

团 体 标 准

T/ZSA 170—2023

商用车燃料电池发动机 技术条件

Technical specification of fuel cell engines for commercial vehicle

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全国团体标准信息平台

前 言

本文件按照GB/T 1.1—2020《标准化工作导则 第1部分：标准化文件的结构和起草规则》的规定起草。

本文件由中关村标准化协会汽车新技术分技术委员会提出并归口。

本文件起草单位：北京亿华通科技股份有限公司、北京聚兴华通氢能科技有限公司、亿氢科技（北京）有限公司、亿华通动力科技有限公司、北京未来氢谷科技有限公司、北京亿华通氢能科技有限公司、宇通客车股份有限公司、北汽福田汽车股份有限公司、一汽解放汽车有限公司、佛山市飞驰汽车科技有限公司、清华大学、北京化工大学、北京市科学技术研究院、同济大学、华北电力大学、中国科学院宁波材料技术与工程研究所、天津大学、北京科技大学、河南工业大学、广东正扬传感器科技股份有限公司、芜湖同优科技股份有限公司、中机寰宇认证检验股份有限公司、北京市产品质量监督检验研究院。

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商用车燃料电池发动机技术条件

1 范围

本文件规定了商用车燃料电池发动机的系统边界、一般要求、性能要求、试验方法和标志、包装、贮存、文件。

本文件适用于装载在商用车上的质子交换膜燃料电池发动机，其他类型车辆可参照执行。

2 规范性引用文件

下列文件中的内容通过文中的规范性引用而构成本文件必不可少的条款。其中，注日期的引用文件，仅该日期对应的版本适用于本文件；不注日期的引用文件，其最新版本（包括所有的修改单）适用于本文件。

- GB/T 191—2008 包装储运图示标志
- GB/T 1859.4—2017 往复式内燃机 声压法声功率级的测定 第4部分：使用标准声源简易法
- GB/T 2408—2021 塑料 燃烧性能的测定 水平法和垂直法
- GB/T 2893.2—2020 图形符号 安全色和安全标志 第2部分：产品安全标签的设计原则
- GB/T 2894—2008 安全标志及其使用导则
- GB/T 3836.1—2021 爆炸性环境 第1部分：设备 通用要求
- GB/T 4026—2019 人机界面标志标识的基本和安全规则 设备端子、导体终端和导体的标识
- GB/T 4208—2017 外壳防护等级（IP代码）
- GB/T 8170—2008 数值修约规则与极限数值的表示和判定
- GB/T 16935.1—2008 低压系统内设备的绝缘配合 第1部分：原理、要求和试验
- GB/T 17045—2020 电击防护 装置和设备的通用部分
- GB 18384—2020 电动汽车安全要求
- GB/T 18411—2018 机动车产品标牌
- GB/T 20042.1—2017 质子交换膜燃料电池 第1部分：术语
- GB/T 24548—2009 燃料电池电动汽车 术语
- GB/T 24554—2022 燃料电池发动机性能试验方法
- GB/T 25319—2010 汽车用燃料电池发电系统 技术条件
- GB/T 28046.3—2011 道路车辆 电气及电子设备的环境条件和试验 第3部分：机械负荷
- GB/T 35178—2017 燃料电池电动汽车 氢气消耗量 测量方法
- GB/T 37154—2018 燃料电池电动汽车 整车氢气排放测试方法

3 术语和定义

GB/T 20042.1—2017、GB/T 24548—2009、GB/T 25319—2009 规定的以下术语和定义适用于本文件。

3.1

工况 work conditions

燃料电池发动机的工作状态，以净输出功率标定工况。

[来源：GB/T 25319—2010，3.1.1，有修改]

3.2

额定工况 rated conditions

制造商用于标定燃料电池发动机按 100%净输出功率规定的工况。

[来源：GB/T 25319—2010，3.1.2，有修改]

3.3

怠速工况 idle conditions

燃料电池发动机处于工作状态，能维持自身工作，但不对外输出功率。

[来源：GB/T 25319—2010，3.1.3，有修改]

3.4

额定功率 rated power

燃料电池发动机在额定工况时的有效净输出功率,并能够在此功率下稳定持续工作。

[来源：GB/T 25319—2010，3.1.5，有修改]

3.5

峰值功率 peak power

燃料电池发动机在一个约定的短时间内产生的不低于额定功率的最大功率。

[来源：GB/T 20042.1—2017，3.2.21，有修改]

3.6

最小功率点 minimum power

燃料电池发动机处于工作状态，减去用于维持自身辅助系统的消耗，所能输出的最低净输出功率（DCDC 前端）。

[来源：GB/T 20042.1—2017，3.2.20，有修改]

3.7

质量比功率 specific power

燃料电池发动机额定功率和其质量的比，单位为 kW/kg。

注：质量比功率通常称为比功率。

[来源：GB/T 20042.1—2017，3.2.26，有修改]

3.8

燃料消耗量 fuel consumption

一定工况下燃料电池发动机在规定时间内消耗的燃料量，注：单位为 kg/h。

[来源：GB/T 20042.1—2017，3.3.3，有修改]

3.9

热态/热机状态 hot state

燃料电池发动机其组成模块温度处于正常工作温度范围内的状态。

[来源：GB/T 20042.1—2017，5.2.3，有修改]

3.10

冷态/冷机状态 cold state

燃料电池发动机内部温度与环境温度相同既没有能量输入也没有能量输出的状态。

[来源：GB/T 20042.1—2017，5.2.7，有修改]

3.11

气体泄漏 external gas leakage

除有意排出的废气之外，产生气体漏出燃料电池的现象。

[来源：GB/T 20042.1—2017，4.2.10]

注：气体泄漏可能产生于：燃料电池堆、相关减压装置、其他气体管路和流体控制部件。

3.12

燃料电池发动机 fuel cell system

包括燃料电池堆和燃料电池辅助系统，在外接氢源的情况下可以正常工作。

[来源：GB/T 24548—2009，3.4.3]

4 系统边界

燃料电池发动机系统边界见图1，其中虚线框内部分为燃料电池发动机，内部包含燃料电池模块、氢气供应系统、空气供应系统及热管理系统，图中相对框内的进出箭头所指为燃料电池发动机的输入和输出。

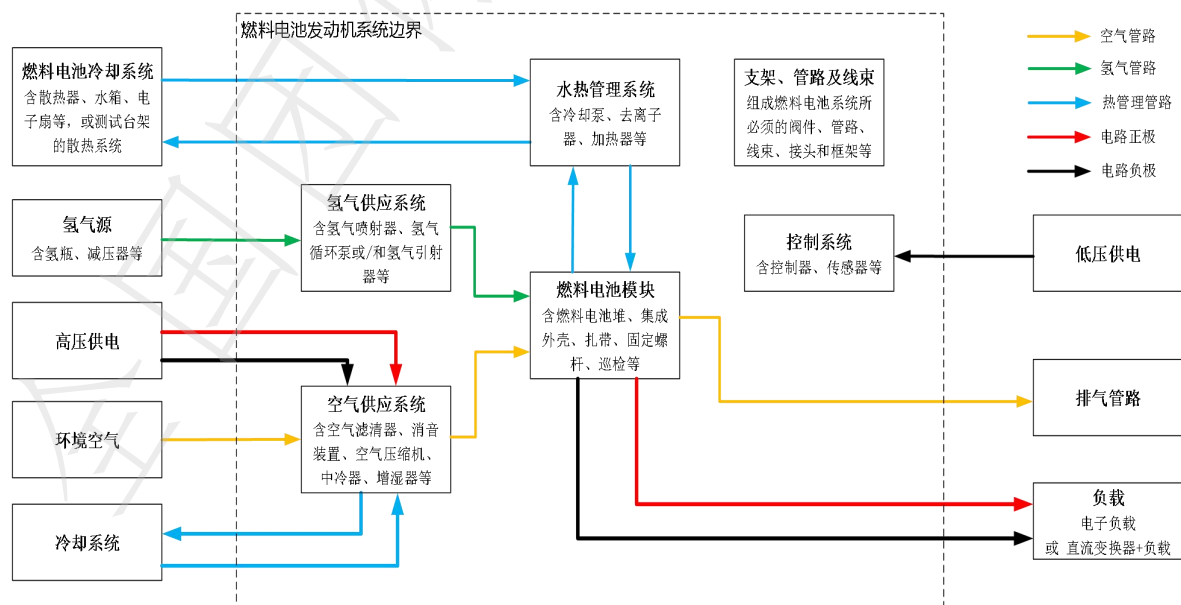


图1 燃料电池发动机系统边界

5 一般要求

5.1 外观结构要求

- 5.1.1 燃料电池发动机外表应清洁, 无机械损伤, 不应有裂纹、污迹及明显变形, 接口触点无锈蚀。
- 5.1.2 燃料电池发动机的可接触部件不应具有可能造成人身伤害的尖锐的边和角。
- 5.1.3 在燃料电池发动机正常运行过程中, 其零部件及其连接件应稳固、可靠, 不应出现失稳、变形、断裂或磨损等现象。
- 5.1.4 燃料电池发动机的通信接口、电源接口、用户接口、氢气进出口等应有明确的标识。
- 5.1.5 燃料电池发动机的正、负极端子及极性应有明显标识, 便于连接。

