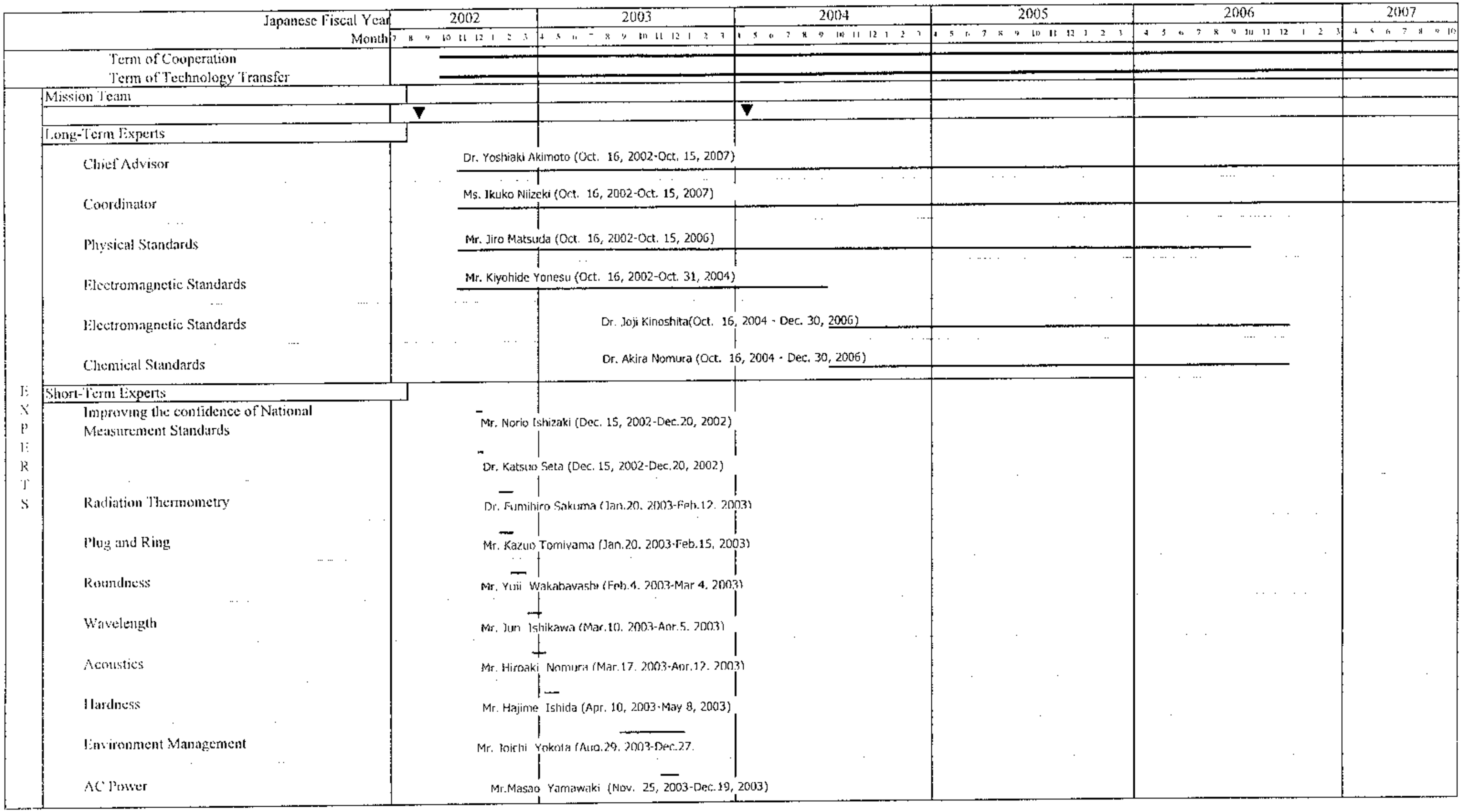
Annex 10: List of the Dispatched Japanese experts

Annex 10 List of the Dispatched Japanese Experts



Term of Cooperation	
Term of Technology Transfer	
EXPERTS	
Mission Team	▼ ▼
Long-Term Experts	
Chief Advisor	Dr. Yoshiaki Akimoto (Oct. 16, 2002-Oct. 15, 2007)
Coordinator	Ms. Ikuko Niizeki (Oct. 16, 2002-Oct. 15, 2007)
Physical Standards	Mr. Jiro Matsuda (Oct. 16, 2002-Oct. 15, 2006)
Electromagnetic Standards	Mr. Kiyohide Yonesu (Oct. 16, 2002-Oct. 31, 2004)
Electromagnetic Standards	Dr. Joji Kinoshita(Oct. 16, 2004 - Dec. 30, 2006)
Chemical Standards	Dr. Akira Nomura (Oct. 16, 2004 - Dec. 30, 2006)
Short-Term Experts	
Improving the confidence of National Measurement Standards	Mr. Norio Ishizaki (Dec. 15, 2002-Dec.20, 2002)
	Dr. Katsuo Seta (Dec. 15, 2002-Dec.20, 2002)
Radiation Thermometry	Dr. Fumihiro Sakuma (Jan.20, 2003-Feb.12, 2003)
Plug and Ring	Mr. Kazuo Tomiyama (Jan.20, 2003-Feb.15, 2003)
Roundness	Mr. Yuji Wakabayashi (Feb.4, 2003-Mar 4, 2003)
Wavelength	Mr. Jun Ishikawa (Mar.10, 2003-Apr.5, 2003)
Acoustics	Mr. Hiroaki Nomura (Mar.17, 2003-Apr.12, 2003)
Hardness	Mr. Hajime Ishida (Apr. 10, 2003-May 8, 2003)
Environment Management	Mr. Toichi Yokota (Aug.29, 2003-Dec.27.
AC Power	Mr.Masao Yamawaki (Nov. 25, 2003-Dec.19, 2003)

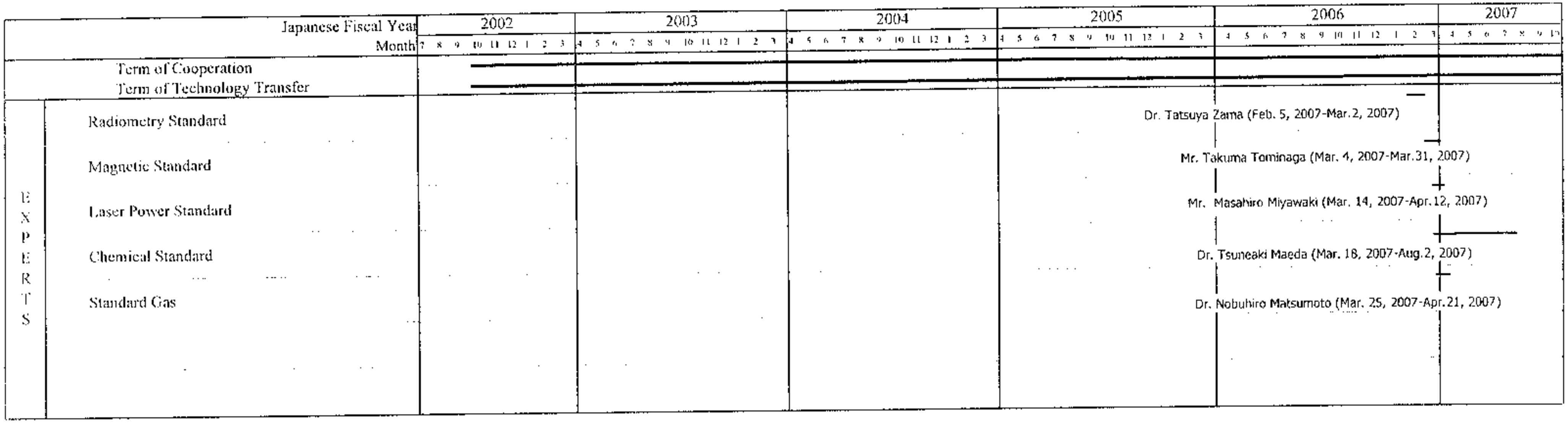
Annex 10 List of the Dispatched Japanese Experts

	Japanese Fiscal Year	2002	2003	2004	2005	2006	2007
	Month	7 8 9 10 11 12 1 2 3	4 5 6 7 8 9 10 11 12 1 2 3	4 5 6 7 8 9 10 11 12 1 2 3	4 5 6 7 8 9 10 11 12 1 2 3	4 5 6 7 8 9 10 11 12 1 2 3	4 5 6 7 8 9 10
	Term of Cooperation						
	Term of Technology Transfer						
EXPERTS	Improving the confidence of National Measurement Standards		Ms. Hiromi Murata (Jan.18. 2004-Jan.24. 2004)				
			Mr. Yuji Neagari (Jan. 18, 2004-Jan.24, 2004) (IA)apan Budget)				
			Dr. Atsushi Onae (Jan.18. 2004-Jan.28. 2004)				
			Mr. Takeshi Fujimori (Jan. 18, 2004-Jan.30,				
	DC High Voltage		Mr.Tomeji Iguchi (Feb. 2, 2004-Feb. 27, 2004)				
	Calibration Procedure		Mr. Ichiro Fujima (Feb. 15, 2004-Feb. 21,				
	CMM		Dr. Sonko Osawa (Feb. 22, 2004-Mar. 20,				
	RF Power/Voltage		Ms. Keiko Sato (Mar. 7, 2004-Apr.24, 2004)				
	Humidity		Dr. Chiharu Takahashi (Apr. 4, 2004-Apr.12,				
	Roughness		Dr. Kazuya Naoi (Aug. 3, 2004-Aug.24, 2004)				
	Calibration Procedure		Mr. Keisaburo Kano (Sep. 1, 2004-Sep.30, 2004)				
	Improving the confidence of National Measurement Standards		Mr. Eizo Yamasaki (Sep. 27, 2004-Oct.1, 2004)				
			Dr. Koichiro Hattori (Sep. 27, 2004-Oct.1, 2004)				
	Environment Management		Mr. Joichi Yokota (Dec. 16, 2004-Apr.15, 2005)				
	Angle Standard		Dr. Tsukasa Watanabe (Jan. 19, 2005-Feb. 18, 2005)				
	RF Attenuation		Mr. Shigeru Igarashi (Feb. 28, 2005-Mar. 30, 2005)				
	Surveillance on Wavelength Standard and Acoustics Standard			Mr. Hiromi Ishige (Jun. 9, 2005-Jun.17, 2005)			
	Flatness Standard			Dr. Toshiyuki Takatsuji (Jun. 26, 2005-Jul.21, 2005)			
	Calibration Procedure			Dr. Tsukasa Watanabe (Sep. 12, 2005-Oct.1, 2005)			

Annex 10 List of the Dispatched Japanese Experts

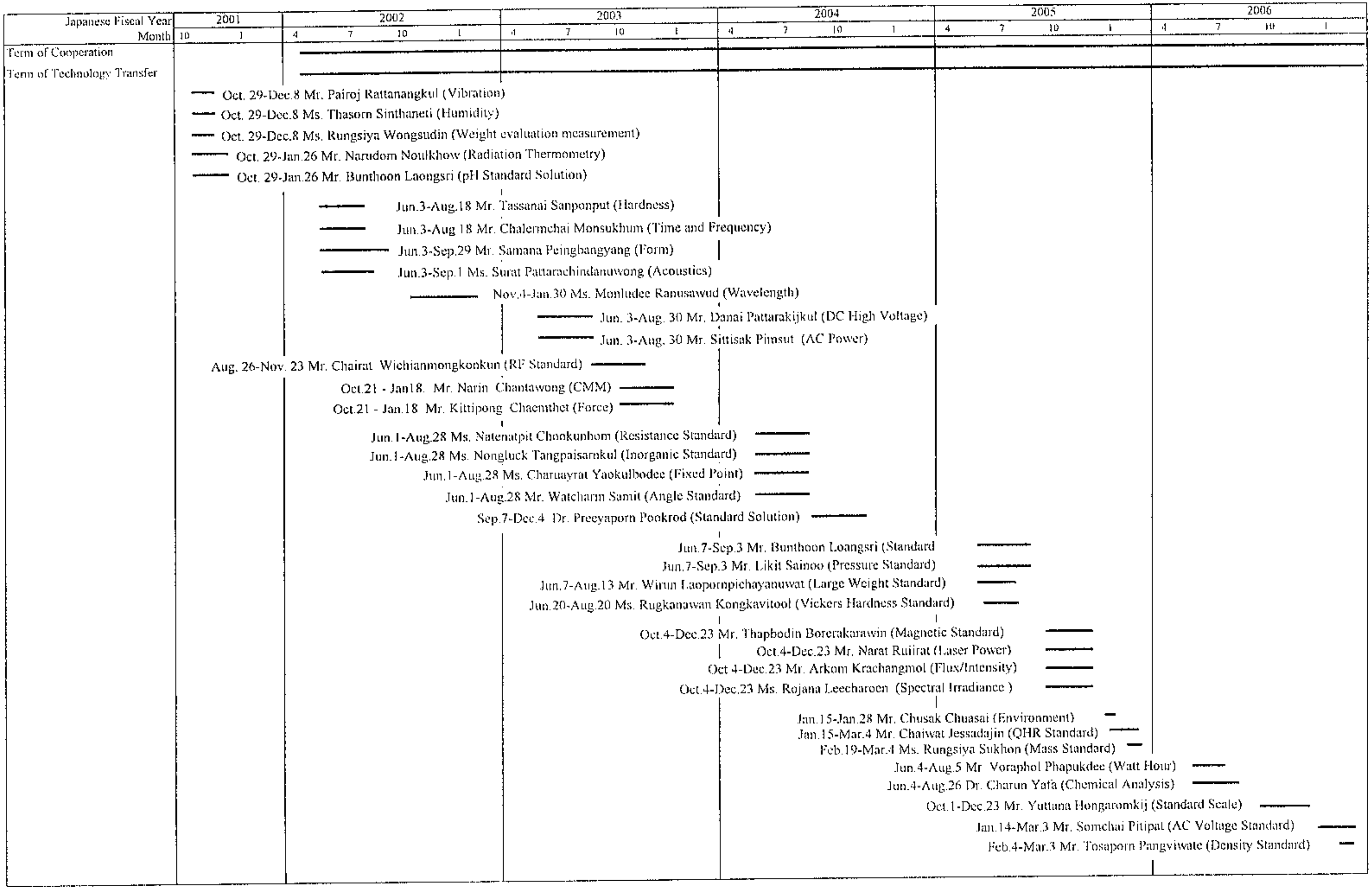
	Japanese Fiscal Year	2002 / 2003 / 2004 / 2005 / 2006 / 2007
	Term of Cooperation	
	Term of Technology Transfer	
E X P E R T S	Acceleration of Vibration Standard	Mr. Akihiro Ota (Nov. 6,2005-Dec.3, 2005)
	Accreditation on Form Standard	Mr. Takashi Horaguchi (Nov. 20, 2005-Nov.27, 2005)
		Mr. Masami Horita (Nov. 20, 2005-Nov.27, 2005)
		Mr. Isao Fujita (Nov. 20, 2005-Nov.27, 2005) (IA Japan Budget)
	Time and Frequency Standard	Dr. Tomonari Suzuyama (Nov. 23, 2005-Dec.22, 2005)
	Hydrogen Ion Activity	Dr. Susumu Nakamura (Feb. 26, 2006-Mar.25, 2006)
	Force Standard	Dr. Toshiyuki Hayashi (Mar. 6, 2006-Mar.18, 2006)
	Large Weight Standard	Dr. Jianxin Sun (Mar. 9, 2006-Mar.18, 2006) (NMIJ Budget)
	Humidity Standard	Mr. Yoshihiro Imura (Mar. 19, 2006-Apr.8, 2006)
	Inorganic Standard	Dr. Akiharu Hioki (Jul. 31, 2006-Aug.19, 2006)
	Standard Solutions	Mr. Katsuhiko Higuchi (Jul. 31, 2006-Aug.26, 2006)
	Calibration Procedure	Mr. Ichiro Fujima (Oct. 29, 2006-Nov.15, 2006)
	Accreditation (Manual Assessment)	Mr. Isao Fujita (Jan. 10, 2007-Feb.10, 2007)
		Mr. Takashi Horaguchi (Jan. 10, 2007-Jan.27, 2007)
	Accreditation (Technical Assessment on pH Standard)	Dr. Igor Maksimov (Jan. 14, 2007-Jan.20, 2007) (NMIJ Budget)
	Accreditation (Technical Assessment on DC High Voltage Standard)	Mr. Takehiro Nakamura (Jan. 21, 2007-Jan.27, 2007)
	Accreditation (Technical Assessment on Vibration Standard)	Dr. Takashi Usuda (Jan. 28, 2007-Feb.3, 2007)
	Accreditation (Technical Assessment on Time & Frequency Standard)	Dr. Takeshi Ikegami (Feb. 4, 2007-Feb.10, 2007)
	Photometry Standard	Mr. Hiroshi Shitomi (Feb. 5, 2007-Mar.2, 2007)

Annex 10 List of the Dispatched Japanese Experts



Annex 11: List of the C/P Trained in Japan

Annex 11 List of the C/P Trained in Japan



Oct. 29-Dec.8 Mr. Pairoj Rattanangkul (Vibration)
Oct. 29-Dec.8 Ms. Thasorn Sinthaneti (Humidity)
Oct. 29-Dec.8 Ms. Rungsiya Wongsudin (Weight evaluation measurement)
Oct. 29-Jan.26 Mr. Narudom Noulkhow (Radiation Thermometry)
Oct. 29-Jan.26 Mr. Bunthoon Laongsri (pH Standard Solution)
Jun.3-Aug.18 Mr. Tassanai Sanponput (Hardness)
Jun.3-Aug 18 Mr. Chalermchai Monsukhum (Time and Frequency)
Jun.3-Sep.29 Mr. Samana Peingbangyang (Form)
Jun.3-Sep.1 Ms. Surat Pattarachindanuwong (Acoustics)
Nov.4-Jan.30 Ms. Monludee Ranusawud (Wavelength)
Jun. 3-Aug. 30 Mr. Danai Pattarakijkul (DC High Voltage)
Jun. 3-Aug. 30 Mr. Sittisak Pimsut (AC Power)
Aug. 26-Nov. 23 Mr. Chairat Wichianmongkonkun (RF Standard)
Oct.21 - Jan18. Mr. Narin Chantawong (CMM)
Oct.21 - Jan.18 Mr. Kittipong Chaemthet (Force)
Jun.1-Aug.28 Ms. Natenatpit Chookunhom (Resistance Standard)
Jun.1-Aug.28 Ms. Nongluck Tangpaisarnkul (Inorganic Standard)
Jun.1-Aug.28 Ms. Charuayrat Yaokulbodee (Fixed Point)
Jun.1-Aug.28 Mr. Watcharin Samit (Angle Standard)
Sep.7-Dec.4 Dr. Preeyaporn Pookrod (Standard Solution)
Jun.7-Sep.3 Mr. Bunthoon Loangsri (Standard
Jun.7-Sep.3 Mr. Likit Sainoo (Pressure Standard)
Jun.7-Aug.13 Mr. Wirun Laopornpichayanuwat (Large Weight Standard)
Jun.20-Aug.20 Ms. Rugkanawan Kongkavitool (Vickers Hardness Standard)
Oct.4-Dec.23 Mr. Thapbodin Borerakarawin (Magnetic Standard)
Oct.4-Dec.23 Mr. Narat Ruirat (Laser Power)
Oct 4-Dec.23 Mr. Arkom Krachangmol (Flux/Intensity)
Oct.4-Dec.23 Ms. Rojana Leecharoen (Spectral Irradiance)
Jan.15-Jan.28 Mr. Chusak Chuasai (Environment)
Jan.15-Mar.4 Mr. Chaiwat Jessadajin (QHR Standard)
Feb.19-Mar.4 Ms. Rungsiya Sukhon (Mass Standard)
Jun.4-Aug.5 Mr Voraphol Phapukdee (Watt Hour)
Jun.4-Aug.26 Dr. Charun Yafa (Chemical Analysis)
Oct.1-Dec.23 Mr. Yuttana Hongaromkij (Standard Scale)
Jan.14-Mar.3 Mr. Somchai Pitipat (AC Voltage Standard)
Feb.4-Mar.3 Mr. Tosaporn Pangviwate (Density Standard)

Annex 12: List of Equipment by Japanese side

Annex 12: List of Equipment by Japanese side

	Item	Product	Date	Quantity	Amount	Location	Purchase	Disposal
1	Notebook Computer	IBM Think Pad R51	2004/11/3	1	58,743.00 B	Project	Local	0
2	PC Software	MS Office XP Pro (OEM)	2004/11/3	1	23,540.00 B	Project	Local	0
3	PC Software	Adobe Acrobat 7.0 Standard	2005/2/22	1	19,923.40 B	Project	Local	0
4	Laser Attachment for quick alignment of ELCOMAT 2000/3000 with power supply	Moller Wedel Optical Brand	8/3/2005	1	84,530.00 B	Project	Local	0
5	Coaxial Cable	Model: TCF358 FF1000 (1m) with Connector	8/3/2005	2	38,500 JPY	Project	Japan	0
6	Laser Color Printer	Canon LBP-2410, LLTA 000656	2005/3/23	1	25,900.00 B	Project	Local	0
7	Micro Drive	IBM IGB+Socket PCMCIA	2005/3/24	1	9,590.00 B	Project	Local	0
8	PC Software	Adobe Acrobat 7.0 Standard	2005/3/29	1	19,923.50 B	Project	Local	0
9	PC Software	Microsoft Access 2003 Full Pack	2005/3/29	1	15,921.75 B	Project	Local	0
10	PC Software	Microsoft Office Visio Pro 2003 Full Pack	2005/3/29	2	44,876.00 B	Project	Local	0
11	PC Software	Yomitorikakumei	2005/3/29	1	9,095.00 B	Project	Local	0
12	Reference Flat	FUJINON FL0079	27/6/2005	1	81,000.00 B	Project	Local	0
13	CASIO Printer	Photo Card Processor Model	1/7/2005	1	29,500.00 B	Project	Local	0
14	PC Software	Microsoft Office 2003 Professional	2005/12/13	1	30,602.00 B	Project	Local	0
15	Precision Balance	PB1501-S EL.1126513027	20/1/2006	1	24,064.30 B	Project	Local	0
16	Print Server	Ethernet 10/100 Base-TX	27/3/2006	1	26,750.00 B	Project	Local	0
17	PC Software	File Maker Pro 8 (J)	27/3/2006	1	20,918.50 B	Project	Local	0
18	Scanner	Canon DR-3080 CII	27/3/2006	1	212,930.00 B	Project	Local	0
19	Office Desk	Bird 150×80×75	30/3/2006	1	7,900.00 B	Project	Local	0
20	Cabinet	SC2080D	31/3/2006	1	8,025.00 B	Project	Local	0

Annex 12: List of Equipment by Japanese side

	Item	Product	Date	Quantity	Amount	Location	Purchase	Disposal
21	Office Desk	STC150	31/3/2006	1	13,364.50 B	Project	Local	0
22	PC Harddisk	2.5 Sumsung 100 Gb	31/3/2006	1	11,342.00 B	Project	Local	0
23	Manual crimper, 11mm caps	Agilent 8710-0979	7/7/2006	1	7,070.00 B	Project	Local	0
24	Manual decrimpter, 11mm caps	Agilent 5181-1213	7/7/2006	1	8,521.00 B	Project	Local	0
25	JIS Handbook	Nondestructive inspection 2006, Japanese	8/11/2006	1	6,420.00 B	Project	Local	0
26	JIS Handbook	Heat Treatment, Japanese	8/11/2006	1	8,881.00 B	Project	Local	0
27	JIS Handbook	Heat Treatment, English	8/11/2006	1	20,330.00 B	Project	Local	0
28	Digital Flowmeter	J&W Scientific ADM1000	22/1/2007	1	95,000 JPY	Project	Japan	0
29	Brooks ROTAMETER	model 1024	9/4/2007	1	42,265.00 B	Project	Local	0
30	Valves	SS-43YFS2	13/4/2007	2	40,260 JPY	Project	Japan	0
31	Flowmeters with Stand 10-100ml/min	RK-1350-20-SS-1/4+1/8SWL-N2-100ML/MIN	13/4/2007	1	34,000 JPY	Project	Japan	0
32	Flowmeters with Stand 50-500ml/min	RK-1350-20-SS-1/4+1/8SWL-N2-500ML/MIN	13/4/2007	1	34,000 JPY	Project	Japan	0
33	Tool Kit	5180-4162	13/4/2007	1	45,000 JPY	Project	Japan	0
34	Barometric Pressure Data Logger Tr-73U	Barometric Pressure Data Logger Tr-73U	4/6/2007	1	14,552.00 B	Project	Local	0
35	GPIB Controller GPIB-USB-HS	GPIB Controller GPIB-USB-HS	4/6/2007	1	75,863.00 B	Project	Local	0

Phase2	932,841 B	3,481,624 JPY
	—	286,760 JPY
		3,768,384 JPY

※ 2007/6統制レート 3.732

Annex 13: List of Machinery and Equipment provided by Thai Side

Annex 13 List of Machinery and Equipment provided by Thai side

No.	Equipment Name	Manufacture/Model	Unit	Laboratory
1.	Standard Weight 1kg, 2kg, 5kg, 10kg, 20kg	OIML Class E1	1	Mass
2.	Cesium Clock Frequency Counter	HP 5071A HP 53132A	1 1	Time & Frequency
3.	Control Bath Voltmeter Calibrator Hydrogen generator	Hart Scientific 7041 Keithley 2182 Xitron Technologies 2000 Whatman 75-32	1 1 1 1	Chemical (pH & Metal) Standard Solution
4.	Temperature & Humidity Control	PGC 1355	1	Humidity
5.	Isolate table Volt Meter	Chuo Precision CRE Agilent 34420A	1 1	Radiation
6.	Frequency Counter	HP 53131A	1	Wavelength
7.	Weight Balance	Kern & Sohn GmbH PB4000-2	1	Hardness
8.	Long Gauge Blocks (steel) Granite Surface Plate	Schut Geometrische Meetech	1	Length
9.	High Voltage Resistor Divider	NML	1	Electrical
10.	Standard Indenter Class-4 type	Asahi Giken Co., Ltd.	1	Hardness
11.	Slide Table	Automation Service Co.	1	Temperature

No.	Equipment Name	Manufacture/Model	Unit	Laboratory
12.	Power Meter	432A	1	Time & Frequency
	Thermistor Mount		1	
	Cable		4	
	Torque Wrench (For SMA/PC3.5 mm)		1	
	Adapter N(f-f)		2	
	Adapter N(m-m)		2	
	Adapter N(m-f)		2	
	Adapter SMA(m)-N(f)		2	
	Adapter SMA(m-m)		4	
	Adapter SMA(f-f)		4	
	Adapter SMA(m-f)		2	
	DC Block N(m-f)		1	
	Power Splitter	11667A	1	
	Sweep Generator	83752	1	
	Isolator	I-A100,110-A1-(F3F3L1a)	2	
	Isolator	I-160,120-A1-(F3F3L1a)	2	
	Tuner	1643C	2	
	Low Pass Filter (100 MHz)		1	
	Low Pass Filter (1200 MHz)		1	
	Low Pass Filter (10 GHz)		1	
	Microwave Converter	11793A	1	
	Power meter	436A	1	
	Sensor module	11722A	1	
13.	Vickers Primary Machine	AKASHI / SHT 41	1	Hardness
	Micro – Vickers Testing Machine	MITUTOYO / HM-124	1	
	Micro – Vickers Testing Machine	Bariess / V-Test	1	
	Uncertified Hardness Block	ASAHI	1	
14.	Ball plate	KOBA	1	CMM
15.	Interface instrument	Toshiba & Ni	1	Wavelength
16.	High Precision Bath	Hart Scientific / 7008IR	1	Radiation
17.	Digital thermometer	Hart Scientific / 1529 Chub-E4	1	Chemical
	Milli-Q water purification	Millipore	1	

No.	Equipment Name	Manufacture/Model	Unit	Laboratory
18.	Coaxial Thermistor Mount	Agilent / 8478B	1	Time & Frequency
19.	Adapter Charger		1	Flow
20.	Stabilized He-Ne laser	Laser / SL03	1	Length
21.	Current Shunt Holt, HCS-110 mA to 20 A	HCS-110 mA to 20 A	1	Electrical
22.	Current Shunt Holt 50 A, HCS-1-AF/50A	HCS-1-AF / 50A	1	Electrical
23.	Current Shunt Holt 100 A, HCS-1-AF/100A	HCS-1-AF / 100A	1	Electrical
24.	Standard Resistor 1 Ohm	L&N / 4210	1	Electrical
25.	Standard Resistor 1 Ohm	L&N / 4210	1	Electrical
26.	Standard Resistor 1 Ohm	L&N / 4210	1	Electrical
27.	Spectrum Analyzer	HP 8590A	1	Electrical
28.	Oscilloscope	Tektronix / 11801B	1	Electrical
29.	Samping Head	Tektronix / SD26	1	Electrical
30.	Base With Only Plumbing	DH Instruments / PG102	1	Pressure
31.	RPM 4 Base	DH Instruments / A700k	1	Flow
32.	MOLBLOC Flow element	DH Instruments / 2E3-S	1	Flow
33.	Sony Magne scale GB-A	Sony / GB-A	1	Force & Torque
34.	Sony detectors	Sony / MD-21/GIBR	1	Force & Torque
35.	National Instrument	PCI-232/8,8 Ports 232	1	Mass
36.	Dead Weight Force Machine	DWM 1 kN	1	Force & Torque
37.	Dead Weight Force Machine	DWM 10 kN	1	Force & Torque
38.	Single Channel Amplifier for Frequency	SBM / ML 60 B	1	Force & Torque
39.	Single Channel Amplifier for StrainGauge	SBM / ML 30 B	1	Force & Torque
40.	Single Channel Amplifier for StrainGauge	SBM / ML 30 B	1	Force & Torque
41.	Communication Processor to Interface	SBM / CP22	1	Force & Torque
42.	Digital Automatic Refractometer	Bellingham / RFM 870	1	Chemical

No.	Equipment Name	Manufacture/Model	Unit	Laboratory
43.	Susceptability Reference with CER	Earth	1	Mass
44.	General EASTERN	Hart / SSM	1	Temperature
45.	Reference Pressure Monitor	DH Instruments / RPM4BG15k	1	Pressure
46.	Reference Standard Weight	Mettler-Toledo / Class E0; 1 kg	1	Mass
47.	Reference Standard Weight	Mettler-Toledo / Class E0; 1 kg	1	Mass
48.	Reference Standard Weight	Mettler-Toledo / Class E0; 1 kg	1	Mass
49.	Handy Logger	Handy / MR2041E	1	Mass
50.	Torque Transducer		1	Force & Torque
51.	Amplifier Supply 220 V.		1	Force & Torque
52.	Reference Torque Wrench	Kriechen / EB0148,DRS20Nm	1	Force & Torque
53.	Reference Torque Wrench	Kriechen / EB0153,DRS1000	1	Force & Torque
54.	Pneumatic Oscillator Vibration		1	Force & Torque
55.	Hardness Tester	Mitutoyo / 0055712-00	1	Force & Torque
56.	Monitor Computer	Samsung / Sync Master213T	1	Force & Torque
57.	Petrotest 26-0017 Specific Gravity Bath	26-0017	1	Chemical
58.	ASI Cooling Circulation Bath		1	Chemical
59.	Glass Bell Cover with High Grade Aluminum	Glass Bell	1	Mass
60.	Glass Bell Cover with High Grade Aluminum	Glass Bell	1	Mass
61.	Hart Carousel Holding Fixture	Hart / 2018	1	Temperature
62.	Chamber Ambient Stability Container		1	Mass

No.	Equipment Name	Manufacture/Model	Unit	Laboratory
*63.	Electric Aspirator	VE-11	2	Chemical
*64.	Dryer SG-WDN	AI-1241-010	1	Chemical
*65.	Dryer SD-50N	AI-1242-010	1	Chemical
*66.	Thermo Hygrograph	TH-26-MN7	6	Chemical
*67.	Ultrasonic Bath	STURDY / UC-150	1	Chemical
*68.	Dehumidifier	RAM 201	5	Chemical
*69.	Hotair Oven	MMM / Ecocell 111	2	Chemical
*70.	Tool Kit	AI-1133-010	3	Chemical
*71.	Autodessicator	Bossman / SBK98	2	Chemical
72.	Universal Length Measuring Machine	Mahr	1	Diameter
73.	Three flat test accessories	Fujinon	1	Flatness
74.	Power Sensor	8481A	1	RF Microwave
75.	Attenuator Switch	11713A	1	RF Microwave
76.	Programmable Step Attenuator	8494N	2	RF Microwave
77.	VSWR Bridge	ZRA	1	RF Microwave
78	Power Standard	-	1	AC Power
79.	GPIB-USB Converters	-	3	Photometry
80.	Thermohygrometers with Loggers	-	2	Photometry
90.	GPIB Cables	-	11	Photometry
91.	Height Gauge	-	1	Photometry
92.	Level Scope for Lamp Alignment	-	1	Photometry
93.	Telescope Stand (Custom Ordered)	-	1	Photometry
94.	Vernier Caliper 600 mm	-	1	Photometry
95.	Gas Regulator	-	1	Photometry
96.	Timer	-	1	Photometry
97.	Power Surge Protection Outlet	-	1	Photometry
98.	Serial PCI Interface	-	2	Photometry
99.	Handheld Digital Multimeter	-	1	Photometry

No.	Equipment Name	Manufacture/Model	Unit	Laboratory
100.	Piston Cylinder	Pressurement	1	Pressure
101.	Bath	Hart Scientific/7341	1	Temperature
102.	Gas Handling System	Hakuto	1	Temperature
103.	Pump	Pfeiffer/DUO20M	1	Temperature
104.	3 Axis NMR Probe Holder for Electromagnet System.	-	1	Magnetic
105.	Compaq DAQ Set	NI	1	Magnetic
106.	3 phase 380 V to 3 phase 220 V (Line to Line) Transformer.	-	1	Magnetic
107.	3 Axis Hall Probe Holder for Helmholtz coil System.	-	1	Magnetic
108.	GPIB to USB cable	NI	1	Magnetic

Annex 14: Annual Budget Allocation of NIMT

Annex 14 Annual Budget Allocation of NIMT

Description of Budget Allocated for JICA Experts per FY 2005

No.	Description	Qty	Unit	Budget	Total Budget	Budget segment of FY 2005
				Price/Unit		
1	Office equipment expenses (single payment)					
	- Employee Card	12	set	100.00	1,200.00	Administrative Work, Material and Expenditure Segment
	- Name Card	12	box	300.00	3,600.00	Administrative Work, Material and Expenditure Segment
	Total (1)				**4,800.00**	
2	Monthly expenses			Budget / Month	Budget FY 2005	(From October 2004 to September 2005)
	- Daily newspaper / Japanese Magazine	12	set	15,000.00	180,000.00	Administrative Work, Material and Expenditure Segment
	- Copy machine rental fee	12	set	10,000.00	120,000.00	Administrative Work, Material and Expenditure Segment
	- House keeper	12	pax	9,000.00	108,000.00	Administrative Work, Material and Expenditure Segment
	- Stationery	12	set	3,000.00	36,000.00	Administrative Work, Material and Expenditure Segment
	- Ink Catridge	12	set	2,500.00	30,000.00	Administrative Work, Material and Expenditure Segment
	- Postage charge	12	month	1,500.00	18,000.00	Administrative Work, Material and Expenditure Segment
	- Transparency / paper	12	set	1,000.00	12,000.00	Administrative Work, Material and Expenditure Segment
	- Battery	12	set	900.00	10,800.00	Administrative Work, Material and Expenditure Segment
	Total (2)				**514,800.00**	
	Grand total (1) + (2)				**519,600.00**	

Annex 14 Annual Budget Allocation of NIMT

Description of Budget Allocated for JICA Experts per FY 2006

No.	Description	Qty	Unit	Budget Price/Unit	Total Budget	Budget segment of FY 2006
1	Office equipment expenses (single payment)					
	- Employee Card	12	set	100.00	1,200.00	Administrative Work, Material and Expenditure Segment
	- Name Card	12	box	300.00	3,600.00	Administrative Work, Material and Expenditure Segment
	Total (1)				**4,800.00**	
2	Monthly expenses			Budget / Month	Budget FY 2006	(From October 2005 to September 2006)
	- Daily newspaper / Japanese Magazine	12	set	15,000.00	180,000.00	Administrative Work, Material and Expenditure Segment
	- Copy machine rental fee	12	set	10,000.00	120,000.00	Administrative Work, Material and Expenditure Segment
	- House keeper	12	pax	9,000.00	108,000.00	Administrative Work, Material and Expenditure Segment
	- Stationery	12	set	3,000.00	36,000.00	Administrative Work, Material and Expenditure Segment
	- Ink Catridge	12	set	2,500.00	30,000.00	Administrative Work, Material and Expenditure Segment
	- Postage charge	12	month	1,500.00	18,000.00	Administrative Work, Material and Expenditure Segment
	- Transparency / paper	12	set	1,000.00	12,000.00	Administrative Work, Material and Expenditure Segment
	- Battery	12	set	900.00	10,800.00	Administrative Work, Material and Expenditure Segment
	Total (2)				**514,800.00**	
	Grand total (1) + (2)				**519,600.00**	

Annex 15: Annual Budget Allocation for the Project from TICA

Annex 15 Annual Budget Allocation for the Project from TICA

Description of Subsidy Budget Allocated for JICA Experts, Other Expenses Segment FY 2005

Name of Expert & Position:	1. Dr. Y. AKIMOTO, Chief Advisor 2. Mr. J. MATSUDA, Standards on Physics 3. Dr. J. KINOSHITA, Standards on Electromagnetic 4. Dr. A. NOMURA, Standards on Chemical 5. Ms. I. NIIZEKI, Project Coordinator
Country:	Japan
To be under:	Ministry of Science and Technology, National Institute of Metrology (Thailand)
Working duration:	October 16, 2002 - October 15, 2007
Budget allocation duration:	October 1, 2004 - September 30, 2005 (12 months)

Description	Approval Rate of Ministry of Finance	Request for Allocation from Implementing Agency	Allocation Approval
Remuneration			
- Housing Allowance - BKK & Regional			
- First 15 days	Per paid but not exceed 1,600 THB/day		
- 15 days after	Per paid but not exceed 10,000 THB/month		
- Housing Allowance - Regional			
- First 30 days	Per paid but not exceed 1,000 THB/day		
- 30 days after	Per paid but not exceed 8,000 THB/month		
- Medical Fee	Per paid but not exceed 5,000 THB/year		
Temporary Payroll			
- Payroll for 1st class Secretary	8,610 THB/month	516,600.00	516,600.00
Social Security Subsidy			
October - September 5%	431 THB/month	25,860.00	25,860.00
- Payroll for 2nd class Secretary	6,590 THB/month		
Social Security Subsidy			
October - September 5%	330 THB/month		
- Payroll for Typist	4,700 THB/month		
Social Security Subsidy			
October - September 5%	235 THB/month		
- Payroll for Driver	4,700 THB/month	282,000.00	282,000.00
Social Security Subsidy			
October - September 5%	235 THB/month	14,100.00	14,100.00
Expsenses			
Travelling Expenditure			
- Upcountry housing expense (Expert)	Per paid but not exceed 1,600 THB/day		
- Travelling per dium (Expert)	500 THB/day		
- Transportation expense (Expert)	Per paid		
- Upcountry housing expense (Secretary)	Per paid but not exceed 1,200 THB/day		
- Travelling per dium (Secretary)	180 THB/day		
- Transportation expense (Secretary)	Per paid		
- Upcountry housing expense (Driver)	Per paid but not exceed 800 THB/day		

- Travelling per dium (Driver)	120 THB/day		
- Transportation expense (Driver)	Per paid		
- Vehicle maintenance	Per paid but not exceed 5,000 THB/year		
- Postage Charge	Per paid but not exceed 1,000 THB/year		
- Treating expense	Rate per Regulations of Disbursement of Treating Expense for Foreign B.E. 2536		
Materials Expenses			
- Gasoline	Per paid but not exceed 36,000 THB/year	180,000.00	180,000.00
- Car Materials	Per paid but not exceed 5,000 THB/year	25,000.00	25,000.00
- Office materials	Per paid but not exceed 6,000 THB/year	30,000.00	30,000.00
Total		**1,073,560.00**	**1,073,560.00**
Grand total allocated from TICA			**805,170.00**

Remark:

1. TICA approves budget allocation 75% of amount of request.
2. Amount approved can be averaged with the expenses, but not exceed the rate approved by the Ministry of Finance in each category, without request for approval to TICA.
3. When the approved amount in each category is not enough, please request for allocation approval as well as disburse the rest amount.

