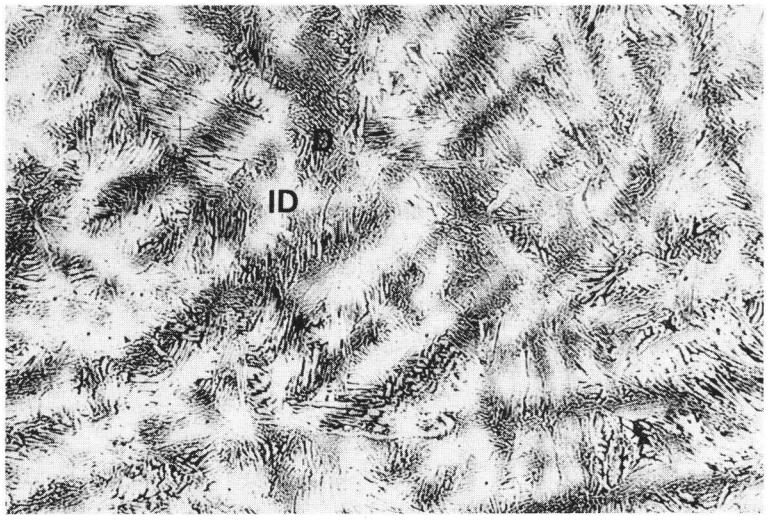


Figure 5
R = 0,5°C/s
Tq = 1200°C
(d_{1200} = 300 μm)
Former δ-dendrites (D).
White interdendritic areas (ID).
(Most of the δ transformed to γ by the peritectic reaction and transformation.)

× 25 400 μm

Figure 6
R = 2,0°C/s
Tq = 1325°C
13 vol-% dendritic ferrite.
Figures 6–9: Note that the residual ferrite only appears in the former δ-dendrites.

× 150 100 μm

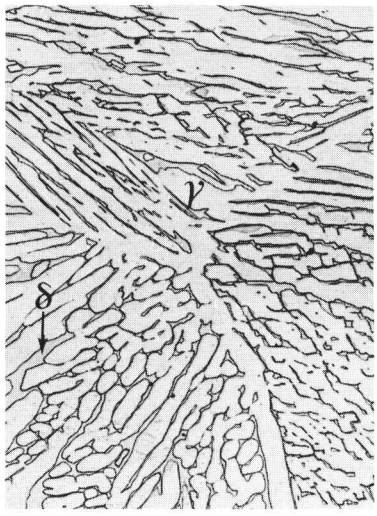


Figure 7
R = 0,5°C/s
Tq = 1325°C
19 vol-% dendritic ferrite (δ).

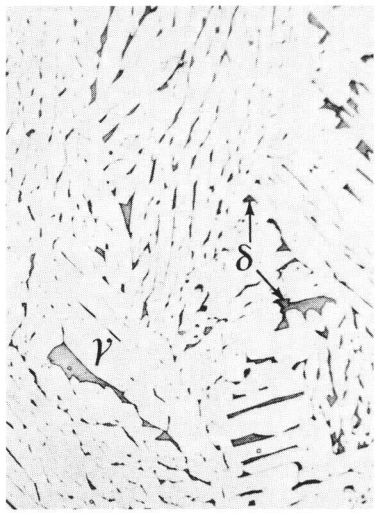


Figure 8
R = 0,5°C/s
Tq = 1200°C
9 vol-% dendritic ferrite (δ).

× 150 100 μm

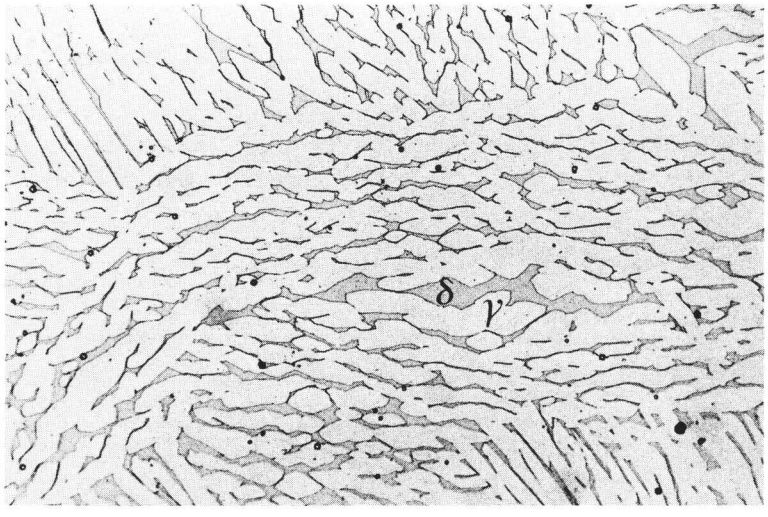


Figure 9
R = 0,1°C/s
Tq = 1325°C
20 vol-% dendritic ferrite.

× 150 100 μm

STEEL 403. 0,02 % C 19 % Cr 10 % Ni STAINLESS STEEL

Designations

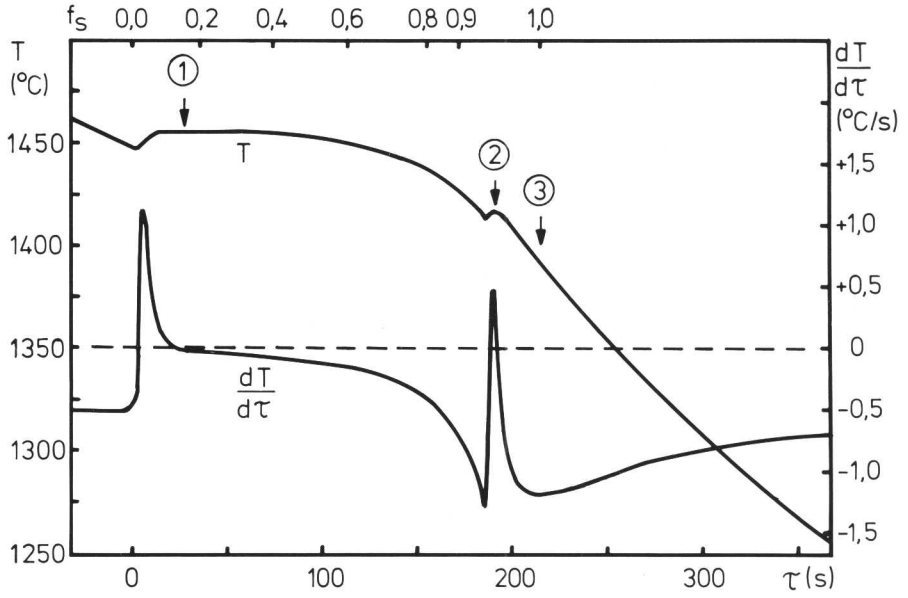
SIS	AISI	Werkstoff Nr
(2352)	304L	1.4316

Composition (wt–%)

C	Si	Mn	P	S	Cr	Ni	Mo	Cu	Co	Al_{tot}	N
0,019	0,31	0,94	0,009	0,010	19,5	10,2	0,11	0,03	0,05	0,002	0,044

$\frac{Cr_{eq}}{Ni_{eq}} = 1,74$

Thermal Analysis



R = 0,5°C/s

	Average Cooling Rate,R, (°C/s)		
	2,0	0,5	0,1
Liquidus temperature, ferritic primary phase, °C ①	1447	1455	1453
Temperature of austenite formation, °C ②	1404	1415	1418
Solidus temperature, °C ③	1365	1390	1405
Solidification range, °C	80	65	50
Solidification time, s	90	220	610
Fraction solidified as ferrite, %	91	92	98

Precipitates

–

Microsegregation

Element	Si	Mn	Cr	Ni
I	1,6	1,5	1,1	1,5
P_D			1,2	0,7

R = 0,5 °C/s
Tq = 1340 °C

Partly solidified

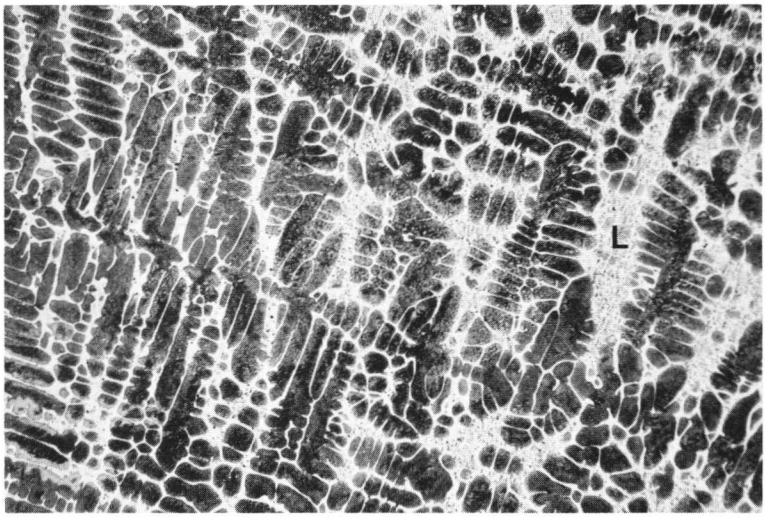


Figure 1
R = 0,5°C/s
Tq = 1450°C
d = 65 μm
δ-dendrites and quenched liquid (L).

× 25 400 μm

Completely solidified

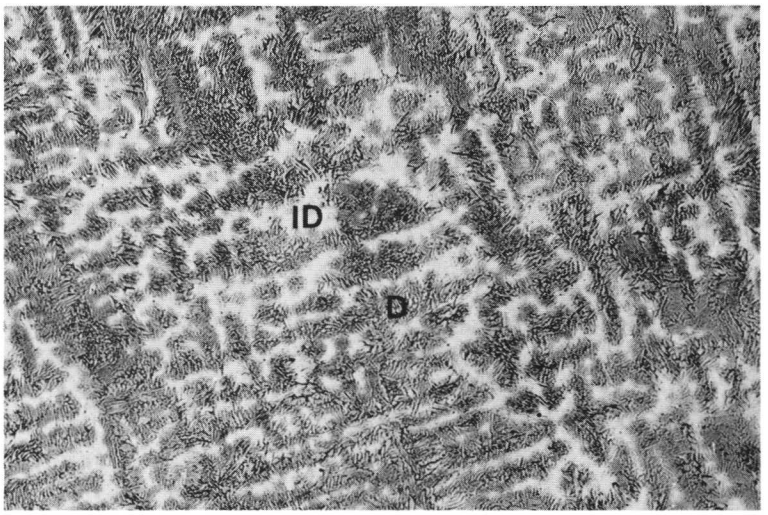


Figure 2
R = 2,0°C/s
Tq = 1340°C
d = 130 μm
Figures 2–4: Former δ-dendrites (D).
White interdendritic areas (ID).
(Most of the δ transformed to γ by the peritectic reaction and transformation.)

× 25 400 μm

Figure 3
R = 0,5°C/s
Tq = 1340°C
d = 160 μm

× 25 400 μm

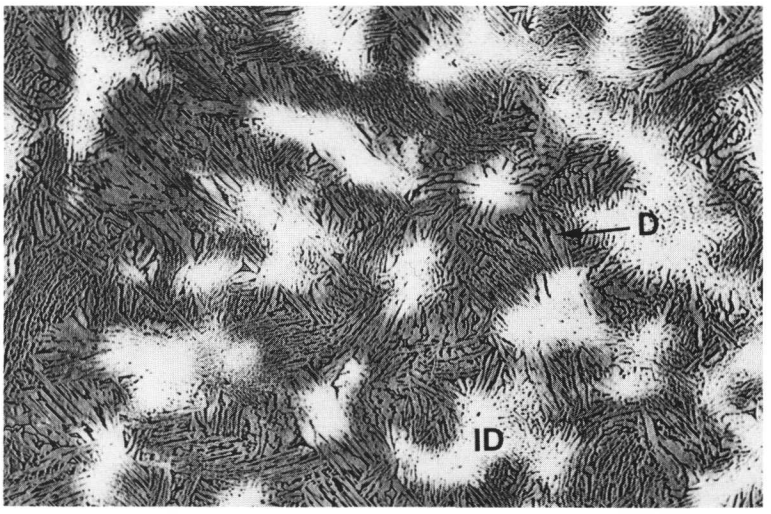


Figure 4
R = 0,1°C/s
Tq = 1340°C
d = 500 μm

× 25 400 μm

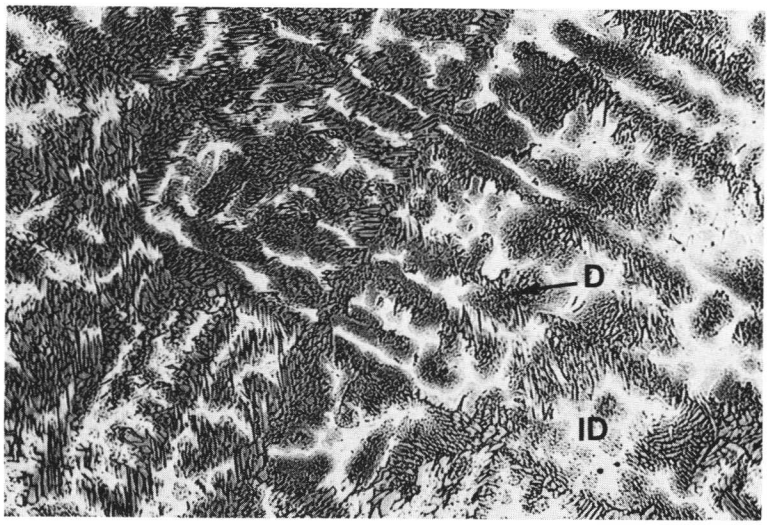


Figure 5
R = 0,5°C/s
Tq = 1200°C
(d_{1200} = 170 μm)
Former δ-dendrites (D).
White interdendritic areas (ID).
(Most of the δ transformed to γ by the peritectic reaction and transformation.)

400 μm × 25

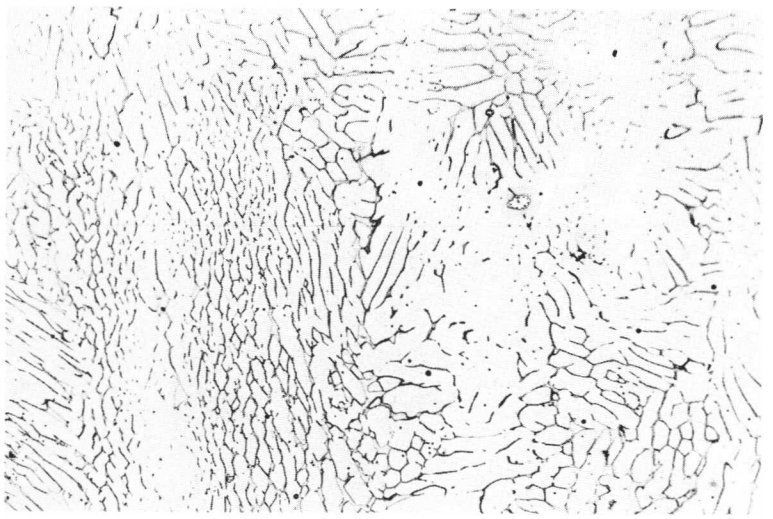


Figure 6
R = 2,0°C/s
Tq = 1340°C
11 vol-% dendritic ferrite.
Figures 6–9: Note that the residual ferrite only appears in the former δ-dendrites (D).

100 μm × 150

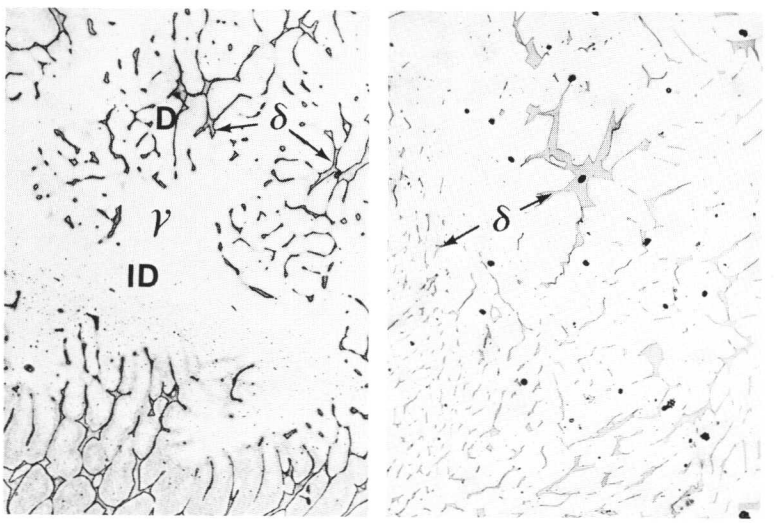


Figure 7
R = 0,5°C/s
Tq = 1340°C
13 vol-% dendritic (D) ferrite (δ).

Figure 8
R = 0,5°C/s
Tq = 1200°C
5,8 vol-% dendritic ferrite.

100 μm × 150

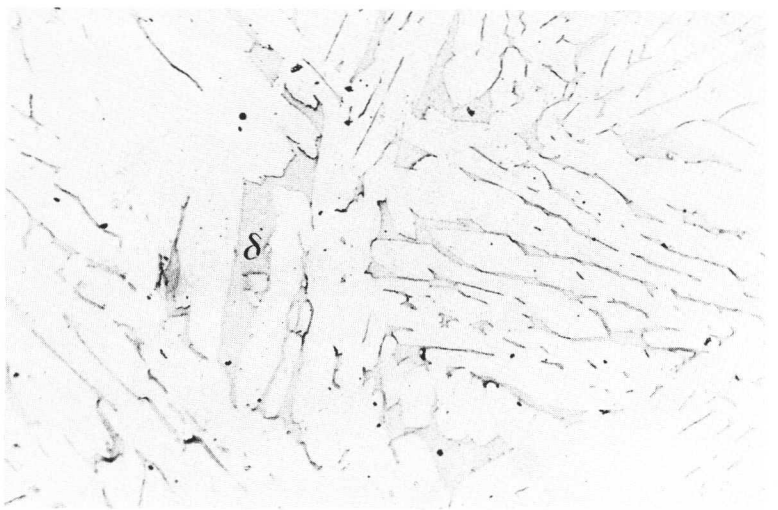


Figure 9
R = 0,1°C/s
Tq = 1340°C
9 vol-% dendritic ferrite.

100 μm × 150

STEEL 404. 0,04 % C 18 % Cr 9 % Ni STAINLESS STEEL

Designations

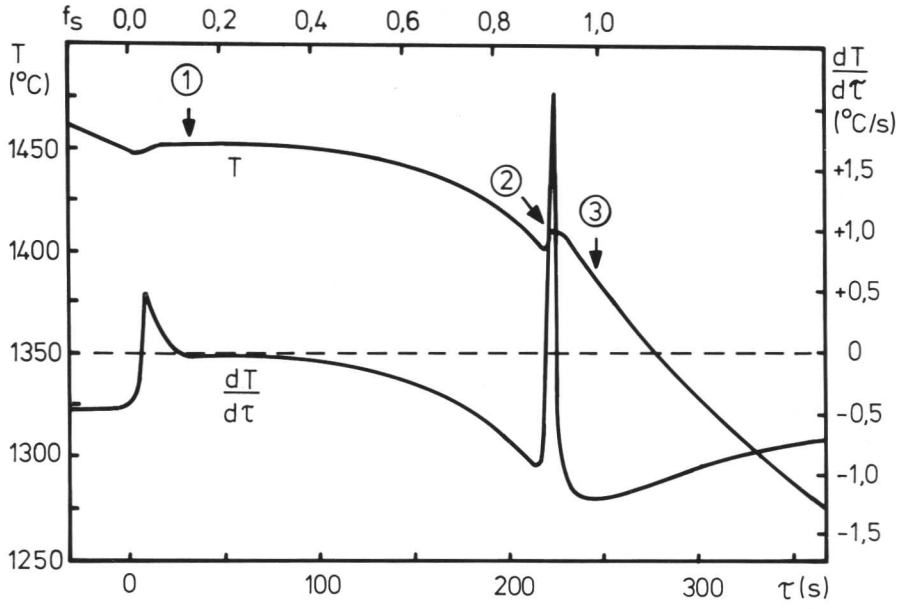
SIS	AISI	Werkstoff Nr
2333	304	1.4301

Composition (wt–%)

C	Si	Mn	P	S	Cr	Ni	Mo	Cu	Co	Al_{tot}	N
0,036	0,44	1,25	0,025	0,010	18,4	9,1	0,38	0,20	0,25	0,002	0,081

$$\frac{Cr_{eq}}{Ni_{eq}} = 1{,}68$$

Thermal Analysis



R = 0,5°C/s

	Average Cooling Rate,R, (°C/s)		
	2,0	0,5	0,1
Liquidus temperature, ferritic primary phase, °C ①	1452	1451	1452
Temperature of austenite formation, °C ②	1423	1409	1424
Solidus temperature, °C ③	1365	1385	1405
Solidification range, °C	90	65	50
Solidification time, s	100	250	720
Fraction solidified as ferrite, %	84	82	86

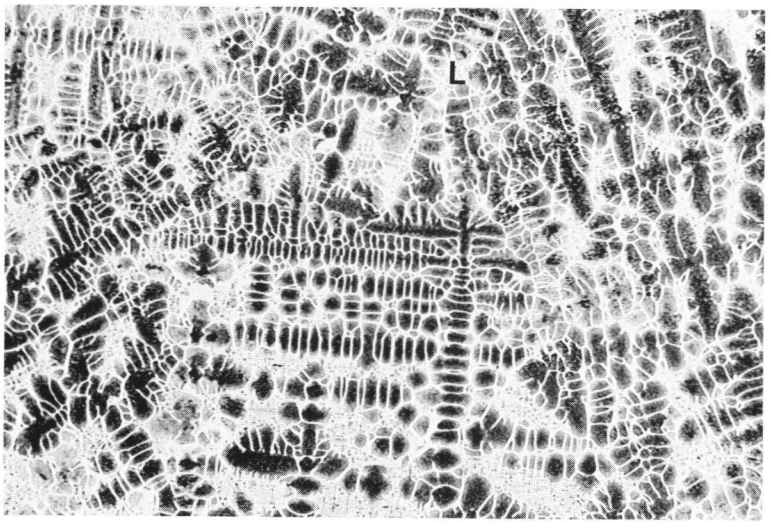
Precipitates

–

Microsegregation

Element	Mn	Cr	Ni
I	1,2	1,1	1,3
P_D		1,2	0,7

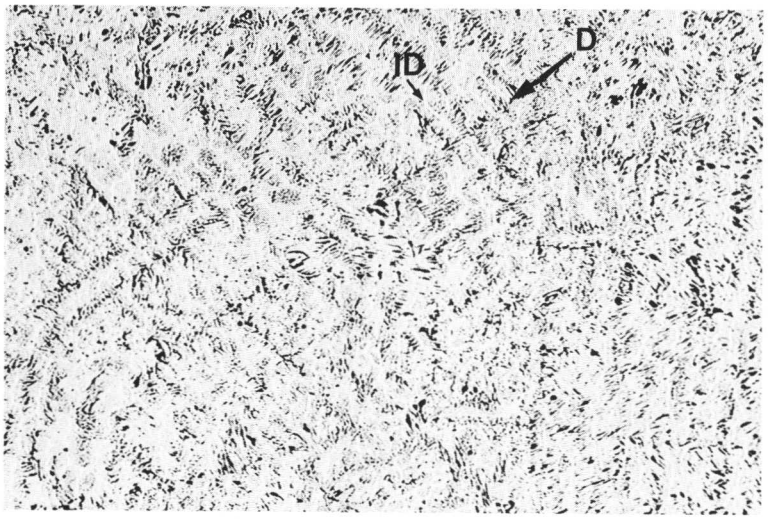
R = 0,5 °C/s
Tq = 1340 °C



Partly solidified

Figure 1
R = 0,5°C/s
Tq = 1447°C
d = 40 μm
δ-dendrites and quenched liquid (L).

