Results and status of three Danish projects with hydrogen

HIPS-NET meeting june 2015

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Content

Danish projects

- Renewable Energy Storage for the Future(DGC)
- Field test of hydrogen in the natural gas grid (DGC)
- Energy Storage – Hydrogen injected into the Gas Grid via electrolysis field test (Energinet.dk)

Renewable Energy Storage for the Future

Analyse of the potential of H2 injection in the DK natural grid and and technical barriers

The project purpose is to define and demonstrate the extent to which the Danish gas distribution system can be used as infrastructure and energy storage for an energy system - fully or partly - based on hydrogen.
Both practical and theoretical considerations are included in the assessment and the economic consequences of a grid conversion from natural gas into hydrogen are compared to a shift from natural gas into renewable energy via electricity and biomass.

Both gas transportation and gas end use are included in the project.

The project is executed in cooperation between DGC, the natural gas distribution companies HMN, DONG Energy and Natural Fyn and the TSO Energinet.dk.

The project is supported (40%) by the Danish research programme EUDP

The project is divided into three phases:

Phase I: Gas system and gas appliance's suitability for hydrogen
Phase II: Design of demonstration project (small grid system)
Phase III: Demonstration of the operation of gas networks with hydrogen

Phase I & II are currently under development.
Phase III was planned to be executed at the end of Phase II, but will not be started at the moment due to the costs involved.

Project structure Phase 1

Phase I: the gas system and the gas appliance's suitability for hydrogen

WP1.1 Review and categorization of materials and components in the Danish gas distribution system.
WP1.2 Review and categorization of domestic gas appliances & commercial, industrial and transport sector.
WP1.3 Safety critical parameters of hydrogen and NG mixtures
WP1.4 Identification of critical components and appliances, which - at a given % hydrogen in natural gas - must either be replaced, adjusted and / or tested and approved before a demonstration.
WP1.5 Regulatory requirements related to hydrogen addition to natural gas system
WP1.6 Assessment of technical and economic feasibility of the conversion of the gas system for operation respectively. 2%, 10% and 100% hydrogen.

Project structure. Phase2

Phase II: Design of demonstration project

WP2.1 Selection of a site

WP2.2 Analysis of the system and gas appliances incl. installation for safety & technical trouble-free operation.

WP2.3 Test Program for the network (leak) and appliances (inspection)

WP2.4 Defining possible lab-testing of critical components and equipment in operation with hydrogen-NG mixtures

WP2.5 Design of the mixing station and the control and monitoring of the gas composition

WP2.6 Establishment of the demonstration program (hydrogen% and control).

WP2.7 Agreements and requirements for safety monitoring

WP2.8 Establishment of legal and business relationship between the distribution company, clients and other stakeholders

WP2.9 Budget and application demonstration project.

Few selected results

(more extended results will be presented once the reports are published)

WP1.1 Review and categorization of materials and components in the Danish gas distribution system.

