Coated Abrasives—Modern Tool of Industry

COATED ABRASIVES
MANUFACTURERS' INSTITUTE

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Preface

"Coated Abrasives—Modern Tool of Industry," sponsored by the Coated Abrasives Manufacturers' Institute, has been prepared and published to answer the great need for an up-to-date reference volume on these products and the great variety of their uses and methods of application.

This book represents the combined efforts over a period of many months of all members of the Institute who not only provided material and illustrations, but whose top technical personnel gave most generously of their time for all of the necessary research and review. The Institute and its members wish to acknowledge with sincere gratitude the aid given by many of the coated abrasive machine manufacturers and the many users of the products who permitted photographs of machines and manufacturing operations to be used. As in the use of any tool, the condition of workpieces, machines, and workmanship causes variations in the results obtained from coated abrasives. The Institute and its members, therefore, accept no responsibility for failures or damage resulting from the recommendations or suggestions herein. However, each procedure is based on substantial and generally proved experience.

Here for the first time is a book on coated abrasives so arranged, so detailed, and so complete, as to afford a most useful service to manufacturers who either now use or are interested in employing these products; to supervisory personnel and factory workers; to coated abrasive machine builders both present and prospective; to the many maintenance and repair services who can or do use the products; to home users; to students; and as a reference or text book for trade schools, technical schools, libraries of all kinds, and engineering and trade societies.

The membership of The Coated Abrasive Manufacturers' Institute consists of the following:

Abrasive Products, Inc.
South Braintree, Massachusetts

Armour and Company
Alliance, Ohio

Atlas Abrasives Corporation
Greenwich, Connecticut

Behr-Manning Co.
A Division of Norton Company
Troy, New York

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Clover Mfg. Company
Norwalk, Connecticut

Michigan Abrasive Company
Detroit, Michigan

Mid-West Abrasive Company
Owosso, Michigan

Minnesota Mining and Manufacturing Company
St. Paul, Minnesota

Sandpaper Incorporated
Rockland, Massachusetts

Contents

through the index, to specific recommendations for definite operations. Though it will be recognized that no book can comprehensively cover the full scope of coated abrasives, the reader will find that the coverage herein is quite sufficient, or that it may be satisfactorily supplemented by utilizing the information and technical services provided by the coated abrasive suppliers.

Fig. 1-6. These specially shaped coated abrasives facilitate working in normally difficult areas.

This book endeavors to attain three objectives: to be an authoritative manual on the use of coated abrasives; to provide information on various coated abrasive applications, so that manufacturers may be able to recognize parallel operations in their own plants which might be accomplished more efficiently and economically by using coated abrasives; and to provide guidance on ways to achieve the most economical usage of these products. While the reader's principal use of this book may be as a manual and quick reference in dealing with specific problems, scanning the entire text can very easily lead to economical changes in processes or adaptation of improved methods, even though proved on totally different products, through the employment of modern coated abrasives.

CHAPTER 2

Coated Abrasives

A coated abrasive consists of a flexible-type backing upon which a film of adhesive holds and supports a coating of abrasive grains. The backing may be paper, cloth, vulcanized fibre, or a combination of these materials. Various types of resin and hide glues are used as adhesives. The abrasives currently in use are flint, emery, crocus, garnet, aluminum oxide, and silicon carbide. Present-day production of coated abrasives from these raw materials is a highly technical process resulting from many years of continued development.

HISTORY OF COATED ABRASIVES

When we speak of an abrasive we mean any hard, sharp material that can be used to wear away another material when one or the other is moved in pressure contact. Abrasives were probably put to use by man long before he learned to write. It is more than likely that early man cleaned and polished ornamental objects by thrusting them into sand. Pictures carved on cave walls give good evidence that early man recognized the properties of hard stones and put them to use as tools. Jewish folklore tells us that Moses used a Shamir stone to engrave the names of the Twelve Tribes of Israel on the breastplate of the high priest. This hard stone, now known as emery, was also used in building Solomon's Temple. Abrasive stones continued to be used for many years for sharpening tools, spears, and like objects. One such stone, still in use today, is a holystone, which was used by the British well before the days of Drake for removing slime and dirt from the decks of vessels and for eliminating splinters.