Annex 15 Annual Budget Allocation for the Project from TICA

Description of Subsidy Budget Allocated for JICA Experts, Other Expenses Segment FY 2006

Name of Expert & Position:	1. Dr. Y. AKIMOTO, Chief Advisor 2. Mr. J. MATSUDA, Standards on Physics 3. Dr. J. KINOSHITA, Standards on Electromagnetic 4. Dr. A. NOMURA, Standards on Chemical 5. Ms. I. NIIZEKI, Project Coordinator
Country:	Japan
To be under:	Ministry of Science and Technology, National Institute of Metrology (Thailand)
Working duration:	October 16, 2002 - October 15, 2007
Budget allocation duration:	October 1, 2005 - September 30, 2006 (12 months)

Description	Approval Rate of Ministry of Finance	Request for Allocation from Implementing Agency	Allocation Approval
Remuneration			
- Housing Allowance - BKK & Regional			
- First 15 days	Per paid but not exceed 1,600 THB/day		
- 15 days after	Per paid but not exceed 10,000 THB/month		
- Housing Allowance - Regional			
- First 30 days	Per paid but not exceed 1,000 THB/day		
- 30 days after	Per paid but not exceed 8,000 THB/month		
- Medical Fee	Per paid but not exceed 5,000 THB/year		
Temporary Payroll			
- Payroll for 1st class Secretary	10,350 THB/month	621,000.00	621,000.00
Social Security Subsidy			
October - September 5%	518 THB/month	31,080.00	31,080.00
- Payroll for 2nd class Secretary	7,730 THB/month		
Social Security Subsidy			
October - September 5%	387 THB/month		
- Payroll for Typist	5,610 THB/month		
Social Security Subsidy			
October - September 5%	281 THB/month		
- Payroll for Driver	5,610 THB/month	336,600.00	336,600.00
Social Security Subsidy			
October - September 5%	281 THB/month	16,860.00	16,860.00
Expsenses			
Travelling Expenditure			
- Upcountry housing expense (Expert)	Per paid but not exceed 1,600 THB/day		
- Travelling per dium (Expert)	500 THB/day		
- Transportation expense (Expert)	Per paid		
- Upcountry housing expense (Secretary)	Per paid but not exceed 1,200 THB/day		
- Travelling per dium (Secretary)	180 THB/day		
- Transportation expense (Secretary)	Per paid		

- Upcountry housing expense (Driver)	Per paid but not exceed 800 THB/day		
- Travelling per dium (Driver)	120 THB/day		
- Transportation expense (Driver)	Per paid		
- Vehicle maintenance	Per paid but not exceed 5,000 THB/year		
- Postage Charge	Per paid but not exceed 1,000 THB/year		
- Treating expense	Rate per Regulations of Disbursement of Treating Expense for Foreign B.E. 2536		
Materials Expenses			
- Gasoline	Per paid but not exceed 36,000 THB/year	180,000.00	180,000.00
- Car Materials	Per paid but not exceed 5,000 THB/year	25,000.00	25,000.00
- Office materials	Per paid but not exceed 6,000 THB/year	30,000.00	30,000.00
Total		**1,240,540.00**	**1,240,540.00**
Grand total allocated from TICA			**930,405.00**

Remark:

1. TICA approves budget allocation 75% of amount of request.
2. Amount approved can be averaged with the expenses, but not exceed the rate approved by the Ministry of Finance in each category, without request for approval to TICA.
3. When the approved amount in each category is not enough, please request for allocation approval as well as disburse the rest amount.

Annex 15 Annual Budget Allocation for the Project from TICA

Description of Subsidy Budget Allocated for JICA Experts, Other Expenses Segment FY 2007

Name of Expert & Position:	1. Dr. Y. AKIMOTO, Chief Advisor 2. Mr. J. MATSUDA, Standards on Physics 3. Dr. J. KINOSHITA, Standards on Electromagnetic 4. Dr. A. NOMURA, Standards on Chemical 5. Ms. I. NIIZEKI, Project Coordinator
Country:	Japan
To be under:	Ministry of Science and Technology, National Institute of Metrology (Thailand)
Working duration:	October 16, 2002 - October 15, 2007
Budget allocation duration:	October 1, 2006 - September 30, 2007 (12 months)

Description	Approval Rate of Ministry of Finance	Request for Allocation from Implementing Agency	Allocation Approval
Remuneration			
- Housing Allowance - BKK & Regional			
- First 15 days	Per paid but not exceed 1,600 THB/day		
- 15 days after	Per paid but not exceed 10,000 THB/month		
- Housing Allowance - Regional			
- First 30 days	Per paid but not exceed 1,000 THB/day		
- 30 days after	Per paid but not exceed 8,000 THB/month		
- Medical Fee	Per paid but not exceed 5,000 THB/year		
Temporary Payroll			
- Payroll for 1st class Secretary	10,350 THB/month	382,950.00	382,950.00
Social Security Subsidy			
October - September 5%	518 THB/month	19,166.00	19,166.00
- Payroll for 2nd class Secretary	7,730 THB/month		
Social Security Subsidy			
October - September 5%	387 THB/month		
- Payroll for Typist	5,610 THB/month	67,320.00	67,320.00
Social Security Subsidy			
October - September 5%	281 THB/month	3,372.00	3,372.00
- Payroll for Driver	5,610 THB/month	274,890.00	274,890.00
Social Security Subsidy			
October - September 5%	281 THB/month	13,769.00	13,769.00
Expsenses			
Travelling Expenditure			
- Upcountry housing expense (Expert)	Per paid but not exceed 1,600 THB/day		
- Travelling per dium (Expert)	500 THB/day		
- Transportation expense (Expert)	Per paid		
- Upcountry housing expense (Secretary)	Per paid but not exceed 1,200 THB/day		
- Travelling per dium (Secretary)	180 THB/day		
- Transportation expense (Secretary)	Per paid		

- Upcountry housing expense (Driver)	Per paid but not exceed 800 THB/day		
- Travelling per dium (Driver)	120 THB/day		
- Transportation expense (Driver)	Per paid		
- Vehicle maintenance	Per paid but not exceed 5,000 THB/year		
- Postage Charge	Per paid but not exceed 1,000 THB/year		
- Treating expense	Rate per Regulations of Disbursement of Treating Expense for Foreign BE. 2536		
Materials Expenses			
- Gasoline	Per paid but not exceed 36,000 THB/year	147,000.00	147,000.00
- Car Materials	Per paid but not exceed 5,000 THB/year	20,417.00	20,417.00
- Office materials	Per paid but not exceed 6,000 THB/year	24,500.00	24,500.00
Total		**953,384.00**	**953,384.00**
Grand total allocated from TICA			**715,038.00**

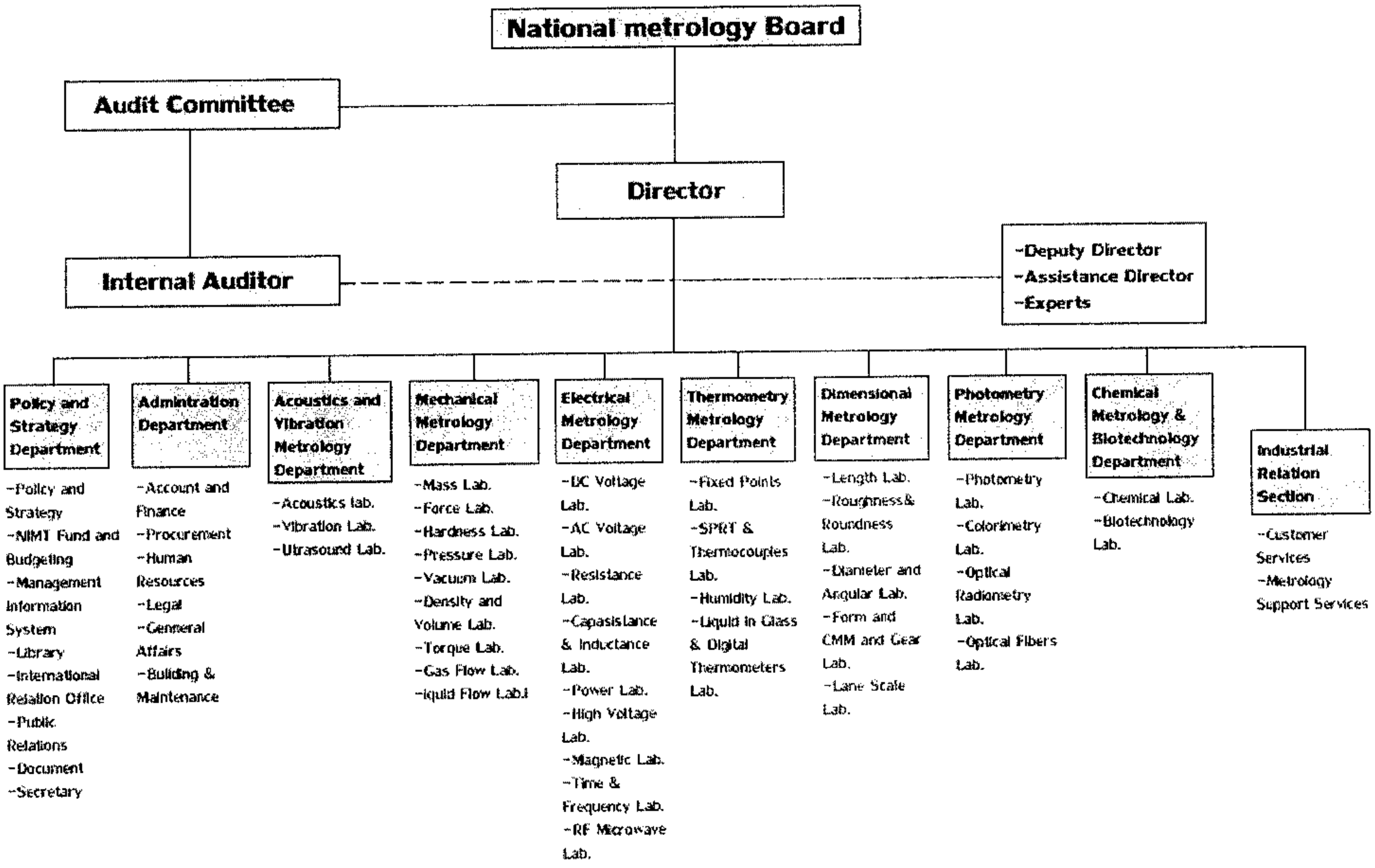
Remark:

1. TICA approves budget allocation 75% of amount of request.
2. Amount approved can be averaged with the expenses, but not exceed the rate approved by the Ministry of Finance in each category, without request for approval to TICA.
3. When the approved amount in each category is not enough, please request for allocation approval as well as disburse the rest amount.

Annex 16: Organization Chart

Annex 16 Organization Chart

National Institute of Metrology(Thailand)



Annex 17: Evaluation Sheet of Technical Transfer

Annex 17 EVALUATION SHEET OF TECHNICAL TRANSFER (Jan 2003 – Feb 2004)

Quantity		Plug/Ring	Radiation	Roundness	Wavelength	Acoustics	Hardness	AC Power	DC High Volt
Name of Counterpart (C/P)		Mr. Samana	Mr. Narudom	Mr. Samana	Ms. Monludee	Ms. Surat	Mr. Tassanai	Mr. Sittisak	Mr. Danai
Skill	Before training	1		1	1	2	0.5	2	1.5
	After training	4.0		4.0	4.0	4.0	4.0	3.0	4.0
Name of Short term expert		Mr. Tomiyama	Dr. Sakuma	Mr. Wakabayashi	Mr. Ishikawa	Mr. Nomura	Mr. Ishida	Mr. Yamawaki	Mr. Iguchi
Period for Transfer		2003-Jan	2003-Jan	2003-Feb	2003-Mar	2003-Mar	2003-Apr	2003-Nov	2004-Feb
Standard Establishment									
Installation		Done	Done	Done	Done	Done	Done	Done	Done
Operation		Done	Done	Done	Done	Done	Done	Done	Done
Evaluation	Stability	Measured	Measured	Measured	Measured	Measured	Measured	Measured	Measured
	Repeatability	Measured	Measured	Measured	Measured	Measured	Measured	Measured	Measured
	Comparison	JQA	NMIJ	NML	NMIJ.SIRIM	NMIJ	NMIJ.VMI	JEMIC	JEMIC
Budget Sheet		Estimated	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated
Calibration Technology									
Installation		Done	Done	Done	Done	Done	Done	Done	Done
Operation		Done	Done	Done	Done	Done	Done	Done	Done
Evaluation	Stability	Measured	Measured	Measured	Measured	Measured	Measured	Measured	Measured
	Repeatability	Measured	Measured	Measured	Measured	Measured	Measured	Measured	Measured
	Calibration Service	Started	Started	Started	Started	Started	Started	Started	Started
Uncertainty		Estimated	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated
Calibration Procedure (CP)		Provided	Provided	Provided	Provided	Provided	Provided	Provided	Provided
Accreditation		Accredited on 30 Oct. 2006	In process	Accredited on 30 Oct. 2006	Accredited on 23 Jun. 2004	Accredited on 23 Jun. 2004	Accredited on 4 Jan. 2004	In process	Accredited on 11 May. 2007
Seminar	Number of Participant	46	29	21	72	38	123	107	184
Remarks			C/P: Overseas		APMP LK-11	APMP KC	APMP CCM.H-S1		

EVALUATION SHEET OF TECHNICAL TRANSFER (Feb 2004 – Jun 2005)

Quantity		CMM	RF Power	RF Voltage	Roughness	Angle	RF Att	Flatness	Resistance
Name of Counterpart (C/P)		Mr. Narin	Mr. Chairat	Mr. Chairat	Mr. Samana	Mr. Watcharin	Mr. Chairat	Mr. Muhammad	Ms. Natenapit
Skill	Before training	0.5	1	1	1	1.5	0.5	2	1.5
	After training	3.5	3.5	3.5	4.0	4.0	3.5	4.0	3.0
Name of Short term expert		Dr. Oosawa	Ms. Sato	Ms. Sato	Dr. Naoi	Dr. Watanabe	Mr. Igarashi	Dr. Takatsuji	Dr. Kinoshita
Period for Transfer		2004--Feb	2004--Mar	2004--Mar	2004-Aug	2005-Jan	2005-Feb	2005-Jun	2004-Nov
Standard Establishment									
Installation		Done	Done	Done	Done	Done	Done	Done	Done
Operation		Done	Done	Done	Done	Done	Done	Done	Done
Evaluation	Stability	Measured	Measured	Measured		Measured	Measured	Measured	Measured
	Repeatability	Measured	Measured	Measured	Measured	Measured	Measured	Measured	Measured
	Comparison	NMIJ	JQA	JQA	NMIJ	NMIJ	JQA	NMIJ	BIPM
Budget Sheet		Estimated	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated
Calibration Technology									
Installation		Done	Done	Done	Done	Done	Done	Done	Done
Operation		Done	Done	Done	Done	Done	Done	Done	Done
Evaluation	Stability	Measured	Measured	Measured		Measured	Measured	Measured	Measured
	Repeatability	Measured	Measured	Measured	Measured	Measured	Measured	Measured	Measured
	Calibration Service	Started	Started	Started	Started	Started	Started	Started	Started
Uncertainty		Estimated	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated
Calibration Procedure (CP)		Provided	Provided	Provided	Provided	Provided	Provided	Provided	Provided
Accreditation		In process	In process	In process	Accredited on 30 Oct. 2006	Accredited on 30 Oct. 2006	In process	Accredited on 30 Oct. 2006	In process
Seminar	Number of Participant	184	76	76	61	73	78	45	76
Remarks		APMP LK-5 and LK-6				APMP LK-3			

EVALUATION SHEET OF TECHNICAL TRANSFER (Nov 2005 – Jul 2006)

Quantity		Vib/Accel	Time/Freq	pH	Force	Large Mass	Humidity	Stand Solution	Inorganic
Name of Counterpart (C/P)		Mr. Pairoj	Mr. Somchai	Ms. Nongluck	Mr. Kittipong	Mr. Wirun	Ms. Thasorn	Dr. Preeyaporn	Ms. Nongluck
Skill	Before training	1	3	2	1	2	2	2	1.5
	After training	4.0	4.0	4.0	3.5	3.0	3.5	2.5	2.5
Name of Short term expert		Mr. Ohta	Dr. Suzuyama	Dr. Nakamura	Dr. Hayashi	Dr. Sun	Mr. Imura	Mr. Higuchi	Dr. Hioki
Period for Transfer		2005-Nov	2005-Nov	2006-Feb	2006-Mar	2006-Mar	2006-Mar	2006-Jul	2006-Jul
Standard Establishment									
Installation		Done	Done	Done	Done	Done	Done		
Operation		Done	Done	Done	Done	Done	Done		
Evaluation	Stability	Measured	Measured	Measured	Measured	Measured	Measured		
	Repeatability	Measured	Measured	Measured	Measured	Measured	Measured		
	Comparison		NMIJ	NML	On planning	On planning			
	Budget Sheet	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated		
Calibration Technology									
	Installation	Done	Done	Done	Done	Done	Done	Done	Done
Operation		Done	Done	Done	Done	Done	Done	Done	Done
Evaluation	Stability	Measured	Measured	Measured	Measured	Measured	Measured	Not yet	Not yet
	Repeatability	Measured	Measured	Measured	Measured	Measured	Measured	Not yet	Not yet
	Calibration Service	Started	Started	Started	Started	Started	Started	Not yet	Started
	Uncertainty	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated	Estimated
Calibration Procedure (CP)		Provided	Provided	Provided	In process	In process	Provided	In process	In process
Accreditation		Accredited on 11 May. 2007	Accredited on 11 May. 2007	Accredited on 11 May. 2007	In process	In process	In process	In process	In process
Seminar	Number of Participant	48	40	96	None	None	44	57	57
Remarks				APMP QM-P06, P08	BC-NMIJ	BC-NMIJ			

EVALUATION SHEET OF TECHNICAL TRANSFER (Jul 2006 – May 2007)

Quantity		Spectral. Irradiance	Photometry	Magnetic	Laser Power	Standard Gas			Chemical Analysis
Name of Counterpart (C/P)		Ms. Rojana	Mr. Arkom	Mr. Thepbodin	Mr. Narat	Mr. Bunthoon			Dr. Charun
Skill	Before training	1	1	0.5	0.5	1			
	After training	3.0	3.0	2.5	2.5	3.0			
Name of Short term expert		Dr. Zama	Dr. Shitomi	Mr. Tominaga	Mr. Miyawaki	Dr. Matsumoto			Dr. Nomura
Period for Transfer		2007-Feb	2007-Feb	2007-Mar	2007-Mar	2007-Mar			2006-Dec
Standard Establishment									
Installation		Done	Done	Done	Done				
Operation		Done	Done	Done	Done				
Evaluation	Stability	Measured	Measured	Measured					
	Repeatability	Measured	Measured	Measured					
	Reproducibility	Measured	Measured	Not yet	Measured				
	Budget Sheet	Need Analysis	Need Analysis	Not yet	Estimated				
Calibration Technology									
	Installation	Done	Done	Done	Done	Done			
Operation		Done	Done	Done	Done	Done			
Evaluation	Stability	Measured	Measured	Measured		Measured			
	Repeatability	Measured	Measured	Measured		Measured			
	Reproducibility	Not yet issued	Not yet issued	Not yet	Measured	Measured			
	Uncertainty	Estimated	Estimated	Not yet	Estimated	Estimated			
Calibration Procedure (CP)		In process	In process	In process	In process	In process			
Accreditation		In process	In process	In process	In process	In process			
Seminar	Number of Participant	32	32	58	30	61			
Remarks			Luminance Intensity: Not yet						

Annex 18: Budget Sheet on Uncertainty
(A part of Department Quality Manual (DQM))

Annex 18 Budget Sheet on Uncertainty

NIMT

Uncertainty Budget

Laboratory: *Form and CMM and Gear*

Department: *Dimensional Metrology*

Cal. Record No.

Page 5 of 5 Pages

Uncertainty budget for CMM, nominal length is 620 mm

Quantity X_i	Estimate x_i	Standard Uncertainty $u(x_i)$		Probability Distribution	Effective degree of freedom	Sensitivity Coefficient c_i	Uncertainty Contribution,	
		Absolute	Relative				Absolute	Relative
l_s	0.0000 mm	2.00E-01	3.50E-07 l	Rectangular	∞	+1	2.00E-01	3.50E-07 l
l_x	0.0000 mm	1.73E-01 µm	-	Normal	2	-1	1.73E-01 mm	-
δl_{ix}	0 mm	5.77E-03 µm	-	Rectangular	∞	-1	5.77E-03 mm	-
$\overline{\alpha} \cdot \delta t$	0 mm	-	2.60E-07 l	Special	∞	1	-	2.60E-07 l
$\delta\alpha \cdot \Delta\overline{T}$	0 mm	-	1.66E-07 l	Special	∞	1	-	1.66E-07 l
$u(l_x)$							7.00E-02 mm^2	1.90E-13 l^2
							2.65E-01 mm	4.36E-07 l
C_x	0.0000 mm			Normal	K	2	0.529 mm	8.7E-07 l

Note : l being the length of the CMM

UNCERTAINTY BUDGET

For Example: Calibration factor of Power Sensor (8481A) at frequency 10 MHz, 1 mW

Quantity (X_i)	Estimate (x_i)	Standard Uncertainty $U(x_i)$		Probability Distribution	Effective Degree of Freedom (ν_i)	Sensitivity Coefficient (c_i)	Uncertainty Contribution $U(y_i)$	
		Relative	Absolute				Relative	Absolute
$K_{s(UUT)}$	0,9600	-	-	-	-	-	-	-
$\delta K_{s1(UUT)}$	0	1,4500	$1,4 \bullet 10^{-2}$	Normal	∞	1,045	1,4500	$1,5 \bullet 10^{-2}$
$\delta K_{s2(UUT)}$	0	$2,9 \bullet 10^{-1}$	$2,8 \bullet 10^{-3}$	Rectangular	∞	1,045	$2,9 \bullet 10^{-1}$	$2,9 \bullet 10^{-3}$
$\delta K_{s3(UUT)}$	0	$6,0 \bullet 10^{-2}$	$5,8 \bullet 10^{-4}$	Rectangular	∞	1,045	$6,0 \bullet 10^{-2}$	$6,1 \bullet 10^{-4}$
P_d	1,0000	-	-	-	-	-	-	-
$P_{d(UUT)}$	0,9535	-	-	-	-	-	-	-
$\delta P_{ds1(UUT)}$	0	$8,5 \bullet 10^{-2}$	$8,1 \bullet 10^{-4}$	t	5	-1,052	$8,5 \bullet 10^{-2}$	$8,5 \bullet 10^{-4}$
$\delta P_{ds2(UUT)}$	0	$6,1 \bullet 10^{-2}$	$5,8 \bullet 10^{-4}$	Rectangular	∞	-1,052	$6,1 \bullet 10^{-2}$	$6,1 \bullet 10^{-4}$
$\delta P_{ds3(UUT)}$	0	$1,4 \bullet 10^{-1}$	$1,3 \bullet 10^{-3}$	Rectangular	5	-1,052	$1,4 \bullet 10^{-1}$	$1,4 \bullet 10^{-3}$
$\delta P_{ds4(UUT)}$	0	$1,8 \bullet 10^{-3}$	$1,7 \bullet 10^{-5}$	Rectangular	2	-1,052	$1,8 \bullet 10^{-3}$	$1,8 \bullet 10^{-5}$
$\delta P_{ds5(UUT)}$	0	$2,5 \bullet 10^{-1}$	$2,4 \bullet 10^{-3}$	Triangular	∞	-1,052	$2,5 \bullet 10^{-1}$	$2,5 \bullet 10^{-3}$
$M_{u(UUT)}$	1,0000	-	-	-	-	-	-	-
$\delta M_{u(UUT)}$	0	$2,7 \bullet 10^{-1}$	$2,7 \bullet 10^{-3}$	U-shape	8	1,003	$2,7 \bullet 10^{-1}$	$2,7 \bullet 10^{-3}$
$K_{s(UUT,50MHz)}$	0,9886	-	-	-	-	-	-	-
$\delta K_{s1(UUT,50MHz)}$	0	1,3387	$1,3 \bullet 10^{-2}$	Normal	∞	-1,015	1,3000	$1,3 \bullet 10^{-2}$
$\delta K_{s2(UUT,50MHz)}$	0	$2,9 \bullet 10^{-1}$	$2,8 \bullet 10^{-3}$	Rectangular	∞	-1,015	$2,8 \bullet 10^{-1}$	$2,8 \bullet 10^{-3}$
$\delta K_{s3(UUT,50MHz)}$	0	$6,0 \bullet 10^{-2}$	$5,8 \bullet 10^{-4}$	Rectangular	∞	-1,015	$5,9 \bullet 10^{-2}$	$5,9 \bullet 10^{-4}$
$P_{d(UUT,50MHz)}$	1,0000	-	-	-	-	-	-	-
$P_{ds(UUT,50MHz)}$	0,9854	-	-	-	-	-	-	-
$\delta P_{ds1(UUT,50MHz)}$	0	$8,3 \bullet 10^{-2}$	$7,9 \bullet 10^{-4}$	t	5	1,018	$8,0 \bullet 10^{-2}$	$8,1 \bullet 10^{-4}$
$\delta P_{ds2(UUT,50MHz)}$	0	$6,1 \bullet 10^{-2}$	$5,8 \bullet 10^{-4}$	Rectangular	∞	1,018	$5,9 \bullet 10^{-2}$	$5,9 \bullet 10^{-4}$
$\delta P_{ds3(UUT,50MHz)}$	0	$1,4 \bullet 10^{-1}$	$1,3 \bullet 10^{-3}$	Rectangular	5	1,018	$1,3 \bullet 10^{-1}$	$1,3 \bullet 10^{-3}$
$\delta P_{ds4(UUT,50MHz)}$	0	$1,8 \bullet 10^{-3}$	$1,7 \bullet 10^{-5}$	Rectangular	2	1,018	$1,7 \bullet 10^{-3}$	$1,7 \bullet 10^{-5}$
$\delta P_{ds5(UUT,50MHz)}$	0	$2,5 \bullet 10^{-1}$	$2,4 \bullet 10^{-3}$	Triangular	∞	1,018	$2,4 \bullet 10^{-1}$	$2,4 \bullet 10^{-3}$
$M_{u(UUT,50MHz)}$	1,0000	-	-	-	-	-	-	-
$\delta M_{u(UUT,50MHz)}$	0	$1,2 \bullet 10^{-1}$	$1,2 \bullet 10^{-3}$	U-shape	8	-1,003	$1,2 \bullet 10^{-1}$	$1,2 \bullet 10^{-3}$
K_a	1,0035						2,06	$2,06 \bullet 10^{-2}$

Expanded Uncertainty: $U = k \cdot u(K_a)$ $= 2 \times 2.06$

$= 4.12$

Round up to $= 4.2$ %

Uncertainty Budget:

Example: RF Voltmeter Calibration at 0.5 mV, 1000 MHz

Quantity (X_i)	Estimate (x_i)	Standard Uncertainty $U(x_i)$		Probability Distribution	Effective Degree of Freedom (v_i)	Sensitivity Coefficient (c_i)	Uncertainty Contribution $U(y_i)$	
		Relative	Absolute				Relative	Absolute
E_{Ind}	0,5	-	-	-	-	-	-	-
δ_{RF-DC}	-183,2	-	-	-	-	-	-	-
$\Delta\delta_{RF-DC1}$	0	-1,9100	3,5000	Normal	∞	0,00062	$12{,}9 \bullet 10^{-4}$	$21{,}5 \bullet 10^{-4}$
$\Delta\delta_{RF-DC2}$	0	-1,5000	2,7400	Rectangular	8	0,00062	$33{,}5 \bullet 10^{-4}$	$16{,}9 \bullet 10^{-4}$
$\Delta\delta_{RF-DC3}$	0	0,0000	0,0000	Rectangular	∞	0,00062	0,0000	0,0000
V_u	0,4999	-	-	-	-	-	-	-
δV_{u1}	0	$5{,}84 \bullet 10^{-4}$	$2{,}90 \bullet 10^{-4}$	Rectangular	∞	-1,0053	$5{,}84 \bullet 10^{-4}$	$2{,}90 \bullet 10^{-4}$
δV_{u2}	0	$8{,}00 \bullet 10^{-4}$	$4{,}00 \bullet 10^{-4}$	U	∞	-1,0053	$8{,}00 \bullet 10^{-4}$	$4{,}02 \bullet 10^{-4}$
δV_{u3}	0	$12{,}9 \bullet 10^{-4}$	$6{,}43 \bullet 10^{-4}$	Rectangular	∞	-1,0053	$12{,}9 \bullet 10^{-4}$	$6{,}46 \bullet 10^{-4}$
δV_{u4}	0	0,0000	0,0000	Rectangular	8	-1,0053	0,0000	0,0000
δV_{avg1}	0	$3{,}46 \bullet 10^{-4}$	$2{,}13 \bullet 10^{-4}$	T	4	0,8169	$3{,}46 \bullet 10^{-4}$	$1{,}74 \bullet 10^{-4}$
δV_{avg2}	0	$0{,}81 \bullet 10^{-4}$	$50{,}0 \bullet 10^{-6}$	T	8	0,8169	$0{,}81 \bullet 10^{-4}$	$40{,}8 \bullet 10^{-6}$
δV_{avg3}	0	0,0000	0,0000	Rectangular	∞	0,8169	0,0000	0,0000
δV_{avg4}	0	$0{,}15 \bullet 10^{-4}$	$9{,}00 \bullet 10^{-6}$	Rectangular	∞	0,8169	$0{,}15 \bullet 10^{-4}$	$7{,}35 \bullet 10^{-6}$
$V_{dc'}$	0,6151	-	-	-	-	-		-
$\delta V_{dc'1}$	0	$0{,}81 \bullet 10^{-4}$	$0{,}50 \bullet 10^{-4}$	Normal	∞	0,4085	$0{,}40 \bullet 10^{-4}$	$0{,}20 \bullet 10^{-4}$
$\delta V_{dc'2}$	0	$0{,}20 \bullet 10^{-4}$	$0{,}12 \bullet 10^{-4}$	Rectangular	8	0,4085	$9{,}75 \bullet 10^{-6}$	$4{,}90 \bullet 10^{-6}$
$\delta V_{dc'3}$	0	$2{,}11 \bullet 10^{-5}$	$1{,}30 \bullet 10^{-5}$	Rectangular	∞	0,4085	$1{,}06 \bullet 10^{-5}$	$0{,}53 \bullet 10^{-5}$
V_{dc}	0,6152	-	-	-	-	-	-	-
$\delta V_{dc'1}$	0	$0{,}81 \bullet 10^{-4}$	$0{,}50 \bullet 10^{-4}$	Normal	∞	0,4085	$0{,}40 \bullet 10^{-4}$	$0{,}20 \bullet 10^{-4}$
$\delta V_{dc\ 2}$	0	$0{,}20 \bullet 10^{-4}$	$0{,}12 \bullet 10^{-4}$	Rectangular	8	0,4085	$9{,}75 \bullet 10^{-6}$	$4{,}90 \bullet 10^{-6}$
$\delta V_{dc'3}$	0	$2{,}11 \bullet 10^{-5}$	$1{,}30 \bullet 10^{-5}$	Rectangular	∞	0,4085	$1{,}06 \bullet 10^{-5}$	$0{,}53 \bullet 10^{-5}$
V_{TE}	2,7743	-	-	-	-	-	-	-
δV_{TE}	0	$0{,}10 \bullet 10^{-4}$	$0{,}29 \bullet 10^{-6}$	Rectangular	∞	0,0905	$0{,}05 \bullet 10^{-4}$	$0{,}02 \bullet 10^{-6}$
V_{TE_set}	2,7743	-	-	-	-	-	-	-
δV_{TE_set}	0	$0{,}10 \bullet 10^{-4}$	$0{,}29 \bullet 10^{-6}$	Rectangular	∞	-0,0905	$0{,}05 \bullet 10^{-4}$	$0{,}02 \bullet 10^{-6}$
$u(E_{cal})$	0,5025						0,560	$2{,}82 \bullet 10^{-3}$

Expanded Uncertainty: $u = k \cdot u(k_u) = 2 \times 0.56$

$= 1{,}1206$

Round up to $= 1{,}13\%$

δt_{flow} - uncertainty due to estimated the flow rate variability

Quantity X_1	Estimate X_i	Standard Uncertainty U(Xi)	Effective Degree of freedom	Probability Distribution	Sensitivity Coefficient	Uncertainty Contribution Ui(Y)
	K	K	(V_i)		(C_i)	K
δh_{std}	xx.xx	0.023	∞	Normal	1	0.023
δt_{d}	0	0.002	∞	Normal	1	0.002
$\delta t_{ch,uniformity}$	0	0.000	∞	rectangular	1	0.000
$\delta t_{ch,stability}$	0	0.003	∞	rectangular	1	0.002
δt_{str}	0	0.00	∞	rectangular	1	0.000
δt_{drop}	0	0.035	∞	rectangular	1	0.010
$\delta t_{short-term}$	0	0.022	∞	rectangular	1	0.006
δt_{flow}	0	0.074	∞	rectangular	1	0.021
δt_{res}	0	0.01	∞	rectangular	1	0.003
t	xx.xx					0.034

Expanded uncertainty of dew-point temperature measurement: $U = k \times u(C_y) = 2 \times 0.034 = 0.068\,^{\circ}C \approx 0.08\,^{\circ}C$

Expanded uncertainty of relative humidity measurement @20.2%rh ≈ 0.2%rh

CALIBRATION PROCEDURE

(CP)

TYPE / MODEL NO.: N/A

NOMENCLATURE: Chilled-Mirror hygrometer

DEW-POINT RANGE: -40 °C to +25 °C at dew-point

DEW-POINT UNCERTAINTY: ± 0.06°C at dew-point

±0.08°C at frost-point

Prepared	Approved
(Thasorn Sinhaneti)	(Ajchara Charoensook)
……/……/……	……/……/……

Page	Original	Change1	Change2	Change3	Change4	Change5	Change6
1	√						
2	√						
3	√						
4	√						
5	√						
6	√						
7	√						
8	√						

Test Instrument Characteristic	Performance Specifications	Test Method
Dew-point Temperature	-40 °C to +25 °C at dew-point	Comparison with standard humidity generator

1.0 MEASUREMENT STANDARDS AND SUPPORT TEST EQUIPMENT REQUIREMENTS:

Normenclature Characteristic	Required Specifications	Calibration Equipment
Low Standard Humidity Generator	frost-point Range: -40 to +15°C and Frost-point uncertainty: ± 0.06 °C	THUNDER SCIENTIFIC model 3900 S/N:0110324
Standard Humidity Generator	dew-point Range: -10 to +70°C and dew-point uncertainty: ± 0.03°C Temperature Range: 0 °C to 70 °C	THUNDER SCIENTIFIC model 2500 S/N:0110324

2.0 PRELIMINARY OPERATIONS

2.1 Low Standard Humidity Generator

3.1.1 Read the operator's manuals of chilled mirror under calibrated before begin the calibration.

Note Be sure all electrical cables are connected correctly.