Arttype	Art	Varenummer	Varebetegnelse
Komponent	MR komponenter	458	Ventiler,kugleventil m. flanger,ANSI 150
Komponent	MR komponenter	459	Ventiler,kugleventil m. flanger,ANSI 300
Komponent	MR komponenter	461	Ventiler,kugleventil m. flanger,ANSI 300
Komponent	MR komponenter	463	Afblæsningsventil, 4 bar
Komponent	MR komponenter	479	Sikkerhedsafspærringsventil, ANSI 300 4"
Komponent	MR komponenter	480	Sikkerhedsafspærringsventil ANSI 150
Komponent	MR komponenter	481	Sikkerhedsafspærringsventil DN 80
Komponent	MR komponenter	482	Sikkerhedsafspæringsventil DN 100
Komponent	MR komponenter	488	Pilotventil type ZSC 2002
Komponent	MR komponenter	490	Regulator axial flow m. Z/ZSC piloter
Komponent	MR komponenter	492	Regulator axial flow m. piloter ANSI 300
Komponent	MR komponenter	493	Regulator axial flow ANSI 300, DN 100
Komponent	MR komponenter	554	Regulatorer, Direxi 200, DN 50
Komponent	MR komponenter	789	Filter 2" med flanger
Komponent	MR komponenter	916	Kuglehane, u/filter, m/flanger PN 10
Komponent	MR komponenter	920	Butterflyventil flangeindspænding
Komponent	Ventiler	1963	Kugleventil,3",m.fl.CL300,full bore
Komponent	Ventiler	1964	Kugleventil,4",m.fl.CL300,full bore
Komponent	Ventiler	1966	Kugleventil,6",m.fl.CL150,full bore
Komponent	Ventiler	1967	Kugleventil,8",m.fl.CL150,full bore
Komponent	MR komponenter	1970	Pilot type RP-MD (styrepilot)
Komponent	MR komponenter	1974	Måler, turbine, Qmax.2500 MZ200,m.NF10
Komponent	MR komponenter	2127	Pilot type RV-MD (fortrykpilot)
Komponent	MR komponenter	2145	Sikkerhedsafbl.FIORIENTINI,VS/AM 56
Element	Trykbeholder	2156	Filter,3",CL300 5.000Nm3/h m.patron
Element	Trykbeholder	2159	Filter,4",CL300,10.000Nm3/h m.patron
Element	Trykbeholder	2160	Forvarmer,4"/3",CL300 10.000-FAM GRIESER
Komponent	MR komponenter	2163	Regulator DN80/54,RR100 m.switch, cl300
Komponent	MR komponenter	2240	Manometer,0 - 6bar,1/2" BSP, nedad
Komponent	MR komponenter	2241	Manometer,0-60bar,1/2" BSP, nedad
Komponent	MR komponenter	2244	Regulator 2" m.SAV Fiorentini reflux
Komponent	MR komponenter	2305	Differenstrykmanometer, Wika, 0-2,5 bar

WP1.2 Review and categorization of domestic gas appliances & commercial, industrial and transport sector.

Tabel 3 Opdeling af gasapparater på forskellige typer efter anvendelse og indreguleringsprincip (Danmark)

Hoved-gruppe	Betegnelse	Under-gruppe	Karakteristika	Indregulering og bemærkninger	Antal
1	Gasblæseluftbrændere	A	<120 kW	Gas/luft forhold	28559
		B	>120 kW (med Driftpersonale)	Gas/luft forhold	15824
2	Gaskedel og forrådsvandvarmere	C	Gulvkedel og forrådsvandvarmer	Dysetryk (atmosfærisk brænder)	2804
		C/D			280
		D	Gulvkedel og forrådsvandvarmer	Dysetryk (atmosfærisk brænder)	3713
		E	Gennemstrømningskedel	Dysetryk (atmosfærisk brænder)	15699
		E/F			1853
		F	Gennemstrømningskede l	Dysetryk (atmosfærisk brænder)	94587
		G	Gennemstrømningskedel	Gas/luft forhold	38847
		H	Gennemstrømningskedel	Gas/luft forhold	14490
		I	Kondenserende kedel	Dysetryk premix	4572
		K	Kondenserende kedel	Gas/luft forhold	132118
		L	Kondenserende kedel	Automatisk gas/luft styring (scot)	61026
3	Gasradiatorer/pejse	M	Gasradiatorer/pejse	Dysetryk (atmosfærisk brænder)	1371
		N	Gasradiatorer/pejse	Dysetryk (atmosfærisk brænder)	558

