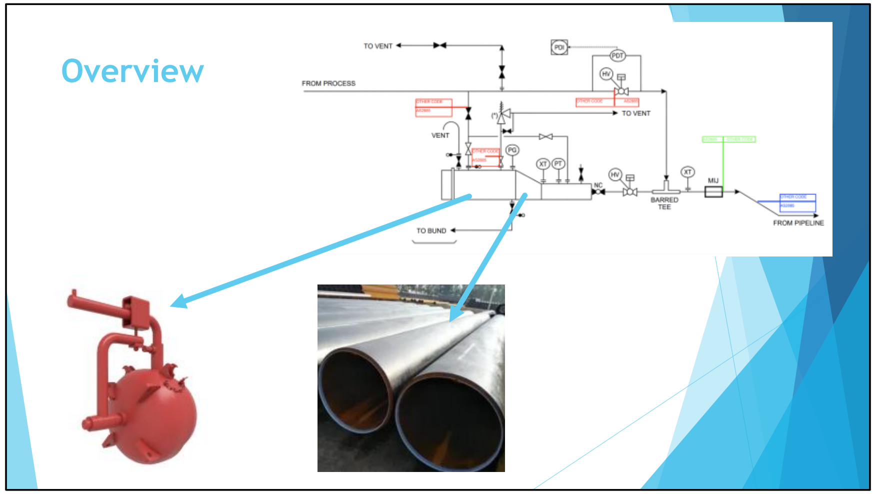
AS/NZS 2885
PIPELINE ASSEMBLIES
Materials

- I'll be walking through materials and welding in pipeline assemblies—with a short interlude along the way.
- I can promise no bullet points, but plenty to keep the engineers entertained: equations, graphs, Venn diagrams, and a few microstructures.
- I'll also share the full slide pack, including notes, with everyone after the webinar.



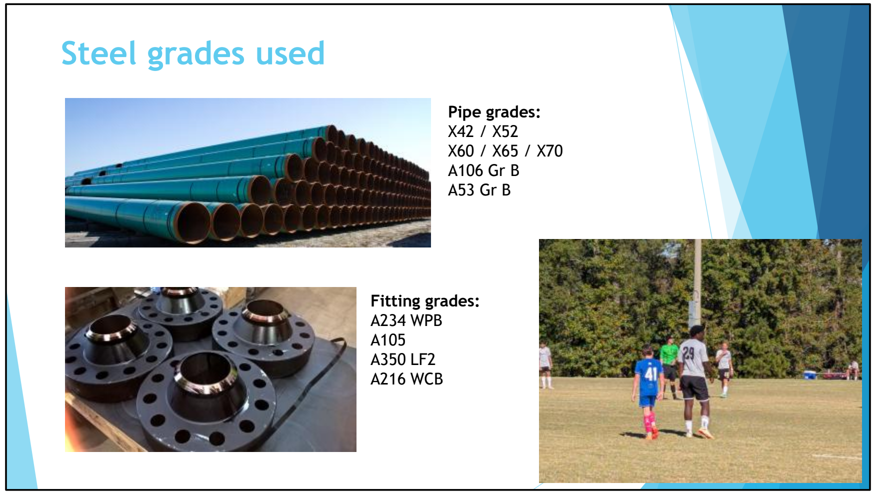
- If you think about it, the P&ID is just a picture — it doesn’t exist until we actually build something from it
- What we’re really doing is turning that drawing into a physical piece of steel sitting out in the field
- That means choosing the real components — pipe, fittings, valves, flanges — that will make up the assembly
- And then making a call about how we will weld and bolt the materials together.
- Every one of those choices brings different materials, thicknesses and manufacturing histories into the same location
- So very quickly, that simple drawing becomes a quite complex mix of steels that all need to behave properly when joined
- And that’s the key point for today — the way we translate the P&ID into materials is what sets up the welding challenge and the integrity risk for the assembly, and we’ll pick that up in more detail when we move into the welding session later on

- Pipeline assemblies are part of the overall pipeline system and must align with AS 2885, particularly preventing fracture initiation
- Many are in accessible areas, so any loss of integrity has direct safety consequences
- They are not equivalent to mainline pipe or general piping, combining complex geometry, multiple components and discontinuities (traps, valves, branches) in a small space
- They operate under high-consequence conditions and concentrate risks such as restraint, thickness transitions and mixed materials
- Small issues can have outsized impacts, and AS 2885 assumes failures are localised, shaping fracture management
- The key requirement is preventing fracture initiation, so materials and welding must provide sufficient toughness and crack resistance
- Microstructural behaviour affects weldability, defect tolerance and long-term integrity, making material selection critical
- Welding controls and materials must avoid creating brittle or crack-prone zones
- This session introduces key materials concepts and links to the practical welding controls covered next

