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ABSTRACT

The metric system is discussed in this information analysis paper with regard to its history, a rationale for the United States' adoption of the metric system, a brief overview of the basic units of the metric system, examples of how the metric system will be used in different occupations, and recommendations for research and development. The intent is to assist curriculum developers, administrators, and program planners in vocational, technical, and adult basic education in understanding issues in metrication, the metric system, and curriculum and instructional strategies as they begin the transition to the metric system of measurement. The basic parts of the metric system (linear measure, area, volume and capacity, mass, temperature, and metric notation) and the changes that will need to be made in different occupations are discussed with illustrations provided where appropriate. Occupations discussed are grouped under the following cluster headings: agribusiness and natural resources, business and office, communication media, construction, environmental control, health occupations, home economics, hospitality and recreation, manufacturing, marketing and distribution, personal services, public services, and transportation. Appendixes include tables of metric unit prefixes and typing and keypunching style sheets for metric notation. (TA)

METRICS FOR OCCUPATIONS

written by

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FOREWORD

The Educational Resources Information Center on Career Education (ERIC/CE) is one of sixteen clearinghouses in a nationwide information system that is funded by the National Institute of Education. The scope of work for ERIC/CE includes the fields of adult-continuing, career, and vocational-technical education. One of the functions of the Clearinghouse is to interpret the literature that is related to each of these fields. This paper on metrics for occupations should be of particular interest to teachers, administrators, curriculum developers, and program planners in vocational, technical, and adult basic education.

The profession is indebted to John C. Peterson, The Center for Vocational Education, The Ohio State University, for his scholarship in the preparation of this paper. Recognition is also due John L. Feirer, Western Michigan University for his critical review of the manuscript prior to its final revision and publication. Wesley E. Budke, Vocational-Technical Specialist at the ERIC Clearinghouse on Career Education, supervised the publication's development. Madelon Plaisted and Jo-Ann Cherry coordinated the production of the paper for publication.

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DESC::*Metric System; *Change Strategies; *Educational Change; Standards; Measurement; Occupational Clusters; *Vocational Education; Educational Planning; Educational Strategies; Adult Basic Education; Information Needs

IDEN::United States

CONTENTS

A BRIEF HISTORY OF THE METRIC SYSTEM

- 1670--Gabriel Mouton, Vicar of St. Paul in Lyons, France, proposed a comprehensive decimal measurement system. No action was taken on this proposal.

- 1786--A complete decimal system of coinage was adopted for the United States. The basic unit for this decimal monetary system was the dollar.

- 1790--During the French Revolution, the National Assembly of France requested the French Academy of Sciences to deduce an invariable standard for all the measures and all the weights. In the same year, Thomas Jefferson submitted a report on weights and measures to Congress. Jefferson, who was then secretary of state under George Washington, submitted two plans. One of the plans would have established a system of weights and measures based on decimal ratios.

- 1791--The French General Assembly adopted the principle of a system of weights and measures based on a unit called the *metre*.

- 1866--The use of the metric system was actually legalized in the United States. President Andrew Johnson signed a bill on July 28, which permitted, but did not encourage, use of the metric system.

- 1875--The Treaty of the Metre was signed in Paris by seventeen nations, including the United States. Among the provisions of the Treaty was the fabrication of new and improved standards for metric weights and measures and the establishment and maintenance of a permanent International Bureau of Weights and Measures. The Treaty was ratified by President Rutherford B. Hayes in 1878.

- 1960--At the 11th General Conference on Weights and Measures, the modernized metric system was officially renamed the *Systeme International d'Unités*--the International System of Units. This is usually shortened to the SI metric system.

•December 23, 1975--President Gerald R. Ford signed the Metric Conversion Act. The Act officially committed the United States government to support an orderly conversion to the metric system. In signing the bill President Ford said:

> It is important to stress that the conversion contemplated in this legislation is to be a completely voluntary one. The Government's function, through a U. S. Metric Board that I shall appoint, will be to coordinate and synchronize increasing use of metric measurement in the various sectors of our economy.
>
> I sign the bill with the conviction that it will enable our country to adopt increasing use of this convenient measurement language. . .both at home in our schools and factories, and overseas with our trading partners. (*Metric Reporter*, Jan. 9, 1976, 1)

Adoption of the Metric Conversion Act has not hastened national conversion to the metric system. Eighteen months after the Act was signed no meetings of the seventeen-member U. S. Metric Board had been held. In fact, it was eight months after the Act was signed before President Ford made his nominations for the Board. Congress adjourned before it acted on these nominees but President Ford renominated the same people in January, 1977. When President Jimmy Carter took office, he withdrew these nominations so that he would be able to study them. As of July, 1977, he had yet to make his own nominations.

WHY CHANGE TO THE METRIC SYSTEM?

The United States is changing to the metric system primarily for three reasons: simplicity, opportunity, and benefits.

SIMPLICITY

The metric system makes calculations more simple and convenient. For most purposes people will need only to know eight metric units for the following four items: for length--millimetre, metre, and kilometre; for volume--litre and millilitre; for weight or mass--gram and kilogram; and for temperature--degree Celsius.

Compare these eight metric units to the ones in our Customary system: length--inch, foot, yard, and mile; volume--ounce, pint, quart, and gallon; weight--ounce and pound; and temperature--degree Farenheit.

The simplicity is evidenced by more than just the fewer number of terms. Converting from one unit to another unit in the metric system is much simpler than in the Customary system. For example, if one needed to change 3¼ miles to feet, the computation would follow a procedure similar to this:

3¼ miles = 3.25 miles	5,280
1 mile = 5,280 feet	x 3.25
3.25 miles = 3.25 x 5,280 feet	260 00
	1056 0
	15840
3.25 miles = 17,160 feet	17160.00

A similar problem in the metric system is to change 3.25 kilometres to metres. The procedure is this:

1 kilometre = 1 000 metres	3.25
3.25 kilometres = 3.25 x 1 000 metres	x 1000
3.25 kilometres = 3 250 metres.	3250.00

There are some people who will need more than the eight previously mentioned units for their work. However, the simplicity of computation within the metric system should provide few problems for these people. Later in this paper some of the units and possible difficulties with their use are examined.

OPPORTUNITY

Conversion to the metric system presents opportunities for industry to review product standards, simplify product lines, and to rationalize and reduce numbers of sizes.

For example, when the Proctor and Gamble Company converted its first equipment to the metric system it selected a machine for stacking Pampers. This machine accumulates Pampers into stacks of the proper count, assembles the proper number of stacks, and loads the stacks into cartons. In making the change to the metric system, the people at Proctor and Gamble made many discoveries. Two in particular point out the opportunity that changing to the metric system provides:

First, our experience indicates that machinery design using SI units will be quicker than similar design in customary dimensions and will contain fewer errors. We predict that the move to metric will reduce our design costs by 5%.

Second, the decision to re-design the stacker in hard metric units permitted us to make deliberate changes which improved it. The metric stacker will be able to operate 25% faster than the customary version, will be easier to maintain and service, will be cleaner in design, and--surprisingly--will be cheaper. We have obtained firm bids from several reputable shops, and the quotes for multiple units indicate a savings of $35,000 per unit when compared with the price of our present equipment. In this respect we seem to be finding the same thing that others have found; namely, that metrication offers an opportunity to improve our designs and even to save money at the same time. (Nassauer, 1977, p. 7)

BENEFITS

The United States is currently at a disadvantage in trading in overseas metric markets. The nine Common Market countries will require the use of the SI metric system by 1978. Dual dimensioning of imports will be allowed only if determined not to be confusing. Since each nation will decide what dual dimensioned products it will import, it is imperative that industries that trade with the Common Market countries adopt the metric system.

This has been a brief examination of some of the reasons for changing to the metric system. But what is the metric system? What changes will people working in different occupations need to make? Or, to put it another way, "How will it (the change to the metric system) affect me and my job?" The remainder of this paper is used to (1) explain the basic parts of the metric system and what most people will need to know about it, and (2) examine the changes that will need to be made by people in different occupations. Occupations are grouped by clusters, and the clusters are listed in alphabetical order.

THE METRIC SYSTEM--WHAT IS IT?

Most people will need to know something about the metric system in categories of linear measure, area, volume and capacity, mass, and temperature. In addition they should know something about correct metric notation. Each of these are discussed in that order.

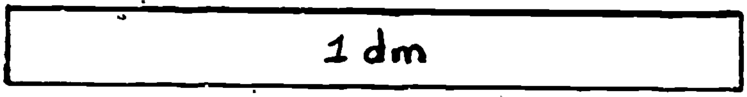
LINEAR MEASURE

Linear measure refers to the length, depth, width, or height of an object. The base unit of linear measure in the SI system is the *metre*. The basic tool for measuring metres is the *metre stick*. The symbol *m* is used to denote metre or metres. No period is placed after the *m* unless it is at the end of a sentence.

> If you place one end of a metre stick on the floor and hold the stick against your leg, you will find that the other end of the metre stick is near your waist. This is the height of a metre.

Because a metre is too long to measure many things, it has been divided into smaller subunits, all of which have the word *metre* in them. A different prefix is used to differentiate between the subunits. The three most common subunits have the prefixes *deci*, *centi*, and *milli*.

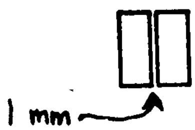
The first subunit is a *decimetre*. It is one-tenth of a metre. The rectangle shown here is one decimetre long. Ten decimetres are equivalent to one metre. The decimetre is a unit that is seldom used, but it is necessary to be aware of this unit in order to have a better understanding of the metric system. The symbol for decimetre is *dm*.



If a decimetre is divided into 10 equal subunits, each of these subunits is called a *centimetre*. Ten centimetres are equivalent to 1 decimetre, or 100 centimetres are equivalent to a metre. The rectangle shown here is 1 centimetre long. Since there are 100 centimetres in 1 metre, each centimetre is one-hundredth of a metre. Most centimetre rulers are 20 or 30 centimetres long. The symbol *cm* is used for centimetre.

Measure the width of a paper clip and a penny. A paper clip is about 1 centimetre wide and a penny is about 2 centimetres wide.

If a centimetre is divided into 10 equal parts, each part is called a *millimetre*. Ten millimetres are equivalent to a centimetre and 1 000 millimetres are equivalent to a metre. Shown here are two small rectangles. The distance between these rectangles is 1 millimetre. The symbol *mm* is used to represent millimetres.



Many people are used to millimetres because they smoke cigarettes that are 100 mm or 120 mm long. They also use 35-mm film in their cameras. Note that a 100-mm cigarette is also 10 cm, or 1 dm, long. A dime is about 1 millimetre thick. A paper clip wire is about 1 millimetre in diameter.

Sometimes it is not convenient to refer to large linear measures in metres. In such circumstances larger units are used. The names of these larger units all have a prefix plus the word *metre*.

The first of these larger units is 10 metres long. It is called a *dekametre* and the symbol *dam* is used. Ten dekametres is a *hectometre (hm)*--100 metres equal one hectometre. Ten hectometres is a *kilometre (km)*--1 000 metres equal one kilometre. Dekametres and hectometres are seldom used. Kilometres are used to designate distances such as the distance between two cities and many signs on interstate highways now give distances in kilometres. Speed and velocity are given in *kilometres per hour (km/h)*.

Table 1 shows the relationship between the base unit (metre) and the other linear units. In addition to the seven units given in Table 1, more units can be formed by using different prefixes. A complete list of the SI prefixes and their relationship to the base unit is given in Appendix A.

