RWE Technology
International GmbH
Pembroke Green Hydrogen
03773-02-04

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Heat and Mass Balance Study

Revision List

Rev.	Date	Description of Change	Prepared by	Checked by	Released by
A	05/04	Draft	Hassan Al Halwachi	Gareth Edwards	Gareth Edwards
B	11/04	First Issue	Conor Wall	Gareth Edwards	Gareth Edwards
C	17/04	Updated Version	Matt Bell	Hassan Al Halwachi	Craig McCafferty

	HEAT & MASS BALANCE			Document No. 03773-02-04-0501-MFB040-0001	Rev. C
RWE	Client RWE Generation UK plc.	Project Pembroke Green Hydrogen I	Job No. 299919-00	Client Document No. 03773-02-04-0501-MFB040-0001	Rev. C

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RWE Generation UK plc.

Pembroke Green Hydrogen I

HEAT & MASS BALANCE

Rev

NOTES

1. This H&MB is to be read in conjunction with project PFDs (Ref. 4 - 11).
2. The following heat and material balance cases are provided:

Case No.	Description
1	Electrolyser Stack Start of Life
2	Electrolyser Stack End of Life

3. Operating conditions estimated based on experience with similar equipment.
4. Compressor trains are duty/standby (2x100%)
5. 6 Electrolyser stacks including 1 standby (6x20%)
6. Cooling water make-up and purge stream flowrates are reported on a time-average basis

ASSUMPTIONS

1. Start of Life cases assume negligible crossover of O_2 into the H_2 outlet stream.
2. End of Life cases assume 0.2 mol% O_2 in H_2 on dry basis at H_2 separator outlet to account for reduced electrolyser performance.
3. Stack lifetime of 9 years is assumed; this is based on 95% plant availability and an assumed stack lifetime of 80000 hours.
4. End of Life cases assume a 1% annual increase in power consumption per kg $H_{2\ (in\ product\ stream)}$ generated.
5. Oxygen vent stream (017) hydrogen content determined by H2:O2 molar ratio of 0.004:1 based on experience with similar equipment.
6. Electrolyser system consists of 6 electrolyser stacks, each rated at 20 MWe. 5 stacks maximum are assumed to be in operation
7. Electrolyte circulation rate set to limit stack operating temperature to 80°C
8. Water reject rate in the deionisation unit is 5%.
9. Electrolyser efficiency has been calculated using a total hydrogen production rate of 2000 kg/h (Ref [1]), electrolyser capacity of 100MWe (Ref. [2])
10. Cooling water inlet to the electrolyser temperature is 35°C.
11. Outlet temperature of air coolers in the hybrid cooling tower package is 32°C. This is based on a temperature approach of 5°C relative to the design ambient temperature of 27°C (Ref.[3]).
12. Demin water leaving the storage tanks is at ambient temperature (25°C assumed) and near atmospheric pressure (Ref. [2]); 0.1 barg used in the H&MB.
13. Pump efficiency is 75% adiabatic
14. Compressor efficiency is 75% adiabatic
15. Electrolyte is 25wt% KOH solution. Electrolyte flow is assumed to split equally between the stack electrodes.

C 16. Electrolyser operating pressure is 0.3 barg (Ref. [12])

HOLDS

1. H&MB to be confirmed following selection of electrolyser OEM.

REFERENCES

1. Email from Zoe Harrison (RWE Generation SE) to CM titled "Pembroke design basis" received on 28 March 2024
2. RWE Technology International, H2 Pembroke - Design Basis, , Rev 1.0, 31/01/2023
3. RWE Technology International, H2 Pembroke – General Requirements, Rev 0.1, 22/06/2022,

C 4. 03773-02-04-0501-MFB020-0001-Rev B - Process Flow Diagram - Hydrogen Generation
C 5. 03773-02-04-0501-MFB020-0002-Rev B - Process Flow Diagram - Hydrogen Compression
C 6. 03773-02-04-0501-MFB020-0003-Rev B - Process Flow Diagram - Hydrogen Purification and Drying
C 7. 03773-02-04-0501-MFB020-0004-Rev B - Process Flow Diagram - Hydrogen Buffer Storage
C 8. 03773-02-04-0501-MFB020-0005-Rev B - Process Flow Diagram - Hydrogen Metering and Export
C 9. 03773-02-04-0501-MFB020-0006-Rev B - Process Flow Diagram - Demineralised Water Supply
C 10. 03773-02-04-0501-MFB020-0007-Rev B - Process Flow Diagram - Closed-Loop Cooling Water System
C 11. 03773-02-04-0501-MFB020-0008-Rev B - Process Flow Diagram - Main Cooling Water System
12. Email from Tom Riley (RWE Generation SE) to MB, HAH titled "Pembroke 1 H&M Balance Update" received on 9 April 2024

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Case No: Case 1, Sheet 1 | Case Description: Electrolyser Stack Start of Life

