1. Introduction of measurement engineering

1.1 What is measurement?

"Measure things" is a work that, recognizing and understanding things correctly, starts from approach to true nature things, this method could be called observation. The result of observation must have universality to connect to analysis, of course, the observation's result must be quantified. Measurement is a work that quantifies or code the result of observation.

The main duty of engineer is not only focus on nature, but also create thing, which is not exist in the nature. The process of "make things" is always has connection with measurement, especially, to make sure compatibility of products during mass production. The method or theory like these is called metrology, which is more science than technology. Recent years, a subject called measurement science was included in it.

On the other hand, the necessity of "Measure things" in our daily from the necessity of weights and measures in business transaction. The Measuring equipment which support these and the quality control have established from long time ago. Begin from prosperity of modern industry, production of equipment and research of measurement method for purpose of "make things" have begun popular, technology of using measuring equipment in production line was appear, and be called instrumentation. The plant of metal industry and chemical industry is stage of instrumentation, of course, the stage also include where control technology is used.

From the above meaning, using measurement and instrumentation instead of measurement in the technical field, the academic system is measurement engineering. So, measurement engineering is, research of measurement, develop and manufacture measuring equipment, of course, include the application, which is instrumentation, and also include the technology about maintain and spread measurement standard.

1.1 Department range and object information of Measurement engineering

Measurement engineering is not only a subject of technology and science, but also has an important position in our society life. Since measurement engineering can be applied in too many fields, it should be used as supplementary technology in differentiated specialized fields, for example, mechanical measurement, electrical measurement, analysis chemistry. This technology view from high altitude, cross-cutting by field can be shown in Fig.1.1.

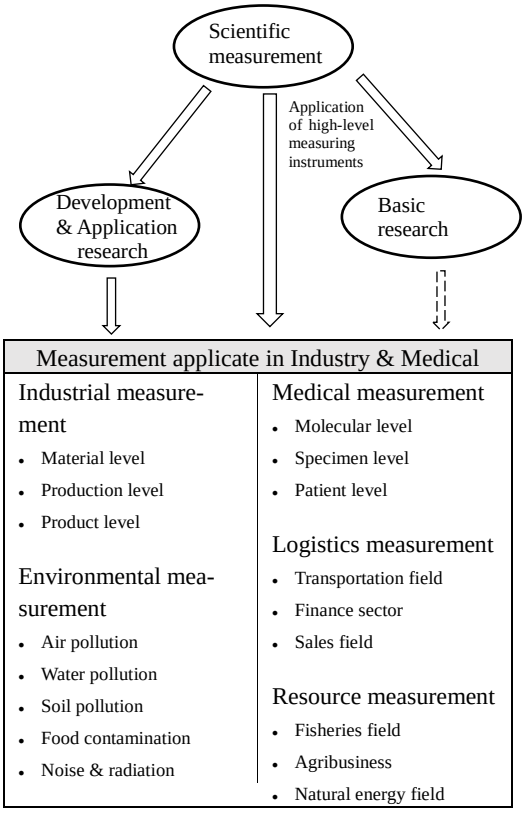

Fig.1.1 Overview of measuring technology

This picture not only show specific measurement object, but also show a big view that measurement and instrumentation technology can be used in extremely wide field. And also understanding that industrial measurement is just a small part of measurement.

Begin from scientific measurement, the practical measurement for industrial and medical, and also general measurement in our daily life, can be classified by the object of measurement.

(a) Object information

Including information such as position, size, shape, motion (displacement, velocity, acceleration, vibration) and related force and torque, and objects such as solid and fluid are objects to be measured. Therefore, flow velocity and flow rate also can be included in this classification.

(b) State quantity information

In physical field, various quantities defining macro state of object can be called state quantity. Specifically, temperature, fluid pressure, electric field, magnetic field, especially, it can be considered that temperature and pressure are main information in field of practical measurement.

(c) Material information

Just like its name, this classification is about

object's material. Material information is mainly based on the type and amount of material components, but set elements and compounds as target, must deeply into micro-components, like atomic and molecular firstly. The word qualitative analysis and quantitative analysis in chemical field, it is a method that acquiring material information. In recent years, start with compounds, until the state of the material that surrounding those compounds, are required practical measurement. The measurement equipment, which for purpose of acquire substance information is called analyzer

(d) Information carrier

Wave like electromagnetic waves and sound wave, flow of electron and ion, are basic information regard to physics and chemical, have relation to (a)~(c), but practical measurement focus on the carrier of information.

Recently, the word sensor is often used. It means information detection element in measurement equipment or system, and could turn information to electric signal to output. Because the output can be analyzed by many electrical and electronic measuring methods, consider information carrier as wide meaning. Light as electromagnetic waves, sonic as mechanical vibration, are usual carrier used by non-contact measurement, object, state quantity, and material information can be putted on those. Sensors to measure electromagnetic waves and sonic wave can be easily found in market. Electromagnetic waves and sonic wave can be used as carrier for send measurement information to a long-distance position.

1.2 Direct measurement and indirect measurement

Direct measurement is a method that compares same kind of standard. For example, use a ruler to measure length of object, or use a weighing cap to measure volume of liquid.

Indirect measurement is a method that measures some quantities, which have some relationship between the object. And then, use some laws to calculating. For example, calculate speed by time and distance, calculate coefficient of thermal expansion by temperature and length. And there is an air data computer, which can display height, speed, Mach number and something else by measuring pressure and height. It is necessary that use law equation to get result of indirect measurement. In old times, people use analog computer, but now digital computer is main.

