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    Fabrication process, volume 9, Edited by Franklin F.Y. Wang,
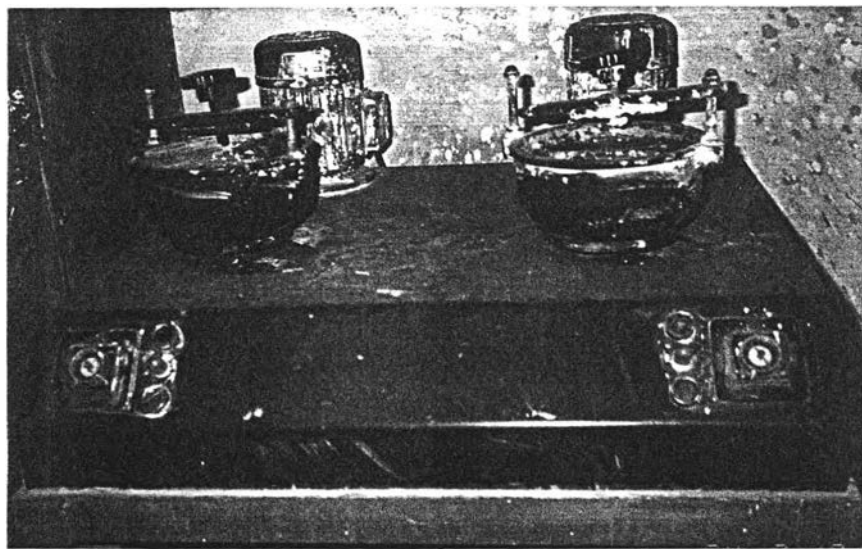   p.71-93.

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    Ferrites with Fine Grain Sizes for Magnetic Heads</u>. Ferrites:
    Proceedings of the Sixth International Conference on Ferrites
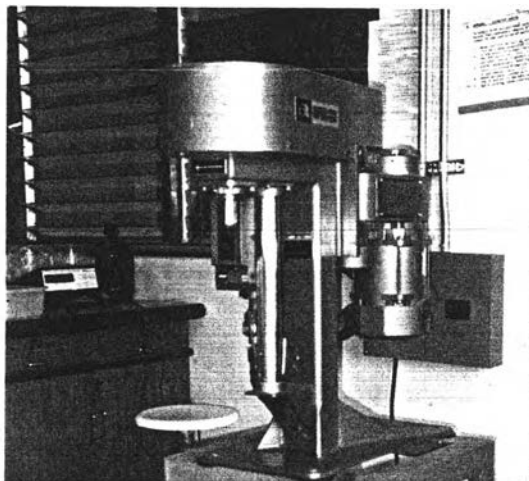   (ICF 6),Tokyo and Kyoto,Japan 1992.
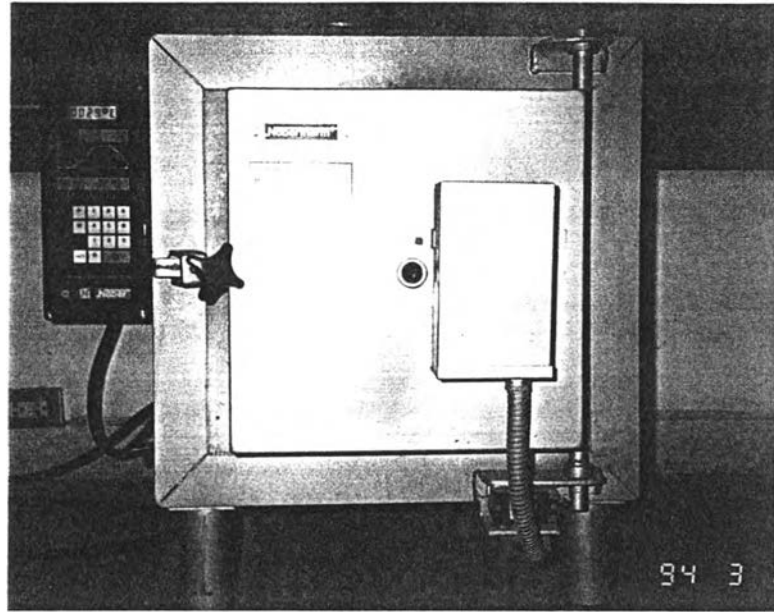
สารบัญภาคผนวก
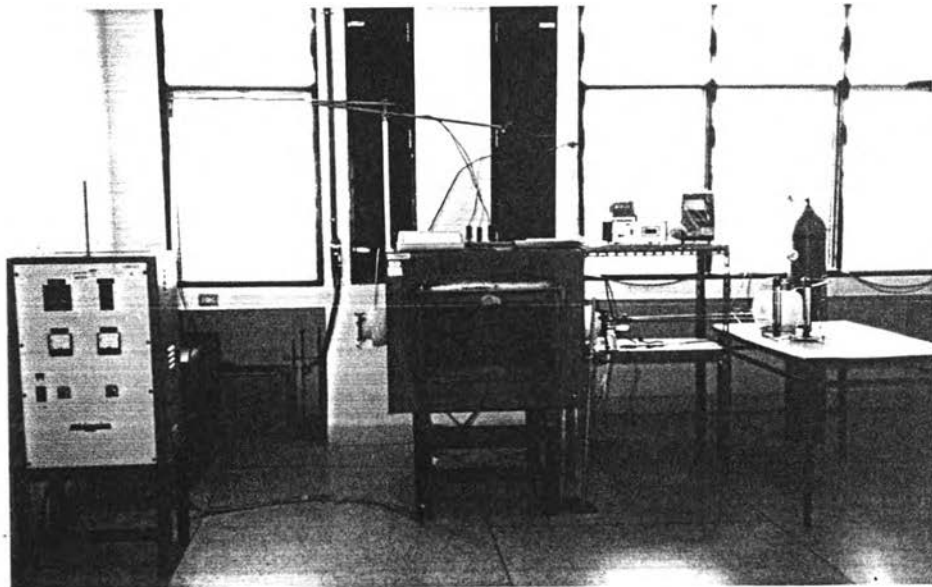
ภาคผนวกที่ 1

รูปภาพเครื่องมือและอุปกรณ์

รูปที่ 1.1 Hi-Speed Mill
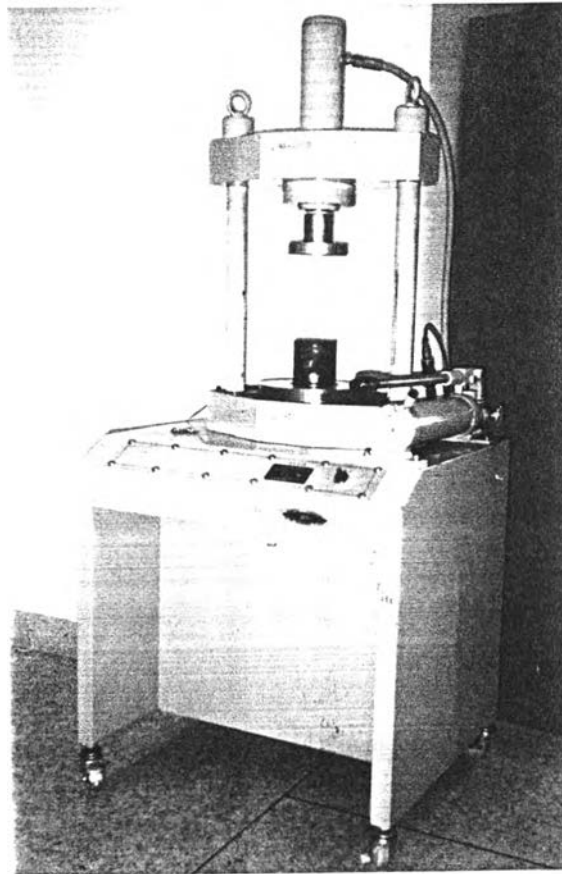

รูปที่ 1.2 Attrition Mill

รูปที่ 1.3   Electrical Furnace

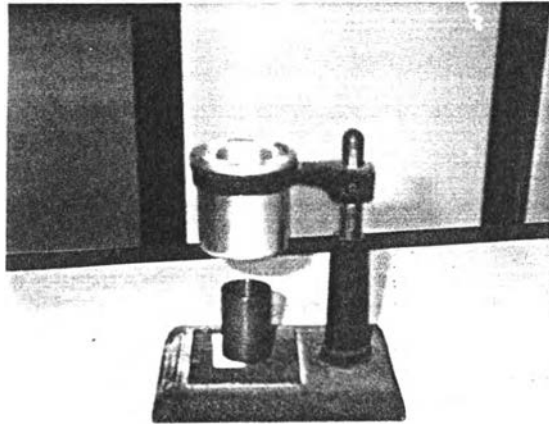รูปที่ 1.4   Tube Furnace

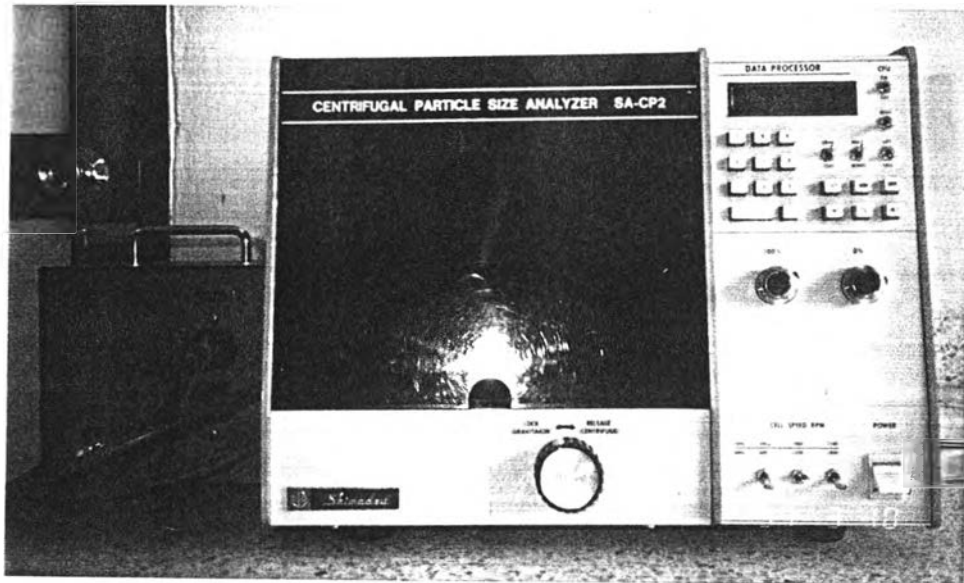รูปที่ 1.5 Hydraulic Press
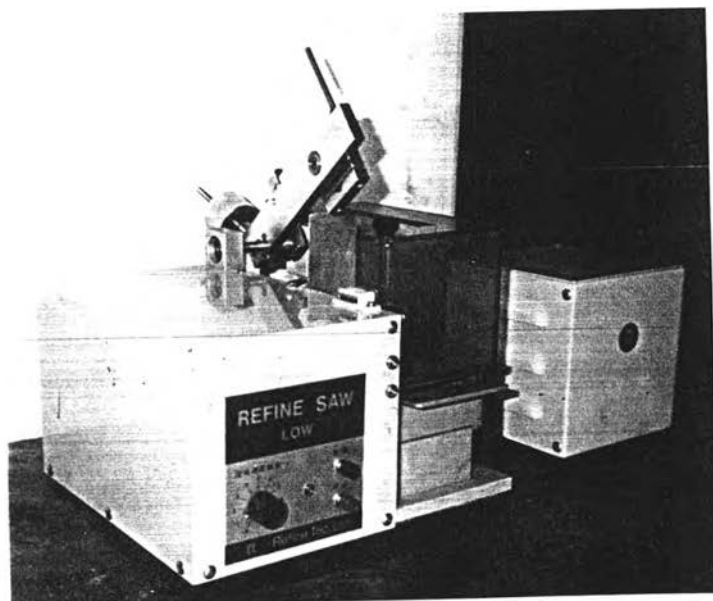
รูปที่ 1.6 Low-Speed Saw

