
HyUSPre

Hydrogen Underground Storage in Porous Reservoirs

Relative permeability curves for the hydrogen-brine system under drainage and imbibition under reservoir conditions

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Executive summary

Geological hydrogen storage in depleted gas fields represents a new technology to mitigate climate change. It comes with several research gaps, around hydrogen recovery, including the flow behaviour of hydrogen gas in porous media. Here, we provide unsteady state relative permeability curves with H₂-Brine, on two different types of sandstones and a carbonate rock.

We investigate the effect of pressure, brine salinity, and rock type on hydrogen flow behaviour and compare it to that of CH₄ and N₂ at high-pressure and high-temperature conditions representative of potential geological storage sites. Finally, we use a history matching method for modelling relative permeability curves using the measured data within the experiments. Our results suggest that nitrogen can be used as a proxy gas for hydrogen to carry out multiphase fluid flow experiments, to provide the fundamental constitutive relationships necessary for large-scale simulations of geological hydrogen storage.

We found that the relative permeability of hydrogen was significantly higher than that of brine in all three rock types. Additionally, the relative permeability of hydrogen was found to increase with increasing temperature, while the relative permeability of brine decreased with increasing temperature. The authors also observed that the relative permeability of hydrogen was higher in sandstone than in carbonate rocks and that the effective porosity of a rock has the most evident impact on H₂-brine relative permeability. We also demonstrate that nitrogen gas can be used as a safer proxy for hydrogen to undertake fluid flow experiments.

The results of this study have significant implications for the development of hydrogen as an energy source. The higher relative permeability of hydrogen in reservoir rocks indicates that it may be feasible to store hydrogen as an energy carrier in large volumes in porous reservoirs in the subsurface, which would be a major step towards the widespread adoption of hydrogen as a renewable energy source.

This deliverable presents the relative permeability curves and associated peer reviewed paper published at <https://doi.org/10.1029/2022GL099433> and the data which is uploaded to "figshare" and publicly accessible at <https://doi.org/10.6084/m9.figshare.19722520.v1>.

About HyUSPRe

Hydrogen Underground Storage in Porous Reservoirs

The HyUSPRe project researches the feasibility and potential of implementing large-scale underground geological storage for renewable hydrogen in Europe. This includes the identification of suitable porous reservoirs for hydrogen storage, and technical and economic assessments of the feasibility of implementing large-scale storage in these reservoirs to support the European energy transition to net zero emissions by 2050. The project will address specific technical issues and risks regarding storage in porous reservoirs and conduct an economic analysis to facilitate the decision-making process regarding the development of a portfolio of potential field pilots. A techno-economic assessment, accompanied by environmental, social, and regulatory perspectives on implementation will allow for the development of a roadmap for widespread hydrogen storage by 2050, indicating the role of large-scale hydrogen storage in achieving a zero-emissions energy system in the EU by 2050.

This project has two specific objectives. Objective 1 concerns the assessment of the technical feasibility, associated risks, and the potential of large-scale underground hydrogen storage in porous reservoirs for Europe. HyUSPRe will establish the important geochemical, microbiological, flow, and transport processes in porous reservoirs in the presence of hydrogen via a combination of laboratory-scale experiments and integrated modelling; and establish more accurate cost estimates to identify the potential business case for hydrogen storage in porous reservoirs. Suitable storage sites will be identified, and their hydrogen storage potential will be assessed. Objective 2 concerns the development of a roadmap for the deployment of geological hydrogen storage up to 2050. The proximity of storage sites to large renewable energy infrastructure and the amount of renewable energy that can be buffered versus time varying demands will be evaluated. This will form a basis for developing future scenario roadmaps and preparing for demonstrations.

Document information, revision history, approval status

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Deliverable responsible:	Katriona Edlmann	2023.03.21
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1 Introduction

The deliverable presents unsteady state hydrogen-brine relative permeability curves for different conditions, such as temperature, pressure, and pore fluid salinity, which are representative of potential storage reservoirs. The study shows that the relative permeability of hydrogen is generally higher than that of brine, and that the viscosity and density of hydrogen have an impact on its displacement. The results provide important inputs for large-scale reservoir simulators and can help to improve the efficiency and safety of hydrogen storage.

2 Methods

Research-grade Hydrogen (H_2), methane (CH_4), and nitrogen (N_2) gases with a purity of 99.9995 vol%, and sodium chloride ($NaCl$) of certified purity of 99.5% were used for the experiments. An integral water purification system (ELGA DV 25) was employed to produce deionized water used for the experiments.

Two sandstone and one carbonate rock samples were taken from gas reservoirs and used for displacement tests. The mineralogy and pore structures of the rock samples were characterized using XRD analysis, MICP experiments, and centrifuge capillary pressure tests. Temperature was controlled via a fan oven housing a Hassler type core holder (Figure 1). A pressure gauge, Rosemont 3051 pressure transmitter from Emerson, Netherlands, was used to continuously record the differential pressure across the sample (i.e., between inlet and outlet face of core sample) value during flooding experiments.

After vacuum drying at 70°C, the core samples were loaded into the core holder and saturated with brine of the relevant salinity. Subsequently, the brine was injected at three different flow rates to determine K_w using Darcy's equation. The obtained brine permeability was used as the base fluid (absolute) permeability for the relative permeability calculations.

The desired gas (i.e., H_2 , N_2 , or CH_4) was injected into the brine-saturated core sample with a pre-defined constant pressure determined by the core's K_w value. The inlet and outlet gas flow rates, the differential pressure between the core faces (i.e., inlet and outlet), and the produced effluent brine volume were recorded with time during the injection process and recording continued until no more brine was seen in the effluent (i.e., when water cut/ratio of water to total fluids is approximately zero).

The recorded data were used to calculate the relative permeabilities of gas (K_{rg}) and brine (K_{rw}) as a function of gas saturation using the Johnson, Bossler, and Naumann method (Johnstone et al, 1959). History matching was used to predict relative permeability from experimental data. The modified Corey model for relative permeability was used to determine the parameters of the models using the software, CYDAR® (CYDAREX, 2018).

Experimental and theoretical evidence have established that relative permeabilities are influenced by many rock and fluid parameters. Accordingly, an extended series of relative permeability pressure tests in sandstone and carbonate core samples at various salinity and pressure conditions were undertaken to investigate the flow behaviour of hydrogen gas relative to the formation of brine in porous media. In addition, core flooding experiments were performed using nitrogen (N_2) and methane (CH_4) as the gaseous phase to compare the flow behaviour of different gases at high pressure conditions (Table 1).

