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ADOPTION OF THE METRIC SYSTEM AND BASIC STANDARDS 2/

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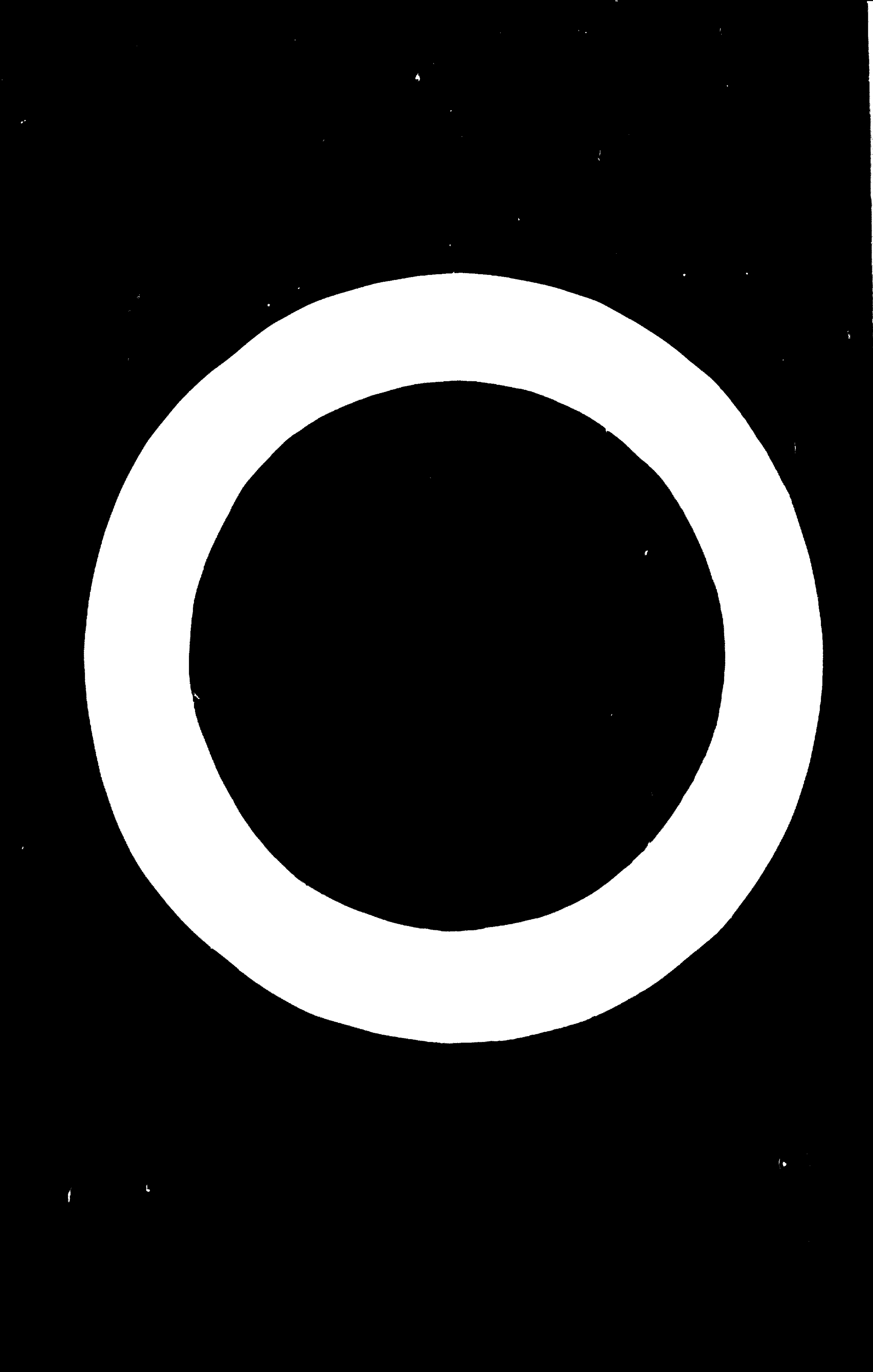

ADOPTION OF THE METRIC SYSTEM AND BASIC STANDARDS

1. HISTROCIAL BACKGROUND

1.1 The system of measurement dates back to the very early days of human civilization. Man has been adopting one thing or the other as the standard of measurement. It is not exactly known when mankind first began to make measurements, but it is evident from the pyramids in Egypt that a system was in existence about 7000 years ago. In the early days, he was using his own limbs as the length standards. From the records available, the following units are known to have been in use:

Digit	=	width of a finger
Palm	=	4 digits (width of 4 fingers)
Span	=	3 palms (width of outstretched hand)
Cubit	=	2 spans or 6 palms (length of forearm)
Orgia	=	4 cubits (length of outstretched arms) (origin of fathom)

These standards relating to the human body were obviously very convenient, readily available and easily portable. Even in the present day many people prefer to make use of them for rough and quick length measurements. However, these standards were different in different regions and because of confusion and lack of precision, the conditions in trade and commerce were not at all satisfactory.

1.2 England a highly coherent nation, separated by sea from many of the turmoils of the European Continent, had long before established standards for weights and measures that have remained essentially unchanged up to the present time. The yard established by Henry II, differs only by about 1 part in a thousand from the yard of today. The pound of Queen Elizabeth I shows similar agreement with the present avoirdupois pound. All the colonies of England, including USA, adopted the weights and measures used in England. It is probable that these were at that time the most firmly established and widely used weights and measures in the world.

However, no such uniformity of weights and measures existed on the European Continent. Weights and measures differed not only from country to country, but even from town to town and from one trade to another. This lack of uniformity led the National Assembly of France on May 8, 1790, to enact a decree, sanctioned by Louis XVI, which called upon the French Academy of Sciences in concert with the Royal Society of London to "deduce an invariable standard for all measures and weights". Having already an adequate system of weights and measures, the English were not interested in the French undertaking. So the French proceeded with their endeavour alone. The result is what is known as the metric system.

