TEXTBOOK NO. 7018 ③

Measurement Control

TEXTBOOK

Mitutoyo

CONTENTS

INTRODUCTION

Measurement has always played an important role in human society with the associated techniques continuously developing since the beginning of the history; it is almost possible to say that "measurement" can be considered a barometer of cultural development. If not for the great advances in measurement, along with those in science and industrial technology, the remarkable development and automatization of the modern manufacturing system in recent years could not have been realized.
This textbook has been compiled to help you acquire the basics of "measurement control". For further information on this subject, please refer to specialized books or references.

1. THE DEFINITION AND PURPOSE OF MEASUREMENT CONTROL

1.1 What is Measurement Control?

"Measurement control" can be defined as "implementing an appropriate, efficient measurement system in a manufacturing process, using a scientific approach in order to fully utilize available resources." A more specific definition could be "standardizing and planning procedures for using and maintaining measuring equipment, carrying out these new procedures, and by carefully reviewing the results, taking the necessary corrective actions to gain maximum productivity."

1.2 The Aims of Measurement Control

The expected goals, as a result of implementing measurement control, are listed below.

① Increased yield (A lower percentage of defective items)
② Enhanced quality and maintenability
③ Improved efficiency (streamlining)
④ Increased service life from measuring equipment
⑤ A good reputation amongst customers

2. THE STANDARD MEASUREMENT CONTROL SYSTEM

Comprehensive measurement control consists of 1) classifying the items to be controlled, 2) grouping them systematically, 3) studying their conditions and interrelationship, 4) implementing the appropriate measurement system, and 5) reviewing the results in order to improve the control system."
To this end, the first task to be undertaken should be the establishing of a basic control system for the maintenance of measuring instruments and safety precautions for that measurement system. This should be then expanded gradually to a comprehensive control system in accordance with the scope of the business. This approach is a faster way to reach the goal than attempting to implement a sophisticated system from the beginning. A standard measurement control system will be described in the following sections.

2.1 Planning

Before putting measurement control into practice, it is important to have a clear grasp of the objectives and to plan ahead. At the planning stage, the following points should be considered.

① Establishing a structured organization.
② Drawing up measurement control rules and supplementary regulations detailing procedures and standardizing the forms for reporting and recording.
③ Studying and analyzing the current situation.
④ Reconfirming the objective of introducing measurement control, and planning and designing the system (implementation into the production line).
⑤ Arranging forms and dockets to match the projected measurement control.

According to each item listed above, the plan should be introduced into operations in both the office and the factory. In order to achieve good results, it is important to pay constant attention to the actual state of working conditions and to review the situation by using information fed back from the sections involved.

2.2 The Organization and System

To introduce efficient measurement control, it is essential to establish an organization and system which carries out the plans and strictly allocates responsibilities and duties to each section of the organization. Although the structure of the organization to be set up may vary depending on the nature and the magnitude of the enterprise, it is usually the case that all production sections are related to measurement in one way or another. On the other hand, the scope of measurement control in an enterprise covers areas such as quality control, process control, heat control, tool control, facility control, warehouse control, safety and sanitary control and so on. Accordingly, the management structure for measurement control inevitably forms a symbiotic relationship with all sections in the whole corporation.

2.2.1 Organization for measurement control

As the structure of an organization for measurement control should be designed according to the conditions found in each area of business, it is obvious that there cannot be a standard model applicable to all types of enterprise. However, we give below some examples of typical organizations.

Fig.1 is an example of an organization chart and **Fig.2** is an example of a directive system chart. **Fig.3** shows an example of the titles and duties allocated to people related to measurement control in an organization.