3.1.2 If the displayed dew point, therefore, drift upward above the true dew point. To determine whether dissolved contaminants are affecting dew point measurement, perform the following step:

3.1.2.1 Clean the mirrors with a clean cotton swab or lint free tissue dampened with distill water.

3.1.2.2 Follow with a dry cotton swab or tissue.

EXAMPLE OF UNCERTAINTY BUDGET:

The chilled mirror hygrometer is calibrated by comparison with two-pressure standard humidity generator at test temperature = 23°C and dew- point temperature –1°C.

Standard Reading		UUC reading	
°C	°C	°C	°C
23.146	-1.017	23.15	-1.28
23.144	-1.017	23.15	-1.28
23.145	-1.023	23.15	-1.28
23.146	-1.018	23.15	-1.29
23.146	-1.028	23.15	-1.28
23.146	-1.032	23.15	-1.28
23.146	-1.029	23.15	-1.28
23.147	-1.026	23.15	-1.28
23.145	-1.030	23.15	-1.29
23.146	-1.027	23.15	-1.3
23.146	-1.025	23.150	-1.284
0.001	0.005	0.000	0.007

- UUC Standard deviation reading: u (t_d)

  The hygrometer to be tested reading was observed 10 measurements. Uncertainty due to be calculated from for average of dew-point temperature measurement. The standard uncertainty due to standard deviation of thermometer reading be define as:

$$u(\delta t_d) = \pm \frac{0.011}{\sqrt{9}}$$

$$= 0.004\ ^{\circ}C$$

- Linearity of the hygrometer to be tested : u(t_{lin})

  The fitting routine yields an uncertainty in the equation and the uncertainty associated with the residuals which is found from the equation:

$$u(\delta corr_{residuals}) = \sqrt{\frac{\sum_{i=1}^{n} res_i^2}{n - order - 1}}$$

$$res_i = corr_{cal} - corr_{fitted}$$

$$u(t_{lin}) = 0$$

- Resolution of UUC , for example was 0.01 °C

  Resolution of ambient hygrometer to be tested in this case is 0.01 °C

$$U(\delta t_{Pesx}) = \pm\frac{0.01}{2\sqrt{3}}$$

$$= \underline{+}\, 0.003\ ^{\circ}C$$

- Standard humidity generator: $u(h_{std})$

  The examination uncertainty due to calculating by combining the estimated uncertainties arising from two-pressure generator calibration in term of dew-point temperature (see appendix A).The standard uncertainty can be defined as

$$u(\delta t_{s}) = \frac{\pm 0.03}{2}$$

$$= 0.015\ ^{\circ}C$$

- Pressure drop across chamber: $u(t_{drop})$

  Measurements of pressure drop have been made from across the chamber and the effects calculated and correction applied for difference humilities (see appendix E). The uncertainty allowance mainly reflects the uncertainty in the pressure-measuring device:

$$\Delta p = \frac{8ql\eta}{(\pi a^{4})}$$

$$= 0.0035\ ^{\circ}C$$

- Short-term stability of hygrometer to be tested: $u(t_{short\text{-}term})$

  During the calibration measurements are made to determine the short-term stability to perform at hygrometer to be tested where it is used. The first point of the range is repeated to gain information over the hysteresis.

$$u(\delta t_{short\text{-}term}) = \frac{\pm 0.03}{2\sqrt{3}}$$

$$= 0.009\ ^{\circ}C$$

- Flow rate variability: $u(t_{flow})$

  Measurements of flow rate of gas can affect thermal equilibration, so there are applied for difference humilities allowance covering both variability in flow:

$$u(\delta t_{flow}) = \frac{\pm 0.025}{2\sqrt{3}}$$

$$= 0.007\ ^{\circ}C$$

- Stability and uniformity of chamber: $u(t_{ch,stability})$, $u(t_{ch,uniformity})$

The temperature stability and the gradients in the chamber during the measurement.

$$u(\delta t_{ch,stability}) = \frac{\pm 0.05}{\sqrt{3}}$$

$$= 0.014\,^{\circ}\mathrm{C}$$

$$u(\delta t_{ch,uniformity}) = \frac{\pm 0.07}{\sqrt{3}}$$

$$= 0.014\,^{\circ}\mathrm{C}$$

MATHEMATICAL MODEL FOR RANGE: -10°C to +25°C

The measurement of the hygrometer under tested at (t_{ch}, t_d)= 23.00°C, -0.91 °C is given below

$$T_{dp} = t_{uuc,dp} + C_{dp}$$

$$C_{dp} = t_{std,dp} - t_{uuc,dp} = ((rh_{std} + \delta h_{std}) \cdot C_{std,sen}) - (t_{uuc} + \delta t_{uuc})$$

where:

C_{dp}	- reduce correction at dew-point temperature
rh_{std}	- value of generated relative humidity (see appendix A)
δh_{std}	- uncertainty due to calculating by combining the estimated uncertainties arising from two-pressure generator calibration (see appendix A)
$C_{std,sen}$	- sensitivity coefficient in term of "relative humidity" (see appendix E)
t_{uuc}	- mean value of 10 measurement dew-point temperature the hygrometer under calibration
t_{ch}	- mean value of 10 temperature measurement of thermometer in chamber which reading from display at hygrometer to be tested
δt_{uuc}	- uncertainty due to combined of the uncertainty component of hygrometer to be tested
δt_{uuc}	$= \delta t_d + \delta t_{res} + \delta t_{lin} + \delta t_{P\,drop} + \delta t_{short\text{-}term} + \delta t_{flow}$
δt_d	- uncertainty due to be calculated from standard deviation for average of dew-point temperature measurement
δt_{res}	- uncertainty due to resolution of the hygrometer to be tested is that of the display
δt_{lin}	- uncertainty due to linearity of the hygrometer to be tested
δt_{drop}	- uncertainty due to the effects of pressure drop across chamber by calculation and correction applied for difference humilities (see appendix C)
$\delta t_{short\text{-}term}$	- uncertainty due to estimated short-term stability during the calibration cycle

Uncertainty budget of depth measurement standard calibration

x_i	Standard Uncertainty $u(x_i)$		Probability Distribution	c_i	Uncertainty Contribution $U_i(y)_i$	
	Absolute	Relative			Absolute	Relative
Z_{ref}	0,00115 µm	-	Rectangular	1	0.00115 µm	-
$Z_{\text{[illegible]}}$	0,00000 µm	-	Normal	1	0,00000 µm	-
$Z_{\text{[illegible]}}$	0,00029 µm	-	Rectangular	1	0,00029 µm	-
$Z_{\text{[illegible]}}$	0,00000 µm	-	Normal	1	0,00000 µm	-
Z_x	0,00029 µm	-	Rectangular	1	0,00029 µm	-
$Z_{\text{[illegible]}}$	0,00289 µm	-	Rectangular	1	0,00289 µm	-
$Z_{\text{[illegible]}}$	0,00173 µm	-	Rectangular	1	0.00173 µm	-
$d_{\text{[illegible]}}$	-	0.01000	Normal	0.43 Z_m	-	0.00429 Z_m
$d_{\text{[illegible]}}$	-	0,00025	Normal	0.43 Z_m	-	0,00011 Z_m
$Z_{\text{[illegible]}}$		0.00289	Rectangular	Z_m	-	0.00289 Z_m
$Z_{\text{[illegible]}}$	0.00025	-	Normal	1	0.00025	-
$Z_{\text{[illegible]}}$	0.00045	-	Normal	1	0.00045	-
$u^2(Z)$					0.00001 µm^2	0.00003 Z_m^2
$u(Z)$					0.0036 µm	0.0052 Z_m
$U_{95\%}(Z)$			Normal	K = 2	0.007 µm	0.010 Z_m

Expanded uncertainty of measurement :

$$U_{95\%}(Z\ ) = 2 \times \sqrt{(0.0036\mu m)^2 + (0.0052 \cdot Z_m)^2} \qquad (9.4.8.20)$$

$$= \sqrt{(0.007\mu m)^2 + (0.010 \cdot Z_m)^2}$$

Z_m being the measured value of the depth measurement standard in µm

Uncertainty budget of roughness standard calibration, R_a parameter

x_i	Standard Uncertainty $u(x_i)$		Probability Distribution	c_i	Uncertainty Contribution $U_i(y)$,	
	Absolute	Relative			Absolute	Relative
$Z_{[illegible]}$	0,00115 µm	-	Rectangular	1	0,00115 µm	-
$Z_{[illegible]}$	0,00000 µm	-	Normal	1	0,00000 µm	-
$Z_{[illegible]}$	0,00029 µm	-	Rectangular	1	0,00029 µm	-
$Z_{[illegible]}$	0,00000 µm	-	Normal	1	0,00000 µm	-
$Z_{[illegible]}$	0,00029 µm	-	Rectangular	1	0,00029 µm	-
$Z_{[illegible]}$	0,00289 µm	-	Rectangular	1	0,00289 µm	-
$Z_{[illegible]}$	0,00173 µm	-	Rectangular	1	0,00173 µm	-
$d_{[illegible]}$	-	0,01000	Normal	0,43 Z_m	-	0,00429 Z_m
$d_{[illegible]}$	-	0,00025	Normal	0,43 Z_m	-	0,00011 Z_m
$Z_{[illegible]}$		0,00289	Rectangular	Z_m	-	0,00289 Z_m
$Z_{[illegible]}$	0,00058 µm	-	Normal	1	0,00058 µm	-
$Z_{[illegible]}$	0.00336 µm	-	Normal	1	0.00336 µm	-
$Z_{[illegible]}$	0.28868 µm	-	Rectangular	0,005	0.00144 µm	
$u^2(Z)$					0.00003 µm^2	0,00003 Z_m^2
$u(Z)$					0,0051 µm	0,0052 Z_m
$U_{95\%}(Z)$			Normal	$k = 2$	0,010 µm	0,010 Z_m

Expanded uncertainty of measurement :

$$U_{95\%}(Z\ ) = 2 \times \sqrt{(0{,}0051\mu m)^2 + (0{,}0052 \cdot Z_m)^2} \qquad (9.4.8.47)$$

$$= \sqrt{(0{,}010\mu m)^2 + (0{,}010 \cdot Z_m)^2}$$

Z_m being the measured value of the depth measurement standard in µm

Uncertainty budget of roughness standard calibration, R_z parameter

x_i	Standard Uncertainty $u(x_i)$		Probability Distribution	c_i	Uncertainty Contribution $U_i(y)$,	
	Absolute	Relative			Absolute	Relative
Z_{ref}	0.00115 µm	-	Rectangular	1	0.00115 µm	-
Z [illegible]	0,00000 µm	-	Normal	1	0.00000 µm	-
Z [illegible]	0.00029 µm	-	Rectangular	1	0,00029 µm	-
Z [illegible]	0.00000 µm	-	Normal	1	0.00000 µm	-
Z [illegible]	0.00029 µm	-	Rectangular	1	0.00029 µm	-
Z [illegible]	0.00289 µm	-	Rectangular	1	0.00289 µm	-
Z [illegible]	0,00173 µm	-	Rectangular	1	0,00174 µm	-
d [illegible]	-	0.01000	Normal	$0.43\ Z_m$	-	$0,00429\ Z_m$
d [illegible]	-	0.00025	Normal	$0.43\ Z_m$	-	$0.00011\ Z_m$
Z [illegible]		0.00289	Rectangular	Z_m	-	$0.00289\ Z_m$
Z [illegible]	0.00150 µm	-	Normal	1	0,00150 µm	-
Z [illegible]	0.01241 µm	-	Normal	1	0.01241 µm	-
Z [illegible]	0.28868 µm	-	Rectangular	0.020	0.00577 µm	-
$u^2(Z)$					0.00041 µm^2	$0,0001\ Z_m^2$
$u(Z)$					0.0201 µm	$0,0073\ Z_m$
$U_{95\%}(Z)$			Normal	K = 2	0,040 µm	$0,015\ Z_m$

Expanded uncertainty of measurement :

$$U_{95\%}(Z\ ) = 2 \times \sqrt{(0{,}0201\mu m)^2 + (0{,}0073 \cdot Z_m)^2} \qquad (9.4.8.70)$$

$$= \sqrt{(0{,}040\mu m)^2 + (0{,}015 \cdot Z_m)^2} \qquad (9.4.8.71)$$

Z_m being the measured value of the depth measurement standard in µm

9.4.4.7 Uncertainty Budget of Autocollimator

Quantity x	Standard Uncertainty u(x)	Probability Distribution	Sensitivity coefficient (c)	Uncertainty contribution U(y)
θ_s	0,071"	Normal	1	0,071"
$\Delta\theta$	0,05"	*t*	1	0,050"
θ_{is}	0,02"	Rectangular	1	0,020"
θ_{ix}	0,02"	Rectangular	1	0,020"
θ_x			*k*=2	0,190"

Where θ_x being the angle deviation of the autocollimator to be calibrated.

9.4.4.8 Expanded uncertainty of measurement:

$U = k \cdot u(\theta_x) = 0.19''$

coverage factor $k = 2$

BMC = 0,20"

9.4.4.9 Reported result:

The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor $k = 2$, which for a normal distribution corresponds to a coverage probability of approximately 95%.

9.4.5.6 Uncertainty Budget of polygon mirror using one autocollimator

Quantity x	Standard Uncertainty $u(x)$	Probability Distribution	Sensitivity coefficient (c)	Uncertainty contribution U(y)
θ_s	0,071"	Normal	1	0,071"
$\Delta\theta$	0,05"	Normal	1	0,050"
θ_{is}	0.02"	Rectangular	1	0,020"
θ_x			k=2	0,178"

Where

θ_x being the absolute angle deviation of the polygon to be calibrated

9.4.5.7 Expanded uncertainty of measurement :

$$U = k \cdot u(\theta_x) = 0.178''$$

coverage factor, $k = 2$

BMC = 0,20"

9.4.5.8 Reported result:

The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor $k = 2$, which for a normal distribution corresponds to a coverage probability of approximately 95%.

9.4.6.8 Uncertainty Budget of angle gauge block

Example for angle gauge block size 0'-15'

Quantity x_i	Standard Uncertainty u(x)	Probability Distribution	Sensitivity coefficient (c)	Uncertainty contribution U(y)
θ_s	0.071"	Normal	1	0.071"
θ_{idx}	0.200"	Normal	1	0.200"
$\Delta\theta$	0.050"	Normal	1	0.050"
θ			k=2	0.438"

9.4.6.9 Expanded uncertainty of measurement :

Angle Gauge Block Size	Best measurement expanded uncertainty (k=2)
0'-15'	0.45" or 0.50"
15°	0.55"
30°	0.45"
45°	0.40"
60°	0.45"
90°	0.35" or 0.45"

9.4.6.10 Reported result :

The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor k = 2, which for a normal distribution corresponds to a coverage probability of approximately 95%.

9.4.7.6 Uncertainty Budget of indexing table

Quantity x_i	Standard Uncertainty $u(x_i)$	Probability Distribution	Sensitivity coefficient (c_i)	Uncertainty contribution $U(y_i)$
θ_s	0.071"	Normal	1	0,071"
$\Delta\theta$	0,050"	Normal	1	0,050"
θ_{is}	0.020"	*t*	1	0,020"
θ_x			*k*=2	0,178"

9.4.7.7 Expanded uncertainty of measurement:

$$U = k \cdot u(\theta_x)$$

$$= 0{,}178''$$

$$\approx 0{,}20''$$

coverage factor, k = 2

BMC = 0,20"

9.4.7.8 Reported result:

The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor *k* = 2, which for a normal distribution corresponds to a coverage probability of approximately 95%.

Uncertainty Budget

Frequency 10 GHz, Attenuation 60 dB

Input		estimate u(xi)	Distribution	Ci	Uncertainty Combination u(yi)		Uncertainty type	Degrees of freedom
Attenuation Standard								
Ustd	60 dB	0.0115	t	1	Std.	0.012	-	-
measurand	60 dB	0.0018	t	1	measurand	0.002	-	5
Signal Generator					SG			
Usg_lev	0 dB	0.0029	Uniform	1	Usg_lev	0.003	B	-
Usg_freq.	0 dB	0.0000	Uniform	1	Usg_freq.		B	-
Usg_harmonic					Usg_harmonic			-
Freq. Converter								
Ufcon_f IF	0 dB	0.0000	Uniform	1	Ufcon_f IF		B	-
Ufcon_lev IF	0 dB	0.0000	Uniform	1	Ufcon_lev IF		B	-
Detector								
Udet_abs	0 dB	0.0000	Uniform	1	Udet_abs	0.000	B	-
Udet_lin	0 dB	0.0035	Uniform	1	Udet_lin	0.003	B	-
Udet_freq. 30 MHz			Uniform	1	Udet_freq. 30 MHz			
System								
Usys_lin	0 dB	0.0035	Uniform	1	Usys_lin	0.003	B	-
Usys_mis	0 dB	0.0034	U	1	Usys_mis	0.003	B	-
Usys_leak	0 dB	0.0481	U	1	Usys_leak	0.0000	B	-
Usys_res	0 dB	0.0003	Uniform	1	Usys_res	0.0003	B	-
Measurand	Estimate of Measurand							**0.013**

Confidence level	95%	
Calculated coverage factor	1.98	
Used coverage factor: k =	2	
Expanded uncertainty	**0.027**	dB

Table 9.4.9.2 Uncertainty budget for the Reference Optical Flat diameter 60 mm

Quantity x_i	Standard Uncertainty U(x$_i$)		Probability Distribution	Sensitivity Coefficient c_i	Uncertainty Contribution U(y$_i$)	
	Absolute	Relative			Absolute	Relative
l_{ox}	0,45 nm	-	Normal	1	0,45 nm	-
l_w	0,001 nm	-	Rectangular	1	0,001 nm	-
l_{p-p}	0,09 nm	-	Rectangular	1	0,09 nm	-
l_{p-v}	0,01 nm	-	Rectangular	1	0,01 nm	-
l_{p-t}	0,91 nm	-	Rectangular	1	0,91 nm	-
l_{m-d}	1,47 nm	-	Rectangular	1	1,47 nm	-
$u(l_x)$					1,79 nm	
l_x				k =2	4 nm	

Expanded uncertainty of measurement :

$U = k \cdot u(l_x)$

$= 2 \cdot 1{,}79$

$= 3{,}58$ nm

≈ 0.004 µm

Coverage factor $k = 2$

BMC = 4 nm

Report Result :

The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor k = 2, which for a normal distribution corresponds to a coverage probability of approximately 95%.

Table 9.4.9.4 Uncertainty Budget for flatness of optical parallel. diameter is 30.00 mm

Quantity x_i	Standard Uncertainty U(x)		Probability Distribution	Sensitivity Coefficient c_i	Uncertainty Contribution U(y)	
	Absolute	Relative			Absolute	Relative
l_{ox}	0,0004 µm	-	Normal	1	0,0004 µm	-
δl_s	0,002 µm	-	Normal	1	0.002 µm	-
δl_{is}	0,00004 µm	-	Rectangular	1	0,00004 µm	-
δl_{c-T}	0,0006 µm	-	Rectangular	1	0,0006 µm	-
δl_D	0.0094 µm	-	Rectangular	1	0.0094 µm	-
$u(l_x)$					0,0096 µm	-
l_x				k =2	0.02 µm	-

Expanded uncertainty of measurement :

$U = k \cdot u(l_x)$

$= 2 \cdot 0.0096$ µm

$= 0{,}0192$ µm

$\approx 0{,}02$ µm

Coverage factor k= 2

BMC = 0.02 µm

Report Result :

The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor k = 2. which for a normal distribution corresponds to a coverage probability of approximately 95%.

Table 9.4.9.6 Uncertainty budget for parallelism of optical parallel

Quantity x_i	Estimate x_i	Standard Uncertainty U(x_i)		Probability Distribution	Sensitivity Coefficient c	Uncertainty Contribution U(y_i)	
		Absolute	Relative			Absolute	Absolute
l_{ox}	0.06 µm	0.003 µm	-	Normal	1	0.003 µm	-
δl_{is}	0 µm	0.004 µm	-	Rectangular	1	0.004 µm	-
δl_c	0 µm	0.018 µm	-	Rectangular	1	0.018 µm	-
$u(l_x)$						0.019 µm	-
l_x	0.06 µm				k =2	0.04 µm	-

Expanded uncertainty of measurement :

$$U = k \cdot u(l_x)$$
$$= 2 \cdot 0.019$$
$$= 0.038 \ \mu m$$
$$\approx 0.04 \ \mu m$$

Coverage factor $k = 2$

BMC = 0.04 µm

Report Result :

The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor $k = 2$, which for a normal distribution corresponds to a coverage probability of approximately 95%.

Table 9.4.9.8 Uncertainty budget for thickness of optical parallel, nominal length is 12.00 mm

Quantity x_i	Standard Uncertainty $u(x_i)$		Probability Distribution	Sensitivity coefficient (c_i)	Uncertainty contribution $U(y_i)$	
	Absolute	Relative			Absolute (a)	Relative (b)
l_{ox}	0.012 µm	-	Normal	1	0.012 µm	-
δl_s	0.025 µm	0.685E-06 l	Normal	1	0.025 µm	0.685E-06 l
δl_{is}	0.004 µm	-	Rectangular	1	0.004 µm	-
$\overline{\alpha} \times \delta t$	-	3.64E-04 l	Special	1	-	3.64E-04 l
$\delta\alpha \times \Delta\overline{T}$	-	7.9E-05 l	Special	1	-	7.9E-05 l
$u(l_x)^2$	▨	▨			$(0.028)^2$	$(3.72\text{E-}04\ l)^2$

$$u(l_x)^2 = (0,028)^2 + (0,37 \cdot 10^{-3} \cdot l)^2 \qquad ;\ \mu m$$

$$u(l_x) = ((0.028)^2 + (0.37 \cdot 10^{-3} \cdot l)^2)^{1/2} \qquad ;\ \mu m$$

Expanded uncertainty of measurement :

$$U = k \cdot u(l_x) = 2 \cdot \sqrt{(0{,}028)^2 + (0{,}37 \cdot 10^{-3} \cdot l)^2} \qquad ;\ \mu m$$

$$= \sqrt{(0{,}06)^2 + (0{,}74 \cdot 10^{-3} \cdot l)^2} \qquad ;\ \mu m$$

Coverage factor $k = 2$

$$BMC = \sqrt{(0{,}06)^2 + (0{,}74 \cdot 10^{-3} \cdot l)^2} \qquad ;\ \mu m$$

Note: l being the nominal size of the Optical Parallel in mm

Report Result :

The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor k = 2, which for a normal distribution corresponds to a coverage probability of approximately 95%.

5.0 Uncertainty Budget

5.1 Uncertainty budget for analog vibration meter at acceleration function

Type	Source of Uncertainty	Value ±	Probability Distribution	Divisor	Ci	u(xi)	Υ_{eff}
A	Repeatability of Standard	U_A	normal	1.0	1.0	U_A	5
B	Reference standard	U_{RS}	normal	2	1.0	$\frac{U_{RS}}{2}$	∞
B	Voltmeter measurement	U_{V0}	rectangular	$\sqrt{3}$	1.0	$\frac{U_{V0}}{\sqrt{3}}$	∞
B	Conditioning amplifier	U_{CA}	rectangular	$\sqrt{3}$	1.0	$\frac{U_{CA}}{\sqrt{3}}$	∞
Uc	Combined Uncertainty		normal				
U	Expanded Uncertainty		normal (k = 2)				
U	Approved Uncertainty						

5.2 Uncertainty budget for analog vibration meter at velocity function

Type	Source of Uncertainty	Value ±	Probability Distribution	Divisor	Ci	u(xi)	Υ_{eff}
A	Repeatability of Standard	U_A	normal	1.0	1.0	U_A	5
B	Reference standard	U_{RS}	normal	2.0	1.0	$\frac{U_{RS}}{2}$	∞
B	Voltmeter measurement	U_{V0}	rectangular	$\sqrt{3}$	1.0	$\frac{U_{V0}}{\sqrt{3}}$	∞
B	Conditioning amplifier	U_{CA}	rectangular	$\sqrt{3}$	1.0	$\frac{U_{CA}}{\sqrt{3}}$	∞
B	Sine Generator	U_{SG}	rectangular	$\sqrt{3}$	1.0	$\frac{U_{SG}}{\sqrt{3}}$	∞
Uc	Combined Uncertainty		normal				
U	Expanded Uncertainty		normal (k = 2)				
U	Approved Uncertainty						

5.0 Uncertainty Budget

5.1 Uncertainty budget for analog vibration meter at acceleration function

Type	Source of Uncertainty	Value ±	Probability Distribution	Divisor	Ci	u(xi)	Υ_{eff}
A	Repeatability of Standard	U_A	normal	1.0	1.0	U_A	5
B	Reference standard	U_{RS}	normal	2	1.0	$\frac{U_{RS}}{2}$	∞
B	Voltmeter measurement	U_{V0}	rectangular	$\sqrt{3}$	1.0	$\frac{U_{V0}}{\sqrt{3}}$	∞
B	Conditioning amplifier	U_{CA}	rectangular	$\sqrt{3}$	1.0	$\frac{U_{CA}}{\sqrt{3}}$	∞
Uc	Combined Uncertainty		normal				
U	Expanded Uncertainty		normal (k = 2)				
U	Approved Uncertainty						

5.2 Uncertainty budget for analog vibration meter at velocity function

Type	Source of Uncertainty	Value ±	Probability Distribution	Divisor	Ci	u(xi)	Υ_{eff}
A	Repeatability of Standard	U_A	normal	1.0	1.0	U_A	5
B	Reference standard	U_{RS}	normal	2.0	1.0	$\frac{U_{RS}}{2}$	∞
B	Voltmeter measurement	U_{V0}	rectangular	$\sqrt{3}$	1.0	$\frac{U_{V0}}{\sqrt{3}}$	∞
B	Conditioning amplifier	U_{CA}	rectangular	$\sqrt{3}$	1.0	$\frac{U_{CA}}{\sqrt{3}}$	∞
B	Sine Generator	U_{SG}	rectangular	$\sqrt{3}$	1.0	$\frac{U_{SG}}{\sqrt{3}}$	∞
Uc	Combined Uncertainty		normal				
U	Expanded Uncertainty		normal (k = 2)				
U	Approved Uncertainty						

5.3 Uncertainty budget for analog vibration meter at displacement function

Type	Source of Uncertainty	Value ±	Probability Distribution	Divisor	Ci	u(xi)	Υ_{eff}
A	Repeatability of Standard	U_A	normal	1.0	1.0	U_A	5
B	Reference standard	U_{RS}	normal	2.0	1.0	$\frac{U_{RS}}{2}$	∞
B	Voltmeter measurement	U_{V0}	rectangular	$\sqrt{3}$	1.0	$\frac{U_{V0}}{\sqrt{3}}$	∞
B	Conditioning amplifier	U_{CA}	rectangular	$\sqrt{3}$	1.0	$\frac{U_{CA}}{\sqrt{3}}$	∞
B	Sine Generator	U_{SG}	rectangular	$\sqrt{3}$	2.0	$\frac{U_{SG}}{\sqrt{3}}$	∞
Uc	Combined Uncertainty		normal				
U	Expanded Uncertainty		normal (k = 2)				
U	Approved Uncertainty						

5.4 Method of calculate uncertainty budget for analog vibration meter

5.4.1 Uncertainty of repeatability of standard (Type A); U_A

$$U_A = \frac{\sigma_{n-1}}{\sqrt{n}}$$

When

$$\sigma_{n-1} = \frac{1}{n-1} \cdot \sqrt{\sum_{i=1}^{n} (x_i - \bar{x})^2}$$

$$\bar{x} = \sum_{i=1}^{n} x_i$$

$$n = 6$$

5.4.2 Uncertainty of reference standard; U_{RS}

$$U_{RS(1\sigma)} = \frac{U_{(95\%)}\text{from Certificate}}{2}$$

5.4.3 Uncertainty of voltmeter measurement; U_{V0}

$$U_{V0(1\sigma)} = \frac{\text{Accuracy specification of voltmeter}}{\sqrt{3}}$$

5.4.4 Uncertainty of sine generator; U_{SG}

$$U_{SG(1\sigma)} = \frac{\text{Accuracy specification of sine generator}}{\sqrt{3}}$$

Remark: Apply only in velocity and displacement function

5.4.5 Uncertainty of conditioning amplifier; U_{CA}

$$U_{BC} = \frac{\text{Accuracy specification of conditioning amplifier}}{\sqrt{3}}$$

5.4.6 Combine uncertainty; U_C

For acceleration function

$$U_C = \sqrt{U_A^2 + U_{RS}^2 + U_{V0}^2 + U_{CA}^2}$$

For velocity function and displacement function

$$U_C = \sqrt{U_A^2 + U_{RS}^2 + U_{V0}^2 + U_{CA}^2 + U_{SG}^2}$$

5.4.7 Welch-Satterwaite equation; Υ_{eff}

$$\Upsilon_{eff} = \frac{U_C^2}{\sum_{i=1}^{n} \frac{U_i^4}{\upsilon_i}}$$

when

U_i = U_A, U_{RS}, U_{V0}, U_{CA}, U_{SG}
υ_i = Degree of freedom = n-1
n = Number of measurement

5.4.8 Expanded Uncertainty; $U_{(95\%)}$

$U_{(95\%)}$ = k x U_c

When Cofactor k=2

5.4.9 Approved Uncertainty by approximate expanded uncertainty (U)

5.5 Uncertainty budget for digital vibration meter at acceleration function

Type	Source of Uncertainty	Value ±	Probability Distribution	Divisor	Ci	u(xi)	Υ_{eff}
A	Repeatability of Standard	U_A	normal	1.0	1.0	U_A	5
B	Reference standard	U_{RS}	normal	2.0	1.0	$\frac{U_{RS}}{2}$	∞
B	Voltmeter measurement	U_{V0}	rectangular	$\sqrt{3}$	1.0	$\frac{U_{BV}}{\sqrt{3}}$	∞
B	Conditioning amplifier	U_{CA}	rectangular	$\sqrt{3}$	1.0	$\frac{U_{CA}}{\sqrt{3}}$	∞
B	Resolution of UUT	U_{BS}	rectangular	$2\sqrt{3}$	1.0	$\frac{U_{BS}}{2\sqrt{3}}$	∞
Uc	Combined Uncertainty		normal				
U	Expanded Uncertainty		normal (k = 2)				
U	Approved Uncertainty						

5.6 Uncertainty budget for digital vibration meter at velocity function

Type	Source of Uncertainty	Value ±	Probability Distribution	Divisor	Ci	u(xi)	Υ_{eff}
A	Repeatability of Standard	U_A	normal	1.0	1.0	U_A	9
B	Reference standard	U_{RS}	normal	2.0	1.0	$\frac{U_{RS}}{2}$	∞
B	Voltmeter measurement	U_{V0}	rectangular	$\sqrt{3}$	1.0	$\frac{U_{V0}}{\sqrt{3}}$	∞
B	Conditioning amplifier	U_{CA}	rectangular	$\sqrt{3}$	1.0	$\frac{U_{CA}}{\sqrt{3}}$	∞
B	Sine Generator	U_{SG}	rectangular	$\sqrt{3}$	1.0	$\frac{U_{SG}}{\sqrt{3}}$	∞
B	Resolution of UUT	U_{BS}	rectangular	$2\sqrt{3}$	1.0	$\frac{U_{BS}}{2\sqrt{3}}$	∞
Uc	Combined Uncertainty		normal				
U	Expanded Uncertainty		normal (k = 2)				
U	Approved Uncertainty						

5.7 Uncertainty budget for digital vibration meter at displacement function

Type	Source of Uncertainty	Value ±	Probability Distribution	Divisor	Ci	u(xi)	Υ_{eff}
A	Repeatability of Standard	U_A	normal	1.0	1.0	U_A	9
B	Reference standard	U_{RS}	normal	2.0	1.0	$\frac{U_{RS}}{2}$	∞
B	Voltmeter measurement	U_{V0}	rectangular	2.0	1.0	$\frac{U_{V0}}{\sqrt{3}}$	∞
B	Conditioning amplifier	U_{CA}	rectangular	$\sqrt{3}$	1.0	$\frac{U_{CA}}{\sqrt{3}}$	∞
B	Sine Generator	U_{SG}	normal	$\sqrt{3}$	2.0	$\frac{U_{SG}}{\sqrt{3}}$	∞
B	Resolution of UUT	U_{BS}	rectangular	$2\sqrt{3}$	1.0	$\frac{U_{BS}}{2\sqrt{3}}$	∞
Uc	Combined Uncertainty		normal				
U	Expanded Uncertainty		normal (k = 2)				
U	Approved Uncertainty						

5.8 Method of calculate uncertainty budget for digital vibration meter

5.8.1 Uncertainty of repeatability of standard (Type A); U_A

$$U_A = \frac{\sigma_{n-1}}{\sqrt{n}}$$

When

$$\sigma_{n-1} = \frac{1}{n-1} \cdot \sqrt{\sum_{i=1}^{n} (x_i - \bar{x})^2}$$

$$\bar{x} = \sum_{i=1}^{n} x_i$$

$$n = 10$$

5.8.2 Uncertainty of reference standard; U_{RS}

$$U_{RS}(1\delta) = \frac{U_{(95\%)} \text{ from Certificate}}{2}$$

5.8.3 Uncertainty of voltmeter measurement; U_{V0}

$$U_{V0}(1\delta) = \frac{\text{Accuracy specification of voltmeter}}{\sqrt{3}}$$

5.8.4 Uncertainty of conditioning amplifier; U_{CA}

$$U_{CA} = \frac{\text{Accuracy specification of conditioning amplifier}}{\sqrt{3}}$$

5.8.5 Uncertainty of sine generator; U_{SG}

$$U_{SG}(1\delta) = \frac{\text{Accuracy specification of sine generator}}{\sqrt{3}}$$

Remark: Apply only in velocity and displacement function

5.8.6 Uncertainty of resolution of UUT; U_{BS}

$$U_{BS} = \frac{\text{digit x 100}}{\text{mean of standard value x } 2\sqrt{3}}$$

5.8.7 Combine uncertainty; U_C

For acceleration function

$$U_C = \sqrt{U_A^2 + U_{RS}^2 + U_{V0}^2 + U_{CA}^2}$$

For velocity function and displacement function

$$U_C = \sqrt{U_A^2 + U_{RS}^2 + U_{V0}^2 + U_{CA}^2 + U_{SG}^2}$$

5.8.8 Welch-Satterwaite equation; Υ_{eff}

$$\Upsilon_{eff} = \frac{U_C^2}{\sum_{i=1}^{n} \frac{U_i^4}{\upsilon_i}}$$

when U_I = U_A, U_{BR}, U_{BV}, U_{BC}, U_{SG}
υ_i = Degree of freedom = n-1
n = Number of measurement

5.8.9 Expanded Uncertainty; $U_{(95\%)}$

$$U_{(95\%)} = k \text{ x } U_c$$

When Cofactor k=2

5.8.10 Approved Uncertainty by approximate expanded uncertainty (U)

5.0 UNCERTAINTY BUDGET:

5.1 Uncertainty budget for vibration exciter at acceleration function

Type	Source of Uncertainty	Value ±	Probability Distribution	Divisor	Ci	u(xi)	Υ_{eff}
A	Repeatability of Standard from Voltmeter	U_{AV}	normal	1.0	1.0	U_{AV}	9
B	Reference standard	U_{RS}	normal	2.0	1.0	$\frac{U_{RS}}{2}$	∞
B	Voltmeter measurement	U_{V0}	rectangular	$\sqrt{3}$	1.0	$\frac{U_{V0}}{\sqrt{3}}$	∞
B	Conditioning amplifier	U_{CA}	rectangular	$\sqrt{3}$	1.0	$\frac{U_{CA}}{\sqrt{3}}$	∞
Uc	Combined Uncertainty		normal				
U	Expanded Uncertainty		normal (k = 2)				
U	Approved Uncertainty						

5.2 Uncertainty budget for vibration exciter at velocity function

Type	Source of Uncertainty	Value ±	Probability Distribution	Divisor	Ci	u(xi)	Υ_{eff}
A	Repeatability of Standard from Voltmeter	U_{AV}	normal	1.0	1.0	U_{AV}	9
A	Repeatability of Standard from Frequency meter	U_{AF}	normal	1.0	1.0	U_{AF}	9
B	Reference standard	U_{RS}	normal	2.0	1.0	$\frac{U_{BR}}{2}$	∞
B	Voltmeter measurement	U_{V0}	rectangular	$\sqrt{3}$	1.0	$\frac{U_{V0}}{\sqrt{3}}$	∞
B	Conditioning amplifier	U_{CA}	rectangular	$\sqrt{3}$	1.0	$\frac{U_{CA}}{\sqrt{3}}$	∞
B	Frequency meter	U_{BF}	rectangular	$\sqrt{3}$	1.0	$\frac{U_{BF}}{\sqrt{3}}$	∞
Uc	Combined Uncertainty		normal				

