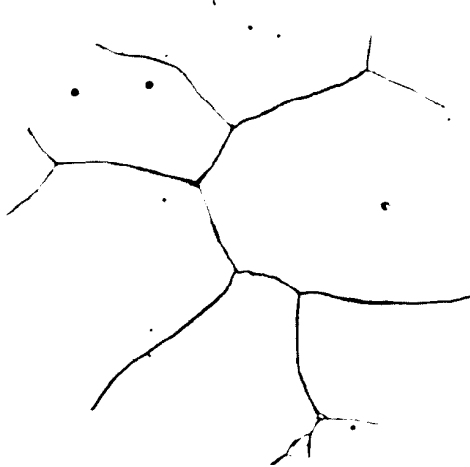
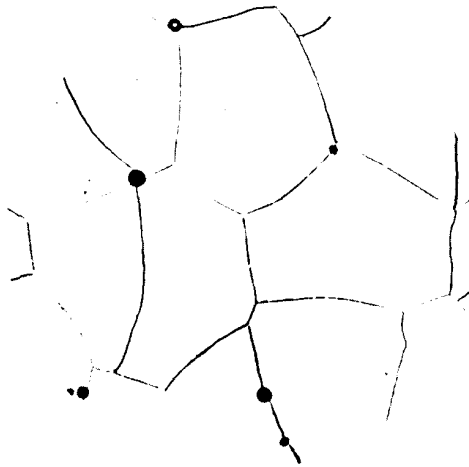


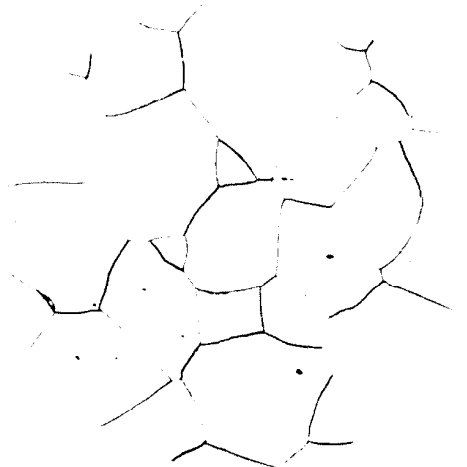
Common Grain Sizes of Low-Carbon Sheet Steel (Specimens Are Rimmed Steel)



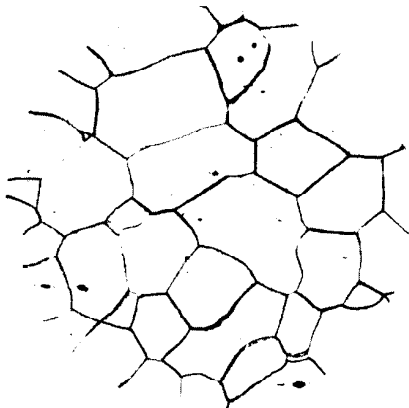
Nital 100×  
**1** Nominal ASTM grain size No. 1 (specimen shown has a calculated grain size of 1.17)



Nital 100×  
**2** Nominal ASTM grain size No. 2 (specimen shown has a calculated grain size of 2)



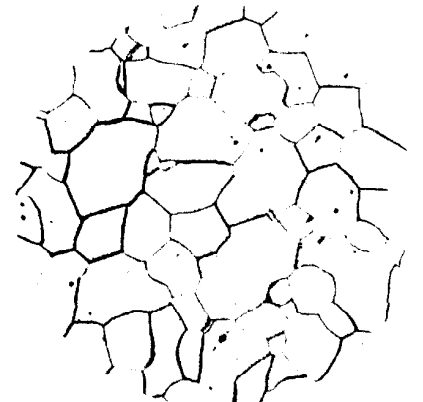
Nital 100×  
**3** Nominal ASTM grain size No. 3 (specimen shown has a calculated grain size of 2.95)



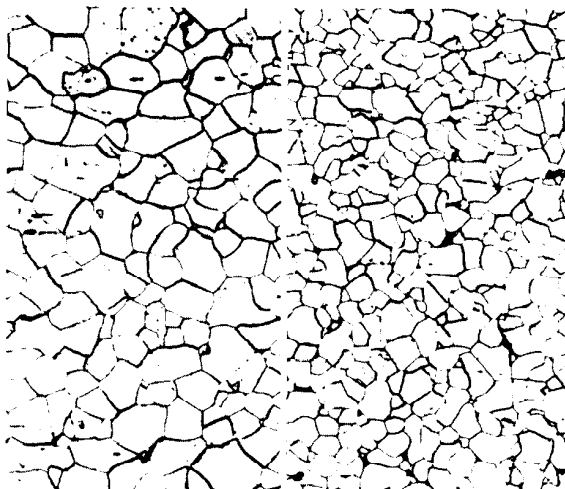
Nital 100×  
**4** Nominal ASTM grain size No. 4 (specimen shown has a calculated grain size of 4.04)