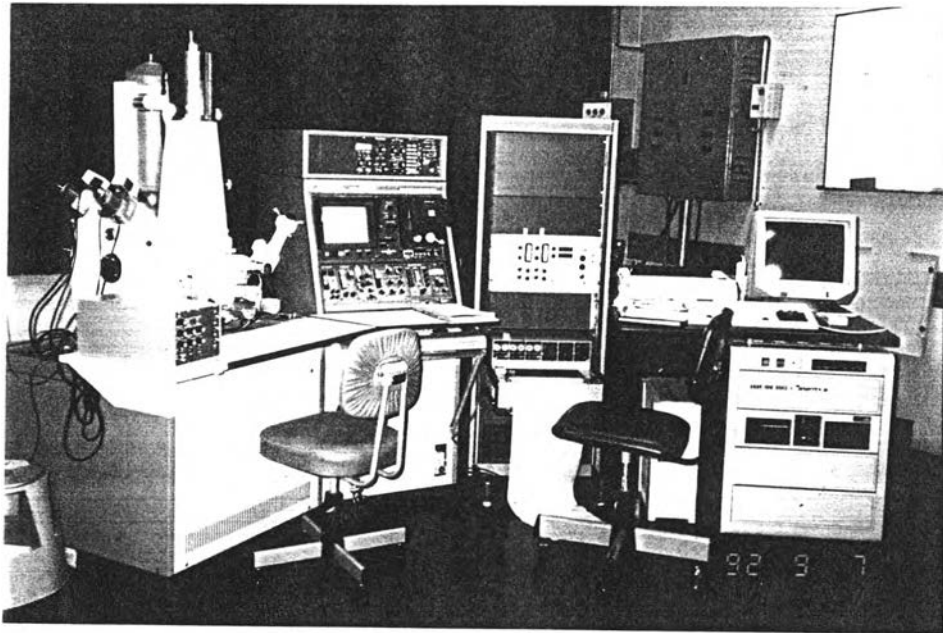รูปที่ 1.7 Hall Flowmeter

รูปที่ 1.8 Volumeter

รูปที่ 1.9 Centrifugal Particle Size Analyser

รูปที่ 1.10 X-ray Fluorescence Spectrometer

รูปที่ 1.11   Scanning Electron Microscope
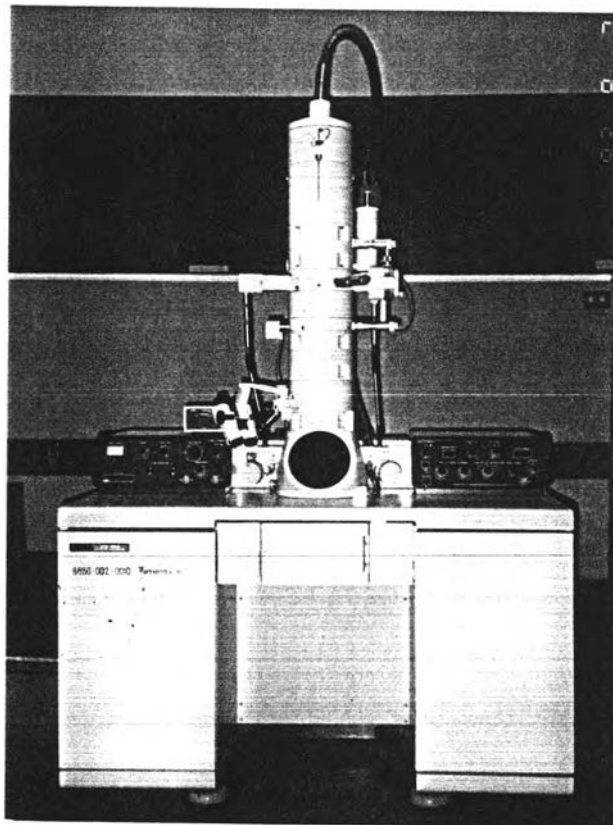
รูปที่ 1.12   Transmission Electron Microscope
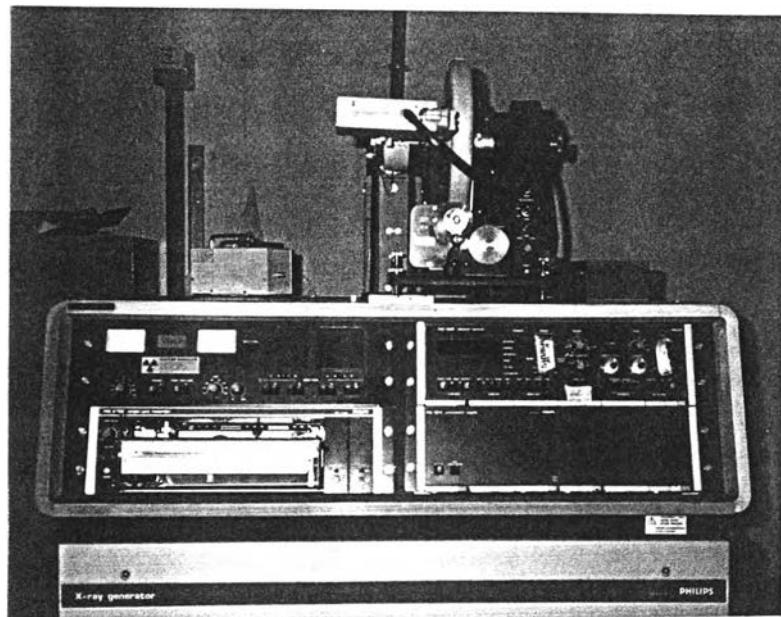
รูปที่ 1.13 X-ray Diffractrometer
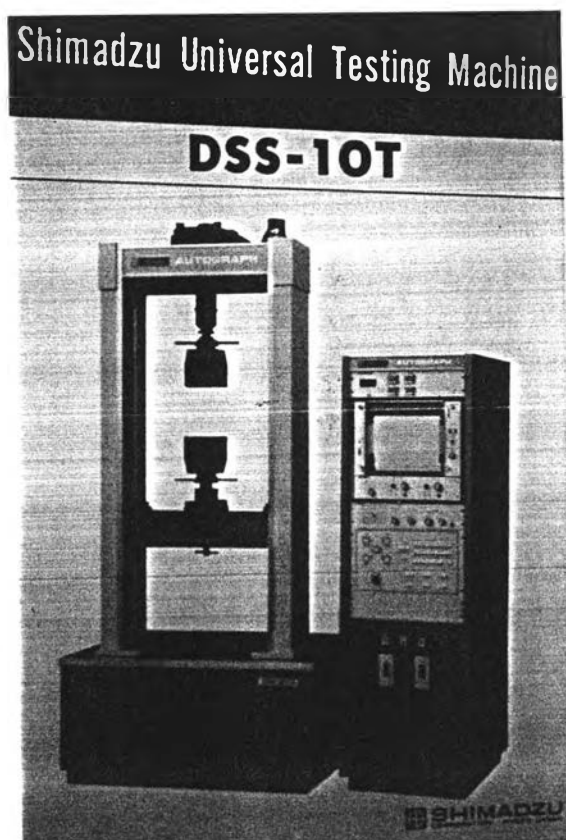
รูปที่ 1.14 Universal Testing Machine

ภาคผนวกที่ 2

ภาพประกอบแบบพิมพ์อัดขึ้นรูปติเฟล็คชันโฮค(ชุดที่ 1)

no of piece	nomenclature	pos no	dim./mat./misc
2	SOCKET HEAD	13	M6×40
4	SOCKET HEAD	12	M8×50
8	SOCKET HEAD	11	M8×40
1	SPRING	10	⌀25×25
2	CLAMP	9	STEEL
1	SUPPORT	8	STEEL
2	GUIDE POST	7	CAST IRON
2	COLUMN	6	⌀25×100
2	GUIDE POST	5	CAST IRON
1	UPPER PUNCH	4	⌀100×60
1	LOWER PUNCH	3	⌀100×90
1	BASE UPPER	2	▭ 25×125×250
1	BASE LOWER	1	▭ 25×125×250
no of piece	nomenclature	pos no	dim./mat./misc

