watermarking wires on the dandy-roll embrace both the light-and-shade and the single-wire techniques (Figure 289). A full sheet of the paper, before cutting into individual cards, is shown in Figure 290. The firm of Whitehead and Company have made and supplied almost eight million of the watermarked cards to the Army, the Navy, Ford, Standard Oil, Bell Telephone, Timken, Anaconda, Kaiser Industries, California Shipbuilding, Consolidated, Martin, Lockheed, Pratt and Whitney, Douglas, and other manufacturing plants. Millions of the Whitehead watermarked cards have been issued, but there has not been a single instance of successful counterfeiting, although numerous attempts have been made. This good fortune is due largely to the watermarked paper, a method of preventing forgery that is almost impossible to duplicate, as the equipment for such work is well beyond the reach of the average counterfeiter.

Fig. 289 A single section of the wire form such as used on the dandy-roll for watermarking paper to be used for identification cards. Both the light-and-shade and single-wire techniques are employed. (Courtesy Harry Bennett, Ford Motor Company)

Fig. 290 A complete sheet of the watermarked identification cards, each sheet making 32 individual cards. The round, dark spots in the paper are different-coloured pieces of confetti, an extra precaution against counterfeiting. (Courtesy Harry Bennett, Ford Motor Company)
The making of paper by hand is still practised in many mills in England and on the Continent. These mills do not all necessarily date from the pre-machine age, but in numerous instances they were established previous to the invention of Nicholas-Louis Robert. The hand mills of Europe have been equipped with modern and efficient appliances and are up to date in every way possible consistent with hand work. In making paper by machine it would not be profitable to operate carelessly and inefficiently, and the same would apply to the present-day handmade-paper industry.

THE MATERIALS

In most European countries only pure rag pulp is used in making handmade papers, and for the very finest sorts of paper only white rags are employed (Figure 291). Inasmuch as hand work is expensive, it would be most shortsighted to make use of any but the best materials throughout the entire process. Therefore in many of the European countries the handmade papers are made from the most superior linen and cotton rags; inferior material is discarded. The rags to be used in the making of paper by hand are subjected to practically the same treatment as like material would undergo for making all-rag machine-made paper. But in the handmade-paper mills the quantity of rags is much smaller and the material can therefore be more carefully sorted, boiled, and beaten. The cleaner and whiter the rags, the less severe the boiling and bleaching, the better will be the finished paper. The boiling of rags for fine paper is usually carried on without pressure, and only limited amounts of caustic soda and lime are used. This permits the strength of the linen and cotton fibres to remain unimpaired.

WASHING AND BEATING

After the rags are boiled, they are placed in "engines" equipped with cylinder washers (Figure 292), and in these low, oblong tubs the loosened dirt is washed from the material, the dirty water leaving the beaters through the screens of the cylinder washers, which do not permit the macerated fibres to escape. Clear water flows into the beaters during the entire process of washing, and when the water leaving the screen cylinders is as clear and fresh as that which enters the beater, it may be assumed that the rags have been cleansed. If bleach is to be added, it is put into the beater at this stage, but the stock must be further washed until tests show that no trace whatever remains of the chlorine. The washing completed, the cylinder is raised and the same beater may be used for
Fig. 292 After boiling, the rags are placed in "engines" equipped with cylinder washers, and the loosened dirt is washed from the material. (Courtesy W. S. Hodgkinson & Company)

Fig. 293 The Hollanders, or beaters, of handmade paper mills are small, holding from two to three hundred pounds of dry stock. They are fitted with light-weight rolls so that freer and longer stock is the result. (Courtesy W. S. Hodgkinson & Company)

macerating the material, although in some mills a breaker is used for the washing process, from which the material is run into special beaters, or Hollanders. These beaters (Figure 293) are small, holding about two hundred pounds of dry stock, and are fitted with light rolls so that freer and longer stock is the result. The beaters in a handmade-paper mill are usually lined with sheet lead or copper and equipped with beater-knives and bed-plates of bronze. It is possible to draw out the fibres to such length that the stock could not be run successfully on a paper-machine, but fibre of this kind makes the strongest handmade paper. It is in the beating process that the strength and enduring qualities of the finished paper are determined.

