U. S. DEPARTMENT OF COMMERCE NATIONAL BUREAU OF STANDARDS

RESEARCH PAPER RP859

Part of Journal of Research of the National Bureau of Standards, Volume 16, February 1936

TREATMENT OF OFFSET PAPERS FOR OPTIMUM REGISTER

By Charles G. Weber and Martin N. V. Geib

ABSTRACT

Paper distortion and misregister of color prints are often serious problems in offset printing; even when the paper is conditioned to equilibrium with the pressroom air and printed under controlled atmospheric conditions. Hence, a study was made of the relation of the hygrometric condition of papers at the start of the first print to changes in moisture content during printing, and to the register of prints.

Experimental printings were made on papers in various hygrometric conditions relative to the surrounding atmosphere, and the behavior during multicolor printing was determined by finding the moisture-content changes, dimensional distortion, and closeness of register. Papers conditioned to equilibrium with the pressroom air by the usual method expanded during the first few printings so that succeeding colors printed inside the first. It was found possible to maintain constant dimensions by two methods of conditioning. Papers conditioned first at a very high relative humidity, then to equilibrium with the pressroom atmosphere by desorption, remained fairly constant. Also, papers prepared for printing by conditioning to equilibrium with relative humidity 5 to 8 percent above the pressroom condition gave very satisfactory results. The latter procedure is the more feasible for commercial practice as it requires conditioning the paper but once. All dimensional changes during printing were accounted for by changes in moisture content, and no evidences of mechanical stretch were found.

CONTENTS

I. INTRODUCTION

The effects of paper conditioning on the hygrometric changes of paper, and the constancy of its dimensions are of great importance in offset printing, because the most serious difficulty encountered, that of obtaining close register of successive color prints, is involved. Lack of information on the subject has resulted in failure to obtain the full benefits of costly air-conditioning equipment and often in wrongfully attributing misregister to the character of the paper being printed rather than to its hygrometric condition.

In previous articles on the influence of atmospheric changes on moisture content and dimensions [1] of paper and the relation of paper

[1] Weber and Snyder, BS J. Research 12, 53 (1934) RP633.

properties to register,[2] the importance of direction coefficient of expansion in paper and of constant atmospheric conditions during printing were pointed out. Further register studies revealed that paper commonly changes dimensions during printing, even when adjusted to moisture equilibrium with the pressroom air and printed under constant conditions of humidity and temperature. Hence the effects of various conditioning factors on changes of moisture content and distortion during printing were investigated in the air-conditioned offset printing plant of the Coast and Geodetic Survey of the U. S. Department of Commerce.

This is one of a series of studies made to assist lithographers in reducing serious economic losses caused by difficulties in offset printing. The work is being done with the active cooperation of the Lithographic Technical Foundation and financial assistance of several offset-paper manufacturers. The industry assists through an advisory committee composed of lithographers, paper manufacturers, and printing-equipment manufacturers under the chairmanship of R. F. Reed, Director of Lithographic Research, University of Cincinnati.

II. PROPERTIES OF OFFSET PAPERS STUDIED

Three different papers were used in the investigation: a chemical wood-fiber offset paper, found in previous studies to have low machine-direction expansion;[3] a rag-content bond; and a 100-percent rag chart paper, surface sized with glue. Although no attempt was made to study the response of different papers, the three papers used represent widely different types. Hence, it is believed that the results obtained will have general application. Test data on the papers are contained in table 1.