U	Expanded Uncertainty		normal (k = 2)				
U	Approved Uncertainty						

5.3 Uncertainty budget for vibration exciter at displacement function

Type	Source of Uncertainty	Value ±	Probability Distribution	Divisor	Ci	u(xi)	Υ_{eff}
A	Repeatability of Standard from Voltmeter	U_{AV}	normal	1.0	1.0	U_{AV}	9
A	Repeatability of Standard from Frequency meter	U_{AF}	normal	1.0	1.0	U_{AF}	9
B	Reference standard	U_{RS}	normal	2.0	1.0	$\frac{U_{RS}}{2}$	∞
B	Voltmeter measurement	U_{V0}	rectangular	$\sqrt{3}$	1.0	$\frac{U_{V0}}{\sqrt{3}}$	∞
B	Conditioning amplifier	U_{CA}	rectangular	$\sqrt{3}$	1.0	$\frac{U_{CA}}{\sqrt{3}}$	∞
B	Frequency meter	U_{BF}	rectangular	$\sqrt{3}$	1.0	$\frac{U_{BF}}{\sqrt{3}}$	∞
Uc	Combined Uncertainty		normal				
U	Expanded Uncertainty		normal (k = 2)				
U	Approved Uncertainty						

5.4 Uncertainty Budget Calculation for analog vibration meter

5.4.1 Uncertainty of repeatability of standard form Voltmeter (Type A); U_{AV}

$$U_{AV} = \frac{\sigma_{n-1}}{\sqrt{n}}$$

When

$$\sigma_{n-1} = \sqrt{\frac{1}{(n-1)}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$$

n = 10

5.4.2 Uncertainty of repeatability of standard form Frequency meter (Type A); U_{AF}

$$U_{AF} = \frac{\sigma_{n-1}}{\sqrt{n}}$$

When

$$\sigma_{n-1} = \sqrt{\frac{1}{(n-1)}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$$

n = 10

5.4.3 Uncertainty of reference standard; U_{RS}

$$U_{RS}(1\sigma) = \frac{U_{(95\%)}\ from\ Certificate}{2}$$

5.4.4 Uncertainty of voltmeter measurement; U_{BF}

$$U_{ro}(1\sigma) = \frac{\text{Accuracy specification of volt meter}}{\sqrt{3}}$$

5.4.5 Uncertainty of frequency meter; U_{BF}

$$U_{BF}(1\sigma) = \frac{Accuracy\ \ specification\ \ of\ \ frequency\ \ meter}{\sqrt{3}} \times C_i$$

Remark: Use in only velocity function and displacement function

5.4.6 Uncertainty of conditioning amplifier; U_{CA}

$$U_{CA}(1\sigma)=\frac{Accuracy\ \ specification\ \ of\ \ conditioning\ \ amplifier}{\sqrt{3}}$$

5.4.7 Combine uncertainty; U_C

For acceleration function

U_C = $\sqrt{U_{AV}^2+U_{AF}^2+U_{RS}^2+U_{V0}^2+U_{CA}^2}$

For velocity function and displacement function

U_C = $\sqrt{U_{AV}^2+U_{AF}^2+U_{RS}^2+U_{V0}^2+U_{CA}^2+U_{BF}^2}$

5.4.8 Welch-Satterwaite equation; Υ_{eff}

$$\Upsilon_{eff} = \frac{U_C^2}{\sum_{i=1}^{n}\frac{U_i^4}{\upsilon_i}}$$

when

U_i = U_A, U_{RS}, U_{V0}, U_{CA}, U_{SG}

$\square_i$ = Degree of freedom = n-1

n = Number of measurement

5.4.9 Expanded Uncertainty; $U_{(95\%)}$

$U_{(95\%)}$ = k x U_c

When Cofactor k=2

5.4.10 Approved Uncertainty by approximate expanded uncertainty (U)

Figure 1 Show the set-up of accelerometer calibration by back to back method

5.0 UNCERTAINTY BUDGET :

5.1 Uncertainty budget for analog vibration meter at acceleration function

Type	Source of Uncertainty	Value ±	Probability Distribution	Divisor	Ci	u(xi)	Υ_{eff}
A	Repeatability of Sensitivity	U_{AS}	Normal	1.0	1.0	U_{AS}	30
B	Reference standard (Accelerometer with charge amplifier)	U_{BR}	Normal	2.0	1.0	$\frac{U_{BR}}{2}$	☐
B	Voltmeter measurement of Standard	U_{BVS}	Rectangular	$\sqrt{3}$	1.0	$\frac{U_{BVS}}{\sqrt{3}}$	☐
B	Voltmeter Measurement of UUT	U_{BVU}	Rectangular	$\sqrt{3}$	1.0	$\frac{U_{Bvu}}{\sqrt{3}}$	☐
B	Conditioning amplifier of UUT	U_{BCU}	Rectangular	$\sqrt{3}$	1.0	$\frac{U_{Bvu}}{\sqrt{3}}$	☐
B	Transverse acceleration	U_{TA}	Special	$\sqrt{\frac{1}{18}}$	1.0	$\frac{U_{TA}}{\sqrt{\frac{1}{18}}}$	☐
Uc	Combined Uncertainty		Normal				
U	Expanded Uncertainty		Normal (k = 2)				
U	Approved Uncertainty						

5.2 Method of calculate uncertainty budget for analog vibration meter

5.2.1 Uncertainty of repeatability of standard (Type A); U_{AS}

$$U_{AS} = \frac{\sigma_{n-1}}{\sqrt{n}}$$

When

$$\sigma_{n-1} = \frac{1}{n-1}\cdot\sqrt{\sum_{i=1}^{n}(x_i-\bar{x})^2}$$

$$\bar{x} = \sum_{i=1}^{n} x_i$$

$$n = 30$$

5.2.2 Uncertainty of reference standard; U_{BR}

$$U_{BR}(1\square) = \frac{U_{(95\%)}\text{ from Certificate}}{2}$$

5.2.3 Uncertainty of voltmeter measurement of standard; U_{BVS}

$$U_{BV}(1\square) = \frac{U_{(95\%)}\text{ from Certificate}}{1.732}$$

5.2.4 Uncertainty of voltmeter measurement of UUT; U_{BVU}

$$U_{SG}(1\square) = \frac{U_{(95\%)}\text{ from Certificate}}{1.732}$$

5.2.5 Uncertainty of conditioning amplifier of UUT; U_{BCU}

$$U_{BC} = \frac{U_{(95\%)}\text{ from Certificate}}{1.732}$$

5.2.6 Uncertainty of Transverse acceleration; U_{TA}

TA $= \sqrt{\left(S_{v,2}^2 + S_{v,1}^2\right) a_T^2}$

Where

$S_{v,1}$ is Transverse sensitivity of reference transducer.(max.=2%)

$S_{v,2}$ is Transverse sensitivity of transducer to be calibrated.

$$U_{TA} = \frac{TA}{\sqrt{\frac{1}{18}}}$$

5.2.7 Combine uncertainty; U_C

$$U_C = \sqrt{U_{AS}^2 + U_{BR}^2 + U_{BVS}^2 + U_{BVU}^2 + U_{BCU}^2 + U_{TA}^2}$$

5.2.8 Welch-Satterwaite equation; Υ_{eff}

$$\Upsilon_{eff} = \frac{U_C^4}{\sum_{i=1}^{n} \frac{U_i^4}{\upsilon_i}}$$

when

U_i = U_{AS}, U_{AU}, U_{BVS}, U_{BVU}, U_R, U_{BC}

$□_i$ = Degree of freedom = n-1

n = Number of measurement

5.2.9 Expanded Uncertainty; $U_{(95\%)}$

$U_{(95\%)}$ = k x U_c

When Cofactor k=2

5.2.10 Approved Uncertainty by approximate expanded uncertainty (U)

5.0 UNCERTAINTY BUDGET :

5.1 Uncertainty budget for ratio method

Type	Source of Uncertainty	Symbol	Probability Distribution	Divisor	Ci	u(xi)	Υ_{eff}
B	Accuracy of ratio counter	U_1	rectangular	$\sqrt{3}$	1.0	$\frac{U_1}{\sqrt{3}}$	∞
A	Repeatability of ratio counter	U_2	normal	1.0	1.0	U_2	9
B	Wavelength instability	U_3	rectangular	$\sqrt{3}$	1.0	$\frac{U_3}{\sqrt{3}}$	∞
B	Accuracy of Sine generator	U_4	rectangular	$\sqrt{3}$	2.0	$\frac{U_4}{\sqrt{3}}$	☐
A	Repeatability of voltage output	U_5	normal	1.0	1.0	U_5	9
B	Accuracy of voltmeter	U_6	rectangular	$\sqrt{3}$	1.0	$\frac{U_6}{\sqrt{3}}$	☐
B	Uncertainty of Charge Amplifier	U_7	normal	2.0	1.0	U_7	☐
B	Effect of distortion	U_8	normal	1.0	1.0	$\frac{U_8}{\sqrt{3}}$	☐
B	Effect of transverse	U_9	special	$\sqrt{18}$	1.0	$\frac{U_9}{\sqrt{18}}$	☐
A	Repeatability of Sensitivity	U_{10}	normal	1.0	1.0	U_{10}	9
B	Resolution of sensitivity	U_{11}	rectangular	$\sqrt{3}$	1.0	$\frac{U_{11}}{\sqrt{3}}$	☐
Uc	Combined Uncertainty		normal				
U	Expanded Uncertainty		normal (k = 2)				
U	Approved Uncertainty						

5.2 Uncertainty budget for minimum point method

Type	Source of Uncertainty	Symbol	Probability Distribution	Divisor	Ci	u(xi)	Υ_{eff}
B	Wavelength instability	U_1	rectangular	$\sqrt{3}$	1.0	$\frac{U_1}{\sqrt{3}}$	∞
B	Accuracy of Sine generator	U_2	rectangular	$\sqrt{3}$	2.0	$\frac{U_2}{\sqrt{3}}$	∞
A	Repeatability of voltage output	U_3	normal	1.0	1.0	U_3	6
B	Accuracy of voltmeter	U_4	rectangular	$\sqrt{3}$	1.0	$\frac{U_4}{\sqrt{3}}$	☐
B	Uncertainty of charge Amplifier	U_5	normal	2.0	1.0	$\frac{U_5}{2}$	☐
B	Effect of distortion	U_6	normal	1.0	1.0	$\frac{U_6}{\sqrt{3}}$	☐
B	Effect of transverse	U_7	special	$\sqrt{18}$	1.0	$\frac{U_7}{\sqrt{18}}$	☐
A	Repeatability of Sensitivity	U_8	normal	1.0	1.0	U_8	6
B	Resolution of FFT Analyzer	U_9	rectangular	$\sqrt{3}$	1.0	$\frac{U_9}{\sqrt{3}}$	☐
B	Resolution of sensitivity report	U_{10}	rectangular	$\sqrt{3}$	1.0	$\frac{U_{10}}{\sqrt{3}}$	☐
Uc	Combined Uncertainty		normal				
U	Expanded Uncertainty		normal (k = 2)				
U	Approved Uncertainty						

5.4 Method of calculate uncertainty budget for ratio method

5.4.1 uncertainty budget for ratio method

No.	Source of uncertainty	Symbol	Method of calculate uncertainty budget
1	Accuracy of ratio counter	U_1	$U_1 = \left(\left\| \frac{LSD}{R_f} \right\| + \left\| \frac{\text{RMS Resolution}}{R_f} \right\| \right) \times 100$ where $\frac{LSD}{R_f} = \frac{1}{\text{Gate Time} \times f_{\max,chA}}$ $\frac{RMS\,\text{Re}\,solution}{R_f} = \frac{2 \times \sqrt{1 + (f_{\max,chA} \times \text{B Trigger Error})^2}}{\text{Gate Time} \times \text{f}_{\max,\text{chA}}}$ B Trigger Error = 0.64 x 10^{-12} s
2	Repeatability of ratio counter	U_2	$U_2 = \frac{S.D._{\text{ratio counter}} \times 100}{Average_{\text{ratio counter}} \times \sqrt{n}}$
3	Specification of Wavelength	U_3	$U_3 = \frac{0.001 \times 100}{632.815 \times 2} = 0.00008\ \%$
4	Accuracy of Sine generator	U_4	U_4 From specification of function/arbitrary waveform generator. $U_4 = 0.004\%$
5	Repeatability of voltage output	U_5	$U_5 = \frac{S.D._{voltage} \times 100}{Average_{voltage} \times \sqrt{n}}$
6	Accuracy of voltmeter	U_6	U_6 From specification of voltmeter.
7	Uncertainty of Charge Amplifier	U_7	U_7 From certification of charge amplifier
8	Effect of distortion	U_8	The effect of distortion can measured by distortion meter on output voltage. $U_8 = \frac{1}{2}(d_{tot})^2 \times 100$

No.	Source of	Symbol	Method of calculate uncertainty budget

	uncertainty		
9	Effect of transverse	U_9	$U_7 = \sqrt{S^2 \times a^2} = \sqrt{.02^2 \times .1^2} = 0.2\ \%$ S = Transverse sensitivity of reference, S,max.2% a = Transverse vibration for vibrator, a,max.10%
10	Repeatability of Sensitivity	U_{10}	$U_{10} = \dfrac{S.D._{sensitivity} \times 100}{Average_{sensitivity} \times \sqrt{n}}$
11	Resolution of sensitivity	U_{11}	$U_{11} = \dfrac{\mathrm{Re}solution \times 100}{Sensitivity \times 2}$

5.4.2 uncertainty budget for minimum point method

The combined uncertainty, $u(\tau_x)$, can be expressed in the form of

$$u(\tau_x) \;=\; \sqrt{u(\delta\text{std})^2 + u(\delta\tau_x)^2 + u(\delta_{\text{UTC(NIMT)}})^2 + u(\delta_{\text{freq}})^2 + u(\delta_{\text{Cable}})^2}$$

The expanded uncertainty will be

$$U \;=\; k \bullet u(\tau_x) \;=\; 2 \bullet u(\tau_x)$$

6.0 UNCERTAINTY BUDGET :

Quantity X_i	Estimate x_i	Standard Uncertainty $u(x_i)$		Probability Distribution	Effective Degree of freedom (ν_i)	Sensitivity Coefficient c_i	Uncertainty Contribution $u_i(y)$	
		Relative	Absolute (s)				Relative	Absolute (s)
τ_{ix}	0	-	-	Normal	999	1	-	-
$\delta\tau_x$	0	-	$814{,}52 \cdot 10^{-12}$	rectangular	∞	1	-	$814{,}52 \cdot 10^{-12}$
$\delta_{\text{UTC(NIMT)}}$	0	-	$9{,}13 \cdot 10^{-13}$	Normal	∞	1	-	$9{,}13 \cdot 10^{-13}$
δ_{freq}	0	-	$1{,}5 \cdot 10^{-12}$	Normal	∞	1	-	$1{,}5 \cdot 10^{-12}$
δ_{cable}	0	-	0	Normal	∞	1	-	0
τ_x	0						-	$814{,}52 \cdot 10^{-12}$

Expanded Uncertainty :

$$\begin{aligned} U &= k \circ u(F_x) \\ &= 2 \bullet 814{,}52 \bullet 10^{-12} \\ &= 1{,}629 \bullet 10^{-12}\ \text{s} \\ &= 2\ \text{ns} \end{aligned}$$

Uncertainty budget of primary pH method
Measurement temperature 25 C
Phthalate buffer solution, Wako reagent

$R := 8.314472$

$F := 96485.3415 \qquad \gamma := 0.9042 \qquad i := 0..3$

$T := 298.15 \qquad m := 0.01001 \qquad Pw := 3173 \qquad AE := 0.90489 \qquad E0 := 0.222477$

$EMF := 0.46380 \qquad P := 99682 \qquad Pa := 99691 \qquad M := 0.005$

$$f0(EMF,T,m,P) := EMF + \frac{R \cdot T \cdot \ln(10)}{F} \cdot \left(2 \cdot \log(m \cdot \gamma) - 0.5 \cdot \log\left(\frac{P - Pw}{101325}\right)\right)$$

$k_0 := \frac{d}{dEMF} f0(EMF,T,m,P) \qquad k_1 := \frac{d}{dT} f0(EMF,T,m,P)$

$k_2 := \frac{d}{dm} f0(EMF,T,m,P) \qquad k_3 := \frac{d}{dP} f0(EMF,T,m,P)$

$$k = \begin{pmatrix} 1 \\ 8.088 \times 10^{-4} \\ 5.133 \\ 1.331 \times 10^{-7} \end{pmatrix} \qquad u := \begin{pmatrix} 5 \cdot 10^{-5} \\ 10^{-2} \\ 3.1 \cdot 10^{-6} \\ 23 \end{pmatrix} \qquad u_{E0} := \sqrt{\sum_i \left(k_i \cdot u_i\right)^2} \qquad W_i := \frac{\left(k_i \cdot u_i\right)^2 \cdot 100}{\sum_i \left(k_i \cdot u_i\right)^2}$$

$u_{E0} = 5.318 \times 10^{-5}$

$$W = \begin{pmatrix} 88.401 \\ 2.313 \\ 8.955 \\ 0.331 \end{pmatrix}$$

$$f(AE,E0,T,M,Pa) := \frac{(AE - E0) \cdot F}{R \cdot T \cdot \ln(10)} + \log(M) - 0.5 \cdot \log\left(\frac{Pa - Pw}{101325}\right)$$

$\Theta_0 := \frac{d}{dAE} f(AE,E0,T,M,Pa) \qquad \Theta_1 := \frac{d}{dE0} f(AE,E0,T,M,Pa)$

$\Theta_2 := \frac{d}{dT} f(AE,E0,T,M,Pa) \qquad \Theta_3 := \frac{d}{dM} f(AE,E0,T,M,Pa) \qquad \Theta_4 := \frac{d}{dPa} f(AE,E0,T,M,Pa)$

$$\Theta = \begin{pmatrix} 16.903 \\ 16.903 \\ -0.039 \\ 86.859 \\ 2.25 \times 10^{-6} \end{pmatrix} \qquad u_\Theta := \begin{pmatrix} 5 \cdot 10^{-5} \\ u_{E0} \\ 10^{-2} \\ 5 \cdot 10^{-6} \\ 23 \end{pmatrix} \qquad i := 0..4$$

$$u_{pa} := \sqrt{\sum_i \left(\Theta_i \cdot u_{\Theta_i}\right)^2} \qquad w_i := \frac{\left(\Theta_i \cdot u_{\Theta_i}\right)^2 \cdot 100}{\sum_i \left(\Theta_i \cdot u_{\Theta_i}\right)^2}$$

$u_{pa} = 1.365 \times 10^{-3}$

$$w = \begin{pmatrix} 38.335 \\ 43.365 \\ 8.033 \\ 10.122 \\ 0.144 \end{pmatrix}$$

$$m_{c} := \begin{pmatrix} 4.973 \times 10^{-3} \\ 0.01 \\ 0.015 \\ 0.02 \end{pmatrix} \qquad V := \begin{pmatrix} 4.0932 \\ 4.0944 \\ 4.0896 \\ 4.0848 \end{pmatrix}$$

$i := 0..3$

$$S := \sqrt{\sum_i \frac{\left[V_i - \left(a_{2s} + b_{2s} \cdot m_{c_i}\right)\right]^2}{N - 1}} \qquad m_{mean} := mean(m_c) \qquad m_{mean} = 0.012496 \qquad S = 1.638 \times 10^{-3}$$

$$u_p := S \cdot \sqrt{\frac{1}{N+1} + \frac{m_{mean}^2}{\sum_i \left(m_{c_i} - m_{mean}\right)^2}} \qquad u_p = 1.917 \times 10^{-3}$$

$corr(m_c, V) = 0.898$

$uncertainty := \sqrt{u_B^2 + u_p^2}$

$uncertainty = 2.4 \times 10^{-3}$

Uncertainty budget of force measurement (according to ISO 376 :1999)

1. Uncertainty of the Force standard machine (u_{fsm})

$u_{fsm} = U_{fsm} /2$

$= 20$ ppm.

2. Uncertainty of reproducibility

$u_{rpo}{}^2 = (b)^2 / 2$

$= 15$ ppm.

3. Uncertainty of repeatability

$u_{rep}{}^2 = (b')^2 / 12$

$= 10$ ppm.

4. Uncertainty of zero deviation

$u_0{}^2 = (f_0)^2 / 12$

$= 8$ ppm.

5. Uncertainty of interpolation

$u_i{}^2 = (f_c)^2 / 6$

$= 4$ ppm.

6. Uncertainty of Reversibility

$u_v{}^2 = (v)^2 / 12$

$= 12$ ppm.

7. Uncertainty of Resolution

$u_{res}{}^2 = (\text{resolution})^2 / 12$

$= 6$ ppm.

Combined standard uncertainty

$u_c{}^2 = (u_{fsm}{}^2) +(u_{rpo}{}^2)+(u_{rep}{}^2)+(u_0{}^2)+ (u_i{}^2) + (u_v{}^2)+ (u_{res}{}^2)$

$= (20)^2 + (15)^2 + (10)^2 +(8)^2 + (4)^2 +(12)^2 +(6)^2$

$= 32$ ppm.

Expanded standard uncertainty

$U = k\,u_c \quad (k = 2)$

$= 2\ (32)$ ppm.

$= 64$ ppm. → 0.0064 %

5 UNCERTAINTY CALCULATION :

5.1 Standard uncertainty of the weighing process, $u_w(\Delta\overline{m}_c)$ (type A)

The standard uncertainty of the weighing process, $u_w(\Delta\overline{m}_c)$, is the standard deviation of the mass difference. For n cycles of measurement :

$$u_w(\Delta\overline{m}_c) = \frac{s(\Delta m_{ci})}{\sqrt{n}} \tag{6}$$

where $s(\Delta m_{ci})$ is pooled standard deviation of mass comparators obtained from the previous performance check made under similar conditions.

$$s(\Delta m_{ci}) = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(\Delta m_{ci} - \Delta\overline{m}_c)^2} \tag{7}$$

For the calibration of 50 kg weights by use mass comparator (CC50001S-L), the standard uncertainty of the weighing process, $u_w(\Delta\overline{m}_c)$ is calculated by

$$u_w(\Delta\overline{m}_c) = \frac{\sqrt{2}xs(\Delta m_{ci})}{2x\sqrt{n}} \tag{8}$$

5.2 Uncertainty of the reference weight, $u(m_{cr})$(type B)

The standard uncertainty $u(m_{cr})$of the reference weight is calculated from the internal calibration results by dividing the expanded uncertainty *U*, by the coverage factor *k* (*k*=2) and should be combined with the uncertainty due to the instability of the reference weight

$$u(m_{cr}) = \sqrt{\left(\frac{U}{k}\right)^2 + u_s^2(m_{cr})} \tag{9}$$

For the calibration several reference weights m_{cri} are combined and the standard uncertainty $u(m_{cr})$ is the linear summation of uncertainties

$$u(m_{cr}) = \sum iu(m_{cri}) \tag{10}$$

where $u(m_{cri})$is the standard uncertainty of the reference weight i.

5.3 Uncertainty of air buoyancy correction , u_b (type B)

The uncertainty of air buoyancy correction is calculated from

$$u_b^2 = \left[m_{cr} \frac{(\rho_r - \rho_t)}{\rho_r \rho_t} u_{\rho a} \right]^2 + [m_{cr}(\rho_a - \rho_0)]^2 \frac{u_{\rho t}^2}{\rho_t^4} + m_{cr}^2 (\rho_a - \rho_0)[(\rho_a - \rho_0) - 2(\rho_{a1} - \rho_0)] \frac{u_{\rho r}^2}{\rho_r^4} \qquad (11)$$

where $u_{\rho a}$ = The standard uncertainty of the air density.

ρ_{a1} = The air density during the previous calibration of the reference weight.

$u_{\rho t}$ = The standard uncertainty of the density of the test weight.

$u_{\rho r}$ = The standard uncertainty of the density of the reference weight.

The standard uncertainty of the air density ($u_{\rho a}$) is estimated from the uncertainty for pressure, temperature and humidity. The variance of the air density is

$$u(\rho_a) = \sqrt{u_F^2 + \left(\frac{\partial \rho_a}{\partial P} u_P \right)^2 + \left(\frac{\partial \rho_a}{\partial T} u_T \right)^2 + \left(\frac{\partial \rho_a}{\partial H} u_H \right)^2} \qquad (12)$$

where u_F = uncertainty of the formula used (for CIPM approximate formula: $u_F = 2\text{x}10^{-4}\ \rho_a$).

$\frac{\partial \rho_a}{\partial P} = 10^{-5}\text{Pa}^{-1}\rho_a$

$\frac{\partial \rho_a}{\partial T} = -3.4\text{x}10^{-3}\text{K}^{-1}\rho_a$

$\frac{\partial \rho_a}{\partial H} = -10^{-2}\rho_a$

and $$\rho_a = \frac{0.34848p - 0.009(hr) \times \exp(0.062t)}{273.15 + t} \qquad (13)$$

If the density of the test and reference weight, or its uncertainty is not known, the mean value recommended by OIML R 111 is used.

5.4 Uncertainty of the balance, u_{ba} (type B)

- Uncertainty due to the sensitivity of the balance

$$u_s^2 = (\Delta\overline{m}_c)^2\left(\frac{u^2(m_s)}{m_s^2}+\frac{u^2(\Delta I_s)}{\Delta I_s^2}\right) \tag{14}$$

where $\Delta\overline{m}_c$ = The average mass difference between the test weight and the reference weight.

m_s = The sensitivity weight of mass.

$u(m_s)$ = The standard uncertainty of the sensitivity weight of mass.

ΔI_s = The change in the indication of the balance due to the sensitivity weight.

$u(\Delta I_s)$ = The uncertainty of ΔI_s.

- Uncertainty due to the display resolution of a digital balance

$$u_d = \left(\frac{d/2}{\sqrt{3}}\right)x\sqrt{2} \tag{15}$$

In order to reduce the negative effect of the eccentric loading and the magnetism of the weight, a levelMatic pan with a number of concentric circles on the top surface is used. The uncertainty contribution due to the eccentric loading is already covered by the uncertainty $u_w(\Delta\overline{m}_c)$ of the weighing process, and the magnetic interaction is reduced by placing the nonmagnetic spacer between the weight and the load receptor. The uncertainties due to the eccentric loading and the magnetism, therefore, can be neglected.

In case AX64004 that the interchange is performed during a calibration procedure which the weighing results are nearly so not necessary interchange

In case CC50001S-L that the interchange is performed during a calibration procedure which the weighing results are not nearly so interchange is necessary, the average of the two indication differences shall be taken as the weighing result and the uncertainties due to the eccentric loading can be neglected.

Consequently, the uncertainty of the balance, u_{ba} is estimated by

$$u_{ba} = \sqrt{u_s^2 + u_d^2} \tag{16}$$

5.5 Expanded uncertainty, $U(m_{ct})$

The combined standard uncertainty of the conventional mass of the test weight is given by

$$u_c(m_{ct}) = \sqrt{u_w^2(\Delta\bar{m}_c) + u^2(m_{cr}) + u_b^2 + u_{ba}^2} \tag{17}$$

The expanded uncertainty, *U*, of the conventional mass of the test weight is as follows

$$U(m_{ct}) = ku_c(m_{ct}) \tag{18}$$

where the coverage factor, *k* = 2, is used.

Uncertainty Evaluation

1. Uncertainty Evaluation for Digital Hall magnetometer its calibration by using NMR magnetometer. (2.5 T to 30 mT)

Uncertainty factor

NMR measurement	γ_p (Gyromagnetic Ratio)
	Frequency Measurement
	Natural width of NMR sample
	NMR probe position (magnetic field homogeneity)
	Resolution of detection circuit
Hall probe position	Angle of Hall probe and measuring magnetic field ($B' = B \cos \theta$)
	Influence by reason of distance of NMR probe and Hall probe
Magnetometer resolution of a digital indication	
Type A	

2. Uncertainty evaluation for Digital Hall magnetometer or Fluxgate magnetometer calibration by using standard field coil (less than 30 mT)

Uncertainty factor

Coil Constant of standard field coil	
Current measurement	Calibration of standard Resistor
	Long term stability of resistor
	Calibration of voltmeter
	Long term stability of voltmeter
	Voltmeter resolution of a digital indication
External magnetic field	Earth's magnetic field
	Magnetic noise (period of measuring)
Probe position	Angle of probe and measuring magnetic field (for example $B'=B\cos\theta$)
	Influence by reason of magnetic field homogeneity
Magnetometer resolution of a digital indication	
Type A (including current variation)	

3. Uncertainty evaluation for Coil constant of standard field coil at 30 mT

Uncertainty factor

NMR measurement	γ_p (Gyromagnetic Ratio)
	Frequency Measurement
	Natural width of NMR sample
	NMR probe position (magnetic field homogeneity)
	Resolution of detection circuit
Current measurement	Calibration of standard Resistor
	Long term stability of resistor
	Calibration of voltmeter
	Long term stability of voltmeter
	Voltmeter resolution of a digital indication
External magnetic field	Earth's magnetic field
	Magnetic noise (period of measuring)
Type A	

4. Uncertainty evaluation for Reference magnet

Uncertainty factor of Reference magnet 2.5 T to 30 mT

NMR measurement	γ_p (Gyromagnetic Ratio)
	Frequency Measurement
	Natural width of NMR sample
	NMR probe position (magnetic field homogeneity)
	Resolution of detection circuit
Hall magnetometer	Angle of Hall probe and measuring magnetic field ($B' = B \cos \theta$)
	Influence by reason of distance of NMR probe and Hall probe
	Short term stability
Type A (including Hall sensor position)	

Uncertainty factor for Reference magnet less than 30 mT

Coil Constant of standard field coil	
Current measurement	Calibration of standard Resistor
	Long term stability of resistor
	Calibration of voltmeter
	Long term stability of voltmeter
	Voltmeter resolution of a digital indication
External magnetic field	Earth's magnetic field
	Magnetic noise (period of measuring)
Probe position	Angle of probe and measuring magnetic field (for example $B'=B\cos\theta$)
	Influence by reason of magnetic field homogeneity
Magnetometer resolution of a digital indication	
Type A (including Hall sensor position)	

Calculation of Measurement Uncertainty (Laser Beam Power Meter Calibration)

Power : 1 mW

Source of uncertainty	Type of uncertainty	Standard uncertainty	Probability distrubution	Degree of freedom	sensitivity coeficient	Uncertainty contribution
1. Repeatability (n=5)	A	0.100%	normal	4	1	0.100%
2. Uncertainty of Standard						
1) Uc from certificate	B	0.150%	normal	∞	1	0.150%
2) Positioning error	B	0.030%	Rectangular	∞	1	0.030%
3) Control error	B	0.010%	Rectangular	∞	1	0.010%
4) DC measuring equipment	B	0.050%	Rectangular	∞	1	0.050%
5) Long term stability	B		Rectangular			
6) -						
3. Uncertainty of DUT						
1) Positioning error	B	0.030%	Rectangular	∞	1	0.030%
2) Resolution	B	0.005%	Rectangular	∞	1	0.005%
			Combined standard uncertainty			0.192%
			Expanded uncertainty		(k=2)	0.384%

Calculation of Measurement Uncertainty (Optical Fiber Power Meter Calibration)

Power : 1 mW

Source of uncertainty	Type of uncertainty	Standard uncertainty	Probability distrubution	Degree of freedom	sensitivity coeficient	Uncertainty contribution
1. Repeatability (n=5)	A	0.100%	normal	4	1	0.100%
2. Uncertainty of Standard						
1) Uc from certificate	B	0.150%	normal	∞	1	0.150%
2) Positioning error	B	0.050%	Rectangular	∞	1	0.050%
3) Control error	B	0.050%	Rectangular	∞	1	0.050%
4) DC measuring equipment	B	0.050%	Rectangular	∞	1	0.050%
5) Long term stability	B	0.050%	Rectangular	∞	1	0.050%
6) NA dependence	B	0.050%	Rectangular	∞	1	0.050%
7) -						
3. Uncertainty of DUT						
1) Positioning error	B	0.050%	Rectangular	∞	1	0.050%
2) Resolution	B	0.050%	Rectangular	∞	1	0.050%
			Combined standard uncertainty			0.224%
			Expanded uncertainty		(k=2)	0.447%

Plan of Accreditation for ISO/IEC 17025

Fiscal Year 2008

1. Field of Measurement: Gas Standard

2. Laboratory: Gas Analysis Laboratory, Department of Chemical Metrology and Biometry

3. Parameter

3.1 Calibration of oxygen standard mixture and paramagnetic oxygen analyzer

3.2 Calibration of carbon monoxide standard mixture and carbon monoxide analyzer

4. Scope of accreditation:

Measurand/Calibration Item	Description/Measurement Range	Best Measurement Capability (*k*=2)
1. Oxygen standard mixture	O_2 in N_2 / 0 – 30 %	1% - 2%*
2. Oxygen analyzer	Paramagnetic sensor / 0 – 30 %	1% - 2%*
3. Carbon monoxide standard mixture	CO in N_2 / 0 – 100 µmol/mol	1% - 2%*
4. Carbon monoxide analyzer	0 – 100 µmol/mol	1% - 2%*

* Waiting for the result of bilateral comparison

5. Attachment

5.1 Traceability chart

5.2 Evaluation of measurement uncertainty

1. Evaluation of measurement uncertainty

The uncertainty of calibration by 3-point calibration is calculated as follow;

1.1 The standard uncertainties of the oxygen contents, $u(x_1)$, $u(x_2)$, $u(x_3)$ are associated with oxygen calibration standards. In the case the expanded uncertainty (U) is given in the certificate, U must be divided by the coverage factor state in the certificate (usually $k = 2$).

1.2 The standard uncertainties of the responses, $u(y_1)$, $u(y_2)$, $u(y_3)$ are from the repeatability of oxygen analyzer responds and estimated by eq 1.

$$u(y_i) = \frac{SD}{\sqrt{n}} \quad ,i = 1...,3 \tag{1}$$

where

SD = the standard deviation of measurement results of calibration standard

n = the number of measurement

N = the number of calibration standards

1.3 Parameter and its uncertainty of the analytical function $x_k = b_{0,k} + b_{1,k}y_k$ were calculated with ISO6143 implementation software "B_LEAST version 1.11".After that, the oxygen contents (x_k) and standard uncertainty $u(x_k)_{6143}$ of sample gas were calculated from the response (y_k) and its uncertainty $u(y_k)$, as follows.

$$u^2(x_k)_{6143} = \left(\frac{\partial G}{\partial y_k}\right)^2 u^2(y_k) + \sum_{i=0}^{N}\left(\frac{\partial G}{\partial b_{i,k}}\right)^2 u^2(b_{i,k}) + 2\sum_{j=0}^{N-1}\sum_{i=j+1}^{N}\left(\frac{\partial G}{\partial b_{j,k}}\right)\left(\frac{\partial G}{\partial b_{i,k}}\right)u(b_{j,k},b_{i,k}) \tag{2}$$

where

$u(x_k)$ = the standard uncertainty of the oxygen content x_k, calculated using $x = G(y)$

$u(y_k)$ = the standard uncertainty of the response y_k

$u^2(b_{i,k})$ = the variance of the parameter $b_{j,k}$ of the analysis function

$u^2(b_{j,k}, b_{i,k})$= the covariance of the parameters $b_{j,k}$, $b_{i,k}$ of the analysis function

The combined standard uncertainty of analytical concentration $u(x_{anal})$ is evaluated from the following equations;

$$u^2(x_{anal}) = u^2(x)_{within\ cycle} + u^2(x)_{between\ cycles} \tag{3}$$

where

$$u^2(x)_{within\ cycle} = \frac{\sqrt{u^2(x_1)_{6143} + ... + u^2(x_k)_{6143}}}{n}, k = 1...,3 \tag{4}$$

$u(x_k)_{6143}$ = the standard uncertainty for each cycle

n = the number of cycle

$$u^2(x)_{between\ cycle} = \frac{SD}{\sqrt{n}} ; \tag{5}$$

SD = the standard deviation of analytical concentration results

n = the number of cycle

1.4 The expanded uncertainty, U, is given by eq. 5 for a coverage factor of two.

$$U(x_{anal}) = k.u(x_{anal}) = 2.u(x_{anal}) \tag{6}$$

Uncertainty budget

Uncertainty of gas analyzer calibration following a 3-point calibration

Uncertainty source	Estimate	Distribution	Standard uncertainty	Sensitivity coefficient	Contribution to standard uncertainty
Analytical concentration	$x_{k,6143}$	normal	$u(x)_{within\ cycle}$	1.0	$u(x)_{within\ cycle}$
Repeatability	$\overline{x_{k,6143}}$	normal	$u(x)_{between\ cycles}$	1.0	$u(x)_{between\ cycles}$
Combined standard uncertainty					$u(x_{anal})$
Expanded uncertainty ($k = 2$)					$2.u(x_{anal})$

Annex 19: Report of Technical Evaluation

Annex 19: Report of Technical Evaluation

1) Improvement of technical capability of NIMT staffs trained in this project

The improvement of technical competence by training was estimated through interviews of six NIMT staffs.

As average, technical competence of NIMT staffs trained in this project was estimated to be improved from 1.2 to 2.8. We can recognize that all counter parts have improved their technical performance through the training in Japan. Many of them keep good relationship with their trainers and it assists to establish their own metrology standards and quality system for calibration.

For AC power supply, the training was mis-matched with the present calibration system and for vibration the training period was too short.

Among 6 staffs, three has experienced to give lectures for their own calibration in ASEAN seminar sponsored by NMIJ/AIST and JICA. They have demonstrated their competence improved in the project.

