Encyclopedia of Chemical Processing and Design

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Abrasives to Acrylonitrile

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Preface

In the last 25 years, the field of chemical processing has placed increasing emphasis on the practical design of the very wide range of equipment, systems, and controls required for economic and effective operation, as well as on the construction of the plant needed to house such equipment. This encyclopedia reflects this development and meets the need for precise information on the subject by devoting a large proportion of the work to practical design problems and their solutions. The articles are written for readers planning to design or develop a process or product. It is presumed they will want to use the principles of technical economics to the optimization of a problem. To do so, they need a clear view of what is possible and practical, operating methods, costs, problems, performance, availability, materials of construction, limitations, precautions, and similar information. To place this into perspective, comparisons are made with other processes and equipment, theory is discussed, and experiences of others are reviewed as are past and future uses.

This encyclopedia is neither a dictionary nor a handbook; nor is it a series of monographs covering only relatively narrow aspects for the benefit of advanced specialists. The work is organized to present the entire field of chemical processing and design. It is intended to serve the needs of most professional chemical engineers, designers, and managers, and the many technical people throughout the entire chemical industry concerned with everyday work in the plant, and for this reason much of the material is on practical application. It is intended to serve the reference needs of the research fields, and thus will be equally useful to scientists and research workers. Chemical engineering students will find the work invaluable, as will students in other fields seeking background information in chemical processing and design. The encyclopedia will of course be a useful and valuable addition to all technical, professional, and university library collections.

The subject matter is descriptive of technologically important chemical materials, processes, methods, practices, standards, and products of the chemical industry, and related industries such as petroleum, rubber, plastics, food, and drugs. It is not dominantly theoretical and mathematical, except where necessary to clarify established principles and provide the necessary background for full understanding and application of the information. Some articles of a theoretical nature have been included where it seemed desirable to present a general article that could serve as a reference for a number of methods, processes, or techniques applying the principle.

The aim of the encyclopedia has been to present a balanced account avoiding any bias for particular products or processes. Generally, controversial or hypothetical material is excluded. Where several processes or methods are used for manufacturing the same product, the objective has been to show in greatest detail the most usual one, or the one generally accepted as the most efficient. Although most articles are written by American engineers, scientists, and technologists, no important foreign source has been neglected, and the work is therefore international in scope.

Throughout, the stress is on depth of treatment. Although the contributors were urged to emphasize basic information, they were also encouraged to express their evaluative opinions, when possible, to suggest future trends. Special attention has been given to illustration of the subject matter and consequently there are abundant figures, graphs, and charts throughout the volumes. Extensive bibliographies are also provided to serve as a further aid to the reader in search of even more complete knowledge.

All articles, in accordance with editorial policy, have been prepared only by authorities in the particular fields. Most of the articles were reviewed by at least one specialist in an organization other than the one with which the writer is associated. This, we hope, has assured objectivity.

The encyclopedia is arranged in alphabetical order, and articles are fully cross-referenced. The final volume will contain a detailed analytical index to the entire work, intended as the principal means for information retrieval.

The editors have frequently found it necessary to turn to their immediate colleagues, and many friends throughout the field, for counsel and advice on specific points of substance and organization during the preparation of the work, and they therefore wish to acknowledge here all who have helped. In particular they would like to thank the International Advisory Board members for the tremendous help they have given to the editors in every phase of producing these volumes.