Rev.	Stream Name	Units	001	002	003	004	005	006	007	008	009	010	011	012	013	014
	Description	-	Demin Water From Existing Demin Water Storage Tank	Demin Water to Demin Water Treatment Package PK-601-001	Demin Water from Demin Water Treatment Package PK-601-001	Reject Water from Demin Water Treatment Package PK-601-001	Ultra Pure Demin Water to Electrolyser Modules 01-06	Ultra Pure Demin Water to Hydrogen Gas Scrubber V-101-003	Water & recovered electrolyte from Hydrogen Gas Scrubber V-101-003	Electrolyte from Hydrogen Gas Separator V-101-001	Combined Electrolyte from Hydrogen Scrubber V-101-003 & Hydrogen Separator V-101-001	Electrolyte from Oxygen Separator V-101-002	Electrolyte to Electrolyser Feed Pump P-101-001	Electrolyte to Electrolyser Feed Heat Exchanger E-101-001	Electrolyte to Electrolyser Stack X-101-001	Raw Hydrogen to Hydrogen Separator V-101-001
C	Overall Vapour Fraction	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12
C	Overall Temperature	°C	25.0	25.0	25.8	25.8	25.8	25.8	40.0	80.0	73.8	80.0	76.2	76.2	50.0	80.0
C	Overall Pressure	barg	0.10	5.00	1.00	1.00	3.00	3.00	0.30	0.30	0.30	0.30	0.30	1.30	0.80	0.30
C	Overall Actual Volume Flow	Am^3/hr	24.3	24.3	24.2	1.3	24.2	4.8	6.7	41.9	48.6	30.5	79.1	79.1	78.1	6602.4
C	Overall Mass Flow	kg/h	24261	24261	24144	1271	24144	4829	6650	46733	53383	34008	87393	87393	87393	49171
C	Overall Mass Density	kg/m^3	997.06	997.27	996.89	996.89	996.98	996.98	995.97	1115.71	1099.37	1113.59	1104.88	1104.91	1119.39	7.45
C	Overall Molecular Weight	-	18.02	18.02	18.02	18.02	18.02	18.02	18.02	22.12	21.51	22.05	21.72	21.72	21.72	20.28
C	Vapour Mass Flow	kg/h	-	-	-	-	-	-	-	-	-	-	-	-	-	2110.5
C	Vapour Actual Volume Flow	m^3/h	-	-	-	-	-	-	-	-	-	-	-	-	-	6560.1
C	Vapour Mass Density	kg/m^3	-	-	-	-	-	-	-	-	-	-	-	-	-	0.32
C	Vapour Mass Heat Capacity	kJ/kg-C	-	-	-	-	-	-	-	-	-	-	-	-	-	4.27
C	Vapour Compressibility	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00
C	Vapour Molecular Weight	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.19
C	Aqueous Mass Flow	kg/h	24261	24261	24144	1271	24144	4829	6650	46733	53383	34008	87393	87393	87393	47060
C	Aqueous Actual Volume Flow	m^3/h	24.33	24.33	24.22	1.27	24.22	4.84	6.68	41.89	48.56	30.54	79.10	79.10	78.07	42.22
C	Aqueous Mass Density	kg/m^3	997	997	997	997	997	997	996	1116	1099	1114	1105	1105	1119	1115
C	Aqueous Mass Heat Capacity	kJ/kg °C	4.18	4.18	4.18	4.18	4.18	4.18	4.18	3.24	3.36	3.26	3.32	3.32	3.30	3.25
C	Aqueous Molecular Weight	-	18.02	18.02	18.02	18.02	18.02	18.02	18.02	22.12	21.51	22.05	21.72	21.72	21.72	22.08
		Component														
C	Overall Component Molar Fraction	H_2O	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.892	0.908	0.894	0.903	0.903	0.903	0.824
C	Overall Component Molar Fraction	H_2	-	-	-	-	-	-	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.082
C	Overall Component Molar Fraction	O_2	-	-	-	-	-	-	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C	Overall Component Molar Fraction	Ethylene Glycol	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C	Overall Component Molar Fraction	KOH	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.108	0.092	0.106	0.097	0.097	0.097	0.094

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Case No: Case 1, Sheet 2 — Case Description: Electrolyser Stack Start of Life

