INSTRUMENT ENGINEERS' HANDBOOK

Fourth Edition

Process Measurement and Analysis

VOLUME I

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Process Measurement and Analysis

VOLUME I

Béla G. Lipták

EDITOR-IN-CHIEF

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Dedicated to you, my colleagues, the instrument and process control engineers. I hope that by applying the knowledge found on these pages you will make our industries more efficient, safer, and cleaner, and thereby will not only contribute to a happier future for all mankind but will also advance the recognition and respectability of our profession.

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INTRODUCTION

Ours is a very young profession: when the first edition of the *Instrument Engineers' Handbook (IEH)* came out, Marks' *Mechanical Engineers' Handbook* was in its fifth edition, and Perry's *Chemical Engineers' Handbook* was in its sixth! Now, as we are starting to work on the fourth edition of the *IEH*, we are already in a new millenium. But while our profession is young, we are also unique and special.

After all, no other engineering profession can claim what we can! No other engineering profession can offer to increase the GDP by $50 billion without building a single new plant, and to do that while *increasing* safety and *reducing* pollution. We can do that! We can achieve that goal solely through the optimization of our existing industries. We can increase productivity without using a single pound of additional raw material, without needing a single additional BTU.

THIS FOURTH EDITION

During the nearly four decades of its existence, the *IEH* has become the most widely used reference source of the instrumentation and control (I&C) engineering profession. During this same period, the tools of our I&C profession have changed as control systems were transformed from the early mechanical and pneumatic ones to today's electronic and digital implementations.

During this period, even the name of our profession has changed. Today, some call it *automation*, while others refer to it by a variety of other names, including *instrumentation, process control, I&C,* and *computer automation*. Yet, while we have not been able to agree even on the name of our profession, our experience and our knowledge of control principles has penetrated all the fields of modern science and technology. I hope that the three volumes of the *IEH* have played a major role in spreading this knowledge and understanding.

In 1968, this handbook started out as a three-volume reference set, and, in that respect, no change has occurred. The first volume deals with measurement, the second with control, and the third with digital networks and software systems.

CONTENTS OF THE *IEH* VOLUMES

In this, the first volume, a chapter is devoted to each major measured variable, and a subchapter (section) is devoted to each different method of making that measurement. Some measurements are relatively simple as, for example, the detection of level; therefore, that chapter has only 21 sections. Others, such as analysis, are more varied, and that chapter has 66 sections.

The individual sections (subchapters) begin with a *flowsheet symbol* and a *feature summary.* This summary provides quick access to specific information on the available sizes, costs, suppliers, ranges, and inaccuracies of the devices covered in that section.

This fourth edition updates the information content of the previously published sections, incorporates the new developments of the last decade by the addition of new sections, and broadens the horizons of the work from an American to a global perspective.

In this first volume, *Process Measurement and Analysis*, the emphasis is on measurement hardware, including the detection of flow, level, temperature, pressure, density, viscosity, weight, composition, and safety sensors.

The second volume of this set, *Process Control*, covers control hardware, including transmitters, controllers, control valves, and displays, and it provides in-depth coverage to the theory of control and explains how the unit processes of pumping, distillation, chemical reaction, heat transfer, and many others are controlled.

The third volume is devoted to *Process Software and Digital Networks*. In combination, the three volumes cover all the topics used by process control or instrument engineers.

READERS OF THE *IEH*

Experienced process control engineers are likely to use this reference set either to obtain quick access to specific information or to guide them in making selections. Less experienced engineers and students of instrument engineering are likely to use this reference work as a textbook. A student might use it to learn about the tools of our profession.

To fulfill the expectations of both the experienced and the beginning engineer, the handbook has been structured to be flexible. On one hand, it contains all the basic information that a student needs, but it also covers the most recent advances and provides quick and easy access to both types of information. Quick access to specific topics and information is provided both by the *feature summary* at the beginning of each section and by an extensive index at the end of each volume.

BIRD'S EYE VIEWS: ORIENTATION TABLES

Another goal of this reference set is to assist the reader in selecting the best sensors for particular applications. To achieve this goal, each chapter begins with a section that provides an application- and selection-oriented overview along with an *orientation table*.

The orientation tables list all the sensors that are discussed in the chapters and summarize the features and capabilities of each. If the reader is using this handbook to select a sensor for a particular application, the orientation table allows the narrowing of the choices to a few designs.

After the options have been reduced, the reader might turn to the corresponding sections and, based on the information in the *feature summaries* at the front of each section, decide if the costs, inaccuracies, and other characteristics meet the requirements of the application. If so, the reader might focus in on the likely candidate and read all the information in the selected section.

NEW NEEDS AND EXPECTATIONS

As I was editing this reference set for the fourth time, I could not help but note the nature of both the new solutions and the new needs of the process control industry.

The new solutions become obvious as you review the contents of the 400 to 500 sections of the 25 or so chapters of this set of handbooks. The new needs are not so obvious. The new needs are the consequences of the evolution of new hardware, new software, and the completely new technologies that have evolved. These needs become obvious only if one is immersed in the topic to the depth and for the duration that I have been. It might speed technological progress if some of these needs are mentioned here.

INTERNATIONAL STANDARDIZATION

In earlier decades, it took some time and effort to agree on the 3 to 15 PSIG (0.2 to 1.0 bar) signal pressure range for the standard pneumatic or on the 4 to 20 mA DC standard analog electronic signal range. Yet, when these signal ranges were finally agreed upon, everybody benefited from having a standard signal.

Similarly, the time is ripe for adopting a worldwide standard for *a single digital communication protocol*. The time is ripe for an internationally accepted digital protocol that could link all the digital "black boxes" and could also act as the "translator" for those that were not designed to "speak the same language." In so doing, the valuable engineering energies that today are being spent to figure out ways for black boxes to communicate could be applied to more valuable tasks, such as increasing the productivity and safety of our processing industries. Optimization can make our industries competitive once again and contribute not to the export of jobs but to the creation of jobs at home.

MEANINGFUL PERFORMANCE STANDARDS

It is also time to rein in the commercial interests and to impose uniform expectations so that all sales literature will provide performance data in the same form. In today's sales literature, the performance-related terms such as *inaccuracy* and *rangeability* are rarely defined properly.

Such terms as "inaccuracy" are frequently misstated as "accuracy," and sometimes the error percentages are given without stating whether they are based on full-scale or actual readings. It is also time for professional societies and testing laboratories to make their findings widely available so that test results can be used to compare the products of different manufacturers.

It is also desirable to have the manufacturers always state not only the inaccuracy of their products but also the rangeability over which that inaccuracy statement is valid. Similarly, it would be desirable if *rangeability* were defined as the ratio between those (maximum and minimum) readings for which the inaccuracy statement is valid.

It would also be desirable to base the inaccuracy statements on the performance of at least 95% of the sensors tested and to include in the inaccuracy statement not only linearity, hysteresis, and repeatability, but also the effects of drift, ambient temperature, overrange, supply voltage, humidity, radio frequency interference (RFI), and vibration.

BETTER VALVES

The performance capabilities of final control elements should also be more uniformly agreed upon and more reliably stated. This is particularly true for the characteristics, gains, and rangeabilities of control valves. For example, a valve should be called linear *only* if its gain (Gv) equals the maximum flow through the valve (Fmax) divided by the valve stroke in percentage (100%).

Valve manufacturers should publish the stroking range (minimum and maximum percentages of valve openings) within which the gain of a linear valve is still Fmax/100%.

Valve rangeability should be defined as the ratio of these minimum and maximum valve openings. Other valve characteristics should also be defined by globally accepted standards in this same manner.

"SMARTER" SENSORS AND ANALYZERS

In the case of transmitters, the overall performance is largely defined by the internal reference used in the sensor. In many cases, there is a need for multiple-range and multiple-reference units. For example, pressure transmitters should have both atmospheric and vacuum references and should have sufficient intelligence to switch automatically from one to the other reference on the basis of their own measurement. Similarly, d/p flow transmitters should have multiple spans and should have the intelligence to automatically switch their spans to match the actual flow as it changes.

The addition of "intelligence" could also increase the amount of information gained from such simple detectors as pitot tubes. If, for example, in addition to detecting the difference between static and velocity pressures, the pitot tube were also able to measure the Reynolds number, it would be able to approximate the shape of the velocity profile. An "intelligent pitot-tube" of such capability could increase the accuracy of volumetric flow measurements.

IMPROVED ON-LINE ANALYZERS

In the area of continuous on-line analysis, further development is needed to extend the capabilities of probe-type analyzers. The needs include the changing of probe shapes to achieve self-cleaning or using "flat tips" to facilitate cleaning. The availability of automatic probe cleaners should also be improved, and their visibility should be increased by the use of sight flow indicators.

An even greater challenge is to lower the unit costs of fiber-optic probes through multiplexing and by sharing the cost of their electronics among several probes. Another important goal for the analyzer industry is to produce devices that are self-calibrating, self-diagnosing, and modular in design. To reduce the overall cost of analyzer maintenance, defective modules should identify themselves and should be easily replaceable.

EFFICIENCY AND PRODUCTIVITY CONTROLLERS

In the area of control, what is most needed is to move from the uncoordinated single loops to optimizing, multivariable envelope, and matrix algorithms. When using such multivariable envelopes, the individual levels, pressures, and temperatures become only constraints, while the overall multivariable envelope is dedicated to maximizing the efficiency or productivity of the controlled process.

In this sense, most of today's digital controls are still only "empty boxes." New software packages are needed to "educate" and to give "personality" to them. Software is needed that, when loaded, will transform a general-purpose unit controller into an advanced and optimized control system serving the particular process, whether it is a chemical reactor, a distillation tower, a compressor, or any other unit operation.

This transformation in the building blocks of control systems would also make the manufacturing of digital control hardware more economical, because all "empty boxes" could be very similar.

UNIT OPERATION CONTROLLERS

The use of such multipurpose hardware could also provide more flexibility to the user, because a unit controller that was controlling a dryer, for example, could be switched to control an evaporator or a pumping station just by loading a different software package into it. Once the particular software package was loaded, the unit controller would require customization only, which could be done in a menu-driven question-and-answer format.

During the customization phase, the user would answer questions on piping configuration, equipment sizes, material or heat balances, and the like. Such customization software packages would automatically configure and tune the individual loops and would make the required relative gain calculations to minimize interaction between loops. It will probably take a couple decades to reach these goals, but to get there, it is necessary to set our sights on these goals now.

COMMON SENSE RECOMMENDATIONS

While talking about such sophisticated concepts as optimized multivariable control, it is very important to keep our feet on the ground, keep in mind that the best process control engineer is still Murphy, and remember that, in a real plant, even Murphy can turn out to be an optimist. For that reason, I list the following common sense, practical advice, and recommendations:

- Before one can control a process, one must fully understand it.
- Being progressive is good, but being a guinea pig is not.
- If an outdated control strategy is implemented, the performance of even the latest digital hardware will be outdated.
- Increased safety is gained through the use of multiple sensors, configured through voting systems or median selectors.
- If an instrument is worth installing, it should also be worth calibrating and maintaining.

- Constancy is the enemy of efficiency; as the load and feed compositions float, the process variables should also be allowed to change with them.
- Control loops can be stabilized by replacing their single set points with control gaps.
- Annunciators do not correct emergencies, they just report problems that the designer did not know how to handle and therefore decided to drop into the laps of the operators. The smaller the annunciator, the better the control system design.
- A good process control engineer will tell the user what he needs to know and not what he wants to hear. The right time for business lunches is not before receiving the purchase order, but after the plant has started up and is running.

HISTORY OF THE HANDBOOK

The birth of this handbook was connected to my own work. In 1962, at the age of 26, I became the chief instrument engineer at Crawford & Russell, an engineering design firm specializing in the building of plastics plants. C&R was growing, and my department had to grow with it. Still, at the age of 26, I did not dare to hire experienced people, because I did not believe that I could lead and supervise older engineers.

But the department had to grow, so I hired fresh graduates from the best engineering colleges in the country. I picked the smartest graduates, and I obtained permission from C&R's president, Sam Russell, to spend every Friday afternoon teaching them. In a few years, not only did my department have some outstanding process control engineers, C&R also saved a lot on their salaries.

By the time I reached 30, I felt secure enough to stop disguising my youth. I shaved off my beard and threw away my thick-rimmed, phony eyeglasses. I no longer felt that I had to look older, but my Friday's notes remained—they still stood in a two-foot high pile on the corner of my desk.

"DOES YOUR PROFESSION HAVE A HANDBOOK?"

In the mid-1960s, an old-fashioned Dutch gentleman named Nick Groonevelt visited my office and asked, "What is that pile of notes?" When I told him, he asked: "Does your profession have a handbook?"

