

LAMPIRAN 1

Contoh Perhitungan Ralat KHN Rata-rata:

Pada substrat yang dinitridasi pada suhu substrat 600°C dan waktu nitridasi 60 menit diperoleh data sebagai berikut:

No.	KHN_n	$\text{KHN}_n - \overline{\text{KHN}}$	$(\text{KHN}_n - \overline{\text{KHN}})^2$
1.	222,2	0,6	0,36
2.	222,2	0,6	0,36
3.	220,5	-1,1	1,21

$$\sum_{n=1}^i \text{KHN}_n = 664,9$$

$$\sum_{n=1}^i (\text{KHN}_n - \overline{\text{KHN}})^2 = 1,93$$

$$\overline{\text{KHN}} = \frac{\sum_{n=1}^i \text{KHN}_n}{n} = \frac{664,9}{3} = 221,6$$

$$\delta \text{ KHN} = \sqrt{\frac{\sum_{n=1}^i (\text{KHN}_n - \overline{\text{KHN}})^2}{n(n-1)}} = \sqrt{\frac{1,93}{6}} = 0,6$$

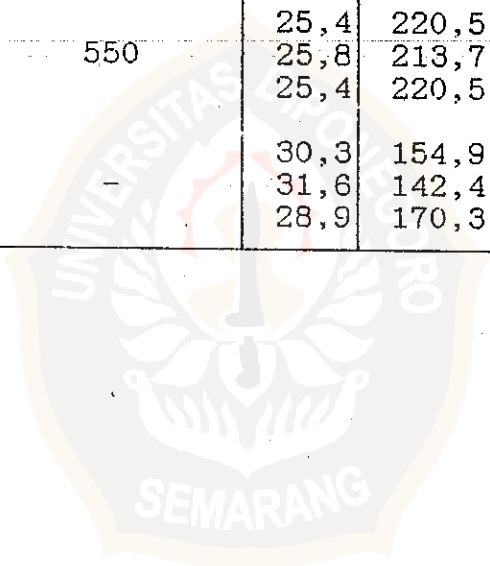
LAMPIRAN II

DATA HASIL UJI KEKERASAN MIKRO KNOOP

(KHN)

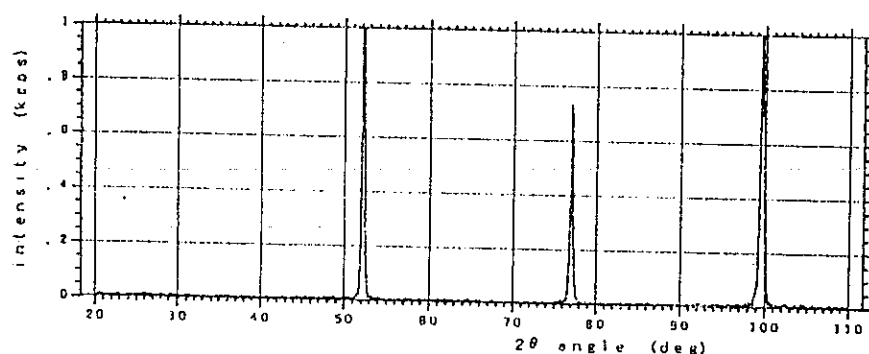
No.	Nitridasi		Hasil Uji Kekerasan			
	Waktu (menit)	Suhu Substrat (°C)	d ₁	KHN	KHN rerata	δ KHN
1.	60	600	25,3 25,3 25,4	222,2 222,1 220,5	221,6	0,6
2.	60	550	23,4 24,5 24,6	259,8 237,0 235,1	244,0	7,9
3.	60	500	25,4 24,5 24,7	220,5 237,0 233,3	230,2	4,9
4.	60	450	26,3 25,8 25,8	205,7 213,7 213,7	211,0	2,7
5.	120	500	26,2 26,4 25,4	207,2 204,1 220,5	210,6	5,0
6.	180	500	26,8 26,3 24,7	198,1 205,7 233,3	207,0	5,5
7.	240	500	28,5 29,6 27,6	175,1 162,4 186,7	174,7	7,0
8.	60	650	25,3 25,5 25,6	222,2 218,8 217,1	219,4	1,5
9.	15	550	24,3 23,4 23,2	240,9 259,8 264,3	255,0	7,2
10.	30	550	22,0 21,7 22,9	295,9 302,1 271,3	289,8	9,4