Rev.	Stream Name	Units	015	016	017	017B	018	019	020	021	021B	022	023	024	025	026
	Description	-	Raw Hydrogen from Hydrogen Gas Scrubber V-101-003	Oxygen / Electrolyte to Separator V-101-002	Oxygen from Electrolyser Module 01 to Vent	Oxygen from Electrolyser Modules 01-06 to Vent	Raw Hydrogen to Hydrogen Compressor K-201/2-001	Raw Hydrogen to Hydrogen Compressor K-201-001	Hydrogen from Hydrogen Compressor K-201-001	Water from Hydrogen Compressor K-201-001 KO Drums	Water from Hydrogen Compressor K-201/2-001 KO Drums	Hydrogen to Deoxo-Dryer Modules 01-02	Hydrogen to Deoxidiser Reactor R-301-001	Hydrogen to Deoxidiser Reactor Cooler E-301-001	Hydrogen to Hydrogen Water Separator V-301-001	Hydrogen to Hydrogen Dryer V-301-002A/B
C	Overall Vapour Fraction	-	1.00	0.08	1.00	1.00	1.00	1.00	1.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00
C	Overall Temperature	°C	40.0	80.0	80.0	80.0	40.0	40.0	40.0	39.2	39.2	40.0	40.0	40.0	40.0	40.0
C	Overall Pressure	barg	0.30	0.30	0.30	0.30	0.30	0.30	18.50	0.90	0.80	18.50	18.50	18.00	17.50	17.50
C	Overall Actual Volume Flow	Am3/hr	4177.3	3238.2	3497.1	17485.3	20886.4	20886.4	1341.4	1.0	1.0	1341.4	1341.4	1376.5	1413.5	1413.5
C	Overall Mass Flow	kg/h	616	38222	4213	21063	3080	3080	2081	1000	1000	2081	2081	2081	2081	2081
C	Overall Mass Density	kg/m^3	0.15	11.80	1.20	1.20	0.15	0.15	1.55	981.12	979.73	1.55	1.55	1.51	1.47	1.47
C	Overall Molecular Weight	-	2.92	22.49	26.85	26.85	2.92	2.92	2.09	18.01	18.01	2.09	2.09	2.09	2.09	2.09
C	Vapour Mass Flow	kg/h	616.1	3939.1	4212.7	21063.4	3080.5	3080.5	2081.0	0.0	0.0	2081.0	2081.0	2081.0	2081.0	2081.0
C	Vapour Actual Volume Flow	m^3/h	4177.3	3207.2	3497.1	17485.3	20886.4	20886.4	1341.4	0.0	0.0	1341.4	1341.4	1376.5	1413.5	1413.5
C	Vapour Mass Density	kg/m^3	0.15	1.23	1.20	1.20	0.15	0.15	1.55	0.19	0.18	1.55	1.55	1.51	1.47	1.47
C	Vapour Mass Heat Capacity	kJ/kg-C	9.84	1.14	1.17	1.17	9.84	9.84	13.70	10.95	10.82	13.70	13.70	13.70	13.70	13.70
C	Vapour Compressibility	-	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.00	1.00	1.01	1.01	1.01	1.01	1.01
C	Vapour Molecular Weight	-	2.92	27.39	26.85	26.85	2.92	2.92	2.09	2.62	2.65	2.09	2.09	2.09	2.09	2.09
C	Aqueous Mass Flow	kg/h	0	34283	0	0	0	0	0	999	999	0	0	-	-	0
C	Aqueous Actual Volume Flow	m^3/h	0.00	31.01	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00	0.00	-	-	0.00
C	Aqueous Mass Density	kg/m^3	996	1106	964	964	996	996	996	997	997	996	996	-	-	747
C	Aqueous Mass Heat Capacity	kJ/kg-C	4.18	3.25	4.20	4.20	4.18	4.18	4.18	4.18	4.18	4.18	4.18	-	-	4.18
C	Aqueous Molecular Weight	-	18.01	22.04	18.02	18.02	18.01	18.01	18.01	18.01	18.01	18.01	18.01	-	-	18.01
		Component														
C	Overall Component Molar Fraction	H_2O	0.057	0.845	0.363	0.363	0.057	0.057	0.004	1.000	1.000	0.004	0.004	0.004	0.004	0.004
C	Overall Component Molar Fraction	H_2	0.943	0.000	0.003	0.003	0.943	0.943	0.996	0.000	0.000	0.996	0.996	0.996	0.996	0.996
C	Overall Component Molar Fraction	O_2	0.000	0.059	0.635	0.635	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C	Overall Component Molar Fraction	Ethylene Glycol	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C	Overall Component Molar Fraction	KOH	0.000	0.096	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

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Case No: Case 1, Sheet 3 | Case Description: Electrolyser Stack Start of Life

