Aluminium – Cadmium – Copper

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Literature Data

The partial system Al-Cd-Al_2Cu was studied by thermal analysis and metallography [1962Boc, 1974Wat] and by electrical resistivity and lattice spacing measurements [1974Wat]. Samples were prepared from 99.999% Al, 99.99% Cu and Cd (KD0) [1962Boc] or from 99.99% Al, 99.99% Cu and 99.9% Cd [1974Wat]. 40 samples were examined by [1974Wat] for constructing the liquidus projection of this section. The samples were homogenized in silica ampoules at 430°C for 24h. No experimental details were given by [1962Boc]. The results of [1962Boc] were summarized as liquidus isotherms. The proposed temperature of the ternary monotectic-eutectic reaction is in good agreement with that of [1974Wat]. Some other works concerned the phase relationships in the solid state near the Al-corner. [1965Boc] carried out electrical conductivity measurements on samples of 54 compositions at 530, 500 and 400°C, some microstructural observations and determined the simultaneous solid solubility of Cd and (Cu) in (Al). Samples with up to 8Cu-0.3Cd (mass%) were prepared from materials of nearly the same purity as used by [1962Boc] and then annealed in evacuated silica tubes at 530, 500 and 400°C for 50, 100 and 500h, respectively. The samples were then quenched in cold water. Before measuring the electrical conductivity the surface of the samples was removed by polishing. Cheng et al. established first the Cu-rich corner with more than 70 mass% Cu [1965Che] and then studied the whole isothermal section at room temperature [1966Che, 1975Che]. The experimental methods used by [1965Che, 1966Che] and [1975Che] are similar. Spectroscopically pure Cd, Al of 99.994% and Cu of >99.9% purity were melted in vacuum in a high frequency induction furnace, Al-Cd-Cu putting Cd on the bottom and Cu on the top and locating the heating coil first on top and moving it downwards to prevent Cd evaporation. The massive alloys were annealed and then filed to powder. The powders were then annealed again and cooled slowly to room temperature. The melting and heat treatment procedures were carried out in evacuated silica tubes. The phases were determined by X-ray diffraction. The annealing and heat treatments were different. Annealing of massive alloys: 500-700°C for 1-2 weeks [1965Che]; 350-700°C for 4-7 weeks [1966Che]; 200-600°C for 2 weeks [1975Che]. Annealing of powders: 400-450°C for 2 days [1965Che]; a little lower than for massive alloys for 2 days [1966Che]; 150-450°C for 2 days [1975Che]. Cooling: 10 K/h [1965Che]; 5 K/h [1966Che]; 10 K/h [1975Che]. The number of alloys examined are: 111 [1965Che]; 278 [1966Che]; 251 [1975Che]. The results of [1966Che, 1975Che] are identical, but differ slightly from [1965Che]. According to [1965Che] Cu_2Cd is in two phase equilibrium with (Cu), γ, δ, η_2, respectively, whereas [1965Che, 1975Che] observed only the two phase equilibrium between Cu_2Cd and (Cu). The reason for these differences was analyzed by [1975Che]. The Al-corner in the solid state was also studied by [1974Wat] at 520°C on 45 alloy compositions. The results are in good agreement with the other works.
The present evaluation continues and updates that of [1991Ran].

Binary Systems

The boundary binary systems Al-Cu, Al-Cd and Cd-Cu are respectively accepted from [2003Gro], [1980Ell, 1982McA] and [1990Sub].

Solid Phases

No ternary compound was observed. Some binary compounds have solubilities for the third element. The isothermal section at room temperature, given in Fig. 1, is from [1966Che, 1975Che, 1979Dri]. All solid phases mentioned in the presented diagrams are listed in Table 1.

Pseudobinary Sections

The section Cd - θ,Cu_2Al was proposed to be a pseudobinary one by [1962Boc], what was confirmed by electrical resistivity, lattice spacings and thermal analysis measurements [1974Wat] and modified for taking into account the peritectic decomposition of θ,$CuAl_2$ at 591°C. Figure 2 shows this section, redrawn from [1974Wat]. The sections Cd - θ,$CuAl_2$ and Cd - η_1,CuAl(r) are characterized by a miscibility gap in the liquid phase theoretically described by [1991But].