No.	Nitridasi		Hasil Uji Kekerasan			
	Waktu (menit)	Suhu Substrat (°C)	d ₁	KHN	KHN rerata	δ KHN
11.	40	550	22,6 23,4 22,8	278,5 259,8 273,7	270,7	5,6
12.	50	550	23,5 23,3 23,5	257,6 262,0 257,6	259,1	1,5
13.	30	500	24,6 24,5 24,6	235,1 237,0 235,1	235,7	1,6
14.	120	550	24,5 25,0 23,4	237,0 227,6 259,8	241,5	9,7
15.	240	550	25,4 25,8 25,4	220,5 213,7 220,5	218,2	2,3
16.	-	-	30,3 31,6 28,9	154,9 142,4 170,3	155,9	8,4



LAMPIRAN III

DATA DIFRAKSI SINAR-X



file No. = 61

[97-12-08 15:12]

< 30

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X-ray: Co 30 kV 30

 slit : (SS) 1 deg
 (DS) 1 deg
 (RS) . 8 mm

 PEAK DATA OUTPUT (DP-61)

 date & time 97-12-09 08:55
 operator

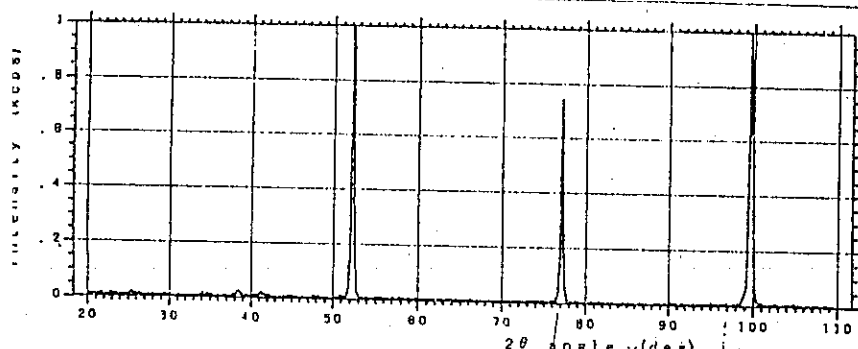
Raw Data

file no. : 61
 comment : BLANK
 date & time : 97-12-08 15:12

peak no.	2θ (deg)	d (Å)	I/I ₁	FWHM (deg)	intensity (kcps)	integrated int (kcps*deg)
1	99.495	1.1720	75	0.673	0.719	0.4663
2	98.628	1.1796	1	0.375	0.014	0.0081
3	76.951	1.4376	33	0.660	0.320	0.2082
4	52.130	2.0357	100	0.650	0.963	0.5951
5	51.046	2.0759	1	1.564	0.009	0.0322

#Strongest 3 peaks

no.	peak no.	2θ (deg)	d (Å)	I/I ₁	FWHM (deg)	intensity (kcps)	integrated int (kcps*deg)
1	4	52.130	2.0357	100	0.650	0.963	0.5951
2	1	99.495	1.1720	75	0.673	0.719	0.4663
3	3	76.951	1.4376	33	0.660	0.320	0.2082



file No. = 59

[97-12-08 14:22]