Three issues were pointed for the training:

1. Period of training should be more flexible since it needed longer time to learn the whole program planned,
2. The training is mis-matched with the calibration activities in NIMT. Calibration method, which the counter part is trained, is not utilized in NIMT for one quantity,
3. In Phase 1, the technical collaboration activities have been limited only for calibration, while it is necessary to include research activities in future.

There were several problems in process, however, the technical competence has been improved evidently by training in this project.

2) Improvement in National Measurement Standards and Calibration Capabilities

All of eight fields, where technical transfer has been completed under this project, the National Measurement Standards have been established completely or in main parts. Also, that of Vibration has almost established by "pre-project" activities. Among them, three quantities, Wavelength, Hardness and Vibration are new fields for NIMT, while other nine quantities big improvement were achieved in methods and/or in accuracy.

For all of these nine fields, the calibration capability has been improved through the JICA project, especially through training in Japan and consultation by the trainers.

The training was mis-matched in AC power measurement. There, JBIC loaned instruments have been operated using the procedure trained in Canada. As total activities of calibration, the capability has been enhanced in the laboratory, but the effectiveness of

JICA training is not good for this quantity.

All of nine fields, measurement uncertainties have been estimated and almost completed in the project. It is key issue to demonstrate their technical competence quantitatively. The calibration manuals also have been documented.

The quality system has been assessed for accreditation in two fields, Wavelength and Acoustic. The quality system has been established in these two fields, although some problems were pointed out by assessors from NMIJ and NITE. After the assessment, the corrective actions were documented with consultation under this project and we can expect to be accredited soon for these quantities.

In other seven quantities, documentation is almost completed and can be expected to be accredited in near future. For Hardness and Vibration, the laboratories plan to apply accreditation within one year. These activities and plans indicate that the calibration capabilities have been enhanced so rapidly.

3) Activities for the CIPM-MRA

In order to participate the CIPM-MRA, two requirements have been established as the criteria, A. To demonstrate quality system of calibration services, B. To participate international comparisons of measurement standards.

For the criterion A, laboratory accreditation is required as the good evidence to demonstrate the quality system. It is in process under the project. On the other hand, the criterion B has not yet well achieved in the project. Some of comparisons have been implemented or planned, but not according with guidelines of international comparisons for the CIPM-MRA. Also, the APMP comparisons seem not enough to cover the quantities of newly established. It is recommended to increase participation in international comparisons considering for the issues below:

1. To require the APMP to arrange regional comparisons NIMT needs,
2. To arrange bilateral comparisons between NIMT and NMIJ according with CIPM-MRA guidelines
3. To organize regional and bilateral comparisons.

These are examples for how to increase the participation in international comparisons and it is necessary for participation in the CIPM-MRA.

4) Report of laboratory visit

The evaluation team visited laboratories of Force, DC high voltage, AC power, Wavelength and Acoustic laboratories. Some findings are written below:

4-1) Equipments

The equipments in laboratories, where the evaluation team visited, are maintained properly and utilized as National Measurement Standards or calibration activities. Some of them were purchased with Yen-loan. It should be pointed that some of new equipments are in trouble, which require to repair by manufacturers. Although the accurate measuring instruments are delicate, but the ratio of instruments with trouble seems to be high comparing with other well-established NMIs. It is recommended to review maintenance system of equipments.

The manuals of equipments and calibration/maintenance records of them are files systematically in all five laboratories. These jobs, required in quality systems are arranged very well.

4-2) Calibration manuals, uncertainty budget and calibration records

Calibration manuals have been documented in all laboratories we visited and they include uncertainty budget of the calibration. These documentation are maintained in suitable way and all staffs can refer them in laboratories. We can say that the documents control is sufficient in many of laboratories.

For force, the training was completed in the last December and short-term expert has not yet visited. Therefore, for this quantity, the estimation is in process of development.

Calibration records are also filed systematically with copies of calibration certicficate.

4-3) Environmental conditions in laboratories

The environmental condition was recorded for temperature. It is done in laboratories of high accuracy measurement. However, considering ground vibration and stability of electric power, the total environment condition seems not so good as high precision laboratories although the air conditioning works sufficiently.

It could be recommended to arrange transport to new building and establish better condition for measurement.

Annex 20: Record of Seminars

Annex 20 Record of Seminars

No.	Date	Measurement Quantity	Short-Term Expert	Counterpart	Title	No. of Participant
1	Feb. 11, 2003	Radiation Thermometer Standard	Dr. Fumihiro SAKUMA	Mr. Narudom Noulkow	Seminar on Measurement Standards and Calibration Service 1. Radiation Thermometer and Calibration in Japan : Dr. Sakuma 2. Extablishment of Radiation Thermometer Standards in Thailand : Mr. Narudom	29 persons
2	Feb. 13, 2003	Plug and Ring Standard	Mr.Kazuo TOMIYAMA	Mr. Samana Piengbangyang	Seminar on Measurement Standards and Calibration Service 1. Japanese Traceability system of Diameter Standard: Mr. Tomiyama 2.Calibration of Ring Gauge using Optical Inner Diameter Measuring : Mr. Samana	46 persons
3	Feb. 28, 2003	Roundness Standard	Mr. Yuji WAKABAYASHI	Mr. Samana Piengbangyang	Seminar on Measurement Standards and Calibration Service 1. Current Situation of Roundness Measurement : Mr. Wakabayashi 2. Calibration of Roundness Tester using Indexing Table : Mr. Samana	21 persons
4	Apr. 2, 2003	Wavelength Standard	Mr. Jun ISHIKAWA	Ms.Monludee Ranusawat	Seminar on Measurement Standards and Calibration Service 1. Current Situation of Wavelength Standard in National Metrology Institute : Mr. Ishikawa 2. Establishment of Length Standard and Traceability system in Thailand : Mr. Anusorn 3. Establishment of Wavelength Standard and Uncertainly measurement of Iodine Stabilization He-Ne Laser : Ms. Monludee	72 persons
5	Apr. 9, 2003	Acoustics Standard	Mr. Hiroaki NOMURA	Miss Surat Pattarachindanuwong	Seminar on Measurement Standards and Calibration Service 1. Technical Transfer to NIMT on Acoustics : Mr. Nomura 2. Verification of SLM and Sound Clibration : Miss Surat	38 persons
6	May 6, 2003	Hardness Standard	Mr. Hajime ISHIDA	Mr. Tassanai Sanponpute	Seminar on Measurement Standards and Calibration Service 1. Rockwell Hardness Measurement and Calibration : Mr.Ishida 2. Rockwell Traceability System of Thailand: Mr. Tassanai	19 persons
7	May 7, 2003	Hardness Standard	Mr. Hajime ISHIDA	Mr. Tassanai Sanponpute	Seminar on Measurement Standards and Calibration Service 1. Rockwell Hardness Measurement and Calibration : Mr.Ishida 2. Rockwell Traceability System of Thailand: Mr. Tassanai	104 persons
8	Dec. 12, 2003	AC Power and Calibration	Mr. Masao YAMAWAKI	Mr. Sittisak Pimsut	Seminar on Measurement Standards and Calibration Service 1. Current Situation of AC Power Standard in JEMIC : Mr. Yamawaki 2. AC Power Calibration Method in JEMIC: Mr. Sittisak	107 persons
9*	Jan.27, 2004	Acoustics Standard	Mr. Takeshi FUJIMORI	Ms. Surat Pattarachindanuwong	Seminar on Measurement Standards and Calibration Service 1. Current Situation of Acoustics Standard in Japan : Mr. Fujimori 2. Acoustics Standard and Calibration Service in Thailand : Mr. Viral 3. Calibration Technique of Sound Level Meter and Acoustical Calibrator at NIMT : Ms. Surat	50 persons

Annex 20 Record of Seminars

No.	Date	Measurement Quantity	Short-Term Expert	Counterpart	Title	No. of Participant
10*	Jan.27, 2004	Wavelength Standard	Mr. Jun ISHIKAWA	Ms. Monludee Ranusawud	Seminar on Measurement Standards and Calibration Service 1. Length Standard today : Mr. Ishikawa 2. The Open Laser Project : Mr. Ishikawa 3. Calibration Technique of Wavelength Standard in NIMT : Ms. Monludee 4. Calibration Service of Gauge Block in Thailand : Mr. Anusorn	191 persons
11*	Feb. 24, 2004	Geometrical Standard	Dr. Sonko OSAWA	Mr. Narin Chanthawong	Seminar on Measurement Standards and Calibration Service 1. Dimensional Metrology in NMIJ : Dr. Osawa 2. Gauge Calibration Technique Using a CMM : Dr. Osawa 3. Calibration Techniques of Gear Wheel Using CMM in NIMT: Mr. Narin 4. Calibration Service of CMM in Thailand : Mr. Anusorn	184 persons
12*	Feb. 24, 2004	DC High Voltage Standard	Mr. Tomeji IGUCHI	Mr. Danai Pattarakijkul	Seminar on Measurement Standards and Calibration Service 1. Current Situation of DC High Voltage Standard in Japan : Mr. Iguchi 2. Traceability of DC Voltage up to 1kV in Thailand : Ms. Ajchara 3. Calibration Technique of DC High Voltage Standard in NIMT : Mr. Danai	83 persons
13	Apr. 22, 2004	RF/Microwave Measurement Standards	Ms. Keiko SATO	Mr. Chairat Wichianmongkonkul	Seminar on Measurement Standards and Calibration Service 1. RF Power and RF Voltage Traceability system in JQA : Ms. Sato 2. RF&Microwave Measurement Fundamentals : Ms. Sato 3. Calibration Technique of RF Power and Calibration Services at NIMT : Mr. Chairat	76 persons
14	Aug. 20,2004	Roughness Standard	Dr. Kazuya NAOI	Mr. Samana PhengBangyang	Seminar on Measurement Standards and Calibration Service 1. Trend of Calibration Technique for Surface Texture Measurement Standards : Dr. Naoi 2. Establishment of Roughness Standard and Calibration Service in NIMT : Mr. Samana 3. Roughness Calibration in NIMT : Mr. Muhummad	61 persons
15	Sep. 23-24, 2004	Calibration Procedure	Mr. Keisaburo KANO		Seminar on Introduction to Accreditation 1. What is Accreditaion 2. Outline of ISO/IEC 17025	78 persons
16*	Jan. 26, 2005	ASEAN Seminar			Plenary lecture 1. JQA Activities for Promoting Industries : Mr. Yamasaki 2. Harmonization of Hardness Standards in the World : Mr. Takagi 3. How to Strengthen Metrology in Chemistry System in ASEAN :Dr.Chainarong 4. World Trends of Resistance Standard : Dr. Kinoshita 5. Metrology Demands for ASEAN and APMP DEC : Dr. Pian 6. Current Situation of JICA/NIMT Project : Dr. Akimoto 7. Importance of the Measurement and Intellectual Infrastructure in Modern Society : Ms. Nakamura	287 persons

Annex 20 Record of Seminars

No.	Date	Measurement Quantity	Short-Term Expert	Counterpart	Title	No. of Participant
17*	Jan. 26, 2005	Hardness Standard	Mr. Satoshi TAKAGI	Mr. Tassanai Sanponpute Ms. Rugkanawan Wongpilthayadisai Mr. Montree Pakkratoke Dr. Khanchai Kosonthongkee	Seminar and Workshop on Measurement Standards and Calibration Service 1. Verification of Indenters for Hardness Standards : Mr. Takagi 2. Calibration Service of Hardness Standard in Vietnam : Mr. Sanh Vo 3. Establishment of Hardness standard in Thailand : Mr. Veera	74 persons
18*	Jan. 26, 2005	Chemical Standard	Dr. Akira NOMURA	Dr. Preeyaporn Pookrod Mr. Bunthoon Loangsri Ms. Nongluck Tangpaisarnkul	Seminar and Workshop on Measurement Standards and Calibration Service 1. Metrology in Chemistry and Certified Reference Materials : Dr. Nomura 2. Calibration Service of Chemical Standard in Malaysia : Mr. Khirul Anuar Mohd 3. DISM Activities in Laos : Mr. Singsonexay Viengkham 4. Recent Activities of Metrology in Chemistry in NIMT: Dr. Preeyaporn	101 persons
19*	Jan. 26, 2005	Resistance Standard	Dr. Joji KINOSHITA	Ms. Natenapit Chookunhom	Seminar and Workshop on Measurement Standards and Calibration Service 1. Dissemination of DC Resistance Standards inThailand : Mrs. Ajchara 2. SPRING Singapore Resistance Standards Calibration Service : Mr. Ang Chee Kiang 3. Calibration Service of Resistance Standard in Vietnam :Mr. Dien Khac Tran 4. How to Maintain Group of 1 Ohm Standard : Ms. Natenapit	76 persons
20	Feb. 16, 2005	Angle Standard	Dr. Tsukasa WATANABE	Mr. Wacharin Samit	Seminar on Measurement Standards and Calibration Service 1. Angle Standard Present condition of National Institute of Metrology (NMI) : Dr. 2. Angle Traceability System in Japan : Dr. Watanabe 3. Autocollimator Calibration System at NMIJ : Dr. Watanabe 4. Rotary Encoder Calibration System at NMIJ : Dr. Watanabe 5. The Calibration Method of Polygon Mirror : Mr. Wacharin 6. The Calibration Method of Angle Gauge Block : Mr. Wacharin 7. Angle Measurement with a Sine Bar : Mr. Wacharin 8. Angle Traceability System in Thailand : Mr. Anusorn	73 persons
21	Mar. 28, 2005	RF Attenuation	Mr. Shigeru IGARASHI	Mr. Chairat Wichianmongkonkun	Seminar on Measurement Standards and Calibration Service 1. The Handling Method in High Frequency Equipments : Mr. Igarashi 2. Calibration Service of RF Attenuation in JQA : Mr. Igarashi 3. Calibration Techniques and Uncertainty of RF Attenuation Measurement : Mr. Chairat	78 persons
22	Jul. 18, 2005	Flatness Standard	Dr. Toshiyuki TAKATSUJI	Mr. Muhummad Madden	Seminar on Measurement Standards and Calibration Service 1. World Trend of Flatness Standard: Dr. Takatsuji 2. Establishment of flatness standard by measure of relative methods: Dr. Takatsuji 3. Application of Interferometer techniques to metrology: Mr. Anusorn 4. Establishment for Thailand flatness standard: Mr. Muhummad	45 persons

Annex 20 Record of Seminars

No.	Date	Measurement Quantity	Short-Term Expert	Counterpart	Title	No. of Participant
23*	Nov. 30, 2005	ASEAN Seminar			Plenary lecture 1. Development and maintenance of Measurement Stadnards-Today and Future in Japan: Ms. Nakamura 2. Recent Activity of CCL: Dr. Matsumoto 3. "e-trace" New Dissemination System for Measurement Standards: Dr. Yoshida 4. World Trends of Vibration and Acceleration Standard: Mr. Ota 5. World Trends of Time and Frequency Standard: Dr. Suzuyama 6. Compact, Low-cost, and Programmable Josephson Voltage Standards System : Dr. Shoji 7. How to make ASEAN Measurement Recognizable: Dr. Pian	183 persons
24*	Nov. 30, 2005	e-trace	Dr. Haruo YOSHIDA Dr. Hitoshi SASAKI	Mr. Chalit Kumtawee	Seminar and Workshop on Measurement Standards and Calibration Service 1. Josephson Voltage Standard for "e-trace": Dr. Yoshida 2. Compact Primary AC-DC Transfer Standard for e-trace Calibration: Dr. Sasaki 3. International Comparison of AC/DC transfer Standard: Mr. Chalit	84 persons
25*	Nov. 30, 2005	Time and Frequency Standard	Dr. Tomonari SUZUYAMA	Mr. Somchai Nuamsettee	Seminar and Workshop on Measurement Standards and Calibration Service 1. Frequency Remote Calibration using GPS Common View Method at NMIJ :Dr. Suzuyama 2. Time and Frequency Activities at NML, SIRIM Berhad, Malaysia: Mr. Ahmad Sahar Omar 3. Time Transfer in Thailand: Mr. Somchai	40 persons
26*	Nov. 30, 2005	Vibration and Acceleration Standard	Mr. Akihiro OTA	Mr. Pairoj Rattanangkul	Seminar and Workshop on Measurement Standards and Calibration Service 1. Recent Progress of Vibration and Acceleration Standard in Japan: Mr. Ota 2. Vibration Standards and Calibration Services, SPRING Singapore :Mr. Chan Chee Keong 3. Vibration Standards and Calibration Services of Vibration in Thailand: Mr. Virat	48 persons
27	Mar. 23, 2006	pH Standard	Dr. Susumu NAKAMURA	Ms. Nongluck Tangpaisarnkul	Seminar on pH Measurement 1. Development of Metrology for pH Measurement in Thailand: Dr. Chainarong 2. Measurement of Hydrogen Ion Activity using the Harned Cell: Dr. Nakamura 3. How to Measure pH Value Accurately by Secondary Methods: Dr. Nakamura 4. pH Meter Calibration: Ms. Nongluck	96 persons
28	Apr. 3, 2006	Humidity Standard	Mr.Yoshihiro IMURA	Ms. Thasorn Sinhaneti	Seminar on Humidity Measurement 1. Two - Pressure Generator Standard : Mr. Imura 2. Hygrometer Calibration in Thailand : Ms. Thasorn	44 persons
29	Aug. 18, 2006	Inorganic and Organic Standard Solutions	Dr. Akiharu HIOKI Mr. Katsuhiko HIGUCHI	Ms. Nongluck Tangpaisarnkul Dr. Preeyaporn Pookrod	Seminar on Inorganic and Organic Standard Solutions 1. Metrology in Chemistry in Thailand - Past, Present and Future : Dr. Chainarong 2. Overview and International Situation on Elemental Standard Solutions and Titrimetry : Dr. Hioki 3. Practice on Elemental Standard Solutions at NIMT : Ms. Nongluck 4. Overview and International Standard on Organic Standard Solutions and Chromatography : Mr. Higuchi 5. Practice on Organic Standard Solutions at NIMT : Dr. Preeyaporn	57 persons

Annex 20 Record of Seminars

No.	Date	Measurement Quantity	Short-Term Expert	Counterpart	Title	No. of Participant
30*	Jan. 31, 2007	ASEAN Seminar			Plenary Lecture 1. CIPM/MRA and APMP Activities : Dr. Usuda 2. Metrology System in Thailand : Dr. Pian 3. Development of Metrology Standards in NMIJ for High-frequency electricity and Electromagnetic fields in relations to other NMI's : Dr. Komiyama 4. Force Standards at SPRING : Mr. Goh Hok Liok 5. Global trend of an Angle standard I : Dr. Watanabe 6. Global trend of an Angle standare II : Dr. Fujimoto 7. NIMT Project - Results, Subject, Prospect : Dr. Akimoto	202 persons
31*	Jan. 31, 2007	Angle Standard	Dr. Tsukasa WATANABE	Mr. Watcharin Samit	Seminar and Workshop on Measurement Standards 1. Angle Standard and Calibration Services in Indonesia : Mr. Agustinus Praba Drijarkara 2. Angle Measurement and Calibration in Japan : Dr. Watanabe, Dr. Hong Zhou and Dr. Fujimoto 3. Angle Standard and Calibration Service in Thailand : Mr. Watcharin	42 persons
32*	Jan. 31, 2007	Force Standard		Mr. Kittipong Chaemthet	Seminar and Workshop on Measurement Standards 1. Force Calibration Service at SPRING, Singapore ; Mr. Goh Hok Liok 2. Development of Force Standard in NML-SIRIM, Malaysia : Mr. Muktar Bin Sawi 3. Force Measurement and Calibration in Thai Airways : Mr. Sumnouw Throngmun	48 persons
33	Feb. 23, 2007	Photometry and Radiometry	Mr. Hiroshi SHITOMI Dr. Tatsuya ZAMA	Mr. Arkom Krachangmol Ms. Rojana Leecharoen	Seminar on Photometry and Radiometry 1. Roles of Photometry and Radiometry in Thailand Research and Industry : Mr. Arkom 2. Photometric Units and Standards : Mr. Shitomi 3. Photometry Calibrations : Mr. Arkom 4. Radiometric Units and Standards : Dr. Zama 5. Radiometry Calibration : Spectral Irradiance : Ms. Rojana	32 persons
34	Mar.28, 2007	Magnetic Standard	Mr. Takuma TOMINAGA	Mr. Thepbodin Borirak-arawin	Seminar on Magnetic Standard 1. Application on Magnetic Standards : Mr. Tominaga 2. Magnetic Standards in Thailand : Mr. Thepbodin	58 persons
35	Apr.2, 2007	Laser Power	Mr. Masahiro MIYAWAKI	Mr. Narat Rujirat	Seminar on Laser Power Standard 1. Laser Theory and Operation and Theory on Laser Power Measurement : Mr. Miyawaki 2. World Trend of Laser Power Standard : Mr. Miyawaki 3. Calibration of Laser Power Meter and Measurement Uncertainty : Mr. Narat	30 persons

Annex 20 Record of Seminars

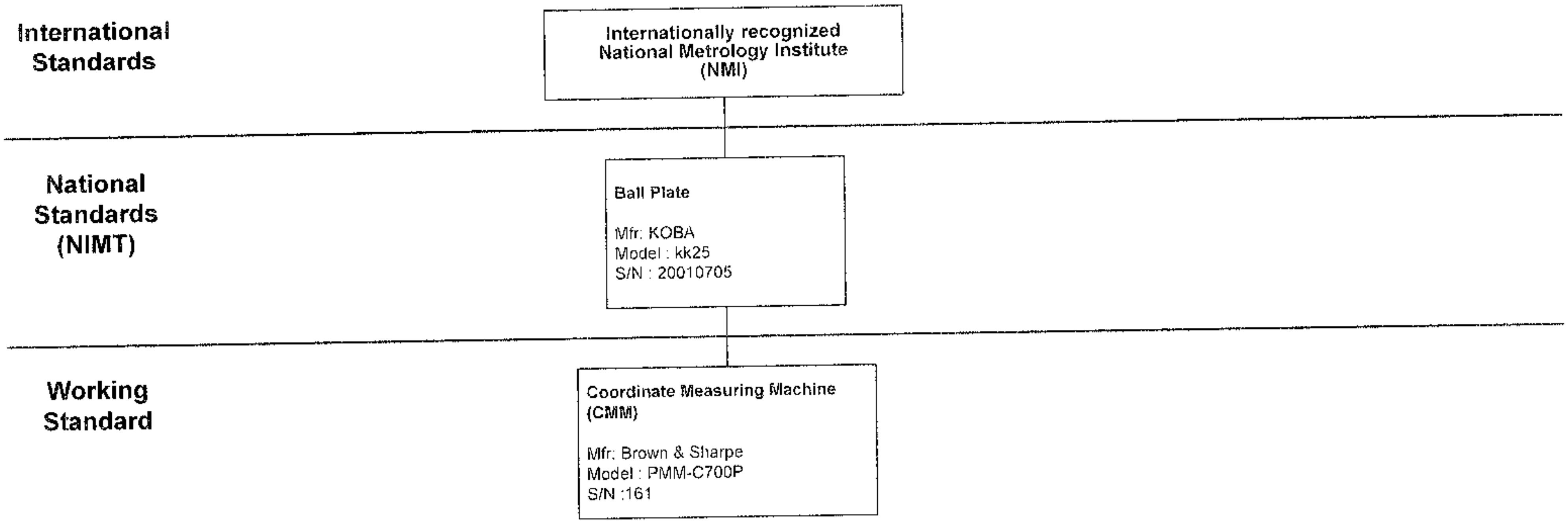
No.	Date	Measurement Quantity	Short-Term Expert	Counterpart	Title	No. of Participant
36	Apr.20, 2007	Standard Gas	Dr. Nobuhiro MATSUMOTO	Mr. Bunthoon Loangsri	Seminar on Standard Gas 1. Introduction of Japan Calibration Service System (JCSS) : Dr. Maeda 2. Gas Metrology at National Metrology Institute : Dr. Matsumoto 3. Role of NIMT in Gas Metrology in Thailand : Dr. Chainarong 4. Activities at NIMT Gas Lab : Mr. Bunthoon	61 persons

Remark:
* ASEAN Seminar

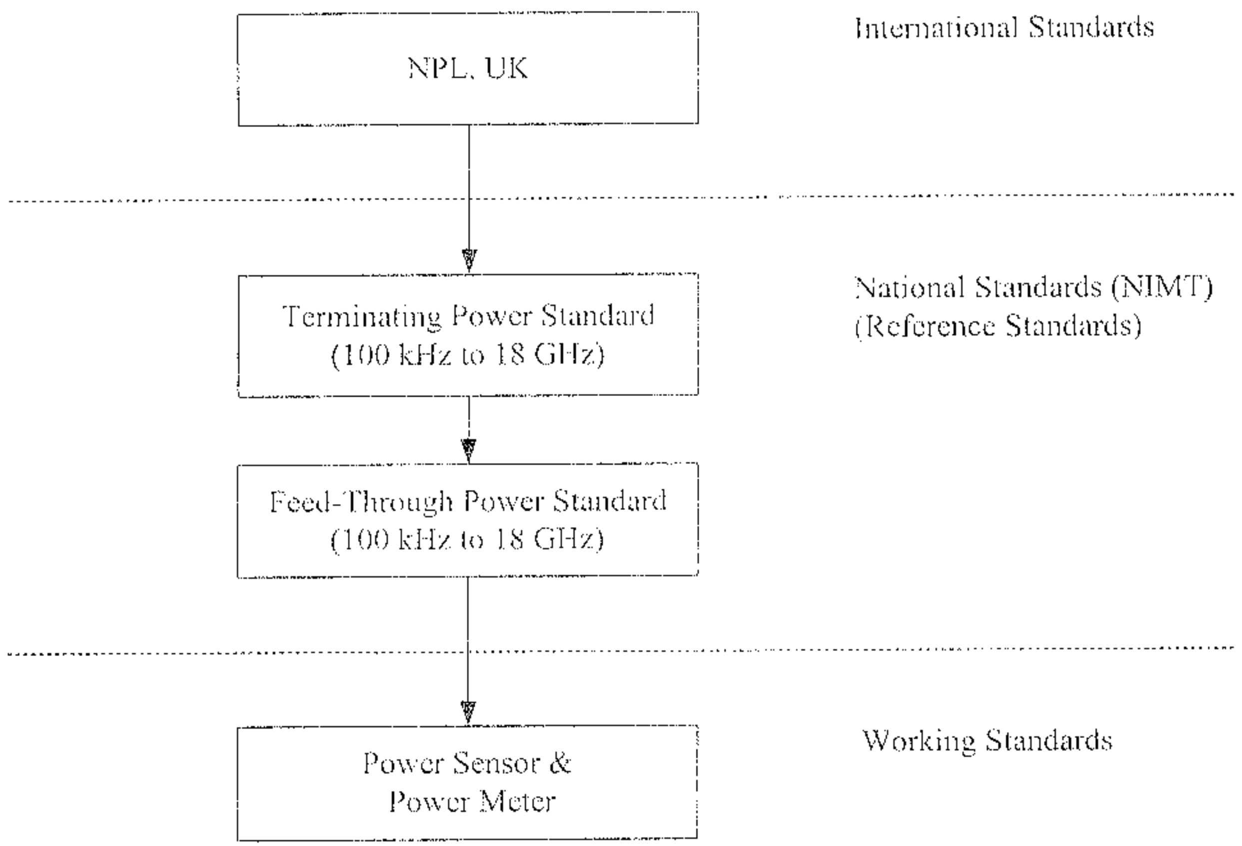
Annex 21: Traceability Chart of NIMT

Annex 21 Traceability Charts of NIMT

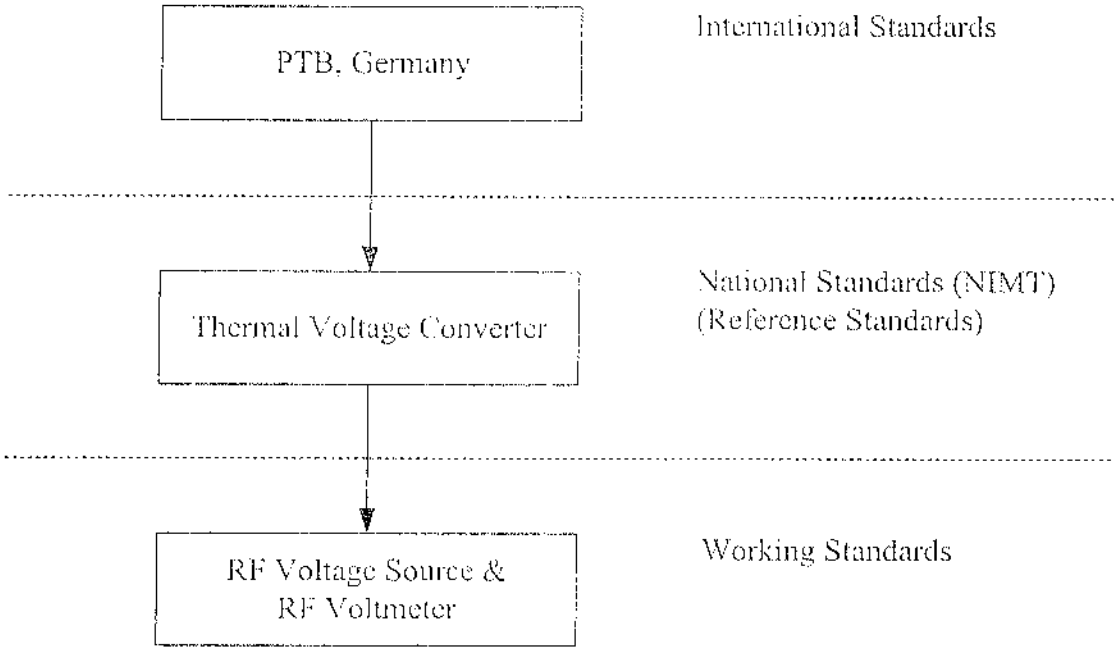
Traceability Chart
Form & CMM & Gear



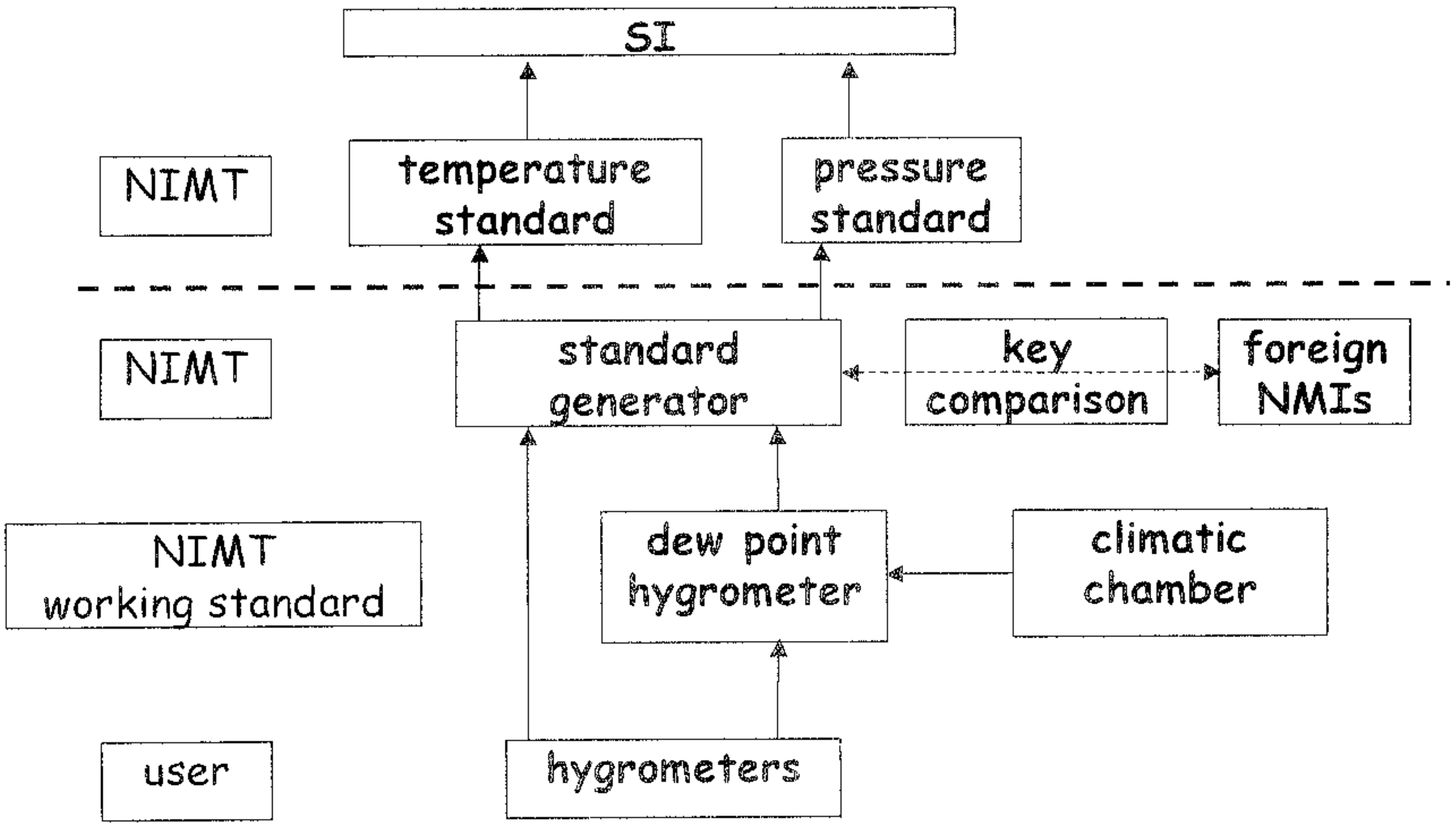
Traceability Chart of RF Power



Traceability Chart of RF Voltage



Tracebility Chart



5.8.4 Traceability Chart for Surface Texture calibration

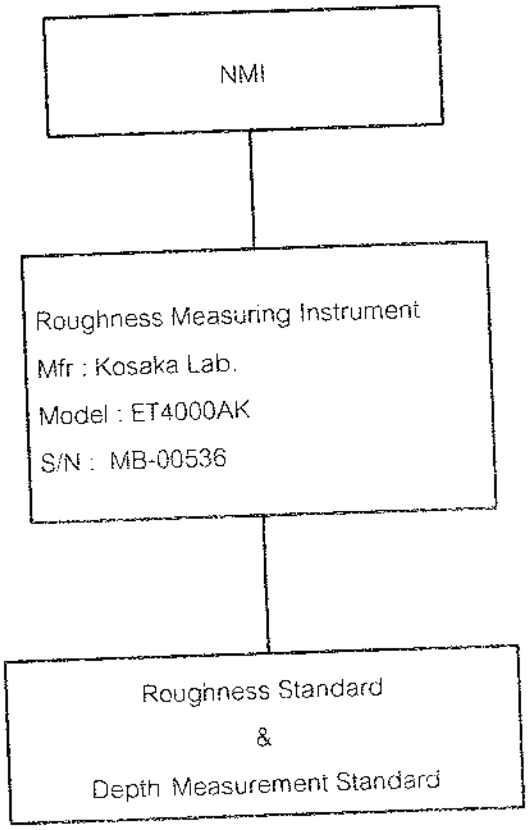
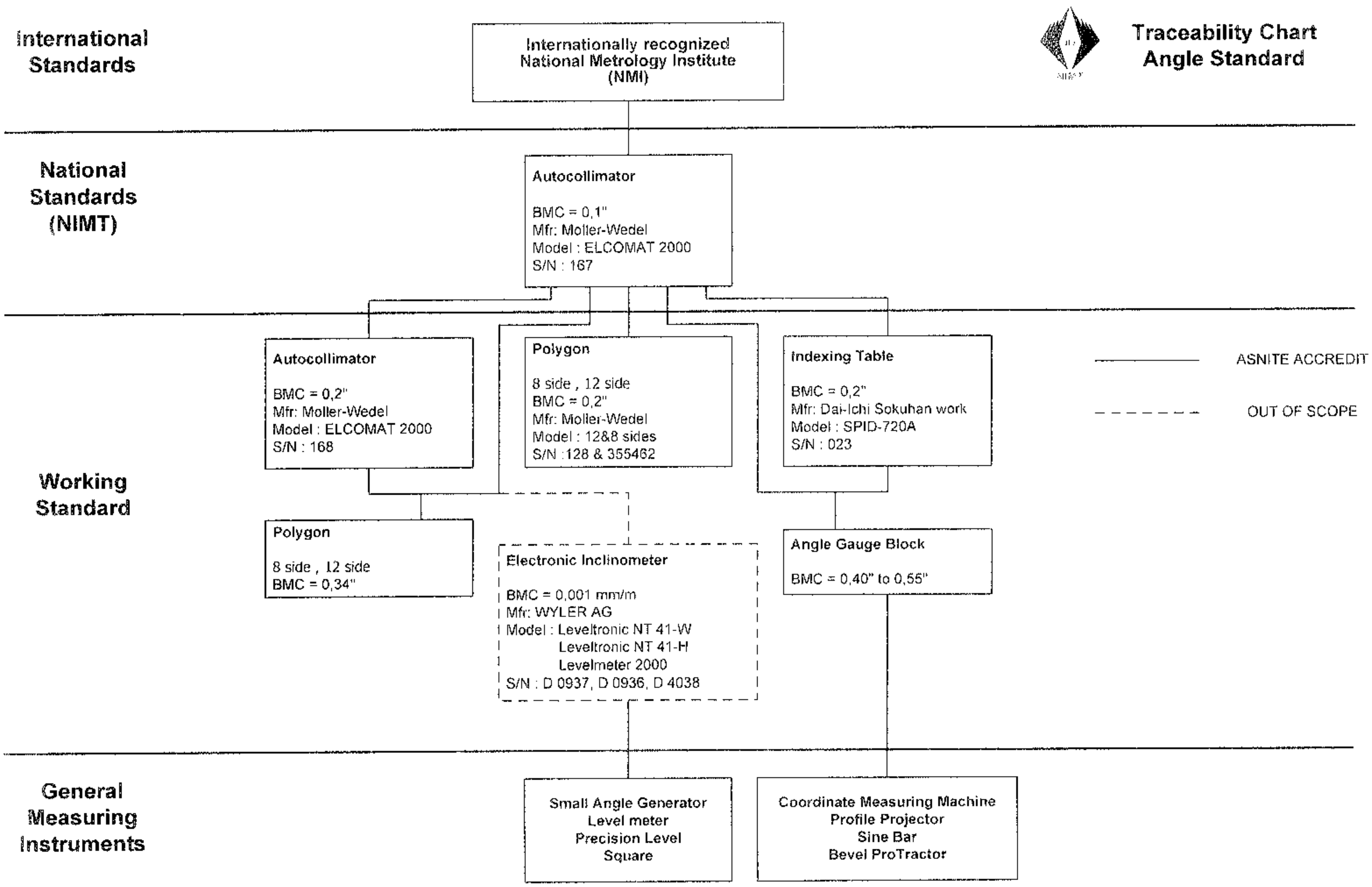
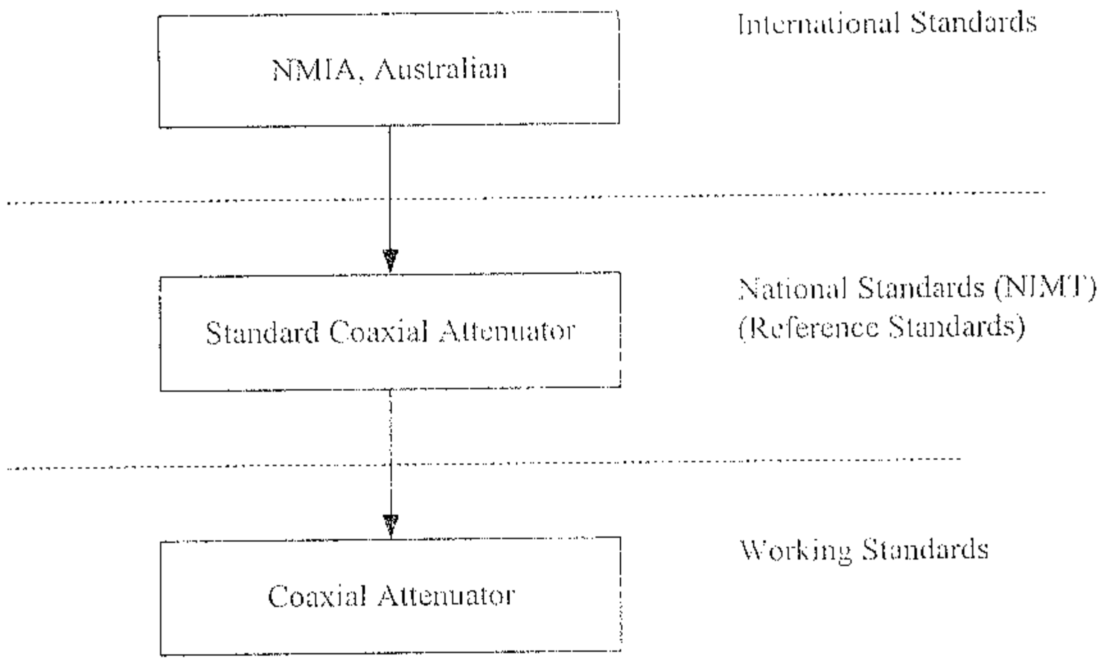


