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Al-Nb-Ni (Aluminum-Niobium-Nickel)

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The previous compilation of data on this system by [1995Vil] presented isothermal sections at 1327, 1287, 900 and 800 °C from [1975Kau], 1200 and 750 °C from [1970Duv], 1200 °C from [1983Och], 1140 °C from [1966Ben], 1000 °C from [1968Hun], and at 900 and 800 °C from [1966Mar]. The data reviewed by [1993Sau] included a partial liquidus projection and a reaction scheme for Ni-rich alloys, a full isothermal section at 1140 °C, partial isothermal sections for Ni-rich alloys at 1200 and 800 °C, and pseudobinary sections along the Ni_3Al-$NbNi_3$ and NiAl-NbNiAl joins. Recently, [2003Du] made a comprehensive thermodynamic assessment of this system and presented a number of computed isothermal sections, a vertical section, and a liquidus surface. The computed data showed satisfactory agreement with the available experimental data.

Binary Systems

The Al-Nb phase diagram [Massalski2] depicts three intermediate phases: Nb_3Al ($A15$, Cr_3Si-type cubic), Nb_2Al ($D8_b$, σCrFe-type tetragonal), and $NbAl_3$ ($D0_{22}$, $TiAl_3$-type tetragonal). Recently, [2003But] reported a eutectoid reaction between Nb_3Al and Nb_2Al (not seen in [Massalski2]), but further experimental confirmation of the results of [2003But] is required. The Al-Ni phase diagram [1993Oka] shows five intermediate phases: $NiAl_3$ (Fe_3C-type orthorhombic), Ni_2Al_3 ($D5_{13}$-type hexagonal), NiAl (CsCl-type cubic), Ni_5Al_3 (Ga_3Pt_5-type orthorhombic), and Ni_3Al ($L1_2$, $AuCu_3$-type cubic; also denoted γ′). Recently, the liquidus and solidus in the (Ni) region were redetermined by [2001Miu2]. The solidus temperatures in the NiAl region were determined by [2002Bit]. The phase boundary between (Ni) and (Ni) + Ni_3Al was investigated between 600 and 1200 °C by [2003Ma]. The Nb-Ni phase diagram [1996Bol, Massalski2] contains three intermediate phases: $NbNi_8$ (stable below 535 °C), $NbNi_3$ ($D0_a$, βCu_3Ti-type orthorhombic), and Nb_7Ni_6 ($D8_5$, Fe_7W_6-type rhombohedral, denoted μ). [2003Du] used the thermodynamic descriptions of the binary subsystems of Al-Nb, Al-Ni, and Nb-Ni from [1998Sau], [1998Hua], and [1996Bol] respectively. Recently, [2004Jou] reassessed the Nb-Ni system, incorporating $NbNi_8$ in the assessment and using new experimental data in the optimization. The liquidus on the Nb-rich side and the homogeneity range of the μ phase computed by [2004Jou] fit the experimental data better than in [1996Bol].