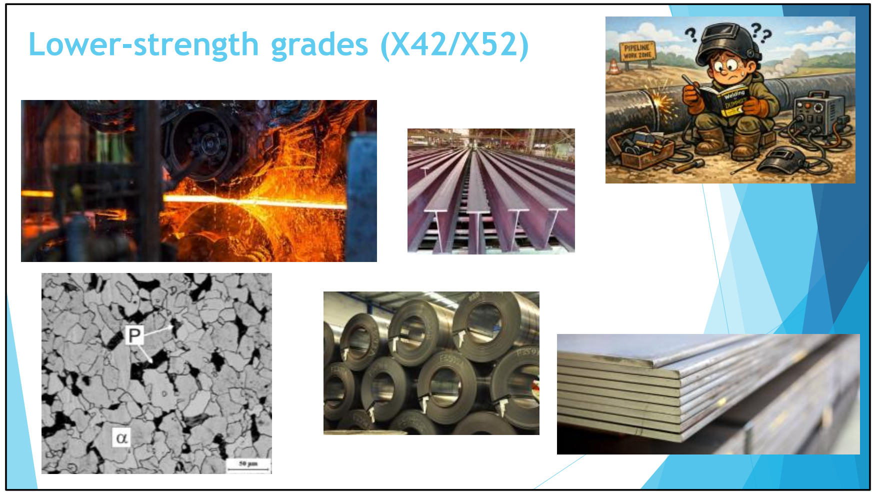
AS 2885 vs pressure piping

- Pipelines frequently run through public areas, so the acceptable risk profile is different to major hazard facilities.
- High-pressure pipelines often operate at low design factors, making fracture behaviour and defect tolerance central considerations.
- A failure in a pipeline context can have severe consequences, which is why fracture-based thinking is embedded in AS 2885.
- Pressure piping is typically inside a fenced facility with buffers, where exposure and consequence assumptions differ from cross-country pipelines.
- These different contexts drive different philosophies in materials, welding and testing requirements.

- Pipeline assemblies commonly include pressure-containing pipe spools, barrels and headers that form the primary pressure boundary.
- As Nick covered earlier they also include fittings such as bends, tees, reducers and caps, which introduce geometry changes and stress concentrations.
- Valve bodies and closures are frequently part of assemblies and may have different metallurgy and manufacturing history than the pipe.
- Flanges and branch connections introduce additional interfaces and bolted joints that must be managed for strength and leak tightness.
- Because multiple product forms are combined at one node, engineers must consider how differences in chemistry, thickness and processing affect weldability.

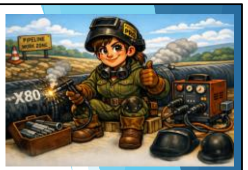


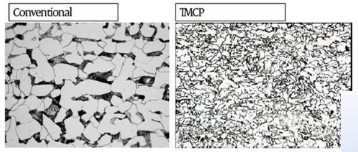
- Pipeline assemblies commonly use pipe steel grades in the range from X42 through to X70 depending on the pipeline design and component supply.
- Lower-strength and higher-strength materials can coexist in the same assembly, particularly where fittings and flanges differ from line pipe.
- Although these steels belong to the same broad standards family, some of which are indicated in the slide, their microstructure and weld response can be quite different, and even materials of the same grade can exhibit significantly different properties depending on their chemistry and manufacturing history. Think of a U13's soccer team where there are small kids and huge kids all playing in the same grade, but they have vastly different abilities.
- Mill certificates provide important traceability and chemistry information, but actual material properties may not always fully align, so verification and testing should be considered.
- Grade labels are a shorthand description of strength and do not, by themselves, describe weldability or cracking risk.
- Understanding metallurgy and chemistry is essential to selecting appropriate welding controls for the specific materials present.