Invariant Equilibria

The section Cd - θ involves a pseudobinary monotectic. A ternary monotectic and eutectic were determined [1962Boc, 1974Wat]. The ternary invariant equilibria are given in Table 2, the compositions given there are approximate values only. A reaction scheme of the partial Al-Cd-$CuAl_2$ system is plotted in Fig. 3.

Liquidus Surface

A partial liquidus surface of the region Al-Cd-$CuAl_2$ after [1974Wat, 1981Wat] is given in Fig. 4. The extension of the lines of double saturation in the cadmium corner are too small to be plotted and therefore are neglected. [1962Boc] plotted liquidus isotherms into the liquidus projection. But the curvatures are smaller than expected from the binary and pseudobinary boundaries so that these liquidus isotherms are not very reliable. This reliability can not be checked because [1962Boc] did not give the data by which the diagram was constructed. Therefore no isothermal line for the liquidus is drawn in Fig. 4.

Isothermal Sections

Partial isothermal sections of the Al-corner in a quite small composition region were constructed by [1965Boc] for 530, 500 and 400°C and by [1974Wat] for 520°C. The two sets of results are in good agreement. Taking the binary diagrams into consideration, Al-Cd-Cu sections at 500 and 400°C are Al-Cd-Cu drawn in Fig. 5a and Fig. 5b. The isothermal section at room temperature (Fig. 1) is taken from [1966Che] and [1975Che]. It includes also the earlier work [1965Che] and is similar to the diagram reproduced by [1980Cha].

Notes on Materials Properties and Applications

Dilatometric tests on Cu_4Al and $CdCu_4Al$ alloys have been carried out by [1969Kar]. The addition of Cd shortens the time of occurrence of the Guinier-Preston zones and formation of a θ” phase. [1984Zol] showed that the strength properties of cast Al-Cu alloys may be improved by addition of Cd, then ageing at 170°C, due to the precipitation of a metastable θ” phase.

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Table 1: Crystallographic Data of Solid Phases

Phase/ Temperature Range [°C]	Pearson Symbol/ Space Group/ Prototype	Lattice Parameters [pm]	Comments / References
(Al) < 660.45	*cF*4 $Fm\overline{3}m$ Cu	a = 404.96	at 25°C [Mas2] 0 to 2.48 at.% Cu 0 to 0.113 at.% Cd [1980Ell]
(Cd) < 321.11	*hP*2 $P6_3/mmc$ Mg	a = 297.87 c = 561.66	21°C, pure, [1980Ben] 0 to 4.5 at.% Al [1980Ell]
(Cu) < 1064.87	*cF*4 $Fm\overline{3}m$ Cu	a = 361.46	25°C, pure, [Mas2] 0 to 19.7 at.% Al
α_2, $Cu_{1-x}Al_x$ < 363	- - $TiAl_3$ long period super-lattice	 a = 366.8 c = 368.0	$0.22 \le x \le 0.235$ [Mas, 1985Mur] 76.5 to 78.0 at.% Cu at 76.4 at.% Cu (subcell only)
γ_1, Cu_9Al_4 < 890	*cP*52 $P\overline{3}m$ Cu_9Al_4	 a = 870.23 a = 870.68	62 to 68 at.% Cu[Mas2, 1998Liu]; powder and single crystal [V-C2] from single crystal [V-C]
δ, $Cu_{1-x}Al_x$ < 686	*hR** $R\overline{3}m$	 a = 1226 c = 1511	$0.381 \le x \le 0.407$ [Mas2, 1985Mur] 59.3 to 61.9 at.% Cu at x = 38.9 [V-C]
ζ_1, ~$Cu_{47.8}Al_{35.5}$(h) 590-530	*oF*88 - 4.7 *Fmm2* $Cu_{47.8}Al_{35.5}$	a = 812 b = 1419.85 c = 999.28	55.2 to 59.8 at.% Cu [Mas2, 1994Mur] structure: [2002Gul]
ζ_2, $Cu_{11.5}Al_9$(r) < 570	*oI*24 - 3.5 *Imm2* $Cu_{11.5}Al_9$	a = 409.72 b = 703.13 c = 997.93	55.2 to 56.3 at.% Cu [Mas2, 1985Mur] structure: [2002Gul]
η_1, CuAl(h) 624-560	*o**32	a = 408.7 b = 1200 c = 863.5	49.8 to 52.4 at.% Cu [V-C2, Mas2, 1985Mur] Pearson symbol: [1931Pre]
η_2, CuAl(r) < 560	*mC*20 *C2/m* CuAl(r)	a = 1206.6 b = 410.5 c = 691.3 β = 55.04	49.8 to 52.3 at.% Cu [V-C2]
θ, $CuAl_2$ < 591	*tI*12 *I4/mcm* $CuAl_2$	 a = 606.7 c = 487.7	31.9 to 33.0 at.% Cu [1994Mur] single crystal [V-C2, 1989Mee]
$CuCd_3$ < 397	*hP*28 $P6_3/mmc$ Al_5Co_2	a = 810 c = 876	[1980Ben, 1990Sub]