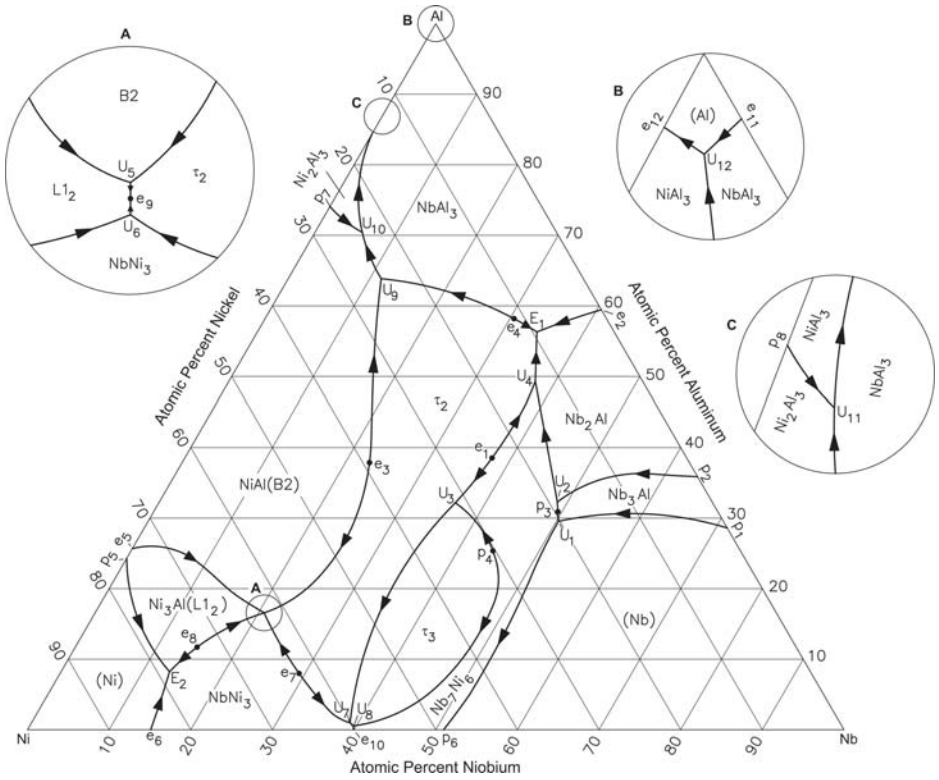

Fig. 1 Al-Nb-Ni computed liquidus projection [2003Du]

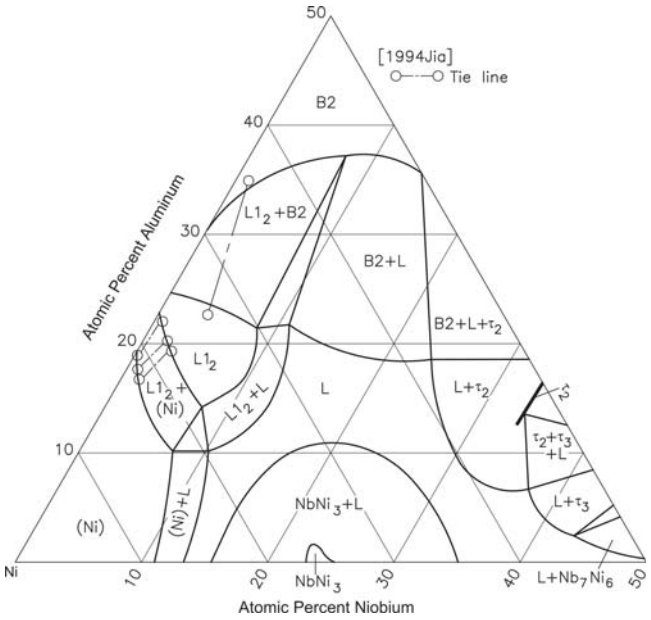

Fig. 2 Al-Nb-Ni computed isothermal section for Ni-rich alloys at 1300 °C [2003Du]

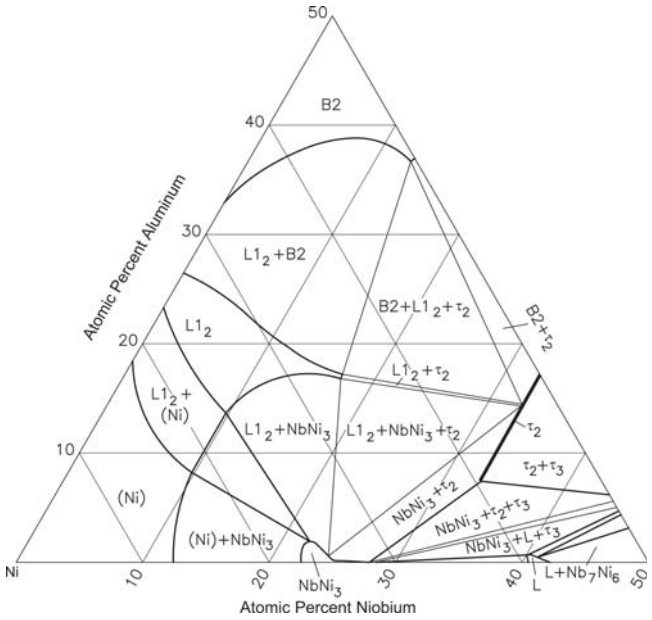

Fig. 3 Al-Nb-Ni computed isothermal section for Ni-rich alloys at 1200 °C [2003Du]

