Achieving ‘Right First Time’ Hydrogen Pipeline Welding

Murdo MacAngus
Serimax NEU Commercial & Operations Director
24th October 2024

Agenda

- Hydrogen applications
- Existing Solutions
- New Pipeline Design Criteria
- Embracing Carbon Steel
- Hydrogen Embrittlement
- Internal Coated Pipelines
- Serimax R&D
- Serimax Welding Solutions

Green Hydrogen

- Production: Generated through electrolysis of water using renewable energy.
- Pipeline Characteristics: Requires high-purity materials; typically involves stainless steel

Blue Hydrogen

- Production: Derived from natural gas
- Pipeline Characteristics: Utilises lower-strength steel.

Existing solutions

H2 transportation the most common solution is full austenic stainless steel (grade 316/316L) pipes.

- Austenic microstructure ensure a good H2 embrittlement resistance when installation stress is limited.

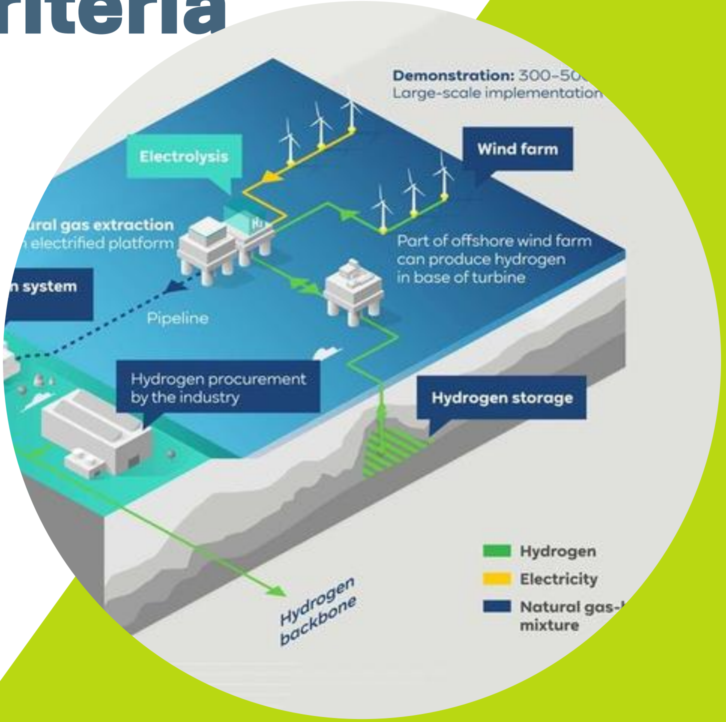
Serimax have proven welding solution for stainless pipelines

- More than 50,000 CRA welds
- Dedicated back purging solution
- Serimax visual inspection for root pass: Scanvision