TABLE 1.—*Lithographic-paper test data* [a]

Paper	Weight 25×40: 500	Thickness	Bursting strength	Folding endurance [b]	
				Machine	Cross
	Pounds	*Inch*	*Points* [c]	*Double folds*	*Double folds*
Chemical wood offset paper no. 1	73	0.0054	26	52	10
Rag-content bond	75	.0045	65	1,485	615
Rag chart paper (tub-sized with glue)	125	.0082	95	15,480	8,330

Paper	Degree of sizing (dry indicator method)	Expansion per 15 percent R. H. increase (machine dir.)	Fibers	
			Rag	Chemical wood
	Seconds	*Percent*	*Percent*	*Percent*
Chemical wood offset paper no. 1	45	0.035		100
Rag-content bond	55	.071	85	15
Rag chart paper (tub-sized with glue)	150	.063	100	

[a] All tests, except expansion, made by methods of the Technical Association of the Pulp and Paper Industry.
[b] For test specimen 15 mm wide and 90 mm between jaws.
[c] Bursting pressure is lb/in.^{2} through a circular orifice 1.2 inches in diameter.

[2] Weber, BS J. Research **13**, 609 (1934) RP730.
[3] Identified as paper no. 1, BS J. Research **13**, 609 (1934) RP730.

III. EXPERIMENTAL PRINTING PROCEDURE

The effects of conditioning treatment of paper on the response to offset printing were determined by experimental printings on lots of paper differing only as regards hygrometric condition at the start of the first print. The hygrometric condition was controlled by taking the paper through definite conditioning cycles, and printings were made under controlled conditions of humidity and temperature. The pressroom atmosphere was maintained at 45 $\pm$ 2 percent relative humidity during a part of the study and at 49 $\pm$ 2 percent for the remainder. In the room where the paper was conditioned and stored, a relative humidity 5 to 8 percent above the pressroom condition was maintained after the benefits of this arrangement were indicated in preliminary tests. The conditioning facilities of the National Bureau of Standards were used for preparing many of the papers, and these papers were taken from the Bureau Laboratory to the printing plant in hermetically sealed containers. Each lot of paper treated contained not less than 10 sheets, and the experimental papers were printed with commercial runs. They were placed at the bottom of the pile of paper being printed so as to receive no more than the normal exposure between printings. Papers were not inspected between printings and received no handling, except as part of the commercial run. In some of the work, the corner register marks were "staggered" to facilitate color identification and measurement after multicolor printings. Closeness of register was determined by measuring with a micrometer rule.[4] The center sheets of each lot of paper were used for register measurements and moisture determinations. Printings were made on two presses with similar results. These were Harris, single-color, offset presses of late design, sizes 36 by 48 and 38 by 52. Both presses were in practically new condition. Inasmuch as misregister in the short or around-the-cylinder direction is not generally considered of great importance because it can be corrected by press adjustment, only the long-direction register was studied.

IV. RELATION OF HYGROMETRIC CONDITION OF PAPER TO RESPONSE IN PRINTING

1. VARIATIONS IN MOISTURE CONTENT DURING PRINTING

Papers conditioned to equilibrium with the pressroom air, then printed in 5 to 9 colors, were found to be still approximately in equilibrium but with increased moisture content. The increased moisture content, averaging 0.5 percent, was obviously due to press moisture picked up during printing. The fact that this added moisture could be held while the paper remains in equilibrium indicated that hysteresis was involved, since it is well known that the moisture content of paper under any given conditions may vary by more than 1 percent according to the history of conditioning.[5] This hysteresis effect is illustrated in figure 1, which shows the curves for maximum and minimum moisture contents for a series of offset papers. From a consideration of these data it appeared possible for papers below the maximum curve to increase the equilibrium moisture content; while paper on the maximum curve obviously could not. Hence, it

[4] C. G. Weber and R. M. Cobb. BS J. Research 9, 431 (1932) RP480.
[5] Weber and Snyder, BS J. Research 12, 53 (1934) RP633.

seemed likely that paper conditioned by desorption from an extremely high moisture content to equilibrium with the pressroom atmosphere and printed under constant atmospheric conditions, would not change as long as it remained in equilibrium. In order to try this, papers were preconditioned in humidities considerably higher than that of the pressroom air, then conditioned to equilibrium with the pressroom