"If it did, would I be teaching from these notes?" I answered with my own question. (Actually, I was wrong in giving that answer, because Behar's *Handbook of Measurement and Control* was already available, but I did not know about it.)

"So, let me publish your notes, and then instrument engineers will have a handbook!" Nick proposed, and in 1968 the first edition of the *Instrument Engineers' Handbook (IEH)* was published.

In 1968, the Soviet tanks (which I fought in 1956) were besieging Prague, so I decided to dedicate the three volumes of the *IEH* to the Hungarian and Czech freedom fighters. A fellow Hungarian-American, Edward Teller, wrote the preface to the first edition, and Frank Ryan, the editor of *ISA Journal*, wrote the introduction.

My coauthors included such names as Hans Baumann, Stu Jackson, Orval Lovett, Charles Mamzic, Howard Roberts, Greg Shinskey, and Ted Williams. It was an honor to work with such a team. In 1973, because of the publication of the first edition of the *IEH*, I was elected the youngest ISA fellow ever.

LATER EDITIONS

By the end of the 1970s, the world of process control had changed. Pneumatics were on the way out, and new approaches, such as distributed control systems (DCS) and on-line analyzers, proliferated. It was time to revise the handbook. By 1975, I also had to run my own consulting office, so I could not devote my full attention to updating the handbook.

Therefore, I hired Kriszta Venczel to do most of the work, and she did her best by inserting metric units and the like. We got some excellent new contributions, from Ed Farmer, Tom Kehoe, Thomas Myron, Richard Oliver, Phillip Schnelle, Mauro Togneri, and Theodore Williams. The second edition was published in 1982. It was well received, but I knew that it would have been better if I had devoted more time to it.

By the mid-1990s, the handbook was ready for another updating edition. By that time, the process control market was becoming globalized, "smart" instruments had evolved, and such hardware inventions as fiber-optic probes and throttling solenoid valves proliferated. Therefore, I stopped teaching at Yale and cut back on consulting to make time to edit the third edition.

By the second half of the 1990s, the first two volumes of the third edition, one on measurement and the other on control, were published. At that time, I realized that a third volume was also needed to cover all of the evolving digital software packages, communication networks, buses, and optimization packages. Therefore, it took the last decade of the twentieth century to publish the three volumes of the third edition.

THE FOURTH EDITION

Work on the fourth edition of the *IEH* started in the new millenium, and this first volume on measurement and analysis is the result of this effort. I do hope that, in three to five years, you might hold all three updated *IEH* volumes in your hands. Now that the fourth edition of the *Measurement and Analysis* volume has been published, I am starting work on the second volume, which is devoted to *process control*.

This second volume will cover control hardware, including transmitters, controllers, control valves, and displays, and it provides in-depth coverage of both control theory and how the unit processes of pumping, distillation, chemical reaction, heat transfer, and many others are controlled and optimized. My main goal is to expand this last area by both increasing the list of unit operations that we cover and, more importantly, by giving much more emphasis to optimization.

WHY DON'T YOU PITCH IN?

I would like to ask you to help me locate the best experts on all five continents for each important unit operation in our processing industries. If you have spent a lifetime learning and understanding the unique personality of a process and have figured out how to maximize its efficiency, don't keep that knowledge to yourself—share it with us.

If you or one of your colleagues would like to participate as a coauthor, please send me an e-mail, and I will send you the table of contents (TOC) of the control volume. If the topic of your interest is not in the TOC, we can add it; if it is, I will consider your offer to update the material that has already appeared in the third edition.

Please understand that I am not looking for people with writing skills, I am looking for engineers with knowledge and experience! This is not to say that I will reject college professors; naturally, I will not, although I might delete some of their differential equations and bring them down from the frequency domain back into the time domain. Similarly, I will consider the contributions of professional consultants if they do not view the *IEH* as a forum for self-promotion. I will also consider manufacturers as coauthors if they are able to be balanced and are willing to give credit where credit is due, even if it means crediting their competition.

But my favorite coauthor is the plant engineer who is short on words but long on experience. I do not mind getting answers such as, "I don't know if this is conductivity or ultrasonics, all I know is that it works!" The *IEH* is written by users and for users, and it is not about fancy packaging—it is about content. So don't worry about your writing skills, I can help with that. Please help make the fourth edition of the *IEH* one we can be proud of. Please drop me an e-mail if you want to pitch in.

We know that there is no greater resource than the combined knowledge and professional dedication of a well educated new generation. We live in an age in which technology can make a difference in overcoming the social and environmental ills on this planet. We live in an age in which an inexhaustible and nonpolluting energy technology must be developed. It is hoped that this handbook will make a contribution toward these goals and that, in addition, it will improve the professional standing of instrument and process control engineers around the world.

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DEFINITIONS

ABSOLUTE (DYNAMIC) VISCOSITY (μ)	Constant of proportionality between applied stress and resulting shear velocity (Newton's hypothesis).
ABSORBANCE (A)	Ratio of radiant energy absorbed by a body to the corresponding absorption of a blackbody at the same temperature. Absorbance equals emittance on bodies whose temperature is not changing. ($A = 1 - R - T$, where R is the reflectance and T is the transmittance.)
ABSORPTION	The taking in of a fluid to fill the cavities in a solid.
ACCUMULATION	The pressure increase over the maximum allowable working pressure of a tank or vessel during discharge through the pressure relief valve. It is given either in percentage of the maximum allowable working pressure or in pressure units such as bars or pounds per square inch.
ADMITTANCE (A)	The reciprocal of the impedance of a circuit. Admittance of an AC circuit is analogous to the conductance of a DC circuit. Expressed in units of Seimens.
ADSORPTION	The adhesion of a fluid in extremely thin layers to the surfaces of a solid.
ALPHA CURVE	The relationship between the resistance change of an RTD vs. temperature. In the European alpha curves, the alpha value is 0.00385 Ω/°C; in the American curves, it is 0.00392 Ω/°C.
AMPACITY	The current (amperes) a conducting system can support without exceeding the temperature rating assigned to its configuration and application.
AMPEROMETRIC TITRATION	Titration in which the end point is determined by measuring the current (amperage) that passes through the solution at a constant voltage.
AMPEROMETRY	The process of performing an amperometric titration. The current flow is monitored as a function of time between working and auxiliary electrodes while the voltage difference between them is held constant; in other designs, the current is monitored as a function of the amount of reagent added to bring about titration of an analyte to the stoichiometrically defined end point. Also called constant *potential voltametry.*
APPARENT VISCOSITY	Viscosity of a non-Newtonian fluid under given conditions. Same as consistency.
ATTENUATION	Loss of communication signal strength.
BACKPLANE	Physical connection between individual components and the data and power distribution buses inside a chassis.
BACKPRESSURE	Pressure on the discharge side of a pressure relief valve. This pressure is the sum of the superimposed and the built-up backpressures. The superimposed backpressure is the pressure that exists in the discharge piping of the relief valve when the valve is closed.
BALANCED SAFETY RELIEF VALVE	A safety relief valve with the bonnet vented to atmosphere. The effect of backpressure on the performance characteristics of the valve (set pressure, blow-down, and capacity) is much less than on the conventional valve. The balanced safety relief valve is made in three designs: (1) with a balancing piston, (2) with a balancing bellows, and (3) with a balancing bellows and an auxiliary balancing piston.
BALLING DEGREES	Unit of specific gravity used in the brewing and sugar industries.
BALUN (BALANCED/ UNBALANCED)	A device used for matching characteristics between a balanced and an unbalanced medium.
BANDPASS FILTER	An optical or detector filter that permits the passage of a narrow band of the

total spectrum. It excludes or is opaque to all other wavelengths.

BANDWIDTH Data-carrying capacity; the range of frequencies available for signals. The term is also used to describe the rated throughput capacity of a given network medium or protocol.

BARKOMETER DEGREES Unit of specific gravity used in the tanning industry.

BASEBAND A communication technique whereby only one carrier frequency is used to send one signal at a time. Ethernet is an example of a baseband network; also called *narrowband*; contrast with *broadband*.

BAUMÉ DEGREES A unit of specific gravity used in the acid and syrup industries.

BLACKBODY The perfect absorber of all radiant energy that strikes it. The blackbody is also a perfect emitter. Therefore, both its absorbance (A) and emissivity (E) are unity. The blackbody radiates energy in predictable spectral distributions and intensities that are a function of the blackbody's absolute temperature (Figure 4.11a). A blackbody can be configured as shown in Figure 4.11b.

BLOWDOWN (BLOWBACK) The difference between the set pressure and the reseating (closing) pressure of a pressure relief valve, expressed in percent of the set pressure, bars, or pounds per square inch.

BOLOMETER Thermal detector which changes its electrical resistance as a function of the radiant energy striking it.

BONDING The practice of creating safe, high-capacity, reliable electrical connectivity between associated metallic parts, machines, and other conductive equipment.

BRIGHTNESS PYROMETER This device uses the radiant energy on each side of a fixed wavelength of the spectrum. This band is quite narrow and usually centered at 0.65 μm in the orange-red area of the visible spectrum.

BRITISH THERMAL UNIT (BTU) The amount of heat required to raise the temperature of 1 lb of water by 1°F at or near 60°F.

BRIX DEGREE A specific gravity unit used in the sugar industry.

BROADBAND A communication technique that multiplexes multiple independent signals simultaneously, using several distinct carriers. A common term in the telecommunications industry to describe any channel having a bandwidth greater than a voice-grade channel (4 kHz). Also called *wideband*. Contrast with *baseband*.

BTU "DRY" This is the heating value that is expressed on a "dry basis." The common assumption is that pipeline gas contains 7 lb (or less) of water vapor per million standard cubic feet.

BTU "SATURATED" This is the heating value that is expressed on the basis of the gas being saturated with water vapors. This state is defined as the condition when the gas contains the maximum amount of water vapors without condensation, when it is at base pressure and 60°F.

BUILT-UP BACKPRESSURE Variable backpressure that develops as a result of flow through the pressure relief valve after it opens. This is an increase in pressure in the relief valve's outlet line caused by the pressure drop through the discharge headers.

BURNING Burning is when the flame does not spread or diffuse but remains at an interface where fuel and oxidant are supplied in proper proportions.

CAPACITANCE (C) The amount of charge, in coulombs, stored in a system necessary to raise the potential difference across it by 1 V, represented in the SI unit *farad*.

CAPACITOR DEVICE This device consists of two conductors electrically isolated by an insulator. The conductors are called *plates*, and the insulator is referred to as the *dielectric*. The larger the capacitor, the smaller its impedance and the more AC current will flow through it.

CHARACTERISTIC IMPEDANCE The impedance obtained from the output terminals of a transmission line that appears to be infinitely long, when there are no standing waves on the line and the ratio of voltage to current is the same for each point of the line (nominal impedance of a waveguide).

CHATTER Rapid, abnormal reciprocating variations in lift during which the disc contacts the seat.

CHRONOPOTENTIOMETRY Process in which the potential difference between a metallic measuring electrode and a reference electrode is monitored as a function of time. At the measuring electrode, an oxidation or reduction of a solution species takes place.

CLOSING PRESSURE (RESEAT PRESSURE) The pressure, measured at the valve inlet, at which the valve closes, flow is substantially shut off, and there is no measurable lift.

COAX Jargon meaning *coaxial cable*, consisting of a center wire surrounded by low-K insulation, surrounded by a second, shield conductor. It has the characteristic of low capacitance and inductance to facilitate transmission of high-frequency current.

COLD DIFFERENTIAL TEST PRESSURE (CDTP) The pressure at which the PRV is adjusted to open during testing. The CDTP setting includes the corrections required to consider the expected service temperature and backpressure.

COMBUSTION AIR REQUIREMENT INDEX (CARI) This dimensionless number indicates the amount of air required (stoichiometrically) to support the combustion of a fuel gas. Mathematically, the combustion air requirement index is defined by the equation below:

$$\text{CARI} = \frac{\text{air/fuel ratio}}{\sqrt{\text{s.g.}}}$$

CONDUCTANCE (G) The reciprocal of resistance in units of Siemens (S, formerly *mhos*).

CONDUCTIVITY (g) The reciprocal of resistivity. All solids and liquids have some degree of conductivity. For the purpose of this section, any material above 1 μS/cm will be considered to be conductive (including most metals and water containing any ions).

CONSISTENCY Resistance of a substance to deformation. It is the same as viscosity for a Newtonian fluid and the same as apparent viscosity for a non-Newtonian fluid.

CONSTANT BACKPRESSURE Backpressure that does not change under any condition of operation, whether the pressure relief valve is closed or open.

CONVENTIONAL SAFETY RELIEF VALVE A safety relief valve with the bonnet vented either to atmosphere or internally to the discharge side of the valve. The performance characteristics (set pressure, blowdown, and capacity) are directly affected by changes of the backpressure on the valve.