5.2 通用安全要求

- 5.2.1 燃料电池发动机氢气回路应配备安全泄压装置, 即使在断电状态也应保证安全泄压装置正常工作。
- 5.2.2 燃料电池发动机燃料供应管路不应通过乘员舱。
- 5.2.3 燃料电池发动机排放燃料设置的排放口应直通商用车外, 并有安全保护措施。
- 5.2.4 燃料电池发动机安装于封闭或半封闭空间时, 应在空间上方或燃料电池发动机上方安装氢气泄漏探测器; 当探测器监测到泄漏时, 控制系统应能自动切断燃料供应。
- 5.2.5 燃料电池发动机上的高压警告标记和 B 级电压电线标记应满足 GB 18384—2020 中 5.1.2 要求。
- 5.2.6 燃料电池发动机的直接接触防护要求应满足 GB 18384—2020 中 5.1.3 要求。
- 5.2.7 燃料电池发动机的电位均衡要求应满足 GB 18384—2020 中 5.1.4.3 要求。
- 5.2.8 材料和元器件以及结构设计应符合 GB/T 3836.1—2021 中 II 类设备的防爆安全规定。
- 5.2.9 燃料电池发动机的电气间隙和爬电距离应符合 GB/T 16935.1—2008 的要求。
- 5.2.10 燃料电池发动机所有电气装置、系统或设备, 按 GB/T 17045—2020 中 I 类设备的规定进行。
- 5.2.11 用于输送氢气介质的塑料或橡胶材料应是能导电的, 或设计上能做到避免静电电荷积累。

6 性能要求

6.1 起动特性

6.1.1 常温起动特性

6.1.1.1 常温怠速冷起动特性

按照 7.2.1.1 进行试验, 要求冷机状态至怠速, 时间应小于 15s。

6.1.1.2 常温怠速热起动特性

按照 7.2.1.2 进行试验, 要求热机状态至怠速, 时间应 \leq 10s。

6.1.2 低温额定功率冷起动特性

按照 7.2.2 进行试验, 要求系统可正常启动, 启动到额定功率时长不超过 4min, 启动过程中的零部件功耗应满足设计要求, 且系统无关机或降载故障。

6.2 额定功率

6.2.1 平原额定功率

按照 7.3.1 进行试验,要求燃料电池发动机在有效测量时长内的输出功率应始终处于有效测量时长 60min 运行功率的平均值的 97%~103%。

6.2.2 高原额定功率

按照 7.3.2 进行试验,应满足如下要求:

- a) 海拔高度为 1000m 时,应满足额定功率 100%输出;
- b) 海拔高度为 2000m 时,应满足额定功率降额不高于 15%;
- c) 海拔高度为 3000m 时,应满足额定功率降额不高于 30%。

6.3 峰值功率

按照 7.4 进行试验,要求最大功率不低于额定功率。

6.4 动态响应特性

按照 7.5 进行试验,要求最小功率点至额定状态的加载时间应 ≤ 12 s,额定状态至最小功率点的卸载时间应 ≤ 8 s。

6.5 稳态特性

燃料电池发动机按 7.6 进行试验时,应提供燃料电池堆的极化特性曲线(V—I 曲线)、燃料电池堆的功率曲线、燃料电池堆的效率曲线、燃料电池发动机的功率曲线、燃料电池发动机的效率曲线和辅助系统的功率曲线等。要求系统效率在 45%以上的工作区间占比,应 $\geq 60\%$,额定点效率应 $\geq 45\%$ 。

6.6 高温运行特性

按照 7.7 进行试验,要求燃料电池发动机的输出功率应始终处于有效测量时长 60min 运行功率的平均值的 95%~105%。

6.7 动态平均效率特性试验

按照 7.8 进行试验,要求系统效率不应低于系统设计要求值,且试验过程中系统无关机或降载故障。

6.8 氢气排放要求

按照 7.9 进行试验,要求燃料电池发动机怠速状态或燃料电池发动机最低功率点,热机状态氢气排放任意连续 3s 内的平均氢气体积浓度应不超过 3%,且瞬时氢气体积浓度不超过 8%。

6.9 噪声

燃料电池发动机本体噪声试验按照 7.10 进行,记录系统的噪声最大值,要求怠速工况噪声应 ≤ 75 dB,额定工况噪声应 ≤ 80 dB。

6.10 气密性要求

燃料电池发动机氢气回路按 7.11 进行气保压试验时,氢气回路压力下降值应同时符合以下规定要求。

- a) 氮气介质,保压 20 分钟,压力下降值 ≤ 12 kPa。
- b) 氢气介质,保压 30 秒,压力下降值 ≤ 14 kPa。

c) 燃料电池发动机在各工况点运行过程中, 氢气回路各连接点氢气泄露浓度 $\leq 0.005\%$ 。

6.11 绝缘电阻

燃料电池发动机的绝缘试验按7.12进行, 要求绝缘电阻值应满足绝缘电阻 $>1000\ \Omega/V$ 。

6.12 质量比功率

按照7.13进行试验, 要求质量比功率应满足系统设计目标, 且不低于 $550W/kg$ 。

6.13 振动性能

按照7.14进行试验, 要求试验完成后, 燃料电池发动机保持连接可靠、结构完好、无明显变形, 燃料电池发动机能够正常工作。

6.14 防水防尘

燃料电池发动机中需要具备防水防尘能力的部件应按7.15的要求进行试验, 试验结果应符合GB/T 4208—2017中IP67及以上等级的要求。

6.15 非金属材料阻燃要求

燃料电池发动机上的非金属材料应使用阻燃材料, 除电池堆外的非金属材料的燃烧特性按照7.16进行试验, 试验结果应符合以下规定:

- a) 满足以下任一条件的零部件, 其材质需满足水平燃烧HB级和垂直燃烧V-0级的要求:
 - 1) 单个零部件重量 $\geq 50g$;
 - 2) 单个燃料电池发动机内相同型号的零部件总重量 $\geq 200g$ 。
- b) 其它非金属零部件材质应满足水平燃烧HB75级和垂直燃烧V-2级的要求。

7 试验方法

7.1 通用试验条件

7.1.1 环境条件

除另有规定, 试验应在如下环境中进行:

- a) 温度为 $23^{\circ}C \pm 5^{\circ}C$;
- b) 相对湿度为 $15\% \sim 90\%$;
- c) 大气压力 $86kPa \sim 106kPa$ 。

注: 本文件所提到的室温, 是指 $23^{\circ}C \pm 5^{\circ}C$ 。

7.1.2 测试仪器要求

7.1.2.1 测量仪器的准确度

除特殊说明外, 不限制测量仪器的量程, 测量仪器精度准确度应满足下列要求:

- a) 电压测试装置: ≥ 0.5 级;
- b) 电流测试装置: ≥ 0.5 级;
- c) 温度测试装置: $\pm 0.5^{\circ}C$;
- d) 时间测量装置: $\pm 0.1\%$;
- e) 尺寸测量装置: $\pm 0.1\%$;
- f) 质量测量装置: $\pm 0.1\%$;

- g) 电导率测试装置：准确度 $\leq\pm 5\%$ ；
- h) 氢气检漏仪：精度 $\geq\pm 5\%FS$ ，量程范围不小于 $0\%\sim 10\%$ 。