< 20-23 B

X-ray: Co 30 kV 30 m

slit : (SS) 1 deg
(DS) 1 deg
(RS) . 8 mm

PEAK DATA OUTPUT (DP-61)

date & time 97-12-09 08:53
operator

Raw Data

file no. : 59
comment : 450 °C.
date & time : 97-12-08 14:22

peak no.	2θ (deg)	d (Å)	I/I1	FWHM (deg)	intensity (kcps)	integrated int (kcps*deg)
1	99.603	1.1710	78	0.662	0.719	0.4605
2	98.628	1.1796	2	0.367	0.017	0.0079
3	77.059	1.4359	30	0.643	0.274	0.1745
4	52.130	2.0357	100	0.648	0.916	0.5665
5	38.365	2.7222	1	0.867	0.011	0.0177

Strongest 3 peaks

no.	peak no.	2θ (deg)	d (Å)	I/I1	FWHM (deg)	intensity (kcps)	integrated int (kcps*deg)
1	4	52.130	2.0357	100	0.648	0.916	0.5665
2	1	99.603	1.1710	78	0.662	0.719	0.4605
3	3	77.059	1.4359	30	0.643	0.274	0.1745

 (PEAK DATA OUTPUT (DP-61))

date & time 97-12-09 08:2
 operator

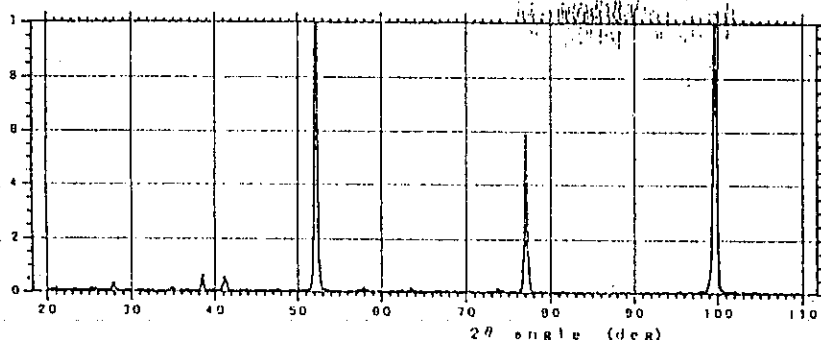
Raw Data

file no. : 46
 comment : 500 °C
 date & time : 97-12-04 12:33

peak no.	2θ (deg)	d (Å)	I/I ₁	FWHM (deg)	intensity (kcps)	integrated int (kcps*deg)
1	100.254	1.1655	1	0.124	0.011	0.0000
2	99.495	1.1720	20	0.665	0.393	0.2518
3	98.628	1.1796	0	0.347	0.009	0.0044
4	77.059	1.4359	10	0.654	0.205	0.1329
5	57.658	1.8550	1	1.517	0.011	0.0216
6	53.431	1.9896	1	1.084	0.013	0.0127
7	52.239	2.0318	100	0.643	1.986	1.2241
8	51.263	2.0677	1	0.791	0.015	0.0047
9	50.179	2.1094	1	0.845	0.016	0.0095
10	44.001	2.3877	0	1.030	0.008	0.0168

#Strongest 3 peaks

no.	peak no.	2θ (deg)	d (Å)	I/I ₁	FWHM (deg)	intensity (kcps)	integrated int (kcps*deg)
1	7	52.239	2.0318	100	0.643	1.986	1.2241
2	2	99.495	1.1720	20	0.665	0.393	0.2518
3	4	77.059	1.4359	10	0.654	0.205	0.1329



file No. = 80

[97-12-08 14:48]