list of parts   design problem no

scale	works	date: 11 Feb.'92	
1:3	MOLD DEFLECTION YOKE (I)		no

GATEWAY NATURAL TRACING PAPER 90/95 gm² SIZE A4

British Made
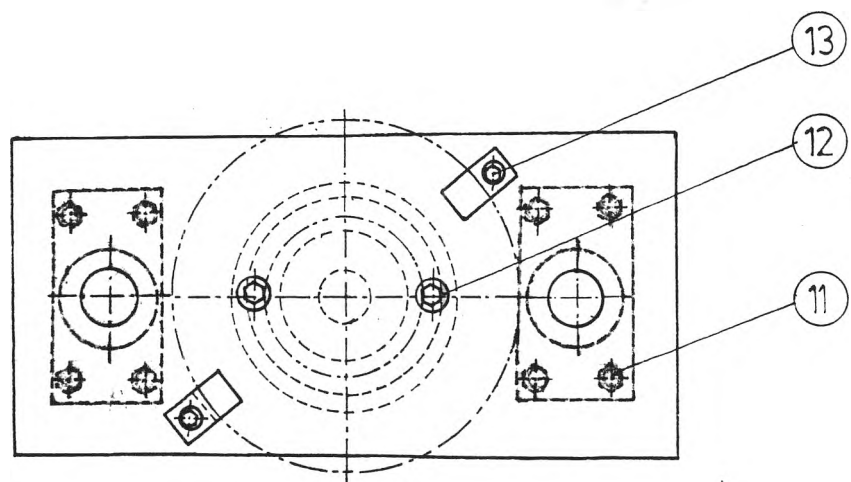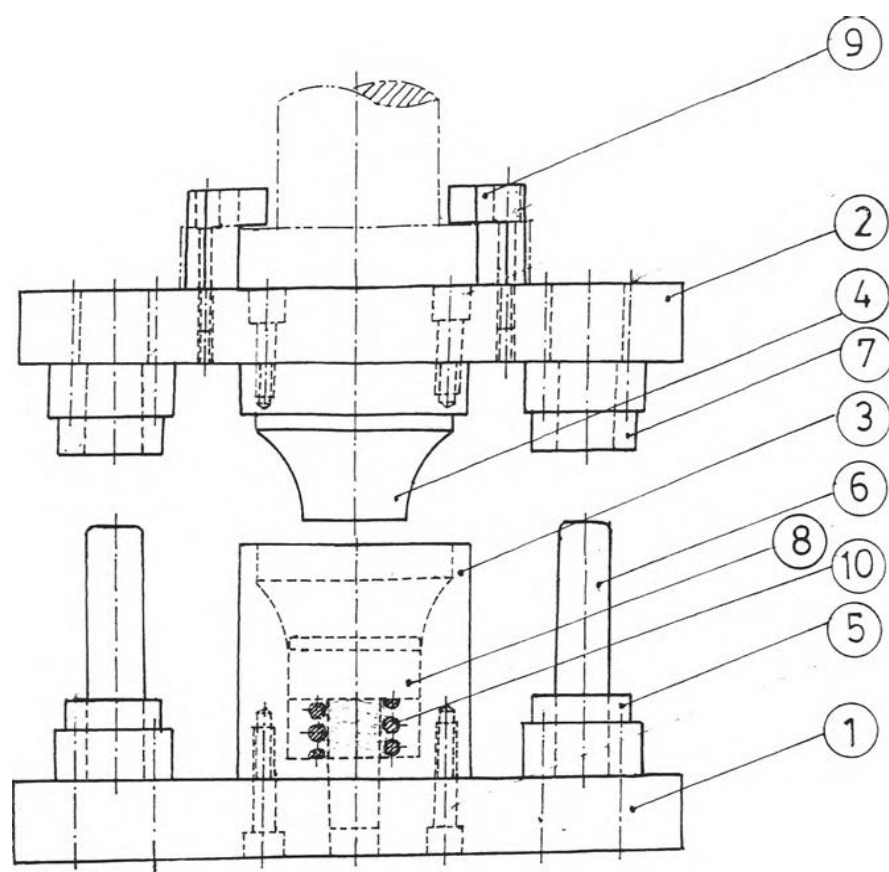
	name:	
scale	works	date: 11 Feb.92
1:3	Mold D.Y.(I)	no
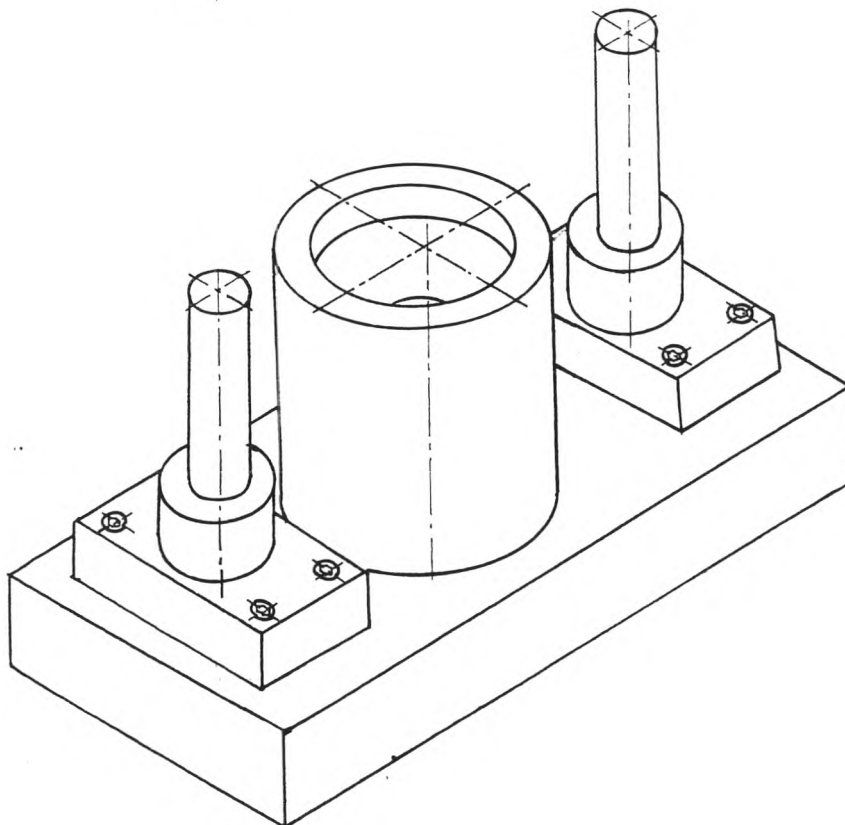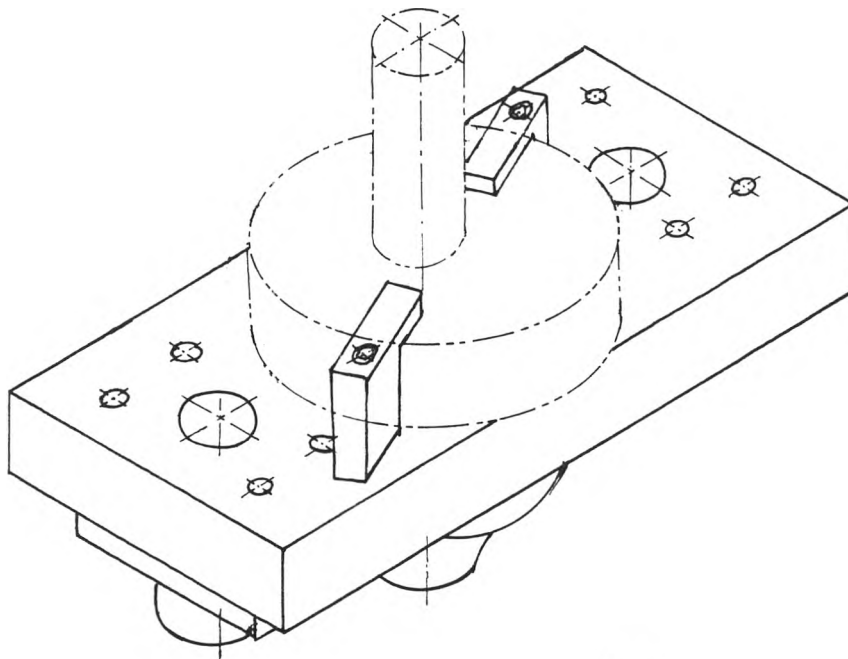
			name:	
scale	works		date: 12 FEB. 92	
1:3		MOLD DEFLECTION YOKE(I)		no
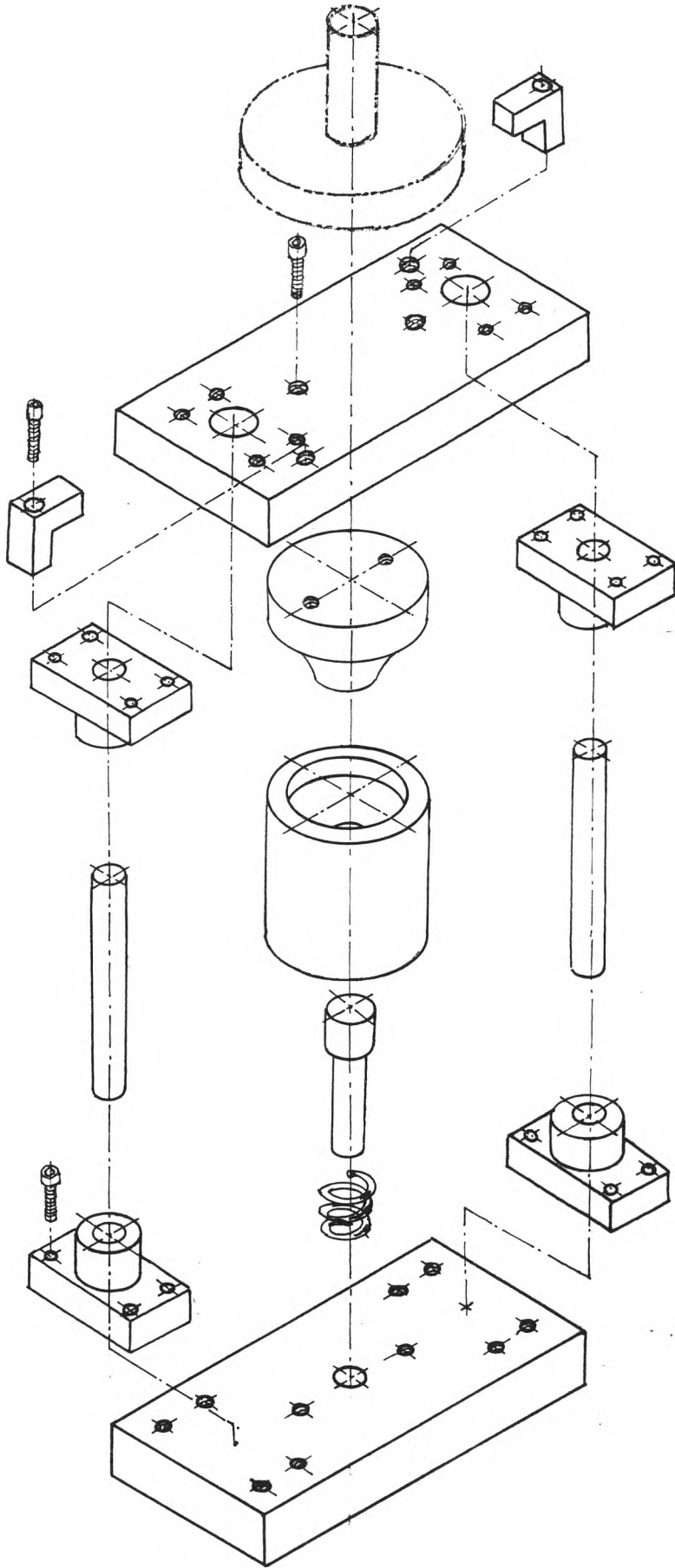
scale	works	name:
1:4	MOLD D.Y.(I)	date: 12 FEB '92
		no

<u>ภาคผนวกที่ 3</u>

ภาพประกอบและแยกชิ้นแบบพิมพ์อัดขึ้นรูปดิเฟล็คชันโฮค(ชุดที่ 2)

