U. S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

TYPEWRITER RIBBONS AND CARBON PAPER

CIRCULAR C431

U. S. DEPARTMENT OF COMMERCE
JESSE H. JONES, Secretary
NATIONAL BUREAU OF STANDARDS
LYMAN J. BRIGGS, Director

CIRCULAR OF THE NATIONAL BUREAU OF STANDARDS C431

TYPEWRITER RIBBONS AND CARBON PAPER

By C. E. WATERS

[Issued June 14, 1941]

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1941

For sale by the Superintendent of Documents, Washington, D. C. - - - - Price 10 cents

I. INTRODUCTION

In spite of the reluctance of many persons to answer letters, the urge to write seems to be one of the strongest impulses of civilized mankind. A lead pencil and a blank wall are as irresistible a combination as a penknife and a tree with smooth bark. A man without sentiment has been defined as one who has never carved initials on a forest tree.

A Circular [1] of this Bureau tells about inks of various kinds. The present one deals with two other writing materials, typewriter ribbons and carbon paper,[2] and briefly discusses a few related subjects.

No statistics are at hand to show the number of inked ribbons made in the United States in a year. A large proportion of the innumerable typewriters and other office machines must be supplied with several new ribbons in a year. A purchase of 1,200 ribbons by the Federal Government is a small one, and it is not unusual for the Procurement Division, which buys for most of the branches of the Government, to place an order for 15,000 ribbons. The Federal Government may be the largest single purchaser, but the general public must buy many more than are sold to the Government.

Much the same remarks can be made about carbon paper. A great deal of it is used for making copies with a lead pencil, as in innumerable stores where sales slips are made out in duplicate. It is indispensable for making one or more copies on a typewriter. In a recent year the Post Office Department, which has various forms that are filled out in duplicate with the aid of carbon paper, asked for bids on 1,661,000 sheets of pencil carbon paper. The Department also asked for bids on 1,435,000 sheets of all sizes of typewriter carbon paper. The Procurement Division sometimes orders 25,000 boxes, each containing 100 sheets, at one time.

Among the innumerable users of typewriter ribbons and carbon paper there are many who wish to know something about the manufacture and testing of these materials. This Circular has been written for the benefit of these persons. The National Bureau of Standards has done no experimental work on the manufacture of ribbons or carbon paper, so this Circular does not give detailed instructions on either subject. It is hoped that the reader will learn from what is said further along that he can not make good ribbons or carbon paper without the aid of mechanical equipment for performing the various operations efficiently and with the required precision. Success in making either material depends upon more than the possession of reliable formulas and supplies of good quality. The manufacturer must have judgment and experience to enable him to work to the best advantage. No reader should think it will be easy for him to take up the manufacture of ribbons or carbon paper as a business, unless he has the means to pay for the equipment and for the costly experiments by which he must gain experience and skill.

---

[1] Cir. NBS C426, Inks (1940).

[2] That many persons are interested in ribbons and carbon paper is indicated by the great demand for the mimeographed Letter Circular LC424, Carbon Paper and Typewriter Ribbons, issued by this Bureau in 1934, and for the revised edition, LC597, dated 1940. Both are superseded by the present Circular.

Every year this Bureau tests many samples of ribbons and carbon paper for different branches of the Government, usually to find out whether the samples meet the requirements of the specifications under which they are bought. Two lots of ribbons or paper of the same brand but bought at different times do not always have the same writing qualities. There may be changes in the formula for the ink or coating, slight differences in the physical properties of the raw materials of which they are made, the inking or coating machine may not always be adjusted exactly the same, and there may be small variations in the ribbon fabric or the paper tissue. Because of all this, it is not safe to assume that a brand once tested and found satisfactory will always be so. This is one reason why the Bureau never recommends brands of either material. Another reason is that the Bureau does not systematically and at regular intervals test all the brands on the market. There are manufacturers who do not bid on Government contracts, so their products are never tested by the Bureau. These products may be of outstanding quality, and not to recommend them along with other brands would be an injustice, though an unintentional one.

Still another reason for not recommending particular brands is that opinions differ concerning what constitutes good ribbons or carbon paper. This seems to be especially true of the copying qualities of carbon paper. Many users evidently think that the best carbon paper is the one that makes the blackest copies. Others, who are in the minority, believe that the important thing to consider is the sharpness and legibility of the carbon copies, and that their blackness is of secondary importance. If only numerical tables are being typed, there can be no question which of the two opinions is correct, because every figure must be readable. This degree of legibility is not so necessary with reading matter, as will be seen when the testing of carbon paper is taken up on a later page.

This Circular tells how anyone can test ribbons and carbon paper and can decide for himself which kinds are the best for his particular uses. He can make the tests with his own machine and paper, and he need not rely upon the opinion and judgment of anyone else.

Before telling any more about ribbons and carbon paper it seems desirable to give a short discussion of the typewriter. This may make it easier to understand some of the things said about the two materials and their testing.

II. THE TYPEWRITER

Because of their number and widespread use, typewriters come next in importance to lead pencils and to pen and ink for writing. The history of the typewriter is outlined in the following quotation:

> A machine for typing letters was patented as early as 1714 by Henry Mill (English); but the prototype of modern machines was that invented (1833) by Xavier Progin (French), having bars of type. Among Americans Charles Thurber is noteworthy as the inventor (1843) of letter spacing by means of a cylinder moving longitudinally. The first practical machine was the combined invention (1867) of three Milwaukee men, Christopher Latham Sholes, Carlos Glidden and Samuel W. Soute.[3]

---

[3] Webster's New International Dictionary of the English Language. 2d ed. (G. & C. Merriam Co., Springfield, Mass., 1937).

There must have been a time when businessmen had to be convinced that they ought to have typewriters, but in these days their advantages are universally admitted.

In ordinary printing, the faces of the type are inked and then pressed against the paper. In one make, at least, of typewriter, the type are on a small wheel and are inked by rubbing against a small roll of felt saturated with ink, when the keys are pushed down. The inked type strike directly against the paper, so that the clearness of the impressions depends upon the sharpness of the type faces and the smoothness of the paper.

On practically all typewriters the type do not touch the paper, but hit against an inked ribbon, which is thus made to give up part of its ink to make a printed character. Behind the paper is the platen, a roller covered with rubber to cushion the blows of the type. For ordinary typing a relatively soft rubber compound is best, but a harder compound should be used when a large number of manifold, or carbon, copies are made at a time. Occasionally, when the greatest possible number of manifold copies must be made, a brass platen with no rubber covering is employed.

The rubber on the platen slowly hardens with age, and in time its surface becomes covered with rows of slightly indented spots from the repeated blows of the type. When the rubber is in this condition, especially if the ink is nearly exhausted from the ribbon, the typing is apt to be unevenly inked. Another common cause of bad typing is the clogging of the type with lint and ink from the ribbons. This happens oftenest with o, n, e, and similar letters. The center of the letter is a gray blur because the type sink in far enough for the inky mass of lint to hit the paper and make a mark. This clogging occurs more often with some ribbons than with others. The type can be cleaned by rubbing them with a rag moistened with carbon tetrachloride or some other solvent for the oil in the ink. Scrubbing with an old toothbrush is also helpful for removing the deposit, and in desperate cases it can be picked out with a pin. In recent years a number of more or less gummy preparations have been made for cleaning the type. When a small piece of the material is pressed against the type it takes hold of the deposit and pulls it out. Although the material is effective, the inky particles picked out of the type remain on the surface of the cleaning material and soil the fingers badly unless great care is taken.

This Bureau cannot give advice about selecting one of the many makes of typewriters and does not test them. They differ in many details that need not be described. The general style of typewriter most often seen is commonly called "standard" to distinguish it from the "noiseless" and "portable" machines. For the present discussion, the most important thing to consider in buying any one make of typewriter is the size of the type. Although typewriters with a variety of special styles and sizes of type can be bought, most of them have either pica or elite type of a fairly standard design. The differences in design are not great enough to attract the notice of the average person, but they are of interest to the student of documents. The expert in such matters can tell what make of machine was used for a certain piece of typewriting, because of characteristic features of the type. By studying and measuring the alinement and spacing of the letters he can say with some confidence whether or not it was written on a particular typewriter.

The size of the type has a direct bearing upon the clearness of carbon copies and also upon the number of sheets of paper needed for writing long documents, as will be explained.

Any typewritten character is a little less sharp than the face of the type, because slight roughnesses of the ribbon and the paper make the two touch one another in spots slightly beyond the sharp edges of the type. If a single carbon copy is made, the characters are a trifle larger and less sharp than those made directly by the ribbon, because the first and the carbon sheets cushion the blow of the type and spread its effect. This spreading is increased a little for each additional sheet of carbon paper and of manifold, or copy, paper inserted between the type and the rubber platen, so each successive carbon copy is a little less sharp and distinct than the one which precedes it. Because of all this, it is not surprising that if as many as ten carbon copies are made at one time, some of the characters on the tenth copy are so blurred as to be practically illegible. On the tenth copy it is often hard to tell c, e, and o from one another, or a from s, or sometimes F from P. With elite type, fewer legible carbon copies can be made than with the larger and more open pica type.

The strongest argument in favor of the use of elite type is that it may be economical of paper. Consider a sheet of paper of the usual business size, 8½ by 11 inches, on which lines 7 inches long are typed, except for ¾-inch margins top and bottom and at each side. Within this area 29 double-spaced or 58 single-spaced lines can be typed with either elite or pica type. In each 7-inch line there are 70 characters or spaces with pica type, but with elite type there are 84, or 20 percent more. To put it in another way, the carriage moves $\frac{1}{10}$ inch to the left every time a key is struck if the typewriter is made for pica type, but only $\frac{1}{12}$ inch if it is made for elite type. If a piece of writing takes five-sixths of a page with elite type, it will take 20 percent more, or exactly a page, with pica type, provided the spacing and length of lines are the same for both. If the writing takes more than five-sixths of a page with elite type, a seecond sheet of paper must be used for pica type. The value of this extra sheet amounts to almost nothing, but it is easy to see that the use of elite type in offices where a great deal of writing is done may result in a real saving.

III. TYPEWRITER RIBBONS

1. THE FABRIC

Typewriter ribbons, with few exceptions, are made from a thin, closely woven cotton fabric. The weave is plain; that is, with the yarns (threads) alternately interlacing. Because the ribbon comes between the type and the paper it must be thin so that it will make sharp impressions. It must also be made of fine yarns and be closely woven, without open spaces between the yarns, so that when the ink is partly exhausted the impressions will still be evenly inked. If the yarns are thick and the weave is open, the strokes of the individual characters will be made up of dots, instead of being solid lines.

In weaving, the warp yarns, which run lengthwise of the fabric, are put on the loom and there is always the same number of them from one end of the piece to the other. The filling [4] is wound on a bobbin in the shuttle, which is thrown back and forth across and between alternate warp yarns. At each throw of the shuttle the filling yarn passes over or under the warp yarn at the edge. This doubling back of the filling makes the selvage (self-edge) of the fabric.