Table 1

Unit	Symbol	Value in Metres	Read as
*kilometre	km	1 000 metres	one thousand metres
hectometre	hm	100 metres	one hundred metres
dekametre	dam	10 metres	ten metres
*metre (base unit)	m	1 metre	one metre
decimetre	dm	0.1 metre	one tenth of a metre
*centimetre	cm	0.01 metre	one hundredth of a metre
*millimetre	mm	0.001 metre	one thousandth of a metre

*Units commonly used

AREA

Area refers to the number of units required to cover a surface completely. An SI unit of area is the *square metre*. The symbol for a square meter is m^2; NOT *sq. m.*

> Take 4 metre sticks and place them on the floor in the shape of a square. If you do this carefully, the area inside this square is a square metre.

There are smaller and larger units than a square metre. In fact, any of the linear units can be used for deriving a unit for area. For example, many instructional materials use the smaller unit *square centimeters* (cm^2) to explain area to students. *Square millimeters* (mm^2) may also be used. There are 100 mm^2 in 1 cm^2. One example of a larger unit is a *square dekametre* (dam^2) which is 100 m^2. Another name that is often used for a dam^2 is *are* and the symbol for *are* is *a*. An even larger unit is the *square hectometre* (hm^2), which is 10 000 m^2. A more common for the hm^2 is the *hectare* for which the symbol *ha* is used. Land measure is often in hectares. The only larger unit of area that is used is the *square kilometre* (km^2) which is used primarily for very large land areas.

VOLUME AND CAPACITY

The *volume* of an object refers to the amount of space the object occupies or encloses. *Capacity* refers to the amount of space enclosed by an object or container.

A unit of *volume* is the *cubic metre* (m^3). A cube or box that is one metre long, one metre wide, and one metre high has a volume of one cubic metre. The symbol for the cubic metre is m^3 and NOT *cu. m.*

There are smaller and larger units than a cubic metre. In fact, any of the linear units can be used for deriving a unit for volume. For example, many textbooks explain volume by using *cubic centimetres* (cm^3). *Cubic millimetres* (mm^3) can also be used. There are 1 000 mm^3 in 1 cm^3. Another unit that can be used is the *cubic decimetre* (dm^3). There are 1 000 cm^3 in 1 dm^3.

The basic unit of *capacity* is the *litre*. A cube or box that is one decimetre long, one decimetre wide, and one decimetre high has a cpapcity of one cubic decimetre, or one litre. The symbol for litre is *l*. This symbol *is not* the numeral one but a small, or lower case, letter el. Because there can be some confusion when the last digit of a number is one, it is very important that a space be left between a numeral and the symbol for litre. If there is any possibility of confusion, the whole word *litre* should be used. The United States Bureau of Standards, the American National Metric Council, the Canadian Standards Association, and the Australian Metric Conversion Board have all adopted the use of the capital letter *L* as the symbol for litre. However, the International Committee for Weights and Measures, which establishes the SI standards, met in September 1976, and chose not to adopt the symbol *L*.

> The litre will be a very common household unit. Milk, motor oil, gasoline, bleach, and soda pop are a few of the products that will be purchased in litres.

The cubic decimetre, or litre, is often too large a unit for many uses. In these circumstances, the small unit that is used is the *millilitre (ml)*. There are 1 000 ml in 1 litre. If the symbol *L* is adopted for litre, then the symbol for millilitre will be *mL*. Millilitre is another name for cubic centimetre. A box that is one centimetre long, one centimetre wide, and one centimetre high is a cubic centimetre.

Units smaller or larger than a litre are often needed. When this is the case, these new units have names with word *litre* preceded by a prefix. Table 2 shows the relationship between the base unit (litre) and the other units of capacity.

Table 2

Unit	Symbol	Value in Litres	Read as
kilolitre	kl	1 000 litres	one thousand litres
hectolitre	hl	100 litres	one hundred litres
dekalitre	dal	10 litres	ten litres
*litre (base unit)	l	1 litre	one litre
decilitre	dl	0.1 litre	one tenth of a litre
centilitre	cl	0.01 litre	one hundredth of a litre
*millilitre	ml	0.001 litre	one thousandth of a litre

*Units commonly used

MASS

The fourth section concerns measuring weight or mass. The mass of an object refers to the amount of matter contained in the object. This amount always remains constant so long as something is not added to or subtracted from the object. *Weight* is the term that most people use when they mean *mass*. Weight, however, is affected by gravity while mass is not. Thus, the weight of an object on the moon is one-sixth its weight on earth. The mass of that same object is the same whether the object is on the moon or on the earth. The term *mass* is used in this paper.

The SI base unit of mass is the *kilogram* and the symbol *kg* is used to designate kilogram or kilograms. Kilogram scales, which come in many shapes and sizes, are used to measure kilograms. A bathroom scale and a scale in a doctor's office are two different types of kilogram scales.

Find your mass on a kilogram scale. Measure the mass of other heavy objects such as a sack of potatoes, a bag of sugar, and a pet. Guess the mass of a friend and various objects and then check your guesses by measuring them. Keep trying until you are able to make fairly accurate guesses.

A kilogram is a rather heavy unit. For this reason it is often necessary to use subunits for expressing the mass of light objects. The one most common subunit is the *gram*. There are 1 000 grams in 1 kilogram. Thus, each gram represents one-thousandth of a kilogram. The symbol *g* is used to represent grams. The units *dekagram* and *hectogram* are very seldom used. There are 10 hectograms in 1 kilogram and 100 dekagrams in 1 kilogram.

Pick up a raisin. Feel how light it is! It has a mass of about 1 gram. Pick up a nickel. The mass of a nickel is about 5 g.

A smaller unit that is often used is the *milligram*, which is one-thousandth of a gram. The symbol *mg* is used for milligram. Milligrams are used mostly for measuring very small amounts such as medicines and vitamins.

A unit larger than a kilogram that is often used is the *metric ton*, which is 1 000 kilograms. The metric ton is used for shipping corn, wheat, and other large quantities. The symtol *t* is used to represent the metric ton. This unit is spelled *tonne* in other English speaking countries; however, in the United States *metric ton* is preferred.

TEMPERATURE

The unit most persons will use for measuring temperatures is *degree Celsius* and the tools for measuring temperatures are Celsius thermometers. The symbol for degree Celsius is °*C*. Usually no space is left between the numeral and the symbol. Thus, 53 degrees Celsius often is written 53°C and NOT 53 °C. *Celsius* and *C* are both capitalized since they are in honor of Anders Celsius, the

Swedish astronomer who developed the Celsius scale. The term *degree centigrade* has been replaced by *degree Celsius*.

> If you place a Celsius thermometer in ice water the reading should be 0°C; if you place it in boiling water the reading should be 100°C. Normal body temperature is 37°C. A comfortable room temperature is 21°C.

METRIC NOTATION

Measures in metric notation are written according to several rules. A quantity such as 15 metres is written as 15 m. A space is left between the numeral *15* and the symbol *m*. No period is placed after the symbol unless it is at the end of a sentence.

A quantity such as 27 litres should be written as 27 l. Again, a space is left between the numeral 27 and the symbol l. This space is important, since a lower case el looks like a numeral one. Some early metric guides used a script el, *l*, but this is discouraged since most typewriters do not have a script el key. As mentioned earlier, some groups are advocating that a capital el be used. When there is a possibility of confusion, the word *litre* should be spelled out.

Numbers that are one thousand and larger use a space instead of a comma to separate groups of three digits. Thus, a quantity such as 25,683,927 centimetres should be written as 25 683 927 cm. However, when there are four digits the space does not have to be used; 3957 and 3 957 are both correct.

When referring to quantities less than one unit in size, a zero (0) is placed to the left of the decimal point. Thus, 0.25 cm should be used, NOT .25 cm. This form is not necessary when there is a combination of whole units and partial units. For example, 2.35 ml is correct; 02.35 ml is not.

Another rule is that two different units are never mixed. It is incorrect to write 6 m and 7 cm. Instead, these measures should be expressed entirely in metres, entirely in centimetres, or entirely in some other linear unit. Since there are 100 cm in 1 m, there are 600 cm in 6 m, hence this length of 6 m and 7 cm could be expressed as 607 cm. It is also possible to express this in metres rather than in centimetres, since 1 cm is the same as 0.01 m (1 centimetre is the same as one-hundredth of a metre). So, 7 cm is 0.07 m, and

6 m and 7 cm would be written 6.07 m. Complete lists of standard metric expressions are provided in Appendices B and C.

THE METRIC SYSTEM: ITS USE IN OCCUPATIONS

The best way to learn the metric system is to use it in all measurements. People who "think metric" understand the metric system and find that they are able to use it easier and faster. However, as advantageous as it may be to use the metric system exclusively, it is not always practical. Most of the measurements currently in use are in the Customary system, and it is often necessary to convert these factors to the metric system.

AGRIBUSINESS AND NATURAL RESOURCES

Farming, horticulture, forestry, and agricultural mechanics are but a few of the occupations in the agribusiness and natural resources cluster. How soon, and to what degree, persons in these occupations will begin to use the metric system will depend on their needs. For example, international sales of wheat and corn must be made in terms of metric tons.

Some of the metric terms that were discussed in the last section will have specific job-oriented uses in agribusiness and natural resources. For example, millimetres will be used to measure rainfall, seed sizes, dimensions of lumber, bolt and screw dimensions, parts sizes, and *dbh--diameter breast height*. (The breast height in the Customary system is 4½ feet above the ground. Since 4½ feet is 1 371.6 mm it may be safe to assume that the dbh in the metric system will be 1 400 mm. However, no official decision has been made.) Metres will be used to measure tree height, rope length, irrigation hoses and pipes, and fences. Liquid fertilizers, pesticides, fungicides, fuel tank sizes, fuel, antifreeze, and oil all will be measured in litres. Heavy lubricants and grease, vehicle load limits, powders and dry chemicals, livestock food, and livestock all will be measured in kilograms.

In addition to these uses of the basic units, each occupation has its special units. Crop yields will be measured in *kilograms per hectare (kg/ha)* or *metric tons per hectare (t/ha)*. Flow rates in irrigation will be in *litres per second (l/s* or *L/s)* and the velocity of flow in irrigation will be in *metres per second (m/s)*.

Application rates of seeds, dry fertilizers, and dry pecticides will be in *grams per square metre* (g/m^2) or kilograms per hectare (kg/ha). Application rates of liquid fertilizer, herbicide, and soil sterilants will be in *litres per square metre* (l/m^2 or L/m^2) or *litres per hectare* (*l/ha* or *L/ha*). A table listing metric terms most commonly used in forestry, horticulture, agricultural supplies and services, agricultural production, and agricultural mechanics is shown on page 13 in the appropriate documents by Cooper and Magisos (1976 [1], [2], [3], [4]).

The *hectare* is the metric unit that will be used for land areas of farms and fields. As previously stated, a hectare is 10 000 m^2 or the area enclosed by a square 100 metres on each side. It is about the size of 2½ acres and so one-tenth of a hectare (0.1 ha) is about the same as a quarter acre. An easy way to get a rough estimate of the number of hectares in a field is to multiply the number of acres by 0.4. Thus, a field that is 97.5 acres is approximately 39 ha (97.5 x 0.4 = 39). A more accurate method is to multiply the number of acres by .4047. So, 97.5 acres is:

```
       97.5 acres
    x 0.4047
    --------
        6825
       3900
    39000
    ----------
    39.45825 hectares
```

Rounded to decimal places, 97.5 acres is 39.46 ha.