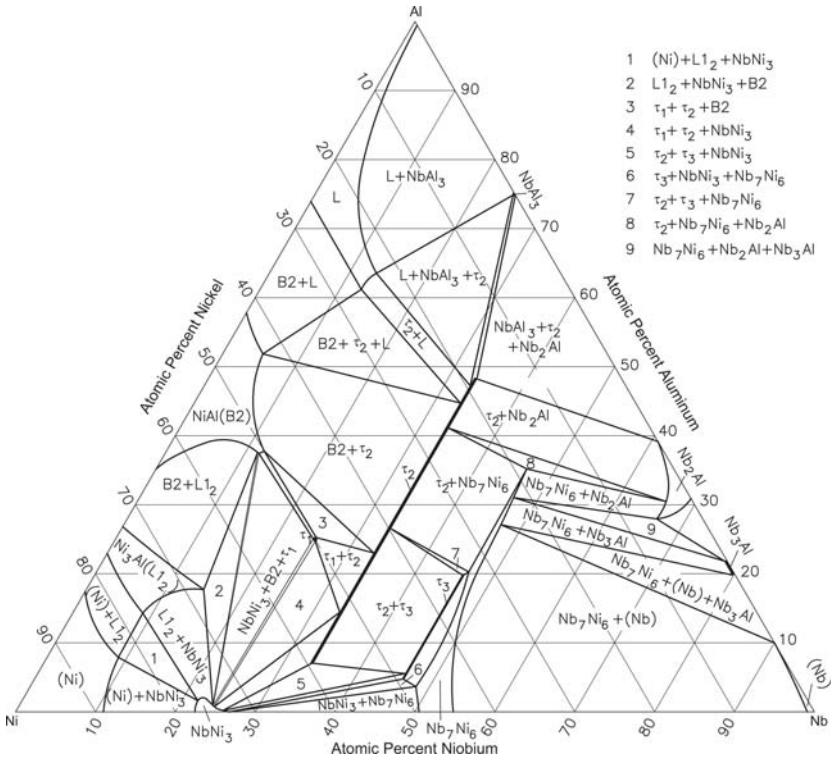

Fig. 4 Al-Nb-Ni computed isothermal section at 1140 °C [2003Du]

Ternary Phases

Three ternary compounds are known in this system. The τ_1 phase (denoted T_1 by [2003Du]) has a narrow range of homogeneity around the composition $AlNbNi_2$ and has the BiF_3-type cubic structure. The τ_2 phase (denoted T_2 by [2003Du]) lies around the line of constant Nb of 33.3 at.% and has a wide range of Al/Ni ratio. It has the *C*14, $MgZn_2$-type hexagonal structure. Its composition is given as AlNbNi in the earlier literature, but it is appropriately assigned the formula $Nb(Al,Ni)_2$ [2003Du]. The third phase τ_3