To make a fabric that is suitable for typewriter ribbons the warp and filling yarns must be thin, and each must touch the yarns parallel and next to it on each side. Only by weaving in this way is it possible to avoid open spaces—meshes—in the finished fabric. In order to secure sufficiently thin and closely woven ribbons, the Federal specifications set an upper limit for the thickness and a lower limit for the number of yarns in a linear inch. This number is often called the "thread count", and perhaps because it makes the weave seem finer, many persons add the number of warp and filling yarns and call the sum the thread count. For instance, if there are 149 warp yarns and 151 filling yarns, the thread count is said to be 300. The fineness of the weave is also expressed as the number of "ends" and "picks" in an inch. The ends are the warp yarns, obviously because they are seen at the ends of the length of fabric. The name pick is derived from the pick or blow that drives the shuttle across the loom each time a filling yarn is added to the fabric.

No matter which term is used, the number of warp yarns in an inch is calculated from the width of the ribbon and the number of yarns across it. Thus, the usual ribbon is ½ inch wide, and if there are 75 yarns in this width, the number in an inch is 150. In a properly cut ribbon the number of warp yarns should be the same from one end to the other. The number of filling yarns is counted at several places along the ribbon, and may vary by 3, 4, or sometimes more. This can be caused by slight differences in the thickness of the yarns when they are spun, or by failure to push them close together during the weaving.

A former Federal specification required that there should be not fewer than 135 yarns per linear inch in either direction. The present specification requires that the number per square inch shall be at least 300, and permits the number in one of the directions to be as low as 148. This count of 300 is not the limit of fine weaving, because a manufacturer once sent the Bureau a sample of his "#400" fabric, with 256 warp and 160 filling yarns, a total of 416 in a square inch.

It takes as many throws of the shuttle and as long a time to weave a yard of ribbon ½ inch wide as it does to weave a yard of fabric many inches wide, if the number of yarns per inch is the same for both. The time cost is the same for both widths, and it is not surprising that the great majority of ½-inch ribbons are not woven of that width, but are cut from the wide fabric. The cost, however, is not the only good reason for using cut ribbons. Because of irregularities in the tension of the filling yarns, ribbons with selvages are said to be not quite so uniform in width as cut ribbons. Some special office machines put a great strain on the ribbons, which must have the slight extra strength imparted by the selvages. The Federal speci-

[4] The old names "weft" and "woof" have been almost completely abandoned.

fication for ribbons used on computing and recording machines indirectly allows for the extra cost of weaving selvage ribbons by permitting the number of filling yarns to be as low as 110 in an inch.

The great majority of typewriter ribbons have cut and gummed edges. The fabric, 42 inches wide and in lengths of 144 yards, is cut by a special machine into strips ½ inch wide. A narrow band of adhesive is applied to each cut edge to keep the warp yarns from coming loose. The cutting into strips is done with surprising exactness, and only now and then is a warp yarn cut across. This is as it should be, because if there were many cut ends of warp yarns along the edges, fraying would be very hard to prevent, in spite of the gumming. An occasional poorly made ribbon may show a few places where the knife cut across three or four warp yarns close together. A ribbon with wavy edges caused by poor cutting may cause trouble in the typewriter. Sometimes when a few feet of a ribbon is held vertically without tension it shows a waviness back and forth in the plane of the ribbon, every four or five inches. This sort of waviness causes no trouble in the typewriter and is not objectionable. Another kind of waviness is sometimes seen when a length of ribbon is laid flat without tension on a table. The edges make short up and down waves. Evidently at some stage of the manufacture the fabric has been stretched more along the edges than in the middle; or else the fabric has shrunk more along the middle than along the edges. This kind of waviness should also cause no trouble when the ribbon is in use.

After the ribbons have been cut and their edges gummed, they are singed to remove the loose ends of cotton fibers. Some manufacturers stretch the ribbons strongly and compress them between steel rolls to reduce their thickness. Other manufacturers say that this treatment injures the ribbons.

Nearly all ribbons are made of cotton, but those who are willing to pay extra for a slight increase in the sharpness of the typewriting buy silk ribbons, which can be made much thinner than cotton ones. A cotton yarn is made of short fibers twisted together. The thinness of the yarn depends upon the fineness of the cotton fibers and upon how few of them can be twisted together to make a yarn that will not fall apart. Silk is in fibers many yards long, and much thinner than the finest cotton. If the silk yarns are made of only a few fibers put together with little twist, the fabric woven from them will be much thinner than is ever possible with cotton. Because they are thin, silk ribbons can not hold so much ink as cotton ribbons, and must be renewed oftener.

Rayon is much cheaper than silk, and is comparable to it in the length and fineness of its fibers. Rayon would seem to be almost ideal for typewriter ribbons, yet almost none of it is used for this purpose. Manufacturers of ribbons say it is hard to ink satisfactorily, apparently because the fibers are so smooth and nonabsorbent.

2. TYPEWRITER RIBBON INKS

(a) GENERAL

The Bureau has done no experimental work on making inks for typewriter ribbons and has tested none of the few formulas that are to be found here and there in print.[5] It must be said of these published formulas that by the time they get into print they may no longer be representative of those actually in use, though they may at one time have made what was considered excellent ink. The printing ink industry as a whole is actively engaged in trying new raw materials and new formulas. Information about the more important advances sooner or later gets into the technical journals, whose readers learn what has been done, but not immediately. Typewriter ribbon inks are only a special kind of printing ink, but they do not seem to get as much publicity as the others. All the reader can expect to find about them in the current technical journals is an occasional abstract [6] of a new patent, and almost never a descriptive article. The manufacturers are not to be blamed for not telling how they make their inks. Because of all this, only the general principles involved in making the inks will be discussed.[7]

Typewriter ribbon inks are fluid mixtures that consist essentially of a liquid portion, or vehicle, and a solid coloring material, or pigment. By properly selecting the ingredients and varying the proportions in which they are mixed, inks of a wide range of fluidities can be made.

The vehicle may consist of mineral, animal, or vegetable oils, or a mixture of them. Sometimes a liquid wax, for instance, sperm oil, is included. The petroleum oils that are not too volatile for making inks differ greatly among themselves, for some of them are even more fluid than a light motor oil, and those at the other extreme flow very slowly. There are similar but not so great differences among the animal and vegetable oils. Familiar examples of the extremes in fluidity are olive oil and castor oil.

Because the majority of ribbons are black, the most important pigment is carbon black, which is the soot formed when natural gas is burned under special conditions. The gas consists of a mixture of hydrocarbons, or chemical compounds made up of the elements carbon and hydrogen. If the gas is burned completely in a sufficient supply of oxygen from the air, all the carbon is oxidized to the gas, carbon dioxide, and all the hydrogen to water. If there is not enough oxygen for complete combustion, the hydrogen gets most of it, and nearly all the carbon is left as soot. Collecting the soot from the flames is made easier by making them play against suitable surfaces of metal, on which much of the carbon black collects and is removed from time to time.[8] Lampblack is made in a similar way, but by burning oils instead of natural gas. Carbon black was at first called

---

[5] Thanks are due to A. G. Weinz for information about the composition of typewriter ribbon inks and carbon paper coatings, as well as for his critical reading of the sections dealing with these materials and with the manufacture of the ribbons and paper.

[6] Abstracts of patents issued in the United States and in a number of foreign countries can be found in the periodical Chemical Abstracts, published semimonthly by the American Chemical Society. It can be found in college, university, and many public libraries.

[7] For those who feel that they must have formulas, the following references are given for what they may be worth:

B. Walther, *Die Fabrikation von Schreibmaschinenfarben und Bändern* (*The manufacture of typewriter inks and ribbons*), Chem.-Ztg. 45, 169–171 (1921).

Anonymous, *Little cousins of the printing ink industry,* Am. Ink Maker 17, 16 (Jan. 1939).

H. Bennett, Practical Everyday Chemistry (Chemical Publishing Co. of New York, New York, N. Y., 1934).

H. Bennett, Chemical Formulary, vol. 4 (Chemical Publishing Co., New York, N. Y., 1939).

Jameson's Manufacturers Practical Recipes (Lewis Jameson & Co., Ltd., London, England, 1929).

[8] Carbon Black—Its Manufacture, Properties, and Uses, Bur. Mines Bul. 192 (1922).

gas black, a more distinctive name, but one which is going out of use.

Although the particles of carbon black are perhaps smaller than could ever be produced by grinding, they cling together in clusters of much greater size. If ink should be made by simply mixing the black with the oil and other materials, the product would be lumpy or granular, instead of smooth and uniform. Grinding does not make the particles smaller, but breaks up the clusters. It not only disperses the particles, that is, separates them from one another, but it also coats them with oil so they will not again cling together. The ink is usually ground by passing it between the polished rollers of a suitable mill a number of times. The rollers are set very close together and are run at different speeds. This causes a shearing action on the mixture as it passes between them, and this helps to break up the clusters of carbon black. Most of the grinding to disperse the particles is done before all the oil is added, because the shearing action is greater with the stiffer mixture than it would be with the more fluid one. After the carbon black is properly dispersed and the last of the oil has been added, one or two more passes between the rollers complete the mixing.

By changing the conditions under which it is produced, a number of grades of carbon black are made. The grade preferred for typewriter ribbon ink has what is known as a "long flow"; that is, a relatively large quantity of it can be added to a given amount of vehicle without making an undesirably stiff ink. This is an advantage because the ink can contain a large amount of pigment and still have the fluidity necessary for its ready flow in the fabric of the ribbon.

Fine powders are often hard to wet, and this is true of carbon black, yet in order to have it dispersed through the ink as it should be, every small particle must be coated with oil. To aid in the dispersion of the particles, a "wetting agent" is sometimes used. A wetting agent is a substance that makes a liquid wet the surface of a solid easily. If the solid is in a fine powder and the liquid does not wet it easily, much air will be trapped between the particles. The addition of a small amount of a wetting agent to the liquid will make it wet the particles and enter the spaces between them, so that the air will be displaced. This action is especially desirable when the particles cling together in clusters, as they do in carbon black, and must be separated from one another and be dispersed through the liquid.

In very thin layers carbon is not jet black, but has a brownish tone. To overcome this, blue or violet "toners" are put in the ink. Their color kills the brown tone of the carbon black, just as bluing in the laundry makes washed linen look snow-white instead of yellowish. The toner may be either a dye lake, a dissolved dye, or both. A dye lake is made by mixing a solution of a dye with a solution of a suitable metal salt. The addition of certain chemical reagents to the mixed solutions causes the formation of an insoluble compound of the metal which, as it is precipitated, carries the dye with it. By this procedure a small amount of dye will make a large amount of lake. The use of lakes instead of dyes is not merely a way of economizing, but is necessary in order to bring out the color of perhaps the majority of dyes. The appearance of a dry powdered dye often gives no hint of the color of its solution or of its lake. For instance, crystalline fuchsine (magenta) and brilliant green have a brassy luster, which does not at all suggest that the first will make an intensely red solution and the second a green one. Many of the dyes are dark brown powders.