400 μm × 25



Completely solidified

Figure 2
R = 2,0°C/s
Tq = 1340°C
d = 125 μm
Figures 2–4: Former δ-dendrites (D).
White interdendritic areas (ID).
(Most of the δ transformed to γ by the peritectic reaction and transformation.)

400 μm × 25

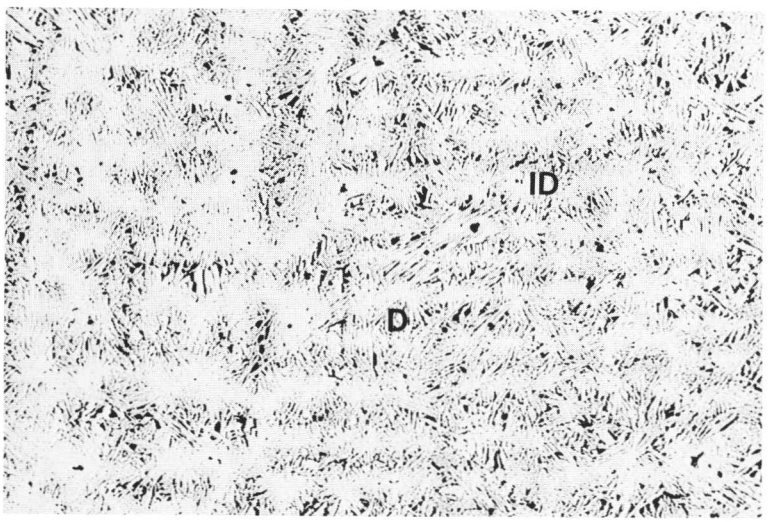


Figure 3
R = 0,5°C/s
Tq = 1340°C
d = 190 μm

400 μm × 25

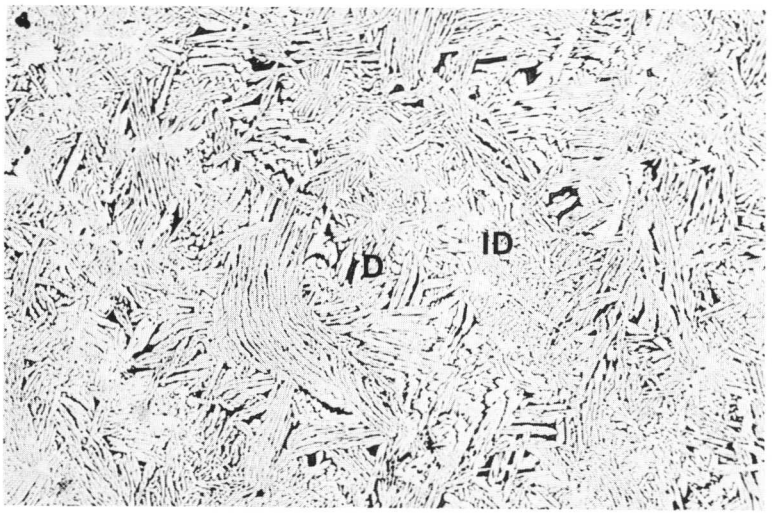


Figure 4
R = 0,1°C/s
Tq = 1340°C
d = 340 μm

400 μm × 25

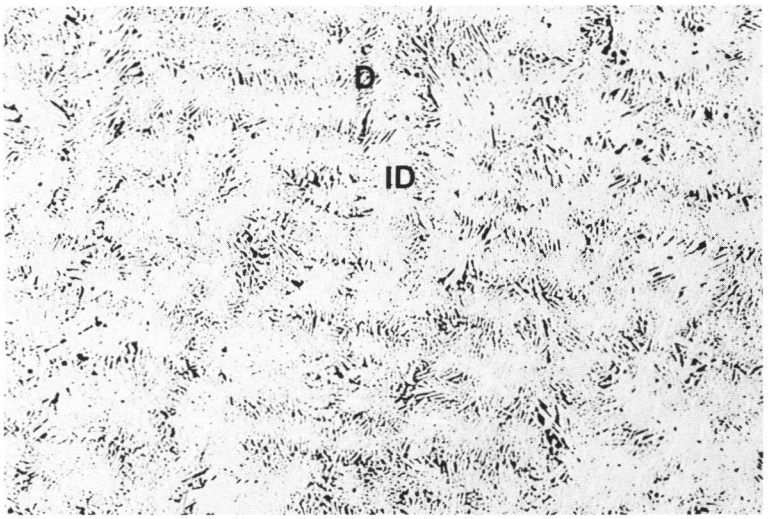


Figure 5
R = 0,5°C/s
Tq = 1200°C
(d_{1200} = 200μm)
Former δ-dendrites (D).
White interdendritic areas (ID).
(Most of the δ transformed to γ by the peritectic reaction and transformation.)

× 25 400 μm

Figure 6
R = 2,0°C/s
Tq = 1340°C
2,3 vol-% dendritic ferrite.
Figures 6–9: Note that the residual ferrite only appears in the former δ-dendrites (D).

× 150 100 μm

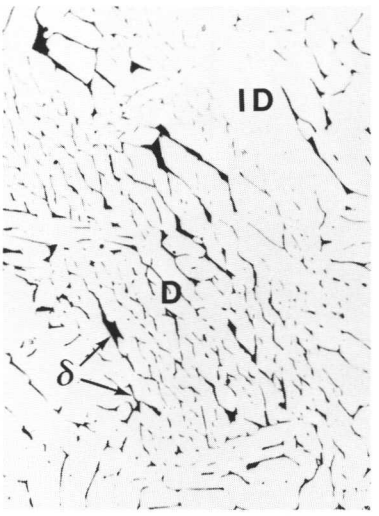


Figure 7
R = 0,5°C/s
Tq = 1340°C
4,7 vol-% dendritic ferrite.

Figure 8
R = 0,5°C/s
Tq = 1200°C
2,0 vol-% dendritic ferrite.

× 150 100 μm

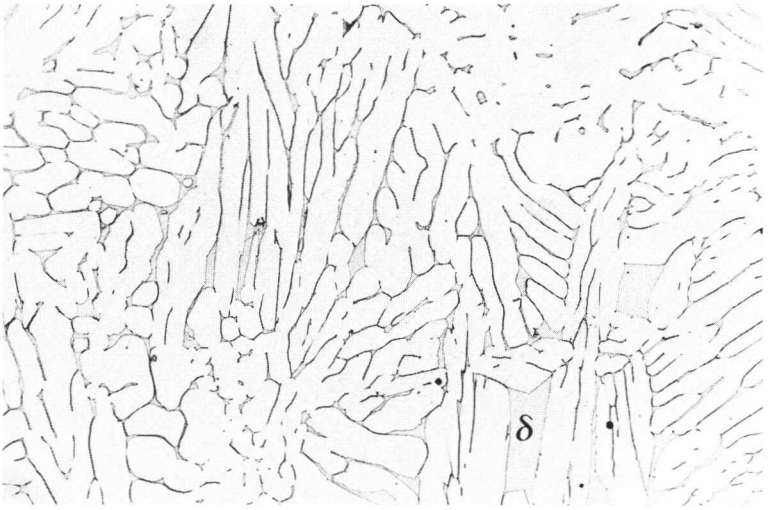


Figure 9
R = 0,1°C/s
Tq = 1340°C
10 vol-% dendritic ferrite.

× 150 100 μm

STEEL 405. 0,07 % C 17 % Cr 10 % Ni Ti STAINLESS STEEL

Designations

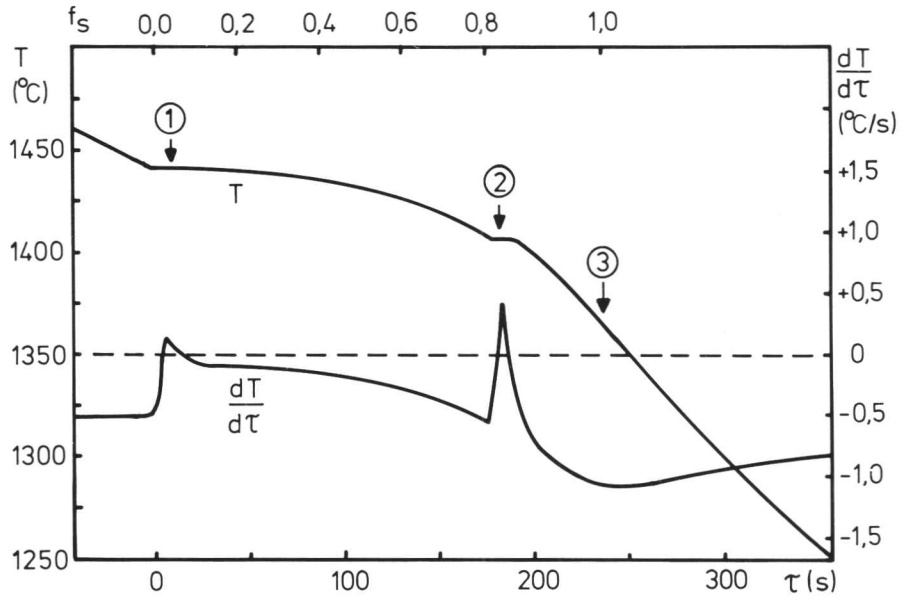
SIS	AISI	Werkstoff Nr
2337	321	1.4541

Composition (wt–%)

C	Si	Mn	P	S	Cr	Ni	Mo	Cu	Co	Ti	Al_{tot}	N
0,068	0,59	1,44	0,028	0,001	17,2	10,3	0,47	0,24	0,27	0,51	0,048	0,005

$$\frac{Cr_{eq}}{Ni_{eq}} = 1{,}61$$

Thermal Analysis



R = 0,5°C/s

	Average Cooling Rate,R, (°C/s)		
	2,0	0,5	0,1
Liquidus temperature, ferritic primary phase, °C ①	1436	1440	1440
Temperature of austenite formation, °C ②	1397	1406	1412
Solidus temperature, °C ③	1335	1370	1390
Solidification range, °C	100	70	50
Solidification time, s	105	235	680
Fraction solidified as ferrite, %	82	82	82

Precipitates

Ti(CN), (see figures 6–8).

Microsegregation

Element	Si	Mn	Cr	Ni
I	1,6	1,6	1,1	1,5
P_D			1,2	0,7

R = 0,5 °C/s
Tq = 1320 °C

Partly solidified

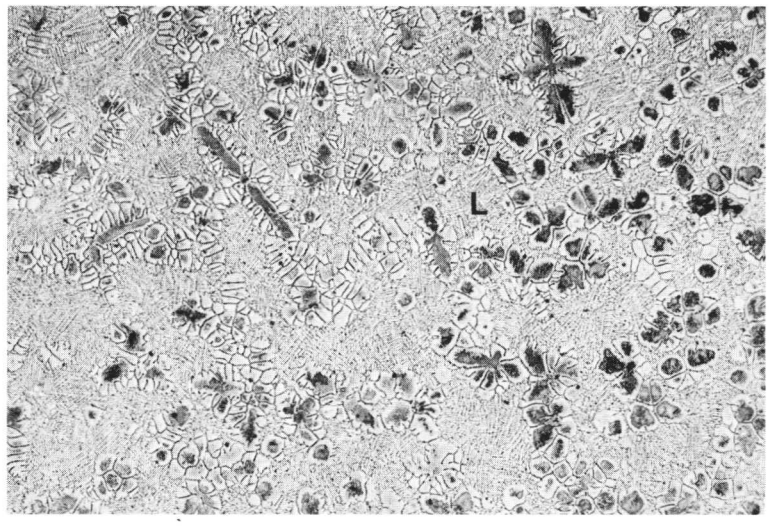


Figure 1
R = 0,5°C/s
Tq = 1430°C
d = 50 μm
δ-dendrites and quenched liquid (L).

× 25 400 μm

Completely solidified

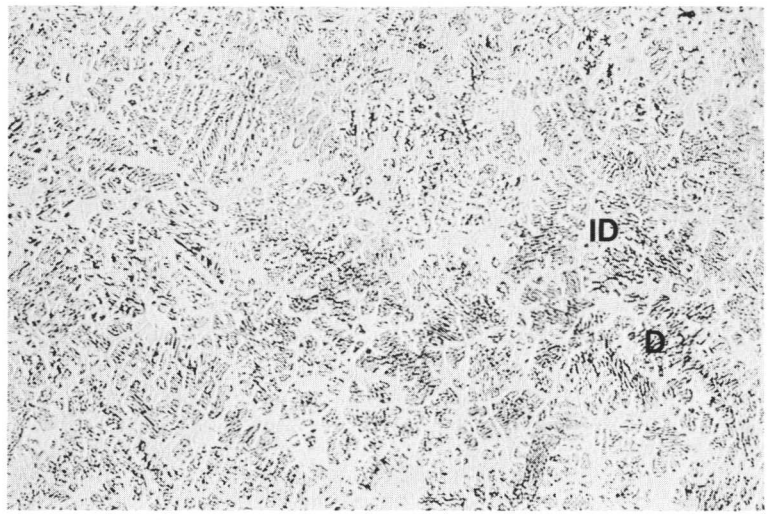


Figure 2
R = 2,0°C/s
Tq = 1320°C
d = 85 μm
Figures 2–4: Former δ-dendrites (D).
White interdendritic areas (ID).
(Most of the δ transformed to γ by the peritectic reaction and transformation.)

× 25 400 μm

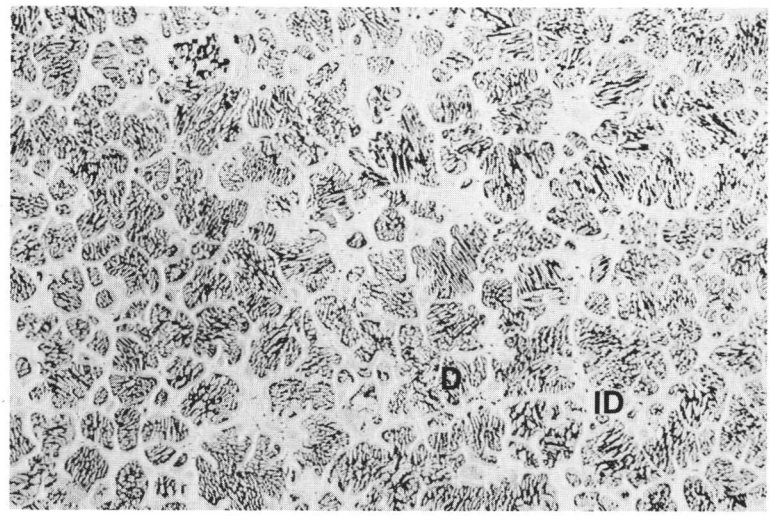


Figure 3
R = 0,5°C/s
Tq = 1320°C
d = 110 μm

× 25 400 μm

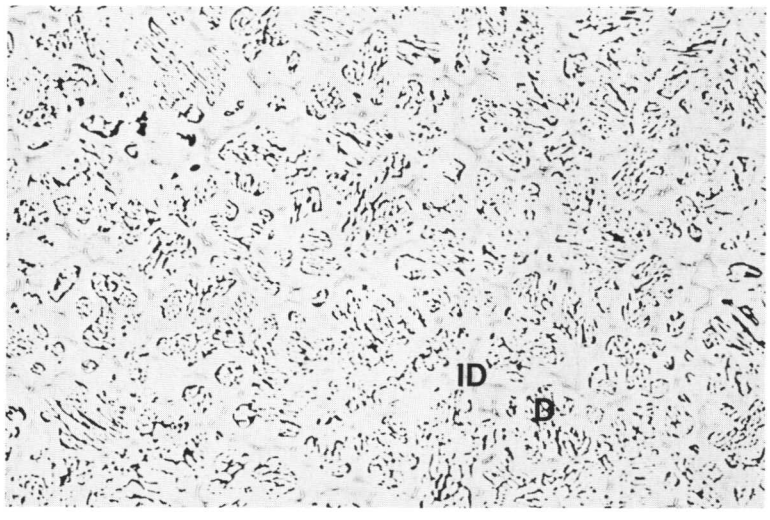


Figure 4
R = 0,1°C/s
Tq = 1320°C
d = 200 μm

× 25 400 μm

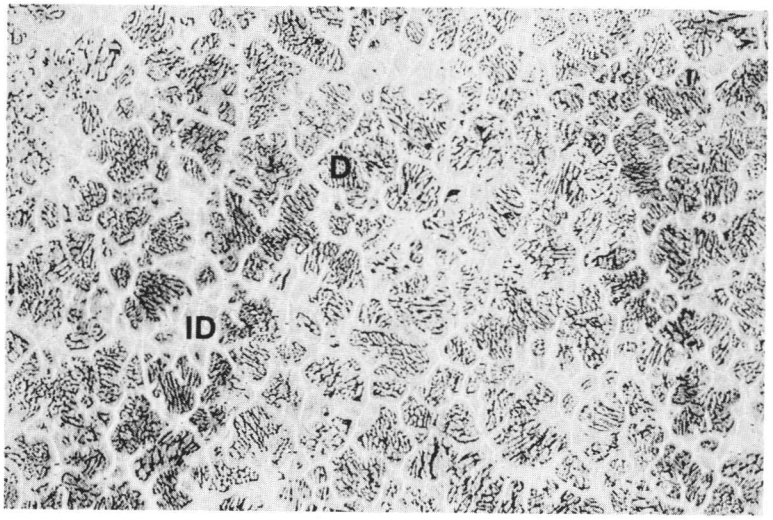


Figure 5
R = 0,5°C/s
Tq = 1200°C
(d_{1200} = 150 μm)
Former δ-dendrites (D).
White interdendritic areas (ID).
(Most of the δ transformed to γ by the peritectic reaction and transformation.)

400 μm × 25

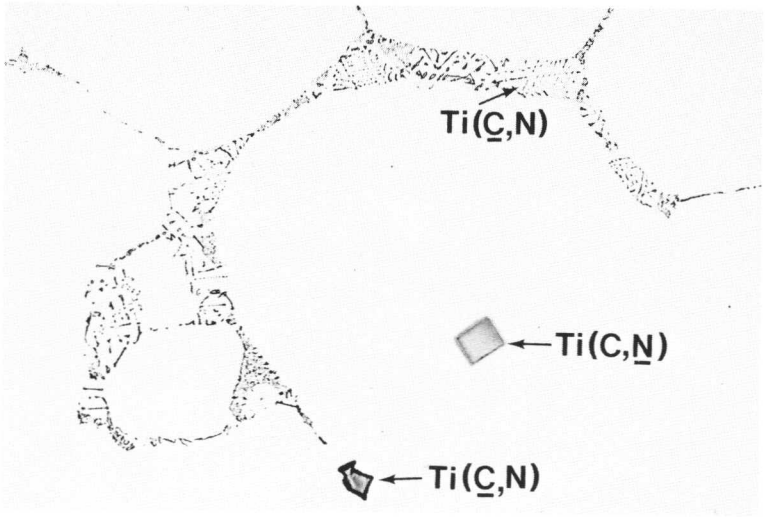


Figure 6
R = 0,5°C/s
Tq = 1380°C
Ti (C,N)

10 μm × 1000

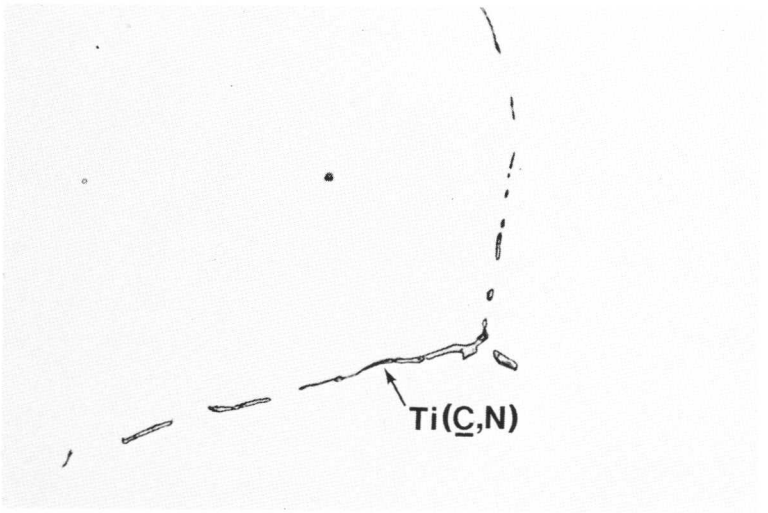


Figure 7
R = 0,5°C/s
Tq = 1200°C
Coalesced eutectic Ti(C,N).

10 μm × 1000

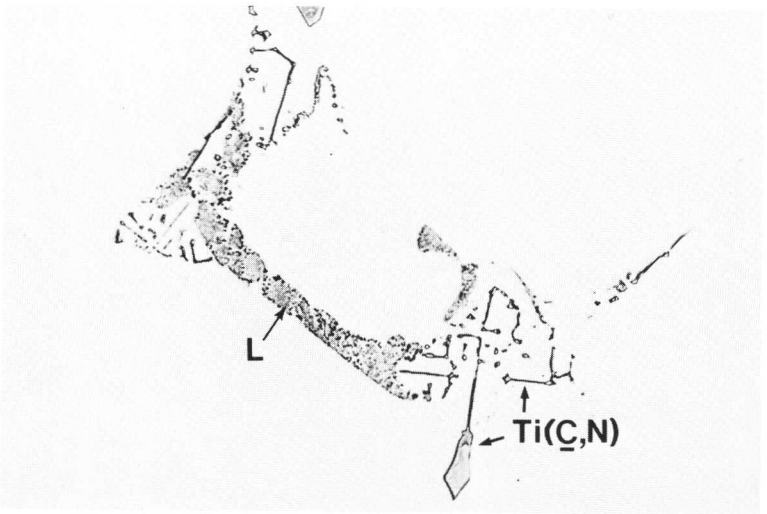


Figure 8
R = 0,1°C/s
Tq = 1380°C
Formation of eutectic Ti(C,N).
($L \rightarrow Ti(C,N) + \gamma$)

10 μm × 1000

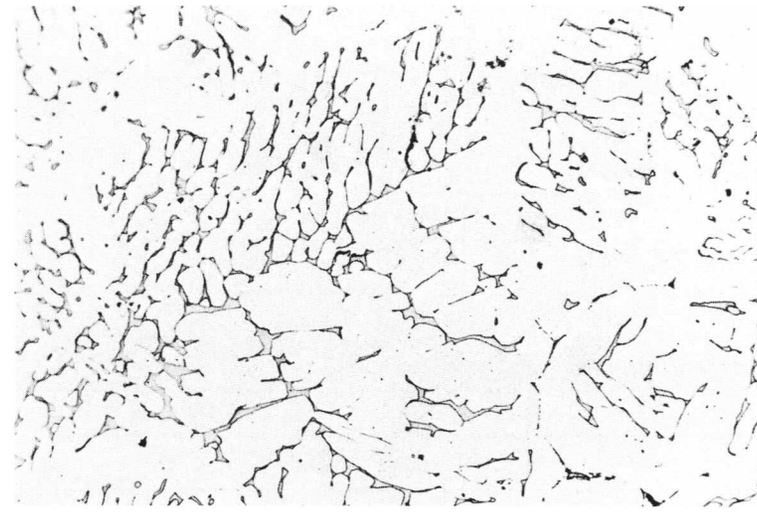


Figure 9
R = 2,0°C/s
Tq = 1320°C
6 vol-% dendritic ferrite.
Figures 9–12: Note that the residual ferrite only appears in the former δ-dendrites (D).