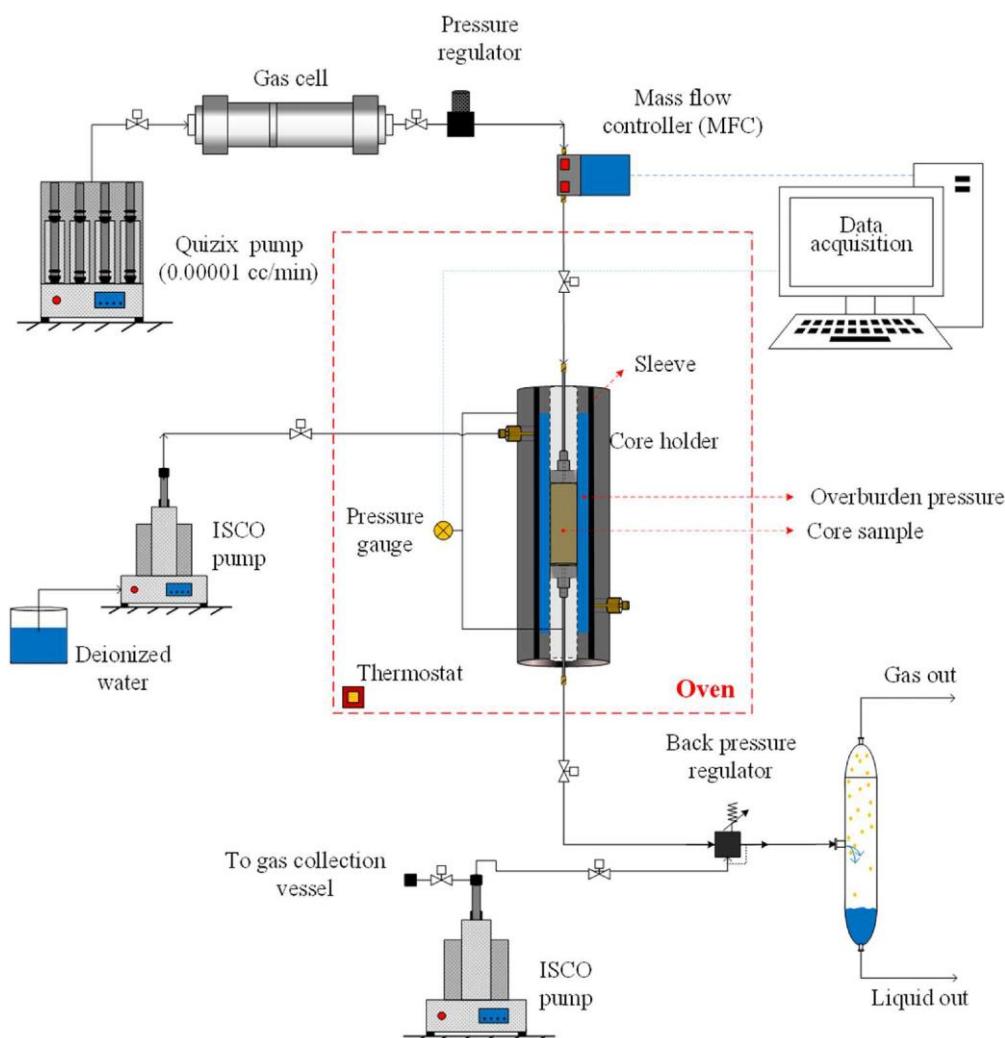


Figure 1. Schematic of the setup used for gas-brine relative permeability measurements; to restrain gravity segregation into the core sample during the gas injection process, the core holder is placed in a vertical mode. The sizes of different objects have been rescaled to make them visible.

Table 1. Different Core Flooding Experiments.

Exp. No.	Rock sample	Gas type	Back pressure (MPa)	Salinity (ppt)	Temperature (K)
1	Sandstone 1	H ₂	0.1	35	353.15
2	Sandstone 1	H ₂	10.34	35	353.15
3	Sandstone 1	H ₂	20.68	35	353.15
4	Sandstone 1	H ₂	20.68	100	353.15
5	Sandstone 1	H ₂	20.68	200	353.15
6	Carbonate 1	H ₂	20.68	35	353.15
7	Sandstone 2	H ₂	20.68	35	353.15
8	Sandstone 2	N ₂	20.68	35	353.15
9	Sandstone 2	CH ₄	20.68	35	353.15

3 Relative Permeability Curves

The relative permeability curves are presented in Figure 2. In all the nine experiments, drainage relative permeability is characteristic of a strongly water-wet system as the wetting phase (brine) relative permeability decreased rapidly at relatively low gas saturations due to its occupancy of smaller and less permeable pores, and curves vary as expected with gas type, salinity, pressure, and bulk rock characteristics.

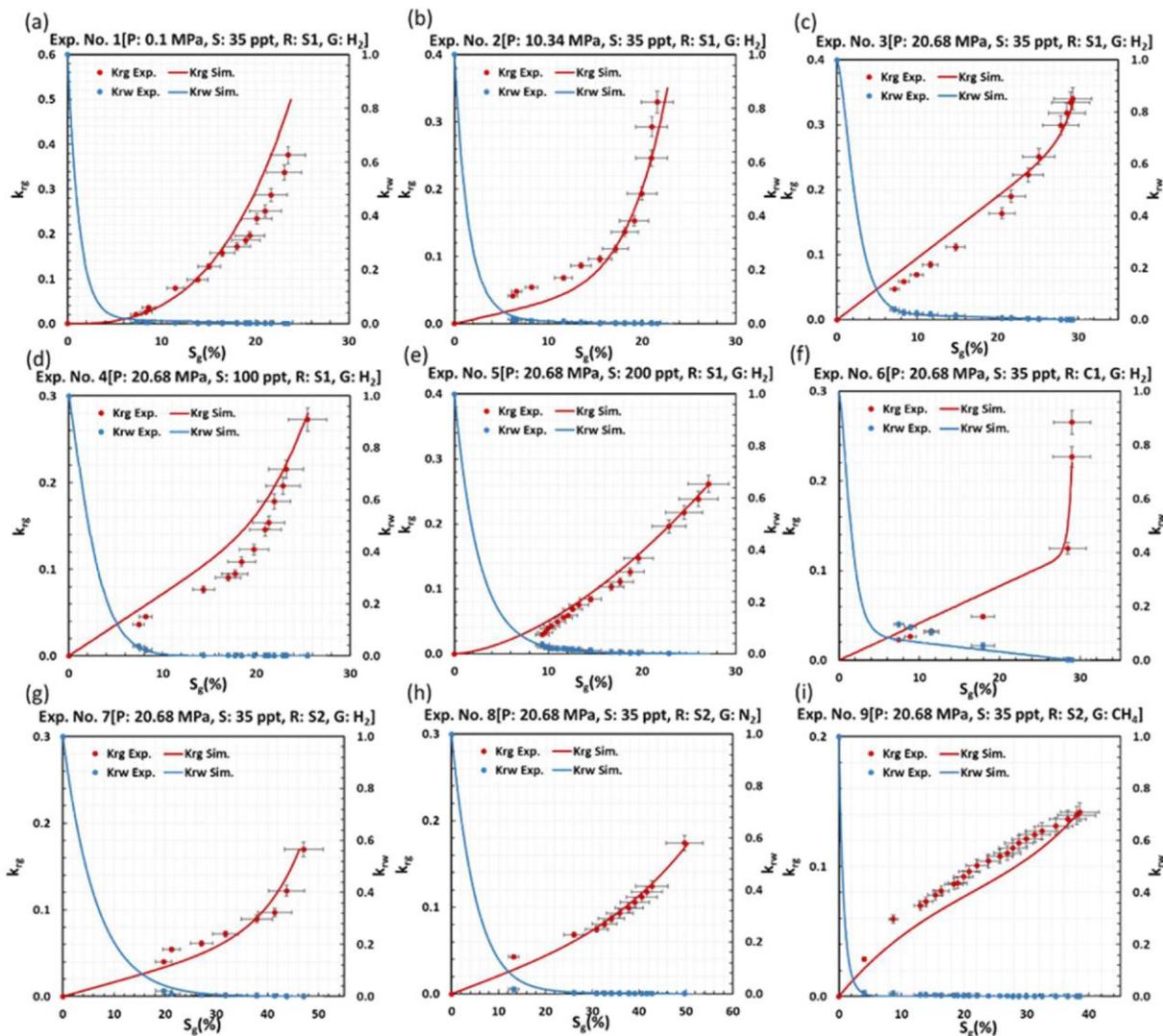


Figure 2 (a-g). Hydrogen and different brine relative permeability curves for 2 sandstone and 1 carbonate samples at different pressures. (h) Nitrogen and brine relative permeability curves for sandstone sample S2, (i) Methane and brine relative permeability curves for sandstone sample S2.

Graphs showing the effects pressure, salinity, rock type (sandstone and carbonate), and gas type (H_2 , N_2 , and CH_4) are shown in Figure 3.

