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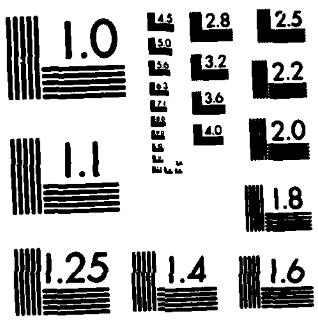

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Status and Outlook of Metric Conversion of Standards: The Views of Nine Selected Major Standards Development Bodies

May 1982

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This Interim Report described the interviews the U.S. Metric Board staff conducted with the nine selected major standards developing bodies that historically have developed a predominant proportion of U.S. voluntary consensus standards, and details the findings from these interviews. The nine standards bodies were suggested by the American National Standards Institute and the American Society for Testing and Materials. The interviews were conducted in the period April 1981 through January 1982. This Interim Report as well as other interim reports and information was used by the U.S. Metric Board in considering recommendations.

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UNITED STATES METRIC BOARD

OFFICE OF RESEARCH, COORDINATION AND PLANNING

Status and Outlook Of Metric Conversion of Standards
The Views of Nine Selected Major Standards Development Bodies

May 1982

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STATUS AND OUTLOOK FOR METRIC CONVERSION OF STANDARDS
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STANDARDS DEVELOPMENT BODIES

EXECUTIVE SUMMARY

Sections 6.4, 6.5 and 6.6 of the Metric Conversion Act (14 Stat. 339; 15 U.S.C. 204-5) call for encouraging the development of metric standards and also for encouraging industry and standards writers to maintain and enhance the current acceptability of superior U.S. technology and products during the transition period to metric.

The Board has proceeded to examine the standards process to determine a practical and appropriate course of action to satisfy the requirements set forth in the Act.

The Board has interviewed major Federal Government and private sector standards developing bodies, has conducted a survey covering over 400 U.S. standards developing bodies, and is in the process of surveying standards and specifications developing groups within the Federal Government to test a strategy for measuring progress in metric standards development in government and industry.

This Interim Report describes the interviews the U.S. Metric Board staff conducted with the nine selected major standards developing bodies that historically have developed a predominant proportion of U.S. voluntary consensus standards, and details the findings from these interviews. The nine standards bodies were suggested by the American National Standards Institute and the American Society for Testing and Materials. The interviews were conducted in the period April 1981 through January 1982. This Interim Report as well as other interim reports and information will be used by the U.S. Metric Board in considering recommendations.

The following are the major findings from the interviews:

(1) Metrication is not recognized as a major issue or problem for standards developing organizations.

(2) Several barriers to the development and use of metric standards exist and have been cited by standards developers. At present, the greatest barrier is simply the lack of demand for such standards. A significant barrier to metrication is competitively priced items or systems, whether in government or industry. Early costs of metric versions of products may be significantly higher than for inch-pound versions. An additional barrier is the dual maintenance (service tools, parts, and training of personnel) costs resulting from the initial conversion which would be expected to last for some period after

conversion. Some concerns related to safety from the development and use of metric standards were cited. Present use of inch-pound standards by regulatory agencies has not served as a significant barrier to the development and use of "metric" versions of standards.

(3) Standards development organizations react to market demand for their standards. Although the Department of Defense has announced a target date of 1990 for having necessary military metric standards available, there is at present no clearly articulated pressing demand for metric standards from industry, government agencies, or other users of standards.

(4) Standards developing organizations acknowledge the need for raising awareness among both the standards users and standards writing organizations of the advantage of continuous attention to consideration of hard metric in new product design, and especially in new technology areas.

(5) Standards work normally follows technology and reflects consensus on design and manufacturing processes. The language of the Metric Conversion Act can be interpreted to recommend anticipatory conversion of standards to support planned future conversion. Since metric standards represent a dimensional or measurement unit change only, such advance conversion of standards is probably technically feasible in most industries, but some experts feel strongly that metric development and conversion of standards which are not based on experience of prior use, testing and evaluation are highly questionable. In addition, since metric conversion appears to be proceeding incrementally and not by major sector coordinated industry-wide timetables it is unlikely that industry will support anticipatory development of metric standards. A national commitment to convert to the metric system, of course, would lead to industry support for anticipatory development of metric standards.

(6) For Federal agencies to have a real impact on the pace of metric standards development, agencies would have to specify metric in procurement, which would lead to some significant extra cost.

(7) Some organizations are concerned about the threat of foreign origin standards displacing U.S. non-metric standards but most standards writing organizations do not view this as a major problem. The standards bodies cited no cases where "foreign origin" international standards have replaced U.S. originated defacto or recognized international standards because these U.S. standards are not metric. Other factors, such as different power system voltage and frequency requirements, are far more important considerations for international acceptance of U.S. standards than whether or not a standard is in metric units.

(8) All of the interviewed standards organizations indicated that as yet the fact that U.S. standards are not metric has not been a substantial deterrent to international acceptance of U.S. inch-pound standards.

(9) Standards developers generally felt that they have the infrastructure in place to respond to a significant increase in demand for the development of metric standards should such a demand develop.

(10) Because of the wide variety of industry economic factors and technology, a single strategy for encouragement of anticipatory conversion of standards is difficult to develop.

(11) There are mixed feelings about the value of a national metric "log" or status report on conversion of standards. There is a feeling that if metrication is merely drifting along as it is now, such a log would not be of much value except in the aerospace area. However, in the event of a national conversion or an industry-wide decision to go metric, a metric log would be useful.

Our investigation of the impact of increasing metric usage on standards producers leads us to conclude that conversion by U.S. industry to metric is proceeding relatively slowly. While some inconvenience may result from lack of convenient and timely availability of new "hard metric" U.S. standards, other economic and social factors are far more significant considerations in the decision to convert manufacturing processes or products to metric.

STATUS AND OUTLOOK FOR METRIC CONVERSION OF STANDARDS THE VIEWS OF NINE SELECTED MAJOR STANDARDS DEVELOPMENT BODIES

I. INTRODUCTION

The U.S. Metric Board was established by the Metric Conversion Act of 1975 "which declares a national policy of coordinating the increasing use of the metric system in the United States, and to establish a U.S. Metric Board to coordinate the voluntary conversion to the metric system".

After considerable delay in Senate confirmation of 17 Board members the Board finally was established in 1978 and has been active in programs of research, coordination and planning, information and education. The Board is dedicated to assisting groups wishing to convert voluntarily to the metric system in the most cost-efficient and least disruptive manner possible.

Although the enabling legislation which created this agency is called the "Metric Conversion Act," conversion in the country is entirely voluntary. Congress established no deadline for it. Thus, the Board has no compulsory power and no mandate to promote conversion to the metric system.

The Board's job is to educate, inform and assist those parties who make a voluntary decision to convert. Because conversion is occurring voluntarily on a company-by-company and industry-by-industry basis, it is difficult to predict when, if ever, the metric system might become the predominant means of measurement in the United States. It may take ten years, or much longer, or it may never occur on a completely voluntary basis. Some view this as a serious flaw in the law and have communicated their concern to the U.S. Metric Board. Others believe that a "laissez faire" approach is best for the U.S. economy.

II. BRIEF REVIEW OF STANDARDS PORTION OF THE ACT

Three sections of the Metric Conversion Act deal directly with standards (a copy of the three sections of the Act is in appendix A).

Briefly, the United States Metric Board is required to:

6(4) encourage organizations to rapidly develop engineering standards on a metric basis and to take advantage of simplification opportunities, rationalization, etc.

6(5) encourage retention in new metric language of U.S. standards, designs, conventions, etc., which

1. embody superior technology, and
2. are now internationally accepted

6(6) work with the Department of State, international organizations, foreign governments, etc. to:

1. seek international acceptance of U.S. standards, and
2. encourage retention of equivalent, customary units in international standards during U.S. conversion.

III. EARLY STANDARDS ACTIVITIES OF THE BOARD

The first two years of the Board's existence were not very active ones as far as standards matters were concerned. The Board did send letters dated March 22, 1979 to 400 standards writing organizations to tell them about the standards sections of the Act and of its desire to cooperate with them.

On December 12, 1979, the Standards Liaison Committee of the U.S. Metric Board agreed to have the staff gather background information and make recommendations for development of a "standards strategy" to meet the requirements of the three sections of the Act that deal with standards. In order to define the problem, and plan a strategy, the Board staff initially visited the following organizations:

American National Standards Institute

American National Metric Council (ANMC), and the ANMC Ad Hoc Standards Task Group

American Society for Testing and Materials

Dr. Howard Forman, then Deputy Assistant Secretary of Commerce for Product Standards, and Chairman of the Interagency Committee on Standards Policy

The Metric Standards Subcommittee of the Interagency Committee on Standards Policy (the staff regularly participates in meetings of this Subcommittee)

Metric Commission Canada, the Canadian Standards Association, and the Standards Council of Canada

National Standards Association

IV. STANDARDS STRATEGY

Based on information collected from these visits, the Board staff developed a strategy for collecting information on a systematic basis from U.S. standards developing bodies, both in the public and private sectors, in order to make recommendations to the Board on how to meet the requirements of the Metric Conversion Act. The staff recommendations on information collection were approved by the USMB Standards Liaison Committee at its November 20, 1980 meeting. These activities were in three parts:

1. The Board explored how it might define the term standards as meant by Congress. After some initial work on a global task of making a complete taxonomic analysis of the world of standards, the Board came to the conclusion that with the resources available it should find a way to simplify the task. The staff settled on use of an already established Federal Material and End Item breakdown structure known as the Federal Cataloging System. The initial effort the staff made was to investigate the feasibility of initially using the Department of Defense portion of the approximately 700 Federal Supply Classes (FSC), groups and areas as a pilot classification system by which the U.S. Metric Board might monitor public and private metric conversion activities and associated supporting standards work. Under this concept the 100 FSC assignee/preparing activities that write the standards for items in each FSC would be asked to provide metric status and outlook information in their annual standardization reports. The Board would ask that the reports would not only indicate firm in-house plans and funded projects but would also indicate the federal technical experts' best information about planned private sector conversion activity and plans for development of metric standards. The results of this survey will be published in late FY82.

2. A brief survey of the over 400 standards development organizations listed in the November 1980 list "U. S. Organizations Represented in the Collection of Standards Maintained by the National Bureau of Standards" was conducted. A survey questionnaire was mailed to those organizations under a memo dated May 29, 1981. Questions included:

a. Does your organization have a formal policy on metrication?

b. What units does your organization use in technical publications, and its codes and standards?

The purpose was to get a general impression on the extent to which standards bodies have official metric policies, what their policies generally require, and the extent of metric usage in standards and codes. The results are given in the report entitled "Status of Metric Conversion, A Survey of U.S. Standards Writing Organizations", issued in 1982.

3. Finally, the Board staff conducted interviews with the following standards developing/writing organizations using the Interview Guide shown in appendix B:

1. Aerospace Industries Association on May 4, 1981
2. American Concrete Institute on April 29 and 30, 1981
3. American Society for Testing and Materials (preliminary meetings on June 26, 1980 and July 31, 1980) and letter dated September 30, 1981 summing up ASTM answers to interview guide
4. The American Society of Mechanical Engineers on May 12, 1981
5. Institute of Electrical and Electronics Engineers on May 12, 1981
6. National Electrical Manufacturers Association on December 8, 1981
7. National Fire Protection Association (letter reply dated March 19, 1981
8. Society of Automotive Engineers on April 21, 1981
9. Underwriters' Laboratories on January 4, 1982

These nine organizations were suggested by the American National Standards Institute and the American Society for Testing and Materials and are thought to be intimately knowledgeable about the processes involved in development of a wide spectrum of engineering standards.

The draft report of the findings were sent to the above standards organizations by letter dated March 19, 1982 asking for comments.

The findings in this report as well as the findings from the other two reports cited above, along with information from the American National Standards Institute, and other sources cited on page 5 are forming the background for any U.S. Metric Board recommendations to be considered at the Board meeting in July 1982.

V. BACKGROUND ON THE NINE INTERVIEWED STANDARDS ORGANIZATIONS.

American Concrete Institute (ACI).

The ACI* is devoted to the solution of technical problems related to the design, construction, and maintenance of concrete and reinforced concrete structures and to the dissemination of information in this field. Standards committee efforts have produced standards, recommended practices, design handbooks, codes, and reports in every important area of concrete technology. There are about 100 technical committees.

There are currently about 30 ACI standards concerning just about every area of concrete practice. Perhaps the most important standard published by ACI is 318-77, "Building Code Requirements for Reinforced Concrete". Of the four model building codes, three reference the Code and one copies most of it. This Code is soft converted; also there is a list of metric equivalents in the back of the publication. The next revision is due in 1983. There will be a metric version available at that time but it is uncertain whether it will be in published or manuscript form. The Code is translated into several other languages. It is used as the basis for the concrete portion of the building codes of many other countries, such as Canada and New Zealand. Other ACI standards cover such areas as concrete pipe, structural plain concrete for buildings, concrete chimneys, concrete pavements and bases, and concrete masonry.

Policy on the use of metric units in standards is shown in the ACI Policy statement in appendix C (paragraph 3.4.5 from the ACI Technical Committee Manual-June 1979). Some ACI standards on proportioning concrete contain metric examples for its foreign membership (Committee 211 standards).

Aerospace Industries Association of America, Inc. (AIA).

AIA is the national trade association representing the principal corporations involved in the research, development, and manufacture of

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*Acronyms for the standards bodies are listed in appendix E. Acronyms are used throughout the rest of this report.

aircraft, space vehicles, missiles and related equipment. One of the many functions of the association is providing a forum for establishing industry consensus on standardization and standardization management issues.

The primary AIA committee responsible for developing standards is the National Aerospace Standards Committee (NASC). Since 1938, the NASC has developed more than 2600 standards for airframe fasteners and other mechanical parts. Personnel from the defense services, Defense Industrial Supply Center and Defense Electronics Supply Center participate actively in the preparation of NAS standards, and liaison is maintained with FAA, NASA, AIA Canada and the airlines. NAS standards are developed on the basis of user requirements, although coordination is accomplished with suppliers and other materially affected interests.

The AIA position is to have metric standards prepared to meet market needs -- a state of "informed readiness." To date, over 130 metric NAS standards have been published. Two metric guidance documents prepared by the NASC have been coordinated widely throughout the aerospace industry: NAS 10000, "NA Documents Preparation and Maintenance in SI (Metric) Units," and NAS 10001, "Preferred Metric Units for Aerospace."

As secretariat of the Aerospace Sector Committee of the American National Metric Council, AIA sponsors a coordinating log tracking development of metric standards relating to aerospace.

AIA also provides the international secretariat for Technical Committee 20, the Aircraft and Space Vehicles standards body of the International Organization for Standardization (ISO).

American Society for Testing and Materials (ASTM).

ASTM is a nonprofit corporation formed for the development of standards on the characteristics and performance of materials, products, systems, and services and the promotion of related knowledge. In ASTM terminology, standards include test methods, definitions, recommended practices, classifications, and specifications. ASTM has some 6600 standards developed by 137 main committees and 1920 subcommittees. The Committees function under definite regulations governing the personnel and methods of procedure. The standards committees themselves determine the technical scope, content, and requirements of the standards, but the standards must conform to certain formats. For ease of reference, the standards are published in collective form and each is also issued in a separate pamphlet form. ASTM publishes the Book of ASTM Standards in 48 volumes annually in various months of the year. Of its 6600 standards, only 66 were hard metric as of April 2, 1982; however the number of hard metric standards has been increasing rapidly each year. All ASTM metric module standards are denoted by an upper case "M". The ASTM metric policy is in appendix C. A list of ASTM (Hard) Metric Standards is in appendix D.

ASTM is the developer and publisher of ASTM E 380-82, Standard for Metric Practice. This standard was developed by consensus procedures and gives guidance for application of the modernized metric system (SI) in the United States. The standard also has an extensive list of conversion factors to provide equivalent values in SI units for miscellaneous units of measure. ASTM also publishes "Use of Metric (SI) Units in ASTM Standards" as Part H of Form and Style for ASTM Standards, June 1980 (copy in appendix C). These instructions are to guide technical committees in the writing of ASTM standards using SI by following ASTM E 380 and its approved supplementary metric practice guides.

The American Society of Mechanical Engineers (ASME).

The development of codes and standards is an important part of ASME's activity in promoting the art and science of mechanical engineering. For nearly 100 years, the Society has pioneered the development of Codes, Standards, and related Certification Programs. Presently, over 7000 engineers and related scientists participate in ASME Codes and Standards activities. There are Committees on Standardization, Safety Standards, Boiler and Pressure Vessels, Performance Test Codes, and International Standards. ASME has published:

(1) ASME Orientation and Guide for Use of SI (Metric) Units, 1978
(2) ASME Text Booklet, SI Units in Strength of Materials, 1976
(3) ASME Text Booklet, SI Units in Dynamics, 1976
(4) ASME Text Booklet, SI Units in Thermodynamics, 1976
(5) ASME Text Booklet, SI Units in Fluid Mechanics, 1976
(6) ASME Text Booklet, SI Units in Kinematics, 1976
(7) ASME Guide for Metrication of Codes and Standards SI (Metric) Units
(8) ASME Text Booklet, SI Units in Heat Transfer, 1977
(9) ASME Text Booklet, SI Units in Vibration, 1976
(10) ASME Steam Tables in SI (Metric) Units For Instructional Use, 1977
(11) Steam Charts, SI (Metric) and U.S. Customary Units, 1976
(12) Transactions of Technical Conference on Metric Mechanical Fasteners, 1975.