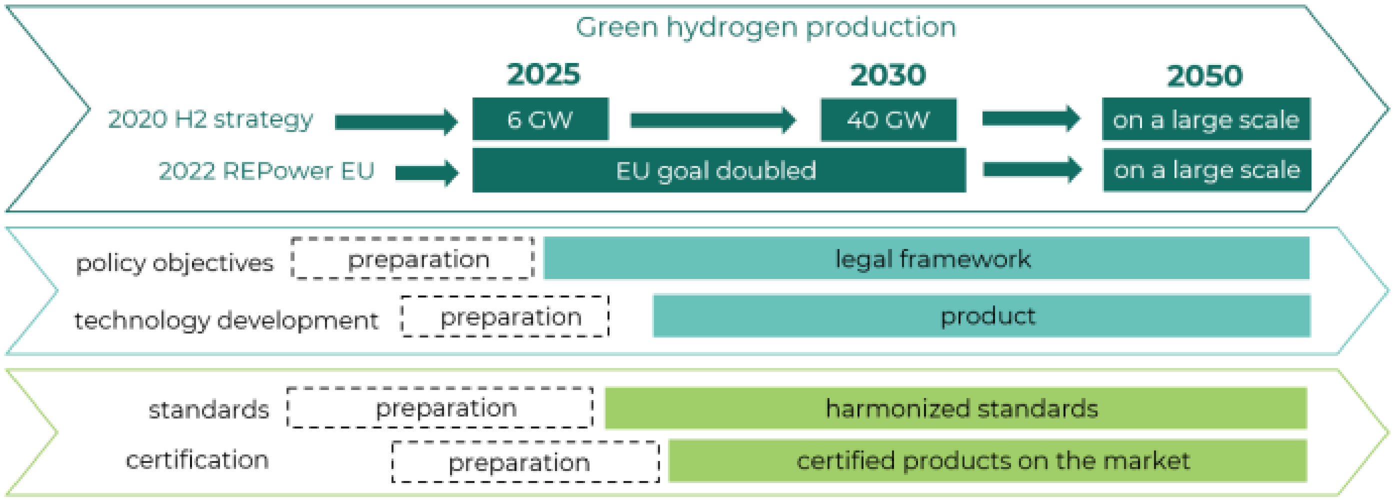
New Pipelines Design Criteria

- Large Scale Hydrogen and Gas Mix pipelines shall require more cost-effective infrastructure

- Transitioning to Carbon Steel shall require methodical approach utilising existing experience and industry collaboration



Green Hydrogen – Regulatory Framework

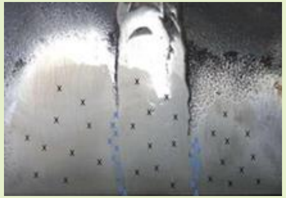
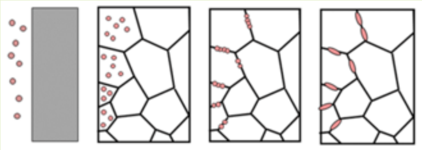


Policy framework in relation to development of hydrogen technologies

Source : European Clean Hydrogen Alliance – Roadmap on Hydrogen Standardisation DocsRoom - European Commission (europa.eu) serimax

Embracing Carbon Steel

Summary of the main technical challenges pertaining to H2 projects on carbon steel pipes:

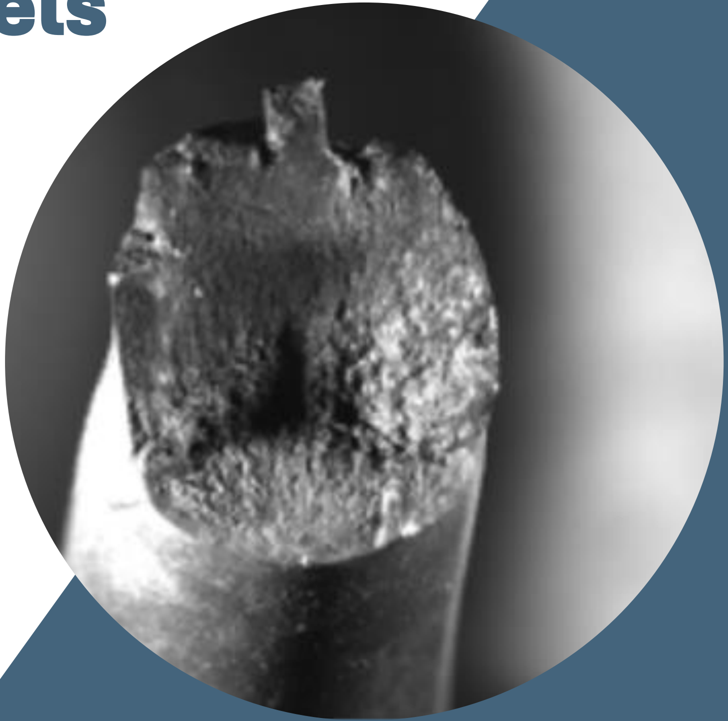
Risk	Description		Main drivers
Hardness level for welding procedure qualification	While awaiting clear guidelines, the main governing standard for welding commonly adopted is **ASME B31.12** (conservative regarding mech. properties, mainly on hardness). Acceptance criteria of **235Hv10** complex to achieve especially when TMCP pipes are involved (TMCP pipes are usually used for onshore projects).		Pipe weldability Welding parameters (heat input/preheating).
Hardness level for production	To ensure that hardness level still under control during production, most of the welding specifications applicable for H2 projects (and based on ASME B31.12) request for **hardness production test**. (on Capping area, incl. weld metal & HAZ, using Telebrineller or ultrasonic hardness testing equipment)	 	Pipe weldability Welding parameters (heat input/preheating). Welding procedure repeatability Monitoring
H2 embrittlement	Main subject remains the material behavior in hydrogen environment, H2 embrittlement causing a corrosive process leading to loss of ductility, load capacity and eventually fracture and material cracking. This ductibility loss have an impact on **Engineering Critical Assessment** done to define the fit for purpose welding acceptance criteria on project basis and lead to reduce those acceptance criteria impacting directly the production.		Pipe material & weldability Filler metal Residual stress Modeling capability
Root pass internally coated compliant (for projects requiring internal field joint coating)	Use of steel internally coated pipes could also be a solution for hydrogen transportation. But root pass profile shall meet the geometric requirement for internal field joint coating.		Root pass profile and regularity