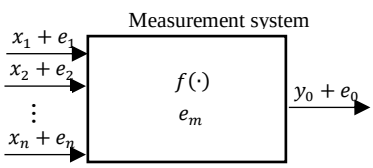

Fig.1.2 Input and Output of Measurement System

The relationship between input and output is shown in Fig. 1.2. $(x_1, x_2, \cdots, x_n)$ is result of measurement, $(e_1, e_2, \cdots, e_n)$ is the error within measure $(x_1, x_2, \cdots, x_n)$. e_m is the error of measurement system. So, the result of measurement system is

$$y_0 + e_0 = f(x_1, x_2, \cdots, x_n : e_1, e_2, \cdots, e_n) + e_m$$

1.4 Basic Method of Measurement

1.4.1 Deflection method

When use spring balance to measure weight, or use voltmeter to measure voltage, a pointer on scale to show the weight or voltage. This method has been widely used, which called deflection method. But in long term, spring constant and electric element will change, and measuring instrument may have error itself. When using this method, the measurement time can be short, but there is a problem in terms of accuracy.

1.4.2 Zero method, Null method

A scale only has vertex near zero, find a balance point (zero) between unknown quantity and known quantity. These methods called zero method or null method, for example, balance and potentiometer. Use weight or variable reference voltage reduction as reference amount to find a zero point for unknown quantity. This method's accuracy depends on reference amount.

The method like zero method, which is find a balance point between unknown quantity and known quantity same as feedback method in measurement engineering. The disadvantage of zero method is takes time.

1.4.3 Compensation method

The method of reading indication scale slightly biased before and after the zero equilibrium point of the balance and correcting the weight value with this value is called compensation method. If correct the indication scale in advance, then the time of correct weight value is not needed any more, and has a very accuracy by zero method to measuring.

The method combines a Deviation type measuring instrument like spring balance with a discrete criterion like weight, is called substitution method. In this situation, it is not necessary to calibrate the scale by the measurement amount, it is only necessary to scale the scale at regular intervals.

The method use spring balance is, firstly, scale unknown object *x* and read scale *X*, and then scale approximate weight m_s and read scale M_s, further, scale minimum weight $m_1(m_s+m_1)$ and read scale M_{s1}. The *x* can be calculated by this three values, *X*, M_s, M_{s1}.

$$x = m_s + \frac{X - M_s}{M_{s1} - M_s} m_1$$

This method's accuracy is between deflection method and zero method.

Generally, method that more than once substitution of known value and unknown value, is been called substitution method, and can avoid the error of measurement device.

1.5 Dimension and unit

Dimension in Physics is, a concept showing the relationship between general physical quantity and basic physical quantity. General physical quantity is an expression that combine some basic quantities through Physics' function and relational expression. In dynamical system, basic quantities are length *L*, weight *M*, time *T*. The combining relationship of basic physical quantity and chosen of International System of Units is,

$$Z = \eta A^{\alpha} B^{\beta} C^{\gamma} \cdots$$

And the dimension of [*Z*] is,

$$[Z] = \left[A^{\alpha} B^{\beta} C^{\gamma} \cdots\right]$$

η is coefficient. The α, β, γ correspond to *A*, *B*, *C*, where are dimension. Angle like solid angle or plan angle is non-dimension.

For example, in dynamical system,

$$[speed] = \frac{[length]}{[time]} = [L^1 T^{-1}]$$

$$[acceleration] = \frac{[speed]}{[time]} = [L^1 T^{-2}]$$

Therefore, $[force] = [L^1 M^1 T^{-2}]$.

And more, current *i* flow resistance *R*, Power *P* is $P = i^2 R$. Using basic quantity, the dimension of resistance $[R] = [L^2 M^1 T^{-3} I^{-2}]$.

Measure amount, decide size of the amount, unknown quantity is times of the amount. Amount like this called unit. Different with dimension, unit has no relationship between size, just an experience of essence of physical quantity.

Type and size of amount can be chosen arbitrarily. Just easy to use and measure. The most important is that unified agreement among communities to use. International System of Units should be used priority.

Example - Temperature measurement (deflection method)

Using thermocouple to measure temperature. The object is temperature of liquid. Voltage aroused by thermocouple can be measured by millivolt meter. Temperature can be requested by temperature-voltage of thermocouple.

The relationship of each part of the device can be shown in fig 1.4

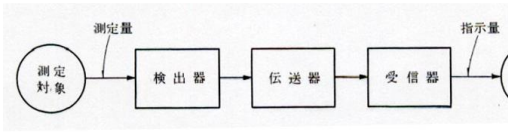

Fig 1.4 Block diagram

Thermocouple can turn temperature θ_i to voltage *e*. Millivolt can turn voltage *e* to position of pointer θ_o. All in one, by the order $\theta_i \rightarrow e \rightarrow \theta_o$, people can read temperature indirectly.

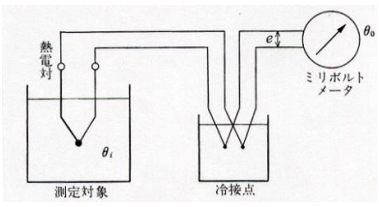

Fig 1.3 Temperature measurement