When solutions of dyes are used as toners, the solvent is generally oleic acid, an oily liquid whose compound with glycerol is a constituent of all animal and vegetable fats and fatty oils. The unpurified, or technical, grade of oleic acid is known commercially as "red oil." Many dye bases are insoluble in water but dissolve readily when heated and ground with oleic acid. A dye base which is often used as a toner is nigrosine. A thick layer of its solution is black, but a thin layer is blue or violet, and this makes it suitable for destroying the brown tone of carbon black. Years ago a manufacturer of ribbons explained the use of oleic acid in the ink by saying that it helped to carry the carbon black into the paper. It is now known that the solution of nigrosine in the acid is an effective wetting agent, and as such it would have the action described.

The ink maker directs his efforts towards producing an ink that has the characteristics he considers necessary and desirable. It must be sufficiently fluid [9] for it to flow readily in the fabric, and must contain enough pigment to impart a satisfactory depth of color. In order to make ink like this he must know how to modify his formulas to adapt them to pigments of different kinds that are unlike in grain size, density, and other respects. Suppose two pigments are ground to particles of the same average size, and that one of them is denser than the other. In the same weight of each there are more particles of the lighter powder than of the heavier and, in order to make two inks of the same fluidity, more oil will be needed with the lighter pigment than with the heavier one.

Another factor that should be considered in making the ink is the fabric of the ribbon. Its power to hold ink and to let it flow from one part to another depends upon its thickness and its compactness which, in turn, are influenced by the length of the cotton fibers (staple length), and the twist and fineness of the yarns.

From all this it will be seen that much depends upon the judgment of the ink maker and upon his ideas about the kind of ink that is satisfactory. Anyone who tests a number of brands of ribbons finds out that different manufacturers do not agree with one another about the composition of the ink and about how much of it should be put on the ribbon. Many ribbons are excellent, but some are very poor.

(b) INKS FOR BICOLOR RIBBONS

Single-color ribbons contain inks which are essentially the same as those in black ribbons, except that dye lakes are used in them instead of carbon black. Many ribbons have inks of two colors, for instance black and red, running side by side. Somewhat specialized inks must be made for these ribbons so that the colors will

[9] In the laboratory the "viscosity" of a liquid is spoken of more often than its "fluidity." The two terms are direct opposites, and if a liquid has a low viscosity it has a high fluidity. The viscosity of a liquid can be determined by the rate at which a given volume of it flows through a capillary tube. If it is expressed in absolute units, the fluidity is the reciprocal of the viscosity.

not diffuse, or "bleed", into one another. Sometimes a new ribbon is seen in which it is evident that coloring matter from the black half has spread into the red. There is no easy way to find out whether some of the red has gone into the black half. The majority of bicolor ribbons received for test by the Bureau show no such diffusion of the color. Some ribbons are so inked that a white "pin stripe" is left between the two colors. It seems to remain white indefinitely.

(c) COPYING INK

Before the days of the typewriter and carbon paper, business letters and other important documents were written longhand with a special copying ink and press copies were made for filing. To make a press copy, a blank sheet of paper is laid upon the writing, and the two are strongly compressed between damp cloths or blotting papers for a short time. The water squeezed out of the cloths dissolves enough of the ink to make a copy of the writing on the blank sheet. Because the writing is reversed in the copy the blank sheet is of thin translucent paper, so that the copied writing can be read on the reverse side. Writing done with ordinary typewriter ribbons will not yield press copies because the pigment and dyes are not soluble in water. Special ribbons are needed for this purpose. A favorite combination seems to be a ribbon that gives black writing and blue press copies. Part of the pigment of the ink is a finely powdered blue dye, which is usually dark brown when in this form, and does not noticeably affect the color of the ribbon copy. In the letter press the water from the damp cloths penetrates the film of oil on the particles of dye and dissolves enough to make strongly colored copies. If the water could not penetrate the films of oil, it might be necessary to make copying inks with glycerol instead. It is said that in the early days of the typewriter glycerol inks were used, but were soon abandoned for oil inks. Because glycerol absorbs water from damp air and gives it up again to dry air, a ribbon might be too wet one day and too dry the next. Besides, glycerol sinks into paper more slowly than oil does, so the typewriting would run the risk of becoming smeared before it had time to dry.

When typewritten matter is to be copied by the hectograph process, the ink on the ribbons must be heavily loaded with a water-soluble dye, and it is applied to only one side of the fabric. The master copy, which is used for transferring the writing to the hectograph pad, thus carries a large quantity of dye.

(d) EXCESSIVE OILINESS

Perhaps the greatest fault of a typewriter ribbon is that the ink contains too much oil in proportion to the amount of pigment. During the past few years this fault has become more common than it used to be, for a reason that is not hard to see. When the ribbon is being used, the type hit it in a narrow band near the edge from one end to the other. The ink in this band gradually becomes exhausted, a little each time it is struck by the type. If the ink were solid, like the coating on carbon paper, it would not be long before the ribbon ceased to write. Just like the coating on carbon paper, the ink in the narrow band would be worn off, and that in the rest of the ribbon would be wasted. The ink is not solid, but fluid, and tends to distribute itself uniformly throughout the fabric by capillarity. The flow of the ink in the ribbon is shown by the "recovery." If 20 or 30 characters are written repeatedly and without interruption with exactly the same short length of the ribbon, each line is a little paler than the preceding one, and finally there is so small an amount of ink left that the writing is almost unreadable. If the ribbon is then allowed to rest for a short time, say 20 minutes, and another line of the characters is written over the same part of the ribbon, it will be found that this line is darker than the 10 or 20, or sometimes more, lines that immediately precede it. Some of the ink has flowed from the surrounding parts of the ribbon to the depleted band. This recovery greatly increases the amount of writing that can be done with a ribbon. The more fluid the ink, the greater the recovery, and the greater the probability that the ink is too oily and will show on the reverse side of the paper. Excessive oiliness makes it harder to erase misprints neatly without smearing. When testing ribbons it has been noticed repeatedly that when the ink is too oily it does not contain enough carbon black. In the "wear-down" test, which is made as outlined in this paragraph, as the successive lines become paler they begin to have the distinctly purplish color of the toner. The ink is colored with dye and not with carbon black. If the ink contains enough carbon the lines change from intense black to light gray by degrees, and are not purplish. This ink almost never shows on the reverse side of the paper.

Another drawback connected with ink that does not contain a sufficient amount of carbon black is that the writing done when the ribbon has been in use for some time will fade when exposed to bright light. Carbon black itself will not fade when exposed to direct sunlight, and it is not changed in any way if the typewritten matter happens to be kept in such a damp place that the paper becomes moldy and falls to pieces. Treating the writing with chemicals that will bleach the dye or even destroy the paper has no effect on the carbon black. Typewriting done with a properly inked ribbon ought to last as long as the paper holds together. Much handling may make the typing paler, because the ink on the very surface of the paper is rubbed off, but the carbon that was carried below the surface as the ink sank into the paper should remain indefinitely. Liquids that will dissolve the oily part of the ink may also dissolve the toner and thus stain the paper, but they seem not to be able to loosen all the particles of carbon black from the paper, so that they can be washed away. If part of a sheet of typewriting done with a properly inked ribbon is exposed to direct sunlight for several days, the dye in the ink will fade and the writing will take on the brownish tone of a thin layer of carbon black. In spite of this, the exposed writing will be practically as intense as that on the rest of the sheet, which was kept in the dark. Little of all this applies to typewriting done with a ribbon that is too oily. Bleaching solutions will remove the dye, and exposure to sunlight will sometimes make even the first few lines written with a new ribbon fade badly. If the ribbon has been used so much that the typing is purplish, exposure to sunlight will make it almost disappear.

(c) DRYING OF INK IN RIBBONS

Manufacturers wrap their ribbons in metal foil or sometimes in transparent sheet material, and pack them in boxes. The reason usually given is that the ribbons are kept from drying out if they must be stored for some months. Whatever drying there is may be the result of two entirely different causes, evaporation and oxidation of the oily part of the ink. The oily materials in the ink evaporate with extreme slowness at ordinary temperatures, yet it is certain that they do evaporate, because the ribbons have an odor. No substance can have an odor unless its vapors, or else fine particles of it enter the nose. If the oils become oxidized they may be converted into solid compounds, and the effect upon the ink will be the same as if part of the oil is lost by evaporation. If a shallow layer of an automobile lubricating oil is exposed to sunlight and air, before long it will begin to deposit a solid oxidation product, and after a number of weeks will become a pasty mass. Oxidation of the oil must take place in the ribbon, but probably at a rate so slow as not to be measurable. The rate will depend less upon the temperature than upon the amount of bright light that falls upon the ribbon. Heating petroleum oil in the dark to nearly the boiling point of water causes less oxidation than exposing it to sunlight at a temperature near the freezing point of water.

Whatever happens to the ink to make the ribbons dry out, the effect cannot be detected in a day or two. The part of the ribbon that crosses from one side of the typewriter to the other has the fullest opportunity to become dry by both evaporation and oxidation. If drying took place rapidly, the first two or three lines typed after the machine has stood idle for a few days would be paler than those typed with the more protected part of the ribbon still wound on the spool. It is believed that no such thing is ever noticed.

The combined effects of evaporation and oxidation may take a long time to become noticeable. At the end of September 1933 a ribbon was tested at this Bureau and was reported to be too oily. It was received unwrapped and unboxed and was on a spool with open ends like wheels with five spokes, so that the edges of the ribbon were freely exposed to the air. This ribbon lay in a table drawer until the end of October 1940, when a writing test was made with it. A short line written about a foot from the free end was quite as dark as the average typing of letters received from correspondents. A second line was written about 5 feet from the end of the ribbon, where it was less likely to have been handled. The writing was about as dark as that of a new lightly inked ribbon. The test was made on the letter paper used by the Bureau. Three days later the first line showed to a slight extent on the reverse side of the paper, and the second line showed so plainly that the ribbon might still have been reported as too oily. Both lines showed slightly yet definitely the purplish color of the toner.

This discussion is not meant to be an argument against the wrapping of ribbons. If wrapping in foil and packing in a metal box ease the mind of the buyer, they are to be recommended, whether or not they are as necessary as he thinks.

3. INKING THE RIBBONS

In discussing typewriter ribbon inks it was pointed out that they cannot be made efficiently by hand. Without the modern ink mills the production of ribbons on a large scale would not be possible. Applying the ink to the fabric is another operation that requires a suitable machine. If a person had the patience to grind by hand enough ink for a few ribbons, he would still have to face the task of spreading it uniformly and in just the correct amount over the 12-yard strips of fabric half an inch wide. How he would ink a two-color ribbon must be left to the imagination. It is not the object of this circular to give detailed instructions for the manufacture of typewriter ribbons, but merely to outline the procedure.