Rev.	Stream Name	Units	027	028	029	030	031	032	033	034	035	036	037	038	039	040
	Description	-	Purified Hydrogen from Hydrogen Dryer V-301-002A/B	Water from Deoxo-Dryer Module 01	Water from Deoxo-Dryer Modules 01 and 02	Purified Hydrogen to Buffer Storage	Hydrogen to Hydrogen Export Fiscal Metering Package PK-501-001	Hydrogen to Export Hydrogen Pipeline	Cooling Water Return from Electrolyser Modules 01-06	Cooling Water Return from Deoxo-Dryer Modules 01-02	Cooling Water Return from Compressor Aftercoolers E-201/2-001 - 005	Combined Cooling Water Return to Closed-Loop Cooling Water Expansion Vessel V-701-001	Cooling Water Supply from Closed-Loop Cooling Water Circulation Pump P-701-001A/B	Cooling Water Supply from Cooling Water Heat Exchanger E-701-001	Cooling Water Supply to Electrolyser Modules 01-06	Cooling Water Supply to Deoxo-Dryer Modules 01-02
C	Overall Vapour Fraction	-	1.00	0.00	0.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C	Overall Temperature	°C	40.0	40.4	40.4	40.0	40.0	40.3	45.0	45.0	45.0	45.0	45.0	35.0	35.0	35.0
C	Overall Pressure	barg	17.00	0.80	0.80	17.00	17.00	12.00	3.50	3.50	3.50	2.50	5.00	4.00	4.00	4.00
C	Overall Actual Volume Flow	Am3/hr	1446.9	0.1	0.1	1446.9	1446.9	2000.2	1750.7	0.0	461.6	2212.5	2212.3	2197.0	1738.6	0.0
C	Overall Mass Flow	kg/h	2003	78	78	2003	2003	2003	1755798	7	462955	2218760	2218760	2218760	1755798	7
C	Overall Mass Density	kg/m^3	1.38	995.71	995.71	1.38	1.38	1.00	1002.89	1002.89	1002.89	1002.83	1002.92	1009.91	1009.91	1009.91
C	Overall Molecular Weight	-	2.02	18.02	18.02	2.02	2.02	2.02	22.89	22.89	22.89	22.89	22.89	22.89	22.89	22.89
C	Vapour Mass Flow	kg/h	2003.3	-	-	2003.3	2003.3	2003.3	-	-	-	-	-	-	-	-
C	Vapour Actual Volume Flow	m^3/h	1446.9	-	-	1446.9	1446.9	2000.2	-	-	-	-	-	-	-	-
C	Vapour Mass Density	kg/m^3	1.38	-	-	1.38	1.38	1.00	-	-	-	-	-	-	-	-
C	Vapour Mass Heat Capacity	kJ/kg-C	14.16	-	-	14.16	14.16	14.15	-	-	-	-	-	-	-	-
C	Vapour Compressibility	-	1.01	-	-	1.01	1.01	1.01	-	-	-	-	-	-	-	-
C	Vapour Molecular Weight	-	2.02	-	-	2.02	2.02	2.02	-	-	-	-	-	-	-	-
C	Aqueous Mass Flow	kg/h	-	78	78	-	-	-	1755798	7	462955	2218760	2218760	2218760	1755798	7
C	Aqueous Actual Volume Flow	m^3/h	-	0.08	0.08	-	-	-	1750.74	0.01	461.62	2212.49	2212.30	2197.00	1738.58	0.01
C	Aqueous Mass Density	kg/m^3	-	996	996	-	-	-	1003	1003	1003	1003	1003	1010	1010	1010
C	Aqueous Mass Heat Capacity	kJ/kg-C	-	4.18	4.18	-	-	-	3.48	3.48	3.48	3.48	3.48	3.41	3.41	3.41
C	Aqueous Molecular Weight	-	-	18.02	18.02	-	-	-	22.89	22.89	22.89	22.89	22.89	22.89	22.89	22.89
		Component														
C	Overall Component Molar Fraction	H_2O	0.000	1.000	1.000	0.000	0.000	0.000	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889
C	Overall Component Molar Fraction	H_2	1.000	0.000	0.000	1.000	1.000	1.000	-	-	-	-	-	-	-	-
C	Overall Component Molar Fraction	O_2	0.000	0.000	0.000	0.000	0.000	0.000	-	-	-	-	-	-	-	-
C	Overall Component Molar Fraction	Ethylene Glycol	-	-	-	-	-	-	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
C	Overall Component Molar Fraction	KOH	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

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Case No: Case 1, Sheet 4 — Case Description: Electrolyser Stack Start of Life

