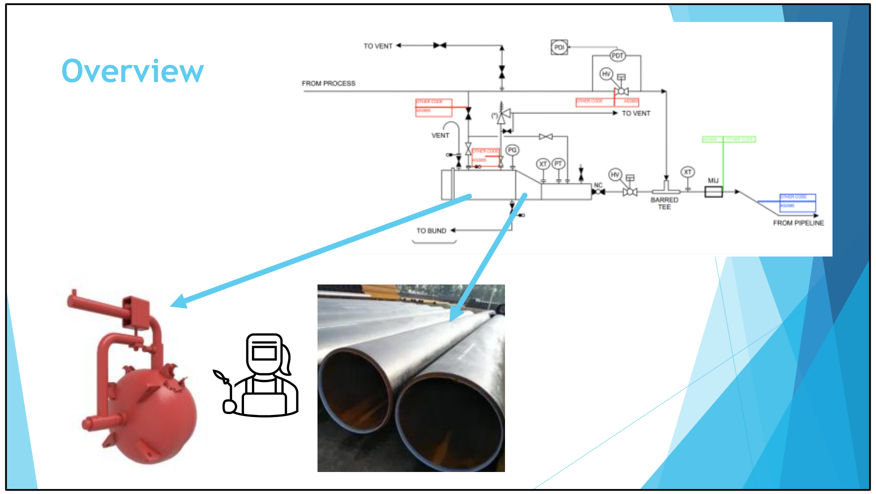
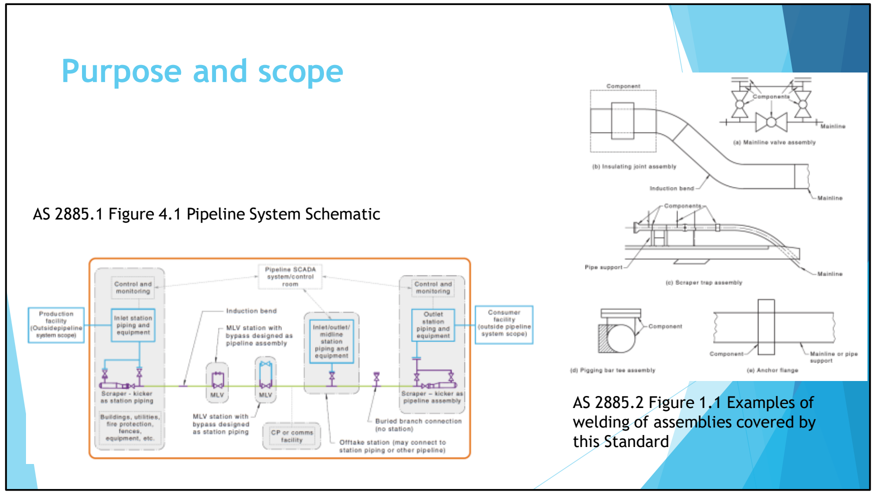
AS/NZS 2885
PIPELINE ASSEMBLIES
Welding



- In the last session we talked about materials — what steels we're dealing with, and how their chemistry and microstructure affect behaviour
- Now we're taking the next step and asking: how do we actually join those materials together to form a pipeline assembly
- What looks simple on a drawing quickly becomes a series of real welds between different grades, thicknesses and product forms
- Those differences matter, because they directly influence how the weld zone behaves during and after welding
- So welding here isn't just fabrication — it's a key control that determines whether the materials we selected will perform safely
- AS 2885 treats welding as part of its safety philosophy, not just something that happens during construction
- This session builds directly on the materials concepts and shows how we use welding controls to manage the risk

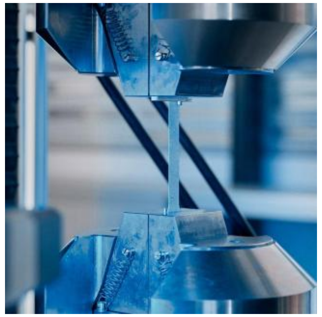


- This session explains the intent of AS 2885 Part 2 and how it is applied to welding of pipeline assemblies.
- It contrasts pipeline production welding with general fabrication welding in order to understand why requirements differ.
- The session frames welding as a system safety control rather than simply a construction activity.
- It links welding controls directly back to materials concepts such as CEQ and hydrogen assisted cold cracking.
- The focus is on what you need to understand about assembly welding, not on detailed construction execution that is covered later.