× 150 100 μm

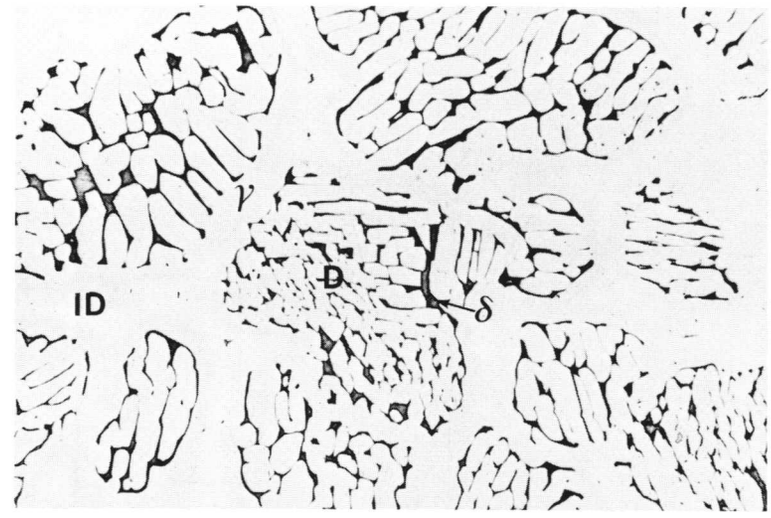


Figure 10
R = 0,5°C/s
Tq = 1320°C
8 vol-% dendritic ferrite.

× 150 100 μm

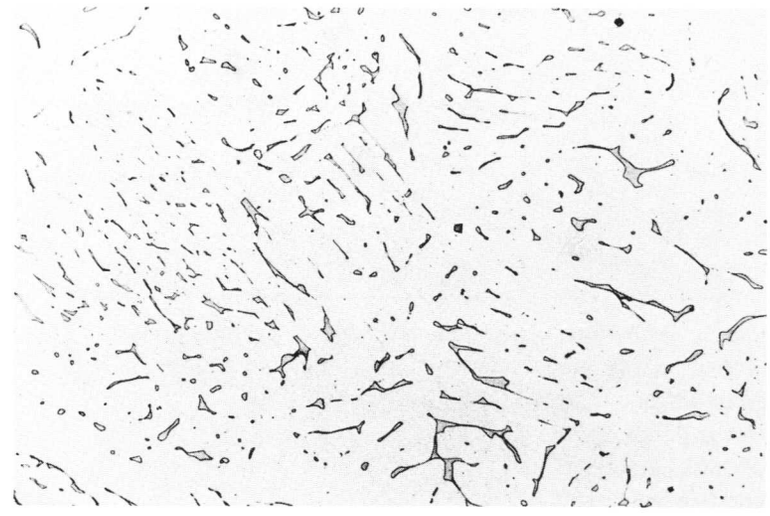


Figure 11
R = 0,5°C/s
Tq = 1200°C
4,1 vol-% dendritic ferrite

× 150 100 μm

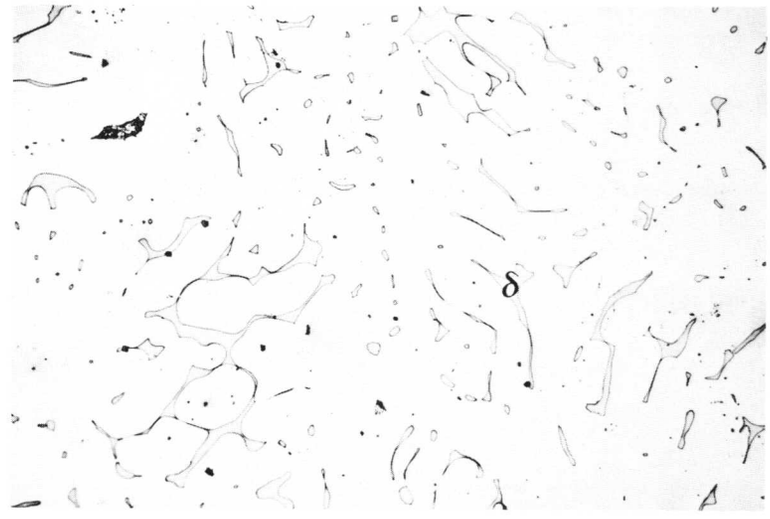


Figure 12
R = 0,1°C/s
Tq = 1320°C
4,8 vol-% dendritic ferrite

× 150 100 μm

STEEL 406. 0,05 % C 17 % Cr 12 % Ni 2,8 %Mo Nb STAINLESS STEEL

Designations

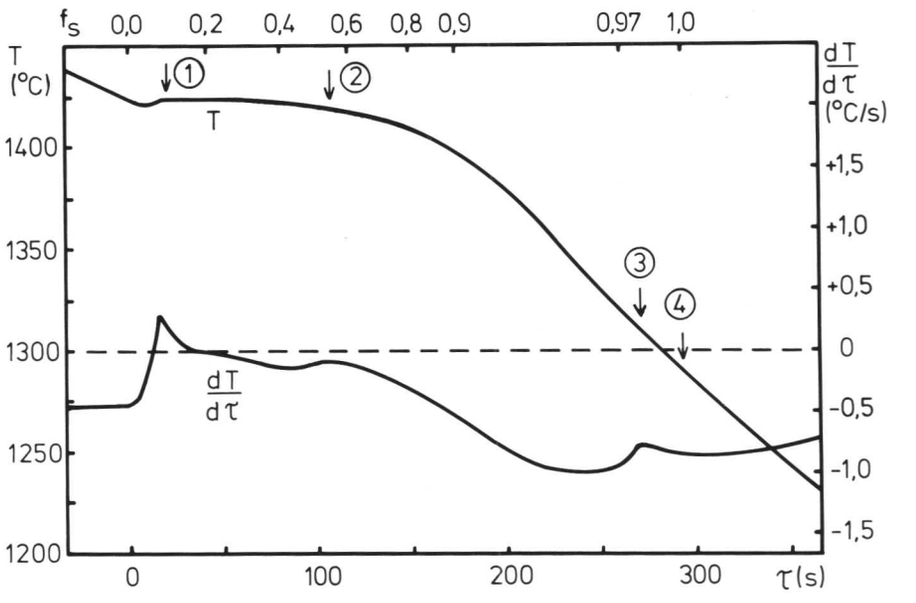
SIS	AISI	Werkstoff Nr
–	316 Cb	1.4583

Composition (wt–%)

C	Si	Mn	P	S	Cr	Ni	Mo	Cu	Co	Nb	Al_{tot}	N
0,052	0,44	1,71	0,013	0,007	17,2	12,6	2,80	0,03	0,03	0,54	0,004	0,010

$$\frac{Cr_{eq}}{Ni_{eq}} = 1{,}58$$

Thermal Analysis



R = 0,5°C/s

	Average Cooling Rate,R, (°C/s)		
	2,0	0,5	0,1
Liquidus temperature, ferritic and austenitic primary phases, °C ①	1420	1423	1424
Temperature of maximum rate of formation of austenite, °C ②	1410	1418	1417
Temperature of carbide formation, °C ③	1330 – 1275	1330 – 1290	1330 – 1305
Solidus temperature, °C ④	1275	1290	1305
Solidification range, °C	145	130	120
Solidification time, s	130	300	1240
Fraction solidified as ferrite, %	<60	<45	<42

Precipitates

1. Interdendritic ferrite, (see figures 4, 6 – 11).
2. Eutectic NbC, (see figures 6, 7, 9 – 11).

Microsegregation

Element	Si	Mn	Cr	Ni
I	1,7	1,5	1,1	1,4
P_D			1,3	0,6
P_{ID}			1,1	0,8

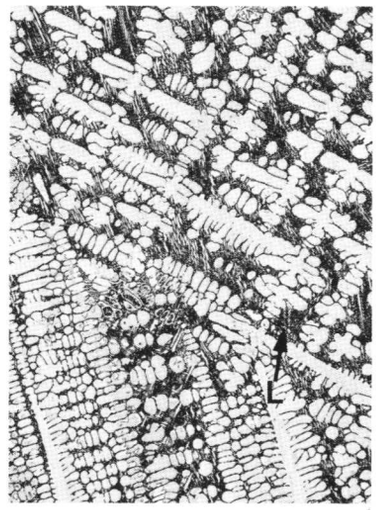
R = 0,5 °C/s
Tq = 1285 °C

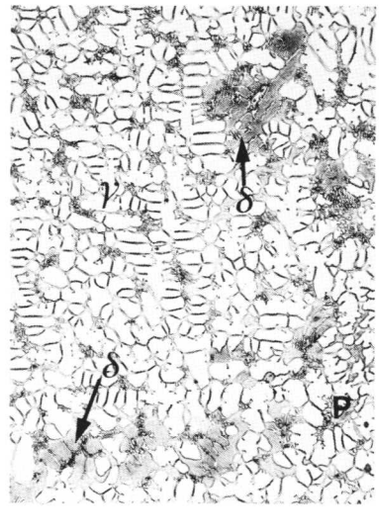
Partly solidified

Figure 1a
R = 0,5°C/s
Tq = 1423°C
d = 45 μm
δ-dendrites and quenched liquid (L).

Figure 1b
R = 0,5°C/s
Tq = 1415°C
d = 45 μm
δ-dendrites, γ-dendrites and quenched liquid (L). Peritectic reaction (P).

× 25 400 μm





Completely solidified

Figure 2
R = 2,0°C/s
Tq = 1270°C
d = 65 μm
Figures 2–3: Former δ-dendrites, γ-dendrites, dendritic and interdendritic ferrite, (compare figures 8–9).

× 25 400 μm

Figure 3
R = 0,5°C/s
Tq = 1285°C
d = 80 μm

× 25 400 μm

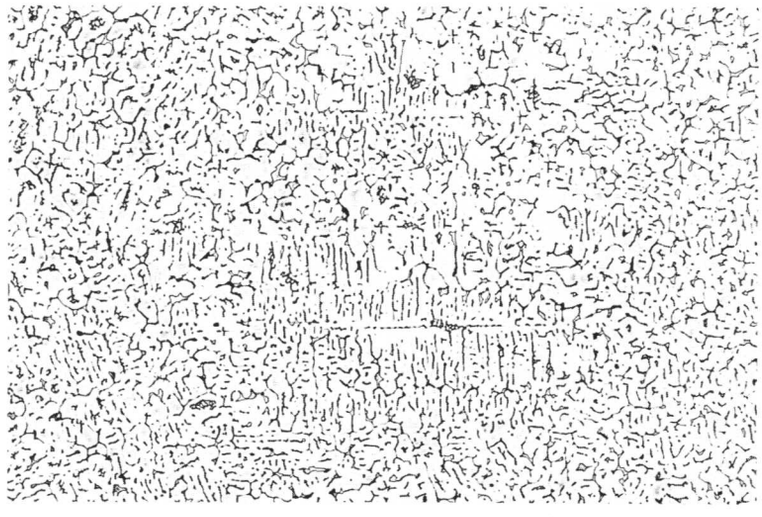
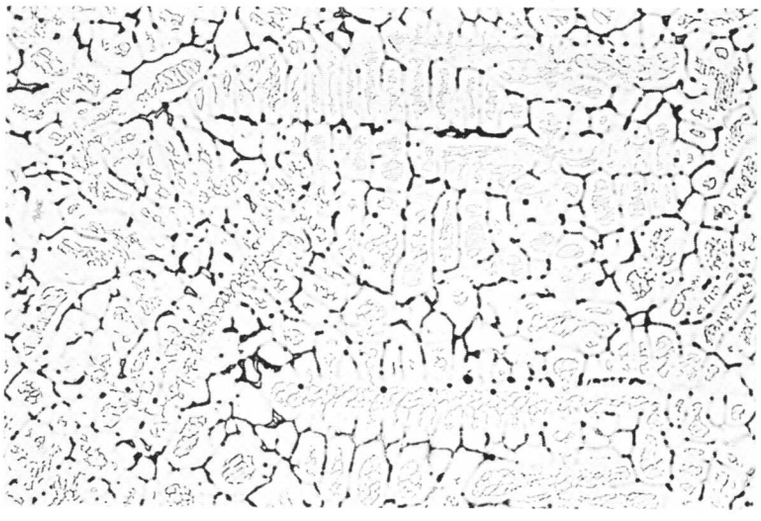


Figure 4
R = 0,1°C/s
Tq = 1300°C
d = 135 μm
Former δ-dendrites, dendritic and interdendritic ferrite, (compare figure 11).

× 25 400 μm



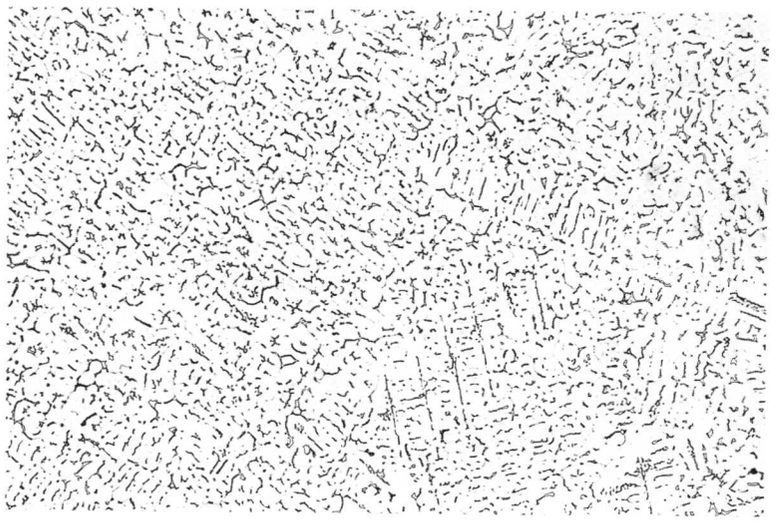


Figure 5
R = 0,5°C/s
Tq = 1200°C
(d_{1200} = 85μm)
Former δ-dendrites, γ-dendrites, dendritic and interdendritic ferrite, (compare figure 10).

400 μm × 25

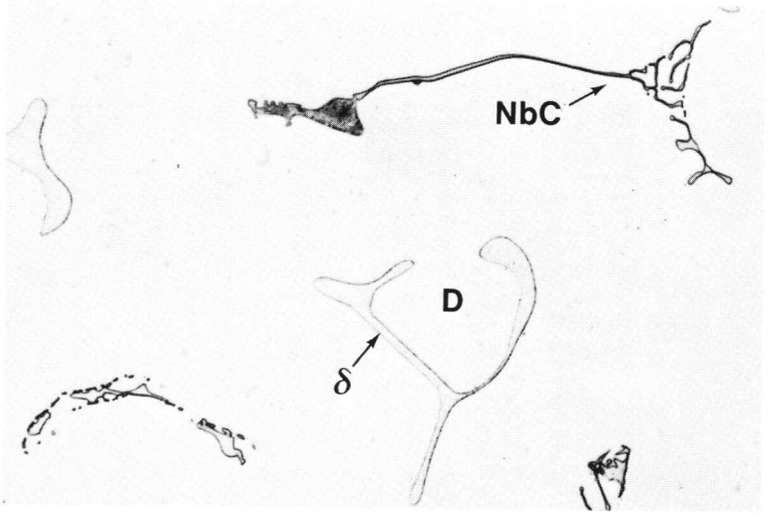


Figure 6
R = 0,5°C/s
Tq = 1200°C
Eutectic NbC and dendritic (D) ferrite (δ).

25 μm × 600

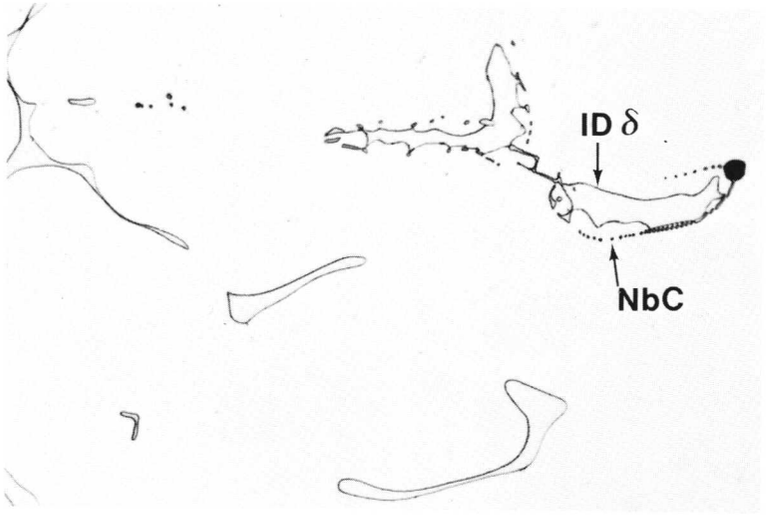


Figure 7
R = 0,5°C/s
Tq = 1200°C
Solid state precipitation of NbC around interdendritic ferrite (IDδ).

25 μm × 600

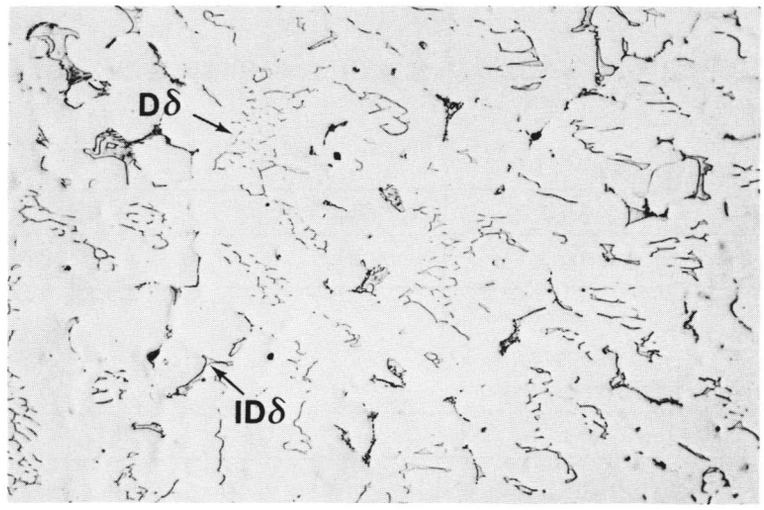


Figure 8
R = 2,0°C/s
Tq = 1270°C
4,0 vol-% ferrite, dendritic (Dδ) and interdendritic (IDδ).

× 150 100 μm

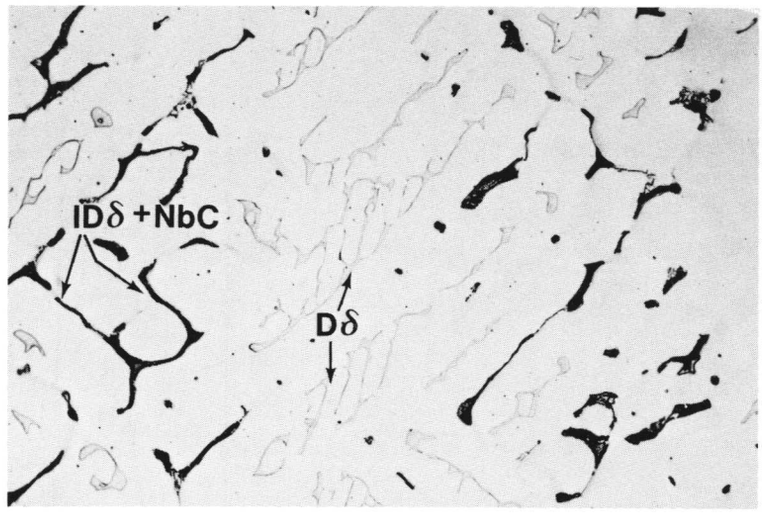


Figure 9
R = 0,5°C/s
Tq = 1285°C
4,0 vol-% ferrite, dendritic (Dδ) and interdendritic (IDδ).

× 150 100 μm

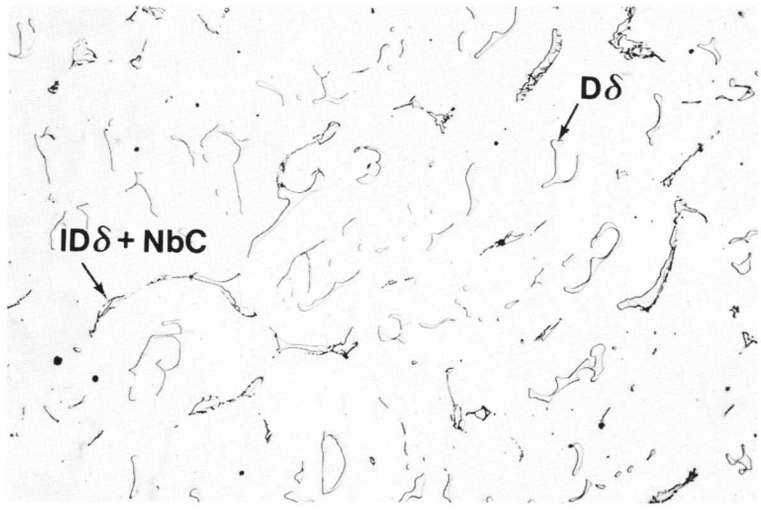


Figure 10
R = 0,5°C/s
Tq = 1200°C
2,9 vol-% ferrite, dendritic (Dδ) and interdendritic (IDδ).

× 150 100 μm

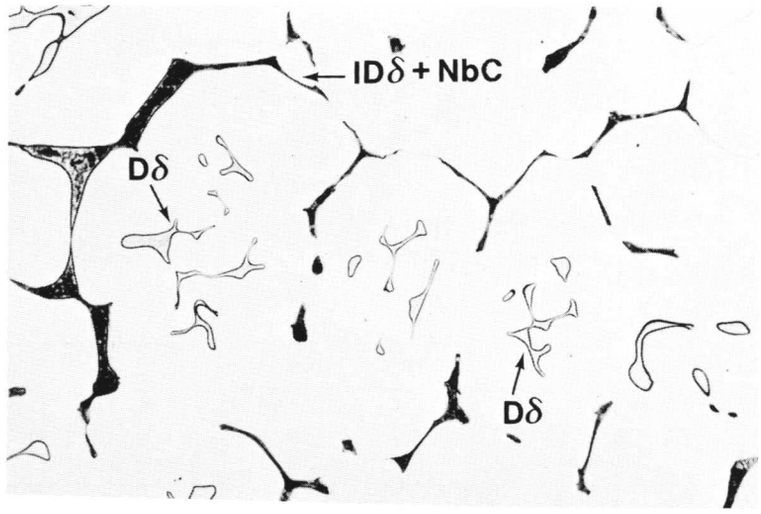


Figure 11
R = 0,1°C/s
Tq = 1300°C
3,9 vol-% ferrite, dendritic (Dδ) and interdendritic (IDδ).