Rev.	Stream Name	Units	041	042	043	044	045	046	047	048	049	050	051			
	Description	-	Cooling Water Supply to Compressor Aftercoolers E-201/2-001 - 005	Raw Water from Raw Water Make-up Pump P-701-003A/B	Cooling Water from Hybrid Cooling Water Package PK-701-001	Cooling Tower Water Losses to Atmosphere	Cooling Water from Main Cooling Water Circulation Pump P-701-002A/B	Cooling Water Circuit Purge Stream	Cooling Water Supply to Closed-Loop Cooling Water System	Cooling Water Return from Closed-Loop Cooling Water System	Condensate from Hydrogen Compression and Purification	Water recycle from Process Drains Flash Vessel Water Pump	Flash Hydrogen from Process Drains Flash Vessel			
C	Overall Vapour Fraction	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00			
C	Overall Temperature	°C	35.0	25.0	25.0	25.0	25.0	25.0	25.0	35.0	39.3	39.4	39.3			
C	Overall Pressure	barg	4.00	1.00	0.10	0.10	3.00	3.00	3.00	2.00	0.80	5.00	0.50			
C	Overall Actual Volume Flow	Am3/hr	458.4	24.7	1849.2	23.5	1848.9	1.3	1847.7	1853.4	1.1	1.1	0.0			
C	Overall Mass Flow	kg/h	462955	24666	1843741	23418	1843741	1248	1842493	1842493	1077	1077	0			
C	Overall Mass Density	kg/m^3	1009.91	997.10	997.06	997.06	997.18	997.18	997.19	994.11	981.56	996.58	0.15			
C	Overall Molecular Weight	-	22.89	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.01	18.01	2.65			
C	Vapour Mass Flow	kg/h	-	-	-	-	-	-	-	-	0.0	-	0.0			
C	Vapour Actual Volume Flow	m^3/h	-	-	-	-	-	-	-	-	0.0	-	0.0			
C	Vapour Mass Density	kg/m^3	-	-	-	-	-	-	-	-	0.19	-	0.15			
C	Vapour Mass Heat Capacity	kJ/kg-C	-	-	-	-	-	-	-	-	10.81	-	10.81			
C	Vapour Compressibility	-	-	-	-	-	-	-	-	-	1.00	-	1.00			
C	Vapour Molecular Weight	-	-	-	-	-	-	-	-	-	2.65	-	2.65			
C	Aqueous Mass Flow	kg/h	462955	24666	1843741	23418	1843741	1248	1842493	1842493	1077	1077	-			
C	Aqueous Actual Volume Flow	m^3/h	458.41	24.74	1849.18	23.49	1848.95	1.25	1847.68	1853.40	1.08	1.08	-			
C	Aqueous Mass Density	kg/m^3	1010	997	997	997	997	997	997	994	996	997	-			
C	Aqueous Mass Heat Capacity	kJ/kg-C	3.41	4.18	4.18	4.18	4.18	4.18	4.18	4.18	4.18	4.18	-			
C	Aqueous Molecular Weight	-	22.89	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.01	18.01	-			
		Component														
C	Overall Component Molar Fraction	H_2O	0.889	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.040			
C	Overall Component Molar Fraction	H_2	-	-	-	-	-	-	-	-	0.000	0.000	0.960			
C	Overall Component Molar Fraction	O_2	-	-	-	-	-	-	-	-	0.000	0.000	0.000			
C	Overall Component Molar Fraction	Ethylene Glycol	0.111	-	-	-	-	-	-	-	-	-	-			
C	Overall Component Molar Fraction	KOH	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000			

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Case No: Case 2, Sheet 1 | Case Description: Electrolyser Stack End of Life

Rev.	Stream Name	Units	001	002	003	004	005	006	007	008	009	010	011	012	013	014
	Description	-	Demin Water From Existing Demin Water Storage Tank	Demin Water to Demin Water Treatment Package PK-601-001	Demin Water from Demin Water Treatment Package PK-601-001	Reject Water from Demin Water Treatment Package PK-601-001	Ultra Pure Demin Water to Electrolyser Modules 01-06	Ultra Pure Demin Water to Hydrogen Gas Scrubber V-101-003	Water & recovered electrolyte from Hydrogen Gas Scrubber V-101-003	Electrolyte from Hydrogen Gas Separator V-101-001	Combined Electrolyte from Hydrogen Scrubber V-101-003 & Hydrogen Separator V-101-001	Electrolyte from Oxygen Separator V-101-002	Electrolyte to Electrolyser Feed Pump P-101-001	Electrolyte to Electrolyser Feed Heat Exchanger E-101-001	Electrolyte to Electrolyser Stack X-101-001	Raw Hydrogen to Hydrogen Separator V-101-001
C	Overall Vapour Fraction	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07
C	Overall Temperature	°C	25.0	25.0	25.8	25.8	25.8	25.8	40.0	80.0	76.2	80.0	77.9	77.9	50.0	80.0
C	Overall Pressure	barg	0.10	5.00	1.00	1.00	3.00	3.00	0.30	0.30	0.30	0.30	0.30	1.30	0.80	0.30
C	Overall Actual Volume Flow	Am^3/hr	24.4	24.4	24.3	1.3	24.3	4.9	6.7	73.6	80.3	62.3	142.6	142.6	140.6	6679.2
C	Overall Mass Flow	kg/h	24301	24301	24181	1273	24181	4836	6669	81671	88340	68986	157329	157329	157329	84135
C	Overall Mass Density	kg/m^3	997.06	997.27	996.89	996.89	996.98	996.98	995.97	1109.22	1099.88	1107.66	1103.28	1103.31	1118.84	12.60
C	Overall Molecular Weight	-	18.02	18.02	18.02	18.02	18.02	18.02	18.02	21.92	21.57	21.87	21.70	21.70	21.70	20.83
C	Vapour Mass Flow	kg/h	-	-	-	-	-	-	-	-	-	-	-	-	-	2144.7
C	Vapour Actual Volume Flow	m^3/h	-	-	-	-	-	-	-	-	-	-	-	-	-	6605.2
C	Vapour Mass Density	kg/m^3	-	-	-	-	-	-	-	-	-	-	-	-	-	0.32
C	Vapour Mass Heat Capacity	kJ/kg-C	-	-	-	-	-	-	-	-	-	-	-	-	-	4.23
C	Vapour Compressibility	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00
C	Vapour Molecular Weight	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.25
C	Aqueous Mass Flow	kg/h	24301	24301	24181	1273	24181	4836	6669	81671	88340	68986	157329	157329	157329	81990
C	Aqueous Actual Volume Flow	m^3/h	24.37	24.37	24.26	1.28	24.25	4.85	6.70	73.63	80.32	62.28	142.60	142.60	140.62	73.96
C	Aqueous Mass Density	kg/m^3	997	997	997	997	997	997	996	1109	1100	1108	1103	1103	1119	1109
C	Aqueous Mass Heat Capacity	kJ/kg °C	4.18	4.18	4.18	4.18	4.18	4.18	4.18	3.28	3.35	3.29	3.32	3.32	3.30	3.28
C	Aqueous Molecular Weight	-	18.02	18.02	18.02	18.02	18.02	18.02	18.02	21.92	21.57	21.87	21.70	21.70	21.70	21.90
		Component														
C	Overall Component Molar Fraction	H_2O	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.898	0.907	0.899	0.903	0.903	0.903	0.856
C	Overall Component Molar Fraction	H_2	-	-	-	-	-	-	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.049
C	Overall Component Molar Fraction	O_2	-	-	-	-	-	-	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C	Overall Component Molar Fraction	Ethylene Glycol	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C	Overall Component Molar Fraction	KOH	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.102	0.093	0.101	0.097	0.097	0.097	0.095

