SOME ARTICLES PUBLISED BY MANUEL MATEOS DE VICENTE

1. Metric System. Science, Sep-1965.
2. Integration of the british and Metric Systems. ASME . marzo 1964
3. Merging with the Metric System . Mechanical Enginee-ring- Nov. 1963
4. Near- Metric System . The Tool and Manufacturing En-gineer . Agosto 1963.
5. Salt Stabilized Roads. Street Engineering. Diciembre 1962.
6. Integrated Measuring System. The Iowa Ennginee-Abril 1962.

called genetics any more, but he otherwise remains unbowed.

I think, too, of the younger generation of biologists. Geneticists are among them, and they are known as geneticists in at least three institutes (to my personal knowledge). The younger generation is better and better trained, alert, imaginative, and unafraid. I found that they were well educated in the liberal arts, too, not through formal courses but because they had read and listened. Certainly they will begin to appear at genetic congresses—and elsewhere!

The authors failed to note that a volume on *Genetics and Selection of Microorganisms* was published in the Soviet Union in 1964—not earth-shaking perhaps, but indicative of scientific adeptness and speed.

HERMAN S. FOREST
19 Genesee Park Boulevard,
Rochester, New York 14611

Making the Scene

Have we stressed molecular biology too much? In a recent examination on evolution, I asked the students to "list the five epochs of the Tertiary Period." One answer I received was: "Pliocene, Miocene, Oligocene, Eocene, and *Cytosine*"!

JAMES H. CARLSON
Fairleigh Dickinson University,
Madison, New Jersey

More on Metrics: Clocks, Compasses, Music, and Milk Bottles

. . . We count by tens because we have ten fingers. But twelve is a much better base, and its advantages are so great that duodecimal currencies, weights, and measures have, I suppose, paralleled the decimal counting system throughout history. Even in France, where the metric system has been longest established, the duodecimal system still flourishes; for example a dozen is used there as it is with us, and eighty is expressed as "four score"; and the divisions of the circle, of the year, day, hour, and minute, once decimal, have reverted to the duodecimal system. Book sizes, time division in music, and the intervals of the diatonic scale, in fact the physiology of the sense of hearing, are all incorrigibly nondecimal. I suspect that a little reflection would produce many other similar instances.

It seems to me that the French and Russian revolutionaries missed their greatest opportunity to improve the world: rather than adopting the minor improvement of a decimal system of weights and measures, they could have made a major improvement by adopting the duodecimal system of counting, and a consistent compatible system of weights and measures. . . .

S. T. FISHER
53 Morrison Avenue,
Mount Royal, Montreal 16

. . . Great numbers of persons are already using the metric system in the U.S., and conversion will be of importance to the scientist. But we have to realize that the whole population of the U.S. is not scientists, and the common man has always been very reluctant to change the units he is used to. In many countries the metric system was enforced by law, and there were fines and prison sentences for those not accepting it. To illustrate the slowness of change, I may cite an experience of our engineering firm. Here in Madrid, 100 years after Spain's adoption of the metric system, in a design project for a new highway the prices of the land were given to us for our counterpart of acres and square feet (which are different from the British and different even from those of other Spanish regions). Of course in our plans we have used metric units. . . .

To gain mass support for a conversion, I have proposed a metricized British system [M. Mateos, *Mech. Eng.* **85**, 50 (1963)]. In this system, by making the quart and the pound slightly bigger we could have 1 metric quart (1 m-quart) = 1 liter, and 1 metric pound (1 m-pound) = ½ kilogram; and by making the inch a bit shorter, 1 metric inch (1 m-inch) = 25 millimeters. This change should be made in stages over a period of at least 10 years. It could be done first as a trial by one big industry —for instance the milk or gasoline industry—in order to appraise the results.

MANUEL MATEOS
Torán y Compañía,
Apartado 14432,
Madrid, Spain

PAPER NUMBER 63-PROD-24

AN
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PUBLICATION

Integration of the British and Metric Systems

MANUEL MATEOS

Research Associate,
Engineering Experiment Station,
Iowa State University,
Ames, Iowa.

Some professional groups are exerting pressure to revise the British system of measures and to study the possibilities of a complete change to the metric system. If any changes are made they will affect the whole population of the United States. Taking into account the experiences of other countries that changed from a British-like system to the metric system, the author proposes an adjustment of the British system to cushion the shock of the transition to the metric system. A metrisized British system could be introduced, since it appears that it would be readily accepted by the whole of the population. Since the conversion from the proposed metrisized British system to the metric can be easily done, it will be better accepted by foreign markets than the present British system. The use of more appealing designations for the most commonly used metric units is also recommended.

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Integration of the British and Metric Systems

MANUEL MATEOS

The controversy over the use of the metric or British systems in the United States is not new as reflected in the literature on this subject. Most of the scientific work is now done in metric units, but we still have the bulk of the population using the British system and unwilling to change to the metric. Regarding the metric system, the author recognizes some operational advantages in it, as it is based in our numerical decimal system, and great advantages due to the relationship among the different units of measure and weights. He also recognizes the vitality of the British system, which is an heritage of thousands of years and has been standardized and is used by the industry of several highly technological nations. The author was educated in the metric system, which he used exclusively until recently and has become familiar with the British through usage during the past 8 years. Based on his experience with both systems he will propose a workable method for integration of both metric and British systems.