The word 'metre' derived from the Greek word 'Metron' meaning 'to measure' was used for the first time by the French Academy of Sciences. This system was based on the metre as the unit of length, which was intended to be one ten-millionth part of the distance from the North Pole to the equator at sea level through Paris.

An attempt was made to measure the meridian from northern France to southern France, from which the true distance from the pole to the equator could be calculated. The best techniques then available were used. Although the operations were carried out during a politically disturbed time, the results were in error only by about 2000 metres. Meanwhile the National Assembly had preempted the geodetic survey, upon which the metre was to be based, and established a provisional metre.

The unit of mass, namely the gram, was decided as the mass of one cubic centimetre of water at its temperature of maximum density. Since this was too small a quantity to be measured with the desired precision the determination was made on one cubic decimeter of water, but even at that the results were found to be in error by about 28 parts in a million. Thus, the metre that was established as the foundation of the system did not approximate the idealized definition on which it was based with the desired accuracy. Also the unit of mass differed from the idealized definition even as given in terms of the erroneously defined metre. Based on these measurements two physical prototype standards, both in platinum, were constructed - one for the metre and one for the kilogram - and deposited in the Archives of the French Republic in 1799.

As a unit for fluid capacity, the founders selected the cubic decimetre and as a unit for land area they selected the area equal to a square having its side ten metres. In this manner, while decimal relationships were preserved between the units of length, fluid capacity, and area, the relationships were not kept to the simplest possible form. Although there was some discussion at the time of decimalizing the calendar and the time of day, the system did not include any unit for time.

1.3 In spite of the hopes of its originators for its unquestioned acceptance by all the advanced nations of the world, the metric system continued to remain dormant for several years, and indeed its universal acceptance even within France was not as stupendous as might have been expected. Voices in favour of world-wide unification of measuring systems on the basis of the metric system continued to be raised from time to time by various learned societies in France as well as other European countries. There arose a general feeling that an international approach to collective action was called for. It was thus that the French Government, in 1870, invited the representatives of several countries to meet in Paris. Twenty-four countries responded to this invitation of whom only 15 could send their delegates because of the out-break of the Franco-Prussian War. These delegates continued the Commission Internationale du Metre, but could take no decision.

The work of this Commission was, however, resumed in 1872 with the participation of delegates from 30 countries. About 40 resolutions were passed dealing with the preparation of new prototypes of kilogram, metre and related matters. The creation of an International Bureau of Weights and Measures was also recommended to the interested governments.

But the members of this international commission, who were all scientists, had no authority to commit their governments. Hence, some years later, in 1875, another conference, attended by representatives of the governments, was held again in Paris. It was called Conference Diplomatique du Metre. This time positive results were achieved. On 20 May, 1875, a Convention du Metre was signed by 18 States. By this Convention, the signatory States bound themselves to set up and maintain at common expense a permanent scientific body of weights and measures at Paris. It was given the name of Bureau International des Poids et Measures (BIPM).

The Governing authority of the Bureau was the Conference Generale des Poids et Measures (CGPM), made up of delegates from all member countries, which were signatories to the Convention du Metre and those which might join the Convention later. The dugies of the General Conference of Weights and Measures were defined briefly as follows:

1) To discuss and adopt necessary measures for the propagation and improvement of the metric system;

2) To study and adopt the results of new fundamental metrological determinations and various scientific resolutions of international importance;

3) To take important decisions concerning the organization and the development of the International Bureau of Weights and Measures.

The CGPM, which meets every six years, being the supreme authority, takes all the major decisions in regard to the new and revised definition of metrological standards and all policy matters including finances and the programme for future developments. It also appoints members of the implementing body called the Comite International des Poids et Mesures (CIPM), consisting of a maximum of 18 specialists chosen from the signatory countries. The CIPM is expected to meet at least every two years or more frequently, if need be. It is charged with the functions of following up the decisions of the Conference and looking after the operation and management of the Bureau. The CIPM appoints its own specialist consultative committees, of which there are seven at present, dealing with definitions of the metre, second, thermometry, electricity, photometry, ionizing radiation and the basic units of the Systeme International d'Unites (SI).

Although the metre, kilogram and the second were the basic units of the metric system so developed, centimetre, gram and second usually were used and the system became known as the CGS System. In this metric system many changes have occurred since its inception. A new unit was created for each situation without regard for other units for the same property, for example, the following decimal units for pressure were devised by different groups; atmosphere, bar, barye, cm of Hg, cm of water, dyne/cm^2, g/cm^2, hbar, kg/cm^2, kg/mm^2, N/m^2, Pascal, Pieze, torr. Similarly, the following units for energy came into being:

calorie, electron volt, erg, frigorie, horse-power hour, joule, kilo-watt hour, therme and watt-second.

Thus a compendium of factors became necessary to convert from one unit to another. At the same time science and technology was becoming more complex and inter-related. The complex relationship among quantities and the multiplicity of the units for the same quantity led Prof. Georgi to propose in 1901 a simplified and rational system i.e. the MKSA system by adopting 'ampere' as the unit of electrical current with a view to linking the electrical and mechanical quantities. This proposal was accepted by the International Electrotechnical Commission (IEC) in 1935 and the International Committee on Weights and Measures in 1946 acting under the authority delegated to it by the CGPM.

The MKSA System was further developed and extended in 1960 by the CGPM by the addition of kelvin and candela as the units of thermodynamic temperature and luminous intensity resulting in a rationalised and coherent system of units which was designated as the International System of Units or the SI.