Our first record of a coated abrasive goes back to about the 13th century when the Chinese bound crushed seashells to parchment with natural gums. Some time before the 16th century Shagreen came into use. This was made by working seeds or other granular material into skins. We know that abrasive paper was used in Europe in the 18th century, but there is no information available as to how it was made. The first known

Toughness. Beside the ability to penetrate an object, an abrasive material must have sufficient resistance to shearing or breaking down so that the initial penetration may continue throughout its use. If a mineral were hard enough to cut into a material but, through brittleness, should break up rapidly, its use would not be economical. The ability to resist fracture under heavy loads is called toughness.

Fracture. The shape characteristic of a mineral is very important in selecting abrasive grains. Electric furnace control and modern crushing techniques provide the best possible sharp, wedge-shaped cutting surfaces and important fracture characteristics. As the sharp edge of the grain is worn away by friction and pressure build-up, proper fracture characteristics cause the grain to refracture, thus exposing new cutting edges.

Coated Abrasive Minerals

There are six important commercial minerals used in the coated abrasive industry. They constitute the primary classification of the industry's products and are called flint, emery, crocus, garnet, aluminum oxide, and silicon carbide. The accompanying table shows their characteristics:

Commercial name	Chemical composition	Mineral name	Origin	Specific gravity	Hardness: Mohs scale	Hardness: Knoop scale	Grain shape
Flint	SiO_2	Quartz	Natural	2.6	6.8-7.0	820	Light wedges
Emery	Al_2O_3, FeO	Impure corundum	Natural	3.7-4.3	8.5-9.0		Blocky
Garnet	SiO_2, FeO, Al_2O_3 complex	Almandite	Natural	3.4-4.3	7.5-8.5		Light wedges
Crocus	FeO	Iron oxide hematite	Synthetic and natural	4.0-5.3	6.0		Fine milled
Aluminum oxide	Al_2O_3 fused	Corundum (alpha)	Synthetic	3.96	9.4	2050	Heavy wedges
Silicon carbide	SiC	Moissanite (alpha)	Synthetic	3.2	9.6	2480	Sharp wedges, slivery

Flint. Flint, as it is known in the trade, is actually quartz and is the mineral used on the common sandpaper sold in hardware stores. It occurs in large, natural deposits all over the United States, but the best comes from Pennsylvania, Maine, and Wisconsin. This quartz, which is chemically silicon dioxide, was early misnamed flint when used as an abrasive, and custom dictates the continued use of that name. Flint fractures into a sharp-edged grain, but because of its lack of toughness, the efficient technical usages of flint sandpaper are largely confined to finishing leather, felt hats, and commutator surfaces for electrical equipment. Its nonconducting characteristic prevents the shorting of commutator segments if a particle of the abrasive becomes lodged between them. However, because of its low cost, flint sandpaper is widely and generally used for ordinary maintenance, cleanup work, and home repairs.

Flint snuffing or buffing paper for leather finishing is available in mesh number grades ranging from 400 through 150, and the former symbol grade designations 11/0 through 2/0, which covered approximately the same range, are being discontinued. Flint pouncing paper for the hat trade is available in mesh number grades ranging from 400 through 150, and,

Fig. 2-1. Flint (quartz) ore.