ORIGIN OF METRIC SYSTEM

After the French Revolution, the establishment of a national system of weights and measures was considered in France. Rather than adopting one of the several systems in use at that time, a completely new system was introduced. The aim in the introduction of the new system was to establish an international rather than a national system.

The basis for the new system was a newly created unit of length – the meter. This unit was taken as the ten millionth part of the peripheral distance between the pole and the equator. However, this assumption proved to be erroneous and new definitions of the meter were necessary.

The word meter, taken from the Latin and Greek words for measure, was probably combined with the French words for gravity and liquid to define the units of weight and capacity; namely, gram and liter. Recurring again to the Greek and Latin the words deci, centi, mili, deca, hecto, kilo and miria were introduced to form units smaller or larger than the basic units. By using these words the liter, for instance, can be divided in 10 deciliter, 100 centiliters and 1000 mililiters, or else 10 liters are a decaliter, 100 liters an hectoliter, 1000 liters a kiloliter and 10,000 liters a mirialiter. The operational advantages of these units, based on our decimal system, are obvious. The words to designate the different units are very easy to learn; nevertheless, except for the basic units, they are very long for common usage and difficult to pronounce.

THE METRIC SYSTEM IN FRANCE

When the metric system was originated, several systems of weights and measures, depending on the regions and sometimes on the provinces, were used in France. These systems, like the present British system and other systems used in other European countries, were in general derived from the Roman system. There was a disagreement of measures for the same units among the different used systems, which pointed towards a unification of them. The philosophy of the French Revolution made possible the introduction of the "scientifically" designed metric system.

The first standard meter, built in 1793, was made legal in 1795 with the introduction of the metric system. In view of difficulties of adoption of the metric system, a decree was passed in 1800 authorizing the use of a more popular nomenclature, and later in 1812 a new parallel system was introduced which integrated both the metric and the old system. This was called the "usual System."

In this system a pound had 500 grams, a foot was 1/3 of a meter, and so on. This system was so well accepted that it was competitive with the metric and so in 1837 the decree of 1812 was repealed. Since 1840 it has been a penal offense to use other systems than the metric. Nevertheless, even today some of the old measures are still in use, many of them metrisized, like the pound of 500 grams, and so on. This is done despite the illegality of the use of the old system, although not in legal transactions to avoid legal prosecutions.

INTRODUCTION OF METRIC SYSTEM
IN OTHER EUROPEAN COUNTRIES

Many nations, like France at the time of introduction of the metric system, had several systems of weights and measures in use. This made it difficult to trade among different cities or regions of the same nation. The increased trade and the development of industry brought the need for unification and standardization of the measures and weights. Most nations favored the adoption of the French metric system rather than to establish one of the systems existing in the nation as the national system. This was the case of Germany, Spain, and others. The metric system was adopted by law in most countries and the use of the old systems was considered a crime and infractors were prosecuted. But, even today, there is a reminiscence of those ancient systems, which are exclusively used in the backward areas of those countries, and many trades still use ancient measures rather than metric.

England was the first country to industrialize, which brought the need for standardization of the system of weights and measures. England did not feel the need to adhere to the metric system because at that time they had standardized and unified their own system. The standard measures were correlated in the United States and in other countries under English influence. The early standardization by England of their system is the main cause of the present existence of the British system.

SOME CONSIDERATIONS ABOUT THE METRIC SYSTEM

The metric system is considered by its detractors as artificial and without vitality. Although it was necessary to enforce its use in the beginning in most of the countries, and still is in some of them, it cannot be considered artifical any longer due to its widespread use. Nevertheless it should be recognized that it lacks in vitality and most of its designations sound artificial.

The multiples and divisions of the basic units are designated by words of a meaning which is easy to grasp. However, words like centiliter, centimeter, and centigram sound very similar and are difficult to pronounce. Most of these words, like decagram, hectogram, mirigram, decigram, centigram, decameter, decaliter, hectoliter, mirialiter, deciliter, centiliter, are never used even in France. When the metric system was established, the derived units were given more appealing names, like "grave" instead of kilogram, and so on, probably through a study of the human psychology and linguistic science. But the short names were soon abolished and substituted for those we now know.

It is obvious that the metric system could have more vitality if some of the multiples and divisions that are never used were dropped. Also the most commonly used measures should be abbreviated, like cem for centimeter, and so on. This has been done in Europe with some of them; for instance by kilo everybody understands kilogram. The use of substitute names should also be introduced; for instance milimeter, a long word, could be well substituted by point or dot; centimeter by the above mentioned cem or by nail. In this way some of the more descriptive ancient names for measures could be revived. The metric system would be more appealing to the common people and, we hope, to the technologist and scientist.

INTEGRATION OF BOTH SYSTEMS

The complete change from the British to the metric system is practically impossible in the United States. The change, in this highly industrialized country, would cost many billions, perhaps several hundreds of billions of dollars. And this is only the material change which although expensive could be made, but it will be impossible to change the concepts of measure and weight of many millions of Americans who are used to and like the present system. Even a complete material change will be impossible. For instance, in land division, tracts a mile square are here to stay.

The change can be done, nevertheless, without disrupting the present concepts and at a cost a small fraction of a complete change. It would only require the restandardization of the British system adjusting the present units to exact numbers of equivalent metric units. This new system could be introduced gradually in this country, and its use would probably spread around the world together with the metric system.

