JPEDAV (2010) 31:180–183
DOI: 10.1007/s11669-010-9654-3
1547-7037 ©ASM International

Fe-Nb-Ni (Iron-Niobium-Nickel)

V. Raghavan

The early review of this ternary system by [1992Rag] presented a tentative isothermal section at 1000 °C from the studies of [1989Sav]. The updates by [2004Rag] and [2007Rag] presented an isothermal section at 1200 °C from [2001Tak] and [2005Tak]. Recently, [2009Mat] carried out a Calphad-type assessment of this ternary system and calculated a number of isothermal sections. This work will be reviewed briefly in this update.

Binary Systems

The Fe-Nb phase diagram [2000Tof] depicts two intermediate phases: Fe_2Nb ($C14$, $MgZn_2$-type hexagonal) and Fe_7Nb_6 ($D8_5$, Fe_7W_6-type rhombohedral). In the Fe-Ni phase diagram [1991Swa], a continuous face-centered cubic solid solution (denoted γ) forms between γFe and Ni and is stable over a wide range of temperature. At 517 °C, an ordered phase $FeNi_3$ ($L1_2$, $AuCu_3$-type cubic) forms congruently from γ. The Nb-Ni phase diagram [2006Che, 1996Bol], has the following intermediate phases: Nb_7Ni_6 ($D8_5$, Fe_7W_6-type rhombohedral), $NbNi_3$ ($D0_a$, Cu_3Ti-type orthorhombic) and $NbNi_8$ (tetragonal). Computed phase diagrams of the above systems were given by [2009Mat].

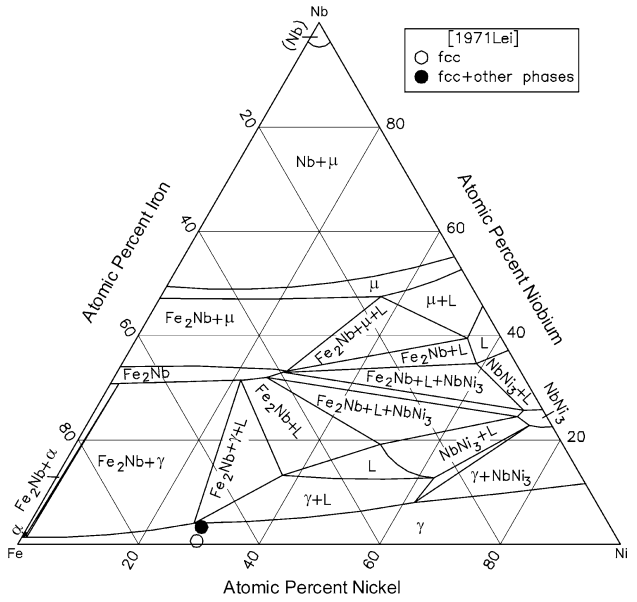

Fig. 2 Fe-Nb-Ni computed isothermal section at 1250 °C [2009Mat]

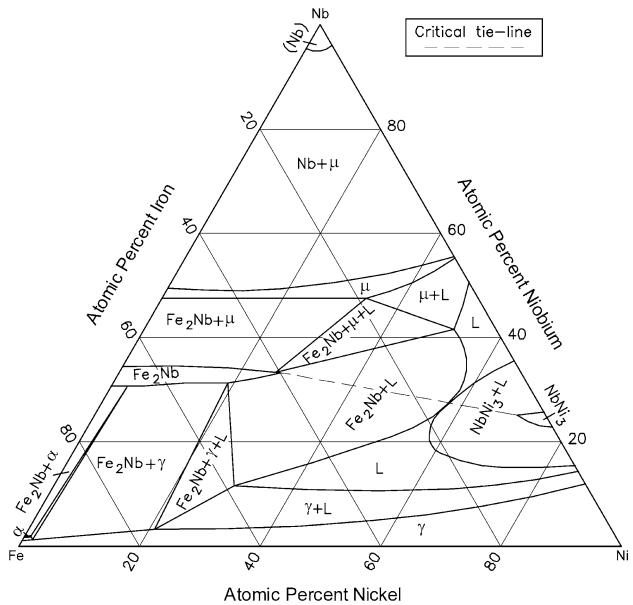

Fig. 1 Fe-Nb-Ni computed isothermal section at 1291 °C [2009Mat]