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Case No: Case 2, Sheet 2 — Case Description: Electrolyser Stack End of Life

Rev.	Stream Name	Units	015	016	017	017B	018	019	020	021	021B	022	023	024	025	026
	Description	-	Raw Hydrogen from Hydrogen Gas Scrubber V-101-003	Oxygen / Electrolyte to Separator V-101-002	Oxygen from Electrolyser Module 01 to Vent	Oxygen from Electrolyser Modules 01-06 to Vent	Raw Hydrogen to Hydrogen Compressor K-201/2-001	Raw Hydrogen to Hydrogen Compressor K-201-001	Hydrogen from Hydrogen Compressor K-201-001	Water from Hydrogen Compressor K-201-001 KO Drums	Water from Hydrogen Compressor K-201/2-001 KO Drums	Hydrogen to Deoxo-Dryer Modules 01-02	Hydrogen to Deoxidiser Reactor R-301-001	Hydrogen to Deoxidiser Reactor Cooler E-301-001	Hydrogen to Hydrogen Water Separator V-301-001	Hydrogen to Hydrogen Dryer V-301-002A/B
C	Overall Vapour Fraction	-	1.00	0.04	1.00	1.00	1.00	1.00	1.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00
C	Overall Temperature	°C	40.0	80.0	80.0	80.0	40.0	40.0	40.0	39.2	39.2	40.0	40.0	73.7	40.0	40.0
C	Overall Pressure	barg	0.30	0.30	0.30	0.30	0.30	0.30	18.50	0.90	0.80	18.50	18.50	18.00	17.50	17.50
C	Overall Actual Volume Flow	Am3/hr	4195.1	3179.4	3491.3	17456.7	20975.7	20975.7	1347.1	1.0	1.0	1347.1	1347.1	1527.3	1411.3	1411.3
C	Overall Mass Flow	kg/h	631	73194	4206	21028	3153	3153	2150	1004	1004	2150	2150	2150	2150	2081
C	Overall Mass Density	kg/m^3	0.15	23.02	1.20	1.20	0.15	0.15	1.60	981.14	979.75	1.60	1.60	1.41	1.52	1.47
C	Overall Molecular Weight	-	2.98	22.11	26.85	26.85	2.98	2.98	2.14	18.01	18.01	2.14	2.14	2.15	2.15	2.09
C	Vapour Mass Flow	kg/h	630.7	3824.1	4205.6	21028.1	3153.4	3153.4	2149.6	0.0	0.0	2149.6	2149.6	2149.6	2081.2	2081.2
C	Vapour Actual Volume Flow	m^3/h	4195.1	3116.3	3491.3	17456.7	20975.7	20975.7	1347.1	0.0	0.0	1347.1	1347.1	1527.3	1411.3	1411.3
C	Vapour Mass Density	kg/m^3	0.15	1.23	1.20	1.20	0.15	0.15	1.60	0.20	0.19	1.60	1.60	1.41	1.47	1.47
C	Vapour Mass Heat Capacity	kJ/kg-C	9.65	1.14	1.17	1.17	9.65	9.65	13.32	10.81	10.69	13.32	13.32	13.33	13.68	13.68
C	Vapour Compressibility	-	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.00	1.00	1.01	1.01	1.01	1.01	1.01
C	Vapour Molecular Weight	-	2.98	27.36	26.85	26.85	2.98	2.98	2.14	2.65	2.68	2.14	2.14	2.15	2.09	2.09
C	Aqueous Mass Flow	kg/h	0	69369	0	0	0	0	0	1004	1004	0	0	-	68	0
C	Aqueous Actual Volume Flow	m^3/h	0.00	63.05	0.00	0.00	0.00	0.00	0.00	1.01	1.01	0.00	0.00	-	0.07	0.00
C	Aqueous Mass Density	kg/m^3	996	1100	964	964	996	996	996	997	997	996	996	-	996	996
C	Aqueous Mass Heat Capacity	kJ/kg-C	4.18	3.28	4.20	4.20	4.18	4.18	4.18	4.18	4.18	4.18	4.18	-	4.18	4.18
C	Aqueous Molecular Weight	-	18.01	21.88	18.02	18.02	18.01	18.01	18.01	18.01	18.01	18.01	18.01	-	18.01	18.01
		Component														
C	Overall Component Molar Fraction	H_2O	0.057	0.873	0.363	0.363	0.057	0.057	0.004	1.000	1.000	0.004	0.004	0.008	0.008	0.005
C	Overall Component Molar Fraction	H_2	0.941	0.000	0.003	0.003	0.941	0.941	0.994	0.000	0.000	0.994	0.994	0.992	0.992	0.995
C	Overall Component Molar Fraction	O_2	0.002	0.030	0.635	0.635	0.002	0.002	0.002	0.000	0.000	0.002	0.002	0.000	0.000	0.000
C	Overall Component Molar Fraction	Ethylene Glycol	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C	Overall Component Molar Fraction	KOH	0.000	0.096	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

