10 kbar Hydrogen Intensifier

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Brief history

10 kbar Hydrogen Intensifier has been chosen as one of the tasks of ***MNI3 FP7 JRA Sample Environment*** project in collaboration with HZB, LLB (2009 – 2012)

Main challenges:

Challenge One: ***High pressure Hydrogen safety issues***

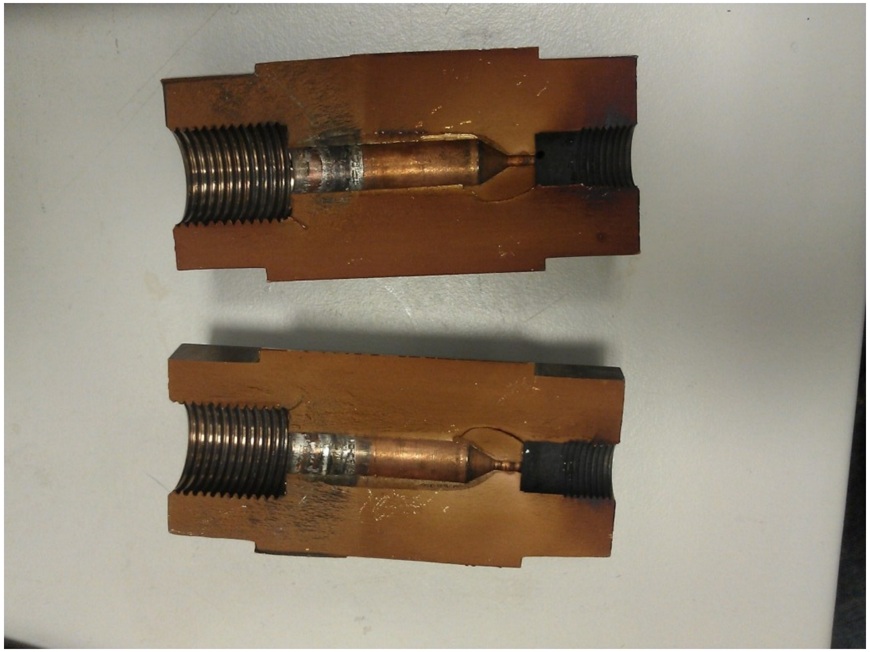
100 bar·L of H_2 is TNT equivalent of hand grenade (~250 gr of TNT)

100 bar·L of H_2 together with energy of compressed high pressure fluid is TNT equivalent of anti-tank grenade (~600 gr of TNT)

Main challenges:

Challenge Two: ***Hydrogen compatible materials***

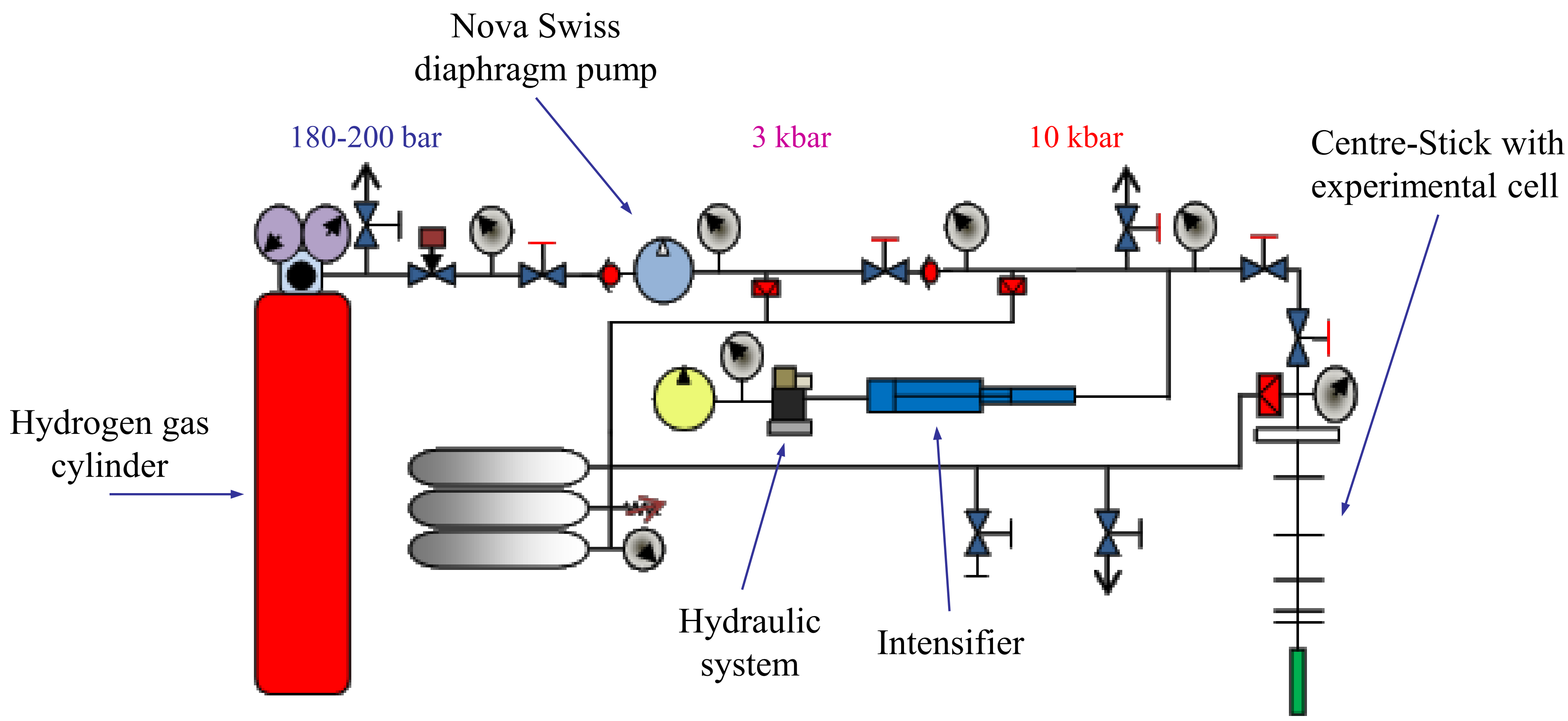
(joint project with ***Imperial College)***