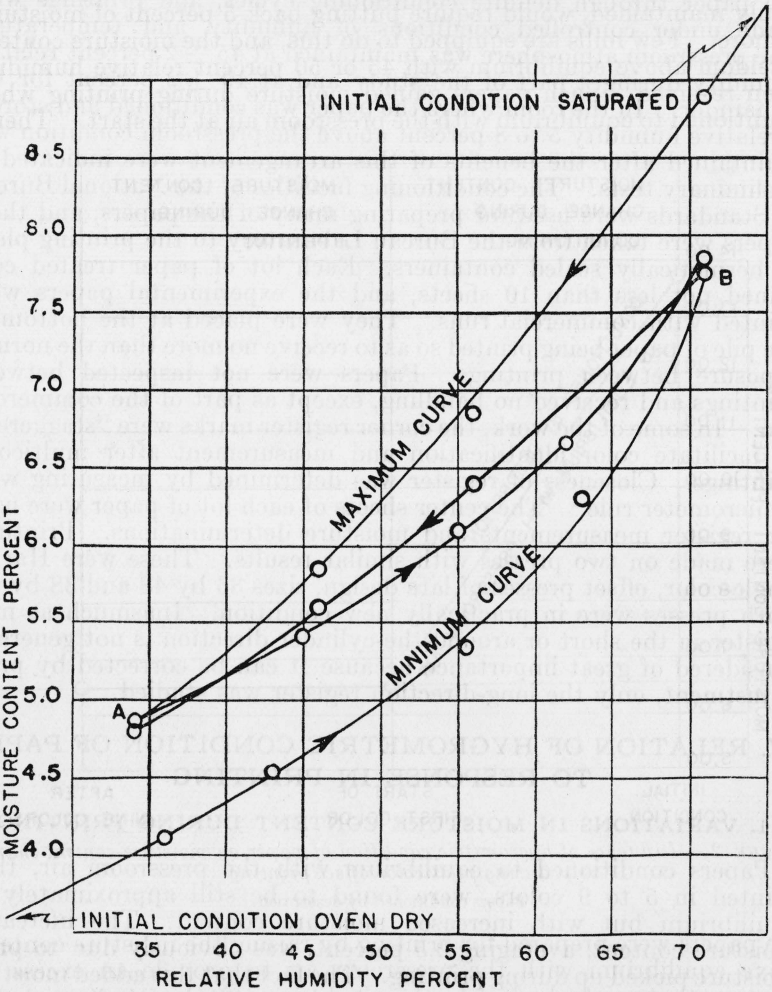

FIGURE 1.—*Equilibrium moisture content of offset papers at different relative humidities*

air and printed. Results of experiments of this kind are shown graphically in figure 2. It will be noted that these papers remained practically constant as regards moisture content during printing. However, this method of conditioning is not feasible for most commercial print shops as it requires two conditioning treatments under widely different atmospheric conditions, and it introduced curling difficulties with the glue-sized paper. Hence, other means of accomplishing similar results were investigated.

Offset papers are normally between the maximum and minimum conditions when received at a print shop, because they must be dried to a moisture content of less than 5 percent in manufacture to permit calendering. To get the moisture content high enough again to place it on the maximum, or desorption, curve after conditioning in the pressroom where 45 to 50 percent relative humidity is commonly maintained, would require putting back 5 percent of moisture, or more. Few mills are equipped to do this, and the moisture content is seldom above equilibrium with 45 or 50 percent relative humidity when received. Such papers gained moisture during printing when conditioned to equilibrium with the pressroom air at the start. There-