Reference	WPQT		Production		
	Zones	Criteria	Zones	Sampling	Criteria
ASME	BM - HAZ - WM	≤ 235 HV10	HAZ - WM	Depends	237 HB (247 HV)

Hydrogen effects on steels

Hydrogen embrittlement (HE)

- HE, also hydrogen induced stress corrosion cracking (HISCC) describes degradation of material in the presence of hydrogen under load
- HE detrimentally affects:
  - Rupture ductility (reduction of area, elongation to failure,..)
  - Fracture toughness
  - Fatigue crack propagation rate
- Embrittled material can fail prematurely after many years of service



Hydrogen Embrittlement

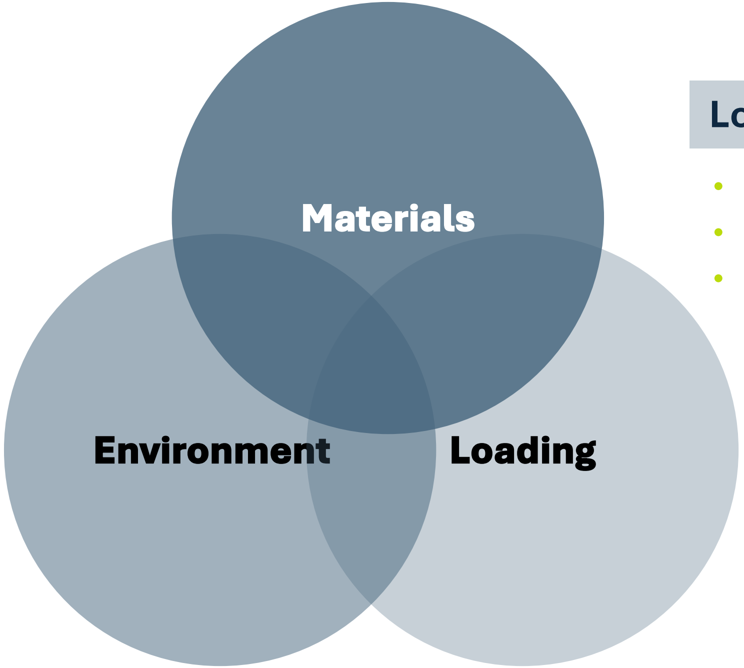
Influencing factors

Materials

- Strength/hardness
- Alloy composition
- Surface condition (flaws, imperfections)
- Microstructure (heat-treatment, welding...)