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Contents of Volume 1

Conversion to SI Units

To convert from	To	Multiply by
acre	square meter (m^2)	4.046×10^3
angstrom	meter (m)	1.0×10^{-10}
are	square meter (m^2)	1.0×10^2
atmosphere	newton/square meter (N/m^2)	1.013×10^5
bar	newton/square meter (N/m^2)	1.0×10^5
barrel (42 gallon)	cubic meter (m^3)	0.159
Btu (International Steam Table)	joule (J)	1.055×10^3
Btu (mean)	joule (J)	1.056×10^3
Btu (thermochemical)	joule (J)	1.054×10^3
bushel	cubic meter (m^3)	3.52×10^{-2}
calorie (International Steam Table)	joule (J)	4.187
calorie (mean)	joule (J)	4.190
calorie (thermochemical)	joule (J)	4.184
centimeter of mercury	newton/square meter (N/m^2)	1.333×10^3
centimeter of water	newton/square meter (N/m^2)	98.06
cubit	meter (m)	0.457
degree (angle)	radian (rad)	1.745×10^{-2}
denier (international)	kilogram/meter (kg/m)	1.0×10^{-7}
dram (avoirdupois)	kilogram (kg)	1.772×10^{-3}
dram (troy)	kilogram (kg)	3.888×10^{-3}
dram (U.S. fluid)	cubic meter (m^3)	3.697×10^{-6}
dyne	newton (N)	1.0×10^{-5}
electron volt	joule (J)	1.60×10^{-19}
erg	joule (J)	1.0×10^{-7}
fluid ounce (U.S.)	cubic meter (m^3)	2.96×10^{-5}
foot	meter (m)	0.305
furlong	meter (m)	2.01×10^2
gallon (U.S. dry)	cubic meter (m^3)	4.404×10^{-3}
gallon (U.S. liquid)	cubic meter (m^3)	3.785×10^{-3}
gill (U.S.)	cubic meter (m^3)	1.183×10^{-4}
grain	kilogram (kg)	6.48×10^{-5}
gram	kilogram (kg)	1.0×10^{-3}
horsepower	watt (W)	7.457×10^2
horsepower (boiler)	watt (W)	9.81×10^3
horsepower (electric)	watt (W)	7.46×10^2
hundred weight (long)	kilogram (kg)	50.80
hundred weight (short)	kilogram (kg)	45.36
inch	meter (m)	2.54×10^{-2}
inch mercury	newton/square meter (N/m^2)	3.386×10^3
inch water	newton/square meter (N/m^2)	2.49×10^2
kilogram force	newton (N)	9.806

To convert from	To	Multiply by
kip	newton (N)	4.45×10^3
knot (international)	meter/second (m/s)	0.5144
league (British nautical)	meter (m)	5.559×10^3
league (statute)	meter (m)	4.83×10^3
light year	meter (m)	9.46×10^{15}
liter	cubic meter (m^3)	0.001
micron	meter (m)	1.0×10^{-6}
mil	meter (m)	2.54×10^{-6}
mile (U.S. nautical)	meter (m)	1.852×10^3
mile (U.S. statute)	meter (m)	1.609×10^3
millibar	newton/square meter (N/m^2)	100.0
millimeter mercury	newton/square meter (N/m^2)	1.333×10^2
oersted	ampere/meter (A/m)	79.58
ounce force (avoirdupois)	newton (N)	0.278
ounce mass (avoirdupois)	kilogram (kg)	2.835×10^{-2}
ounce mass (troy)	kilogram (kg)	3.11×10^{-2}
ounce (U.S. fluid)	cubic meter (m^3)	2.96×10^{-5}
pascal	newton/square meter (N/m^2)	1.0
peck (U.S.)	cubic meter (m^3)	8.81×10^{-3}
pennyweight	kilogram (kg)	1.555×10^{-3}
pint (U.S. dry)	cubic meter (m^3)	5.506×10^{-4}
pint (U.S. liquid)	cubic meter (m^3)	4.732×10^{-4}
poise	newton second/square meter ($N \cdot s/m^2$)	0.10
pound force (avoirdupois)	newton (N)	4.448
pound mass (avoirdupois)	kilogram (kg)	0.4536
pound mass (troy)	kilogram (kg)	0.373
poundal	newton (N)	0.138
quart (U.S. dry)	cubic meter (m^3)	1.10×10^{-3}
quart (U.S. liquid)	cubic meter (m^3)	9.46×10^{-4}
rod	meter (m)	5.03
roentgen	coulomb/kilogram (c/kg)	2.579×10^{-4}
second (angle)	radian (rad)	4.85×10^{-6}
section	square meter (m^2)	2.59×10^6
slug	kilogram (kg)	14.59
span	meter (m)	0.229
stoke	square meter/second (m^2/s)	1.0×10^{-4}
ton (long)	kilogram (kg)	1.016×10^3
ton (metric)	kilogram (kg)	1.0×10^3
ton (short, 2000 pounds)	kilogram (kg)	9.072×10^2
torr	newton/square meter (N/m^2)	1.333×10^2
yard	meter (m)	0.914

Abrasives, Coated Cutting Tools

Coated abrasives are highly versatile, multiple point cutting tools which can be used in a wide variety of geometric configurations. Historically, this abrasive tool was more commonly called "sandpaper" because it did in fact consist of flint or sand held on a paper substrate by animal glue. While some sandpaper is still made and used, these materials have been largely supplanted by tougher man-made minerals and adhesives. For more severe grinding operations, a wide variety of reinforced fabrics are utilized in addition to a wide spectrum of treated papers. Thus the more general term "coated abrasives" appears to be more appropriate.