The ASME also has a Metric Policy developed by the Special Committee of the Council on Metric System and issued on May 4, 1977; a copy is in appendix C.

ASME has 462 separate committees which have effected 1150 codes and standards. ASME publishes a number of metric modular standards such as in the B-18 fastener, screw thread, and B-32 sizes (e.g., sheet thicknesses, tubing sizes) areas. Most of the ASME metric standards are in areas where there is significant international trade. Until recently, there was insufficient need for a hard metric version of the ASME Boiler and Pressure Vessel Code and industry would not support the metric version. The Code is not a one time effort - every six months, both the SI and customary versions would have to be updated. A soft conversion of the Code would not have been a satisfactory solution to the need for a metric version of the Boiler Code. There are about 300 engineers and allied scientists involved in maintaining the Code. However, one of the 22 parts of the Code now has a metric counterpart. The staff engineers will continue to prepare hard metric parts of the Code with the intent of publishing a complete metric Code by October 1, 1983. At present, the customary version is used worldwide. The Code is an international standard under the GATT Code. There are engineers and allied scientists from many countries who participate in the development and maintenance of the Code.

Institute of Electrical and Electronics Engineers (IEEE).

Standards activities within the Institute are entrusted to the Standards Board which is responsible for final approval of IEEE standards and for representing the IEEE in matters relating to units and standards. The Standards Board is responsible for authorization and coordination of standards projects within the Institute. The work of preparing IEEE standards is carried out within the Technical Committees of the 31 groups and societies within the Institute. There are presently about 450 IEEE standards covering electrical and electronics equipment, test methods, units, symbols, definitions, and rating methods. In addition, there are about 250 projects underway for the development of new standards.

While the major portion of IEEE membership is within the United States, the Institute is international in character, and its standards activities are neither limited to U.S. members, nor are its standards generated for the exclusive use of the U.S. engineering community.

Most IEEE standards are in metric already. Most IEEE standards are concerned with systems and non-dimensional standards. The IEEE is the developer and publisher of IEEE Standard 268-1982, IEEE Standard Metric Practice. This standard was developed by consensus procedures and gives guidance for application of the modernized metric system (SI) in the United States. The standard also has an extensive list of conversion factors to provide equivalent values in SI units for miscellaneous units of measure.

National Electrical Manufacturers Association (NEMA).

NEMA is the "Nation's largest trade association for manufacturers of products used in the generation, transmission, distribution, control and end-use of electricity". NEMA deals with heavy electrical equipment like motors and generators, rather than electronics or home appliances. NEMA is a leading developer of voluntary standards (some 200). It is concerned about the quality and reliability of members' products, and safety in manufacture and use. A large part of the work of any NEMA Subdivision is keeping its standards current and ensuring that new voluntary standards are developed when needed. Many NEMA Subdivisions also participate in other standards - making organizations, both national and international. The increasing importance of international standards makes NEMA's participation in the International Electrotechnical Commission (IEC) vital to industry. NEMA activities are divided into 75 product sectors (wire, generators, and circuit breakers are examples). Every company member has one vote on each of the committees. These sectors have technical committees which write draft standards. The draft standards are voted upon by the sector before it goes to the Codes and Standards Committee for publication approval. The NEMA staff also reviews the standards before publication to make sure procedures have been followed. The Codes and Standards Committee is a committee of 25 senior members from NEMA companies (e.g., director of standards in a company). Many of the technical committees have members who are active on IEC technical committees, and therefore are quite familiar with IEC activities. They try to harmonize IEC and NEMA standards to prevent inconsistencies. The NEMA Metric Conversion Subcommittee of the Codes and Standards Committee wrote the NEMA metric policy statement dated June 3, 1976 (copy in appendix C). This Subcommittee has not met much lately. NEMA has provided the Chairman and the Secretary of the ANMC Electrical Goods Sector Committee.

NEMA has a list of "Metricated NEMA Standards" dated August 14, 1981 (copy in appendix D). One standard is hard converted into metric modules, and three are "SI units only". The rest of the 41 standards on the list are "fully metricated, in that they use metric units of measurement consistently". NEMA has a set of "Legal Guidelines for Metrication of NEMA Standards" (copy in appendix C).

National Fire Protection Association (NFPA).

The NFPA is a nonprofit, technical and education organization to promote science and improve the methods of fire protection. One of the main functions of NFPA is in the standards making field under which codes, standards, and recommended practices are developed as guides to engineering protection for reducing loss of life and property by fire. The standards activity is handled by 162 committees and sectional committees whose membership is comprised of approximately 2100 individuals representing qualified international, national and regional organizations, NFPA sections or technical committees. Fire safety has broad applications and the standards formulated and adopted by the Association cover a wide range of subjects. The standards are combined and published yearly as National Fire Codes which include volumes in such areas as Gases, Building Construction and Facilities, and Electrical (including the National Electrical Code). There are over 200 standards published in the National Fire Codes.

These codes and standards are nationally recognized and widely adopted by the Federal, state and local governments. Being an international organization with members in more than 80 countries, NFPA is involved in international standards programs in ISO and the Canadian Electrical Code Committee. NFPA is by far the largest publisher of standards in the fire field, but does not write product standards per se. The impact of NFPA standards on the marketplace pertains primarily to installation practices rather than product specifications. NFPA has issued a directive to soft convert all of its standards within five years.

Society of Automotive Engineers (SAE).

SAE is considered the second largest developer of standards behind ASTM. It develops about 500 standards per year mostly in the area of vehicles (construction equipment, snowmobiles, underwater vehicles, as well as on-the-road and aerospace vehicles). It has been active in safety, environmental, and fuel economy standards (for example, there are 32 standards on truck fuel efficiency alone). SAE has been involved in screw thread standards since almost the turn of the century. It has been involved in physical characteristics and composition of materials standards. Many SAE standards are adopted for non-vehicular uses (e.g., drawing standards).

Most SAE standards are highly technical. In many cases the necessary data is not quite adequate to write a standard and thus it is necessary to have research programs to develop the technology. SAE often cooperates with company research programs; these programs are not involved in proprietary development or activity. SAE has worked closely with government agencies and has served as a forum for government and industry.

There are roughly 600 SAE committees which are grouped under seven councils. The councils approve the standards. All councils and many committees have metric advisory subcommittees. SAE also has a metric committee. SAE standard J916, "Rules for SAE Use of SI Metric Units" (copy in appendix C) is a SAE Recommended Practice. The SAE Statement of Metric Policy is also in appendix C. SAE has been a leader in the development of metric standards (for the farm equipment industry, for example). SAE has a series of standards on aerospace materials which have parallel customary and metric versions. However, there are other customary standards where metric parallels will not be available for some time because expensive testing is required.

Underwriters' Laboratories, Inc. (UL).

UL is a not-for-profit organization established to evaluate electrical and mechanical products, building materials, construction systems, fire protection equipment, and marine products, to determine that their design provides for reduction of the risk of injury to persons and damage to property incident to their use; to identify such products correctly through a system of marking that permits their recognition by consumers, authorities having jurisdiction, and others; and to establish, through contractual arrangements with manufacturers for UL's audit of production, conformance of the products with applicable requirements. Federal, state, and municipal authorities, plant operators, architects, building owners and users may either accept or require listing or classification by UL as a condition of their recognition of devices, systems, and materials having a bearing upon life and fire hazards, and upon theft and accident prevention.

UL is divided into several engineering departments, each dealing with distinct and separate subjects as follows: electrical; heating, air-conditioning, and refrigeration; casualty and chemical hazards; burglary protection and signaling; fire protection; and marine. Each of these departments has prepared standards providing specifications and requirements for construction and performance under test and actual use of systems, materials, and appliances of numerous classes submitted to the laboratories.

UL has issued more than 450 standards for safety based on sound engineering principles, actual experience, and an appreciation of the problems of manufacturing, installation, and utility. These standards for safety are the result of years of research and collaboration by engineers, manufacturers, consumers, and recognized specialists in many fields, including the members of the five UL Engineering Councils and its Consumer Advisory Council. UL standards are not developed by the Committee method. UL standards and requirements represent the basis upon which UL's registered marking may be affixed to complying products by subscribers to UL's services.

A catalog listing all available UL standards for safety is published twice each year. Many of the UL standards are recognized as American National Standards by the American National Standards Institute.

Since 1972, UL has provided "soft" SI metric units in its standards. The standards reflect the preferences of the industries concerned with the standards. If the industries involved, individually or collectively, express a need for the development of "hard" metric standards, UL would have no difficulty responding to the need. This has already occurred in several UL standards.

VI. FINDINGS

Question 1. For each of your committees, what do they perceive as the main barriers or reasons for not developing metric standards?

At present, the greatest barrier to the development and use of metric standards is simply the lack of demand for such standards. Standards development organizations see themselves as suppliers reacting to the marketplace. The Government, industry, trade groups and other users of standards determine the demand for standards. Several of the interviewed organizations (e.g., SAE, ASTM, ASME) said that until top technical management in an industry makes the decision to go metric, metrication, including development of metric standards, will not progress in that industry. UL said that there is no barrier or reason for not developing metric standards - only a lack of need.

When metric standards are needed, the standards developers say they can and will react. Of 6600 ASTM standards, only 66 as of April 1, 1982, were in hard metric dimensions; however, the number of hard metric standards has been increasing rapidly each year because the demand is growing.

For each of the organizations, the committees of the organizations determine the requirements for standards, including metric requirements, not the society headquarters staff. (UL however, is an exception since it does not develop standards by the committee method; it develops standards for each product category investigated by UL). The people on the committees represent industrial firms, government agencies, and other affected interests. Until those industries or agencies determine the need for metric, metric module standards will not be developed. When it makes economic sense to develop and use metric standards, industry will do so. For example, farm equipment is designed in metric because its design, manufacture, and use is a world market as automobiles are. One standards body said that "metrication has lost steam because of bad economic conditions; people are afraid of the costs of metrication."*

A significant barrier to metrication is buying the cost effective item or system, whether in government or industry. For example, DoD directives say buy the most cost effective item. The early acquisition cost may be significantly higher for a metric version during the first few years of its life in a predominant non-metric environment even though total life cycle cost may be less for the metric version after the environment in which it then exists makes it less "special" than its inch-pound equivalent. Even though the life cycle costs over say 30 years may be less for the metric version, industry or government "cannot be completely logical in this". The long term savings of a metric design often are not of sufficient magnitude to overcome the higher initial cost barrier. Since there is a strong feeling among those interviewed that the U.S. eventually will go metric, the committees and staffs are on the alert to considering hard metric standards. But, at present "we all have to be in the real world and go with the need. We will be there with metric standards whenever they are needed".

Another reason cited was the difficulty in developing metric parts standards when the system or product design standards are not metric. Much time is required to develop design standards and then a long time is required to validate them. NFPA standards may contain, references to other standards which are not in metric; for example, a table of wire sizes and the capacity of those wire sizes. The Committee would not change the table unless the wire industry converted completely to metric sizes. This has not happened as yet. IEEE points out that the hard conversion of the very common electrical wiring conductors - 10, 12, and 14 AWG - should be recognized as a major problem. Electrical conductor hard metric size conversion presents problems in such areas as:

a) compression connector assembly tools are sensitive to wire diameter,
b) existing requirements limit the current per unit cross section of wire,
c) overcurrent protection device ratings are coordinated with existing AWG wire sizes, and
d) electrical appliance current demands are coordinated with branch circuit ratings (and indirectly to wire size).

The lack of metric sizes for basic components and materials such as lumber, concrete blocks, sheet metal, and reinforcing bars also present barriers to hard conversion in many areas. (ASTM, however, has come out with ASTM A615M "Deformed and Plain Billet Steel Bars for Concrete Reinforcement").

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*U.S. Metric Board funded research studies have shown that this is a common perception. However, these studies have shown that the actual conversion costs of companies now making metric products have been nominal. For example, one principal finding from the report "The Consequences of Metric Conversion for Small Manufacturers", a report funded by the U.S. Metric Board and released in 1982 is "Investments in conversion are routine, insubstantial, and difficult to isolate from other business costs. As such, metrication costs pale in comparison to small businesses' concerns with inflation, energy and material costs, interest rates, and general economic conditions."

Several standards organizations cited concerns related to safety from the conversion of standards. For example, the S-7 Committee on Cockpits of SAE has been very concerned about conversion. "Metrication is not a case of merely putting new faces on dials; the whole thinking process has to be changed." In spite of these problems, there is the recognition by the Committee that some metric standards may be needed.

One standards organization said that a perceived barrier to the development of metric standards is the feeling that adoption and use of metric standards makes it easier for foreign competition to enter the U.S. market.

Finally, AIA says that the major barrier to developing metric standards is the philosophical one of writing standards before the needs arise. Standards work generally follows technology because there is more confidence in standards which have been developed with a history of hardware use and test data. However, it is possible to translate inch-pound experiences into metric and it is feasible to manage metric standards development to support planned product conversion to metric. Even though feasible, however, certain equipment applications such as aircraft and weapon systems may impose costly qualification testing requirements on new metric parts. With a few exceptions, there is no support in industry for such anticipatory conversion of standards to metric.

Standards developing organizations acknowledge the need for raising awareness among both the standards users and standards writing organizations of the advantage of continuous attention to consideration of hard metric in new product design, and especially in new technology areas (e.g. solar energy).

Question 2. What impact on the development and use of metric standards do you see from the issuance of OMB Circular A-119?

The OMB Circular No. A-119 was issued by the Office of Management and Budget on January 17, 1980. The Circular stated that "It is the general policy of the Federal Government to:

a. Rely on voluntary standards both domestic and international with respect to Federal procurement, whenever feasible and consistent with law and regulation pursuant to law;

b. Participate in voluntary standards bodies when such participation is in the public interest and is compatible with agencies' missions, authorities, priorities, and budget limitations. Such participation, however, is limited to those voluntary bodies that conduct their standards activities in accordance with the criteria listed in paragraph 6c (of the Circular), unless such participation is required by law; and

c. Coordinate agency participation in voluntary standards bodies so that (1) the most effective use is made of Federal agency representatives; and (2) the views expressed by such representatives are in the public interest and, as a minimum, do not conflict with the interests and established views of Federal agencies.

The Department of Commerce on April 29, 1981, postponed the effective date of the Implementation Procedures for the Circular. Since that time, OMB has been developing a proposed revision of the Circular. It was too late to remove the question from the Interview Questionnaire sent to the nine standards bodies. The Report includes the views of the standards organizations expressed in response to this question.

The consensus of the standards organizations was that the issuance of the OMB Circular A-119, if ever implemented, will have virtually no impact, one way or another, on development of metric standards versus inch-pound standards. The OMB Circular is neutral on which units are used. The Circular deals with coordination of standards in general and with due process. The American Society of Mechanical Engineers believes that the Circular will cause Federal participants to follow the GATT Standards Code; but the GATT Code does not specify the units to be used. The National Electrical Manufacturers Association felt that the fact that the Department of Defense will be relying more and more on industry standards and that it has shown an interest in metric standards may have some effect in this case.

Question 3. Does present use of inch-pound standards by regulatory agencies serve as a barrier to development and use of the "metric" versions of these standards? What are some examples? For each of your committee areas, what can be done to remove these barriers?

The standards developing bodies generally felt that present use of inch-pound standards by regulatory agencies has not served as a significant barrier to the development and use of "metric" versions of these standards. Generally, if a consensus of industry wants to use metric standards and metric-sized products, these bodies believe that the regulatory bodies would be willing to adapt.

Most regulatory standards involve test methods (e.g., SAE brake hose standards are recognized by the Commonwealth of Pennsylvania), or human factor standards, both of which are relatively easy to change. Government regulations have usually followed industry practice. Several standards bodies mentioned that agency preference for one measurement system over the other often is due not to agency policy, but to the preference of individual officials - this can be a slight barrier to development and use of metric standards. In the event of conversion which affects a regulatory agency, some metric training will need to be given to regulatory personnel.

An official in one standards organization said he could give 100 cases of "regulatory" barriers but that in many cases such stated barriers are really excuses for not updating standards. Actual regulatory barriers "may affect one standard in 500."

There are no existing mechanisms for systematically collecting information on regulatory barriers to the development and use of metric standards. There seems to be no in-house need for such collection since the standards developers react to the needs of the marketplace. However, several examples of regulatory barriers were cited:

The Louisiana Offshore Oil Port, Inc. (LOOP, Inc.) reported at the December 1980 meeting of the U.S. Metric Board that it had designed its total facility and systems in metric but that several Federal, State, and local building code and environmental bodies would not accept reporting in metric units.

The Society of Automotive Engineers told of its model of a human being used in design, evaluation and test of cars giving eye and human parts locations. If SAE went metric on the model, the Federal agencies would not be able to use the data. Every automotive design must meet and be consistent with the requirements of the model.

Airline pilots and the Federal Aviation Administration have resisted metrication of operational standards such as airplane separation distances for safety reasons. The ICAO Annex 5 on air operations, which is not mandatory but followed by most countries, is considering metric distances but does not have an agreed-upon replacement for the foot. The FAA has to respond to proposed changes and it is a sensitive matter because of the certification of aircraft (supporting documents for certification are in inch-pound) and perceived safety problems. Because of the long life of aircraft, the aircraft industry is concerned with certification requirements in metric units.

The inch-pound Boiler and Pressure Vessel Code is the current standard. Until an alternative SI version of the Code is completed by ASME (scheduled for October 1, 1983), the inch-pound version is required for satisfying ASME requirements.