Fig. 5.8.1 Traceability Chart for surface texture calibration

Traceability Chart
Angle Standard



Traceability Chart of Attenuation



5.9.4 Traceability Chart for Flatness calibration

5.9.4.1 For Flatness

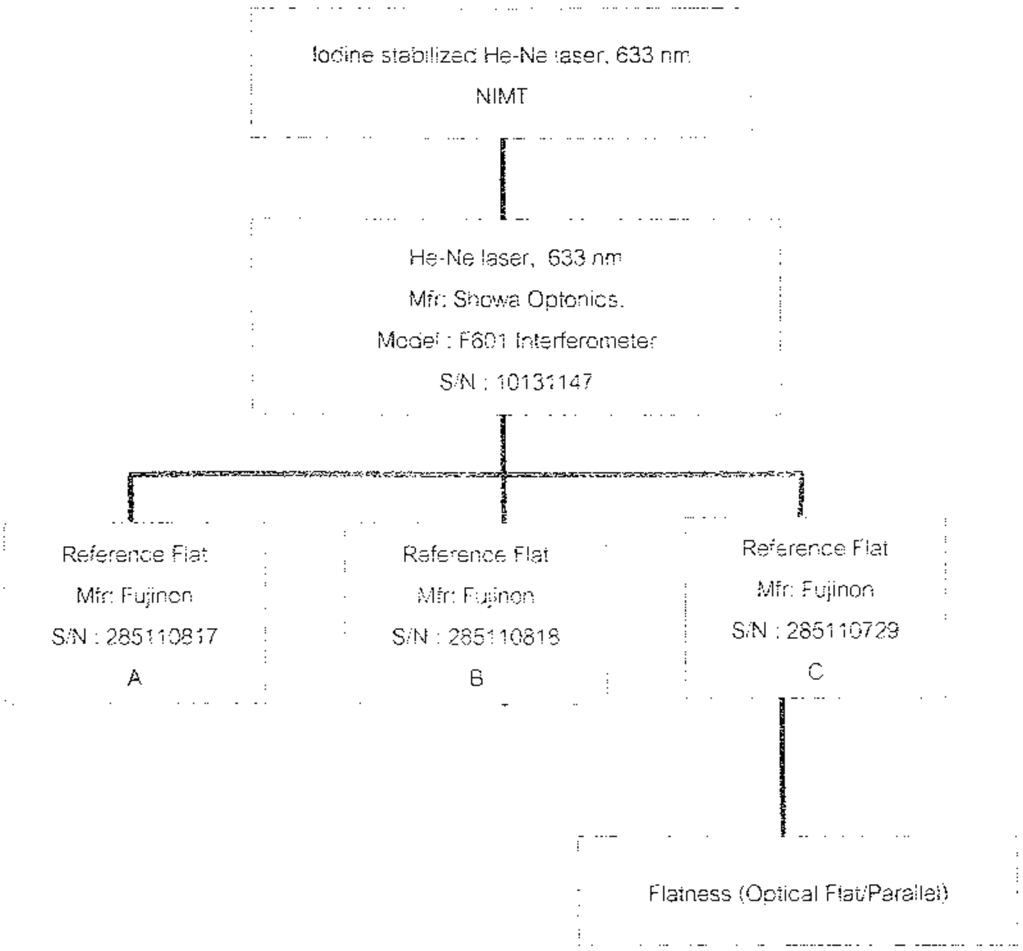
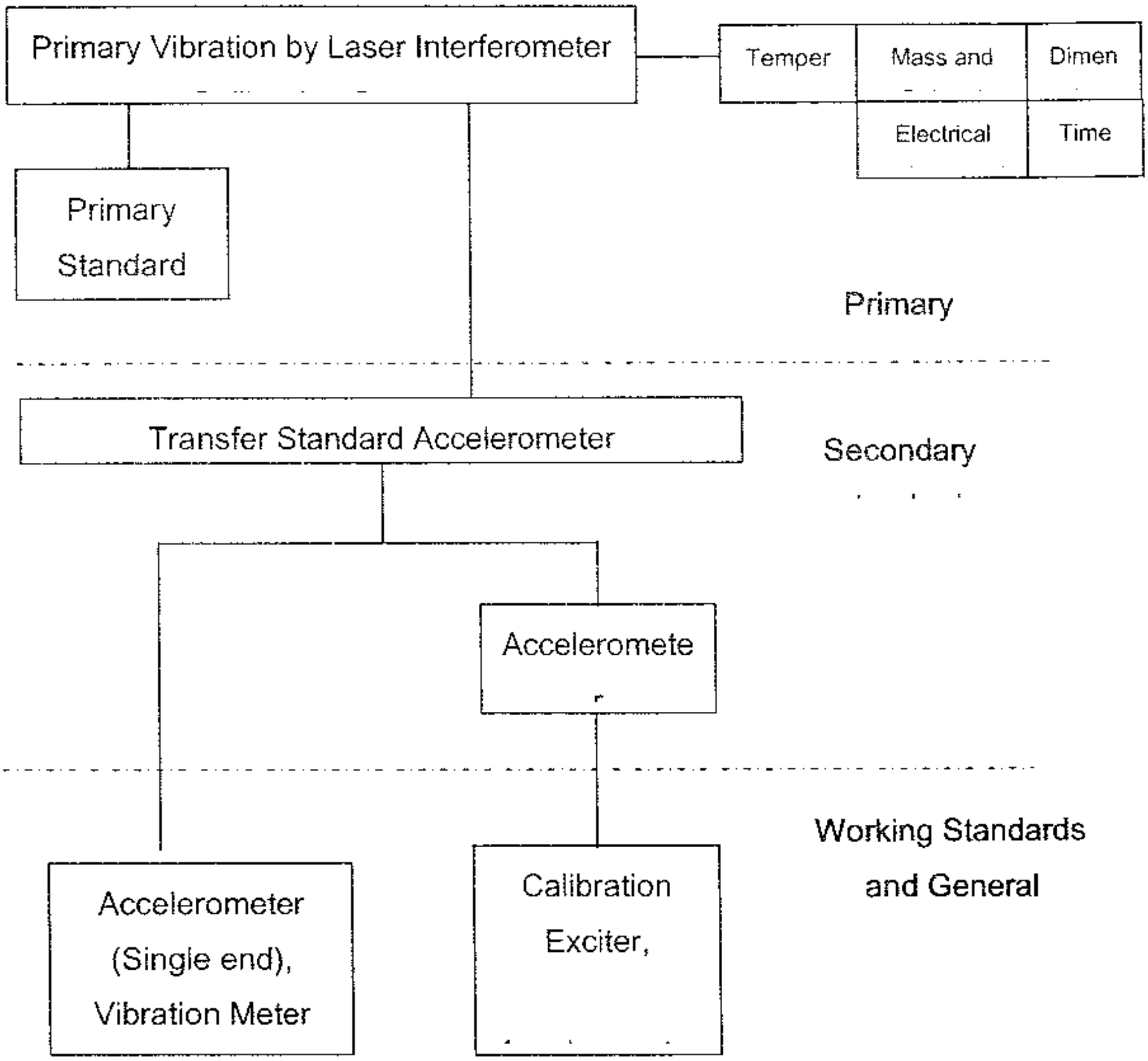


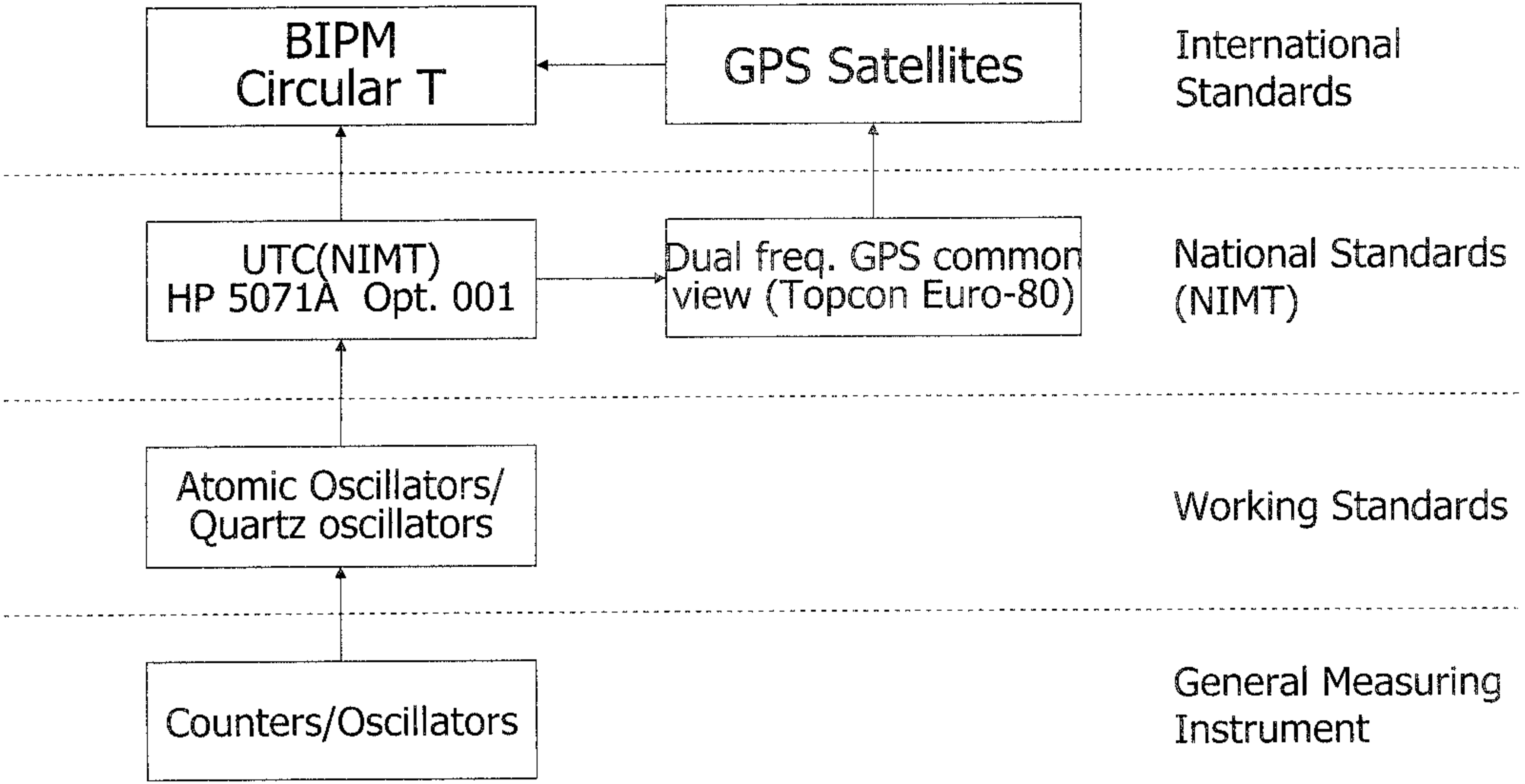
Fig. 5.9.1 Traceability Chart for flatness calibration

5.3 Traceability to National Standards

The traceability chart of Vibration Laboratory is shown in figure 5.1



Traceability of Time and Frequency Laboratory, NIMT



BIPM
Circular T

GPS Satellites

International
Standards

UTC(NIMT)
HP 5071A Opt. 001

Dual freq. GPS common
view (Topcon Euro-80)

National Standards
(NIMT)

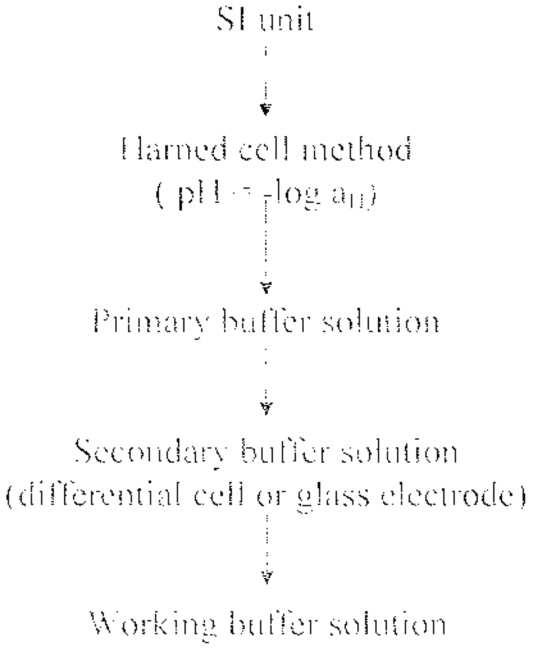
Atomic Oscillators/
Quartz oscillators

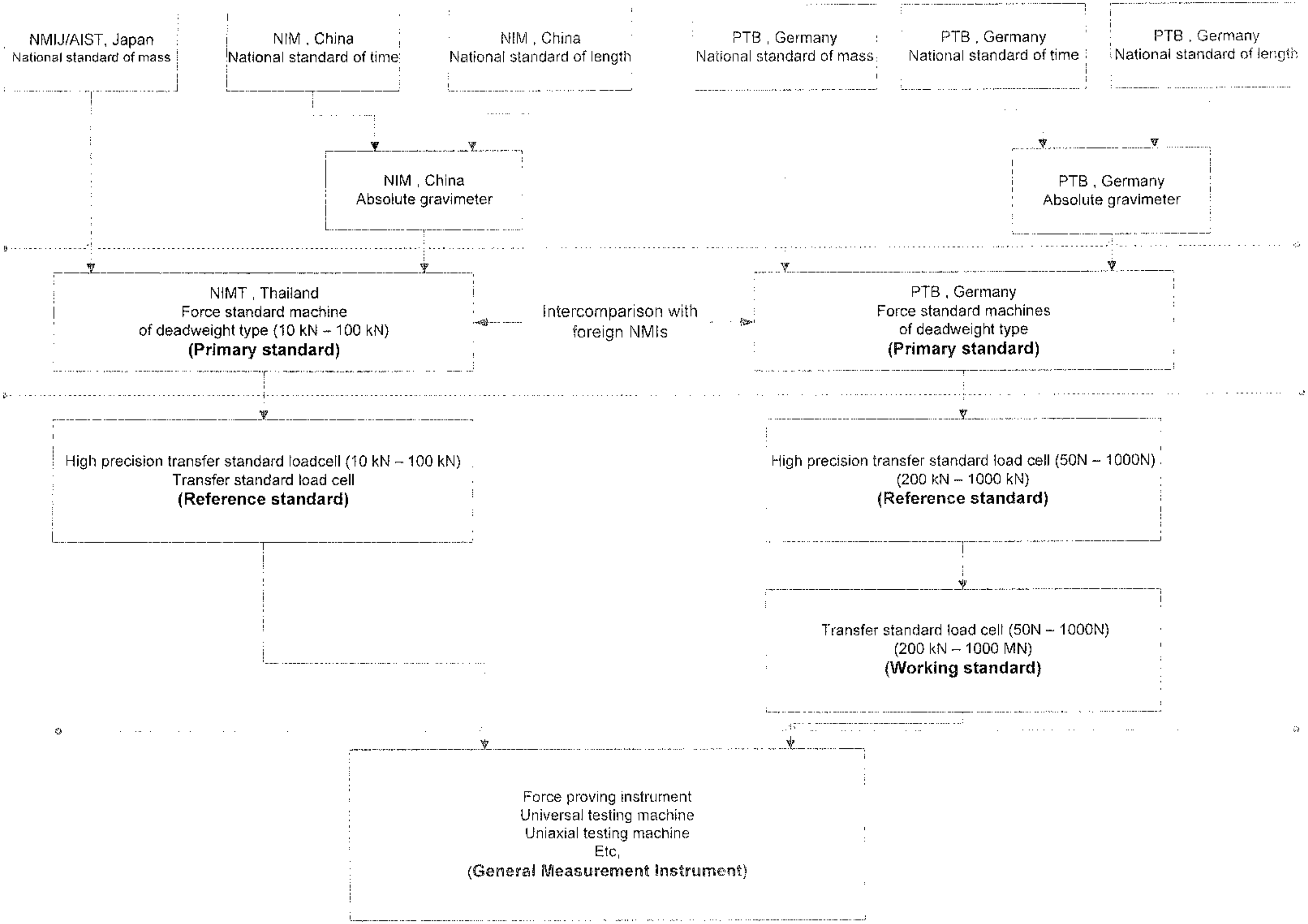
Working Standards

Counters/Oscillators

General Measuring
Instrument

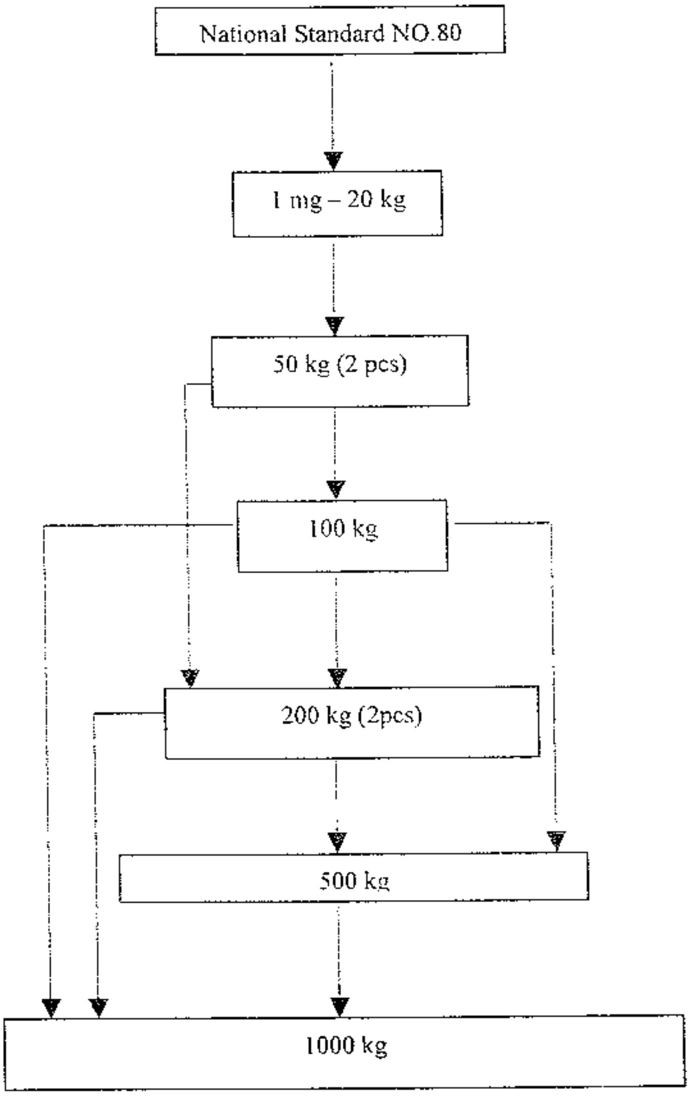
Traceability chart for pH measurement



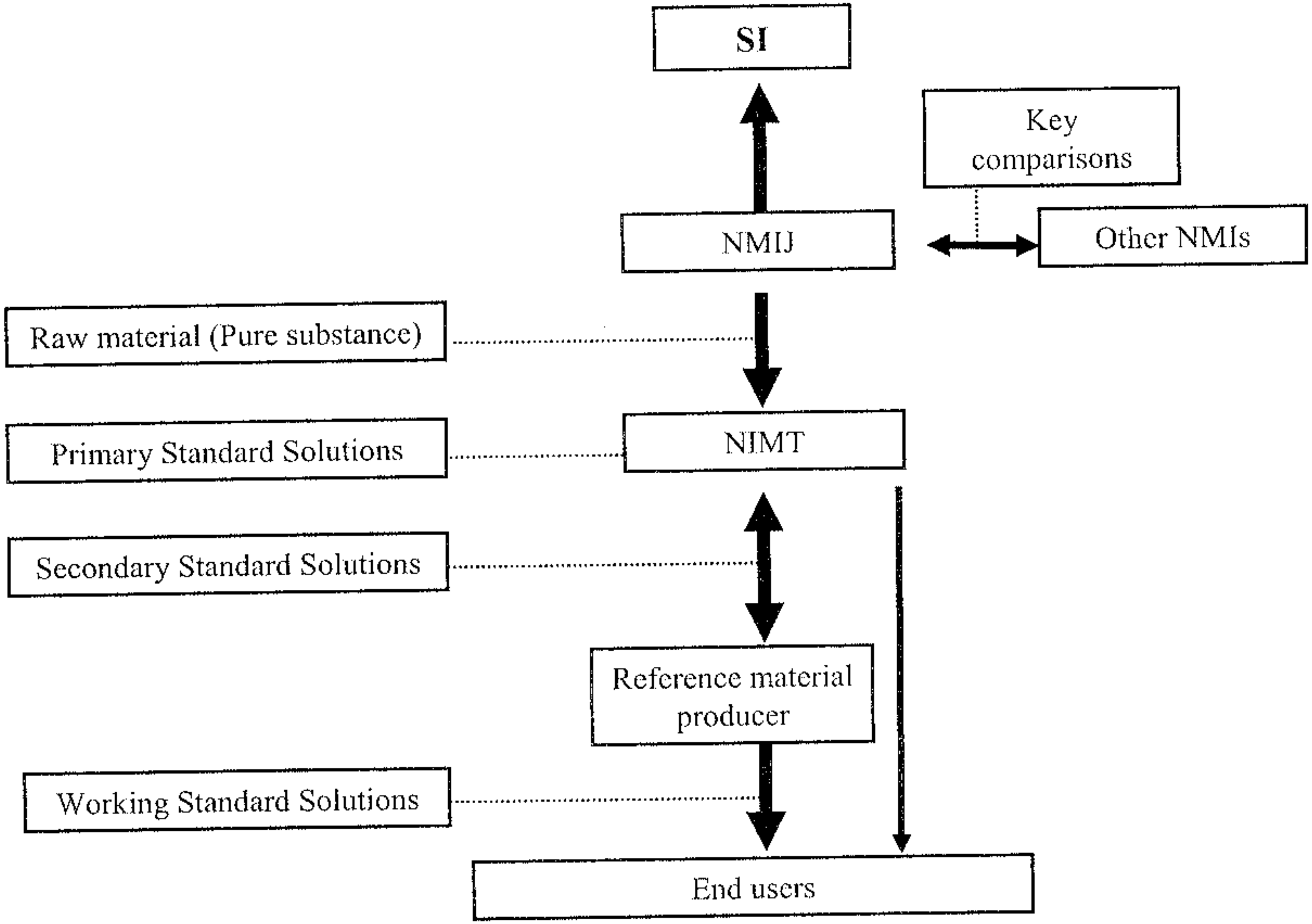


Traceability of chart of force NIMT

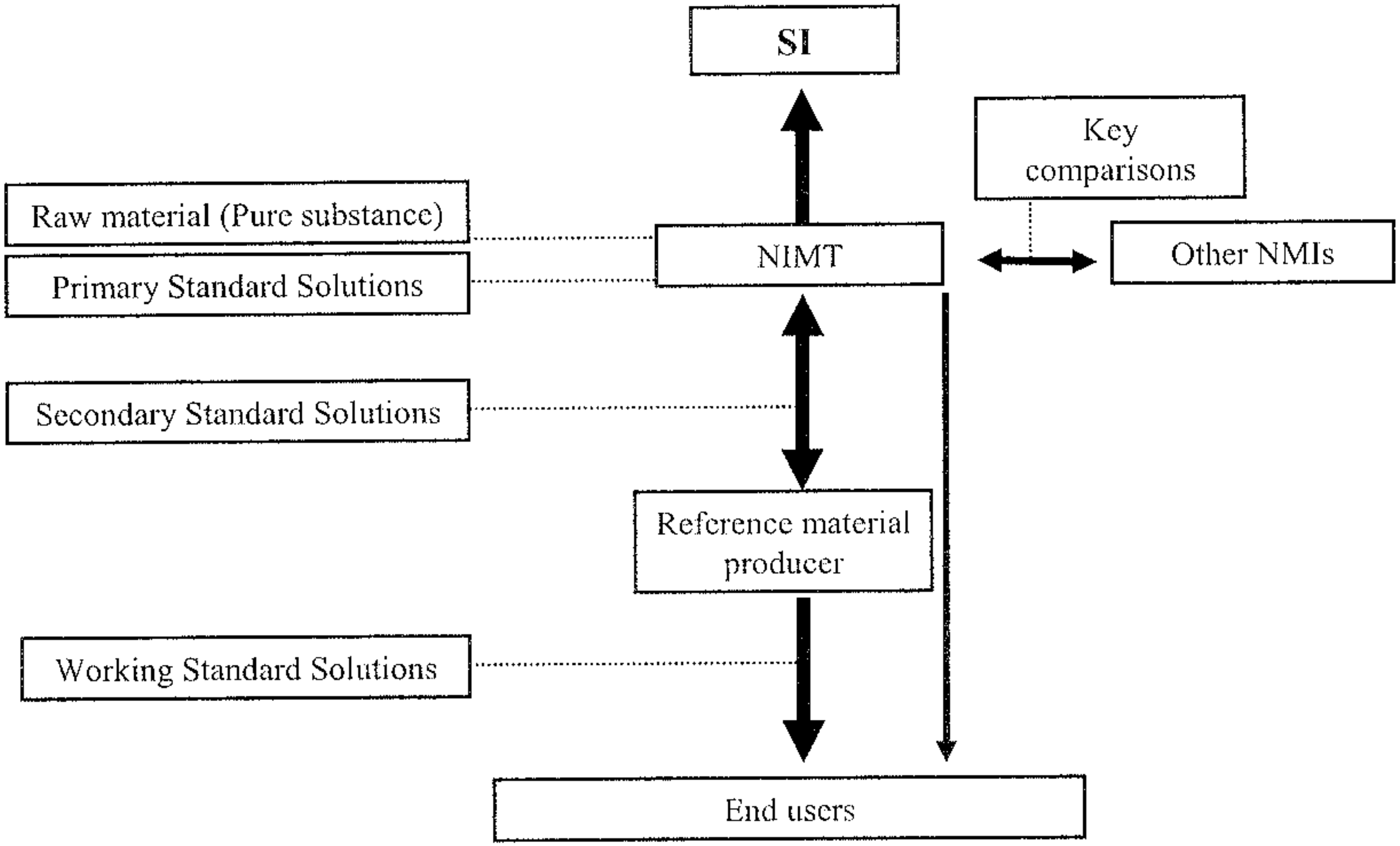
Traceability chart in Future



Traceabilty Chart for Organic Standard Solutions (Step1)



Traceabilty Chart for Organic Standard Solutions (Step2)



SI

Key
comparisons

Raw material (Pure substance)