Phase/ Temperature Range [°C]	Pearson Symbol/ Space Group/ Prototype	Lattice Parameters [pm]	Comments / References
Cu_5Cd_8 < 563	*cI*52 $I\bar{4}3m$ Cu_5Zn_8	*a* = 965.4	34 to 47.8 at.% Cu [1980Ben, 1990Sub]
Cu_4Cd_3 < 547	*cF*1124 $F\bar{4}3m$ Cd_3Cu_4	*a* = 2587.1	55.9 to 58.2 at.% Cu [1980Ben, 1990Sub]
Cu_2Cd < 549	*hP*12 $P6_3/mmc$ $MgZn_2$	*a* = 496 *c* = 799	[1980Ben]

Table 2: Invariant Equilibria

Reaction	*T* [°C]	Type	Phase	Composition (at.%)		
				Al	Cd	Cu
$L_1 \rightleftharpoons L_2 + \theta$	586	e_2	L_1 L_2 θ	65.4 4 65.7	2.9 94.3 2.5	31.7 1.7 31.8
$L_1 + \eta_1 \rightleftharpoons L_2 + \theta$	~ 582	U_1	L_1 η_1 L_2 θ	~ 66 49.5 ~ 3 65.7	~ 3 1 ~ 95 2.5	~ 31 49.5 ~ 2 31.8
$L_1 \rightleftharpoons L_2 + (Al) + \theta$	544	E_1	L_1 L_2 (Al) θ	77.7 2.2 97.7 66	6.1 97.0 0.1 2.0	16.2 0.8 2.0 32
$L \rightleftharpoons (Cd) + \theta$	321	e_4	L (Cd) θ	~0 0 66.7	~100 100 0	~0 0 33.3
$L \rightleftharpoons (Al) + (Cd) + \theta$	320	E_2	L (Al) (Cd) θ	0.5 98.9 0 66.7	99 0.1 100 0	0.5 1.0 0 33.3