THE STUFF–CHEST AND VAT

The beating completed, the stock, or stuff, flows by gravity, or is pumped, into the stuff-chest, where the fibrous material is kept from settling by the action of a slow-moving, upright agitator. From the stuff-chest the stock runs through a pipe into the lifting-box, or bucket-pump, by the vat, which in turn lifts it and throws it into the knotter. This appliance is a boxlike apparatus with a

Fig. 294 Looking into an empty lead-lined vat from above. This photograph shows the knotter in the foreground. The knotter, agitated by two tappets, separates the knots, specks, and foreign matter from the stock before it enters the vat. The agitator, or "hog," used in preventing the stock, or pulp, from settling, may be seen across the bottom of the vat; the drain-off pipe, at the far end of the vat, may be raised or lowered. A mould, with deckle, rests upon the stay, while another mould, without deckle, leans against the apron. The bridge along which the moulds slide is plainly visible.
A scale model of a present-day handmade paper mill in the Science Museum, South Kensington, London. This model shows the stuff-chest, lifter-box, knitter, vat equipment, and hydraulic press. The model was built in 1910 by T. J. Marshall & Company, London.

floor made up of a series of slitted brass plates through which the stock passes, removing the knots, flecks, and foreign matter from the flowing pulp. From the knitter the stock flows into the vat through a regulating cock which to some degree determines the consistency of the stock in the vat. A lead pipe at the back of the vat carries the pulp back to the lifting-box so the stock in the vat is in constant movement and is continually being strained through the knitter. When the stock leaves the beater, it is warm through circulation and agitation, and this heat is retained in the vat through the action of a steam pipe; warm stock facilitates the vatman’s work. The stock is kept stirred while in the vat by means of a horizontal agitator, termed a “hog.”

During the making of paper, the temperature of the pulp in the vat should be from 80° to 95°F; never should the temperature be allowed to go above about 112°F. The vat (Figure 294, Diagrams

Fig. 294 (1) The vat, lifter-box, and knitter equipment of a modern English handmade paper mill. The various parts are designated by letters: (a) the vat made of iron, lined with lead; (b) the bridge upon which the coucher slides the moulds; (c) the asp, or horn, against which the coucher leans the moulds for draining; (d) the stay, upon which the vatman places the moulds before they are leaned against the asp; (e) the agitator, or “hog,” revolving paddles that keep the stock in suspension in the vat; (f) back water pipe; (g) stool where the vatman stands at his work; (h) fresh water cistern for supplying hand boxes and washing-moulds; (i) vatman’s hand rinsing-boxes; (j) pipe to vat from knitter-box, and cock for regulating flow of stock; (k) the knitter used for separating the knots, specks, and foreign matter from the stock; (l) the two tappets that agitate the knitter; (m) lifter-box containing the four bucket pumps; (n) drawer that catches stock delivered by bucket pumps; (o) chute for delivering stock from drawer to knitter; (p) pipe that conveys the stock from the stuff-chest to the lifter-box. Scale: 3 inch to 1 foot.
Fig. 294 (II)  The vat equipment from the front, or from the position of the vatman. The same letters apply that are shown in Figure 294 (I). One of the cam and tappet devices that agitate the knotter is shown at (I). Scale: ½ inch to 1 foot.

Fig. 294 (III)  The apparatus of a present-day handmade paper mill as viewed from the rear. The four bucket pumps (t) lift the diluted stock, or pulp, from the bottom of the lifter-box (m) after it enters from the stuff-chest through the pipe (p). The bucket pumps throw the stock into the drawer (n) from where it travels to the knotter. Scale: ½ inch to 1 foot.
Fig. 294 (IV) The vat from the left end, or from where the coucher stands. The draw-off pipe (r) may be raised or lowered so that water can be drawn from the upper part of the vat after the stock has settled to the bottom. The end of the four-bladed agitator is shown at (e) and the outlet for cleaning the vat appears at (s). The slanting shape of the interior and the rounded section under the agitator are shown by a dotted line. Scale: 3/4 inch to 1 foot.

Fig. 296 A full-size handmade paper equipment in the Paper Museum of the Massachusetts Institute of Technology, Cambridge. The finest book, writing, drawing, water-colour, etching, architectural, and engineering papers are still made by hand by using appliances of this design. This equipment was originally in the mill at Wookey Hole, Somerset, England.