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Case No: Case 2, Sheet 3 — Case Description: Electrolyser Stack End of Life

Rev.	Stream Name	Units	027	028	029	030	031	032	033	034	035	036	037	038	039	040
	Description	-	Purified Hydrogen from Hydrogen Dryer V-301-002A/B	Water from Deoxo-Dryer Module 01	Water from Deoxo-Dryer Modules 01 and 02	Purified Hydrogen to Buffer Storage	Hydrogen to Hydrogen Export Fiscal Metering Package PK-501-001	Hydrogen to Export Hydrogen Pipeline	Cooling Water Return from Electrolyser Modules 01-06	Cooling Water Return from Deoxo-Dryer Modules 01-02	Cooling Water Return from Compressor Aftercoolers E-201/2-001 - 005	Combined Cooling Water Return to Cloed-Loop Cooling Water Expansion Vessel V-701-001	Cooling Water Supply from Closed-Loop Cooling Water Circulation Pump P-701-001A/B	Cooling Water Supply from Cooling Water Heat Exchanger E-701-001	Cooling Water Supply to Electrolyser Modules 01-06	Cooling Water Supply to Deoxo-Dryer Modules 01-02
C	Overall Vapour Fraction	-	1.00	0.00	0.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C	Overall Temperature	°C	40.0	40.3	40.3	40.0	40.0	40.3	45.0	45.0	45.0	45.0	45.0	35.0	35.0	35.0
C	Overall Pressure	barg	17.00	0.80	0.80	17.00	17.00	12.00	3.50	3.50	3.50	2.50	5.00	4.00	4.00	4.00
C	Overall Actual Volume Flow	Am3/hr	1444.4	0.2	0.2	1444.4	1444.4	1996.7	2763.6	32.8	463.6	3260.1	3259.8	3237.3	2744.4	32.5
C	Overall Mass Flow	kg/h	2000	150	150	2000	2000	2000	2771577	32847	464934	3269358	3269358	3269358	2771577	32847
C	Overall Mass Density	kg/m^3	1.38	959.30	959.30	1.38	1.38	1.00	1002.89	1002.89	1002.89	1002.83	1002.92	1009.91	1009.91	1009.91
C	Overall Molecular Weight	-	2.02	18.01	18.01	2.02	2.02	2.02	22.89	22.89	22.89	22.89	22.89	22.89	22.89	22.89
C	Vapour Mass Flow	kg/h	1999.8	0.0	0.0	1999.8	1999.8	1999.8	-	-	-	-	-	-	-	-
C	Vapour Actual Volume Flow	m^3/h	1444.4	0.0	0.0	1444.4	1444.4	1996.7	-	-	-	-	-	-	-	-
C	Vapour Mass Density	kg/m^3	1.38	0.19	0.19	1.38	1.38	1.00	-	-	-	-	-	-	-	-
C	Vapour Mass Heat Capacity	kJ/kg-C	14.16	10.67	10.67	14.16	14.16	14.15	-	-	-	-	-	-	-	-
C	Vapour Compressibility	-	1.01	1.00	1.00	1.01	1.01	1.01	-	-	-	-	-	-	-	-
C	Vapour Molecular Weight	-	2.02	2.69	2.69	2.02	2.02	2.02	-	-	-	-	-	-	-	-
C	Aqueous Mass Flow	kg/h	-	150	150	-	-	-	2771577	32847	464934	3269358	3269358	3269358	2771577	32847
C	Aqueous Actual Volume Flow	m^3/h	-	0.15	0.15	-	-	-	2763.59	32.75	463.59	3260.12	3259.83	3237.29	2744.39	32.52
C	Aqueous Mass Density	kg/m^3	-	996	996	-	-	-	1003	1003	1003	1003	1003	1010	1010	1010
C	Aqueous Mass Heat Capacity	kJ/kg-C	-	4.18	4.18	-	-	-	3.48	3.48	3.48	3.48	3.48	3.41	3.41	3.41
C	Aqueous Molecular Weight	-	-	18.01	18.01	-	-	-	22.89	22.89	22.89	22.89	22.89	22.89	22.89	22.89
		Component														
C	Overall Component Molar Fraction	H_2O	0.000	1.000	1.000	0.000	0.000	0.000	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889
C	Overall Component Molar Fraction	H_2	1.000	0.000	0.000	1.000	1.000	1.000	-	-	-	-	-	-	-	-
C	Overall Component Molar Fraction	O_2	0.000	0.000	0.000	0.000	0.000	0.000	-	-	-	-	-	-	-	-
C	Overall Component Molar Fraction	Ethylene Glycol	-	-	-	-	-	-	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
C	Overall Component Molar Fraction	KOH	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