ARTS AND HUMANITIES

The arts and humanities cluster includes such occupations as theatrical costuming, stage lighting, broadcast announcing, and theatre management. As with all occupations, the ones in this cluster have specialized uses for the standard measures. Millimetres will be used for the dimensions of drafting paper, button thickness and spacing, layouts, posters, display ads, program sizes, cable diameters, lens sizes, focal lengths, film size, length and diameter of bolts and screws, and wire thickness. Centimetres are primarily used to measure people and their clothing. Consequently, centimetres will be used for fabric width, seam and dart lengths, zippers, and actor's measurements, as well as sheets of gel, spot sizes, and display ads. Fabric, yarn, thread, light throw, floor length, auditorium dimensions, sports, certain data in accident reports by broadcasters, and short distances will be given in metres.

Square centimetres will be used for sketch paper, pattern properties, scale drawings, lens surfaces, posters, and graphics. Square metres will be used for studio, acting, work and storage space, orchestra pits, and paint coverage.

Volume and capacity units of millilitres and litres will be used for liquid dyes, lubricants, liquid cleaning supplies, chemicals, and paint. In addition, dilutions or concentrates will be expressed in *grams per litre (g/l* or *g/L)* for the mixing rate of powdered concentrates to liquid. Examples include dye mixes, dry paint, powdered drink mixes, pesticides, and cleaning solution. The mixing proportions of liquid concentrates to water--such as liquid dyes with water, liquid thinner with paints and glue, and beverage solutions--will be in *millilitres per litre (ml/l* or *mL/L)*.

Electrical and mechanical power will be expressed in *kilowatts (kW)*; electrical resistance in dimmers and switches in *ohms* (Ω); the amount of light emitted from a light source in *lumens (lm)*, lamp efficiency in *lumens per watt (lm/W)*, and illumination or the intensity of light on a given space in *lumens per square metre* (lm/m^2) or, as it is also called, *lux (lx)*. Some temperatures, as in scientific and technical reporting or in the color temperature of a light source, will be in *Kelvin (K)*. A temperature measured in Kelvin is exactly 273.15 degrees higher than the same temperature in degrees Celsius. Thus, 0°C = 273.15 K; 100°C = 373.15 K; and 185°C = 458.15 K. Specific information regarding the application of metric measurements in arts and humanities is contained in the series of publications by Cooper and Magisos (1976 [5], [6], [7], [8], and [9]).

BUSINESS AND OFFICE

As with any occupation, the specific metric knowledge that business and office personnel need to have depends on the particular functions of that business or office. The suggestions for this cluster are divided into two categories: clerical and managerial.

Clerical Functions

Several aspects of clerical functions that will be affected by a change to the metric system include typing, shorthand, and key punch operation.

Typing. The SI metric system is a very precise system and since it is an international system many efforts have been made to reduce the possibilities of confusion over measurements. Part of these efforts have focused on the special notation and symbolism that is used.

Some of the new symbols that are employed in the metric system are µ, Ω, °, ², and ³. There have been several proposals for a "metric" typewriter keyboard which would include most of these symbols. It is usually suggested that such a keyboard be designed by eliminating (1) the uppercase period and comma, (2, the fractions ½ and ¼, and (3) any one or more of @, #, and $. At the present time the typewriter manufacturers have not published any decision as to which symbols would be replaced or if additional keys would be added to the keyboard.

Regardless of whether a new keyboard is adopted, some adjustments have to be made. Some of these require only an adjustment in thinking. (For example, the fact that there are 10 pica spaces in an inch will be replaced by either 10 pica spaces in 2.5 cm or 4 pica spaces in 1 cm.) The standard paper size will be called A4 and will measure 210 mm wide by 297 mm long. This is slightly narrower and slightly longer than the standard typewriting paper of 8½ by 11 inches (215 mm by 280 mm). A4 paper has 70 typewriting lines to a page instead of the 66 lines for the present typewriter paper.

There are several excellent references for typing the metric system correctly. Perhaps the best of these are the American National Metric Council (ANMC) (1975); IBM (date unknown); Delta Pi Epsilon (1976), and Cooper and Magisos (1976 [10]). Reprints of two complete sections from Cooper and Magisos (1976 [10]) are given in Appendices B and C. Appendix B contains the correct rules for typing. Appendix C contains correct writing and spelling of different units and their symbols.

Shorthand. New terms are being introduced with the metric system. Some possible Gregg Shorthand brief forms for metric terms may include those found in Figure 1 (Delta Pi Epsilon, 1976). Whether these are the brief forms that are actually adopted is a decision that will be made by the publishing companies who will distribute information concerning specific changes.

Key Punch Operation. A special set of symbols is needed by key punch operators. Key punch machines print in all upper case letters. In the metric system, one must be very careful to use the correct symbol for some prefixes. The symbol for the prefix *milli* is *m* and for the prefix *mega* is *M*. A *millimetre (mm)* represents 0.001 m; and a *megametre (Mm)* represents 1 000 000 m. A keypunch machine

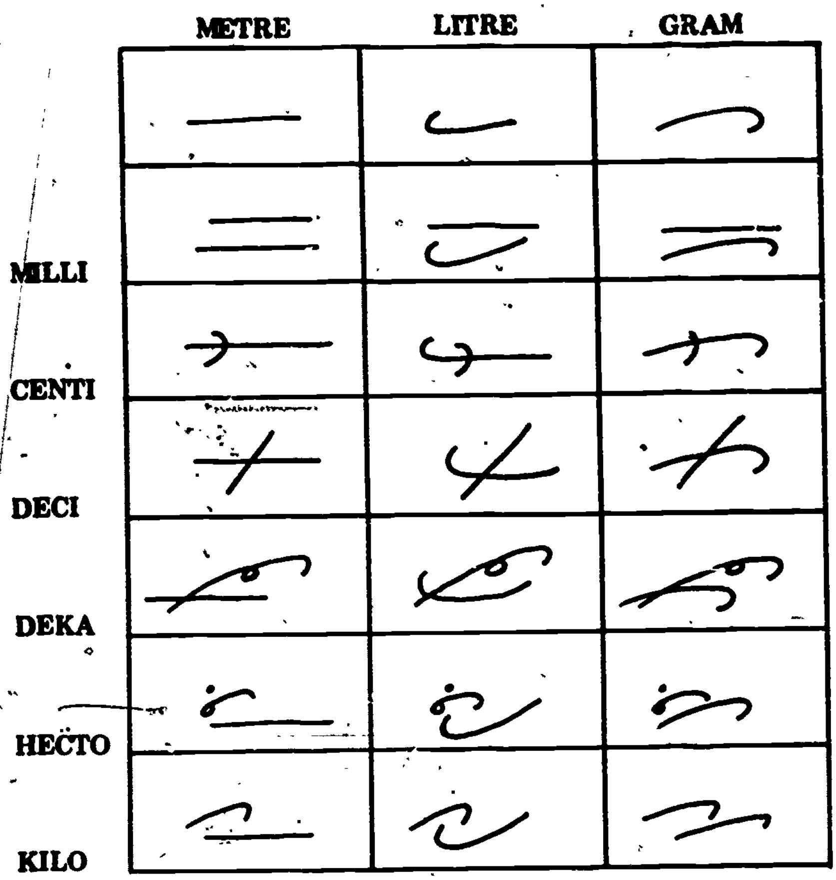


Figure 1. Metric Shorthand Symbols

would print both of these as *MM*, so different symbols had to be devised. The keypunch symbol for milli is *M* and for mega is *MA*. Thus, a keypunch operator would punch millimetre as MM and megametre as *MAM*. The keypunch symbol for micro (µ) is *U*. The special keypunch symbols for various units are given in Appendix C.

Management Functions

There is very little literature on the management aspects of converting to the metric system. One excellent article concerning the cost of businesses to convert and the management of these costs is by Benedict (1976). Pokorney (1973) discussed the major tasks that should be used to minimize the impact of metrication on an organization's data processing system. He stated that the data processing manager must lead the way to a structured solution. The major tasks were:

> 1. The data processing manager should initiate a metric awareness program at the top level of the organization.
>
> 2. An analysis of every data processing system application in operation or being designed should be conducted. This analysis should determine the degree to which the system's input, processing or output is dependent upon measurement sensitive data.
>
> 3. Each data processing manager should develop a metric conversion plan. This plan should be a major element of a corporate metric conversion plan whenever possible.
>
> 4. All new systems being designed should reflect the results of the impact analysis study. (p. 20)

Benedict (1976) stated the following:

> The accepted general management strategy is to incorporate metric management into the existing organizational structure. The objective is to undergo a realistic and practical change. The advantage of this approach is direct management control which enables cost-effective programming. In the metrication context, references to "cost control" do not imply total accounting of all costs (or benefits); this is not practical or realistic. Instead, the key is specific control of expenditures and potential costs.
>
> * * *
>
> Critical importance is assigned to joint planning, good communication, and active coordination among company and industry groups whose metric changeover programs are interdependent. The *key* to control of costs in any firm engaged in metric conversion is the development of a master plan that is dovetailed into its industry sector program and transition timetable.

COMMUNICATION MEDIA

The communication media cluster includes occupations such as architectural drafting, bindery operation, commercial photography, layout and design, type composition, litho photography, and offset printing press operation. Most metric units used in this cluster are the ones for length, mass, area, volume/capacity, and temperature.

Millimetres are used for litho-plates, paper size, gripper margins, film holders, film width, press size, line length, ribbons, headliner, type size, wrapping paper and cellophane, chamfer, length and width of drafting papers, and fixture dimensions. Centimetres are used for padding tape, ring binders, covers, length of a T-square, panel and pavement thickness, sheet film, print paper, layout, and masking sheet, type size, Rubylith, acetate, enlargements, and reductions.

One of the first daily newspapers to convert to the metric system in its advertising measurements and contracts was the Iowa City (Iowa) *Press-Citizen*. The basic unit used by the newspaper is the centimetre. Contracts are quoted in centimetres and rate cards are in centimetres rather than column inches (*Metric Reporter*, 1976).

Surface finishes will be measured in *micrometres* (µm)--1 µm = 0.001 mm = 0.000 001 m. Metres will be used to measure rolls of white print paper, road width, and curve radius; kilometres will be used in road construction and surveys.

Square millimetres (mm^2) are used for cross-sectional areas of wire, reinforcing rod and pipe, paper, cardstock, oil span, print paper, retouching, and enlarging. Square centimetres will be used for some of the same things as square millimetres--enlargements, print paper, card stock, and oil span--plus the area of drafting paper, size of openings, and cross sections. Square metres are used for studio and darkroom sizes, floor area, sidewalks, driveways, and ventilating systems.

Grams are used for postage, ink, dryer, etch gum, mass of powders, crystals, erasing compound, concrete coloring, soil samples, and adhesives. Another unit of mass, the kilogram, is used for press weight, steel, structure, equipment, furnishings and equipment, shipping, and quantity purchase of supplies. Metric tons (t) are used in the drafting occupations for steel, machinery, concrete, sand, gravel, fill, and asphalt.

Volume and capacity units of millilitre, litre, cubic centimetre, and cubic metre are all used in the occupations in the communication media cluster. Cubic metres are used in drafting for earth excavations, concrete, landfill, backfill, sand and gravel, and in bindery operations for storage and shipping space. Millilitres and litres are used for developing, fixing, and hypo solutions, laquer, padding cement, oil, alcohol, tank and tray capacity.

Millilitres per litre (ml/l or mL/L) are used for mixing solutions. *Grams per litre (g/l or g/L)* are used for mixing powders or crystals to liquids, electrostatic solutions, and toner. Air pressure and vacuum settings will be in *kilopascals (kPa)*. More complete listings can be found in Cooper and Magisos (1976 [13], [14], [15], [16], [17], and [18]).