COULOMETRY Process of monitoring analyte concentration by detecting the total amount of electrical charge passed between two electrodes that are held at constant potential or when constant current flow passes between them.

CPVC Chlorinated polyvinyl chloride, a low-cost, reasonably inert polymer, used in the construction of some noninsertion sensors. It is easily solvent welded. The maximum temperature range is up to about 225°F.

CRYSTALLOGRAPHY How atoms are arranged in an object; the direct relationship between these arrangements and material properties (conductivity, electrical properties, strength, etc.).

CURIE (CI) A unit of radiation source size corresponding to 37 billion disintegrations per second.

DATA SERVERS A standard interface to provide data exchange between field devices and data clients.

DEAD BAND The range through which an input can be varied without causing a change in the output.

DEFLAGRATION OR EXPLOSION A process in which a flame front advances through a gaseous mixture at subsonic speeds.

DEIONIZED Refers to water of extremely high purity, with few ions to carry current. If exposed to air for any significant period, it will have a conductivity of about 5 μS/cm because of dissolved CO_2.

DEMULTIPLEXING Separation of multiple input streams that were multiplexed into a common physical signal back into multiple output streams.

DESIGN PRESSURE This pressure is equal to or less than the maximum allowable working pressure. It is used to define the upper limit of the normal operating pressure range.

DETONATION A process in which the advancement of a flame front occurs at supersonic speeds.

DEVICE DESCRIPTION A clear, unambiguous, structured text description that allows full utilization/operation of a field device by a host/master without any prior knowledge of the field device.

DEW POINT Saturation temperature of a gas–water vapor mixture.

DIELECTRIC An electrical insulator (includes metal oxides, plastics, and hydrocarbons).

DIELECTRIC COMPENSATION A scheme by which changes in insulating liquid composition or temperature can be prevented from causing any output error. Requires a second sensor and homogeneous liquid. A dielectric is a material that is an electrical insulator or in which an electric field can be sustained with a minimum of dissipation of power.

DIELECTRIC CONSTANT A unit expressing the relative charge storage capability of various insulators. Full vacuum is defined as 1.0, and all gases are indistinguishable for practical purposes. TFE has a dielectric constant of 2.0, cold water about 80. There are no related units, because this is the ratio of absolute dielectric constant to that of vacuum. The dielectric values of selected materials are given in Tables 3.3q and 3.14a.

DIODE A two-terminal electronic (usually semiconductor) device that permits current flow predominantly in only one direction.

DISCONTINUITY An abrupt change in the shape (or impedance) of a waveguide (creating a reflection of energy).

DUST-IGNITION-PROOF Enclosed in a manner to exclude ignitable amounts of dust or amounts that might affect performance. Enclosed so that arcs, sparks, and heat otherwise generated or liberated inside of the enclosure will not cause ignition of exterior accumulations or atmospheric suspensions of dust.

EFFECTIVE COEFFICIENT OF DISCHARGE This is a coefficient used to calculate the minimum required discharge area of the PRV.

ELECTROCHEMICAL PROCESS The changes in voltage or current flow that occur between two electrodes in a solution (electrolyte) over time. The oxidation or reduction of the analyte provides data related to concentration.

ELECTROLYTIC PROBE A probe that is similar to a galvanic probe, except that a potential is applied across the electrodes, and the electrodes are not consumed. Dissolved oxygen detection is a primary application of this type of probe.

ELECTROMAGNETIC WAVE (ENERGY) A disturbance that propagates outward from any electric charge that oscillates or is accelerated; far from the charge, it consists of vibrating electric and magnetic fields that move at the speed of light and are at right angles to each other and to the direction of motion.

ELECTRON MICROSCOPE Electron microscopes are scientific instruments that use a beam of highly energetic electrons to examine objects on a very fine scale.

EMISSIVITY OR EMITTANCE (E) The emissivity of an object is the ratio of radiant energy emitted by that object divided by the radiant energy that a blackbody would emit at that same temperature. If the emittance is the same at all wavelengths, the object is called a *gray body*. Some industrial materials change their emissivity with temperature and sometimes with other variables. Emissivity always equals absorption, and it also equals 1 minus the sum of reflectance and transmittance (E = A = 1 − T − R).

EQUIVALENT TIME SAMPLING (ETS) A process that captures high-speed electromagnetic events in real time (nanoseconds) and reconstructs them into an equivalent time (milliseconds), which allows easier measurement with present electronic circuitry.

ETHERNET A baseband local area network specification developed by Xerox Corporation, Intel, and Digital Equipment Corp. to interconnect computer equipment using coaxial cable and transceivers.

EXPLOSION-PROOF All equipment is contained within enclosures strong enough to withstand internal explosions without damage, and tight enough to confine the resulting hot gases so that they will not ignite the external atmosphere. This is the traditional method and is applicable to all sizes and types of equipment.

FARAD (F) A unit of capacitance. Because this is a very large unit, a unit equal to one trillionth of a farad (called a *picofarad*, *pF*) is commonly used in RF circuits.

FEP Fluorinated ethylene propylene, a fluorocarbon that is extremely chemically inert, melts at a reasonable temperature, and can be plastic-welded fairly easily. It is difficult to bond with adhesives. The maximum temperature range is limited to the 300°F (150°C) area.

FIELDBUS An all-digital, two-way, multidrop communication system for instruments and other plant automation equipment.

FIREWALL A router or access server designated as a buffer between any public networks and a private network.

FLASH POINT The lowest temperature at which a flammable liquid gives off enough vapors to form a flammable or ignitable mixture with air near the surface of the liquid or within the container used. Many hazardous liquids have flash points at or below room temperatures. They are normally covered by a layer of flammable vapors that will ignite in the presence of a source of ignition.

FLUIDITY Reciprocal of absolute viscosity; unit in the cgs system is the rhe, which equals 1/poise.

FLUTTER Rapid, abnormal reciprocating variations in lift during which the disc does not contact the seat.

FUEL CELLS Cells that convert the chemical energy of fuel and oxygen into electrical energy while the electrode and the electrolyte remain unaltered. Fuel is converted at the anode into hydrogen ions, which travel through the electrolyte to the cathode, and electrons, which travel through an external circuit to the cathode. If oxygen is present at the cathode, it is reduced by these electrons, and the hydrogen and oxygen ions eventually react to form water.

GALVANIC PROBE A probe for which no external voltage is applied across electrodes; current flows as the cell is depolarized when diffusion of the analyte occurs. Electrodes are consumed during this operation and require periodic replacement.

GRAY BODY This is an object having an emittance of less than unity, but this emittance is constant at all wavelengths (over that part of the spectrum where the measurement takes place). This means that gray-body radiation curves are identical to the ones shown in Figure 4.11a, except that they are dropped down on the radiated power density scale.

GROSS CALORIFIC VALUE The heat value of energy per unit volume at standard conditions, expressed in terms of British thermal units per standard cubic feet (Btu/SCF) or as kilocalories per cubic Newton meters ($Kcal/N \cdot m^3$) or other equivalent units.

GROUND A conducting connection, whether intentional or accidental, between an electrical circuit or equipment and the Earth, or to some conducting body that serves in place of Earth. (See NFPA 70–100.)

GROUND FAULT PROTECTOR A device used to open ungrounded conductors when high currents, especially those resulting from line-to-ground fault currents, are encountered.

GUARD The "electronic guard" (called a *shield* in some RF level literature) consists of a concentric metallic element with an applied voltage that is identical to the voltage on the conductor that it is "guarding." This negates the capacitance between the guarded conductor and the outside world.

GUIDED WAVE RADAR (GWR) A contact radar technology for which time domain reflectometry (TDR) has been developed into an industrial-level measurement system in which a probe immersed in the medium acts as the waveguide.

HAGEN-POISEUILLE LAW Defines the behavior of viscous liquid flow through a capillary.

HOME RUN WIRING Wire between the cabinet where the Fieldbus host or centralized control system resides and the first field junction box or device.

HUB (SHARED) Multiport repeater joining segments into a network.

HYGROMETER An apparatus that measures humidity.

HYGROSCOPIC MATERIAL A material with a great affinity for moisture.

IMPEDANCE Maximum voltage divided by maximum current in an alternating current circuit. Impedance is composed of resistive, inductive, and capacitive components. As in DC circuits, the quantity of voltage divided by current is expressed in ohms (Ω).

INFRARED The portion of the spectrum whose wavelength is longer than that of red light. Only the portion between 0.7 and 20 μm gives usable energy for radiation detectors.

INTERFACE (1) Shared boundary; for example, the physical connection between two systems or two devices. (2) Generally, the point of interconnection of two components, and the means by which they must exchange signals according to some hardware or software protocol.

INTEROPERABILITY A marketing term with a blurred meaning. One possible definition is the ability for like devices from different manufacturers to work together in a system and be substituted one for another without loss of functionality at the host level (HART).

INTRINSIC SAFETY Available energy is limited under all conditions to levels too low to ignite the hazardous atmosphere. This method is useful only for low-power equipment such as instrumentation, communication, and remote control circuits.

KINEMATIC VISCOSITY (υ) Dynamic viscosity/density = $\upsilon = \mu/\rho$.

LAMBDA The desired closed-loop time constant, often set to equal the loop lag time.

LATENCY Latency measures the worst-case maximum time between the start of a transaction and the completion of that transaction.

LIFT The rise of the disc in a pressure-relief valve.

LINE DRIVER Inexpensive amplifier and signal converter that conditions digital signals to ensure reliable transmissions over extended distances without the use of modems.

LOWER EXPLOSIVE LIMIT (LEL) The lowest concentration of gas or vapor in air at which, once ignition occurs, the gas or vapor will continue to burn after the source of ignition has been removed.

LOWPASS FILTERS Filters that are used to remove high-frequency interference or noise from low-frequency signals.

MANCHESTER A digital signaling technique that contains a signal transition at the center of every bit cell.

MANUFACTURING RANGE A range around the specified burst pressure within which the marked or rated burst pressure must fall. Manufacturing range is not used in ISO standards.

MAXIMUM ALLOWABLE OPERATING PRESSURE (MAOP) The maximum pressure expected during normal operation.

MAXIMUM ALLOWABLE WORKING PRESSURE (MAWP) This is the maximum pressure allowed for continuous operation. As defined in the construction codes (ASME B31.3) for unfired pressure vessels, it equals the design pressure for the same design temperature. The maximum allowable working pressure depends on the type of material, its thickness, and the service conditions set as the basis for design. The vessel may not be operated above this pressure or its equivalent at any metal temperature other than that used in its design; consequently, for that metal temperature, it is the highest pressure at which the primary pressure relief valve can be set to open.

MECHANICAL EMISSIVITY ENHANCEMENT Mechanically increasing the emissivity of a surface to near-blackbody conditions (using multiple reflection).

MICRON Equals 001 mm, 10,000 angstroms (Å). A unit used to measure wavelengths of radiant energy.

MODEM Modulator-demodulator; a device that converts digital and analog signals. At the source, a modem converts digital signals to a form suitable for transmission over analog communication facilities. At the destination, the analog signals are returned to their digital form. Modems allow data to be transmitted over voice-grade telephone lines.

MORPHOLOGY The shape and size of the particles making up the object; the direct relationship between these structures and their material properties (ductility, strength, reactivity, etc.).

MULTIPLEXING A scheme that allows multiple logical signals to be transmitted simultaneously across a single physical channel. Compare with *demultiplexing*.

NARROWBAND PYROMETER A radiation pyrometer that is sensitive to only a narrow segment of wavelengths within the total radiation spectrum. Optical pyrometers are among the devices in this category.

NET CALORIFIC VALUE The measurement of the actual available energy per unit volume at standard conditions, which is always less than the gross calorific value by an amount equal to the latent heat of vaporization of the water formed during combustion.

NETWORK All of the media, connectors, and associated communication elements by which a communication system operates.

NEWTON The internationally accepted unit of force, defined as the force required to accelerate 1 kg by 1 m/sec^2. It equals 0.2248 pound-force or about 4 oz.

NONFRAGMENTING DISC A rupture disc design that, when burst, does not eject fragments that could interfere with the operation of downstream equipment (i.e., relief valves).

NONINCENDIARY Equipment that, in normal operation, does not constitute a source of ignition; i.e., surface temperature shall not exceed ignition temperature of the specified gas to which it may be exposed, and there are no sliding or make-and-break contacts operating at energy levels capable of causing ignition. Used for all types of equipment in Division 2 locations. Relies on the improbability of an ignition-capable fault condition occurring simultaneously with an escape of hazardous gas.

OIL IMMERSION Concept in which equipment is submerged in oil to a depth sufficient to quench any sparks that may be produced. This technique is commonly used for switchgears, but it is not utilized in connection with instruments.