7.1.2.2 控制仪器的控制精度

控制仪器的控制精度应满足下列要求：

- a) 电压： $\pm 1\%$ ；
- b) 电流： $\pm 1\%$ ；
- c) 温度： $\pm 1^{\circ}C$ 。

7.1.2.3 试验数据采集仪器要求

试验过程中，数据采集频率计加载误差应满足以下要求：

- a) 试验数据采集频率不应低于 $5Hz$ ；
- b) 在功率、效率等参数计算中，按GB/T 8170—2008的规定修约至小数点后2位，特殊说明除外。

7.1.3 试验预处理

7.1.3.1 常温浸机方法

常温浸机要求如下：

- a) 浸机前完成一次燃料电池发动机开关机过程，关闭燃料电池发动机；
- b) 将燃料电池发动机（冷却液加注完成）在室温环境条件下静置，浸机时间应不少于 $12h$ ；
- c) 在浸机期间，不应应对燃料电池发动机做任何改动。

7.1.3.2 低温（ $0^{\circ}C$ 以下）浸机方法

在燃料电池发动机低温冷起动试验中，用于燃料电池发动机的散热器或者热交换器应置于环境舱中。具体要求如下：

- a) 在浸机过程中，在达到设定温度前，可在环境舱降至厂商指定温度后并持续一定时间（制造商根据产品技术要求确定），进行一次开关机操作；
- b) 燃料电池发动机应起动至怠速状态（或燃料电池发动机最低功率点），持续时间（含起动）不超过 $3min$ ；
- c) 然后立即关闭燃料电池发动机；
- d) 当环境温度达到设定温度的时候，开始计时，有效浸机时间应不少于 $12h$ 。

注1：在整个低温冷起动以及低温运行过程中，环境舱的温度控制在设定温度的 $\pm 2.0^{\circ}C$ ，且低于 $0^{\circ}C$ 。

注2：有效浸机时间是指从环境舱的温度达到设定温度后开始计时到浸机结束所用的时间。

7.1.3.3 高温（ $50^{\circ}C$ 以下）浸机方法

高温浸机要求如下：

- a) 浸机前完成一次燃料电池发动机开关机过程，关闭燃料电池发动机；
- b) 在燃料电池发动机高温运行试验中，用于燃料电池发动机的散热器或者热交换器应置于环境舱中；
- c) 将环境舱的温度设为 $50.0^{\circ}C$ ，相对湿度设为 $40\%\sim 90\%$ ，当环境温度达到设定温度的时候开始计时，有效浸机时间应不少于 $2h$ 。

注1：在整个高温浸机以及高温运行过程中，环境舱的温度控制在设定温度的 $\pm 2.0^{\circ}C$ 内。

注2：有效浸机时间是指从环境舱的温度达到设定温度后开始计时到浸机结束所用的时间。

7.1.3.4 热机方法

按照制造商的使用规定，使燃料电池发动机工作在一定功率，同时检测燃料电池发动机冷却液的出口温度，燃料电池发动机冷却液的出口温度达到正常工作温度（该温度由制造商指定），既认为燃料电池发动机达到热机状态。

7.2 起动特性试验

7.2.1 常温起动特性试验

7.2.1.1 常温怠速冷起动特性

按照 GB/T 24554—2022 中 8.1.1.1 规定的试验方法进行，试验前燃料电池发动机处于常温环境下，按照 7.1.3.1 的浸机方法进行浸机处理。试验过程应自动进行，不应有人工干预。试验结果应满足 6.1.1.1 的要求。

7.2.1.2 常温怠速热起动特性

按照 GB/T 24554—2022 中 8.1.1.2 规定的试验方法进行，试验前燃料电池发动机处于常温环境下，按照 7.1.3.4 的浸机方法进行浸机处理。试验过程应自动进行，不应有人工干预。试验结果应满足 6.1.1.2 的要求。

7.2.2 低温额定功率冷起动特性

按照 GB/T 24554—2022 中 8.1.2.2 规定的试验方法进行，试验前燃料电池发动机处于常温环境下，按照 7.1.3.2 的浸机方法进行浸机处理（环境舱温度 $\leq -35^{\circ}\text{C}$ ）。试验过程应自动进行，不应有人工干预。试验结果应满足 6.1.2 的要求。

7.3 额定功率试验

7.3.1 平原额定功率试验

按照 GB/T 24554—2022 中 8.2 规定的试验方法进行，功率计算方法见附录 A，试验前燃料电池发动机的状态为热机状态，试验过程应自动进行，不应有人工干预。试验结果应满足 6.2.1 的要求。

7.3.2 高原额定功率试验

选用实地或者使用环境舱模拟高海拔地区的气压条件，试验前燃料电池发动机的状态为热机状态，试验过程应自动进行，不应有人工干预。在怠速、部分加载、额定工况、过载工况等各个工况下，分别测取：

- a) 燃料消耗量；
- b) 电池堆的输出电流和电压、燃料电池发动机净输出的电流电压；
- c) 测量辅助支持运行系统的功耗；
- d) 记录进气温度、进气压力、冷却水温度、环境温度和湿度等；

在额定工况和过载工况时，记录燃料电池发动机输出电流和电压随时间变化的历程，功率计算方法见附录 A，试验结果应满足 6.2.2 的要求。

注：额定工况下燃料电池发动机稳定运行 1h，过载工况下燃料电池发动机稳定运行 60s。

7.4 峰值功率试验

按照 GB/T 24554—2022 中 8.3 项规定的试验方法进行，试验前燃料电池发动机的状态为热机状态，试验过程应自动进行，不应有人工干预。试验结果应满足 6.3 的要求。

7.5 动态响应试验

按照 GB/T 24554—2022 中 8.4 项规定的试验方法进行, 试验结果应满足 6.4 的要求。

7.6 稳态特性试验

按照 GB/T 24554—2022 中 8.5 项规定的试验方法进行, 试验结果应满足 6.5 的要求。

7.7 高温特性试验

按照 GB/T 24554—2022 中 8.6 项规定的试验方法进行, 试验前燃料电池发动机处于环境舱中, 将环境舱的温度设为 50.0℃, 按照 7.1.3.3 的浸机方法进行浸机处理。试验过程应自动进行, 不应有人工干预。试验结果应满足 6.6 的要求。

7.8 动态平均效率特性试验

按照 GB/T 24554—2022 中 8.7 项规定的试验方法进行, 具体计算方式见附录 B, 试验结果应满足 6.7 的要求。

7.9 氢气排放试验

氢气排放试验按照 GB/T 37154—2018 的 6.1 进行试验, 具体试验步骤如下:

- a) 怠速状态下持续运行时间为 10min;
- b) 然后依次在 10%~90%额定功率点持续运行, 每个功率点持续运行时间均为 10min;
- c) 连续记录怠速以及各个功率点持续运行过程中的氢气浓度。

试验结果应满足 6.8 的要求。

7.10 噪声试验

按照 GB/T 1859.4—2017 中规定的噪声试验方法进行, 试验结果应满足 6.9 的要求。

7.11 气密性试验

气密性试验步骤如下:

- a) 关闭燃料电池发动机排气、排水阀等与外部联通的开关;
- b) 将燃料电池发动机氢气回路中充满氢气或氮气等惰性气体, 压力设定为 50kPa;
- c) 压力稳定后, 立即关闭进气阀;
- d) 进行保压并实时记录压力值, 进而计算得出压力下降值。

试验结果应满足 6.10 的要求。

7.12 绝缘(静态)试验

按照 GB/T 24554—2022 8.9 中规定的试验方法进行测试, 试验结果应满足 6.11 的要求。

7.13 质量比功率试验

按照 GB/T 24554—2022 8.10 中规定的试验方法进行测试, 试验结果应满足 6.12 的要求。

7.14 振动试验

按照 GB/T 28046.3—2011 中条款 4.1.2.7 测试标准规定进行振动试验, 按 Z、Y、X 方向每个方向 32h, 试验结果应满足 6.13 的要求。