NIMT

Other NMIs

Primary Standard Solutions

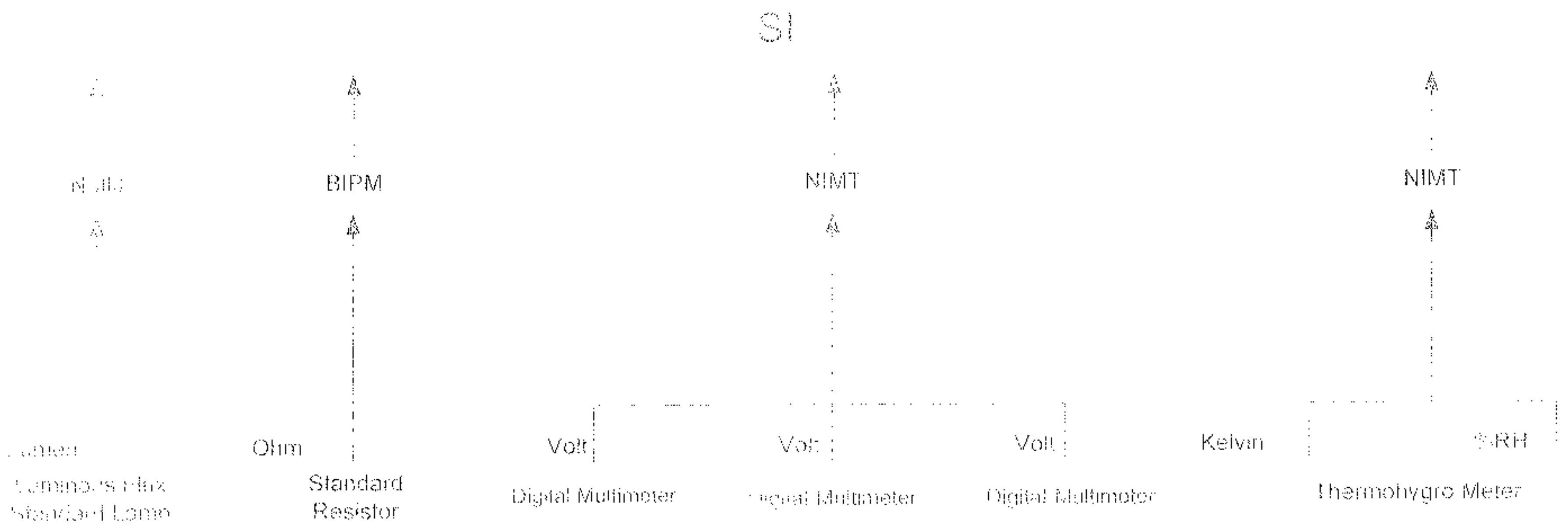
Secondary Standard Solutions

Reference material
producer

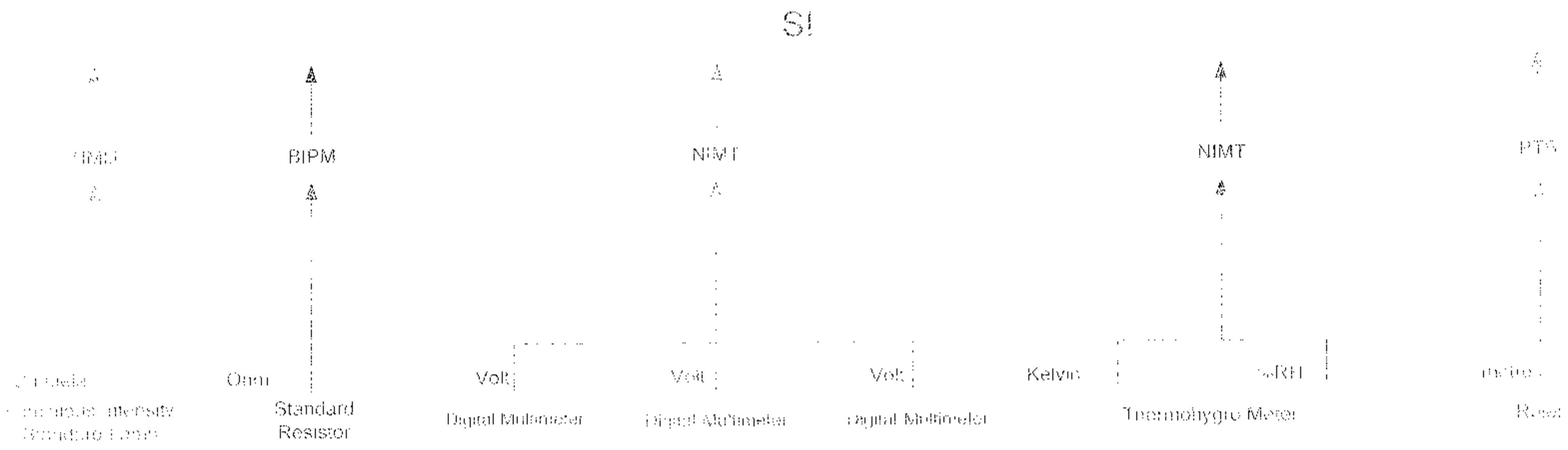
Working Standard Solutions

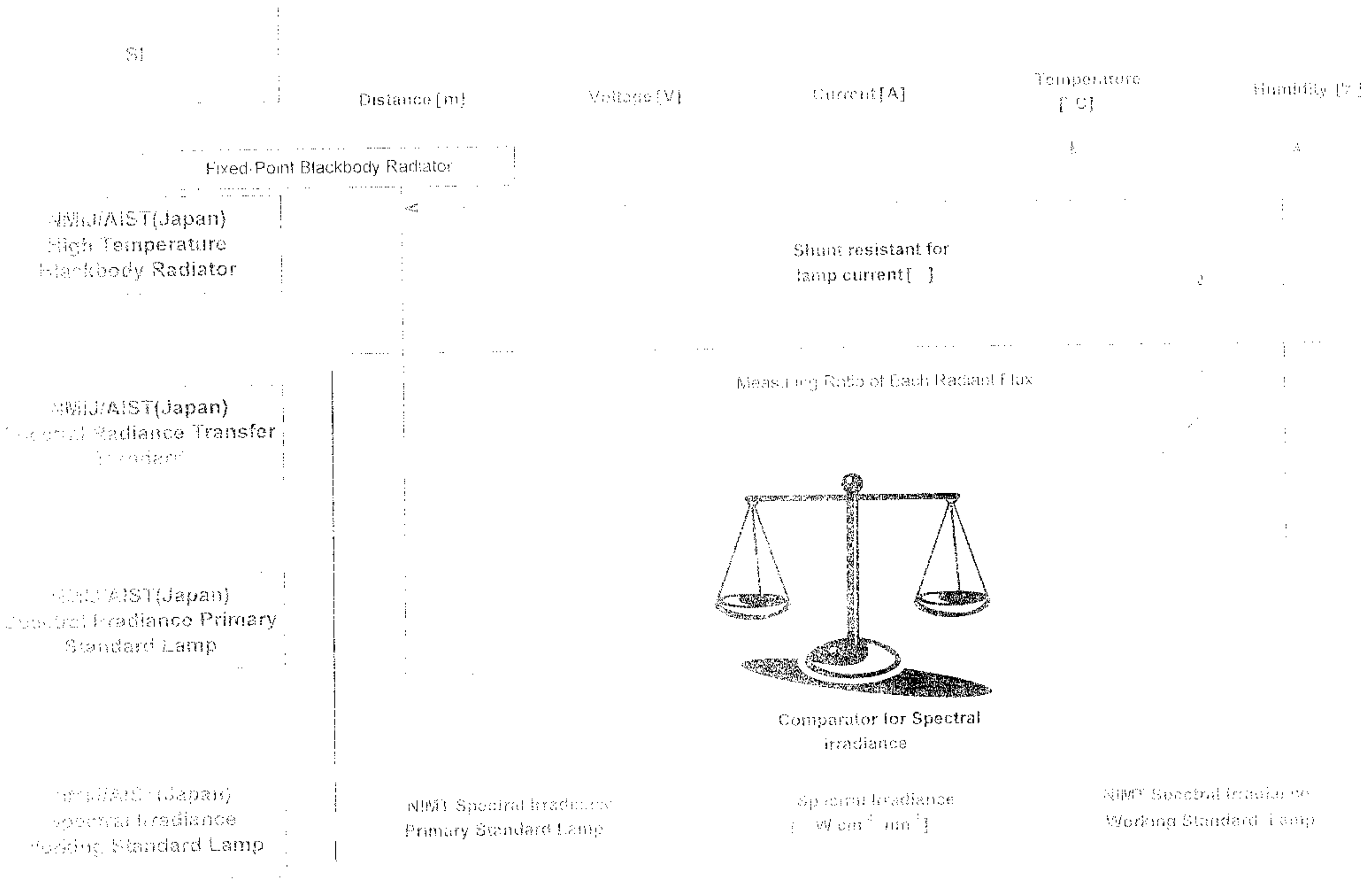
End users

Traceability Diagram of Luminous Flux Standard and Measuring System

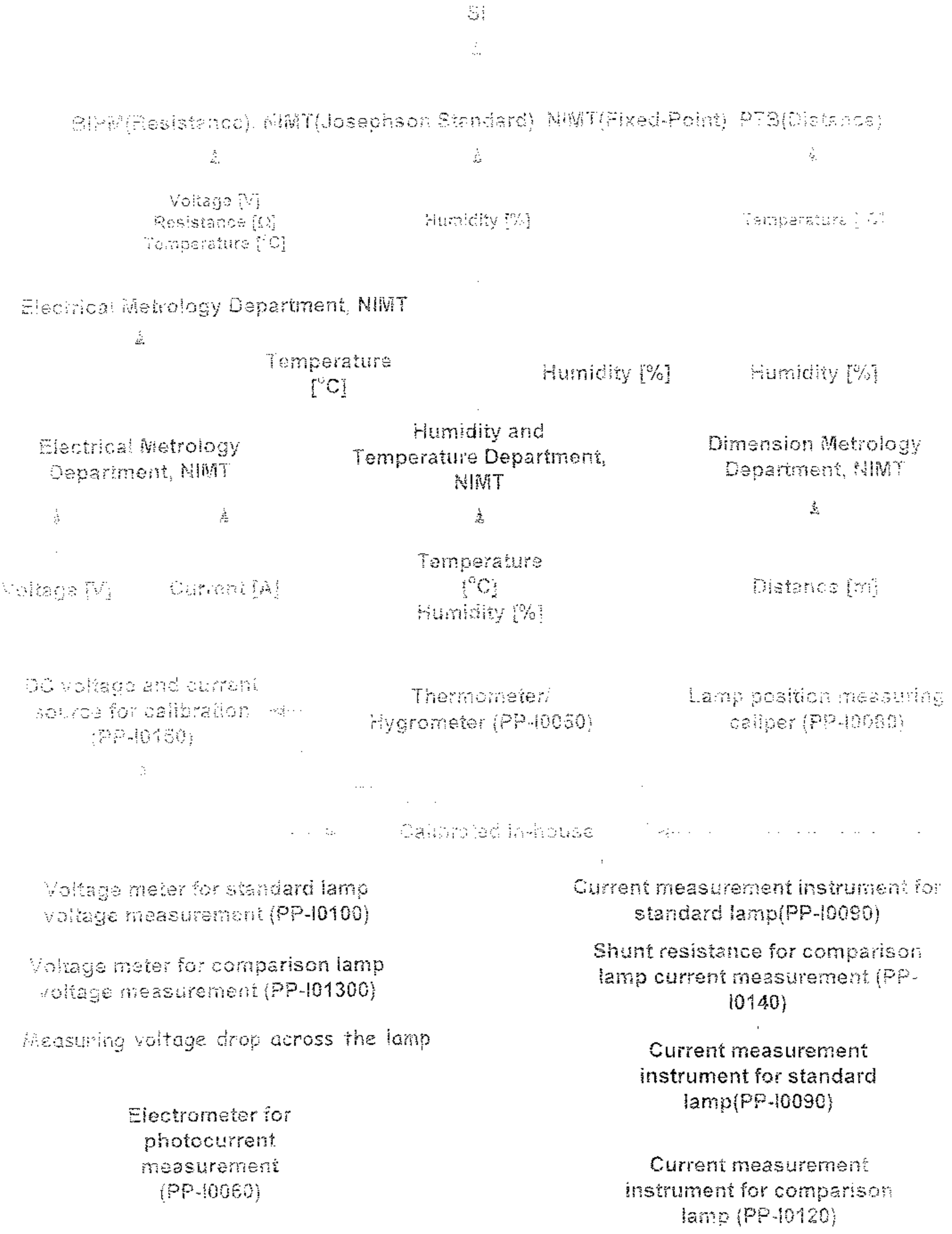


Traceability Diagram of Luminous Intensity Standard and Measuring System



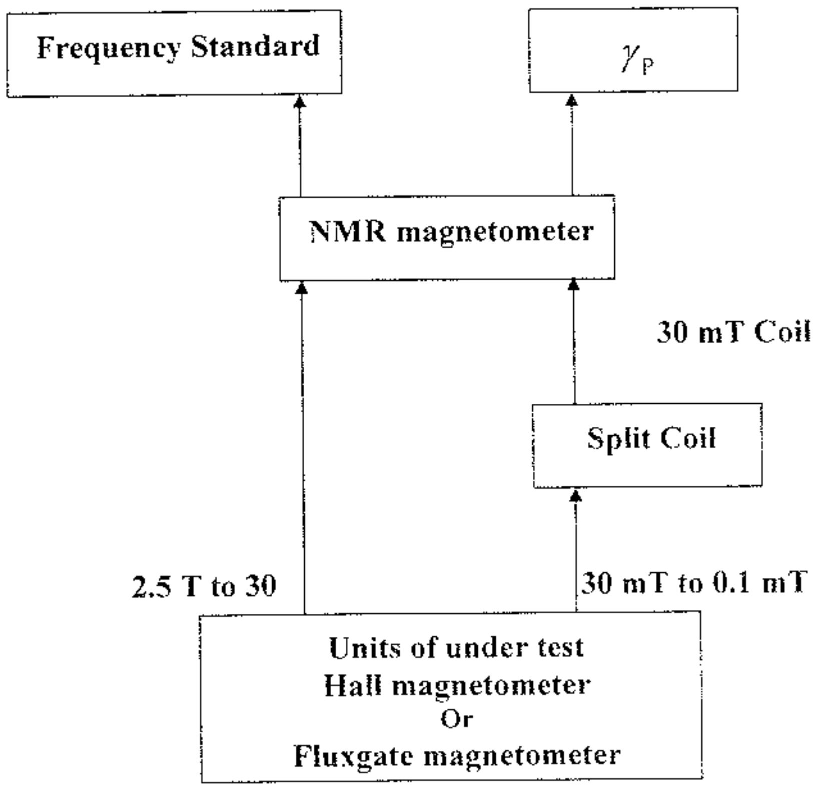


Traceability Diagram of Spectral Irradiance Standard at NIMT

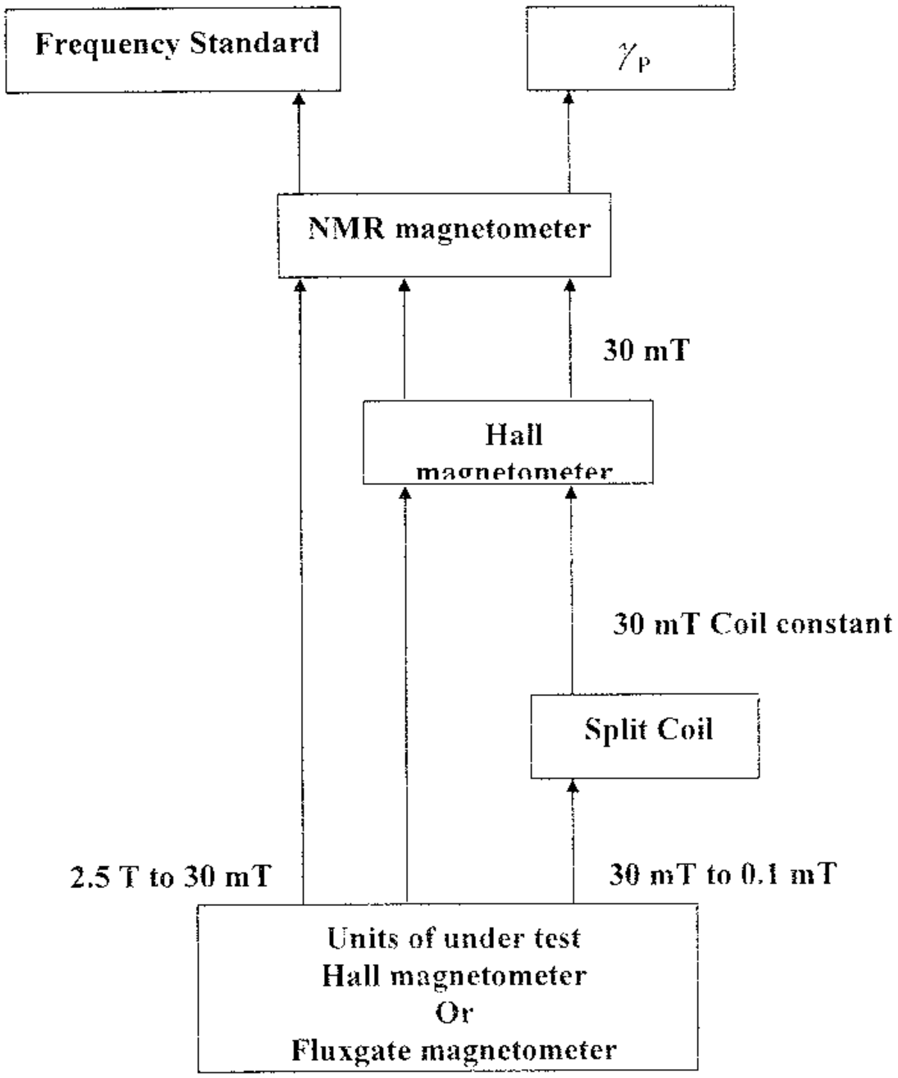


Traceability Diagram of Spectral Irradiance Measuring System at NIMT

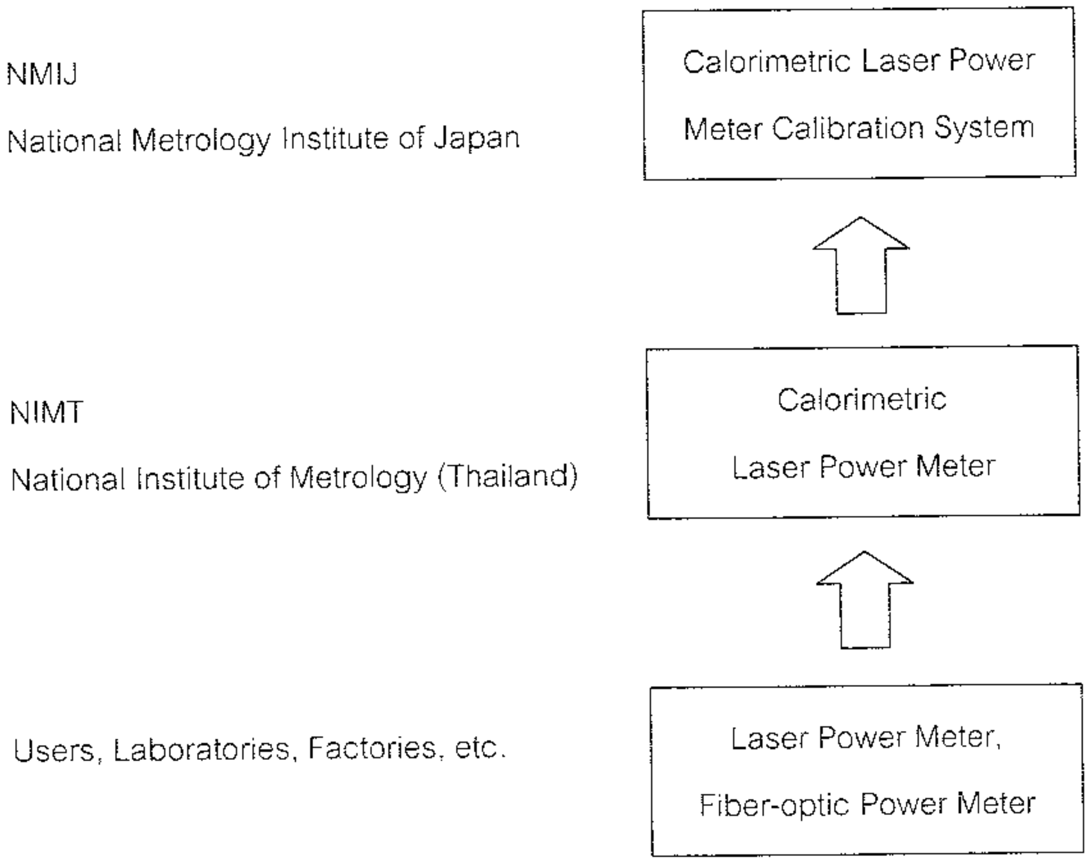
Traceability Chart 1. for Hall or Fluxgate magnetometer



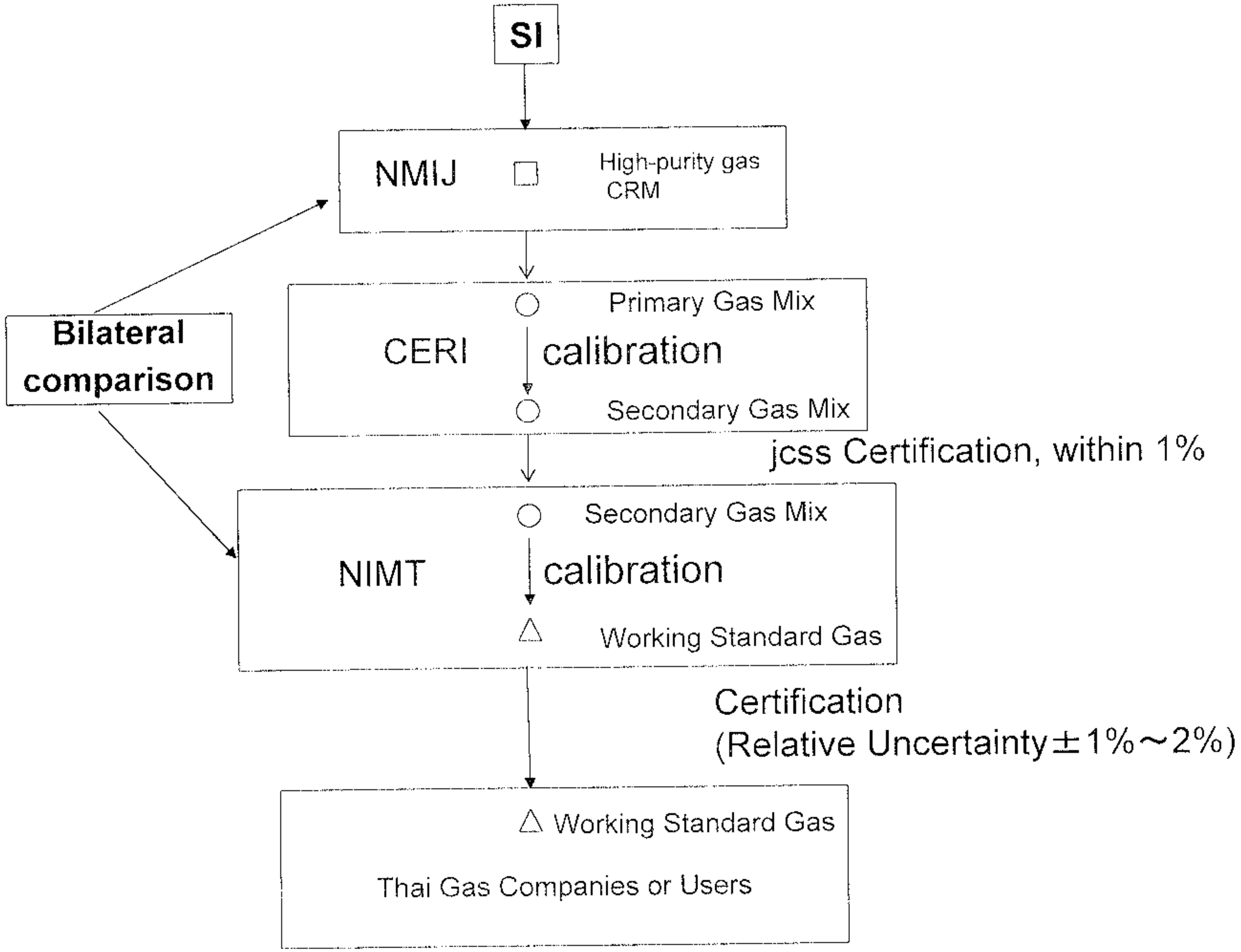
Traceability Chart 2. for Hall or Fluxgate magnetometer



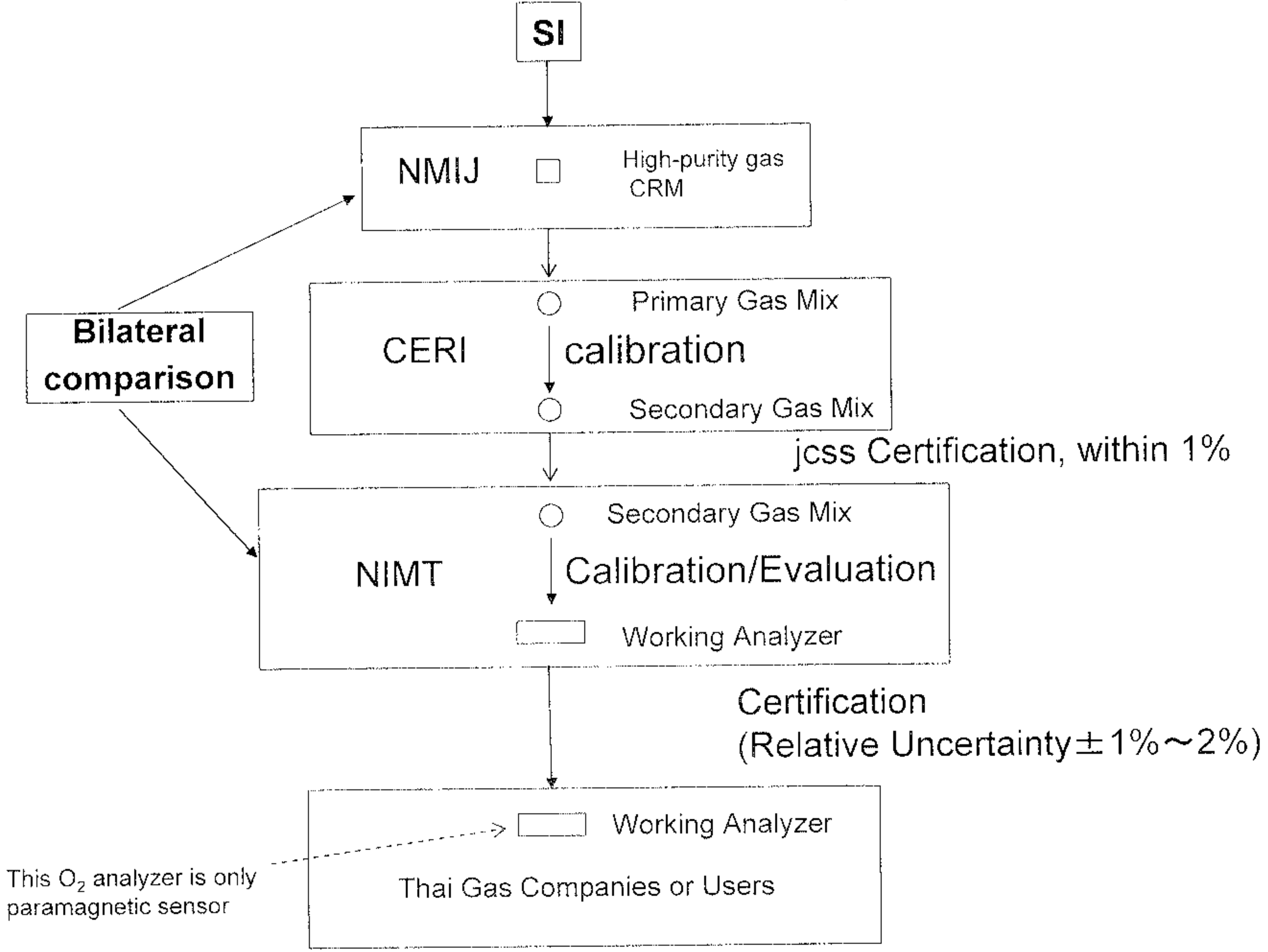
Traceability System of NIMT's Laser Power Standard



Traceability Chart on Calibration of Gas Mixture (O_2/N_2 & CO/N_2)



Traceability Chart on Calibration of Oxygen Analyzer and Carbon Monoxide Analyzer



Annex 22: List of Calibration Procedure

Annex 22 List of Calibration Procedure

	Quantity	Name of C/P	Status	Remarks
1	Plug/Ring	Mr. Samana	Provided	Accredited on 30 Oct. 2006
2	Radiation Thermometry	Mr. Narudom	Provided	
3	Roundness	Mr. Samana	Provided	Accredited on 30 Oct. 2006
4	Wavelength	Ms. Monludee	Provided	Accredited on 23 Jun. 2004
5	Acoustics	Ms. Surat	Provided	Accredited on 23 Jun. 2004
6	Hardness	Mr. Tassanai	Provided	Accredited on 4 Jan. 2005
7	AC Power	Mr. Sittisak	Provided	
8	DC High Voltage	Mr. Danai	Provided	Accredited on 11May 2007
9	CMM	Mr. Narin	Provided	
10	RF Power/Voltage	Mr. Chairat	Provided	
11	Humidity	Ms. Thasorn	Provided	
12	Roughness	Mr. Samana	Provided	Accredited on 30 Oct. 2006
13	Angle	Mr. Watcharin	Provided	Accredited on 30 Oct. 2006
14	RF Attenuation	Mr. Chairat	Provided	
15	Flatness	Mr. Muhummad	Provided	Accredited on 30 Oct. 2006
16	Vibration	Mr. Pairoj	Provided	Accredited on 11May 2007
17	Time and Frequency	Mr. Somchai	Provided	Accredited on 11May 2007
18	Hydrogen Ion Activity	Ms. Nongluck	Provided	Accredited on 11May 2007
19	Force	Mr. Kittipong	In Process	
20	Large Weight	Mr. Wirun	In Process	
21	Inorganic	Ms. Nongluck	In Process	
22	Standard Solutions	Dr. Preeyaporn	In Process	
23	Photometry	Ms. Rojana	In Process	
24	Radiometry	Mr. Arkom	In Process	
25	Magnetic	Mr. Thapbodin	In Process	
26	Laser Power	Mr. Narat	In Process	
27	Standard Gas	Mr. Bunthoon	In Process	

Annex 23: Survey and Verify NIMT's Activities

Annex 23 SURVEY AND VERIFY NIMT'S ACTIVITIES

1. Participation in CGPM

Since the establishment of National Institute of Metrology (Thailand), NIMT participated in CGPM twice as following:

- 1999, Mr. Prayoon Shiowattana, Former Director, participated in the 21st CGPM and also signed the Mutual Recognition Arrangement (MRA).
- 2003, Dr. Pian Totarong, Director, and Mr. Somsak Charkkian, Assistant Director, participated the 22nd CGPM.

2. Participation in APMP

Thailand has been the membership of APMP since 1979 and since the establishment of NIMT in 1998, NIMT has been participated in APMP Meeting, Symposium and General Assembly every year.

3. Hold DEC-WG

NIMT and APMP jointly organized APMP IPRT/LIGT Comparison Workshop during February 16-19, 2004 in Bangkok by the sponsorship of PTB and supervision of NML. There were participants from 8 economies to participate the workshop as follows: Australia. Indonesia, Malaysia, Nepal, Philippines, Singapore, Thailand, and Vietnam.

4. Entry to CMC

NIMT's Electrical measurement capability has been putting in the Appendix C of BIPM Website since July 18, 2003, and Pressure and Mass measurement capability also has been putting in the Appendix C of BIPM Website since April 18, 2006.

5. Host to organize the TC Chair Meeting

NIMT was the host to organize the 3rd APMP TC Chair Meeting in May 2004, and the 6th APMP TC Chair and 10th DEC Meeting in May 2005.

6. Host to organize the APMP Workshop

NIMT is the host to organize the 2nd Pressure and Vacuum Workshop in Sep. 2004, the APMP DEC Planning Workshop in May 2005, and the APMP/TCQM Workshop on Gas CRM in Feb. 2006.

7. Accreditation by DKD

NIMT applied for an accreditation to DKD and was accredited by DKD in Mass, Electrical, Pressure and Length standards in 2002, and extended in Mass, Electrical, Pressure and Length standards in November 2003 and in process of accreditation in Temperature.

8. Accreditation by IAJapan

NIMT obtained Accreditation on Acoustics and Wavelength standards on 23 June 2004, on Rockwell Hardness Standard (HRC) on 4 January 2005, on Form standard (Plug/Ring gauge, Flatness standard, Roughness standard, Roundness standard, and Angle standard) on 30 Oct. 2006, and Acceleration and Vibration, DC High Voltage, Time and Frequency, and pH standards on 11 May 2007.

Annex 24: Price List

Annex 24

NIMT

Price List

สถาบันมาตรวิทยาแห่งชาติ

National Institute of Metrology (Thailand)

National Institute of Metrology (Thailand)

3/4-5 Moo 3, Klong 5, Klong Luang, Pathumthani, 12120, Thailand

Tel. +66 2577 5100 (Please contact : Customer Service Section Ext. 3101-3102) Fax. +66 2577 3659 Website : http://www.nimt.or.th

Contents

Calibration Fee

Reference Materials For Sale

Note : 1. In the case of accreditation calibration certificate, 500 THB shall be added.

2. * Please contact Custermer Service Section at Rama VI Road. (Tel. +66 2354 3700)

Price List

Calibration Fee

National Institute of Metrology (Thailand)
3/4-5 Moo 3, Klong 5, Klong Luang, Pathumthani, 12120, Thailand
☎ 2577 5100 (Please contact : Customer Service Section Ext. 3101, 3102) Fax. +66 577 3659 Website : http://www.nimt.or.th

Price List
Calibration Fee

Item No.	Description	Range	Accuracy / Uncertainty	Price (THB)	Remark	Line No.
Dimensional Metrology						
1	Iodine Stabilized He-Ne laser	633 nm	5.0×10^{-11}	36,000/piece		1
2	Stabilized He-Ne laser	633 nm	1.0×10^{-9}	21,000/piece		2
3	Laser interferometer (Laser Head)	633 nm	0.1×10^{-5}	21,000/piece		3
	- Temperature sensor			2,300 first point + 400/next point		4
	- Humidity sensor			2,400 first point + 440/next point		5
	- Air pressure			2,700/piece		6
4	Short Gauge Block, Material : Steel, Ceramic, Tungsten Carbide, Chromium Carbide (Metric Rectangular Gauge Block)	0.1 mm to 125 mm	Grade K or 00	1,800 first piece + 1,200/next piece	Optical Interferometry method, Deviation from central length Measuring faces inspection and lapping. Both side wringing	7
5	6 pairs Gauge Block, according to EAL-G21 : 1996	0.5 mm to 100 mm	Grade K or 00	1,800 first piece + 1,200/next piece	Optical Interferometry method, Deviation from central length Measuring faces inspection and lapping. Both side wringing	8
6	Short Gauge Block, Material : Steel, Ceramic, Carbide (Metric Rectangular Gauge Block)	0.1 mm to 125 mm	Grade 0	1,800 first piece + 500/next piece	Comparison method, *D/c* , Deviation from central length , Variation (fo, fu) Measuring faces inspection and lapping	9
7	Short Gauge Block, Material : Steel, Ceramic, Carbide (Inch. Rectangular Gauge Block)	0.005 inch to 4 inch	Grade 0	1,800 first piece + 500/next piece	Comparison method, *D/c* , Deviation from central length , Variation (fo, fu) Measuring faces inspection and lapping	10
8	Long Gauge Block (Metric Rectangular, Square)	125 mm to 500 mm 125 mm to 1000 mm 125 mm to 1000 mm	Grade 0 Grade 1 Grade 2	2,700/piece 2,250/piece 1,800/piece	Comparison Method, *D/c* , Deviation from central length, Variation *(fo, fu)* Measuring faces inspection and lapping	11 12 13
9	Length Bar	5 mm to 600 mm	Grade 1 Grade 2	2,250/piece 1,800/piece	Comparison Method, *D/c* , Deviation from central length, Variation *(fo, fu)* Measuring faces inspection and lapping	14 15
10	Gauge Block Comparator	Up to 100 mm	0.032 μm	21,600/piece	EAL-G21, 11 Gauge Blocks 0.5 to 100 mm	16
11	Universal Length Measuring Machine (ULM)	Up to 1000 mm	$0.05\ \mu m + 1.37 \times 10^{-5} l$	15,000/piece	Comparison with gague block grade K	17
12	Autocollimator (Analog, Digital)	± 1000"	0.2"	14,400/piece		18
13	Polygon	8 faces 12 faces 36 faces 72 faces	0.2"	7,200/piece 9,000/piece 14,400/piece 36,000/piece	Cal. by one autocollimator Flatness measurement + 450/face	19 20 21 22
14	Polygon	8 faces 12 faces 36 faces 72 faces	0.34"	5,400/piece 6,750/piece 10,800/piece 27,000/piece	Cal. by two autocollimator Flatness measurement + 450/face	23 24 25 26
15	Angle Gauge Block	up to 90°	0.4" to 0.55" 0.6"	2,700 first piece + 900/next piece 1,800 first piece + 900/next piece	Cal. by autocollimator and indexing table	27 28
16	Indexing Table	0° to 360°	0.2"	7,200/piece	Cal. by polygon 8 and 12 faces	29
17	Concise Semi-Circle	0° to 360°	1'	3,600/piece		30
18	Gauge Template	0° to 360°	1'	3,600/piece		31
19	Overlay Chart	0° to 360°	1'	3,600/piece		32
20	Electronic Inclinometer	±1000" or 4.85 mm/m	0.4" or 2 μm/m	6,300/piece		33
21	Precision Level	Full range	10 μm/m	4,500/piece		34
22	Cylindrical Square	Up to 600 mm	$2\ \mu m + 6.0 \times 10^{-6} l$	5,400/piece		35
23	Standard Square	Up to 600 mm	$0.4\ \mu m + 2.4 \times 10^{-6} l$	4,500/piece		36
24	Square Master	Up to 600 mm	$1\ \mu m + 7.2 \times 10^{-6} l$	3,600/piece		37

Price List
Calibration Fee

Item No.	Description	Range	Accuracy / Uncertainty	Price (THB)	Remark	Line No.
25	Precision Square	Up to 600 mm	1 µm+ 7.2x10^{-6} l	2,700/piece		38
26	Bevel Protector	0° to 360°	1'	2,700/piece		39
27	Combination Set	0° to 360°	40"	3,600/piece		40
28	Surface Plate	< 0.25 m^2	0.3 µm+ 2.8x10^{-6} l	4,500/piece		41
		> 0.25 m^2		5,400/piece		42
29	Straight Parallel	2 faces	0.9 µm+ 6.5x10^{-6} l	2,700/piece		43
		4 faces		5,400/piece		44
30	Small Angle Generator	Up to 1000 mm	1 µm+ 2.8x10^{-6} l	5,400/piece		45
31	Sine Bar	up to 500 mm	1"	3,600/piece	include angle deviation and flatness	46
				5,400/piece	angle deviation, flatness of measuring face, straightness of rollers, difference of rollers dia., center distance of rollers, parallelism of 2 rollers, parallelism of measuring face and 2 rollers	47
32	Ring Gauge (Plain/Limit)	0.1 to 300 mm	0.37 µm+1.84x$10^{-6}d$	1,800 first piece + 450/next piece	Roundness measurement + 2,700/piece	48
33	Go-No Go ring gauge (Plain/Limit)	0.1 to 300 mm	0.37 µm+1.84x$10^{-6}d$	1,800 first piece + 900/next piece	Roundness measurement + 2,700/piece	49
34	Taper plain ring gauge	1 to 300 mm	0.5 µm+1.84x$10^{-6}d$	2,250 first piece + 450/next piece		50
35	Go-No Go taper plain ring gauge	1 to 300 mm	0.57 µm+1.84x$10^{-6}d$	2,250 first piece + 900/next piece		51
36	Plug Gauge (Plain/Limit)	0.1 to 1 mm	0.235 µm	2,250 first piece + 450/next piece	Roundness measurement +	52
		1 to 100 mm	0.230 µm+1.43x$10^{-6}d$		2,700/piece	53
		100 to 300 mm	0.290 µm+1.81x$10^{-6}d$		uncertainty 0.1 µm	54
37	Go-No Go plug gauge (Plain/Limit)	0.1 to 1 mm	0.236 µm	2,250 first piece + 900/next piece	Roundness measurement +	55
		1 to 100 mm	0.290 µm+1.81x$10^{-6}d$		2,700/piece	56
		100 to 300 mm	0.290 µm+1.81x$10^{-6}d$		uncertainty 0.1 µm	57
38	Pin Gauge	0.1 to 1 mm	0.236 µm	2,250 first piece + 450/next piece	Roundness measurement +	58
		1 to 100 mm	0.290 µm+1.81x$10^{-6}d$		2,700/piece	59
		100 to 300 mm	0.290 µm+1.81x$10^{-6}d$		uncertainty 0.1 µm	60
39	Steel Ball	dia. Up to 300 mm	0.290 µm+1.81x$10^{-6}d$	2,250 first piece + 450/next piece	Roundness measurement + 2,700/piece	61
40	3-Wire	All sizes	0.2 µm + 2.3x$10^{-6}d$	2,250 first set + 900/next set		62
41	Plain (Limit) Snap Gauge	All ranges	1 µm + 2.6x$10^{-6}d$	2,250 first piece + 450/next piece		63
42	Go-No Go Plane (Limit) Snap gauge	All ranges	1 µm + 2.6x$10^{-6}d$	2,250 first piece + 450/next piece		64
43	Thread Snap Gauge	All ranges	1 µm + 2.6x$10^{-6}d$	2,250 first piece + 450/next piece		65
44	Go-No Go Thread Snap gauge	All ranges	1 µm + 2.6x$10^{-6}d$	2,250 first piece + 450/next piece		66
45	Flat Internal Limit Gauge	All ranges	0.1 µm + 2.6x$10^{-6}d$	2,250 first piece + 450/next piece		67
46	Taper plain plug gauge	1 to 300 mm	0.290 µm+1.81x$10^{-6}d$	2,250 first piece + 450/next piece		68
47	Go-No Go Taper plain plug gauge	1 to 300 mm	0.290 µm+1.81x$10^{-6}d$	2,250 first piece + 900/next piece		69
48	Thread plain ring gauge	from 6 mm, pitch 1 mm	1 µm + 2.6x$10^{-6}d$	2,250 first piece + 450/next piece		70
49	Go-No Go Thread plain ring gague	from 6 mm, pitch 1 mm	1 µm + 2.6x$10^{-6}d$	2,250 first piece + 900/next piece		71
50	Taper thread ring gauge	from 6 mm, pitch 1 mm	1 µm + 2.6x$10^{-6}d$	2,250 first piece + 450/next piece		72
51	Go-No Go Taper thread ring gauge	from 6 mm, pitch 1 mm	1 µm + 2.6x$10^{-6}d$	2,250 first piece + 900/next piece		73
52	Thread plain plug gauge	from 1 mm, pitch 0.3 mm	1 µm + 2.6x$10^{-6}d$	2,250 first piece + 900/next piece		74
53	Go-No Go Thread plain plug gauge	from 1 mm, pitch 0.3 mm	1 µm + 2.6x$10^{-6}d$	2,250 first piece + 900/next piece		75
54	Taper thread plug gauge	from 1 mm, pitch 0.3 mm	1 µm + 2.6x$10^{-6}d$	2,250 first piece + 900/next piece		76