The use of inch-pound standards by building code regulatory bodies could become a barrier to the development and use of metric codes and standards. Since there appears to be no significant metric construction in the U.S., however, there has been little demand for metric standards. There are no known examples where codes have prevented metric construction. It is felt, though, that if and when the construction industry wants to go metric, the codes and standards groups and regulatory bodies would move with industry wishes as long as safety and public interest requirements are accommodated.

There are standards-based regulations on electrical machinery set forth by the Occupational Safety and Health Administration (OSHA) and the Consumer Product Safety Commission (CPSC). NEMA believes that even though standards conversion could be tedious and time consuming, OSHA and CPSC would be willing to go along, again as long as the public interest is accommodated.

The National Fire Protection Association believes that the use of inch-pound standards by regulatory agencies does serve as a barrier. NFPA standards are widely adopted as regulations by government agencies at all levels for purposes of regulating public safety. At the local level, the regulations are promulgated by the fire service, the electrical inspection departments, building officials, and the like. Those regulatory authorities have not been particularly interested in metric standards. "Until the enforcing authorities are resigned to the use of metric units, this barrier will continue to be prevalent. It is a matter of education".

Both UL and IEEE agree that up to now, regulatory agencies have not been a barrier. No examples can be recalled by them. They feel that regulatory agencies generally are not concerned with which measurement system is used as long as requirements and features are met. If either the industry or the regulatory agency wanted metric, the other probably would accept metric as long as there were coordination of the conversion. Very little of the National Electrical Code is written around dimensional requirements, and these requirements can be easily changed to metric in the view of IEEE. This Code is adopted by most states. In the event of a conversion, inspectors would have to get metric measuring devices for some purposes (for measurement of clearances from electrical power and communication overhead lines, etc). *Both systems are arbitrary:* identify the need, set the requirements, and use either system for measuring to see if requirements are met. It is likely that in the event of a conversion, a grandfather clause would be incorporated to allow maintenance of existing inch-pound facilities, but require metric only after a certain date. If regulatory agencies change, there would be need for some metric training for inspectors.

Question 4. What domestic impact have you seen and do you expect to see from use of metric procurement specifications and equipment standards by NATO and other treaty organizations? How are these impacts affecting or expected to affect each of your committees?

Most of the standards organizations have seen no domestic impact from use of metric procurement specifications and equipment standards by NATO and other treaty organizations. These organizations believe either that their constituencies (1) are little affected directly by NATO and other treaty organizations, even though some of their products may be involved, (2) can operate in a metric environment anyway (e.g., electronics), or (3) do not write product standards. These include ASME, NFPA, IEEE, ASTM, ACI, NEMA and UL. These bodies can think of few examples: for example, NEMA mentioned high temperature wire for aircraft. SAE believes that if metric is put into Federal procurement specification documents because of treaty requirements (or other reasons), industries would quickly change and the standards developers would change with the marketplace demand. IEEE said that even if connectors, etc. were in metric, there is no guarantee that they would be accepted worldwide; these are standardization problems, not metric problems.

The Aerospace Industries Association said that it has not seen much NATO metric procurement activity yet, but NATO is looking to metric in establishing preferred standards. Once the NATO list of preferred standards is developed, there may be an impact from metrication. The "second source" and maintenance could be problems. According to AIA, the Defense Department and NATO are working toward a two-way street in procurement in that both sides of the Atlantic have equal opportunity for contracting to build systems. With regard to standards, NATO's order of preference is international standards (ISO, IEC), then regional standards, lastly national standards. For this reason, U.S. national standards fall last in order of precedence. AIA feels that so far an adequate mechanism does not exist for getting industry input into NATO matters.

ASTM suggested in its response that the Department of Defense, a large user of ASTM standards, state its belief on the domestic impact from use by NATO of metric procurement specifications and equipment standards. In response to a letter to the Defense Department, Mr. Howard B. Ellsworth, DoD Metric Coordinator, in a letter dated January 27, 1982, said:

> The U.S., in coordination with the other members of NATO's AC/301 Committee, is looking at Standardization Agreements (STANAGs) as well as like documents developed by the IEC and ISO. From these we are developing a family of metric documents whose review and approval schedules will be handled through the AC/301 Committee.
>
> Since the U.S. will be an integral part of the approval process, we will use these approved documents in solicitations to U.S. industry for goods and services for co-production programs. I have asked that ANMC sector conversion plans list the significant standards and specifications that need to reflect metric criteria in order that these plans can succeed, including a priority structure. ANMC has agreed.
>
> Thus, with competent federal representatives and advisors on sector committees reviewing such listings, it seems probable to me that use of internationally-coordinated documents can readily be applied to contracts when both U.S. industry

and the Federal Government agree that their incorporation into competitive/negotiated acquisitions is proper as prescribed under Federal Acquisition Regulations (FAR).

Using this coordinated approach, impact on our domestic industry should have no more impact than DoD's current use of documents listed in the Department of Defense Index of Specifications and Standards (DODISS).

Question 5. Would the issuance of a policy and coordinated timetable for Federal Government-wide availability of metric standards similar to the policy and schedule set in the attached DoD memo allow each of your committees to develop metric standards more easily? The memorandum is the so-called Perry memorandum issued on March 7, 1980 from William J. Perry, Under Secretary of Defense for Research and Engineering. (A copy is in appendix B attached to the Interview Guide).

The standards developing bodies generally believe that agencies would have to go beyond setting schedules or timetables in order to see substantial progress in the development of metric standards. To have a real impact, agencies would have to specify metrics in procurement. "In Federal procurement, lowest price wins and that usually leaves metric out." If agencies purchase only metric products, standards developing bodies together with the industries involved will respond with development of metric standards.

SAE feels that if high level Federal representatives met with SAE councils and justified metrication, there would be metrication results. Such justification could be given to such groups as the Air Transport Association, Aerospace Industries Association and Aerospace Council of SAE.

ASME believes a Federal timetable for metrication would be undesirable. The control should be with the standards writing committees and these committees will move when industry top management makes a commitment. As far as the Perry memorandum (issued March 7, 1980 from William J. Perry, Under Secretary of Defense for Research and Engineering) is concerned, if the Defense Department describes in the future that all parts will be purchased in metric by 1990, ASME will cooperate in writing standards. It was felt that a Federal timetable on availability of metric standards for consumer products would not be productive.

AIA believes the Perry memo is affecting its constituency in a very general way in that it helps get resources to work on metric standards. Within DoD, both the Air Force and the Defense Industrial Supply Center have put forth a management plan in response to the Perry memo. It is estimated that within these two organizations, about one-third of the standards are obsolete, about one-third are not measurement sensitive, and about one-third will have metric versions prepared by the Defense Department or industry. The AIA's National Aerospace Standards Committee is working with DOD to set priorities for change.

AIA believes its constituency would object to a national timetable on metrication, but would probably not object to a timetable limited to standards. It is doubtful that the aerospace industry will ever have a conversion plan, unless there were good reasons such as the European Community cutting off all inch-pound imports by a certain date. The airlines are against conversion. The main place where the Federal government can pace aerospace metrication is through the Defense Department. Until the Defense Department institutes a positive firm requirement that it will pay costs of metrication, metrication is a disadvantage in the procurement area.

The remaining organizations believe that a Perry-type memo will have little impact in that it would not provide any more incentive than exists now. Many agencies such as the Tennessee Valley Authority, Department of Housing and Urban Development, General Services Administration, and the military housing groups basically follow commercial practice. Many standards bodies have soft converted, or are soft converting, their standards and, therefore, believe they already meet the requirements of a Perry-type memo.

Question 6. How could each of your committees effectively respond to a significant demand for the development of metric standards? Would you need increased support in the form of experts? How much more? Increased travel support for participants? Would development of coordinated national timetables supported by industry be useful? Could your committees respond without this formal industry agreement?

All of the standards developers felt that they have the infrastructure in place to respond to a significant increase in the development of metric standards. However, the standards bodies would need the backing of top management in industry before embarking on anticipatory metric standards preparation efforts. Federal representation is welcomed by standards bodies generally but they would be against direct Federal funding support for increased metrication efforts. It was also generally felt that additional experts or travel monies will not hasten the process of developing standards. It takes about the same period of time to develop a metric-based standard as an inch-pound based standard. It is still emphasized that industry would have to have the support of top management in order for committees to undertake the extra work of developing significant numbers of metric-based standards. But the standards bodies would be able to respond.

Several organizations pointed out the need for some new expertise if significant numbers of metric standards were to be developed. New physical requirements would need to be developed. UL said that additional expertise would be needed to develop "hard" metric requirements relating to safety since these could result in different values to those currently in effect. Also, in any large scale conversion of standards, there could be some problem of proliferation of metric terms (improper metric practice such as use of kilogram-force instead of newton), but this is seen as controllable.

Several standards bodies (e.g., ASME) said that there is a waiting list of people willing to serve on committees; therefore there would be committee members available to work on conversion efforts. Several others (e.g., UL) say most of their work is done by correspondence. In some cases where metrication of standards is getting underway, there may be some need for additional travel to describe what has to be done. Establishing metric dimensions is not a significant problem, but the decision to use hard metric is a problem.

Question 7. For each of your committees, is there a significant risk of "foreign origin" international standards replacing U.S. originated defacto or recognized international standards because these U.S. standards are not "metric"? If international standards replaced U.S. standards, what effect would there be on your industry area?

Up to the present, standards organizations have cited no cases where "foreign origin" international standards have replaced U.S. - originated defacto or recognized international standards because these U.S. standards are not metric. Metric versus non-metric has not been a significant concern as far as international acceptance is concerned. For example, NEMA reported that different voltage, frequencies, insulation requirements, mechanical practices, and certification requirements are far more important considerations for international acceptance than whether or not a standard is in metric units. For example, the Europeans subdivide voltage for transformers differently than the United States does. Several organizations mentioned cases where U.S. representatives had trouble getting U.S. standards adopted internationally. But, in no case did these problems involve which measurement system to use. It is a standards problem rather than a metric problem. The standards organizations believe that its standards have had good acceptance worldwide.

ASTM pointed out that there is a problem of definition of a metric standard. ASTM says that its standards all have SI units per Part H of the "Form and Style for ASTM Standards". The standards of most of the other interviewed organizations either have dual units and notation or conversion tables if they are not "metric" already.

It is generally recognized that there will be a slow increase in metric standards as time goes on because it is the predominant measurement system in the world. Therefore, several standards bodies were more concerned than others about risk from foreign origin standards replacing U.S. standards as international standards. There is some risk here since the world is calling for metric standards. For example, several companies have been telling SAE that they cannot provide replacement parts for imported items because of a lack of U.S. products made to international (metric) standards. The vehicle support industry is of tremendous size (bearings, generators, etc.) and there is a lack of industry standards there (e.g., brake fluid lines in trucks, fuses in Japanese cars). U.S. companies would like to make these parts, but cannot because standards do not exist.

ACI feels that in the future there may be some probability of replacement of U.S. standards by other standards in Middle East countries, because U.S. standards are not in metric. However, no specific standards can at this point be identified. When U.S. construction companies work in developing countries, they usually have to work in metric units and this could be a slight disadvantage in competing with construction companies from Germany, Italy, Japan and elsewhere. Otherwise, concrete is a low-cost, heavy, local type of product, and therefore is not shipped over great distances.

AIA definitely has a concern here since there is active movement in the European Association of Aerospace Manufacturers (AECMA) for development of a complete line of metric standards. AECMA is a consortium of nine European standards bodies to develop common aerospace standards. AIA is working with AECMA and they have agreed "to adopt some of yours if you adopt some of ours". Both recognize that the International Organization for Standards (ISO) is very cumbersome and slow in developing standards (e.g., takes about seven years to develop a standard). NATO has encouraged AIA and AECMA to get together. If ISO ever gets involved in developing parts standards, then replacement of U.S. originated standards by foreign regional or foreign origin international standards would become a real problem. AIA has been trying to keep its parts standards compatible with ISO Committee Standards. ISO Committee TC-20 standards have been concerned mostly with vocabulary agreements, environmental conditions for operations, interface areas, and design parameters to date. But, the Europeans and AECMA are pushing for ISO parts standards. However, compromise factors, etc. do work against hardware standards at the leading edge of technology.

AIA wants its Standard 3610, "Specification for Cargo Unit Load Devices", adopted as an ISO standard. A metric version may be required. ISO Technical Committee TC-20 chose the AECMA format for aircraft materials standards. ISO has not published these standards yet, but the impact is that the U.S. is losing some battles.

With regard to the second question, many ISO standards specify less stringent requirements than comparable U.S. standards. This is a particular concern in high technology areas such as aerospace. If international standards replaced U.S. standards, parts manufacturers would have to change engineering documents and there could also be a compromise of product quality.

The Europeans and Soviets are looking to ISO to develop metric parts standards. Most European metric aerospace standards were developed by DIN, but it is not as complete a set as the U.S. The Soviet standards body (GOST) has about 83,000 standards compared with 28,000 voluntary U.S. standards and 40,000 DOD standards and specifications. The AIA is making a comprehensive study to see what problem areas exist. In ISO Committee TC-20, Aircraft and Space Vehicles, the Soviets are not submitting an appreciable number of proposed standards whereas the US and AECMA are. The Japanese do not participate in TC-20 and are not involved to a great extent in aerospace standardization at present.

Others of the interviewed standards bodies appear to believe that the future risks are minimal. NFPA says it has submitted some of its standards to ISO for consideration. When an NFPA standard is accepted by the ISO committee, the standard is made metric by the Committee, and this has not been a problem for NFPA. IEEE believes that by the year 2000, U.S. standards in the electrical/electronics area will be compatible with International Electrotechnical Commission (IEC) standards, but that there probably is little chance that foreign origin standards will replace U.S. standards because of metric. There probably will be some compromise between U.S. and foreign standards (in areas of connectors and adaptors, for example).

NEMA says that there has been a tendency for Third World countries to use IEC standards whenever possible, rather than U.S. standards. This has little to do with which units are used, however. If U.S. bodies make substantive changes in standards for international considerations, metric probably will be incorporated. "But metric or not is not enough of a consideration to revise the standards. There will be a gradual increase in the number of metric standards." NEMA also pointed out that rarely is there a "no-overlap standard between an IEC standard and a national standard." For example, it might take three IEC standards to cover what one NEMA standard on transformers covers.

All the interviewed standards bodies work with international standards bodies and therefore can monitor what is happening and work to encourage international acceptance of their standards. It is the cost of participation in international standards work and other standardization problems, rather than metric or non-metric, which may work against U.S. interests. The standards developers are aware of the European Community requirements on metric labeling and carton readings as stated in the Directive (1979-12-20) of the Council of the European Communities on the approximation of the laws of the Member States relating to the units of measurement (Official Journal of the European Communities, No. L39, 1980-02-15, page 40).

Question 8. For each of your committee areas, what are examples of U.S. - originated standards which are technologically superior, but have not been internationally accepted because they are not "metric"?

a. Internationally accepted

i. legally

ii. defacto

b. Accepted by international organizations

i. legally

ii. defacto

This question really involves two questions. It involves the matter of whether or not U.S. standards are technologically superior; and secondly, whether or not U.S. standards have been accepted internationally because they are not metric. It was pointed out that there is a problem of defining "technologically superior." It is felt that when standards are issued, they reflect the current state of the science, technology, or art at that point in time. Obviously, U.S. committees feel that their standards are technologically superior, but these are matters that are argued at the ISO or IEC committee level.

All of the standards organizations interviewed indicated that as yet the fact that U.S. standards are not metric has not been a deterrent to international acceptance. No examples due to measurement system used could be conclusively cited. The common feeling is that in terms of getting U.S. standards accepted, "metric is not the problem; it is the cost of participating as U.S. representatives on ISO Committees", and "metric is only one small facet of a big problem."

Comments from several organizations are cited. AIA does not know of examples where U.S. - originated standards have not been internationally accepted because they are not metric. Currently, world aerospace usage is inch-pound, following the U.S. lead. For example, U.S. inch practices in bearings are accepted worldwide, but ISO is trying to develop metric standards in this area. The ISO proposal has two columns -preferred inch-pound and preferred metric. The AIA approach has been to get agreement on metric preferences early. If it comes to the point where ISO standards are contractually required, the U.S. will have to fight for its positions more strongly. For that reason part (b.) of the question is of serious concern. AIA has in the past felt that ISO parts standards are way down the road but it is re-evaluating this feeling.

SAE standards tend to be in advanced technology areas, and tend to be generally superior in the international sphere. They cannot think of any U.S. originated standards which are superior but not accepted because of metric. ISO is willing to accept soft metric standards, but considers hard metric standards more acceptable. SAE standard J517 on hydraulic fittings is a defacto international standard even though it is soft metric. SAE believes that quite a few of its standards will be accepted by ISO. Also European Community regulations often reference SAE standards.

Since SAE gets draft standards from other countries, there are rarely any surprises. Because it takes so long for international standards to be developed, U.S. representatives on ISO committees have enough time to get their standards ready. "Metric is not the problem, it is the cost of participating as U.S. representatives on ISO committees." So far it has not been a significant problem but, in the future, parts may be designed in Japan and produced here and problems can arise. But this is not a metric problem.

IEEE knows of no products where its standards have not been accepted because of measurement units used (most are metric anyway). There is argument of which transmission system is better (60 hertz versus 50 hertz) but both systems are based on metric units. There are a number of IEEE standards which are accepted defacto. None are accepted legally outside of the U.S. except for some in several Caribbean countries; also some are accepted in Canada on a voluntary basis. Quite a number are accepted defacto by IEC.