I, II, III, IV, and Figures 295 and 296) may be made of stone, copper, or iron; in the latter case it is lined with lead to prevent rust. The vat is about 5 by 6 feet with a depth of 38 inches, the front and back walls slanting toward the bottom, as shown. When made of stone, the walls are about three inches thick, with the joints mortised and laded; if made of metal, the corners are bolted; the lead lining, about one-eighth inch in thickness, is soldered at the joints. The “hog,” before mentioned, extends the full length of the vat and is used to prevent the fibres from falling to the bottom; the “hog,” or agitator, is operated at slow speed. Each vat in a mill is supplied with its own stuff chest. Across the top of the vat, toward the back, is a wooden platform fitted with rounded brass rails; this is termed the “bridge.” At the left end of the bridge there is a wider portion which supports the “asp” or “horn” and the “stay.” The other essential appliances directly connected with the vat are the “couching tray,” the press, and the
“lay stool.” The last is used to support the moist sheets of paper after they are taken from the felts immediately after pressing.

FORMING AND COUCHING THE SHEETS

In making paper at the vat three workers are required. The most skilled of these is the vatman, who forms the sheets upon the moulds. Next in importance is the coucher, who removes the sheets from the moulds by “couching” them upon the felts. The third workman is the layman, whose duty it is to separate the sheets of paper from the felts, after pressing, lay the paper in a neat pile, and return the felts to the coucher for further work. Each step in the process will be described in the order in which it is performed:

The vatman stands on a platform in front of the vat and grasps the mould (Figure 297), with one hand on either side at a convenient point of balance. With the deckle in position, his thumbs extend along the top of the deckle, and his fingers are under the mould. He should hold the mould firmly, but not in a tense manner, since a great deal depends upon the freedom of the muscles under his control. The vatman now holds the mould nearly at arm’s length over the vat in an almost vertical position, and with a quick, but steady, scooping movement, he plunges it into the vat, bringing it out again covered with pulp into a horizontal position close to his body, a few inches above the surface of the vat. By an almost imperceptible tilt forward, he causes a wave of pulp to flow across the surface of the mould from back to front, and this has the effect of levelling the pulp. As this wave flows across the mould, a few rapid side shakes are imparted to it, which causes some of the fibres to set in a cross direction, and as the wave reaches the far side, the mould is shaken several times somewhat vigorously, first toward the vatman and then away from him, until the bulk of water in the pulp has passed through the wires of the mould and the fibres appear set in the form of an even sheet on top of it. This manipulation of the mould is called the “vatman’s stroke” (Figures 298, 299, 300). In the course of practice the vatmen become so dextrous that the formation of a sheet from the time the mould is dipped to the time the final shake is given occupies only a few seconds. Some vatmen pick up on the mould
only sufficient pulp to make a sheet of the required weight, while others pick up more than is sufficient and throw off the excess at the end of the stroke, just before the fibres become "set." The thickness of the sheet of paper being made depends upon the consistency of the pulp in the vat and also upon the vatman's knowing just how much stock to pick up upon his mould. Except in the case of small moulds, great care must be taken not to submerge the mould completely when making a sheet of paper; if the mould is entirely submerged, a little difficulty would be experienced in bringing it out, owing to the suction. This not only would make the work extremely laborious, but would also interfere with the vatman's stroke and prevent a well-formed sheet being made. To avoid the suction, only about three fourths of the mould should be actually submerged.

After the sheet of paper has been formed upon the mould, the
In the meantime another mould has been pushed along the bridge by the coucher to the vatman, who now places the deckle on the second mould and proceeds as before to make another sheet (Figure 301). When the mould just used, which leans against the horn with the semi-wet sheet on it (Figure 302), has had a few moments for draining, the coucher grasps the upper edge of it with his left hand and swings it across in front of him, seizing the other side with his right hand, at the same time releasing it with his left. The mould is now held in a vertical position, with the lower edge on the right edge of the post of felts; it is then turned over so that the semi-moist sheet comes in contact with the uppermost felt (Figure 303). By giving the requisite amount of pressure on the mould during the turning-over movement, the sheet of paper adheres to the felt and detaches itself completely from the face of the mould. The mould is now turned up again into a vertical position on the left side of the post, and from this position it is raised and pushed along the bridge until it comes to rest in front of the vatman. The coucher usually shoves the empty mould along the bridge with considerable energy, and to enable the mould to find its proper position directly in front of the vatman, the far end of the bridge has a slight incline, which causes the mould to slide back into its right place. The coucher’s next duty is to “pitch” a felt on top of the sheet he has just couched. This motion requires a great deal of skill and accuracy. Catching up a felt from the felt board on his right side, he grasps one of the short ends with both hands; holding it up in front of him well clear of the post, and with an outward swinging movement, he drops the felt squarely upon the wet sheet, without dragging or wrinkling; otherwise the newly couched sheet would be ruined. He then proceeds to couch another sheet on top of the preceding one, and in this manner the post is built up to a height of about eighteen inches, every sheet
of moist paper interleaved by a felt. When extra-large sheets of paper are being made, a boy is required to help the coucher in handling the mould and in pitching the felts. It is advisable to place three or four felts on the couching tray to receive the first sheet of paper inasmuch as it would be difficult to couch a sheet of paper on a single felt laid directly upon a hard surface.