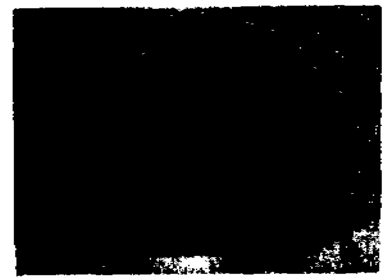

Fig. 2-2. Emery ore.

again, the former symbol grade designations of 10/0 through 2/0, which covered approximately the same range are being discontinued. Flint finishing paper is still available in the old flint symbol grades of 7/0 through 2/0, but gradings of the more widely used and less technical flint papers have been simplified to cover just five practical grades from Extra Fine through Extra Coarse. The comparative grading chart, figure 2-6, shows the approximate relationship of these flint product grades.

Emery. Emery is a natural composite of corundum and iron oxide, found in large deposits both in the Near East and the United States. Turkish emery is considered the best, as it contains a larger percentage of corundum than the others. Emery is magnetic and partly soluble in hydrochloric acid. The grains are blocky, cut slowly, and tend to polish the material being abraded.

Emery cloth, long a stock hardware store item, is mainly used in maintenance work for polishing metals but has been replaced by synthetic aluminum oxide cloth wherever appreciable removal of metal is required.

for coated abrasives by carefully controlled crushing processes, is the hardest and sharpest of the synthetic abrasives.

Its hardness and sharpness make silicon carbide the ideal coated abrasive for sanding low-tensile metals, glass, plastics, fibrous woods, leather, enamel, and other relatively soft materials. It is generally regarded as less tough than aluminum oxide; although tests carried out at Massachusetts

Technical Grades		Simplified Grades		Other Grades	
Aluminum Oxide Silicon Carbide Garnet & Flint					
Mesh	Symbol	Flint	Emery	Flint Finishing	Emery Polishing
600					4/0 3/0
500					2/0
400	10/0				0
360					
320	9/0			7/0	½
280	8/0			6/0	
240	7/0			5/0	IG
220	6/0			4/0	2
		Extra Fine			
180	5/0			3/0	3
			Fine		
150	4/0			2/0	
120	3/0	Fine			
			Medium		
100	2/0				
80	0	Medium	Coarse		
60	½				
			Extra Coarse		
50	1				
		Coarse			
40	1½				
36	2				
		Extra Coarse			
30	2½				
24	3				
20	3½				
16	4				
12	4½				

Fig. 2-6. Comparative grading chart.

Institute of Technology seem to disprove that point. While the point of toughness may be in academic dispute, experience and results of many tests have confirmed the fact that in operations where toughness (ability to resist fracture) is the main requisite, aluminum oxide out-performs silicon carbide. However, silicon carbide is superior in its ability to penetrate and cut fast under light pressure. It is available for coated abrasives in the full range of grades from 600 through 12 as shown in the comparative grading chart, figure 2-6.

Crushing and Grading Abrasives

Flint, emery, garnet, aluminum oxide, and silicon carbide are all, in general, crushed and graded by the same methods; although the standards for grade sizes of each are different. Large pigs or concentrates are crushed on primary crushers. Powerful jaw crushers then reduce the lumps to about ¾-inch size, and roll crushers break up these small pieces into a usable range from the very coarsest to the very finest particle sizes. The crushed particles are then separated into individual grade sizes by passing