ACI Committees do not know of any cases where U.S. standards which are technologically superior have not been internationally accepted because they are not metric. ISO is developing a building code for rules on design of concrete structures similar to ACI standard 318.77. ISO is starting with a draft from the European Concrete Committee instead of 318.77. However, metric or lack of it has had very little to do with the decision. It was a political decision, and if they cited metric as a reason, it would merely be an excuse.

Question 9. Would a national metric "log" or status report of standards (including those planned, under development, and approved) containing the following types of information be useful to your organization, to your committees, or the users of your committees' standards?

a. What information should the log contain to be most useful? For example:

- o Standards planned, under development, approved.
- o U.S. standards usable in a metric environment.
- o U.S. originated standards internationally accepted.
- o Other information? Please suggest format or content or both.

b. If a standards log would be useful, who should develop and maintain the log?

The standards bodies believe that if metrication is merely drifting along as it is now, such a log would not be of much value except in the aerospace area. The AIA has been developing a log which now lists 890 standards. Twice a year, AIA asks the preparing activities the status of standards. The preparing activities are in the Defense Department, SAE, AIA, and a few others such as the Tire and Rim Association. AIA is not looking at broader standards such as the ASTM standards.

It is generally felt that individual companies as well as sector conversion committees would find a log useful in the beginning of a national conversion effort as the standards bodies would be developing a family of standards. One group (ASME) felt that such a log would be useful only for published standards; several bodies felt that such a log would not be useful because standards are already predominantly metric (IEEE) or adequate communication with affected parties already exists (ACI). Most of the bodies who believed that a metric log would be useful believed that ANSI and the National Bureau of Standards (NBS) would be the proper place to develop and maintain the log.

NFPA raised the question of how a metric standard is defined. In its work a metric standard is simply a standard that contains units which are given in the metric system. If this is so, NFPA believes that a national metric log or status report would not be particularly helpful.

SAE said that there are two parties to consider, the standards developers and the standards users. It was felt that the ANMC Sector Committees would find logs useful. For standards developers, a log would be useful in the beginning as they are developing a conversion plan, but would not be useful after that. SAE cannot speak for standards users. There is a need to ask users about the usefulness of a log; they would have more of an economic interest in the log. By definition, a log would be useful for users but it is hard to tell who users of standards are. SAE does not verify use of its standards. SAE does, however, run a survey every five years to determine what should be done with its standards.

NEMA and UL believe that in the event of a national conversion or an industry wide decision to go metric, a national log would be helpful in that it would show what others are doing. Such a log would help define the scope, minimize overlapping standards, avoid duplication of efforts, and assist in establishing a standards developing timetable. For example, in the electrical area there is a whole spectrum of parts and processes from the generating station all the way to the electrical appliances. Changes would have to be coordinated throughout the whole system, and a log would help in this effort.

Most of the bodies felt that NBS would be the logical place for the development and maintenance of a metric standards log. The OMB Circular A119 provides for a central Federal government sponsored office that would maintain a roster of all U.S. standards and it is assumed that this roster would include those standards under development in addition to those already approved. SAE felt that ANMC should have an interest in maintaining the metric log. NEMA felt that the ANSI "Standards Action" section of the ANSI Reporter may be an appropriate vehicle to show metric standards in process of development. It is understood that ANSI is working on a list of all draft standards. ASTM suggested that since a metric log might be viewed as a coordinating effort, then possible candidates would be ANSI or possible the ANMC. All organizations recognized that a metric standards log would not be financially self supporting. Several of the organizations said they would be willing subscribers.

ASTM said that its Part 48 of the Annual Book of ASTM Standards is its subject index and numerical list. Each year, it shows which standards are "M" (metric) standards. It could be incorporated in any national log.

AIA feels that the U.S. Metric Board could be a big help in encouraging a wider national metric log. Certainly the Board could not maintain the log, but it could encourage someone to do it. Since the aerospace log is not a big seller, it is doubtful whether a national log would be economically viable. Outside support, such as time devoted by ANMC sector committee people, would probably be needed. There is need for a common format and a willingness to focus on industry needs. AIA felt that the log needs to be done on a sector basis with a focus on priorities. ANMC at present has neither the funds nor the staff.

A Final Word

Our investigation of the impact of increasing metric usage on standards producers leads us to conclude that conversion by U.S. industry to metric is proceeding relatively slowly and that while some inconvenience may result from lack of convenient and timely availability of new "hard metric" U.S. standards, other economic and social factors are far more significant considerations in the decision to convert manufacturing processes or products to metric.

Public Law 94-168
94th Congress, H. R. 8674
December 23, 1975

An Act

APPENDIX A

To declare a national policy of coordinating the increasing use of the metric system in the United States, and to establish a United States Metric Board to coordinate the voluntary conversion to the metric system.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "Metric Conversion Act of 1975".

Policy implementation. 15 USC 205e.

SEC. 6. It shall be the function of the Board to devise and carry out a broad program of planning, coordination, and public education, consistent with other national policy and interests, with the aim of implementing the policy set forth in this Act. In carrying out this program, the Board shall—

. . .

(4) encourage activities of standardization organizations to develop or revise, as rapidly as practicable, engineering standards on a metric measurement basis, and to take advantage of opportunities to promote (A) rationalization or simplification of relationships, (B) improvements of design, (C) reduction of size variations, (D) increases in economy, and (E) where feasible, the efficient use of energy and the conservation of natural resources;

(5) encourage the retention, in new metric language standards, of those United States engineering designs, practices, and conventions that are internationally accepted or that embody superior technology;

(6) consult and cooperate with foreign governments, and intergovernmental organizations, in collaboration with the Department of State, and, through appropriate member bodies, with private international organizations, which are or become concerned with the encouragement and coordination of increased use of metric measurement units or engineering standards based on such units, or both. Such consultation shall include efforts, where appropriate, to gain international recognition for metric standards proposed by the United States, and, during the United States conversion, to encourage retention of equivalent customary units, usually by way of dual dimensions, in international standards or recommendations;

. . .

APPENDIX B

November 21, 1980

Interview Questionnaire for Selected Standards Organizations

Questions relating primarily to Section 6(4)

1. For each of your committees, what do they perceive as the main barriers or reasons for not developing metric standards?

2. What impact on the development and use of metric standards do you see from the issuance of OMB Circular A-119 (copy attached)?

3. Does present use of inch-pound standards by regulatory agencies serve as a barrier to development and use of the "metric" versions of these standards? What are some examples? For each of your committee areas, what can be done to remove these barriers?

4. What domestic impact have you seen and do you expect to see from use of metric procurement specifications and equipment standards by NATO and other treaty organizations? How are these impacts affecting or expected to affect each of your committees?

5. Would the issuance of a policy and coordinated timetable for Federal Government-wide availability of metric standards similar to the policy and schedule set in the attached DoD memo allow each of your committees to develop metric standards more easily?

Standards Questionnaire Draft, dated 11/4/80

6. How could each of your committees effectively respond to a significant demand for the development of metric standards? Would you need increased support in the form of experts? How much more? Increased travel support for participants? Would development of coordinated national timetables supported by industry be useful? Could your committees respond without this formal industry agreement?

Question Relating Primarily to Section 6(5)

7. For each of your committees, is there a significant risk of "foreign origin" international standards replacing U.S.-originated defacto or recognized international standards because these U.S. standards are not "metric"? If international standards replaced U.S. standards, what effect would there be on your industry areas?

Question Relating Primarily to Section 6(6)

8. For each of your committee areas, what are examples of U.S.-originated standards which are techologically superior, but have not been internationally accepted because they are not "metric"?

   a. Internationally accepted

      i. legally

      ii. defacto

b. Accepted by international organizations

i. legally

ii. defacto

Question Relating to Sections 6(4), 6(5), and 6(6)

9. Would a national metric "log" or status report of standards (including those planned, under development, and approved) containing the following types of information be useful to your organization, to your committees, or the users of your committee's standards?

a. What information should the log contain to be most useful? For example:

- Standards planned, under development, approved.
- U.S. standards usable in a metric environment.
- U.S.-originated standards internationally accepted:
- Other information? Please suggest format or content or both.

b. If a standards log would be useful, who should develop and maintain the log?

THE UNDER SECRETARY OF DEFENSE

WASHINGTON, D C 20301

RESEARCH AND ENGINEERING

7 MAR 1980

MEMORANDUM FOR THE ASSISTANT SECRETARY OF THE ARMY (RESEARCH, DEVELOPMENT AND ACQUISITION)
THE ASSISTANT SECRETARY OF THE NAVY (RESEARCH, ENGINEERING AND SYSTEMS)
THE ASSISTANT SECRETARY OF THE AIR FORCE (RESEARCH, DEVELOPMENT AND LOGISTICS)
THE DIRECTORS OF DEFENSE AGENCIES

SUBJECT: Metric Specifications and Standards

Achieving effective NATO standardization requires that we utilize the metric system in design of new weapon systems and equipments to the maximum practical extent because all other NATO countries are metric users. This is a principal basis for metric policies layed out in DoD Directive 4120.18, "Use of the Metric System of Measurement." It has not been practical for many recent programs to employ metric measurements due in large part to unavailability of metric specifications and standards.

The availability of such specifications and standards is a key factor in any decision to use the metric system in new design. Progress in developing metric specifications and standards has been extremely slow, and national standardization bodies have not moved as fast as we had hoped.

To provide a firm date on which future plans can be based, I am establishing a target date of 1 January 1990 for availability of a complete spectrum of metric specifications and standards which can be used in place of the 40,000 documents listed in the DoD Index of Specifications and Standards. Initial emphasis will be placed on documents for common hardware items, materials, engineering practices and other common areas.

I would appreciate it if you would:

- Begin scheduling preparation of metric specifications and standards on an accelerated basis at the earliest practical date, emphasizing common areas where the private sector cannot or will not prepare the documents.

- Participate with national standardization activities of the private sector in preparation of metric documents and assume a fair share of the workload.

- Adjust five-year standardization plans (DoD Standardization Manual 4120.3M) accordingly.

APPENDIX C

Excerpts taken from the

American Concrete Institute

TECHNICAL COMMITTEE MANUAL

(June 1979)

3.4.5 Metric Units

All ACI publications shall show the values for all quantities in the International System of Measurement (SI). The International System is the currently recommended form of the metric system and the ACI Board has set a target date of 1983 for availability of standards in the SI system. Where the work on which a publication was based was performed in U.S. customary units, both sets of units should be shown (See Appendix A3).

The Board of Direction has stated "The latest ASTM E380 Standard Metric Guide is adopted for use within the Institute as a means for implementing SI." ASTM E380, "Standard for Metric Practice" is available from ACI or ASTM headquarters.

PART H
USE OF METRIC (SI) UNITS IN ASTM STANDARDS

H1. Scope

H1.1 These instructions are to guide technical committees in the writing of ASTM standards using the International Systems of Units (SI) by following ASTM Standard E 380 for Metric Practice and its approved supplementary metric practice guides. Each part of the *Annual Book of ASTM Standards* contains an excerpt in the Related Material section. ASTM E 380 appears in its entirety in Part 41, General Test Methods, and is also available as a complete separate publication. Additional guidance may be obtained from Committee E-43 on Metric Practice.

H2. Rules for Introducing SI Units

H2.1 SI units of measurement shall be included in all ASTM standards that do not contain a companion standard in "hard" metric units. (SI units as used in this rule include certain deviations covered in H5.1.)

H2.2 Each technical committee shall have the option of giving preference to SI or inch-pound units.

H2.2.1 When preference is given to SI units, the inch-pound units may be either omitted or given in parentheses.

H2.2.2 When preference is given to inch-pound units the SI equivalent shall be given in parentheses, or in a supplementary table as described in Section H3.

H2.3 The system of units to be used in referee decisions shall, in doubtful cases, be stated in the scope of each standard. Examples of such statements are as follows:

1.3 The values stated in inch-pound units are to be regarded as the standard.

1.4 The values given in parentheses are provided for information purposes only.

H2.4 The calculated SI equivalent for an inch-pound value should be rounded to the proper number of significant figures as described in the section on Rules for Conversion and Rounding of E 380. No attempt should be made to change to different values that are used or may be adopted by other countries, except as covered in H2.5 below.

H2.5 In standards that have alternative or optional procedures based on apparatus graduated or dimensioned in either inch-pound or SI units, converted values need not be included. If the optional procedures or dimensions produce equally acceptable results, the options may be shown similarly to conversions using the word "or" rather than parentheses: for example, in a 2-in. gage length metal tension test specimen, the gage length may be shown as 2 in. or 50 mm.

H2.6 A specific equivalent, for example, 1.00 in. (25.4 mm), need be inserted only the first time it occurs in each paragraph of a standard.

H2.7 When a standard specifies that results should be expressed in an inch-pound unit in a general sense, the preferred SI unit should be stated. For example, "Report the twist of yarns in twists per inch (or twists per metre)" not ". . . in twists per inch (25.4 mm)."

H2.8 For methods of including SI equivalents in tables, see *Section H3.*

H2.9 On simple illustrations the SI equivalents may be included in parentheses. On more complicated illustrations the dimensions are preferably indicated by letters and the corresponding inch-pound and SI units shown in an accompanying table (see H4.4). In the case of charts or graphs, dual scales may be used to advantage.

H2.10 The need for SI equivalents can be avoided in the case of tolerances if the limits are expressed in percent.

H2.11 In converting standard sieve sizes, use the metric values given in Table 1 of Specification E 11, for Wire-Cloth Sieves for Testing Purposes.

H3. Introducing SI Units in Tables

H3.1 *Case 1. Limited Tabular Material*—**Provide SI equivalents in tables in parentheses or in separate columns as illustrated below:**

TABLE 0 Mechanical Properties[A] of Small-Diameter and Light-Wall Tubing (Converter Sizes)

Condition	Tensile Strength, psi (MPa)	Yield Strength (0.2% offset),[B] min, psi (MPa)	Elongation in 2 in. or 50 mm, min, %	Rockwell Hardness[C] (or Equivalent)
		Nickel		
Annealed[D]	75 000 (515) max	15 000 (105)	33	B 70 max
Half-hard[E]	80 000 (550) min	40 000 (275)	12	B 75 to B 90
Full-hard[F]	95 000 (655) min	75 000 (515)	4	B 90 to C 30
		Low-Carbon Nickel		
Annealed[D]	70 000 (485) max	12 000 (85)	35	B 62 max
Half-hard[E]	70 000 (485) min	30 000 (205)	12	B 70 to B 85
Full-hard[F]	85 000 (585) min	65 000 (450)	4	B 80 to B 95

[A] Not applicable to outside diameters under 1/8 in. (3.2 mm) and wall thickness under 0.015 in. (0.38 mm).
[B] See 14.3.
[C] Hardness values, indicative of tensile strength, are shown for information only. All tests are subject to confirmation by tension tests. For hardness conversions see Hardness Conversion Tables E 140.
[D] This condition is sometimes designated as "No. 1 Temper."
[E] This condition is sometimes designated as "No. 2 Temper."
[F] This condition is sometimes designated as "No. 3 Temper."

TABLE 0 Typical Properties

Density, Mg/m³	Tensile Strength		Elongation in 1 in. or 25 mm, %	Yield Point in Compression (0.1% offset)		Hardness, HRH
	psi	MPa		psi	MPa	
5.8	29 500	205	0.5	28 500	195	85
6.2	34 000	235	1	30 000	205	90

H3.2 *Case 2. One or Two Large Tables*—**When the size of a table and limitations of space (on the printed page) make it impractical to expand the table to include SI equivalents, the table should be duplicated in inch-pound units and SI units as shown below. If this procedure will result in increasing the standard by more than three pages, apply Case 3 or Case 4 as applicable.**

TABLE 0 **Water Pressure Ratings at 23°C (73°F) for Schedule 80 ABS Plastic Pipe**

	SI Units							
	Pressure Ratings, MPa							
Nominal Pipe Size, in.	ABS1208		ABS1210		ABS1316		ABS2112	
	Unthreaded	Threaded	Unthreaded	Threaded	Unthreaded	Threaded	Unthreaded	Threaded
1/8	...	...	...	...	6.8	3.4	...	...
1/4	...	...	...	...	6.2	3.1	...	...
3/8	...	...	...	...	5.0	2.5	...	...
1/2	2.3	1.2	2.9	1.4	4.7	2.3	3.6	1.8
3/4	1.9	1.0	2.3	1.2	3.8	1.9	3.0	1.5
1	1.7	0.9	2.2	1.1	3.4	1.7	2.7	1.3
1 1/4	1.4	0.7	1.8	0.9	2.9	1.4	2.3	1.1
1 1/2	1.3	0.6	1.6	0.8	2.6	1.3	2.0	1.0
2	1.1	0.6	1.4	0.7	2.2	1.1	1.7	0.9
2 1/2	1.2	0.6	1.4	0.7	2.3	1.2	1.9	0.9
3	1.0	0.5	1.3	0.6	2.1	1.0	1.6	0.8
3 1/2	1.0	0.5	1.2	0.6	1.9	1.0	1.5	0.8
4	0.9	0.4	1.1	0.6	1.8	0.9	1.4	0.7
5	0.8	0.4	1.0	0.5	1.6	0.8	1.2	0.6
6	0.8	0.4	1.0	0.5	1.5	0.8	1.2	0.6
8	0.7	0.3	0.8	0.4	1.4	0.7	1.0	0.5
10	0.6	0.3	0.8	0.4	1.3	0.6	1.0	0.5
12	0.6	0.3	0.8	0.4	1.2	0.6	1.0	0.5

	Inch-Pound Units							
	Pressure Ratings, psi							
Nominal Pipe Size, in.	ABS1208		ABS1210		ABS1316		ABS2112	
	Unthreaded	Threaded	Unthreaded	Threaded	Unthreaded	Threaded	Unthreaded	Threaded
1/8	...	...	...	...	980	490	...	...
1/4	...	...	...	...	900	450	...	...
3/8	...	...	...	...	730	370	...	...
1/2	340	170	420	210	680	340	530	260
3/4	280	140	340	170	550	280	430	210
1	250	130	320	160	500	250	390	200
1 1/4	210	100	260	130	420	210	330	160
1 1/2	190	90	240	120	380	190	290	150
2	160	80	200	100	320	160	250	130
2 1/2	170	80	210	110	340	170	270	130
3	150	70	190	90	300	150	230	120
3 1/2	140	70	170	90	280	140	220	110
4	130	60	160	80	260	130	200	100
5	120	60	140	70	230	120	180	90
6	110	60	140	70	220	110	170	90
8	100	50	120	60	200	100	150	80
10	90	50	120	60	190	90	150	70
12	90	50	110	60	180	90	140	70

H3.3 *Case 3. Extensive Tabular Material*—When the number of tables requiring duplication of SI equivalents, as in Case 2, would increase the size of the printed standard by more than three pages, prepare a summary appendix listing all of the units that appear in the various tables, as shown in Appendix X1 of the example below. If this procedure would result in an increase of the standard by more than one page, apply Case 4.