NO OF PIECE	NOMENCLATURE	POS NO	DIM / MAT/MISC
1	SUPPORT	11	φ 65 × 35
2	SUPPORT	10	20 ×50×115
1	EJECTOR	9	φ 40 ×80
1	EJECTOR	8	φ 41 ×100
1	EJECTOR	7	φ 53 ×100
1	PIN	6	φ 10 ×100
1	CYLINDRICAL	5	φ 125×40
1	UPPER BUSH	4	φ 88 × 60
1	LOWER BUSH	3	φ 58 × 90
1	UPPER PUNCH	2	φ 80 × 150
1	LOWOR PUNCH	1	φ 125×150
NO OF PIECE	NOMENCLATURE	POS NO	DIM / MAT/MISC

LIST OF PARTS	DESIGN PROBLEM NO

SCALE	WORKS	DATE	
1:2	MOLD DEFLECTION YOKE II		NO
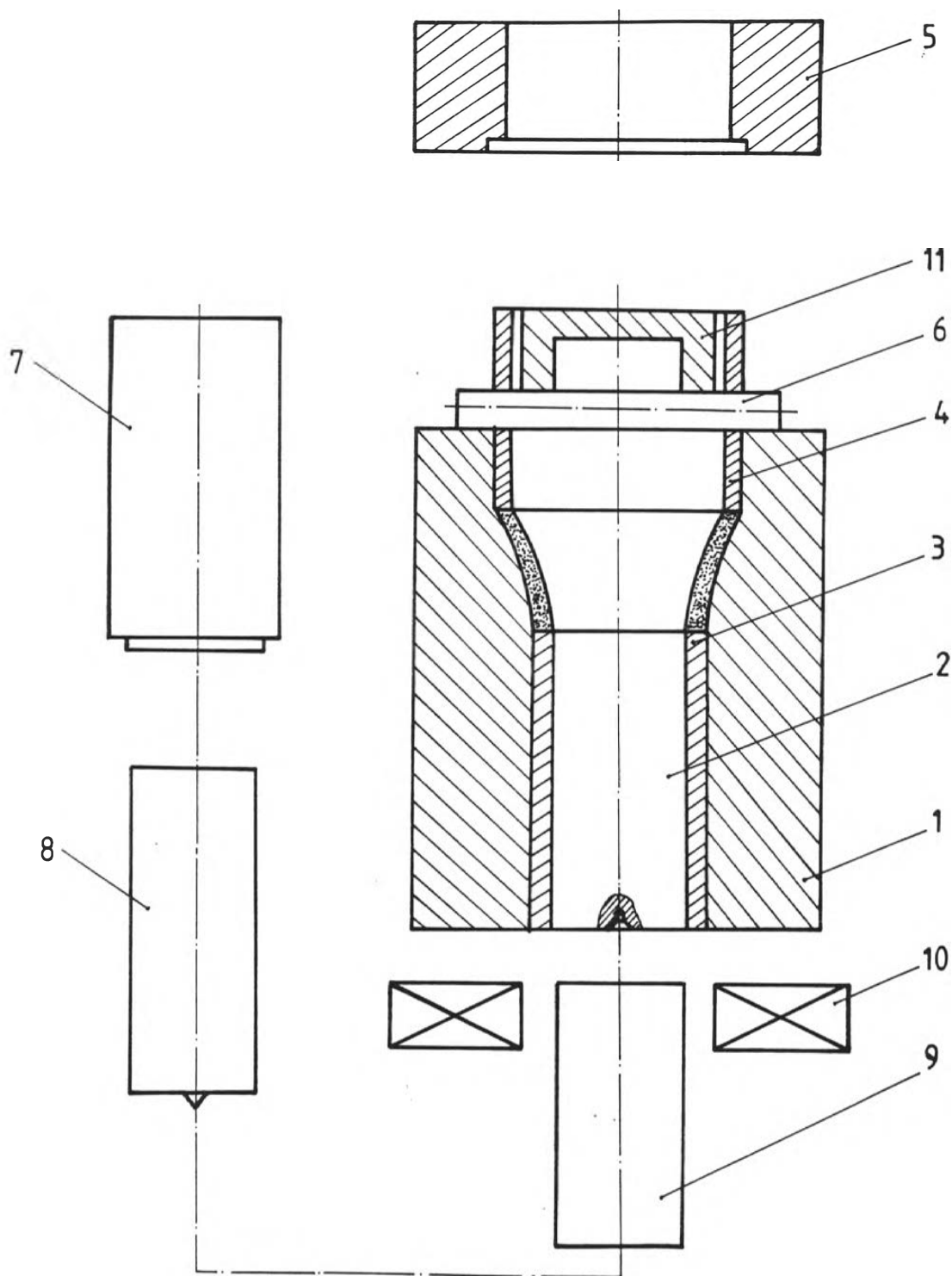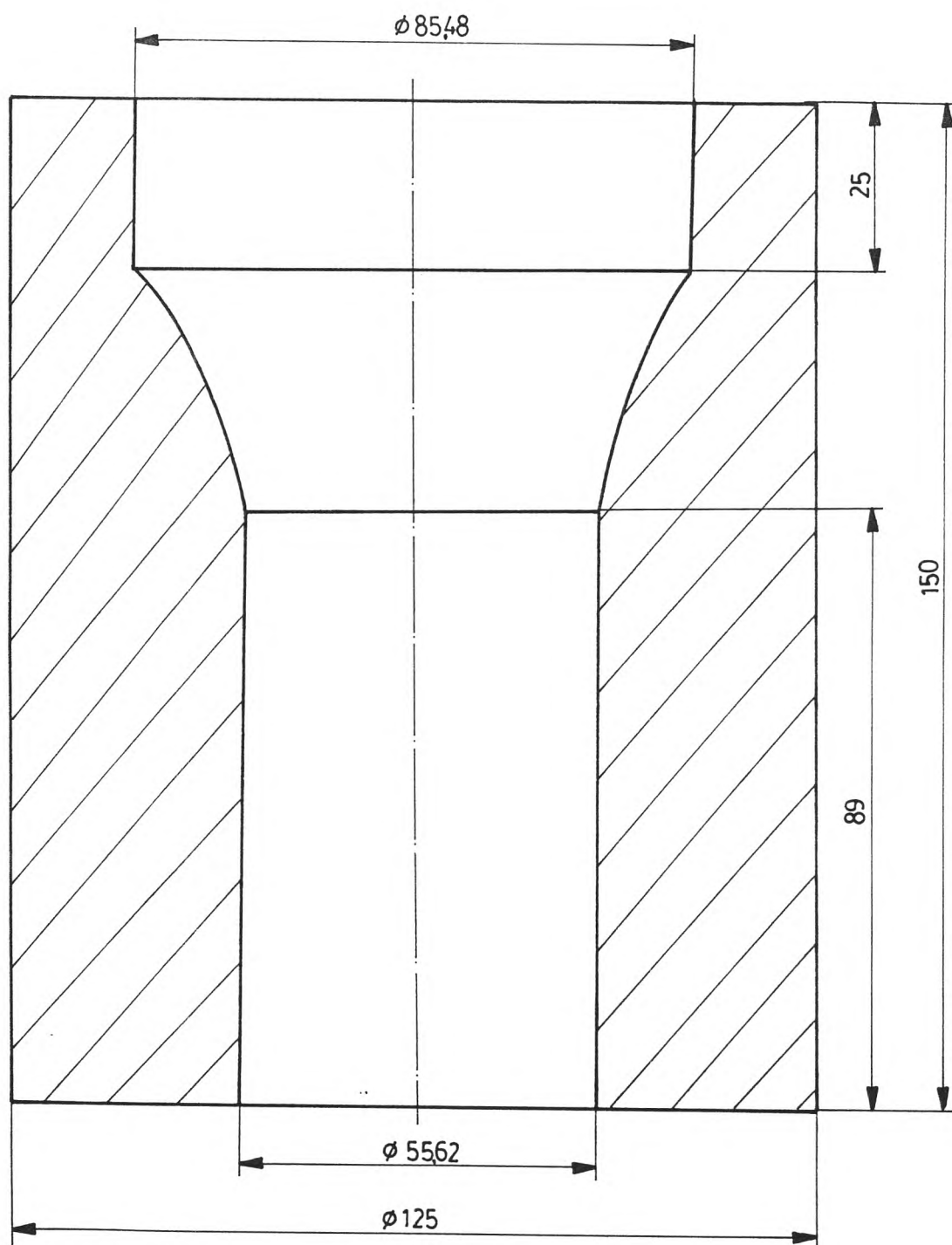
No.1   เหล็กแข็ง(ชุบแข็ง)ผิวเจียรไน จำนวน 1 ชิ้น