There are different types of machines for inking the fabric. One has a series of rolls that distribute over the fabric the quantity of ink needed for the desired degree of inking. Another applies a large amount of ink and then squeezes out the excess. The individual ribbons, usually 12 yards long, are not inked one by one. Instead, the fabric is in a strip long enough to make many ribbons, which passes through the machine. After the inking the fabric is cut into lengths, and any metal parts that are needed are attached to the ends of the ribbons, which are then wound on spools to fit the various makes of typewriters. The final steps are to wrap the spools and put them into the boxes.

There are no generally accepted standards for the degrees of inking: light, medium, and heavy. Each manufacturer has his own ideas on the subject. Some of them have intermediate inkings, or provide ribbons with light, medium, and heavy inkings for pica type, and others with corresponding inkings for elite type. At first sight it might seem easy to set standards for the degrees of inking by requiring that for each degree there must be a definite weight of ink in a given length of ribbon. This might be done if all ribbons were exactly alike in thickness, number of yarns per inch, and twists of yarns, all of which have an influence upon the amount of ink a ribbon can hold and upon how easily it gives up the ink when in use. It would also be necessary to standardize the ink, and especially to require it to have a definite fluidity. The more fluid the ink is, the more of it is transferred to the paper when typing.

The typist thinks of degrees of inking in terms of the blackness of the writing and of the length of time a ribbon can be used before the ink is exhausted. He is not interested in the weight of ink in a yard of ribbon, but in how much of the ink can be turned into writing. Determining the amount of ink would take a considerable length of time, and when the task was completed it would tell less about the writing qualities of the ribbon and its degree of inking than could be learned by making an actual "weardown" test. This is done by writing line after line of the same letter over exactly the same part of the ribbon, and observing how many lines of good intensity can be written. More is said about this in the section on testing ribbons.

Now and then the complaint is made that a ribbon is unevenly inked. The typewritten matter shown as evidence of this may have a few pale letters in groups here and there at irregular intervals. From the way ribbons are inked, on a carefully adjusted machine, it is hard to see how the inking can be as uneven as the typing seems to show. It is far more likely that the pale letters are written at more or less regular intervals because the touch of the operator varies, or else because of some defect in the typewriter. It would seem as if the manufacturer would have to make a special effort to produce ribbons as unevenly inked as some users think they are. If a defective roll in the machine caused alternating spots to have light and heavy inking, the normal flow of ink in the fabric would probably soon even out the differences.

From time to time the Bureau is asked what to do to a ribbon that has been used for a long time, to make it write as well as a new one. Of course only reinking will do this, yet a ribbon that seems to have been exhausted of ink can be made to give darker writing by treating it with a few drops of oil, applied as evenly as possible and given time to spread in the fabric. The ink tends to distribute itself uniformly in the fabric and will flow from the parts of the ribbon where it is abundant to a part from which some of it has been removed by typing. This is the cause of the recovery when a ribbon is used and is then left alone for a time. The type hit it in a narrow band, usually near its upper edge, while the rest of it is untouched. It might be supposed that when the writing becomes pale, the original blackness could be restored by turning the ribbon over so that the type would hit its unused edge. Little is gained by doing this because the available ink has flowed to the used edge and from there has been transferred to the paper. The flow of ink will continue until there is left in the entire ribbon only enough of it to cover the fibers with a thin film and to fill the tubular cotton fibers and other small spaces. The application of a few drops of oil, for instance a light motor oil, will dilute the remaining ink so that some flow is again possible and the ribbon will write. Because of the dilution the writing will not be as dark as that done with a new ribbon, and in a comparatively short time it will again be pale. Besides, the writing will show all the ill effects of having too oily an ink. Only a very uncritical user would be satisfied with a ribbon that has been treated with oil in the way described.

4. TESTING TYPEWRITER RIBBONS

(a) PHYSICAL MEASUREMENTS

A typewriter ribbon is a device for writing, and the principal tests made on it are intended to directly determine its writing qualities. The width, length, number of yarns per inch, and the thickness are also determined. The last two are much less important than the writing tests, but they help the laboratory to make sure that deliveries of ribbons bought are all made of the same fabric as the bid sample on which the contract was awarded. The ribbons for some office machines must be extra strong, so according to the Federal specification, ribbons for computing and recording machines must meet a requirement as to tensile strength. The details of this and of some of the other tests need not be given because they are set down in a Federal specification.[10] A few comments on the determination of the

[10] Federal Specification CCC–T–191a, Textiles; General Specifications, Test Methods.

thickness and the thread count, as it is commonly called, are in order. According to the Federal specification for typewriter ribbons, the thickness of the inked ribbon shall not be more than 0.0055 inch. The machinist thinks nothing of measuring the thickness of a sheet of metal to ten-thousandths of an inch, because he has a practically unyielding material to work on. Yet if he turns the screw of his micrometer caliper gently one time and hard the next, the two readings of the thickness will not agree. A woven fabric is far more compressible than a sheet of metal, and in order that different laboratories shall agree in their measurements of its thickness a special gage for textiles must be used. The gage described in the general specification for textiles has a presser foot 0,375 inch in diameter, and it is pressed down on the fabric under a total load of 6 avoirdupois ounces. The dial can be read to 0.0001 inch. Several measurements are made at different places on the ribbon and the readings are averaged. Although the thickness is specified to the fourth decimal place and the average is reported in the same way, nobody really believes that the thickness of any fabric can be measured with such accuracy.

For the thread count, a thin steel scale with 1 inch graduated in sixteenths is laid upon the ribbon, and the number of filling yarns or picks in an inch is counted at several places. The average is reported as the number of filling yarns per inch. Nearly all typewriter ribbons are ½ inch wide, so the number of warp yarns or ends per inch is calculated from the number in ½ inch of the ribbon. Care must be taken to measure the actual width of the ribbon, and not to assume that it is exactly ½ inch.

(b) WRITING TESTS

It is comparatively easy to come to an agreement when there is a difference of opinion about the thickness of a ribbon or about the number of yarns per inch. It is nearly hopeless when the bidder on a contract does not accept the report of the testing laboratory that his ribbon does not have as good writing qualities as the specification intends that it should have. Sometimes a bidder will admit that his ribbon does not write the required number of lines, yet he will say that it should be accepted "because it will give very good service." The only reply is that the testing laboratory must decide whether or not a ribbon passes the tests in the specification, and must report accordingly. The decision about the quality of the writing rests upon the judgment of the one who makes the tests, and who is not personally concerned whether or not the ribbon passes. The bidder has a financial interest in it, and is not to be blamed for thinking better of the ribbon than it deserves. Because so much depends upon judgment, rather than upon measurements that can be expressed numerically, it is the practice at this Bureau for two persons to rate the writing tests independently of one another when there is any doubt, or when a number of bid samples are tested and a contract involving a large sum of money is to be awarded. This seems fair enough, yet it must be admitted that the two persons come to have practically the same mental standard for the writing quality of ribbons. In a sense, this gives the testing laboratory two votes to the bidder's one, but at any rate it makes the decision seem less arbitrary.

(1) *Wear-down.*—The number of lines that can be written one after another over the same short length of ribbon is known as the "wear-down." It is sometimes called the "serviceability," a less accurate term because it implies other qualities than the one under consideration. For a number of years the Government specifications [11] for typewriter ribbons told how to make the wear-down test on an ordinary typewriter. The present Federal Specification DDD-R-311a, Nov. 1935, requires the use of a special typewriter, the "Electromatic," which is run by an electric motor. The keys have a trigger action and merely release the typebars. The force of the blow of the type against the ribbon and paper is regulated by a revolving "power cylinder" on the under side of the machine. The faster the the cylinder turns, the harder the blow of the type. To make the wear-down test according to the present specification, the machine is so adjusted that the type strike a fairly heavy blow, in order to exhaust the ink so rapidly that only 100 lines need be written with a heavily inked ribbon. This number of lines can be typed on a sheet of paper 21 inches long. The sheets can be specially cut, or two of ordinary size can be pasted together end to end. By having long sheets the test can be completed without any delay caused by having to change to a new sheet of paper. Instead of putting the ribbon in the machine as usual, a length of it about a yard from the end is fastened to the ends of the carriage by clips. One clip is fastened and the ribbon is then put under a tension of 50 grams (1¾ avoir oz) by means of a weight. The second clip is now fastened and the writing can be started.

A line of about 30 B's, K's, or R's is now typed, the platen is turned so as to shift the paper a single space, the carriage is pushed back to the starting point, and the same letters are again written over exactly the same part of the ribbon. According to the specification, it should be possible to write 50 lines of good intensity with a lightly inked ribbon. If the ribbon has medium inking, 75 lines should be typed, and 100 lines if the inking is heavy. There should be no stopping from the first line to the last, yet the lines must be counted. This is done without any delay by typing one or two extra letters at the right-hand end of every line that is an odd multiple of 5, and three or four at the end of every line that is an even multiple of 5. Anyone can tell at a glance when 5 lines have been typed, and it takes only a fraction of a second to write the extra letters as markers. The wear-down lines make a compact column, and the extra letters stand out conspicuously. Like the scales on thermometers and other instruments, the marks indicating the 10's are longer than those which show the 5's.

Sometimes the 50th line written with a so-called lightly inked ribbon is much darker than is expected. When this occurs, the writing is continued for 25 lines more, to see whether the 75th line justifies classing the ribbon as having medium inking. Similarly, if the ribbon is marked "medium inking," 100 lines are typed instead of the usual 75. In either case the report of the laboratory should say

---

[11] United States Government Master Specification for Typewriter Ribbons No. 167, July 1924, and its revision, No. 167a, July 1927, both issued as editions of BS Cir. 186; and Fed. Spec. DDD-R-311, Ribbons; Typewriter, Dec. 1930. All these are superseded by the revised Fed. Spec. DDD-R-311a, Nov. 1935, with Amendment No. 1, May 1940.

that the ribbon is incorrectly marked, or else that its inking is heavier than is usual for the claimed degree of inking.

When the present Federal specification for typewriter ribbons was being worked on, the suggestion was made, but not adopted, that one of the well-known adding machines should be used for the testing. The large type of this machine hit the ribbon rather lightly, and it is easily possible to write 1,000 or 1,200 lines in the wear-down test. This takes a strip of paper several feet long. The sight of so many typed lines is impressive to one who has never tested a ribbon, and who does not know that the test adopted by the committee shows just as much about a ribbon as can be learned by the use of the adding machine. It takes longer to make the test on the adding machine than it does on the typewriter, and the long sheet needed for 1,200 lines is inconvenient to handle.

Anyone with a reasonably even touch can make acceptable wear-down tests on a ordinary typewriter, and can find out what make of ribbons and what degree of inking give the most satisfactory writing under the conditions in the office in which they are to be used.