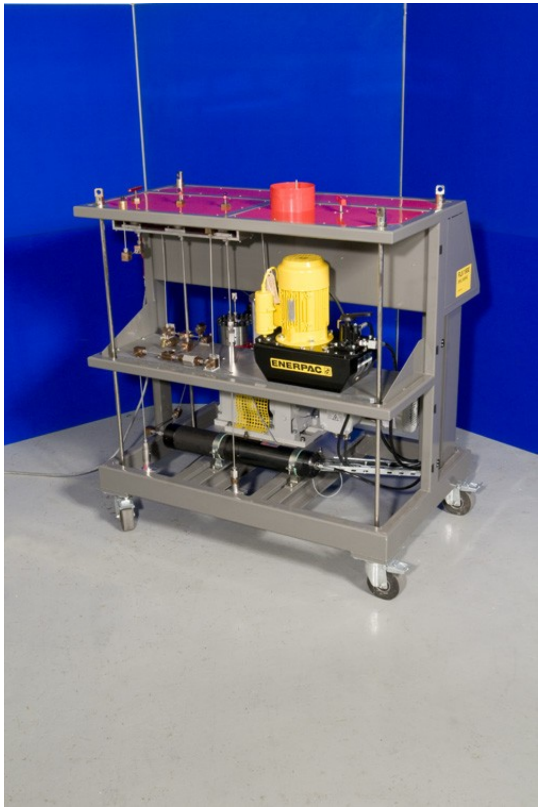
High pressure copper beryllium cell fell apart after exposure to hydrogen at elevated temperature, most possibly due to the Hydrogen embritlement.

Hydrogen embritlement is a process where certain materials become brittle following exposure to hydrogen.

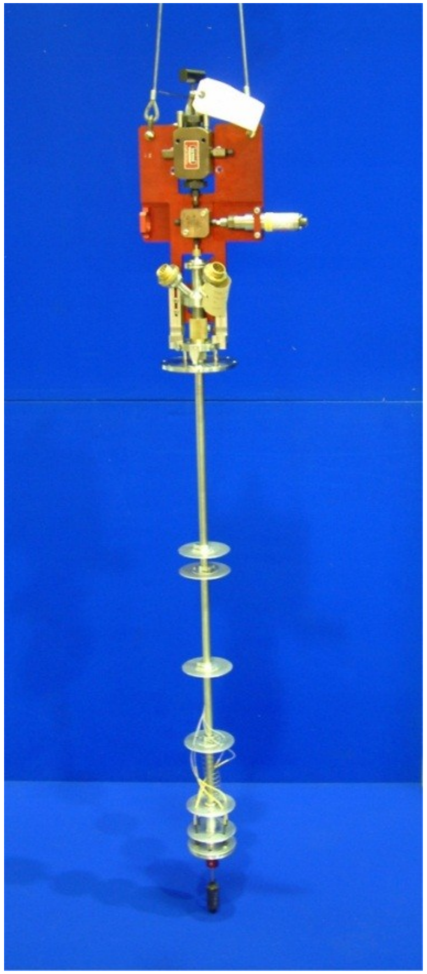
10 kbar Hydrogen Intensifier Concept Diagram