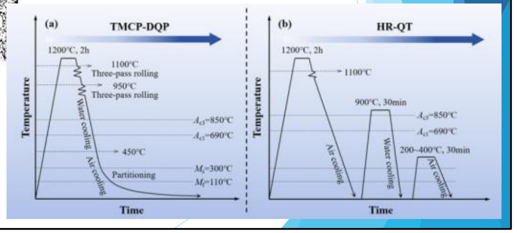


- Lower-strength grades such as X42 and X52 are commonly ferrite–pearlite steels as shown in the microstructure, which tend to respond predictably to welding.
- These steels are often produced by conventional hot-rolling routes as show in the photo, or by forging, rather than advanced thermo-mechanical controlled processing or TMCP, which I'll discuss next.
- Some typical product forms are shown for these products such as hot rolled beams, plate and strip.
- They can have comparatively higher carbon content than modern TMCP steels, which influences hardness and cracking behaviour.
- Their heat-affected zones are often softer and more tolerant of variations in welding heat input.
- As a result, these grades are generally more weldable, although cracking controls may still be required depending on thickness and restraint.

Higher-strength grades e.g. X60/X70/X80 Thermo-Mechanical Controlled Processing (TMCP)

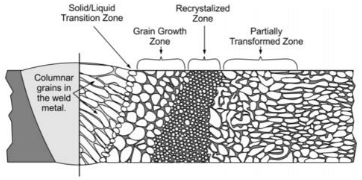


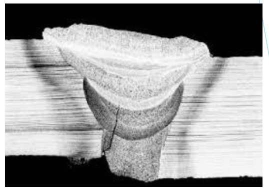


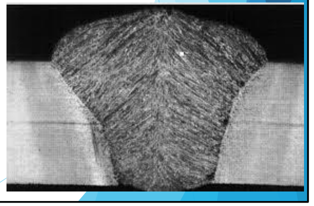


- Higher-strength grades achieve strength through microstructural control. Line pipe grades such as X70 are often produced by thermo-mechanical controlled processing (TMCP) with direct water quenching or less commonly by hot rolling then separate heat treatment involving reheating, water quenching and then tempering.
- TMCP steels gain strength from fine grain structures rather than simply increasing alloy content, which changes how welding affects the heat-affected zone. This finer grain structure in shown in the microstructure.
- These steels often have lower carbon content, which can improve weldability when procedures are controlled appropriately.
- However, TMCP steels can be sensitive to heat input because welding can locally alter the carefully produced microstructure.
- It should be noted that high strength fittings such as flanges, can be manufactured by a combination of moderate alloying in combination with quenching and tempering to achieve strength through microstructural control.
- Disciplined welding procedure specifications (WPS) are therefore needed to maintain toughness and avoid creating brittle or hard regions.

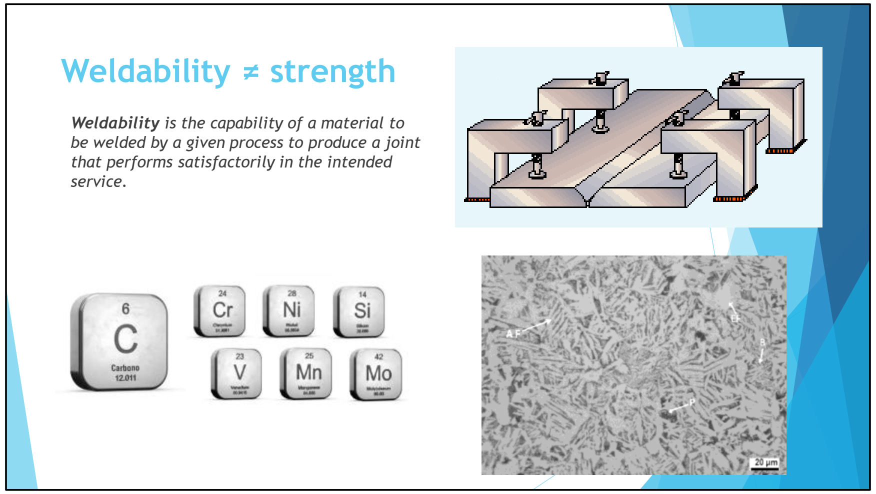
Welding effects on microstructure







- Welding reheats the parent metal locally and creates a heat-affected zone (HAZ) with properties that can differ vastly from the base material.
- In many cases, the HAZ governs performance because it can be the location of peak hardness or reduced toughness.
- For TMCP steels, the microstructural benefits achieved at the mill can be reduced or lost near the weld depending on the thermal cycle.
- Hardness and toughness can change significantly with cooling rate, restraint and heat input, which directly affects crack susceptibility.
- Controlling heat input through qualified procedures is critical to achieving consistent welds and HAZ properties.