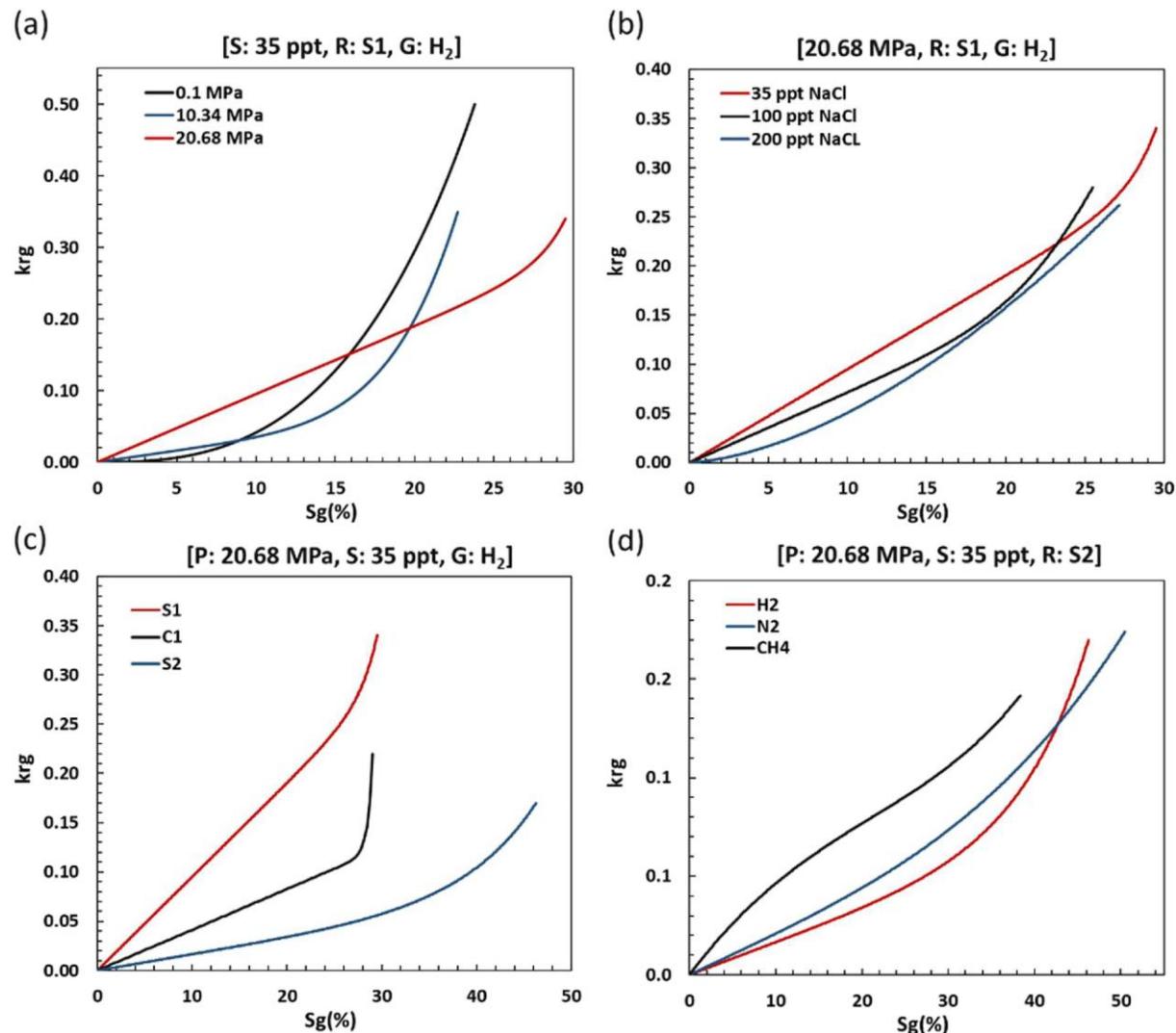


Figure 3. Hydrogen relative permeability curves versus gas saturation to compare (a) effect of pressure on drainage hydrogen relative permeability (b) effect of salinity on hydrogen relative permeability (c) effect of rock type and rock pore structure on hydrogen relative permeability and (d) hydrogen relative permeability with that of N_2 and CH_4 .

4 Relative Permeability Data

All data is publicly accessible at <https://doi.org/10.6084/m9.figshare.19722520.v1>.

5 References

Johnson, E. F., Bossler, D. P., & Bossler, V. O. (1959). Calculation of relative permeability from displacement experiments. Transactions of the AIME, 216, 370–372, <https://doi.org/10.2118/1023-G>.

Appendix

The appendix shows the data referring to the relative permeability curves shown in this report. Data can also be downloaded in Excel format from this source: <https://doi.org/10.6084/m9.figshare.19722520.v1>.

Appendix 1 to HyUSPRe report D4.2

Edlmann, K., Hassanpourouzband, A. (2023): Relative permeability curves for the hydrogen-brine system under drainage and imbibition under reservoir conditions.

Exp No. 1 H2-S1-S(3.5)-P(14.5)			Exp No. 2 H2-S1-S(3.5)-P(1500)			Exp No. 3 H2-S1-S(3.5)-P(3000)			Exp No. 4 H2-S1-S(10)-P(3000)			Exp No. 5 H2-S1-S(20)-P(3000)			Exp No. 6 Carbonate			Exp No. 7 H2-S2-S(3.5)-P(3000)			Exp No. 8 N2-S2			Exp No. 9 CH4-S2		
	water	gas		water	gas		water	gas		water	gas		water	gas		water	gas		water	gas		water	gas		Water	Gas
Kr max:	1,00	0,50	Kr max:	1,00	0,35	Kr max:	1,00	0,34	Kr max:	1,00	0,28	Kr max:	1,00	0,26	Kr max:	1,00	0,22	Kr max:	1,00	0,17	Kr max:	1,00	0,17	Kr max:	1,00	0,14
alpha:	10,05	2,72	alpha:	10,07	5,60	alpha:	16,00	13,71	alpha:	10,86	7,20	alpha:	6,71	1,71	alpha:	25,27	57,29	alpha:	4,38	5,02	alpha:	5,00	3,50	alpha:	6,71	1,86
H:	0,02	0,00	H:	0,01	0,21	H:	0,03	0,83	H:	0,00	0,65	H:	0,01	0,07	H:	0,10	0,55	H:	0,01	0,45	H:	0,01	0,60	H:	0,01	1,60
V:	19,16	3,11	V:	15,45	4,65	V:	2,00	3,90	V:	5,75	2,50	V:	10,52	1,66	V:	2,00	30,00	V:	7,05	4,00	V:	9,50	2,00	V:	10,52	1,50
(Sg)	Krw	Krg	(Sg)	Krw	Krg	(Sg)	Krw	Krg	(Sg)	Krw	Krg	(Sg)	Krw	Krg	(Sg)	Krw	krg	(Sg)	Krw	Krg	(Sg)	Krw	Krg	(Sg)	Krw	Krg
23,8	0	0,5	22,7	0	0,35	29,5	0	0,34	25,5	0	0,28	27,1693	0	0,262	29	0	0,22	46,26408	0	0,17	50,46729	0	0,174	38,43196	0	0,142
23,5596	1,93E-04	0,484473	22,47071	0,000144	0,333924	29,44088	5,61E-05	0,337381	25,4489	7,35E-30	0,278598	27,11485	2E-05	0,261129	28,70707	0,001023	0,171438	46,17137	2,00401E-05	0,168645	50,36615	1,60E-05	0,173304	38,35494	3,13E-82	0,141574
23,31919	3,86E-04	0,46932	22,24141	0,000287	0,318557	29,38176	0,000112	0,334839	25,3978	1,37E-26	0,277199	27,0604	4,01E-05	0,260259	28,41414	0,002046	0,145789	46,07866	4,00802E-05	0,167305	50,26502	3,21E-05	0,17261	38,27792	3,38E-73	0,14115
23,07879	5,79E-04	0,454535	22,01212	0,000431	0,303873	29,3265	0,000168	0,332368	25,34669	1,12E-24	0,275802	27,00596	6,01E-05	0,259391	28,12121	0,003069	0,131597	45,98594	6,01203E-05	0,165979	50,16388	4,81E-05	0,171919	38,2009	6,51E-68	0,140729
22,83838	0,000772	0,44011	21,78283	0,000574	0,289846	29,26353	0,000224	0,329968	25,29559	2,54E-23	0,274408	26,95151	8,02E-05	0,258523	27,82828	0,004092	0,123379	45,89323	8,01606E-05	0,164668	50,06274	6,41E-05	0,17123	38,12388	3,66E-64	0,140309
22,59798	0,000965	0,426038	21,55354	0,000718	0,276451	29,20441	0,000281	0,327634	25,24449	2,86E-22	0,273017	26,89706	0,0001	0,257657	27,53535	0,005115	0,11836	45,80051	0,00010201	0,163372	49,96161	8,02E-05	0,170543	38,04687	2,96026E-61	0,139892
22,35758	0,001158	0,412311	21,32424	0,000861	0,263664	29,14529	0,000337	0,325364	25,19339	2,07E-21	0,271629	26,84261	0,00012	0,256792	27,24242	0,006138	0,115077	45,7078	0,00012042	0,16209	49,86047	9,62E-05	0,169859	37,96985	7,03979E-59	0,139476
22,11717	0,001351	0,398924	21,09495	0,001005	0,251463	29,08617	0,000393	0,323157	25,14228	1,11E-20	0,270245	26,78817	0,00014	0,255928	26,94949	0,00716	0,11274	45,61509	0,000140283	0,160822	49,75933	0,0001122	0,169178	37,89283	7,18841E-57	0,139063
21,87677	0,001544	0,385868	20,86566	0,001148	0,239823	29,02705	0,000449	0,321009	25,09118	4,72E-20	0,268865	26,73372	0,00016	0,255065	26,65657	0,008183	0,110919	45,52237	0,000160326	0,159567	49,65819	0,0001283	0,168498	37,81581	3,9534E-55	0,138652
21,63636	0,001737	0,373138	20,63636	0,001292	0,228723	28,96794	0,000505	0,318918	25,04008	1,70E-19	0,267488	26,67927	0,00018	0,254204	26,36364	0,009206	0,10938	45,42966	0,000180369	0,158327	49,55706	0,00014433	0,167822	37,73879	1,35537E-53	0,138242
21,39596	0,001929	0,360727	20,40707	0,001435	0,218142	28,90882	0,000561	0,316882	24,98898	5,32E-19	0,266116	26,62482	0,0002	0,253344	26,07071	0,010229	0,107994	45,33695	0,000200414	0,1571	49,45592	0,0001603	0,167147	37,66178	3,20067E-52	0,137835
21,15556	0,002122	0,348629	20,17778	0,001579	0,208059	28,8497	0,000617	0,314898	24,93788	1,50E-18	0,264747	26,57038	0,00022	0,252485	25,77778	0,011252	0,10669	45,24423	0,00020462	0,155886	49,35478	0,0001764	0,166475	37,58476	5,5903E-51	0,13743
20,91515	0,002315	0,336837	19,94848	0,001722	0,198454	28,79058	0,000673	0,312965	24,88677	3,85E-18	0,263384	26,51593	0,00024	0,251627	25,48485	0,012275	0,105429	45,15152	0,000240511	0,154686	49,25365	0,0001924	0,165805	37,50774	7,61149E-50	0,137026
20,67475	0,002508	0,325345	19,71919	0,001866	0,189307	28,73146	0,000729	0,311081	24,83567	9,19E-18	0,262025	26,46148	0,000261	0,25077	25,19192	0,013298	0,104193	45,05881	0,000260564	0,153498	49,15251	0,0002084	0,165138	37,43072	8,40777E-49	0,136625
20,43434	0,002701	0,314147	19,4899	0,002009	0,1806	28,67234	0,000786	0,309244	24,78457	2,06E-17	0,260671	26,40703	0,000281	0,249914	24,89899	0,014321	0,102968	44,96609	0,000280621	0,152324	49,05137	0,0002245	0,164473	37,3537	7,77218E-48	0,136225
20,19394	0,002894	0,303238	19,26061	0,002153	0,172313	28,61323	0,000842	0,307452	24,73347	4,35E-17	0,25932															