7.15 防水防尘试验

按照 GB/T 4208—2017 规定的试验方法进行，试验结果应满足 6.14 的要求。

7.16 非金属材料阻燃试验

按照 GB/T 2408—2021 规定的水平法和垂直法进行非金属材料的燃烧特性试验，试验结果应满足 6.15 的要求。

8 标志、包装、贮存、文件

8.1 标志

8.1.1 产品标志

在燃料电池发动机的适当位置上，应有可靠固定的标志：

- a) 产品铭牌的内容、外观、性能等应符合 GB/T 18411—2018 的规定；
- b) 铭牌上的内容应至少包括燃料电池发动机的额定功率、输出电压、输出电流、环境温度、防护等级及出厂编号，且具有可追溯性；
- c) 安全标志应符合 GB/T 2893.2—2020 的规定。

8.1.2 氢气接口标志

燃料电池发动机应明确标示系统中氢气的入口和出口。

8.1.3 极性标志

若燃料电池发动机电气接头有极性之分，应予以标明。

8.1.4 B 级电压线缆标志

B 级电压电路中电缆和线束的外皮应用橙色加以区别。

8.1.5 接地标志

接地点应有明显的接地标志，接地标志依据 GB/T 4026—2019 中“保护接地”⊕图形符号，必要时用字母符号“PE”标志。

注：这些标志不应放在螺栓、可拆卸的垫圈或用作连接导线的可能拆卸的零部件上。

8.1.6 禁止蹬踏标志

对于发动机安装后可能被人员蹬踏但自身不具备安全蹬踏条件的零部件，应具有禁止蹬踏标识，标识应满足 GB/T 2894—2008 中要求，标识应粘贴在醒目位置。如图 2 所示，标识下方应增加文字辅助信息，具体要求应满足 GB/T 2894—2008 中 4.5 要求。



图 2 禁止蹬踏标志

8.1.7 警示标志

存在危险的燃料电池发动机部位应使用警示标志,包括但不限于:

- a) 触电危险;
- b) 高温,见图3;
- c) 易燃气体;
- d) 腐蚀和有毒介质;
- e) 高压气体,见图4。



图3 当心高温表面标志



图4 高压警告标志

8.1.8 包装标志

燃料电池发动机包装上应有标志并符合 GB/T 191—2008 的规定。

8.2 包装

燃料电池发动机包装应满足下列要求:

- a) 防潮、防振、防污染,无氨气、硫化物、挥发性有机气体产生;
- b) 确保固定良好,并保留合适的间隙;
- c) 在箱体上标注包装储运图示标志。

8.3 贮存

8.3.1 常温贮存

常温贮存时应满足下列要求:

- a) 应将所有产品对外的管路接口用硅胶帽或胶带密封上,防止灰尘、异物进入系统以及燃料电池内部,堵塞管路和燃料电池的流道;
- b) 应将产品对外的接插件接口,有胶带封住,防止灰尘、异物进入接插件内部,降低绝缘阻值或导致两个插针间短路;
- c) 应将产品对外连接线束的端头,用绝缘胶布缠上,防止两根线束间短接或与其他外供电设备的线束搭接,造成不必要的危害。

8.3.2 低温贮存

低温贮存时应满足下列要求：

- a) 若产品为干堆状态，则可以直接存放，且最低存放温度可达-40℃；
- b) 若产品为湿堆状态，则需要对其进行冷吹扫，具体操作如下：
 - 1) 为产品供应氢气/氮气；
 - 2) 为产品空气安装简易空滤模块；
 - 3) 连接产品上的 24V 以及高压供电接插件和控制接插件；
 - 4) 执行冷吹扫控制命令，至该过程完成；
 - 5) 以上步骤完成后执行低温存储。

8.4 文件

燃料电池发动机出厂时应至少提供以下文件：

- a) 产品合格证；
- b) 产品说明书；
- c) 产品安装手册；
- d) 装箱清单。

附录 A
(规范性)
常见的计算公式

A.1 燃料电池发动机功率

燃料电池发动机功率按公式 (A.1) 计算:

$$P_F = U_F I_F / 1000 \dots\dots\dots (A.1)$$

式中:

P_F ——燃料电池发动机的功率, 单位千瓦 kW;

U_F ——燃料电池发动机的电压, 单位伏特 V;

I_F ——燃料电池发动机的电流, 单位安培 A。

附录 B
(规范性)
动态平均功率试验数据处理

B.1 燃料电池发动机实际氢气消耗量

氢气消耗量的测量方法按照 GB/T 35178 规定的方法。如果氢气以流量单位记录结果，则燃料电池发动机功率在某段时间内的实测氢气消耗量按公式 (B.1) 计算：

$$M_{H_2} = \int_{T_1}^{T_2} m_{H_2} dt \dots\dots\dots(B.1)$$

式中：

- M_{H_2} —燃料电池发动机功率实测氢气消耗量，单位为克 (g)；
- m_{H_2} —燃料电池发动机功率实测氢气流量，单位为克每秒 (g/s)；
- T_1 —起始时间，单位为秒 (s)；
- T_2 —结束时间，单位为秒 (s)；

B.2 燃料电池发动机能量

燃料电池发动机的能量按公式 (B.2) 计算：

$$Q_F = \int_{T_1}^{T_2} P_F dt \dots\dots\dots(B.2)$$

式中：

- Q_F —某段时间内燃料电池发动机能量，单位为千焦 (kJ)；
- P_F —燃料电池堆的功率，单位为千瓦 (kW)。

B.3 燃料电池发动机动态平均效率

燃料电池发动机动态平均效率按公式 (B.3) 计算：

$$\eta_{FD} = \frac{1000Q_F}{M_{H_2}LHV_{H_2}} \times 100\% \dots\dots\dots(B.3)$$

式中：

- Q_F —某段时间内燃料电池发动机能量，单位为千焦 (kJ)；
- M_{H_2} —燃料电池发动机功率实测氢气消耗量，单位为克 (g)；
- LHV_{H_2} —氢气低热值， 1.2×10^5 kJ/kg；
- η_{FD} —燃料电池发动机动态平均效率。

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Preface

This document is drafted in accordance with the provisions of GB/T 1.1-2020 Guidelines for Standardized Work Part 1: Structure and Drafting Rules for Standardized Documents.

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Technical specification of fuel cell engines for commercial vehicle

1 Scope

This document specifies the system boundary, general requirements, performance requirements, test methods and marking, packaging, storage and documentation of fuel cell engines for commercial vehicles.

This document applies to proton exchange membrane fuel cell engines loaded on commercial vehicles, and other types of vehicles can refer to the implementation.

2 Normative references

The contents of the following documents constitute indispensable provisions of this document through normative references in the text. Where a document is cited with a date, only the version corresponding to that date applies to this document; where a document is cited without a date, the latest version (including all change orders) applies to this document.

GB/T 191—2008 Packaging, Storage and Transportation Graphic Marking

GB/T 1859.4-2017 Reciprocating internal combustion engines Determination of sound power level by sound pressure method Part 4: Simple method using standard sound sources

GB/T 2408-2021 Plastics Determination of flammability properties Horizontal and vertical methods

GB/T 2893.2-2020 Graphical symbols Safety colors and safety signs Part 2: Design principles for product safety labels

GB/T 2894-2008 Safety signs and guidelines for their use

GB/T 3836.1-2021 Explosive environment Part 1: General requirements for equipment

GB/T 4026-2019 Basic and safety rules for marking and labeling of man-machine interface Marking of equipment terminals, conductor terminals and conductors

GB/T 4208-2017 Enclosure protection level (IP code)

GB/T 8170-2008 Numerical modification rules and limit value representation and determination

GB/T 16935.1-2008 Insulation fit of equipment within low voltage systems Part 1: Principles, requirements and tests

GB/T 17045-2020 General part of electric shock protection devices and equipment

GB 18384-2020 Safety requirements for electric vehicles

GB/T 18411-2018 Motor vehicle product labeling

GB/T 20042.1-2017 Proton exchange membrane fuel cell Part 1: Terminology

GB/T 24548-2009 Fuel cell electric vehicles Terminology

GB/T 24554-2022 Test methods for fuel cell engine performance

GB/T 25319-2010 Fuel cell power generation system for automobile Technical conditions

GB/T 28046.3-2011 Road vehicles Environmental conditions and tests for electrical and electronic equipment Part 3: Mechanical loads

GB/T 35178-2017 Fuel cell electric vehicles Hydrogen consumption Measurement method

GB/T 37154-2018 Fuel cell electric vehicles Hydrogen emission test methods for the whole vehicle

3 Terminology and definitions

The following terms and definitions stipulated in GB/T 20042.1-2017, GB/T 24548-2009 and GB/T 25319-2009 are applicable to this document.