⌀42.29

90

146

25

⌀77.01

No.2   เหล็กแข็ง(ชุบแข็ง)ผิวเจียรไน จำนวน 1 ชิ้น

Ø 42, 31

Ø 55, 60

90
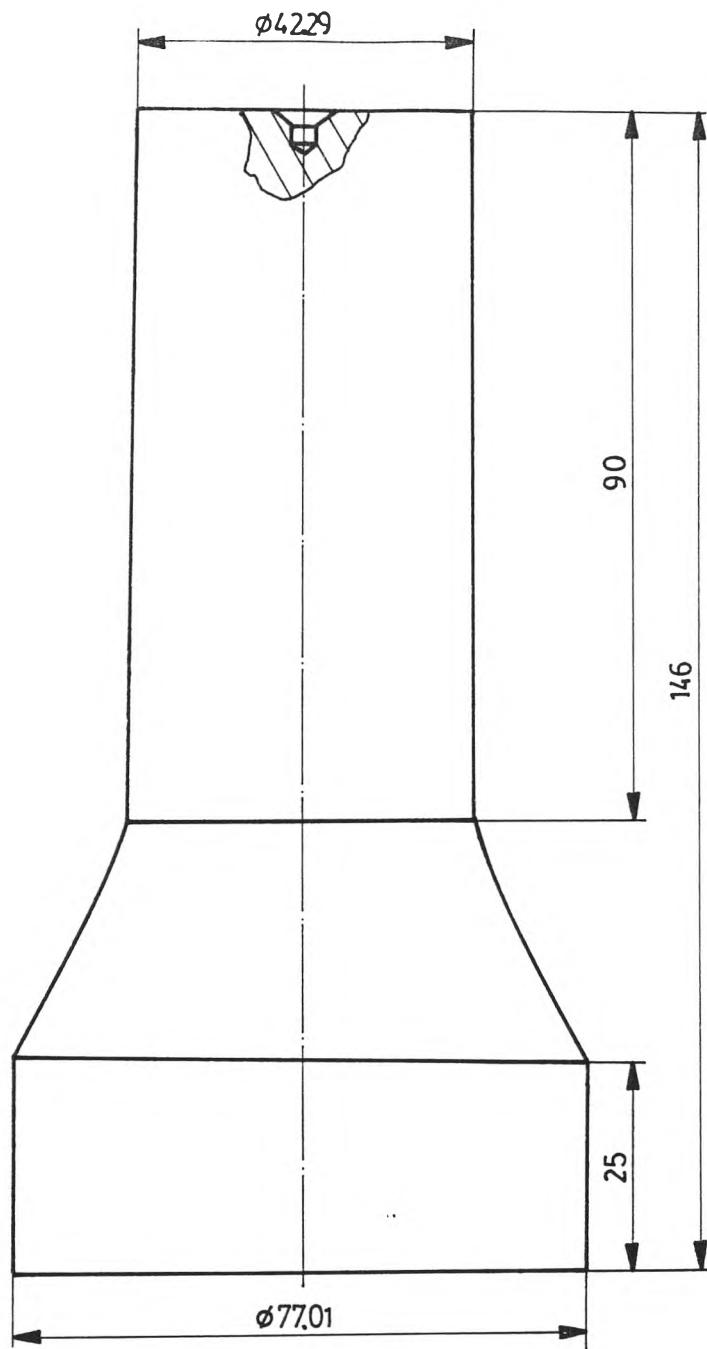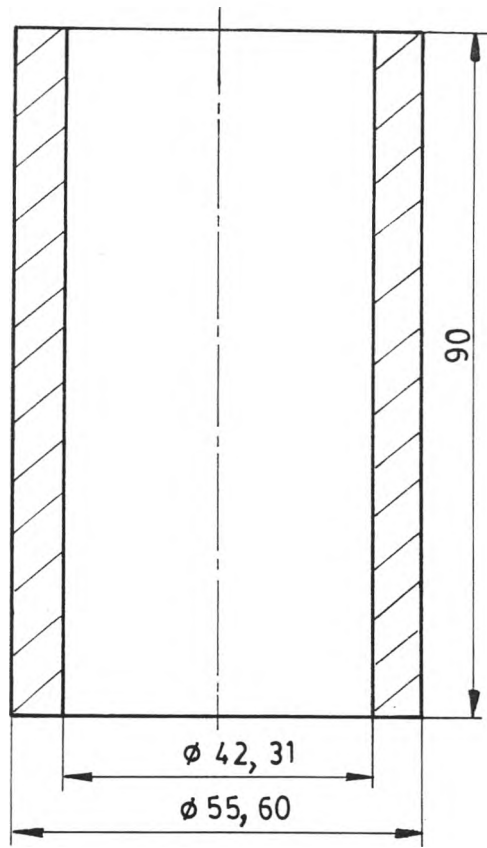
No.3   เหล็กแข็ง(ชุบแข็ง)ผิวเจียรใน จำนวน 1 ชิ้น

Ø10

60

30

Ø72, 02

Ø 85,46
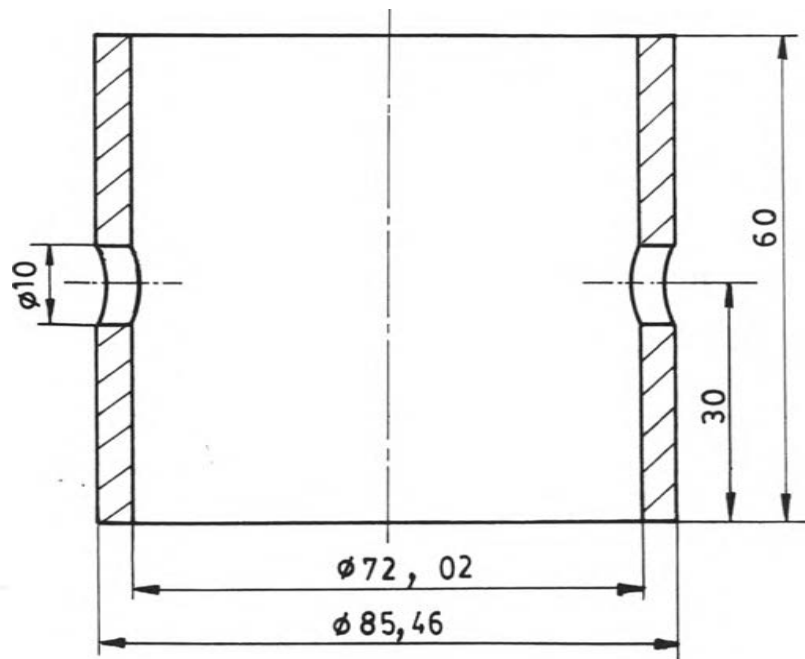
No.4   เหล็กแข็ง(ชุบแข็ง)ผิวเจียรใน จำนวน 1 ชิ้น
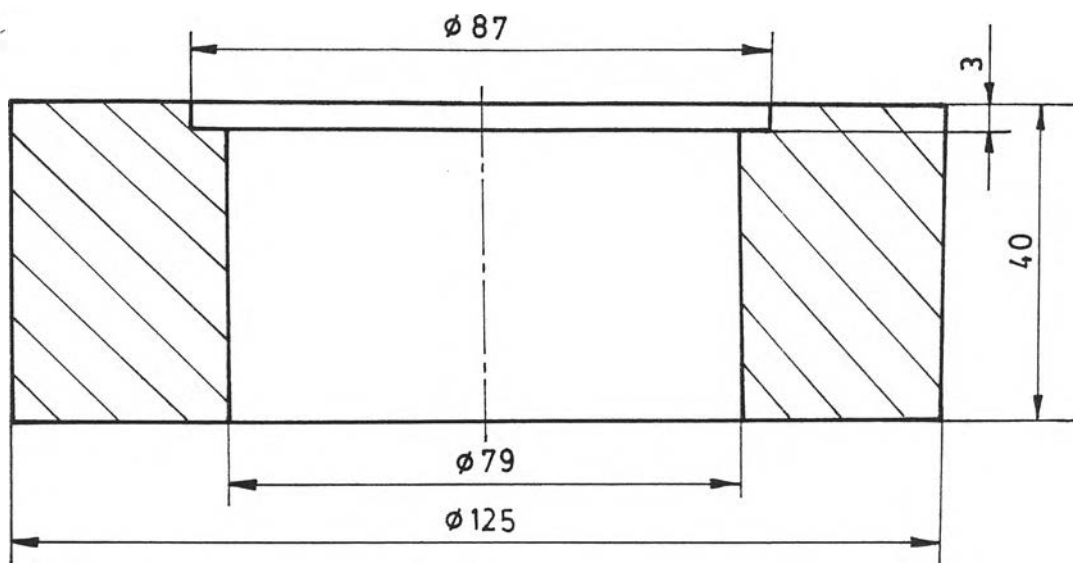
No.5 เหล็กเหนี่ยวผิวกลึง จำนวน 1 ชิ้น
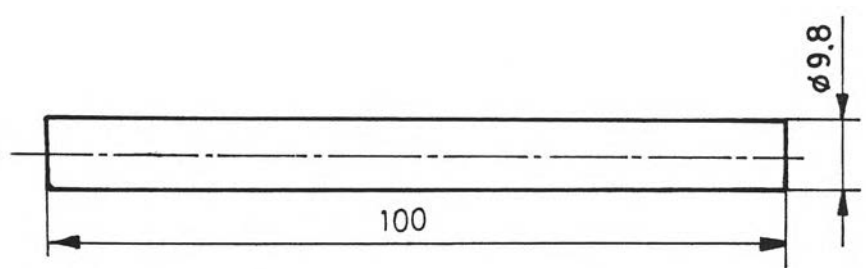
No.6 เหล็กเหนี่ยวผิวกลึง จำนวน 1 ชิ้น
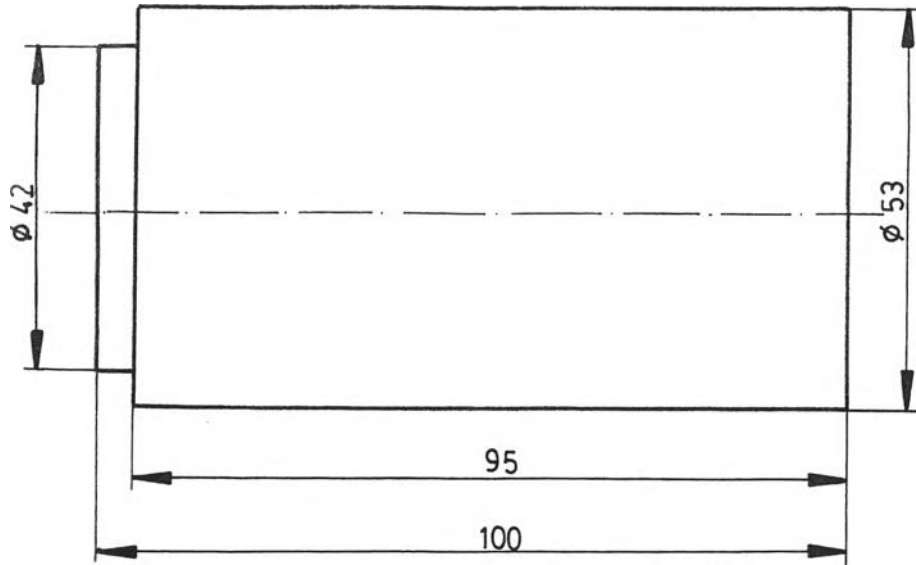
No.7 เหล็กเหนี่ยวผิวกลึง จำนวน 1 ชิ้น

115
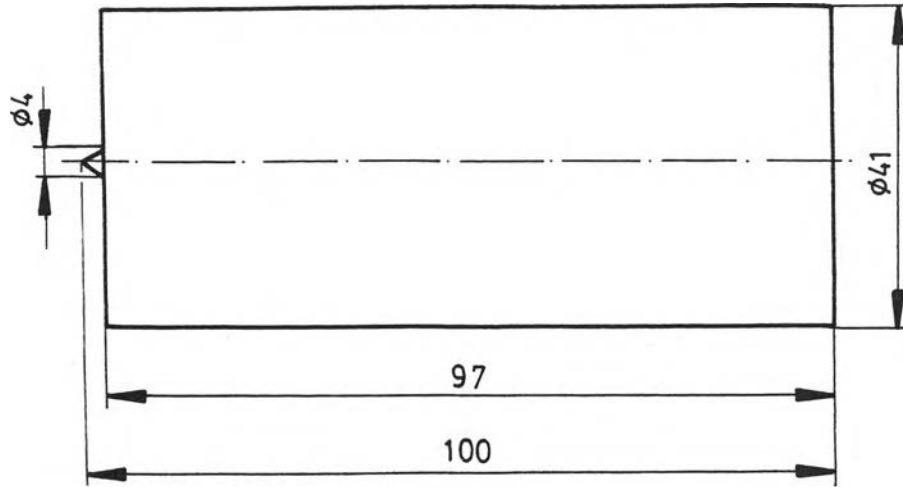
No.8 เหล็กเหนี่ยวผิวกลึง จำนวน 1 ชิ้น
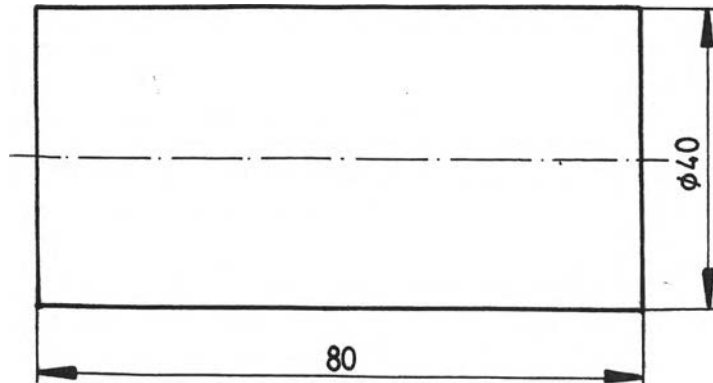
No.9 เหล็กเหนี่ยวผิวกลึง จำนวน 1 ชิ้น