**Nominal Number of Grains per Square Millimeter (at 1×) and per Square Inch (at 100×) for the Ten Grain Sizes Shown**

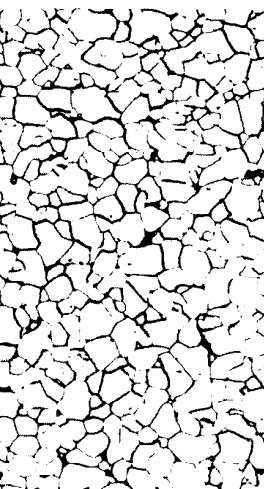
Grain-size No.	Nominal number of grains		Grain-size No.	Nominal number of grains	
	Per sq mm at 1×	Per sq in. at 100×		Per sq mm at 1×	Per sq in. at 100×
<b>ASTM Grain Sizes (ASTM E112)</b>			<b>Calculated Grain Sizes Shown</b>		
1	15.5	1.0	1.17	17.4	1.13
2	31.0	2.0	2	31.0	2.00
3	62.0	4.0	2.95	59.9	3.86
4	124	8.0	4.04	128	8.23
5	248	16.0	4.98	245	15.8
6	496	32.0	6.08	524	33.8
7	992	64.0	7.13	1090	70.0
8	1980	128	8.03	2030	131
9	3970	256	8.97	3890	251
10	7940	512	10	7940	512



Nital 100×  
**5** Nominal ASTM grain size No. 5 (specimen shown has a calculated grain size of 4.98)



Nital 100×  
**6** Nominal ASTM grain size No. 6 (specimen has a calculated grain size of 6.08)



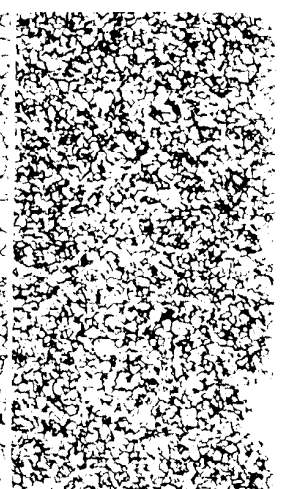
Nital 100×  
**7** Nominal ASTM grain size No. 7 (specimen has a calculated grain size of 7.13)



Nital 100×  
**8** Nominal ASTM grain size No. 8 (specimen has a calculated grain size of 8.03)



Nital 100×  
**9** Nominal ASTM grain size No. 9 (specimen has a calculated grain size of 8.97)



Nital 100×  
**10** Nominal ASTM grain size No. 10 (specimen has a calculated grain size of 10)

Standard methods for estimating the average grain size of metals are presented in ASTM E112, together with formulas for calculating grain size and a table of size relationships for all ASTM grain-size numbers (100 to 14.0, with half sizes).

# APPENDIX

## Identification of Etchants

The accompanying table lists the chemical compositions of etchants that are referred to by name or ASTM number, or that are not fully defined, in captions in this Atlas. All etchants noted in the captions are aqueous solutions unless indicated otherwise.

This table is intended solely to describe etchants that were used in preparing specimens that are illustrated in this Atlas; it is not intended to be a general formulary or guide for the preparation and use of etchants.

**Safety Precautions.** All chemicals are potentially dangerous, and persons formulating and using etchants should be thoroughly familiar with the chemicals involved, and with the proper procedures for handling and mixing them.

Etchants that contain cyanide are extremely dangerous. Cyanide is poisonous by contact as well as by ingestion. The use of an exhaust hood when etching with solutions that contain cyanide is mandatory. Used solutions should be neutralized (or turned basic) with am-

monia before being poured into a drain. After receiving the neutralized solution, the drain should be flushed thoroughly with a copious amount of water.

When mixtures of perchloric acid and acetic acid are used for electrolytic etching, the acetic acid should be added to the perchloric acid slowly and with extreme care, and the electrolyte should never be allowed to exceed 75 F (24 C).