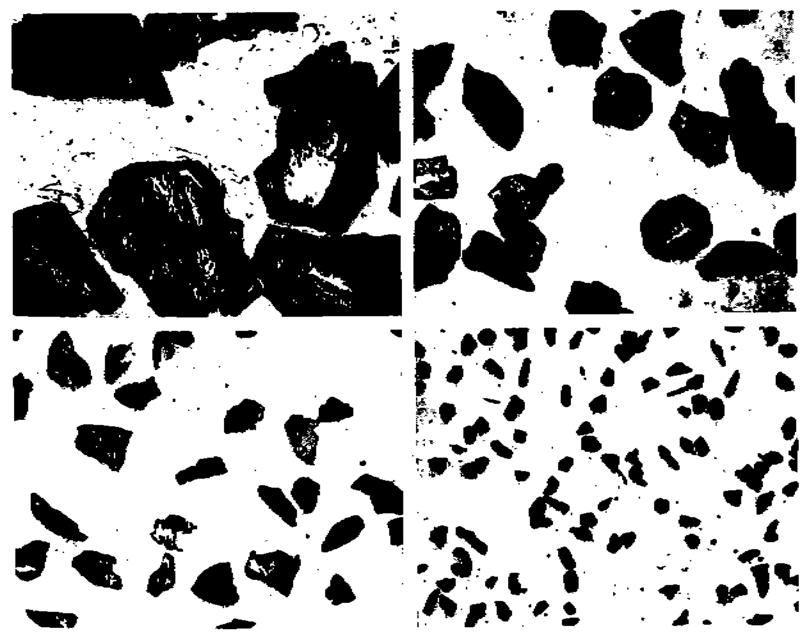

Fig. 2-7. Microphotographs (38 diameters), showing relative size of various screen grades, upper left—grade 24, upper right—grade 50, lower left—grade 80, lower right—grade 180.

Constant weighing and other tests are maintained throughout the paper mill runs to insure that these characteristics are standard and uniform.

Cloth. Virtually all cloth backings for coated abrasives are made from cotton yarns spun from middling cotton not less than 15⁄16 inch staple. The gray or greige goods, as these cotton fabrics are called when they come from the looms, must go through a number of finishing processes to make them suitable backings. Desizing, shrinking, dyeing, stretching, filling, and calendering are all required to obtain the necessary strength, flexibility, and coating surface.

The two most common types of gray goods are drills, imprinted with the designating letter X on the back, and jeans, which carry the letter J. However, a heavy twill, marked with the letter H, is not uncommon, and there are a few other cloth backings used for specialties. Two types of drills are used, both having the same unfinished weight basis of 2.29 square yards per pound. The more common type has a thread count of 76 × 48, that is, 76 warp threads per inch (lengthwise direction) and 48 woof threads per inch (crosswise direction). The other type has a thread count of 72 × 48. The jeans also fall into two classes, a 96 × 64 thread count weighing 3.32 square yards per pound and a 84 × 56 thread count weighing 2.92 square yards per pound. All the drills and jeans have a twill weave and are specially woven for the coated abrasive industry. The principal difference between them is that the drills are made from heavier threads, though fewer in number, and are always heavier and stronger than jeans. Drills therefore are used mainly for heavy work and for coarse grades, whereas jeans are preferred where considerable flexibility is required.

Fig. 2-9. Cloth finishing machine.

Vulcanized Fibre. Vulcanized fibre is a very hard, strong, flexible backing. Thirty-mil fibre (0.030 inch thick) has the highest strength of any

of the coated abrasive backings and is used chiefly as a backing for resin-bonded discs which are used on heavy-duty portable sanders. Twenty-mil fibre (0.020 inch thick) is used as a backing principally for the coarse grades in heavy drum-sanding operations.

Vulcanized fibre is made by treating a cotton rag base paper with zinc chloride which gelatinizes the cotton cellulose. Several sheets of gelatinized paper are combined to form a sheet of 5 to 7 plies, which is then vulcanized by heat and calendered to a smooth finish.

Adhesives

Three types of bonds or adhesives are used in the manufacture of coated abrasives: glue, resin, and varnish. The glue is generally animal hide glue. The resins and varnishes are basically liquid phenolics or ureas, but, depending on their use, they are modified in various ways to give shorter or longer drying times, greater strength, more flexibility, or other desirable properties.

MANUFACTURING PROCESS

Coating

A continuous strip of backing for one specific item moves through each coating step of the manufacturing process and is wound up finally in jumbo rolls, each about 3 feet in diameter. Although the equipment used by the several manufacturers is far from identical, it all has the same general pattern and sequences of processing.

