
30	4079	4541	5025
25	3410	3786	4180
20	2910	3225	3555
15	2595	2872	3161
10	2334	2581	2838
5	1955	2161	2377
0	1663	1836	2018
-5	1643	1813	1991
-10	1624	1791	1965
-15	1606	1769	1940
-20	1588	1749	1916
-25	1571	1729	1892
-30	1555	1709	1870
-35	1538	1690	1848
-40	1523	1672	1827

Table D59 - H35 FM60 or H70 FM60/FM90/FM300 t_{final} - V_{CHSS} 5000 L and 350 L < TVL ≤ 800 L

	MATc (°C)																	
T_{amb} (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	724	814	912	1022	1145	1286	1468	1771	2158	2634	3215	3917	4757	5754	6902	8179	9549	10955
45	567	629	699	780	894	1027	1186	1379	1621	1915	2263	2671	3144	3686	4296	4980	5744	6590
40	477	536	604	685	778	887	1012	1158	1329	1535	1776	2058	2381	2746	3154	3604	4103	4653
35	474	532	600	680	773	881	1004	1148	1316	1516	1750	2021	2329	2674	3054	3467	3919	4408
30	444	497	558	630	712	807	916	1039	1181	1342	1532	1751	2000	2279	2584	2917	3277	3666
25	419	466	522	586	660	744	841	949	1072	1209	1365	1546	1751	1982	2235	2509	2806	3126
20	395	439	489	547	614	689	776	873	981	1101	1235	1385	1558	1752	1965	2196	2446	2715
15	379	420	467	520	582	652	731	821	920	1030	1150	1284	1436	1607	1794	1998	2219	2456
10	364	402	446	496	553	617	691	774	866	967	1077	1198	1332	1484	1650	1831	2029	2240
5	337	371	410	454	503	559	623	695	775	863	958	1061	1174	1297	1433	1581	1743	1918
0	313	344	378	417	461	510	566	628	699	776	859	950	1047	1152	1266	1388	1523	1669
-5	312	342	377	415	459	508	563	625	695	772	855	945	1041	1145	1258	1378	1511	1655
-10	311	341	375	414	457	506	561	622	692	768	850	939	1035	1139	1250	1368	1499	1641
-15	310	340	374	412	455	503	558	620	688	764	846	935	1030	1132	1242	1359	1488	1627
-20	309	339	372	411	453	501	556	617	685	760	842	930	1024	1125	1234	1350	1477	1614
-25	307	337	371	409	451	499	553	614	682	756	837	925	1018	1119	1226	1341	1466	1601
-30	306	336	370	407	450	497	551	611	679	753	833	920	1013	1112	1219	1332	1455	1589
-35	305	335	368	406	448	495	548	608	675	749	829	915	1007	1106	1212	1324	1445	1576
-40	304	334	367	404	446	493	546	605	672	745	825	910	1002	1100	1204	1315	1435	1564

	MATc (°C)		
T_{amb} (°C)	-4	-2	0
50	12351	13696	14982
45	7510	8485	9498
40	5256	5905	6600
35	4934	5492	6080
30	4083	4525	4991
25	3469	3830	4211
20	3003	3307	3626
15	2710	2977	3257
10	2466	2703	2952
5	2106	2304	2512
0	1826	1993	2169
-5	1809	1973	2145
-10	1793	1953	2121
-15	1776	1934	2099
-20	1761	1915	2077
-25	1746	1897	2056
-30	1731	1880	2036
-35	1716	1863	2016
-40	1703	1847	1997

D.1.6 H35 FM60 or H70 FM60/FM90/FM300 t_{final} Tables - Option B

Tables D60 through D71 are the H70 t_{final} tables for the application of Basic Option B in Equation C45.