The vatman and the coucher must regulate their movements so that they work in perfect unison, which involves much more hardship than might be imagined (Figures 304, 305). The number of sheets that can be made each hour depends upon the size of the moulds, the thickness of the sheet, and the grade of pulp. The two workers should shake their hands at their sides after each sheet has been formed, as even a small drop of water on the surface of a newly formed sheet will cause a transparent spot in the finished sheet of paper. With all the precautions exercised by careful workmen these spots are common in both old and modern handmade papers.
PRESSING THE POST

The couching tray, holding the completed post, is rolled on a track to the hydraulic press, where the pile is subjected to a pressure of from 100 to 150 tons, which expels a large proportion of the water (Figure 306). Before opening the press it is well to scrape off the excess water from the edges of the felting with a wooden paddle, as when the press is opened this water would have a tendency to run back into the felts and paper. When the post is removed from the bed of the press, the third workman, called a layer or layman, separates the sheets of paper from the felts (Figures 307, 308, 309). This is done by taking each sheet by the two corners nearest to him and lifting the sheet so that it pulls away from the felt evenly and without strain. He places the sheets of paper in a pile, taking care that the four corners of each sheet fall directly over the corresponding corners of the sheet underneath. The worker places the felts upon the felt board, ready for the coucher to use in making the following post. After the sheets of paper have been made into a neat pile, they are pressed slightly and allowed to remain in the press overnight. The next day they are separated and built up again in different order and then again pressed. This procedure is called "exchanging" or "parting," and may be repeated until the desired degree of finish is obtained. The sheets are next ready to be taken to the drying-loft, later explained. The vats should be drained and washed thoroughly every few days; the felts should undergo washing with wool soap every week or ten days. The moulds should be well rinsed in clear water after each day's work, because if allowed to dry, the linen and cotton fibres cling tenaciously to the wires.

The skill required of the vatman is most exacting. To make each
sheet of a ream of paper weigh the same and be of uniform thickness throughout its entire extent requires that the vatman possess a great amount of skill and practice. The larger the mould, the more difficult it is to form a perfect sheet. Therefore the beginner should start with small moulds and gradually increase the size until the larger ones can be handled with dexterity. It is not possible to make really even sheets without at least five or six years of constant application at the vat; even then the “stroke” may be lost and the worker may become unable to make any kind of handmade paper. The work at the vat requires patience, endurance, strength, and an almost superhuman sense of weight, and as the vatman’s hands and arms are constantly in and out of warm water, the work is anything but agreeable. Unless one has a whole-hearted desire and enthusiasm to make paper by hand, one should never attempt it.

**DRYING, SIZING AND FINISHING**

The drying-loft of a handmade-paper mill should be arranged so as to get circulation of air from all sides by means of shutters for summer drying; for winter and rainy weather the loft should be heated, the temperature ranging from 75° to 80° F. The paper should be dried slowly. When the paper comes from the press, after the last exchanging, or parting, the sheets are in more or less of a solid mass. The paper is taken off in spurs of four or five sheets, no attempt being made to separate them, and these spurs are hung separately over hair rope, about three quarters of an inch in thickness, or over half-round wooden poles. These ropes and poles are arranged so as to fill the loft completely, using all the space available (Figures 310, 311). The spurs are hung up by use of a cross-bar and handle resembling the letter T, and frequently called a “cross” (Figures 312, 313). The length of time required to dry paper depends upon the temperature of the loft, the size and thickness of the sheets, the amount of exchanging, or parting, and the width of the supports upon which the paper is hung to dry. All paper should be left in the drying-loft until thoroughly dry, and
the dryness is determined by the rustle of the sheets. When the spurs are taken down, the sheets of paper are still somewhat stuck together, and they must be separated, or “stripped,” before the next process of sizing is undertaken.