It has always been admitted that the weak point in writing tests of ribbons is that too much depends upon the judgment of the operator, who must decide whether the final line of the wear-down test is of satisfactory intensity or is too pale. Attempts were made to avoid this when the specification was being revised. One suggestion was to insert in each copy of the Federal specification a sheet on which were printed several lines with black ink and a series of progressively paler gray inks. The intention was to require that the same number of lines be written with all ribbons, no matter how they were inked. In each case the last line was to be no paler than a specified one of the gray lines. Because of technical difficulties in the preparation of a series of properly graded gray inks, and for other reasons, this plan was abandoned.

Attempts to match the writing against standardized gray papers failed. In spite of the compact letters selected for the wear-down test there is so much white paper in a typewritten line and the strokes of the letters show such variations in intensity that it was found impossible to say when the typing matched the standard gray paper. The plan was also tried of cutting a small square piece from the last few lines of the wear-down and spinning this rapidly. The resulting blur was not of uniform intensity, but was made up of a series of light and dark concentric circles and could not be matched against the standard gray paper.

Finally, a photometer intended for measuring the amount of light reflected from painted surfaces was tried. The idea was to measure the reflection from the white paper and from the part of it on which the last few lines of the wear-down were typed. The difference between the two would be a measure of the blackness of the typewriting. This method gave fair promise of success, but it was decided that because the instrument is expensive and somewhat complicated, it would be unwise for the specification to require its use. The method finally adopted, to write a different number of lines for each degree of inking, seems to be as satisfactory as could have been expected. The present specification is based upon the results of tests made on a number of ribbons supplied by several manufacturers who were asked to send their best brands. It turned out that in most cases the 50th line of a lightly inked ribbon was about equal in intensity to the 75th and 100th lines, respectively, of the other degrees of inking. A few of these best brands did not meet the requirements decided upon for the specification.

(2) *Recovery.*—After the required number of lines has been written, the ribbon is left undisturbed for 20 minutes, and then one more line of the letters is written. This shows the "recovery." The Federal specification requires that the recovery line of a lightly inked ribbon shall be at least as dark as the 40th line in the wear-down. Similarly, for the medium-inked and heavily inked ribbons, the recovery lines shall be as dark as the 60th and 75th lines, respectively. Because the inks in bicolor ribbons can not be very fluid, the ribbons are treated in every respect as if they were lightly inked.

Once in a while the recovery line of a single-color ribbon is little if any darker than the last line of the wear-down. It is a much commoner fault that the recovery line is excessively black. It has been pointed out that in their efforts to give their ribbons a longer life, some manufacturers make the ink too oily. A person who tests many ribbons comes to look with suspicion on a recovery line that is unusually black, because it almost always indicates too oily an ink. The specification requires that the wear-down sheet be examined on the reverse side after 24 hours. If the writing of the first few lines has penetrated the paper to too great an extent, the ribbon should be rejected.

(3) *Clogging of type.*—In the section on the typewriter it was said that one of the causes of bad writing is the clogging of the type with a mixture of lint and ink from the ribbon. This happens oftenest with e, n, o, and similar letters that have spaces within which the mixture can lodge. Ribbons differ greatly in their tendency to clog the type. To test for this, the ribbon is put on the machine in the usual way, and the letter e is typed 800 times. If there is any serious clogging, the ribbon is rejected. One particular ribbon was so bad in this respect that it is remembered. The e was completely clogged by the time it had been written about 200 times. Then the ribbon picked the mass of lint and ink out of the type and the next few impressions were sharp and clean. Evidence of clogging soon reappeared, and after a time the ribbon again filled and cleaned the type. All this occurred three or four times while the 800 e's were being written.

(4) *Other tests.*—When a copying ribbon is tested the wear-down sheet is cut in two lengthwise and one half is used for making a press copy in the regular way. The copy must be sharp, of good intensity, and easily legible.

The permanence of the writing is tested by exposing part of lines 5 to 15 of the wear-down test to the radiation from a glass enclosed carbon-arc lamp.[12] If the ribbon is black, the sample of writing is exposed for 48 hours. Colored writing is exposed only 24 hours. Colored ribbons are not rejected if the writing fades considerably, provided it retains enough color to be easily read. Black ribbons are rejected if the writing shows definite fading, apart from the

[12] According to the Federal specification, the commercial lamp known as the Fade-Ometer is to be used. The housing of the lamp has special holders for the samples.

development of a brown tone because of the fading of the toner. It happens far too often in routine testing that the writing fades badly, though it might be expected that the ink of lines 5 to 15 would still contain enough carbon black to prevent this.

It is not necessary to go into the details of testing hectograph ribbons or those for computing and recording machines. In testing hectograph ribbons the writing of the wear-down test is transferred to a hectograph pad and copies are made in the usual way. Some of the special office machines must have ribbons of extra strength, so the Federal specification requires that they shall have a breaking strength of at least 40 pounds per inch of width. This is determined with a suitable tensile testing machine.

IV. CARBON PAPER

It is necessary for a business man to keep copies of the letters he writes. In the days before the typewriter, press copies were made in the way already outlined. This custom has not yet died out, perhaps because a press copy is a facsimile of the original handwriting with all its characteristics. The extra time required for making press copies, to say nothing of the inconvenience, and of the blurring when a little too much water is used, have no doubt had a great deal to do with the widespread use of carbon paper. Another advantage of using carbon paper is that a number of copies can be made with no more loss of time than is necessary for assembling the sheets of paper.

Carbon paper is paper covered on one side with a thin, even coating of a mixture of colored pigment with waxy and oily materials. The general name is given because most of the carbon paper made is black and is colored with carbon.

1. CARBON PAPER TISSUE

Typewriter ribbons must be thin, so as to give sharp writing. There is even greater reason for making carbon paper thin, because the blow of the type is spread more or less by being transmitted through the ribbon, the first sheet of paper, and the carbon paper itself before it can make a copy. This spreading of the force of the blow is increased a little for each additional carbon copy made. The paper, or tissue as it is commonly called, requires great skill in manufacturing, for it must be thin, of uniform thickness, and free from pinholes. According to the Federal specifications, 1,000 sheets, each 20 by 30 inches, of the decoated tissue of "light-weight" carbon paper shall not weigh more than 10 pounds. The corresponding weight of the decoated tissue of "standard-weight" carbon paper is 18 pounds. On the same basis the weight of the paper of this circular is 50.8 pounds. The thicknesses are roughly proportioned to the weights, but not exactly so because the papers are not of the same compactness. The manufacturers of carbon paper express the weight of the tissue in terms of the ream of 500 sheets. On this basis the limiting weights in the Federal specifications are 5 and 9 pounds. By the trade these are called 4-pound and 7-pound papers.

The tissue of the light-weight carbon paper must consist entirely of rag, manila, hemp, or jute rope stock, or a mixture of these. They are considered as equivalent to one another for making paper that does not soon become brittle when stored. Samples of carbon paper have been kept by this Bureau for more than 6 years without seeming to have become weak or brittle. The Federal specification for standard-weight carbon paper is less strict. The only requirement is that the tissue shall contain no ground woodpulp, which deteriorates rather rapidly. To the paper maker ground woodpulp means the fibers ground from logs, and not purified in any way. Their durability is far less than that of woodpulp that has been purified by chemical treatment.

The kind of tissue is not a matter of indifference to the manufacturer of carbon paper, because he finds it is harder to make the carbon coating adhere to some tissues than to others. The adhesion is largely influenced by the compactness and surface finish of the tissue. As one manufacturer put it, papers made with certain fibers, "if well closed so as to avoid pinholes, are hard-surfaced, tinny, and lacking in that feature of pliability which characterizes carbon tissue demanded in the commercial world." Paper of this kind cannot be used "for carrying good carbon coatings either in quality or quantity of coating. The brittleness of the tissue makes this impossible. Flaking may easily happen, the coating readily leaves the tissue, the sheets become dirty to handle, inferior copies and fewer copies result." According to another manufacturer, paper of this kind "is brittle and non-absorbent, necessitating the use of a soft, oily carbon dope which cannot possibly give as satisfactory a 'write' as the harder dopes used on the less dense, more absorbent, and more resilient rag papers."

When testing carbon paper, no attempt is made to measure its thickness or that of the decoated tissue. The thickness of the decoated tissue is controlled by limiting the weight, though not with great exactness because some tissues are more compact than others. One paper may be several percent thicker than another of the same weight. What really counts is the thickness of the carbon paper as it is used; that is, the thickness of the tissue and coating together. The specification does not set a limit to this combined thickness.

2. CARBON PAPER COATING

(a) GENERAL

No formulas have been given for typewriter ribbon inks, for what seem to be good reasons.[13] The situation with respect to coatings for carbon paper is the same as that with respect to ribbon inks, and for similar reasons the coatings will be discussed in a general way, but no formulas will be given.[14]

---

[13] See footnote 5.

[14] For those who wish to take the trouble to look up formulas, which are to be accepted with reservations, the following references are given:

B. Walther, *Die Fabrikation von Pausfarben und Durchschlagpapieren* (*The manufacture of tracing colors and carbon papers*), Chem.-Ztg. 45, 287–288 (1921).

H. Bennett, Practical Everyday Chemistry (Chemical Publishing Co. of New York, New York, N. Y., 1934).

H. Bennett, Chemical Formulary, vol. 4 (Chemical Publishing Co., New York, N. Y., 1939).

Anonymous, *Little cousins of the printing ink industry,* Am. Ink Maker 17, 16 (Jan. 1939).

Jameson's Manufacturers Practical Recipes (Lewis Jameson & Co., Ltd., London, England, 1929).

Some of the manufacturers speak of the coating as "dope", but others call it "ink", which seems a more appropriate name. It can be considered as the end member of a long series of inks of different consistencies, from the most fluid writing inks made by dissolving dyes in water to the thickest printing ink. The demand for faster and faster printing has comparatively recently led to the invention of a printing ink that is solid at ordinary temperatures, and must be melted when it is used. It hardens as soon as it becomes cold.

(b) TYPEWRITER CARBON PAPER

The coating on carbon paper for use on ordinary, or standard, typewriters must cling firmly to the paper tissue and have no tendency to flake off when the sheet is wrinkled, yet the sharp tap of the type must transfer enough to the second sheet to make a clean carbon copy of good intensity. In addition to this, so much of the coating must be left in place that several more carbon copies can be made, even though the type hit in exactly the same spots as at first. With some carbon papers so much of the coating is removed the first time it is used that the writing can be read when the sheet is held up against a light. Unless the paper tissue has been dyed a dark color, the writing appears light against the dark, opaque background of the untouched part of the sheet. This is sometimes called "stenciling."

Carnauba wax has for many years been considered necessary for making coatings for typewriter carbon paper. Almost no other natural wax is so hard or has so high a melting point. Although a new proposed substitute is as hard as carnauba wax and has as high a melting point, it may yet not prove satisfactory. It is said that some of the other waxes that have been tried do not wet the pigments as readily as melted carnauba wax does, and do not make an ink that spreads as easily and smoothly as ink made with carnauba wax. Yet this need not mean that at some time just as good a wax, and possibly an even better one, may not be found. It will be found only by trial under practical conditions.