Table D60 - H35 FM60 or H70 FM60/FM90/FM300 t_{final} - 248.6 L ≤ V_{CHSS} ≤ 1000 L and 50 L ≤ TVL ≤ 200 L

	MAT$_C$ (°C)																				
T_{amb} (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6	-4	-2	0
50	268	325	401	520	773	1122	1596	2245	3190	4672	6805	8712	10212	11395	12380	13227	13971	14640	15269	15846	16357
45	211	246	289	343	465	638	859	1131	1457	1838	2283	2804	3415	4116	4892	5720	6561	7383	8161	8889	9567
40	177	200	230	265	325	428	561	723	915	1134	1381	1655	1960	2297	2663	3059	3488	3951	4438	4941	5456
35	177	191	219	252	307	402	525	677	855	1057	1281	1529	1799	2089	2399	2726	3072	3436	3817	4206	4602
30	177	177	190	217	254	323	413	526	659	812	982	1170	1374	1593	1824	2067	2322	2590	2867	3156	3451
25	177	177	177	193	227	269	337	422	526	645	778	926	1088	1262	1445	1637	1839	2050	2269	2495	2726
20	177	177	177	177	206	241	285	349	430	524	632	751	882	1024	1174	1332	1498	1671	1851	2036	2226
15	177	177	177	177	192	223	260	307	371	450	541	643	755	877	1007	1143	1287	1437	1593	1753	1917
10	177	177	177	177	179	207	240	281	330	391	468	556	652	758	871	990	1116	1248	1386	1527	1671
5	177	177	177	177	177	184	211	244	282	328	383	445	519	603	693	789	892	1000	1113	1230	1350
0	177	177	177	177	177	177	188	215	246	283	326	376	433	498	569	646	729	819	913	1013	1116
-5	177	177	177	177	177	177	185	211	242	278	320	368	424	487	557	632	713	801	893	990	1091
-10	177	177	177	177	177	177	182	208	238	273	314	361	416	477	545	618	698	783	874	968	1067
-15	177	177	177	177	177	177	179	205	234	268	308	354	407	467	533	605	683	767	855	948	1043
-20	177	177	177	177	177	177	177	201	230	263	302	347	399	458	522	593	669	751	837	927	1021
-25	177	177	177	177	177	177	177	198	227	259	296	341	391	448	512	581	655	735	820	908	1000
-30	177	177	177	177	177	177	177	195	223	254	291	334	384	440	501	569	642	720	803	889	979
-35	177	177	177	177	177	177	177	192	219	250	286	328	376	431	491	557	629	705	787	871	959
-40	177	177	177	177	177	177	177	189	216	246	281	322	369	422	481	546	616	691	771	854	940

Table D61 - H35 FM60 or H70 FM60/FM90/FM300 t_{final} - 1000 L < V_{CHSS} ≤ 2000 L and 50 L ≤ TVL ≤ 200 L

	MAT$_C$ (°C)																				
T_{amb} (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6	-4	-2	0
50	426	493	577	683	817	985	1198	1487	1889	2430	3101	3939	5107	6464	7830	9079	10216	11226	12144	12971	13723
45	337	382	433	491	559	641	736	890	1094	1340	1650	2021	2447	2932	3479	4091	4768	5494	6250	7004	7744
40	276	310	348	391	437	488	573	679	811	966	1147	1356	1591	1870	2178	2512	2877	3274	3701	4154	4630
35	264	296	333	373	417	478	559	661	786	934	1106	1301	1519	1760	2037	2331	2645	2980	3333	3702	4083
30	232	259	289	323	371	427	492	572	669	784	916	1068	1238	1425	1626	1842	2076	2330	2598	2876	3164
25	205	229	259	295	337	385	441	506	583	675	781	901	1037	1188	1351	1525	1710	1907	2115	2331	2558
20	189	212	240	272	309	351	399	454	518	592	679	778	889	1012	1146	1290	1444	1608	1780	1959	2145
15	180	201	226	255	289	327	371	420	477	541	615	700	796	903	1019	1144	1279	1421	1571	1727	1889
10	177	191	213	240	271	306	346	391	441	498	562	636	720	813	915	1025	1143	1268	1401	1539	1682
5	177	177	194	217	243	273	308	346	389	436	488	546	612	687	769	857	953	1055	1164	1278	1397
0	177	177	177	197	220	246	276	309	346	386	430	479	532	592	659	731	810	895	985	1080	1180
-5	177	177	177	195	217	243	272	305	341	381	424	472	524	583	648	719	796	878	967	1059	1156
-10	177	177	177	193	215	240	268	301	337	376	418	465	517	574	638	707	782	863	949	1040	1134
-15	177	177	177	190	212	237	265	297	332	371	413	459	509	565	627	695	769	848	932	1021	1113
-20	177	177	177	188	209	234	261	293	328	366	407	452	502	557	618	684	756	833	916	1002	1093
-25	177	177	177	186	207	231	258	289	323	361	402	446	495	549	608	673	744	819	900	985	1073
-30	177	177	177	184	204	228	255	285	319	356	396	440	488	541	599	662	732	806	885	968	1054
-35	177	177	177	182	202	225	252	281	315	351	391	434	481	533	590	652	720	793	870	951	1036
-40	177	177	177	180	200	222	248	278	311	347	386	428	475	525	581	642	708	780	856	935	1018