For further details on safety precautions in the use of etchants, refer to ASTM E340-68 and E407-70.

### Identification of Etchants Referred to in This Atlas

Common name (or active constituents)	ASTM No.(a)	Composition
Acetic-glycol	119	20 ml acetic acid, 1 ml HNO <sub>3</sub> , 60 ml diethylene glycol, 20 ml H <sub>2</sub> O
Acetic-H <sub>2</sub> O <sub>2</sub>	57	75 ml acetic acid, 25 ml H <sub>2</sub> O <sub>2</sub> (30%)
Acetic-nitric	113	15 ml acetic acid, 15 ml HNO <sub>3</sub> , 60 ml glycerol
Acetic-nitric	114	15 ml acetic acid, 20 ml HNO <sub>3</sub> , 80 ml H <sub>2</sub> O
Acetic-picral	124	5 ml acetic acid, 6 g picric acid, 10 ml H <sub>2</sub> O, 100 ml ethanol (95%)
Acetic-picral	127	20 ml acetic acid, 3 g picric acid, 20 ml H <sub>2</sub> O, 50 ml ethanol (95%)
Acid ferric chloride	82	5 g FeCl <sub>3</sub> , 5 drops HCl, 100 ml H <sub>2</sub> O
Alkaline sodium picrate	85	2 g picric acid, 25 g NaOH, 100 ml H <sub>2</sub> O
Ammonium hydroxide plus hydrogen peroxide:		
For unalloyed copper, and Ag-Cu alloys	30	25 ml NH <sub>4</sub> OH, 50 ml H <sub>2</sub> O <sub>2</sub> (3%), 25 ml H <sub>2</sub> O
For copper alloys	44	50 ml NH <sub>4</sub> OH, 20 to 50 ml H <sub>2</sub> O <sub>2</sub> (3%), 0 to 50 ml H <sub>2</sub> O
For unalloyed silver	173	50 ml NH <sub>4</sub> OH, 10 to 30 ml H <sub>2</sub> O <sub>2</sub> (50%)
Ammonium molybdate reagent	...	140 ml NH <sub>4</sub> OH, 100 g molybdic acid (85%), 240 ml H <sub>2</sub> O; filter, and add filtrate to 45 ml HNO <sub>3</sub> , 15 ml H <sub>2</sub> O
Ammonium persulfate	31	10 g (NH <sub>4</sub> ) <sub>2</sub> S <sub>2</sub> O <sub>8</sub> , 100 ml H <sub>2</sub> O
Aqua regia	12	20 ml HNO <sub>3</sub> , 60 ml HCl
Barker's reagent	5	4 to 5 ml HBF <sub>4</sub> , 200 ml H <sub>2</sub> O
Chrome regia	101	2 g CrO <sub>3</sub> , 20 ml HCl, 80 ml H <sub>2</sub> O
Chromic acid (for Ni-base heat-resisting alloys)	18	2 to 10 g CrO <sub>3</sub> , 100 ml H <sub>2</sub> O
Chromic acid (for copper alloys)	32	60 g CrO <sub>3</sub> , 100 ml H <sub>2</sub> O
Chromic acid and sulfuric acid	175	1 g CrO <sub>3</sub> , 1 ml H <sub>2</sub> SO <sub>4</sub> , 1000 ml H <sub>2</sub> O
Ferric chloride (for nitrided case structures)	100	10 g FeCl <sub>3</sub> , 90 ml H <sub>2</sub> O
Ferric chloride (for copper alloys)	...	5 g FeCl <sub>3</sub> , 10 ml HCl, 100 ml H <sub>2</sub> O