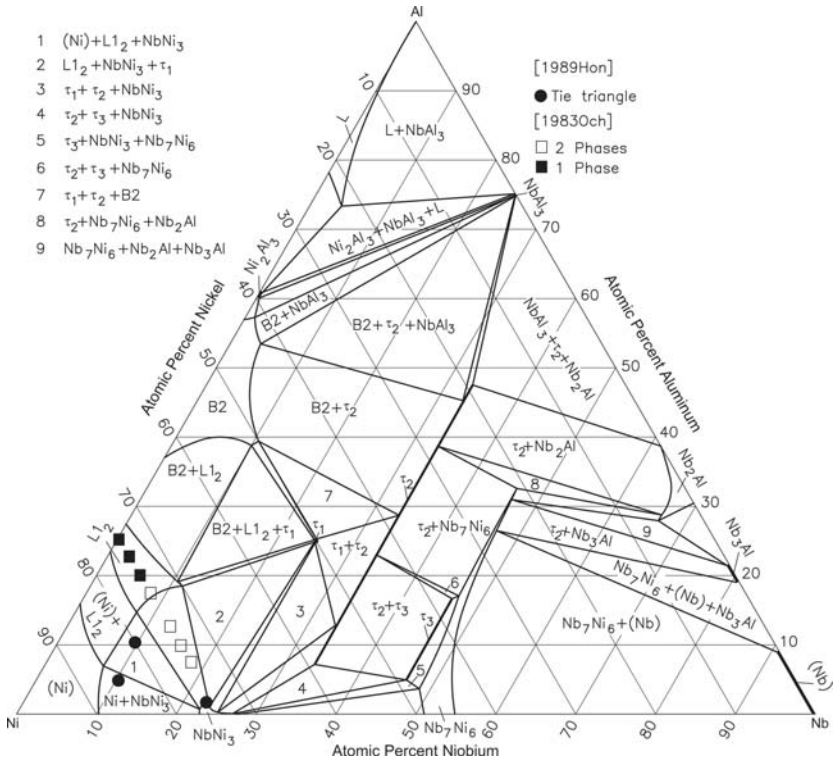

Fig. 5 Al-Nb-Ni computed isothermal section at 1027 °C [2003Du]

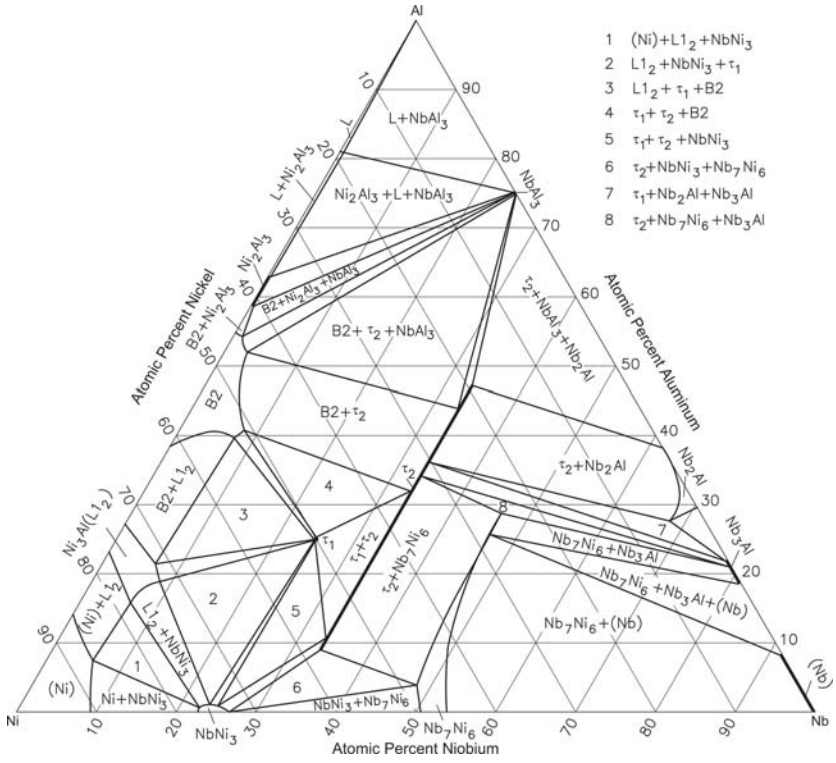

Fig. 6 Al-Nb-Ni computed isothermal section at 900 °C [2003Du]

with a nominal composition $Al_3Nb_{10}Ni_9$ has orthorhombic symmetry (space group *Pnma*) [1967Sho]. [2003Du] has modeled this phase as $Nb_6(Al,Ni)_7$. It is not a μ-type phase. It may be noted that the binary μ phase of rhombohedral symmetry Nb_7Ni_6 (denoted NbNi by [2003Du]) is close to τ_3 and dissolves up to 30 to 35 at.% Al.