< 24

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X-ray: Co 30 kV 30 r

slit : (SS) 1 deg
(DS) 1 deg
(RS) 6 mm

PEAK DATA OUTPUT (DP-61)

date & time 97-12-09 08:54
operator

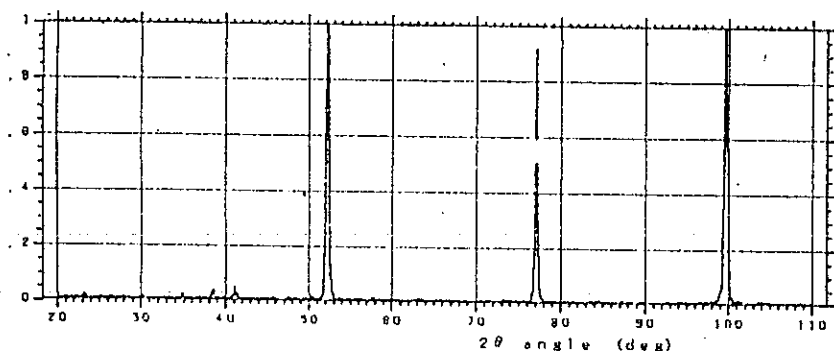
Raw Data

file no. : 60
comment : 550 °C
date & time : 97-12-08 14:48

peak no.	2θ (deg)	d (Å)	I/I1	FWHM (deg)	intensity (kcps)	integrated int (kcps*deg)
1	99.495	1.1720	61	0.660	0.729	0.4657
2	98.736	1.1786	1	0.358	0.012	0.0063
3	77.059	1.4359	21	0.651	0.245	0.1578
4	73.808	1.4896	1	0.831	0.009	0.0124
5	63.402	1.7022	1	0.686	0.008	0.0107
6	57.766	1.8518	1	0.813	0.009	0.0127
7	52.130	2.0357	100	0.661	1.188	0.7351
8	41.183	2.5432	2	0.710	0.020	0.0180
9	38.474	2.7148	1	0.710	0.017	0.0144
10	27.852	3.7166	1	0.686	0.009	0.0076

#Strongest 3 peaks

no.	peak no.	2θ (deg)	d (Å)	I/I1	FWHM (deg)	intensity (kcps)	integrated int (kcps*deg)
1	7	52.130	2.0357	100	0.661	1.188	0.7351
2	1	99.495	1.1720	61	0.660	0.729	0.4657
3	3	77.059	1.4359	21	0.651	0.245	0.1578



file No. = 58
 [97-12-08 13:51]
 < 22 B >
 X-ray: Co 30 kV 30 mA
 slit : (SS) 1 deg
 (DS) 1 deg
 (RS) .8 mm

PEAK DATA OUTPUT (DP-61)

date & time 97-12-09 08:52
 operator

Raw Data

peak no.	2θ (deg)	d (Å)	I/I1	FWHM (deg)	intensity (kcps)	integrated int (kcps*deg)
1	99.495	1.1720	65	0.660	0.643	0.4106
2	98.628	1.1796	1	0.303	0.014	0.0053
3	77.059	1.4359	32	0.645	0.318	0.2020
4	52.130	2.0357	100	0.661	0.995	0.6190
5	41.075	2.5496	1	0.867	0.013	0.0168
6	38.474	2.7148	1	0.795	0.011	0.0128

#Strongest 3 peaks

no.	peak no.	2θ (deg)	d (Å)	I/I1	FWHM (deg)	intensity (kcps)	integrated int (kcps*deg)
1	4	52.130	2.0357	100	0.661	0.995	0.6190
2	1	99.495	1.1720	65	0.660	0.643	0.4106
3	3	77.059	1.4359	32	0.645	0.318	0.2020

LAMPIRAN IV

CONTOH PENGİNDEKSAN STRUKTUR KRİSRTAL

Data XRD untuk baja karbon sebelum dinitridasi:

Peak No.	2θ (deg)	d (Å)	$\sin^2 \theta$	I/I_1
4	52,130	2,0357	0,1931	100
3	76,951	1,4376	0,3871	33
1	99,495	1,1720	0,5825	75

$$\frac{\sin^2 \theta_1}{\sin^2 \theta_2} = \frac{0,1931}{0,3871} = 0,4988 \approx 0,5 \approx \frac{2}{4}$$

$$\frac{\sin^2 \theta_2}{\sin^2 \theta_3} = \frac{0,3871}{0,5825} = 0,6645 \approx 0,66 \approx \frac{4}{6}$$

