Best Practice Guidelines for Design and Fabrication

Table 3-3 Composition ranges for commonly specified nickel-base filler metals used in the fabrication of DMWs between 9%Cr CSEF steels and austenitic stainless steels [25–27]

| ENIFeCr-4 ERNIFeCr-4 (EPRI P87) | 0.08-0.14 | 0:02-0:50 | 1.2–1.8 | 8.5–9.5 | 54 max | 0.9—1.4 | 38-42 | 0.05 max | 0.01 max | 0.01 max | 1.8–2.2 | | 0.25 max | 0.0005-0.02 | 0.10-0.20 | 0.02 max |
|---------------------------------------|---|---|--|--|--|---|---|---|--|--|---|---|---|--|---|---|
| ERNICrCoMo-1 (FM 617) | 0.05-0.15 | 1.0 max | 1.0 max | 20.0–24.0 | Bal. | | 3.0 max | 0.60 max | 0.03 max | 0.015 max | 8.0-10.0 | 10.0–15.0 | 0.50 max | | 0.8 to 1.5 | |
| ENiCrCoMo-1 (IN 117) | 0.05-0.15 | 0.75 max | 0.3–2.5 | 21.0–26.0 | Bal. | 1.0 max | 5.0 max | | 0.03 max | 0.015 max | 8.0–10.0 | 9.0–15.0 | 0.50 max | | | |
| ERNICrMo-3 (FM 625) | 0.10 max | 0.50 max | 0.50 max | 20.0–23.0 | 58 min | 3.15-4.15 | 1.0 max | 0.40 max | 0.02 max | 0.015 max | 8.0–10.0 | | 0.50 max | | 0.40 max | |
| ENiCrMo-3 (IN 112) | 0.10 max | 0.75 max | 1.0 max | 20.0–23.0 | 55 min | 3.15-4.15 | 7.0 max | | 0.02 max | 0.03 max | 8.0–10.0 | | 0.50 max | | | |
| ENICrFe-2 (INCO A) | 0.10 max | 0.75 max | 1.0–3.5 | 13.0–17.0 | 62 min | 0.5-3.0 | 12.0 max | | 0.03 max | 0.02 max | 0.5–2.5 | | 0.50 max | | | |
| ERNICr-3 (FM 82) | 0.10 max | 0.50 max | 2.5–3.5 | 18.0 - 22.0 | 67 min | 2.0–3.0 | 3.0 max | 0.75 max | 0.03 max | 0.015 max | | | 0.50 max | | | |
| ENiCrFe-3 (IN 182) | 0.10 max | 1.0 max | 5.0-0.5 | 13.0–17.0 | 59 min | 1.0–2.5 | 10.0 max | 1.0 max | 0.03 max | 0.015 max | | | 0.50 max | | | |
| Element | С | Si | чW | c | Ni | Nb+Ta | Ъе | ΪŢ | Ч | S | oW | Co | Cu | В | Ы | Ν |
| | Element ENICrFe-3 ERVICr-3 ENICrFe-2 ENICrMo-3 ERVICrMo-3 ENICrMo-4 ENICrCoMo-1 ERVICrCoMo-1 ERVIFeCr-4 (IN 182) (FM 82) (IN 112) (FM 625) (IN 117) (FM 617) (EPRI P87) | Element ENICFE-3 ERNICF-3 ENICFE-2 ENICFMO-3 ERNICFMO-1 ERNIFECF-4 ENIFECF-4 (IN 182) (FM 82) (IN 0112) (FM 625) (IN 117) (FM 617) (ERNIFECF-4 C 0.10 max 0.10 max 0.10 max 0.10 max 0.10 max 0.05-0.15 0.05-0.15 0.08-0.14 | Element ENICFE-3 ERNICF-3 ENICFR-2 ENICFMO-3 ERNICFMO-3 ENICFCOMO-1 ERNIFECF-4 ENIFECF-4 ENIFECF-4 ENIFECF-4 ERNIFECF-4 | Hemantalementation Envicre-3 Envicre-3 Envicre-2 Envicre-3 Envicre-3 Envicre-3 Envicre-4 | HeatmentENICFEe-3ENVICF-3ENVICFE-2ENVICFMo-3ENVICFMo-3ENVICFMo-3ENVICFGMO-1ENVICFGMO-1(IN 182)(FM 82)(IN 043)(IN 043)(IN 112)(FM 625)(IN 117)(FM 617)ERVIFECF-4(IN 182)0.10 max0.10 max0.10 max0.10 max0.10 max0.05-0.150.08-0.14(IN 112)1.0 max0.10 max0.10 max0.10 max0.10 max0.05-0.150.08-0.14(IN 112)1.0 max0.10 max0.10 max0.10 max0.10 max0.05-0.150.08-0.14(IN 10 max0.50 max0.75 max0.75 max0.75 max0.75 max1.0 max0.05-0.50(IN 110)5.0-9.51.0-3.51.0 max0.50 max0.50 max0.3-2.51.0 max1.2-1.8(IN 112)18.0-22.013.0-17.020.0-23.020.0-23.021.0-26.020.0-24.08.5-9.5 | Hement ENICFEe-3 ENICFE-2 ENICFE-2 ENICFEO-3 ENICFCOMO-1 ENICFCOM0-1 ENICFCOM | Fluench Envicre-3 Envicre-3 Envicre-3 Envicre-3 Envicre-3 Envicre-3 Envicre-4 | Hurcreadement ENICFG-3 ENICFG-3 ENICFG-3 ENICFG-3 ENICFG-4 ENICFG-4 (IN 182) (FM 82) (INCO A) (IN 112) (FM 625) (IN 117) (FM 617) ENIFEGT-4 C 0.10 max 0.10 max 0.10 max 0.10 max 0.10 max 0.05-0.15 0.08-0.15 0.08-0.14 Si 1.0 max 0.10 max 0.10 max 0.10 max 0.10 max 0.10 max 0.05-0.15 0.08-0.15 0.08-0.14 Nin 5.0-9.5 2.5-3.5 1.0-3.5 1.0 max 0.50 max 0.50 max 0.75 max 1.0 max 1.0 max 1.08-0.16 Nh 5.0-9.5 2.5-3.5 1.0-3.5 1.0 max 0.50 max 0.3-2.5 1.0 max 1.02-0.16 1.2-1.8 Nh 5.0-9.5 2.5-3.5 1.0 max 0.50 max 0.50 max 0.3-2.5 1.0 max 1.2-1.8 Nh 5.0-9.5 2.10-3.0 2.10-2.5.0 2.10-2.6.0 2.10-2.6.0 1.2-1.8 Nh 5.0 max 0.50 max | Here Envicte-3 Envica Envica Envica <th>Here Here (IN 182)ERNICrFe-3 (FM 82)ENICrFe-2 (IN 012)ENICrCeMo-1 (FM 625)ENICrCeMo-1 (FM 617)ENIFCC-4-4 (FM 617)ENIFCC-4-4 (FM 617)ENIFCC-4-4 (FM 617)ENIFCC-4-4 (FM 617)ENIFCC-4-4 (FM 617)ENIFCC-4-4 (FM 617)ENIFCC-4-4 (FM 617)ENIFCC-4-4 (FM 617)ENIFCC-4-4 (FM 617)ENIFCC-4-4 (FM 617)ENIFCC-4-4 (FM 617)ENIFCC-4-4</br></br></br></br></br></br></br></br></br></th> <th>Hubble Envicred-a Envicre-a Envicre-a<th>Hutch Envicte-3 Envicte-3 Envicto-0-1 Envico-0 Envico-0 Envico-0<</th><th>Heinert ENUCF6-3 ENUCF6-3 ENUCF6-3 ENUCF0-3 ENUCF0-4 ENUCF6-4 (IN 182) (FM 82) (FM 82) (IN 112) (FM 82) (IN 112) (FM 617) (ENIFECF4 C 0.10 max 0.10 max 0.10 max 0.10 max 0.10 max 0.05-0.15 0.08-0.15 0.08-0.16 Si 1.0 max 0.50 max 0.75 max 0.10 max 0.05-0.15 0.08-0.16 (ENIFGC4 Si 1.0 max 0.75 max 0.10 max 0.10 max 0.10 max 0.05-0.15 0.08-0.16 0.08-0.16 Nin 5.0-9.5 2.5-3.5 1.0 max 0.75 max 0.50 max 0.3-2.5 1.0 max 0.05-0.50 0.08-0.16 Nin 5.0-9.5 2.5-3.5 1.0 max 0.75 max 0.50 max 0.3-2.5 1.0 max 0.05-0.50 0.08-0.16 0.08-0.16 0.08-0.16 0.08-0.16 0.08-0.16 0.08-0.16 0.05-0.50 0.08-0.16 0.08-0.16 0.08-0.16 0.08-0.16 0.08-0.16 0.08-0.16 0.08-0.16 0.0.