- High strength does not automatically mean poor weldability, because weldability depends on chemistry, microstructure and restraint as much as strength.
- Likewise, low strength does not automatically mean safe or easy welding, because cracking risk can still be driven by carbon content and thickness.
- Chemical composition strongly influences hardness and cracking behaviour in the weld metal and heat-affected zone.
- The processing route, such as hot-rolling versus TMCP, affects microstructure and how the steel responds to welding thermal cycles.
- Because of these factors, carbon equivalent is used as a practical indicator to guide welding controls.

Carbon Equivalent (CEQ)

Hardenability is the tendency of the base metal and heat-affected zone (HAZ) to form hard, brittle microstructures during the weld thermal cycle as the material cools.

- Carbon equivalent (CEQ) is used as a single numeric indicator that helps describe how readily a steel can be welded without cracking. It is used in both AS 2885 and API 5L.
- CEQ represents the combined effect of carbon and alloying elements that influence hardenability and HAZ hardness.
- A higher CEQ generally indicates higher susceptibility to hydrogen assisted cold cracking under restraint, which we'll cover in more detail later.
- CEQ is used to set welding controls such as preheat, process selection and inspection timing.
- In practice, CEQ provides a common language linking materials selection to welding and integrity decisions in the AS 2885 context.

IIW CEQ formula, and lets mention Pcm

CEQ = C + Mn/6 + (Cr+Mo+V)/5 + (Ni+Cu)/15

Pcm = C + Si/30 + Mn/20 + Cu/20 + Ni/60 + Cr/20 + Mo/15 + V/10 + 5B

Aspect	Pcm	CE (IIW)
Best for	TMCP / modern steels	Older C-Mn steels
Carbon weighting	Lower	Higher
Welding relevance	HAZ cracking risk	General hardenability

- The International Institute of Welding (IIW) CEQ formula expresses weldability using the relationship as shown.
- Carbon is typically the dominant contributor in CEQ because it strongly influences hardenability and maximum HAZ hardness.
- Alloying elements such as chromium, molybdenum and vanadium increase hardenability, delay ferrite/pearlite formation, and increase hydrogen-assisted cracking risk.
- For modern low-carbon, TMCP and pipeline steels, Pcm is often used instead of CEQ because CEQ can be overly conservative.
- Whilst Pcm is not referenced in AS 2885 or API 5L, you might find it in supplementary specifications.
- Pcm places less weighting on carbon and better reflects HAZ hardening behaviour under welding thermal cycles typical of pipeline construction.
- Very small changes in chemistry, including carbon, manganese, micro-alloying elements or boron, can significantly change CEQ or Pcm and move a material into a higher weldability risk category.
- Boron has a factor of 5 in Pcm because even tiny amounts have a disproportionately large effect on hardenability and cracking risk, so the multiplier scales its impact to match its real influence on weld behaviour.

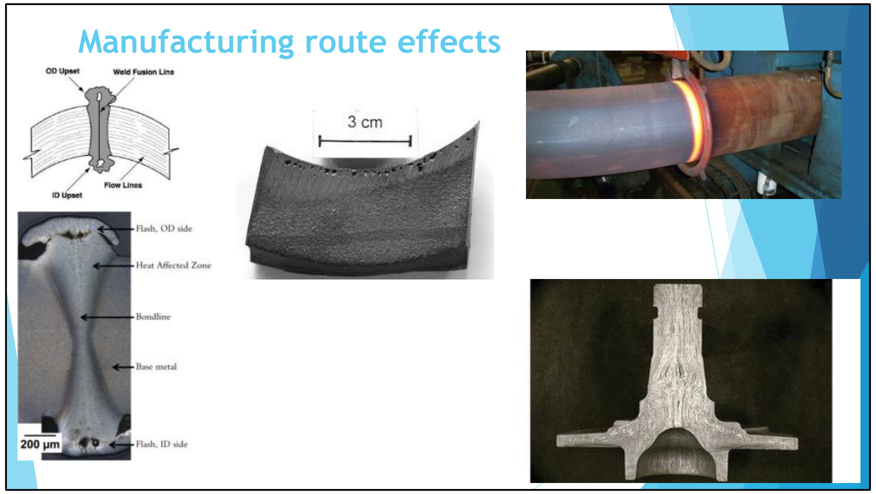
- Different heats of the same nominal grade can therefore have materially different weldability, making reliance on grade designation alone potentially misleading.