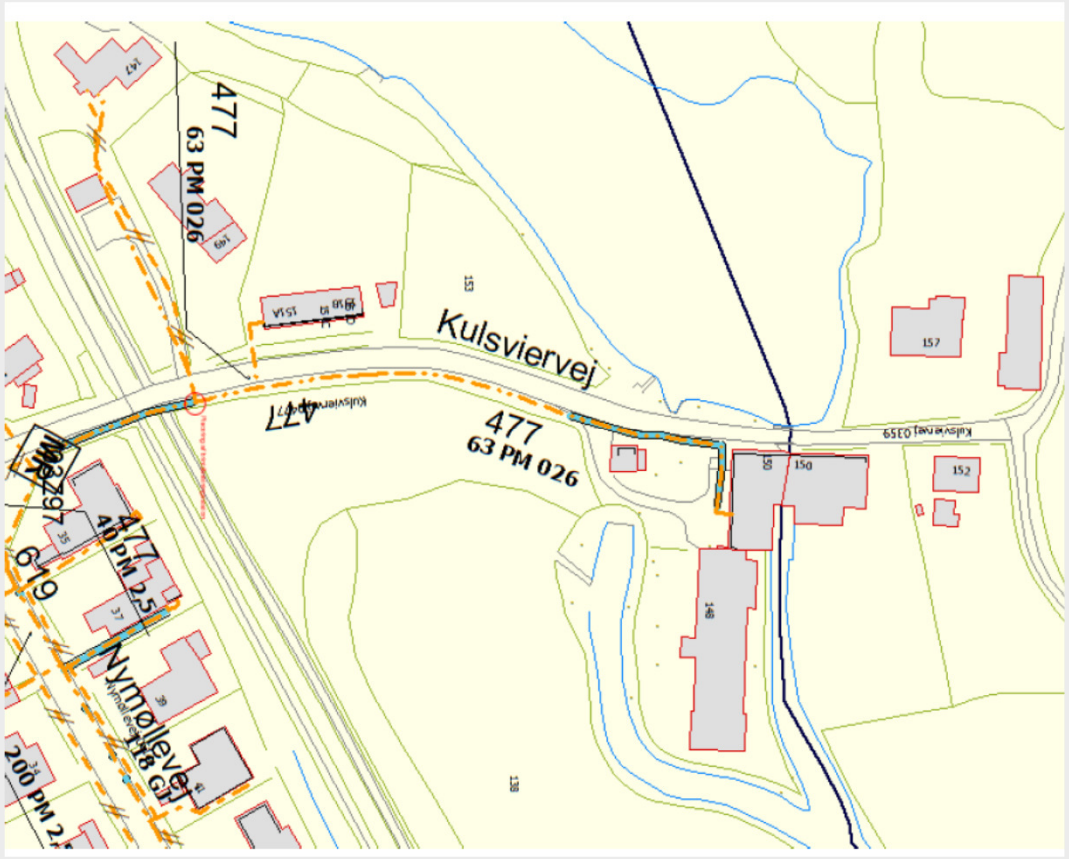
Hoved-gruppe	Betegnelse	Under-gruppe	Karakteristika	Indregulering og bemærkninger	Antal
4	Kaloriefere/strålerør	O	Kaloriefere/strålerør	Dysetryk (atmosfærisk brænder)	2222
		P	Kaloriefere/strålerør	Dysetryk (atmosfærisk brænder)	1057
		Q	Kaloriefere/strålerør	Gas/luft forhold	2797
		R	Kaloriefere/strålerør	Gas/luft forhold	4948
5	Køkkenudstyr husholdning	S	Komfurbrændere og grill	Dysetryk (atmosfærisk brænder)	45070
		T	Gasovn	Dysetryk (atmosfærisk brænder)	5
6	Storkøkken udstyr	U	Komfurbrændere	Dysetryk (atmosfærisk brænder)	2535
		V	Grillbrændere	Dysetryk (atmosfærisk brænder)	7
		W	Gasovn	Dysetryk (atmosfærisk brænder)	2
		X	Gasovn	Dysetryk (atmosfærisk brænder)	81
7	Vaskeriudstyr	Y	Tørretumblere	Dysetryk (atmosfærisk brænder)	2098
		Z	Vandopvarmning (Damp/hedvand)	Dysetryk (atmosfærisk brænder)	11
8	Proces	Æ	Højtemperaturovne	Gas/luft forhold	189
		Ø	Tørreovne(lavtemperatur)	Gas/luft forhold	793
		Å	Håndværktøj	Dysetryk (atmosfærisk brænder)	35
		ÅÅ	Diverse åbne brændersystemer	Dysetryk (atmosfærisk brænder)	2252
9	Special komponenter og diverse	YY	-	Bundsenbrændere og fakler	198
10	Gasmotorer	MT	Alle gasmotorer	pr indgang i energiproducenttælling	495
11	Gasturbiner	TU	Alle gasturbiner	pr indgang i energiproducenttælling	30
12	Ukendt type	ZZ	-	ukendt	1323

WP1.4 Identification of critical components and appliances

Certain batches of electrofusion fittings are leaking with hydrogen, and would need a replacement.

No test have been carried out with appliances. We rely on DGC previous tests (boilers; cookers) from NATURALHY & HIPs project results and further investigations (DOMHYDRO, etc.)

WP2.1 Selection of a site



Several adapted sites that can be isolated from the main grid have been identified.
Details on the appliances (type/ number etc.) installed have also be gathered.