2. ADVANTAGES OF METRIC SYSTEM

2.1 The metric system was conceived as a measurement system to the base ten; that is, the units of the system, their multiples and submultiples should be related to each other by simple factors of ten. This is a great convenience because it links up with the commonly used system of decimal counting. Thus to convert between units, their multiples and submultiples, it is not necessary to perform a difficult multiplication or division process, but simply to shift the decimal point. This innovation itself was a great step forward, for it simplified calculations and gave promise of saving millions of man-hours of time of the users at all levels of society. Incidentally, this step also brought the system close to the Indian tradition, where the zero and decimal system had been originally invented. According to Lavoisier: "Never has man come out with anything greater and simpler, or anything more coherent in all its parts".

When we compare some 53 concepts and terms used in the Imperial System of Weights and Measures with which we are familiar, with the three simple terms, metre, litre and gram, which constitute the metric system, the simplicity of the metric system becomes at once evident and it can be envisaged from the metre stick.

Another advantage of the metric system is the one to one correspondence in its units - in the sense that one cubic centimetre of water has one centimetre for its cubic dimension and weighs one gram. There is no such correspondence in the Imperial System. One cubic foot of water weighs approximately 62½ pounds. This correspondence effects a tremendous simplicity in computation.

By far the greatest advantage the metric system has over the Imperial System is the decimal division of its units. To illustrate this let it be required to reduce 23 miles, 297 rods, 3 yards, 2 feet and 9 inches to inches.

IMPERIAL METHOD

i)
```
      23 miles
    x320 (rods per mile)
     460
     69
    7360 rods
    +297 rods
    7657 rods
```

ii)
```
    7657 rods
    x5.5 (yards per rod)
   38285
  38285
 42113.5  (yards)
      +3  (yards)
 42116.5
```

iii)
```
  42116.5  (yards)
       x3  (feet per yard)
 126349.5  feet
       +2  feet
 126351.5  feet
```

iv)
```
  126351.5  feet
       x12  (inches per foot)
  2527030
 1263515
 1516218.0  inches
        +9  inches
 1516229.0  inches
```

METRIC METHOD

In a similar metric example, let it be required to reduce 23 kilometres, 978 metres, 86 centimetres, 9 millimetres to millimetres.

Here is the work required:

Just copy the figures and label answer:

23, 978, 869 millimetres.

The time required here would be about 3 seconds in the metric system as compared with approximately 3 minutes using the Imperial System.

The big fundamental advantage underlying the logical reasoning for use of the metric system comes from the fact that our whole number system in all of its fundamental operations of adition, subtraction, multiplication and division plus the four fundamental operations in decimals plus all of the cases in percentage use the decimal procedure which is metric.

In this connection, it is worth quoting Prof. E.D. Tagg, a specialist in the teaching of mathematics in UK who says thus:

> "If we use the same decimal system in measuring as we do in counting then no new techniques of calculation have to be acquired and the time that is or was spent on this saved. Each year in UK this time might be estimated as that of about one or two million children for 100 or 200 hours or say 2 x 10^9 child hours per year or about 6 x 10^7 teacher hours in schools - say all told about £100 million per year. Thus this enormous saving of money and time even at the primary level is worth saving for any country".

The metric system is the most commonly used world system of measurement. 75 percent of the world trade is now being carried on in metric system and the present trend towards metric suggests that by 1975 only the North American continent may still be using primarily a system other than the metric system. This one reason itself is the greatest advantage of the use of metric system in the present context of development in the world. No country in any part of the world is self-sufficient in all its requirements. Greatest emphasis is laid by all the countries for export of its commodities and also import of raw materials, machinery and technical know-how. This is particularly so in the case of developing countries. Two different systems of measurement, one for export and another for import would contribute to great many problems for any country in addition to increase in cost of the products, training of personnel in dual systems of measurement, documentation, stocking and identification of materials, billing etc.

The choice, therefore, of a system for world-wide adoption, lies between a system in uniform use by 85 percent of the world's population, which most would agree was intrinsically simpler than any other, and a system used with important variations by the remaining 15 percent. There can be very little argument.

3. INTERNATIONAL SYSTEM OF UNITS (SI)

3.1 What are SI Units - As mentioned earlier to the metre, kilogram, second and ampere were added the candela (cd) for luminous intensity and the kelvin (K) for thermodynamic temperature. In the international system of units these are the six basic units from which all units for any quantity required in any science or technology could be derived through first principles. In addition there are two supplementary units and a number of derived units some of which have special names. The six basic units with a unit symbol assigned to them are listed in Table 1 below:

TABLE 1 BASIC SI UNITS

Sl No	Physical Quantity	Name of Unit	Symbol
1.	Length	metre	m
2.	Mass	kilogram	kg
3.	Time	second	s
4.	Electric current	ampere	A
5.	Thermodynamic temperature	kelvin	K
6.	Luminous intensity	candela	cd

The metre has been defined in terms of a particular wavelength in the krypton-86 emission spectra; the second has been defined in terms of a particular transition frequency of the cesium 133 atom; the kilogram has been represented by a prototype standard kept at Sevres in France; the ampere has been defined as the current which will produce a specified force between parallel wires one metre apart; the kelvin has been defined in terms of triple point of water; and the candela has been defined in terms of luminous intensity of a perfect radiator at the freezing point of platinum.

3.2 Supplementary Units - The supplementary units are the one for measuring plane angle and solid angle. These are radian (rad) and steradian (sr) respectively.

3.2.1 One radian is the angle between two radii of a circle which cuts off on the circumference an arc equal in length to the radius.

3.2.2 One steradian is the solid angle which, having its vertex at the centre of a sphere, cuts off an area of the surface of the sphere equal to that of a square with sides of length equal to the radius of the sphere.