Because carnauba wax is so hard and brittle it must be mixed with an oil to temper it. A petroleum oil is used for this, because animal and vegetable oils are in general oxidized too easily, and are thereby hardened. This is what happens when a film of linseed oil paint is spread on wood and exposed to the air. Sometimes additional toughness is imparted to the coating by the addition of ozokerite, montan wax, beeswax, or paraffin to the mixture of carnauba wax and oil.

Because of the color of most of the carbon paper that is made, the principal pigment is carbon black. It has already been explained that a blue or violet toner must be added to neutralize the brownish tone of thin layers of carbon black. As in typewriter ribbon ink, the toner in the carbon paper coating can be either a lake pigment or else a dye base dissolved in technical oleic acid—red oil.

Blue carbon paper may be colored with a dye lake or with one of the several varieties of prussian blue, which is often called iron blue. Dye lakes are used in the coating of carbon paper of a few other colors.

The stroke of a noiseless typewriter is quite different from that of a standard machine. The type on the standard machine tap the paper sharply, but those of the noiseless typewriter push against it. Carbon paper that is suitable for one machine may not give good results with the other. It is said that for use with a noiseless machine a mixture of montan wax and castor oil makes a better coating than the carnauba wax and petroleum oil that are ordinarily employed. Sometimes ozokerite is added to the montan wax to increase its toughness. As a toner for the carbon black, crystal violet is dissolved in the castor oil, instead of using a pigment toner.

1. *Degrees of hardness.*—There are numerous grades of typewriter carbon paper, which differ in weight of tissue and in the hardness of their coatings. There are no trade or other standards for the composition of the coatings, their hardness, or the amount that should be applied to a given area of paper. Each manufacturer has his own ideas about these important matters. He makes what he considers hard, medium, and soft coatings, and often others in between. He may say that he can match the carbon paper of any of his competitors, and there is much truth in this, because if he and they use the same raw materials, he may by patient experimenting hit upon a mixture in which they are contained in the right proportions.

The hardness of the coating to a great extent determines the suitability of the carbon paper for a given kind of work, but there are other factors that influence the results. Among these are the thickness and stiffness of the first and copy sheets and of the carbon paper itself, the number of copies made at one time, the size of the type, the hardness of the platen and other characteristics of the typewriter, and the touch of the operator. If only one to three copies are made at one time, hard carbon paper is best, because it makes sharper copies and is cleaner. If a large number of copies must be made at one time, the carbon paper should have a rather soft coating. Too many users of carbon paper prefer the soft coating for ordinary work in which only one or two copies are made. Because it makes blacker copies, they ignore its faults. It soils the fingers easily, and smears badly when erasures are made, and although the copies are blacker, they are not as sharp and legible as those made with harder paper. Because there seems to be no method for measuring the hardness of the coating, the best way to find out whether the carbon paper is suitable for a given class of work is to make writing tests. These are described further on.

(2) *Aging of coating.*—It is an interesting fact that carbon paper definitely improves in writing quality for several weeks after it is made. Nobody seems to know just why this should be so, yet the fact cannot be disputed. This Bureau has been asked to retest samples of carbon paper that have been reported as not quite passing the wear-down test. The manufacturer says that he had to deliver freshly made paper, and that it would easily pass the test if given time to age. By the time the buyer has debated the subject with the manufacturer by an exchange of letters, and this Bureau has at last been asked to test the paper again, several weeks have elapsed. It has happened in more than one case of this kind that the paper has passed in the second test. Some manufacturers think that the improvement

in the coating is due to the absorption of part of its oil by the paper, yet this does not seem likely, for the back of the sheet rarely if ever looks oily. Another explanation, which seems probable, is that the improvement is due to the "setting,"—probably crystallization—of some of the constituents of the coating.

The Bureau has samples more that 6 years old that still do fairly satisfactory work, but if carbon paper is kept for a very long time its coating deteriorates and it will not make good copies. According to an English manufacturer,[15] "there appears to be a minimum limit of about 4 grammes [per square meter of tissue] below which bad ageing qualities are almost certain, irrespective of the nature of the coating. On the other hand, we have found that coatings above 10 grammes appear to be the least affected by the passage of time." No American manufacturer has ever discussed this subject at the Bureau. It is possible that the deterioration is caused by the slow oxidation of the coating, but because even the heaviest coating is surprisingly thin, it is hard to see why it should not be oxidized almost as rapidly as a thin coating. Some of the materials in the coating are lighter than water, and others are heavier, so the specific gravity of the mixture cannot differ greatly from 1. For the present purpose it is assumed that this is the correct value, and that 4 grams of the coating will occupy the same volume as 4 grams of water, or 4 cubic centimeters. If this is spread over a square meter, or 10,000 square centimeters, it will make a film only 0.0004 centimeter, or 0.00016 inch thick. A 10-gram coating will be 0.001 centimeter, or 0.00039 inch, thick. These are average thicknesses, because irregularities in the surface of the paper will make the film much thicker in some places and thinner in others. When carbon paper is tested, no measurement is made of the thickness of the finished sheet or of its coating.

(c) PENCIL CARBON PAPER

The manufacturer of pencil carbon paper has another problem to solve. The sliding of a pencil point over the paper is not like the tap or the thrust of type. The carbon coating must be rather soft, and at the same time tough. Montan wax, ozokerite, beeswax, and paraffin are used in it, with sometimes a little carnauba wax to promote the even flow of the melted mixture while the tissue is being coated. The waxes are blended with petrolatum (petroleum jelly), or sometimes with a heavy mineral oil.

(d) COATING THE TISSUE

Not much need be said about coating the tissue. It is done on machines that can be adjusted with great exactness to apply the desired amount of coating evenly from one end to the other of the long, wide roll of tissue. A coating machine is essentially an arrangement of polished steel rolls, which are hollow so that they can be heated with steam or cooled with water, as may be necessary. One machine, for example, has a heated roll that picks up the melted "ink" from a reservoir and transfers it to the paper. The excess is removed by passing the paper between another roll and a rod on

[15] The quotation is from a letter written by A. G. Rendall, of Morland & Impey, Ltd. (Kalamazoo-Print, Ltd.), Birmingham, England.

which a wire is closely wound over its entire length. The diameter of the wire controls the size of the groove between each two of its adjacent turns, and this regulates the amount of coating left on the paper as the rod passes over its surface. The purpose of the succeeding rolls is to cool and harden the coating in a uniform layer with a smooth surface. The rate at which the coating is cooled has an effect upon its writing quality. If it is cooled slowly, there is time for the formation of relatively large crystals of some of the components of the wax. It will make blacker copies than are obtained with a coating of the same composition, but cooled rapidly so that the crystals are small.

The finished paper is cut to the desired sizes and packed in the boxes in which it is sold.

3. TESTING CARBON PAPER

(a) TYPEWRITER CARBON PAPER

In the Federal specifications the first two things to consider in connection with testing carbon paper are the fiber composition of the tissue and the weight of the tissue after the coating has been removed. These may not have a direct bearing upon the writing qualities of the carbon paper, but are intended to eliminate tissues of inferior quality and to aid in comparing delivery samples with the bid samples on which contracts are awarded. Those who test their own carbon paper can omit the determinations of fiber composition and weight, if they have no laboratory facilities.

(1) *Fiber composition.*—The fiber composition is determined microscopically with the aid of suitable staining agents which help to distinguish between fibers of different kinds. The coating is removed from a small piece of the carbon paper by means of carbon tetrachloride, benzene, or some other solvent for the wax and oil. A bit of the cleaned tissue is teased in a drop of water on a glass slide and the separated fibers are examined under a microscope. The details can be learned from various publications [16] and from the examination of fibers of known kinds.

(2) *Weight of decoated tissue.*—For determining the weight of the decoated tissue, the carbon coating must be removed by means of a solvent, aided by scrubbing with a brush. The safest solvent is carbon tetrachloride, because it does not burn. No matter what solvent is used, its vapor should not be breathed too freely. In a special machine devised by the Bureau [17] the solvent is gently boiled and its vapor is condensed directly over the sheet of carbon paper, which is fastened around a revolving cylinder. The drops of liquid from the condensed vapor fall upon the carbon paper, and because they are warm they quickly dissolve the oil and wax. The

[16] For instance, the following Government publications, two of which are sold by the Superintendent of Documents, U. S. Government Printing Office. They can be seen in many libraries throughout the country:
Federal Specification UU-P-31a, Paper; General Specifications. 5 cents.
M. F. Merritt, Pulp and Paper Fiber Composition Standards, BS Tech. Pap. T250. 15 cents.
R. E. Lofton and M. F. Merritt, Method for Differentiating and Estimating Unbleached Sulphite and Sulphate Pulps in Paper, BS Tech. Pap. T189. Out of print.

[17] F. T. Carson, *An extractor and friction cleanser,* Paper Trade J. (March 19, 1925).
F. T. Carson and F. V. Worthington, *New types of equipment for testing paper,* Paper Trade J. (October 20, 1932).

carbon or other pigment is scrubbed off with a cylindrical brush that presses against the paper on the revolving cylinder. After four or five sheets have been cleaned they are hung for some hours in a room in which the temperature and humidity are controlled. This "conditioning" of the paper is standard practice when paper of any kind is to be weighed. If the sheets are hung in a very dry atmosphere until the carbon tetrachloride evaporates, they will be too light. If they are dried in the humid air of summer, the paper will absorb too much water and will be too heavy. In addition, the cooling caused by the rapid evaporation of the tetrachloride may condense some water on the paper and thus add further to its weight.

The cleaned and conditioned sheets must be weighed accurately, because their combined weight is multiplied by a large factor to get the weight of 1,000 sheets that are 20 by 30 inches. Five sheets of the letter size, 8 by 10½ inches, used by the Government have a total area of 420 square inches, which is less than the area of a single sheet 20 by 30 inches. The weight of the five sheets multiplied by 1428.55 gives the weight of 1,000 of the large sheets. If an error of only 0.1 gram (1.543 grains) is made in the combined weights of five decoated sheets, the error in the calculated weight of 1,000 sheets will be 142.9 grams, or 5 avoirdupois ounces.

(3) *Wear-down test.*—Two writing tests, wear-down and manifolding, are made on typewriter carbon paper. The wear-down test gives an idea of the number of times a sheet of the paper can be used before the coating is worn off. The manifolding test shows how many copies can be made at one time. As it is with typewriter ribbons, so in testing carbon paper the judgment of the operator is an important factor.