Perhaps the most interesting innovation that the metric system will bring about in this cluster is in the proposed paper measurements. International paper sizes are referred to by the letters ISO (International Organization for Standardization) with three size series: A, B, and C. The A series is for general printed matter, cut stationery, and publications. Series B is for posters, wall charts, maps, and similar items. Series C is for folders, post cards, and envelopes designed to hold paper from the A series.

All three series are based on a rectangle whose sides are in the ratio of $1:\sqrt{2}$ (1: 1.414). This means that each time the paper is halved along the longer side or doubled along the shorter side the ratio remains the same.

There are eleven sizes in the A series (A0 through A10). The largest, A0, measures 841 mm x 1 189 mm and has an area of 1 m^2. The next smaller size, A1, is 594 mm x 841 mm. In order to make the sheets measure in whole millimetres, whenever halving a side results in a length in partial millimetres, the part less than a millimetre is dropped. For example, the size of A1 was obtained by halving 1 189 to get 594.5. The 0.5 was dropped to get the length 594 mm. The area of a sheet of A1 is approximately half of a sheet of A0.

Similar procedures are used for obtaining the B series and the C series. B series sizes are about midway between two A series sizes. The basic size in the B series is B0. It measures 1 414 mm x 1000 mm and so its area is 1.414 $m^2 = \sqrt{2}\ m^2$. B1 measures 1 000 mm x 707 mm. The B series has eleven sizes (B0--B10).

The C series has ten sizes (C0--C8 and DL). The basic C0 size is 917 mm x 1 297 mm (area is $\sqrt{2}$), C1 is 648 mm x 917 mm, and so forth. A C4 envelope holds a flat sheet of A4 paper; a C5 envelope holds a flat sheet of A5 paper (or a sheet of A4 folded once along the longer side), and so forth. A4 will be used for normal typing paper. In order to accommodate this size of paper with the typical two folds, a special envelope size was created. This size, DL, measures 110 mm x 220 mm. Further discussion of paper standards are in Lindbeck (1975), Fecik (1974), Spangler (1972), and Cameron (1972).

CONSTRUCTION

Occupations in the construction cluster include plumbers; pipefitters; electricians; heating, refrigeration, and air conditioning engineers; carpenters; and masons. Examination of applications of the metric system in the construction cluster will show some of the uses for various units.

The linear unit, millimetre, will be used for the size of pipe, tubes, ducts, and fittings, electrical wire thickness, length and diameter of fasteners, and lumber sizes. Centimetres and metres will be used for the length of pipe, tube, duct, fixtures, and wire.

Area units of square millimetres will be used for the cross-sectional area of wires; square centimetres for pipe chase areas, wall sleeve space, and fixtures; and square metres for floor space, window and door openings, roof and ceiling area, roof drains, and floor drains.

The mass of fixtures, pipes, fittings, chemicals, and panels will be in kilograms. The mass of boilers and solar panels will be in metric tons (t).

Trench construction; septic tank size; the size (volume) of a room or building; volume of air in a space to be cooled, heated, or exhausted; and the capacity of cylinders and tanks will be in cubic metres. The space needed for, or available inside, a wiring box will be in cubic centimetres.

Some new units are *millilitres per second (ml/s* or *mL/s)* and *litres per second (l/s* or *L/s)*, both of which will be used to measure the velocity of flow in fittings and the frictional backwash in pipes. They will also measure flow rates for circulating pumps and automatic gas valves. Other flow rates such as air flow for heating or cooling will be in *litres per minute (l/min* or *L/min)* or for pump or metre capacities will be in *litres per hour (l/h* or *L/h)*. Measures of air exchange in a region or of exhaust and air exchange system ratings will be in *cubic metres per second* (m^3/s).

Pressure for water system design; calculating pump sizes in air lines; and in heating, ventilating, and air conditioning will be in *kilopascals (kPa)*. Pressure drops in plumbing systems will be measured in *kilopascals per second (kPa/s)*. Heat energy used to warm the air to heat a room or to produce hot water or steam will be measured in *kilojoules (kJ)*. More details can be found in Cooper and Magisos (1976 [19], [20], and [21]). An example of some metric pipe dimensions are given in Figure 2 taken from Cooper and Magisos (1976 [21]).

Metric lumber sizes have yet to be established for the United States. Some recommendations are that softwood sizes selected be "appropriate for modular construction based on the 100 mm module. This provides for 300, 400, 600, and 1200 mm spacing where even metric units appear to be more important in design than the actual dimensions of the members themselves" (Wyatt, 1976, p. 10).

Sizes of plasterboard, plywood, and hardboard panels do not seem to present as much of a problem. "It is almost certain that the common 4 x 8 foot panel can be hard converted to a 1200 x 2400 mm size. . . . This size is based on the 100 mm module and fully utilizes the 300, 400, and 600 mm spacings" (Wyatt, 1976, p. 10).

ENVIRONMENTAL CONTROL

Wastewater technology is an important part of environmental control. People who work in wastewater technology will use millimetres for the length of manometer tubes and U-tubes, centimetres for the diameter of a pipe or tubing; and metres for the length of a channel or sewer.

The area units and their uses are square centimetres for the area of the nappe over weir; square metres for the area of a clarifier and a trucking filter; hectares for the area of a lagoon; and kilometers for the area of a collection system.

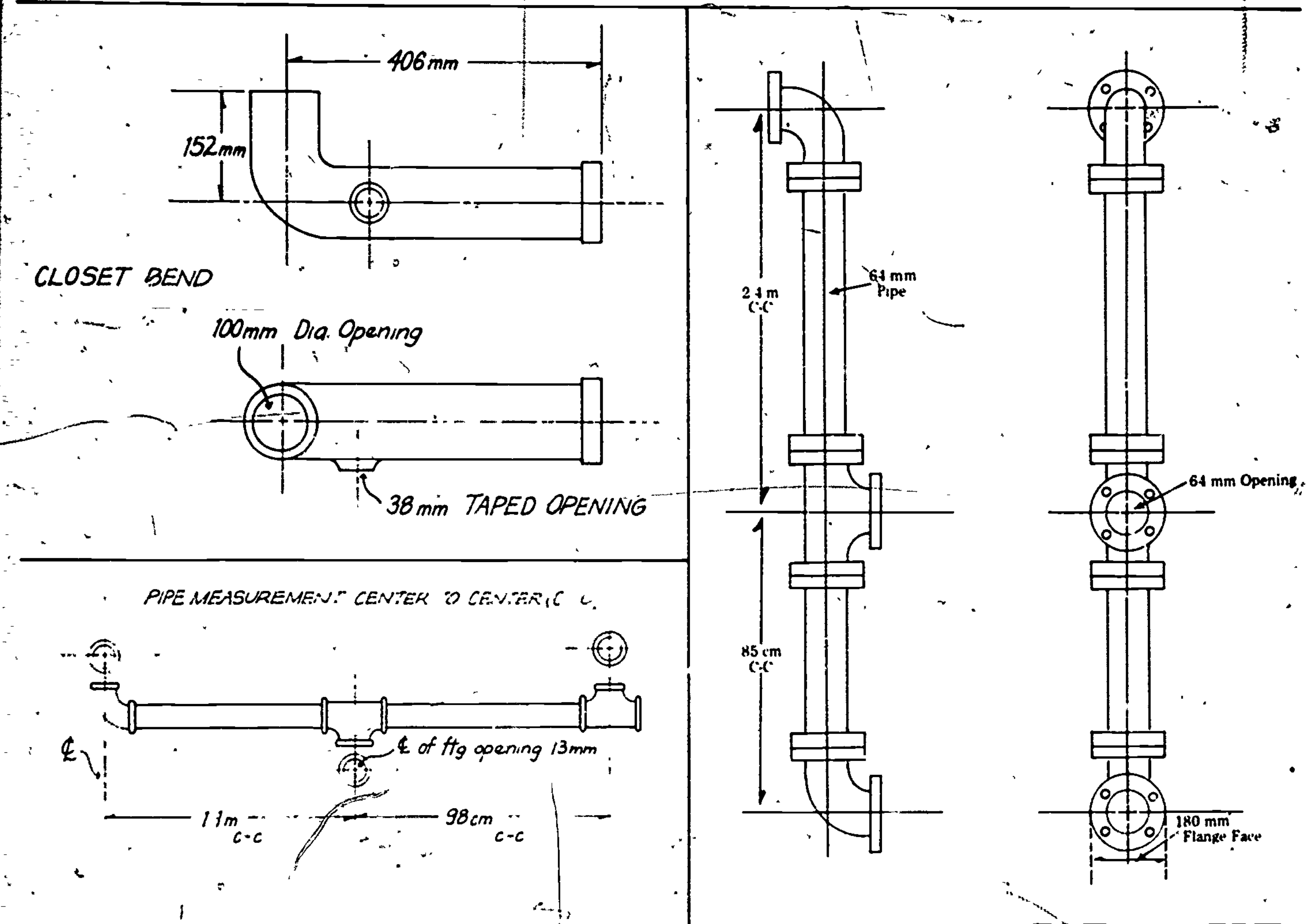
Litres will be used for lab samples; millilitres for the volume of thiosulfate for a DO titration; and cubic metres for the capacity of an aeration tank.

The mass of a dry reagent will be in grams, or sludge in kilograms, and truck loads of sludge in metric tons.

Flow rates over a weir will be in *cubic metres per second* (m^3/s); through a channel in *cubic metres per minute* (m^3/min); and through a wastewater plant in *cubic metres per day* (m^3/d).

FIGURE 2

METRIC PIPING DIMENSIONS



Application rates for the amount of chlorine used per cubic metre of water will be in *grams per cubic metre* (g/m^3). A chlorinator setting will be in *kilograms per day* (kg/d) and the grit removed per flow unit will be in *cubic metres per cubic megametre* (m^3/Mm^3).

Wastewater technology uses metric units combined in series to describe specific events. The rate of flow through a pipe is expressed in cubic metres per second (m^3/s). The amount of water flow each day (m^3/d) compared with the sand filter surface area (m^2) provides the compound expression $m^3/d/m^2$. The exercise in Table 3 (Cooper & Magisos, 1976 [22]) provides a good example of the variety of compound expressions used in wastewater technology. Thirteen descriptions are given in the left-hand column and readers are to list in the right-hand column the appropriate metric expression for each description. Answers have been provided here in parentheses in the right-hand column.

HEALTH OCCUPATIONS

Dental assistants, dietetic technicians, licensed practical nurses, nurses aides, and others who are employed in the health occupations have been using the metric system for many years. For example, injections have been given in *cc*. One cc. is one cubic centimetre (cm^3) and is the same as one millilitre. Will people in the health occupations continue to use cc. or will they use cm^3 or ml? Because speed and accuracy are often the difference between life and death, one can speculate that the term cc. will be retained for it is easier and faster to say.

Dental assistants will use millimetres for x-ray slides, rubber dams, packing materials, drill appliances, and the length and diameter of molar roots. Nurses will use millimetres for anatomical measurements, dressings, needle sizes, and tubing. Centimetres will be used by dental assistants for sutures, dental tape, and carbon; by nurses for anatomical part measurements, orthopedic apparatus and ropes, and the height or length of a patient; and by dietetic technicians for the thickness of dough and meat, dimensions of pans, work surfaces, equipment, and the diameter of cookies.

Persons in nursing also will use square centimetres for decubitus protective devices, pharmaceutical ointment, linens, and bed protectors. Dental technicians will give the sizes of x-ray slides and surgical preparations in square millimetres.

TABLE 3 MEASURING UP IN WASTEWATER TREATMENT

List the appropriate metric expression for the description given.