Environment

- Hydrogen partial pressure
- Temperature
- Gas composition and purity



Loading

- Loading rate
- Load cycle frequency
- Geometry

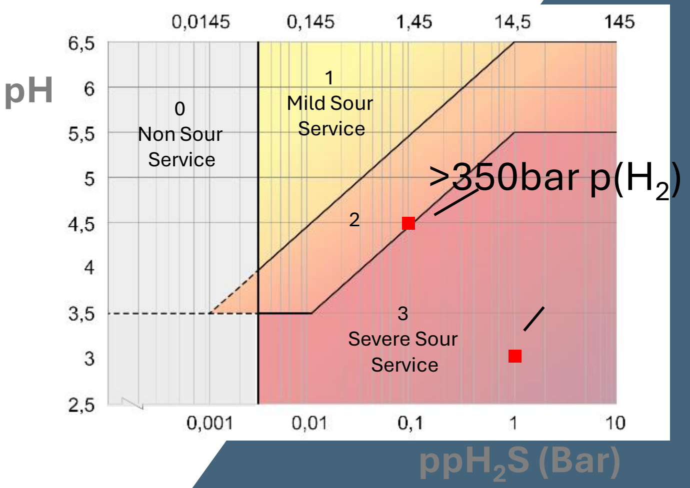
H2 COMPATIBILITY OF MATERIALS MUST BE VALIDATED FOR SPECIFIC CONDITIONS

H^2 Embrittlement: Sour Service Similarities

Sour service O&G projects helped to develop our solutions

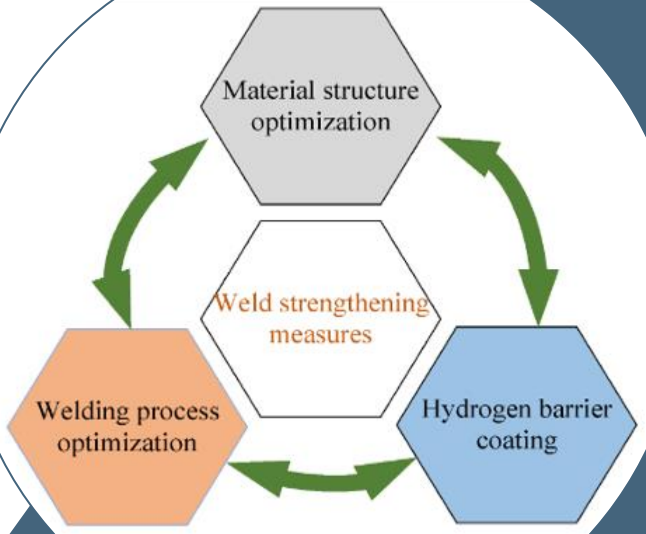
- Line pipe steel grades with optimised chemistries, microstructure
- Full set of welding & NDT techniques with
- associated acceptance criteria
- capable to withstand extreme hydrogen charging
- superimposed with high mechanical loads

NACE MR0175 chart



Internally coated pipes

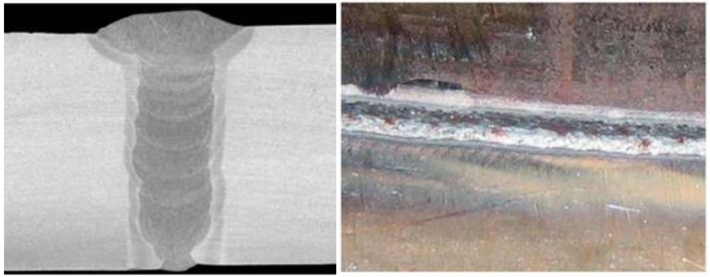
- Use of internally coated steel pipes could also be a solution for hydrogen transportation.
- Integrity/homogeneity of this hydrogen diffusion barrier shall be ensured even in the weld area.
- Serimax has developed and used suitable welding strategy on internally coated pipes.



