Compilation of comments received on the committee draft ISO/CD 14687-3	
Date **2011-04-12**	
Title of TC or SC concerned **ISO/TC 197 *Hydrogen technologies***	

This document is circulated to all P- and O-members, organizations and committees in liaison, with copy to the ISO Central Secretariat and the TC secretariat in the case of a subcommittee.

Doc.	**ISO/TC 197 N 486**	Circulation: **2010-12-10**	Deadline: **2011-03-10**
English title	**Hydrogen Fuel — Product Specification — Part 3: Proton exchange membrane (PEM) fuel cell applications for stationary appliances**		
French title	*Carburant hydrogène — Spécification de produit — Partie 3: Applications pour piles à combustible à membrane échangeuse de protons (PEM) pour applications stationnaires*		

Results (the compilation of results is given as an annex)

Further procedures (attribution to TC/SC/WG, Project Leader, development procedure, meetings, etc.)

Please find enclosed the comments received on the committee draft **ISO/CD 14687-3** *Hydrogen Fuel — Product Specification — Part 3: Proton exchange membrane (PEM) fuel cell applications for stationary appliances,* which was circulated as ISO/TC 197 doc. **N 486**.

We are forwarding these comments to ISO/TC 197 WG 14 for its consideration in preparation of the DIS text.

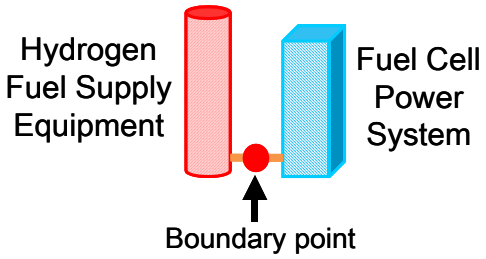
Secretariat	Date	Signature of the TC or SC Secretary
SCC/BNQ	2011-04-12	

☒ **Comments appended in Annex A**

ISO/TC 197 RESULTS: Question: Do you have comments on ISO/CD 14687-3

ISO/TC 197 Member body	Status P/O/Liaison	Do you have comments on ISO/CD 14687-3			Comments	No reply
		Yes	No	Abst.		
Argentina	P	X				
Brazil	P			X		
Canada	P	X				
China	P		X			
Denmark	P			X		
Egypt	P		X			
France	P					X
Germany	P					X
India	P		X			
Italy	P			X	Abstention due to lack of technical expertise	
Japan	P	X				
Netherlands	P		X			
Norway	P					X
Republic of Korea	P		X			
Russian Federation	P		X			
Spain	P		X			
Sweden	P			X		
Switzerland	P			X		
United Kingdom	P	X				
United States	P	X				
Totals (P-members only)		**5**	**7**	**5**		**3**

Compilation of comments received on ISO/CD 14687-3					Date:2011-04-11	Document: Annex A
MB[1]	**Clause No./ Subclause No./ Annex**	**Paragraph/ Figure/ Table/ Note**	**Type of comment**[2]	Comment (justification for change) by the MB	Proposed change by the MB	**Secretariat observations** on each comment submitted
US 1	Title			The basis for this fuel specification is unclear.	Change the title to: "*Hydrogen fuel — Product specification — Part 3: hydrocarbon fuel reformate (unpurified or partially purified) for stationary appliances*"	
UK	Introduction and whole of document	-	Ed	All abbreviations should be defined in full when first used (e.g. PEFC, PAFC, MCFC, SOFC). Some abbreviations are defined multiple times.	Define abbreviations in full when first used.	
UK	Whole document	-	Ge	The documents do not specify explicitly whether different testing methods are required based on the source of the hydrogen and/or the type of fuel cell being used. Is this covered by section 5.2?	Consider, and add text if required.	
UK	Whole document	-	Ge	No mention is given to the transportation of samples for analysis, and specifically whether this is allowed by current regulations. This is an important issue as there are currently very few labs worldwide who are able to carry out analysis to the specification required by this standard.	Add a clause discussing the issues regarding the transportation of hydrogen samples.	
UK	Whole document		Ge	No consideration has been given to ensuring that the analyses are carried out in a manner compliant with internationally–accepted best practice and using methods traceable to national standards. Should the measurement be accredited to, for example, ISO 17025?	Add a compliance statement to the text.	
UK	2	Final paragraph	Ed	The reference to ISO/TS 14687-2 needs updating. This document is no longer a TS.	Update reference.	
US 2	2			Reference ISO/DIS 14687-2 as the TS is being revised to an IS.	Change ISO/TS to ISO/DIS	
JP4	3.		te	Need to define “hydrogen fuel supply equipment”	Make sub-clause “hydrogen fuel supply equipment” as below. hydrogen fuel supply equipment equipment to make hydrogen (for example, fuel processing system) or to store hydrogen (for example, hydrogen tank or cylinder) or to deliver hydrogen (for example, hydrogen pipeline)	