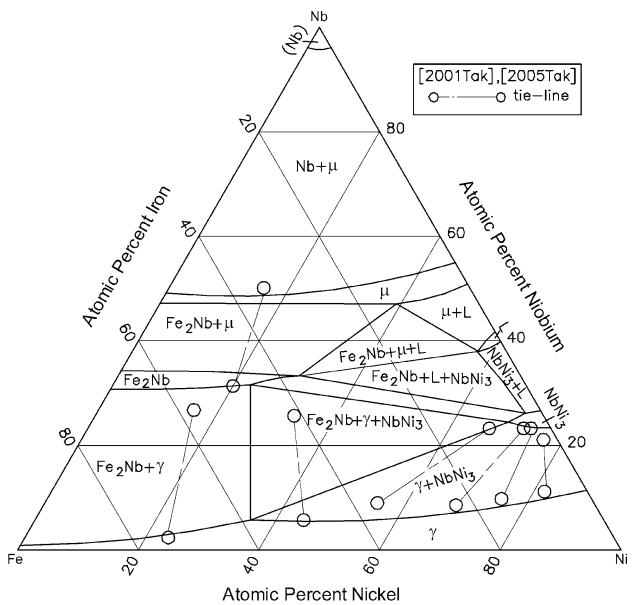

Fig. 3 Fe-Nb-Ni computed isothermal section at 1200 °C [2009Mat]

Computed Isothermal Sections

The liquid, disordered fcc and disordered bcc phases were modeled as substitutional solutions by [2009Mat]. The magnetic contribution to the Gibbs energy of the bcc and fcc phases was taken into account. The binary phases $C14$, $D8_5$, $D0_a$ and $L1_2$ were described by appropriate sublattice models, providing for ternary solubility. In addition, the modeling included metastable phases $L1_0$, $D0_{22}$ and $C15$, to facilitate the future extension of the thermodynamic description to higher order systems. Ab-initio calculations were done by [2009Mat] to estimate the enthalpies of formation of the elements and the compounds on the basis of the Density Functional Theory, using the Generalized

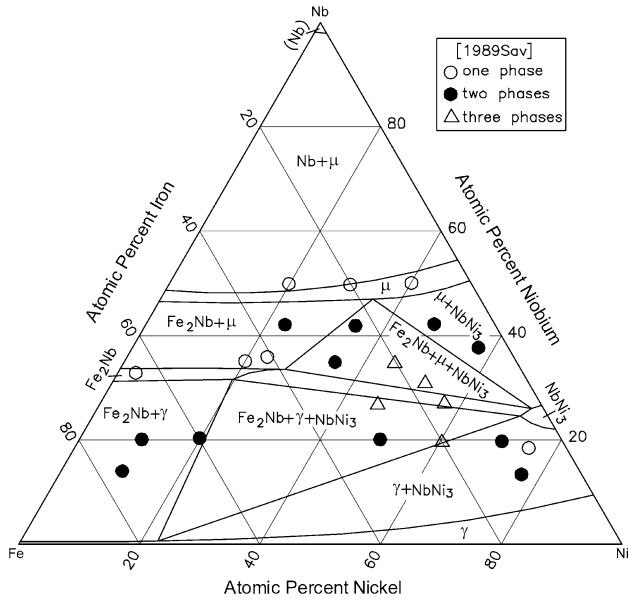

Fig. 4 Fe-Nb-Ni computed isothermal section at 1000 °C [2009Mat]