Table D62 - H35 FM60 or H70 FM60/FM90/FM300 t_{final} - 2000 L < V_{CHSS} ≤ 3000 L and 50 L ≤ TVL ≤ 200 L

	MATc (°C)																	
Tamb (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	535	608	692	792	916	1069	1262	1507	1837	2325	2943	3628	4376	5466	6659	7857	8991	10044
45	423	475	532	596	665	743	838	989	1176	1400	1662	1969	2345	2782	3275	3826	4437	5103
40	346	385	429	478	530	602	688	789	911	1056	1224	1417	1636	1882	2153	2455	2797	3170
35	332	369	411	457	519	592	675	773	889	1027	1186	1368	1572	1798	2044	2310	2599	2917
30	292	325	367	415	470	533	604	684	777	884	1009	1151	1310	1486	1677	1883	2104	2340
25	270	301	338	380	429	484	545	615	692	779	879	993	1121	1263	1418	1584	1762	1952
20	252	280	313	350	393	442	496	557	625	699	781	874	980	1097	1224	1361	1509	1666
15	239	265	295	330	369	413	463	518	579	646	719	800	891	992	1103	1223	1351	1488
10	228	252	279	311	346	387	433	483	539	600	666	738	817	906	1003	1108	1221	1342
5	209	230	254	281	312	346	385	429	477	530	586	647	712	784	861	946	1038	1136
0	192	211	232	255	282	312	346	384	426	471	521	573	629	690	755	823	899	980
-5	190	209	229	253	279	309	342	379	420	466	514	566	622	681	745	812	885	965
-10	188	207	227	250	276	305	338	375	415	460	508	559	614	672	735	801	873	951
-15	186	205	225	248	273	302	334	370	411	454	502	552	606	664	725	790	861	937
-20	185	203	223	245	270	298	330	366	406	449	496	546	599	656	716	780	849	923
-25	183	201	220	243	267	295	327	362	401	444	490	539	592	648	707	770	837	910
-30	181	199	218	240	265	292	323	358	396	438	484	533	585	640	698	760	826	897
-35	180	197	216	238	262	289	319	353	391	433	478	526	578	632	690	751	815	885
-40	178	195	214	235	259	286	316	349	387	428	472	520	571	625	681	741	805	873

	MATc (°C)		
Tamb (°C)	-4	-2	0
50	11012	11890	12708
45	5807	6527	7246
40	3575	4007	4462
35	3258	3614	3985
30	2590	2853	3130
25	2153	2363	2582
20	1833	2007	2188
15	1633	1785	1942
10	1470	1603	1743
5	1242	1352	1467
0	1068	1160	1256
-5	1051	1140	1235
-10	1034	1122	1214
-15	1018	1104	1194
-20	1003	1087	1174
-25	988	1070	1156
-30	974	1054	1138
-35	960	1038	1120
-40	946	1023	1104