Ferric nitrate	28	1 g Fe(NO <sub>3</sub> ) <sub>3</sub> · 9H <sub>2</sub> O, 100 ml H <sub>2</sub> O
Fry's reagent	79	40 ml HCl, 5 g CuCl <sub>2</sub> , 30 ml H <sub>2</sub> O, 25 ml ethanol (95%) or methanol (95%)
Glyceresia	87	10 ml HNO <sub>3</sub> , 20 to 50 ml HCl, 30 ml glycerol
Glycol	118	75 ml diethylene glycol, 1 ml HNO <sub>3</sub> , 25 ml H <sub>2</sub> O
HCl (for cobalt-base alloys)	16	5 to 10 ml HCl, 100 ml H <sub>2</sub> O
HCl (for platinum, other precious metals)	171	Concentrated HCl
HCl, CuCl <sub>2</sub> , FeCl <sub>3</sub> , HNO <sub>3</sub> , methanol, water	...	400 ml HCl, 8 g CuCl <sub>2</sub> , 28 g FeCl <sub>3</sub> , 20 ml HNO <sub>3</sub> , 800 ml methanol, 400 ml H <sub>2</sub> O
HCl, ethanol, CuCl <sub>2</sub> , H <sub>2</sub> O <sub>2</sub>	...	35 ml HCl, 65 ml ethanol (95%), 1 g CuCl <sub>2</sub> , 7 drops H <sub>2</sub> O <sub>2</sub> (30%)
HCl, ethanol, H <sub>2</sub> O <sub>2</sub>	...	35 ml HCl, 65 ml ethanol (95%), 7 drops H <sub>2</sub> O <sub>2</sub> (30%)
HCl, HNO <sub>3</sub> , acetic acid	...	15 ml HCl, 10 ml HNO <sub>3</sub> , 10 ml acetic acid
HCl, HNO <sub>3</sub> , CuCl <sub>2</sub> , H <sub>2</sub> O	109	50 ml HCl, 25 ml HNO <sub>3</sub> , 1 g CuCl <sub>2</sub> , 150 ml H <sub>2</sub> O
HCl, HNO <sub>3</sub> , FeCl <sub>3</sub>	24	200 ml HCl, 5 ml HNO <sub>3</sub> , 65 g FeCl <sub>3</sub>
HCl plus H <sub>2</sub> O <sub>2</sub>	22	100 ml HCl, 0.5 ml H <sub>2</sub> O <sub>2</sub> (30%)
HCl, methanol	23	5 ml HCl, 95 ml methanol (95%)
H <sub>2</sub> CrO <sub>4</sub> , HCl	33	10 g CrO <sub>3</sub> , 2 to 4 drops HCl, 100 ml H <sub>2</sub> O
HF, HNO <sub>3</sub> , HCl	193	2 drops HF, 1 drop HNO <sub>3</sub> , 3 ml HCl, 25 ml glycerol
HNO <sub>3</sub> -acetic	50	10 ml HNO <sub>3</sub> , 5 ml acetic acid, 85 ml H <sub>2</sub> O
HNO <sub>3</sub> plus HCl plus CrO <sub>3</sub>	...	10 ml HNO <sub>3</sub> , 10 ml HCl, 10 g CrO <sub>3</sub> , 30 ml H <sub>2</sub> O
HNO <sub>3</sub> plus HCl plus glycerol	...	10 ml HNO <sub>3</sub> , 20 ml HCl, 10 ml glycerol
HNO <sub>3</sub> plus HF, in glycerol	90	10 ml HNO <sub>3</sub> , 20 ml HF, 20 to 40 ml glycerol
HNO <sub>3</sub> plus H <sub>2</sub> SO <sub>4</sub> plus CrO <sub>3</sub> plus NH <sub>4</sub> Cl	...	50 ml HNO <sub>3</sub> , 50 ml H <sub>2</sub> SO <sub>4</sub> , 40 g CrO <sub>3</sub> , 7.5 g NH <sub>4</sub> Cl, 900 ml H <sub>2</sub> O