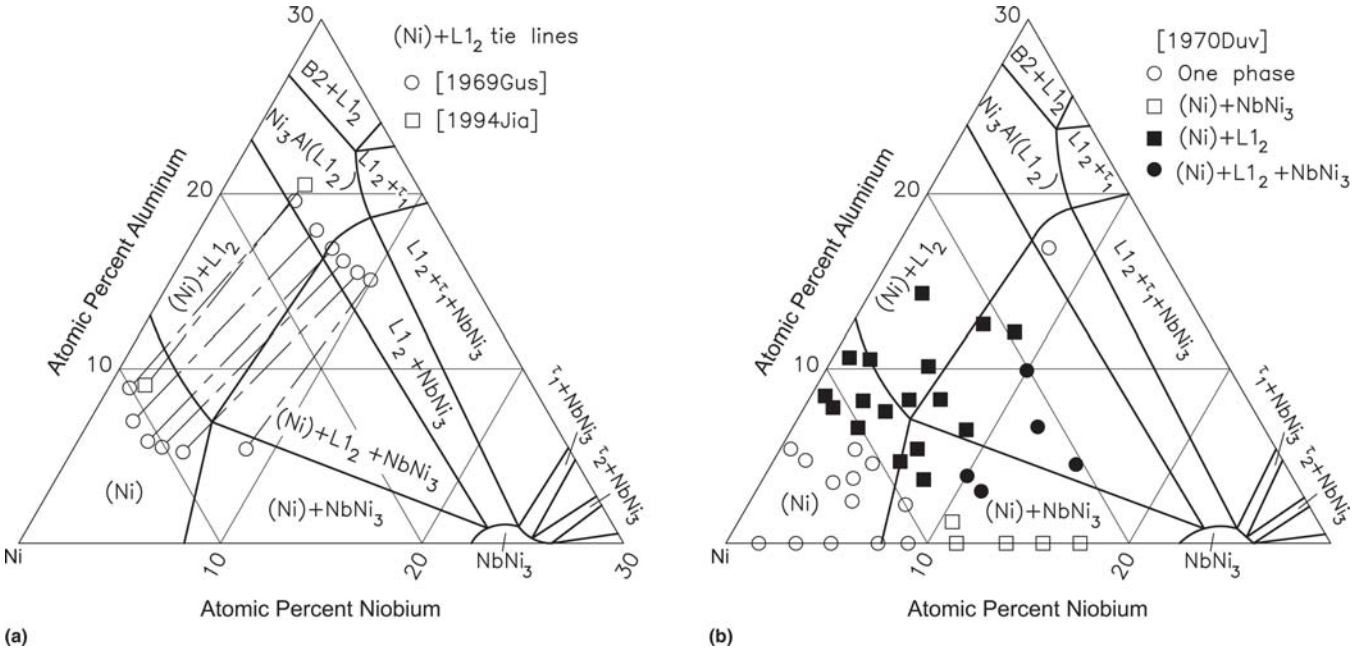

Fig. 7 Al-Nb-Ni computed isothermal sections for Ni-rich alloys at (a) 800 °C and (b) 750 °C [2003Du]