The change of the units of capacity, for instance, could be done in the following way. The present unit is the gallon which equals to 3.785 liters. The American gallon differs from the English or Canadian gallon. It is proposed to restandardize the present American gallon to measure 4.000 liters. This new gallon should be called in the metrisized British system a metric gallon or m-gallon. Automatically when

1 m-gallon = 4.000 liters

1 quart = 1 liter

and so the British system would be integrated in the metric. Readjustments of the other measures of capacity would be necessary for a complete integration of the system. This change in the units of capacity can be done overnight with practically no strain to those persons used to the British system.

For a complete adoption in the country the cooperation of only two major industries is needed; i.e., the petroleum and dairy industries. All other industries are expected then to change to the new system.

The material change may require about 10 years; during which time both systems of measures of capacity would be in use. Then only the m-gallon would be the basic unit of capacity, which after a few years of exclusive use could be called just gallon.

As indicated in the foregoing this change should be gradual. The first change to be introduced should be in the units of capacity. If this change is welcomed by industry and the public, other units could be gradually integrated. For instance the pound, now of 453.6 grams could be restandardized to 500 grams. In this way

2 m-pounds = 1 kilogram

The foot now 30.48 centimeters could be restandardized to 30 centimeters, and so

1 m-foot = 30 centimeters

3 1/3 m-feet = 1 meter

1 m-inch = 25 milimeters

These changes may be confusing for a time and may need replacement of machinery in some industries. But it is a feasible way for passing to the metric system. It deserves to be tried for the measures of capacity for appraisal of the cost, and for public reaction. This will give us a basis for changing the other units or continuing the use of the British system indefinitely.

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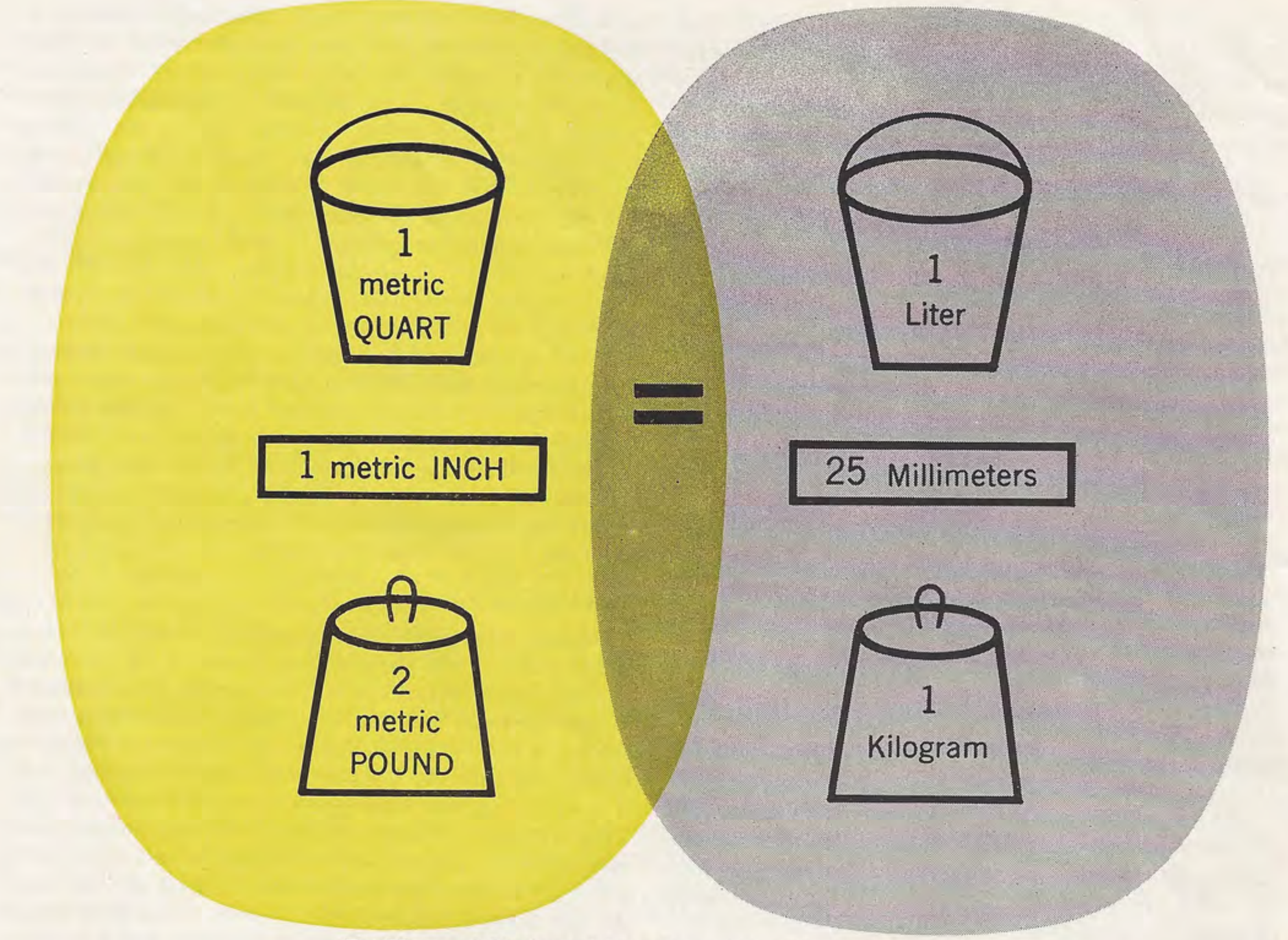


By Manuel Mateos,[1] Iowa State University, Ames, Iowa

MERGING WITH THE METRIC SYSTEM

Suppose one gallon equaled four liters (a slight change in the gallon would accomplish this). One "metric quart" would equal one liter. If the foot, now 30.48 centimeters, became 30 cm, one "metric inch" would then be 25 cm. With the pound which is now 453.6 grams restandardized to 500 grams, two "metric pounds" would equal one kilogram.