What AS 2885.2 is mainly written for…

- Pipeline construction involves large numbers of repeated welds, so any procedural weakness can be rapidly replicated across many joints
- Errors in welding procedures can propagate quickly and remain hidden due to backfilling until inspection or in-service exposure
- This creates a systemic defect risk that is fundamentally different from small-scale or one-off facility piping
- AS 2885.2 is written for long-distance, high-pressure pipelines with repeated production welding and high consequence of failure, such as a propagating fracture in a highly populated location.
- It supports a low design factor philosophy, relying on system controls and proven welding performance rather than heavy wall conservatism
- The standard emphasises early procedure qualification and production-scale quality and repeatability to ensure defects are prevented before high-volume welding proceeds

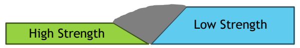
Fracture control philosophy



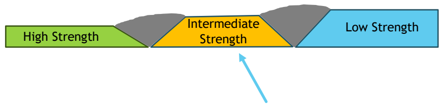
- High-pressure pipelines can fail by fast fracture, so fracture behaviour becomes a primary safety concern rather than an edge case.
- Part 2 supports the broader AS 2885 objective of preventing fracture initiation at welds and heat-affected zones.
- It also seeks to ensure that the system has adequate defect tolerance, so small imperfections do not become catastrophic failures.
- Toughness is therefore critical, because toughness governs resistance to brittle fracture and crack propagation.
- Strength alone is insufficient because a high-strength weld can still be brittle or crack-susceptible under the wrong conditions.

Typical assembly welds

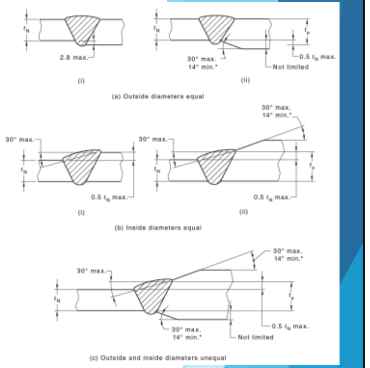
High Strength + Low Strength > Taper Joint



Strength ratio acceptable



Strength ratio NOT acceptable > TRANSITION PIECE

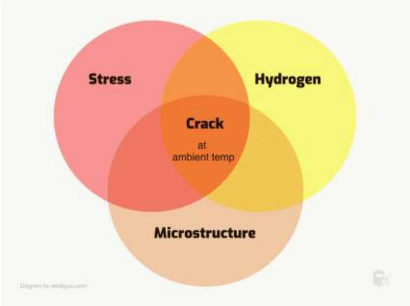


AS 2885.2 Figure 5.3 – Weld preparations for butt welds – Unequal nominal thickness or grade

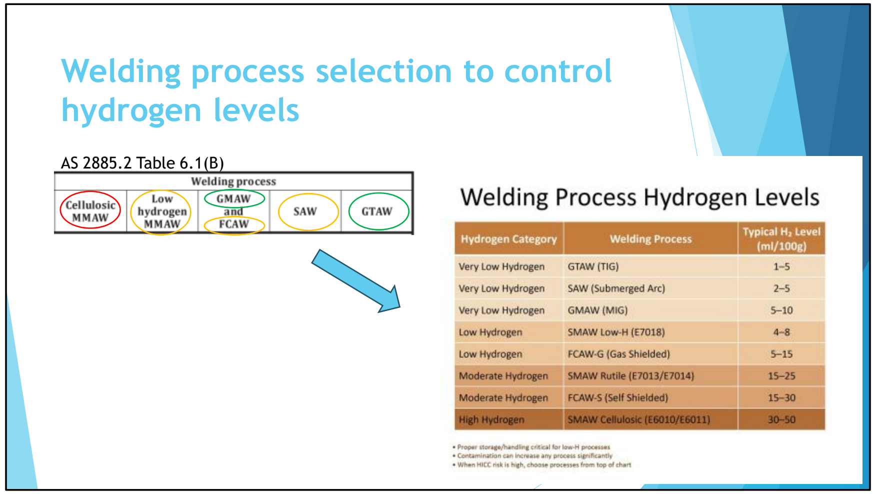
- Assembly welding includes girth welds between spools that must achieve consistent strength and toughness.
- Branch and tee welds introduce complex geometry and higher restraint than straight girth welds.
- Closures and end caps can involve thicker sections and challenging joint configurations.
- Thickness transitions create uneven heating and cooling, which can increase hardness and residual stress locally.
- High restraint is common in assemblies, which increases tensile stress during cooling and therefore increases cracking risk.
- The diagram on the left shows the challenge of welding a thin high strength material to a thicker lower strength material.
- As shown on the right, AS 2885 has guidance on welding unequal thicknesses and sometimes an intermediate strength, transition piece is required.