(Table continued on next page)

## Identification of Etchants Referred to in This Atlas (Continued)

Common name (or active constituents)	ASTM No.(a)	Composition
HNO <sub>3</sub> plus K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> , and CrO <sub>3</sub> plus Na <sub>2</sub> SO <sub>4</sub> .....	174	25 ml HNO <sub>3</sub> , 1 g K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> , 1000 ml H <sub>2</sub> O (solution A); 40 g CrO <sub>3</sub> , 3 g Na <sub>2</sub> SO <sub>4</sub> , 200 ml H <sub>2</sub> O (solution B); use 1:1 mixture of A and B
H <sub>2</sub> O <sub>2</sub> , lactic acid, HF, HNO <sub>3</sub> .....	...	7 ml H <sub>2</sub> O <sub>2</sub> (3%), 7 ml lactic acid, 5 ml HF, 5 ml HNO <sub>3</sub>
H <sub>3</sub> PO <sub>4</sub> .....	...	4 to 12 ml (6 ml preferred) H <sub>3</sub> PO <sub>4</sub> , 100 ml H <sub>2</sub> O
H <sub>2</sub> SO <sub>4</sub> , CH <sub>3</sub> OH .....	...	15 ml H <sub>2</sub> SO <sub>4</sub> , 100 ml methanol
H <sub>2</sub> SO <sub>4</sub> , H <sub>3</sub> PO <sub>4</sub> , HNO <sub>3</sub> .....	107	50 ml H <sub>2</sub> SO <sub>4</sub> , 10 ml H <sub>3</sub> PO <sub>4</sub> , 40 ml HNO <sub>3</sub>
Kalling's reagent .....	95	2 g CuCl <sub>2</sub> , 40 ml HCl, 40 to 80 ml ethanol (95%) or methanol (95%), 40 ml H <sub>2</sub> O
Kalling's reagent 2 .....	94	2 g CuCl <sub>2</sub> , 40 ml HCl, 40 to 80 ml ethanol (95%) or methanol (95%)
Keller's reagent .....	3	2 ml HF, 3 ml HCl, 5 ml HNO <sub>3</sub> , 190 ml H <sub>2</sub> O
K <sub>3</sub> Fe(CN) <sub>6</sub> plus NaOH .....	...	10 ml K <sub>3</sub> Fe(CN) <sub>6</sub> (30%), 10 ml NaOH (10%)
KOH .....	97	45 g KOH, 60 ml H <sub>2</sub> O
Kroll's reagent .....	187	10 ml HF, 30 ml HNO <sub>3</sub> , 50 ml H <sub>2</sub> O
Kroll's reagent .....	192	1 to 3 ml HF, 2 to 6 ml HNO <sub>3</sub> , 100 ml H <sub>2</sub> O
Lactic acid, HF, HNO <sub>3</sub> .....	...	30 ml lactic acid, 5 ml HF, 10 ml HNO <sub>3</sub>
Marble's reagent .....	25	10 g CuSO <sub>4</sub> , 50 ml HCl, 50 ml H <sub>2</sub> O
Murakami's reagent .....	98	10 g K <sub>3</sub> Fe(CN) <sub>6</sub> , 10 g KOH or NaOH, 100 ml H <sub>2</sub> O
Murakami's reagent (modified) .....	...	15 g K <sub>3</sub> Fe(CN) <sub>6</sub> , 2 g NaOH, 100 ml H <sub>2</sub> O
NaCN, (NH <sub>4</sub> ) <sub>2</sub> S <sub>2</sub> O <sub>8</sub> .....	47	5 g NaCN, 5 g (NH <sub>4</sub> ) <sub>2</sub> S <sub>2</sub> O <sub>8</sub> , 100 ml H <sub>2</sub> O
Nital .....	74	1 to 5 ml HNO <sub>3</sub> , 100 ml ethanol (95%) or methanol (95%)
Oxalic acid .....	13	10 g oxalic acid, 100 ml H <sub>2</sub> O
Phospho-picral .....	121	0.7 ml H <sub>3</sub> PO <sub>4</sub> , 4 g picric acid, 100 ml ethanol (95%)
Picral .....	76	10 g picric acid, 100 ml ethanol (95%) or methanol (95%)
Potassium dichromate .....	29	1 g K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> , 4 ml H <sub>2</sub> SO <sub>4</sub> , 50 ml H <sub>2</sub> O, 2 drops HCl just before using
Potassium permanganate, sodium carbonate .....	...	4 g KMnO <sub>4</sub> , 2 g Na <sub>2</sub> CO <sub>3</sub> , 94 ml H <sub>2</sub> O, a few drops of wetting agent
Struer's D-2 reagent .....	...	250 ml H <sub>3</sub> PO <sub>4</sub> , 250 ml ethanol (95%), 500 ml H <sub>2</sub> O, 2 ml of wetting agent
Super picral .....	77	10 g picric acid, 5 drops HCl, 100 ml ethanol (95%) or methanol (95%)
Tucker's reagent .....	...	45 ml HCl, 15 ml HNO <sub>3</sub> , 15 ml HF, 25 ml H <sub>2</sub> O
Vilella's reagent .....	80	5 ml HCl, 1 g picric acid, 100 ml ethanol (95%) or methanol (95%)
Waterbury reagent .....	...	20 g CrO <sub>3</sub> , 4.5 g NH <sub>4</sub> Cl, 18 ml HNO <sub>3</sub> , 15 ml H <sub>2</sub> SO <sub>4</sub> , H <sub>2</sub> O to make 1 liter; dilute 2 to 1 with H <sub>2</sub> O before using

(a) These numbers refer to those in ASTM E407-78, Standard Methods for Microetching Metals and Alloys.