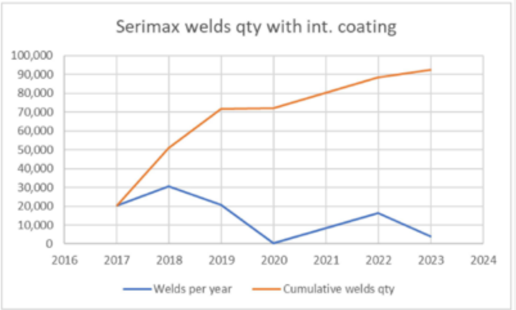
Internally coated pipes

- The use of mGMAW-STT welding process for root pass in combination with an ILUC and "spatter trap", ensures a smooth and repeatable root bed profile pre-requisite to internal field joint coating.

Optimal groove spatter trap



mGMAW-STT ensure flat root pass profile with smooth transition throughout the circumference



100 000 welds with internal field joint coating already performed in operation

Learning Getting it Right First Time

- Utilising our extensive track record
- Embracing the R&D
- Developing the Standards with Operators & Contractors
- Embracing the experts in each other's fields to collaboratively deliver.

SMX R&D Programs & Ongoing Activities

1978

2021

2022

2023

2024

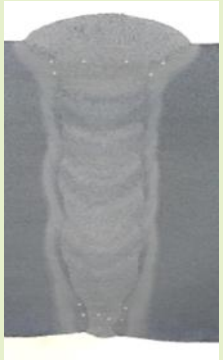
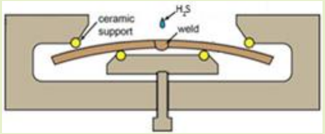
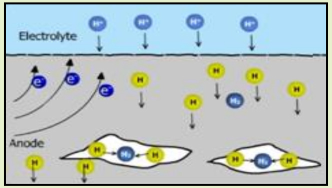
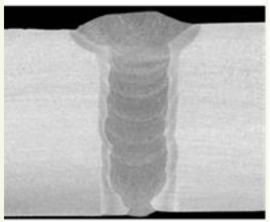
Collaborative Partners

1978	2021	2022	2023	2024
Serimax extensive track record on CRA, Sour Service and High-Quality Pipeline Welding Activities	Test and characterize standard NG girth weld coupons in H2 environment to assess reversibility of existing NG existing pipeline network.	Test and characterize material grades and mechanized welding combinations in H2 storage environment	The project aims to develop a bridging, simulation-based framework to establish an extended safety assessment guideline for steel pipelines under hydrogen loading. It can be expected that this framework will also be highly beneficial for future developments of steels with improved resistance against hydrogen-induced failure.	Pipe laying project for H2 transportation Pipe weldability for H2 storage project

Welding Solutions

Risk	Main drivers	Serimax answers
Hardness level for welding procedure qualification	Pipe weldability Welding parameters (heat input/preheating).	**Track records:** Serimax has extensive track records on O&G sour service projects with very stringent requirements on hardness level ex. **235Hv10 max** (i.e. EXXON severe sour service projects). **Development:** To assess the weldability of TMCP pipes for H2 project, Serimax has been working for several years, on **R&D projects**, on different alloying strategies to develop suitable welding solutions (process/parameters/ thermal cycle) aiming to **secure the hardness level** in pipe HAZ. **Flexibility:** Off the shelf Serimax welding equipment have all embarked features to adapt to a wide spectrum of welding strategies to meet H2 projects requirements/specification.    
Hardness level for production	Pipe weldability Welding parameters (heat input/preheating). Welding procedure repeatability Monitoring	Even if a good welding strategy is developed during welding procedure qualification stage, it is paramount to ensure its repeatability on the field, hence the need to organize and design the spread means adequately to warrant that all preset conditions are met allowing reaching that compliance goal (mechanical properties): • **Mechanized welding** shall be used to reduce the human factor impact on final result, • **Full monitoring and traceability** shall be applied at each production steps, Serimax mechanized welding equipment natively integrate dedicated monitoring software that control and record each welding parameters that could impact the weld mechanical properties (up to 40 parameters regulated and recorded for Dual mGMAW-Pulsed welding). Through our **Cleverweld** solution a full monitoring of the production spread is possible. 