To make the wear-down test, a piece of carbon paper about 1 by 2 inches is fastened, coated side out, to a sheet of the paper used for the first or ribbon copy. The carbon paper is fastened by means of a piece of gummed label or a piece of one of the permanently tacky kinds of adhesive tape that have become so popular. The label is pasted across one of the ends of the piece of carbon paper, so that the free end of the latter will be up when the combination is put in the typewriter. The sample so prepared and a sheet of thin manifold, or copy, paper are put in the typewriter in the usual way. The sheet carrying the sample is fastened by means of clips to the back of the carriage in such a way that the carbon paper will not move when the platen is turned to shift the manifold sheet a single-spaced line. Before the writing is started the platen is given a slight turn so as to pull taut the sheet that carries the carbon paper. A line of g's is then typed across the piece of carbon paper. The carriage is pushed back to the starting point, the platen is turned so as to shift the manifold sheet a single-spaced line, and another line of g's is typed across the same part of the sample as before. All this is repeated until four or five more than the required number of lines have been typed. According to the Federal specifications, standard-weight carbon paper must write at least 15 easily legible lines of good intensity, and light-weight paper must write at least 12. Because the light-weight paper is intended for making a number of copies at one time, it must be as thin as possible. The tissue itself is thin and the coating only thick enough to give a reasonable amount of service. For this reason it is not required to write as many wear-down lines as the standard-weight paper. In order to favor the carbon paper as much as possible, the Federal specifications say that the Electromatic typewriter, which is used for testing, shall be run at a low speed so that the type will not hit the paper very hard. For years the test was made with an ordinary, or standard, typewriter, and the operator typed with as light and uniform a touch as possible.

In the wear-down test every effort is made to have not the slightest shifting of the carbon paper, or otherwise the type will not always hit it at exactly the same place. If there is the least shifting or slippage of the carbon paper this will show by a darker edge of each of the g's in the carbon copy. If the carbon paper has shifted to the right, the black margins will be on the left side of the g's, and vice versa. If the type bar should be loose enough to have too much play to one side or the other, there will be regularity about the positions of the black margins. Slippage is by far the commoner fault. When judging the test sheet black margins due to either cause must be discounted, and if they are very noticeable the test should be repeated. Slippage occurs much too often, but it can be lessened by putting the sample of carbon paper on a full-width sheet of letter paper and not on a strip just wide enough to hold it. The wide piece can be fastened to the carriage more firmly.

If a sheet of carbon paper will make 12 or 15 satisfactory copies in the test it can be used many more times in actual service. In the test the aim is to exhaust the coating on the part where the type hit, while in ordinary typing there is not exact register of the lines each time the carbon paper is used, and the various letters of the alphabet are written in every conceivable order. For this reason a greater proportion of the coating is used when letters are written than is used when the wear-down test is made. At the end of a test the sample, if held up to the light, plainly shows the g's against an untouched background, while a sheet that has been used a number of times for writing letters looks entirely different, because its coating is removed irregularly from all over the surface, except the margins.

As with typewriter ribbons, the wear-down of carbon paper is often called the "serviceability." This term should be dropped, because in the present connection it means less than it implies.

(4) *Manifold test.*—To make the manifold test, a sheet of letter paper for the ribbon copy and the required number of sheets of thin manifold paper and carbon paper should be assembled in the usual way and put in the typewriter. For convenience, half-sheets are generally used at the Bureau. For obvious reasons the typewriter must be run at such a speed that the type hit a comparatively hard blow. Standard-weight carbon paper must make at least 5 easily legible manifold copies of good intensity, and light-weight paper must make 10 copies. The entire alphabet, both capitals and small letters, and all the numerals are written twice over in unrelated order, and the last manifold copy is then examined. A copy of good intensity is not passed merely for that reason, because it must be of satisfactory legibility. The specifications require that all the numerals shall be legible. The reasonableness of this cannot be disputed, because if a numeral cannot be read, there is generally no clue to help the reader to guess what it is meant to be. Light-weight carbon

paper is accepted if not more than 4 of the 104 letters on the tenth carbon copy are so much blurred that they cannot be read. The corresponding limit for standard-weight carbon paper is 3 illegible letters.

The current Federal specifications for light-weight and standard-weight carbon paper are based upon the results of a series of tests made on samples which a number of leading manufacturers submitted as their best grades. After the test sheets were compared, strict yet reasonable requirements were set for inclusion in the specifications. Not all of these special samples met the requirements decided upon as strict yet reasonable for the specifications.

When sentences are typed, and not merely the letters of the alphabet in unrelated order, the carbon copies may have many more than 3 or 4 illegible letters in every 104, particularly if elite type is used, yet the sentences can generally be read with little difficulty because the other letters of the words or the adjacent words in the sentences help the reader to guess at what is meant. An example will illustrate this. In the carbon copy of a letter of transmittal that was received with a sample to be tested the following sentence occurred. The hyphens represent the letters that were so badly blurred that they could not be read. Although the hyphens show that there are 30 of these letters in a total of 175, or at the rate of 18 in 104, there can be little doubt about what the sentence says:

> A- this i- -n extr---ly urg-nt order, it is r-q-e-ted that t-sts and an-ly-is be rushed, r--ults b-ing phon-d thi- -ffice at the -arliest practicabl- mom-nt; -ritt-n r-port in qu-druplicat- -o be forw-rded lat-r.

Further along in the same letter the sample was identified as follows:

> On- quar- ---ple of sp-r -i-ing -arni-- for -luminum paint.

In this the illegible letters are at the rate of 28 in 104. The man in the laboratory recognizes "-i-ing" as "mixing", and anyone with the slightest knowledge of varnish will see that "sp-r" is "spar," and not "spur." There is no other possibility.

(5) *Fading and curling.*—Copies made with black carbon paper should not fade when exposed to direct sunlight, though they will become brownish on account of the destruction of the toner. A carbon copy suffers more from handling than does a ribbon copy, because most of the color of the carbon copy lies on the surface of the paper and can be rubbed off. The fluid part of the ink in a ribbon sinks into the paper, and part of the carbon goes with it and adheres to the fibers of the paper. Much of the ink is thus protected against being rubbed off.

A complaint often made by users of carbon paper is that it curls, instead of lying flat, when it is taken from the box. This is an effect of changes in the humidity of the atmosphere, which causes corresponding changes in the amount of moisture in the paper. If the paper takes up more moisture from the air than it contained while lying in the box, it will expand, and because the waxy coating has little tendency to absorb moisture its size will not be altered. The coated sheet may then curl with the coated side in. If the air is very dry, the paper will lose moisture and will shrink, and the sheet may curl with the coated side out. Some manufacturers treat the tissue to prevent its taking up and losing moisture rapidly, so that it will not curl readily. The Bureau has tested a few samples by keeping them in a moist atmosphere overnight. Four of the nine or ten samples had apparently had the tissue so well treated that they curled with the coating on the outside, as if the waxes had absorbed more water than the paper. It is said that tricresyl phosphate, an oily liquid, is used for treating the tissue to prevent its curling.

The Federal specifications have never had tests for the permanence of carbon copies to light, their resistance to erasure by the rubbing incident to handling, nor for the curling of the carbon paper itself. Permanence to light could be determined in the apparatus used for testing typewriting, and resistance to curling by hanging sheets of the carbon paper in an atmosphere of a relatively high humidity and temperature, and others in an atmosphere of low humidity and a lower temperature.

(b) PENCIL CARBON PAPER

There is no Federal specification for pencil carbon paper, but the Post Office Department buys large quantities on its own specification. The decoated tissue must weigh 10 pounds per ream of 500 sheets, 20 by 30 inches, and it must contain no ground woodpulp. According to the specification, a piece of the paper is laid face-down on a sheet of white paper, and two or three words are written near the top with a well-sharpened No. 4 pencil. The carbon paper is moved down about half an inch and the same words are written again. The point of the pencil is supposed to follow exactly the same path on the carbon paper as before. In all, 20 copies are made in this way, and the last one must be of satisfactory intensity and legibility.

It is very difficult to make the pencil point move over the same track 20 times in succession and to keep the pressure on it the same from start to finish. The Bureau has worked out another method of testing that is easier and more exact, and that can be duplicated at any time because differences in muscular pressure are avoided. A strip of the sample is fastened, face-outward, to a sheet of letter paper by means of gummed labels or suitable adhesive tape, so that the carbon paper will come in contact with the second sheet in the usual way. On the other side of the letter sheet, and directly behind the carbon paper, a small ruler is fastened by means of gummed labels or adhesive tape. The sheet thus prepared is laid on the second sheet, which must rest on a smooth, hard surface. Then with a stylus of the kind used for drawing or writing on duplicating stencils a line is drawn across the carbon paper. The upper sheet is moved down the page a short distance and another line is drawn. This is repeated until 20 lines have been drawn. The stylus is held in a clamp so arranged that it can be weighted. One set of lines is drawn with a total load of 150 grams on the point of the stylus, and another set with a load of 450 grams. Of course, before drawing the second set the ruler must be shifted so that its edge will be behind a different part of the carbon paper. Not a great deal of testing has been done with this arrangement, but it has already been found that two samples may closely match at one load yet be quite different from one another at the other load. Naturally the sample which gives good results at both loads is the one to be preferred.

Pen carbon paper is similar to pencil carbon paper, but the coating is even softer, because a pen is commonly used with a lighter pressure than a pencil. This Bureau has never tested any pen carbon paper and can give no detailed information about it.

(c) SPIRIT CARBON PAPER

Spirit carbon paper is a development of the past few years. The coating contains a dye that dissolves in alcohol ("spirit") and in some other organic liquids. The carbon paper is placed with its coated side against the back of the first or ribbon sheet of paper, so that the typewritten matter makes a reversed carbon copy on the back of the sheet. This reversed typewriting is the master copy from which prints are made. There is a special machine for the printing. The master copy is fastened to a roll, and blank sheets are fed in one by one and are pressed against the master copy. Just before they come in contact with it they pass between two rolls, one of which carries a film of alcohol or other suitable liquid for moistening them. The liquid dissolves enough of the ink from the master copy to make prints on the blank sheets. By this process a great many surprisingly sharp copies can be made.

It is said that the production of good spirit carbon paper presents unusual difficulties because of the special properties the coating must have.

V. THE HECTOGRAPH

Something should be said about the hectograph, because it is an important means of duplicating. It is connected with the other subjects of this circular by special typewriter ribbons and carbon paper, and is no longer used solely with pen and ink.

In hectographing, a master copy is first made by typing with a hectograph ribbon, with hectograph carbon paper, or by writing with a special ink that contains a large proportion of a water-soluble dye of good color intensity; that is, one of which a very little will color a large volume of water. The master copy is pressed into close contact with a special pad, usually made of gelatin or glue and glycerol (glycerin), and after a short time is stripped off. It is then seen that part of the ink from the master copy has been transferred to the pad, where it forms a reversed copy of the original writing. If sheets of blank paper are pressed against this copy, one by one, a series of prints can be made. Each successive copy is a little paler than the one which precedes it, because each print takes some of the ink from the pad. Hectograph copies can be made by hand, but there are machines for the purpose that work more rapidly and make more and better copies.