Dengan menggunakan tabel indeks Miller pada lampiran VIII maka didapatkan bidang-bidang hkl sebagai berikut:

2θ (deg)	$(h^2 + k^2 + l^2)$	(hkl)
52,130	2	(110)
76,951	4	(200)
99,495	6	(211)

Ini menunjukkan bahwa bidang hkl yang direfleksikan dimiliki oleh struktur kristal bcc.

LAMPIRAN V

PERHITUNGAN PARAMETER KISI UNTUK SUBSTRAT BAJA KARBON YANG TIDAK DINITRIDASI:

Data yang diperoleh:

2θ (deg)	d (Å)	Bidang (hkl)
52,130	2,0357	(110)
76,951	1,4376	(200)
99,495	1,1720	(211)

Dengan menggunakan persamaan (2-14)

$$\frac{1}{d^2} = \frac{(h^2 + k^2 + l^2)}{a^2}$$

$$\frac{1}{(2,0357)^2} = \frac{(1^2 + 1^2 + 0)}{a^2}$$

$$0,2413 = 2/a^2$$

$$a = 2,8789$$

$$\frac{1}{(1,4376)^2} = \frac{(2^2 + 0 + 0)}{a^2}$$

$$0,4838 = 2/a^2$$

$$a = 2,8753$$

$$\frac{1}{(1,1720)^2} = \frac{(2^2 + 1^2 + 1^2)}{a^2}$$

$$0,7280 = 6/a^2$$

$$a = 2,8708$$

sehingga parameter kisi yang diperoleh adalah:

Bidang (hkl)	d (Å)	a (Å)
(110)	2,0357	2,8789
(200)	1,4376	2,8752
(211)	1,1720	2,8708

LAMPIRAN VI

PERHITUNGAN PARAMETER KISI (c)

Contoh untuk substrat baja karbon rendah yang dinitridasi pada suhu substrat 550°C dengan waktu nitridasi 1 jam.

2θ (deg)	d (Å)	Bidang (hkl)
52,130	2,0357	(110)
76,951	1,4376	(200)
99,495	1,1720	(211)

Dengan menggunakan persamaan (2-15)

$$\frac{1}{d^2} = \frac{h^2 + k^2}{a^2} + \frac{l^2}{c^2}$$

diperoleh tiga buah persamaan dengan dua variabel:

$$\frac{1}{(2,0357)^2} = \frac{2}{a^2} \quad (1)$$

$$\frac{1}{(1,4359)^2} = \frac{4}{a^2} \quad (2)$$

$$\frac{1}{(1,1720)^2} = \frac{5}{a^2} + \frac{1}{c^2} \quad (3)$$

Dari persamaan (1) dan (2) diperoleh:

$$0,2413 = \frac{2}{a^2} \quad (1)$$

$$0,4850 = \frac{4}{a^2} \quad (2)$$

$$- 0,2437 = - \frac{2}{a^2}$$

$$a^2 = 8,2068 \quad (4)$$

$$a = 2,8647$$

Dari persamaan (2) dan (3)

$$0,4850 = \frac{4}{a^2} \quad (2)$$

$$0,7280 = \frac{5}{a^2} + \frac{1}{c^2} \quad (3)$$

$$-0,2430 = -\frac{1}{a^2} - \frac{1}{c^2} \quad (5)$$

Persamaan (4) disubstitusi ke persamaan (5):

$$-0,2430 = -\frac{1}{8,2068} - \frac{1}{c^2} \quad (5)$$

$$c^2 = 8,2542$$

$$c = 2,8730$$

Karena $a \neq c$ maka struktur kristalnya adalah bct.