1. Flow over weirs	(m^3/s)	______
2. Amount of wet solids disposed of each year	(m^3/yr)	______
3. Amount of air compared to the amount of wastewater treated	(m^3/m^3)	______
4. Surface area weir length ratio	(m^2/m)	______
5. Amount of solids per day per surface area	$(g/d/m^2)$	______
6. Mass each day of volatile solids compared to digester volume	$(g/d/m^3)$	______
7. Heat required per amount of water evaporated	(kJ/kg)	______
8. Mass of BOD applied each day compared to the volatile solids under aeration	$(g/d/g)$	______
9. Flow each day per weir length	$(m^3/d/m)$	______
10. Mass of wet sludge each hour per unit of hearth area	$(kg/h/m^2)$	______
11. Amount of chlorine per the amount of wastewater	(g/m^3)	______
12. Rate of water evaporated each hour	(m^3/h)	______
13. Depth of wet sludge placed on a drying bed per year	(m/yr)	______

Dental assistants will give the amount of injections, plaster, topical fluoride applications, aseptics, and alginate in litres, millilitres, or cubic centimetres (cc. or cm^3). These same units will be used by nurses for I and O (intake and output) measurements. Oxygen and i.v.'s will be administered in litres while bodily secretions, dietary containers, intramuscular injections, and pharmaceutical measurements will be in cubic centimetres (cc. or cm^3) or millimetres.

Temperatures will be in degree Celsius. Normal oral body temperature is 37°C. Degree Celsius will be used not only for body temperature but for the temperature of baths, rooms, and X-ray developing solution. Pertinent readings on a clinical thermometer and on a bath thermometer are shown in Figure 3. Dietetic technicians will use degree Celsius for the temperature of ovens and refrigeration and freezing units.

Pressure in sterilizers, oral aspirators, the central venous system, and pressure cookers will be in kilopascals. Fluid flows in millimetres per minutes will be used for article decontamination and foley drainage collection.

Food energy is very important to the dietetic technicians. The unit that will replace the calorie is the kilojoule (kJ). One calorie is equivalent to 4.2 kilojoules. So, a 100 calorie apple contains about 420 kJ. Energy requirements of people, energy value of food, and energy content of diets all will be in kilojoules. Calculating, recording, and reporting total or fractional intake will be in *megajoules (MJ)*. Calculating portion serving size, counting food energy value intake, and planning menus will be in *kilojoules per gram (kJ/g)* or *kilojoules per kilogram (kJ/kg)*. Energy content of diet requirements and calculating and planning therapeutic diets will be in *kilojoules per day (kJ/d)* and *megajoules per day (MJ/d)*. Further information can be found in the publications by Cooper and Magisos (1976 [23], [24], [25], [26], and [27]).

HOME ECONOMICS

Occupations within the home economics cluster probably will have the most direct influence on people's everyday lives. Occupations in this cluster directly affect everyone every day--bakers, meat cutters, child care aides, interior designers, homemakers, tailors, and health aides.

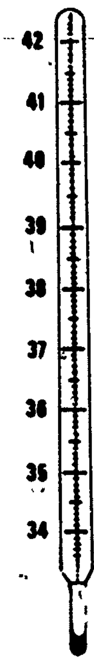
TEMPERATURE

Normal body temperature is 37°C. Abnormal subnormal temperature is 36°C and below. Elevations of temperature are 39°C and above.

Low fever	=	37.5°C -- 38.0°C
Mild fever	=	38.0°C -- 39.5°C
High fever	=	39.5°C — 42.0°C

Clinical thermometers in degrees Celsius

Dangerous fever	41°C
High fever	39°C
Low grade fever	38°C
Normal temp.	37°C
Subnormal temp.	36°C



Bath thermometer in degrees Celsius

Hot water bottle temp.	49°C
Sitz bath temp.	46°C
Bed bath temp.	44°C
Tub bath temp.	44°C

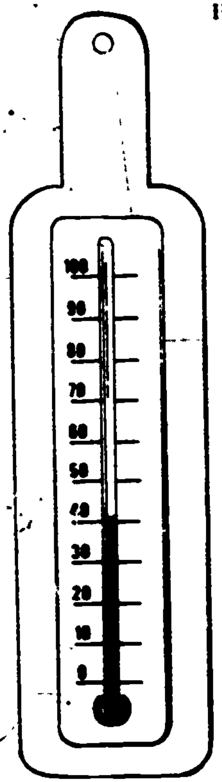


Figure 3. Bath and Clinical Celsius Thermometers

Tailors and alteration specialists will use centimetres for fabric width, body measurements, patterns, seam and dart widths, seam and inseam lengths, and zippers. They will use metres for fabric, tape, webbing, piping, and thread lengths. Cleaning fluids, fabric treatment solutions, dye solutions, and sewing machine oil will be in millilitres and litres, and pressing temperatures will be in degree Celsius.

Interior designers must work with room dimensions, floor plans, and architectural drawings. Most of these are in metres and millimetres; carpeting rolls also will be in metres. Furniture, windows, fabric lengths and widths, and wallpaper will all be in centimetres. In fact, at the present time much of the wallpaper is dual-dimensioned. Carpeting, room sizes, and window coverings will be in square metres. In order to plan lighting levels and determine the intensity of light on a given space, interior designers will need to work in lumens per square meter (lm/m^2) which are also called lux (lx).

Cooking, baking, and meat cutting use many of the same measurement units as the dietetic technician. Meat-cut thickness will be in millimetres or centimetres; pan dimensions, portion sizes, utensil sizes, and cookie diameters will be in centimetres. Liquid ingredients will be measured in millilitres, litres, and the like. Some cookware standards are being established now. The *Metric Reporter* (1977) stated that the Metal Cookware Manufacturers Association had completed a Metric Guide for metal cookware and bakeware.

> The capacities of liquid measure will be one litre, 500 milliliters, and 250 milliliters. Dry measures will have capacities of 500, 250, 125, and 50 milliliters. Small measures will have capacities of 25, 15, 5, 2, and 1 milliliters. The words "cup" and "spoon" will not appear in conjunction with metric measures. (p. 4)

Most prepackaged meats and cheeses will be in kilograms. Today's automated weighing/pricing/packaging machines give the weights of these items in decimal pounds. For example, one pound seven ounces of hamburger is labeled as 1.44 lb., so consumers should have little trouble adjusting to decimal versions in kilograms (1.44 lb. = 0.655 kg) or in grams (655 g).

Much of the nutritional information that now is labeled on packages is in the metric system. Actually, the nutrition information is given in three systems such as is shown in Table 4. This information was taken from a box of dry breakfast cereal and is in the

TABLE 4 NUTRITION INFORMATION

NUTRITION INFORMATION PER SERVING		
Serving Size............1 ounce (1¼ cups)		
Servings per Container..............15		
	1 oz.	plus ½ cup vitamin D milk
Calories	110	190
Protein, grams	4	8
Carbohydrate, grams	20	26
Fat, grams	2	6
Percentage of U.S. Recommended Daily Allowances (U.S. RDA)		
Protein	6	15
Vitamin A	25	30
Vitamin C	25	25
Thiamin	25	30
Riboflavin	25	35
Niacin	25	25
Calcium	4	20
Iron	25	25
Vitamin D	10	25
Vitamin B_6	25	30
Vitamin B_{12}	25	35
Phosphorus	15	25
Magnesium	10	15
Zinc	6	8
Copper	8	8

Customary system (ounces and calories), the metric system (grams), and a percentage system (percent of U. S. RDA).

One other major concern in cooking will be oven temperatures. Water freezes at 0°C and boils at 100°C. (As is true when cooking temperatures in the Customary system are given, these are sea level temperatures. No adjustments are necessary at low elevations but some are necessary at higher elevations, such as in Denver.) A very slow oven is 120-135°C, a slow oven 150-165°C, a moderate oven 175-190°C, and a hot oven 205-220°C, and a very hot oven 230-245°C. Common cooking temperatures are shown in Figure 4 taken from Cooper and Magisos (1976 [30]).

Child care aides and homemakers will need to understand how a person should dress in various temperatures. For example, if it is 20°C outside should a heavy coat be put on a child who wants to go out to play? With today's energy conservation measures, 20°C is considered a comfortable room temperature. More complete information on units and their uses is in Cooper and Magisos (1976 [28], [29], [30], [31], and [32]).

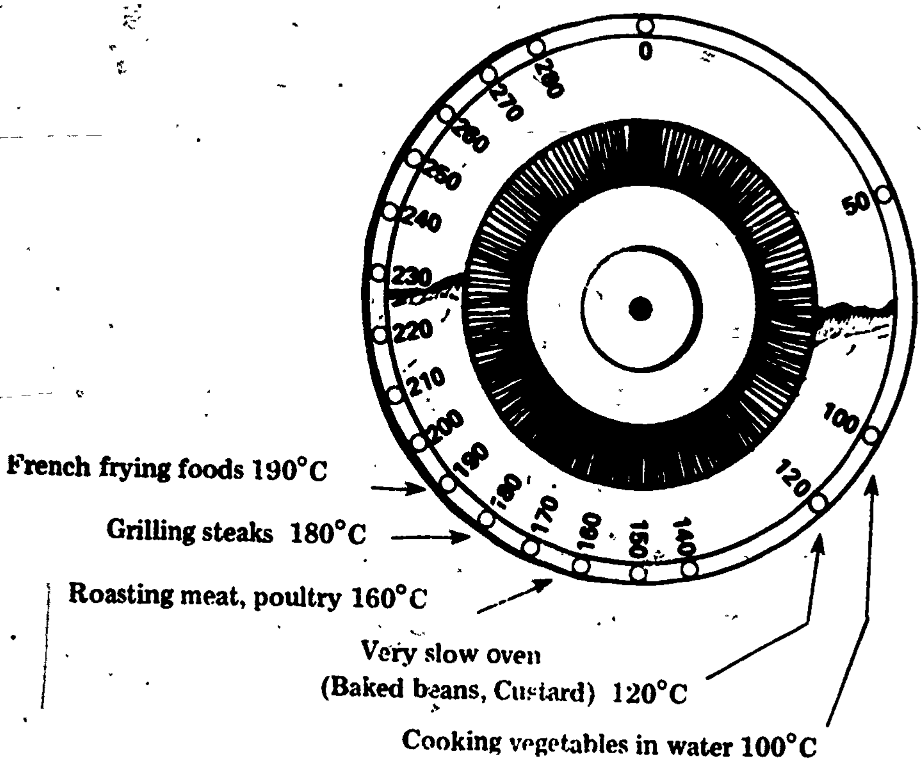


Figure 4. Celsius Oven Dial

Lindbeck (1975) gave many illustrations of possible metric sizes for men's shirts, women's dresses, and fabric widths. No concensus has been reached concerning whether or not these will be the metric sizes adopted for use in the United States. Lindbeck also gave an example of the monodopoint shoe size system that is being considered for international use. While a standardized international shoe sizing system would be beneficial to consumers, none has yet been adopted.

HOSPITALITY AND RECREATION

The hospitality and recreation cluster includes occupational categories such as food services, hotel and lodging, and recreation and tourism.

Most of the units used by people in the food service occupations already have been discussed in the occupations of dietetic technician, food preparation, baking, meat cutting, and homemaker. Perhaps the only other units that food service people will use are for application rates. Dry or granular pesticides or cleaning powders will be applied in grams per square metre. Liquid pesticides and cleaning solutions will be applied in millilitres per square metre.

