TECHNICAL SPECIFICATIONS

Grade 91 (9Cr-1Mo-V) welding reference: preheat, PWHT, filler selection, and NDE

Grade 91 alloy steel (ASTM A335 P91 pipe; A182 F91 fittings and flanges; A387 Gr. 91 plate) is a 9% chromium, 1% molybdenum, vanadium-modified ferritic/martensitic steel developed for high-temperature steam service above 1000°F. Its creep strength advantage over P22 allows thinner walls and lighter systems, but its welding requirements are significantly more stringent.

Inadequate preheat, PWHT, or inter-pass temperature control can result in Type IV cracking in the heat-affected zone — the primary failure mode responsible for several major power plant incidents in the past two decades.

Parameter	Requirement	Notes
Preheat	400°F minimum	Maintain throughout welding
Interpass temperature	400°F min / 600°F max	Monitor with contact pyrometer
PWHT temperature	1350–1425°F	Soak at temperature — do not exceed 1450°F
PWHT ramp rate	≤200°F/hr above 600°F	Both heating and cooling
PWHT hold time	2 hours minimum per inch of thickness	Based on maximum weld thickness
Post-weld cooling	Cool to <200°F before PWHT	Prevent delayed cracking
Hardness (HAZ)	≤265 HBW (EPRI guideline)	Soft HAZ >200 HBW preferred
Filler metal (GTAW)	ER90S-B9 (AWS A5.28)	Matching composition
Filler metal (SMAW)	E9018-B9 (AWS A5.5)	Low hydrogen, bake before use

- Visual examination: 100% per WPS and ASME B31.1
- Radiographic Testing (RT): 100% of all P91 butt welds in HEP systems
- Phased Array UT (PAUT): supplemental or alternative to RT per engineering approval
- Hardness testing: every weld after PWHT — base metal, HAZ, and weld metal readings

- Magnetic Particle Testing (MT): after back-gouging and prior to final RT
- Creep replication: at baseline and per CPS inspection interval for in-service welds

- Allowing temperature to drop below 400°F preheat during any welding interruption
- Performing PWHT before weld has cooled below 200°F (promotes hydrogen cracking)
- Exceeding 1450°F PWHT temperature (Ac1 transformation temperature)
- Using ER80S-B2 (P22 filler) in a P91 application — non-conforming
- Skipping hardness verification after PWHT
- Failing to maintain inter-pass temperature records for documentation