In its July, 1962, issue, Mechanical Engineering presented a four-part article entitled "The Metric System: Should we convert?" It took up four viewpoints: "All Out—Now," "Let Industry Decide," "Decimalize the Inch," and "The Transition." The writer on transition pointed out that "... the solutions proposed have been uncompromisingly drastic, with little understanding of the temperament of our people and their reverence for their unit heritage..." We present, here, a fifth suggestion, the possibility that the English and metric systems can be integrated gently and slowly. Is this a solution?

THE WHOLE population of the United States will be affected by any change from the British system of measures to the metric system. A substantial body of opinion believes that some form of standardization between the Continental and Anglo-American system may be inevitable, so that any suggestion tending to integrate both systems easily without altering the basics of either is worth close study.

When the metric system was originated after the French Revolution, several systems of weights and measures, depending on the regions and sometimes on the provinces, were used in France. These systems, like the present British system and other systems used in other European countries, were in general derived from the Roman system. There was a disagreement of measures for the same units among the different systems used, which pointed toward unification. The philosophy of the French Revolution made possible the introduction of the "scientifically" designed metric system.

The first standard meter, built in 1793, was made legal in 1795 with the introduction of the metric system. In view of difficulties of adoption of the metric system, a decree was passed in 1800 authorizing the use of a more popular nomenclature, and later in 1812 a new parallel system was introduced which integrated both the metric and the old system. This was called the "usual system."

In this system a pound had 500 grams, a foot was $^1/_3$ of a meter, and so on. This system was so well accepted that it was competitive with the metric,

[1] Research Associate at the Engineering Experiment Station.

material is transported away from the cutting edge and wear is dependent on the orientation of the aluminum oxide crystals. Work hardened alumina ceramics are more wear resistant in metal-cutting.

While alumina is a highly inert material, it does react slightly with metal oxides, and these reactions contribute to tool wear. Iron oxide reacts with alumina to cause a spinel on the surface of the tool, and wear results from the removal of this reacted surface. The presence of water accelerates the reaction and hence the rate of tool wear. If the steel being cut is coated with an oil film, the reaction is greatly reduced.

Microspalling is an intermittent phenomenon in which whole alumina grains or small aggregates of grains are suddenly removed from the tool. A qualitative correlation exists between size of alumina grains and width of wear grooves. Spalling is believed to result from weakening of the mechanical bonds that lock a grain in the adjacent grains. The cavity produced by the pulling out of a grain acts as a stress raiser on the next grains which are pulled out in their turn, producing the characteristic striations observed on ceramic cutting tools.

From a paper "Ceramic Tool Wear" by A. G. King, Norton Company. American Society of Mechanical Engineers, 345 E 47th St., New York 17, N. Y.

TO REQUEST COMPLETE PAPERS WRITE TO THE ADDRESS AND ORGANIZATION INDICATED AT THE END OF EACH ABSTRACT

Near-Metric System

With the ultimate aim of unifying the measuring systems, a twofold proposal is advanced which would gradualize the conversion of the British into the metric units by restandardizing British units to exact numbers of equivalent metric units.

As a first step, the gallon would be changed so as to make it exactly four liters. Later the pound would be made exactly 500 grams, and the foot would be made equal to 30 centimeters.

At the same time, some of the names for multiples and submultiples of metric units would be changed to provide easier identification, and some of the multiples, practically never used in practice, would be abandoned.

From a paper "Integration of the British and Metric Systems" by M. Mateos, Iowa State University. American Society of Mechanical Engineers, 345 E 47th St., New York 17, N. Y.

Molybdenum-Modified Stainless Steels

Corrosion resistance of ten Cr-Ni-Mn-austenitic and autenitic-ferritic stainless steels containing up to 5 percent moly-

Circle No. 177 on Page 39

Sodium chloride may be stored outdoors with simple protective covering.

Salt Stabilized Roads

By John B. Sheeler
Associate Professor of Civil Engineering

and

Manual Mateos
Research Engineer
Iowa State University

Table 1
Effects of sodium chloride in soils

Beneficial Effects:
- *Better water retention during compaction*
- *Increases maximum density*
- *Reduces surface permeability*
- *Forms a hard surface crust*
- *Reduces the freezing point of soil water*
- *Causes cementation by calcium carbonate*
- *Increases the density upon "curing"*

Detrimental effects or limitations:
- *Successful use requires a well graded soil*
- *Rain leaches salt from roadway*
- *Salt may cause increased slipperiness*

SODIUM chloride has been used in soil stabilization for the last 30 years particularly since Proctor's 1933 demonstration of the moisture-density relationships of compacted soils stimulated considerable interest in the use of soil as a construction material. This also aroused interest in the use of additives as an aid in compaction or to produce a more compact soil. There are now many thousands of miles of roads stabilized with this material.

Type of Sodium Chloride

Any type of sodium chloride can be used as a soil stabilizer regardless of where it comes from—sea water, rock salt mines or other sources. A certain amount of impurity can be tolerated since most of the impurities associated with sodium chloride are salts that act with soils in a manner very similar to sodium chloride. The salt should be crushed so that individual particles will pass a No. 4 sieve (opening of 0.187 in. = 4.76 mm) otherwise the performance may be erratic due to heterogeneity with respect to the salt in the mass.