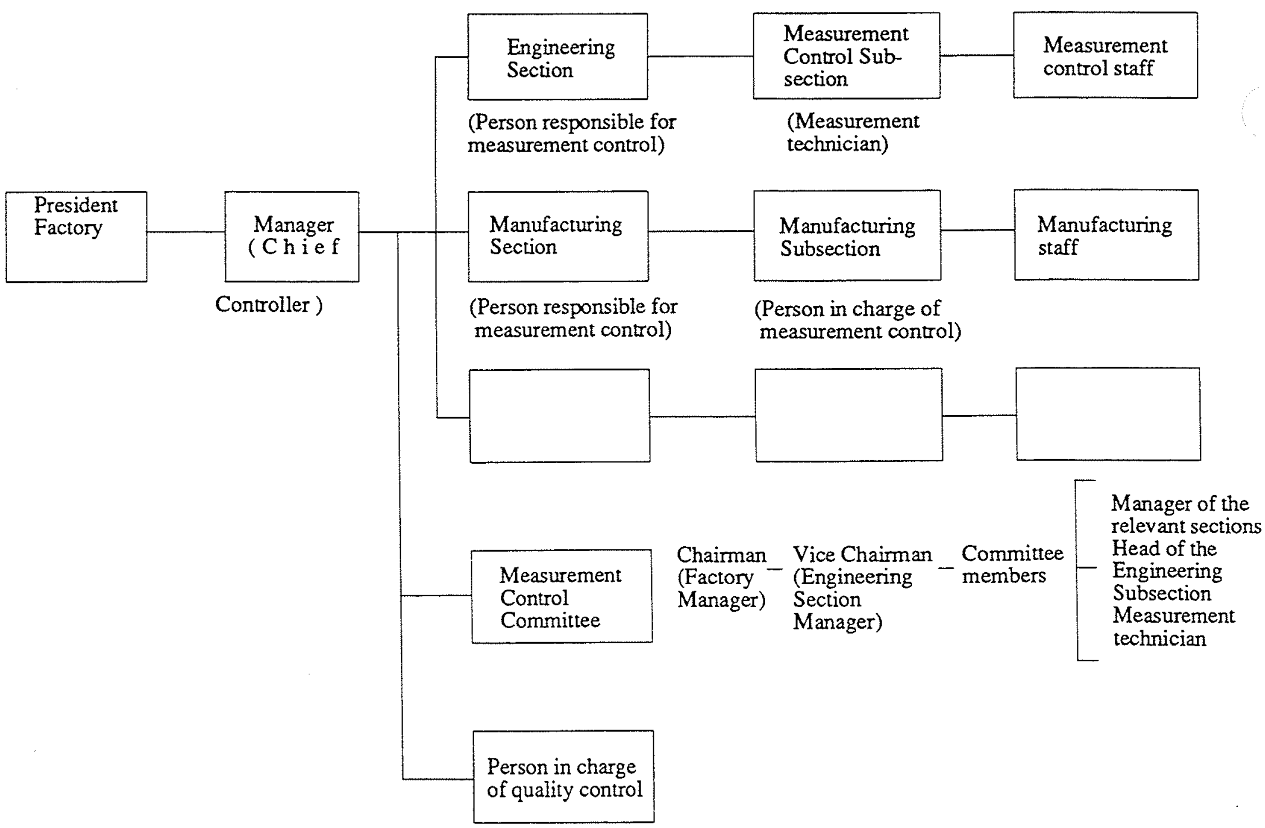

Fig.1 Example of an organization chart

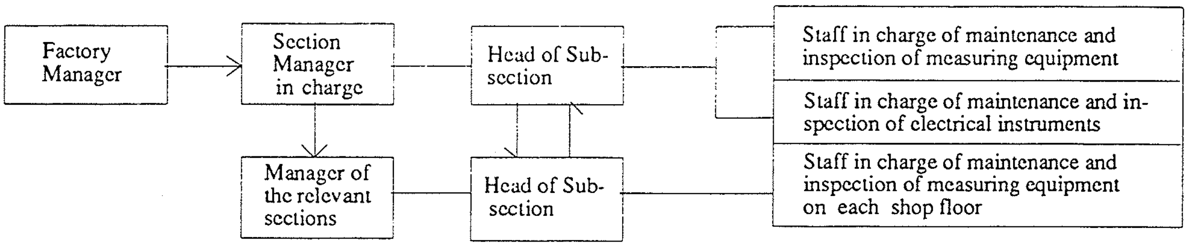

Fig.2 Example directive system chart

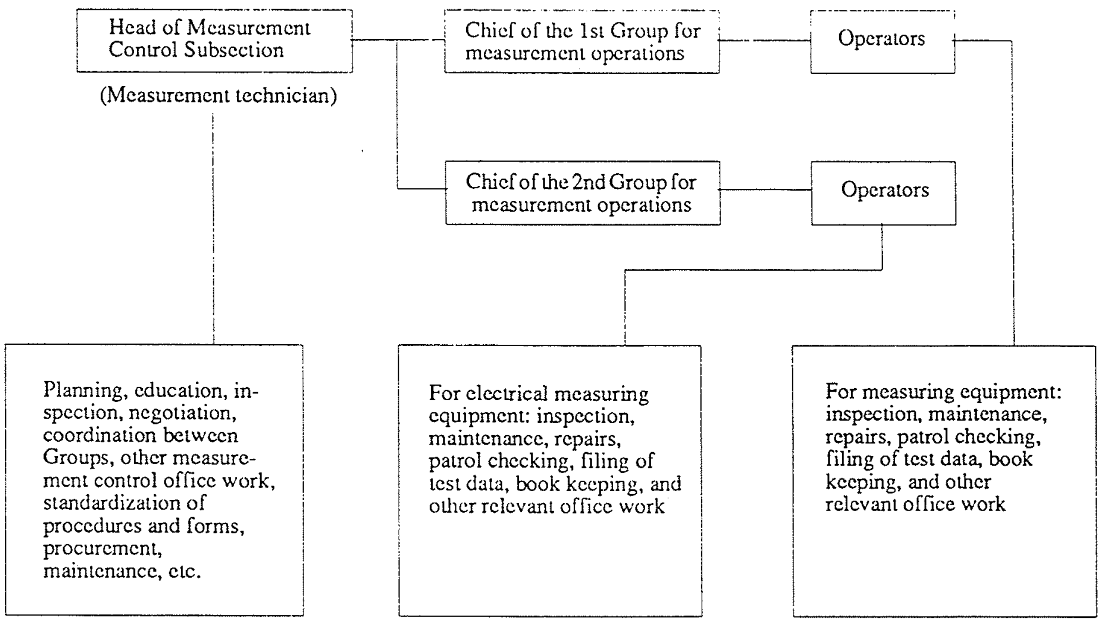

Fig.3 Example of titles and duty allocation

2.2.2 The system

Once the organizational structure has been established, the next thing to do is to draw up the measurement control rules and the relevant specifications and standards so that the plan works systematically.

(1) Measurement control rules

The smooth operation of measurement control is achieved by an efficiently functioning organization and a streamlined working management system. To achieve this end, measurement control rules compiled in a written form are required to have the whole company completely aware of the objectives and unified for a joint effort. Amongst the items to be incorporated into the rules are:

① The objectives of the control system
② The organizational structure and operating policies
③ Methods of measurment equipment maintenance and storage
④ Personnel safety in measurement work
⑤ Other relevant items (office procedures, etc.)

(2) Regulations on work procedures and standardization of forms

In order to carry out measurement control smoothly, standardization of work procedures and regulations is necessary and this should be compiled in a written form for easy reference. These standards or regulations, which are to be prepared based on the measurement control rules previously described and adjusted to meet the conditions found in each company, should include the following items.

① Measuring equipment handling standards (standard practices concerning purchase, repair, and use)
② Inspection standards for measuring equipment
③ The form of books and papers used for measurement control

2.2.3 Items related to measurement control

(1) Quantitative control

① Measurement of base materials, raw materials
② Measurement of in-process goods
③ Measurement of finished products

(2) Maintenance and storage of measuring equipment

① Purchase, maintenance and storage of measuring equipment
② Maintenance and storage of reference standards
③ Inspection of measuring equipment
④ Maintenance and calibration of measuring equipment
⑤ Repair of measuring equipment
⑥ Test and research of measuring equipment

(3) General control

① Improvement of measuring methods
② Research into measurement applications (manufacturing process instrumentation)
③ Formalization and preparation of books, forms, dockets, etc.
④ Purchase and replacement of inspecting tools

2.3 Management

The operation management should be conducted systematically in accordance with the provisions of measurement control rules and relevant regulations. Factory managers formally assume the highest level of responsibility, however, it is normal practice that the section manager in charge of measurement is the man who is essentially responsible for carrying out the scheme. One of the most important factors for the projected measurement system to be a success is the cooperation amongst all members in making an effort toward the same end under systematic management.