Hotel and lodging personnel will need to know the same metric units for application rates. They also will need to know the units for quantities of dilutions or concentrations. Dry mixes of pesticides, cleaning powders, and food will be in grams per kilogram. Liquid dilutions or concentrates such as pesticides, cleaning solutions, and drinks will be in millilitres per litre, and chlorine for swimming pools will be in grams per litre.

Recreation and tourism occupations will have many different uses for metric units already discussed as well as some that have not been discussed. Map reading and ammunition will both use millimetres. Some ammunition is currently measured in millimetres. Sleeping bags, bows, targets, golf clubs, and ski equipment will be measured in centimetres. Skiers in the United States have been specifying ski lengths in centimetres for several years. Golf fairway distances, boat and canoe lengths, tennis courts, and target distances will be in metres. Several baseball stadiums have distances in metres from home plate painted on the outfield wall. Track distances and swimming distances are already in metres; the 1976 Montreal Olympic Games made many people aware of metric distances and the metric system. Some directions, travel distances, walking and biking trails are now in kilometres and will be in even greater use in the future.

Square metres will be used to measure the area of pool tables, skating rinks, bowling alleys, and tennis courts. Park areas; golf courses; golf, rifle, and archery ranges will be in hectares. Bait and bailing buckets, fuel tanks, water tanks, and thermos bottles will be measured in litres. Swimming pool capacity will be in *kilolitres (kl or kL)*. Firewood will be sold in cubic metres or *steres (st)*. A stere is another name for a cubic metre and is used for quantities of firewood only. (Crossword puzzle fans are well aware of the metric unit *stere* since it is a frequent answer.)

Speed limits and wind speeds will be in *kilometres per hour (km/h)*. The current speed limit on most interstate highways is 88 km/h. Muzzle and arrow velocities will be expressed in *metres per second (m/s)*. Liquid chemical dilutions for swimming facilities will be in *litres per kilolitre (l/kl or L/kL)* or *kilograms per kilolitre (kg/kl or kg/kL)*.

Newtons will be used to express the tension on a fishing line or of the bow draw force. A *newton (N)* is the amount of force needed to give a mass of one kilogram an acceleration of one metre per second per second. Thus, a newton is equivalent to a kilogram•metre per second squared ($N = kg \cdot m/s^2$). Trajectories of rifles, hand guns, and arrows will be expressed in *centimetres per metre (cm/m)*. The publications by Cooper and Magisos (1976 [33], [34], and [35]) contain more detailed information on occupations in the hospitality and recreation cluster.

MANUFACTURING

Occupations in the manufacturing cluster include blueprint reading, welding and cutting, industrial electronics, radio and television repair, sheet metal working, appliance repair, and numerical control operating.

Blueprint readers will need to use several linear units: micrometres (µm) for surface finishes; millimetres for chamfer dimensions; length and diameter of drills and hole sizes; metres for the length of stock, angle iron, tool beds, and highway widths. Area units of square millimetres will be used for the area of the end of a punch; square centimetres for sheet metal fabrication and size of openings; and square metres for the size of parking lots and machine locations. Cylinder capacity or engine displacement will be in cubic centimetres or litres. (Some European automobiles express engine displacement in *centilitres*. Thus, a 240 centilitre engine is equivalent to a 2.4 litre engine.) Excavation concrete, sand, and backfill will all be measured in cubic metres Structural steel, machine steel, machinery, and equipment will be measured in kilograms or metric tons. Air, gas, hydraulic, and plumbing system pressure will be measured in kilopascals.

Metal patternmakers will use micrometres for surface finishes; millimetres for shrinkage, blueprint dimensions, screw and bolt lengths and diameters, tool and drill hole dimensions; centimetres for the dimensions of sandpaper; and metres for wire length. The Industrial Fasteners Institute (1976) has published a book which lists the metric standards for screw threads, materials, bolts, screws and studs, slotted and recessed screws, nuts, and nonthreaded fasteners.

Metal patternmakers will use square millimetres for sectional areas of wire and the area of small openings. Square centimetres will be used for the area of paper and pattern surfaces. Core box volume or capacity will be measured either in cubic centimetres or in millilitres, and large tanks and containers will be measured in cubic metres. Packages of screws and bolts, pattern weights, and dry or solid supplies will be in kilograms. The power output of motors on lathes, drills, grinders, and other equipment will be measured in kilowatts (kW).

Numerical control (N.C.) operators will need to measure surface finishes in micrometres; length and diameter of screws and bolts, wrench openings, drill hole sizes, and N.C. tape in millimetres; and the length of N.C. tape in metres. The cross-sectional area of wire, small openings, and holes will be measured in square millimetres and the area of a machined face or surface will be in square centimetres. The mass of small machined parts will be in grams and of steel in kilograms and metric tons. Coolant temperature will be measured in degree Celsius. The feed rate of cutting, grinding, and shaping speeds for machining operations will be measured in *metres per minute (m/min)* and the flow rate of coolant will be in millilitres per second.

Tool and die makers will have many of the same uses for metric units as numerical control operators but they also will need to know some additional units. For example, tool and die makers will need to know that the unit for force of a ram or pressure pad setting will be in newtons and that torque specifications will be in *newton metres (N•m)*.

Welders will use millimetres for the size of a fillet weld, screw and bolt lengths and diameters, wrench sizes, and the diameter of welding rods; centimetres for the length of a weld, channel, pipe, I-beam, or rod; and metres for the length of pipe or conduit. Square millimetres will be used for the area of plug weld; square centimetres for the area of steel plate; and square metres for the area of a welding room floor. Quality liquids, gasoline, acetylene and oxygen purchases, and tank capacities will be in litres. The mass of cans of flux will be in grams, and packages of welding rods in kilograms. Wire feed rate for heliarc welding will be in *millimetres per second (mm/s)*. The electrode force will be in newtons and the flow rate of argon or carbon dioxide gas flow for gas-shielded welding will be measured in *litres per minute (l/min or L/min)*. Oxygen, gas, and hydraulic pressures and tensile strength will all be in kilopascals (kPa).

Industrial electronics, radio, television, and audio equipment repair occupations will use millimetres for the lengths and diameters of fasteners, screws, bolts, taps and dies, and resistors and capacitors. Metric sizes of some of these are shown in Figure 5 (Cooper and Magisos, 1976 [37]).

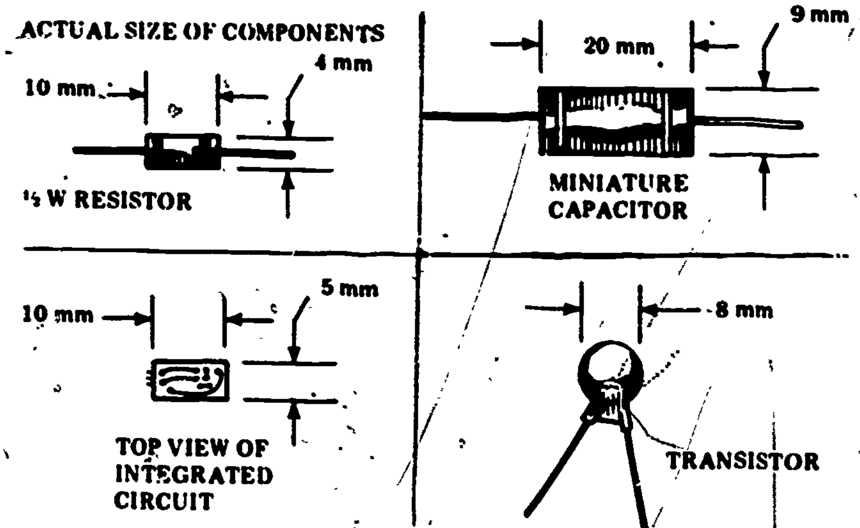


Figure 5. ELECTRONIC COMPONENTS

Lengths of control shafts, wire lengths, and switch openings will be measured in centimetres; wiring runs and antenna lengths in metres. The area of capacitor plates will be in square millimetres; of speaker baffle sizes, chassie layouts, and P/C boards in square centimetres; and of the space for installing audio control consoles in square metres. Stylus *pressure* on a phonograph record will be in grams and the mass of roll solder will be in grams and kilograms. (Since stylus *pressure* is a unit of force, it possibly will be given in newtons rather than grams--a unit of mass.) Energy dissipation and lamp sizes will be in watts (W) and kilowatts (kW). More detailed information on the metric units that will be used for the occupations in this cluster may be found in Cooper and Magisos (1976 [36], [37], [38], [39], [40], [41], and [43]).

MARKETING AND DISTRIBUTION

Occupations in the marketing and distribution cluster include automotive merchandising, petroleum marketing, food distribution, hard goods merchandising, soft goods merchandising, and transportation.

People who work in these occupations will have an important part in helping the public adjust to the metric system and to new standards. Those in general merchandise, hardware, building materials, and farm and garden supplies are likely to be affected first. They can help their customers translate needs into metric sizes and packages. Sears, Roebuck & Company has announced plans to be completely metric by the mid-1980s. Dean Swift, president of Sears, stated at the Third Annual Conference of the American National Metric Council that:

> Three-quarters of all American adults walk through a Sears store in a single year. That means we have a great opportunity to assist most of the American population.
>
> Our company employs more than 400,000 persons who probably reflect the same level of understanding as most Americans on the subject of SI measurement. If Sears is to implement a new system of measurement, we must have a plan. We will do it carefully, in stages, and with the least expense, confusion, and aggravation possible. . . .
>
> To inform our customers, we will gear every part of our organization, from our selling practices to our store signing, toward giving our customers a good working knowledge of the system so they can buy merchandise intelligently and confidently. This can be accomplished only if we ourselves have a good working knowledge of the system.
>
> We are setting about that task right now. This spring [1977], the Sears Extension Institute will offer a course to Sears employees on SI. We will train our buyers, headquarters people, and selling personnel in the system. (Swift, 1977, p. 8-9)

People in soft goods merchandising will need to know millimetres for button sizes, ribbon, and stationery; centimetres for clothing, shelving, zippers, and jewelry; and metres for hanging rods, layout, fabric, and carpeting. Cologne, perfume, liquid polish, after shave, wines, and soda pop will all be in millilitres. Pesticides, liquid cleaning agents, paint, paint remover will be in litres. Several soft drinks are already being bottled in one litre sizes. (While most people will use millilitres and litres only, it is possible to purchase merchandise from other countries that is labled in centilitres or decilitres. Thus, a 75 cl bottle of French wine contains the same amount of wine as a bottle that contains 750 ml.) Vitamins, nonprescription drugs, and spices will be in milligrams; paste polish, body powders, and direct mail will be in grams; and packages, solid cleaning agents, and candy will be in kilograms. Dilutions of cleaning agents, spot removers, and pesticides will be in grams per kilogram, millilitres per litre, or grams per litre. Application rates of cleaning agents and pesticides will be expressed in grams per square metre, millilitres per square metre, or litres per square metre.

Hard goods merchandisers will need to know millimetres for buttons, ammunition, bolts, screws, and lock pins; centimetres for cookware, sporting goods, and fans; and metres for wire, chain, and shelving. Concrete will be in cubic metres; cookware, water tanks, dehumidifiers, paint, and cleaning agents will be in litres. Kilograms will be used for washer and dryer loads, bowling balls, and small hand appliances. Power input and output for appliances and equipment motors will be in watts and kilowatts. Sound levels of motors and stereo hi-fi equipment will be measured in *decibels (dB)*--just as they are now. Quantities of evaporation or condensation of humidity control equipment will be litres per day.