JP5	3.		te	Need to define “particulate”	Make sub-clause “particulate” as below. Particulate Solid particle that may be entrained somewhere in the delivery, storage or transfer of the hydrogen fuel	
AR	3		Te	Terms and definitions “For the purposes of this document, the terms and definitions given in ISO 14687-1 and the following apply” However, to keep this sentence, some definitions that are missing should be added	For instance, “particulate” shall be defined in this clause. Particulate should be defined as follows:: 3.12 Particulate “solid or aerosol particle, including oil mist, potassium and sodium compounds that may be entrained somewhere in the delivery, storage, or transfer of the hydrogen fuel” Then, renumber the last definitions after the new one.	
UK	3	First line	Ed	Is referencing terms and definitions in another standard acceptable to ISO?	Confirm with ISO Secretariat and revise text if required.	
JP1	3.1		te	Need to move “boundary point” section from 3.1 to 6.“Sampling” Need to clarify “Hydrogen Fuel Supply Equipment” and “PEM Fuel Cell System” in detail (see JP3 and JP4)	Make sub-clause “6.1 boundary point” as blow, Boundary point is the point where the quality characteristics of hydrogen fuel should be determined, which should be set between hydrogen fuel supply equipment and fuel cell power system. 	

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MB[1]	**Clause No./ Subclause No./ Annex**	**Paragraph/ Figure/ Table/ Note**	**Type of comment**[2]	Comment (justification for change) by the MB	Proposed change by the MB	**Secretariat observations** on each comment submitted
US 3	3.1 and 6.2			Installations could have several PEM fuel cell systems. The definition should more accurately reflect what will be present at apartment complexes, etc. In order to accomplish this, the definition in 3.1 should be modified and guidance for selecting the boundary point should be added to 6.2 (as requirements should not be embedded in definitions).	Change the definition in 3.1 so that it is clear that the delivery could be to one or more power plants: "point **between the hydrogen fuel supply and one or more PEM fuel cell power plants** where the quality characteristics of hydrogen fuel ~~should~~ **is to** be determined~~, which should be set between hydrogen fuel supply equipment and PEM fuel cell power system~~" Modify the first paragraph of 6.2 as follows: "~~Gaseous~~ **A boundary point shall be established so that** gaseous samples ~~shall be~~ **are** representative of the hydrogen supplied to the PEM fuel cell power plants. In the case of one power plant, the boundary point should be as close as practical to the fuel inlet to the power plant. In the case of multiple power plants, the boundary point should be selected to represent the "worst case" fuel fed to any power plant. ~~supply. Samples shall be obtained using one of the following procedures~~. Move the figure in 3.1 to 6.2 and add a second figure to illustrate a multiple power plant situation. After making all changes to Clause 6, consider re-organization of the subsections. Subclause 6.1 should be “Selection of the Sampling Point”, and Subclause 6.2 should be the “Sampling Procedure”.	