SIZING THE PAPER

The sizing of paper is the process giving to its surface a thin coating that renders the sheets impervious to ink. Without the sizing the paper would be like blotting paper and would absorb any ink that was applied to it. Writing papers should be more highly sized than papers used for printing. Animal size is usually used for handmade papers. It may be made direct from hide cuttings, or it may be purchased already prepared in the regular commercial form. In the latter case, which is the most satisfactory, the cakes of size are soaked in cold water, and the temperature is raised until about 95°F. is reached. Paper made from hard rags, slightly boiled, will require a thin size at a high temperature, but for paper made from old, soft rags a thick size at a lower temperature will be found better practice. Owing to the high cost of the regular commercial glue cakes, some European papermakers prepare the size themselves direct from the hides, hoofs, and bones of animals.
In sizing paper the older practice was to put the liquid size in a copper tank of suitable dimensions and keep it hot by means of a steam pipe or hot-water coil. The workman then took a pile of paper, from 100 to 150 sheets, and holding one end of the pile in his left hand, he used the other hand to spread out the sheets and immersed the lot in the hot size, taking care to have all surfaces of the paper come in contact with the liquid. After a pile about a foot high had been sized, the sheets were placed in a press and slightly compressed. The lower plate of the press had a metal drain around it to catch the size that is forced out of the sheets; this excess is saved and again used. In most of the modern handmade-paper mills of Europe a mechanical sizing-machine is used which is both thorough and efficient. This machine consists of a wooden tub about thirty feet in length, twelve inches in depth, and of sufficient width to permit sizing of the largest paper. The paper passes through the hot size held in the tub. This is accomplished by an endless felt operated over wooden rollers and driven by power (Figures 314, 315).
FINISHING THE PAPER

The sizing process completed, the paper has to be dried and "finished" by a method similar to that used for the finest grades of machine-made papers. This consists in pressing the sheets between zinc plates or Fuller board, a pressboard with a highly smoothed surface (Figure 316). After being finished, or platted, the paper is placed in piles, separated every six or eight inches with inch-thick boards, and allowed to remain in the dry press for several days (Figure 317). This treatment gives added finish. The nature of the finish given to the paper naturally depends upon the purpose for which the paper will eventually be used. The papers used for water-colour painting and some drawing papers are only slightly pressed, as a fairly rough surface is desired. For writing, etching, engraving, and letterpress printing, the sheets are given a higher degree of finish; the amount of sizing depends upon individual re-

requirements. The varieties of finish and texture that may be imparted to handmade papers are practically unlimited and any taste may be satisfied.

THE WASTE IN MAKING PAPER BY HAND

There is considerable loss in making paper by hand, owing to tears in the sheets, knots, water drops, hairs from the felts embedded in the paper, drops of size, bubbles, holes, blurred watermarks, ruffled laid-lines, and pieces of rust from some part of the vat, but particularly the steam pipe. It is not unusual to discard as imperfect about twenty per cent of the paper produced. The best of the discarded sheets are sold as "seconds," or "retree," and the remainder is repulped and made into paper for wrapping the perfect reams. *

AMATEUR PAPERMAKING

It is feasible to make paper by hand by the use of a small vat and miniature mould as a hobby or diversion, but this manner of working should not be confused with professional papermaking by hand. With the most limited skill it is possible to make a few hundred sheets of paper in an improvised vat and without proper equipment, but this sort of dilettante papermaking is far removed from the actual work of a regulation handmade-paper mill. To produce paper in ream lots, day after day, in usable sizes, in equal weight and thickness, it is absolutely essential to have

* The term "retree" is no doubt a corruption of the French retrait (withdrawal, shrinkage), from rétrait (to withdraw), and is used to designate sheets of paper that bear slight imperfections such as short tears, small holes, wrinkles, blurred laid- and chain-lines, vatman's drip, etc. The retree is usually sold at ten per cent less than the good paper, and it is customary for a customer having a specially watermarked handmade paper manufactured to accept from ten to twenty per cent retree at the lower cost. Retree is indicated on the ream packages by two crosses (XX) or the letter "R." The defects in paper clasped as retree are usually so slight that they pass unnoticed, especially after printing. The paper that is more severely harmed is termed "outsides" and is placed at the top and bottom of the reams when wrapped. The price of outsiders is twenty per cent that of good paper. The term "cassie," or "case," from the French word cassé, meaning broken, is now seldom used, but the term "broke" is common in even machine mills. The sorters of handmade paper do not always agree on what may be classed as retree, outsiders, and broke, and variations may be expected.