APPENDIX

X1. SI EQUIVALENTS

X1.1 Table X1 contains the SI equivalents of the inch-pound units used in the body of the standard.

TABLE X1 SI EQUIVALENTS

Inches to Millimetres					
in.	mm	in.	mm	in.	mm
0.015	0.38	0.350	8.89	0.987	25.07
0.020	0.51	0.375	9.52	1.000	25.40
0.028	0.71	0.383	9.73	1.128	28.65
0.038	0.97	0.431	10.95	1.178	29.92
0.044	1.12	0.437	11.10	1.270	32.26
0.050	1.27	0.487	12.37	1.410	35.81
0.056	1.42	0.500	12.70	1.571	39.90
0.064	1.63	0.540	13.72	1.963	49.86
0.071	1.80	0.612	15.55	2.356	59.84
0.143	3.63	0.625	15.88	2.749	69.82
0.191	4.85	0.700	17.78	3.142	79.81
0.239	6.07	0.750	19.05	3.544	90.02
0.262	6.65	0.790	20.07	3.990	101.35
0.286	7.26	0.875	22.22	4.430	112.52
0.334	8.48	0.889	22.58		

Square Inches to Square Centimetres					
in.^{2}	cm^2	in.^{2}	cm^2	in.^{2}	cm^2
0.11	0.71	0.44	2.84	1.00	6.45
0.20	1.29	0.60	3.87	1.27	8.19
0.31	2.00	0.79	5.10	1.56	10.06

Pounds per Foot to Kilograms per Metre					
lb/ft	kg/m	lb/ft	kg/m	lb/ft	kg/m
0.376	0.560	1.502	2.235	3.33	4.96
0.668	0.994	2.044	3.042	4.303	6.403
1.043	1.552	2.670	3.973	5.313	7.906

Pounds-Force per Square Inch to Megapascals			
psi	MPa	psi	MPa
50 000	345	80 000	550
60 000	415	90 000	620

H3.4 *Case 4. Unusual Number of Large Tables*—When Case 1, 2, or 3 do not apply because of the size and number of tables, include the pertinent conversion factors in a footnote under each table, as in the following illustration:

Table 0

Nominal Size, in.	Outside Diameter, in.[A]	Wall Thickness, in.[A]	Nominal Mass, Plain End, lb/ft[B]	Weight Class	Schedule No.	Test Pressure, psi[C]		
						Butt-Welded	Grade A	Grade B
20	20.000	0.250	52.73	...	10	...	450	500
		0.281	59.18	...	...	...	500	600
		0.312	65.60	...	...	...	550	650
		0.344	72.21	...	...	...	600	700
		0.375	78.60	STD	20	...	700	800
		0.406	84.96	...	...	...	750	850
		0.438	91.51	...	...	...	800	900
		0.469	97.83	...	...	...	850	950
		0.500	104.13	XS	30	...	900	1000
		0.594	123.11	...	40	...	1100	1200
		0.812	166.40	...	60	...	1500	1700
		1.031	208.87	...	80	...	1900	2200
		1.281	256.10	...	100	...	2300	2700
		1.500	296.37	...	120	...	2700	2800
		1.750	341.10	...	140	...	2800	2800
		1.969	379.17	...	160	...	2800	2800
24	24.000	0.250	63.41	...	10	...	400	450
		0.281	71.18	...	...	...	400	500
		0.312	78.93	...	...	...	450	550
		0.344	86.91	...	...	...	500	600
		0.375	94.62	STD	20	...	550	650
		0.406	102.31	...	...	...	600	700
		0.438	110.22	...	...	...	650	750
		0.469	117.86	...	...	...	700	825
		0.500	125.49	XS		...	750	900
		0.562	140.68	...	30	...	850	1000
		0.688	171.29	...	40	...	1000	1200
		0.938	231.03	...	...	...	1400	1600
		0.969	238.85	...	60	...	1500	1700
		1.219	296.58		90	...	1800	2100
		1.531	367.39	...	100	...	2300	2700
		1.812	429.39		120	...	2700	2800
		2.062	483.12		140	...	2800	2800
		2.344	542.14	...	160	...	2800	2800
26	26.000	0.250	68.75	...	...	...	350	400
		0.281	77.18	...	...	...	390	450
		0.312	85.60	...	10	...	430	500
		0.344	94.26	...	...	...	480	560
		0.375	102.63	STD	...	...	520	610
		0.406	110.98	...	...	...	560	660
		0.438	119.57	...	...	...	610	710
		0.469	127.88	...	...	...	650	760
		0.500	136.17	XS	20	...	690	810
		0.562	152.68	...	...	...	780	910

[A] 1 in. = 25.4 mm (exact)
[B] 1 lb/ft = 1.488 164 kg/m
[C] 1 psi = 6.894 757 kPa

H3.5 *Case 5. Large and Small Tables Representing a Combination of Two or More of the Preceding Cases*—When a standard contains some small tables and several full-page tables, representing a combination of the preceding cases, insert the SI equivalents in the small tables and apply the rules for Cases 2 through 4, as applicable, for the remaining tables.

H4. Submittal of SI Equivalents for Existing Standards

NOTE— The examples that follow show preference given to inch-pound units. When preference is given to SI, these units are inserted before the inch-pound units and the latter are shown in parentheses.

H4.1 For text material show the SI equivalent in the margin of a reprint or photocopy, as illustrated below:

12. **Length**

12.1 Unless otherwise specified, the lengths of rails at a temperature of 60°F (15.5°C) shall be 60 or 62 ft [(18.3 or 18.9 m)] for those sections in which the weight per yard will permit; excepting girder-guard rails which shall be 30 or 32 ft [(9.1 or 9.8 m)] unless otherwise specified.

12.2 The lengths shall not vary more than ½ in. [(13 mm)] on 60 and 62-ft [(18.3 and 18.9 m)] rails, except that on 15 % of the order a variation of ⅝ in. [(16 mm)] will be allowed; nor more than ¼ in. [(6 mm)] on 30 and 32-ft [(9.1 and 9.8 m)] rails, except that on 15 % of the order a variation of ⅜ in. [(10 mm)] will be allowed.

12.3 Shorter lengths, varying by 1 ft [(0.3 m)] down to 40 ft [(12.2 m)] for plain- and grooved-girder rails and 24 ft [(7.3 m)] for girder-guard rails, will be accepted to the extent of 10 % by weight of each class on the order.

H4.2 For tables insert the SI equivalents when there is sufficient space as illustrated below:

Wall Thickness, in.	Wall Thickness, mm	Elongation in 2 in. or 50 mm, %
5/16 (0.31)	7.9	30.0
9/32 (0.28)	7.1	29.5
1/4 (0.25)	6.4	27.0
7/32 (0.22)	5.6	25.5
3/16 (0.19)	4.8	24.0
5/32 (0.16)	4.0	22.0
1/8 (0.12)	3.2	21.0
3/32 (0.09)	2.4	19.5
1/16 (0.06)	1.6	18.0

H4.3 For tables where space does not permit the SI equivalents to be written in, retype the table.

H4.4 For new illustrations it is preferable to indicate the dimensions with letters, as illustrated below:

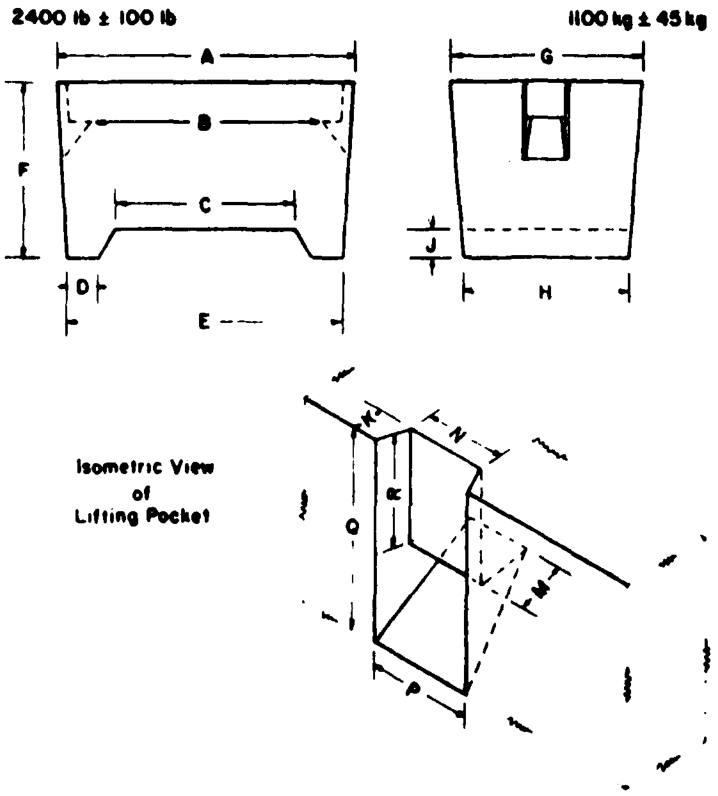
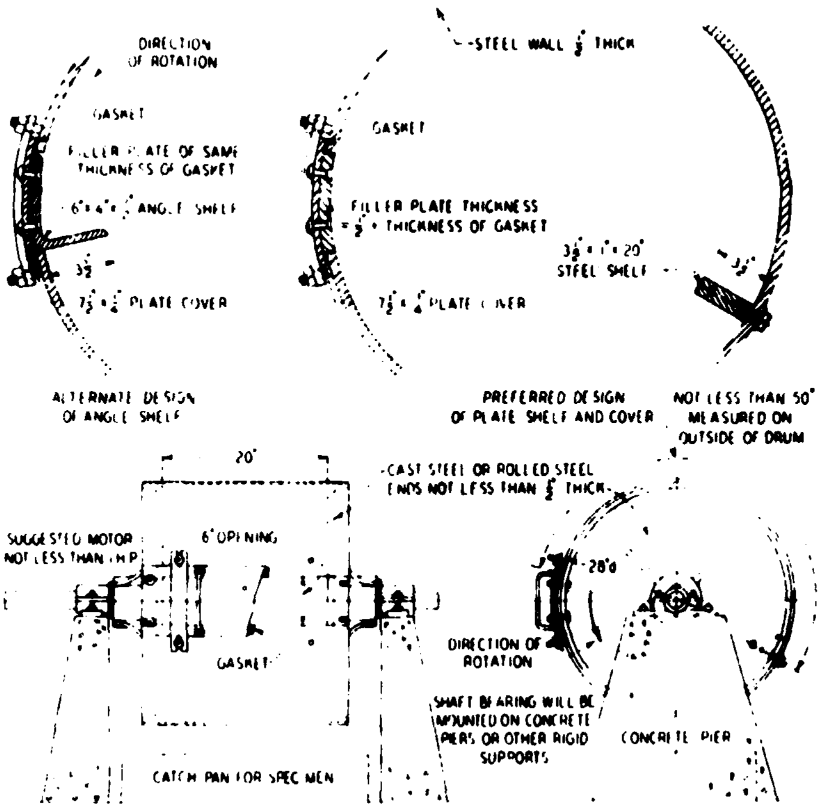


Table of Dimensions

	in.		mm			in.		mm	
	Dimension	Tolerance	Dimension	Tolerance		Dimension	Tolerance	Dimension	Tolerance
A	31	1/2	787	13	J	3	1/2	76	13
B	24	1/2	610	13	K	1 1/4	1/8	32	3
C	19	1/2	483	13	M	2	1/8	51	3
D	3	1/2	76	13	N	3 3/4	1/4	95	6
E	28 1/2	1/2	724	13	P	4 1/4	1/4	114	6
F	19	3/4	483	19	Q	8 1/2	1/2	216	13
G	20	1/2	508	13	R	4 1/2	1/2	114	13
H	17 1/2	1/2	444	13					

FIG. 0 Standard Jumbo Ingot

H4.5 For existing illustrations a tabulation of SI equivalents may be inserted beneath the illustration, as illustrated below:



SI Equivalents

in.	1/4	1/2	1	3 1/2	4	6	7 1/2	20	28	50	1 hp
mm	6.4	12.7	25.4	89	102	152	190	508	711	1270	746 W

FIG. 0 Los Angeles Abrasion Testing Machine

H5. Permissible Exceptions to SI Units

H5.1 Certain non-SI units have been widely used in engineering practice and will be permitted in ASTM standards without addition of SI units in parentheses only under the following conditions:

H5.1.1 If approved for use in Standard E 380 for Metric Practice, or

H5.1.2 If approved for use in a Supplementary Metric Practice Guide prepared in accordance with the recommendations of Committee E-43 on Metric Practice.

ASTM, 1916 Race St., Philadelphia, PA 19103 (215) 299-5400

20 February 1981

CIRCULAR LETTER NO. 655

TO: Technical Committee Officers

SUBJECT: Supplementary Metric Practice Guides

Committee E-43 on Metric Practice has balloted the enclosed document entitled Recommendations for Preparation and Issuance of "Supplementary Metric Practice Guides" which they have submitted to the Committee on Standards.

The intent of the document is to serve as a basis for revising "Part H Use of Metric (SI) Units in ASTM Standards" of the June 1980 Form and Style for ASTM Standards (Blue Book).

The Committee on Standards would like to have comments on the document for the COS Task Force on revising the "Blue Book".

Please comment to me at Headquarters prior to June 1, 1981.

Sincerely,

G.O. Atkinson
Vice President
Standards Development

GOA/kd

9/30/80

RECOMMENDATIONS FOR PREPARATION AND ISSUANCE OF "SUPPLEMENTARY METRIC PRACTICE GUIDES"

1. SCOPE

1.1 This document establishes guidelines and recommendations for preparing Supplementary Metric Practice Guides. These guides will provide for metric practices specifically related to ASTM Standards over which a committee has jurisdiction.

2. RESPONSIBILITY FOR PREPARATION

2.1 Each ASTM committee, if it deems necessary, should prepare a Supplementary Metric Practice Guide to minimize deviations from ASTM E 380 and encourage the selection and consistent use of preferred units and numbers.

2.2 Supplementary Metric Practice Guides may be prepared by any ASTM subcommittee when approved by the responsible ASTM Main Committee.

3. REQUIREMENTS FOR PREPARATION

3.1 Supplementary Metric Practice Guides are to be prepared in accordance with these recommendations.

3.2 The supplementary Metric Practice Guides are limited to areas related to the standards under the jurisdiction of the ASTM committee that prepares the guide.

3.3 Consideration should be given to coordinate metric practice with committees having related standards.

4. RECOMMENDED UNITS

4.1 Each Supplementary Metric Practice Guide should include the SI units, preferred prefixes, and preferred numbers related to the subject or field involved.

4.2 The Supplementary Metric Practice Guide should include conversion factors for converting inch-pound and other non-SI units to the recommended SI units. Base, supplementary, and derived unit conversion factors which are already in ASTM E 380 should be kept to a minimum.

4.3 Committee E-43 should be contacted for additional help needed beyond that provided in ASTM E 380.

5. PRECISION, ACCURACY AND TOLERANCES

5.1 The recommended precision (number of decimal places or number of significant figures) and tolerances for specific sizes and properties may be included in the guide.

5.2 The recommended precision shall maintain the same degree of precision that was implied in the original value or the accuracy necessary for interdependencies between values.

6. ROUNDING

6.1 A recommended rounding practice for the specified quantities should be considered for inclusion in the guide.

7. PROCEDURE FOR USING THE GUIDE

7.1 A Supplementary Metric Practice Guide should contain guidelines, procedures, or recommendations for using the guide in developing new metric standards, or converting old standards to SI units or in other technical work of the Committee including:

a) Recommendations as to which SI unit (and prefix) is to be used for each particular application. (See Sec. 4.1)

b) Proper use of non SI units that are applicable and unique to the special field covered by the guide.

c) Explanation or precautions involving special practices (See Sec. 8.1) or conversion factors (See Sec. 4.2), if applicable

d) Rounding practice together with percentage variation, when applicable.

e) Recommended precision for specified sizes, when applicable.