HASIL PERHITUNGAN PARAMETER KISI (c) UNTUK VARIASI SUHU SUBSTRAT DENGAN WAKTU PROSES 1 JAM

Suhu substrat (°C)	KHN rata-rata (gf/μm ²)	Parameter kisi (c) (Å)
450	(211,0 ± 2,7)	2,85819
500	(230,2 ± 4,9)	2,86746
550	(244,0 ± 7,9)	2,87289
600	(221,6 ± 0,6)	2,87289

CRYSTAL STRUCTURE DATA

(S.B. The symbols A1, B1, etc.. in this Appendix are those used in *Strukturbericht* to designate certain common structural types.)

Element and modification	Type of structure	Lattice parameters (Å)		c or axial angle	Temperature for which constants apply	Distance of closest approach (Å)
		a	b			
Hydrogen, para	Hexagonal	3.76	...	6.13	-271°C	
Illinium	See Promethium					
Indium	FC tetragonal, A6	4.594	...	4.951	20°C	3.25
Iodine	Orthorhombic	4.787	7.266	9.793	20°C	2.71
Iridium	FCC, A1	3.8389	...	...	20°C	2.714
Iron, α^*	BCC, A2	2.8664	...	...	20°C	2.481
γ (extrapolated)	FCC, A1	3.571	...	...	20°C	2.525
γ (908-1403°C)	...	3.656	...	...	950°C	2.585
δ (>1403°C)	BCC, A2	2.94	...	...	1425°C	2.54
Krypton	FCC, A1	5.69	...	...	-191°C	4.03
Lanthanum, α^*	HCP, A3	3.762	...	6.075	20°C	3.74
β	FCC, A1	5.307	...	...	Room	3.762
Lead	FCC, A1	4.9495	...	...	20°C	3.499
Lithium	BCC, A2	3.5089	...	...	20°C	3.039
(cold worked)	FCC, A1	4.40	...	...	-195°C	3.11
	HCP, A3 (?)	3.08	...	4.82	-195°C	3.08
Lutecium	HCP, A3	3.516	...	5.570	20°C	3.446
Magnesium	HCP, A3	3.2092	...	5.2103	20°C	3.196
Manganese, α^*	Cubic, A12	8.912	...	...	20°C	2.24
β (727-1095°C)	Cubic, A13	6.313	...	...	Room	2.373
γ (1095-1133°C)	FC tetragonal, A6	3.782	...	3.533	Room	2.587
δ (>1133°C)						
Masurium	(Technetium)					
Mercury	Rhombohedral, A11	2.006	...	70°31.7'	-46°C	3.006
Molybdenum	BCC, A2	3.1466	...	...	20°C	2.725
Neodymium, α^*	HCP, A3 (?)	3.657	...	...	20°C	5.902
Neon	FCC, A1	4.51	...	...	-268°C	3.21
Neptunium						
Nickel	FCC, A1	3.5238	...	...	20°C	2.491
(unstable, with H ₂ or N ₂)	HCP, A3	2.66	...	4.32	Room	
(unstable) (?)	Tetragonal, D ₁₇ 14	4.00	...	3.77	Room	
Niobium	BCC, A2	3.3007	...	...	...	2.859
Nitrogen, α	Cubic	5.67	...	...	-252°C	1.06
β	Hexagonal	4.04	...	6.60	-234°C	
Osmium	HCP, A3	2.7333	...	4.3191	...	2.575
Oxygen, α	Orthorhombic	5.51	3.83	3.45	-252°C	
β	Rhombohedral	6.20	...	99.1°	-238°C	
γ	Cubic	6.84	...	...	-225°C	
Palladium	FCC, A1	3.8902	...	...	20°C	2.750
Phosphorus, white	Cubic	7.18	...	...	-35°C	
Black	Orthorhombic, A16	3.32	4.39	10.52	Room	2.17
Platinum	FCC, A1	3.9237	...	...	20°C	2.775
Plutonium						
Polonium, α	Simple cubic	3.345	...	...	...	3.35
β (above 75°C)	Simple rhombohedral	3.359	...	98°13'	...	4.40
Potassium	BCC, A2	5.344	...	...	20°C	4.627
Praseodymium, α^*	HCP, A3 (?)	3.669	...	5.920	20°C	3.640
β	FCC, A1	5.161	...	...	Room	3.649
Promethium						
Protactinium						
Radium						
Radon						