OPERATING PRESSURE The operating pressure of a vessel is the pressure, in pounds per square inch gauge (PSIG), to which the vessel is usually subjected in service. A processing vessel is usually designed for a maximum allowable working pressure, in PSIG, that will provide a suitable margin above the operating pressure to prevent any undesirable operation of the relief device. It is suggested that this margin be approximately 10% or 25 PSI (173 kPa), whichever is greater. Such a margin will be adequate to prevent the undesirable opening and operation of the pressure relief valve caused by minor fluctuations in the operating pressure.

OPERATING PRESSURE MARGIN The margin between the maximum operating pressure and the set pressure of the PRV.

OPERATING PRESSURE RATIO The ratio of the maximum operating pressure to the set pressure of the PRV.

OPERATING RATIO OF A RUPTURE DISC (1) The ratio of the maximum operating pressure to the marked burst pressure expressed as a percentage (common U.S. definition). (2) The ratio of the maximum operating pressure to the minimum of the performance tolerance expressed as a percentage (common ISO definition).

OPTICAL PYROMETER Also called *brightness pyrometer*, it uses a narrow band of radiation within the visible range (0.4 to 0.7 μm) to measure temperature by color matching and other techniques.

OVERPRESSURE The pressure increase over the set pressure of the primary relief device. When the set pressure is the same as the maximum allowable operating pressure (MAOP), the accumulation is the same as the overpressure. Pressure increase over the set pressure of the primary relieving device is overpressure. We may observe from this definition that, when the set pressure of the first (primary) safety or relief valve is less than the maximum allowable working pressure of the vessel, the overpressure may be greater than 10% of set pressure.

PARTIAL PRESSURE In a mixture of gases, the partial pressure of one component is the pressure of that component if it alone occupied the entire volume at the temperature of the mixture.

PASCAL-SECOND (PA · S) Internationally accepted unit of absolute (dynamic) viscosity. One Pa·s = 1 Newton-sec/m^2 = 10 poise = 1000 centipoise.

PDVF (POLYVINYLIDENE FLUORIDE) This fluorocarbon has substantially lower temperature limits than the others (250°F or 120°C) and is less inert chemically. It is dissolved by the ketones (acetone, MEK, MIBK) and attacked by benzene and high concentrations of sulfuric acid. The most insidious enemy is caustic, which causes brittleness and cracking. It has much better toughness and abrasion resistance than the other fluorocarbons, as well as unique electrical properties (K = 8).

PE (POLYETHYLENE) A low-temperature insulation that is compatible with a wide range of corrosives but is attacked by most petroleum products. Generally limited to situations where fluorocarbons and chlorocarbons are not allowed, such as the tobacco and nuclear power industries. Maximum allowable temperature is in the 180°F (80°C) area.

PEEK (POLYETHER ETHERKETONE) A high-temperature, injection-molded polymer that is chemically quite inert. This material has wide chemical application. Temperature capability is high at 450 to 500°F (225 to 260°C). Avoid any liquids with "phenol" in their names. Adhesive bonding to the molded parts would be difficult.

PFA (PERFLUOROALKOXY) A fluorocarbon that is quite inert chemically, melts at a fairly high temperature, and is easily plastic welded. It can be used up to 550°F (290°C) but, as a probe insulation, it is generally limited to 350°F (175°C) because of bonding limitations with the metal rod.

PHASE DIFFERENCE SENSOR (PDS) A contact radar technology; unlike TDR-based systems, which measure using subnanosecond time intervals, PDS derives level information from the changes in phase angle.

PHOTODETECTOR A device that measures thermal radiation by producing an output through release of electrical changes within its body. They are small flakes of crystalline materials, such as CdS or InSb, that respond to different portions of the spectrum, consequently showing great selectivity in the wavelengths at which they operate.

PIXEL ("PICTURE ELEMENT") A dot that represents the smallest graphic unit of display in a digital image, used in machine vision and camera technology.

PLENUM Air distribution ducting, chamber, or compartment.

POISE (μ) Unit of dynamic or absolute viscosity (dyne-sec/cm^2).

POISEUILLE (PI) Suggested name for the new international standard unit of viscosity, the pascal-second.

POLAROGRAPHY Process for monitoring the diffusion current flow between working and auxiliary electrodes as a function of applied voltage as it is systematically varied. The concentration of analyte allows for the flow of the diffusion current, which is linearly dependent on the analyte concentration. Polarography can be applied using direct current, pulsed direct current, and alternating current voltage excitation waveforms. Dissolved oxygen determination is an example of an application for which polarography is used.

POTENTIOMETRY When no current is passing between electrodes. Examples: ORP, pH, selective-ion electrodes. The electromotive force or potential difference (at zero current) is monitored between the measuring and reference electrodes.

POTTING Refers to the use of a potting compound to completely surround all live parts, thereby excluding the hazardous atmosphere; has been proposed as a method of protection. There is no known usage except in combination with other means.

PP (POLYPROPYLENE) Similar to PE. Used for low cost and where fluorocarbons and chlorocarbons are excluded. Maximum temperature is in the area of 200°F.

PRESSURE-RELIEVING DEVICE The broadest category in the area of pressure-relief devices; includes rupture discs and pressure relief valves of both the simple spring-loaded types and certain pilot-operated types.

PRESSURE RELIEF VALVE (PRV) A generic term that can refer to relief valves, safety valves, and pilot-operated valves. The purpose of a PRV is to automatically open and to relieve the excess system pressure by sending the process gases or fluids to a safe location when its pressure setting is reached.

PRIMARY STANDARD A measuring instrument calibrated at a national standard laboratory such as NIST and used to calibrate other sensors.

PROOF A unit of specific gravity used in the alcohol industry.

PROTOCOL Formal description of a set of rules and conventions that govern how devices on a network exchange information.

(P)TFE (TETRAFLUOROETHYLENE) The oldest, highest-temperature, and most inert fluorocarbon probe insulation. Extremely difficult to adhesive bond, it is usable up to 550°F (290°C) but, on probes, its temperature limit is determined by the type of bonding to the probe rod (300, 450, or 550°F). This is the most common probe insulation in the industry. Because it never melts (it disintegrates, producing HF at >600°F), it is difficult to fabricate, is impossible to plastic weld, and exhibits a high degree of microporosity. Can be destroyed by butadiene and styrene monomer. (The "P" in (P) TFE stands for polymerized.)

PURGING, PRESSURIZATION, VENTILATION This refers to the maintenance of a slight positive pressure of air or inert gas within an enclosure so that the hazardous atmosphere cannot enter. Relatively recent in general application, it is applicable to any size or type of equipment.

QUEVENNE DEGREE A specific gravity unit used in expressing the fat content of milk.

RACEWAY A general term for enclosed channels, conduit, and tubing designed for holding wires and cables.

RADAR (RADIO DETECTION AND RANGING) A system using beamed and reflected radio frequency energy for detecting and locating objects, measuring distance or altitude, navigating, homing, bombing, and other purposes; in detecting and ranging, the time interval between transmission of the energy and reception of the reflected energy establishes the range of an object in the beam's path.

RADIO FREQUENCY (RF) A frequency that is higher than sonic but less than infrared. The low end of the RF range is 20 kHz, and its high end is around 100,000 MHz.

RADIO FREQUENCY INTERFERENCE (RFI) A phenomenon in which electromagnetic waves from a source interfere with the performance of another electrical device.

RATED RELIEVING CAPACITY The maximum relieving capacity of the PRV. This information is normally provided on the nameplate of the PRV. The rated relieving capacity of the PRV exceeds the required relieving capacity and is the basis for sizing the vent header system.

RATIO PYROMETER See two-color pyrometer.

REACTANCE (X) The portion of the impedance of a circuit that is caused by capacitance, inductance, or both. Expressed in ohms.

REAR MOUNT A technique for making long inactive sections by mounting the probe on the end of a pipe, with its coax cable running through the pipe to the top of the tank. The coax must survive the process temperature, so it is often of high-temperature construction.

REFLECTANCE OR REFLECTIVITY (R) The percentage of the total radiation falling on a body that is directly reflected without entry. Reflectance is zero for a blackbody and nearly 100% for a highly polished surface. ($R = 1 - A - T$, where A is the absorbance and T is the transmissivity.)

RELATIVE HUMIDITY The ratio of the mole fraction of moisture in a gas mixture to the mole fraction of moisture in a saturated mixture at the same temperature and pressure. Alternatively, the ratio of the amount of moisture in a gas mixture to the amount of moisture in a saturated mixture at equal volume, temperature, and pressure.

RELATIVE VISCOSITY Ratio of absolute viscosity of a fluid at any temperature to that of water at 20°C (68°F). Because water at this temperature has a μ of 1.002 cP, the relative viscosity of a fluid equals approximately its absolute viscosity in cP. Because the density of water is 1, the kinematic viscosity of water equals 1.002 cSt at 20°C.

RELIEF VALVE An automatic pressure-relieving device actuated by the static pressure upstream of the valve, which opens in proportion to the increase in pressure over the operating pressure. It is used primarily for liquid service.

RELIEVING PRESSURE The sum of opening pressure plus overpressure. It is the pressure, measured at a valve's inlet, at which the relieving capacity is determined.

REOPENING PRESSURE The opening pressure when the pressure is raised as soon as practicable after the valve has reseated or closed from a previous discharge.

RESISTIVE COMPONENT AC current can be separated into two components; the portion that is *in phase* with the excitation voltage is the resistive component.

RESISTIVITY (ρ) The property of a conductive material that determines how much resistance a unit cube will produce. Expressed in units of ohm-centimeters (Ω·cm).

RICHTER DEGREES A unit of specific gravity used in the alcohol industry.

ROENTGEN (R) A unit for expressing the strength of a radiation field. In a 1-R radiation field, 2.08 billion pairs of ions are produced in 1 cm^2 of air.

ROENTGEN EQUIVALENT MAN (REM) A unit of allowable radiation dosage, corresponding to the amount of radiation received when exposed to 1 R over any period of time.

ROOT VALVE The first valve off the process.

RUPTURE TOLERANCE OF A RUPTURE DISC The tolerance range on either side of the marked or rated burst pressure within which the rupture disc is expected to burst. Rupture tolerance may also be represented as a minimum–maximum pressure range. Also referred to as performance tolerance in ISO standards.

SAFETY RELIEF VALVE An automatic pressure-actuated relieving device suitable for use as either a safety or relief valve.

SAFETY VALVE An automatic pressure-relieving device actuated by the static pressure upstream of the valve and characterized by rapid and full opening or pop action. It can be used for steam, gas, or vapor service.

SAND FILLING All potential sources of ignition are buried in a granular solid, such as sand. The sand acts partly to keep the hazardous atmosphere away from the sources of ignition and partly as an arc quencher and flame arrester. It is used in Europe for heavy equipment; it is not used in instruments.

SATURATION A condition in which RF current from a probe to ground is determined solely by the impedance of the probe insulation. Increased conductivity in the saturating medium, even to infinity, will not cause a noticeable change in that current or in the transmitter output.

SATURATION PRESSURE The pressure of a fluid when condensation (or vaporization) takes place at a given temperature. (The temperature is the saturation temperature.)

SATURATED SOLUTION A solution that has reached the limit of solubility.

SAYBOLT FUROL SECOND (SFS) A time unit referring to the Saybolt viscometer with a Furol capillary, which is larger than a universal capillary.

SAYBOLT UNIVERSAL SECOND (SUS) A time unit referring to the Saybolt viscometer.

SAYBOLT VISCOMETER (UNIVERSAL, FUROL) Measures time for given volume of fluid to flow through standard orifice; units are seconds.

SEALING Excluding the atmosphere from potential sources of ignition by sealing such sources in airtight containers. This method is used for components such as relays, not for complete instruments.

SEAL-OFF PRESSURE The pressure, measured at the valve inlet after closing, at which no further liquid, steam, or gas is detected at the downstream side of the seat.

SEGMENT The section of a network that is terminated in its characteristic impedance. Segments are linked by repeaters to form a complete network.

SERVICE Term used by NFPA-70 (NEC) to demarcate the point at which utility electrical codes published by IEEE (NESC) take over. Includes conductors and equipment that deliver electricity from utilities.

SET PRESSURE (OPENING PRESSURE) The pressure at which a relief valve is set to open. It is the pressure, measured at the valve inlet of the PRV, at which there is a measurable lift or at which discharge becomes continuous as determined by seeing, feeling, or hearing. In the pop-type safety valve, it is the pressure at which the valve moves more in the opening direction as compared to corresponding movements at higher or lower pressures. A safety valve or a safety relief valve is not considered to be open when it is simmering at a pressure just below the popping point, even though the simmering may be audible.