- Pipeline assemblies are typically welded in workshops to achieve consistent control over fabrication conditions and to take advantage of specialised equipment in one location
- Controlled environments reduce variability in fit-up, heat input, moisture, wind and temperature, improving repeatability, weld quality and preheat stability
- Hydrogen management is more reliable, with proper storage, handling, baking, tracking of consumables and less impact from the environment
- Stable, measurable preheat can be applied and maintained using controlled heating methods, unlike open construction corridors
- Rotators and cranes provide better welding access and positioning, improving weld quality and safety
- Workshops enable more consistent inspection, supervision and documentation, strengthening overall quality oversight
- Reduced manual handling, improved access and fewer environmental hazards result in a safer working environment for personnel

Recap: Hydrogen Assisted Cold Cracking (HACC)



- As a recap from the materials session, HACC directly threatens pipeline integrity and can lead to catastrophic failure if not controlled, and therefore gets a lot of focus in Part 2.
- Cracking can occur hours or days after welding, so defects may not be detected during inspection
- Modern high-strength steels are more susceptible due to harder HAZ microstructures
- It drives significant rework, cost, and strict welding procedure requirements
- Given the significant impact of HACC on pipeline assembly integrity, we'll look at ways to control it in more detail



Hydrogen Category	Welding Process	Typical H_2 Level (ml/100g)
Very Low Hydrogen	GTAW (TIG)	1–5
Very Low Hydrogen	SAW (Submerged Arc)	2–5
Very Low Hydrogen	GMAW (MIG)	5–10
Low Hydrogen	SMAW Low-H (E7018)	4–8
Low Hydrogen	FCAW-G (Gas Shielded)	5–15
Moderate Hydrogen	SMAW Rutile (E7013/E7014)	15–25
Moderate Hydrogen	FCAW-S (Self Shielded)	15–30
High Hydrogen	SMAW Cellulosic (E6010/E6011)	30–50

- Low-hydrogen processes reduce diffusible hydrogen and are preferred for pipeline assemblies to minimise HACC risk
- Common low-hydrogen processes include gas tungsten arc welding, gas metal arc welding, flux cored arc welding, and low-hydrogen manual metal arc welding
- Cellulosic processes introduce higher hydrogen and therefore increase cracking risk
- Cellulosic welding has a legacy role, e.g. high productivity mainline welding, but is generally unsuitable for assembly welds, especially with higher CEQ materials
- If cellulosic processes are used, they must be tightly controlled and are often avoided for assemblies
- Welding process selection directly influences HACC risk and drives qualification and inspection requirements

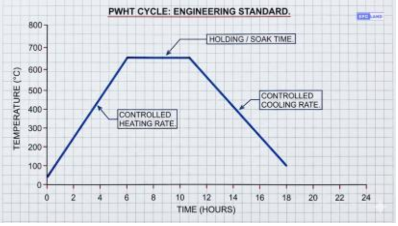
Material CEQ selection to control microstructure

- High strength and/or thin wall fittings might have high CEQ
- Material grade / group cannot be relied upon
- CEQ fitting >> CEQ pipe
  High CEQ fittings (>0.42)

- CEQ governs which welding processes are appropriate because it strongly influences HAZ hardness and cracking susceptibility.
- Forged fittings and flanges often drive this decision because their CEQ can be significantly higher than the adjacent line pipe.
- For higher-risk joints, low-hydrogen processes combined with appropriate preheat are generally preferred controls.
- Effective welding requires materials and welding choices to align, rather than treating welding process selection as a convenience decision.