Table D63 - H35 FM60 or H70 FM60/FM90/FM3000 t_{final} - 3000 L < V_{CHSS} ≤ 5000 L and 50 L ≤ TVL ≤ 200 L

	MATc (°C)																	
Tamb (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	727	817	916	1026	1149	1290	1464	1684	1960	2311	2776	3401	4037	4980	6051	7180	8300	9366
45	569	632	702	779	861	948	1070	1214	1383	1585	1821	2095	2411	2773	3182	3691	4261	4887
40	463	510	566	634	713	801	899	1007	1128	1264	1416	1593	1794	2020	2269	2543	2844	3176
35	449	499	558	626	702	788	884	989	1106	1236	1381	1547	1734	1942	2169	2415	2683	2971
30	415	460	511	570	637	711	794	886	986	1094	1213	1343	1489	1652	1830	2021	2228	2450
25	385	426	471	523	581	646	719	800	888	982	1083	1192	1311	1442	1585	1741	1908	2087
20	359	395	436	482	533	591	656	727	805	889	978	1073	1174	1285	1402	1530	1669	1817
15	341	374	411	453	500	553	612	677	748	825	907	993	1085	1183	1288	1398	1518	1647
10	324	354	389	428	471	519	572	632	697	768	844	923	1008	1097	1190	1289	1394	1507
5	296	323	353	386	424	465	511	561	618	679	744	814	888	966	1046	1130	1219	1312
0	271	295	322	351	383	419	459	503	551	604	661	723	788	857	929	1002	1079	1159
-5	269	292	319	348	380	415	454	497	545	597	654	714	779	847	918	990	1066	1144
-10	266	290	316	345	376	411	450	492	539	591	646	706	770	837	907	978	1053	1130
-15	264	287	313	342	373	407	445	487	534	584	639	698	761	828	896	967	1040	1116
-20	262	285	310	338	369	403	441	482	528	578	632	690	752	818	886	956	1028	1102
-25	260	283	308	335	366	399	436	477	522	572	625	683	744	809	876	945	1016	1089
-30	258	280	305	332	363	396	432	472	517	566	618	675	736	799	866	934	1004	1076
-35	255	278	302	329	359	392	428	468	512	559	611	667	727	790	856	923	993	1064
-40	253	275	300	327	356	388	424	463	506	554	605	660	719	782	846	913	981	1052

	MATc (°C)		
Tamb (°C)	-4	-2	0
50	10360	11278	12127
45	5557	6252	6957
40	3537	3933	4373
35	3281	3608	3953
30	2687	2937	3200
25	2277	2477	2687
20	1975	2140	2314
15	1785	1929	2080
10	1629	1756	1889
5	1410	1514	1624
0	1243	1331	1421
-5	1227	1312	1401
-10	1211	1294	1381
-15	1195	1277	1362
-20	1180	1260	1344
-25	1166	1244	1326
-30	1151	1229	1309
-35	1138	1214	1292
-40	1124	1199	1276

Table D64 - H35 FM60 or H70 FM60/FM90/FM300 t_{final} - 248.6 L ≤ V_{CHSS} ≤ 1000 L and 200 L < TVL ≤ 350 L