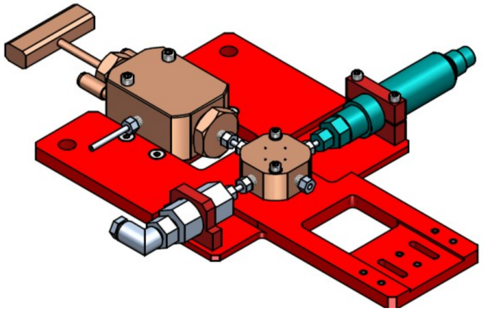
High Pressure Hydrogen "Red" Intensifier

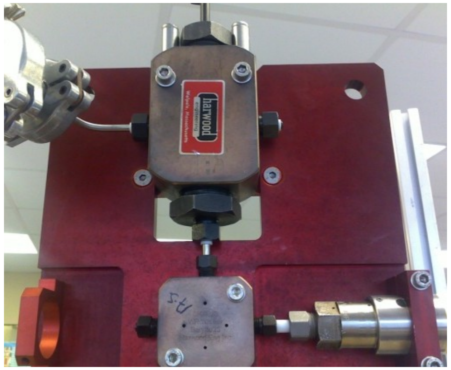


High Pressure Hydrogen Centre-Stick



High Pressure Hydrogen Stick

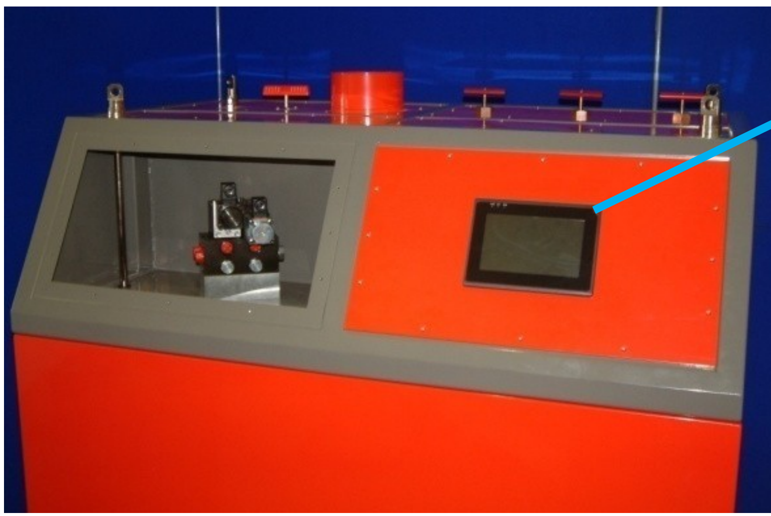




Harwood C-4133 H2 10kbar valve assembly on Centre-Stick

Interactive Semi-automated Control System

Status of the system monitored and displayed on Human Machine Interface (HMI) touch sensitive screen.



10 kbar Hydrogen Intensifier

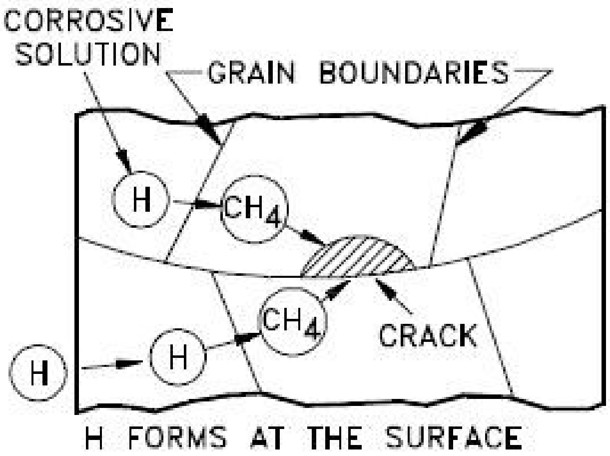
Nematron system with touch sensitive screen

First Test Results

- 10 kbar with He gas – all specification requirements satisfied!
- Safe – failure at little bit less than 11kbar (burst disk, system leak self-detection etc.)
- High pressure Hydrogen – system failed three times at similar pressures just around 6 kbar, in similar way, in completely safe mode (exactly as expected). The reason is the Hydrogen embrittlement of a high pressure valve material.