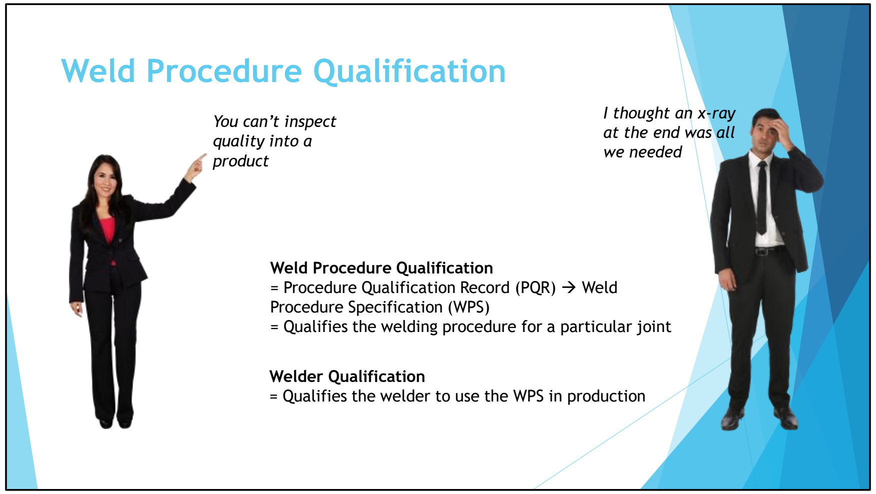
- Preheat slows the cooling rate after welding, which reduces the formation of hard microstructures in the heat-affected zone.
- Preheat also promotes hydrogen diffusion out of the weld region before it can become trapped in susceptible microstructures.
- By lowering HAZ hardness, preheat reduces susceptibility to HACC.
- Preheat reduces residual stress by raising the base metal temperature, which lowers thermal gradients, reduces restraint during expansion and contraction, and slows cooling, resulting in less differential strain being locked into the weld.
- Preheat is particularly critical for high-CEQ materials and for thick or highly restrained joints typical in assemblies.
- Flame preheating as shown in the left image is easy to apply in the field but more difficult to control, electric resistance heating shown in the middle is more common in workshops and is slower to apply but more controlled, induction heating shown on the right is done in a workshop and whilst rapid to apply it takes more set up time and is used mainly for repetitive joints.
- If the preheat is determined and applied correctly, it is the secret sauce for preventing HACC.

Post Weld Heat Treatment (PWHT)

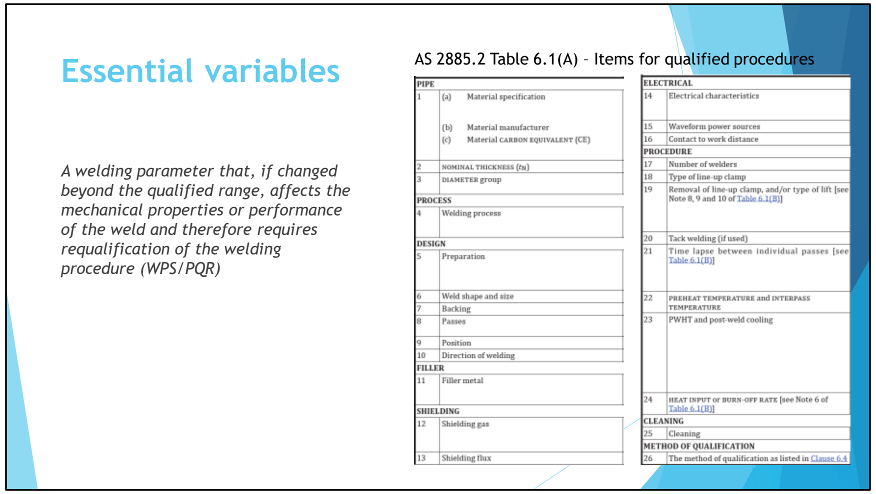


- Post weld heat treatment reduces HACC risk by allowing hydrogen to diffuse out while tempering hard microstructures and relieving residual stresses, also improving toughness and reducing hardness in the heat-affected zone.
- PWHT is either done on individual weld joints using electric resistance heating blankets as shown in the upper picture, or the whole assembly is placed in a heat treatment furnace as shown in the bottom picture.
- As shown in the left hand picture, it takes considerable time as the joint must be heated to several hundred degrees at a controlled rate.
- Preheat is particularly critical for high-CEQ materials and for thick or highly restrained joints.
- PWHT can also introduce metallurgical risks, including potential reductions in toughness if not carefully controlled. Component or coating damage can also occur.
- Because pipelines are fracture-sensitive systems, any heat treatment that alters toughness must be treated cautiously.
- PWHT is therefore used only when it is unavoidable and when the engineering basis is clearly justified.
- Where PWHT is applied, it requires a specific engineering assessment to confirm that required properties are achieved and maintained.