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Field test of hydrogen in the natural gas grid

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Project goals

- *The purpose* of this project was to reveal the possibilities of transport of hydrogen via the existing Danish natural gas grid. The investigation only covers the distribution grid. For this purpose, a standalone "miniature gas grid" was built**.** That means:
- Testing used materials, components and connections from the natural gas distribution grid by exposing them to pure hydrogen for at least one year.
- Leakage rates and oxygen penetration.
- Steel pipes (19 bar) and plastic pipes (PE, 4 bar) and connections.
- Residential installation (20 mBar) and connections.
- Gas meters: Stability and precision of industrial gas meters as rotational and turbine types and household bellow types.

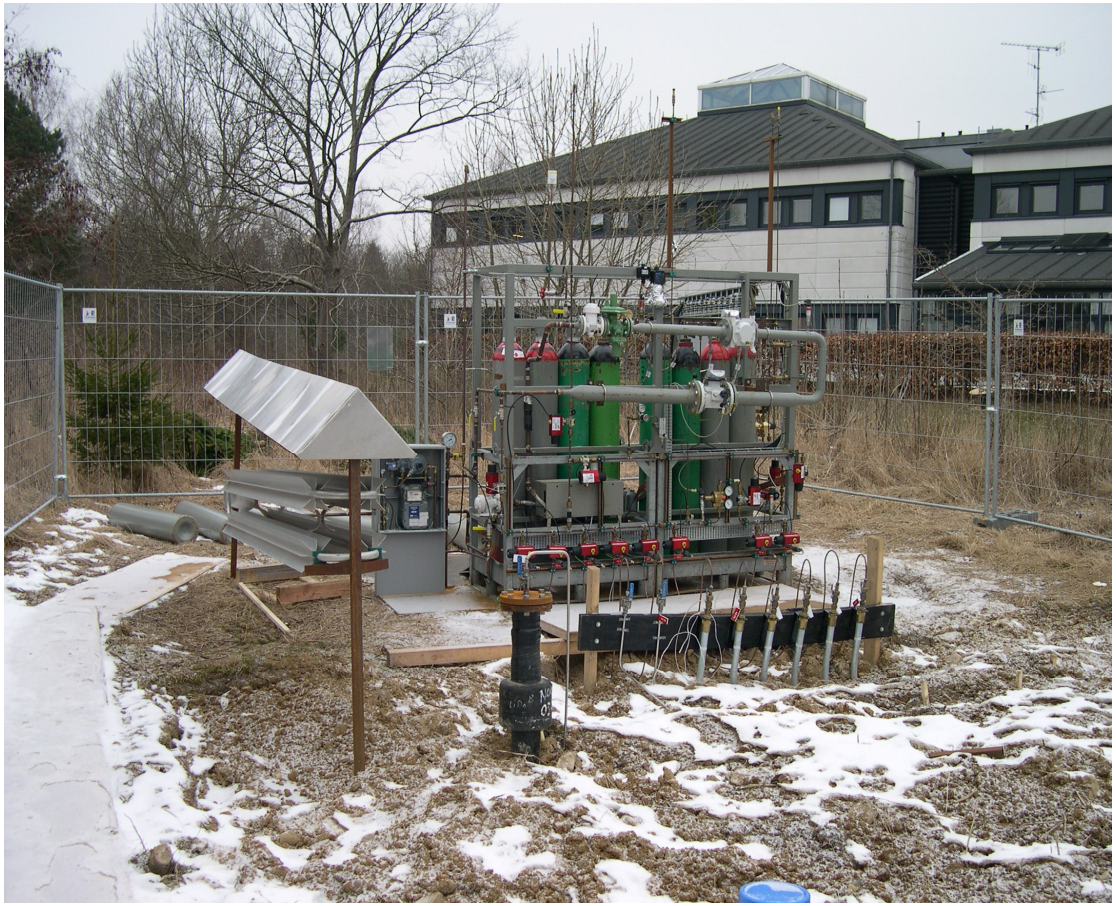
Test set up

Grid facilities for distribution of hydrogen; test of gas meters, and systems for control, regulation and monitoring of the test facility were developed by DGC.

Steel and plastic pipes from the existing gas distribution grid were adapted for a small standalone gas grid, constructed according to existing standards and authority regulations by the Greater Copenhagen Natural Gas Company (HNG).