8. SPECIAL PRACTICES

8.1 Recognition of and provision for special practices applicable and unique to the field covered by the Supplementary Metric Practice Guide may be included.

9. <u>RESPONSIBILITY FOR REVIEW</u>

9.1 Supplementary Metric Practice Guides prepared by Subcommittees shall be submitted to Committee E-43 by the responsible ASTM Main Committee.

9.2 Committee E-43 is responsible for a timely* review, in accordance with its scope, of submitted Supplementary Metric Practice Guides prior to publication to ensure compliance with ASTM E 380 and the special units and the practices in Section 7 and 8 as above.

9.3 Each committee should designate an individual to act as liaison with Committee E-43 during review of a Supplementary Metric Practice Guide.

10. <u>PUBLICATION</u>

10.1 Supplementary Metric Practice Guides will be published in the related materials section ("gray pages") as supplements to ASTM E 380 in the appropriate part of the <u>Annual Book of ASTM Standards</u>.

10.2 Supplementary Metric Practice Guides must be identified by title and the phrase "Committee _____ Supplement to E 380", for example, "Abbreviated Metric Practice Guide for the Roofing Industry/Committee D-8 Supplement to E 380" and will not be assigned an ASTM designation number unless the responsible ASTM Committee makes a special request to the Committee on Standards (COS) including the justification why an ASTM designation number is needed. In the latter case, the Metric Practice Guide will be published as a standard in the appropriate part of the <u>Annual Book of ASTM Standards</u> and include the phrase "Committee _____ Supplement to E 380."

* To be agreed upon between E-43 and submitting committee on document-by-document basis.

KP/df
6355S

The American Society of Mechanical Engineers
United Engineering Center/345 E. 47th St., New York, N.Y. 10017/212 644-7722

P-9.1
5/4/77

COUNCIL POLICY

<u>Metric System</u>

The Society supports a coordinated voluntary national program of conversion to the International System of Measurement. ASME will cooperate with other organizations and societies in implementing this policy. The ASME interpretation of SI is contained in "ASME Guide SI-1, ASME Orientation and Guide for Use of SI-Metric".

All works, papers and periodicals published by the Society shall require units to be in the International System (SI). Customary units may also be included.

The Council directs the Policy Board, Codes and Standards to assure that Codes and Standards shall be published in SI units at the appropriate time as determined by industry, government, public and society needs consistent with national plans for coordinating and managing development of SI Standards.

Responsibility: Special Committee of the Council on Metric System

Adopted October 24, 1975
Revised April 22, 1977

engineering department bulletin

No. 79

June 3, 1976

GUIDELINES FOR METRIC CONVERSION OF NEMA STANDARDS

This document is prepared by the NEMA Metric Subcommittee as a tool to help all the NEMA Sections in converting their standards to metric. The following points may not be complete but are some of the important considerations in this conversion process.

1. Each Section should determine the timetable for the standards pertaining to the equipment in their product scope.

2. All standards should be identified which should be converted. Many of these standards may be outside of the control of the Section and should be brought to the attention of the proper standards authority.

3. Priorities must be established for the conversion of the Section standards.

4. A decision must be made as to whether the conversion will be hard or soft. The reasons for this change should be carefully considered.

5. The Section should consider the impact of its changes on other NEMA Sections for the use of this equipment in their product, and similarly, the impact of these changes on the products within its own Section.

6. The interface of products is an important consideration, since most electrical products are used in conjunction with other electrical products.

7. All NEMA Standards will follow the metric practice as shown in Z210.1 (latest edition).

NEMA

National Electrical Manufacturers Association
155 East 44th Street • New York, N Y 10017 • 212-682-1500

8. Consideration should be given to the applicable ISO or IEC standards. It is not mandatory to follow these international standards, but appropriate sections may be used.

9. A method should be determined for tolerancing to provide interchangeability of products.

10. Metric standards for sheet metal thicknesses and bar stock have been approved by ANSI and are now listed. (B32.3 and B32.4). These new dimensions should be considered.

11. A program should be implemented to notify the users and other NEMA Sections on the implications of the changeover to metrics in the new or revised standard.

Approved by Metric Conversion Subcommittee on April 21, 1976.

Approved by the Federal Product Regulations Committee on April 28, 1976.

Approved by the Codes and Standards Committee on May 17-18, 1976.

Legal Guidelines For Metrication of NEMA Standards

Metricizing NEMA Standards can present risks of liability under the antitrust laws. Standardization itself is legal, but it is illegal to use it as part of a price-fixing scheme, to exclude competitors from the field, to curtail production or otherwise to restrain trade.

To comply with the foregoing legal requirements NEMA standardization activities must be carried on in accord with the guidelines listed below. These guidelines are divided into two categories: general and special. Each category of guidelines is equally important, but the heading "special" is included to emphasize concerns particular to the metric conversion process.

General Guidelines

1. Voluntary Adherence to Standards. Adherence or non-adherence to a NEMA Standard must be left to the individual discretion of every manufacturer unaffected by agreements, understandings or direction of any type by the Association or among manufacturers.

2. Engineering and Technical Considerations. NEMA activity in the field of standardization shall be confined to the definition of the engineering and technical characteristics of electrical products within the scope of NEMA.

3. Commercial Standards. NEMA Standards shall not include provisions which are a part of the commercial relationship between the manufacturer and the purchaser such as warranties, allocation of the risk of loss, conditions of acceptance or rejection, or the determination of which party is to provide certain services incidental to the installation of a standard item.

4. Standard Practice. The statement that a certain method or procedure shall be the "standard practice" or any similar statement should be examined carefully before inclusion in NEMA Standards. The statement must be shown to refer to an engineering or technical method or procedure and not constitute a recommendation or statement of what the actual procedures of the various manufacturers should be.

5. "Special" Products. NEMA Standards shall not include statements to the effect that certain items are to be considered as "special" or some similar term which might infer a difference between the production policies, and consequently the prices, covering such items and those covering other items.

6. Minimums and Maximums. If a standard is framed to specify a technically adequate level of performance or characteristic it should be phrased in such a way as to not constitute a ceiling preventing the development of a superior product. Normally this will be accomplished by specifying the technically adequate level as a minimum. In the case of certain undesirable characteristics such as leakage current or radio influence voltage, the technically adequate level will be expressed as a maximum.

In some cases, however, where the minimum or maximum of a whole class is inappropriate due to the complexity of the relationship among the various characteristics of the product or because of other valid technical or engineering reasons, it is permissible to fix on specific or "preferred" ratings. A NEMA Standard must present an adequate number of ratings so that the field is adequately covered and no exclusion or restriction takes place.

7. Exclusion of Products. NEMA Standards should be drawn so as to include all technically adequate equipment in the field; that is, all products which fall within the definitions or the criteria of the standard. They must not unjustifiably exclude the products of any member or non-member manufacturer. If a standard incidentally excludes a certain product, however, solely because it is considered dangerous or inadequate on engineering or technical grounds, no question is raised.

8. Patented Items. NEMA Standards should include items whose production is covered by patents only if the patent holder agrees to and does make available to any interested and qualified person a license on reasonable terms. NEMA Standards should not be drawn so as intentionally to exclude patented items.

9. Accessories. Normally NEMA Standards do not include standards for accessories. Standards for accessories require particularly close scrutiny because of the prevalent suspicion of the promotion of inessential accessories. Such standards must be completely justified by engineering and technical considerations, and must be limited to matters genuinely needed for the proper and safe operation of the NEMA product which is the subject of the Standards Publication.

10. Approval by Counsel. Since the substance of standards differs, all NEMA Standards shall be approved by NEMA Counsel for compliance with NEMA policies and the law prior to their adoption.

Special Guidelines

1. Decision to Metricize Standards. A decision to metricize a NEMA Standard should be made in the informed judgement of each NEMA Subdivision unaffected by anticompetitive motives. Decisions to convert NEMA Standards into metric standards, whether through

a "soft" or "hard" conversion, prompted by considerations of stimulating international competition, fostering technical change or furthering governmental policy announced in the Metric Conversion Act should not present antitrust problems.

2. Conduct of Meetings. At NEMA meetings, there can be no discussion of prices, costs, sales or production quotas, territories, allocations, boycotts, identified individual company statistics, inventories, warranties, guarantees, or other terms and condition of sale and any other similar topics.

It is appropriate during metrication of NEMA Standards to discuss technical matters, priorities for development of metric standards and voluntary timetables for the standards covering electrical products within the Subdivisions' stated scope. However, there can be no discussion of when an industry or members of an industry should as a group manufacture products according to NEMA Metric Standards.

3. Effective Date. The effective date of a NEMA (Metric) Standard is the date of its approval by the Codes and Standards Committee. When such approval is subject to the assent of one or more Subdivisions, the effective date is the date of the meeting of the Codes and Standards Committee at which the assent of all such Subdivisions is reported.

4. User Input. NEMA Subdivisions formulating NEMA Metric Standards should avail themselves of the widest possible user input in shaping new or revised standards. The process of obtaining user input should include coordination with other standards organizations and affected parties. Serious consideration should be given to inviting members of industry, users, and other parties to NEMA meetings to express views on proposed metric standards.

A corollary to this general requirement for user input in NEMA Metric Standards is that the availability of NEMA's appeals procedures should be made known when disagreements arise concerning the contents of a NEMA Metric Standard.

5. Relations With The Metric Board. The Metric Conversion Act of 1975 provides for the establishment of a governmental body whose general functions are planning, coordination and public education with the aim of furthering the increasing use of the metric system in the United States. NEMA and its Subdivisions may engage in some contacts with the Metric Board consistent with NEMA policies and the Board's functions.

The participation of a government body in conduct that violates the antitrust laws is generally no defense to such conduct. Because particular activities of the Metric Board may have antitrust risks connected with them, each NEMA Subdivision should consult with Counsel prior to taking any action regarding contacts with the Metric Board.

Distribution:

President
Codes and Standards Committee
Federal Products Regulations Committee
Metric Conversion Subcommittee
Subdivision Secretaries
Engineering & Safety Regulations Department
NEMA Counsel

SAE STATEMENT OF METRIC POLICY

The Society of Automotive Engineers recognizes the rapid growth of metric usage, particularly in the industries it serves. It is the policy of SAE to change to the modern metric system (SI) in a manner and on a schedule that is in harmony with the provisions of the U.S. Metric Conversion Act of 1975, and that best serves the interests of SAE members and the public at large.

To assure good communications during this period of transition in measurement, SAE will -

- o include SI units, with customary units where necessary, in all SAE publications - technical papers, special publications, transactions, standards and related reports.
- o encourage the use of SI units in preferred position in SAE publications and publish reports and papers using only SI units where judgment indicates that old units are not needed by the users.
- o take steps to gradually phase out the use of old units when they are no longer necessary, with a goal of completion by 1985.

Considering the influence of measurement systems on standards and the urgent need for good international standards by the industries served, SAE will -

- o consider international needs in SAE standards development, preparing standards with international use in mind.
- o promote suitable U.S. standards for worldwide use, and accept and use suitable international standards.
- o encourage SAE committees to work and think in metric, using SI as a basis for new standards wherever interface with existing standards permits.
- o encourage using the change to SI as a basis for simplifying and reducing variety in existing standards during the revision process, wherever existing relationships are not adversely affected.

Approved by the SAE Board of Director
December 2, 1976
Editorial correction 3/3/77

NOTE: Appendices of SAE J916, "Rules for SAE Use of SI (Metric Units" are not attached here.

RULES FOR SAE USE OF SI (METRIC) UNITS— SAE J916 JUN80

SAE Recommended Practice

Report of the Publication Policy Committee, approved June 1965, last revised by Metric Advisory Committee June 1980.

1. Introduction—In the spring of 1969 the SAE Board of Directors issued a statement that "SAE will include SI[1] units in SAE Standards and other technical reports." Much investigation has attended the determination of units of measure for use, since measurement practice all over the world is to some degree in a state of transition. Engineering use of measurement units in nearly every metric country of the world, and in all of those nations adopting metric units, is confronted with the struggle between the noncoherent technical metric units, such as kilogram-force and calorie, and the SI units, such as newton and joule.

This document establishes the rules for the use of SI units in SAE reports, including specifications and standards. It must be remembered that a technical committee may produce its reports in any units it feels are proper for the users—U. S. inch-pound, SI, or other metric. However, if the units used do not conform to the Units Approved for SAE Use (see paragraph 2), they must be followed by SI units in parentheses.

Throughout this document, SI is intended to include recognized SI units as established by the international General Conference on Weights and Measures,[2] (CGPM) and a limited number of other units that are not formal SI units.

These other units are all included in the American National Standard Z210.1, "Standard for Metric Practice" in "The Metric System of Measurement" issued by the Secretary of Commerce in the 10-26-77 Federal Register, and in ISO 1000, the worldwide document for use by all ISO[3] committees.

By careful contact with other countries, the General Conference, and ISO, this document will be updated as often as necessary to keep the use of SI units in SAE reports as nearly as possible in harmony with the units that will be adopted for United States and world use.

2. Units Approved for SAE Use—All SAE documents produced under the Board of Directors' directive to "include SI units" must utilize as applicable:

2.1 Base Units of SI

Quantity	Unit (symbol)
length	—meter[4] (m)
mass	—kilogram (kg)
time	—second (s)
electric current	—ampere (A)
thermodynamic temperature	—kelvin (K)
amount of substance	—mole (mol)
luminous intensity	—candela (cd)

2.2 Supplementary Units of SI

Quantity	Unit (symbol)
plane angle	—radian (rad)
spherical angle	—steradian (sr)

2.3 Recognized Derived Units of SI with Special Names

Quantity	Unit (symbol)	Formula
absorbed dose	—gray (Gy)	J/kg
activity (of a radionuclide)	—becquerel (Bq)	1/s, s^{-1}
Celsius temperature	—degree Celsius (°C)	5
dose equivalent	—sievert[6] (Sv)	J/kg
electric capacitance	—farad (F)	C/V
electric conductance	—siemens (S)	A/V
electric inductance	—henry (H)	Wb/A
electric potential diff.	—volt (V)	W/A
electric resistance	—ohm (Ω)	V/A
energy, work	—joule (J)	N·m
force	—newton (N)	$kg \cdot m/s^2$
frequency	—hertz (Hz)	1/s, s^{-1}
illuminance	—lux (lx)	lm/m^2
luminous flux	—lumen (lm)	cd·sr
magnetic flux	—weber (Wb)	V·s
magnetic flux density	—tesla (T)	Wb/m^2
power	—watt (W)	J/s
pressure or stress	—pascal (Pa)	N/m^2
quantity of electricity	—coulomb (C)	A·s

See Z210.1 paragraph 2, for more complete description.

2.4 Other Units that May be Used with SI

Quantity	Unit (symbol)
plane angle	—degree (°) (decimal divisions preferred)
time	—minute (min), hour (h), day (d), week, and year
mass	—metric ton (t)
area	—hectare (ha)
sound pressure level	—decibel (dB)
volume	—liter[4] (L)[7]
navigation velocity	—knot (kn)[8]
distance	—nautical mile (nmi)[8]

When these units are used, they need not be followed by SI units unless it suits the purpose of the document.

The liter which the General Conference established as a special name for the cubic decimeter, is approved for SAE use, normally for fluid measurement only, and the only prefixed use allowed is mL.

In the case of time, committees are urged to use the second and its multiples, but the units given above are permitted.

The unit metric ton (exactly 1 Mg) is in wide use but should be limited to commercial description of vehicle mass, or freight mass, and no prefix is permitted.

[1] SI—The International System of Units (Systeme International) officially abbreviated "SI" in all languages—the modern metric system.

[2] CGPM Resolutions and Recommendations are published in NBS Special Publication 330, "The International System of Units (SI)."

[3] The International Organization for Standardization.

[4] "re" spelling is also used.

[5] In 1976 the CIPM decided that the degree Celsius is a special name for the kelvin, to be used to express Celsius temperature. For formula see paragraph 8.

[6] Approved by CGPM in 1979.

[7] In 1979 the CGPM approved the symbol "L" for liter and it is recommended for North American use. The alternative symbol "l" will also be used during a transition period.

[8] Abbreviation, not a symbol.

The unit hectare (exactly 1 hm²) is restricted to land and water area measurement.

2.5 Other derived units that are formed from those units and derived units indicated above are also acceptable. For example, the SI unit designation for electric field strength is V/m; however, it is also expressed in terms of base units as $kg \cdot m/(s^3 \cdot A)$ or $kg \cdot m \cdot s^{-3} \cdot A^{-1}$. Likewise, torque and bending moment $(N \cdot m)$ may also be expressed as $kg \cdot m^2/s^2$ or $kg \cdot m^2 \cdot s^{-2}$.

3. Units Not Approved for Use as SI—Gravimetric force units, such as kilogram-force, or kilogram-force per square millimeter, which have been common in some countries, must not be used in SAE reports. Similarly, calorie, bar, angstrom, and dyne are not SI units and are not to be used. However, as stated in Section 1, this restriction does not preclude use of these units where a committee considers them to be the proper units for the users of the report, and provided they are followed with approved SI units in parentheses.