2.4 Education

Almost every section of the whole company has something to do with the issue of measurement control, and it is not only desirable that the people directly in charge are experts but also it is necessary that members of the senior staff and general working staff should understand the significance of measurement control and the roles they should play in their respective positions.
The following shows some of the items to be included in an education and training program concerning measurement control.

(1) Senior staff education

① Attend meetings and lectures dealing with the subject of measurement control.
② Read reports and other papers concerning measurement control.

(2) Education for staff in charge of meas urement at the work site.

① Attend lectures held outside the company.
② Participate in gatherings and events related to measurement control.
③ Take measurement training courses at a technical training center, etc. when circumstances permit.
④ Should be assigned the job of educating general staff members.

(3) Education for general working staff

① Take company training courses.
② Receive training at the work site. (On-the-job training)
③ Hold meetings among working staff.
④ Supply posters, pamphlets, company periodicals, notice boards, etc. concerning measurement con trol
⑤ Participate in gatherings and events related to measurement control.

3. THE RELATIONSHIP BETWEEN MEASUREMENT CONTROL AND QUALITY CONTROL

It is generally said that product quality depends on four major factors, i.e., material, machines, manufacturing methods and workmanship. However, the fact should not be overlooked that the information used for judging product quality is essentially obtained through measurement, which is another important factor involved in quality control. Correct judgment depends on correct measurement. This fact is very important because quality control relies on statistical analysis of data obtained from measurements to reach a judgment. Therefore, in order for the data to be reliable for statistical analyses, it must be obtained from correct measurement procedures.
As a conclusion, quality control can not exist without measurement control.

4. THE PERIODIC INSPECTION SYSTEM

Measuring tools and instruments cannot maintain their initially rated performance and accuracy level forever. As time goes on under working condition, the accuracy degrades gradually. There may also be cases where measurement errors develop without users' knowledge, due to incorrect operation or accidents. This might not cause any grave effects when the accuracy deterioration is small, however, it could result in serious consequences during subsequent stages with large numbers of rejects, or worse, could even inconvenience customers, ruining the company reputation if the error is large.
In order to avoid such situations, in addition to normal daily checks, a system must be established to conduct periodic inspections at a pre-determined intervals. This is what is generally called *the periodic inspection system*.

4.1 The time between periodic inspections

The required time interval between inspections varies depending on the the type of the measuring equipment, conditions under which it is used, required degree of accuracy, the rated performance of the equipment, etc. The normal practice adopted is 2 to 4 times a year for measuring tools in frequent use, and annual inspections for measuring instruments less frequently used.

4.2 Inspected Items

At the time of periodic inspection, there is no need of carrying out extensive tests, as compared with an initial inspection, which is carried out in full for new purchases. It is enough to inspect a minimum of characteristics depending on the conditions of use and the type of the measuring instrument in question.

4.3 The Criteria for Inspection Result Judgments

The criteria for judging the results of a periodic inspection may be rated in two or three different categories, according to the usage and the tolerance of the measuring equipment. As a general practice, equipment whose performance level is rated in the lower classes are used for limited purposes that do not require the rated accuracy of the equipment.
Fig. 4 shows an example of rated criteria adopted by "Company-A" for micrometers.