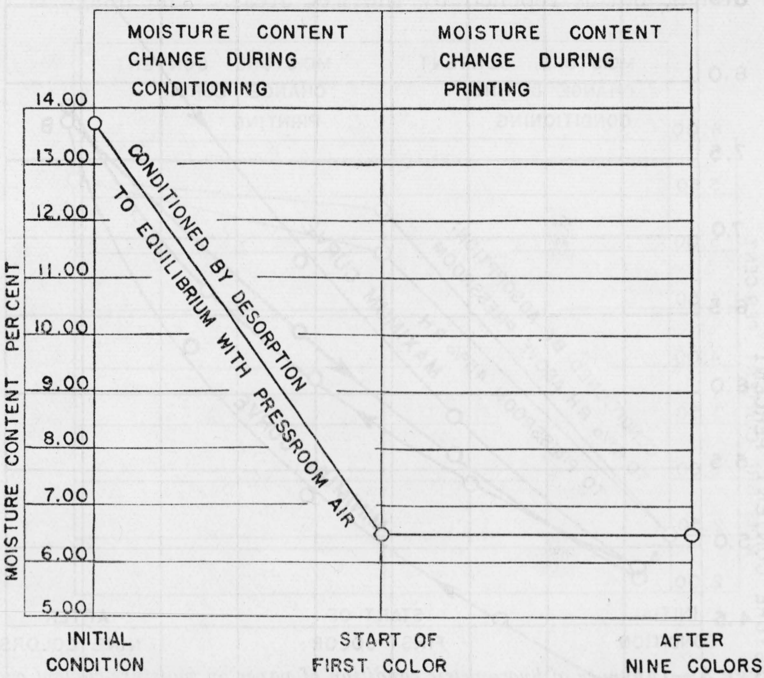

FIGURE 2.—*Influence of hygrometric condition of paper on moisture-content change during multicolor offset printing*

Papers conditioned by desorption.

fore papers were prepared for printing by raising the moisture content above equilibrium with the pressroom air to provide an excess of moisture that might be lost to the air during printing to compensate for the press moisture picked up. These experiments were very successful. It was found that the moisture content of paper conditioned to equilibrium with relative humidity 5 to 8 percent above the pressroom condition remained practically constant during printing. Those conditioned still higher lost some moisture. Typical results showing changes of moisture content during printing are shown in figure 3.

All papers printed reached hygrometric equilibrium with the pressroom air after five or six colors were printed, but never before three colors were printed. This indicates that the exposure of the paper during printing is sufficient to adjust the moisture content slowly to conform to the room condition. However, it gives no clue as to why the equilibrium moisture content is 0.5 percent higher after printing than before. That is explained, it is believed, by the manner in which the press moisture is applied.

The mutual repellence of greasy ink and water is the basis of lithography. Offset lithography employs a metal plate on which the design is water-repellent and the remainder is grained to hold water. In printing, water is applied to the plate, and it wets all of the plate except the design. Ink is next applied, and it adheres to the design, but is repelled by the wet areas. The image is then

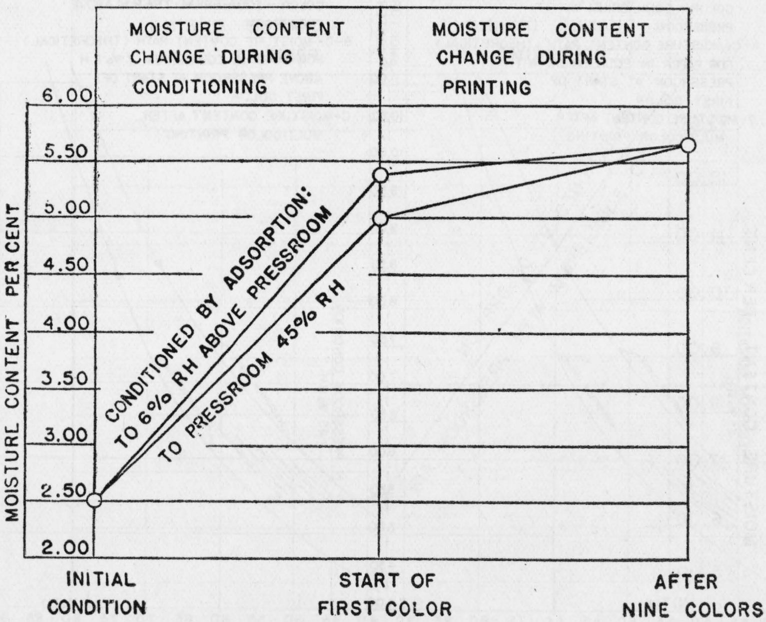

FIGURE 3.—*Influence of hygrometric condition of paper on moisture-content change during multicolor offset printing.*