1. HECTOGRAPH PADS

Many formulas for making hectograph pads can be found in reference books. All of them call for glue or gelatin, glycerol, and water, with sometimes other ingredients, for instance, kaolin (white clay) to make the mixture whiter, and sugar to increase the absorption of the ink. These extra substances seem unnecessary because a perfectly satisfactory pad can be made without them. In the following formula, which is typical of the many that have been published, all the materials are in parts by weight:[18] Glue or gelatin, 15 parts; water, 20 parts; glycerol (30° Baumé), 60 parts. Glue and gelatin are chemically the same, except that gelatin contains fewer impurities and for that reason makes a stiffer jelly than an equal weight of glue, if both are melted in the same amount of water, and the jellies are tested under the same conditions. A good grade of animal, or so-called hide, glue, which is sold in paint stores, can be used. Flake glue is recommended instead of powdered glue, which requires special care when mixing it with water, or else it will form at first a gummy mass filled with air bubbles that are not always easy to get rid of. Air bubbles in the hectograph pad may cause imperfections in the printed copies. If they are at the surface they will break and form little pits in the pad. The bubbles will gradually rise to the top and can be skimmed off if the mixture is kept melted, but long heating lowers the jelly strength of glue, so that the pad will be softer than it will be if it is not kept melted too long. Flake glue holds fewer bubbles than the powder. The warning should be added that the mixture should not be stirred too vigorously while the glue is melting, and should not be poured into the hectograph pan too rapidly, or more bubbles will be introduced.

The required 20 parts of cold water is poured over the dry glue and the two are allowed to stand at room temperature until all the water is absorbed. Some of the pieces of glue will be softened hardly at all, but no more water should be added. Instead pour in the glycerol, stir gently, and let the whole stand several hours longer to complete the softening of the glue. Glycerol of 30° Baumé—that is, 30° on the Baumé hydrometer—has a specific gravity of about 1.262. It is not anhydrous, but contains about 4 percent by weight of water. This content of water is to be expected of a liquid that absorbs water from damp air as readily as glycerol does. The grade sold by druggists as meeting the requirements of the United States Pharmacopoeia is suitable for the present use. When the glue is all softened, set the container in a vessel of water and heat, but not to a higher temperature than 60° C (140°F), and stir gently at intervals until all the glue is melted and the mixture is uniform throughout. Then pour it into the hectograph pan and set it in a cool place to jell.

Some of the published formulas call for a larger proportion of water than is required in the formula given here, and the directions say that the excess shall be boiled off. This treatment cannot fail to lower the jelly strength of the mixture, especially because the presence of the glycerol raises the boiling point several degrees above that of pure water or of water and glue.

Other things being equal, the consistency of the pad will depend upon the jelly strength of the glue. This is low for the poorer grades and increasingly higher for glues of better and better quality. It is highest of all for the best grade of gelatin. A given hectograph pad will also vary in softness according to the temperature and relative humidity of the air in contact with it. In the very dry air of most heated buildings in winter, the pad will lose part of its water and become harder. In summer it may absorb so much water from the humid air that, aided by the high temperature, it may be too soft.

[18] R. H. Bogue, Chemistry and Technology of Gelatin and Glue, McGraw-Hill Book Co., Inc., New York, N. Y., 1922).

The mixture when freshly prepared by the formula has a specific gravity of about 1.2, from which the amounts of the materials for a pan of a given size can be calculated. Suppose the unit weight decided upon is ½ avoirdupois ounce. The formula will then be

Glue	15 parts or	7.5 ounces.
Water	20 parts or	10.0 ounces.
Glycerol	60 parts or	30.0 ounces.
Total		47.5 ounces.

The 47.5 ounces of the mixture will occupy the same volume as 47.5/1.2, or 39.6 avoirdupois ounces, of water. A quart of water weighs about 33.3 avoirdupois ounces and occupies a volume of 57.75 cubic inches. From this it is easily calculated that 39.6 avoirdupois ounces of water will have a volume of 68.7 cubic inches. In a pan which measures 10 by 12 inches, and is conveniently large for paper of the usual size of business letters, 8½ by 11 inches, this will make a layer not less than ½ inch deep (68.7/120=0.57 in.), when unavoidable losses are allowed for.

The figures given in the preceding paragraph should not be taken as exact, on account of the nature of the materials. The apparently dry glue when bought may contain from 10 percent or a little less of absorbed water up to 15 to 18 percent, according to the atmospheric conditions under which it has been kept. The glycerol may not contain exactly 4 percent of water, but a little more or less, again according to the atmospheric conditions to which it may have been exposed during its production. In addition, when preparing the mixture more or less of the water will evaporate while the glue is melting. The volume of the pad will not always be the same.

The glue-glycerol mixture is not always made into a pad by pouring it into a shallow pan. For some special machines it must be on strips of paper or cloth of different widths and several feet long. The coating is made smooth and uniform in thickness, about $\frac{1}{16}$ inch, by passing the strips between a set of rollers.[19]

Glue-glycerol mixtures have the disadvantage of becoming softer in warm weather, when the humidity is apt to be high, while in the cooler and much dryer air of heated buildings in winter, water is lost and the mixtures become harder. A partial remedy for all this is to have different mixtures for summer and winter. The mixture for summer would contain a smaller proportion of glycerol than the winter one.

It may happen that a new pad is either too soft or too hard after it has been exposed to the air for a day or two and has had time to adjust its moisture content to that of the air. If it is too soft, the remedy is to remelt it and to mix with it a little glue that has been thoroughly softened by soaking in water. If the pad is too hard, melt it and add a little more glycerol. If the pad is too hard it will give temporary relief to wet the surface of the pad with water and to allow this to be absorbed.

A kind of hectograph pad that does not change in consistency with changes in temperature is a mixture of kaolin (white clay), glycerol, and water. The specification used by the Panama Canal for buying the material requires that it shall contain about 70 percent by weight

[19] R. H. Bogue, Chemistry and Technology of Gelatin and Glue, p. 548 (McGraw-Hill Book Co., Inc., New York, N. Y., 1922).

of kaolin. The remainder must contain not less than 22 parts by weight of anhydrous glycerol, together with water to make a total of 100 parts. The object is to make a mixture that can be pressed and rolled to a smooth, flat layer. It must be somewhat stiffer than putty. A little leeway is given in the amounts of the ingredients because clays differ in plasticity, and if the same weights of several clays, glycerol, and water were always used, the mixtures would not all have the same consistency. A certain amount of water must be permitted, because glycerol is not anhydrous unless it is specially prepared and handled, and it may pick up more water from the air while the mixture is being prepared, as well as in the interval between the time of its manufacture and its arrival in the testing laboratory.

The kaolin-glycerol mixture works well if the printing is done with a special machine. If the copies are made by hand it is not as satisfactory. Pressing the blank sheets against the pad with the fingers so as to get perfect contact causes the mixture to spread a little, and because it is not elastic it does not return to its original size when the sheet of paper is stripped off. Each successive print causes a little more spreading, and soon the writing becomes too much blurred to be read. The glue-glycerol pad has a rubbery elasticity and there is no permanent spreading when it is in use.

Before transferring the master copy to a glue-glycerol pad, the surface of the pad should be sponged with water, particularly in winter, when it is apt to be slightly hardened from loss of water. When the copies have all been printed the pad should be sponged again in order to remove as much as possible of the writing. If this is left too long, it may spread in the pad and cause stains the next time the hectograph is used.

2. HECTOGRAPH INK

Typewriter ribbons, carbon paper, and writing ink for use with the hectograph can be bought. Those who wish to make their own writing ink can try the following formula:[20] Acetone, 8; glycerol, 20; acetic acid, 28-percent, 10; dextrin, 2; dye, 10; water, 50; all in parts by weight. If the unit weight is 1 gram, this will make a little more than 90 milliliters, or about 3 fluid ounces, of ink.

First dissolve the dextrin in the water, which must be heated, but need not be boiled. It is best to set the container in a vessel of hot water, because direct heat may char the lumps of dextrin that cling to the bottom. Cool the solution of dextrin and add the other liquids. Acetone is an inflammable liquid with a boiling point many degrees below that of water, and if it should be poured into the hot solution of dextrin, much of it would boil away. The acetic acid is one of the regular commercial grades. As its name shows, 10 parts of it by weight contains 2.8 parts of the anhydrous acid. The remaining 7.2 parts is water. Drugstores may not sell acid of this strength, but are likely to have the 36-percent acid, because it is in the United States Pharmacopoeia. In 7.8 parts of it there is the required 2.8 parts of anhydrous acetic acid, and 2.2 parts of water should be added to it. This will make 10 parts of 28-percent acid.

A number of dyes of different colors were made into inks in order

[20] From the Division of Tests and Technical Control, U. S. Government Printing Office. Acetone is substituted for the ethyl alcohol originally called for.

to find out which would give the most copies of good intensity. Methyl violet was found to make more copies than any other dye of whatever color, and crystal violet was almost as good. Rhodamine *B* was the best red dye. Fuchsine (magenta) was next, but because it is not very soluble, only 3.5 grains of it, instead of 10, could be dissolved in 90 grams of the solvent. The first and second choices for two other colors were brilliant green and malachite green, victoria blue *B* and soluble blue, respectively.

The paper on which the master copy is written should be of good quality; that is, it should be well-sized so that not too much of the ink will sink into it. The ideal would be to have all the ink dry on the surface of the paper, and for most of it to be transferred to the hectograph pad. The writing is given time to dry, and is then pressed or rolled down on the pad. If the pad is a glue-glycerin composition, it should first be sponged with a wet cloth to soften the surface skin, and when the scattered drops of water have been absorbed it is ready to receive the master copy. This is left in contact with it for a minute or two, and is then stripped off. A large number of copies can now be made by pressing sheets of paper upon the pad in succession, just as was done with the master copy.

VI. FEDERAL SPECIFICATIONS

Those who are interested can get copies of the Federal specifications for ribbons and carbon paper from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. Payment should not be made in postage stamps, and money is sent at the buyer's risk. Postal money orders, express orders, New York drafts, and coupons sold by the Superintendent of Documents at $1 for 20 are accepted. The coupons are good until used. Publications are sent under frank to all parts of the United States and its possessions, and to countries that extend the franking privilege.

The Federal specifications for ribbons and carbon paper are listed below. In the list are included two that tell how to test the fabric of ribbons or how to examine the tissue of carbon paper, and two that describe the kinds of paper used for testing. Each of the specifications costs 5 cents a copy.

CCC–T–191a, Textiles; General Specifications, Test Methods.
DDD–R–271, Ribbons; Computing and Recording-machine.
DDD–R–291, Ribbons; Hectograph.
DDD–R–311a, Ribbons; Typewriter.
UU–P–31a, Paper; General Specifications.
UU–P–121b, Paper; Bond, White and Colored.
UU–P–151a, Paper; Carbon, Light-weight (Typewriter), Black.
UU–P–156a, Paper; Carbon, Standard-weight (Typewriter), Black.
UU–P–328a, Paper; Manifold.

The "a" or "b" after the number indicates the first or second revision, respectively, of the original Federal specification. The superseded issues are not sold by the Superintendent of Documents.

WASHINGTON, March 22, 1941.

○