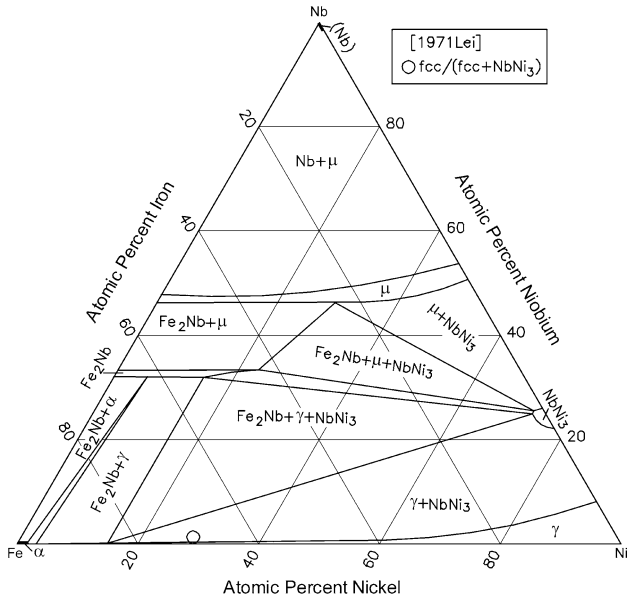

Fig. 6 Fe-Nb-Ni computed isothermal section at 800 °C [2009Mat]

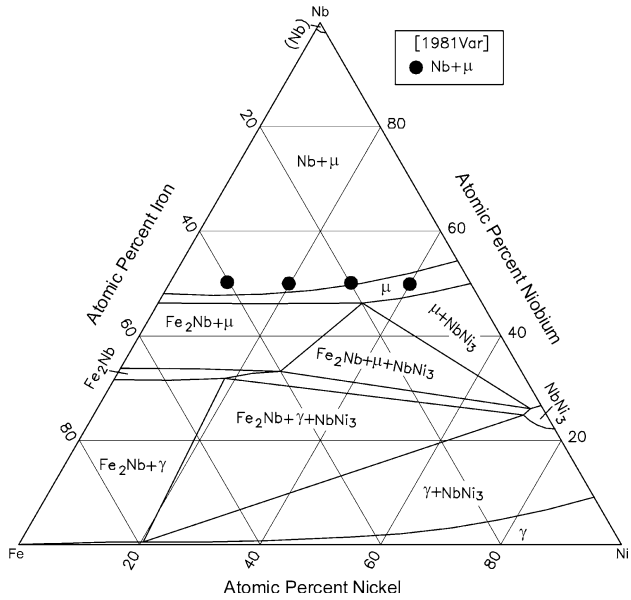

Fig. 5 Fe-Nb-Ni computed isothermal section at 950 °C [2009Mat]

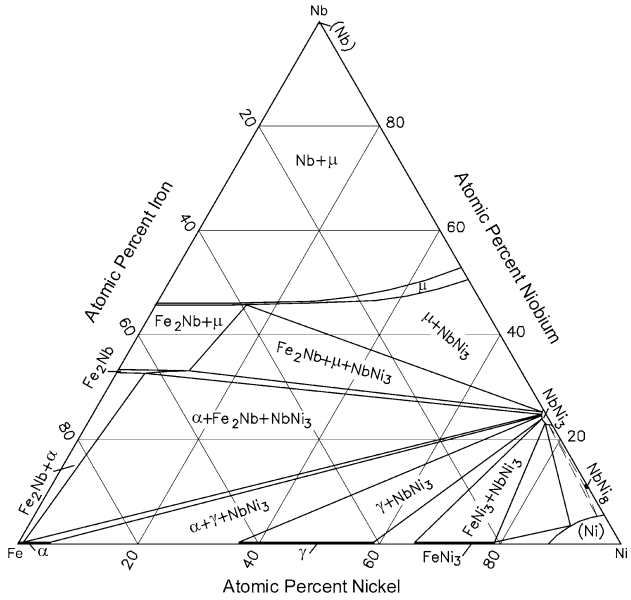

Fig. 7 Fe-Nb-Ni computed isothermal section at 450 °C [2009Mat]