The first step is through the so-called making machine which is in reality a grouping of three units: printer, adhesive coater, and abrasive grain dispenser. A large roll of the desired type of backing is started through the printing press where it is imprinted on the back with the trademark, brand name, manufacturer, mineral, grade number, backing designation, and other identifications. From the printer the backing moves on to receive the first application of adhesive bond in a carefully regulated film, varying in concentration and quantity according to the particle size of the mineral to be bonded. The selected abrasive grains are then applied either by a mechanical or an electrostatic method. The amount of abrasive grains deposited on the adhesive-covered sheet is controlled to an almost unbelievable accuracy and can be varied from a very sparse open coat to a dense mass heavily studding the sheet.

There are two types of abrasive grain coatings made in coated abrasives: closed coat and open coat. Some are made with one, some with the other; and in a few instances both open and closed coats are available in the same grades and identical backings. A closed coat is one in which the abrasive grains completely cover the coatside surface of the backing.

Closed coats are designed for severe service and are used for most applications. An open coat is one in which the individual grains are spaced at predetermined distances from one another. In open coat materials about 50 to 70 percent of the coated surface is covered with abrasive. Open coat has greater flexibility and resistance to filling or clogging than closed coat.

From the making machine, the product is carried by a festoon conveyor system through a drying chamber to the sizing machine, where a second application of adhesive bond, called the sizing coat, is made. This sizing film unites with the making film and is applied in the degree necessary to anchor the grain securely.

Leaving the sizing machine, the coated web is carried by another longer festoon conveyor through the final drying chambers, in which the temperature and humidity are closely controlled to insure uniformity of drying and curing.

When the bond is dried and cured to the proper degree, the coated goods are wound into jumbo rolls and stored in that form for subsequent conversion into marketable forms of coated abrasives.

Finishing or Converting Operations

Flexing. Usually the first step in the treatments and operations necessary to convert the jumbo rolls of coated goods into the final forms, sizes, shapes, and condition required by consumers, is one or more flexing processes. A coated abrasive must be flexed to the degree required by the particular sanding operation for which it is intended. Some flexing is done on narrow widths and cut shapes but in general goods are flexed in the original coating width. The theory of flexing is the same in all cases: an actual controlled breaking of the continuous bonded abrasive coating with some detrimental effect on the bond or backing. The important feature of the flexing operation is to control the spacing and direction of the breaks.

When flexing is done at a 90-degree angle to the machine (lengthwise) direction of the coated abrasive sheet, it is referred to as single-flex. This type of flex leaves the sheet stiff in one direction and yet provides a degree of flexibility in the other, which allows the abrasive article to conform to the arc of a drum or pulley, without incurring irregular and deleterious breaking or rupture. Flexing the sheet at two 45-degree angles to its machine (lengthwise) direction is called a double-flex or biflex, and gives it all around flexibility because the bonded abrasive surface is broken in two directions at 90 degrees to one another. Double-flexes are required on coated abrasives intended for the sanding of many contours, such as those on moldings or shoulders. A combination of single-flex and double-flex is necessary to sand certain very sharp or irregular contours, and this

flexing is referred to as triple-flex. Any flexing, because it breaks the continuity of the bond, tends to decrease the durability of coated abrasives. For that reason, the minimum flexibility consistent with operating requirements is always the economical selection.