Nominal size	Class A	Class B	Class C
0- 25 mm	± 2 µm	± 4 µm	± 8 µm
25 - 50 mm	± 2 µm	± 5 µm	± 10 µm
Application	Inspection and grinding sections	Lathing and milling sections	Casting section

Fig. 4 Example of rated accuracy standards for micrometer by "Company-A"

4.4 Periodic Inspection Procedures

There are two optional inspection procedure methods; one is to conduct the inspection at location where the measuring equipment is used by carrying the inspecting tools to the spot (patrol method), and the other is to conduct inspections at one place, gathering all the measuring equipment in one location (collective method).
The former method allows quick feed-back of information to the work site on the test results as well as on the environmental conditions for the equipment, whether it is being properly handled or not, etc. This method also needs less replacements or spare measuring tools to be in stock. Conversely, it is difficult to get accurate data from an inspection conducted in a place where vibration and dust conditions are severe.
The latter method has the advantage of being able to provide highly reliable inspection results, as the inspection is conducted in a measuring room or laboratory where the desired environmental conditions are maintained. In order to facilitate an inspection, however, a considerable number of spare measuring tools have to be in stock.

4.5 Post-Inspection Procedures

After completing a periodic inspection, the tools and gages inspected should be classified into groups of each rating, and separated into two groups, repairable and non-repairable. It is recommended to put color paint, color tapes or tags on the tools and gages for easy recognition of the various groups.

It is also desirable, though it may be somewhat laborious, to prepare an instrument service book or card for each tool and gage to record the results of each inspection. This can determine the optimum interval between periodic inspections, the accuracy deterioration rate and the degree of tool/gage wear at each work site, thus providing useful information for planning future purchases as well as the important checking points.

4.6 Repair

Whether tools and gages found to be below-standard during a periodic inspection should be repaired or scrapped is a controversial point.

If the measuring tools/gages in question are for general use and inexpensive, i.e. micrometers and calipers, it may be better to replace rather than repair them. A new one may be less expensive that one would consider, because it is mass produced on streamlined processing and assembling lines; while repair is seldom carried out by simple part replacement and patch mending is often time-consuming as well as more costly than one would assume. The repaired tool may regain its former performance level for a while, but its remaining life is far shorter than the life of a new product. Taking these factors into account, we may conclude that it is generally better to replace a tool than repair it.

Note) Refer to the descriptions in the textbooks prepared for the Micrometer/Calipers Training Course, as to the criteria determining whether a micrometer is repairable or non-repairable.

5. INDUSTRIAL STANDARDS IN VARIOUS COUNTRIES

5.1 Names and Abbreviations of Industrial Standards in the Major Developed Countries

Table 1 shows the names and abbreviations of industrial standards in Japan and other major advanced countries.

Table 1 Names and abbreviations of industrial standards

Abbreviations	Names
ISO	International Orgnization for Standardization
BS	British Standards
DIN	Deutsche Normen
VSM	Normen des Schweizerischer Mashinenindustrieller
Fed. Spec	Federal Specification and Standards
MIL. STD	Military Standards
NF	Normens Francaises
JIS	Japanese Industrial Standard

5.2 Comparisons between the Standards of Major Advanced Countries on the Numbering of Measuring Equipment

Table 2 shows a comparison of the classification numbers of main precision measuring equipment items in each country .

Table 2 Comparison of classification numbers for precision measuring tools in each country

	ISO	JIS	BS	DIN	Fed. Spec.	VSM
Outside micrometer	3611	B7502	870	863-1	GGG C-105b	58080
Inside micrometer		Single rod type only B7508	959	863-4	"	
Depth micrometer				863-2	"	
Micrometer (caliper type)					"	
Micrometer head		B7504	1734	863-2		
Vernier calipers	6906 3599	B7507	887	862	GGG C-111a	
Height gage		B7517	1643		"	
Dial indicator	R463	B7503 B7509	907	878		
Lever-type dial indicator		B7533	2795	2270		
Dial depth gage						
Bore gage		B7515				
Indicating micrometer		B7520				
Gauge block	3650	B7506	4311	861	GGG G-15a	
Electronic comparator		B7536		879-3		
Precision surface plate		B7513 R7513	817	876		
Microindicator				879		
Combination square set					GGG S-656b	

6. SI UNITS (THE INTERNATIONAL SYSTEM OF UNITS)

This chapter describes the International System of Units known as SI (short for the French "Système International") and its usage, and non-SI units that can be used in conjunction with the SI units.