</th><th>Ehement (IN 112) ENUCF-a. (IN 112) ENUCF-a. (IN 112) ENUCF-a. (IN 112) ENUCF-a. (IN 117) ENUCF-a. (FM 677) ENUFCC-Mo-1 (FM 677) ENUFCC-Mo-1 (FM 677) ENUFCC-Mo-1 (FM 677) ENUFCC-Mo-1 (FP R1 F6C/-a. C 0.10 max 0.10 max 0.10 max 0.10 max 0.10 max 0.05-0.15 0.08-0.15 0.08-0.16 Si 1.0 max 0.50 max 0.75 max 0.75 max 0.05-0.15 0.08-0.16 0.08-0.16 Ni 5.0-9.5 1.0 max 0.75 max 0.75 max 0.75 max 10.7-18 0.08-0.16 Ni 5.0-9.5 1.0 max 0.75 max 0.75 max 0.75 max 10.8-0.16 0.08-0.16 Ni 5.0-9.5 2.5-3.5 1.0 max 0.75 max 0.25 max 0.25 max 0.25 max 0.25 max Ni 5.0-10.0 18.0-22.0 13.0-17.0 210-25.0 210-25.0 210-25.0 210-25.0 210-8 Ni 1.0-25.0 1.0 max 0.50 max 0.50-25.0 210-25.0 210-25.0 210-25.0 210-25.0</th><th>Herrorial constant ENICFG-3 ENICFG-3 ENICFG-3 ENICFG-3 ENICFG-3 ENICFG-3 ENIFEG-3 ENIFEG-3<th>Hement (IN 182) ENICrFe-3 (IN 182) ENICrFe-3 (IN 0182) ENICrFe-3 (IN 17) ENICrCoMo-1 (IN 17) ENICrCoMo-1 (FM 617) ENICrCoMo-1 (ENIF67-1 C 0.10 max 0.10 max 0.10 max 0.10 max 0.05-0.15 0.06-0.15 ENICrFo-3- (IN 17) Si 1.0 max 0.10 max 0.10 max 0.10 max 0.05-0.15 0.08-0.14 ENIFIC-7- (IN 17) Si 1.0 max 0.10 max 0.10 max 0.05-0.15 0.08-0.15 0.08-0.14 Ni 50-045 2.5-3.5 1.0-3.5 1.0 max 0.50 max 0.05-0.15 0.08-0.14 Ni 50-045 2.5-3.5 1.0-3.5 1.0 max 0.50 max 0.50-0.15 0.08-0.14 Ni 50-045 2.5-3.5 1.0-3.5 1.0 max 0.50 max 0.50-0.15 0.05-0.16 Ni 50-045 2.5-3.5 1.0 max 0.50 max 0.50 max 0.50-0.16 0.55-0.5 Ni 50-045 2.5-3.5 1.0 max 0.50 max 0.50-24.0 8.5-4.16 Ni 1.0 2</th></th></th> | Here Here (IN 182)ERNICrFe-3 (FM 82)ENICrFe-2 (IN 012)ENICrCeMo-1 (FM 625)ENICrCeMo-1 (FM 617)ENIFCC-4-4 (FM 617)ENIFCC-4-4 | Hubble Envicred-a Envicre-a Envicre-a <th>Hutch Envicte-3 Envicte-3 Envicto-0-1 Envico-0 Envico-0 Envico-0<</th> <th>Heinert ENUCF6-3 ENUCF6-3 ENUCF6-3 ENUCF0-3 ENUCF0-4 ENUCF6-4 (IN 182) (FM 82) (FM 82) (IN 112) (FM 82) (IN 112) (FM 617) (ENIFECF4 C 0.10 max 0.10 max 0.10 max 0.10 max 0.10 max 0.05-0.15 0.08-0.15 0.08-0.16 Si 1.0 max 0.50 max 0.75 max 0.10 max 0.05-0.15 0.08-0.16 (ENIFGC4 Si 1.0 max 0.75 max 0.10 max 0.10 max 0.10 max 0.05-0.15 0.08-0.16 0.08-0.16 Nin 5.0-9.5 2.5-3.5 1.0 max 0.75 max 0.50 max 0.3-2.5 1.0 max 0.05-0.50 0.08-0.16 Nin 5.0-9.5 2.5-3.5 1.0 max 0.75 max 0.50 max 0.3-2.5 1.0 max 0.05-0.50 0.08-0.16 0.08-0.16 0.08-0.16 0.08-0.16 0.08-0.16 0.08-0.16 0.05-0.50 0.08-0.16 0.08-0.16 0.08-0.16 0.08-0.16 0.08-0.16 0.08-0.16 0.08-0.16 0.0.