- So while PWHT can address some issues, it may also introduce others and therefore should not be considered a silver bullet for preventing HACC in pipeline assemblies.



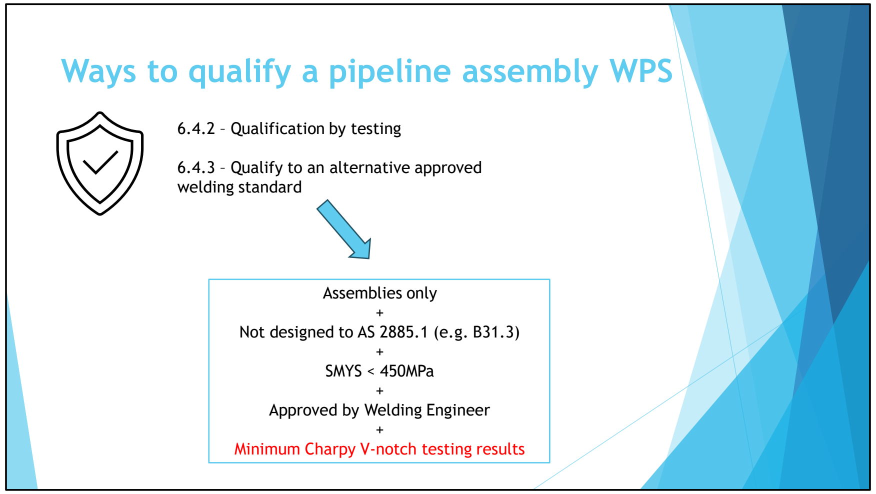
- Weld procedure qualification is the process of proving that a proposed welding procedure can reliably produce acceptable welds.
- In the AS 2885 context, qualification must demonstrate both strength and toughness performance appropriate for fracture control.
- Qualification is based on worst-case conditions so that production welding remains within proven boundaries.
- Procedure qualification is different from welder qualification because it validates the method, not just the person.
- Weld procedure qualification is central to Part 2 because it prevents systematic defects being replicated across many joints.



PIPE	
1	(a) Material specification (b) Material manufacturer (c) Material CARBON EQUIVALENT (CE)
2	NOMINAL THICKNESS (t_N)
3	DIAMETER group
PROCESS	
4	Welding process
DESIGN	
5	Preparation
6	Weld shape and size
7	Backing
8	Passes
9	Position
10	Direction of welding
FILLER	
11	Filler metal
SHIELDING	
12	Shielding gas
13	Shielding flux
ELECTRICAL	
14	Electrical characteristics
15	Waveform power sources
16	Contact to work distance
PROCEDURE	
17	Number of welders
18	Type of line-up clamp
19	Removal of line-up clamp, and/or type of lift [see Note 8, 9 and 10 of Table 6.1(B)]
20	Tack welding (if used)
21	Time lapse between individual passes [see Table 6.1(B)]
22	PREHEAT TEMPERATURE and INTERPASS TEMPERATURE
23	PWHT and post-weld cooling
24	HEAT INPUT or BURN-OFF RATE [see Note 6 of Table 6.1(B)]
CLEANING	
25	Cleaning
METHOD OF QUALIFICATION	
26	The method of qualification as listed in Clause 6.4

- Essential variables are the procedure parameters that materially affect weld quality and mechanical properties.
- Part 2 controls process limits so that heat input and metallurgy stay within qualified boundaries.
- Heat input is tightly managed because it governs cooling rate, hardness and toughness in the HAZ.
- Consumables are controlled because they influence hydrogen level, strength matching and toughness performance.
- Joint geometry is controlled because changes in bevel, fit-up or thickness can change restraint and the weld thermal cycle
- These essential variables are generally tighter than under ASME IX.