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water	gas	water	gas	water	gas	water	gas	Water	Gas
Kr max: 1,00 alpha: 10,05 H: 0,02 V: 19,16	Kr max: 1,00 alpha: 10,07 H: 0,01 V: 15,45	Kr max: 1,00 alpha: 16,00 H: 0,03 V: 2,00	Kr max: 1,00 alpha: 10,86 H: 0,00 V: 5,75	Kr max: 1,00 alpha: 6,71 H: 0,01 V: 10,52	Kr max: 1,00 alpha: 25,27 H: 0,10 V: 2,00	Kr max: 1,00 alpha: 4,38 H: 0,01 V: 7,05	Kr max: 1,00 alpha: 5,00 H: 0,01 V: 9,50	Kr max: 1,00 alpha: 6,71 H: 0,01 V: 10,52	Kr max: 1,00 alpha: 6,71 H: 0,01 V: 1,14
20,80962 0,008249 0,198226 20,7505 0,008305 0,19765 20,69138 0,008361 0,197075 20,63226 0,008417 0,1965 20,57315 0,008473 0,195926 20,51403 0,008529 0,195352 20,45491 0,008585 0,194778 20,39579 0,008641 0,194205 20,33667 0,008697 0,193632 20,27756 0,008754 0,19306 20,21844 0,008811 0,192488 20,15932 0,008866 0,191916 20,1002 0,008922 0,191345 20,04108 0,008978 0,190774 19,98196 0,009034 0,190203 19,92285 0,00909 0,189633 19,86373 0,009146 0,189063 19,80461 0,009202 0,188493 19,74549 0,009259 0,187924 19,68637 0,009315 0,187355 19,62725 0,009371 0,186786 19,56814 0,009427 0,186217 19,50902 0,009483 0,185649 19,4499 0,009539 0,185081 19,39078 0,009595 0,184513 19,33166 0,009651 0,183945 19,27255 0,009707 0,183377 19,21343 0,009764 0,18281 19,15431 0,00982 0,182243 19,09519 0,009876 0,181676 19,03607 0,009932 0,181109 18,97695 0,009988 0,180543 18,91784 0,010044 0,179977 18,85872 0,0101 0,179491 18,7996 0,010156 0,178844 18,74048 0,010213 0,178278 18,68136 0,010269 0,177713 18,62224 0,010325 0,177147 18,56313 0,010381 0,176582 18,50401 0,010437 0,176016 18,44489 0,010493 0,175451 18,38577 0,010549 0,174886 18,32665 0,010606 0,174321 18,26754 0,010662 0,173756 18,20842 0,010718 0,173192 18,1493 0,010774 0,172627 18,09018 0,01083 0,172062 18,03106 0,010886 0,171498 17,97194 0,010942 0,170934 17,91283 0,010999 0,170369 17,85371 0,011055 0,169805 17,79459 0,011111 0,169241 17,73547 0,011167 0,168677 17,67635 0,011223 0,168113 17,61723 0,011279 0,167549 17,55812 0,011336 0,166986 17,499 0,011392 0,166422 17,43988 0,011448 0,165858 17,38076 0,011504 0,165295 17,32164 0,01156 0,164731 17,26253 0,011617 0,164168 17,20341 0,011673 0,163604 17,14429 0,011729 0,163041 17,08517 0,011785 0,162478 17,02605 0,011842 0,161915 16,96693 0,011893 0,161351 16,90782 0,011954 0,160788 16,8487 0,01201 0,160225 16,78958 0,012067 0,159662 16,73046 0,012123 0,159099 16,67134 0,012179 0,158536 16,61222 0,012236 0,157973 16,55311 0,012292 0,157471 16,49399 0,012348 0,156847	20,80962 0,008249 0,198226 20,7505 0,008305 0,19765 20,69138 0,008361 0,197075 20,63226 0,008417 0,1965 20,57315 0,008473 0,195926 20,51403 0,008529 0,195352 20,45491 0,008585 0,194778 20,39579 0,008641 0,194205 20,33667 0,008697 0,193632 20,27756 0,008754 0,19306 20,21844 0,008811 0,192488 20,15932 0,008866 0,191916 20,1002 0,008922 0,191345 20,04108 0,008978 0,190774 19,98196 0,009034 0,190203 19,92285 0,00909 0,189633 19,86373 0,009146 0,189063 19,80461 0,009202 0,188493 19,74549 0,009259 0,187924 19,68637 0,009315 0,187355 19,62725 0,009371 0,186786 19,56814 0,009427 0,186217 19,50902 0,009483 0,185649 19,4499 0,009539 0,185081 19,39078 0,009595 0,184513 19,33166 0,009651 0,183945 19,27255 0,009707 0,183377 19,21343 0,009764 0,18281 19,15431 0,00982 0,182243 19,09519 0,009876 0,181676 19,03607 0,009932 0,181109 18,97695 0,009988 0,180543 18,91784 0,010044 0,179977 18,85872 0,0101 0,179491 18,7996 0,010156 0,178844 18,74048 0,010213 0,178278 18,68136 0,010269 0,177713 18,62224 0,010325 0,177147 18,56313 0,010381 0,176582 18,50401 0,010437 0,176016 18,44489 0,010493 0,175451 18,38577 0,010549 0,174886 18,32665 0,010606 0,174321 18,26754 0,010662 0,173756 18,20842 0,010718 0,173192 18,1493 0,010774 0,172627 18,09018 0,01083 0,172062 18,03106 0,010886 0,171498 17,97194 0,010942 0,170934 17,91283 0,010999 0,170369 17,85371 0,011055 0,169805 17,79459 0,011111 0,169241 17,73547 0,011167 0,168677 17,67635 0,011223 0,168113 17,61723 0,011279 0,167549 17,55812 0,011336 0,166986 17,499 0,011392 0,166422 17,43988 0,011448 0,165858 17,38076 0,011504 0,165295 17,32164 0,01156 0,164731 17,26253 0,011617 0,164168 17,20341 0,011673 0,163604 17,14429 0,011729 0,163041 17,08517 0,011785 0,162478 17,02605 0,011842 0,161915 16,96693 0,011893 0,161351 16,90782 0,011954 0,160788 16,8487 0,01201 0,160225 16,78958 0,012067 0,159662 16,73046 0,012123 0,159099 16,67134 0,012179 0,158536 16,61222 0,012236 0,157973 16,55311 0,012292 0,157471 16,49399 0,012348 0,156847	20,80962 0,008249 0,198226 20,7505 0,008305 0,19765 20,69138 0,008361 0,197075 20,63226 0,008417 0,1965 20,57315 0,008473 0,195926 20,51403 0,008529 0,195352 20,45491 0,008585 0,194778 20,39579 0,008641 0,194205 20,33667 0,008697 0,193632 20,27756 0,008754 0,19306 20,21844 0,008811 0,192488 20,15932 0,008866 0,191916 20,1002 0,008922 0,191345 20,04108 0,008978 0,190774 19,98196 0,009034 0,190203 19,92285 0,00909 0,189633 19,86373 0,009146 0,189063 19,80461 0,009202 0,188493 19,74549 0,009259 0,187924 19,68637 0,009315 0,187355 19,62725 0,009371 0,186786 19,56814 0,009427 0,186217 19,50902 0,009483 0,185649 19,4499 0,009539 0,185081 19,39078 0,009595 0,184513 19,33166 0,009651 0,183945 19,27255 0,009707 0,183377 19,21343 0,009764 0,18281 19,15431 0,00982 0,182243 19,09519 0,009876 0,181676 19,03607 0,009932 0,181109 18,97695 0,009988 0,180543 18,91784 0,010044 0,179977 18,85872 0,0101 0,179491 18,7996 0,010156 0,178844 18,74048 0,010213 0,178278 18,68136 0,010269 0,177713 18,62224 0,010325 0,177147 18,56313 0,010381 0,176582 18,50401 0,010437 0,176016 18,44489 0,010493 0,175451 18,38577 0,010549 0,174886 18,32665 0,010606 0,174321 18,26754 0,010662 0,173756 18,20842 0,010718 0,173192 18,1493 0,010774 0,172627 18,09018 0,01083 0,172062 18,03106 0,010886 0,171498 17,97194 0,010942 0,170934 17,91283 0,010999 0,170369 17,85371 0,011055 0,169805 17,79459 0,011111 0,169241 17,73547 0,011167 0,168677 17,67635 0,011223 0,168113 17,61723 0,011279 0,167549 17,55812 0,011336 0,166986 17,499 0,011392 0,166422 17,43988 0,011448 0,165858 17,38076 0,011504 0,165295 17,32164 0,01156 0,164731 17,26253 0,011617 0,164168 17,20341 0,011673 0,163604 17,14429 0,011729 0,163041 17,08517 0,011785 0,162478 17,02605 0,011842 0,161915 16,96693 0,011893 0,161351 16,90782 0,011954 0,160788 16,8487 0,01201 0,160225 16,78958 0,012067 0,159662 16,73046 0,012123 0,159099 16,67134 0,012179 0,158536 16,61222 0,012236 0,157973 16,55311 0,012292 0,157471 16,49399 0,012348 0,156847	20,80962 0,008249 0,198226 20,7505 0,008305 0,19765 20,69138 0,008361 0,197075 20,63226 0,008417 0,1965 20,57315 0,008473 0,195926 20,51403 0,008529 0,195352 20,45491 0,008585 0,194778 20,39579 0,008641 0,194205 20,33667 0,008697 0,193632 20,27756 0,008754 0,19306 20,21844 0,008811 0,						