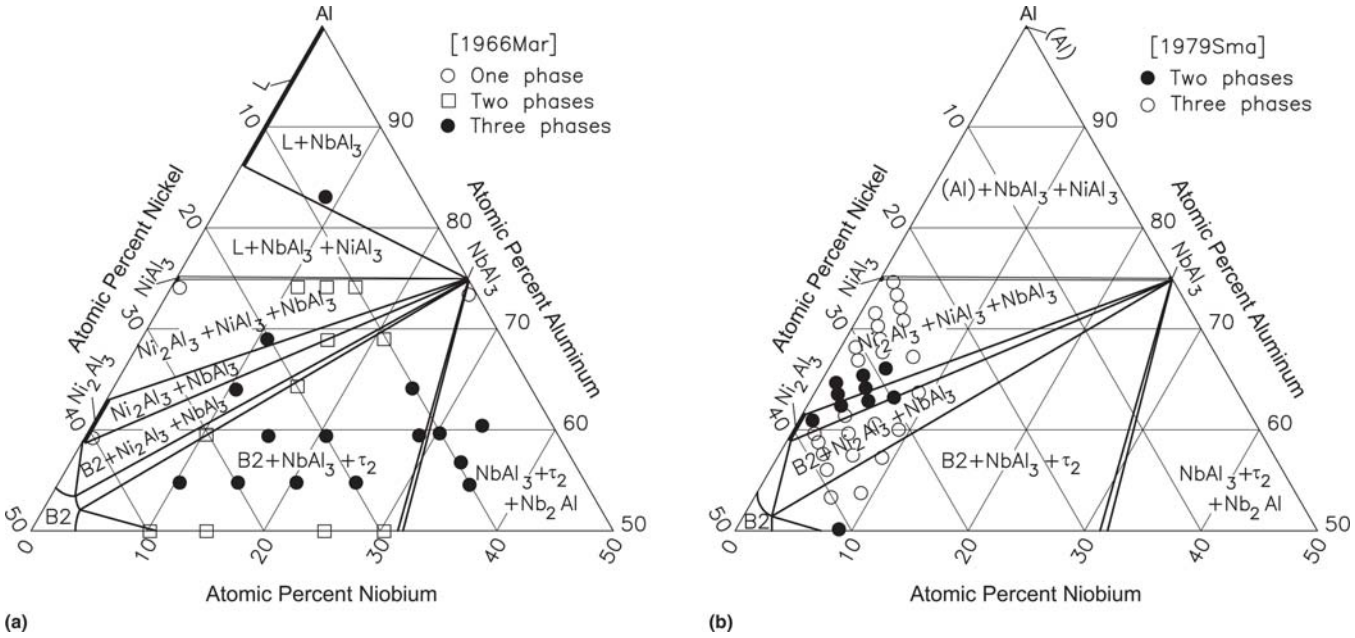

Fig. 8 Al-Nb-Ni computed isothermal sections for Al-rich alloys at (a) 800 °C and (b) 600 °C [2003Du]

Computed Phase Equilibria

[2003Du] reviewed the available experimental data and ruled out inconsistent information in their optimization. They used a two-sublattice model to describe both the ordered and disordered states of *A*2 and *B*2 as well as *A*1 and $L1_2$. The optimized interaction parameters for the ternary phases and the binary phases (with ternary extensions) were listed.

The liquidus projection calculated by [2003Du] is redrawn in Fig. 1. Sparse experimental data are available to compare with Fig. 1. The fields of primary crystallization are marked in the figure. There are two ternary eutectic reactions E_1 and E_2 (denoted I_1 and I_2 by [2003Du]) and twelve U-type transition reactions (denoted as type II reactions by [2003Du]). Several temperature maxima and minima are seen in Fig. 1, from where three-phase equilibria originate. Only one of them e_8 is known experimentally and

was used by [2003Du] in the optimization. The ternary compounds τ_2 and τ_3 originate at temperature maxima on the liquidus lines. τ_1 does not take part in the liquid-solid equilibria. The binary phase Nb_7Ni_6 forms in the ternary region at the temperature maximum p_3 at 1635 °C.