Fig. 1: Al-Cd-Cu.
Isothermal section at room temperature

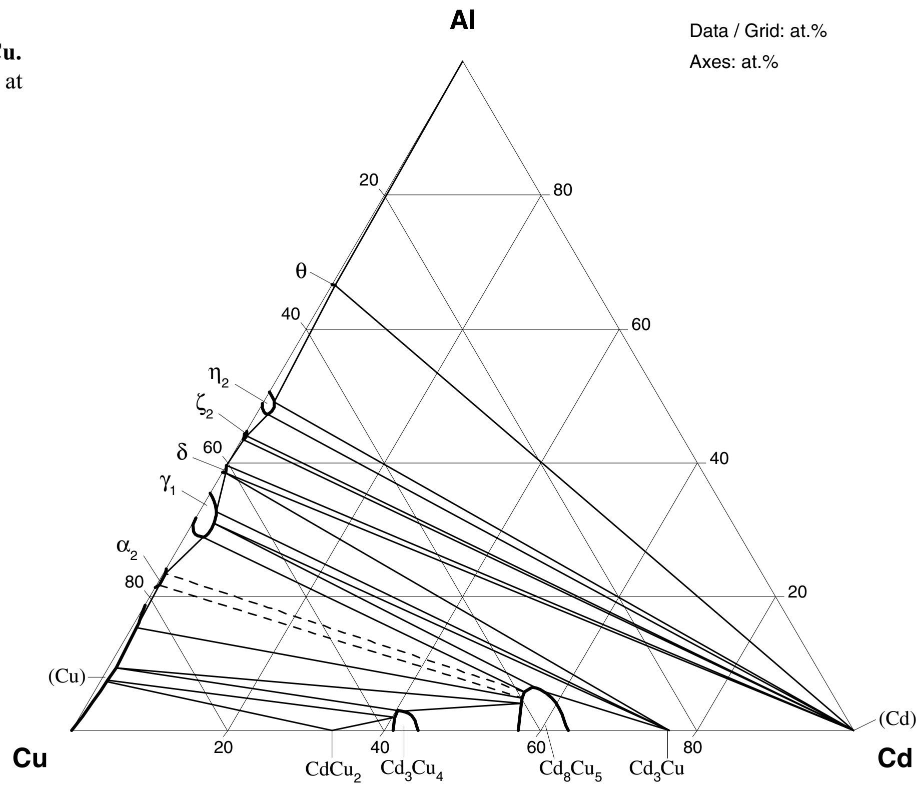
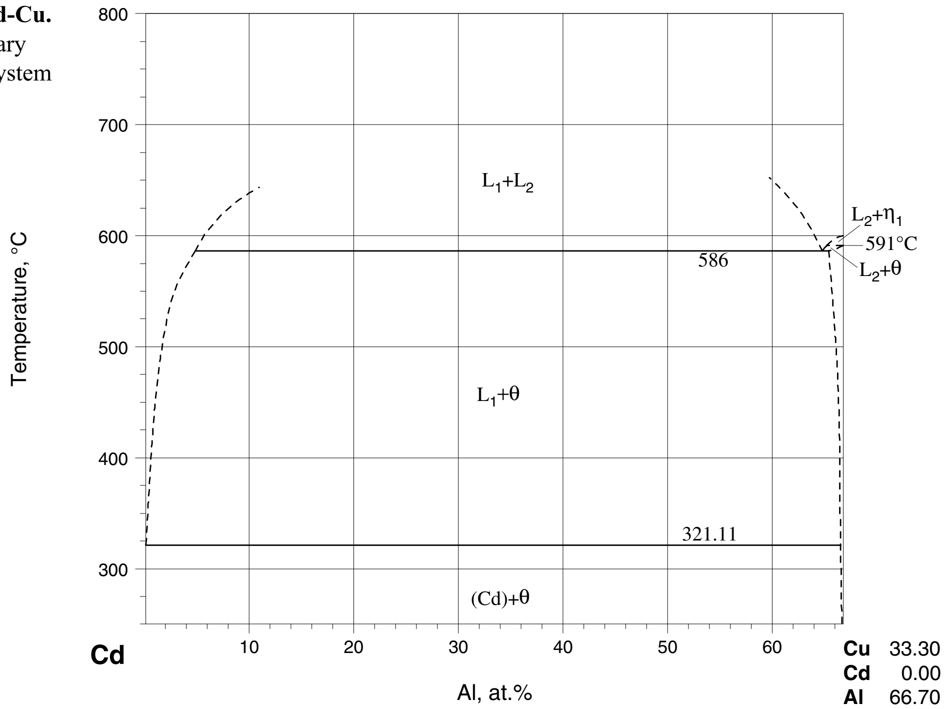