Action of Sodium Chloride

The presence of common salt in the water used for compaction brings about changes in the structural arrangement of the fine particles of the soil. These changes are not well known although they may be related to the state of flocculation or dispersion of the soil colloids. The effects of these changes are somewhat reflected in the maximum density of the soil for a given compactive effort. The addition of certain amounts of sodium chloride to some soils increases the maximum density for a constant compactive effort (Figure 1). The state of flocculation depends on the amount of salt as can be easily seen in Figure 1. The increase in density also causes an increase in strength as measured by the California Bearing Ratio test (Figure 2). This

Soil-aggregate road to be treated with salt is first scarified to make mixing easier.

The rate of salt application can be controlled by a tailgate spreader.

means that a stronger base for the same compactive effort is produced or that less compactive effort is needed to obtain the same strength.

The presence of sodium chloride in the soil water depresses the freezing point (Figure 3), and lower temperatures are required to freeze the soil water. The soil is thus subjected to fewer freezing cycles and remains frozen for shorter periods during the winter months. Consequently the overall disruptive effects of freezing temperatures upon the soil are reduced.

A solution of sodium chloride has a lower vapor pressure than water alone so that water from a solution does not evaporate as easily as pure water. This water retention characteristic is useful at the time of compaction and during the life of the road. During construction, water containing sodium chloride is not lost as rapidly as pure water so that compaction may be continued for longer periods of time without the need of additional water. This peculiarity of salt solutions aids in achieving economical road construction in dry climates where water is difficult to obtain. During the life of a road the presence of salt tends to maintain the moisture, which is advantageous in friable soils.

Sodium ions which are supplied by the sodium chloride, absorb more water than other common ions in soil. The substitution of sodium ions for other ion types causes soils to be less permeable to the flow of water. For this reason, the presence of sodium ions in the clay at the surface of a road probably causes the surface to seal at the beginning of a rain thus forcing the water to run off rather than to percolate into the road. Sodium ions may increase the plasticity of the soil binder, mainly if montmorillonitic clay is present; this may cause slipperiness when wet. The extent of these phenomena is difficult to evaluate and depends on the gradation of the soil, type of clay, and other variables.

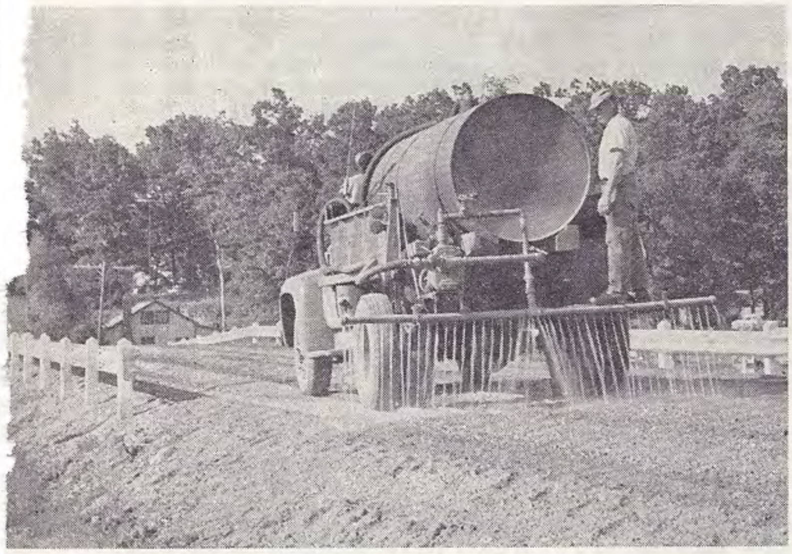
When calcitic aggregates are used, the sodium chloride solution is thought to increase the solubility of the calcium carbonate rocks and thereby contribute indirectly to additional stability. The additional stability results when drier conditions prevail and cause an increase in the concentration of the solution by evaporation of water, calcium carbonate precipitates and acts as a cementing agent for the road aggregates.

The hygroscopicity of sodium chloride is very low, consequently high relative humidities are required before any moisture is absorbed from the atmosphere. Generally, at the immediate surface of a granular road, the water evaporates and the sodium chloride crystallizes. The salt crystals interlock with the soil particles forming a hard crust which benefits the durability of the pavement. The drying of the sodium chloride stabilized soil also causes an increase in dry density of the soil mass. The mechanism of this increase in density is not well understood and is thought to be due to the increase in surface tension of the solution with an increase in the concentration of sodium chloride, combined with an increase in the forces of absorption created by the evaporation of part of the moisture.

Construction

Sodium chloride can be added to the soil either dry or in solution. Also, it may be either plant mixed or mixed in place.

The plant mix method provides a more uniform mixture since the different quantities of aggregates,



The salt treated material is watered so that the moisture content is brought up to near the optimum value.

Soil, sodium chloride and water must be thoroughly mixed for best results.

salt and water can be blended in exact amounts. The performance of plant mixed roads is an optimum. Plant mixing is the most expensive method and may be too expensive for some projects.

For the road mix or mix-in-place method, single or multiple pass roto-mixers, blade grader, or discs can be used. The roto-mixers give a very uniform mix and, if the amounts of salt and water are properly controlled, produce a mix of a quality near that produced in stationary plants.