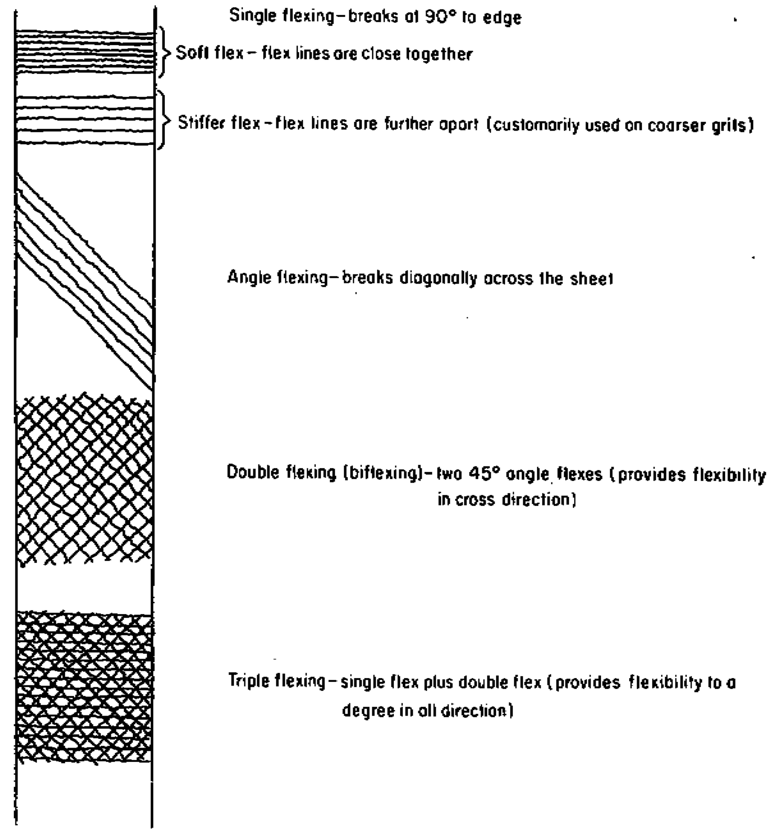

Fig. 2-15. Different types of flexes.

Slitting. Some coated abrasives are supplied to consumers in rolls of the original coating width, but most of those in roll form have trimmed edges or are narrower, slit widths. Material intended for abrasive belts and some cut shapes is also slit stock. Trimmed and narrow rolls are produced on a machine that utilizes circular knives against a hardened steel roll, with rewinding to the desired length. The standard coated abrasive roll is 50 yards, regardless of width; though there are some specialties will form the bottom part of the joint. Such a joint is referred to as single skived. Other belts, in order to run smoothly, must have both ends skived before joining; so that the thickness of the lap will be little if any thicker than the body of the belt. Where the bonded abrasive is thus ground off both the bottom and top laps, the joint is called double skived. This grinding or skiving operation is usually performed with diamond wheels because of the extreme toughness of the bonds used to anchor the abrasive grains. The skiving machines are accordingly rugged, but they must have the most accurate controls possible in order to regulate the depth of cut for a uniform thickness throughout the joint without impairing its strength.

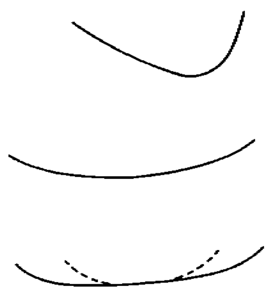

Fig. 2-18. Common configurations of the surface of molded rolls of coated abrasives. Mold conforms to curved surface being worked.

Just before or after skiving, the belt lengths are imprinted on the back with an arrow or other directional sign showing the direction in which they are to be run. It is important that the user mount the belt on the sanding machine pulleys so that it will run in the designated direction, because working against the overlap of the joint may prevent smooth running or break the belt.

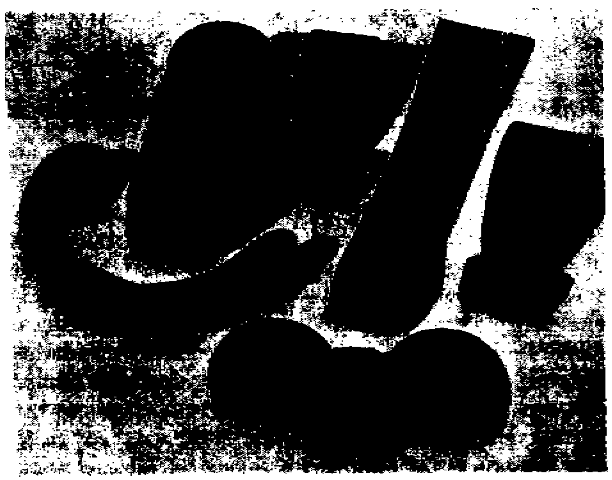

Fig. 2-19. Finished forms of coated abrasives. Belts and discs are two widely used forms.