Fig. 2: Al-Cd-Cu.
The pseudobinary (Cd) - $CuAl_2$ system



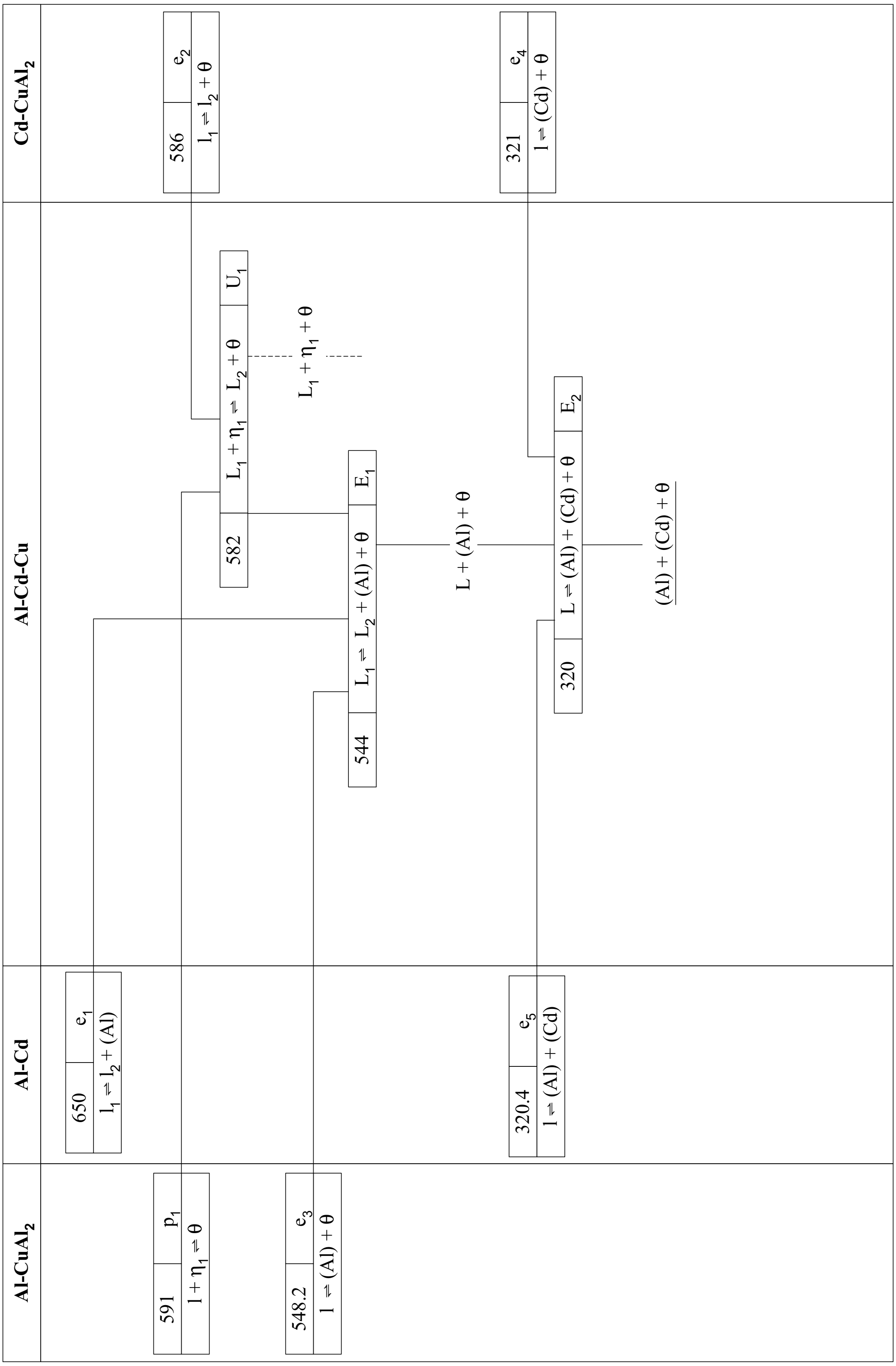


Fig. 3: Al-Cd-Cu. Reaction scheme of the partial system Al-Cd-CuAl$_2$

Fig. 4: Al-Cd-Cu. Schematic liquidus surface of the region Al - Cd - $CuAl_2$