3.3 Derived Units with Special Names - The derived units having special names are given in Table 2.

TABLE 2 DERIVED SI UNITS HAVING SPECIAL NAMES

Derived Quantity (1)	Name of Unit and Symbol in Bracket (2)	Physical Law Connecting the Quantity to Fundamental Quantities (3)	Definition of Unit (4)
Force	newton (N)	$N=kg.m/s^2$	Force producing unit acceleration (m/s^2) in unit mass (kg).
Energy, work or quantity of heat	joule (J)	J=Nm	Unit force (N) acting through unit distance (m).
Power	watt (W)	W=N m/s=J/s	Unit work (N m) done in unit time (s).
Quantity of electricity or electric charge	coulomb (C)	C=As	Quantity of electricity transported in unit time (s) by a unit current (A).
Electric potential	volt (V)	V=W/A	Volt is the difference of electric potential between two points of a conducting wire carrying a constant current of one ampere, when the power dissipated between these points is one watt.

TABLE 2 DERIVED SI UNITS HAVING SPECIAL NAMES (Contd)

Derived Quantity	Name of Unit and Symbol in Bracket	Physical Law Connecting the Quantity to Fundamental Quantities	Definition of Unit
(1)	(2)	(3)	(4)
Electric capacitance	farad (F)	$F = \frac{As}{V}$	Capacitance of an electric capacitor between the plates of which appears a difference of electric potential of one volt when it is charged by a quantity of electricity of one coulomb.
Electric Resistance	ohm (Ω)	Ω = V/A	Electric resistance between two points of a conductor when a constant unit potential difference produces a unit current (A) provided no electromotive force is generated in the conductor.
Magnetic flux	weber (Wb)	Wb=Vs	That flux which, when linked with a circuit of one turn produces an EMF of 1 volt if uniformly reduced to zero in unit time.
Inductance	henry (H)	H=Vs/A	Inductance of a closed circuit in which an EMF of 1 volt is produced by a uniform current change at the rate of 1 A/s.
Magnetic flux density	tesla (T)	$T = Wb/m^2$	Unit magnetic flux (Wb) per unit area (m^2).
Luminous flux	lumen (lm)	lm=cd sr	Unit intensity (cd) x unit solid angle (sr).
Illumination	lux (lx)	$lx = lm/m^2$	Unit luminous flux (lm) per unit area (m^2).

3.4 Decimal Multiples and Submultiples of SI Units

3.4.1 Provision is also made for multiplying or dividing units by factors which are powers of ten. For convenience in oral or written expression, these factors have been given names and are used as prefixes to the units on which they are to operate. Table 3 shows these factors together with the symbols:

TABLE 3 PREFIXES TO BE USED FOR FORMATION OF DECIMAL MULTIPLES AND SUBMULTIPLES OF SI UNITS

Factor by which the unit is multiplied	Prefix	Symbol
1 000 000 000 000 = 10^{12}	tera	T
1 000 000 000 = 10^{9}	giga	G
1 000 000 = 10^{6}	mega	M
1 000 = 10^{3}	kilo	k
100 = 10^{2}	hecto	h
10 = 10^{1}	deca	da
0.1 = 10^{-1}	deci	d
0.01 = 10^{-2}	centi	c
0.001 = 10^{-3}	milli	m
0.000 001 = 10^{-6}	micro	μ
0.000 000 001 = 10^{-9}	nano	n
0.000 000 000 001 = 10^{-12}	pico	p
0.000 000 000 000 001 = 10^{-15}	femto	f
0.000 000 000 000 000 001 = 10^{-18}	atto	a

3.5 Why SI Units

3.5.1 In the sense that it employs existing metric units as basic units the system is not new. What is refreshingly new about it is the concept that from the six basic units alone, there should be derived, through scientific first principles, units for any and every other required quantity. The system is thus a rationalized version of current metric systems; a very worthwhile exercise in variety reduction has been carried out which will ensure that all like physical quantities will be measured in terms of the same unit and the mind of the scientist and technologist will require to retain only the first principles and cease to be cluttered with a multiplicity of arbitrary units and their conversion factors.

3.5.2 The features which make SI a superior system of measurement are:

i) For any quantity there is one and only one SI unit, e.g. the unit for energy is the joule whether derived from chemical, electrical, mechanical or nuclear sources,

ii) For each quantity there is a unique unit differing from the units for other quantities e.g. kilogram is used only as a unit of mass and newton is the only unit of force,

iii) The factors for obtaining the derived units from the elemental units is always unity e.g. 1 N=1 kg. 1 m/1 s^2 and 1 N. 1 m = 1 J = 1 W. 1 s,

iv) A unique set of symbols and abbreviations are used for units,

v) The Arabic system of numbering to the base 10 is used exclusively so that multiples and submultiples have decimal relationship to the unit,

vi) To facilitate working with magnitudes much smaller or larger than the SI units, the prefix before the unit can be used (see Table 3),

vii) All of the basic units except the kilogram are defined in terms of physical experiments that could be made in the laboratory without recourse to the prototype standards,

viii) It is a coherent system of units, that is one in which the product or quotient of any two unit quantities gives rise to the unit of the resultant quantity and hence the units are very handy, e.g. 1 m x 1 m = 1 m^2 (unit of area),

ix) The ballast of non-decimal coefficients as in F.P.S. System are avoided, such as the numerical coefficients in the relationship 1 ft = 12 in., and 1 mile = 5280 ft.,

x) In contrast with CGS system it has relatively large main units like 'kilogram' and not 'gram' for mass and 'Newton' and not 'dyne', for force and hence it is more convenient,

xi) As it is closely related (only by powers of 10) with the CGS System which the scientists have been using since long, it facilitates collaboration between scientists and technologists. This collaboration is now very important especially in modern fields like measurements, control, automation, cybernetics, aerodynamics, nuclear engineering and physics,

xii) Introduction of one energy unit both in mechanics and heat, viz. the 'joule' and one power unit the 'watt' will eliminate calorie and horse-power.