T_{amb} (°C)	MAT$_C$ (°C)																				
	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6	-4	-2	0
50	268	324	400	585	903	1360	2013	3001	4770	7977	10501	12166	13436	14481	15363	16154	17282	18291	19214	20074	20835
45	211	246	288	364	518	730	1003	1343	1756	2247	2828	3523	4342	5284	6305	7331	8302	9346	10427	11427	12372
40	177	200	229	265	354	476	635	832	1065	1332	1633	1997	2412	2873	3377	3926	4521	5161	5844	6548	7268
35	177	191	219	252	333	445	592	774	989	1233	1532	1871	2243	2648	3080	3538	4024	4536	5070	5617	6173
30	177	177	190	225	274	353	459	593	752	954	1185	1444	1729	2036	2362	2707	3070	3451	3849	4259	4679
25	177	177	177	205	245	299	371	471	604	763	946	1151	1377	1623	1883	2158	2447	2749	3065	3389	3722
20	177	177	177	188	223	267	325	400	499	626	772	939	1123	1325	1539	1766	2004	2254	2514	2781	3055
15	177	177	177	177	208	246	296	360	441	541	666	809	967	1141	1327	1524	1731	1948	2174	2406	2644
10	177	177	177	177	195	229	272	327	396	481	582	703	841	992	1155	1328	1511	1702	1902	2106	2316
5	177	177	177	177	177	203	238	280	334	400	478	569	674	791	921	1061	1210	1368	1533	1704	1880
0	177	177	177	177	177	182	211	246	288	340	402	474	558	653	757	870	992	1123	1261	1405	1555
-5	177	177	177	177	177	180	208	242	283	334	394	465	547	640	742	852	972	1099	1234	1375	1521
-10	177	177	177	177	177	177	205	239	279	328	387	456	537	627	727	835	952	1077	1209	1346	1488
-15	177	177	177	177	177	177	202	235	274	323	380	448	526	615	713	819	933	1055	1184	1318	1457
-20	177	177	177	177	177	177	200	232	270	317	373	440	516	603	699	803	915	1034	1161	1292	1427
-25	177	177	177	177	177	177	197	229	266	312	367	431	506	591	685	787	897	1014	1138	1266	1399
-30	177	177	177	177	177	177	194	225	262	307	360	424	497	580	672	772	880	994	1116	1242	1371
-35	177	177	177	177	177	177	192	222	258	302	354	416	488	569	659	757	863	975	1094	1218	1345
-40	177	177	177	177	177	177	189	219	255	297	348	409	479	559	647	743	847	957	1074	1195	1319

Table D65 - H35 FM60 or H70 FM60/FM90/FM300 t_{final} - 1000 L < V_{CHSS} ≤ 2000 L and 200 L < TVL ≤ 350 L

T_{amb} (°C)	MATC (°C)																	
	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	426	493	576	683	817	985	1199	1675	2328	3165	4252	5693	7509	9480	11314	12944	14380	15660
45	336	381	432	491	559	650	815	1034	1348	1752	2225	2774	3408	4136	4960	5876	6869	7907
40	276	310	348	390	446	530	640	782	961	1178	1458	1792	2166	2581	3035	3530	4068	4653
35	264	296	332	374	439	520	627	764	936	1143	1394	1705	2049	2425	2827	3256	3713	4197
30	231	258	295	342	398	465	549	657	790	951	1140	1357	1613	1905	2217	2546	2896	3264
25	210	239	274	315	364	421	491	577	684	812	963	1137	1333	1551	1795	2061	2343	2638
20	198	224	255	291	335	385	445	516	603	707	830	972	1134	1314	1509	1719	1942	2187
15	189	213	241	275	315	360	414	477	552	642	748	871	1010	1166	1336	1519	1715	1923
10	181	203	229	260	296	338	387	444	510	588	680	787	908	1045	1194	1355	1528	1712
5	177	187	210	236	268	304	345	393	447	510	582	666	763	872	992	1122	1263	1414
0	177	177	193	216	243	274	311	352	398	450	509	576	654	743	840	947	1063	1188
-5	177	177	191	214	241	272	307	348	394	445	503	569	646	732	828	932	1046	1168
-10	177	177	189	212	239	269	304	344	389	440	497	562	637	722	816	918	1030	1150
-15	177	177	188	210	236	266	301	341	385	435	491	555	629	712	804	905	1014	1131
-20	177	177	186	208	234	264	298	337	381	430	486	548	620	702	793	891	999	1114
-25	177	177	184	207	232	261	295	334	377	426	480	541	612	693	782	879	984	1097
-30	177	177	183	205	230	259	292	330	373	421	475	535	605	684	771	866	969	1080
-35	177	177	181	203	228	256	289	327	369	416	469	529	597	675	760	854	955	1064
-40	177	177	180	201	226	254	286	324	365	412	464	522	590	666	750	842	942	1049