Papers conditioned by adsorption.

transferred indirectly from the plate to the paper by printing on a rubber blanket from which the actual impression is made. In this operation, water from the wet, nonprinting areas of the plate is transferred to the paper in the same manner that the ink is transferred. Hence, it is likely that the surface of the paper in the wetted areas is at or near the saturation point when the paper goes into the pile on the delivery end of the press. In the pile, the excess moisture can leave the wet areas only by diffusion, and it appears possible that this leaves small portions of the paper with a moisture content equivalent to that on the curve for maximum or desorption moisture content. This may happen with each printing until all of the surface contacting the blanket has been raised to near the condition of maximum moisture content or covered with water-resisting ink. This explanation is shown graphically in figure 4, which shows the minimum or adsorption and the maximum or desorption curves, and theoretical behavior of moisture content during printing for paper: "A" in equilibrium at the start; "B" conditioned to equilibrium at relative humidity 7 percent above the pressroom condition at start.

It is not probable that A—C and B—C represent the actual paths for total moisture content, but rather the mean between the unmoistened portions of the paper, and the smaller wet portions that follow the path 1—2. The steps in the curves A—C and B—C are based on the fact that, for the papers conditioned to equilibrium with the pressroom at the start, the moisture content increased approximately 0.5 percent during five printings, or an average of 0.1 percent per color. Actually,

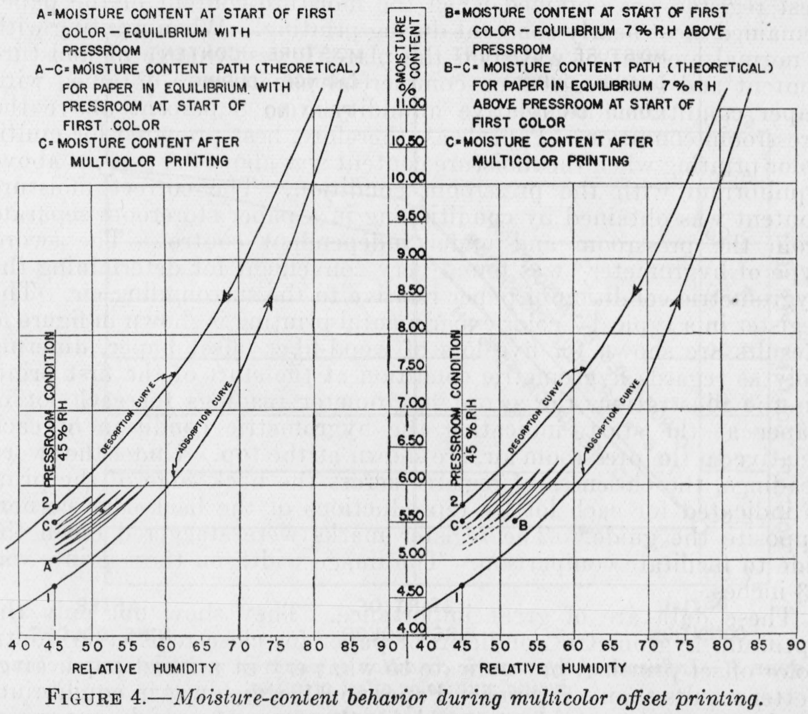

FIGURE 4.—*Moisture-content behavior during multicolor offset printing.*

Minimum or adsorption curves, curves numbered 1, and maximum or desorption curves numbered 2.

the increase was never in equal increments, the greatest increase being for the first colors. The dotted portions of curve B—C represent the probable path if the paper had been exposed sufficiently between printings to come to complete equilibrium with the air. However, the exposure for each color printing is apparently only sufficient for the paper to lose its excess moisture at about the same rate that it takes up press moisture, keeping a balance, when the excess moisture is approximately 0.5 percent at the start.