While coated abrasives may have been made in batch-type processes in the past, this product is almost entirely made in a continuous fashion today. Wide rolls of backing material move through a "maker" where adhesive and mineral are successfully applied followed by movement into ovens where the product is cured. The versatility of the product stems from the wide variety of forms into which the product is subsequently converted. These include belts in widths of over 100 in or only a fraction of an inch, disks, and many other forms. The product may be soft and flexible for fine finishing, or it may be rigid and hard for rapid stock removal operations.

Product Description

A typical coated abrasive is produced from three basic raw materials: a mineral, an adhesive "bond," and a backing. In the manufacturing process the backing serves as the base upon which a coating of adhesive known as the "make" coat is uniformly applied to anchor a single layer of mineral particles. Individual mineral particles are applied to the make coat and oriented in an electrostatic field or with a mechanical process to maximize the probability that a particle will be positioned with its major or long axis perpendicular to the backing. The make coat is solidified through a series of drying or curing ovens. After the make coat has cured, a second coating of adhesive, known as the "size" coat, is applied over the surface to further support the particle and give rigid anchorage to the backing. The completed construction proceeds into another series of ovens for a thorough and final curing. In coated abrasive terminology, the make and size coat are considered as a unit and commonly referred to as an adhesive "bond."

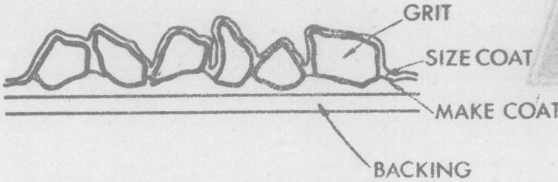

FIG. 1

The coated abrasive manufacturing process is capable of producing many product variations with a given set of raw materials to satisfy specific grinding requirements. The most common product variations are "closed" and "open" coat abrasives. The closed coated abrasive is one whose backing is fully covered with mineral particles to maximize the number of cutting points available and, therefore, produce a high rate of cut in a grinding operation. However, grinding operations on softer materials, such as aluminum and brass, frequently clog or load the space between particles, rendering the coated abrasive ineffective. To combat a "loading" condition, coated abrasive manufacturers produce an open coat construction which widens the area between particles and produces a self-cleaning action during grinding. In coated abrasive terminology, an open coat construction has 50 to 70% of its backing surface covered with mineral.

In cross section, a typical coated abrasive appears in Fig. 1. The variety of applications for coated abrasives prohibits the manufacture of a single product for all grinding operations. As a result, manufacturers produce an extensive range of tools by using backing, bond, mineral, grade, and fabrication variations. Tables 1–3 summarize most of the choices available to a user.

Glue bonded abrasives have make and size adhesives of animal hide glue which is completely soluble in water.

TABLE 1 Minerals

Commercial Name	Mineral Name	Origin	Hardness Mohs	Hardness Knoop	Shape
Silicon carbide	Moissonite (Alpha)	Synthetic	9.6	2480	Sharp wedges, slivery
Aluminum oxide	Corundum (Alpha)	Synthetic	9.4	2100	Heavy wedges
Emery	Impure Corundum	Natural	8.5–9.0	2100 (and less)	Blocky
Garnet	Almandite	Natural	7.5–8.5	1360	Light wedges
Flint	Quartz	Natural	6.8–7.0	820	Light wedges
Crocus	Iron oxide hematite	Natural and synthetic	6.0	—	Fine milled (rouge)

TABLE 2 Bonds

Name	Backing Type	Make Coat	Size Coat
Glue bond	Nonwaterproof	Glue	Glue
Modified glue bond	Nonwaterproof	Modified glue	Modified glue
Resin over glue bond	Nonwaterproof	Glue	Resin
Resin over resin bond	Nonwaterproof	Resin	Resin
Waterproof bond	Waterproof	Resin	Resin

Modified glue bonded abrasives have make and size adhesives of animal hide glue containing a mineral filler. The mineral filler is not soluble in water.

Resin over glue bonded abrasives have an animal hide glue make adhesive and a size adhesive of a cured resin which is insoluble in readily available solvents such as water, alcohol, or caustic. Either or both adhesives may contain a mineral filler.