3.1

work conditions

The operating state of the fuel cell engine to calibrate the working conditions in terms of net output power.

[Source:GB/T 25319—2010, 3.1.1, modified]

3.2

rated conditions

Used by manufacturers to calibrate fuel cell engines to operating conditions specified at 100% net output power.

[Source:GB/T 25319—2010, 3.1.2, modified]

3.3

idle conditions

The fuel cell engine is in working condition and can sustain itself but does not output power to the outside world.

[Source:GB/T 25319—2010, 3.1.3, modified]

3.4

rated power

The effective net output power of the fuel cell engine at rated operating conditions, and the ability to work stably and continuously at this power.

[Source:GB/T 25319—2010, 3.1.5, modified]

3.5

peak power

The maximum power produced by a fuel cell engine in an agreed upon short period of time that is not less than the rated power.

[Source:GB/T 20042.1—2017, 3.2.21, modified]

3.6

minimum power

The minimum net output power (DCDC front end) that can be delivered by a fuel cell engine in operating condition, minus the consumption used to maintain its own auxiliary systems.

[Source:GB/T 20042.1—2017, 3.2.20, modified]

3.7

specific power

The ratio of the rated power of a fuel cell engine to its mass in kW/kg.

Note: Mass specific power is often referred to as specific power.

[Source:GB/T 20042.1—2017, 3.2.26, modified]

3.8

fuel consumption

The amount of fuel consumed by a fuel cell engine in a specified time under certain working conditions, note: unit is kg/h.

[Source:GB/T 20042.1—2017, 3.3.3, modified]

3.9

hot state

A state in which the temperature of the fuel cell engine's constituent modules is within the normal operating temperature range.

[Source:GB/T 20042.1—2017, 5.2.3, modified]

3.10

cold state

A state in which the internal temperature of the fuel cell engine is the same as the ambient temperature with neither energy input nor energy output.

[Source:GB/T 20042.1—2017, 5.2.7, modified]

3.11

external gas leakage

Generation of gas leakage out of the fuel cell other than intentional exhaust.

[Source: : GB/T 20042.1—2017, 4.2.10]

NOTE: Gas leaks can occur from: fuel cell stacks, associated depressurizers, other gas lines and fluid control components.

3.12

fuel cell system

Including fuel cell stack and fuel cell auxiliary system, it can work normally under the condition of external hydrogen source.

[Source:GB/T 24548—2009, 3.4.3]

4 System boundaries

The boundary of the fuel cell engine system is shown in Fig. 1, in which the part in the dotted line box is the fuel cell engine, and the internal part contains the fuel cell module, the hydrogen supply system, the air supply system, and the thermal management system, and the in and out arrows in the relative boxes in the figure refer to the input and output of the fuel cell engine.

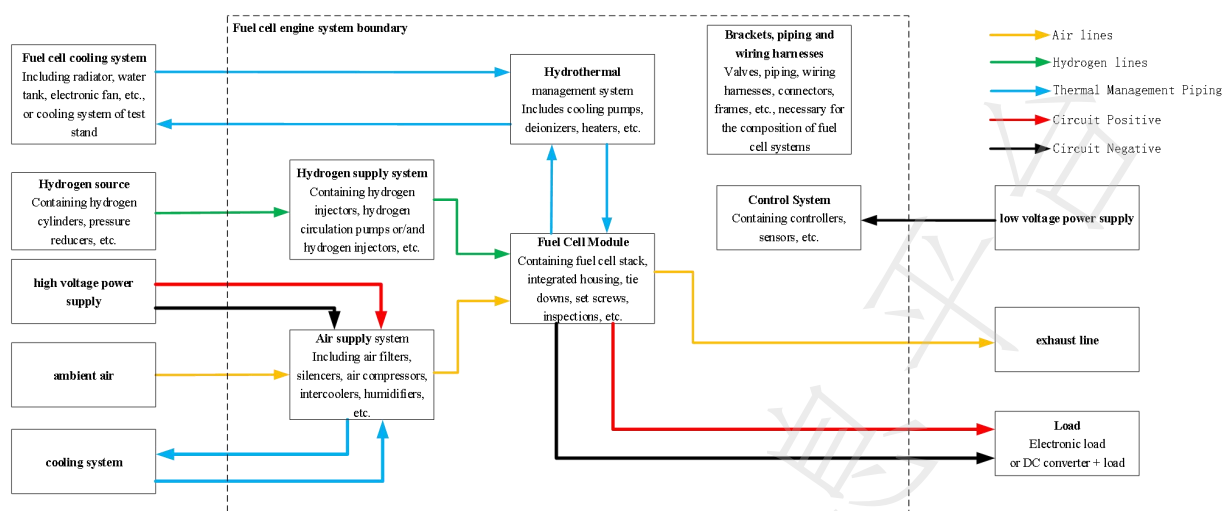


Fig. 1 Fuel cell engine system boundary

5 General requirements

5.1 Exterior structural requirements

5.1.1 The exterior of fuel cell engines should be clean, free of mechanical damage, cracks, stains and obvious deformation, and the interface contacts should be free of corrosion.

5.1.2 The accessible parts of the fuel cell engine should not have sharp edges and corners that may cause personal injury.

5.1.3 During the normal operation of the fuel cell engine, its parts and their connectors should be stable and reliable, and there should be no instability, deformation, fracture or wear and tear.

5.1.4 The communication interface, power interface, user interface, hydrogen import and export of the fuel cell engine should be clearly labeled.

5.1.5 The positive and negative terminals and polarity of the fuel cell engine should be clearly marked for easy connection.

5.2 General safety requirements

5.2.1 The hydrogen circuit of fuel cell engine should be equipped with a safety pressure relief device, and the safety pressure relief device should be ensured to work normally even in the state of power failure.

5.2.2 The fuel cell engine fuel supply line shall not pass through the passenger compartment.

5.2.3 The vent set up for fuel cell engine discharge fuel should be straight to the outside of the commercial vehicle and have safety protection measures.

5.2.4 When the fuel cell engine is installed in an enclosed or semi-enclosed space, a hydrogen leakage detector should be installed above the space or above the fuel cell engine; when the detector monitors the leakage, the control system should be able to automatically cut off the fuel supply.

5.2.5 The high-voltage warning marking and Class B voltage wire marking on the fuel cell engine shall meet the requirements of 5.1.2 in GB 18384-2020.

5.2.6 The direct contact protection requirements for fuel cell engines shall meet the requirements of 5.1.3 of GB 18384-2020.

5.2.7 Potential equalization requirements for fuel cell engines shall meet the requirements of 5.1.4.3 of GB 18384-2020.

5.2.8 5.2.8 The materials and components as well as the structural design shall meet the explosion-proof safety requirements for Class II equipment in GB/T 3836.1-2021.

5.2.9 The electrical clearance and creepage distance of the fuel cell engine shall meet the requirements of GB/T 16935.1-2008.

5.2.10 All electrical devices, systems or equipment of fuel cell engines shall be in accordance with the provisions of Class I equipment in GB/T 17045-2020.

5.2.11 Plastic or rubber materials used to transport hydrogen medium should be conductive, or designed to do to avoid static charge accumulation.

6 Performance requirements

6.1 Starting characteristics

6.1.1 Normal temperature starting characteristics

6.1.1.1 Cold Start Characteristics at Ambient Idle Speed

The test is carried out in accordance with 7.2.1.1, which requires that the time from cold condition to idle, shall be less than 15s.

6.1.1.2 Room temperature idle hot start characteristics

The test is carried out in accordance with 7.2.1.2, which requires a warm-up condition to idle speed, and the time shall be ≤ 10 s.

6.1.2 Low Temperature Rated Power Cold Start Characteristics

Tests are conducted in accordance with 7.2.2, requiring that the system can be started normally, the length of time to start to rated power does not exceed 4min, the power consumption of components during startup should meet the design requirements, and the system has no shutdown or load shedding faults.