SHEAR VISCOMETER Viscometer that measures viscosity of a non-Newtonian fluid at several different shear rates. Viscosity is extrapolated to zero shear rate by connecting the measured points and extending the curve to zero shear rate.

SIKES DEGREE A unit of specific gravity used in the alcohol industry.

SIMMER (WARN) The condition just prior to opening at which a spring-loaded relief valve is at the point of having zero or negative forces holding the valve closed. Under these conditions, as soon as the valve disc attempts to rise, the spring constant develops enough force to close the valve again.

SMART FIELD DEVICE A smart field device is a microprocessor-based process transmitter or actuator that supports two-way communications with a host, digitizes the transducer signals, and digitally corrects its process variable values to improve system performance. The value of a smart field device lies in the quality of data it provides.

SPECIFIC HUMIDITY The ratio of the mass of water vapor to the mass of dry gas in a given volume.

SPECIFIC VISCOSITY Ratio of absolute viscosity of a fluid to that of a standard fluid, usually water, both at the same temperature.

SPECTRAL EMISSIVITY The ratio of emittance at a specific wavelength or very narrow band to that of a blackbody at the same temperature.

START-TO-LEAK PRESSURE The pressure at the valve inlet at which the relieved fluid is first detected on the downstream side of the seat before normal relieving action takes place.

STICTION Combination of sticking and slipping when stroking a control valve.

STOKE Unit of kinematic viscosity, υ (cm^2/sec).

STRESS Force/area (F/A).

SUBCHANNEL In broadband terminology, a frequency-based subdivision creating a separate communication channel.

SUPERIMPOSED BACKPRESSURE Variable backpressure that is present in the discharge header before the pressure relief valve starts to open. It can be constant or variable, depending on the status of the other PRVs in the system.

SWITCHED HUB A multiport bridge joining networks into a larger network.

TEFLON®, TFE, FEP, AND PFA Most people interchange the name Teflon with TFE. This is *completely* incorrect but understandable. TFE was the first fluorocarbon polymer to carry the trade name "Teflon" at E.I. DuPont. Dupont chose to use the Teflon trade name for a whole *family* of fluorocarbon resins, so FEP and PFA made by Dupont are also called Teflon. To complicate the matter, other companies now manufacture TFE, FEP, and PFA, which legally cannot be called Teflon, because that name applies only to DuPont-made polymers.

THERMOPILE A device that measures thermal radiation by absorption to become hotter than its surroundings. It is a number of small thermocouples arranged like the spokes of a wheel with the hot junction at the hub. The thermocouples are connected in series, and the output is based on the difference between the hot and cold junctions.

TRALLES DEGREE A unit of specific gravity used in the alcohol industry.

THROUGHPUT The maximum number of transactions per second that can be communicated by the system.

TIME DOMAIN REFLECTOMETER (TDR) An instrument that measures the electrical characteristics of wideband transmission systems, subassemblies, components, and lines by feeding in a voltage step and displaying the superimposed reflected signals on an oscilloscope equipped with a suitable time-base sweep.

TIMEOUT An event that occurs when one network device expects to hear from another network device within a specified period of time but does not. The resulting timeout usually results in a retransmission of information or the dissolving of the session between the two devices.

TOPOLOGY (1) Physical arrangement of network nodes and media within an enterprise networking structure. (2) The surface features of an object—"how it looks" or its texture; a direct relation between these features and the material's properties (hardness, reflectivity, etc.).

TOTAL EMISSIVITY The ratio of the integrated value of all spectral emittance to that of a blackbody.

TRANSISTOR A three-terminal, solid state electronic device made of silicon, gallium arsenide, or germanium and used for amplification and switching in circuits.

TRANSMITTANCE OR TRANSMISSIVITY (T) The percentage of the total radiant energy falling on a body that passes directly through it without being absorbed. Transmittance is zero for a blackbody and nearly 100 percent for a material such as glass in the visible spectrum region. ($T = 1 - A - R$, where A is the absorbance and R is the reflectance.)

TWADDELL DEGREE A unit of specific gravity used in the sugar, tanning, and acid industries.

TWO-COLOR PYROMETER A device that measures temperature as a function of the radiation ratio emitted around two narrow wavelength bands. Also called a *ratio pyrometer*.

UPPER EXPLOSIVE LIMIT (UEL) The highest concentration of gas or vapor in air in which a flame will continue to burn after the source of ignition has been removed.

VARACTOR A voltage-sensitive capacitor.

VARIABLE BACKPRESSURE Backpressure that varies as a result of changes in operation of one or more pressure-relief valves connected into a common discharge header.

VELOCITY GRADIENT (SHEAR) Rate for change of liquid velocity across the stream—V/L for linear velocity profile, dV/dL for nonlinear velocity profile. Units are V–L = ft/sec/ft = sec^{-1}.

VELOCITY HEAD The velocity head is calculated as $v^2/2\,g$, where v is the flowing velocity, and g is the gravitational acceleration (9.819 m/s^2 or 32.215 ft/s^2 at 60° latitude).

WAVEGUIDE A device that constrains or guides the propagation of electromagnetic waves along a path defined by the physical construction of the waveguide; includes ducts, a pair of parallel wires, and coaxial cable.

WIDEBAND (TOTAL) PYROMETER A radiation thermometer that measures the total power density emitted by the material of interest over a wide range of wavelengths.

WOBBE INDEX AGA 4A defines the Wobbe index as a numerical value that is calculated by dividing the square root of the relative density (a key flow orifice parameter) into the heat content (or BTU per standard cubic foot) of the gas. Mathematically, the Wobbe index is defined by the equation below:

$$WI = CV/\sqrt{SQ}$$

where:
WI = the Wobbe index
CV = the calorific value
SG = the specific gravity

ABBREVIATIONS, NOMENCLATURE, ACRONYMS, AND SYMBOLS

2D	two-dimensional
3D	three-dimensional

A

a	acceleration
A	(1) area; (2) ampere, symbol for basic SI unit of electric current; (3) admittance
Å	angstrom (= 10^{-10} m)
AA	atomic absorption
AAS	atomic absorption spectrometer
abs	absolute (e.g., value)
AC	alternating current
ACFM	actual cubic feet per minute; volumetric flow at actual conditions in cubic feet per minute (= 28.32 alpm)
ACL	asynchronous connectionless
ACMH	actual cubic meters per hour
ACMM	actual cubic meters per minute
ACS	analyzer control system
ACSL	advanced continuous simulation language
A/D	analog to digital, also analog-to-digital converter
AD	actuation depth
ADC	analog-to-digital converter
ADIS	approved for draft international standard circulation
A&E	alarm and event
AES	atomic emission spectrometer
AF, a-f	audio frequency
AFD	adjustable frequency drive
AGA3	American Gas Association Report No. 3
ai	Adobe Illustrator®
AI	analog input
a(k)	white noise
ALARA	as low as reasonably achievable
ALARP	as low as reasonably practicable
alpm	actual liters per minute
alt	altitude
AM	amplitude modulated or actual measurement
amp	ampere; also A
AMPS	advanced mobile phone system
AMS	asset management solutions or analyzer maintenance solutions
AO	analog output
AOTF	acousto-optical tunable filters
AP	access point
APC	automatic process control
APDU	application (layer) protocol data unit
API	application programming interface or absolute performance index
°API	API degrees of liquid density
APM	application pulse modulation
AR	autoregressive
ARA	alarm response analysis
ARIMA	autoregressive integrated moving average
ARP	address resolution protocol
ASCII	American Standard Code for Information Interchange
AS-i	actuator sensor interface
ASIC	application-specific integrated circuit
ASK	amplitude shift keying
asym	asymmetrical; not symmetrical
ATG	automatic tank gauging
atm	atmosphere (= 14.7 psi)
ATP	adenosine triphosphate
ATR	attenuated total reflectance
AUI	attachment unit interface
aux	auxiliary
AWG	American wire gauge

B

b	dead time
°Ba	balling degrees of liquid density
bar	(1) barometer; (2) unit of atmospheric pressure measurement (= 100 kPa)
barg	bar gauge
bbl	barrels (= 0.1589 m^3)
BCD	binary coded decimal
BCS	batch control system

°Bé	Baumé degrees of liquid density
BFO	beat frequency oscillator
BFW	boiler feedwater
bhp	brake horsepower (= 746 W)
°Bk	Barkometer degrees of liquid density
blk	black (wiring code color for AC “hot” conductor)
BMS	burner management system
BOD	biochemical oxygen demand
bp, b.p.	boiling point
BPCS	basic process control system
BPS, b/sec	bits per second
BPSK	binary phase shift keying
Bq	becquerel, symbol for derived SI unit of radioactivity, joules per kilogram, J/kg
°Br	Brix degrees of liquid density
Btu	British thermal unit (= 1054 J)
BWG	Birmingham wire gauge
B2B	business to business

C

c	(1) velocity of light in vacuum (3×10^8 m/s); (2) centi, prefix meaning 0.01
C	coulombs, symbol for discharge coefficient, capacitance
°C	Celsius degrees of temperature
ca.	*circa* (about, approximately)
CAC	channel access code
CAD	computer aided design
Cal	calorie (gram = 4.184 J); also g-cal
CAN	control area network or control and automation network
CARI	combustion air requirement index
CATV	community antenna television (cable)
cc	cubic centimeter (= 10^{-6} m^3)
CCD	charge-coupled device
CCF	common cause failure or combination capacity factor
Ccm	cubic centimeter per minute
CCR	central control room
Ccs	constant current source
CCS	computer control system or constant current source
CCTV	closed circuit television
CCW	counterclockwise
CD	dangerous coverage factor
cd	candela, symbol for basic SI unit of luminous intensity
CD	compact disk or collision detector
CDDP	cellular digital data packet
CDF	cumulative distribution function
CDMA	code division multiple access
CDPD	cellular digital packet data
CDT	color detection tube
CDTP	cold differential test pressure
CEMS	continuous emissions monitoring system
CENP	combustion engineering nuclear power
CE	Conformité Européne (European Conformity), applicable to electrical safety
CFA	Continuous flow analyzer
CFM, cfm, ft^3/min	cubic feet per minute (28.32 lpm)
CFR	Code of Federal Regulations
CF/yr	cubic foot per year
Ci	curie (= 3.7 × 1010 Bq)
CI	cast iron
CIM	computer integrated manufacturing
CIP	computer aided production or control and information protocol (an application layer protocol supported by DeviceNet, ControlNet, and Ethernet/IP)
CJ	cold junction
CIP	clean in place
CL1	electrically hazardous, Class 1, Division 1, Groups C or D
CLD	chemiluminescence detector
CLP	closed-loop potential factor
cm	centimeter (= 0.01 m)
CM	condition monitoring or communication (interface) module
CMF	Coriolis mass flowmeter
CMMS	computerized maintenance management system
CMPC	constrained multivariable predictive control
cmph, m^3/h	cubic meter per hour
CNI	ControlNet International
CO	controller output or carbon monoxide
CO_2	carbon dioxide
CO_2D	carbon dioxide demand
COD	chemical oxygen demand
COF	coefficient of haze
COM	component object model
COTS	commercial off-the-shelf
cpm	cycles per minute; counts per minute
Co	cobalt
cos	cosine (trigonometric function)
cp, c.p.	(1) candle power, (2) circular pitch, (3) center of pressure (cp and ctp sometimes are used for centipoise)
cps	(1) cycles per second (hertz, Hz); (2) counts per second; (3) centipoise (= 0.001 Pa·S)
CPS	computerized procedure system
CPU	central processing unit
CPVC	chlorinated polyvinyl chloride
CR	corrosion rate
CRC	cyclical redundancy check or cyclic redundancy code. (An error detection coding technique based on modulo-2 division. Sometimes misused to refer to a block check sequence type of error detection coding.)
CRDS	cavity ring-down spectroscopy

CRLF	carriage return-line feed
CRT	cathode ray tube
Cs	cesium
CS	carbon steel
CSL	car seal lock
CSMA/CD	carrier sense, multiple access with collision detection
CSO	car seal open
CSS	central supervisory station
cSt	centistoke
CSTR	continuous-stirred tank reactor
CT	cooling tower or the product of C for disinfectant concentration and T for time of contact in minutes
CTDMA	concurrent time domain multiple access
CTMP	chemi-thermo-mechanical pulp
CVAAS	cold vapor atomic absorption spectroscopy
CVF	circular variable filters
cvs	comma-separated variables
CW	clockwise