CEQ and Pcm thresholds

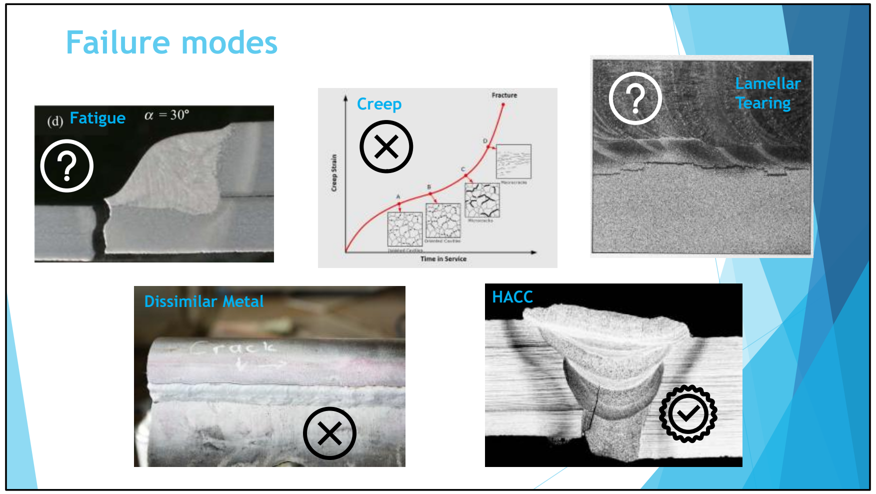
- A CEQ below about 0.38 is commonly treated as lower risk for hydrogen-assisted cold cracking when low hydrogen welding practices are used; for modern low-carbon and TMCP steels, a similar judgement is often made using Pcm less than 0.18 to avoid hydrogen assisted cold cracking.
- There is no hard limit for either CEQ or Pcm in AS 2885.2, as hydrogen assisted cold crakcing depends on multiple interacting factors including heat input, cooling rate, restraint and hydrogen control.
- Increasing CEQ or Pcm is commonly treated as indicating increasing cracking risk and usually triggers additional controls.
- These CEQ and Pcm values represent practical guidance derived from industry experience rather than absolute boundaries applicable to all welding conditions.
- CEQ and Pcm thresholds are used to inform decisions such as minimum preheat temperature, allowable heat-input range, and whether low hydrogen welding processes are required.
- Because CEQ and Pcm are widely used across industry, they provide a consistent basis for communicating welding risk and controls, particularly when comparing different heats or products of the same nominal grade.

CEQ mismatch in assemblies

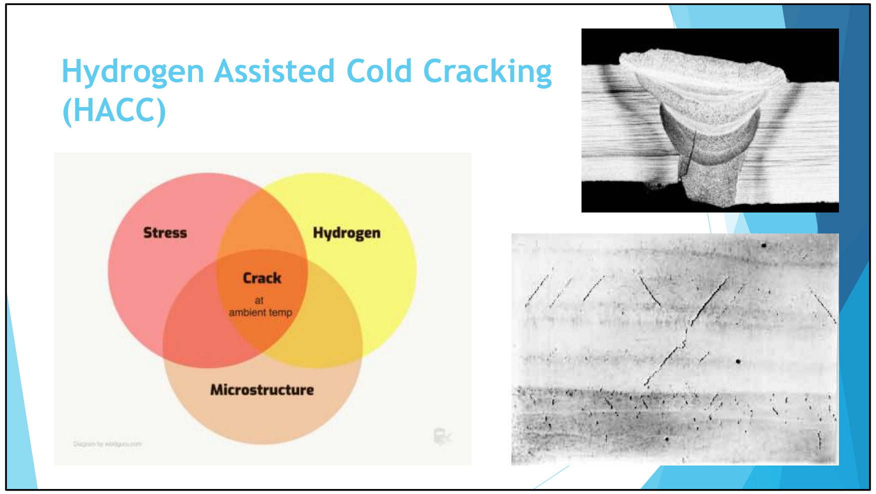
- Line pipe, particularly modern TMCP X70, can have very low CEQ values and can be comparatively weldable when procedures are controlled.
- Forged components such as flanges and fittings can have much higher CEQ values, which increases cracking risk at the weld.
- Assemblies often include thickness transitions that create uneven heating and cooling, increasing local stress and hardness risk.
- The geometry and stiffness of assemblies create high restraint, which increases tensile stress during cooling.
- Because low- and high-CEQ materials are commonly joined together, assemblies are frequent hotspots for hydrogen assisted cold cracking.