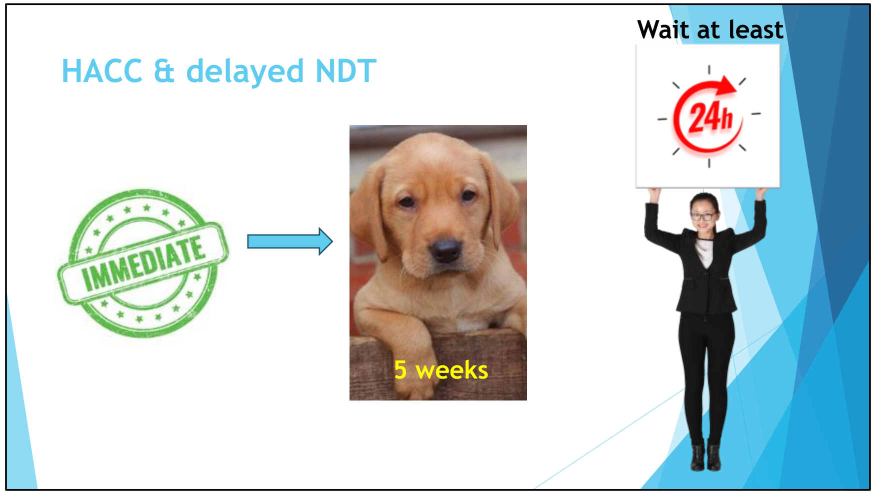
- The 2020 edition of Part 2 loosened the essential variables for most welding processes used for pipeline assembly welding.
- This change better reflects workshop pipeline assembly fabrication practices and the use of modern semi-automatic welding processes.
- The update acknowledges that high-quality outcomes can be achieved using a broader range of essential variables when properly qualified.
- Despite rationalizing and clarifying essential variables for more welding processes, the standard retained its fracture-focused intent and requirements.
- Importantly, the update did not relax the need to demonstrate toughness where required for fracture control.



- There are four ways to qualify a welding procedure in Part 2, but I'll cover the two most common methods for pipeline assemblies.
- A welding procedure can be qualified directly to AS 2885.2 by completing the required testing to demonstrate compliance.
- For pipeline assemblies only, alternative welding standards can be used under strict conditions, as shown in the box.
- Part 2 qualification typically requires demonstrating toughness performance where fracture control is relevant.
- Attempting to extend a procedure from ASME IX is often limited because ASME IX qualification is commonly strength-based without mandatory toughness tests.
- Many workshops also qualify to AS 3992, so procedures may be dual qualified for broader pressure equipment work.
- Where ASME IX and AS 3992 are already in place, adding AS 2885.2 often creates a practical 'triple qualification' requirement with significant additional testing scope.

Code consistency

- It's important to reflect that the design code establishes the failure model and assumptions, so the welding code must align with that same model.
- If a pipeline assembly is designed to Part 1 the welding must comply with Part 2 because the standards are paired by intent.
- Mixing AS 2885 design with pressure piping welding standards can break the fracture and defect tolerance logic that the design relies upon.
- If the assembly is instead designed to an alternative pressure code, then welding qualification must follow the corresponding welding standard for that code.
- Avoiding code mixing preserves a defensible safety case because the design assumptions, qualification tests and acceptance criteria remain consistent.



- The biggest NDT challenge in pipeline assemblies is HACC due to the fine nature of the cracking and its delayed formation.
- Hydrogen assisted cold cracking can occur after welding is complete, so immediate inspection may miss defects that form later.
- Higher CEQ materials increase the risk of delayed cracking, particularly in restrained assembly welds.
- Delayed inspection is used so that time-dependent cracks have an opportunity to form and be detected before commissioning.
- Delayed NDT is common for assemblies because they often include high-CEQ forgings and high restraint geometry.
- This approach prevents early-life failures by catching cracks before the pipeline or assembly enters service.

Hydrotesting philosophy

- Under AS 2885, hydrostatic testing is used as a system-level strength and integrity verification step.
- A hydrotest is not intended to be a substitute for proper weld procedure qualification or for robust welding controls.
- The philosophy assumes welding quality is assured through qualification, supervision and inspection before testing is performed.
- This differs from some pressure piping approaches where hydrotest is more directly relied upon as a validation step for fabrication quality.
- The difference reflects high pressure pipeline failure modes and the need to prevent brittle fracture rather than simply proving leak tightness.

Welding takeaways

- Getting welding right on assemblies matters because this is where different materials, thicknesses and geometries come together, creating the highest risk of cracking and failure
- The objective isn't just "make a weld" — it's to consistently produce welds that meet both strength and toughness requirements for fracture control
- We can't rely on inspection or hydrotest at the end — quality has to be built in through procedure qualification and controlled
- Carbon equivalent becomes a key decision driver, because it directly affects cracking risk and how we weld the joint
- That means process selection, preheat, consumables and inspection timing are all linked back to the materials we discussed earlier
- The standard only works if design, materials and welding are aligned — mixing codes breaks the safety logic
- So overall, integrity comes from disciplined, repeatable control of the welding process — not from fixing problems after the fact