× 150 100 μm

STEEL 407. 0,02 % C 17 % Cr 13 % Ni 2,5 % Mo STAINLESS STEEL

Designations

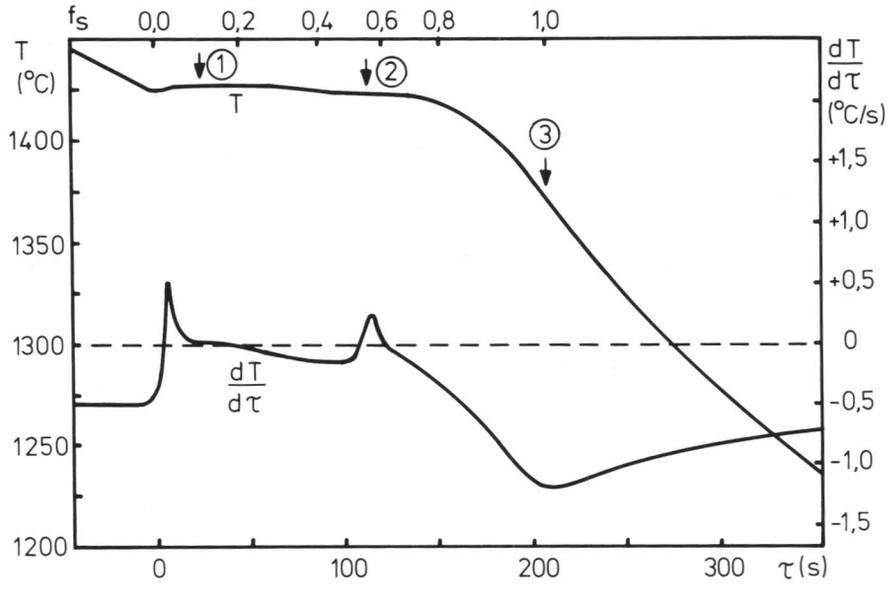
SIS	AISI	Werkstoff Nr
2353	316 L	1.4435

Composition (wt–%)

C	Si	Mn	P	S	Cr	Ni	Mo	Cu	Co	Al_{tot}	N
0,023	0,53	1,58	0,020	0,006	17,2	13,5	2,63	0,19	0,07	0,004	0,031

$$\frac{Cr_{eq}}{Ni_{eq}} = 1{,}43$$

Thermal Analysis



R = 0,5°C/s

	Average Cooling Rate,R, (°C/s)		
	2,0	0,5	0,1
Liquidus temperature, ferritic and austenitic primary phases, °C ①	1423	1427	1428
Temperature of maximum rate of formation of austenite, °C ②	1418	1421	1425
Solidus temperature, °C ③	1345	1375	1380
Solidification range, °C	80	50	45
Solidification time, s	100	210	660
Fraction solidified as ferrite, %	<46	<50	<34

Precipitates

Interdendritic ferrite, (see figures, 5, 8–12).

Microsegregation

Element	Mn	Cr	Ni	Mo
I	1,5	1,2	1,2	2,2
P_{ID}		1,2	0,8	

R = 0,5 °C/s
Tq = 1320 °C

Partly solidified

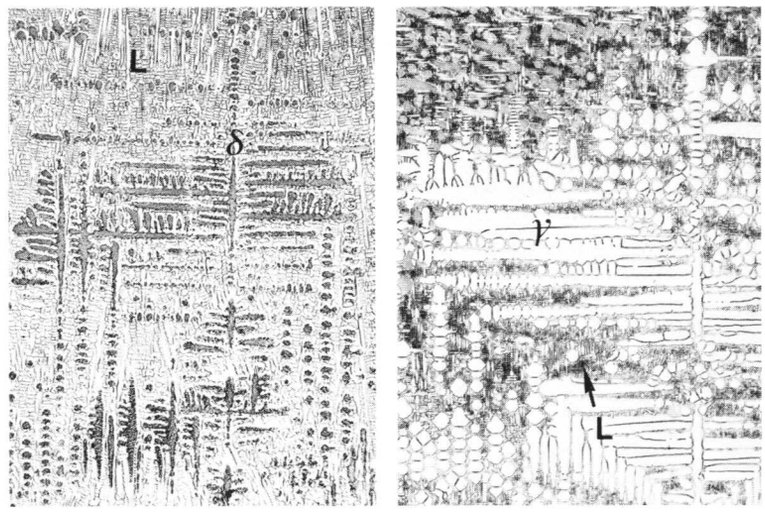


Figure 1
R = 0,5°C/s
Tq = 1427°C
d = 55 μm
δ- and γ- dendrites, growing simultaneously and quenched liquid (L).

× 25 400 μm

Completely solidified

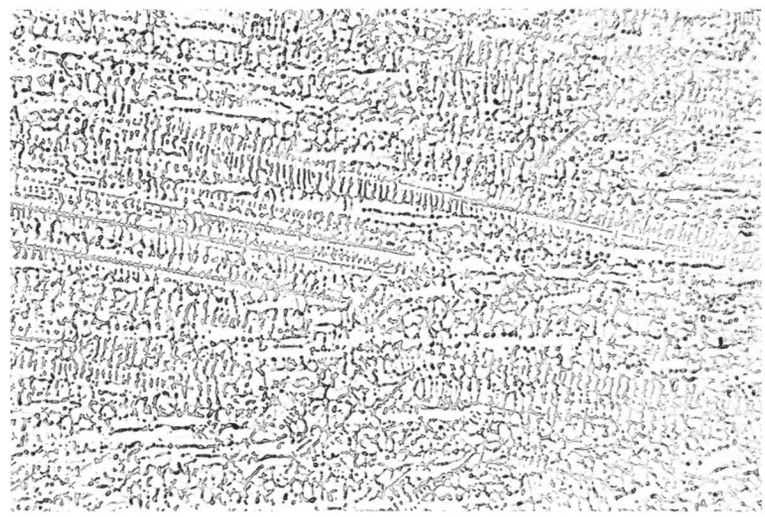


Figure 2
R = 2,0°C/s
Tq = 1320°C
d = 40 μm
Former δ-dendrites, γ-dendrites, dendritic and interdendritic ferrite, (compare figure 9).

× 25 400 μm

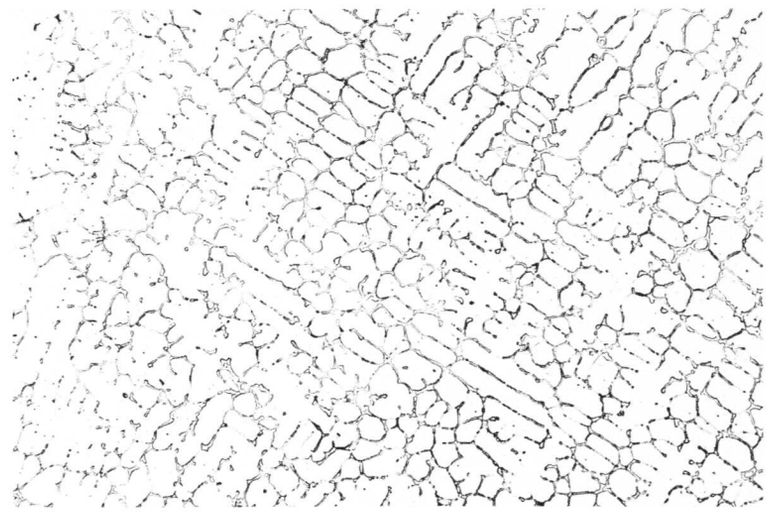


Figure 3
R = 0,5°C/s
Tq = 1320°C
d = 90 μm
Figures 3—4: Former δ-dendrites, γ-dendrites and interdendritic ferrite, (compare figures 10 and 12).

× 25 400 μm

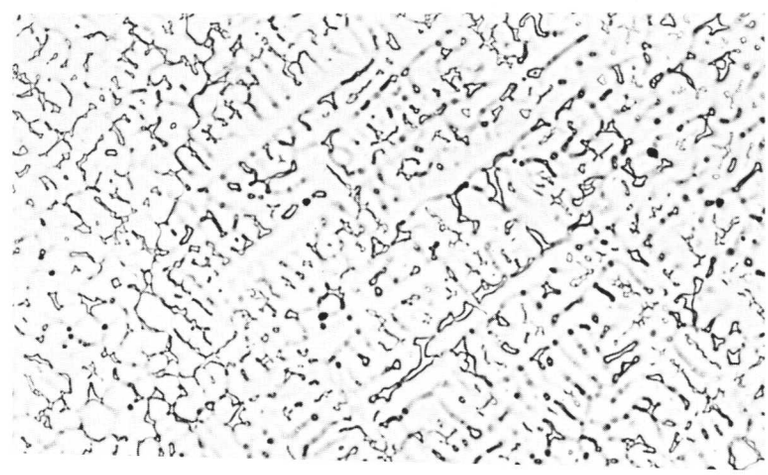


Figure 4
R = 0,1°C/s
Tq = 1320°C
d = 100 μm

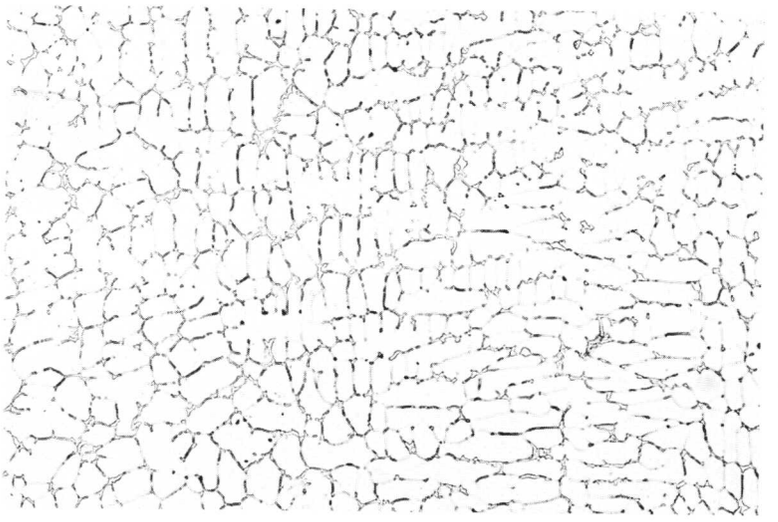


Figure 5
R = 0,5°C/s
Tq = 1200°C
(d_{1200} = 100 μm)
Former δ-dendrites, γ-dendrites and interdendritic ferrite, (compare figure11).

400 μm × 25

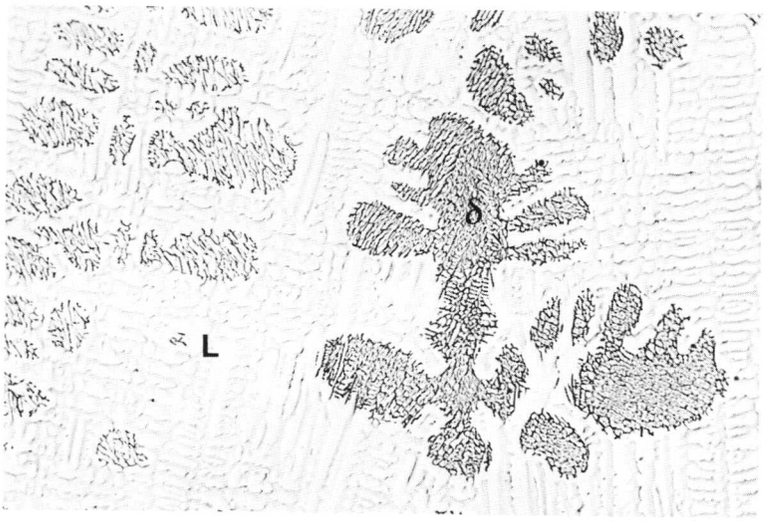


Figure 6
R = 0,5°C/s
Tq = 1427°C
δ-dendrites and quenched liquid (L), (compare figure 1).

100 μm × 150

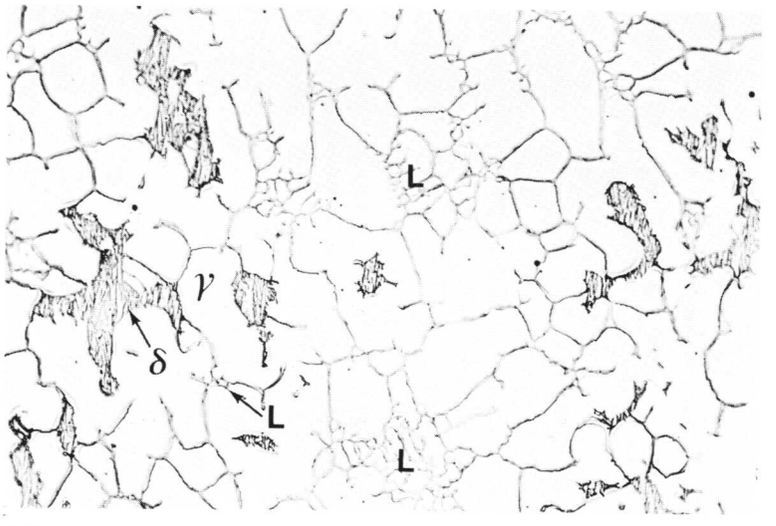


Figure 7
R = 0,5°C/s
Tq = 1415°C
γ growing into both δ-dendrites and liquid.

100 μm × 150

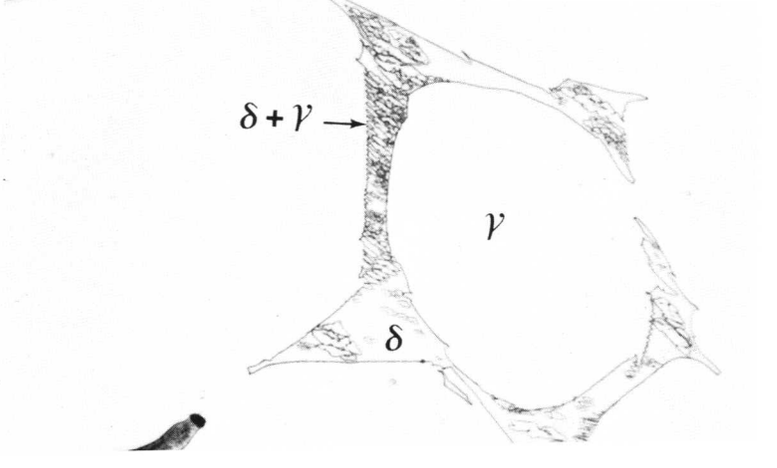


Figure 8
R = 0,5°C/s
Tq = 1320°C
Austenite precipitated in interdendritic ferrite during quenching. Dark structure in figure 10.

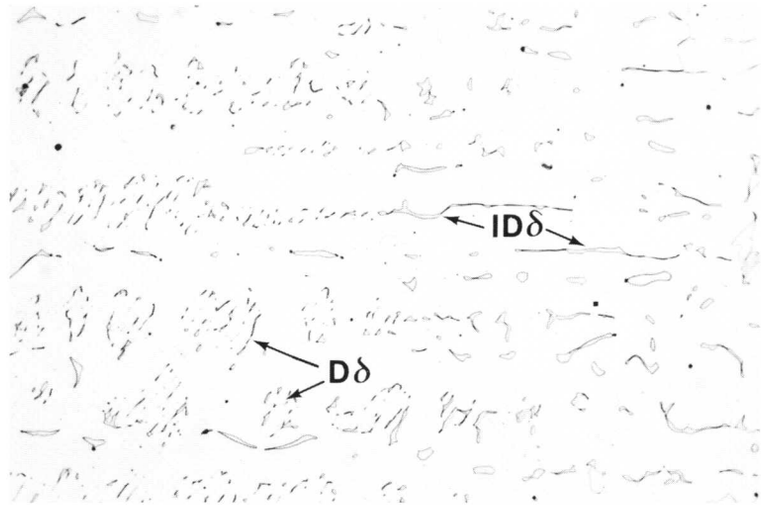


Figure 9
R = 2,0°C/s
Tq = 1320°C
5,5 vol-% ferrite, dendritic (Dδ) and interdendritic (IDδ).

× 150 100 μm

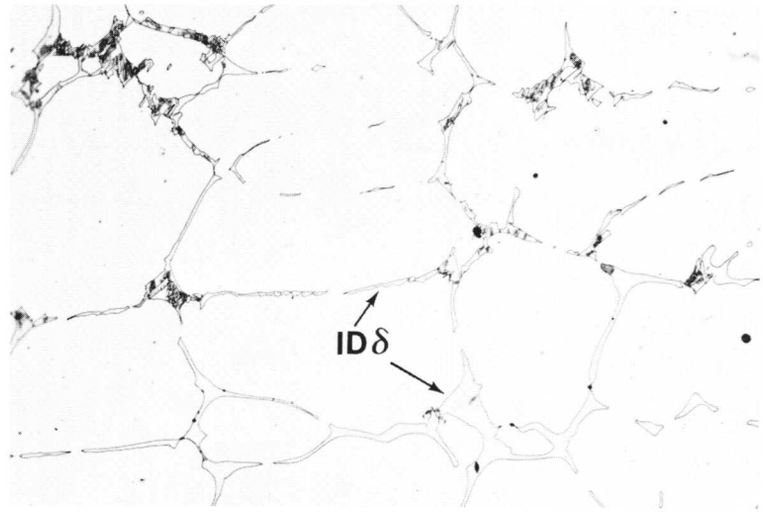


Figure 10
R = 0,5°C/s
Tq = 1320°C
5,6 vol-% ferrite, mainly interdendritic (IDδ).

× 150 100 μm

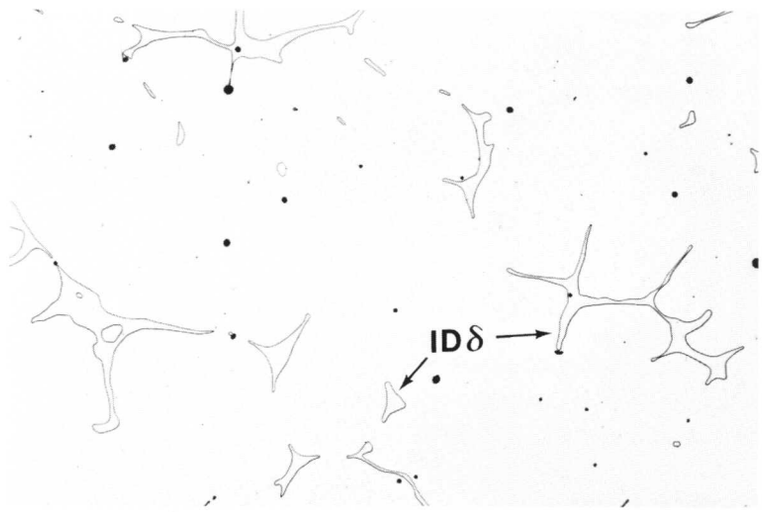


Figure 11
R = 0,5°C/s
Tq = 1200°C
3,5 vol-% ferrite, mainly interdendritic (IDδ).

× 150 100 μm

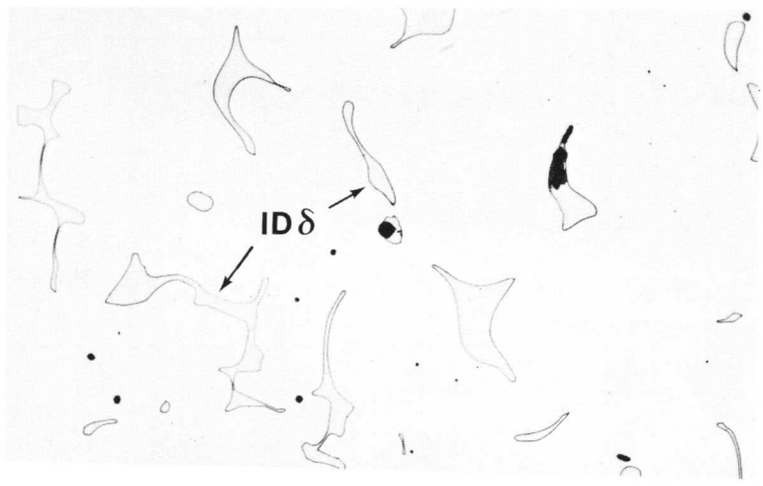


Figure 12
R = 0,1°C/s
Tq = 1320°C
4,4 vol-% ferrite, mainly interdendritic (IDδ).

STEEL 408. 0,05 % C 18 % Cr 13 % Ni 2,5 % Mo STAINLESS STEEL

Designations

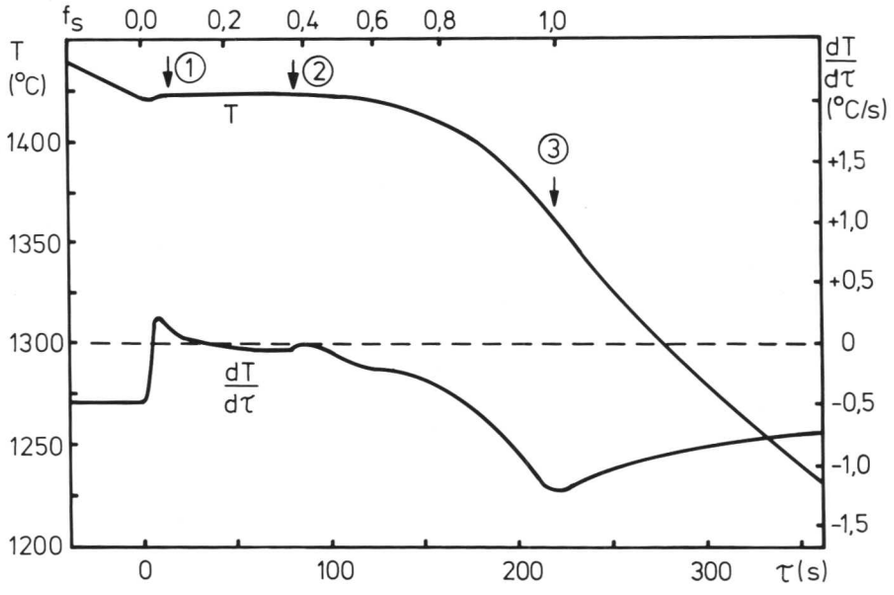
SIS	AISI	Werkstoff Nr
2343	316	1.4401

Composition (wt–%)

C	Si	Mn	P	S	Cr	Ni	Mo	Cu	Co	Al_{tot}	N
0,048	0,63	1,65	0,018	0,007	17,7	13,4	2,68	0,15	0,07	0,004	0,045

$$\frac{Cr_{eq}}{Ni_{eq}} = 1,42$$

Thermal Analysis



R = 0,5°C/s

	Average Cooling Rate,R, (°C/s)		
	2,0	0,5	0,1
Liquidus temperature, ferritic and austenitic primary phases, °C ①	1419	1423	1421
Temperature of maximum rate of formation of austenite, °C ②	1414	1422	1415
Solidus temperature, °C	1330	1360	1370
Solidification range, °C	85	60	50
Solidification time, s	100	220	670
Fraction solidified as ferrite, %	<36	<35	<34

Precipitates

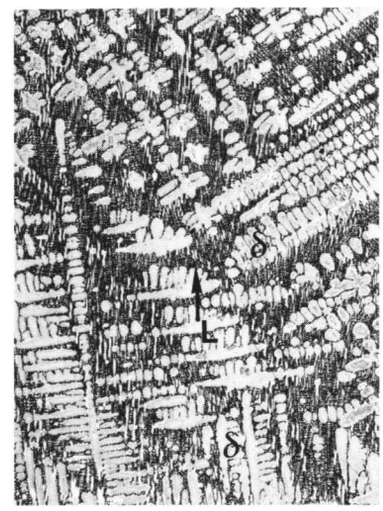
Interdendritic ferrite, (see figures, 5, 8–11).

Microsegregation

Element	Mn	Cr	Ni	Mo
I	1,6	1,2	1,2	2,1
P_{ID}		1.2	0.7	

R = 0,5 °C/s
Tq = 1305 °C

Partly solidified



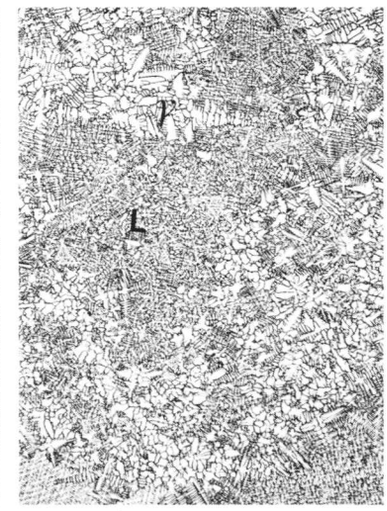


Figure 1
R = 0,5°C/s
Tq = 1423°C
d = 50 μm
δ- and γ- dendrites, growing simultaneously, and quenched liquid (L).