Persons who work in automotive merchandising and petroleum marketing will use millimetres and centimetres for tolerances, tools, hoses, lines, wire, and tire sizes. Engine displacement will be in litres or cubic centimetres. Consumption rate of fuel will be in *kilometres per litre (km/l* or *km/L)* or, as is the practice in Europe, litres per 100 kilometres (l/100 km or L/100 km). Tire and air hose pressure will be in kilopascals, engine power in kilowatts, and torque for tightening fastenings in newton•metres. More detailed information on the metric units which will be used in the marketing and distribution cluster are in Cooper and Magisos (1976 [44], [45], [46], [47], and [48]), and in Lindbeck (1975).

PERSONAL SERVICES

Occupations in personal services include cosmetology, barbering, mortuary services, and household pet services. Most of the units and their uses are similar to those used by persons every day. Some special uses are centimetres for hair styling, cutting, and equipment dimensions (combs, scissors, and so forth). Amounts of shampoo, tints, hair clipper oil, and sterilizer concentrates will be in millilitres and litres. Shampoos, rinses, tints, bleaches, and sanitizers from liquid concentrates will be mixed in millilitres per litre.

Morticians will use centimetres for body and clothing sizes and grams for purchasing makeup. Cooper and Magisos (1976 [49]) provide many good examples of how metric units will be used in cosmetology.

PUBLIC SERVICES

Persons in some public service occupations issue patents, licenses, construction contracts, and deeds and will need to know the appropriate metric units. Most of these units have been discussed in previous clusters. Electrical energy units will not change so there should be few problems at electrical generating plants as a result of conversion to the metric system. (This information should provide relief to people who live in cities that suffer frequent blackouts.) Law enforcement and fire services will have need for several metric units.

Law enforcement personnel will need to know millimetres for gun descriptions, ammunition, and scale drawings; centimetres for ballistics, criminal investigations, and body measurements; metres for skid marks, accident descriptions, and target practice; and kilometres for traffic violations, landmark locations, and reporting position. The area measure of square centimetres will be used for tread marks and damaged areas. Square metres will be used for areas of search, scattered debris, and damaged areas. Narcotics and ammunition will be in grams; narcotics, body masses, and load limits will be in kilograms. Many law enforcement people are familiar with the slang expression of kilo for kilogram. Kilometres per hour will be used for moving violations, accident reports, and wind speed. Liquids in poisonings, alcoholic drinks, and liquid chemicals will be in millilitres.

Firefighters will use millimetres for fittings and wrenches; centimetres for hose diameters; metres for hose lengths, ladders, and building heights. Oxygen tank sizes will be in cubic centimetres and cubic metres. Oxygen and water quantities, liquid fuel and chemicals will be given in litres. Soda and foam will be in grams; dry fire retardant mix and fire extinguishers in kilograms. Dry mixes that are mixed in liquids such as soda-acid and foam extinguishers will be in grams per litre and fire retardant slurry will be in kilograms per litre. Pumping rates will be in kilolitres per second. Kilopascals per metre will be used to measure friction loss in a hose. More detailed information on metrics for law enforcement and fire services is in Cooper and Magisos (1976 [50] and [51]).

TRANSPORTATION

Occupations in the transportation cluster include auto mechanics, aviation electronics, diesel mechanics, and small engine repair. Many of the people in these occupations have worked with metrically dimensioned tools, equipment, and machines for some time. Most foreign and many domestic automobiles are already metric; over 90 percent of the parts on 1979 General Motors automobiles will be metric. Many school shops have metric tools and equipment.

Auto mechanics will use millimetres for shaft sizes and centimetres for bearing sizes. Piston head surfaces will be measured in square centimetres. Cylinder bores will be in cubic centimetres. Thermostats, engine-operating temperature ranges, and oil temperature ranges will all require an understanding of degree Celsius. Tire weights will be measured in grams; batteries and engines in kilograms. Manifold pressure compressions and air hose pressure will be in kilopascals and the work efficiency of an engine will be in kilowatt-hours (kW•h). *Rules for SAE Use of SI (Metric) Units* (Society of Automotive Engineers, 1973) contains further information beneficial to auto mechanics.

In addition to the units used by auto mechanics, diesel mechanics will use centimetres for journals and wrenches; millilitres for brake fluid and lubricating oils; kilograms for the mass of pistons and small engines; metric tons for the mass of large engines and load limits; and degree Celsius for ignition temperature, engine-operating temperature ranges, and thermostats.

Small engine repair people will use millimetres for cam shafts, spark gaps, spark plug lengths, stroke and bore tolerances, and length and diameter of fasteners. Centimetres will be used for hose lengths. Grease and heavy lubricants and the mass of a counter balance will be measured in grams and kilograms. Compression ratings and the pressure differential for fuel pumps will be measured in kilopascals. Output ratings of fuel pumps will be in millilitres per second or litres per second. Further details can be found in Cooper and Magisos (1976 [52], [53], [54], and [55]).

FURTHER RESEARCH AND DEVELOPMENT

The ERIC System contains many references on the metric system and its implications for occupations. Fifty-five of these references are from the same source--Cooper and Magisos (1976). The question to be answered is, "What is needed in the way of further research and development?"

Experiences gained by other countries that have adopted the metric system have been expremely valuable in the educational programs that have been advocated in the United States. Most people believe that the best way to learn the metric system is to learn it as a separate system and not by comparing it with the Customary system. Thus, persons should become familiar with estimating, measuring, and thinking in the metric system. People will need to be able to convert from the metric system to the Customary system and vice versa. Hopefully, they will have some conversion tables handy so that they do not have to learn the conversion rules or compute the needed data.

One advantage that the metric system is supposed to bring is a reduction in the use of fractions. No longer will there be measurements such as 4 3/16 inches. Instead, all measurements will be in the decimal system. Converting from one unit to another unit within the metric system should, theoretically, be much simpler. Yet, people who have attempted to teach the metric system to high school and post-high school students have had difficulty teaching conversion within the metric system (or, as it is often called, metric-metric conversion). Basic research is needed with regard to the most effective methods of teaching a better understanding of the decimal numeration system and the metric-metric conversion.

During the advent of the modern mathematics movement, one part of the curriculum that was being promoted was the study of different numeration systems. Much time was spent teaching students such numeration systems as base 2, base 8, and base 12 with the hope that by working in and studying these systems, students would gain a better understanding of the decimal (base 10) numeration system. For various reasons this was not the case. Students did not seem to understand the decimal system any better, and their computational skills decreased. If students are to have a better understanding of the metric system and of metric-metric conversion, they will need to better understand the decimal numeration system. Several basic research studies should be undertaken in an attempt to determine the best methods for teaching an understanding of the decimal numeration system.

If it is assumed that students do have a good understanding of the decimal numeration system, will they then be able to convert within the metric system? It seems to follow that students who do understand the decimal numeration system would have less difficulty with metric-metric conversion. Students who have learned the metric system with materials such as those developed by Cooper and Magisos (1976) do not perform well on questions of metric-metric conversion. Why? Is it because they do not have a good background in the decimal numeration system? Is it because they just have not had enough experience working with the metric system? Is it because the methods used to teach them metric-metric conversion were not the most effective? Research needs to be conducted to determine which of the questions should be answered "yes" and which should be answered "no." In addition, research needs to be conducted to discover which methods for teaching metric-metric conversion are the most effective.

At the present time very little is needed in the way of curriculum development. As various government agencies and professional organizations establish standards, then curricular materials need to be developed which show students how to use these standards and the metric system in their occupations. These curricular materials should be specific to the occupations and should contain many examples showing how the metric system is used in performing different tasks.

SUMMARY

This paper has addressed the subject of the metric system with regard to its history, a rationale for the United States' adoption of the metric system, a brief overview of the basic units of the metric system, examples of how the metric system will be used in different occupations, and some recommendations for research and development. The United States has come a long way toward adopting the metric system. There is still a long way to go. But, an understanding of the metric system and how it affects occupations will help make the transition easier.

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[1]	Metrics for Agricultural Mechanics	(ED 135 952)
[2]	Metrics for Agricultural Supplies & Services. Agricultural Production	(ED 135 953)
[3]	Forestry	(ED 135 954)
[4]	Horticulture	(ED 135 955)
[5]	Assistant Theatre Manager	(ED 134 751)
[6]	Broadcast Announcing	(ED 134 752)
[7]	Stage Lighting Technology	(ED 134 753)
[8]	Technical Theatre Assistant	(ED 134 754)
[9]	Theatrical Costuming	(ED 134 755)
[10]	General Office Clerks, Clerk-Typists, Typists	(ED 135 956)
[11]	Key Punch Operators	(ED 135 957)
[12]	Secretarial, Stenography	(ED 135 958)
[13]	Architectural, Civil, Mechanical Drafting	(ED 135 959)
[14]	Bindery Operation	(ED 135 960)
[15]	Commercial Photography	(ED 135 961)
[16]	Copy Preparation, Layout and Design, Type Composition	(ED 135 962)
[17]	Litho Photography, Offset Stripping, Offset Platemaking	(ED 135 963)
[18]	Offset Printing Press Operation	(ED 135 964)

[19]	Air Conditioning & Refrigeration, Heating, Ventilating	(ED 135 965)
[20]	Commercial, Industrial, Residential Electricity	(ED 135 966)
[21]	Plumbing, Pipefitting	(ED 135 967)
[22]	Wastewater Technology	(ED 134 756)
[23]	Dental Assistants	(ED 134 757)
[24]	Dietetic Technicians	(ED 134 758)
[25]	Licensed Practical Nursing	(ED 134 759)
[26]	Nurses Aides	(ED 134 760)
[27]	Nursing (RN)	(ED 134 761)
[28]	Alterations Specialists & Tailoring	(ED 134 762)
[29]	Child Care Aides	(ED 134 763)
[30]	Food Preparation, Baking, Meat Cutting	(ED 134 764)
[31]	Homemaker and Health Aides	(ED 134 765)
[32]	Interior Design Assistants	(ED 134 766)
[33]	Food Services	(ED 135 968)
[34]	Hotel and Lodging	(ED 135 969)
[35]	Recreation and Tourism	(ED 135 970)
[36]	Blueprint Reading	(ED 134 767)
[37]	Industrial Electronics, Radio-T.V. Repair, Audio Equipment Repair	(ED 134 768)
[38]	Metal Patternmaking	(ED 134 769)
[39]	Numerical Control Operators	(ED 134 770)
[40]	Sheet Metal Working	(ED 134 771)
[41]	Small Appliance Repair, Major Applicance Repair	(ED 134 772)
[42]	Tool and Die Making	(ED 134 773)
[43]	Welding and Cutting	(ED 134 774)
[44]	Automotive Merchandising, Petroleum Marketing	(ED 134 775)
[45]	Food Distribution	(ED 134 776)
[46]	Hard Goods Merchandising	(ED 134 777)
[47]	Soft Goods Merchandising	(ED 134 778)
[48]	Transportation	(ED 134 779)
[49]	Cosmetology	(ED 134 780)
[50]	Fire Service	(ED 134 781)
[51]	Law Enforcement	(ED 134 782)
[52]	Auto Mechanics	(ED 134 783)
[53]	Aviation Electronics	(ED 134 784)
[54]	Diesel Mechanics	(ED 134 785)
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APPENDIX A SI UNIT PREFIXES

Multiplication Factor	Prefix	Symbol	Pronunciation (USA)	Meaning (in USA)	In Other Countries
1 000 000 000 000 000 000 = 10^{18}	exa	E	ex' a (a as in about)	One quintillion times	trillion
1 000 000 000 000 000 = 10^{15}	peta	P	as in petal	One quadrillion times	thousand billion
1 000 000 000 000 = 10^{12}	tera	T	as in terrace	One trillion times	billion
1 000 000 000 = 10^{9}	giga	G	jig' a (a as in about)	One billion times	milliard
1 000 000 = 10^{6}	mega	M	as in megaphone	One million times	
1 000 = 10^{3}	kilo	k	as in kilowatt	One thousand times	
100 = 10^{2}	hecto	h	heck' toe	One hundred times	
10 = 10	deka	da	deck' a (a as in about)	Ten times	
0.1 = 10^{-1}	deci	d	as in decimal	One tenth of	
0.01 = 10^{-2}	centi	c	as in sentiment	One hundredth of	
0.001 = 10^{-3}	milli	m	as in military	One thousandth of	
0.000 001 = 10^{-6}	micro	μ	as in microphone	One millionth of	
0.000 000 001 = 10^{-9}	nano	n	nan' oh (an as in ant)	One billionth of	milliardth
0.000 000 000 001 = 10^{-12}	pico	p	peek' oh	One trillionth of	billionth
0.000 000 000 000 001 = 10^{-15}	femto	f	fem' toe (fem as in feminine)	One quadrillionth of	thousand billionth
0.000 000 000 000 000 001 = 10^{-18}	atto	a	as in anatomy	One quintillionth of	trillionth

APPENDIX B TYPE IT METRIC STYLE

1. CAPITALIZATION

1.1 Units

Unit names are typed in lower case except for the unit Celsius. The modifier "degree" in "degree Celsius" is lower case.