</th> <th>Ehement (IN 112) ENUCF-a. 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(IN 112) ENUCF-a. (IN 112) ENUCF-a. (IN 112) ENUCF-a. (IN 117) ENUCF-a. (FM 677) ENUFCC-Mo-1 (FM 677) ENUFCC-Mo-1 (FM 677) ENUFCC-Mo-1 (FM 677) ENUFCC-Mo-1 (FP R1 F6C/-a. C 0.10 max 0.10 max 0.10 max 0.10 max 0.10 max 0.05-0.15 0.08-0.15 0.08-0.16 Si 1.0 max 0.50 max 0.75 max 0.75 max 0.05-0.15 0.08-0.16 0.08-0.16 Ni 5.0-9.5 1.0 max 0.75 max 0.75 max 0.75 max 10.7-18 0.08-0.16 Ni 5.0-9.5 1.0 max 0.75 max 0.75 max 0.75 max 10.8-0.16 0.08-0.16 Ni 5.0-9.5 2.5-3.5 1.0 max 0.75 max 0.25 max 0.25 max 0.25 max 0.25 max Ni 5.0-10.0 18.0-22.0 13.0-17.0 210-25.0 210-25.0 210-25.0 210-25.0 210-8 Ni 1.0-25.0 1.0 max 0.50 max 0.50-25.0 210-25.0 210-25.0 210-25.0 210-25.0 | Herrorial constant ENICFG-3 ENICFG-3 ENICFG-3 ENICFG-3 ENICFG-3 ENICFG-3 ENIFEG-3 <th>Hement (IN 182) ENICrFe-3 (IN 182) ENICrFe-3 (IN 0182) ENICrFe-3 (IN 17) ENICrCoMo-1 (IN 17) ENICrCoMo-1 (FM 617) ENICrCoMo-1 (ENIF67-1 C 0.10 max 0.10 max 0.10 max 0.10 max 0.05-0.15 0.06-0.15 ENICrFo-3- (IN 17) Si 1.0 max 0.10 max 0.10 max 0.10 max 0.05-0.15 0.08-0.14 ENIFIC-7- (IN 17) Si 1.0 max 0.10 max 0.10 max 0.05-0.15 0.08-0.15 0.08-0.14 Ni 50-045 2.5-3.5 1.0-3.5 1.0 max 0.50 max 0.05-0.15 0.08-0.14 Ni 50-045 2.5-3.5 1.0-3.5 1.0 max 0.50 max 0.50-0.15 0.08-0.14 Ni 50-045 2.5-3.5 1.0-3.5 1.0 max 0.50 max 0.50-0.15 0.05-0.16 Ni 50-045 2.5-3.5 1.0 max 0.50 max 0.50 max 0.50-0.16 0.55-0.5 Ni 50-045 2.5-3.5 1.0 max 0.50 max 0.50-24.0 8.5-4.16 Ni 1.0 2</th> | Hement (IN 182) ENICrFe-3 (IN 182) ENICrFe-3 (IN 0182) ENICrFe-3 (IN 17) ENICrCoMo-1 (IN 17) ENICrCoMo-1 (FM 617) ENICrCoMo-1 (ENIF67-1 C 0.10 max 0.10 max 0.10 max 0.10 max 0.05-0.15 0.06-0.15 ENICrFo-3- (IN 17) Si 1.0 max 0.10 max 0.10 max 0.10 max 0.05-0.15 0.08-0.14 ENIFIC-7- (IN 17) Si 1.0 max 0.10 max 0.10 max 0.05-0.15 0.08-0.15 0.08-0.14 Ni 50-045 2.5-3.5 1.0-3.5 1.0 max 0.50 max 0.05-0.15 0.08-0.14 Ni 50-045 2.5-3.5 1.0-3.5 1.0 max 0.50 max 0.50-0.15 0.08-0.14 Ni 50-045 2.5-3.5 1.0-3.5 1.0 max 0.50 max 0.50-0.15 0.05-0.16 Ni 50-045 2.5-3.5 1.0 max 0.50 max 0.50 max 0.50-0.16 0.55-0.5 Ni 50-045 2.5-3.5 1.0 max 0.50 max 0.50-24.0 8.5-4.16 Ni 1.0 2 |