4. Multiplying Prefixes—Table 1 lists the prefixes to be used with SI units, observing the rules given in Section 5.

TABLE 1—SI UNIT PREFIXES

Multiples and Submultiples	Prefixes	Symbols	Pronunciations
10^{18}	exa	E	ex'a
10^{15}	peta	P	pet'a
10^{12}	tera	T	ter'a
10^{9}	giga	G	ji'ga
10^{6}	mega	M	meg'a
10^{3}	kilo	k	kil'o
10^{2}	hecto	h	hek'to
10	deka	da	dek'a
10^{-1}	deci	d	des'i
10^{-2}	centi	c	sen'ti
10^{-3}	milli	m	mil'i
10^{-6}	micro	μ	mi'kro
10^{-9}	nano	n	nan'o
10^{-12}	pico	p	pe'co
10^{-15}	femto	f	fem'to
10^{-18}	atto	a	at'to

5. Rules for Use of Units

5.1 Requirements of this document establish the use of SI units in one of the following manners:

5.1.1 *As regular units followed by other units in parentheses.*

5.1.2 In parentheses following other units.

5.1.3 As regular units where presently usable by the user, in which case no units need be added in parentheses.

5.1.4 Under special circumstances it is permissible to deviate from these rules. See Appendix B.

5.2 SI units must be those shown in Appendix A or their decimal multiples, except as covered in paragraph 6.2. In case of need for other units the Metric Advisory Committee of the SAE Technical Board should be consulted. If units for quantities not included in Appendix A and not clearly covered by paragraph 6.2 are required, the above committee should be contacted for guidance.

An apparent anomaly exists in the use of the joule for work $(J = N \cdot m)$ and the use of $N \cdot m$ for torque or bending moment. These are, however, entirely different units. In the former, the unit of work results from unit force moving through unit distance. In the latter, there is no implication of movement, and unit force acts at right angles to the lever arm of unit length. This would be readily seen if vectors were incorporated in the unit symbols. For these reasons, it is important to express work or energy in joules and moment of force or torque in newton meters, not joules.

5.3 Use of Prefixes

5.3.1 Use of prefixes representing 10 raised to a power which is a multiple of 3 is recommended. *In the case of prefixed units which carry exponents,* such as units of area and volume, this may not be practical, however, and any listed prefix may be used.

5.3.2 Compound prefixes, such as milli-micro, are never used.

5.3.3 In general, prefixes in the denominator of a compound unit should be avoided except for established usage. (Since the kilogram is a base unit of SI, use of kg in the denominator is not contrary to this guidance.)

5.3.4 When expressing a quantity by a numerical value and a unit, prefixes should preferably be chosen so that the numerical value lies between 0.1 and 1000. This is, of course, not true where certain multiples and units have been agreed to for particular use, such as kPa for pressure, or where tabular use requires the same unit in a series, even though this means exceeding the preferred range of 0.1-1000.

5.3.5 The prefix becomes a part of the symbol or name with no separation (meganewton, MN).

5.3.6 Errors in *calculations* can be minimized if all quantities are expressed in SI units, and prefixes are replaced by powers of 10.

5.3.7 With SI units of higher order, such as m² or m³, the prefix is also raised to the same order; for example, 1 mm³ is $(10^{-3} m)^3$ or $10^{-9} m^3$.

5.4 Symbols and Abbreviations

5.4.1 Distinction—The distinction between unit symbols and unit abbreviations is not always recognized, particularly with certain U. S. inch-pound units of measurement. The symbols for some U. S. units are also abbreviations (ft, in, yd). In many cases the unit symbol and the abbreviation are not the same (such as unit symbol ft³/min and abbreviation cfm; unit symbol A and abbreviation amp; unit symbol in³ and abbreviation cu in). A positive distinction can be made between unit symbols and unit abbreviations. The SI unit symbol designation is the same in all languages. Abbreviations are conventional representations of words or names in a particular language; they may be different in different languages.

5.4.2 Unit Symbol Composition—Unit symbols are letters or groups of letters predominantly from the English alphabet representing the units in which physical quantities are measured (m for meter, W·h for watthour). Non-English alphabet unit symbols are (Ω) for ohm, (°) for the plane angle degree or used with the Celsius (°C) temperature scale, and (μ) for the prefix micro. All unit symbols are printed in Roman (upright) type.

5.4.3 Unit Symbol Style[a]—Unit symbols are, in general, shown as lower case letters. If, however, the symbol is derived from a proper name, it or the

[a]Handling of Unit Names—Names of units are never capitalized except at the beginning of sentences or in titles. (Modifiers used in unit names are capitalized if proper names; for example, degree Fahrenheit.) Compound unit names are formed with a space for product and the word "per" for quotient. Prefixes become part of the word: ampere (A), milliampere (mA), ampere second (A·s), meter per second (m/s).

◆ TABLE 2—ABBREVIATIONS AND SYMBOLS FOR UNITS OTHER THAN SI

Unit Name	Symbol	Abbreviation	Unit Name	Symbol	Abbreviation
brake horsepower		bhp	inch pound—force	in·lbf	
Brinell hardness number		Bhn	kilocycle	kc	
British thermal unit	Btu		kilogram—force	kgf	
calorie	cal		mile	mi	
candlepower		cp	mile per hour	mi/h	mph
cubic foot per minute	ft³/min	cfm	minute (angle)	'	min
cubic foot per second	ft³/s	cfs	ounce	oz	
cycle per minute	c/min	cpm	ounce—force	ozf	
cycle per second	c/s	cps	part per gallon		ppg
cycle	c		pint	pt	
degree Fahrenheit	°F		pound	lb	
degree Rankine	°R		poundal	pdl	
dram	dr		pound—force	lbf	
foot	ft		pound—force per		
footcandle	fc		square inch	lbf/in²	psi
foot per minute	ft/min		pound—force per		
foot per second	ft/s		square inch absolute		psia
foot pound—force	ft·lbf		pound—force per		
friction horsepower		fhp	square inch gage		psig
gallon	gal		quart	qt	
gallon per minute	gal/min	gpm	revolution per minute	r/min	rpm
gallon per second	gal/s	gps	revolution per second	r/s	rps
horsepower	hp		Saybolt universal second		SUS
inch	in				
inch of mercury	in Hg		second (angle)	"	sec
inch of water	in H_2O		yard	yd	

first letter (where more than one) is an upper case letter (*Hz*, Wb, *Pa*). An exception to the above permits the upper case (L) to represent the unit liter because of the confusion that can occur between the lower case unit symbol (l) and the number one (1).

The letter style must be followed for SI unit symbols and prefixes even in applications where all other lettering is upper case (such as technical drawings). The only exception allowed is for computer and machine displays with *limited character sets. For symbols for use in systems with limited character* sets, refer to ANSI X3.50 or ISO 2955. The symbols for limited character sets must never be used when the available character set permits the use of the proper symbols as given herein.

5.4.4 Quantity Symbols—Unit symbols must not be confused with quantity symbols. Quantity symbols are single letters representing the magnitude of physical quantities (*I* for electric current, *e* for charge of an electron) and are established in upper or lower case that must always be maintained (*f*—frequency, *F*—force, *m*—mass, *M*—moment of force).

Quantity symbols are single letters of the English or Greek alphabet, and are printed in italic (slanting) type.

5.4.5 Abbreviations—Abbreviations are *shortened forms of words or* phrases formed in various ways that have been accepted and established (ANSI Y1.1). They are generally letters from the word being abbreviated, except where the abbreviation is taken from another language (no for number, lb for pound). Abbreviations are never to be used when a mathematical operation sign is involved, unless the abbreviation is also the symbol.

5.4.6 *Symbolized Compound (Derived) Units*[9]—Compound (derived) *units constitute a mathematical expression.* Where compound units include the solidus (/), it must not be repeated in the same expression. In complicated cases, negative powers or parentheses should be used. For example, write: m/s² or m·s⁻² but not m/s/s; or write kg·m/(s³·A) or kg·m·s⁻³·A⁻¹ but not kg·m/s³/A.

5.4.7 Plural—The form of symbols and abbreviations is the same for singular or plural (1 in, 10 in, 1 s, 27 s).

5.4.8 Periods are not used after symbols or abbreviations. The same abbreviation is used for related noun, verb, adverb, etc. (inclusion, include, inclusive are all abbreviated incl). When these rules would cause confusion, spell out the word. Words of four letters or less are not abbreviated.

5.4.9 When writing a quantity, a space should *be left* between the *numerical* value and a unit symbol—for example, write 35 mm, not 35mm. An exception occurs when the symbols for degree of plane angle or degree Celsius are used, in which case the space is omitted (25°C).

5.5 Miscellaneous

5.5.1 With nominal sizes that are not measurements but are names for items, no conversion should be made: for example, 1/4-20 UNC thread, 1 in *pipe, 2 x 4 lumber*.

5.5.2 The decimal marker used by SAE is the dot on the line (.) for quantities in either U.S. customary or SI units.

To facilitate the reading of numbers having five or more digits, the digits should be placed in groups of three separated by a space instead of a comma, counting both to the left and to the right of the decimal point. In the case of four digits, the spacing is optional. This style also avoids confusion caused by the use elsewhere of the comma to express the decimal marker.

For example, use

1 532 or 1532 instead of 1,532
132 541 816 instead of 132,541,816
983 769 788 16 instead of 983,769.78816

5.5.3 Surface roughness expressed in microinches should be converted to micrometers (μm).

5.5.4 Linear dimensions on engineering drawings *will customarily* be given in millimeters regardless of length.

6. General

6.1 The principal departure of SI from the gravimetric form of metric engineering units is the separate and distinct units for mass and force. The kilogram is restricted to the unit of mass. The newton is the unit of force and should be used in place of the kilogram-force. The newton instead of the *kilogram-force* should be used in combination units which include force, for example, pressure or stress (N/m² = Pa), energy (N·m = J), and power (N·m/s = W).

Considerable confusion exists in the use of the term weight to mean either force or mass.

In scientific use, the term *weight* of a body usually means a force related to gravity,[10] which varies in time and space. Weight, if used to mean force also varies. Observed values differ by over 0.5% at various points on the earth's surface.

In commercial and everyday use, the term weight is nearly always synonymous with mass. Thus, in speaking of a person's weight, the quantity referred to is mass.

Because of this dual use, it is wise to avoid the term weight, except under circumstances in which its meaning is completely clear. When the term is used, it is important to know whether mass or *force is intended, and to use* SI units properly as clarified in the first paragraph of this section, using kilograms for mass and newtons for force.

6.2 Many units for rates are not shown in Appendix A, but should be derived from approved units. For example, the proper unit for mass per unit *time* is kg/s.

6.3 Expressions that can be stated as a ratio of the same unit, such as 0.006 inch per inch, should be *changed to a designation of a ratio* such as 0.006:1. Where an expression might be shown in two different units one of which is a multiple of the other, reduce the expression to a common unit and show it as a ratio. Example: 1.50 in per ft = 0.125 ft per ft. Express as a ratio 0.125:1.

6.4 It has been internationally recommended that pressure units themselves should not be modified to indicate whether the pressure is *absolute* (that is, *above zero*) or *gage* (that is, above atmospheric pressure). If, therefore, the context leaves any doubt as to which is meant, the word *pressure* must be qualified appropriately.

For example:

"... at a gage pressure of 200 kPa" or
"... at an absolute pressure of 95 kPa" or
"... reached an absolute pressure of 95 kPa".
etc.

7. Conversion Techniques—Conversion of quantities between systems of units involves careful determination of the number of significant digits to be retained. To convert "1 *quart of oil*" to "0.9463529 *liter of oil*" is, of course, nonsense because the intended accuracy of the value does not warrant expressing the conversion in this fashion.

This section provides information to be used as a guide in the conversion of quantities specified in SAE Standards. In certain circumstances, reasons may exist for using other guidance. For example, in the case of interchangeable dimensions on engineering drawings, a more specific approach is outlined in SAE J390, Dual Dimensioning, although the methods given here will usually produce the same results.

All conversions, to be logically established, *must* depend upon an intended precision of the original quantity—either implied by a specific tolerance, or by the nature of the quantity. The first step in conversion is to *establish this* precision.

7.1 Precision of a Value—It is absolutely necessary to determine the intended precision of a value before converting.

The intended precision of a value *should* relate to the number of significant digits shown. The implied precision is plus or minus one-half unit of the last significant digit in which the value is stated. This is true because it may be assumed to have *been rounded from a greater number of digits*, and *one-half* unit of the last significant digit retained is the limit of error resulting from rounding. For example, the number 2.14 may have been rounded from any number between 2.135 and 2.145. Whether rounded or not, a quantity should always be expressed with this implication of precision in mind. For instance, 2.14 in implies a precision of ±0.005 in, since the last significant digit is in units of 0.01 in.

Two problems interfere with this, however:

(a) *Quantities may* be *expressed* in digits which are not intended to be significant. The dimension 1.1875 in may be a very precise one in which the digit in the fourth place is significant, or it may in some cases be an exact decimalization of a rough dimension $1\frac{3}{16}$ in, in which case the dimension is given with too many decimal places relative to its intended precision.

(b) Quantities may be expressed omitting significant zeros. The dimension 2 in may mean "about 2 in", or it may, in fact, mean a very precise expression which should be written 2.0000 in. In the latter case, while the added zeros are not significant in establishing the value, they are very significant in expressing the proper intended precision.

Therefore, it is necessary to determine an approximate implied precision before converting. This can usually be done by using knowledge of the circumstances or information on the accuracy of measuring equipment.

If accuracy of measurement is known, this will provide a convenient lower limit to the precision of the dimension, and in some cases may be the only basis for establishing it. The implied precision should never be smaller than the accuracy of measurement.

A tolerance on a dimension will give a good indication of the intended precision, although the precision will, of course, be much smaller than the tolerance. A dimension of 1.635 ± 0.003 in obviously is intended to be quite precise, and the precision implied by the number of significant digits is correct (±0.0005 in, total 0.001 in). A dimension of 4.625 ± 0.125 in is obviously a different matter. The use of thousandths of an inch to express a tolerance of

[10] The force which if applied to the body would give it acceleration equal to the local acceleration of free fall.

0.25 in is probably the result of decimalization of fractions, and the expression is probably better written 4.62 ± 0.12, with an implied precision of ±0.005 (total implied precision 0.01 in). The circumstances, however, should be examined and judgment applied.

A rule of thumb often helpful for determining implied precision of a toleranced value is to assume it is one-tenth of the tolerance. Since the implied precision of the converted value should be no greater than that of the original, the total tolerance should be divided by 10, converted, and the proper significant digits retained in both the converted value and converted tolerance such that total implied precision is not reduced—that is, such that the last significant digit retained is in units no larger than one-tenth the converted total tolerance.

EXAMPLE: 200 ± 15 psi. Tolerance is 30 psi, divided by 10 is 3 psi, converted is about 20.7 kPa. The value (200 psi) converted is 1 378.9514 ± 103.421 355 kPa which should be rounded to units of 10 kPa, since 10 kPa is the largest unit smaller than one-tenth the converted tolerance. The conversion should be 1380 ± 100 kPa.

EXAMPLE: 25 ± 0.1 oz of alcohol. Tolerance is 0.2 oz, one-tenth of tolerance is 0.02 oz, converted is about 0.6 cm^3. The converted value (739.34 ± 2.957 cm^3) should be rounded to units of 0.1 cm^3 and becomes 739.3 ± 3.0 cm^3.

7.2 Conversion Procedure. In the sections that follow, the "total implied precision" discussed in paragraph 7.1 is referred to as "TIP".

7.2.1 First determine TIP.

7.2.2 Convert the dimension, TIP, and the tolerance if any, by the accurate conversion factor given in this document or ANSI Z210.1.

7.2.3 Choose the smallest number of decimals to retain, such that the last digit retained is in units equal to or smaller than the converted TIP.

7.2.4 Round off to this number of decimals by the following rules:

7.2.4.1 Where the digit next beyond the last digit to be retained is less than 5, the last digit retained should not be changed. Example: 4.46325 if rounded to three places would be 4.463.

7.2.4.2 Where the digits beyond the last digit to be retained amount to more than 5 followed by zeros, the last digit retained should be increased by one. Example: 8.37652 if rounded to three places would be 8.377.

7.2.4.3 Where the digit next beyond the last digit to be retained is exactly 5, the last digit retained, if even, is unchanged; but if odd, the last digit is increased by one. Example: 4.36500 becomes 4.36 when rounded to two places. 4.35500 also becomes 4.36 when rounded.

7.2.5 Examples

7.2.5.1 Test pressure 200 ± 15 psi

TIP not evident in this case

Total tolerance 30 psi, divided by 10 is 3 psi converted equals 20.68 kPa, for TIP use 10 kPa

Units to use, 10 kPa

200 ± 15 psi equals 1 378.9514 ± 103.421 355 kPa, round to 1380 ± 100 kPa

7.2.5.2 A stirring rod 6 in long

Estimate of TIP: Assume intended precision $\pm \frac{1}{16}$ in, TIP = $\frac{1}{8}$ in

Converted TIP $\frac{1}{8} \times 25.4 = 3.17$ mm

Units to use, 1 mm

6 in equals 152.4 mm, round to 152 mm

7.2.5.3 50 000 psi tensile strength

Estimate of TIP 400 psi from nature of use and precision of measuring equipment

Converted TIP 2.8 MPa

Units to use, 1 MPa

50 000 psi equals 344 737.85 MPa, round to 345 MPa

7.2.5.4 5.163 in length

Estimate of TIP 0.001 in (significant digits judged correct)

Converted TIP 0.0254 mm

Units to use, 0.01 mm

5.163 in equals 131.1402 mm, round to 131.14 mm

7.2.5.5 12.125 in length

Estimate of TIP 0.06 in from nature of use

Converted TIP 1.524 mm

Units to use 1 mm

12.125 in equals 307.975 mm, round to 308 mm

7.2.6 In dealing with toleranced quantities or quantities that establish limits, the rounding may be required in one direction only. When *maximum* or *minimum* are specified and judgment shows that these terms are mandatory, a *maximum quantity* must be rounded downward and a minimum rounded upward. The following illustrations show rounding of a dimension to two decimal places under different circumstances.