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JP2	3.6		te	Need to clarify “hydrogen fuel”	Change as below, hydrogen fuel collective expression for fuel that is high in hydrogen (e.g., high-purity hydrogen supplied through high pressure tanks or pipeline from a distant hydrogen production plant, and reformate produced with a fuel processing system which converts fossil fuel to hydrogen-rich fuel composed primarily of hydrogen and carbon dioxide)	
JP3	3.7		te	Need to clarify in detail “fuel cell power system”	Changes as below, ~~hydrogen~~ fuel cell power systems Generator system that uses a fuel cell module(s) to generate electric power and heat, except for fuel processing system, typically containing the following ~~sub~~systems: fuel cell stack(s) or module(s), air processing system, thermal management system, water treatment system, power conditioning system and automatic control system. Fuel cell power system does not contain hydrogen fuel supply equipment, for example, fuel processing system, hydrogen tank and hydrogen cylinder.	
JP6	4.3	L.5	ed	Need to correct mistake	Change as below, Type 1 Grade E 999 Hydrogen (hydrogen fuel index: 99.9% minimum) → Type I Grade E 99 Hydrogen (hydrogen fuel index: 99% minimum)	
JP7	4.3		te	Need to explain the reason for three categories	Make new Annex A for explanation See below this table, Add Note as below, Note Annex-A provides the rationale for the categories (CD Annex-A, B, C changes to Annex-B, C, D)	

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UK	4.3	Third bullet	Te	The specification of 'Type 1 Grade E 999 hydrogen (99.9% minimum)' is inconsistent with the specification in Table 1, which is 'Type 1 Grade E 99 hydrogen (99% minimum)'	Revise text to ensure consistency with Table 1.	
CA	4.3 and 4.4	Table 1	te	Last bullet in 4.3 refers to Grade E 999 hydrogen while Table 1 – to 99 hydrogen. 99 hydrogen will require excessive purging.	Increase hydrogen grade in Table 1 to 999 H2 as stated in Clause 4.3; change H2 fuel index to 99.9% and adjust the total non-hydrogen gases to 0.1%	
US 4	4.3 and Table 1		te	The hydrogen index in the text is not the same as the value in the table.	Change "999" to "99" and "99.9%" to "99%".	
US 4	4.3 and Table 1		te	The hydrogen index in the text is not the same as the value in the table.	Change "999" to "99" and "99.9%" to "99%".	
JP8	4.3 4.4 Table-1		te	Need to change the minimum hydrogen fuel index of Reformate-A and Reformate-B from 60% to 50% assuming ATR(auto thermal reactor) Need to change the hydrogen fuel index of Reformate-A from 60% - 80% to 60% minimum to match that of Reformate-B	Change as below, Type I Grade E Reformate-A (hydrogen fuel index: 50% minimum) Type I Grade E Reformate-B (hydrogen fuel index: 50% minimum)	
JP9	4.4	L.1	ed	Need to use same expression	--- at the boundary point defined between the hydrogen supply and the fuel system, --- → --- at the boundary point defined between hydrogen fuel supply equipment and fuel cell power system, ---	
UK	4.4	Final line	Ed	'….customer other than Table 1' should read '…customer other than the specification shown in Table 1'	Revise text	
US 5	4.4		ge	Simpler, less expensive fuel cell systems may be able to operate on fuel grades that are compliant with ISO/DIS 14687-2.	Add a second sentence to the second paragraph of this clause that reads: Alternatively, the specifications in ISO/DIS 14687-2 may be used. Delete "other than Table 1" from the third paragraph.	
US 6	Table 1		ge	What does reformate A represent? Is this reformate after a low shift without a PSA?	Clarify what is the basis for the selection of the fluid.	