115

50

20
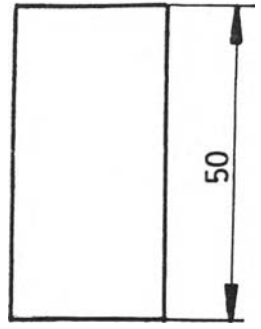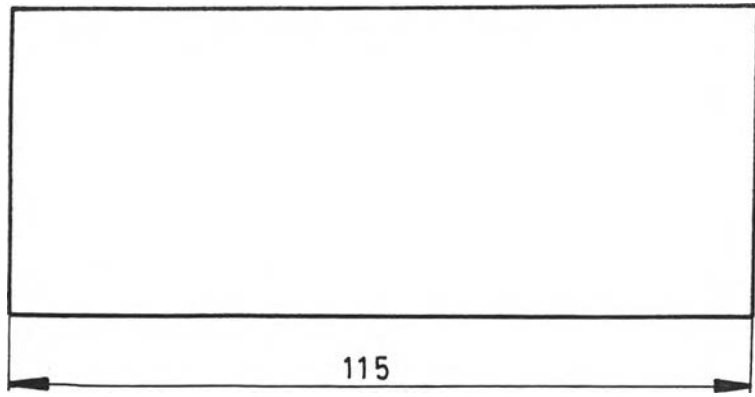
No.10 เหล็กเหนียวผิวละเอียด จำนวน 2 ชิ้น

Ø35

10

10

25

35

Ø65
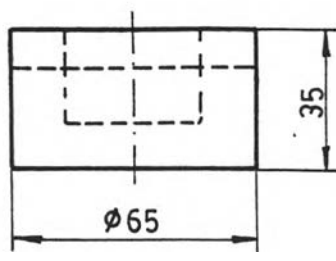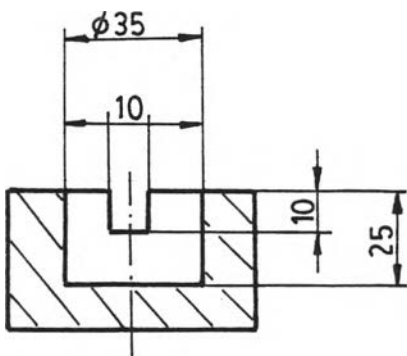
มาตราส่วน 1:2

No.11 เหล็กเหนียว จำนวน 1 ชิ้น

ภาคผนวกที่ 4

เอ็กซเรย์แนทเทิร์นของ DY-1 ถึง DY-6

s=spinel
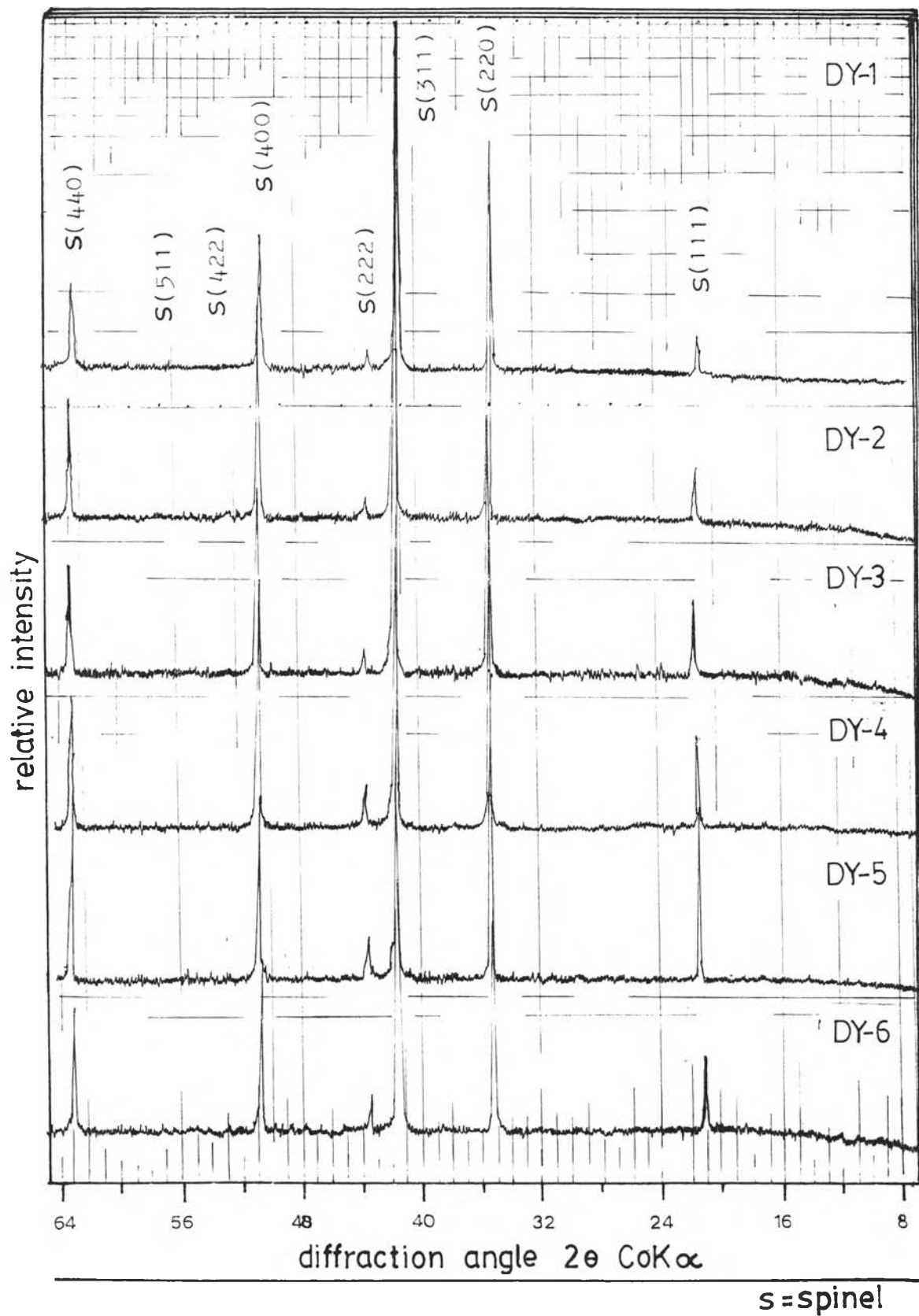
ภาคผนวกที่ 5

ไฟล์นัมเบอร์(File No.)ของสารเคมี

17-464

d	2.53	2.96	1.48	4.84	MgFe$_2$O$_4$ (low temperature)
I/I$_1$	100	40	35	4	Magnesium Iron Oxide (Magnesioferrite, low)

Rad. CuKα λ 1.542   Filter Ni   Dia.
Cut off   I/I$_1$ Diffractometer
Ref. W.C. Allen, School of Ceramics, Rutgers Univ.,
New Brunswick, N.J. (1965)

Sys. Cubic   S.G. Fd3m (227)
a$_0$ 8.375 b$_0$ c$_0$ A   C
α   β   γ   Z 8 Dx 4.522
Ref. Ibid.

εα   n ω β 2.35 (calc)ε γ   Sign
2V   D   np   Color Red to brown
Ref. Ibid.

Synthetic, by solid state reaction of MgO,Fe$_2$O$_3$ in air at 1600°C equilibrated at temp. below 350°C and quenched. Spinel structure 18% normal.
Magnesioferrites equilibrated at temperatures between 350 and 950 and quenched have cell sizes which range linearly between this form and the high temp. form.

| d Å	I/I$_1$	hkl	d Å	I/I$_1$	hkl
4.84	4	111	0.821	4	862
2.96	40	220	.810	8	951,773
2.525	100	311			
2.418	2	222			
2.094	25	400			
1.709	14	422			
1.612	30	511,333			
1.481	35	440			
1.324	6	620			
1.277	8	533			
1.208	2	444			
1.119	4	642			
1.090	12	731,553			
1.047	6	800			
0.987	4	822,660			
.967	8	751,555			
.936	2	840			
.893	<1	664			
.878	6	931			
.855	10	844			

22-1012

d	2.54	2.98	1.49	4.87	ZnFe$_2$O$_4$
I/I$_1$	100	35	35	7	Zinc Iron Oxide (Franklinite)

Rad. CuKα$_1$ λ 1.54056 Filter Mono. Dia.
Cut off   I/I$_1$ Diffractometer I/I$_{cor.}$=3.8
Ref. National Bureau of Standards, Mono. 25, Sec. 9 (1971)

Sys. Cubic   S.G. Fd3m (227)
a$_0$ 8.4411 b$_0$ c$_0$ A   C
α   β   γ   Z 8   Dx 5.324
Ref. Ibid.

εα   n ω β >2.00   εγ   Sign
2V   D   mp   Color
Ref. Ibid.

Pattern at 25°C.
The sample was prepared by co-precipitation of the hydroxides, followed by heating at 600°C for 17 hours and one hour at 800°C.
Spinel type.

d Å	I/I$_1$	hkl	d Å	I/I$_1$	hkl
4.87	7	111	.9684	2	662
2.984	35	220	.9439	2	840
2.543	100	311	.8999	1	664
2.436	6	222	.8848	5	931
2.109	17	400	.8616	8	844
1.937	1	331	.8277	4	1020
1.723	12	422	.8159	6	951
1.624	30	511	.8122	2	1022
1.491	35	440			
1.4270	1	531			
1.3348	4	620			
1.2872	9	533			
1.2721	4	622			
1.2184	2	444			
1.1820	1	711			
1.1280	5	642			
1.0990	11	731			
1.0553	4	800			
0.9949	2	822			
.9747	6	751			

7-2 3 9 MINOR CORRECTION

d	2.37	1.77	1.79	4.77	Mg(CH)₂		
I/I₁	100	90	55	90	MAGNESIUM HYDROXIDE		(BRUCITE)

Rad.CuKα₁ λ 1.5405 Filter Ni Dia.
Cut off I/I₁ Diffractometer
Ref. NBS Circular 539, Volume 6 (1956)

Sys. Hexagonal (Trigonal) S.G. D³₃d – P3m1 (164)
a₀ 3.147 b₀ c₀ 4.769 A C 1.5154
α β γ Z: Dx 2.37
Ref. Ibid.