INDEKS MILLER

QUADRATIC FORMS OF MILLER INDICES

$h^2 + k^2 + l^2$	Cubic				Hexagonal	
	hkl				$h^2 + hk + k^2$	hk
	Simple	Face-centered	Body-centered	Diamond		
1	100				1	10
2	110		110		2	
3	111	111		111	3	11
4	200	200	200		4	20
5	210				5	
6	211		211		6	
7					7	21
8	220	220	220	220	8	
9	300, 221				9	30
10	310		310		10	
11	311	311		311	11	
12	222	222	222		12	22
13	320				13	31
14	321		321		14	
15					15	
16	400	400	400	400	16	40
17	410, 322				17	
18	411, 330		411, 330		18	
19	331	331		331	19	32
20	420	420	420		20	
21	421				21	41
22	332		332		22	
23					23	
24	422	422	422	422	24	
25	500, 430				25	50
26	510, 431		510, 431		26	
27	511, 333	511, 333		511, 333	27	33
28					28	42
29	520, 432				29	
30	521		521		30	
31					31	51
32	440	440	440	440	32	
33	522, 441				33	
34	530, 433		530, 433		34	
35	531	531		531	35	
36	600, 442	600, 442	600, 442		36	60
37	610				37	43
38	611, 532		611, 532		38	
39					39	52
40	620	620	620	620	40	
41	621, 540, 443				41	
42	541		541		42	
43	533	533		533	43	61
44	622	622			44	
45	630, 542				45	
46	631		631		46	
47					47	
48	444	444	444	444	48	44
49	700, 632				49	70, 53
50	710, 550, 543		710, 550, 543		50	
51	711, 551	711, 551		711, 551	51	
52	640	640	640		52	62
53	720, 641				53	
54	721, 633, 552		721, 633, 552		54	
55					55	
56	642	642	642	642	56	
57	722, 544				57	71
58	730		730		58	
59	731, 553	731, 553		731, 553	59	

SPESIFIKASI PERALATAN

Osilator Radio Frekuensi (RF)	
Buatan	: PPNY BATAN Yogyakarta
Tegangan input/frekuensi	: 220 - 240 V AC/50 Hz
Tegangan output maksimum	: 3000 V
Daya output	: 375 W
Arus output	: 176 mA
Jenis komponen utama	: Tabung Trioda QB 3/300
Pengukur Kevakuman	
Nama alat	: Thermistor/Ionization Gauge
Buatan	: Dynavac PTY LTD. Australia
Jangkauan	: 10 ⁻⁷ - 10 Torr
Tegangan input/frekuensi	: 230 - 250 V AC/50 Hz
Arus input	: 16 mA
Pengukur Suhu	
Nama alat	: Digital Thermometer 2168
Buatan	: John Fluke MFG. Co. USA
Jangkauan	: -200 °C - 1300 °C
Tegangan input/frekuensi	: 220 - 240 V AC/50 Hz
Jenis termokopel	: Jenis K
Pengukur Aliran Gas	
Nama alat	: Flowmeter 7449 T
Buatan	: Matheson USA
Jangkauan	: 0,1 - 5 liter/menit
Tekanan maksimum aliran	: 17 Bar
Variac	
Nama alat	: Regulator Model 3 KM
Buatan	: Matsunaga MFG. Co. Ltd. Japan
Tegangan input/frekuensi	: 110 - 220 V AC/50 - 60 Hz
Tegangan output maksimum	: 3000 V