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CA	Table 1		te	Reformate B needs to include ATR, which has a lower H2 content fuel	Lower H2 fuel index to 50% and the total non-hydrogen gases to 50%	
US 7	Table 1		ge	What does reformate B represent? Is this reformate after a low shift with a small PSA?	Clarify what is the basis for the selection of the fluid.	
CA	Table 1		te	Type II grade E liquid H2 for stationary applications does not make sense. Liquid hydrogen is liquid hydrogen and should have only one grade for all applications.	Remove from Table	
US 12	Table 1		te	What is the point of Type II, grade E? Hydrogen which has gone through liquefaction has stripped out everything except helium. At -253C (the boiling point of liquid hydrogen) all the other compounds are solids. Thus in practice, the only variable is helium concentration. Therefore, in practice, how is this different than 14687-1 Type II. This has been repeatedly pointed out to the 14687-2 team also which is also carrying a liquid grade.	Delete the liquid grade. Additionally, liquid grades are rarely supplied by pipeline.	
UK	Table 1	'Water' row	Te	The specification for water content of 99 Hydrogen (Type 1 or Type 2) is confusing - is this also intended to be non-condensing? 5ppm max water at an ambient temperature of -20°C enables the pressure to be raised to 200 bar before condensation is expected. Is the 5ppm limit necessary for lower pressure systems also? We have interpreted this as meaning that water is non-condensing for reformate A and B, but not for 99 hydrogen, and that water is to be removed from the analysis for the reason that it needs only to be considered non-condensing. Is the 5ppm specification also meant to imply non-condensing water, or is 5ppm a specific value above which water content shall cause problems for use with such a fuel cell?	Clarify by revising the text.	

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US 8	Table 1		te	What is the reformate water content? Is it -40C? or the pipe line transmission temperature (~15C) which would condense at many sites when the pipeline runs above ground and is exposed to the elements (not buried).	Clarify the basis of the water content. Ensure that condensation is not possible. Add the following as a new footnote to Table 1 for Water (H_2O), Reformate A and Reformate B: "Each site must be evaluated to determine the appropriate dew point specification depending upon the lowest expected ambient temperature."	
UK	Table 1	'Total non-hydrogen gases' row	Te	No units are stated.	State 'mole fraction' in the first column	
UK	Table 1	'N_2, Ar & He' row	Te	No units are stated.	State 'mole fraction' in the first column	
JP10	Table 1		te	Need to match CO value for 99 Hydrogen with that of ISO/DIS14687-2 (Hydrogen fuel – Product specification – Part2)	Change 0,1µmol/mol to 0,2µmol/mol	
US 9	Table 1		te	The level of CO for "99 hydrogen" is less than the current value in the -2 draft specification.	Change the allowable CO for "99 hydrogen" from 0,1 to 0,2 (to harmonize with the -2 specification.	
JP11	Table 1		te	Need to change HCHO value for Reformate-A according JARI Data	Change 3µmol/mol to 5µmol/mol	
JP12	Table 1		te	Need to change HCOOH value for Reformate-A according JARI Data	Change 12µmol/mol to 20µmol/mol	
US 10	Table 1		te	Are the Reformate subgrades going to require clean-up (HCHO, HCOOH) of fuel at the fuel cell? Testing funded by NEDO and US DOE indicate these compounds at the levels listed will limit PEM CSA life to around 5000 hrs. This will not be acceptable to the general public.	Recommend changing Reformate A value to Reformate B value for HCHO and HCOOH.	
CA	4.4	Table 1	te	Reformate A : Particulates should be specified in all grades as they can erode seals and block valves	Insert a particulate threshold level of 1mg/kg for Reformate A	