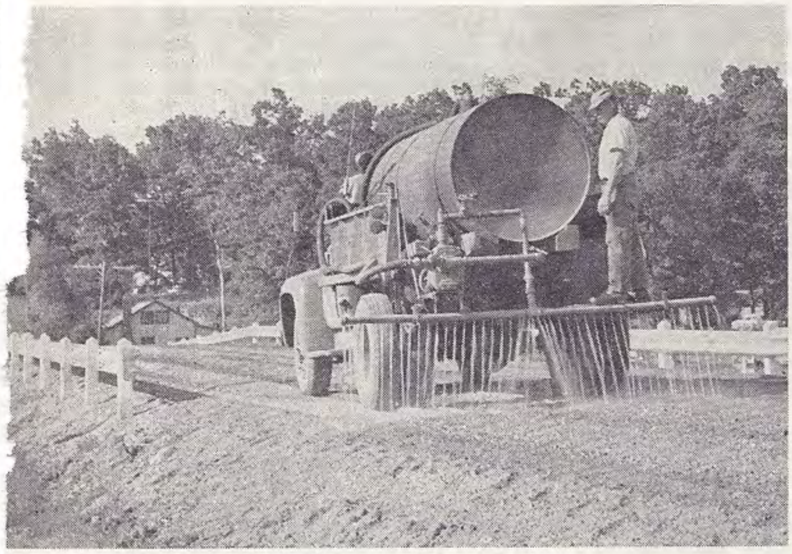
The optimum amount of sodium chloride needed is very low, between 0.5 and 1.0 percent based on the dry weight of the soil and usually nearer to the lower value. Excessive amounts of sodium chloride may not give the desired benefits of increase in density and strength, and may cause detrimental effects such as slipperiness during wet weather. So, care should be taken to avoid over treating in order to insure maximum results.

Immediate compaction with any type of roller is preferred, but it can be done at any time after mixing. The choice of compaction equipment depends on the characteristics of the soil used and, obviously, the availability of equipment.

Maintenance

The road should be regularly maintained and if signs of deterioration are observed it should be lightly bladed immediately following the next rain. If pot holes develop, patch them with a damp mixture of soil and salt compacted to maximum density. Sometimes potholes are filled by blading but this is the least satisfactory method. The surface of the road can be occasionally sprinkled with sodium chloride to replace any salt lost through the action of traffic or that was washed away by run-off water. The rate of addition of maintenance sodium chloride is about one pound per square yard. When the sodium chloride stabilized soil is used as a base or subbase course and is covered with an impervious mat, no further maintenance of the salt treated base or

The mixture is compacted with a pneumatic-tired multi-wheeled roller until the rollers fail to make an imprint.



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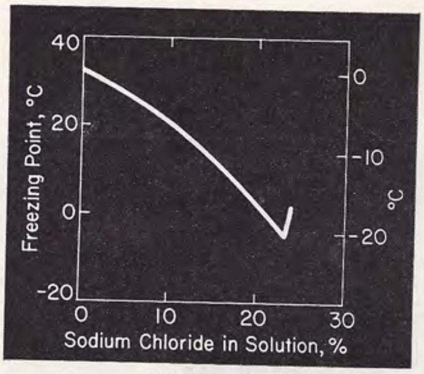

Figure 3.

subbase is required.

For best results the gradation of the soil should meet the AASHO: M147-57; ASTM: D 1241-55T requirements for a base, subbase or surface course. An excessive amount of fines with a high content of montmorillonitic clay may cause some surface slipperiness when treated with sodium chloride.

It is recommended that the road be maintained free of traffic for a few days to let the "crust" form to prevent undue surface raveling.

Salts collecting under automobiles sometimes accentuate corrosion of the metal parts. However, the amounts of sodium chloride associated with soil stabilization are small and are responsible for far less corrosion than the various salts used in deicing operations on paved roadways. Automobile manufacturers are aware of the problem and design changes are being made to minimize corrosion effects. ■

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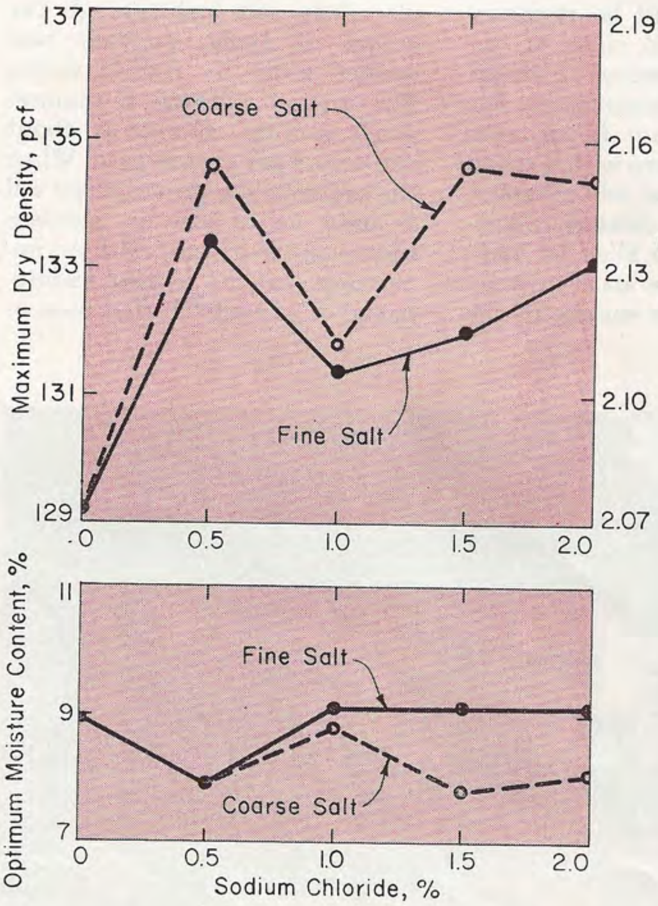