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Case No: Case 2, Sheet 4 — Case Description: Electrolyser Stack End of Life

Rev.	Stream Name	Units	041	042	043	044	045	046	047	048	049	050	051			
	Description	-	Cooling Water Supply to Compressor Aftercoolers E-201/2-001 - 005	Raw Water from Raw Water Make-up Pump P-701-003A/B	Cooling Water from Hybrid Cooling Water Package PK-701-001	Cooling Tower Water Losses to Atmosphere	Cooling Water from Main Cooling Water Circulation Pump P-701-002A/B	Cooling Water Circuit Purge Stream	Cooling Water Supply to Closed-Loop Cooling Water System	Cooling Water Return from Closed-Loop Cooling Water System	Condensate from Hydrogen Compression and Purification	Water recycle from Process Drains Flash Vessel Water Pump	Flash Hydrogen from Process Drains Flash Vessel			
C	Overall Vapour Fraction	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00			
C	Overall Temperature	°C	35.0	25.0	25.0	25.0	25.0	25.0	25.0	35.0	39.4	39.4	39.4			
C	Overall Pressure	barg	4.00	1.00	0.10	0.10	3.00	3.00	3.00	2.00	0.80	5.00	0.50			
C	Overall Actual Volume Flow	Am3/hr	460.4	36.5	2724.8	34.6	2724.4	1.8	2722.6	2731.0	1.2	1.2	0.0			
C	Overall Mass Flow	kg/h	464934	36346	2716765	34507	2716765	1839	2714926	2714926	1154	1154	0			
C	Overall Mass Density	kg/m^3	1009.91	997.10	997.06	997.06	997.18	997.18	997.19	994.11	977.06	996.53	0.16			
C	Overall Molecular Weight	-	22.89	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.01	18.01	2.68			
C	Vapour Mass Flow	kg/h	-	-	-	-	-	-	-	-	0.0	-	0.0			
C	Vapour Actual Volume Flow	m^3/h	-	-	-	-	-	-	-	-	0.0	-	0.0			
C	Vapour Mass Density	kg/m^3	-	-	-	-	-	-	-	-	0.19	-	0.16			
C	Vapour Mass Heat Capacity	kJ/kg-C	-	-	-	-	-	-	-	-	10.70	-	10.70			
C	Vapour Compressibility	-	-	-	-	-	-	-	-	-	1.00	-	1.00			
C	Vapour Molecular Weight	-	-	-	-	-	-	-	-	-	2.68	-	2.68			
C	Aqueous Mass Flow	kg/h	464934	36346	2716765	34507	2716765	1839	2714926	2714926	1154	1154	-			
C	Aqueous Actual Volume Flow	m^3/h	460.37	36.45	2724.77	34.61	2724.44	1.84	2722.57	2731.00	1.16	1.16	-			
C	Aqueous Mass Density	kg/m^3	1010	997	997	997	997	997	997	994	996	997	-			
C	Aqueous Mass Heat Capacity	kJ/kg-C	3.41	4.18	4.18	4.18	4.18	4.18	4.18	4.18	4.18	4.18	-			
C	Aqueous Molecular Weight	-	22.89	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.01	18.01	-			
		Component														
C	Overall Component Molar Fraction	H_2O	0.889	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.040			
C	Overall Component Molar Fraction	H_2	-	-	-	-	-	-	-	-	0.000	0.000	0.959			
C	Overall Component Molar Fraction	O_2	-	-	-	-	-	-	-	-	0.000	0.000	0.001			
C	Overall Component Molar Fraction	Ethylene Glycol	0.111	-	-	-	-	-	-	-	-	-	-			
C	Overall Component Molar Fraction	KOH	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000			