Appendix 1 to HyUSPRe report D4.2

Edlmann, K., Hassanpourouzband, A. (2023): Relative permeability curves for the hydrogen-brine system under drainage and imbibition under reservoir conditions.

Exp No. 1 H2-S1-S(3.5)-P(14.5)		Exp No. 2 H2-S1-S(3.5)-P(1500)		Exp No. 3 H2-S1-S(3.5)-P(3000)		Exp No. 4 H2-S1-S(10)-P(3000)		Exp No. 5 H2-S1-S(20)-P(3000)		Exp No. 6 Carbonate		Exp No. 7 H2-S2-S(3.5)-P(3000)		Exp No. 8 N2-S2		Exp No. 9 CH4-S2				
		water	gas	water	gas	water	gas	water	gas	water	gas	water	gas	water	gas	Water	Gas			
Kr max:	1,00	0,50	Kr max:	1,00	0,35	Kr max:	1,00	0,34	Kr max:	1,00	0,28	Kr max:	1,00	0,26	Kr max:	1,00	0,17	Kr max:	1,00	0,14
alpha:	10,05	2,72	alpha:	10,07	5,60	alpha:	16,00	13,71	alpha:	10,86	7,20	alpha:	6,71	1,71	alpha:	25,27	57,29	alpha:	5,00	3,50
H:	0,02	0,00	H:	0,01	0,21	H:	0,03	0,83	H:	0,00	0,65	H:	0,01	0,07	H:	0,10	0,55	H:	0,01	0,60
V:	19,16	3,11	V:	15,45	4,65	V:	2,00	3,90	V:	5,75	2,50	V:	10,52	1,66	V:	2,00	30,00	V:	7,05	4,00
16,43487	0,012405	0,156285	14,20641	0,000212	0,103227	15,1364	0,00619	0,099837	25,77438	0,015443205	0,046237	28,11605	0,0052648	0,067146	21,41099	7,08684E-12	0,080548			
16,37575	0,012461	0,155722	14,15531	0,000223	0,102816	15,08196	0,006265	0,099249	25,68167	0,015693237	0,046017	28,01491	0,0053263	0,066824	21,33397	8,11509E-12	0,080342			
16,31663	0,012518	0,155159	14,10421	0,000234	0,102405	15,02751	0,006341	0,098663	25,58895	0,015947199	0,045799	27,91377	0,0053889	0,066503	21,25695	9,28688E-12	0,080136			
16,25752	0,012574	0,154596	14,05311	0,000245	0,101996	14,97306	0,006418	0,098079	25,49624	0,016205147	0,045581	27,81263	0,0054527	0,066183	21,17994	1,06214E-11	0,07993			
16,1984	0,012631	0,154034	14,002	0,000258	0,101587	14,91861	0,006497	0,097496	25,40352	0,01646714	0,045365	27,71115	0,0055175	0,065864	21,10292	1,21405E-11	0,079723			
16,13928	0,012687	0,153471	13,9509	0,00027	0,10118	14,86417	0,006578	0,096914	25,31081	0,016733234	0,045149	27,61036	0,0055836	0,065547	21,0259	1,38687E-11	0,079517			
16,08016	0,012744	0,152908	13,8998	0,000283	0,100773	14,80972	0,00666	0,096334	25,2181	0,017003488	0,044935	27,50922	0,0056509	0,06523	20,94888	1,58335E-11	0,079311			
16,02104	0,0128	0,152346	13,8487	0,000297	0,100368	14,75527	0,006743	0,095755	25,12538	0,017277963	0,044721	27,40809	0,0057195	0,064914	20,87186	1,80661E-11	0,079105			
15,96192	0,012857	0,151783	13,7976	0,000312	0,099963	14,70082	0,006829	0,095178	25,03267	0,017556719	0,044508	27,30695	0,0057893	0,064599	20,79485	2,06017E-11	0,078898			
15,90281	0,012913	0,15122	13,74649	0,000327	0,099559	14,64638	0,006916	0,094602	24,93996	0,017839817	0,044296	27,20581	0,0058604	0,064285	20,71783	2,34797E-11	0,078692			
15,84369	0,01297	0,150658	13,69539	0,000343	0,099156	14,59193	0,007004	0,094028	24,84724	0,018127319	0,044086	27,10468	0,0059329	0,063972	20,64081	2,67446E-11	0,078485			
15,78457	0,013027	0,150095	13,64429	0,000359	0,098754	14,53748	0,007095	0,093454	24,75453	0,018419289	0,043875	27,00354	0,0060068	0,06366	20,56379	3,04463E-11	0,078279			
15,72545	0,013083	0,149533	13,59319	0,000376	0,098353	14,48303	0,007187	0,092883	24,66182	0,01871579	0,043666	26,9024	0,006082	0,063349	20,48677	3,46411E-11	0,078072			
15,66633	0,01314	0,14897	13,54208	0,000394	0,097953	14,42859	0,007281	0,092312	24,5691	0,019016888	0,043458	26,80127	0,0061587	0,063039	20,40976	3,93921E-11	0,077866			
15,60721	0,013197	0,148408	13,49098	0,000413	0,097553	14,37414	0,007377	0,091744	24,47639	0,019322648	0,043251	26,70013	0,0062369	0,06273	20,33274	4,477E-11	0,077659			
15,5481	0,013254	0,147845	13,43988	0,000432	0,097154	14,31969	0,007475	0,091176	24,38367	0,019633136	0,043044	26,59899	0,0063166	0,062422	20,25572	5,08546E-11	0,077452			
15,48898	0,013311	0,147283	13,38878	0,000453	0,096756	14,26524	0,007575	0,09061	24,29096	0,019948422	0,042838	26,49786	0,0063978	0,062115	20,1787	5,77349E-11	0,077245			
15,42986	0,01336	0,14672	13,33768	0,000474	0,096359	14,2108	0,007676	0,090046	24,19825	0,020268572	0,042634	26,39672	0,0064806	0,061809	20,10168	6,55111E-11	0,077038			
15,37074	0,013425	0,146158	13,28657	0,000496	0,095963	14,15635	0,00778	0,089483	24,10553	0,020593658	0,042429	26,29558	0,0065656	0,061503	20,02467	7,42954E-11	0,076831			
15,31162	0,013482	0,145596	13,23547	0,000519	0,095567	14,1019	0,007886	0,088921	24,01282	0,020923749	0,042226	26,19444	0,0066511	0,061199	19,94765	8,42132E-11	0,076624			
15,25251	0,013539	0,145033	13,18437	0,000543	0,095172	14,04745	0,007994	0,088361	23,92011	0,021258918	0,042024	26,09331	0,0067389	0,060895	19,87063	9,54052E-11	0,076417			
15,19339	0,013596	0,144471	13,13327	0,000568	0,094778	13,99301	0,008104	0,087802	23,82739	0,021599236	0,041822	25,99217	0,0068285	0,060593	19,79361	1,08029E-10	0,076209			
15,13427	0,013653	0,143908	13,08216	0,000594	0,094384	13,93856	0,008217	0,087245	23,73468	0,021944779	0,041621	25,89103	0,0069198	0,060291	19,71659	1,2226E-10	0,076002			
15,07515	0,013711	0,143346	13,03106	0,000621	0,093992	13,88411	0,008331	0,086689	23,64197	0,02229562	0,041421	25,7899	0,007013	0,05999	19,63958	1,38296E-10	0,075794			