εα 1.561 nωβ 1.581 εγ Sign +
2V D 2.39 mp Color Colorless
Ref. Ibid. Dana's System of Mineralogy 7th Ed. Vol 1

Sample prepared at NBS from MgO and water held at 60°C and 20,000 PSI for 3 days; spect. analysis shows <0.1% Ca; <0.01% Ag, Al, B, Fe, Si, Sr, Ti; <0.001% Ba, Cr, Cu. CdI₂ structure type. Pattern made at 26°C.

d Å	I/I₁	hkl	d Å	I/I₁	hkl
4.77	90	001	0.9001	<1	105
2.725	6	100	.8974	2	204
2.365	100	101	.8923	2	301
1.794	55	102	.8643	6	213
1.573	35	110	.8156	4	115
1.494	18	111	.7865	4	220
1.373	16	103			
1.363	2	200			
1.310	12	201			
1.192	2	004			
1.183	10	202			
1.118	2	113			
1.092	4	104			
1.034	6	203			
1.030	2	210			
1.0067	8	211			
0.9543	2	005			
.9503	6	114			
.9455	8	212			
.9085	4	300			

24 - 7 2

CALCULATED PATTERN-PEAK HEIGHT
See 24-72A
24-72A

2.70	2.52	1.70	100	70	36

Fe₂O₃
Iron Oxide Hematite

Ref. Smith et al., Annual Report to the Joint
Committee on Powder Diffraction Standards (1973)

Sys. Hexagonal S.G. R3c (167) Dx 5.255 Z 6
a₀ 5.038 b₀ c₀ 13.772
α β γ
Ref. Blake et al., Am. Min., 51 123 (1966)

Scale factor (Integrated Intensities)
λ 1.54050

d A	I/I₀	h k l	d A	I/I₀	h k l
3.686	33	012	2.080	2	202
2.703	100	104	1.8428	31	024
2.519	70	110	1.6966	36	116
2.295	2	006	1.6013	8	018,122
2.208	17	113	1.4873	22	214

d A	I/I₀	h k l
1.4543	21	300
1.3514	2	208
1.3133	7	1010
1.3078	4	119
1.2595	4	220
1.2285	2	306,036
1.1908	3	128,312
1.1645	3	0210
1.1416	4	134
1.1042	4	226
1.0571	4	2110
0.9611	3	324
.9596	5	0114
.9521	2	410
.9090	2	1310
.8794	2	416,146
.8448	2	1213,054

FORM CP

16-154

d	2.49	2.77	1.54	4.94	Mn₃O₄		MnO.Mn₂O₃
I/I₁	100	90	80	30	Manganese Oxide		Hausmannite

Rad. FeKα λ 1.9373 Filter Mn Dia. 57.3mm
Cut off I/I₁ Visual
Ref. E.W. Nuffield, in Berry & Thompson, Geol. Soc. Amer. Mem. 85 195 (1962)

Sys. Tetragonal S.G. I4₁/amd (141)
a₀ 5.76 b₀ c₀ 9.44 A C 1.649
α β γ Z 4 Dx 4.84
Ref. Aminoff, Z. Krist. 64 475 (1926) - Langban.

εα 2.15 (Li) nωβ 2.46 (Li) εγ Sign -
2V D 4.84 mp Color Brownish black
Ref. Dana's System of Mineralogy, 7th Edition

Sample from Ilmenau, Thuringia, Germany. Same pattern given by mineral from Langban, Sweden and Ilfeld, Harz. (Ramdohr, Symp. on Manganese Tom 1, Int. Geol. Congress Mexico, 1956)

d Å	I/I₁	hkl	d Å	I/I₁	hkl
4.94	30	011	1.280	40	143
3.09	50	112	1.246	10	242
2.89	30	020	1.233	20	044
2.77	90	013	1.194	30	127,136
2.49	100	121	1.180	30	008
2.36	40	004	1.133	10	244
2.04	40	220	1.125	40	145
1.825	20	024	1.101	20	152
1.795	50	015	1.083	40	053,343
1.706	30	132	1.064	20	251,046
1.642	20	033	1.030	40	237,336
1.579	50	231	1.019	50	154
1.544	80	224			
1.468	10	116			
1.445	40	134,040			
1.423	5	233			
1.382	5	141,026			
1.350	30	035			
1.306	10	332			
1.292	10	240			

5-0664 MAJOR CORRECTION

d	2.48	2.82	2.60	2.816	ZnO
I/I₁	100	71	56	71	ZINC OXIDE (ZINCITE)

Rad. CuKα₁ λ 1.5405 Filter Ni						
Dia. Cut off Coll.						
I/I₁ G. C. Diffractometer d corr. abs.?						
Ref. Swanson and Fuyat, NBS Circular 539, Vol. 2 25 (1953)						

Sys. Hexagonal S.G. C_{6v}^4 - P6₃mc
a 3.249 b c 5.205 A C 1.60
α β γ Z 2
Ref. Ibid.

ε a n ω β ε γ Sign
2V Dx 5.680 mp Color
Ref. Ibid.

Sample from New Jersey Zinc Co.
Spect. analysis shows < 0.001% each of Mg, Si and Ca.
X-ray pattern at 26°C.

To replace 1-1136, 3-0752, 3-0888, 3-0891.

d Å	I/I₁	hkl	d Å	I/I₁	hkl
2.816	71	100	0.9069	12	213
2.602	56	002	.8826	6	302
2.476	100	101	.8675	1	006
1.911	29	102	.8369	6	205
1.626	40	110	.8290	2	106
1.477	35	103	.8237	2	214
1.407	6	200	.8125	5	220
1.379	28	112			
1.359	14	201			
1.301	3	004			
1.238	5	202			
1.1812	3	104			
1.0929	10	203			
1.0639	4	210			
1.0422	10	211			
1.0158	5	114			
0.9848	4	212			
.9764	7	105			
.9555	1	204			
.9382	4	300			

4-0777 MAJOR CORRECTION

d 4-0777	2.41	1.70	2.78	2.778	CaO
I/I₁ 4-0777	100	45	34	34	CALCIUM OXIDE (LIME)

Rad. CuKα₁ λ 1.5405 Filter Ni
Dia. Cut off 50 Coll.
I/I₁ G. C. Diffractometer d corr. abs.?
Ref. Swanson and Tatge, JC Fel. Reports, NBS (1950)

Sys. Cubic S.G. O_h^5 - Fm3m
a 4.8105 b c A C
α β γ Z 4
Ref. Ibid.

ε a n ω β 1.937 ε γ Sign
2V D 3.345 mp (WA) Color
Ref. (NBS)

NBS analysis shows about 0.2% MgO, 0.1% Ba, and no other impurity over 0.04% at 27°C
To replace 1-1160, 2-1089, 3-1123

d Å	I/I₁	hkl	d Å	I/I₁	hkl
2.778	34	111			
2.405	100	200			
1.701	45	220			
1.451	10	311			
1.390	5	222			
1.203	4	400			
1.1036	4	331			
1.0755	9	420			
0.9819	9	422			
.9258	3	511			
.8504	4	440			
.8131	5	531			
.8018	6	600			

5-0490 MINOR CORRECTION

d	3.34	4.26	1.82	4.26	SiO₂
I/I₁	100	35	17	35	SILICON OXIDE QUARTZ, LOW

Rad. CuKα₁ λ 1.5405 Filter Ni
Dia. Cut off Coll.
I/I₁ G.C. Diffractometer d corr. abs.?
Ref. Swanson and Fuyat, NBS Circular 539, Vol. III (1953)

Sys. Hexagonal S.G. D_3^4 - P3₁21
a 4.913 b c 5.405 A C 1.10
α β γ Z 3
Ref. Ibid.

ε a n ω β 1.544 ε γ 1.553 Sign +
2V Dx 2.647 mp Color
Ref. Ibid.

Sample from Lake Toxaway, N.C. Spect. anal.:
<0.01% Al; <0.001% Ca,Cu,Fe,Mg.
X-ray pattern at 25°C.

Replaces 1-0649, 2-0458, 2-0459, 2-0471, 3-0419, 3-0427, 3-0444.

d Å	I/I₁	hkl	d Å	I/I₁	hkl
4.26	35	100	1.228	2	220
3.343	100	101	1.1997	5	213
2.458	12	110	1.1973	2	221
2.282	12	102	1.1838	4	114
2.237	6	111	1.1802	4	310
2.128	9	200	1.1530	2	311
1.980	6	201	1.1408	<1	204
1.817	17	112	1.1144	<1	303
1.801	<1	003	1.0816	4	312
1.672	7	202	1.0636	1	400
1.659	3	103	1.0477	2	105
1.608	<1	210	1.0437	2	401
1.541	15	211	1.0346	2	214
1.453	3	113	1.0149	2	223
1.418	<1	300	0.9896	2	402,115
1.382	7	212	.9872	2	313
1.375	11	203	.9781	<1	304
1.372	9	301	.9762	1	320
1.288	3	104	.9607	2	321
1.256	4	302	.9285	<1	410

<u>ภาคผนวกที่ 6</u>

มาตรฐานอเมริกันสำหรับวัสดุและการทดสอบ

ASTM Designation: B 212 – 89

Standard Test Method for
Apparent Density of Free-Flowing Metal Powders[1]

1. Scope

1.1 This test method describes a procedure for determining the apparent density of free-flowing metal powders and is suitable for only those powders that will flow unaided through the specified Hall flowmeter funnel.

1.2 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*
B 213 Test Method for Flow Rate of Metal Powders[2]
B 215 Practices for Sampling Finished Lots of Metal Powders[2]
B 243 Terminology of Powder Metallurgy[2]

3. Summary of Test Method

3.1 A volume of powder is permitted to flow into a container of definite volume under controlled conditions. The weight of powder per unit volume is determined and reported as apparent density.

4. Significance and Use

4.1 This test method provides a guide for evaluation of the apparent density physical characteristic of powders. The density measured bears some relationship to the weight of powder that will fill a fixed volume press cavity when parts are being made. The degree of correlation between the results of this test and the quality of powders in use will vary with each particular application.