4. PRESENT SITUATION

4.1 About 125 countries accounting for 85 percent of the world population use the metric system. Of these about 26 countries have either made SI units as the only legally accepted system or they are in the process of doing so. It would be reasonable to assume that 75 percent of the world trade is carried out in metric units and the present trend towards the metric change suggests that by 1975 only the North American Continent may still be using primarily a system other than the metric system.

The UK has been officially committed to changeover to the metric system in industries in May 1965. Since then through concerted effort and systematic programming with the close collaboration of the British Standards Institution, remarkable progress has been made in the process of changing over to the metric system in different industries. The British industry expects to change over completely to the metric system by 1975.

Other countries which are in the process of changing over to the metric system are:

Eire, Kenya, Pakistan, Tanzanya, Ghana, Kuwait, South Africa and Uganda.

According to a recent announcement, New Zealand is expected to change over to metric system by the end of 1976.

The Prime Minister of Australia announced on 19 January 1970 that the Federal Cabinet of the country had accepted the recommendation to changeover to metric system which is expected to be completed in about 10 years time and a Metric Conversion Board will be set up to guide and facilitate conversion.

As recently as August 1968, the Congress of the United States had authorized the United States Bureau of Standards to make a comprehensive study of the question whether the USA should switch-over to the metric system of measurements. It would appear that considerable interest already exists in that country in favour of such a changeover. Reproduced below is the extract from a report published in August 1968 in the United Kingdom:

> "Closely allied to America, both economically and geographically, is Canada, which for some time now, has been following closely the progress made in the UK. Virtually all of Britain's former recent colonies, dependencies and Commonwealth associates have already announced their intentions to change, which clearly must be a warning that their trade will tend towards countries manufacturing in metric. With South and East Africa already formulating their plans, soon the whole of the African continent will be metric. Australia and New Zealand too have been gathering information and considering a changeover. A decision from this part of the world is also likely in near future, following the recent recommendations of a select committee to the Australian Senate, that metric system should be introduced and become the only system in use in that country."

A report by the Committee on Metric System was presented to the Board of Directors of the Canadian Standards Association (CSA) in their 67th meeting held in 1966. This report contained, among others, the issuance of a statement of CSA policy on the practicability of gradual evolution, at the educational level, with regard to eventual metric conversion.

5. ROLE OF STANDARDS

5.1 It would be adequate to quote the following two examples to illustrate the important role that standards and the national standards institutions have to play in the changeover to the metric system of a country: While the Indian Standards Institution was set up, one of the objectives included in the Resolution for which the Institution was set up was "to consider and recommend to Government of India national standards for the measurement of length, weight, volume and energy". In fact the ultimate decision to changeover to the metric system in India was based on a comprehensive report prepared by the Indian Standards Institution and submitted to the Government.

Similarly, in UK, the President of the Board of Trade, in his announcement to the House of Commons in May said "the foundation for the change must be a series of metric British Standards".

The Indian Standards Institution and the British Standards Institution have played a major role in organising a smooth change-over to the metric system in these countries.

5.2 The very methodology for the formulation of national standards in many of the countries provides an opportunity for all concerned to effectively participate in the technique of formulation of the standards with the result the published standards represent the best compromise of all the interests. Naturally, these standards should, by and large, be acceptable to those concerned. Therefore, the standards institutions have to play a very important role in the changeover to the metric system. The necessary function is the provision of metric standards, wherever possible, aligned to international recommendations, which will enable particular sectors of industry to work in metric units. Industry cannot successfully go metric without full information about the metric sizes and quality ranges to be built into the new specifications.

The main task, therefore, of the standards institutions was:

i) Preparation of basic standards to assist in the changeover to the metric system;

ii) Procedure to be adopted for conversions;

iii) Metricisation of existing standards; and

iv) To evolve a policy for the preparation of new standards.

It is rather difficult to define exactly what basic standards are. Broadly, in the context of changeover to the metric system, the following constitute the basic standards:

i) Guide for specifying metric values in standards;

ii) Guide for interconversion of values from non-metric to metric values;

iii) Guide for precise conversion of inch and metric dimensions to ensure interchangeability;

iv) Rounding off numerical values from non-metric to metric;

v) Guide for adoption of rationalized metric values, and

vi) Guide for the use of preferred numbers for specification of values, quantities, etc.

vii) Physical quantities, units and symbols.

Examples of other standards which are basic to the industry are:

i) Limits and fits;

ii) Preferred sizes for semi-finished materials like rods, bars, wires, sheets, tubes, screw threads, drawing office practices;

iii) Other aids for changeover to the metric system such as standard conversion tables, conversion slides, handbooks etc.

5.3 In addition to the work relating to the preparation of basic standards, it is also necessary to convert the existing standards into metric system. It is important to note that this is not a matter of converting existing standards into metric units on a mathematical basis but re-aligning them with overseas metric standards and with the recommendations of the international standards body. Apart from this, advantage could also be taken of eliminating unnecessary varieties. The work involved in all these is fairly complicated and time-consuming and the cost involved in the changeover would be greatly affected by the national standards that are formulated.

5.3.1 To give the example of the Indian experience, one of the first standards published was a guide for specifying metric values in standards which laid down the principles which should be followed by all standards committees. This guide outlines three main steps for conversion:

i) Interchangeable conversion from non-metric to metric values;

ii) Rounding off values converted from non-metric to metric; and

iii) Adoption of rationalised metric values.

5.3.2 A time-table was also agreed for the conversion of the existing standards and the procedure for preparation of new standards after the decision for changeover to the metric system was taken by the Government of India. In order to assist the industry and the user, in the initial stages, inch units were given within brackets along with the metric units; in the subsequent revisions of the standards, the inch units were omitted altogether.

5.4 In UK from the very beginning the British Standards Institution is playing a major role in formulating a programme for the changeover for the preparation of the metric standards in each of the fields.