6.2 Rated power

6.2.1 Plain power ratings

Tests in accordance with 7.3.1 require that the output power of the fuel cell engine during the effective measurement period shall always be 97% to 103% of the average value of the operating power for 60 min of the effective measurement period.

6.2.2 Plateau ratings

Tests in accordance with 7.3.2 shall meet the following requirements:

- a) At an altitude of 1000m, 100% of the rated power output shall be met;
- b) At an altitude of 2000m, the rated power derating shall be no more than 15%;
- c) At an altitude of 3000m, it shall meet the rated power derating of not more than 30%.

6.3 Peak power

Perform the test in accordance with 7.4, requiring that the maximum power is not less than the rated

power.

6.4 Dynamic Response Characterization

Test in accordance with 7.5, requiring that the loading time from the minimum power point to the rated state shall be ≤ 12 s, and the unloading time from the rated state to the minimum power point shall be ≤ 8 s.

6.5 Steady-state properties

When the fuel cell engine is tested according to 7.6, the polarization characteristic curve (V-I curve) of the fuel cell stack, the power curve of the fuel cell stack, the efficiency curve of the fuel cell stack, the power curve of the fuel cell engine, the efficiency curve of the fuel cell engine and the power curve of the auxiliary system shall be provided. It is required that the proportion of the operating interval in which the system efficiency is above 45% should be $\geq 60\%$, and the rated point efficiency should be $\geq 45\%$.

6.6 High temperature operating characteristics

Tests in accordance with 7.7 require that the output power of the fuel cell engine shall always be in the range of 95% to 105% of the average value of the operating power for 60 min of valid measurement time.

6.7 Dynamic average efficiency characterization test

Tests in accordance with 7.8 require that the system efficiency shall not be less than the system design requirement value and that the system does not have an off-line or load shedding fault during the test.

6.8 Hydrogen emission requirements

Tests in accordance with 7.9 require that the average hydrogen volume concentration of hydrogen emissions from a fuel cell engine at idle or at the lowest power point of the fuel cell engine shall not exceed 3% for any consecutive 3s period in the warm-up state, and that the instantaneous hydrogen volume concentration shall not exceed 8%.

6.9 Noise

Fuel cell engine body noise test is carried out in accordance with 7.10, the maximum value of the noise of the system is recorded, and it is required that the noise of idling condition should be ≤ 75 dB, and the noise of rated condition should be ≤ 80 dB.

6.10 Airtightness requirements

When the hydrogen circuit of the fuel cell engine is subjected to gas holding pressure test according to 7.11, the pressure drop value of the hydrogen circuit shall simultaneously meet the requirements of the following regulations.

- a) Nitrogen medium, holding pressure for 20 minutes, the pressure drop value ≤ 12 kPa.
- b) Hydrogen medium, holding pressure for 30 seconds, pressure drop ≤ 14 kPa.
- c) Fuel cell engine in various operating conditions during operation, hydrogen circuit of hydrogen leakage concentration $\leq 0.005\%$ at all connection points.

6.11 Insulation resistance

The insulation test of the fuel cell engine is carried out in accordance with 7.12, and the required insulation resistance value shall meet the insulation resistance $> 1000 \Omega/V$.

6.12 Mass Specific Power

The test is conducted in accordance with 7.13, and the required mass specific power shall meet the system design objective and shall not be less than 550W/kg.

6.13 Vibration performance

Conduct the test in accordance with 7.14, and require that after the completion of the test, the fuel cell engine maintains reliable connection, intact structure, no obvious deformation, and the fuel cell engine can work normally.

6.14 Waterproof and dustproof

Components in the fuel cell engine that need to have waterproof and dustproof capability shall be tested in accordance with the requirements of 7.15, and the test results shall meet the requirements of IP67 and above in GB/T 4208-2017.

6.15 Flame retardant requirements for non-metallic materials

The non-metallic materials on the fuel cell engine shall use flame retardant materials, and the combustion characteristics of the non-metallic materials except the battery stack shall be tested in accordance with 7.16, and the test results shall comply with the following provisions:

a) The materials of the parts meeting any of the following conditions shall meet the requirements of horizontal combustion class HB and vertical combustion class V-0:

- 1) The weight of a single component is $\geq 50\text{g}$;
- 2) The total weight of parts of the same model in a single fuel cell engine $\geq 200\text{g}$.

b) The materials of other non-metallic parts should meet the requirements of horizontal combustion HB75 and vertical combustion V-2.

7 Test methods

7.1 General test conditions

7.1.1 Environmental conditions

Unless otherwise specified, the test shall be conducted in the following environment:

- a) A temperature of $23^{\circ}\text{C} \pm 5^{\circ}\text{C}$;
- b) Relative humidity of 15% to 90%;
- c) Atmospheric pressure of 86kPa to 106kPa.

Note: References to room temperature in this document are to $23^{\circ}\text{C} \pm 5^{\circ}\text{C}$.

7.1.2 Test instrument requirements

7.1.2.1 Accuracy of measuring instruments

Unless otherwise specified, there is no restriction on the range of the measuring instrument, and the precision accuracy of the measuring instrument shall meet the following requirements:

- a) Voltage test device: ≥ 0.5 grade;
- b) Current test device: ≥ 0.5 grade;
- c) Temperature test device: $\pm 0.5^{\circ}\text{C}$;

- d) Time measurement device: $\pm 0.1\%$;
- e) Dimension measuring device: $\pm 0.1\%$;
- f) Mass measuring device: $\pm 0.1\%$;
- g) Conductivity testing device: accuracy $\leq \pm 5\%$;
- h) Hydrogen leak detector: accuracy $\geq \pm 5\%$ FS, range not less than $0\% \sim 10\%$.

7.1.2.2 Control accuracy of control instruments

The control accuracy of the control instrument shall meet the following requirements:

- a) Voltage: $\pm 1\%$;
- b) Current: $\pm 1\%$;
- c) Temperature: $\pm 1^\circ\text{C}$.

7.1.2.3 Test data acquisition instrument requirements

During the test, the data acquisition frequency meter loading error shall meet the following requirements:

- a) The test data acquisition frequency shall not be lower than 5Hz;
- b) In the calculation of power, efficiency and other parameters, it shall be trimmed to 2 decimal places according to GB/T 8170-2008, except for special instructions.

7.1.3 Test pre-processing

7.1.3.1 Ambient immersion methods

The requirements for ambient immersion are as follows:

- a) Before immersion, complete the process of switching on and off the fuel cell engine once and turn off the fuel cell engine;
- b) The fuel cell engine (with coolant filling completed) shall be left to stand at room temperature under ambient conditions for a period of not less than 12h;
- c) During the immersion period, no changes shall be made to the fuel cell engine.

7.1.3.2 Low temperature (below 0°C) immersion method

For the fuel cell engine low temperature cold start test, the radiator or heat exchanger used for the fuel cell engine shall be placed in an environmental chamber. The specific requirements are as follows:

- a) During the immersion process, before the set temperature is reached, an on/off operation may be performed after the environmental compartment has been lowered to the manufacturer's specified temperature and has lasted for a certain period of time (determined by the manufacturer according to the technical requirements of the product);
- b) The fuel cell engine shall be started to idle (or the lowest power point of the fuel cell engine) for a duration (including starting) of not more than 3min;
- c) Then immediately turn off the fuel cell engine;
- d) When the ambient temperature reaches the set temperature, the timing shall start and the effective soaking time shall be not less than 12h.

Note 1: During the whole low temperature cold start and low temperature operation, the temperature of the ambient chamber is controlled at $\pm 2.0^\circ\text{C}$ of the set temperature and below 0°C .

Note 2: Effective immersion time means the time from the start of timing after the temperature of the environmental chamber reaches the set temperature to the end of immersion.

7.1.3.3 High temperature (below 50°C) immersion method

The requirements for high temperature immersion are as follows:

- a) Before immersion, complete a fuel cell engine switching process and turn off the fuel cell engine;
- b) The radiator or heat exchanger used for the fuel cell engine shall be placed in the environmental chamber during the fuel cell engine high temperature operational test;
- c) The temperature of the environmental chamber shall be set to 50.0°C and the relative humidity shall be set to 40% to 90%, and timing shall start when the ambient temperature reaches the set temperature, and the effective immersion time shall be not less than 2h.