× 25 400 μm

Completely solidified

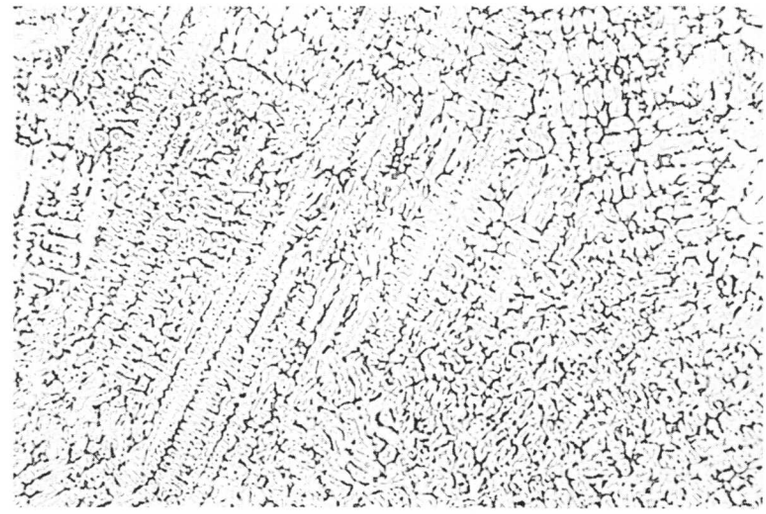


Figure 2
R = 2,0°C/s
Tq = 1305°C
d = 55 μm
Former δ-dendrites, γ-dendrites and interdendritic ferrite. Some dendritic ferrite can also be seen, (compare figure 8).

× 25 400 μm

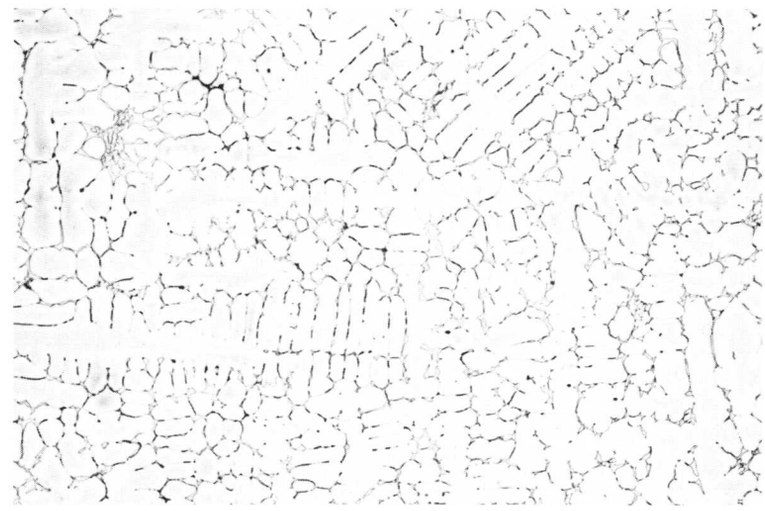


Figure 3
R = 0,5°C/s
Tq = 1305°C
d = 85 μm
Former δ-dendrites, γ-dendrites and interdendritic ferrite, (compare figure 9).

× 25 400 μm

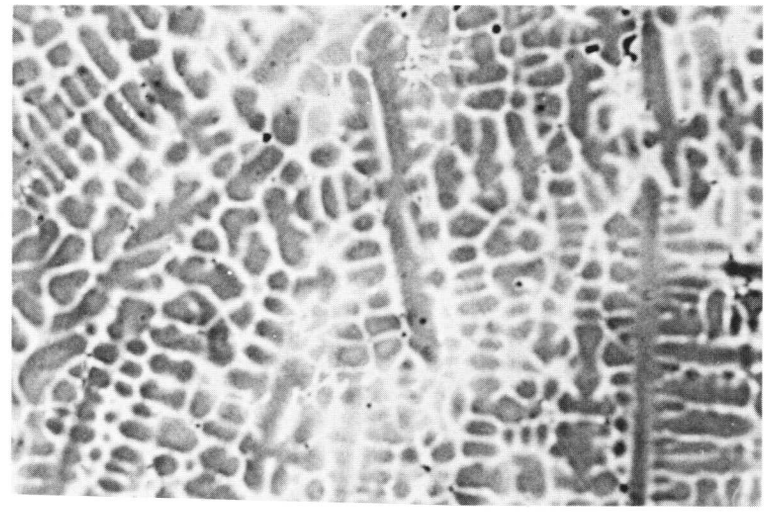


Figure 4
R = 0,1°C/s
Tq = 1305°C
d = 140 μm
Former δ-dendrites and γ-dendrites. White interdendritic areas, (compare figure 11).

× 25 400 μm

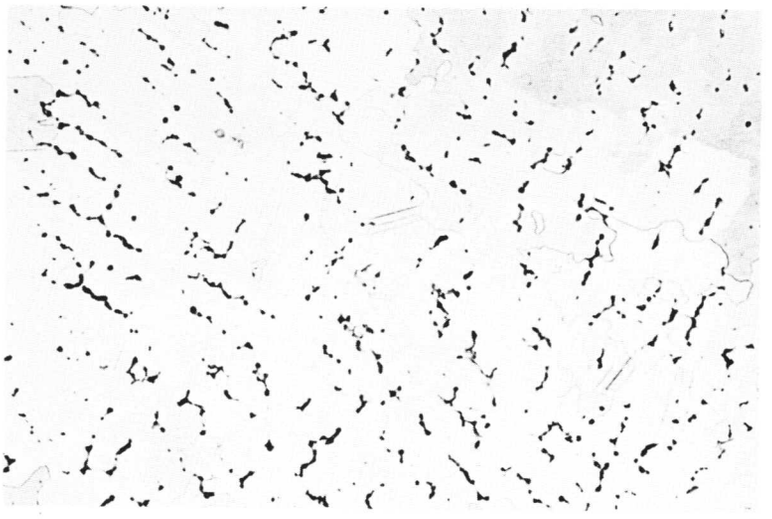


Figure 5
R = 0,5°C/s
Tq = 1200°C
(d_{1200} = 190 μm)
Former δ-dendrites, γ-dendrites and interdendritic ferrite, (compare figure 10).

400 μm × 25

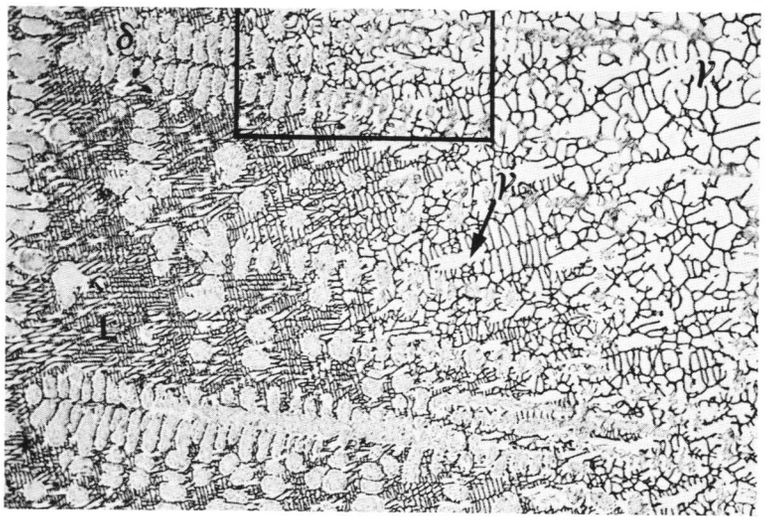


Figure 6
R = 0,5°C/s
Tq = 1420°C
Simultaneous growth of δ- and γ- dendrites. The transformation of δ into γ can also be seen, (peritectic reaction and transformation, compare figure 7).
L = quenched liquid.

200 μm × 50

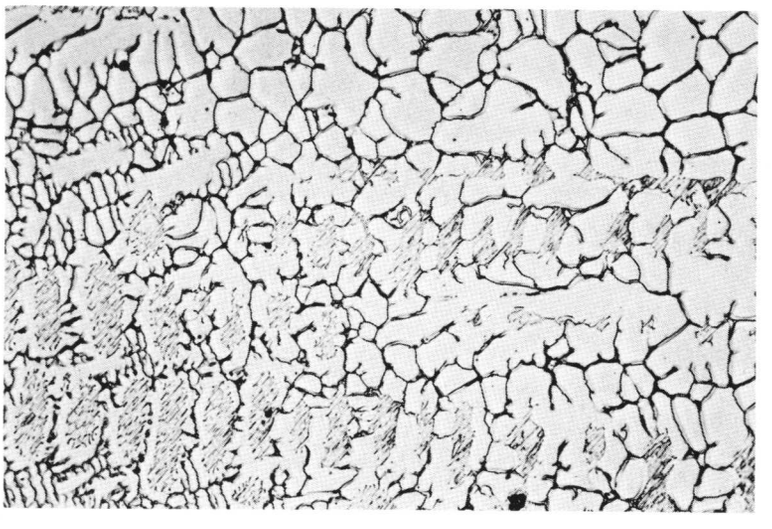


Figure 7
R = 0,5°C/s
Tq = 1420°C
Transformation of δ-dendrites.
Detail of figure 6.

100 μm × 150

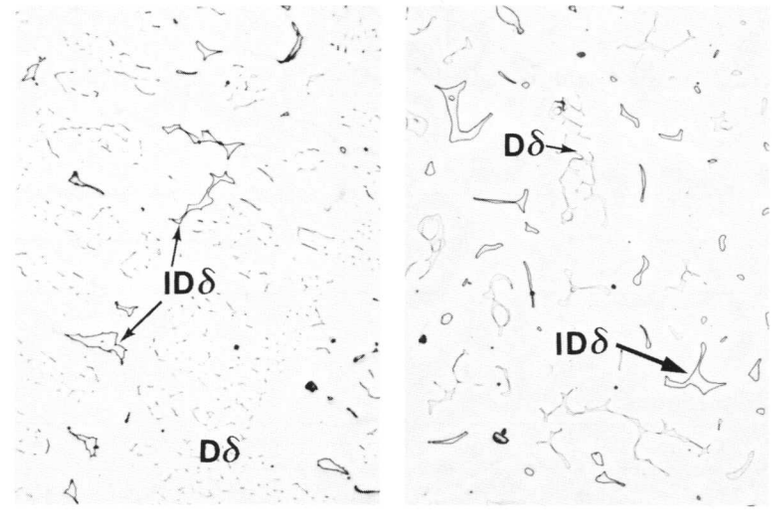


Figure 8
R = 2,0°C/s
Tq = 1305°C
4,0 vol-% ferrite, dendritic (Dδ) and interdendritic (IDδ).

× 150 100 μm

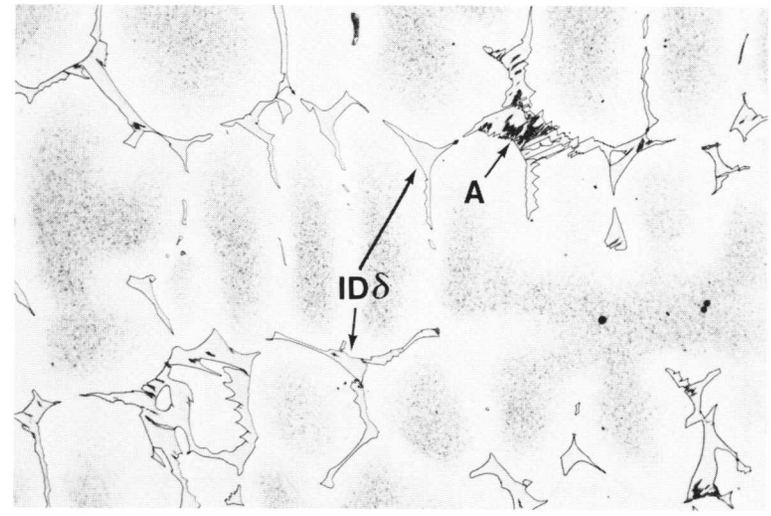


Figure 9
R = 0,5°C/s
Tq = 1305°C
5,0 vol-% ferrite, mainly interdendritic (IDδ). (Dark structure (A), austenite precipitated in ferrite during quenching.)

× 150 100 μm

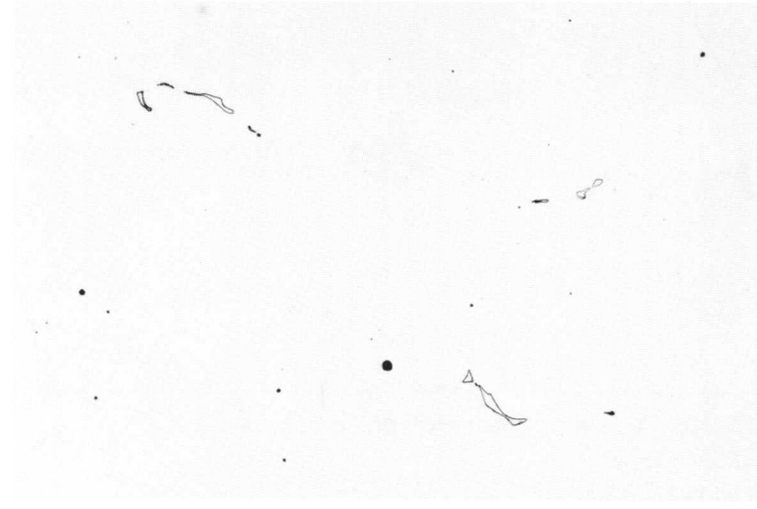


Figure 10
R = 0,5°C/s
Tq = 1200°C
0,1 vol-% ferrite, mainly interdendritic.

× 150 100 μm

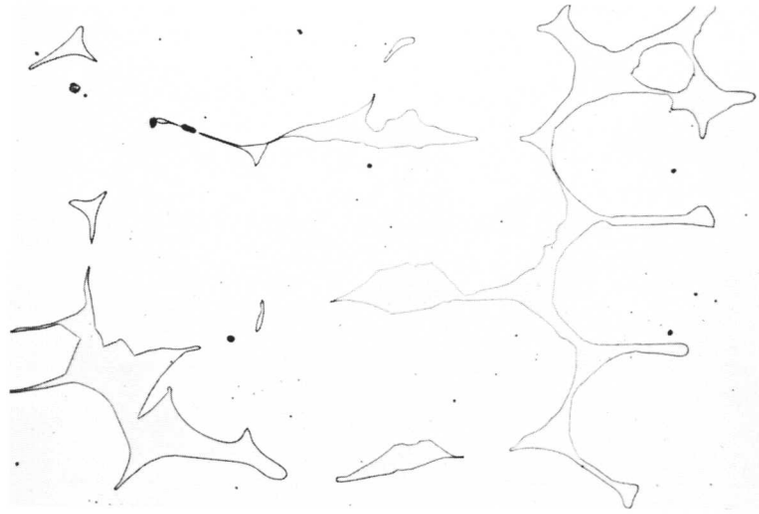


Figure 11
R = 0,1°C/s
Tq = 1305°C
5,5 vol-% ferrite, mainly interdendritic.

× 150 100 μm

STEEL 409. 0,02 % C 17 % Cr 13 % Ni 2,5 % Mo 0,2 % N STAINLESS STEEL

Designations

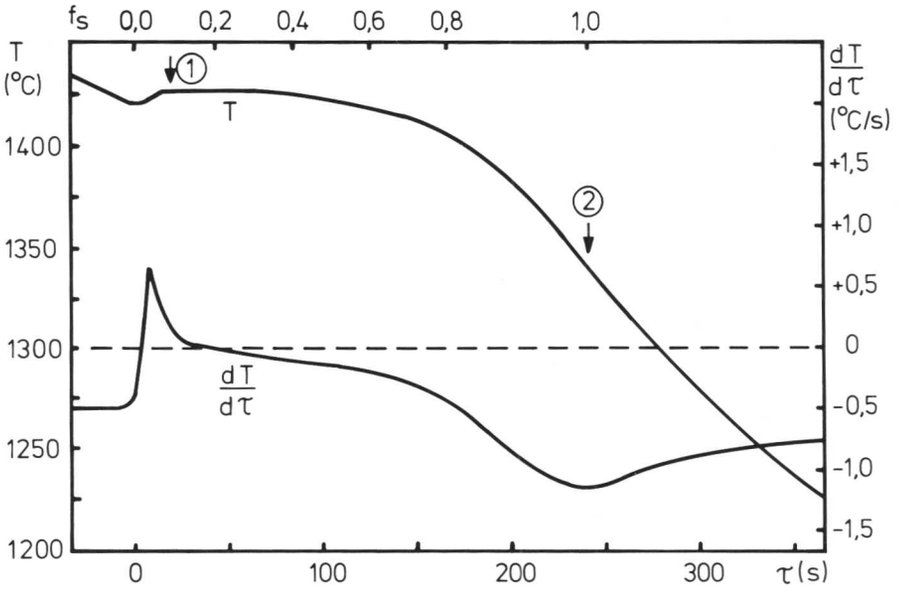
SIS	AISI	Werkstoff Nr
2375	316 N	1.4429

Composition (wt–%)

C	Si	Mn	P	S	Cr	Ni	Mo	Cu	Co	Al_{tot}	N
0,024	0,58	1,79	0,009	0,011	17,4	12,8	2,77	0,03	0,03	0,002	0,20

$$\frac{Cr_{eq}}{Ni_{eq}} = 1{,}32$$

Thermal Analysis



R = 0,5°C/s

	Average Cooling Rate,R, (°C/s)		
	2,0	0,5	0,1
Liquidus temperature, austenitic primary phase, °C (1)	1411	1421	1422
Solidus temperature, °C (2)	1310	1350	1370
Solidification range, °C	105	70	50
Solidification time, s	85	245	640

Precipitates

Interdendritic ferrite, (see figures 5, 8–11).

Microsegregation

Element	Mn	Cr	Ni	Mo	
I	1,6	1,2	1,1	2,1	R = 0,5 °C/s Tq = 1305 °C

Partly solidified

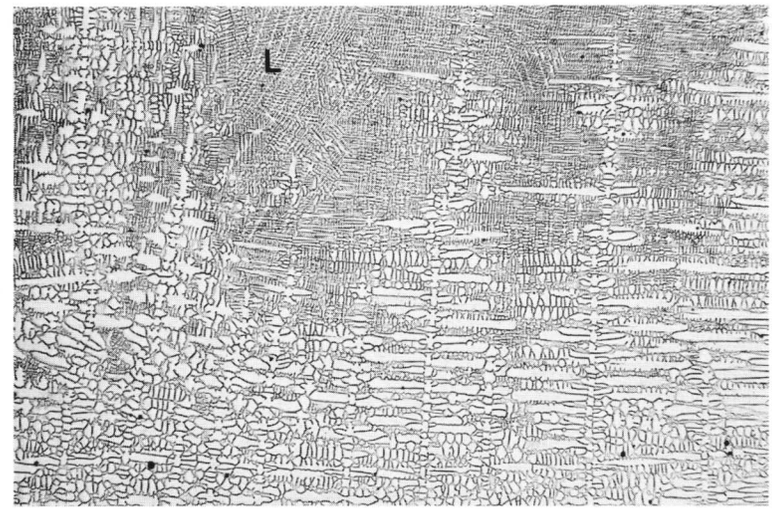


Figure 1
R = 0,5°C/s
Tq = 1415°C
d = 40 μm
γ-dendrites and quenched liquid (L).

× 25 400 μm

Completely solidified

Figure 2
R = 2,0°C/s
Tq = 1305°C
d = 45 μm
Figures 2–4: γ-dendrites and interdendritic ferrite.

× 25 400 μm

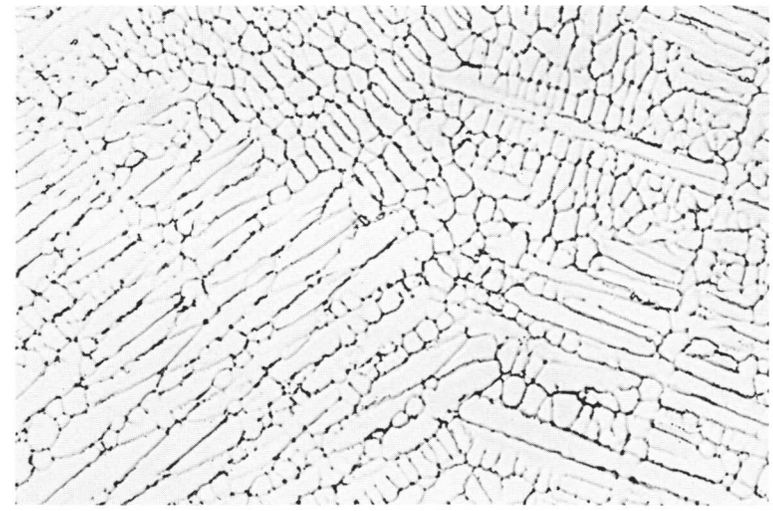


Figure 3
R = 0,5°C/s
Tq = 1305°C
d = 70 μm

× 25 400 μm

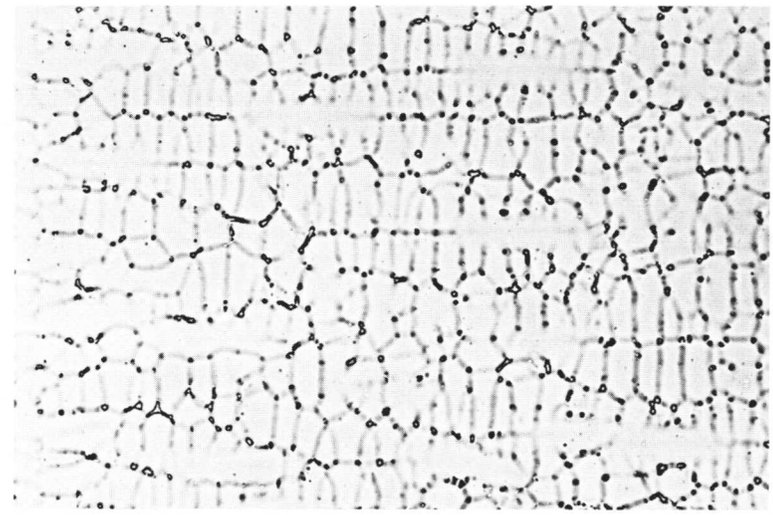


Figure 4
R = 0,1°C/s
Tq = 1305°C
d = 105 μm

× 25 400 μm

Figure 5
R = 0,5°C/s
Tq = 1200°C
(d_{1200} = 75 μm)
γ-dendrites and interdendritic ferrite.

400 μm × 25

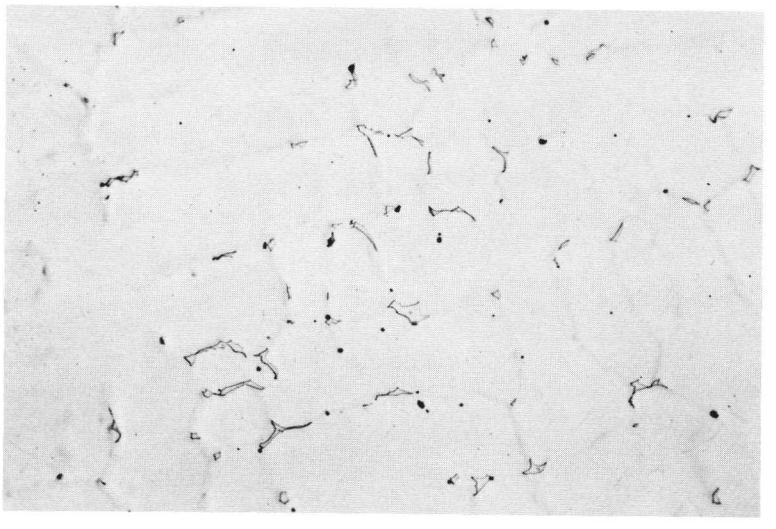


Figure 6
R = 2,0°C/s
Tq = 1305°C
0,8 vol-% interdendritic ferrite.