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JP13	Table 1		te	Need to define particulate value for Reformate-A For maximum particulates concentration, 1mg/kg is appropriate because the same value as Reformate-B and 99 Hydrogen. For particulates diameter, 75μm is appropriate assuming 200mesh filter.	Change “not specified” as below, Maximum particulates concentration: 1mg/kg Maximum particulates diameter: 75μm	
US 11	Table 1		te	Will the particulate levels of Reformate A going to cause issues with control surfaces in the pipeline, clean-up and/or fuel cell hardware? How does an end user size a filter if they don’t know the particulate levels of Reformate A they will be dealing with?	Specify a threshold level of 1 mg/kg for Reformate A for particulate levels or selection of control equipment and/or filtration elements will be problematic.	
UK	Table 1	Note 1	Ed	The term ‘non-hydrogen impurities’ seems unnecessary.	Change to ‘non-hydrogen constituents’ or ‘impurities’.	
UK	Table 1	Note 2	Ed	The final sentence: ‘The tolerances in the applicable gas testing method are to be the tolerances of the acceptable limit’ doesn’t make sense – please explain.	Revise the text to make the meaning clearer	
JP14	4.4	L.1-2	ed	Need to use same expression	--- at the boundary point defined between the hydrogen supply and the fuel system, --- → --- at the boundary point defined between hydrogen fuel supply equipment and fuel cell power system, ---	
UK	5	-	Ge	No specification is given as to how often will impurity testing is required for stationary applications. Is this covered by clause 5.2 (‘requirement…shall be determined by agreement between the customer and the supplier’)?	Consider introducing a specification for the required frequency of analysis.	

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US 13	5.2.1		ed	Currently worded with a specific process then the general, overall processes. Flip order of paragraphs to reverse this information. Deletion of word "other" allows for analytical requirements for the qualification tests all on-site hydrogen production processes to be determined by supplier and customer agreement.	Move second paragraph to first paragraph, and also delete the word "other."	
JP15	5.3	L.1	ed	Need to add “determination limit” to subject of 1st sentence	The detection limits for analytical methods --- → The detection and determination limits for analytical methods ---	
JP16	5.3	L.2	ed	Need to change “detectable limits“ to “determination limits” from the meaning of sentence	These detectable limits shall be below --- → These determination limits shall be below ---	
UK	6.1	-	Te	Sample volume is one of the main issues with performing all the analysis specified by this standard. We recommended that a statement (or note) is added stating that large sample volumes / pressures may be required if multiple analytical methods (particularly ion chromatography) are to be used.	Add statement or note stating this.	
UK	6.2	First paragraph	Ed	The text states ‘using one of the following procedures’, but only one procedure is then listed.	Revise text	
UK	6.2	NOTE	Ed	Ensuring that the sampling vessel is free of impurities is absolutely essential to ensure that a meaningful analysis is carried out. Evacuating the vessel before sampling is a better way to do this than purging.	Revise the text so that it is recommended that the sampling vessel is evacuated. Where this is not possible, purging may be used as an alternative, but a minimum number of purges (10) should be specified.	
US 14	6.2	pp 2	te	In hydrogen production process of on-site and off-site supply, withdraw a sample from the boundary point through a suitable connection into the sample container. **No regulator shall be used between** the boundary point and the sample containers (a suitable purge valve may be used). This proposal can be extremely hazardous, unless a specific test methodology with stipulated sampling hardware required.	Add a cautionary note: "CAUTION: Sampled gases are potentially flammable and toxic. Measures shall be taken to avoid hazardous situations per Clause 9 *Safety*."	

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JP17	6.3		ed	Need to relax sampling method	Particulates in hydrogen are sampled from the boundary point, using a filter <u>if possible</u> under the same conditions (pressure and flow rate) ---	
UK	7.2	(a) and (b)	Te	- micromoles per mole is also a unit of amount fraction - milligrams per kilogram is a unit of mass fraction	Change test to: (a) mole fraction, expressed as a percentage (% mol/mol) or micromoles per mole (□mol/mol) (b) mass fraction expressed as milligrams per kilogram (mg/kg) [particulate concentration only].	
UK	7.2	Third paragraph (starting 'calibration')	Te	The use of traceable calibration gas standards that are accredited to ISO 17025 or ISO Guide 34 would be beneficial.	Update the text to reflect this comment.	
AR	7.3		Te	FTIR is a well known technique but it should be defined within the document to avoid confusion or misunderstandings	Define the acronym FTIR as (Fourier Transform Infrared Spectroscopy) and any other of the analytical techniques the first time that they appear within the text	
UK	7.3	-	Te	A hygrometer (which may or may not be an 'electrostatic capacity type moisture meter') can be used for the measurement of water content.	Add 'a hygrometer' to the list	
UK	7.3	-	Te	Analysis for water can also be carried out using GC-MS	Add GC-MS to the list	