D

d	(1) derivative, (2) differential as in dx/dt, (3) deci, prefix meaning 0.1, (4) depth, (5) day
D	diameter; also dia and ϕ or derivative time of a controller
DA	data access
D/A	digital-to-analog
DAC	device access code
DACU	data acquisition and control unit
DAE	differential algebraic equation
DAMPS	digital advanced mobile phone system
dB	decibels
DBB	double-block and bleed
DBPSK	differential binary phase shift keying
DC	diagnostic coverage
DC, dc	direct current
DCE	data communications equipment
DCOM	distributed COM
DCS	distributed control system
DD	data definition or dangerous component failure is detected in leg or a device description written using DDL
D/DBP	disinfectants/disinfection byproducts
DDC	direct digital control
DDE	dynamic data exchange
DDL	device description language (an object-oriented data-modeling language currently supported by PROFIBUS, FF, and HART)
deg	degree; also ° (π/180 rad)
DES	data encryption standard
DFIR	diffused infrared
DFR	digital fiber-optic refractometer
DFT	digital Fourier transform
DH	data highway
DI	discrete (digital) input
dia	diameter; also, D and ϕ
DIAC	dedicated inquiry access code
DIR	diffused infrared
DIS	draft international standard
DIX	Digital-Intel-Xerox (DIX is the original specification that created the *de facto* Ethernet standard. IEEE 802.3 came later, after Ethernet was established.)
d(k)	unmeasured disturbance
D(k)	measured disturbance
DLE	data link escape
DLL	dynamic link library
DMA	dynamic mechanical analyzer
DMM	digital multimeter
DN	diameter normal, the internal diameter of a pipe in rounded millimeters
DO	dissolved oxygen or discrete (digital) output
DOAS	differential optical absorption spectroscopy
d/p cell	differential pressure transmitter (a Foxboro trademark)
DPD	*N*,*N*-diethyl-*p*-phenylenediamine
DPDT	double-pole double-throw (switch)
dpi	dots per inch
DQPSK	differential quadrature phase shift keying
DSL	digital subscriber line
DSP	digital signal processing
DSR	direct screen reference
DSSS	direct sequence spread spectrum
DT	dead time (second or minutes)
DTC	digital temperature compensation
DTE	data terminal equipment
DTGS	deuterated tryglycine sulfate
DTM	device type manager (An active-X component for configuring an industrial network component. A DTM "plugs into" an FDT.)
DU	dangerous component failure occurred in leg, but undetected
DVM	digital voltmeter

E

e	(1) error, (2) base of natural (Naperian) logarithm, (3) exponential function; also exp $(-x)$ as in e^{-x}
E	(1) electric potential in volts, (2) scientific notation as in 1.5E − 03 = 1.5×10^{-3}
E{.}	expected value operator
EAI	enterprise application integration
EAM	enterprise asset management
EBCDIC	extended binary code for information interchange
EBR	electronic batch records
ECD	electron capture detector
ECKO	eddy-current killed oscillator
ECN	effective carbon number

ECTFE	ethylene chloro-tetra-fluoro-ethylene (Halar)
EDS	electronic data sheet (DeviceNet)
EDTA	ethylenediaminetetraacetic acid
EDXRF	energy dispersive x-ray fluorescence
E/E/PE	electrical/electronic/programmable electronic
E/E/PES	electrical/electronic/programmable electronic system
EFD	engineering flow diagram
e.g.	*exempli gratia* (for example)
EHC	electrohydraulic control
EHM	equipment health management
e(k)	feedback error
E.L.	elastic limit
Emf, EMF	(1) electromotive force (volts), (2) electromotive potential (volts)
EMI	electromagnetic interference
EMI/RFI	electromagnetic interference/radio frequency interference
em(k)	process/model error
EN	European standard
EPA	enhanced performance architecture, Environmental Protection Agency
EPC	engineering-procurement-construction (firm or industry)
EPCM	engineering, procurement, and construction management (companies)
EPDM	ethylene propylene diene terpolymer
EPS	electronic pressure scanner, Encapsulated PostScript file or emergency power supply
EQ, eq	equation
ERM	enterprise resource manufacturing
ERP	enterprise resource planning, effective radiated power
ERW	electric-resistance welded
ESD	emergency shutdown (system), electrostatic discharge
ESN	electronic serial number
ETFE	ethylene-tetrafluoroethylene copolymer (Tefzel®)
ETS	equivalent time sampling
Exp	exponential function as in exp (– at) = e^{-at}; also e

F

F	frequency (also freq.)
F	farad, symbol for derived SI unit of capacitance, ampere-second per volt, A·s/V
°F	degrees Fahrenheit [t°C = (t°F – 32)/1.8]
FAT	factory acceptance testing
FBAP	function block application process (FF)
FBD	function block diagram
FBG	fiber bragg grating
FC	flow controllers
FCC	fluid catalytic cracking unit
FCOR	filtering and correlation (method)
FCS	frame check sequence
FDE	fault disconnection electronics
FDL	fieldbus data link
FDMA	frequency division multiple access
FDS	flame-detection system
FDT	field device tool (a Windows®-based Microsoft framework for engineering and configuration tools)
FE	final elements
FEED	front end engineering and design
FEGT	furnace exit gas temperature
FEP	fluorinated ethylene propylene
FES	fixed end system
FF-HSE	Foundation Fieldbus, high-speed Ethernet
FFT	fast Fourier transform
FH	frequency hopping
Fhp	fractional horsepower (e.g., 1/4-hp motor)
FHSS	frequency hopped spread spectrum
FI	flow indicator
FIA	flow injection analyzer
FIC	flow indicator controller
FID	flame ionization detector
FIE	flame ionization element
FIFO	first-in, first-out
Fig.	figure
FISCO	fieldbus Intrinsic Safety COncept
fl.	fluid
fl. oz.	fluid ounce (= 29.57 cc)
FM	frequency modulated
FMCW	frequency modulated carrier wave
FMEA	failure mode and effects analysis
FMEDA	failure modes, effects and diagnostic analysis
FMS	fieldbus message specification or fieldbus messaging services/system
FO	fiber optic or fail open
FOP	fiber-optic probe
FOV	field of view
fp, f.p.	freezing point
FPC	fine particle content
FPD	flame photometric detector
FPM, fpm, ft/min	feet per minute (= 0.3048 m/m)
fps, ft/s	feet per second (= 0.3048 m/s)
FRC	flow recording controller
FRM	frequency response method
FS, fs	full scale
FSC	fail safe controller
FSD	full scale deflection
FSK	frequency shift keying
FT	Fourier transform
FTA	fault tree analysis
FTIR	Fourier transform infrared
FTNIR	Fourier near infrared
FTP	file transfer protocol
FTS	fault-tolerant system
FTU	formazin turbidity unit

G

g acceleration resulting from gravity (= 9.806 m/s^2) or conductivity
G giga, prefix meaning 10^9, or process gain or conductance
gal gallon (= 3.785 liters)
GB gigabyte, 1,000,000,000 bytes
GbE gigabit Ethernet
gbps, GBPS gigabits per second
G_c feedback controller transfer function
GC gas chromatograph
g-cal gramcalorie, see also cal
G_d unmeasured disturbance transfer function
GD measured disturbance transfer function
GD approximate feedforward transfer function model
GEOS geosynchronous Earth orbit satellite
G_{ff} feedforward controller transfer function
GFC gas filter correlation
GHz gigahertz
GIAC general inquiry access code
GLR gas-to-liquid ratio
G-M Geiger-Mueller tube, for radiation monitoring
G_m model transfer function
GMR giant magneto resistive
GPH, gph, gal/h gallons per hour (= 3.785 lph)
G_p process transfer function
GPM, gpm, gal/min gallons per minute (= 3.785 lpm)
GPS global positioning satellite, global positioning system
g gram
grn green (wiring code color for grounded conductor)
GSC gas-solid chromatography
GSD Profibus version of an electronic data sheet
GUI graphical user interface
GWR guided wave radar
Gy gray, symbol for derived SI unit of absorbed dose, joules per kilogram, J/kg

H

h (1) height, (2) hour
H (1) humidity expressed as pounds of moisture per pound of dry air; (2) henry, symbol of derived SI unit of inductance, volt-second per ampere, V·s/A
H1 field-level fieldbus; also refers to the 31.25 kbps intrinsically safe SP-50, IEC61158–2 physical layer
HAD historical data access
H&RA hazard and risk analysis
HART highway addressable remote transducer
HAZOP HAZard and OPerability studies
HC horizontal cross-connect
HCN hydrogen cyanide
HEC header error check
HF hydrogen fluoride or hydrofluoric acid
HFE human factors engineering
HFT hardware fault tolerance
hhv higher heating value
HIPS high-integrity protection systems
HIPPS high-integrity pressure protection system
HIST host interface system test
HMI human-machine interface
HMSD hexamethyldisiloxane
hor. horizontal
HP, hp horsepower (U.S. equivalent is 746 W)
HPLC high-pressure (or high-precision) liquid chromatography
HSE high-speed Ethernet (host-level fieldbus)
HSI human system interface
HTG hydrostatic tank gauging
HTML hypertext markup language
HTTP hypertext transfer protocol
HVAC heating, ventilation, and air conditioning
H/W hardware
HWD height, width, depth
Hz hertz, symbol for derived SI unit of frequency, one cycle per second (l/s)

I

I integral time of a controller in units of time/repeat
IA instrument air
IAC inquiry access code
IAE integral of absolute error
I&C instrumentation and control or information and control
I&E instrument and electrical
IAQ indoor air quality
ibidem in the same place
IC integrated circuit, intermediate cross-connect, or inorganic carbon
ICA independent computing architecture
ICCMS inadequate core cooling monitoring system
ICMP internet control message protocol
ICP inductively coupled plasma
ID inside diameter
i.e. *id est* (that is)
IEH *Instrument Engineers' Handbook*
IETF Internet engineering task force
IIS Internet information server
IL instruction list
ILD instrument loop diagrams
IMC internal model control
iMEMS integrated microelectromechanical system
in. inch (= 25.4 mm)

InGaAs	iridium gallium arsenide
in-lb	inch-pound (= 0.113 N × m)
I/O	input/output
I-P	current-to-pressure conversion
IP	Internet protocol or ionization potential
IPA	isopropyl alcohol
IPL	independent protection layer
IPTS	international practical temperature scale
IR	infrared
IS	intermediate system
ISAB	ionic strength adjustment buffer
ISE	integral of squared error or ion selective electrode
ISFET	ion-selective field-effect transistor
ISM	industrial, scientific, medical
ISP	Internet service provider or interoperable system provider
IT	information technology (as in IT manager or IT department)
ITAE	integral of absolute error multiplied by time
ITSE	integral of squared error multiplied by time
ITT	intelligent temperature transmitters
JTU	Jackson turbidity unit
IXC	interexchange carrier

J

J	joule, symbol for derived SI unit of energy, heat or work, Newton-meter, N·m
JIT	just-in-time (manufacturing)

K

k	kilo, prefix meaning 1000
K	coefficient, also dielectric constant
K	Kelvin, symbol for SI unit of temperature or process gain (dimensionless), not used with degree symbol
kbs, kbps, kb/sec	kilobits per second
kBps, kB/sec	kilobytes per second
k-cal	kilogram-calories (= 4184 J)
kg	kilogram symbol for basic SI unit of mass
kg-m	kilogram-meter (torque, = 7.233 foot-pounds)
KHP	potassium acid phthalate
kip	1000 pounds (= 453.6 kg)
km	kilometers
KOH	potassium hydroxide
K_p	proportional gain of a PID controller
kPa	kilopascal
kVA	kilovolt-amperes
kW	kilowatts
KWD	kilowatt demand
kWh	kilowatt-hours (= 3.6 × 10^6J)

L

l	liter (= 0.001 m^3 = 0.2642 gal), also L
L	(1) length, (2) inductance, expressed in henrys
L2F	laser two-focus anemometer
Lab	CIE functions for lightness, red/green, blue/yellow
LAN	local area network
LAS	link active scheduler (FF)
lat	latitude
lb	pound (= 0.4535 kg)
LC	level controller or liquid chromatography
LCD	liquid crystal display
Lch	CIE functions for lightness, chroma, hue
LCM	life cycle management
LCSR	loop current step response
LD	ladder diaphragm
LDA	laser Doppler anemometer
LDP	large display panel
LEC	local exchange carrier or lower explosive limit
LED	light-emitting diode
LEL	lower explosive limit
LEOS	low Earth orbit satellites
LF	linear feet
LGR	liquid-to-gas ratio
LI	level indicator
LIC	level indicator controller
LIDAR	laser induced doppler absorption radar or light detection and ranging
lim	limit
lin	linear
liq	liquid
LLC	logical link control
lm	lumen, symbol for derived SI unit of luminous flux, candela-steradian, cd·sr
ln	Naperian (natural) logarithm to base e
LNG	liquefied natural gas
LO	lock open
LOC	limiting oxygen concentration
log, log_{10}	logarithm to base 10; common logarithm
LOI	local operation interface
long.	longitude
LOPA	layers of protection analysis
LOS	line of sight
LP or LPG	liquefied petroleum or propane gas
LPC	large particle content
LPG	liquefied petroleum gas
lph	liters per hour (0.2642 gph)
lpm	liters per minute (0.2642 gpm)
LPR	linear polarization resistance
LQG	linear quadratic Gaussian
LRC	longitudinal redundancy check or level recording controller
LRL	lower range limit
LRV	lower range value