100 μm × 150

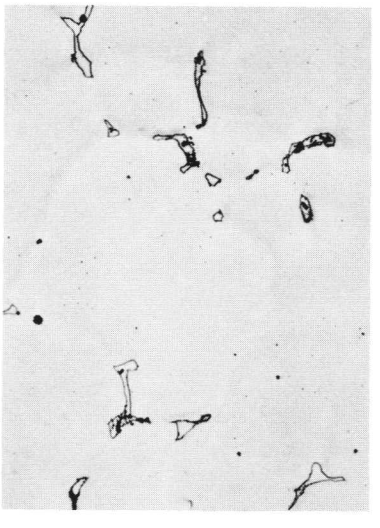


Figure 7
R = 0,5°C/s
Tq = 1305°C
0,8 vol-% inter-dendritic ferrite.

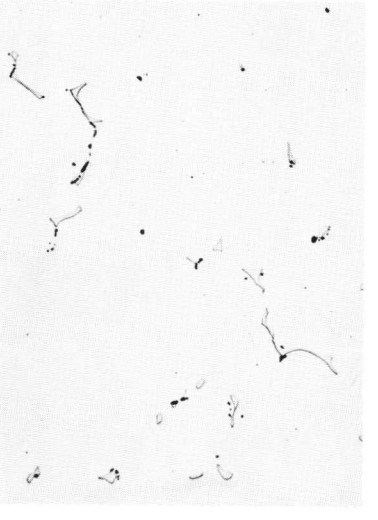


Figure 8
R = 0,5°C/s
Tq = 1200°C
0,1 vol-% inter-dendritic ferrite.

100 μm × 150

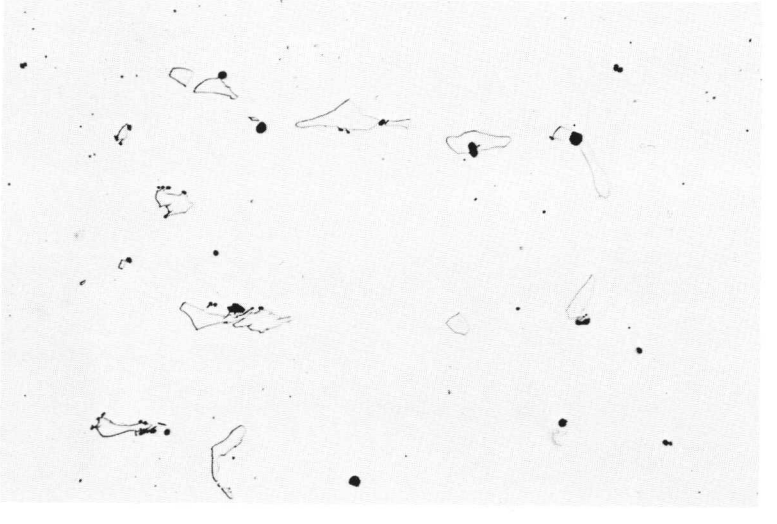


Figure 9
R = 0,1°C/s
Tq = 1305°C
0,8 vol-% interdendritic ferrite.

100 μm × 150

STEEL 410. 0,01 % C 25 % Cr 22 % Ni 2 % Mo STAINLESS STEEL

Designations

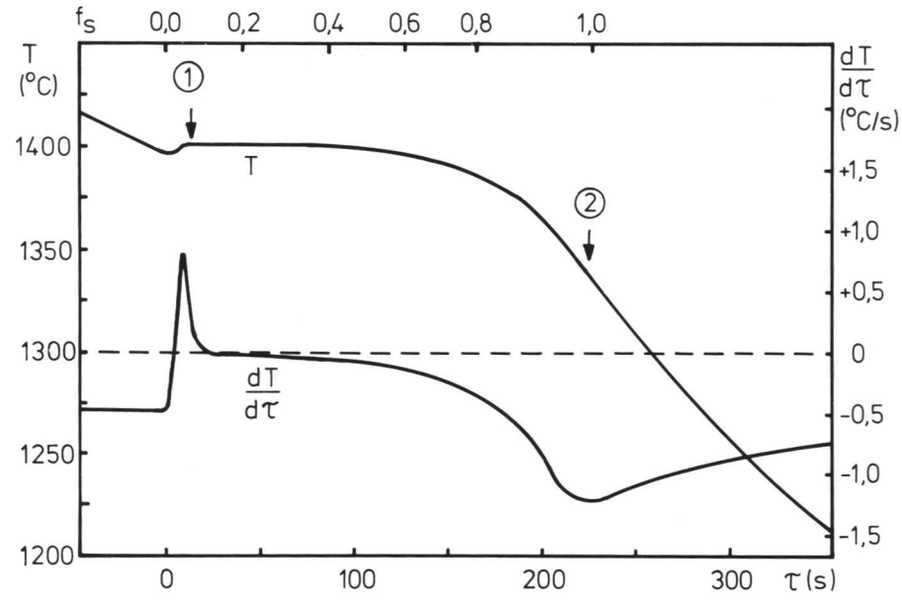
SIS	AISI	Werkstoff Nr
–	–	–

Composition (wt–%)

C	Si	Mn	P	S	Cr	Ni	Mo	Cu	Co	Ti	Al_{tot}	N
0,008	0,24	1,77	0,009	0,008	25,1	22,2	2,3	0,02	0,02	0,08	0,002	0,067

$$\frac{Cr_{eq}}{Ni_{eq}} = 1{,}21$$

Thermal Analysis



R = 0,5°C/s

	Average Cooling Rate,R, (°C/s)		
	2,0	0,5	0,1
Liquidus temperature, austenitic primary phase, °C (1)	1401	1402	1401
Solidus temperature, °C (2)	1335	1345	1355
Solidification range, °C	65	60	45
Solidification time, s	95	225	700

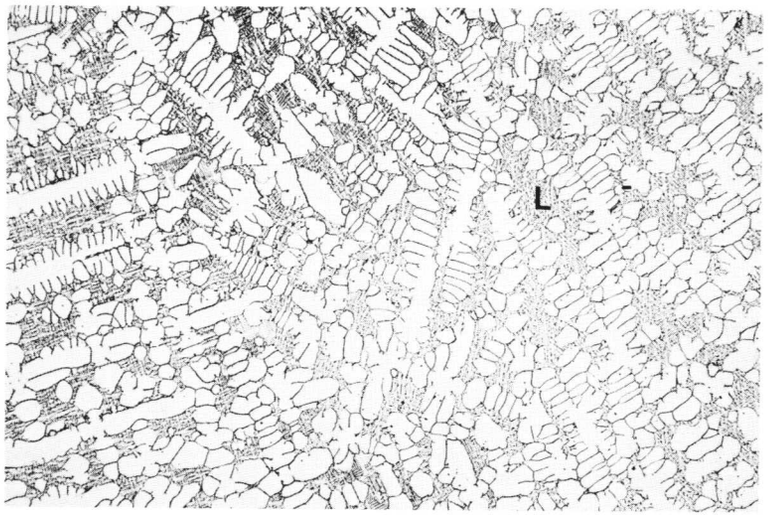
Precipitates

1. Interdendritic ferrite, (see figures 8–11).
2. Sigma-phase, (see figures 6 and 7).

Microsegregation

Element	Mn	Cr	Ni	Mo
I	1,6	1,2	1,1	2,3
P_{ID}		1,2	0,8	

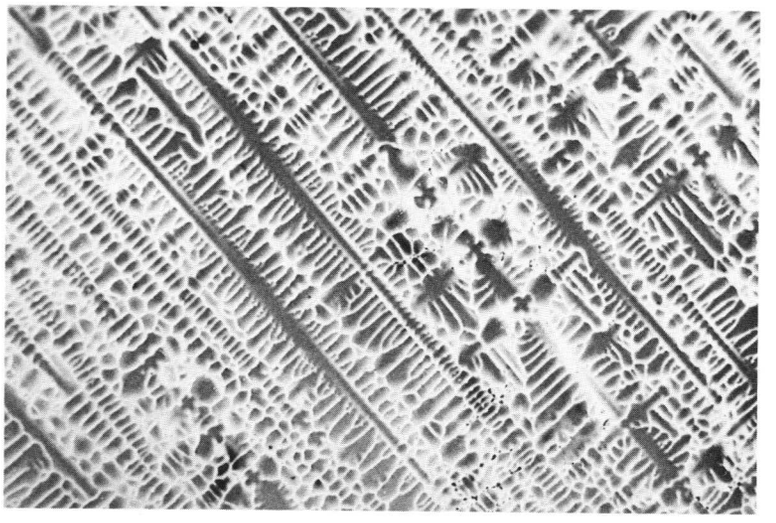
R = 0,5 °C/s
Tq = 1310 °C



Partly solidified

Figure 1
R = 0,5°C/s
Tq = 1398°C
d = 60 μm
γ-dendrites and quenched liquid (L).

400 μm × 25



Completely solidified

Figure 2
R = 2,0°C/s
Tq = 1310°C
d = 60 μm
Figures 2–4: γ-dendrites.
White interdendritic areas.

400 μm × 25

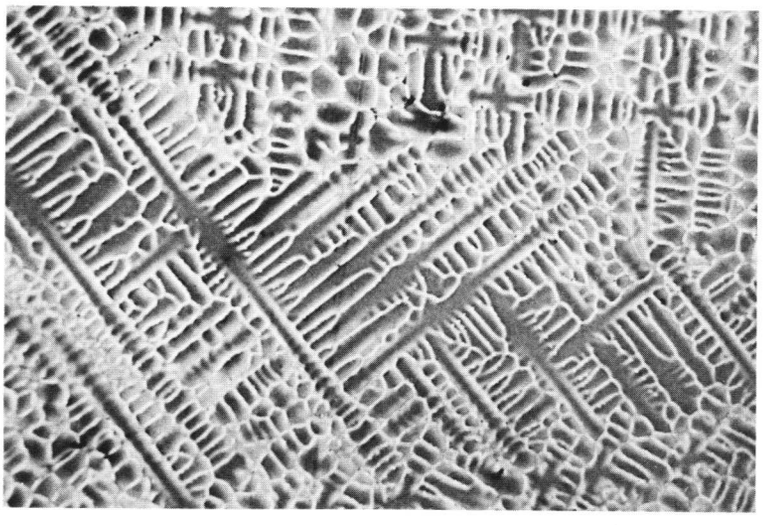


Figure 3
R = 0,5°C/s
Tq = 1310°C
d = 80 μm

400 μm × 25

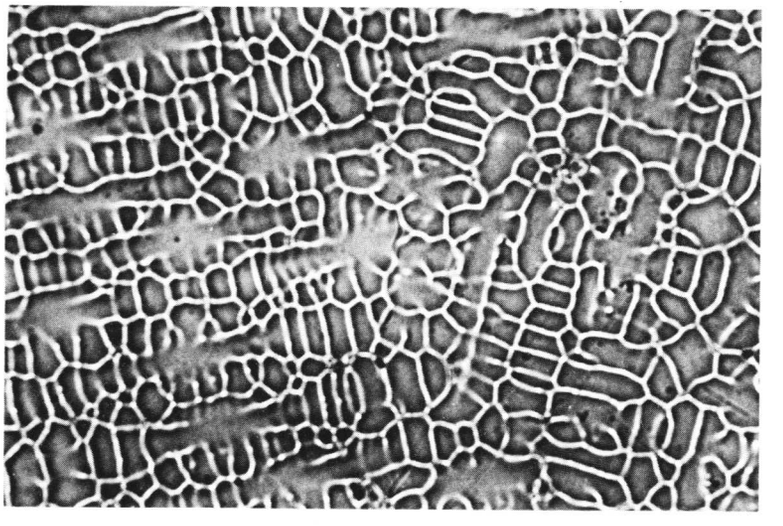


Figure 4
R = 0,1°C/s
Tq = 1310°C
d = 160 μm

400 μm × 25

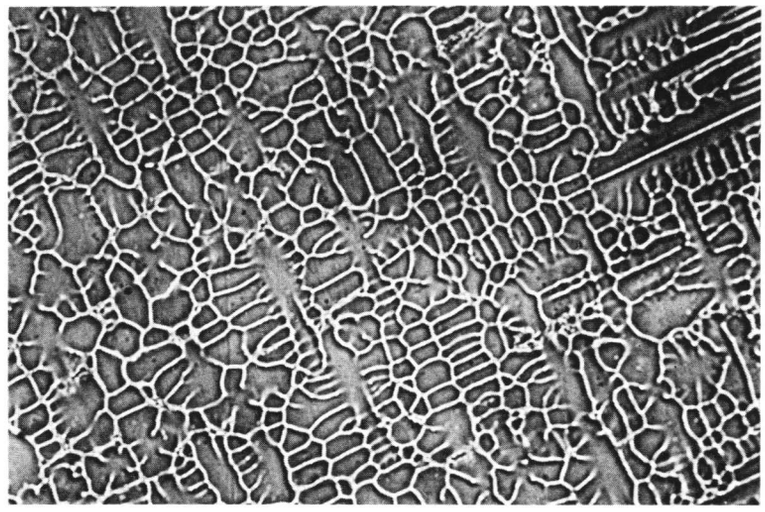


Figure 5
R = 0,5°C/s
Tq = 1200°C
(d_{1200} = 110 μm)
γ-dendrites.
White interdendritic areas.

× 25 — 400 μm

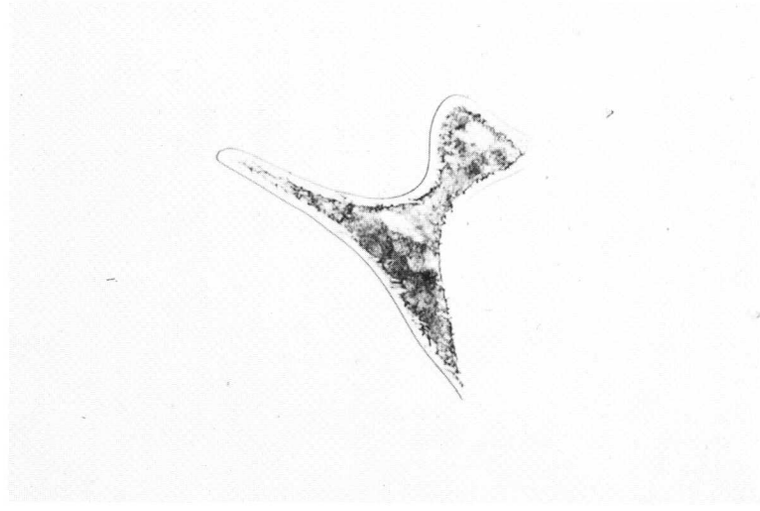


Figure 6
R = 0,1°C/s
Tq = 1310°C
Sigma-phase precipitated in ferrite, (dark structure in figures 9 and 11).

× 600 — 25 μm

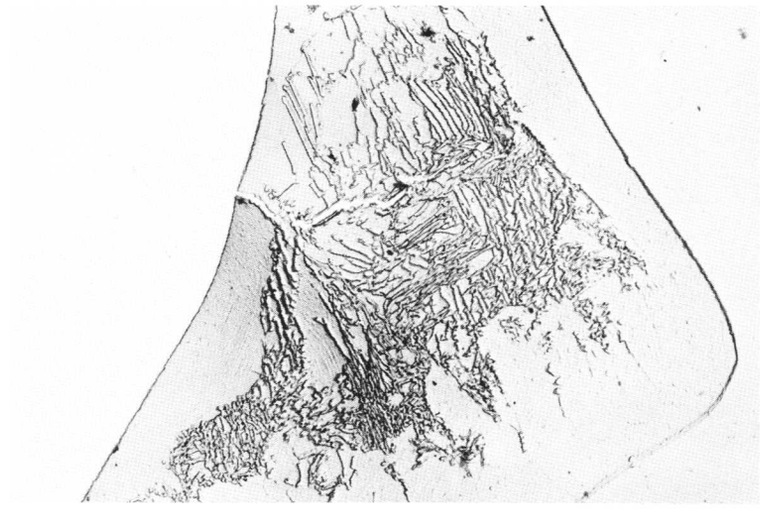


Figure 7
R = 0,1°C/s
Tq = 1310°C
Sigma-phase precipitated in ferrite.
(Electron micrograph.)

× 3 000 — 5 μm

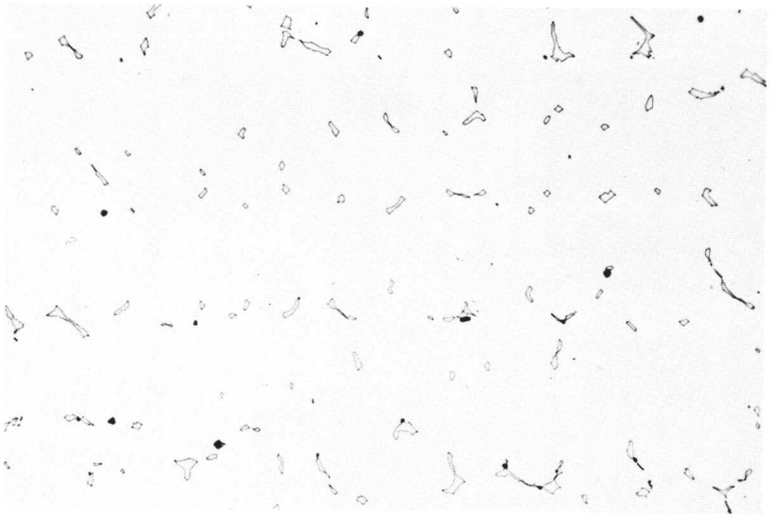


Figure 8
R = 2,0°C/s
Tq = 1310°C
1,0 vol-% interdendritic ferrite.

100 μm × 150

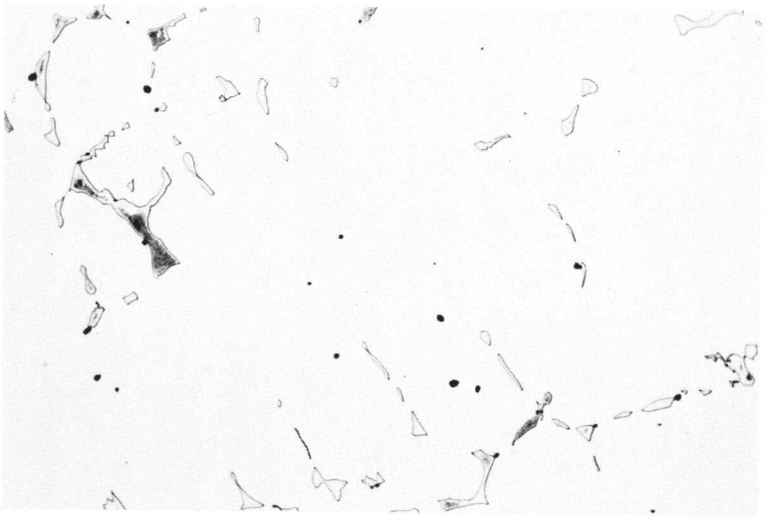


Figure 9
R = 0,5°C/s
Tq = 1310°C
1,0 vol-% interdendritic ferrite.

100 μm × 150

Figure 10
R = 0,5°C/s
Tq = 1200°C
0,7 vol-% interdendritic ferrite.

100 μm × 150

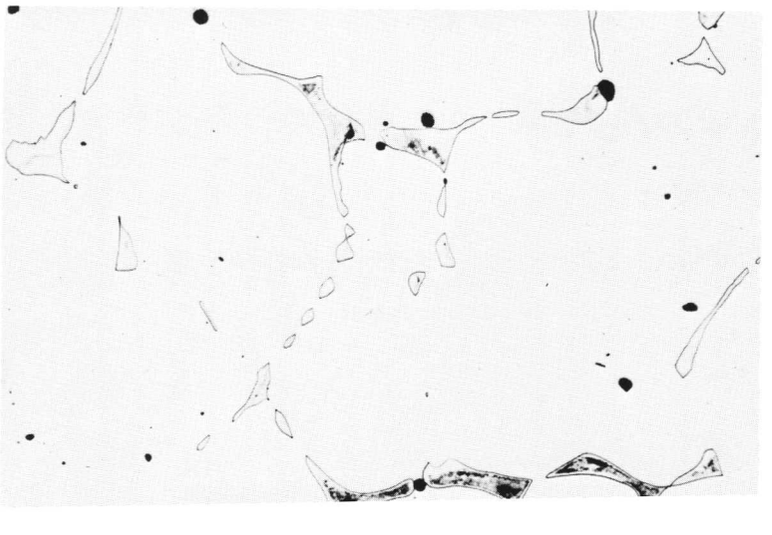


Figure 11
R = 0,1°C/s
Tq = 1310°C
1,0 vol-% interdendritic ferrite.

100 μm × 150

STEEL 411. 0,07 % C 24 % Cr 20 % Ni HEAT RESISTANT STEEL

Designations

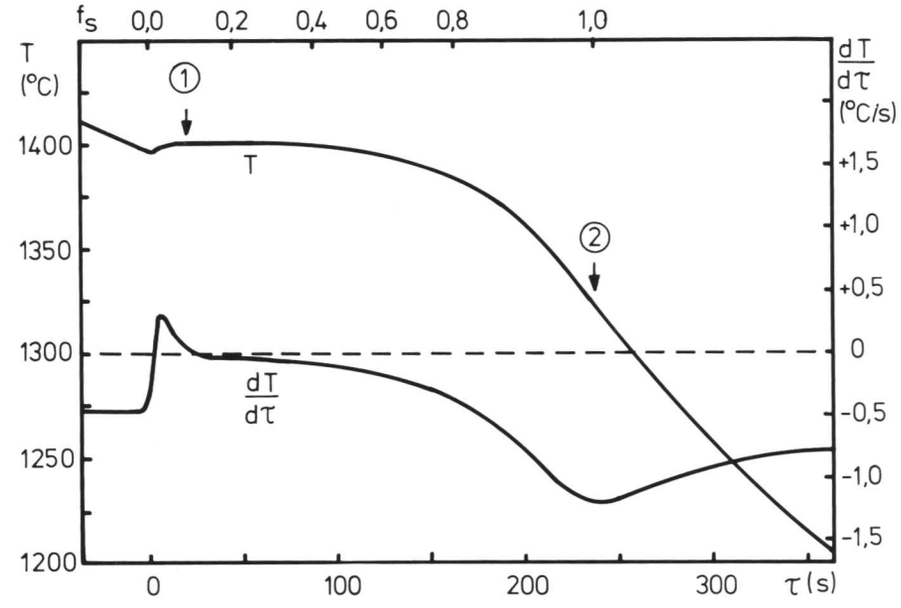
SIS	AISI	Werkstoff Nr
2361	310 S	1.4842

Composition (wt–%)

C	Si	Mn	P	S	Cr	Ni	Mo	Cu	Co	Ti	Al_{tot}	N
0,055	1,20	1,75	0,011	0,008	24,2	20,4	0,08	0,02	0,03	0,09	0,015	0,051

$$\frac{Cr_{eq}}{Ni_{eq}} = 1{,}15$$

Thermal Analysis



R = 0,5°C/s

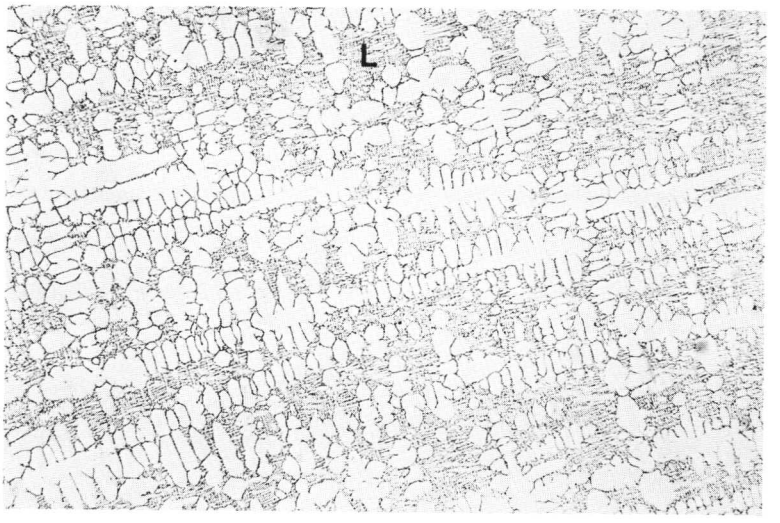
	Average Cooling Rate,R, (°C/s)		
	2,0	0,5	0,1
Liquidus temperature, austenitic primary phase, °C ①	1399	1401	1399
Solidus temperature, °C ②	1315	1330	1350
Solidification range, °C	80	70	50
Solidification time, s	105	230	750

Precipitates

Interdendritic ferrite, (see figures 6–8).