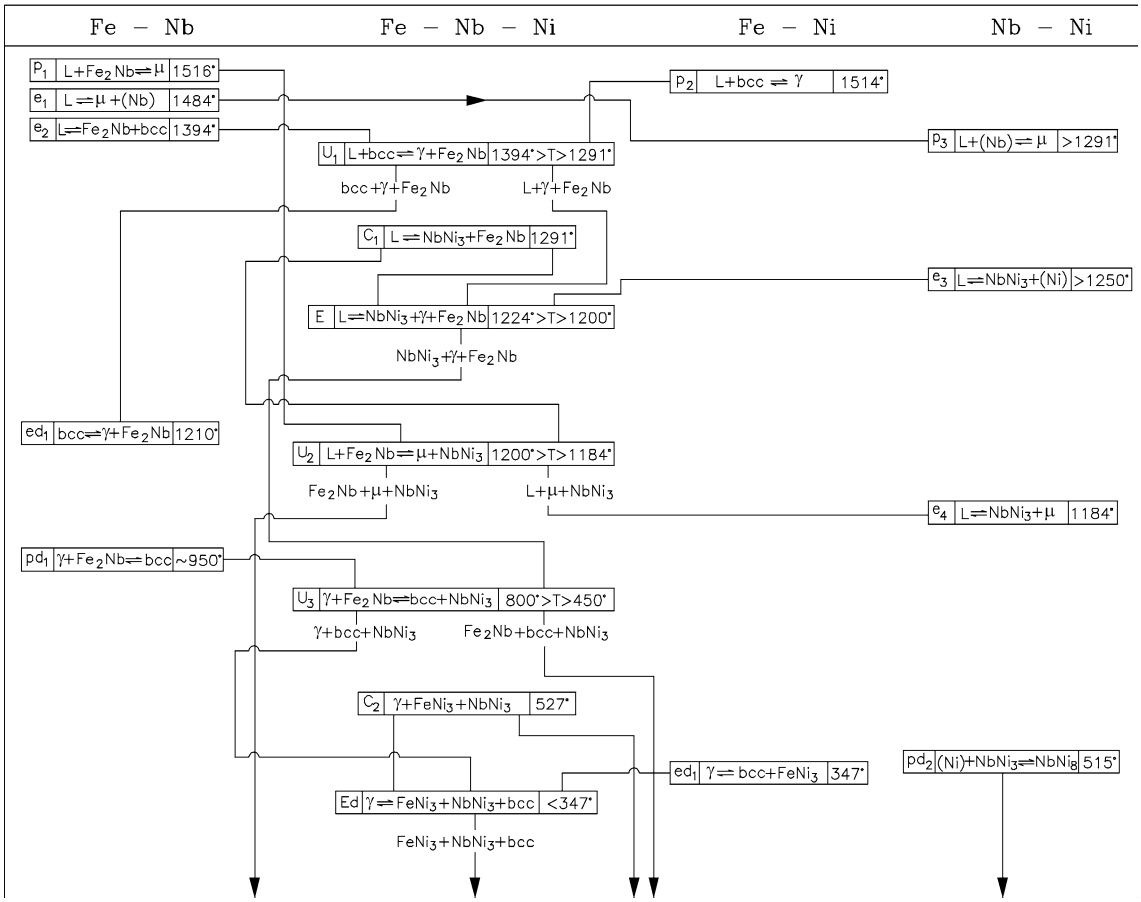

Fig. 8 Fe-Nb-Ni tentative reaction sequence

Gradient Approximation method. The ab-initio values were used in the optimization. Detailed discussion and comparison of the modeling, the magnetic contribution and the ab-initio calculations were presented by [2009Mat]. The available experimental phase diagram data, with the exception of one or two results, were used in the optimization. The optimized parameters were listed.

[2009Mat] computed seven isothermal sections at 1291, 1250, 1200, 1000, 950, 800 and 450 °C and compared them with the available experimental data. The overall agreement was found to be satisfactory. These sections are shown in Fig. 1-7. At 1291 °C (Fig. 1), the critical line of the three-phase equilibrium of (L + $NbNi_3$ + Fe_2Nb) is seen. This temperature is just 1 °C above the experimental pseudobinary eutectic temperature reported by [1975Pan] along the $NbNi_3$-Fe_2Nb join. The $D8_5$ binary compounds with the nominal composition Fe_7Nb_6 and Nb_7Ni_6 form a continuous solid solution μ at this temperature as well as at lower temperatures down to at least 450 °C. At 1250 °C (Fig. 2), the liquid originating on the Ni-Nb side has split into two parts and is separated by a three-phase field of ($NbNi_3$ + Fe_2Nb + L). At 1200 °C (Fig. 3), that part of the liquid which lies within the ternary region has solidified, probably through a ternary eutectic reaction E, see the reaction sequence in Fig. 8. At 1000 °C (Fig. 4), no liquid phase is present in the system. Solid-state transition reactions occur below 950 °C (Fig. 5), to yield the phase distribution seen at 800 and 450 °C (Fig. 6 and 7). Based on the computed isothermal sections of [2009Mat] and the binary systems, a tentative reaction sequence is shown in Fig. 8.