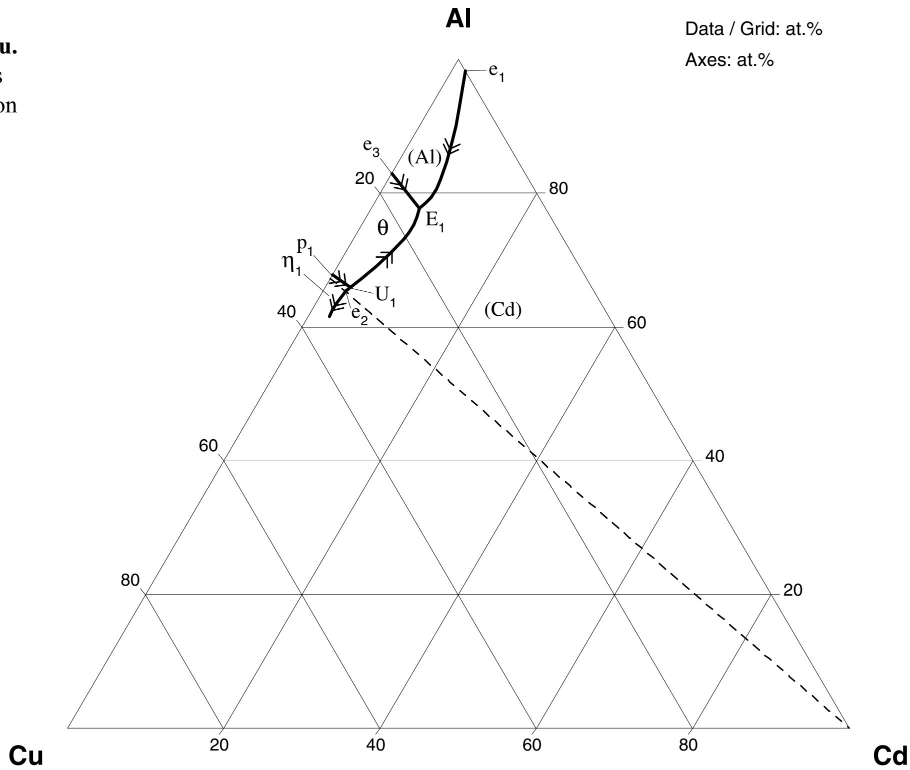


Fig. 5a: Al-Cd-Cu. Partial isothermal section at 500°C

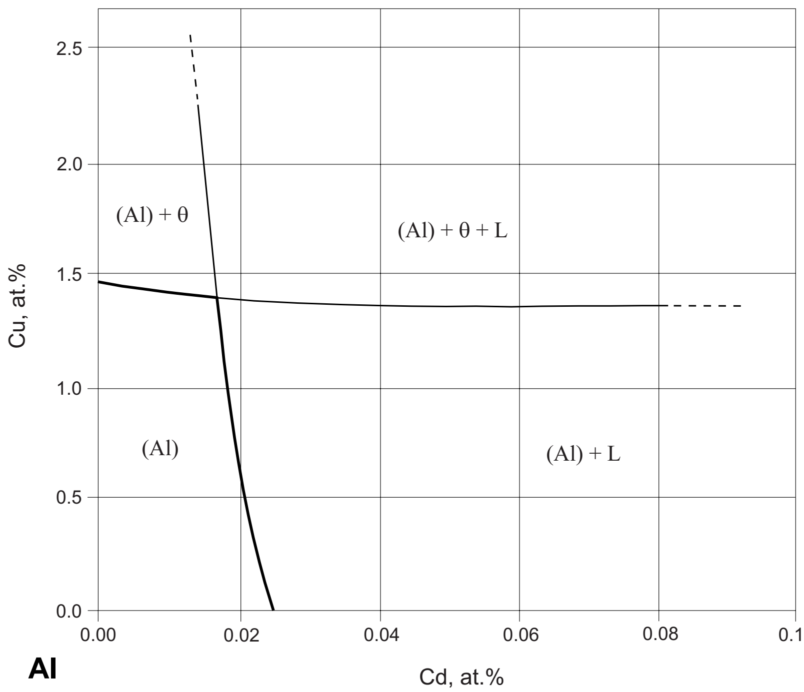


Fig. 5b: Al-Cd-Cu. Partial isothermal section at 400°C