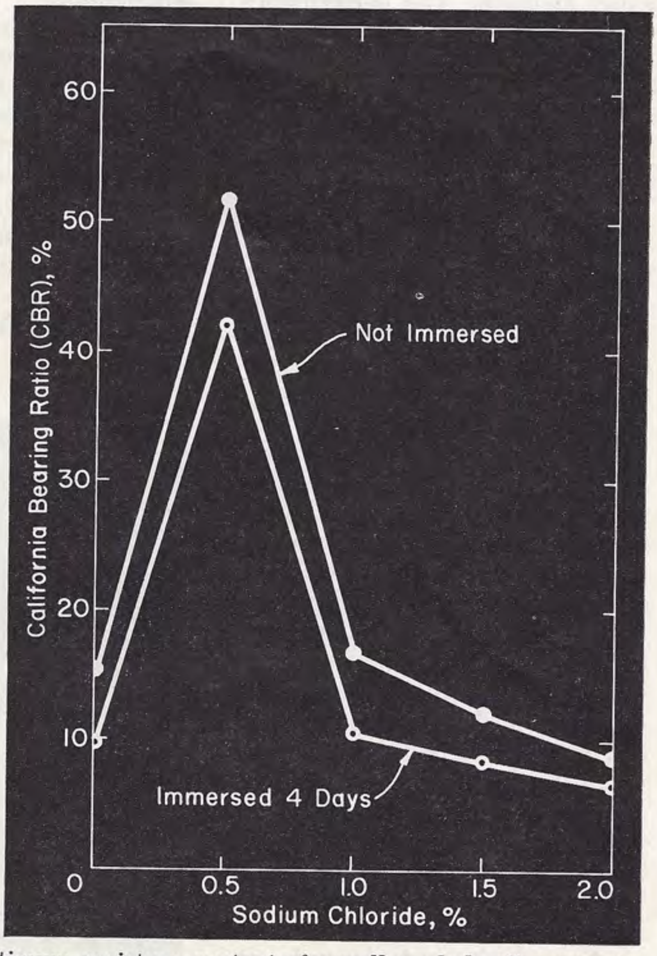

Figure 1. Influence of salt on the compacted density and optimum moisture content of a well-graded soil-aggregate mixture (A-2-4 AASHO Classification). *Figure 2.* CBR values for the same soil of Figure 1 treated with different percentages of a fine grained salt.

An I.S.U. professor proposes an . . .

Integrated Measuring System

by Dr. Manuel Mateos
Research Associate

DURING THE PAST year the controversy over the metric and British systems was revived in the magazine, *Civil Engineering*, through several articles and letters. The conclusion drawn from that controversy is that disagreement is complete on whether to change to the metric system or keep using the British. The writer recognizes some operational advantages of the metric system, as it is based in our numerical decimal system, and great advantages due to the relationship among the different units of measure and weights. He also recognizes the vitality of the British system, which is a heritage of thousands of years and has been standardized and is used by the industry of several highly technologically developed nations. The writer was "educated" in the metric system, which he used exclusively until recently and has become familiar with the British system through usage during the last eight years. Based on his experience with both systems he will propose a workable method for integration of both the metric and British systems.

Origin of the metric system

After the French Revolution, the establishment of a national system of weights and measures was considered in France. Rather than adopting one of the several systems in use at that time, a completely new system was introduced. The aim in the introduction of the new system was to establish an international rather than a national system.

The basis for the new system was a newly created unit of length: the meter. This unit was taken as the ten millionth part of the peripheral distance between the pole and the equator. However, this assumption proved to be erroneous and new definitions of the meter were necessary.

The word meter, taken from the Latin and Greek words for measure, was probably combined with the French words for gravity and liquid to define the units of weight and capacity: gram and liter. Referring again to Greek and Latin, the words deci, centi, mili, deca, hecto, kilo and miria were introduced to form units smaller or larger than the basic units. By using these words, the liter, for instance, can be divided in 10 deciliters, 100 centiliters and 1000 mililiters; or, 10 liters are a decaliter, 100 liters a hectoliter, 1000 liters a kiloliter and 10,000 liters a mirialiter. The operational advantages of these units, based on our decimal system, are obvious. The words to designate the different units are very easy to learn; nevertheless, except for the basic units, they are very long for common usage and difficult to pronounce.

The metric system in France

When the metric system was originated, several systems of weights and measures, depending on the regions and sometimes on the provinces, were used in France. These systems, like the present British system and other systems used in other European countries, were in general derived from the Roman system. There was a disagreement of measures for the same units among the different systems used, which pointed towards a unification of them. The philosophy of the French Revolution made possible the introduction of the "scientifically" designed metric system.

The first standard meter, built in 1793, was made legal in 1795 with the introduction of the metric system. In view of difficulties of adoption of the metric system, a decree was passed in 1800 authorizing the use of a more popular nomenclature, and later in 1812 a new parallel system was introduced which integrated both the metric and the old system. This was called the Usual System. In this system a pound had 500 grams, a foot was ⅓ of a meter, etc.