6.1 Terminology and Definition

6.1.1 The International System of Units

In 1960, the General Conference of Weights and Measures adopted and recommended the use of a standardized metric system called the International System of Units (abbreviated SI). The system consists of the base units, supplementary units, derived units, and other units related to these units by a factor of 10^n.

6.1.2 SI Units

The SI Units refers to the names of the base units, supplementary units and derived units in the International System of Units.

(1) Base units
Table 3 shows the base units defined by the International System of Units.

Table 3 Base units

Quantity	Name of unit	Unit symbol
Length	meter	m
Mass	kilogram	Kg
Time	second	S
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	Cd

(2) Supplementary units
Table 4 shows the supplementary units defined by the International System of Units.

Table 4 Supplementary units

Quantity	Name of unit	Unit symbol
Plane angle	radian	r a d
Solid angle	steradian	s r

(3) Derived units
These are the units derived arithmetically from base units and supplementary units in the International System of Units. **Table 5** shows some of these derived units.
Table 6 lists those derived units which are called by proper names.

Table 5 Examples of derived units

Quantity	Name of unit	Unit symbol
Area	square meter	m^2
Volume	cubic meter	m^3
velocity	meter per second	m/s
Acceleration	meter per second squared	m/s^2
Density	kilogramper cubic meter	kg/m^3
Current density	ampere per square meter	A/m^2
Magnetic field strength	ampere per meter	A/m
Luminance	candela per square meter	Cd/m^2

Table 6 Derived units with proper names

Quantity	Name of unit	Unit symbol	Definition
Frequency	hertz	Hz	1 Hz = $1s^{-1}$
Force	newton	N	1 N = 1kg m/s^2
Pressure	pascal	Pa	1 Pa = 1 N/m^2
Energy/Work/ Quantity of heat	joule	J	1 J = 1 Nm
Power	watt	W	1 W = 1 J/S
Quantity of electricity	coulomb	C	1 C = 1 As
Electric potential/ Electromotive force	volt	V	1 V = 1 J/C
Electric capacitance	farad	F	1 F = 1 C/V
Electric resistance	ohm	Ω	1 Ω = 1 V/A
Electric conductance	siemens	S	1 S = $1\Omega^{-1}$
Magnetic flux	weber	Wb	1 Wb = 1 Vs
Magnetic flux density	tesla	T	1 T = 1 Wb/m^2
Inductance	henry	H	1 H = 1 Wb/A^2
Luminous flux	lumen	lm	1 lm = 1 cd • sr
Illuminance	lux	lx	1 lx = 1 lm/m^2

6.2 Multiples and Sub-multiples of SI Units by a Factor of 10^n

6.2.1 Prefixes

Table 7 shows the prefixes and their abbreviations used to indicate multiples or sub-multiples of the SI Units by a factor of 10^n.

Table 7 Prefixes

Multiplier	Name	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	K
10^{2}	hecto	h
10^{1}	deka	d a
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

6.2.2 How to use prefixes

Symbols for prefixes are appended to the unit symbol without space between them. Distinctions between upper and lower case letters must be observed. Compound prefixes should not be used. For example, the use of mμm (millimicrometers) to express nm (nanometers) is incorrect.

6.3 Units not Included in the SI Units

6.3.1 Unit usable combined with SI Units

Table 8 shows those units that are not included in the SI units but still can be used with SI units because of their practical importance.

Table 8 Units usable combined with SI Unit

Quantity	Name	Definition	
Time	minute	min	1 min=60 s
	hour	h	1 h=60 min
	day	d	1 d=24 h
Angle	degree	°	1°=(π/180) rad
	minute	'	1=1°/60
	second	"	1=1'/60
Volume	liter		1 =1 dm^3
Mass	ton	t	1 t=10^3 kg

6.3.2 Derived units including those unitsin Table 8

There are limited cases when derived units are made that are constituted by those units in Table 8 combined with SI units (including their multiples).

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