5.5 Further to national standards, company metric standards also play a major role. Wherever possible, selection from the relevant national standards will assist the designers and draughtsmen to plan the production within each industrial unit. This would assist in quickening the pace of changeover to the metric system.

6. CHANGEOVER TO THE METRIC SYSTEM

6.1 As mentioned earlier, it is expected that by 1975 practically all countries except the North American Continent would changeover to the metric system. The North America is also seriously considering the question of changeover to the metric system. If this happens, it would really be a great day when there will be a uniform system of weights and measures all over the world.

6.2 The changeover from one system of weights and measures to another system in any country is always a very complicated problem. The more industrially advanced a country is, complexity of the problems is more. It is, therefore, important that the developing countries should give consideration to this question at the very early stage of development to minimise the cost of such a changeover, time required for the purpose and also the problems connected with it.

6.3 The changeover to the metric system has to be very carefully planned so that the national economy of the country is least affected. For this purpose there has to be very close collaboration between the Government, the industry, the standards body and the consumers. A careful pre-planning and education is also very essential. Where decimal currency system does not exist at present, steps would have to be taken for the introduction of the decimal currency almost simultaneously. The programmes established for the changeover of the engineering industry would basically provide the key for programming the change in the rest of the industry. It is obvious that during the transition period great many problems may be encountered and two systems of measurement would continue to be used in many of the industries to facilitate ultimately the complete changeover to the metric system.

6.4 The changeover to the metric system in the engineering field could broadly be classified in the following:

i) Raw Materials and Semi-Finished Products - Steel sheets, plates, bars, sections etc.

ii) Tools and measuring equipment - measuring scales, gauges, drills, fasteners, bearings etc.

iii) Equipment and finished products - Motors, pumps, water tanks etc.

iv) Process Industries - Chemical engineering, manufacture of bolts and nuts, textile, sugar manufacturing equipment, etc.

The normal difficulties experienced in these fields are:

i) Creation of a demand for the metric products,

ii) Tooling,

iii) Planned wearing out of the existing equipment meant to produce in inch system (rolls cut for the production of inch sections in the steel plants,

iv) Continued manufacture of spare parts in the inch units to cater to some of the equipment imported from the non-metric countries and also the existing equipment till a complete changeover is accomplished,

v) Catering to the export market using the inch system.

6.5 There can be no ready-made solution to these problems and each problem has to be tackled to suit the national requirements but with concerted efforts of all concerned these difficulties are not insurmountable. For example, in order to create the demand for the metric raw materials, semi-finished and finished products, the Government would have to give a lead in instructing its various Departments to indent only for the materials and products in the metric system after a specified date. The industry could be requested to organize its production in the metric system by that date.

Based on the phases of programme of changeover the existing tools will also have to be suitably modified or new tools installed after taking into consideration the cost involved. Similarly, in the example quoted for rolls for rolling steel sections, a programme has to be chalked out such that, wherever possible, the existing rolls would have to be dressed for the production of the metric sections and, where this is not possible, the rolls should be allowed to wear out and till such time inch sections would also have to be produced.

Organizations which are exporting to countries using the inch system could describe their products in metric terms while retaining the inch system for its manufacture. They can also contribute greatly to the progress of the metric system by accepting metric supplies as far as possible.

6.6 The fields that will be affected by the changeover to the metric system can broadly be classified as:

i) Engineering industries,

ii) Trade and commerce,

iii) Postal,

iv) Education,

v) Transport,

vi) Construction industry,

vii) Printing and stationery,

viii) Land records,

ix) Railways,

x) Revenue accounting etc.

6.7 Cost for Changeover - It would not be possible to give any indication of the cost for changeover to the metric system as this differs from country to country depending upon the stage of industrial development and its economical tie-up with other countries.

6.7.1 When India decided to changeover to the metric system, it was estimated that the cost of changeover would be of the order of U$ 1.3 million per year (Rs. 10 million per year spread over a period of ten years). This represented about 0.1 percent of the net annual output from establishments and only 0.05 to 0.1 percent of the total net industrial development which was expected during the Second Five-Year Plan.

6.8 The main items of cost may, however, be classified under the following broad heads:

i) Replacement of weights and measures by the public, trade, industry and other users;

ii) Conversion of weighing machines;

iii) Other miscellaneous costs to the industry, transport and trade - these include conversion of various types of measuring instruments, training of staff, replacement of labels, registers, forms, accounts, etc.,

iv) Cost to Government on enforcement publicity, replacement of weighing and measuring instruments and other equipment in public undertakings like the railways, post offices etc.,

v) Changing of milestones on highways.

In India no special grant was given to the industry for changeover to the metric system. The Government policy in UK is that no special grants would be made available from public funds to cover the cost of change since the long-term economic performance will more than balance the immediate outlay. However, replacement of capital plant and machinery for manufacture will, in many cases, be subsidised by normal income-tax and corporation tax allowances.

6.9 Based on the experience gained in India, the following suggestions are made:

i) It is necessary to create a permanent Directorate of Weights and Measures by the Government;

ii) Qualified officials should be appointed to man organizations for the enforcement of weights and measures. They should also be given proper training in order to equip them to carry out their work satisfactorily;

iii) It is important to educate the general public about the use of the new system of weights and measures using all publicity media;

iv) The law relating to enforcement of weights and measures should be kept under constant review and made flexible so that it can be applied without too much alteration to the fast-changing conditions of trade and industry during the period of changeover;

v) Sufficient attention should be devoted to the field of education. It would be useful to change the curricula, text-books and the teaching at one time to the use of metric system rather than in two stages as was done in India. Such education should be started right from the school stage;

vi) In the field of technical education, it is important to train the lecturers and professors and also provide text-books to facilitate changeover.

vii) In the industrial sphere, it is essential that the preparation of rational metric specifications for commodities and products should be taken on a priority basis at a very early stage. The specifications prepared should be rational and not merely converted values. These specifications should, as far as possible, be prepared to conform to the recommendations published by the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC).