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US 15	7.3-7.15		te	These sections are not actionable unless an industry accepted, commercial test method is referenced. The industrially accepted methods should be used unless the buyer and seller mutually agree on an alternate test method.	Reference an industry accepted sampling technique. ASTM has generated one the US DOE has supported. It is in the publishing cycle and should be referenced. ISO/IEC Directives, Part 2, 6.2.2, allows for normative references to documents published by other bodies. Recommend including the following ASTM standards: ASTM D7550-09, *Standard Test Method for Determination of Ammonium, Alkali and Alkaline Earth Metals in Hydrogen and Other Cell Feed Gases by Ion Chromatography* ASTM D7650-10, *Standard Test Method for Test Method for Sampling of Particulate Matter in High Pressure Hydrogen used as a Gaseous Fuel with an In-Stream Filter* ASTM D7651-10, *Standard Test Method for Gravimetric Measurement of Particulate Concentration of Hydrogen Fuel* There are additional ASTM standards in development that would be appropriate as normative references in ISO 14687-3. The TAG would submit these as part of any comments on the CD or DIS drafts if they are made available by ASTM	
UK	7.10	-	Te	Recent work in the UK has developed a method to allow total sulphur species to be measured to 1ppb without using a pre-concentration device.	Add GC-SCD (without pre-concentration) to the list. This is already listed in Table C1.	
US 16	9		te	Given the allowable amounts of CO, for example, toxicity of sampled gas is also an issue and should be added.	Add an additional paragraph warning the user of toxic exposure. Add the following as a new paragraph 2: Additionally, constituents of the hydrogen-rich stream may be toxic. Precautionary measures should be taken to avoid exposure.	
UK	Annex B	-	Ge	Ensure that Annex B in this Part of the Standards is identical to Annex B in Part 2 of the Standard – it looks as though this is the case at the moment.	Ensure consistency between Annex B in Part 2 and Annex B in Part 3.	

UK	Annex B	B.2	Te	To comply with IUPAC terminology, change 'paraffinic hydrocarbons' to 'alkenes' (if this is what is meant here).	Revise text.	
UK	Annex B	B.2	Ed	'…inert since' should read '…inert gas since'	Revise text.	
AR	B5		Ed	In the second sentence CO2 should be written properly	Write as follows: "With CO_2 very much higher than the specification…"	
UK	Annex B	B.5	Ed	'CO2' should read …'CO_2'	Revise text.	
UK	Annex B	B.7	Te	This section only specifies one mercaptan (methyl mercaptan), where Table 1 (note c) specifies 'mercaptans'	Revise text to ensure consistency with Table 1.	
US 17	Annex B		ge	A description of the source of these requirements should be added.	Either add this information into the existing Annex B or add an informative annex to describe the types of fuel supplies being addressed.	
JP18	Annex C	Table C.1	ed	Need to change "period" to "comma"	Need to change in the row of Nitrogen, Total sulphur compounds and Ammonia,	
JP19	Annex C	Table C.1	ed	Need to delete Analytical methods that these detection limit and determination limit are blank	Delete the rows as below, Water: Electrostatic capacity type moisture meter Water: FTIR Oxygen: GC/MS and jet pulse injection Oxygen: GC/TCD Carbon dioxide: FTIR Formaldehyde: FTIR Formic acid: FTIR Formic acid: GC/ELCD Ammonia: GC/ELCD Total halogenated compounds: ECD	
JP20	Annex C	Table C.1	te	Need to change detection limit and determination limit of maximum particulates concentration according to data in Japan	Detection limit: 0.1mg/kg → 0.0005mg/kg Determination limit: 0.3mg/kg → 0.0015mg/kg	