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Edlmann, K., Hassanpourouzband, A. (2023): Relative permeability curves for the hydrogen-brine system under drainage and imbibition under reservoir conditions.

Exp No. 1 H2-S1-S(3.5)-P(14.5)	Exp No. 2 H2-S1-S(3.5)-P(1500)	Exp No. 3 H2-S1-S(3.5)-P(3000)	Exp No. 4 H2-S1-S(10)-P(3000)	Exp No. 5 H2-S1-S(20)-P(3000)	Exp No. 6 Carbonate	Exp No. 7 H2-S2-S(3.5)-P(3000)	Exp No. 8 N2-S2	Exp No. 9 CH4-S2									
water	gas	water	gas	water	gas	water	gas	Water	Gas								
Kr max:	1,00	0,50	Kr max:	1,00	0,35	Kr max:	1,00	0,22	Kr max:	1,00	0,17	Kr max:	1,00	0,14			
alpha:	10,05	2,72	alpha:	10,07	5,60	alpha:	6,71	1,71	alpha:	4,38	5,02	alpha:	5,00	3,50			
H:	0,02	0,00	H:	0,01	0,21	H:	0,01	0,07	H:	0,01	0,45	H:	0,01	1,60			
V:	19,16	3,11	V:	15,45	4,65	V:	2,00	3,90	V:	2,00	30,00	V:	9,50	2,00			
12,06012	0,016958	0,114674	10,42485	0,004874	0,074603	11,10729	0,018569	0,060289	18,91357	0,049370291	0,032027	20,63192	0,0156372	0,045721	15,71166	4,11718E-08	0,064834
12,001	0,017037	0,114111	10,37375	0,005057	0,074231	11,05284	0,018892	0,059811	18,82086	0,050132903	0,031855	20,53078	0,0159214	0,04546	15,63464	4,55727E-08	0,064609
11,94188	0,017117	0,113549	10,32265	0,005245	0,07386	10,99839	0,019221	0,059334	18,72815	0,050096846	0,031684	20,42964	0,0162121	0,0452	15,55763	5,04269E-08	0,064383
11,88277	0,017198	0,112987	10,27154	0,005544	0,073489	10,94395	0,019556	0,058858	18,63543	0,051692284	0,031513	20,32851	0,0165093	0,04494	15,48061	5,5779E-08	0,064157
11,82365	0,01728	0,112425	10,22044	0,005641	0,073118	10,8895	0,019898	0,058385	18,54272	0,052489385	0,031342	20,22737	0,0168134	0,044681	15,40359	6,16784E-08	0,06393
11,76453	0,017364	0,111863	10,16934	0,005849	0,072747	10,83505	0,020247	0,057912	18,45	0,053298321	0,031172	20,12623	0,0171243	0,04422	15,32657	6,81789E-08	0,063703
11,70541	0,017449	0,111301	10,11824	0,006064	0,072376	10,7806	0,020603	0,057442	18,35729	0,054119263	0,031002	20,0251	0,0174424	0,044164	15,24955	7,53393E-08	0,063475
11,64629	0,017536	0,110739	10,06713	0,006286	0,072006	10,72616	0,020966	0,056972	18,26458	0,054952388	0,030832	19,92396	0,0177677	0,043907	15,17254	8,32242E-08	0,063247
11,58717	0,017624	0,110176	10,01603	0,006516	0,071635	10,67171	0,021336	0,056505	18,17186	0,055797873	0,030663	19,82282	0,0181004	0,04365	15,09552	9,1904E-08	0,063018
11,52806	0,017714	0,109614	9,96493	0,006753	0,071265	10,61726	0,021714	0,056039	18,07915	0,0566559	0,030494	19,72169	0,0184407	0,043394	15,0185	1,01456E-07	0,062788
11,46894	0,017805	0,109052	9,913828	0,006997	0,070895	10,56281	0,022099	0,055574	17,98644	0,057526651	0,030326	19,62055	0,0187887	0,043139	14,94148	1,11964E-07	0,062558
11,40982	0,017898	0,10849	9,862725	0,00725	0,070526	10,50837	0,022491	0,055111	17,89372	0,058410312	0,030157	19,51941	0,0191448	0,042884	14,86446	1,23521E-07	0,062328
11,3507	0,017993	0,107928	9,811623	0,007511	0,070156	10,45392	0,022892	0,05465	17,80101	0,059307074	0,029989	19,41828	0,0195089	0,042629	14,78745	1,36227E-07	0,062096
11,29158	0,01809	0,107366	9,760521	0,007783	0,06978	10,39947	0,023301	0,05419	17,7083	0,060217127	0,029822	19,31714	0,0198814	0,042375	14,71043	1,50193E-07	0,061865
11,23246	0,01819	0,106804	9,709419	0,008059	0,069417	10,34502	0,023717	0,053732	17,61558	0,061140666	0,029654	19,216	0,0202624	0,042122	14,63341	1,65537E-07	0,061632
11,17335	0,018291	0,106242	9,658317	0,008346	0,069048	10,29058	0,024142	0,053275	17,52287	0,062077889	0,029487	19,11487	0,0206522	0,04187	14,55639	1,82392E-07	0,061399
11,11423	0,018394	0,105679	9,607214	0,008643	0,068679	10,23613	0,024575	0,05282	17,43016	0,063028996	0,02932	19,01373	0,0210508	0,041618	14,47937	2,009E-07	0,061166
11,05511	0,0185	0,105117	9,556112	0,008849	0,06831	10,18168	0,025017	0,052366	17,33744	0,06399419	0,029154	18,91250	0,0214586	0,041366	14,40236	2,21218E-07	0,060931
10,99599	0,018608	0,104555	9,50501	0,009265	0,067941	10,12723	0,025468	0,051914	17,24473	0,064973678	0,028987	18,81145	0,0218757	0,041115	14,32534	2,43516E-07	0,060697
10,93687	0,018719	0,103993	9,453908	0,009591	0,067573	10,07279	0,025928	0,051464	17,15201	0,065967669	0,028822	18,71032	0,0223023	0,040865	14,24832	2,67979E-07	0,060461
10,87776	0,018833	0,103431	9,402806	0,009927	0,067204	10,01834	0,026397	0,051015	17,0593	0,066976377	0,028656	18,60918	0,0227388	0,040615	14,1713	2,9481E-07	0,060225
10,81864	0,018949	0,102869	9,351703	0,010274	0,066836	9,963891	0,026875	0,050568	16,96659	0,068000016	0,02849	18,50804	0,0231852	0,040366	14,09428	3,24229E-07	0,059988
10,75952	0,019068	0,102307	9,300601	0,010632	0,066468	9,909444	0,027362	0,050122	16,87387	0,069038807	0,028235	18,40691	0,0236418	0,040117	14,01727	3,56476E-07	0,059751
10,7004	0,019191	0,101745	9,249499	0,011001	0,06661	9,854996	0,02786	0,049678	16,78116	0,07009297	0,02816	18,30577	0,0241089	0,039869	13,94025	3,91814E-07	0,059513
10,64128	0,019136	0,101182	9,198397	0,011381	0,065732	9,800549	0,028367	0,049236	16,68845	0,071162731	0,027996	18,20463	0,0245866	0,039621	13,86323	4,30527E-07	0,059274
10,58216	0,019445	0,100662	9,147295	0,011774	0,065364	9,746101	0,028884	0,048795	16,59573	0,07224832	0,027831	18,1035	0,0250754	0,039374	13,78621	4,72926E-07	0,059035
10,52305	0,019577</td																