[2003Du] computed nine isothermal sections at 1300, 1200, 1140, 1080, 1027, 900, 800, 750 and 600 °C and compared them with the experimental data from the literature. The agreement was generally satisfactory and lends credence to their thermodynamic assessment. Figure 2 shows the computed section at 1300 °C, in which four tie-lines of [1994Jia] are compared with the computed boundaries. Figure 3 is the computed isothermal section at 1200 °C, which shows satisfactory agreement with a number of experimental points (not shown) from [1997Uey], [1994Jia], [1980Nas], [1970Cis], [1970Duv], and [1969Gus]. Figure 4 shows the computed section at 1140 °C, which is in good agreement with the results of [1966Ben], except that the narrow homogeneity range of τ_1 and the small variation of Nb content of τ_2 around the isoconcentrate line of 33.3 at.% Nb were not modeled. Figure 5 compares the computed section at 1027 °C with the Ni-rich data points of [1989Hon] and [1983Och]. Among the early experimental work, [1966Mar] determined a full isothermal section for this system at 900 °C, see [1995Vil] for the experimental diagram. The computed diagram of [2003Du] (Fig. 6) is in satisfactory agreement with [1966Mar], except at the Nb end, where the (Nb) + Nb_7Ni_6 two-phase field is much larger in the computed diagram. Figure 7 shows the computed isothermal sections in the Ni-rich region at 800 and 750 °C, which are in reasonable agreement with the results of [1969Gus] and [1970Duv] respectively. Figure 8 shows the computed Al-rich region at 800 and 600 °C, compared with the experimental data of [1966Mar] and [1979Sma] respectively.

Figure 9 compares the data of [1962Min] along the $AlNi_3$-$NbNi_3$ join, with the computed pseudobinary section of [2003Du]. A reaction scheme was given by [2003Du], which corresponds to the liquidus surface in Fig. 1. The scheme was also extended to the solid-state reactions.

With starting metals of 99.99% Al, 99.95% Nb, and 99.95% Ni, [2001Miu1] arc melted a limited number of ternary alloys under Ar atmosphere. They used differential thermal analysis at a cooling rate of 10 °C/min to map the temperature profile of the liquidus and solidus surfaces of the (Ni) solid solution of this ternary system. The profiles

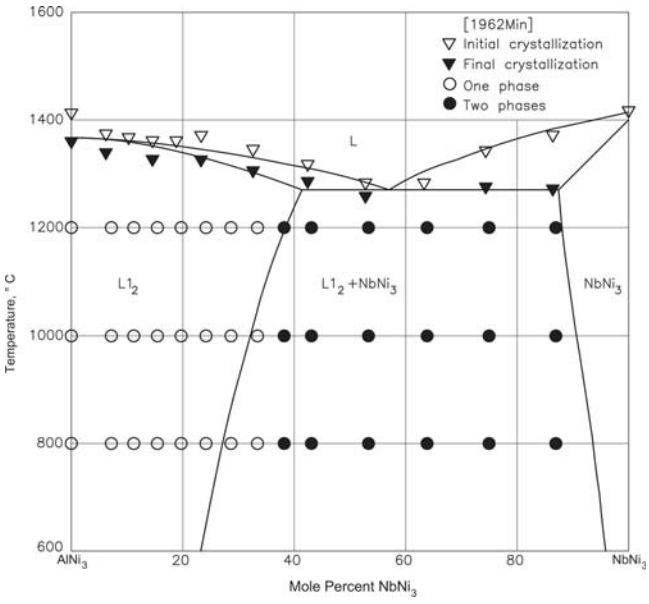

Fig. 9 Al-Nb-Ni computed vertical section along $AlNi_3$-$NbNi_3$ join [2003Du]