Price List
Calibration Fee

Item No.	Description	Range	Accuracy / Uncertainty	Price (THB)	Remark	Line No.
55	Go-No Go Taper thread plug gauge	from 1 mm, pitch 0.3 mm	1 µm + 2.6x10^{-6}d	2,250 first piece + 900/next piece		77
56	Height Master (analog/digital)	0 to 300 mm 0 to 600 mm	0.3 µm + 3x10^{-6} l	10,800/piece 18,000/piece		78 79
57	Riser Block	0 to 150 mm 0 to 300 mm 0 to 600 mm	0.3 µm + 3x10^{-6} l	5,400/piece	Height and Parallelism	80 81 82
58	Depth Micro-Checker	0 to 150 mm 0 to 300 mm	0.3 µm + 3x10^{-6} l	7,200/piece 9,000/piece		83 84
59	Inside Micro-Checker	0 to 300 mm 0 to 600 mm	0.4 µm + 2x10^{-6} l	7,200/piece 10,800/piece		85 86
60	Caliper Checker/ Vernier Checker	0 to 300 mm 0 to 600 mm	0.4 µm + 2x10^{-6} l	7,200/piece 10,800/piece		87 88
61	Vernier Caliper	0 mm to 1000 mm 0 mm to 1500 mm 0 mm to 2000 mm	0.01 mm + 1.0 x 10^{-5}l	2,700 first function + 900/next function 3,600 first function + 900/next function 5,400 first function + 900/next function		89 90 91
62	Height Gauge	0 mm to 1000 mm	6 µm + 1.0 x10^{-6}l	4,500/piece		92
63	External Micrometer	300 mm to 500 mm > 500 mm to 1000 mm > 1000 mm to 2000 mm	1 µm + 1.0 x10^{-6}l	2,250/piece 2,700/piece 3,600/piece	+ 450/piece of setting zero rod	93 94 95
64	Setting Zero Rod	Up to 1000 mm	0.2 µm + 2.3x10^{-6} l	1,800 first piece + 450/next piece		96
65	Micrometer Head	0 mm to 25 mm 0 mm to 50 mm	0.6 µm + 2.3x10^{-6} l	2,700/piece 3,600/piece		97 98
66	Calibration Tester	0 mm to 1 mm 0 mm to 5 mm 0 mm to 50 mm 0 mm to 100 mm	0.25 µm + 2.3x10^{-6} l 0.2 µm + 2.3x10^{-6} l	6,300/piece 6,300/piece 7,200/piece 9,000/piece		99 100 101 102
67	Dial Gauge Tester - Scale - Digital	0 mm to 25 mm	0.6 µm + 2.3x10^{-6} l 0.3 µm + 2.3x10^{-6} l	5,400/piece		103
68	Torsinal Recovery	0 mm to 40 mm	0.01 µm + 7.0 x10^{-6} l	2,700/piece		104
69	Electronic Comparator (Mu-Checker / Millitron) (Include; Probe and display unit) Analog M-Checker	5 µm 15 µm 50 µm 150 µm 500 µm 1500 µm	0.06 µm + 7.0 x10^{-6} l 0.06 µm + 7.0 x10^{-6} l 0.06 µm + 7.0 x10^{-6} l	3,600 first range + 900/next range/direction	Request stand and Jig fixture	105 106 107 108 109 110
70	Calibration Gague for Seam Metal	0 to 10 mm	1.5 µm + 2.3x10^{-6} l	2,250 + 450/function		111
71	Laser Hologage	0 to 10 mm 0 to 25 mm	0.04 µm + 2.3x10^{-6} l	9,000/piece		112
72	Radius Gauge	All sizes	0.01 mm + 2.3x10^{-6}R	1,800 first piece + 450 next/piece		113
73	Pitch Gauge	All sizes	1 µm	1,800 first piece + 450 next/piece		114
74	Feeler Gauge	All sizes	1 µm + 2.3x10^{-6}l	1,800 first piece + 450 next/piece		115
75	Standard Foil	All ranges	0.1 µm + 2.3x10^{-6} l	1,800 first piece + 450 next/piece		116
76	Laser Scan Micrometer (Display Unit, Measuring Unit)	Up to 100 mm	0,7 µm + 1,3 10^{-5} l	9,000/piece		117
77	Digimatic Holtest	Up to 100 mm	1.5 µm + 1.5 10^{-6} d	1,800 first piece + 450/next piece		118
78	LSM Calibration Tool	Up to 5 mm	50.0 µm + 2.5x10^{-6} l	1,800 first step + 450/next step		119
79	Arm Calibrator	All ranges	0.01 mm + 9.5 10^{-6} l	2,250 first point + 900/next point		120
80	Surfacetest Step Gauge	All ranges	0.05 µm + 2.3x10^{-6} l	1,800 first step + 900/next step		121

Price List
Calibration Fee

Item No.	Description	Range	Accuracy / Uncertainty	Price (THB)	Remark	Line No.
81	Magnification Checker	Full scale	0.7 µm + 2.3x10^{-6} /	4,500/piece		122
82	Orefice Plate	Up to 1000 mm	0.02 µm + 2.3x10^{-6}/	25,200/piece		123
83	Optical Parallel	max. dia. 60 mm	0.02 µm (F) 0.04 µm (P) 0.06 µm+0.74x10^{-6}/ (T)	1,800 first piece + 450/next piece	F being Flatness P being Parallelism T being Thickness	124
84	Optical Flat	max. dia. 60 mm	0.02 µm	1,800/piece		125
85	Glass Hemisphere	dia. Up to 355 mm	5nm+1.1% of Reading	9,000/piece		126
86	Magnification Setting Standard	dia. Up to 355 mm	7nm+1.1% of Reading	9,000/piece		127
87	Roughness Standard (Type A), Step Height	up to 3 µm	7nm+0.010xZ_m	5,400/step	Z_m being the measured value	128
88	Roughness Standard (Type C or Type D), Roughness Specimen	up to 3 µm	U(R_a)=0.010µm+0.010xZ_m U(R_z)=0.040µm+0.015xZ_m	5,400/range	Z_m being the measured value	129
89	Standard Glass Scale	0 mm to 50 mm	0.5 µm + 2.6x10^{-6}/	2,700/piece		130
		0 mm to 150 mm	0.7 µm + 2.6x10^{-6}/	3,600/piece		131
		0 mm to 300 mm	0.7 µm + 2.6x10^{-6}/	5,400/piece		132
		0 mm to 500 mm	0.7 µm + 2.6x10^{-6}/	7,200/piece		133
90	Standard Metal Scale	0 mm to 1000 mm	8 µm + 2.3x10^{-5}/	7,200/piece		134
91	Working Standard Scale	0 mm to 200 mm	0.7 µm + 2.3x10^{-6}/	2,700/piece		135
		0 mm to 500 mm	1.0 µm + 2.3x10^{-6}/	4,500/piece		136
		0 mm to 600 mm	1.0 µm + 2.3x10^{-6}/	5,400/piece		137
		0 mm to 1000 mm	1.0 µm + 2.3x10^{-6}/	6,300/piece		138
92	Reading Scale	0 mm to 300 mm	1.0 µm + 2.3x10^{-6}/	2,700/piece		139
93	Calibration Grid	100-0- 100 mm	2.0 µm + 2.3x10^{-6}/	3,600/piece	Over 100 mm : 5,400	140
94	Reticle of Scale Lupe	0 to 20 mm	0.01 mm + 2.3x10^{-6}/	1,800 first function + 900/next function		141
95	Digimatic Scale Unit	Up to 1000 mm	0.01 mm + 2.3x10^{-6}/	3,600/piece		142
96	Linear Scale	0 mm to 1000 mm	7 µm + 2.3x10^{-6}/	4,500/piece		143
		0 mm to 2000 mm		5,400/piece		144
97	Check Master/ Step Gauge	0 to 300 mm	0.4+1.34x10^{-6}/	7,200/piece		145
		0 to 600 mm		10,800/piece		146
		0 to 1000 mm				147
98	Gear standard Spur gear : Profile slope deviation	25 to 400 mm	1.0 to 3.0 µm	6,300/piece		148
99	Gear standard Spur gear : Helix slope deviation	up to 45°	1.0 to 2.0 µm	6,300/piece		149
100	Spur gear : Pitch	up to 400 mm	2.0 µm	6,300/piece		150
101	Bevel Gear : form deviation	up to 300 mm	2.0 µm	6,300/piece		151
102	Ball Plate	up to 1000 mm	0.60µm+1.9x10^{-5}/	36,000/piece		152
Electrical Metrology						
103	DC Voltage Standard	10 V /1.018 V	0.5 x 10^{-6} @ 10 V 0.9 x 10^{-6} @ 1.018 V	10,800/piece		153
	Standard Cell	1 V / 1.018 V	0.9 x 10^{-6}	10,800/piece		154
104	AC/DC Transfer Standard	2 mV to 1 kV (10 Hz to 1 MHz)	13 x 10^{-6} to 0.25 x 10^{-3}	72,000/item		155
105	Thermal Transfer Standard	0.5 V to 1 kV (10 Hz to 1 MHz)	13 x 10^{-6} to 0.25 x 10^{-3}	54,000/item		156
106	Single Junction Thermal Voltage Converter Standard	0.5 V to1 kV (10 Hz to 1 MHz)	13 x 10^{-6} to 0.25 x 10^{-3}	7,200/piece		157
107	AC Measurement Standard	10 mV to 1 kV (10 Hz to 1 MHz)	As specification	54,000 to 63,000	Excluded WB Option	158
				63,000 to 68,400	With WB Option	159
108	AC/DC Current Shunt	5 mA to 20 A (10 Hz to 100 kHz)	As specification	(5,400 to 7,200)/piece		160

Price List
Calibration Fee

Item No.	Description	Range	Accuracy / Uncertainty	Price (THB)	Remark	Line No.
109	Standard Resistor (Calibrate in oil or in air)	1 µΩ to 1 TΩ	1 x 10^{-6} to 10%	4,500/piece		161
		1 mΩ to 10 kΩ	≤ 1 x 10^{-5}	5,400/piece		162
		>10 KΩ to 1GΩ	≤ 500 x 10^{-6}	6,300/piece		163
		0 Ω to 1 TΩ	As specification	1,800/point test		164
110	Digital Thermometer (indicator)	up to 10 MΩ	≤ 5 ppm	3,600/point		165
			≥ 5 ppm	1,800/point		166
111	Decade Resistance Box	1 mΩ to 10 MΩ	As specification	3,600 first decade + 2,700/next step		167
		10 MΩ to 1 TΩ	As specification	7,200 first decade + 5,400/next step		168
112	High Resistance Meter	Up to 1 TΩ	As specification	1,800/point		169
113	Resistance Calibrator	0 Ω to 100 MΩ	As specification	18,000/piece		170
114	Fixed, Fused Silica Dielectric Standard Capacitors	1 pF, 10 pF and 100 pF @ 1000 Hz	≤ 1 x 10^{-6}	10,800/piece	direct substitution method with the reference standard capacitors	171
115	Fixed Three Terminal, Nitrogen Dielectric Standard Capacitors	10 pF, 100 pF and 1000 pF @ 1000 Hz	> 5 x 10^{-6}	9,000/piece	a null method which uses the basic ratio bridge	172
116	Two or Three Terminal Mica Dielectric Standard Capacitors	0.001 µF, 0.01 µF, 0.1 µF and 1 µF @ 1000 Hz	> 0.12 x 10^{-3}	4,500/piece	a null method which uses the basic ratio bridge	173
	Additional Measurement at another Frequency	0.001 µF, 0.01 µF, 0.1 µF and 1 µF @ 100, 120, 200, 400, 500 Hz, 2 kHz, 5 kHz, 10 kHz	> 0.12 x 10^{-3}	1,000/frequency	a null method which uses the basic ratio bridge	174
117	Fixed Standard Capacitors	1 pF to 1 F @ 1000 Hz	> 0.20 x 10^{-3}	3,600/piece	measured by RLC Digibridge and/or Precision LCR Meter, direct measurement, at desired frequency	175
	Additional Measurement at another Frequency	1 pF to 1 F @ 12 Hz to 1 MHz	> 0.20 x 10^{-3}	500/frequency	measured by RLC Digibridge and/or Precision LCR Meter, direct measurement, at desired frequencies	176
118	Decade capacitor	1 pF to 10 µF @ 1000 Hz	> 0.12 x 10^{-3}	4,500 first decade + 1,000 next step	a null method which uses the basic ratio bridge	177
		1 pF to 1 F @ 1000 Hz	> 0.20 x 10^{-3}	3,600 first decade + 1,000 next step	measured by RLC Digibridge and/or Precision LCR Meter, direct measurment, at desired frequencies	178
	Additional Measurement at another Frequency	1 pF to 1 F @ 12 Hz to 1 MHz	> 0.20 x 10^{-3}	(3,600 first decade + 1,000 next step) per one frequency	measured by RLC Digibridge and/or Precision LCR Meter, direct measurment, at desired frequencies	179
119	Fixed Standard Inductors	100 µH, 1 mH, 10 mH, 100 mH, 1 H and 10 H @ 1000 Hz	> 0.16 x 10^{-3}	9,000/piece	measured by the direct substitution method with the reference standard inductors	180
	Additional Measurement at another Frequency	100 µH, 1 mH, 10 mH, 100 mH, 1 H and 10 H @ 12 Hz to 1 MHz	> 0.20 x 10^{-3}	500/frequency	measured by RLC Digibridge and/or Precision LCR Meter, direct measurement, at desired frequencies	181
120	Decade Inductors	1 µH to 10 H @ 1000 Hz	> 0.20 x 10^{-3}	3,600 first decade + 1,000 next step	measured by RLC Digibridge and/or Precision LCR Meter, direct measurement, at desired frequencies	182
	Additional Measurement at another Frequency	1 µH to 10 H @ 12Hz to 1 MHz	> 0.20 x 10^{-3}	(3,600 first decade + 1,000 next step) per one frequency	measured by RLC Digibridge and/or Precision LCR Meter, direct measurement, at desired frequencies	183
121	Precision Capacitance Bridge	1 pF, 10 pF, 100 pF and 1000 pF @ 1000 Hz or 1592 Hz	≥ 1 x 10^{-6}	27,000/item	calibrated by comparing its reading against the reference standard capacitors. The correction functions are used to correct additional error due to the test fixture and test leads before measurement	184
122	LCR Meter with 4 terminal pair configuration/without 4 terminal pair configuration	0.001 µF, 0.01 µF, 0.1 µF and 1 µF @ 100, 120, 200, 400, 500 Hz, 1 kHz, 2 kHz, 5 kHz, 10 kHz	> 0.12 x 10^{-3}	To be determined	calibrated by comparing its reading against the standard capacitors, standard inductors and standard resistors. The correction functions are used to correct additional error due to the test fixture and test leads before measurement	185
		1 pF, 10 pF, 100 pF, 1000 pF @ 1000 Hz*	> 0.12 x 10-3			
		100 µH, 1 mH, 10 mH, 100 mH, 1 H and 10 H @ 1000 Hz	> 0.16 x 10^{-3}		*For 4 terminal pair configuration	
		1 Ω, 10 Ω, 100 Ω, 1000 Ω @ 1 kHz	> 0.20 x 10^{-3}			

Price List
Calibration Fee

Item No.	Description	Range	Accuracy / Uncertainty	Price (THB)	Remark	Line No.
123	Standard Watt Converter	Volt : 600 V Current : 100 A AC Power : 60 kW Frequency : 50 Hz, 60 Hz Power Factor : ± 0 to 1	50 ppm	14,400 to 21,600/item		186
124	AC Wattmeter, Digital Power Meter	Volt : 1000 V Current : 80 A AC Power : 80 kW Frequency : 15 Hz to 450 Hz Power Factor : ± 0 to 1	250 ppm	7,200 to 21,600/item		187
125	Phase Meter	Phase Angle : 0.000° to ± 360.000° Frequency : 15 Hz to 100 kHz Amplitde : 50 mVrms to 120 Vrms	10 m° to 100 m°	14,400/item		188
126	Phase Source	0.000° to 999.999° 50 mV to 120 Vrms 1 Hz to 100 kHz	10 m° to 100 m°	21,600/item		189
127	Power Analyzer, Harmonics and Flicker	Output Voltage : 1020 V Output Current : 80 A Frequency : 20 Hz and up to 1 kHz Harmonics : 100 th, up to 6 kHz Flicker : 16 Hz to 9 kHz	Voltage : 100 ppm Current : 150 ppm Power : 200 ppm Frequency : 50 ppm	10,800 to 21,600/item		190
128	Frequency Source - Rubidium - Quartz, Others	1 MHz, 5 MHz, 10 MHz, 1 PPS	$\leq 1 \times 10^{-12}$	10,800/item		191
129	Synthesizer Signal Generator	Up to 225 MHz	As specification	5,400/item		192
130	Frequency Counter Timer Counter	Up to 1 GHz	1×10^{-5} to 1×10^{-8}	3,600/item		193
131	Function Generator	As specification	As specification	5,400/item		194
132	Tachometer	As specification	As specification	2,700item		195
133	Stopwatch	As specification	As specification	1,600/item		196
134	Feedthrough Mount	100 kHz to 18 GHz, 1 mW	1.1%	10,800/item		197
135	Power Sensor	100 kHz to 18 GHz, 1 mW	1.1%	10,800/item		198
136	Power meter	As specification	As specification	9,000/item		199
137	RF Attenuator					
	- Fix Attenuator	10 MHz to 18 GHz	0.07 dB	1,800/Freq. Point		200
	- Step Attenuator	10 MHz to 18 GHz	0.07 dB	1,800/Freq. Point/Step		201
138	Spectrum Analyzer	As specification	As specification	36,000/item		202
139	Oscilloscope	As specification	As specification	7,200/item		203
140	RF Signal Generator	As specification	As specification	27,000/item		204
141	Accessories of RF Microwave	As specification	As specification	As Cost		205
142	RF Voltmeter	10 MHz to 1 GHz	As specification	9,000/item		206
143	RF Voltage Source	As specification	As specification	10,800/item		207
144	Multifunction Calibrator DMM Calibrator	DC Voltage : 0 V to 1 kV	40×10^{-6} to 0.6×10^{-6}	10,800 to 27,000/item		208
		AC Voltage : 10 mV to 1 kV @ 10 Hz to 1 MHz AC Voltage : 30 V to 1 kV @ 10 Hz to 100 kHz	3.03×10^{-3} to 20×10^{-6}			
		DC Current : 0 A to 20 A	150×10^{-6} to 4.5×10^{-6}			
		AC Current : 100 mA to 20 A @ 10 Hz to 100 kHz	1.1×10^{-3} to 65×10^{-6}			
		Resistance : 0 Ω to 10 Ω	1.3×10^{-3} to 1.8×10^{-6}			
		Others	As specification			
	Wideband Option	Up to 30 MHz	As specification	9,000/option	additional	209
	Scope Option	Up to 600 MHz	As specification	10,800/option	additional	210

Price List
Calibration Fee

Item No.	Description	Range	Accuracy / Uncertainty	Price (THB)	Remark	Line No.
145	Oscilloscope Calibrator	Up to 600 MHz	As specification	10,600/channel		211
		Up to 2.1 GHz	As specification	36,000/item		212
146	Amplifier / Precision Power Amplifier	Up to 1kV 10 Hz up to 100 kHz	As specification	7,200/item		213
147	Digital Multimeter	6 1/2 digit	As specification	7,200 to 10,800/item		214
		7 1/2 digit	As specification	10,800 to 18,000/item		215
		8 1/2 digit	As specification	18,000 to 21,600/item		216
148	Nano Voltmeter	DC Voltage : 1 mV to 100 mV	As specification	9,000 to 10,800/item		217
149	DC High Voltage Divider	1 kV to 100 kV	$\geq 24 \times 10^{-6}$ (Division Ratio)	$\leq$ 10 kV 2,700 first point + 1,800 next point		218
				> 10 kV 3,600 first point + 1,800 next point		219
150	DC High Voltage Source	1 kV to 10 kV 10 kV to 100 kV	$\geq 33 \times 10^{-6}$ $\geq 85 \times 10^{-6}$	5,400 to 12,600/item		220
151	DC High Voltage Meter	1 kV to 2 kV 2 kV to 10 kV 10 kV to 20 kV 20 kV to 100 kV	$\geq$2 kV : 72×10^{-6} $\geq$10 kV : 88×10^{-6} $\geq$20 kV : 168×10^{-6} $\geq$100 kV : 175×10^{-6}	3,600 to 12,600/item		221
Mechanical Metrology						
152	Weight or Weight Set	1 mg to 1 kg	Class E1	3,600/piece	Mass and Conventional mass	222
153	Weight or Weight Set	1 mg to 1 kg	Class E2	1,440/piece		223
		2 kg		1,800/piece		224
		5 kg		2,200/piece		225
		10 kg		2,500/piece		226
		20 kg		3,600/piece		227
		1 mg to 1 kg	Class F1	1,080/piece	Conventional mass	228
		2 kg		1,440/piece		229
		5 kg		1,800/piece		230
		10 kg		2,200/piece		231
		20 kg		2,500/piece		232
		50 kg	Class F2	5,000/piece		233
		50 kg	Class M1 or lower	3,600/piece		234
154	Density and volume of weight	1 g to 1 kg		2,500/piece	Any class which no cavity by hydrostatic weighing method	235
		1 g	120 kg/m^3, 0.002 cm^3			
		2 g	60 kg/m^3, 0.002 cm^3			
		5 g	20 kg/m^3, 0.002 cm^3			
		10 g	15 kg/m^3, 0.002 cm^3			
		20 g	10 kg/m^3, 0.004 cm^3			
		50 g	5.6 kg/m^3, 0.004 cm^3			
		100 g	4.4 kg/m^3, 0.004 cm^3			
		200 g	3.8 kg/m^3, 0.007 cm^3			
		500 g	2.7 kg/m^3, 0.018 cm^3			
		1 kg	2.6 kg/m^3, 0.036 cm^3			
155	Volume magnetic susceptibility of weight	1 g to 20 kg	In the range of 10% to 20%	1,800/piece	By the susceptometer method	236
156	Pycnometer	50 ml to 500 ml	0.1% to 1%	1,800/piece		237
157	Force-proving instrument (load cell, proving ring)	10 kN to 100 kN ≈ 1 tonf. to 10 tonf. ≈ 1,020 kgf. to 10,200 kgf. ≈ 2,248 lbf. to 22,480 lbf.	0.01%	9,300/direction	Calibrated by deadweight force standard machine Ascessories shall be provided by client. Digital indicator shall be provided by client.	238
		20 kN to 100 kN ≈ 2 tonf. to 10 tonf. ≈ 2,040 kgf. to 10,200 kgf. ≈ 2,248 lbf. to 22,480 lbf.	0.05%	6,500/direction	Calibrated by force-comparator machine Ascessories shall be provided by client.	239
		> 100 kN to 500 kN ≈ 1 tonf. to 50 tonf. ≈ 10,200 kgf. to 50,968 kgf. ≈ 22,480 lbf. to 112,404.5 lbf.	0.05%	8,500/direction	Digital indicator shall be provided by client.	240

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Item No.	Description	Range	Accuracy / Uncertainty	Price (THB)	Remark	Line No.
158	Static Torque Measuring Devices (Torque Transducer)	1 N·m to 1000 N·m	According to DIN 51309	5,400/range		241
159	Static TorqueTransfer Wrenches	1 N·m to 1000 N·m	According to DKD R 3-7 Class 0.2 to 5	5,400/range		242
160	Static Torque Calibration devices					
	- Torque Wrench Calibration Devices	1 N·m to 1000 N·m	According to DKD R 3-8 Class 1	2,700/range		243
	- Torque Screwdriver Calibration Devices	1 N·m to 10 N·m	1%	2,700/range		244
161	Hand Torque Tools					
	- Wrench,Torsion ro Flexion Bar	1 N·m to 1000 N·m	According to ISO 6789	1,800/range		245
	- Screwdriver, with Scale or Dial or Display	1 N·m to 10 N·m	According to ISO 6789	1,800/range		246
162	Recalibration of Reference Block Rockwell Scale : HRA, HRB, HRC	20 HRA to 88 HRA	0.45 HRA	3,000/piece	Reference Block shall be provided by client.	247
		20 HRB to 100 HRB	1 HRB			248
		20 HRC to 65 HRC	0.45 HRC			249
163	Callibration of Testing Machine Rockwell Hardness testing machine	20 HRA to 88 HRA	According to ISO 6508-2	5,400/machine	On-site only	250
		20 HRB to 100 HRB				251
		20 HRC to 65 HRC				252
164	Gas Pressure Balances	70 bar max	> $5x10^{-4}xPe$ to $1x10^{-4}xPe$	21,600	1. Price per 1 piston & cylinder assembly 2. Calibration of weight set is included.	253
			< $1x10^{-4}xPe$	32,400		254
		>70 bar to 400 bar max	> $5x10^{-4}xPe$	21,600		255
			$5x10^{-4}xPe$ to $1x10^{-4}xPe$	32,400		256
			< $1x10^{-4}xPe$	39,600		257
165	Hydraulic Pressure Balances	1400 bar max	> $5x10^{-4}xPe$ to $1x10^{-4}xPe$	21,600		258
			< $1x10^{-4}xPe$	32,400		259
166	Gas Pressure Measuring Instruments (gauge pressure, Pe)	- 10 mbar to 0 mbar	> $6 x 10^{-3} x Pe$	3,600/range		260
			$6x10^{-3}xPe$ to $1x10^{-3}xPe$	4,500/range		261
			< $1x10^{-3}xPe$, but not smaller than 0,003 mbar	5,400/range		262
		0 mbar to 30 mbar	> $6x10^{-3}xPe$	3,600/range		263
		0 mbar to 100 mbar	> $1x10^{-3}xPe$	4,500/range		264
			≤ $1x10^{-3}xPe$, but not smaller than 0,003 mbar	6,300/range		265
		0.1 bar to 70 bar	> $6x10^{-3}xPe$	2,700/range		266
		0.015 bar to 70 bar	$6x10^{-3}xPe$ to $1x10^{-3}xPe$	4,500/range		267
			< $1x10^{-3}xPe$	5,400/range		268
		> 70 bar to 1000 bar	> $6x10^{-3}xPe$	4,500/range		269
			$6x10^{-3}xPe$ to $1x10^{-3}xPe$	6,300/range		270
			< $1x10^{-3}xPe$	8,100/range		271
		0 bar to –1 bar	Not smaller than 0.2 mbar	7,200/range		272
			Not smaller than 1 mbar	2,700/range		273
167	Gas Pressure Measuring Instruments (absolute pressure, Pabs)	850 mbar to 1050 mbar	< $1x10^{-3}xPabs$	6,300/range		274
			Not smaller than 0.35 mbar	2,700/range		275
		0.2 bar to 70 bar	Not smaller than 0.35 mbar	2,700/range		276
		0.015 bar to 400 bar	≥ $1x10^{-4}xPabs$	7,200/range		277
168	Mercury Barometers	850 mbar to 1050 mbar	Not smaller than 0.35 mbar	4,500/range	Cistern type	278
				5,400/range	Fortin type	279
169	Hydraulic Pressure Measuring Instruments (gauge pressure, Pe)	0.6 bar to 1400 bar	> $6x10^{-3}xPe$	3,600/range		280
			$6x10^{-3}xPe$ to $1x10^{-4}xPe$	6,300/range		281
170	Gas Differential Pressure at High Static Line ressure (not higher than 400 bar), ΔP	3500 mbar maximum differential pressure	$3.5 x 10^{-5} x \Delta P$, but not less than 2.9 Pa	12,600/sensor head	Price per 1 range of differential pressure and 1 range of high static line pressure	282
171	Vacuum Gauges (absolute pressure : pirani gauge, thermal conductivity gauge)	10^{3} mbar to 10^{-3} mbar	0.3% rdg to 1% rdg	4,500/sensor head	Calibration 10 points minimum	283
172	Vacuum Gauges (absolute pressure : capacitance diaphragm gauge)	10^{3} mbar to 10^{-3} mbar	0.2% rdg to 0.45% rdg	8,100/sensor head	Calibration 3 decades for the head range (1000, 100,10, 1) torr Calibration 2 decades for the head range 0.1 torr	284
173	Vacuum Gauges (absolute pressure : hot cathode ion gauge, cold cathode ion gauge)	10^{-3} mbar to 10^{-7} mbar	0.5% rdg to 6% rdg	5,400 + (1,800 per decade)		285

Price List
Calibration Fee

Item No.	Description	Range	Accuracy / Uncertainty	Price (THB)	Remark	Line No.
174	Vacuum Gauge (absolute pressure : spinning rotor gauge)	10^{-2} mbar to 10^{-5} mbar	0.6% rdg to 4.5% rdg	to be determined		286
175	Additional cost for electrical calibration (which the accuracy is not better than +/-0.01% rdg)			1,800		287
176	Adjustment charge			25% of the calibration cost of each range		288
177	Liquid Flowmeter	0.19 L/min to 190* L/min	0.1%**	11,000/range	Calibration Fluid ; Water	289
178	Gas Flowmeter	0.001 SLM to 1000 SLM	0.2% to 0.3%**	13,800/range	Calibration Fluid : Dry Air, Nitrogen SLM = Standard Liter per Minute Reference Conditions @ 0 degree C, 101.325 kPa * Consult Lab. ** Uncertainty of Laboratory's Facilities	290
Thermometry Metrology						
179	Fixed point cells	- 38.8344 °C to 660.323 °C	0.001 °C to 0.007 °C	24,000/point	By fixed Points comparison through SPRT	291
180	Optical Pyrometer	156 °C to 1064 °C	0.3 °C to 0.5 °C	12,000/point	By Comparison with Black Body Fixed Points	292
181	Optical Pyrometers & Infrared Thermometer	450 °C to 2500 °C	0.5 °C to 5.0 °C	6,000 first point + 2,000/next point	By Comparison with Transfer Standard Pyrometer	293
182	Infrared Thermometers/ Thermal imagines	-10 °C to 420 °C	0.3 °C to 0.5 °C	6,000 first point + 1,000/next point	By Comparison with PRT through Black Body Furnace or liquid bath	294
183	Disappearing-filament Optical Pyrometer	700 °C to 2200 °C	4 °C to 6 °C	6,000 first point + 2,000/next point	By Comparison with the brightness of standard lamp	295
184	Standard Platinum Resistance Thermometers (SPRTs)	- 38.8344 °C to 660.323 °C	0.001 °C to 0.008 °C	6,500/point	By Fixed Points comparison	296
185	Semi- Standard Platinum Resistance Thermometers or Platinum Resistance Thermometers	- 38.8344 °C to 419.527 °C	0.001 °C to 0.004 °C	6,500/point	By Fixed Points comparison	297
186	Standard Platinum Resistance Thermometers (SPRTs), Semi-Standard Platinum Resistance Thermometers or Platinum Resistance Thermometers	- 40 °C to 420 °C	0.02 °C to 0.03 °C	3,600 first point + 720/next point At least 6 points	By Comparison with SPRTs in stirred liquid bath	298
187	Industrial Platinum Resistance Thermometers (IPRTs)	- 40°C to 550 °C	0.02 °C to 0.05 °C	3,600 first point + 720/next point At least 6 points	By Comparison with SPRTs in stirred liquid bath	299
188	Thermocouples (Type S, Type R)	0 °C to 960 °C	0.4 °C to 0.5 °C	6,000/point	By Fixed Points comparison	300
189	Thermocouples (Type S, Type R)	0 °C to 1100 °C	0.5 °C to 1.5 °C	3,600 first point + 720/next point	By Comparison with TC type S or SPRT in comparison furnace or stirred liquid bath	301
190	Thermocouples (Base Metal)	0 °C to 1100 °C	1.0 °C to 3.0 °C	2,300 first point + 500/next point	By Comparison with TC type S or SPRT in comparison furnace or stirred liquid bath	302
191	Temperature Bath	- 40 °C to 420 °C	0.03 °C to 0.1 °C	3,000 first point + 700/next point	By Comparison with SPRTs	303
192	Dry Block and Furnace	- 40 °C to 420 °C	0.1 °C	3,000 first point + 700/next point	By Comparison with SPRTs	304
193	Liquid-in-glass Thermometer	- 40 °C to 110 °C 110 °C to 250 °C	0.02 °C 0.05 °C	1,800 first point + 400/next point	By Comparison with SPRTs in stirred liquid bath	305
194	Digital Thermometer (with probe) (resolution<0.2K) Digital Thermometer (with probe) (resolution>0.2K)	- 40 °C to 250 °C 250 °C to 450 °C - 40 °C to 450 °C	0.02 °C 0.05 °C 0.1 °C	1,800 first point + 400/next point	By Comparison with SPRTs in stirred liquid bath	306
195	Dew Point Hygrometer	- 75 °C to -10 °C	0.06 °C to 0.2 °C	3,300/point	Comparison with two temperature two pressure Humidity Generator	307
		-10 °C to 25 °C	0.06 °C to 0.1 °C	2,700/point	Comparison with two pressure Humidity Generator	308
196	Thermo-Hygrograph Thermo-Hygrometer	Temperature 15 °C to 35 °C Humidity (20 to 80)%RH	(0.5 to 0.8) °C (1.5 to 3)%RH	2,440 first point + 440/next point	Comparison with PRT and Chilled Mirror Hygrometer in Controlled Chamber	309
197	Data Logger	Temperature 15 °C to 35 °C Humidity (20 to 80)%RH	(0.5 to 0.8) °C (1.5 to 3)%RH	2,440 first point + 440/next point	Comparison with PRT and Chilled Mirror Hygrometer in Controlled Chamber	310

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Calibration Fee

Item No.	Description	Range	Accuracy / Uncertainty	Price (THB)	Remark	Line No.
Chemical Metrology and Biometry						
198	Micropipette	20 μL to 1 mL	0.15 μL	1,900/piece		311
199	Volumetric Flask Pipette Burette	25 mL to 2000 mL 1 mL to 50 mL Up to 100 mL	Class A (A) Class A (A) Class A (A)	1,900/piece		312
200	pH meter with associated electrode	1 - 11 pH	0.02 pH	2,000/set		313
201	Assigned pH value for sample	1.00 - 11.00 pH	0.02 pH	2,000/piece		314
202	Potassium Dichoromate Standard Solutions (Recalibrate)	20, 40, 60, 80 and 100 mg/kg (each set choose from the concentrations above)	0.01 A	7,000/set	Set 6 : 5 concentrations Set 5 : 4 concentrations Set 4 : 3 concentrations Set 3 : 2 concentrations Set 2 : 1 concentration	315
203	Potassium Iodide Standard Solution (Recalibrate)	10 g/L	0.5 nm	6,500/set		316
204	Holmium Filter (Recalibrate)	200 nm to 700 nm	0.5 nm	4,500/piece		317
205	Didymium Filter (Recalibrate)	200 nm to 700 nm	0.5 nm	4,500/piece		318
206	Neutral Density Filter (Recalibrate)	400 nm to 700 nm	0.5 nm	7,000/piece		319
Acoustics and Vibration Metrology						
207	Measurement Microphone type LS1P by the reciprocity technique (Pressure sensitivity level)	20 Hz to 10 kHz	0.04 dB to 0.07 dB	8,500/piece		320
208	Measurement Microphone type LS2P by the reciprocity technique (Pressure sensitivity level)	20 Hz to 20 kHz	0.04 dB to 0.10 dB	8,500/piece		321
209	Measurement Microphone by the comparison method (free-field sensitivity level)	31.5 Hz to 16 kHz 74 dB	0.1 dB to 0.4 dB	6,300/piece		322
210	Measurement Microphone by the insert voltage technique (pressure sensitivity level)	250 Hz and 1 kHz	0.08 dB	4,900/piece		323
211	Pistonphone or Sound Calibrator	74 dB to 124 dB 250 Hz, 1kHz	0.08 dB	3,900 first level 1,000/next level		324
212	Multifunction Acoustic Calibrator or Multi-frequency Sound Calibrator	74 dB to 124 dB 31.5 Hz to 16 kHz	0.09 dB	13,500/piece		325
213	Sound Level Meter	Based on IEC 61672	Class 1, 2	8,700/piece		326
214	Sound Level Meter (Free-field sound pressure response level and absolute sensitivity)	31.5 Hz to 16 kHz 74 dB	0.2 dB to 0.4 dB	6,300/piece		327
215	Absorption Coefficient of Material	60 Hz to 6300 Hz	1.5% to 4.0%	3,500/piece		328
216	Vibration Meter	10 m/s^2 to 100 m/s^2 50 Hz to 5 kHz	1.0 %	8,000/piece		329
217	Vibration Calibrator	10 m/s^2 to 100 m/s^2 50 Hz to 5 kHz	1.0 %	4,000 first point 1,000/next point		330
218	Charge Amplifier	20 Hz to 10 kHz	0.1%	4,300/piece		331
219	Accelerometer by comparison to reference transducer	10 m/s^2 to 100 m/s^2 50 Hz to 5 kHz	1.0%	7,000 for first point 1,000/next point		332

Price List

Reference Materials For Sale

Price List
Reference Materials For Sale

Item No.	Description	Range	Accuracy / Uncertainty	Price (THB)	Remark	Line No.
Mechanical Metrology						
220	Calibration of Reference Block	20 HRA to 88 HRA	0.45 HRA	7,000/piece	Certified Reference Block for sale	333
	Rockwell Scale : HRA, HRB, HRC	20 HRB to 100 HRB	1 HRB			334
		20 HRC to 65 HRC	0.45 HRC			335
Chemical Metrology and Biometry						
221	Secondary pH standards	3.99 - 4.02 pH	0.02 pH	1,000/piece (500mL)	Phthalate pH standard	336
		6.85 - 6.88 pH	0.02 pH		Phosphate pH standard	
		9.17 - 9.20 pH	0.02 pH		Tetraborate pH standard	
222	Potassium Dichoromate Standard Solutions (Certified Reference Material)	20, 40, 60, 80 and 100 mg/kg (each set choose from the concentrations above)	0.01 A	37,000/set	Set 6 : 5 concentrations	337
				33,000/set	Set 5 : 4 concentrations	338
				29,000/set	Set 4 : 3 concentrations	339
				25,000/set	Set 3 : 2 concentrations	340
				20,000/set	Set 2 : 1 concentration	341
223	Potassium Iodide Standard Solution (Certified Reference Material)	10 g/L	0.5 nm	20,000/set		342