Note 1: During the whole high-temperature immersion and high-temperature operation, the temperature of the environmental chamber is controlled within $\pm 2.0^{\circ}\text{C}$ of the set temperature.

Note 2: Effective immersion time means the time from the start of timing after the temperature of the environmental chamber reaches the set temperature to the end of immersion.

7.1.3.4 Warm-up method

In accordance with the manufacturer's operating regulations, operate the fuel cell engine at a certain power while checking the outlet temperature of the fuel cell engine coolant. When the outlet temperature of the fuel cell engine coolant reaches the normal operating temperature (which is specified by the manufacturer), the fuel cell engine is considered to have reached the warm-up state.

7.2 Starting characteristic test

7.2.1 Normal temperature starting characteristic test

7.2.1.1 Cold Start Characteristics at Ambient Idle Speed

The test shall be conducted in accordance with the test method specified in 8.1.1.1 of GB/T 24554-2022, and the fuel cell engine shall be at room temperature before the test, and the immersion treatment shall be conducted in accordance with the immersion method of 7.1.3.1. The test process shall be carried out automatically without manual intervention. The test results shall meet the requirements of 6.1.1.1.

7.2.1.2 Room temperature idling hot start characteristics

The test shall be conducted in accordance with the test method stipulated in 8.1.1.2 of GB/T 24554-2022. Before the test, the fuel cell engine shall be at ambient temperature, and the engine shall be immersed in accordance with the immersion method in 7.1.3.4. The test process shall be carried out automatically without human intervention. The test results shall meet the requirements of 6.1.1.2.

7.2.1.3 Low temperature rated power cold start characteristics

The test shall be conducted in accordance with the test method stipulated in 8.1.2.2 of GB/T 24554-2022, and the fuel cell engine shall be at ambient temperature before the test, and the immersion treatment shall be carried out in accordance with the immersion method of 7.1.3.2 (ambient compartment temperature $\leq -35^{\circ}\text{C}$). The test process shall be carried out automatically without manual intervention. The test results shall meet the requirements of 6.1.2.

7.3 Rated power test

7.3.1 Plain rated power test

Conduct the test in accordance with the test method specified in 8.2 of GB/T 24554-2022, and the power calculation method is shown in Appendix A. The state of the fuel cell engine is warmed up before the test, and the test process shall be carried out automatically without artificial intervention. The test results shall meet the requirements of 6.2.1.

7.3.2 Plateau rated power test

Select the field or use the environmental chamber to simulate the air pressure conditions at high altitude, the state of the fuel cell engine before the test is the warm-up state, and the test process shall be carried out automatically without manual intervention. Under each working condition, such as idling, partially loaded, rated working condition, overloaded working condition, etc., the following are measured separately:

- a) Fuel consumption;
- b) The output current and voltage of the battery stack, and the net output current and voltage of the fuel cell engine;
- c) Measure the power consumption of the auxiliary support operating system;
- d) Recording of intake air temperature, intake air pressure, cooling water temperature, ambient temperature and humidity;

At rated operating conditions and overload conditions, record the course of fuel cell engine output current and voltage over time, the power calculation method is shown in Appendix A, and the test results shall meet the requirements of 6.2.2.

Note: The fuel cell engine runs stably for 1h under rated working condition and 60s under overloaded working condition.

7.4 Peak power test

Conduct the test in accordance with the test method specified in item 8.3 of GB/T 24554-2022, the state of the fuel cell engine before the test is the warm-up state, and the test process shall be carried out automatically without artificial intervention. The test results shall meet the requirements of 6.3.

7.5 Dynamic response test

The test shall be conducted in accordance with the test method specified in item 8.4 of GB/T 24554-2022, and the test results shall meet the requirements of 6.4.

7.6 Steady state characteristic test

Conduct the test in accordance with the test method specified in item 8.5 of GB/T 24554-2022, and the test results shall meet the requirements of 6.5.

7.7 High temperature characteristic test

Conduct the test in accordance with the test method stipulated in item 8.6 of GB/T 24554-2022, with the fuel cell engine in the environment chamber before the test, set the temperature of the environment chamber at 50.0°C, and conduct the immersion treatment in accordance with the immersion method of 7.1.3.3. The test process shall be carried out automatically without human intervention. The test results shall meet the requirements of 6.6.

7.8 Dynamic average efficiency characteristic test

Conducted in accordance with the test method specified in item 8.7 of GB/T 24554-2022, see Appendix B

for specific calculations, and the test results shall meet the requirements of 6.7.

7.9 Hydrogen emission test

The hydrogen emission test is conducted in accordance with 6.1 of GB/T 37154-2018, and the specific test steps are as follows:

- a) The continuous running time at idle speed is 10min;
- b) Then run continuously at 10%~90% rated power points in sequence, and the continuous running time of each power point is 10min;
- c) Continuously record the hydrogen concentration during idling and continuous operation at each power point.

The test results shall meet the requirements of 6.8.

7.10 Noise test

Conduct the noise test in accordance with the noise test method specified in GB/T 1859.4-2017, and the test results shall meet the requirements of 6.9.

7.11 Air tightness test

The gas tightness test steps are as follows:

- a) Close the fuel cell engine exhaust and drain valves and other switches connected to the outside;
- b) Fill the hydrogen circuit of the fuel cell engine with inert gas such as hydrogen or nitrogen, and set the pressure at 50kPa;
- c) Close the inlet valve immediately after the pressure is stabilized;
- d) Hold pressure and record the pressure value in real time, and then calculate the pressure drop value.

The test results shall meet the requirements of 6.10.

7.12 Insulation (static) test

Test in accordance with the test methods specified in GB/T 24554-2022 8.9, and the test results shall meet the requirements of 6.11.

7.13 Mass ratio power test

Test in accordance with the test methods specified in GB/T 24554-2022 8.10, and the test results shall meet the requirements of 6.12.

7.14 Vibration test

Conduct the vibration test in accordance with the provisions of clause 4.1.2.7 of GB/T 28046.3-2011 test standards, according to the Z, Y, X direction of each direction 32h, the test results shall meet the requirements of 6.13.

7.15 Waterproof and dustproof test

Conduct the test according to the test methods specified in GB/T 4208-2017, and the test results shall meet the requirements of 6.14.

7.16 Flame retardant test for non-metallic materials

Conduct the test of combustion characteristics of non-metallic materials in accordance with the horizontal

and vertical methods specified in GB/T 2408-2021, and the test results shall meet the requirements of 6.15.

8 Marking, Packaging, Storage, Documentation

8.1 Signs

8.1.1.1 Product marking

On the appropriate position of the fuel cell engine, there shall be a reliably fixed sign:.

a) The content, appearance and performance of the product nameplate shall comply with the provisions of GB/T 18411-2018;

b) The contents on the nameplate shall at least include the rated power, output voltage, output current, ambient temperature, protection level and factory number of the fuel cell engine with traceability;

c) The safety marking shall comply with the provisions of GB/T 2893.2-2020.

8.1.1.2 Hydrogen interface marking

The fuel cell engine shall clearly mark the inlet and outlet of hydrogen in the system.

8.1.1.3 Polarity marking

If the fuel cell engine electrical connectors have polarity, it should be marked.

8.1.1.4 Class B voltage cable marking

Class B voltage circuits in the cable and harness sheath should be distinguished by orange color.

8.1.1.5 Grounding mark

The grounding point should have obvious grounding symbols, which are based on the graphic symbol of "protective grounding" in GB/T 4026-2019, and the symbol "PE" is used if necessary.

Note: These symbols should not be placed on bolts, removable washers or parts that may be dismantled for use as connecting wires.

8.1.2 No-treading signs

For engine installation may be stomped on by personnel, but they do not have the safety of stomping on the parts of the conditions, should be prohibited to stomp on the logo, the logo should meet the requirements of GB/T 2894-2008, the logo should be affixed in a conspicuous position. As shown in Figure 2, the logo should increase the text below the auxiliary information, the specific requirements should meet the requirements of GB/T 2894-2008 in 4.5.



Figure 1 No Stomping Sign

8.1.3 Warning signs

Warning signs shall be utilized on fuel cell engine areas where hazards exist, including but not limited to.