LTI	linear time-invariant
LVDT	linear variable differential transformer
LVN	limiting viscosity number
lx	lux, symbol for derived SI unit of illuminance, lumen per square meter, lm/m^2

M

m	(1) meter, symbol for basic SI unit of length, (2) milli, prefix meaning 10^{-3}, (3) minute (temporal) (also min)
M	(1) 1000 (in commerce only), (2) mach number, (3) molecular weight; mole; (4) mega, prefix meaning 10^6
mA	milliampere (= 0.001 A)
MAC	medium access control
MACID	medium access control identifier
MAE	minimum absolute error
MAOP	maximum allowable operating pressure
MAP	manufacturing automation (access) protocol
MAU	media access unit
MAWP	maximum allowable working pressure
max.	maximum
Mb	megabit, 1,000,000 bits
MB	megabyte, 1,000,000 bytes
Mbps, Mb/sec	megabits per second
MBps, MB/sec	megabytes per second
MC	main cross-connect
mCi, mC	millicuries (= 0.001 Ci)
m.c.p.	mean candle power
MCR	main control panel
MCT	mercury cadmium telluride
MDBS	mobile data base station
MDIS	mobile data intermediate system
m/e	mass-to-energy ratio
med.	medium or median
MEDS	medium Earth orbit satellite
MEMS	microelectromechanical system
m.e.p.	mean effective pressure
MES	manufacturing execution system or mobile end station
MeV	mega-electron volt
MFD	mechanical flow diagram
MFE	magnetic flux exclusion
mfg	manufacturer or manufacturing
mg	milligrams (= 0.001 g)
mho	outdated unit of conductance, replaced by siemens (S)
mi	mile (= 1.609 km)
MI	melt index
MIB	management information base
micro	prefix meaning 10^{-9}; also μ (mu); sometimes (incorrectly) u, as in ug to mean μg [both meaning microgram (= 10^{-9} kg)]
micron	micrometer (= 10^{-6} m) (term now considered obsolete)
MIE	minimum ignition energy
MIMO	multiple-input, multiple-output
MIMOSA	machinery information management open system alliance
min.	(1) minute (temporal), also m, (2) minimum, (3) mobile identification number
MIR	multiple internal reflection
MIS	management information system
ml	milliliter (= 0.001 l = 1 cc)
MLR	multiple linear regression
mm	millimeter (= 0.001 m) or millimicron (= 10^{-9} m)
mmf	magnetomotive force in amperes
MMI	man-machine interface
mmpy	millimeters per year
MMS	machine monitoring system or manufacturing message specification
MOC	management of change
MODEM	modulator/demodulator
MON	motor octane number
MOS	metal oxide semiconductor
MOSFET	metallic oxide semiconductor field-effect transistor
mol	mole, symbol for basic SI unit for amount of substance
mol.	molecule
MOON	M out of N voting system
mp, m.p.	melting point
MPa	megapascal (10^6 Pa)
MPC	model predictive control
MPFM	multiphase flowmeter
mph, MPH, mi/h	mile per hour (1.609 km/h)
mps, m/s	meters per second
MPS	manufacturing periodic/aperiodic services
mpy	mills per year
mR	milliroentgen (= 0.001 R)
mrd	millirad (= 0.001 rd)
mrem	milliroentgen-equivalent-man
MRP	material requirement planning or manufacturing resource planning
ms, msec	millisecond (= 0.001 s)
MS	mass spectrometer, Microsoft®
MSA	metropolitan statistical areas
MSB	most significant bit
MSD	most significant digit
MSDS	material safety data sheet
MT	measurement test
MTBE	methyl tertiary butyl ether
MTBF	mean time between failures
MTSO	mobile telephone switching office
MTTF	mean time to failure
MTTFD	mean time to fail dangerously
MTTFS	mean time to spurious failure
MTTR	mean time to repair
MTU	master terminal unit

MVC	minimum variance controller
MW	megawatt (= 10^6 W)
MWC	municipal waste combustors
MWD	molecular weight distribution

N

N	Newton, symbol for derived SI unit of force, kilogram-meter per second squared, kg·m/s^2
n	(1) nano, prefix meaning 10^{-6}, (2) refractive index
N_0	Avogadro's number (= 6.023×10^{23} mol^{-1})
N-16	nitrogen-16
NAAQS	national ambient air quality standards
NAP	network access port/point
NAT	network address translation
NB	nominal bore, internal diameter of a pipe in inches
NC, N/C	normally closed (switch contact)
NC	numeric controller
NDIR	nondispersive infrared
NDM	normal disconnect mode
NDT	nondestructive testing
NEC	National Electrical Code
NESC	National Electrical Safety Code
NEXT	near-end crosstalk
NIC	network interface card
NIP	normal incident pyrheliometer
NIR	near infrared
nm	nanometer (10^{-9} m)
NMR	nuclear magnetic resonance
NO, N/O	normally open (switch contact)
NPS	nominal pipe size, the internal diameter of a pipe in inches
NRM	normal response mode
NRZ	non-return to zero (refers to a digital signaling technique)
NS	nominal pipe size, the internal diameter of a pipe in inches
NTC	negative temperature coefficient
NTP	network time protocol or normal temperature and pressure corresponding to 1 atm absolute (14.7 psia) and 0°C (32°F)
NTSC	National Television Standards Code
NTU	nephalometric turbidity unit
NUT	network update time

O

OCD	orifice-capillary detector
OD	outside diameter or oxygen demand
ODBC	open database connectivity or communication
OES	optical emission spectrometer
oft, OFT	optical fiber thermometry
ohm	unit of electrical resistance; also Ω (omega)
OJT	on-the-job training
OLE	object linking and embedding
OLE_DB	object linking and embedding data base
OMMS	optical micrometer for micromachine
ON	octane number
OPC	object link embedding (OLE) for process control
OP-FRIR	open path Fourier-transform infrared
OP-HC	open-path hydrocarbon
OP-TDLAS	open-path tunable diode-laser absorption spectroscopy
OP-UV	open-path ultraviolet
or	orange (typical wiring code color)
ORP	oxidation-reduction potential
OS	operator station or operating system
OSFP	open shortest path first
OSI	open system interconnect (model)
OSI/RM	open system interconnect/reference model
OT	operator terminal or open tubular
OTDR	optical time domain
oz	ounce (= 0.0283 kg)

P

P&ID	piping and instrumentation diagram
p	(1) pressure; (2) pico, prefix meaning 10^{-12} (3) variable for resistivity
Pa	pascal, symbol for derived SI unit of stress and pressure, Newtons per square meter, N/m^2
PA	plant air
PAC	path average concentration
PAL	phase alternating line
PAN	personal area network
P&ID	piping (process) and instrumentation diagram (drawing)
Pas, Pa·s	pascal-second, a viscosity unit
PAS	process automation system (successor to DCS)
PB	proportional band of a controller in percent (100%/controller gain)
PC	personal computer (usually Microsoft Windows®-based) or pressure controller
PCA	principal component analysis
PCCS	personal computer control system
PCDD	polychlorinated dibenzo-*p*-dioxine
PCDF	polychlorinated dibenzo furans
PCR	principal component regression
PCS	process control system or personal communication services
pct	percent; also%
PCTFE	polychlorotrifluoroethylene
PCV	pressure control valve
PD	positive displacement or proportional and derivative
PDA	personal digital assistant or photodiode array
PDD	pulsed discharge detector

PDF	probability density function, probability of failure or portable document file
PDS	phase difference sensor
PDU	protocol data unit
PDVF	polyvinylidene fluoride
PE	polyethylene
PED	pressure equipment directive
PEEK	poly ether ether ketone
PEL	permissible exposure level
PES	programmable electronic system
PFA	per-fluoro-alkoxy copolymer
PFC	procedure functional chart
PFD	process flow diagram
PdM	predictive maintenance
pF	picofarad (= 10^{-12} F)
PF, p.f.	power factor
PFA	perfluoralkoxy (a form of Teflon)
PFD	process flow diagram
PFD	probability of failure on demand
PFDavg	average probability of failure on demand
PFPD	pulsed flame photometric detector
PGNAA	prompt gamma neutron activation analysis
PGC	process gas chromatograph
pH	acidity or alkalinity index (logarithm of hydrogen ion concentration)
PHA	process hazard analysis
pi, pl	Poiseuille, a viscosity unit
PI	proportional and integral, or pressure indicator
P/I	pneumatic to current (conversion)
PIC	pressure indicating controller or path integrated concentration
PID	proportional, integral, and derivative (control modes in a classic controller), or photoionization detector
PI-MDC	path integrated minimum detectable concentration
PIMS	process information management system
PIP	process industry practices
PIR	precision infrared radiometer
PLC	programmable logic controller
PLS	physical layer signaling or partial least squares
PM	photomultiplier
PMA	physical medium attachment
PMBC	process model based control
PMD	photomultiplier detector
PMF	probability mass function
PMMC	permanent magnet moving coil
PMT	photomultiplier tube or photometer tube
POPRV	pilot-operated pressure relief valve
PP	polypropylene
ppb, PPB	parts per billion
ppm, PPM	parts per million
PPP	point-to-point protocol
ppt	parts per trillion
PRC	pressure recording controller
PRD	pressure relief device
precip	precipitate or precipitated
PRV	pressure relief valve
PS	power supply (module)
PSAT	pre-startup acceptance test
PSD	power spectral density or photosensitive device
PSG	phosphosilicate glass
PSI	pre-startup inspection
psi, PSI, lb/in^2	pounds per square inch (= 6.894 kPa)
PSIA, psia	absolute pressure in pounds per square inch
PSID, psid	differential pressure in pounds per square inch
PSIG, psig	above atmospheric (gauge) pressure in pounds per square inch
PSK	phase shift keying
PSM	process safety management
PSSR	re-startup safety review
PSTN	public switched telephone network
PSU	post-startup
PSV	pressure safety valve
pt	point, part, or pint (= 0.4732 liter)
PTB	Physikalisch-Technische Bundesanstalt
PTC	positive temperature coefficient
PTFE	polytetrafluoroethylene (conventional Teflon)
PUVF	pulsed ultraviolet fluorescence
PV	process variable (measurement) or the HART primary variable
PVC	polyvinyl chloride
PVDF	polyvinylidene fluoride
PVLO	process variable low (reading or measurement)
PVHI	process variable high (reading or measurement)
PWM	pulse width modulation
PWR	pressurized water reactor
PZT	lead-zirconate-titanate ceramic

Q

q	(1) rate of flow, (2) electric charge in coulombs, C
q^{-1}	backward shift operator
Q	quantity of heat in joules, J, or electric charge
°Q	Quevenne degrees of liquid density
QA	quality assurance
QAM	quadrature amplitude modulation
QCM	quartz crystal microbalance
QPSK	quadrature phase shift keying
qt	quart (0.9463 l)
QV	quaternary variable

R

r	radius; also rad
r^2	multiple regression coefficient

R	(1) resistance, electrical, in ohms, (2) resistance, thermal, meter-Kelvin per watt, m·K/W, (3) gas constant (= 8.317 × 107 erg·mol^{-1},°C^{-1}), (4) roentgen, symbol for accepted unit of exposure to X and gamma radiation (= 2.58 × 10^{-4} C/kg)
Ra	radium
rad	(1) radius, also r, (2) radian, symbol for SI unit of plane angle measurement or symbol for accepted SI unit of absorbed radiation dose (= 0.01 Gy)
RADAR	radio detection and ranging
RAID	redundant array of inexpensive disks
RAM	random access memory
R&D	research and development
RASCI	responsible for, approves, supports, consults, informed
RCU	remote control unit
RDP	remote desktop protocol
rem	roentgen equivalent man (measure of absorbed radiation dose by living tissue)
rev	revolution, cycle
Re	Reynolds number
Re_D	Reynolds number corresponding to a particular pipe diameter
RF, rf	radio frequency
RFC	request for comment (an Internet protocol specification)
RFF	remote fiber fluorimetry
RFI	radio frequency interference
RFQ	request for quote
RGA	residual gas analyzer
RGB	red, green, blue
RGM	reactive gaseous mercury
RH	relative humidity
RI	refractive index
RIP	routing information protocol
r(k)	set point
RMS, rms	root mean square (square root of the mean of the square) or rotary mirror sleeves
ROI	return on investment
ROM	read-only memory
RON	research octane number
RPC	remote procedure call (RFC1831)
RPM, rpm, r/min	revolutions per minute
RVP	Reid vapor pressure
rps, r/sec	revolutions per second
RRF	risk reduction factor
RRT	relative response time (the time required to remove most of the disturbance)
RS	recommended standard
RSA	rural service areas
RSS	root sum squared
RTD	resistance temperature detector
RTO	real-time optimization or operation
RTOS	real-time operating system
RTR	remote transmission request
RTS	ready (or request) to send
RTS/CTS	request to send/clear to send
RTU	remote terminal unit
RUDS	reflectance units of dirt shade
RV	relief valve
RWS	remote workstation