T_{amb} (°C)	MATC (°C)		
	-4	-2	0
50	16810	17850	18804
45	8964	9993	10975
40	5281	5941	6627
35	4707	5235	5778
30	3650	4051	4464
25	2948	3269	3599
20	2445	2710	2984
15	2142	2369	2604
10	1906	2107	2315
5	1574	1741	1915
0	1321	1462	1608
-5	1299	1436	1579
-10	1277	1411	1551
-15	1257	1388	1524
-20	1237	1365	1498
-25	1217	1343	1473
-30	1198	1322	1450
-35	1180	1301	1426
-40	1162	1281	1404

Table D66 - H35 FM60 or H70 FM60/FM90/FM300 t_{final} - 2000 L < V_{CHSS} ≤ 3000 L and 200 L < TVL ≤ 350 L

	MAT																	
T_{amb} (°C)	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6
50	534	607	691	791	916	1065	1258	1560	2030	2656	3428	4383	5562	6968	8513	10077	11580	12981
45	422	474	532	595	664	773	927	1126	1376	1680	2052	2516	3051	3661	4346	5110	5953	6864
40	346	385	429	488	563	651	758	891	1056	1255	1489	1761	2072	2435	2844	3292	3781	4313
35	331	369	420	482	556	643	747	875	1035	1225	1449	1707	1998	2324	2690	3088	3515	3970
30	302	342	388	443	507	581	668	772	897	1047	1223	1425	1653	1908	2184	2481	2804	3154
25	284	319	360	409	465	531	606	693	794	915	1057	1220	1404	1610	1834	2076	2335	2610
20	267	299	336	379	430	487	553	629	715	814	931	1065	1217	1387	1573	1773	1989	2219
15	255	284	318	358	405	458	518	586	664	751	852	968	1100	1248	1410	1585	1774	1975
10	243	271	303	340	382	431	486	549	619	698	786	887	1003	1133	1276	1430	1596	1774
5	225	249	277	309	346	388	435	489	550	616	689	770	862	967	1081	1206	1342	1487
0	208	230	254	283	315	351	393	439	492	549	612	681	756	840	934	1037	1149	1269
-5	207	228	253	280	312	348	389	436	487	544	606	674	749	831	923	1024	1133	1252
-10	205	227	251	278	310	345	386	432	483	539	600	667	741	822	912	1011	1119	1235
-15	204	225	249	276	307	342	382	428	479	534	594	661	733	813	902	999	1105	1218
-20	203	223	247	274	305	339	379	424	474	529	589	654	726	804	891	987	1091	1202
-25	201	222	245	272	302	337	376	420	470	524	583	648	719	796	882	975	1077	1187
-30	200	220	244	270	300	334	373	416	466	519	578	642	711	788	872	964	1064	1172
-35	198	219	242	268	297	331	369	413	461	515	573	635	704	780	862	953	1051	1157
-40	197	217	240	266	295	328	366	409	457	510	567	629	697	772	853	942	1039	1143

	MAT_C (°C)		
T_{amb} (°C)	-4	-2	0
50	14280	15471	16569
45	7819	8794	9760
40	4888	5497	6139
35	4452	4955	5476
30	3526	3912	4314
25	2901	3207	3528
20	2462	2716	2979
15	2188	2410	2640
10	1962	2159	2363
5	1642	1805	1975
0	1399	1535	1678
-5	1378	1511	1651
-10	1359	1489	1625
-15	1340	1467	1600
-20	1321	1446	1576
-25	1304	1426	1554
-30	1286	1406	1531
-35	1270	1387	1510
-40	1254	1369	1489