Welding Solutions

Risk	Main drivers	Serimax answers
H2 embrittlement	Pipe material & weldability Filler metal Residual stress Modeling capability	To reduce the residual stress induced by welding, Serimax apply narrow gap bevel for his mechanized welding strategy. This allow also to improve the productivity compared to other solution and the quality by reducing the quantity of welding beads. Our sour service services track records validate the filler metal used by Serimax. For sour service project the weld is tested under H_2S environment to demonstrate its resistance to hydrogen sulfide stress cracking. During this test, the weld is also exposed to H_2 embrittlement phenomena thanks to H_2S pressure (up to 16 bars during testing) and H_2 diffusion into the weld structure, allowing to validate that Serimax filler metal is compliant (supply according our particular purchase specification).   
Root pass internally coated compliant (for projects requiring internal field joint coating)	Root pass profile and regularity	Serimax track records on internal coated welds (closed to 100 000 welds with internal coating already done in production) allow to confirm the capability of our welding strategy to meet the specifics requirements associated with this configuration. Our base case mGMAW-STT + mGMAW welding strategy is also compatible with stringent hardness requirements (welding strategy used for H2S projects).  

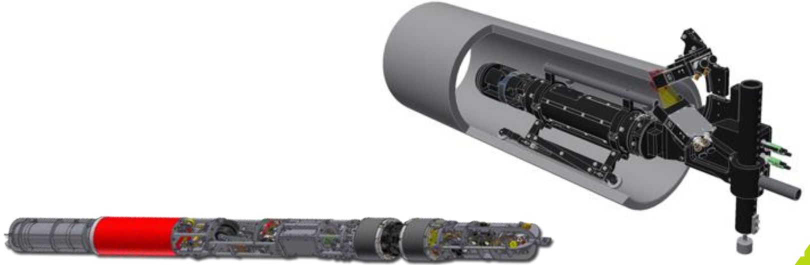
Welding Solutions

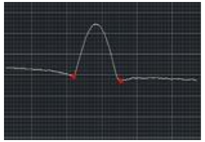
- Mechanical properties required for H2 pipelines are very similar to H2S sour/severe sour projects (i.e. hardness requirements)
- Strong Serimax track records on O&G H2S service project with proven welding strategies.
- Continuous improvement ongoing through our involvement in EU/International R&D programs.
- Welding procedure & equipment H2 ready for operation using pipes with internal coating.
- Pipe being a key component of the process control, pipe weldability for H2 project is a MUST since for landline project, most of the pipe are TMCP. The alloying strategy used shall be validated based on project requirements to ensure good HAZ behavior.

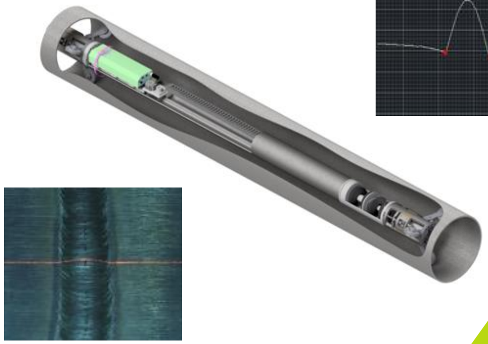
Welding **Solutions**

Carbon steel

- ML : Narrow gap mechanised single and dual torch GMAW/PGMAW / STT
- Tie-Ins: Manual - Low hydrogen SMAW or GTAW
- Thin welding layer with proper inter-passes reheating
- No PWHT
- Possibly required :
  - Pipe end measurement to minimise HiLo
  - Internal video and profiling inspection







Q&A

For all enquiries contact

info@serimax.com

serimax.com

Your Welding Partner

Follow us