Correct:	Incorrect:
metre	METRE
litre	Litre
watt	Watt
degree Celsius	degree celsius

1.2 Symbols

All symbols are typed in lower case except for those units named after people, and for the prefixes mega-, giga-, and tera-.

Correct:	Incorrect:
kg	Kg
m	M
W (James Watt)	w
°C (Anders Celsius)	°c
M (mega-)	m
T (tera-)	t
G (giga-)	g

1.3 Table Headings

Units of measure in a table heading can be typed in either all capitals or all lower case. Do not mix capital and lower case letters in an individual unit of measure.

Correct	Incorrect
GRAMS	Grams
litres	Litres

2 PUNCTUATION

2.1 Period

Do not use a period after a metric symbol unless the symbol ends a sentence.

Correct	Incorrect
12 cm	12 cm.
350 g	350 g.
90 km/h	90 km /h.
50 ml	50 m l.

2.2 Semicolon

A semicolon separates numbers in a sequence.

Correct

61 211.1; 9.2; 0.45

Incorrect

61 211.1, 9.2, 0.45

2.3 Hyphen

2.3.1 Compound units

Use a hyphen or space to type compound unit names in full.

Correct:	Incorrect:
newton-metre	newton·metre
newton metre	newtonmetre

2.3.2 Prefixes

There is no hyphen or space between a prefix and a unit of measure.

Correct:	Incorrect:
millimetre	milli-metre
kilogram	kilo-gram
megahertz	mega hertz

3 SPACING

3.1 Prefix and Unit Symbols

Do not leave a space between a symbol or name having a prefix.

Correct	Incorrect:
mm	m m
millimetre	milli metre
kg	k g
kilogram	kilo gram

3.2 Numbers and Symbols

A space is left between a number and a symbol. The symbol for "degree Celsius" can be written with or without a space.

Correct	Incorrect
10 ml	10ml
8 m	8m
21°C or 21 °C	21° C

3.3 Grouping Numbers

Numbers that are 1 000 and larger use a space instead of a comma to separate groups of three digits. A space is left after each group of three numbers both to the left and to the right of the decimal point. In a four digit number the space does not have to be used except to align with tabulation.

Correct:	Incorrect:
12 486 g	12,486 g
1.035 26 m	1.03526 m
1025 cm or 1 025 cm	
25 987 m	25 987 m
6 025 m	6025 m
10 340 m	10 340 m
42 352 m	42 352 m

APPENDIX B--*continued*

APPENDIX B--continued

3.4 **Decimals**

No space is used before or after the decimal point.

Correct:	Incorrect:
56.45 m	56. 45 m
1 964.36 kg	1 964 .36 kg

3.5 **Mathematical Signs**

Leave a space on each side of mathematical operation signs (multiplication, division, etc.) except within a compound symbol.

Correct:	Incorrect:
2 cm × 4 cm	2 cm x 4 cm
8 g + 5 g	8 g+5 g
kg/m³	kg / m³
N·m	N · m

4. **SPELLING**

4.1 "re" or "er"

Both "re" and "er" are correct for the metric terms metre/meter and litre/liter. Whichever spelling you use, use that spelling consistently.

4.2 **Plurals**

4.2.1 Unit symbols

Do not add an "s" to a symbol to show a plural

Correct	Incorrect:
8 cm	8 cms
46 g	46 gs
3 ml	3 mls

4.2.2 Unit names

Unit names are made plural when required.

Correct	Incorrect:
75 metres	75 metre
2.2 kilograms	2.2 kilogram
3 litres	3 litre

4.2.3 Decimal fractions

Decimal fractions which are one or less are singular
Decimal fractions more than one are always plural

Correct	Incorrect:
0.5 gram (five tenths of a gram)	0.5 grams
0.8 metre (eight tenths of a metre)	0.8 metres
2.2 kilograms (two and two tenths kilograms)	2.2 kilogram
25.1 millilitres (25 and one tenth millilitre)	25.1 millilitre

4.3 Double Vowels

The final vowel in a prefix is omitted in megohm, kilohm, and hectare. For all other cases both vowels are retained and pronounced. Do not use a space or hyphen to separate the double vowels.

Correct:	Incorrect:
hectare	hectoare
milliampere	millampere
	milli-ampere
	milli ampere

5. FRACTIONS AND MATHEMATICAL OPERATIONS

5.1 Fractions

5.1.1 Decimals

Decimal notation is preferred for all fractions. However, common fractions with a denominator of 2, 3, 4, or 5 are acceptable.

Correct:	Incorrect:
4.43 km	4 43/100 km
0.375 m	3/8 m
0.75 g or 3/4 g	
1.2 m or 1 1/5 m	

5.1.2 Quantities less than one

In numbers less than one, a "0" precedes the decimal point.

Correct:	Incorrect:
0.46 cm	.46 cm
0.871 g	.871 g
0.75 ml	.75 ml

5.2 Multiplication

5.2.1 Unit symbols

Use a raised dot to indicate symbols for units derived as a product.

Correct	Incorrect
N·m (newton-metre)	N-m
Pa·s (pascal second)	Pas

5.2.2 Metric number calculations

Use "x" as a multiplier symbol for calculations. Do not use the "product dot."

Correct:	Incorrect:
6.2 mm x 5	6.2mm·5
120 cm x 10	120 cm·10
72 mm x .01	72 m·01

APPENDIX B--*continued*

APPENDIX B--*continued*

5.3 Division

Division is indicated by the diagonal (oblique stroke or solidus). Only one diagonal should be used in a compound unit of measure.

Correct	Incorrect
cm/s	$\frac{cm}{s}$
km/h	km ÷ h

5.4 Powers

5.4.1 Squares and cubes

Use metric symbols with a superscript to indicate area and volume.

Correct	Incorrect
55 mm^2	55 sq. mm
10 cm^3	10 cu. cm
3.4 m^2	3.4 sq. m

5.4.2 Scientific notation

Division can also be shown by using a negative exponent.

Example: $m \cdot s^{-1} = m/s$
$km \cdot h^{-1} = km/h$
$m \cdot s^{-2} = m/s^2$

6 OTHER SUGGESTIONS

6.1 Combining Metric Units

Do not combine metric units in one expression.

Correct	Incorrect
10.21 m	10 m 20 cm 1 mm
100 cm by 750 cm	100 cm by 7.5 m

6.2 Combining Words and Symbols

Do not combine metric words and symbols in one expression.

Correct	Incorrect
kilowatts per hour	kilowatts/h
kW/h	kW/hour

6.3 Prefixes

Use one prefix with a unit of measure.

Correct	Incorrect
Mg (megagram)	kkg (kilokilogram)
mm (millimetre)	dcm (decicentimetre)

6.4 Customary and Metric Symbols

Do not combine Customary and metric symbols in the same expression

Correct	Incorrect
kg/m^3	kg/ft^3
ml/m^2	oz/m^2

6.5 The Use of "Per"

Use the word "per" when writing out a metric expression. Substitute a diagonal (oblique stroke or solidus) to indicate the word per when writing metric symbols.

Correct	Incorrect
kilometres per hour	kilometres/hour
km/h	kph
joule per kilogram	joule/kilogram
J/kg	J per kg

6.6 Typing Suggestions

6.6.1 Typeface

Type metric symbols in upright (roman) type. Use of italic (script) letters should be avoided.

Correct	Incorrect
m	*m*

6.6.2 micro μ

If the symbol μ (mu) is not available, spell out the unit name. If necessary, the symbol can be made by striking the lowercase "u" and adding a tail to the lower left side.

Correct micrometre μm

6.6.3 ohm Ω

If the symbol Ω (Omega) is not available, spell out the unit name.

Correct ohm Ω

6.6.4 litre l

The symbol for litre is the lowercase "el". This is often confused with the numeral "1" (one). In cases where confusion might exist, spell out the unit name in full.

Correct 0.5 litre
70 l

APPENDIX B--*continued*

APPENDIX C   METRIC KEYPUNCH SYMBOLS

Quantity	Unit	Plural	Symbol	Special Key Punch Symbol
length	metre	metres	m	M
	centimetre	centimetres	cm	CM
	millimetre	millimetres	mm	MM
	kilometre	kilometres	km	KM
area	square metre	square metres	m^2	M2
	square centimetre	square centimetres	cm^2	CM2
	square millimetre	square millimetres	mm^2	MM2
volume capacity	cubic metre	cubic metres	m^3	M3
	cubic centimetre	cubic centimetres	cm^3	CM3
	litre	litres	l	L
	millilitre	millilitres	ml	ML
mass	gram	grams	g	G
	kilogram	kilograms	kg	KG
	metric ton	metric tons	t	TNE
temperature	degree Celsius	degrees Celsius	°C	CEL
	kelvin	kelvins	K	K
time	day	days	d	D
	hour	hours	h	HR
	minute	minutes	min	MIN
	second	seconds	s	S
velocity	metre per second	metres per second	m/s	M/S
frequency	hertz	hertz	Hz	HZ
	megahertz	megahertz	MHz	MAHZ

Quantity	Unit*	Plural	Symbol	Special Key Punch Symbol
force	newton	newtons	N	N
conductance	siemens	siemens	S	SIE
electric current	ampere	amperes	A	A
electric charge	coulomb	coulombs	C	C
electric potential	volt	volts	V	V
electric capacitance	farad	farads	F	F
electrical resistance	ohm	ohms	Ω	OHM
power	watt	watts	W	W
	kilowatt	kilowatts	kW	KW
energy	joule	joules	J	J
	kilojoule	kilojoules	kJ	KJ
illuminance	lux	lux	lx	LX
luminous intensity	candela	candelas	cd	CD
density	kilogram per cubic metre	kilograms per cubic metre	kg/m^3	KG/M3
pressure, stress	pascal	pascals	Pa	PA
	kilopascal	kilopascals	kPa	KPA
amount of substance	mole	moles	mol	MOL
luminous flux	lumen	lumens	lm	LM
magnetic flux	weber	webers	Wb	WB
magnetic induction	tesla	teslas	T	T
inductance	henry	henries	H	H

*The upper-case letters used to represent metric symbols are intended primarily for the use of data processing systems and equipment. They should never be printed out for publication or for other forms of public information. In these cases the special symbols must be replaced by the proper metric symbol or by the full names of the units.