Figure 3-4

Effect of composition on the formation of carbide and embrittling phases at the fusion line between ferritic steels and commonly specified nickel-base filler metals (simulation conditions listed in Table 3-4) [24]

Table 3-4

Descriptions for the DMW simulations in Figure 3-4 [24]

| Simulation | Ferritic Material | Weld Metal | PWHT ^{1,2} | Service Simulation ³ | | |
|------------|-------------------|------------------|---------------------|---------------------------------|--|--|
| 1 | | | None | 625°C (1157°F) | | |
| 2 | Crada 01 | | 675°C (1247°F) | 625°C (1157°F) | | |
| 3 | Grade 91 | | | 625°C (1157°F) | | |
| 4 | | ENICIPE-2 | 760°C (1400°F) | 550°C (1022°F) | | |
| 5 | 9%Cr-1Mo | | | 625°C (1157°F) | | |
| 6 | Grade 22 | | 730°C (1346°F) | 550°C (1022°F) | | |
| 7 | | | | 550°C (1022°F) | | |
| 8 | | ENICIPE-3 | | 625°C (1157°F) | | |
| 9 | | | 760°C (1400°E) | 550°C (1022°F) | | |
| 10 | | EINICHWO-3 | 700°C (1400°F) | 625°C (1157°F) | | |
| 11 | Crada 01 | ENIC:CoMo 1 | | 550°C (1022°F) | | |
| 12 | Grade 91 | | | 625°C (1157°F) | | |
| 13 | | | None | 625°C (1157°F) | | |
| 14 | | ENiFeCr-4 | 675°C (1247°F) | 625°C (1157°F) | | |
| 15 | | (Code Case 2734) | 760°C (1400°E) | 625°C (1157°F) | | |
| 16 | | | 700°C (1400°F) | 550°C (1022°F) | | |

1 PWHT = $\underline{P}ost \underline{W}eld \underline{H}eat \underline{T}reatment$

2 All PWHT simulations = 4-hour duration

3 All service simulations = 50,000-hour duration