Installation of plastic and steel pipes

Hydrogen distribution system and gas meter test cycle



Test results, an overview

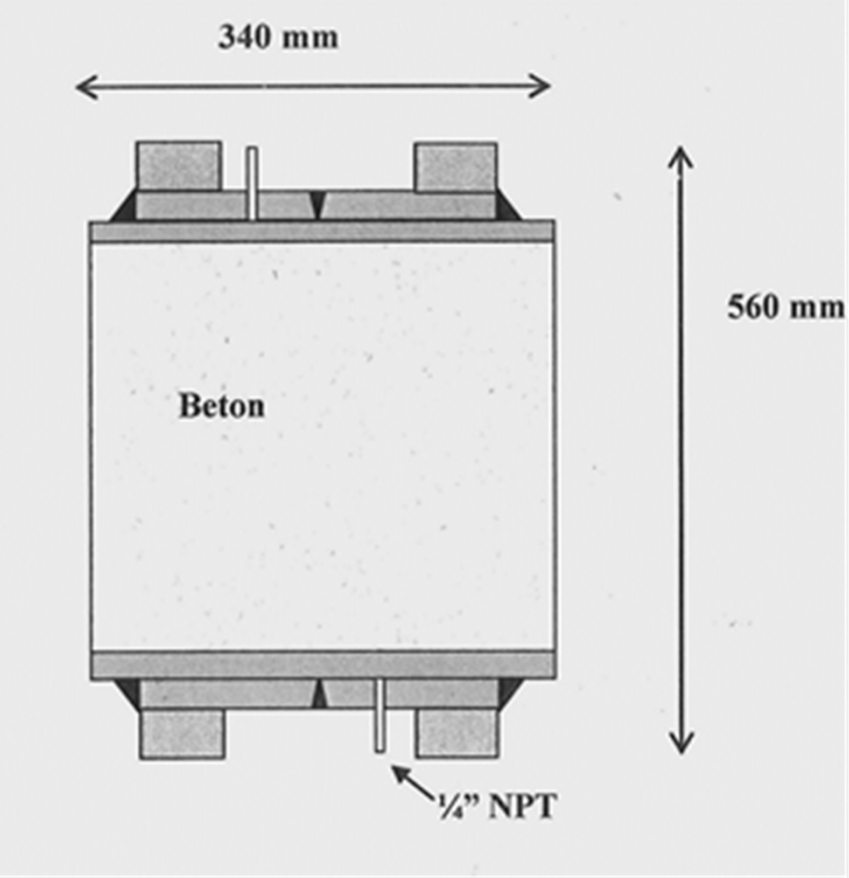
- Operation for 12 months without significant problems.
- Initial leak test during installation showed that about 50% of a widely used plastic coupling (4 bar PE grid) was leaking heavily. An alternative make solved the problem.
- Turbine type gas meters showed remarkable dependence of temperature.
- Oxygen penetration does not seem to be a problem.
- A few leaks were detected after 6 months of operation: Threaded connections only.
- No long-time leaks in steel pipes and only moderate leaks in polymer pipe system.
- Indication of increased leaks from residential system.

Phase II (2005-2009) project

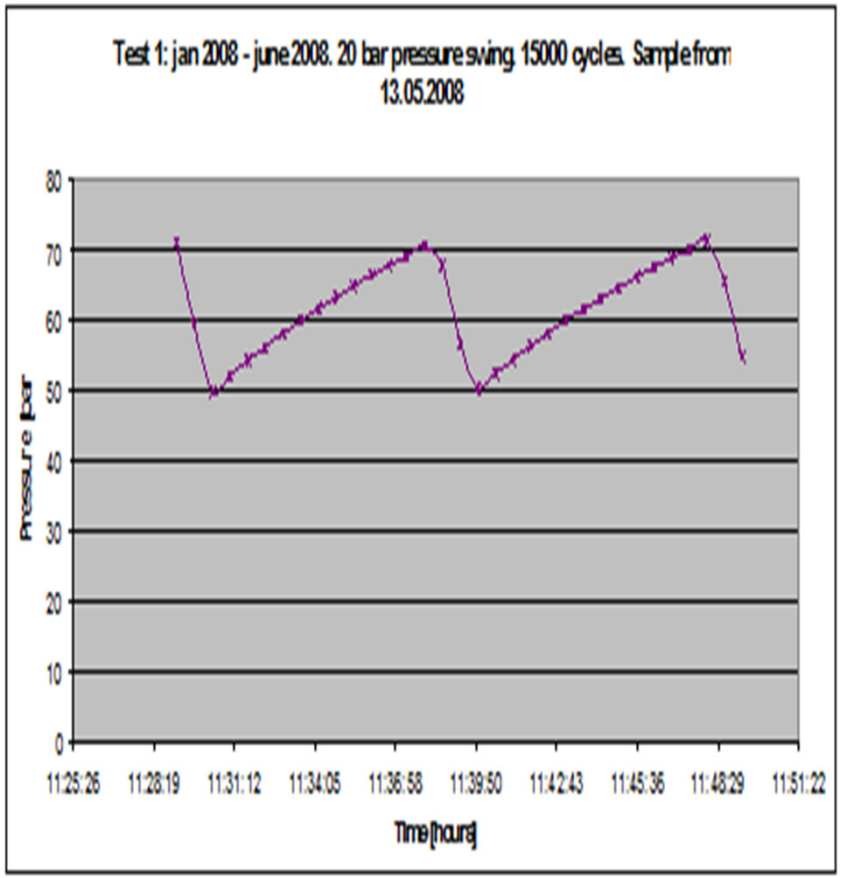
X70 steel natural gas transmission pipeline test and analysis:

- **Introduction and objectives**
- Most studies aiming to describe the fatigue limits of existing pipelines for hydrogen gas distribution has been based on fracture mechanics principle and it was found of less use to try to reproduce this work. Instead, it was decided to make **a series of full scale test exposing pipes to fluctuating pressures of hydrogen gas**.

- **The object of the steel pipe test:**
- Analyze the effect on fatigue life of existing natural gas transmission lines with hydrogen replacing natural gas. The test and analysis focused on the effect of hydrogen on fatigue cracking in pipeline girth welds.



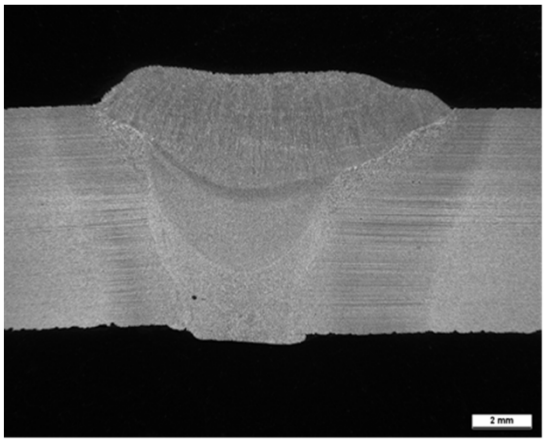
- Full scale tests was performed using cut-out API 5L X70 pipe sections 20 inch diameter by 7 mm WT retrieved after more than 20 years in the Danish natural gas transmission system. The pipe sections contained field girth weld (SMAW) made during the installation of the pipe line in eighties. The weld quality is assumed to repre-sent the Danish gas lines

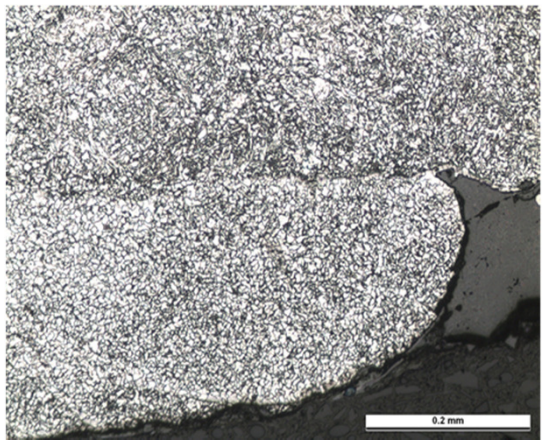


- The internal test environment consisted of 100% hydrogen gas at fluctuating pressures representing the daily peak to peak variation in the gas transmission line. The maximum pressure was 70 barg and the maximum pressure amplitude used was 30 bar.
- 2 test series were conducted with increasing pressure amplitude from 20 barg to 30 barg.

Results of steelpipe analysis

- The girth welds has been dissected and subjected to metallographic and MPI examination in addition to the ultrasonic testing in order to describe possible defects and defect growth in the weld zones.
- No indications of any fatique related fractures has been found.





Conclusion of Steel testing and analysis

- The dynamic testing equivalent of 80 years service with twice the maximal pressure variations found in the danish gas transmissionssystem (that is 2 x 15 bar equal to 40 to 70 bar in 30000 cycles) has not shown any defect growth.