Appendix 1 to HyUSPRe report D4.2

Edlmann, K., Hassanpourouzband, A. (2023): Relative permeability curves for the hydrogen-brine system under drainage and imbibition under reservoir conditions.

Exp No. 1 H2-S1-S(3,5)-P(14,5)		Exp No. 2 H2-S1-S(3,5)-P(1500)		Exp No. 3 H2-S1-S(3,5)-P(3000)		Exp No. 4 H2-S1-S(10)-P(3000)		Exp No. 5 H2-S1-S(20)-P(3000)		Exp No. 6 Carbonate		Exp No. 7 H2-S2-S(3,5)-P(3000)		Exp No. 8 N2-S2		Exp No. 9 CH4-S2				
water	gas	water	gas	water	gas	water	gas	water	gas	water	gas	water	gas	water	gas	Water	Gas			
Kr max:	1,00	0,50	Kr max:	1,00	0,35	Kr max:	1,00	0,34	Kr max:	1,00	0,28	Kr max:	1,00	0,26	Kr max:	1,00	0,17	Kr max:	1,00	0,14
alpha:	10,05	2,72	alpha:	10,07	5,60	alpha:	16,00	13,71	alpha:	10,86	7,20	alpha:	6,71	1,71	alpha:	25,27	57,29	alpha:	5,00	3,50
H:	0,02	0,00	H:	0,01	0,21	H:	0,03	0,83	H:	0,00	0,65	H:	0,01	0,07	H:	0,10	0,55	H:	0,01	0,60
V:	19,16	3,11	V:	15,45	4,65	V:	2,00	3,90	V:	5,75	2,50	V:	10,52	1,66	V:	2,00	30,00	V:	7,05	4,00
7,685371	0,035208	0,073076	6,643287	0,054794	0,047423	7,078174	0,072028	0,029209	12,05277	0,15064545	0,020008	13,14779	0,0691615	0,027827	10,01233	3,40271E-05	0,046375			
7,626253	0,035903	0,072514	6,592184	0,056408	0,047057	7,023727	0,07342	0,028852	11,96005	0,15290318	0,019852	13,04665	0,0706512	0,027601	9,935315	3,69069E-05	0,046095			
7,567134	0,036625	0,071952	6,541082	0,058064	0,046692	6,969279	0,07484	0,028497	11,86734	0,155194096	0,019695	12,94552	0,0721736	0,027375	9,858297	4,00218E-05	0,045814			
7,508016	0,037374	0,07139	6,48998	0,059764	0,046327	6,914832	0,076289	0,028143	11,77463	0,15751868	0,019539	12,84438	0,0737295	0,02715	9,781279	4,33901E-05	0,045532			
7,448898	0,038151	0,070828	6,438878	0,061508	0,045962	6,860384	0,077767	0,027791	11,68191	0,15987742	0,019383	12,74324	0,0753194	0,026925	9,704261	4,70319E-05	0,044966			
7,38978	0,038957	0,070266	6,387776	0,063297	0,045597	6,805937	0,079276	0,027441	11,5892	0,16227081	0,019227	12,64211	0,0769441	0,0267	9,627243	5,09684E-05	0,044966			
7,330661	0,039794	0,069703	6,336673	0,065132	0,045232	6,751489	0,080815	0,027092	11,49649	0,16469935	0,019072	12,54097	0,0786044	0,026475	9,550225	5,52228E-05	0,044681			
7,271543	0,040662	0,069141	6,285571	0,067014	0,044867	6,697042	0,082385	0,026746	11,40377	0,16716355	0,018916	12,43983	0,0803009	0,026251	9,473207	5,98196E-05	0,044396			
7,212425	0,041563	0,068579	6,234469	0,068945	0,044502	6,642594	0,083988	0,026401	11,31106	0,169663925	0,01876	12,3387	0,0820344	0,026028	9,39619	6,47856E-05	0,044109			
7,153307	0,042498	0,068017	6,183367	0,070925	0,044137	6,588147	0,085623	0,026058	11,21834	0,172200996	0,018605	12,23756	0,0838056	0,025804	9,319172	7,01492E-05	0,044109			
7,094188	0,043468	0,067455	6,132265	0,072956	0,043772	6,533699	0,087291	0,025717	11,12563	0,174775294	0,018449	12,13642	0,0856154	0,025581	9,242154	7,59412E-05	0,043533			
7,03507	0,044474	0,066893	6,081162	0,075038	0,043407	6,479252	0,088994	0,025377	11,03292	0,177387355	0,018294	12,03529	0,0874644	0,025358	9,165136	8,21945E-05	0,043243			
6,975952	0,045518	0,066331	6,03006	0,071713	0,043042	6,424804	0,090732	0,02504	10,9402	0,180037723	0,018138	11,93415	0,0893536	0,025135	9,088118	8,89447E-05	0,042952			
6,916834	0,046602	0,065769	5,978958	0,079361	0,042677	6,370357	0,092505	0,024704	10,84749	0,182726951	0,017983	11,83301	0,0912836	0,024913	9,0111	9,62297E-05	0,04266			
6,857715	0,047726	0,065206	5,927856	0,081605	0,042312	6,315909	0,094314	0,02437	10,75478	0,185455596	0,017828	11,73187	0,0932554	0,024691	8,934082	0,000104091	0,042368			
6,798597	0,048891	0,064644	5,876754	0,083904	0,041947	6,261462	0,09616	0,024037	10,66206	0,188224227	0,017672	11,63074	0,0952697	0,024469	8,857064	0,00012571	0,042074			
6,739479	0,050101	0,064082	5,825651	0,086261	0,041582	6,207014	0,098045	0,023707	10,56935	0,191033417	0,017517	11,5296	0,0973275	0,024248	8,780046	0,000121718	0,041779			
6,680361	0,051355	0,063552	5,774549	0,088676	0,041217	6,152567	0,099968	0,023378	10,47664	0,19388375	0,017362	11,42846	0,0994295	0,024026	8,703028	0,000131583	0,041483			
6,621242	0,052656	0,062958	5,723447	0,091151	0,040852	6,098119	0,10193	0,023052	10,38392	0,196775816	0,017207	11,32733	0,1015767	0,023805	8,62601	0,00014222	0,041186			
6,562124	0,054006	0,062396	5,672345	0,093687	0,040408	6,043672	0,103934	0,022727	10,29121	0,199710212	0,017052	11,22619	0,1037701	0,023585	8,548992	0,000153686	0,040889			
6,503006	0,055405	0,061834	5,621242	0,096285	0,040123	5,989224	0,105978	0,022404	10,1985	0,202687546	0,016897	11,12505	0,1060104	0,023364	8,471974	0,000166045	0,04059			
6,443888	0,056857	0,061272	5,570104	0,098946	0,039758	5,934777	0,108064	0,022082	10,10578	0,205708433	0,016743	11,02392	0,1082987	0,023144	8,394956	0,000179364	0,04029			
6,384777	0,058362	0,060709	5,519038	0,101672	0,039393	5,880329	0,110194	0,021763	10,01307	0,208773494	0,016588	10,992278	0,1106359	0,022924	8,317938	0,000193715	0,039988			
6,325651	0,059922	0,060147	5,467936	0,104463	0,039028	5,825882	0,112367	0,021445	9,920354	0,211883363	0,016433	10,82164	0,1130229	0,022704	8,240992	0,000209174	0,039686			
6,266553	0,06154	0,059585	5,416834	0,1073																