Resin over resin bonded abrasives have resins for both the make and the size adhesives. The cured resins are insoluble in readily available solvents such as water, alcohol, or caustic, and either or both adhesives may contain mineral fillers.

Waterproof bonded abrasives differ from other bonds in that the backing is a waterproof type. The make and size adhesives are composed of a cured resin or a varnish which is insoluble in water.

Mineral Grades

In the coated abrasives industry, mineral grade refers to a closely controlled *range* of particle sizes. Regardless of the methods by which crude mineral is crushed to size and divided into individual grades, the coated grade will usually be subject to size tolerances as prescribed in a voluntary standard of the trade known as Product Standard 8–67, U.S. Department of Commerce, National Bureau of Standards. A copy of this standard may be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

The data in Table 4 are designed to give the reader a list of grade sizes available and a practical measurement of their respective size (in microns). These data were derived from Product Standard 8–67 and are intended to show the size of each grade as: (1) the approximate *maximum* mineral particle diameter size (Column 3, Table 4), and (2) the approximate *average* mineral particle diameter size (Column 4, Table 4). No measurements are given for fine particle portions of a grade since they are rarely a determining factor in the selection of a grade.

TABLE 3 Backings

Name	Weight/ Symbol Designation[a]	Minimum Tensile Strength (lb/in) Lengthwise	Crosswise	Characteristics
		Nonwaterproof		
Paper	A (#40)	25	12	Lightweight flexible; known as "finishing" paper
Paper	None (#55)	35	15	For flint paper sheets
Paper	None (#60)	40	20	For flint paper sheets
Paper	C (#70)	50	25	Intermediate weight; known as "cabinet" paper
Paper	D (#90)	65	35	Increased tear resistance
Paper	E (#130)	90	45	Heavyweight; for belt and roll stock
Paper	F (#170)	118	59	Heavyweight; for belt and roll stock
Cloth	X[b]	145	40	Strong; wear resistant; low stretch
Cloth	J[b]	100	45	Flexible; lightweight; conformable
Fiber	20 Mil	230	120	Stronger; more wear resistant than paper
Fiber	30 Mil	350	180	Heavy duty; rigid; for disks only
Combination	Paper	120	60	Paper and cloth laminate; more flexible than fiber; more tear resistant than paper
Combination	Fiber	280	135	Fiber and cloth laminate; more flexible than 30 mil fiber; for disks only
		Waterproof		
Paper	A (#48)	20	12	Lightweight and flexible
Paper	C (#80)	40	20	Intermediate weight; increased tear resistance
Cloth	X[b]	135	34	Strong; wear resistant; heavyweight; low stretch
Cloth	Open mesh	28	18	Screen-like fabric coated on both sides for disks, sheets, and rolls

[a]The data in parentheses refer to the weight of 480 sheets, 24″ × 36″, and are known as the "basis" weight of paper backings in coated abrasive terminology.
[b]For stretch characteristics, see the section titled "Choosing the Backing," page 11.

TABLE 4 Mineral Grades

Product Type	Printed Grade	Maximum Mineral Particle Diameter Size (μm)	Average Mineral Particle Diameter Size (μm)
Silicon carbide	600	32.0	14.5
Aluminum oxide	500	34.6	18.2
Garnet	400	40.0	22.1
	360	50.0	27.3
	320	62.5	34.3
	280	73.0	42.3
	240	79.5	51.8
	220	99.1	66
	180	132	80
	150	168	95
	120	239	116
	100	333	150
	80	417	204
	60	546	286
	50	635	375
	40	772	482
	36	897	591
	30	1158	704
	24	1410	834
	20	2000	1028
	16	2380	1365
	12	3360	1840
Emery	Fine	282	84
	Medium	500	150
	Coarse	772	207
	Extra coarse	1158	350
Flint	Extra fine	282	72
	Fine	500	114
	Medium	772	215
	Coarse	897	391
	Extra coarse	1158	636
Crocus	No printed grade	105	—

Mechanical Flexing

At the conclusion of the manufacturing process, coated abrasives are wound into large rolls known as "drums" or "jumbos." The fully cured or dried materials at this point are quite stiff and inflexible. In order to restore some of the backing's inherent flexibility, coated abrasives are given a so-called "flex." Flexing is a mechanical operation designed to break the adhesive bond at closely spaced, predictable intervals.