7. METRIC CHANGEOVER IN INDIA

7.1 It would now be worthwhile to explain briefly the introduction of the metric system in India to illustrate the methodology which, it is hoped, would be of some assistance to the countries which are contemplating to changeover to the metric system in the near future.

7.1.1 India took a final decision to changeover to the metric system in 1955. The Indian Standards Institution took a leading role in assisting the Government of India to changeover to the metric system and in the implementation of this decision. As pointed out earlier, the first task entrusted to ISI after it was set up was "to consider and recommend to the Government, national standards for the measurement of length, weight, volume and energy." The Committee set up by ISI to study this problem submitted a report recommending a programme of action for the changeover, the creation of a central liaison agency, adoption of decimalised currency and initiation of central legislation, together with the adoption of a model legislation for the States.

7.1.2 As per the recommendations, the changeover to the metric system was to be carried out in different stages as under:

a) The Preparatory Stage of three to five years, when no extensive change would be enforced but intensive education and dissemination of information on the metric system of weights and measures would be carried out, and where practicable, gradual introduction of metric system would be encouraged. During this period, decimalized currency could be introduced and intensive education and propaganda carried out. Among other things, the following actions could be taken:

i) Teaching in elementary and secondary schools and in technical and engineering institutions; schools to keep samples of all standard metric weights and measures;

ii) Press and radio publicity;

iii) Public speeches and press conferences by eminent people;

iv) Publicity films (using mobile cinemas, wherever possible);

v) Popular exhibitions;

vi) Publication of informative bulletins and pamphlets, including conversion tables;

vii) Free distribution of conversion tables through post offices;

viii) Public discussions and symposia;

ix) Publicity through village panchayats; and

x) Sale by Government to the public of standard metric weights and measures at the beginning; later, private parties to produce and sell these units;

xi) All Central and provincial units to initiate preliminary preparations and estimates of cost of equipment for conversion to the new system;

xii) Wherever regulated markets existed, the authorities controlling them might introduce the use of the metric system in their day-to-day operations;

xiii) All agencies to initiate designing their new schemes of development on the metric system with the ultimate object of going over entirely to that system at an appropriate stage;

xiv) All engineering designs and plans, which may be considered necessary to be executed on the basis of foot-pound-system to give metric equivalent;

xv) Centre to establish an official agency for the preparation, deposition and checking of primary, secondary and reference standards;

xvi) Planning of enforcement agencies by State units wherever they may be needed and augmentation of existing agencies for the new task; and

xvii) If any of the State Governments felt ready for the adoption of the model form of legislation to be suggested by the Centre, they could do so even during this period.

b) The Changeover Stage of 5 years in which the changeover was to be effected in the agencies under the control of Central and State administrations and in public life.

During this period, the undermentioned actions were suggested:

i) Adoption by all State Governments of the model legislation to be proposed by the Centre;

ii) Implementation of the plans suggested to be prepared under (xi) above;

iii) All central agencies to go over to the new system from a red letter day to be declared by each agency, retaining existing facilities only for replacement of parts of existing machinery;

iv) All engineering designs and plans to be based on the metric system, giving foot-pound equivalents where considered necessary;

v) In everyday public use and for trade purposes, the metric system to be gradually and progressively introduced; and

vi) Land records to be changed to the new system at the time of transactions, such as transfer, sale or any other registration of land.

c) The Final Stage of 3 to 5 years, when the country was to be brought over to the metric system entirely, and after which no other system was to be regarded as legal. This stage was to be in the nature of a period of grace during which the change-over to the metric system was to be finalized and the use of all other systems eliminated from the legitimate activities of all Departments, Central or State, and from everyday public life. Old land records, were, however, to remain in the older system of measurement until any transaction took place, when they were to be changed to the new system. After the end of this period, the metric system was to be the only recognized system having legal sanction.

7.2 Central Liaison Agency - This agency was to be created to guide educational activity, carry on intensive propaganda to popularise the new system, co-ordinate the activities of Central and State Governments in respect of all the measures connected with the changeover and to act as a clearing house of all information connected with the subject.

7.3 Decimalized Currency - The introduction of the metric system was to be preceded by the adoption of decimalized currency, and the weights and dimensions of the new coins were to be related to the metric system of weights and measures, so as to facilitate propagation of general knowledge of the magnitude of the new units among the public.

7.4 Central Legislation - The Centre was to initiate legislation on the subject of weights and measures which, among other things, was to provide for the following:

a) Standards of weights and measures (linear, square, cubic and capacity) based on the metric system.

b) Nomenclature based on the international basic units and fractions and multiples thereof:

i) Use of international nomenclature for basic units to be compulsory and universal; and

ii) Indian nomenclature for multiples and sub-multiples could be adopted, but in all these cases any name applying to a fraction or a multiple was to contain the name of the basic unit, for example, 'centimetre' could be termed 'satakmeter'.

c) Schedule specifying commodities of everyday use which have to be sold on the basis of specific units of either weight, volume, linear measure, square measure or number. A schedule or schedules might be found necessary for specifying the use of more than one set of units for certain commodities;

d) A model form of legislation for adoption by States for the purpose of enforcement of standards. This model, among other things, was to include tolerances of weights and measures to be allowed for different purposes. The States were to be required to adopt this model legislation as such, but minor modifications could be permitted, if found absolutely necessary to suit local conditions;

e) Creation of a Central Agency for education, propaganda and co-ordination of activities of Central Departments and Provincial and State units in respect of all activities envisaged to be carried out during the three stages of development; and

f) Defining the three stages of changeover and provision for periodic review of the time limits allocated for each.