- The manufacturing route can further affect weldability
- Seamless and welded pipe products can have different weld seam characteristics and toughness behaviour, which can affect assembly performance. The pictures on the left show an electric resistance weld, or ERW, which is the common method of completing the longitudinal weld in line pipe.
- Castings like those shown in the middle image can be suitable where quality assurance is rigorous and toughness is confirmed for the intended service. However, they often contain subsurface defects such as porosity that may meet product acceptance criteria but can grow into larger flaws under the thermal cycles associated with welding.
- Forged components as shown in the bottom right picture, have the advantage of aligned microstructures and reduced internal defects. However, they often have higher CEQ values and therefore may require tighter welding controls to avoid cracking.
- Induction bends as shown in the top right picture, have a thermal history that can influence microstructure and therefore welding response near the bend.
- Because the manufacturing route affects chemistry, microstructure and toughness, it must be considered alongside nominal grade selection.



- Let's look at the common failure modes in welds.
- Cracks are the most critical failure mode in welded joints from an integrity point of view, as they can propagate under stress and lead to loss of containment.
- Fatigue is generally screened by design and operational limits in transmission gas pipelines, rather than being the dominant welding concern.
- Creep is not relevant for typical transmission gas pipeline operating temperatures, so it is not a governing design or welding failure mode.
- Dissimilar metal issues are generally avoided by design in gas transmission pipelines, so they are not usually central to assembly welding requirements.
- Lamellar tearing can occur in rolled plate due to through-thickness strain and inclusion alignment, but it is generally not a concern for pipeline welding unless wall thickness is relatively high and restraint is significant.
- Hydrogen assisted cold cracking - HACC is the most credible failure mode in pipeline assembly welding.
- AS 2885 prioritises the dominant credible risks for gas transmission pipelines rather than attempting to treat every theoretical mechanism equally.
- This risk-based prioritisation is why the standard focuses heavily on fracture control and hydrogen cracking rather than facility-type failure modes.



- HACC occurs when three factors come together: diffusible hydrogen, a susceptible microstructure (typically hard martensite), and tensile stress from restraint or residual stresses. Cracking usually begins after cooling, once the material has transformed and the hydrogen has diffused.
- As CEQ increases, hardenability increases, raising the likelihood of forming higher-hardness, crack-susceptible HAZ microstructures—especially under faster cooling conditions.
- Assembly restraint and increasing thickness both elevate risk by increasing tensile stress, residual stress, and constraint effects while influencing cooling rate.
- HACC is typically delayed, with cracks forming hours or days after welding, meaning welds may initially appear acceptable.
- Because delayed cracking may not be detected immediately by inspection, HACC is treated as a dominant pipeline welding risk and must be controlled through welding procedures, not inspection alone.

- Low-hydrogen processes and consumables are used to minimise the amount of diffusible hydrogen introduced during welding.
- Consumable control, including storage and handling, is required so that low-hydrogen consumables remain low hydrogen in practice.
- Preheat is applied based on CEQ, thickness and restraint so that cooling rates and hardness are controlled.
- Avoiding excessive hardness in the HAZ reduces the susceptibility of the microstructure to hydrogen cracking.
- The overall approach emphasises preventing cracks from forming rather than relying on post-weld repair to fix problems.
- I'll talk more in the welding session about how the avoidance of Hydrogen cracking is achieved in practice.

Common pitfalls

- So what are the common pitfalls of pipeline assembly welding.
- A common pitfall is treating all carbon steels as if they behave the same, which can lead to inadequate welding controls.
- Another pitfall is ignoring the higher CEQ chemistry often present in forged components such as flanges and fittings.
- Restraint is often underestimated in assemblies, which can cause cracking even when materials appear benign.
- If welding input is not included during material selection, procurement may deliver components that are difficult to weld safely.
- These issues often emerge late, creating schedule, cost and quality impacts when weldability problems are discovered during fabrication.

Materials takeaways

- Let's wrap up the key materials takeaways for pipeline assembly welding.
- Microstructure and processing history often explain weld behaviour more reliably than grade labels alone.
- Carbon equivalent is a central metric for assessing weldability and selecting welding controls.
- Assemblies frequently mix materials with very different CEQ values and manufacturing histories, which increases welding risk.
- High-CEQ components require stricter controls such as low-hydrogen processes, preheat and appropriate inspection strategy.
- Material selection decisions effectively set the welding risk profile for the assembly and must be made with welding in mind.
- In the next session, we will explore how various components are safely welded together to form a complete pipeline assembly.