The validity of the theory that the surface wetting during printing may raise the equilibrium moisture content of paper was checked by laboratory tests. Papers were moistened on one side with a damp sponge; one-half of each lot was conditioned immediately in an atmosphere of 50-percent relative humidity and the other half left in the center of a pile 18 hours and then conditioned. The equilibrium moisture content for the half left in the pile 18 hours after moistening was higher in every case. The moistening and standing in the pile were analogous to what takes place for each color printing except that more water was applied in the former case.

2. REGISTER OF PRINTS

In all experiments, the register of successive prints was proportioned to the distortion of the paper during printing, and all measurable paper distortion was accompanied by corresponding changes in moisture content. Briefly, the misregister could in all instances be attributed to paper distortion due to gain or loss of moisture. The best register was obtained when the moisture content of the paper remained most nearly constant during printing. When printing with a normal amount of water on the plate, lowest change of moisture content and best register on commercial papers were obtained with paper conditioned to relative humidity 5 to 8 percent above the pressroom condition. Paper was, therefore, best prepared for multicolor printing when the moisture content was about 0.5 percent above equilibrium with the pressroom condition. The correct moisture content was obtained by conditioning in a paper storeroom separate from the pressroom and under independent control. The sword type of hygrometer [6] was found very convenient for determining the hygrometric condition of paper relative to the surrounding air. The register in a typical 7-color experimental printing is shown in figure 5. Results are shown for five lots of wood-fiber offset paper, differing only as regards hygrometric condition at the start of the first print. In the illustration, the sword hygrometer readings for each lot of paper at the start, indicating the hygrometric condition of each relative to the pressroom air, are shown at the top. Under the sword readings, the closeness of register across the back edge of the print is indicated for each lot by reproductions of the back-edge corners opposite the guide.[7] The register marks were staggered down the side to facilitate comparison. The image width on these prints was 43 inches.

These data are of great importance. They show not only the optimum hygrometric condition of paper for close register in multicolor offset printing, but indicate to what extent a moist paper gives better results than a dry one. Paper no. 11, which was in equilibrium at the start, gave no better register than no. 41, which was moist relative to the pressroom air by a sword reading equivalent to 2 percent of moisture content. Paper no. 31, moist by a reading equivalent to 1 percent of moisture, gave much better register than the paper in equilibrium at the start. Optimum results were obtained with papers conditioned to relative humidity 6 to 8 percent above that of the pressroom air, and these papers gave a moist reading on the sword as shown for no. 21 in the illustration. The reading indicates a moisture content approximately 0.5 percent above equilibrium with the air. This conditioning practice has been followed at the Coast and Geodetic Survey on commercial jobs of 9 to 17 colors with most satisfactory results from the start. As compared with the former method of

[6] The Paper Hygroscope, Bulletin of the Lithographic Technical Foundation, New York.
[7] The back-edge corner of a print on the side opposite the guide is the point on the print furthest from all press alignment. Hence, it is the point of maximum lengthwise misregister.