7.4.1 The Government after examining these recommendations, took a final decision to changeover to the metric system in consultation with the Indian Parliament. India being a very large country with a Central Government and State Governments, it was realised that the implementation of the reform would be an extremely complex undertaking. It was, therefore, essential to mobilise the assistance of all the interests concerned and to associate with the implementation of the changeover, several Central Government Departments, State Governments, Scientific and Technical Bodies e.g. Indian Standards Institution and the National Physical Laboratory, representatives of trade and industry, and those of the ordinary consuming public. A Central Metric Committee under the charge of the Union Minister was established to lay down policies in consultation with various sectors concerned. The Central Government Departments, State Government Departments, and the Associations of the trade and industry, were in turn requested to set up small committees for examining the problems involved and to take measures to implement the decision.

7.4.2 Two important decisions of principles were taken at a very early stage of the programme. The first was the decision that ten-year period for the changeover to the metric system would be taken to apply to commerce and trade and to the normal day-to-day activities of the public, and not to the field of industrial activity and techniques and processes of production in factories. It was realized that the complete change-over to the new system in industrial production would be highly complex, involving extensive re-designing. To force the pace of change in this field would involve scrapping of costly machinery, resulting in prohibitive expense and might even retard the tempo of India's growth and development in the short-term. It was, therefore, agreed that each industrial plant in the country would draw up a programme for the changeover depending upon its complexity and having regard to the optimum benefit from the point of view of cost, and adhere to it, even though the period involved was more than ten years.

The second decision related to the nomenclature of the new weights and measures. There was a strong lobby which desired that the country should have Indian names for the various metric units. Here again, the decision to adhere to the international nomenclature proved to be a correct decision. In order to ensure a measure of uniformity in regulation and enforcement, a draft Model Weights and Measures Enforcement Bill was drawn up by the Government of India. After discussions, the Model Bill was amended and was adopted by all the State Governments.

7.4.3 The next step was to create weights and measures organizations in all the States. Once these State organizations came into being, they became the nuclei for implementing the changeover in the different States in discussion with the various other authorities under their respective governments. These States' weights and measures organizations had to be provided with specialized equipment to enable them to discharge their functions. Arrangements were made with the Government of India Mints for the production and supply to the State Government organizations of working standards, secondary standards and reference standards of weights and measures and balances. Recourse had also to be had with private organizations for the production of precision balances of high accuracy.

In order to educate the common man as well as the sophisticated individuals in charge of trade, industry and administration, a sustained and systematic publicity campaign was conducted using all available media namely, the press, the radio, films, posters and exhibitions. The metric system of units was also publicized through conversion tables and demonstrations of specimen weights and measures. The success of the programme of changeover and the smoothness with which it was carried out could be attributed mainly to the system of joint consultations, discussions and mutually agreed target dates, which at every step were kept flexible, in order to accommodate difficulties and problems which arose in the course of implementation. The initial rough overall review of the problem of the changeover to the metric system brought out one clear conclusion namely, the reform of this magnitude could be implemented only in stages according to a systematic well-defined programme. The Standards of

Weights and Measures Act 1956 gave the Government of India discretion to introduce the new weights and measures in convenient stages. Thus, it was decided that a beginning of the reform should be made by the introduction of metric weights in Government departments and undertakings, organized industries and selected urban areas. Accordingly, it was notified that from 1 October 1958, metric commercial weights would be legal in the urban areas namely, Bombay, Calcutta and Madras. In April 1961, metric capacity measures were introduced. Gradually, extensions were made to other areas, undertakings and fields of activity. When new weights or measures were introduced in an area or a class of undertaking or a field of activity, the older weights and measures were allowed to be used for a period not exceeding three years. This transitional period was intended to serve two purposes:

i) To facilitate the completion of the preparatory steps by all concerned so that the changeover to the new system would be smooth and without hardship, and

ii) The traders, industrialists and the public would gradually become familiar with the new units and be able to understand their values in comparison with the old.

The organized industries in which the metric system was then introduced included among others, jute, cotton, textiles, iron and steel, heavy engineering, chemicals, cement, rubber, coir, sugar, vanaspati, paint, biscuits, soap, drugs, fertilizers, tea, coffee and petroleum.

The preparatory steps involved the making of arrangements for the progressive production of tens of millions of new weights and large numbers of capacity and length measures. Precise specifications had to be drawn up for these in consultation with the various interests concerned and keeping in mind the interests of the consumer. The production of working standards and secondary standard weights, balances, capacity and length measures had also to be organized. In all this work, assistance had to be drawn from the Government of India Mints, the Indian Standards Institution, and the National Physical Laboratory.

7.5 Education - It was in the fitness of things that education should occupy a very important place in the scheme of the changeover. It was realized at the outset that the ultimate success of the metric reform would depend upon the young ones at school. The generation at school would have the experience of the metric system from a very early age and would have had no need to use the old units of the FPS System. Systematic steps were, therefore, taken to revise the text-books and introduce new curricula for the teaching of mathematics and science in all classes in the schools from bottom to top.

7.5.1 The adoption of the metric system in the field of higher technical education, particularly engineering education, however, presented difficulties. The 'fps' system was almost exclusively in use in the engineering colleges and technological institutes in the country. The change involved the replacement or re- calibration of the measuring tools and instruments to conform to the new system. The curricula followed and the very large majority of the text-books in use were based on the fps system. The revision of the text-books was not easy and would have had to be undertaken by persons specifically selected for the purpose. Considering these difficulties, a phased programme covering a period of five years was drawn up for the adoption of the metric system in the engineering colleges and institutes of technology. Today, the majority of the colleges and the institutes have switched over to the metric system in the teaching of engineering subjects. Indian authors are being encouraged to write text-books in original in the metric system or to translate standard text-books from French, German, Russian and other European languages which follow the metric system. The response has been encouraging.

The procedure for changeover in the various disciplines of the industry was considered and specific decisions relating to each industry were taken.

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3. Publications of the United States, Department of Commerce

4. Indian Standards.

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