Microsegregation

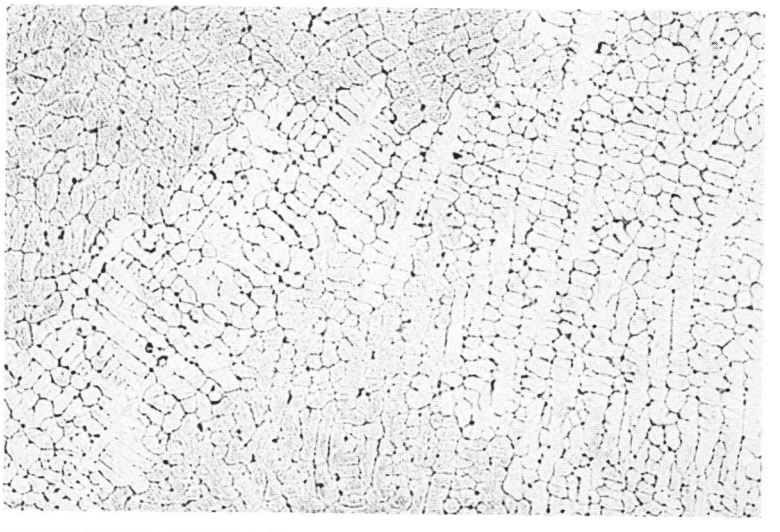
Element	Si	Mn	Cr	Ni	
I	2,4	1,9	1,2	1,2	R = 0,5 °C/s Tq = 1290 °C



Partly solidified

Figure 1
R = 0,5°C/s
Tq = 1395°C
d = 65 μm
γ-dendrites and quenched liquid (L).

400 μm × 25



Completely solidified

Figure 2
R = 2,0°C/s
Tq = 1290°C
d = 55 μm
Figures 2–4: γ-dendrites.

400 μm × 25

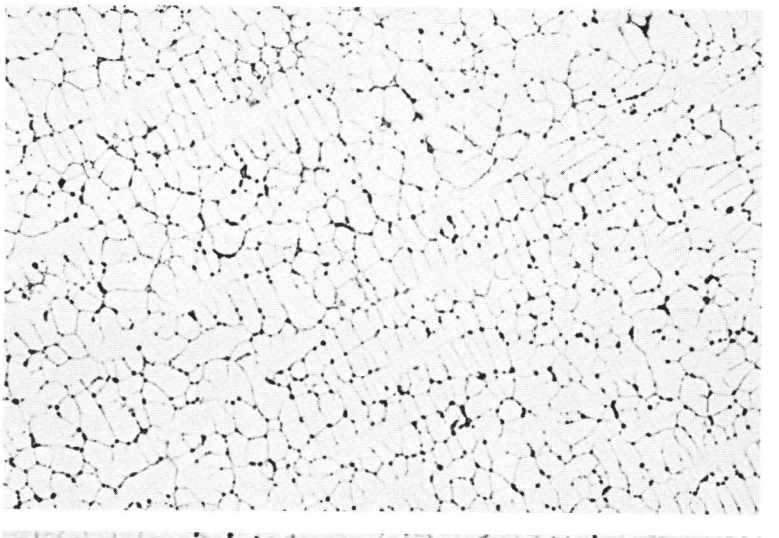


Figure 3
R = 0,5°C/s
Tq = 1290°C
d = 85 μm

400 μm × 25

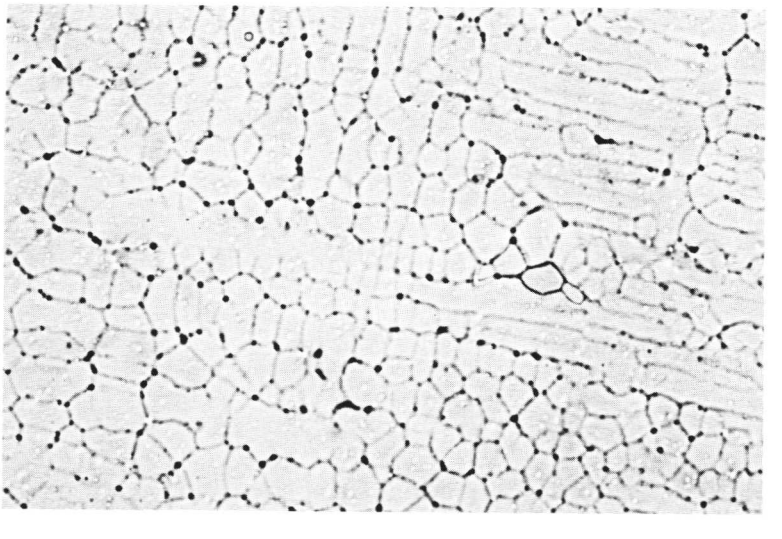


Figure 4
R = 0,1°C/s
Tq = 1290°C
d = 125 μm

400 μm × 25

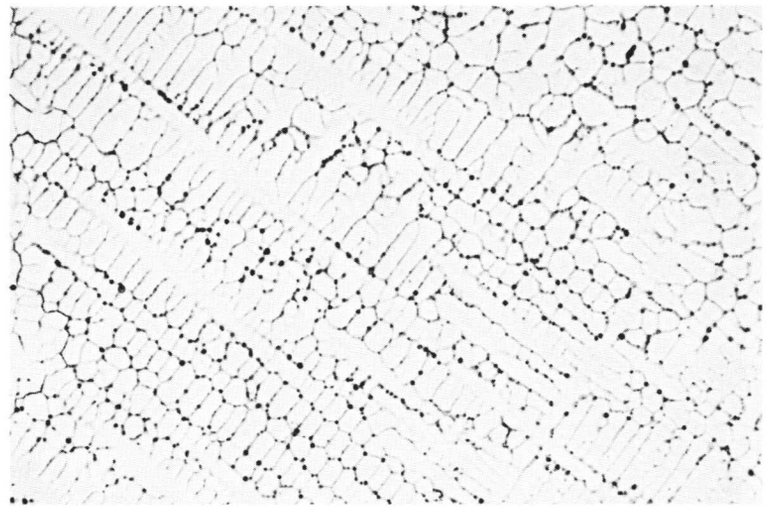


Figure 5
R = 0,5°C/s
Tq = 1200°C
(d_{1200} = 90 μm)
γ-dendrites.

× 25 400 μm

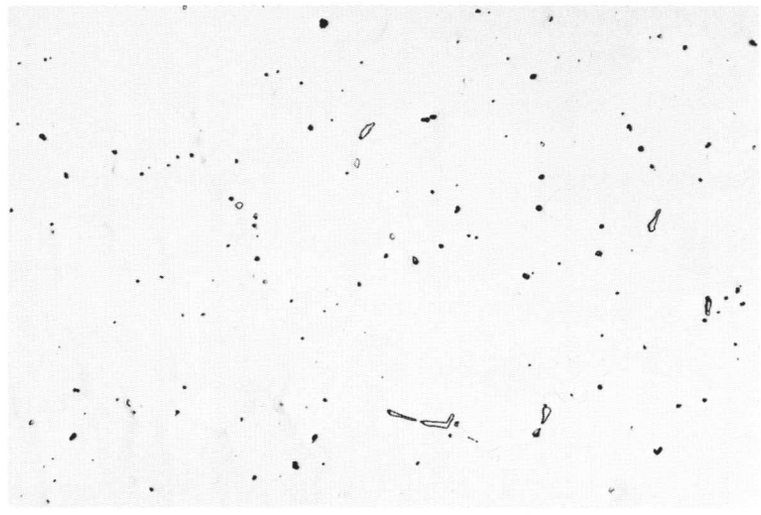


Figure 6
R = 2,0°C/s
Tq = 1290°C
Figures 6–8: Small amounts of interdendritic ferrite.

× 150 100 μm

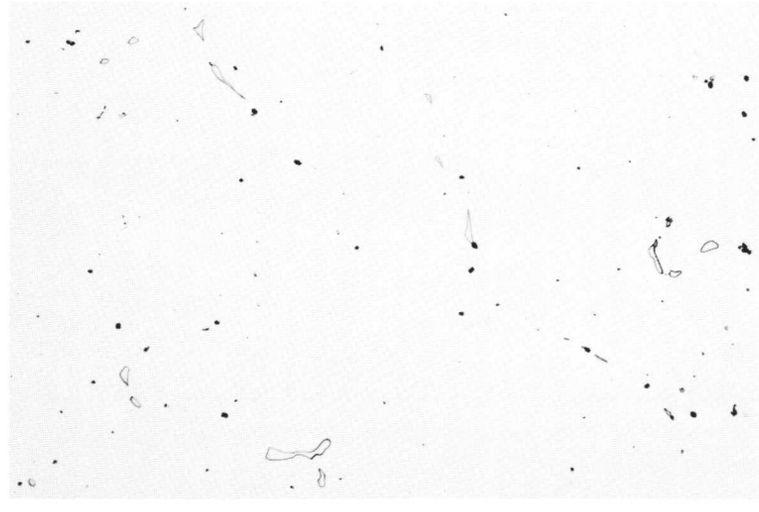


Figure 7
R = 0,5°C/s
Tq = 1200°C

× 150 100 μm

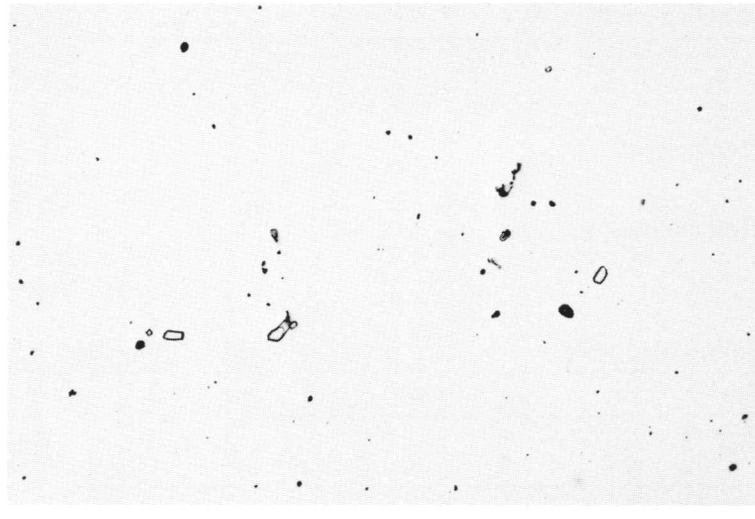


Figure 8
R = 0,1°C/s
Tq = 1290°C

× 150 100 μm

STEEL 412. 0,1 % C 24 % Cr 20 % Ni HEAT RESISTANT STEEL

Designations

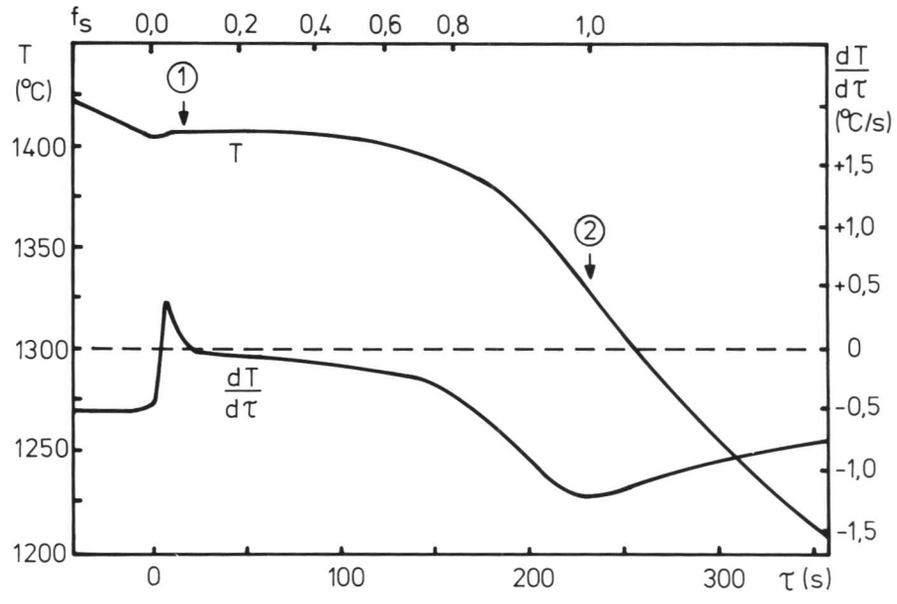
SIS	AISI	Werkstoff Nr
–	310	1.4845

Composition (wt–%)

C	Si	Mn	P	S	Cr	Ni	Mo	Cu	Co	Ti	Al_{tot}	N
0,13	0,52	1,67	0,009	0,003	24,3	20,5	0,11	0,03	0,04	0,08	0,023	0,053

$\frac{Cr_{eq}}{Ni_{eq}} = 1{,}03$

Thermal Analysis



R = 0,5°C/s

	Average Cooling Rate,R, (°C/s)		
	2,0	0,5	0,1
Liquidus temperature, austenitic primary phase, °C ①	1405	1407	1405
Solidus temperature, °C ②	1325	1335	1355
Solidification range, °C	80	70	50
Solidification time, s	95	230	690

Precipitates

Interdendritic ferrite, (see figures 6–8).

Microsegregation

Element	Si	Mn	Cr	Ni	
I	2,5	1,9	1,2	1,2	R = 0,5 °C/s Tq = 1300 °C

Partly solidified

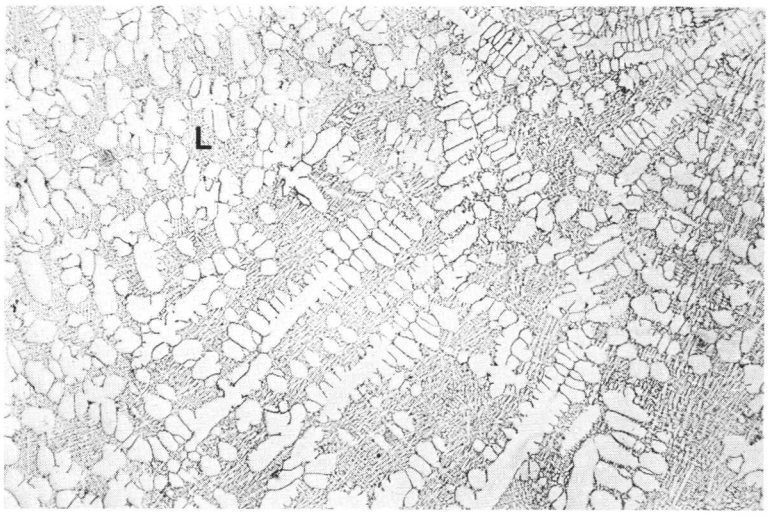


Figure 1
R = 0,5°C/s
Tq = 1400°C
d = 60 μm
γ-dendrites and quenched liquid (L).

× 25 400 μm

Completely solidified

Figure 2
R = 2,0°C/s
Tq = 1300°C
d = 65 μm
Figures 2–4: γ-dendrites.

× 25 400 μm

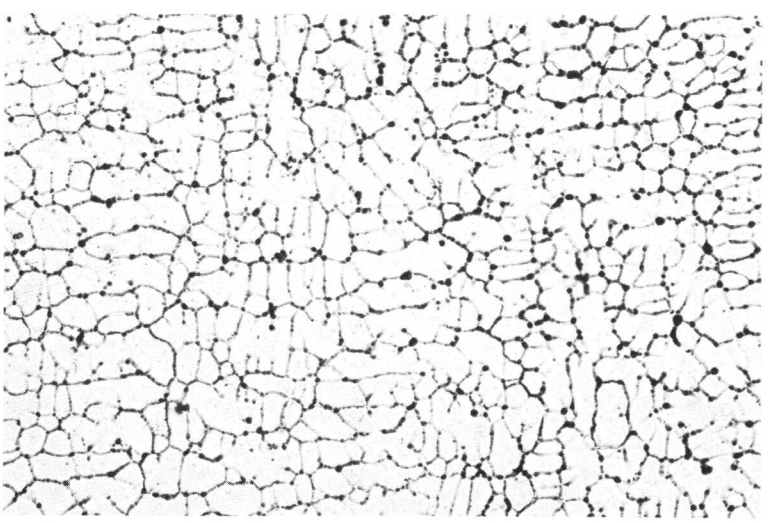


Figure 3
R = 0,5°C/s
Tq = 1300°C
d = 90 μm

× 25 400 μm

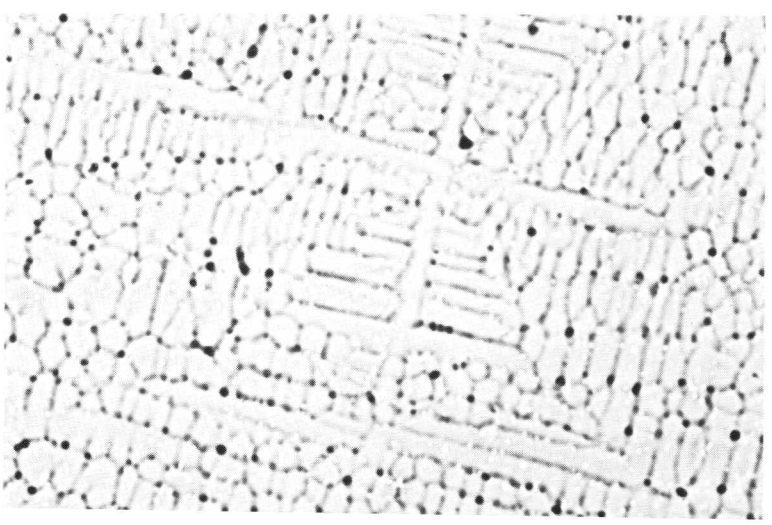


Figure 4
R = 0,1°C/s
Tq = 1300°C
d = 125 μm

× 25 400 μm

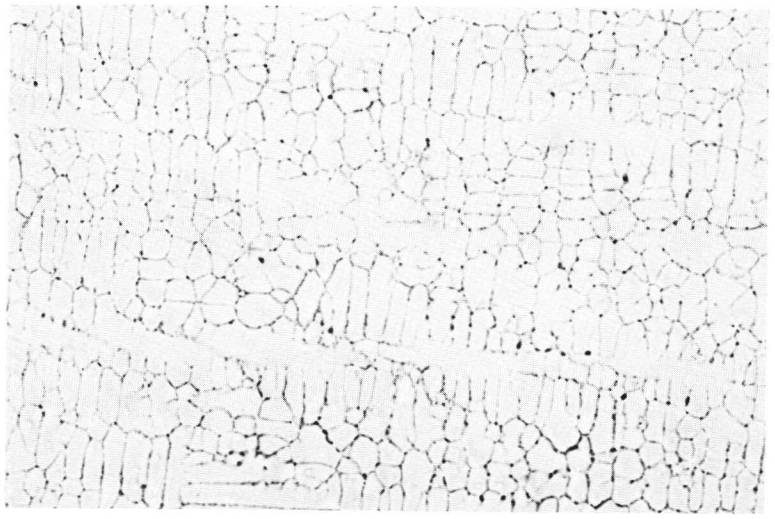


Figure 5
R = 0,5°C/s
Tq = 1200°C
(d_{1200} = 100 μm)
γ-dendrites.

400 μm × 25

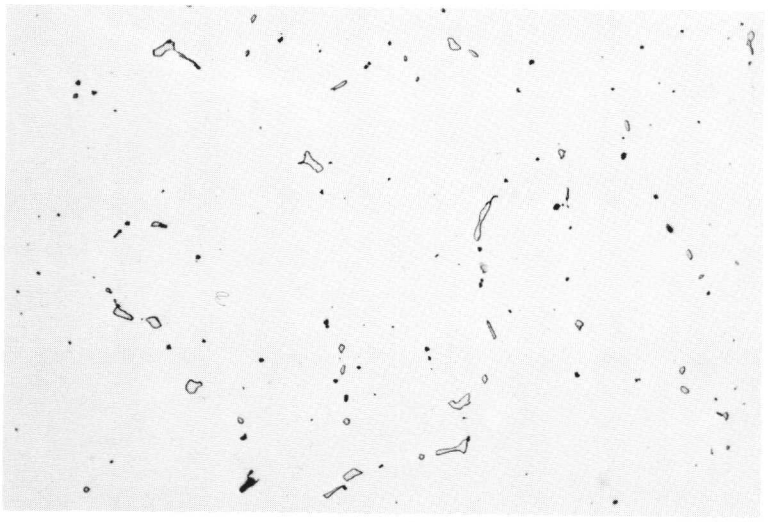


Figure 6
R = 2,0°C/s
Tq = 1300°C
0,5 vol-% interdendritic ferrite.

100 μm × 150

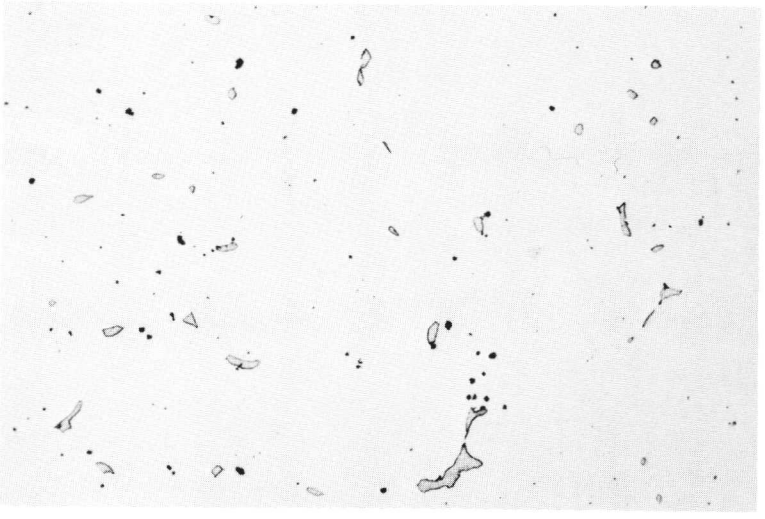


Figure 7
R = 0,5°C/s
Tq = 1200°C
0,4 vol-% interdendritic ferrite.