5. Apparatus

5. *Powder Flowmeter Funnel[3]*—A standard Hall flowmeter funnel (Fig. 1) having a calibrated orifice.

5.2 *Density Cup[3]*—A cylindrical cup (Fig. 1) having a capacity of 25 ± 0.05 cm^3.

5.3 *Stand[3]*—A stand (Fig. 1) to support the powder flowmeter concentric with the density cup so that the bottom of the powder flowmeter orifice is 1 in. (25 mm) above the top of the density cup when the apparatus is assembled as shown in Fig. 1.

5.4 *Base*—A level, vibration-free base to support the powder flowmeter.

5.5 *Balance*, having a capacity of at least 200 g and a sensitivity of 0.1 g.

6. Test Specimen

6.1 The test specimen shall consist of a volume of approximately 30 to 40 cm^3 of metal powder.

6.2 The test specimen shall be tested as sampled. Note, however, that moisture, oils, stearic acid, stearates, waxes, etc., may alter the characteristics of the powder.

7. Procedure

7.1 Carefully load the test specimen into the flowmeter funnel and permit it to run into the density cup through the discharge orifice. Take care not to move the density cup.

7.2 When the powder completely fills and overflows the periphery of the density cup, rotate the funnel approximately 90° in a horizontal plane so that the remaining powder falls away from the cup.

7.3 Using a nonmagnetic spatula with the blade held perpendicular to the top of the cup, level off the powder flush with the top of the density cup. Take care to avoid jarring the apparatus at any time.

7.4 After the leveling operation, tap the density cup lightly on the side to settle the powder to avoid spilling in transfer.

7.5 Transfer the powder to the balance and weigh to the nearest 0.1 g.

8. Calculation

8.1 Calculate the apparent density as follows:

$$\text{Apparent density, g/cm}^3 = \text{weight in grams} \times 0.04$$

9. Report

9.1 Results shall be reported as apparent density to the nearest 0.01 g/cm^3.

10. Precision and Bias

10.1 The following criteria should be used to judge acceptability of the results at the 95 % confidence level.

10.1.1 *Repeatability*—Duplicate results by the same operator should be considered suspect if they differ by more than 0.9 %.

10.1.2 *Reproducibility*—The results submitted by each of two laboratories should not be considered suspect unless they differ by more than 6.0 %.
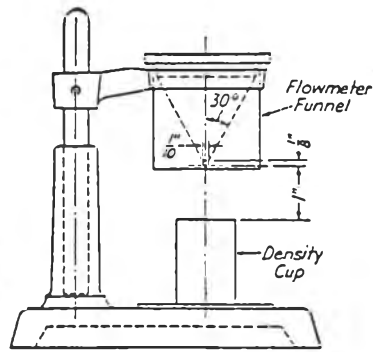
B 212

Metric Equivalents

in.	mm
1/10	2.5
1/8	3.2
1	25

FIG. 1   Flowmeter Apparatus

ASTM Designation: B 527 – 85 (Reapproved 1991)[ε1]

Standard Test Method for
Tap Density of Powders of Refractory Metals and Compounds by Tap-Pak Volumeter[1]

[ε1] NOTE—The Keywords section was added editorially, and other editorial changes made, in August 1991.

1. Scope

1.1 This test method covers determination of the tap density (packed density) of refractory metal powders and compounds by means of the Tap-Pak Volumeter.[2]

1.2 *This standard does not purport to address the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Significance and Use

2.1 This test method covers the evaluation of the tapped density physical characteristic of powders. The degree of correlation between the results of this test and the quality of powders in use will vary with each particular application and has not been fully determined.

3. Apparatus

3.1 *Graduated Cylinder,*[3] calibrated to contain 25 mL at 20°C, internal diameter 15 mm, height 180 mm and weight approximately 60 g.

3.2 *Holder*—A cylinder holder weighing 1 lb (454 g).

3.3 *Tapping Device*, consisting of a baseplate with single-phase a-c condenser motor, with worm drive, reduction ratio 15 to 1, cam shaft speed 250 r/min, tapping stroke travel 3.2 mm.

3.4 *Counter*—A four-digit adjustable counter, which can be preset to deliver numbers of taps between 1 and 9999.

3.5 *Balance*, having a capacity of at least 100 g and a sensitivity of 0.1 g.

4. Test Specimen

4.1 The test specimen shall be 50 g except as noted in 4.2.

4.2 For refractory metal and compound powders too voluminous to fit into the 25-mL graduated cylinder, reduce sample size to 20 g or 10 g, as necessary, and follow the standard procedure.

5. Procedure

5.1 Weigh 50 g of the test specimen to an accuracy of ±0.1 g.

5.2 Pour the test specimen carefully into the graduated cylinder, using a funnel. To ensure proper level, rotate the funnel while pouring the test specimen.

5.3 Preset the counter for 3000 taps.

5.4 Start tapping device.

5.5 Read the tapped volume, V, in millilitres, by calculating the mean value between the highest and the lowest point at the tapped volume.

6. Calculation and Report

6.1 Calculate tap density in grams per cubic centimetre, to the nearest tenth by dividing 50 g (10 or 20 g for samples as noted in 4.2) by the tapped volume, V, read in millilitres, as follows:

$$\text{Tap density, g/cm}^3 = 50 \text{ g}/V$$

7. Precision and Bias

7.1 Precision has been determined from round-robin testing performed prior to the approval of this test method. Those results which have been re-verified show a precision of from ± 1 to 2 % of the value determined as the 2 σ limits. The variation depends upon the tap density of the powder being determined which can vary between 2.0 and 8.0 g/cm^3.

7.2 Bias cannot be stated since there is no universally accepted standard instrument, nor are instruments sold as certified standards.

8. Keywords

8.1 molybdenum; packed density; powder(s); refractory metals; rhenium; tantalum; tap density; Tap-Pak Volumeter; tungsten; tungsten carbide

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B 527

ASTM Designation: C 373 – 88

Standard Test Method for
Water Absorption, Bulk Density, Apparent Porosity, and
Apparent Specific Gravity of Fired Whiteware Products[1]

1. Scope

1.1 This test method covers procedures for determining water absorption, bulk density, apparent porosity, and apparent specific gravity of fired unglazed whiteware products.

1.2 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Significance and Use

2.1 Measurement of density, porosity, and specific gravity is a tool for determining the degree of maturation of a ceramic body, or for determining structural properties that may be required for a given application.

3. Apparatus and Materials

3.1 *Balance*, of adequate capacity, suitable to weigh accurately to 0.01 g.

3.2 *Oven*, capable of maintaining a temperature of 150 ± 5°C (302 ± 9°F).

3.3 *Wire Loop, Halter, or Basket*, capable of supporting specimens under water for making suspended mass measurements.

3.4 *Container*—A glass beaker or similar container of such size and shape that the sample, when suspended from the balance by the wire loop, specified in 3.3, is completely immersed in water with the sample and the wire loop being completely free of contact with any part of the container.

3.5 *Pan*, in which the specimens may be boiled.

3.6 *Distilled Water.*

4. Test Specimens

4.1 At least five representative test specimens shall be selected. The specimens shall be unglazed and shall have as much of the surface freshly fractured as is practical. Sharp edges or corners shall be removed. The specimens shall contain no cracks. The individual test specimens shall weigh at least 50 g.

5. Procedure

5.1 Dry the test specimens to constant mass (Note) by

heating in an oven at 150°C (302°F), followed by cooling in a desiccator. Determine the dry mass, D, to the nearest 0.01 g.

Note—The drying of the specimens to constant mass and the determination of their masses may be done either before or after the specimens have been impregnated with water. Usually the dry mass is determined before impregnation. However, if the specimens are friable or evidence indicates that particles have broken loose during the impregnation, the specimens shall be dried and weighed after the suspended mass and the saturated mass have been determined, in accordance with 5.3 and 5.4 In this case, the second dry mass shall be used in all appropriate calculations.

5.2 Place the specimens in a pan of distilled water and boil for 5 h, taking care that the specimens are covered with water at all times. Use setter pins or some similar device to separate the specimens from the bottom and sides of the pan and from each other. After the 5-h boil, allow the specimens to soak for an additional 24 h.

5.3 After impregnation of the test specimens, determine to the nearest 0.01 g the mass, S, of each specimen while suspended in water. Perform the weighing by placing the specimen in a wire loop, halter, or basket that is suspended from one arm of the balance. Before actually weighing, counterbalance the scale with the loop, halter, or basket in place and immerse in water to the same depth as is used when the specimens are in place. If it is desired to determine only the percentage of water absorption, omit the suspended mass operation.

5.4 After the determination of the suspended mass or after impregnation, if the suspended mass is not determined, blot each specimen lightly with a moistened, lint-free linen or cotton cloth to remove all excess water from the surface, and determine the saturated mass, M, to the nearest 0.01 g. Perform the blotting operation by rolling the specimen lightly on the wet cloth, which shall previously have been saturated with water and then pressed only enough to remove such water as will drip from the cloth. Excessive blotting will introduce error by withdrawing water from the pores of the specimen. Make the weighing immediately after blotting, the whole operation being completed as quickly as possible to minimize errors due to evaporation of water from the specimen.

6. Calculation

6.1 In the following calculations, the assumption is made that 1 cm³ of water weighs 1 g. This is true within about 3 parts in 1000 for water at room temperature.

6.1.1 Calculate the exterior volume, V, in cubic centimetres, as follows:

$$V = M - S$$

6.1.2 Calculate the volumes of open pores V_{OP} and impervious portions V_{IP} in cubic centimetres as follows:

$$V_{OP} = M - D$$
$$V_{IP} = D - S$$

6.1.3 The apparent porosity, P, expresses, as a percent, the relationship of the volume of the open pores of the specimen to its exterior volume. Calculate the apparent porosity as follows:

$$P = [(M - D)/V] \times 100$$

6.1.4 The water absorption, A, expresses as a percent, the relationship of the mass of water absorbed to the mass of the dry specimen. Calculate the water absorption as follows:

$$A = [(M - D)/D] \times 100$$

6.1.5 Calculate the apparent specific gravity, T, of that portion of the test specimen that is impervious to water, as follows:

$$T = D/(D - S)$$

6.1.6 The bulk density, B, in grams per cubic centimetre, of a specimen is the quotient of its dry mass divided by the exterior volume, including pores. Calculate the bulk density as follows:

$$B = D/V$$

7. Report

7.1 For each property, report the average of the values obtained with at least five specimens, and also the individual values. Where there are pronounced differences among the individual values, test another lot of five specimens and, in addition to individual values, report the average of all ten determinations.

8. Precision and Bias

8.1 This test method is accurate to ± 0.2 % water absorption in interlaboratory testing when the average value recorded by all laboratories is assumed to be the true water absorption. The precision is approximately ± 0.1 % water absorption on measurements made by a single experienced operator.

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