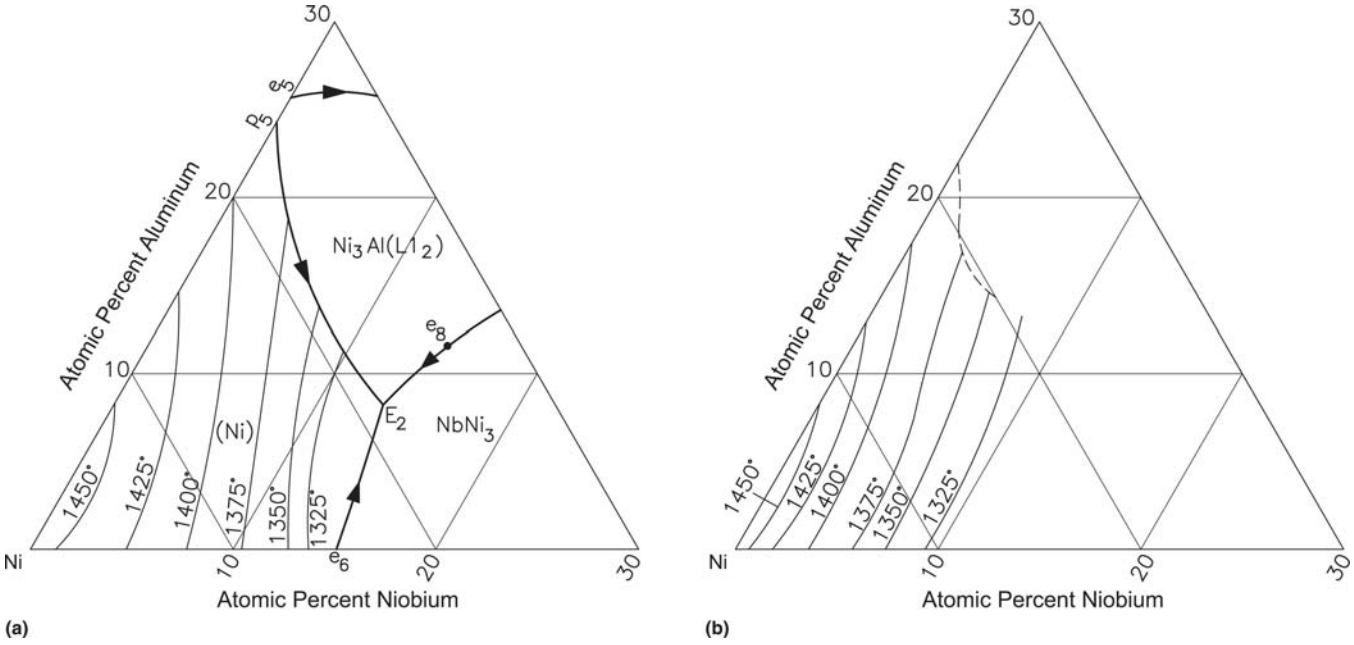

Fig. 10 Al-Nb-Ni isotherms on (a) the liquidus, and (b) the solidus surfaces [2001Miu1]

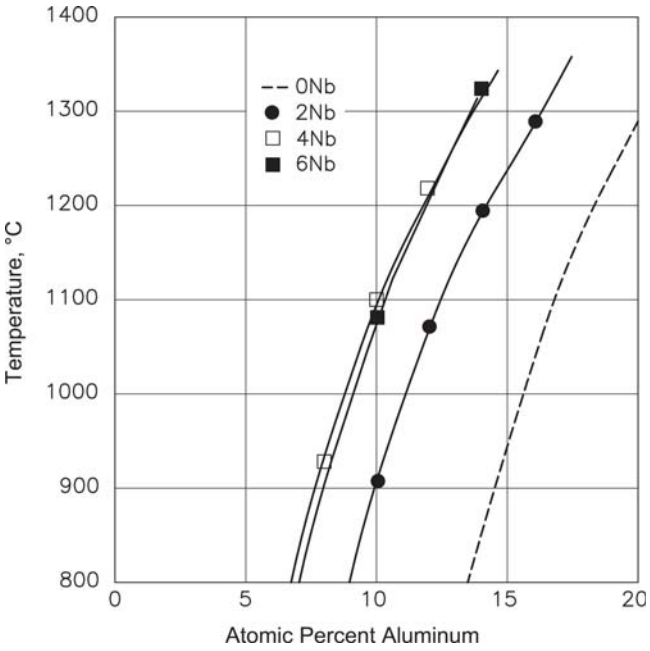

Fig. 11 Al-Nb-Ni solvus temperature of (Ni) as a function of Al and Nb [2001Miu1]

are shown in Fig. 10. Figure 11 shows the (Ni) solvus temperature as a function of Al and Nb content [2001Miu1].

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