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UK	Annex C	Last sentence	Ed	Change 'numbers' to values'	Revise text.	
UK	Annex C	Table C1 – water row	Te	Recent work in the UK has developed a method to measure water using GC-MS with a detection limit of 0.2 ppm and a determination limit of 0.8 ppm.	Add this information to the table.	
UK	Annex C	Table C1 – oxygen row	Te	Recent work in the UK has developed a method to measure oxygen using GC-TCD with a detection limit of 1 ppm and a determination limit of 3 ppm.	Add this information to the table.	
UK	Annex C	Table C1 – total sulphur compounds row	Te	Recent work in the UK has developed a method to measure total sulphur compounds using GC-SCD (with no pre-concentration) with a detection limit of 0.001 ppm and a determination limit of 0.003 ppm.	Add this information to the table.	
UK	Annex C	Table C1 – total sulphur compounds row	Te	Can IC really measure total sulphur compounds down to 0.1ppb? What sample volume is needed for this?	Respond to question and, if required, amend text.	

New Annex-A (Informative)
Rationale for the categories

This Annex, as informative, is intended to provide categories of Type I Grade E hydrogen fuel. Proton exchange membrane (PEM) fuel cell power systems include several applications such as distributed power generation, back-up power generation, remote power generation, power generation for telecom applications and cogeneration for residential and commercial applications. Table-A1 provides a list of hydrogen fuel characteristics, operation conditions and fuel cell performances for each application. Reformate-A, Reformate-B and 99 Hydrogen are listed in Table-A1. These numbers may change as technology will develop.

Table-A1 – List of categories of Type I Grade E hydrogen fuel

Categories	Reformate-A	Reformate-B		99 Hydrogen			
Fuel Characteristics	Reformate	Reformate		Cylinder			
Application	Cogeneration	Remote Power	Distributed Power	Back-Up Power	Remote Power	Telecom Backup	Distributed Power
Current Density	0.2 - 0.3 a/cm2	Up to 1.0 a/cm2	0.5 - 1.0 a/cm2	0.5 - 1.0 a/cm2	Up to 1.0 a/cm2	Up to 1.0 a/cm2	0.5 - 1.0 a/cm2
Operating Hours	40,000 hr	40,000	60,000	2,000	40,000	2,000	60,000
Calendar Lifetime	90,000 hr	90,000	90,000	90,000	90,000	90,000	90,000
Lifetime Shutdown/Startup Cycles	4,000	Up to 4000	4,000	500	Up to 4000	TBD	4,000
Steady-State Temperature	65-80 C	65-80 C	65-80 C	65-80 C	65-80 C	65-80 C	65-80 C
Operating Pressure	ambient	ambient	ambient	ambient - 30 psig	ambient	ambient	ambient
Ambient Temperature Range	-20 to 40 C	-40 to 40 C	-40 to 40 C	-40 to 40 C	-40 to 40 C	-40 to 40 C	-40 to 40 C
Electrical Efficiency	> 35% LHV						
Hydrogen Recycle	No	Yes or No	Yes or No	Yes or No	Yes or No	Yes or No	Yes or No
Air Bleed	Yes or No	Yes or No	Yes or No	No	Yes or No	No	Yes or No
Nominal Operating Voltage	0.75 v	0.6 v		0.6 v	0.6 v	?	
Anode Cell Humidity	100%	100%	50-100%	0 - 100%	100%	0-100%	50-100%
Anode Catalyst Loading	0.1- 0.2 mg/cm2	0.1- 0.2 mg/cm2	0.1- 0.2 mg/cm2	0.5- 1.0 mg/cm2	0.1- 0.2 mg/cm2	0.5- 1.0 mg/cm2	0.1- 0.2 mg/cm2