Dimension converted to 131.7625 mm
Round to two decimal places

(a) Normal dimension, untoleranced
Round to 131.76 mm (closest to original)

(b) Dimension stated as *minimum*
Round to 131.77 mm (rounded *up*)

(c) Dimension stated as *maximum*
Round to 131.76 mm (rounded *down*)

Similarly, a toleranced quantity may be rounded as in item (a). However, if critical it may be first converted to limits and each limit rounded in the appropriate fashion depending on the nature of the individual limit. For absolute maintenance of the original limits, the upper limit should be rounded down and the lower limit rounded up. (This is method B described in ANSI Z210.1.)

8. *Temperature Conversion*—The SI unit for temperature is the kelvin. SAE will use kelvins principally for thermodynamics, but the Celsius[11] temperature scale will also be commonly used.

The Celsius scale is related to the kelvin scale as follows:

One degree Celsius equals one kelvin exactly. Celsius temperature ($t_{°C}$) is related to kelvin temperature (T_K) as follows:

$$T_K = 273.15 + t_{°C}$$

The Celsius scale is related to the Fahrenheit scale as follows:

One degree Celsius equals $\frac{9}{5}$ of a degree Fahrenheit, exactly. Celsius temperature ($t_{°C}$) is related to Fahrenheit temperature ($t_{°F}$) as follows:

$$t_{°C} = \frac{5}{9}(t_{°F} - 32)$$

General guidance for converting tolerances from degrees Fahrenheit to kelvins or degrees Celsius is given below:

Conversion of Temperature Tolerance Requirements

Tolerance, °F	Tolerance, K or °C
±1	±0.5
±2	±1
±5	±3
±10	±5.5
±15	±8.5
±20	±11
±25	±14

Normally, temperatures expressed in a whole number of degrees Fahrenheit should be converted to the nearest 0.5 kelvin (or degree Celsius). As with other quantities, the number of significant digits to retain will depend upon implied accuracy of the original dimension, for example:

100 ± 5°F: implied accuracy estimated to be 2°F.
37.7777 ± 2.7777°C rounds to 38 ± 3°C.

1000 ± 50°F: implied accuracy estimated to be 20°F.
537.7777 ± 27.7777°C rounds to 540 ± 30°C.

9. *Bibliography*

American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103.

American National Standards Institute (ANSI), 1430 Broadway, New York, NY 10018.

Standard for Metric Practice (ANSI Z210.1 and ASTM E380).

American National Standards Institute.

ANSI X3.50, Representations for U. S. Customary, SI, and Other Units to be Used in Systems with Limited Character Sets.

International Organization for Standardization,[12] Geneva, Switzerland:

ISO 1000, SI Units and Recommendations for the Use of their Multiples and of Certain Other Units.

ISO 2955, Information Processing—Representations of SI and Other Units for Use in Systems with Limited Character Sets.

Superintendent of Documents, U. S. Government Printing Office, Washington, DC 20402.

National Bureau of Standards, NBS Special Publication 330, The International System of Units (SI).

National Bureau of Standards, Washington, DC 20234.

Federal Register Notice of 10-26-77, NBS Letter Circular LC1078 The Metric System of Measurement as issued by the Secretary of Commerce.

[11] The term "Celsius" officially replaced "Centigrade" to eliminate confusion with French metric decimalized angular measurement (a "grad" or "grade" is 1% of a right angle, and a "centigrad" or "centigrade" is 1% of a "grad").

[12] Available in U. S. from American National Standards Institute.

ASTM (HARD) METRIC STANDARDS

A 109M - 77	Spec. for Steel, Carbon, Cold-Rolled Strip (Metric)
A 227M - 80	Spec. for Steel Wire, Cold Drawn for Mechanical Springs (Metric)
A 325M - 79	Spec. for High-Strength Bolts for Structural Joints (Metric)
A 407M - 80	Spec. for Steel Wire, Cold Drawn, for Coiled-Type Springs (Metric)
A 417M - 80	Spec. for Steel Wire, Cold Drawn, for Zig-Zag Square-Formed and Sinuous-Type Upholstery Spring Units (Metric)
A 446M - 80	Spec. for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, Structural (Physical) Quality (Metric)
A 510M - 77	Spec. for General Requirements for Wire Rods and Coarse Round Wire, Carbon Steel (Metric)
A 525M - 80	Spec. for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, General Requirements (Metric)
A 563M - 80	Spec. for Carbon and Alloy Steel Nuts (Metric)
A 568M - 77	Spec. for Steel, Carbon and High-Strength Low-Alloy Hot-Rolled Sheet, Hot-Rolled Strip, and Cold-Rolled Sheet, General Requirements (Metric)
A 574M - 80	Spec. for Alloy Steel Socket-Head Cap Screws (Metric)
A 615M - 81b	Spec. for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement (Metric)
A 619/A 619M-82	Spec. for Steel Sheet, Carbon, Cold-Rolled, Drawing Quality
A 620/A 620M-82	Spec. for Steel Sheet, Carbon, Cold-Rolled, Drawing Quality, Special Killed
A 621/A 621M-82	Spec. for Steel Sheet and Strip, Carbon, Hot-Rolled, Drawing Quality
A 622/A 622M-82	Spec. for Steel Sheet and Strip, Carbon Hot-Rolled, Drawing Quality, Special Killed
A 623M - 78	Spec. for General Requirements for Tin Mill Products (Metric)

A 624M - 79	Spec. for Tin Plate, Single-Reduced Electrolytic (Metric)
A 626M - 79	Spec. for Tin Plate, Double-Reduced Electrolytic (Metric)
A 635M - 81	Spec. for Steel Sheet and Strip, Carbon (0.15% max), Hot-Rolled Commercial Quality, Heavy-Thickness Coils (Formerly Plate) (Metric)
A 680/A 680M-81	Spec. for Steel, High Carbon, Strip, Cold-Rolled Hard, Untempered Quality
A 682M - 77	Spec. for Steel, High-Carbon, Strip, Cold-Rolled, Spring Quality, General Requirements (Metric)
A 684/A 684M-81	Spec. for Steel, High Carbon, Strip, Cold-Rolled Soft, Untempered Quality
A 749M - 77	Spec. for Steel, Carbon, and High-Strength, Low-Alloy, Hot-Rolled Strip, General Requirements (Metric)
B 16M - 82	Spec. for Free-Cutting Brass Rod, Bar, and Shapes (Metric)
B 21M - 82	Spec. for Naval Brass, Rod, Bar, and Shapes (Metric)
B 133M - 82	Spec. for Copper, Rod, Bar, and Shapes (Metric)
B 139M - 82	Spec. for Phosphor Bronze Rod, Bar and Shapes (Metric)
B 140M - 80	Spec. for Copper-Zinc-Lead (Leaded Red Brass or Hardware Bronze) Rod, Bar, and Shapes (Metric)
B 151M - 81	Spec. for Copper-Nickel-Zinc Alloy (Nickel Silver) and Copper-Nickel Rod and Bar (Metric)
B 159M - 82	Spec. for Phosphor Bronze Wire (Metric)
B 196M - 81	Spec. for Copper-Beryllium Alloy Rod and Bar (Metric)
B 197M - 81	Spec. for Copper-Beryllium Alloy Wire (Metric)
B 209M - 82	Spec. for Aluminum-Alloy Sheet and Plate (Metric)
B 210M - 82	Spec. for Aluminum-Alloy Drawn Seamless Tubes (Metric)
B 211M - 82	Spec. for Aluminum-Alloy Bar, Rod, and Wire (Metric)

B 221M - 82	Spec. for Aluminum-Alloy Extruded Bars, Rods, Wire, Shapes, and Tubes (Metric)
B 234M - 82	Spec. for Aluminum-Alloy Drawn Seamless Tubes for Condenser and Heat Exchanger (Metric)
B 247M - 80	Spec. for Aluminum-Alloy Die and Hand Forgings (Metric)
B 248M - 80	Spec. for General Requirements for Wrought Copper and Copper-Alloy Plate, Sheet, Strip, and Rolled Bar (Metric)
B 249M - 82	Spec. for General Requirements for Wrought Copper and Copper-Alloy Rod, Bar, and Shapes (Metric)
B 250M - 79	Spec. for General Requirements for Wrought Copper-Alloy Wire (Metric)
B 251M - 81	Spec. for General Requirements for Wrought Seamless Copper and Copper-Alloy Tube (Metric)
B 491M - 82	Spec. for Aluminum and Aluminum-Alloy Extruded Round Tubes for General Purpose Applications (Metric)
B 557M - 81	Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products (Metric)
B 666M - 80	Practice for Identification Marking of Aluminum Products (Metric)
C 14M - 81	Spec. for Concrete Sewer, Storm Drain, and Culvert Pipe (Metric)
C 76M - 82	Spec. for Reinforced Concrete Culvert Storm Drain, and Sewer Pipe (Metric)
C 118M - 81	Spec. for Concrete Pipe for Irrigation or Drainage (Metric)
C 361M - 78	Spec. for Reinforced Concrete Low-Heat Pressure Pipe (Metric)
C 412M - 81a	Spec. for Concrete Drain Tile (Metric)
C 443M - 81a	Spec. for Joints for Circular Concrete Sewer and Culvert Pipe, Using Rubber Gaskets (Metric)
C 444M - 80a	Spec. for Perforated Concrete Pipe (Metric)

C 478M - 82	Spec. for Precast Reinforced Concrete Manhole Sections (Metric)
C 497M - 82	Testing Concrete Pipe, Sections, or Tile (Metric)
C 505M - 80a	Spec. for Nonreinforced Concrete Irrigation Pipe with Rubber Gasket Joints (Metric)
C 506M - 81a	Spec. for Reinforced Concrete Arch Culvert, Storm Drain, and Sewer Pipe (Metric)
C 507M - 81a	Spec. for Reinforced Concrete Elliptical Culvert, Storm Drain, and Sewer Pipe (Metric)
C 654M - 80a	Spec. for Porous Concrete Pipe (Metric)
C 655M - 81	Spec. for Reinforced Concrete D-Load Culvert, Storm Drain, and Sewer Pipe (Metric)
C 789M - 81	Spec. for Precast Reinforced Concrete Box Sections for Culverts, Storm Drains, and Sewers (Metric)
C 850M - 81	Precast Reinforced Concrete Box Sections for Culverts, Storm Drains and Sewers with Less than 0.6 m of Cover Subjected to Highway Loadings (Metric)
C 877M - 80	Spec. for External Sealing Bands for Noncircular Concrete Sewer, Storm Drain, and Culvert Pipe (Metric)
C 923M - 80	Spec. for Resilient Connectors Between Reinforced Concrete Manhole Structures and Pipes (Metric)
C 924M -	Practice for Low-Pressure Air Test of Concrete Pipe Sewer Lines
C 969M - 82	Practice for Infiltration and Exfiltration Acceptance Testing of Installed Precast Concrete Pipe Sewer Lines (Metric)
D 638M - 81	Test for Tensile Properties of Plastics (Metric)
D 790M - 81	Test for Flexural Properties of Plastics and Electrical Insulation Materials (Metric)
D 885M - 79	Testing Tire Cords, Tire Cord Fabrics, and Industrial Filament Yarns Made from Man-Made Organic-Base Fibers (Metric)
D 2860M -	Test for Adhesion of Pressure-Sensitive Tape to Fiberboard at 90-deg Angle and Constant Stress

D 2970M - 80	Testing Tire Cords, Tire Cord Fabrics, and Industrial Yarns Made from Glass Filaments (Metric)
D 3330M - 81	Test for Peel Adhesion of Pressure-Sensitive Tape at 180-Deg. Angle (Metric)
F 467M - 80	Spec. for Nonferrous Nuts for General Use (Metric)
F 468M - 80	Spec. for Nonferrous Bolts, Hex Cap Screws, and Studs for General Use (Metric)

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APPENDIX D

METRICATED NEMA STANDARDS

The following NEMA Standards Publications are fully metricated, in that they use metric units of measurement consistently. Partially-metricated Standards (such as those which express temperature in degrees Celsius but otherwise use customary units) are not listed. Likewise, Standards that are not dimension-sensitive, such as those limited to general definitions or symbols, are not listed.

Unless otherwise noted, the publications are "soft" converted (customary measurements algebraically translated to metric equivalents) and dual-dimensioned, the customary units listed first with SI equivalents following in parentheses.

"Hard" indicates hard conversion, or selection of measured quantities in rational metric magnitudes.

"SI Preferred" indicates that SI units are listed first, with customary units in parentheses.

BC1-1979	Bituminous Fiber Duct for Underground Installation	SI Preferred
CB1-1977	Brushes for Electrical Machines	
CG1-1980	Manufactured Graphite Electrodes	
CG2-1969 (R1974, 1980)	Graphite Electrolytic Electrodes	
DC2-1976	Quick Connect Terminals	
DC3-1978	Low-voltage Room Thermostats	SI Preferred
DC12-1979	Hot-water Immersion Controls	SI Preferred
DC13-1979	Line-voltage Integrally Mounted Thermostats for Electric Heaters	SI Preferred
DC15-1979	Line-voltage Room Thermostats	SI Preferred
EW1-1971 (R1976)	Electric Arc-welding Apparatus	Note 1
EW3-1976	Semiautomatic Wire Feed Systems for Arc Welding	
IB4-1979	Determination of Amperehour and Watthour Capacity of Lead-acid Industrial Storage Batteries for Stationary Service	Note 1

IB5-1979	Life Testing of Lead-acid Industrial Storage Batteries for Stationary Service	Note 1
IB7-1970	Testing Arrestor Vents Used on Lead-acid Industrial Storage Batteries for Stationary Service	SI Units Only
II1-1976	Digital Panel Instruments	Hard, SI Preferred
NU1-1980	Performance Measurements of Scintillation Cameras	SI Units Only
PV5-1976	Constant-potential-type Electric Utility (Semiconductor Static Converter) Battery Chargers	Note 1
PV1-1971	Thyristor Power Supplies For Metal Rolling Mill Main Drives	Note 1
RI2-1966 (R1971, 1976)	General-purpose and Communication Battery Chargers	Note 1
RI3-1962 (R1971, 1976)	Semiconductor Rectifier Units Used as Power Supplies of 300kW or Less	Note 1
RI9-1968 (R1973)	Silicon Rectifier Units for Transportation Power Supplies	Note 1
TC2-1978	Electrical Plastic Tubing (EPT) and Conduit (EPC-40 and EPC-80)	
TC3-1978	PVC Fittings for Use With Rigid PVC Conduit and Tubing	
TC5-1978	Corrugated Polyolefin Coilable Plastic Utilities Duct	
TC6-1978	PVC and ABS Plastic Utilities Duct for Underground Installation	
TC7-1978	Smooth-wall Coilable Polyethylene Electrical Plastic Duct	

TC8-1978	Extra-strength PVC Plastic Utilities Duct for Underground Installation	
TC9-1978	Fittings for ABS and PVC Plastic Utilities Duct for Underground Installation	
TC10-1978	PVC and ABS Plastic Communications Duct for Underground	
TR1-1980	Transformers, Regulators and Reactors	
TR27-1965 (R1971, 1976)	Commercial, Institutional and Industrial Dry-type Transformers	Note 1
TR98-1978	Guide for Loading Oil-immersed Power Transformers with 65° Average Winding Rise	Note 1
WC2-1980	Steel Armor and Associated Coverings for Impregnated-paper-insulated Cables	
WC3-1980	Rubber-insulated Wire and Cable for the Transmission and Distribution of Electrical Energy	
WC4-1976	Varnished-cloth-insulated Wire and Cable for the Transmission and Distribution of Electrical Energy	
WC5-1973 (R1979)	Thermoplastic-insulated Wire and Cable for the Transmission and Distribution of Electrical Energy	
WC7-1971 (R1976)	Cross-linked-thermosetting-polyethylene-insulated Wire and Cable for the Transmission and Distribution of Electric Energy	
WC8-1976	Ethylene-propylene-rubber-insulated Wire and Cable for the Transmission and Distribution of Electrical Energy	

XR5-1974 (R1979)	**Measurement of Dimensions of Focal Spots of Diagnostic X-ray Tubes**	**SI Units Only**
XR7-1979	**High-voltage X-ray Cables and Receptacles**	**SI Preferred**
250-1979	**Enclosures for Electrical Equipment (1000 Volts Maximum)**	**SI Preferred**

NOTE:

1. Standard is inherently "metricated" in that it uses only common technical units such as degrees Celsius, volts, amperes, decibels, etc. which are common to both the customary and metric systems of measurement.

Appendix E

Acronyms for Organizations Used in This Report.

ACI	American Concrete Institute
AECMA	European Association of Aerospace Manufacturers
AIA	Aerospace Industries Association of America
ANMC	American National Metric Council
ANSI	American National Standards Institute
ASME	The American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
DOD	Department of Defense
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardization
NBS	National Bureau of Standards
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
SAE	Society of Automotive Engineers
UL	Underwriters' Laboratories, Incorporated
USMB	United States Metric Board

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