S

s	second (also sec), symbol for basic SI unit of time; also Laplace variable
S	siemens (siemens/cm), symbol for unit of conductance, amperes per volt, A/V
s^2y	sample variance of output y
SAP	service access point
sat.	saturated
SAT	site acceptance test or supervisory audio tone
SAW	surface acoustic wave
SC	system codes
SCADA	supervisory control and data acquisition
SCCM	standard cubic centimeter per minute
SCD	streaming current detector
SCFH	standard cubic feet per hour
SCCM	standard cubic centimeter per minute
SCD	sulfur chemilumenesce detector
SCE	saturated calomel electrode
SCFH	standard cubic feet per hour
SCFM	standard cubic feet per minute (air flow at 1.0 atm and 70°F)
SCM	station class mark
SCMM	standard cubic meters per minute
SCO	synchronous connection oriented
SCOT	support coated open tubular (column)
SCR	silicon-controlled rectifier
SCS	sample control system
SD	component in leg has failed safe and failure has been detected
SDIU	Scanivalve digital interface unit
SDN	send data with no acknowledgement
SDS	smart distributed system
SEA	spokesman election algorithm
sec	second, also s
SER	sequence of event recorder
SFC	sequential function chart
SFD	system flow diagram or start of frame delimiter
SFF	safe failure fraction
SFI	sight flow indicator
SFR	spurious failure rate
S.G.	specific gravity, also sp. gr.
SHE	standard hydrogen electrode
SHS	sample handling system
SID	system identification digit (number)
SIF	safety instrumented function
SIG	special interest group

SIL	safety integrity level
sin	sine, trigonometric function
SIS	safety instrumented system
SISO	single-input single output
SG, SpG	specific gravity; also sp. gr.
SIL	safety integrity level
SIS	safety instrumented system
SKU	stock keeping units
SLAMS	state and local air monitoring stations
SLC	safety life cycle
slph	standard liters per hour
slpm	standard liters per minute
SMR	specialized mobile radio
SMTP	simple mail transfer (management) protocol
S/N	signal-to-noise (ratio)
SNG	synthetic natural gas
SNMP	simple network management protocol
SNR	signal-to-noise ratio
SOAP	simple object access protocol (an Internet protocol that provides a reliable stream-oriented connection for data transfer)
SOE	sequence of events
SONAR	sound navigation and ranging
SOP	standard operating procedure
SP	set point
SPC	statistical process control
SPDT	single-pole, double-pole throw (switch)
SPL	sound pressure level or sound power level
SPRT	standard platinum resistance thermometer
SPST	single-pole, single-throw (switch)
sq	square, squared
SQC	statistical quality control
SQL	structured (or standard) query language
Sr	steradian, symbol for SI unit of solid angle measurement
SRD	send and request data with reply
SRS	safety requirements specification
SRV	safety relief valve
SS	stainless steel
SSL	secure socket layers
SSU	Saybolt seconds universal
std.	standard
ST	structural text
STEL	short-term exposure limit
STEP	standard for the exchange of product model data
STP	shielded twisted pair, or standard temperature and pressure, corresponding to 70°F (21.1°C) and 14.7 psia (1 atm abs)
STR	spurious trip rates
SU	security unit or component in leg has failed safe and failure has not been detected
SUS	Seybold universal seconds
SV	secondary variable or safety valve
S/W	software

T

T	(1) ton (metric = 1000 kg), (2) time, (3) thickness
T	(1) temperature, (2) tera, prefix meaning 10^{-12}, (3) period (= 1/Hz, in seconds), (4) tesla, symbol for derived SI unit of magnetic flux density, webers per square meter, Wb/m^2
$T^1/_2$	half life
tan	tangent, trigonometric function
TAS	thallium arsenic selenide
tau, τ	process time constant (seconds)
TBM	tertiary butyl mercaptan
t/c	thermal coefficient of linear expansion
TC	thermocouple, temperature controller, or total carbon
TCD	thermal conductivity detector
TCP	transmission control protocol
TCP/IP	transmission control protocol/internet protocol
TCV	temperature control valve
td	process dead time (seconds)
T_d	derivative time (in seconds) of a PID controller
TDLAS	tunable diode laser absorption spectroscopy
TDM	time division multiplexing
TDMA	time division multiple access
TDR	time domain reflectometry
T/E	thermoelectric
TEM	transmission electron microscope
TG	thermogravimetry
Ti	integral time (in seconds) of a PID controller
TI	time interval between proof tests (test interval), temperature indicator
TIC	temperature indicating controller or total inorganic carbon
TIFF	tagged image file format
TISAB	total ionic strength adjustment buffer
TLV	threshold limit value
TMP	thermomechanical pulp
TMR	triple modular redundancy
TN	total nitrogen
TOC	total organic carbon
TOD	total oxygen demand
TOF	time of flight
TQM	total quality management
TOP	technical and office protocol
TR	temperature recorder
T/R	transmit/receive
TRC	temperature recording controller
T.S.	tensile strength
TTFM	transit time flow measurement
TTP	through the probe
TV	tertiary variable

°Tw	Twaddell degrees of liquid density
TWA	time weighed average

U

u	prefix = 10^{-6}, used incorrectly when the Greek letter μ is not available
UART	universal asynchronous receiver transmitter
UBET	unbiased estimation
UCMM	unconnected message manager
UDP	user/universal data protocol (an Internet protocol with low overhead but no guarantee that communication was successful)
UEL	upper explosive limit
$u_{fb}(k)$	feedback controller output
UFD	utility flow diagram
$u_{ff}(k)$	feedforward controller output
UHF	ultra-high frequency
UHSDS	ultra-high-speed deluge system
u(k)	controller output
UML	universal modeling language
UPS	uninterruptible power supply
UPV	unfired pressure vessel
URL	upper range limit
URV	upper range value
USB	universal serial bus
UTP	unshielded twisted pair
UTS	ultimate tensile stress
UUP	unshielded untwisted pair
UV	ultraviolet
UV-VIS-NIR	ultraviolet-visible-near infrared

V

v	velocity
V	volt, symbol for derived SI units of voltage, electric potential difference and electromotive force, watts per ampere, W/A
Vac	voltage, alternating current
V&V	verification and validation
VBA	Visual Basic for Applications
VDF	vacuum fluorescent display
VDT	video display tube
VDU	video display unit
vert.	vertical
VFD	variable frequency drive
VFIR	very fast infrared
VHF	very high frequency
VIS	visible
V-L	vapor-liquid (ratio)
VLF	very low frequency
V/M	voltmeter
VME	Virsa Module Europa (IEEE 1014–1987)
VMS	vibration monitoring system
VOC	volatile organic compounds
VR	virtual reality
VRML	virtual reality modeling language
vs.	versus

W

w	(1) width, (2) mass flow rate
W	(1) watt, symbol for derived SI unit of power, joules per second, J/s, (2) weight (also wt)
w.	water
WAN	wide area network
Wb	weber, symbol for derived SI unit of magnetic flux, volt-seconds, V·s
WCOT	wall coated open tubular (column)
WDXRF	wavelength dispersion x-ray fluorescence
WG	standard (British) wire gauge
wh	white (wiring code color for AC neutral conductor)
WI	Wobbe index
WLAN	wireless local area network
WPAN	wireless personal area network
WS	workstation
wt	weight, also W

X

X	reactance in ohms
XML	extensible markup language
x-ray	electromagnetic radiation with a wavelength <100 Å
XRF	x-ray fluorescence
XYZ	tristimulus functions

Y

Y	expansion factor
y(k)	process output
yd	yard (= 0.914 m)
yr	year

Z

Z	(1) atomic number (proton number), (2) electrical impedance (complex), expressed in ohms
ZEB	zero energy band

SOCIETIES AND ORGANIZATIONS

AATCC	American Association of Textile Chemists and Colorists
ACC	American Chemistry Council
ACGIH	American Conference of Governmental Industrial Hygenists
ACS	American Chemical Society
AGA	American Gas Association
AIA	Automatic Imaging Association
AIChE	American Institute of Chemical Engineers
AMTEX	American Textile Partnership
ANSI	American National Standards Institute
AOCS	American Oil Chemists Society
APHA	American Public Health Association
API	American Petroleum Institute
ARI	Air Conditioning and Refrigeration Institute
ASA	American Standards Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASRE	American Society of Refrigeration Engineers
ASTM	American Society for Testing and Materials, or ASTM International
AWWA	American Water Works Association
BSI	British Standards Institution
CARB	California Air Resources Board
CCITT	Consultative Committee for International Telegraphy and Telephony
CENELEC	European Committee for Electrotechnical Standardization
CIE	Commission International del'Eclairage
CII	Construction Industry Institute
CIL	Canadian Industries Limited
CPAC	Center for Process Analytical Chemistry
CSA	Canadian Standards Association
DARPA	Defense Advanced Research Projects Agency
DIERS	Design Institute for Emergency Relief Systems
DIN	Deutsche Institut fuer Normung
DOD	Department of Defense (United States)
DOE	Department of Energy
DOT	Department of Transportation
EIA	Electronic Industries Association
EIA/TIA	Electrical Industries Alliance/Telecommunications Industries Alliance
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
EXERA	Association des Exploitants d'Equipements de Mesure, de Régulation et d'Automatisme, an instrument user's association based in France
FCI	Fluid Control Institute
FDA	Food and Drug Administration
FF	Fieldbus Foundation
FIA	Fire Insurance Association
FM	Factory Mutual
FMRC	Factory Mutual Research Corporation
FPA	Fire Protection Association
FSEC	Florida Solar Energy Center
GERG	Groupe Europeen de Recherches GaziSres (European Gas Research Group), Brussels
GRI	Gas Research Institute
HCF	HART Communication Foundation
IAEI	International Association of Electrical Inspectors
ICE	Institute of Civil Engineers
ICEA	Insulated Cable Engineer's Association
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineers
IETF	Internet Engineering Task Force
IGT	Institute of Gas Technology
IPTS	International Practical Temperature Scale
IrDA or IRDA	Infrared Data Association
ISA	Instrumentation, Systems, and Automation Society
ISO	International Standards Organization
ISSeP	International Soros Science Education Program
ISTM	International Society for Testing and Materials

ITA	Instrumentation Testing Association
JBF	Japan Batch Forum
JPL	Jet Propulsion Laboratory
KEPRI	Korean Electric Power Research Institute
LCIE	Laboratoire Central des Industries Electriques
LPGA	National LP-Gas Association
MCA	Manufacturing Chemists' Association
NAMUR	Normen-Arbeitsgemeinschaft für Meß-und Regulungstechnik in der Chemischen Industry (German standardization association for process control)
NASA	National Aeronautics and Space Administration
NBFU	National Board of Fire Underwriters
NBS	National Bureau of Standards
NEMA	National Electrical (Equipment) Manufacturers Association
NEPSI	National Supervision and Inspection Center for Explosion Protection and Safety Instrumentation
NFPA	National Fire Protection Association
NIOSH	National Institute of Occupational Safety and Health
NIST	National Institute of Standards and Technology
NRC	Nuclear Regulatory Commission
NSC	National Safety Council
NSPE	National Society of Professional Engineers
OSHA	Occupational Safety and Health Administration
OTS	Office of Technical Services
SAE	Society of Automotive Engineers
SAMA	Scientific Apparatus Manufacturers Association
SIREP	An international instrument user's association based in the United Kingdom
TAPPI	Technical Association of the Pulp and Paper Industry
TIA	Telecommunications Industries Alliance
UL	Underwriters Laboratories, Inc.
USASI	USA Standard Institute
USNRC	U.S. Nuclear Regulatory Commission
WBF	World Batch Forum
WEF	Water Environment Federation
WIB	An international instrument user's association based in the Netherlands

NOTES

1. Whenever the abbreviated form of a unit might lead to confusion, it should not be used, and the term should be written out in full.
2. The values of SI equivalents were rounded to three decimal places.
3. The words "meter" and "liter" are used with their accepted English spelling instead of those in European standards (i.e., metre and litre).