References

1971Lei: K. Leitch and M. Chaturvedi, Ageing Behavior of Fe-30Ni Alloys Containing Nb, *Metall. Trans*., 1971, **2**, p 1407-1413

1975Pan: L.A. Panteleimonov and L.V. Aleshina, Alloys of the Fe_2Nb-Ni_3Nb System, *Vestn. Mosk. Univ., Khim*., 1975, **16**(5), p 630, in Russian

1981Var: K.K. Varli, T.I. Druzhinia, N.P. D'yakonova, S.E. Pirogova, and A.M. Rutman, The Influence of Alloying with Cobalt and Nickel in the Phase Stability of the Fe-Nb System, *Izv. VUZ Chern. Metall*., 1981, (9), p 116-118, in Russian

1989Sav: V.V. Savin, Formation and Stability of Laves Phases in the Nickel-Iron-Niobium System, *Fiz. Met. Metalloved*., 1989, **68**(1), p 143-149,. in Russian; TR: *Phys. Met. Metallogr*., 1989, **68**(1), p 141-146

1991Swa: L.J. Swartzendruber, V.P. Itkin, and C.B. Alcock, The Fe-Ni (Iron-Nickel) System, *J. Phase Equilib*., 1991, **12**(3), p 288-312

1992Rag: V. Raghavan, The Fe-Nb-Ni (Iron-Niobium-Nickel) System, *Phase Diagrams of Ternary Iron Alloys, Part 6B*, Indian Institute of Metals, Calcutta, 1992, p 1025-1027

1996Bol: A. Bolcavage and U.R. Kattner, Reassessment of the Calculated Ni-Nb Phase Diagram, *J. Phase Equilib*., 1996, **17**(2), p 92-100

1997Uey: T. Ueyama, M.M. Ghanem, N. Miura, M. Takeyama, and T. Matsuo, Phase Stability of Ni_3Nb-δ in Ni-Nb-M Systems at Elevated Temperatures, *THERMOMEC-97, International Conference of Thermomechanical Processing of Steels and Other Materials*, Vol 2, 2nd ed., T. Chandra and T. Sakai, Ed., The Minerals, Metals and Materials Society, Warrendale, PA, 1997, p 1753-1760

2000Tof: C. Toffolon and C. Servant, Thermodynamic Assessment of the Fe-Nb System, *CALPHAD*, 2000, **24**(2), p 97-112

2001Tak: M. Takeyama, S. Morita, A. Yamauchi, M. Yamanaka, and T. Matsuo, Phase Equilibria Among γ, Ni_3Nb-δ and Fe_2Nb-ε Phases in Ni-Nb-Fe and Ni-Nb-Fe-Cr at Elevated Temperatures, *Superalloys 718, 625, 706 and Various Derivatives*, E.A. Loria, Ed., The Minerals, Metals and Materials Society, Warrendale, PA, 2001, p 333-344

2004Rag: V. Raghavan, Fe-Nb-Ni (Iron-Niobium-Nickel), *J. Phase Equilib. Diffus*., 2004, **25**(6), p 552

2005Tak: M. Takeyama, N. Gomi, S. Morita, and T. Matsuo, Phase Equilibria and Lattice Parameters of Fe_2Nb Laves Phase in Fe-Ni-Nb Ternary System, *Mater. Res. Soc. Symp. Proc*., 2005, **842**, p 461-466

2006Che: H. Chen and Y. Du, Refinement of the Thermodynamic Modeling of the Nb-Ni System, *CALPHAD*, 2006, **30**(3), p 308-315

2007Rag: V. Raghavan, Fe-Nb-Ni (Iron-Niobium-Nickel), *J. Phase Equilib. Diffus*., 2007, **28**(4), p 389-390

2009Mat: M. Mathon, D. Connetable, B. Sundman, and J. Lacaze, Calphad-Type Assessment of the Fe-Nb-Ni Ternary System, *CALPHAD*, 2009, **33**, p 136-161