Appendix 1 to HyUSPRe report D4.2

Edlmann, K., Hassanpourouzband, A. (2023): Relative permeability curves for the hydrogen-brine system under drainage and imbibition under reservoir conditions.

Exp No. 1 H2-S1-S(3.5)-P(14.5)		Exp No. 2 H2-S1-S(3.5)-P(1500)		Exp No. 3 H2-S1-S(3.5)-P(3000)		Exp No. 4 H2-S1-S(10)-P(3000)		Exp No. 5 H2-S1-S(20)-P(3000)		Exp No. 6 Carbonate		Exp No. 7 H2-S2-S(3.5)-P(3000)		Exp No. 8 N2-S2		Exp No. 9 CH4-S2																	
water	gas	water	gas	water	gas	water	gas	water	gas	water	gas	water	gas	water	gas	Water	Gas																
Kr max:	1,00	0,50	Kr max:	1,00	0,35	Kr max:	1,00	0,34	Kr max:	1,00	0,28	Kr max:	1,00	0,26	Kr max:	1,00	0,22	Kr max:	1,00	0,17													
alpha:	10,05	2,72	alpha:	10,07	5,60	alpha:	16,00	13,71	alpha:	10,86	7,20	alpha:	6,71	1,71	alpha:	25,27	57,29	alpha:	4,38	5,02													
H:	0,02	0,00	H:	0,01	0,21	H:	0,03	0,83	H:	0,00	0,65	H:	0,01	0,07	H:	0,10	0,55	H:	0,01	0,45													
V:	19,16	3,11	V:	15,45	4,65	V:	2,00	3,90	V:	5,75	2,50	V:	10,52	1,66	V:	2,00	30,00	V:	7,05	4,00													
3,310621 0,277126 0,031479		2,861723 0,36823 0,020425		3,04906 0,311644 0,007846		5,191961 0,44773536 0,008586		5,663664 0,3299534 0,011749		4,313005 0,008758843 0,022736		3,251503 0,285733 0,030917		2,810621 0,376457 0,02006		5,099248 0,454292009 0,008433		5,562527 0,3367905 0,011538		4,235987 0,009413892 0,022371													
3,192385 0,29458 0,030355		2,759519 0,384824 0,019695		2,940165 0,324664 0,007424		5,006534 0,460941969 0,00828		5,46139 0,3437611 0,011327		4,158969 0,01019215 0,022004		3,133267 0,303671 0,029793		2,708417 0,393332 0,019331		4,91382 0,467686502 0,008126		5,360253 0,3508677 0,011116		4,081951 0,010878936 0,021637													
3,074148 0,313011 0,02923		2,657315 0,40198 0,018966		2,885717 0,331385 0,007216		2,83127 0,338251 0,00701		4,821107 0,474526885 0,007973		5,259116 0,3581126 0,010905		4,004933 0,01169756 0,021268		3,01503 0,322601 0,028668		2,606212 0,41077 0,018601		4,728393 0,481464414 0,007819		5,15798 0,3654983 0,010694		3,927915 0,012580005 0,020897											
2,955912 0,332447 0,028106		2,55511 0,419701 0,018236		2,722375 0,352428 0,006606		4,63568 0,488500398 0,007666		5,056843 0,3730272 0,010483		3,850897 0,01353165 0,020525		2,896794 0,34255 0,027544		2,504008 0,428775 0,017872		4,542966 0,495636163 0,007513		3,773879 0,014558382 0,020152		2,837675 0,352914 0,026982		2,452906 0,437991 0,017507		4,450252 0,502873052 0,007359		4,854569 0,388525 0,010062		3,696861 0,01566647 0,019777					
2,778557 0,3635451 0,02642		2,401804 0,447349 0,017142		2,559032 0,374859 0,006017		4,357539 0,510212423 0,007206		4,753432 0,3964991 0,009851		3,619844 0,016863515 0,019401		2,719439 0,374433 0,025858		2,350701 0,45685 0,016778		4,264825 0,517655651 0,007053		3,542826 0,018156742 0,019024		2,6660321 0,385593 0,025296		2,299599 0,466493 0,016413		4,172112 0,525204129 0,006899		3,465808 0,019554848 0,018645							
2,601202 0,397022 0,024733		2,248497 0,476278 0,016048		2,39569 0,398772 0,005449		4,079398 0,532859265 0,006746		3,445002 0,4213535 0,00922		3,38879 0,021067198 0,018265		2,542084 0,40872 0,024171		2,197395 0,486204 0,015683		2,341242 0,407089 0,005265		3,986684 0,540622486 0,006592		3,311772 0,022704096 0,017883		2,482966 0,420689 0,023609		2,146293 0,496271 0,015319		2,232347 0,424266 0,004903		3,893971 0,548495234 0,006439		3,247454 0,024476891 0,024754			
2,423848 0,432929 0,023047		2,09519 0,506477 0,014954		2,232347 0,424266 0,004903		3,801257 0,55647897 0,006286		4,146611 0,4476641 0,008589		3,157736 0,026398089 0,017116		2,364729 0,445438 0,022485		2,044088 0,516823 0,014589		3,708544 0,564575173 0,006132		3,080718 0,028481485 0,01673		2,030742312 0,016342		2,050911 0,498146 0,019674		1,788577 0,570592 0,012766		1,905662 0,48043 0,003877		3,244976 0,606796184 0,005366		2,695628 0,041924392 0,014778			
2,01002 0,526058 0,019112		1,737475 0,581741 0,012401		1,851215 0,490512 0,003715		3,152262 0,615599241 0,005213		3,438653 0,5151574 0,007119		2,61861 0,045363557 0,014383		1,891784 0,554954 0,017988		1,635271 0,604418 0,011671		1,74232 0,511333 0,003399		2,337689 0,598114844 0,005519		2,640927 0,4949616 0,007539		2,772646 0,038766742 0,015171		1,832665 0,569752 0,017426		1,584168 0,61594 0,011307		1,687872 0,522082 0,003245		2,874121 0,642754876 0,004753		2,387556 0,057665988 0,01319	
1,773547 0,584771 0,016864		1,533066 0,627581 0,010942		1,633425 0,533065 0,003093		2,781408 0,652061061 0,004599		3,034106 0,5578777 0,00628		2,310538 0,062543881 0,012789																							