- This provides some confidence for addition of hydrogen to the existing Danish gas transmission pipeline - provided it is free of significant weld defects.

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Appetizer: Energy Storage – Hydrogen injected into the Gas Grid via electrolysis field test

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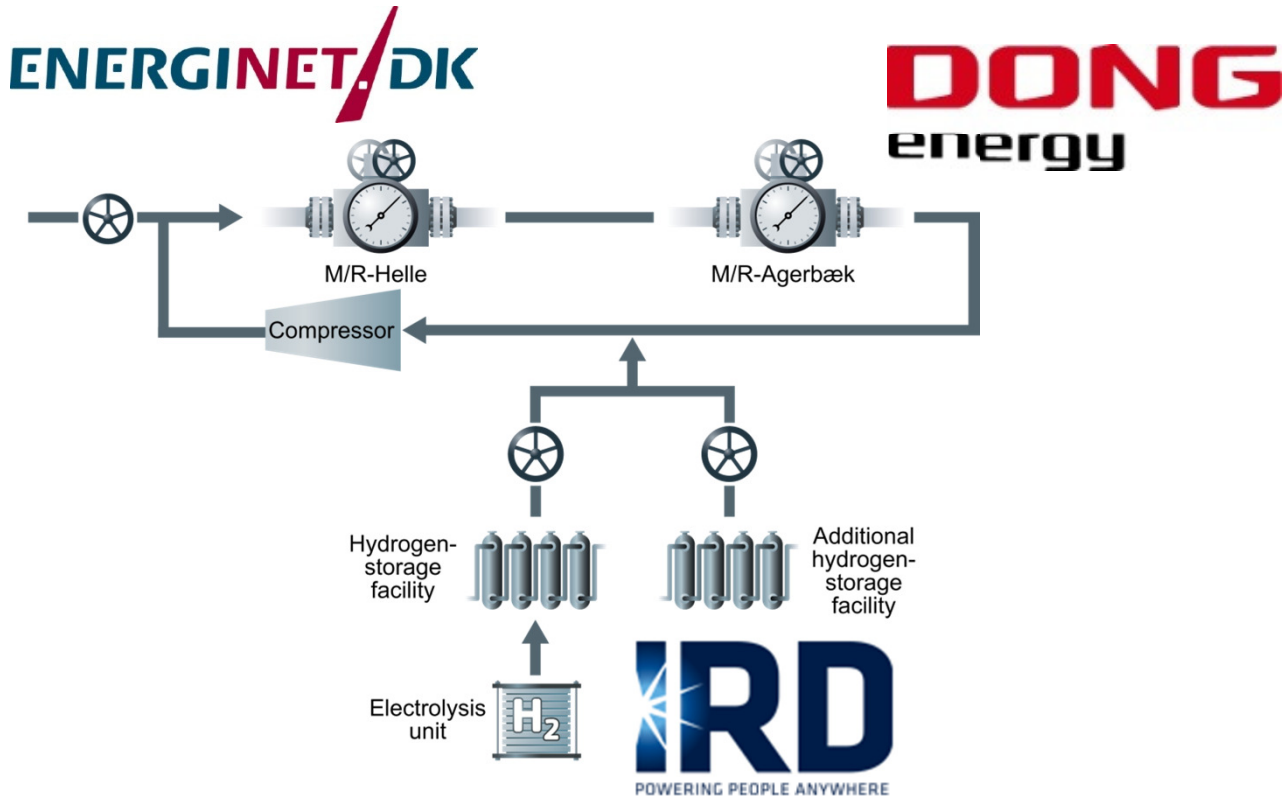
The test setup and project partners



Consultant:

Danish Gas Technology Centre
- R&D, consulting and measurement services in energy and environment

Scope of the project

To acquire knowledge of the solutions and costs of upgrading the gas grid to handle hydrogen admixed in the natural gas
Important to build up competences in the participating companies

Test period: 2 years
Up to 15 % hydrogen
Hydrogen content will be varied during the test

Total costs around 1 mill. €
Funded partly by EUDP: Energy Technology Development and Demonstration Programme

Summary

Project started January 2014
The 2 year test phase starts autumn 2015

The project results will be:

- A practical, public guideline that describes
- how the M/R stations and gas grid must be adapted to handle the injection of hydrogen in the natural gas grid
- including experience from regulatory approvals and operation & maintenance.

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