100 μm × 150

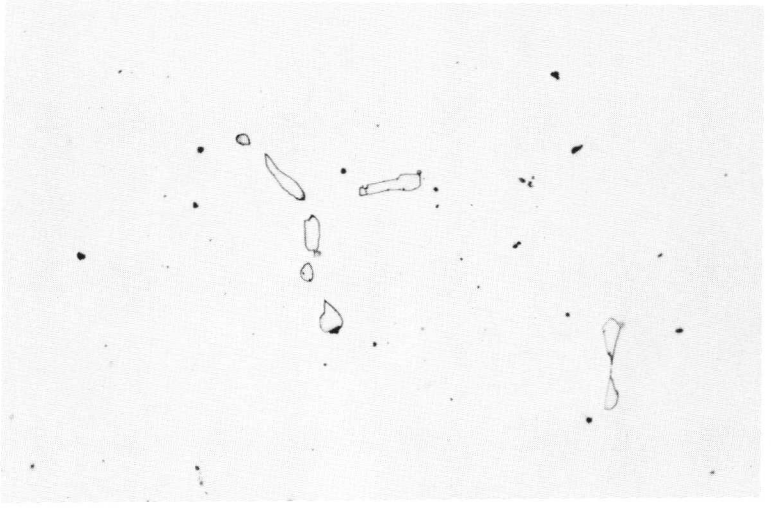


Figure 8
R = 0,1°C/s
Tq = 1300°C
0,5 vol-% interdendritic ferrite.

100 μm × 150

STEEL 413. 0,01 % C 19 % Cr 25 % Ni 4 % Mo 1,5 % Cu STAINLESS STEEL

Designations

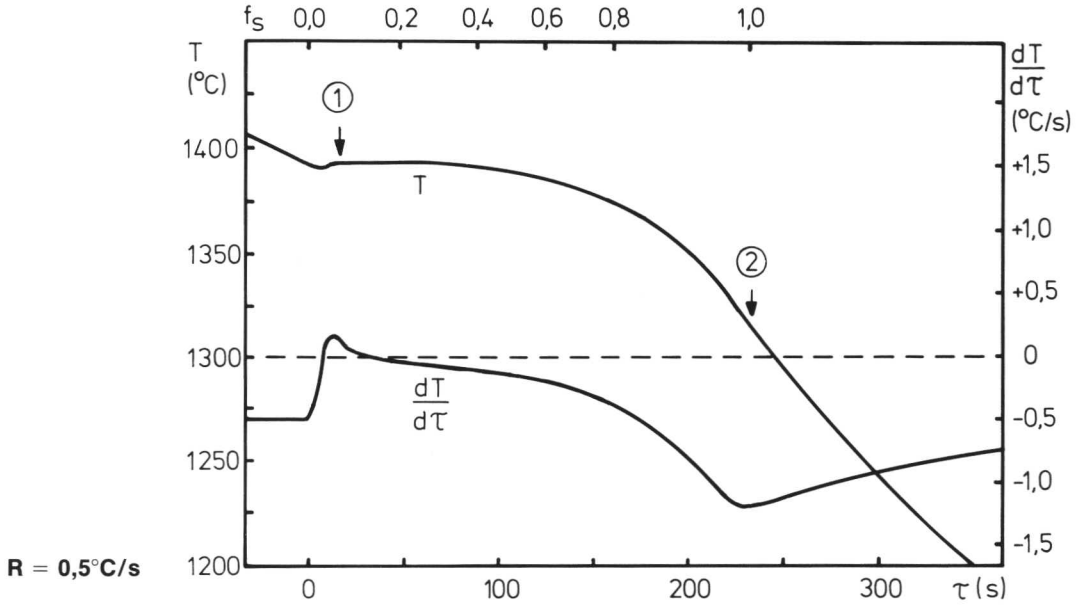
SIS	AISI	Werkstoff Nr
–	–	1.4539

Composition (wt–%)

C	Si	Mn	P	S	Cr	Ni	Mo	Cu	Co	Ti	Ce	Al_{tot}	N
0,013	0,48	1,74	0,007	0,003	19,2	25,1	4,44	1,51	0,02	0,07	0,07	0,034	0,035

$$\frac{Cr_{eq}}{Ni_{eq}} = 0,94$$

Thermal Analysis



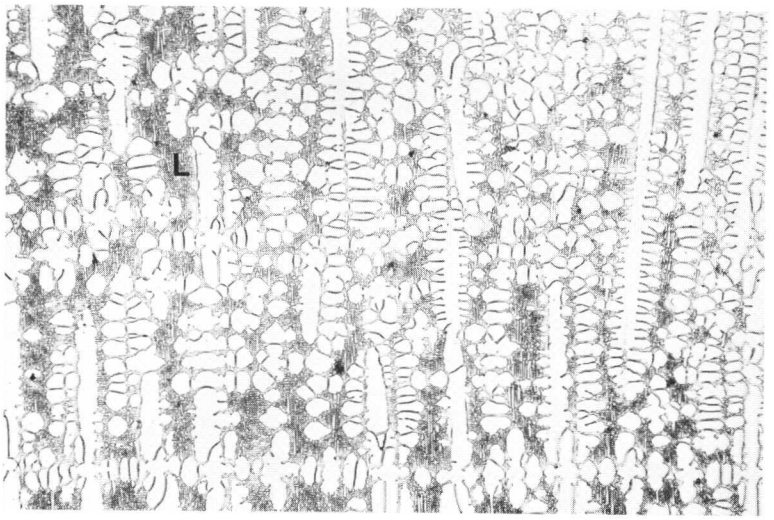
	Average Cooling Rate,R, (°C/s)		
	2,0	0,5	0,1
Liquidus temperature, austenitic primary phase, °C ①	1389	1391	1391
Solidus temperature, °C ②	1305	1315	1345
Solidification range, °C	85	75	45
Solidification time, s	100	230	760

Precipitates

–

Microsegregation

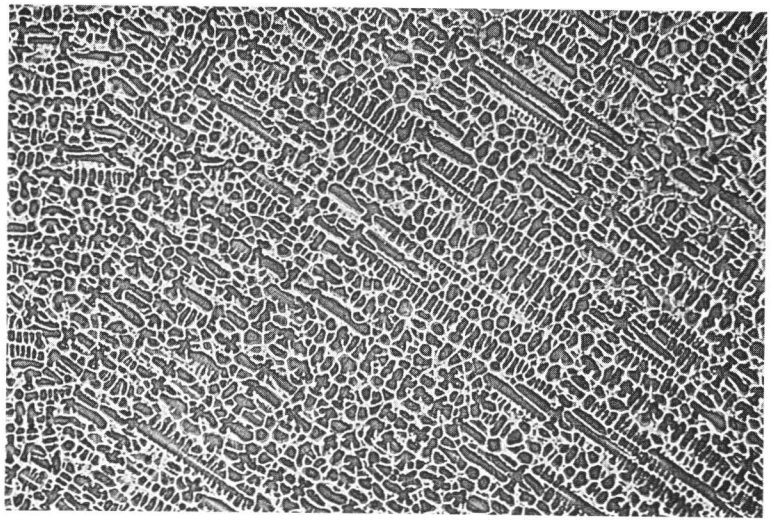
Element	Si	Mn	Cr	Ni	Mo	
I	1,8	1,7	1,2	1,1	2,0	R = 0,5 °C/s Tq = 1280 °C



Partly solidified

Figure 1
R = 0,5°C/s
Tq = 1385°C
d = 70 μm
γ-dendrites and quenched liquid (L).

400 μm × 25



Completely solidified

Figure 2
R = 2,0°C/s
Tq = 1280°C
d = 55 μm
Figures 2–4: γ-dendrites.
White interdendritic areas.

400 μm × 25

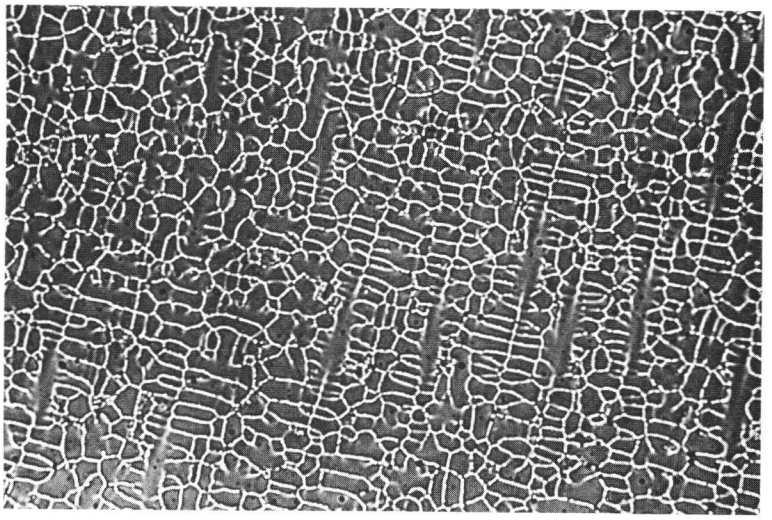


Figure 3
R = 0,5°C/s
Tq = 1280°C
d = 80 μm

400 μm × 25

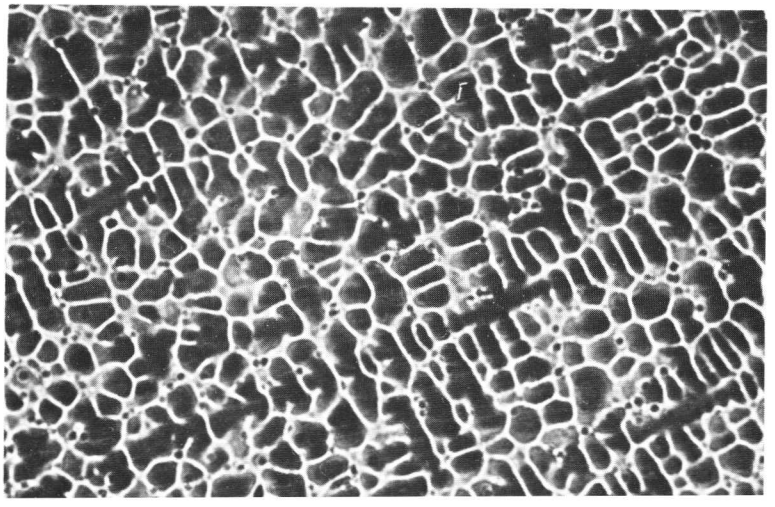


Figure 4
R = 0,1°C/s
Tq = 1280°C
d = 120 μm

400 μm × 25

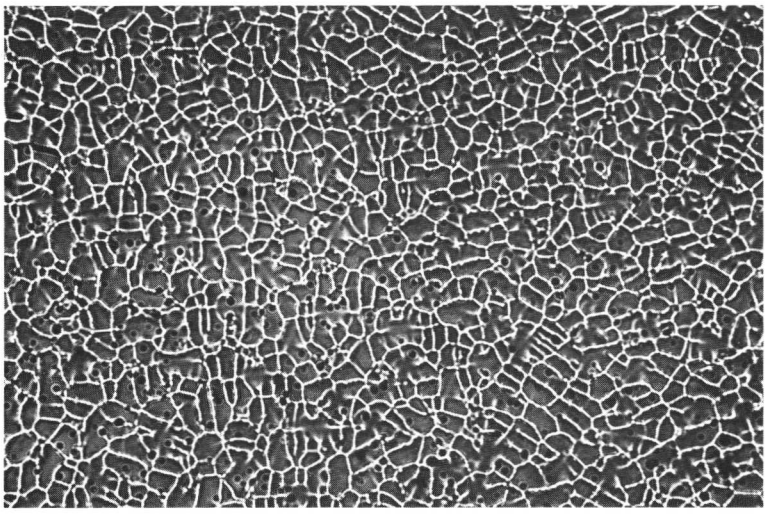


Figure 5
R = 0,5°C/s
Tq = 1200°C
(d_{1200} = 90 μm)
γ-dendrites.
White interdendritic areas.

× 25 400 μm

STEEL 414. 0,4 % C 25 % Cr 20 % Ni HEAT RESISTANT STEEL

Designations

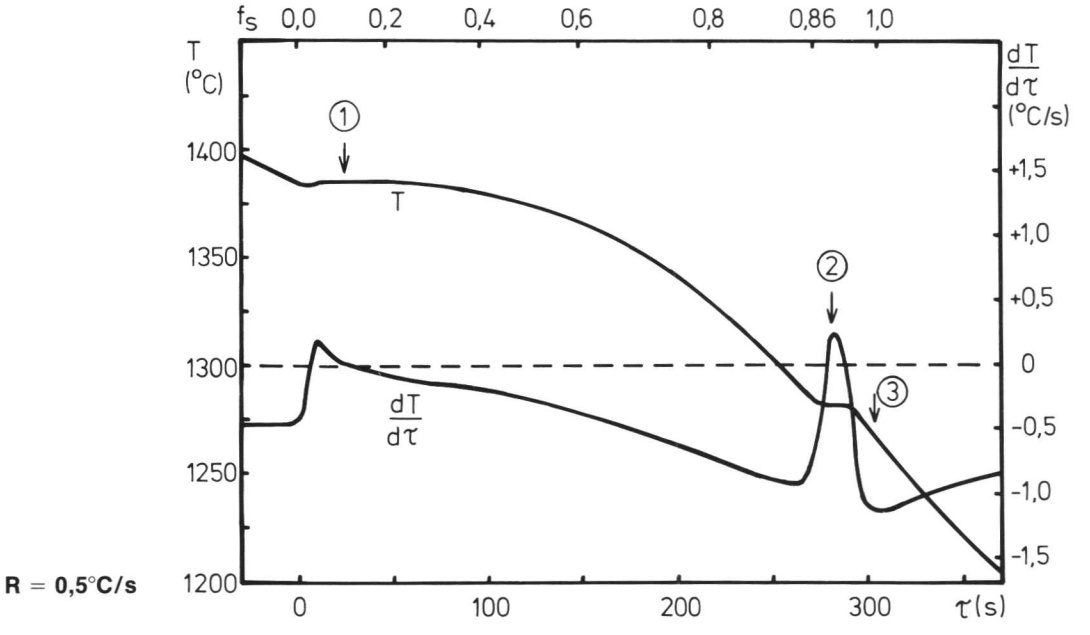
SIS	AISI	Werkstoff Nr
–	310 HC	–

Composition (wt–%)

C	Si	Mn	P	S	Cr	Ni	Mo	Cu	Co	Ti	Al_{tot}	N
0,41	1,00	1,34	0,007	0,010	25,2	20,6	0,08	0,02	0,06	0,10	0,016	0,022

$\frac{Cr_{eq}}{Ni_{eq}} = 0,89$

Thermal Analysis



	Average Cooling Rate,R, (°C/s)		
	2,0	0,5	0,1
Liquidus temperature, austenitic primary phase, °C ①	1383	1385	1385
Temperature of formation of eutectic, °C ②	1275–1260	1285–1275	1290–1280
Solidus temperature, °C ③	1260	1275	1280
Solidification range, °C	125	110	105
Solidification time, s	125	290	1140

Precipitates

Interdendritic $M_{23}C_6$ – eutectic. The amount of carbide eutectic increased with increasing cooling rate, (see figures 6–12).

Microsegregation

Element	Si	Mn	Cr	Ni
I	2,1	1,6	1,2	1,1
P_{ID}	Carbide/γ		1,6	

R = 0,5 °C/s
Tα = 1230 °C

Partly solidified

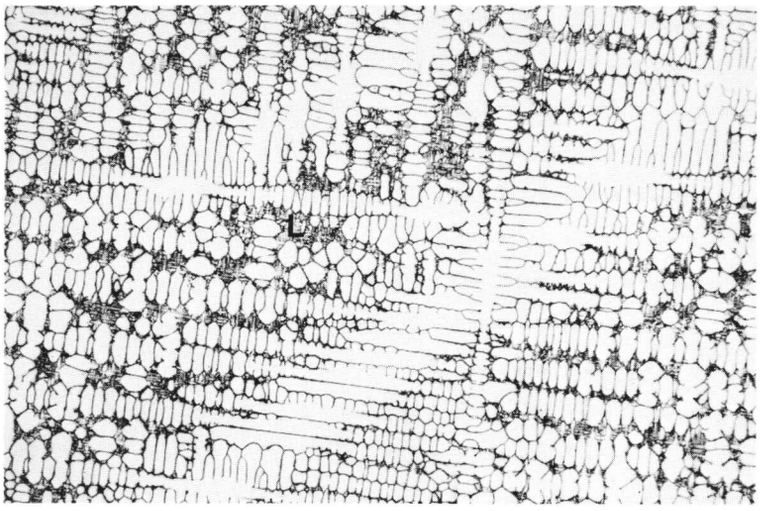


Figure 1
R = 0,5°C/s
Tq = 1375°C
d = 60 μm
γ-dendrites and quenched liquid (L).

× 25 400 μm

Completely solidified

Figure 2
R = 2,0°C/s
Tq = 1230°C
d = 50 μm
Figures 2–4: γ-dendrites and interdendritic carbide eutectic, (compare figures 6–10, 12).

× 25 400 μm

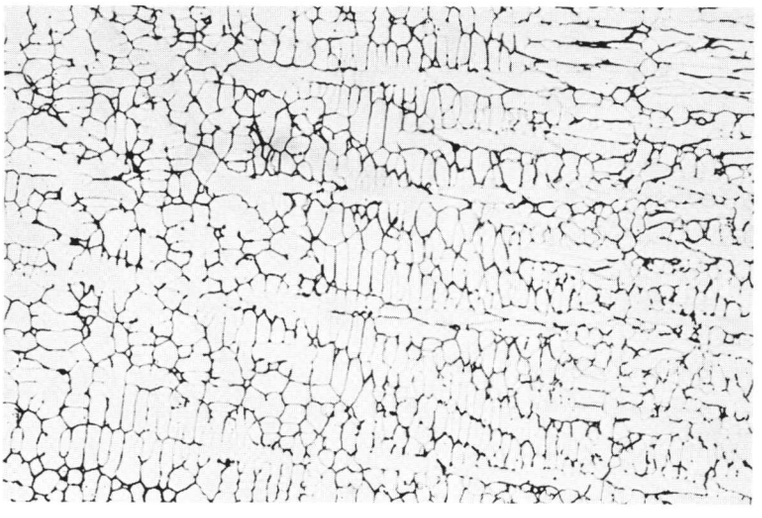


Figure 3
R = 0,5°C/s
Tq = 1230°C
d = 80 μm

× 25 400 μm

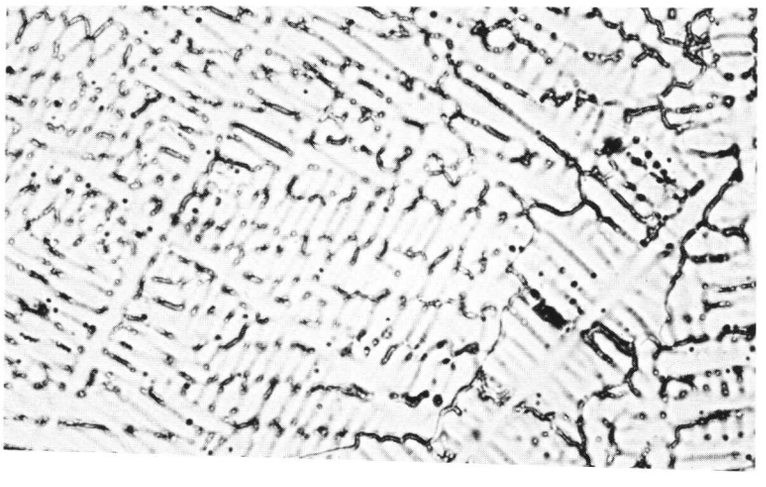


Figure 4
R = 0,1°C/s
Tq = 1230°C
d = 105 μm

Figure 5
R = 0,5°C/s
Tq = 1100°C
(d_{1100} = 90 μm)
γ-dendrites and interdendritic carbide eutectic, (compare figure 11).

400 μm × 25

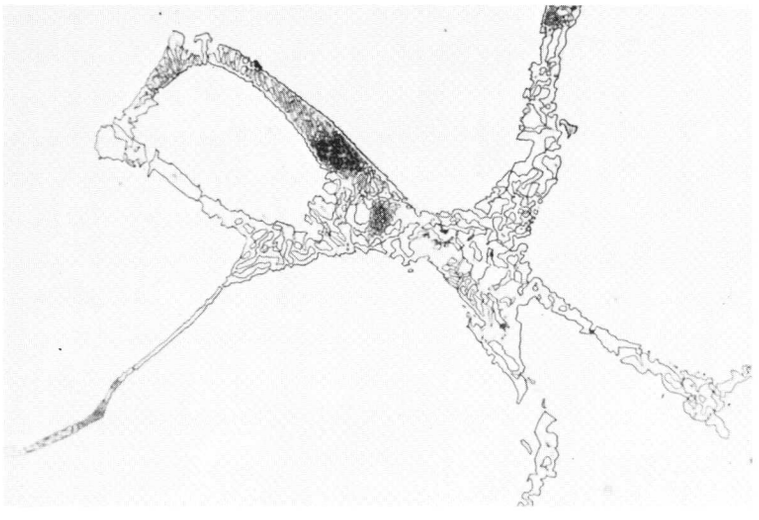


Figure 6
R = 2,0°C/s
Tq = 1230°C
$M_{23}C_6$-γ eutectic
Figures 6–8: Note the influence of cooling rate on carbide coarseness.

25 μm × 600

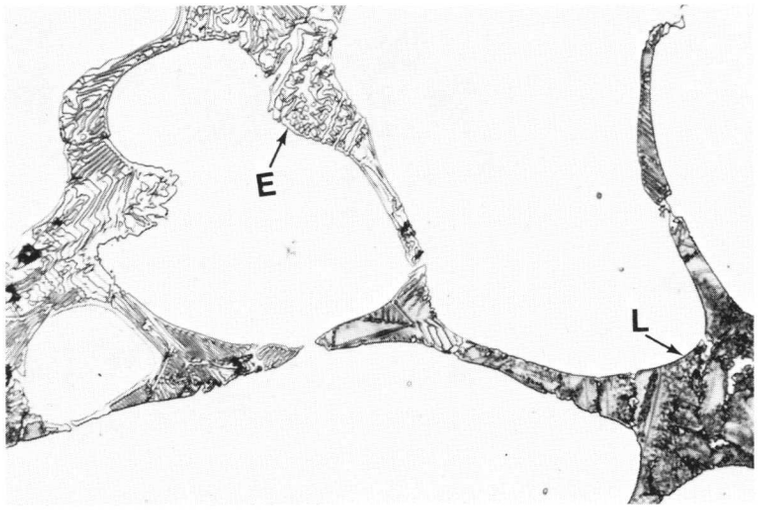


Figure 7
R = 0,5°C/s
Tq = 1230°C
$M_{23}C_6$-γ eutectic (E) and residual melt (L).

25 μm × 600

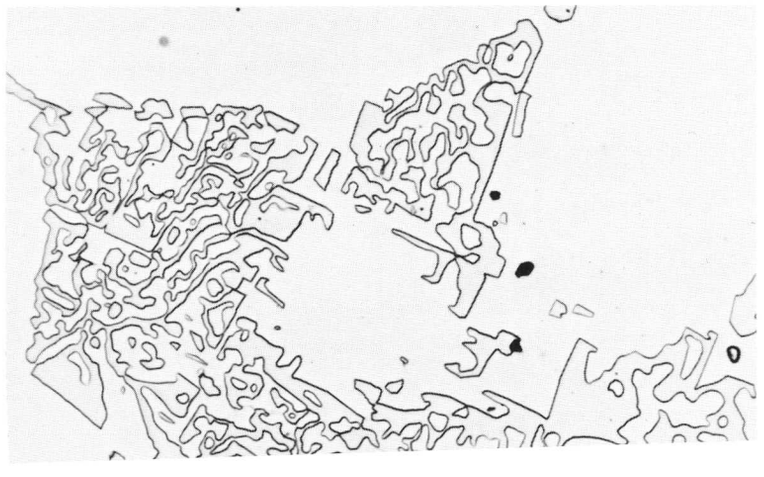


Figure 8
R = 0,1°C/s
Tq = 1230°C
$M_{23}C_6$-γ eutectic.