- a) Electrical shock hazard;
- b) High temperatures, see Figure 3;
- c) Flammable gases;
- d) Corrosive and toxic media;
- e) gases under pressure, see Figure 4.



Figure 1 Beware of High Temperature Surface Markings



Figure 1 High voltage warning signs

8.1.4 Packaging symbols

Fuel cell engine packaging should be labeled and comply with the provisions of GB/T 191-2008.

8.2 Packaging

Fuel cell engine packaging should meet the following requirements:

- a) Moisture-proof, vibration-proof, pollution-proof, and free from ammonia, sulfide, and volatile organic gases;
- b) Ensure good fixation and retain suitable clearance;
- c) Labeling on the box with graphic symbols for packaging, storage and transportation.

8.3 Storage

8.3.1 Ambient storage

The following requirements shall be met when storing at room temperature:

- a) All external piping interfaces of the product should be sealed with silicone caps or tapes to prevent dust and foreign matter from entering the system and inside the fuel cell and blocking the piping and the flow path of the fuel cell;
- b) The external connector interface of the product should be sealed with adhesive tape to prevent dust and foreign matter from entering the inside of the connector, which will reduce the insulation resistance value or lead to a short circuit between the two pins;
- c) The product should be externally connected to the end of the wire harness, wrapped with insulating tape to prevent shorting between the two harnesses or lapping with other external power supply equipment, resulting in unnecessary hazards.

8.3.2 Low temperature storage

The following requirements shall be met for low temperature storage:

- a) If the product is dry stacked, it can be stored directly and the minimum storage temperature can be up to -40°C ;
- b) If the product is in wet stacks, it needs to be cold purged as follows:
 - 1) Supply the product with hydrogen/nitrogen gas;
 - 2) Install a simple air filter module for the product air;
 - 3) Connect the 24V and high-voltage power and control connectors on the product;
 - 4) Execute the cold purge control command until the process is complete;
 - 5) Execute cryogenic storage after the above steps are completed.

8.4 Documentation

Fuel cell engines shall be shipped with at least the following documentation.

- a) Certificate of Product Conformity;
- b) Product instruction manual;
- c) Product installation manual;
- d) Packing list.

APPENDIX A
(Normative)
Common Calculation Formulas

A.1 Fuel Cell Engine Power

Fuel cell engine power is calculated according to formula (A.1):

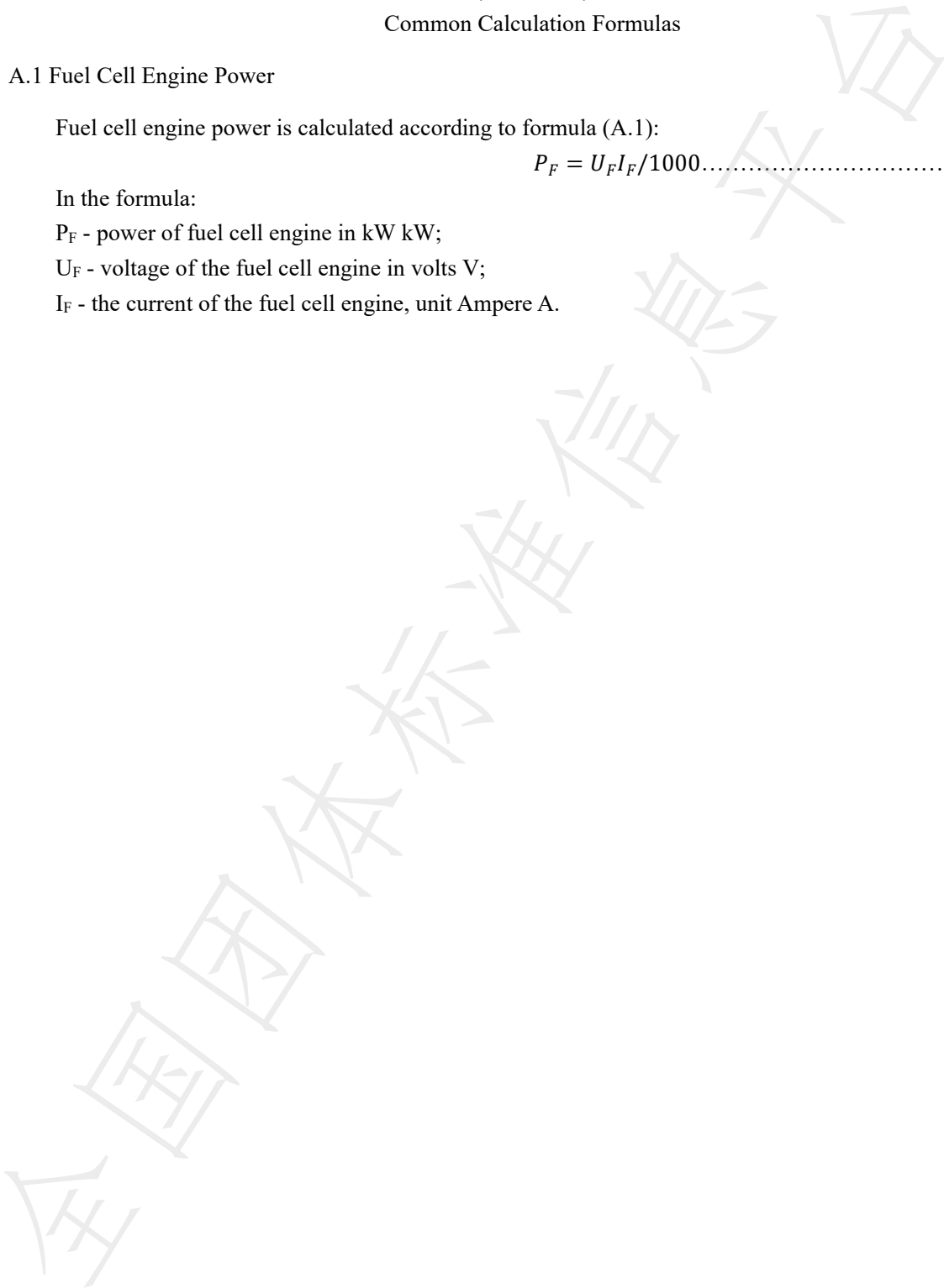
$$P_F = U_F I_F / 1000 \dots \dots \dots (A.1)$$

In the formula:

P_F - power of fuel cell engine in kW kW;

U_F - voltage of the fuel cell engine in volts V;

I_F - the current of the fuel cell engine, unit Ampere A.



APPENDIX B

(Normative)

Dynamic Average Power Test Data Processing

B.1 Actual hydrogen consumption of fuel cell engine

Hydrogen consumption is measured according to the method specified in GB/T 35178. If hydrogen is recorded as a result in flow unit, the measured hydrogen consumption of fuel cell engine power during a certain period of time is calculated according to formula (B.1):

$$M_{H_2} = \int_{T_1}^{T_2} m_{H_2} dt \dots\dots\dots(B.1)$$

In the formula:

- M_{H_2} —measured hydrogen consumption of fuel cell engine power in grams (g);
- m_{H_2} —fuel cell engine power measured hydrogen flow in grams per second (g/s);
- T_1 —start time in seconds (s);
- T_2 —end time in seconds (s);

B.2 Fuel Cell Engine Energy

The fuel cell engine energy is calculated according to equation (B.2):

$$Q_F = \int_{T_1}^{T_2} P_F dt \dots\dots\dots(B.2)$$

In the formula:

- Q_F —Fuel cell engine energy in a certain period of time in kilojoules (kJ);
- P_F —Power of the fuel cell stack in kilowatts (kW).

B.3 Dynamic average efficiency of fuel cell engine

The fuel cell engine dynamic average efficiency is calculated according to equation (B.3):

$$\eta_{FD} = \frac{1000Q_F}{M_{H_2}LHV_{H_2}} \times 100\% \dots\dots\dots(B.3)$$

In the formula:

- Q_F —Energy of the fuel cell engine during a certain period of time in kilojoules (kJ);
 - M_{H_2} —measured hydrogen consumption of fuel cell engine power in grams (g);
 - LHV_{H_2} —low calorific value of hydrogen, 1.2×10^5 kJ/kg;
 - η_{FD} —dynamic average efficiency of fuel cell engine.
-