This system was so well accepted that it was competitive with the metric and so in 1837 the decree of 1812 was repealed. Since 1840 it has been a penal offense to use other systems than the metric. Nevertheless, even today some of the old measures are still in use, many of them metrisized, like the pound of 500 grams, etc. This is done despite the illegality of the use of the old system, although not in legal transactions to avoid legal prosecutions.

Introduction of the metric system in other European countries

Many nations, like France at the time of introduction of the metric system, had several systems of weights and measures in use. This made it difficult to trade among different cities or regions of the same nation. The increased trade and the development of industry brought the need for unification and standardization of the measures and weights. Most nations favored the adoption of the French metric system rather than to establish one of the systems existing in the nation as the national system. This was the case of Germany, Spain, etc. The metric system was adopted by law in most countries and the use of the old systems was considered a crime and infractors were prosecuted. But, even today, there is a reminiscence of the ancient systems, which are exclusively used in the backward areas of those countries. Many trades still use ancient measures rather than metric.

England was the first country to industrialize, which brought the need for standardization of the system of weights and measures. England did not feel the need to adhere to the metric system because at that time they had standardized and unified their own system. The standard measures were correlated in the United States and in other countries under English influence. The early standardization by England of their system is the main cause of the present existence of the British system.

We have in the world today two widely used systems of weights and measures and we are faced with the need for an unification of them. The trend in most countries is toward the metric system, and pressure is being exerted in the United States by several groups to change to the metric system.

The metric system is considered by its detractors as artificial and without vitality. Although it was necessary to enforce its use in the beginning in most of the countries, and still is in some of them, it can not be considered artificial any longer due to its widespread use. Nevertheless it should be recognized that it lacks in vitality and most of its designations sound artificial.

The multiples and divisions of the basic units are designated by words of a meaning which is easy to grasp. However, words like *centliter, centimeter* and *centigram* sound very similar and are difficult to pronounce. Most of these words, like *decagram, hectogram, miriagram, decigram, centigram, decameter, decaliter, hectoliter, miriaiter, deciliter, centiliter,* are never used even in France. When the metric system was estabilshed, the derived units were given more appealing names, like *"grave"* instead of *kilogram*, etc., probably through a study of the human psychology and linguistic science. But the short names were soon abolished and substituted for those we now know.

It is obvious that the metric system could have more vitality if some of the multiples and divisions that are never used were dropped. Also the most commonly used measures should be abbreviated, like *cem* for *centimeter*, etc. This has been done in Europe with some of them; for instance by *kilo* everybody understands *kilogram*. The use of substitute names should also be introduced; for instance *milimeter*, a long word, could be well substituted by *point* or *dot; centimeter* by the above mentioned *cem* or by *nail*. In this way some of the more descriptive ancient names for measures could be revived. The metric system will be more appealing to the common people and, we hope, to the technologist and scientist.

Integration of both systems

The complete change from the British to the metric system is practically impossible in the United States. The change, in this highly industrialized country, would cost many billions, perhaps several hundreds of billions of dollars. And this is only the material change which although expensive could be made, but it will be impossible to change the concepts of measure and weight of many millions of Americans who are used to and like the present system. Even a complete material change will be impossible. For instance, in land division, tracts a mile square are here to stay.

The change can be done, nevertheless, without disrupting the present concepts and at a cost a small fraction of a complete change. It would only require the re-standardization of the British system adjusting the present units to exact numbers of equivalent metric units. This new system could be introduced gradually in this country, and its use would probably spread around the world together with the metric system.

The change of the units of capacity, for instance, could be done in the following way. The present units is the gallon which equals to 3.785 liters. The American gallon differs from the English or Canadian gallon. It is proposed to restandardize the present American gallon to measure 4.000 liters. This new gallon should be called in the metrisized British system a metric gallon or m-gallon. Automatically when

1 m-gallon = 4.000 liters
1 quart = 1 liter

and so the British system would be integrated in the metric. Readjustments of the other measures of capacity would be necessary for a complete integration of the system. This change in the units of capacity can be done overnight with practically no strain to those persons used to the British system.

For a complete adoption in this country the cooperation of only two major industries is needed: the petroleum and dairy industries. All other industries are expected then to change to the new system.

The material change may require about ten years; during which time both systems of measures of capacity would be in use. Then, only the m-gallon would be the basic unit of capacity, which after a few years of exclusive use could be called just gallon.

As indicated above this change should be gradual. The first change to be introduced should be in the units of capacity. If this change is welcomed by industry and the public, other units could be gradually integrated. For instance the pound, now of 453.6 grams could be restandardized to 500 grams. In this way

2 m-pounds = 1 kilogram

The foot, now 30.48 centimeters, could be re-standardized to 30 centimeters, and so

1 m-foot = 30 centimeters
3⅓ m-feet = 1 meter
1 m-inch = 25 milimeters.

These changes may be confusing for a time and replacement of machinery in some industries may be needed. But it is a feasible way for passing to the metric system. It deserves to be tried for the measures of capacity and the cost and public reaction for this partial change should be appraised. This will give us basis for a change of the other units or to continue the use of the British system indefinitely.

The author would welcome any comments concerning the ideas expressed in this article. Address them to Dr. Manuel Mateos, Iowa Engineering Experiment Station, ISU; or Iowa Engineer, Bldg. J, I.S.U.