Skived and stamped for direction of run, the belt lengths next have an accurately measured film of adhesive applied to the ends where they are to be joined. The two ends of each belt are then brought together in perfect alignment between the platens of a press, and the joining bond is completed under pressure. Some of the presses for wide joints can exert pressures of over 50 tons. Proper belt joining is an expensive and carefully controlled operation. Throughout the several steps, specialized equipment and skilled workmanship are required. However, the results are well worth the expense and effort, because smooth running and maximum belt life are assured. Unless a belt so made has been drastically abused, it is highly unlikely that failure will occur at the joint during the life of the abrasive.

Molded Coils or Rolls. Certain industries, shoe manufacturing for instance, require coated abrasives having a preformed contour across the width designed to conform to curved surfaces being sanded. Narrow width rolls are molded to shape by softening the backing and then

Fig. 2-20. Some other converted forms of coated abrasive products, including sheets, spiral-wound bands, spiral-wound strips, edge-slotted discs, and cartridge rolls—both straight and tapered.

Raw Material Tests and Inspection Coverage (Cont.)

Raw material	Test or inspection coverage	Remarks
	Folding endurance test	Measures the number of times paper can be folded without breaking
Backings (cloth)	Defects	Lumps, hanging threads, low tensile strength
	Color	
	Filler	Weight, uniformity of application, stiffness or flabbiness
	Smoothness	
	Processing defects	Wrinkles, torn edges, dirt, oil spots
	Specifications check	Weight per ream, width, thickness, thread count, kind, and, in some cases, air resistance
Backings (vulcanized fibre)	Tensile strength	Tests on vulcanized fibre material are performed under very exacting conditions of temperature and humidity
	Flexing	
	Bending	
	Surface adhesion	
Combination	Tests of combinations involve the normal tests given the products that comprise the combination, plus additional tests of the ply adhesion, flexibility, etc.	
Adhesives		
Glues	Viscosity	All tests of glues are carried out with laboratory equipment under exacting conditions. Some tests are not to qualify the product but rather to govern the application
	Gel strength	
	Moisture	
	Grease	
	Ash	
	Foam	
	pH	
Resins and varnishes	Viscosity	All tests of resins and varnishes are carried out with laboratory equipment under exacting conditions. Some tests are not to qualify the product but rather to govern the application
	Volatility	
	Specific gravity	
	Water tolerance	
	pH	
	Gel time at 121° C	
	Stroke cure	
Finished product	Grain adhesion	
	Grain size	
	Grain sharpness	
	Performance	Laboratory-controlled test of cutting and wearing properties

In addition to the above tests there are many in-process tests. Beta ray gages and analysis of cut samples give an accurate indication of the uniformity and exactness of the coating process at each stage.

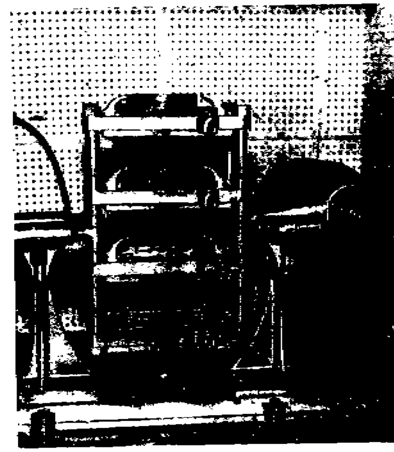

Fig. 2-21. Grain grading machine for determining particle size in screen-grade abrasives.

Fig. 2-22. Sedimentation testing equipment for determining particle size in the subsieve grades.