Hydrogen Embrittelement of Stainless Steel

(suggested mechanism of crack formation)



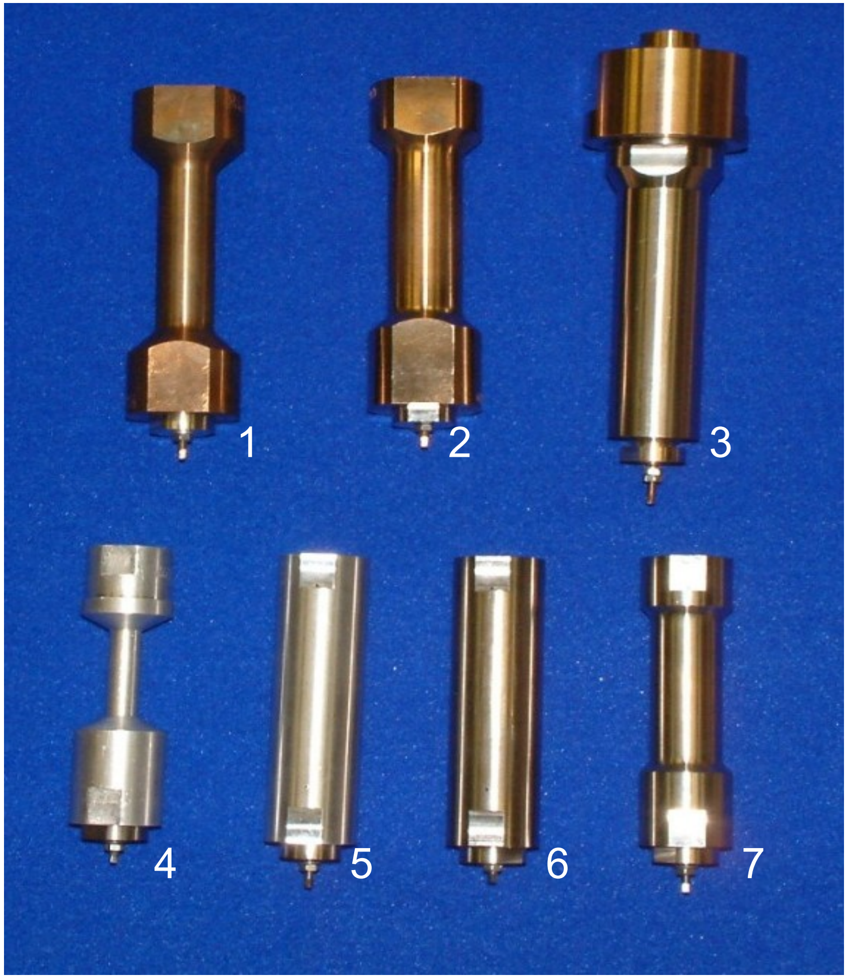
According to one of the mechanisms the Hydrogen embrittelement occurs when hydrogen diffuses along the grain boundaries and combines with the carbon, which is alloyed with the iron, to form methane gas.

The methane gas is not mobile and collects in small voids along the grain boundaries where it builds up enormous pressures that initiate cracks.

DOE Fundamentals Handbook Chemistry Volume 1 of 2 DOE-HDBK-1015/1-93 January 1993

MP35N high strength steel:
Ni (35%) Co(35%) Cr(20%) Mo (10%)
Up to 0.025% Carbon (?)

High pressure cells



- ***(1)*** ***6 kbar*** hydrogen gas BeCu cell with temperature up to ***20 C***;
- ***(2)*** ***7.36 kbar*** hydrogen gas BeCu cell with temperature up to ***20 C***;
- ***(3)*** ***8 kbar*** hydrogen gas BeCu/TiZr cell (sleeved cell) with temperature up to ***20 C***;
- ***(4)*** ***300 bar*** hydrogen gas Aluminium cell up to ***100 C***;
- ***(5)*** ***4.4 kbar*** hydrogen gas Aluminium cell up to ***20 C***;
- ***(6)*** ***5.4 kbar*** inert gas TiZr cell up to ***20 C***;
- ***(7)*** ***6.35 kbar*** hydrogen gas Inconel cell up to ***20 C*** and ***4 kbar*** *up to* ***400 C***

High Pressure Hydrogen

In collaboration with ***LLB, HZB, Imperial College London, Paris University, Stansted Fluid Power Ltd***

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