Fig. 2-23. Measurement of refractive index is a common step in laboratory control of abrasive grain quality.

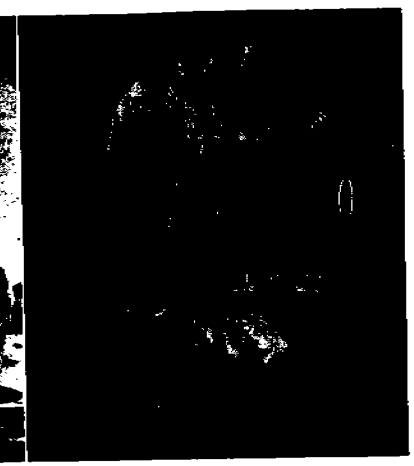

Fig. 2-24. The oscilloscope. Determining characteristics of particles under controlled conditions.

cuts a clean chip which is easily directed away from the work, whereas a coated abrasive grain will often produce a furrow, the edges of which must be cleared away by other grains.

There is of course a greater similarity between the cut of a grinding wheel and the cut of a coated abrasive than between that of an ordinary cutting tool and a coated abrasive, but, here again, there are important differences. The grains of a grinding wheel, as those of a coated abrasive, are only in contact with the work for a very short period of time. The heat generated during the course of cutting by each grain of a grinding wheel tends to be transmitted to the bond of the wheel and, unless coolants are used, the build-up of heat is quite rapid. In the case of a coated abrasive, the heat generated during the cut is likewise transmitted to the bond. However, by the time any point of the belt or other form, has made a complete revolution and returned to the work area, the heat has been dissipated to the surrounding air, and the coated abrasive surface is therefore cooler than that of a grinding wheel.

These basic differences of action between the machine tool, the grinding wheel, and the coated abrasive, make a great difference in their proper selection, speed of operation, and depth of cut or applied pressure, as well as the possible use of coolants and lubricants. While each may have a place in producing finished work, the distinctive advantages of the coated abrasive, and the possibilities of its economic substitution in part or in whole for the other two, are of the utmost importance to every manufacturing plant and its personnel. The following chapters, therefore, deal in considerable detail with equipment available for the use of coated abrasives and proper selection of abrasive mineral, grade number, bond, and backing, as well as operating speeds, pressures, and lubricants, for representative operations in cutting, grinding, and polishing.

CHAPTER 3

Coated Abrasive Machines and Special Forms of Coated Abrasives

One of the major reasons for the spectacular increase in the use of coated abrasives by manufacturers has been the development of machines which can employ these new tools to best advantage. Coated abrasive machines are now achieving rates of production, efficiency, quality finishing, and economy never realized by any other grinding or polishing medium. Some of these new machines have been designed for great efficiency within a limited application, while others have achieved new economies by virtue of their versatility.

Machines vary greatly in complexity and cost. The mammoth moving-head or reciprocating table types of wide-belt surface grinders (figure 3-1), which will taper a 40-foot slab of aluminum 8 inches thick and 84 inches wide, lengthwise from 8 inches down to a few thousandths of an inch, costs a quarter of a million dollars; whereas converting a polishing jack to a backstand idler arrangement to use coated abrasive belts (figure 3-2) may run less than 100 dollars. Attachments that will permit many machines to utilize coated abrasives, such as discs and specialties (figure 3-3), often cost less than a dollar.

BASIC TYPES OF COATED ABRASIVE MACHINES

Coated abrasive machines may be classified in many ways. Generally speaking there are: manually operated machines, which require that the work be brought, positioned, and fed to the machine by hand; semiautomatic machines, which will generally control the positioning and cut but still require the work to be brought to the fixture or conveyor by hand; and fully automatic machines, which handle the whole process from bringing the work to the machine to an orderly ejection after the operation has been completed. Coated abrasive machines may also be classified by the form of the coated abrasive they employ; drum cover, belt, disc,