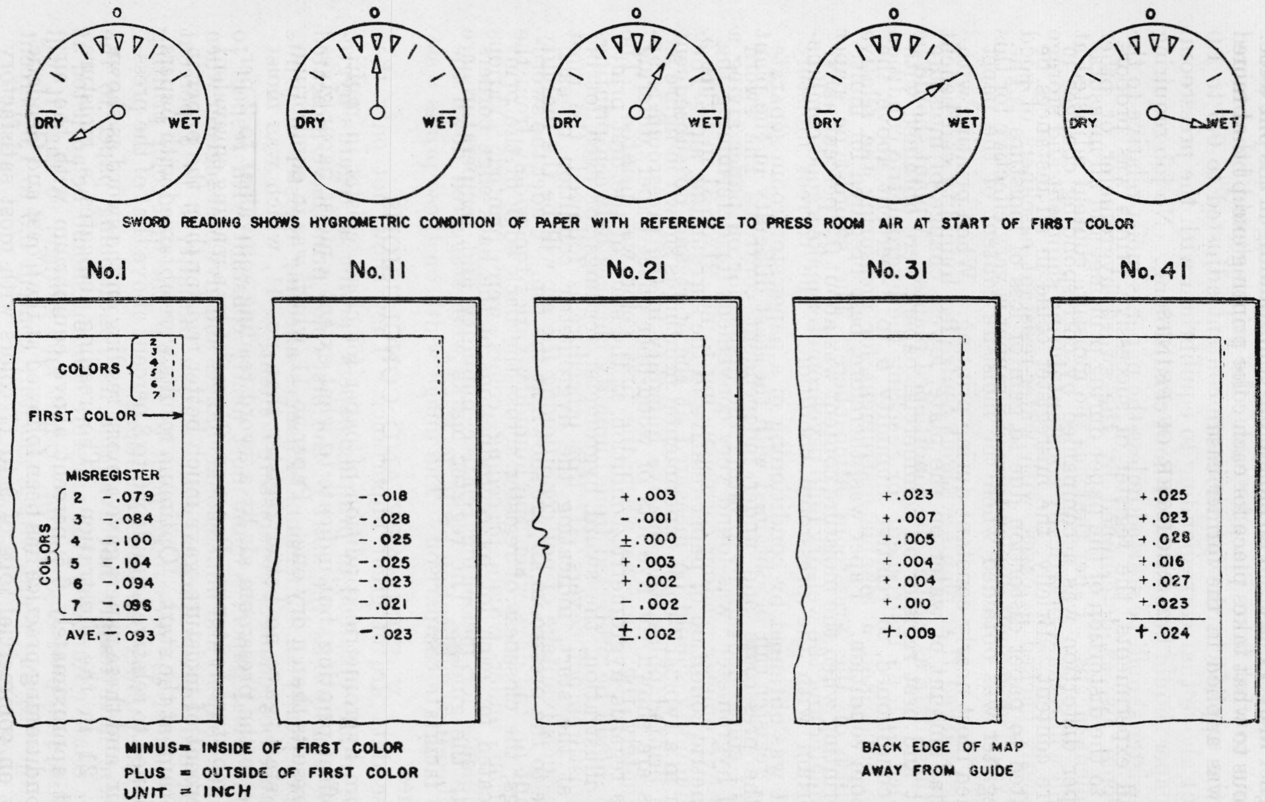

FIGURE 5.—*Relation of paper conditioning to register.*

The sword-hygrometer readings, showing hygrometric condition at the start, are reproduced at the top, and the resultant register for each lot is shown directly underneath. The misregister is shown for the back edge of the map on the side opposite the guide. Plus or minus signs indicate whether the prints are longer or shorter than the first color print. The values given are decimal fractions of an inch.

conditioning to equilibrium with the pressroom, it has resulted in better quality work, decreased spoilage, and higher production.

Where facilities are not available for conditioning in a room under separate control from the pressroom, the paper should be obtained from the manufacturer with moisture content adjusted to 0.5 to 1.0 percent above that corresponding to equilibrium with the pressroom. This paper should be printed without conditioning. No job requiring fine register should be started unless the paper is moist relative to the pressroom air, as determined by the sword hygrometer or other equivalent means. Paper that has the moisture content adjusted at the mill will remain practically constant during shipment and storage if properly packed in cases, with water-resistant caseliners of good quality. The asphalt duplex type of wrapper is very effective for this purpose.

It is believed that plants without controlled humidity can benefit from these data as well as the conditioned plants. A plant should be provided with an instrument for checking the hygrometric condition of the paper and a reliable instrument for measuring the relative humidity of the pressroom atmosphere. The sword-type paper hygrometer and the wet-dry bulb psychrometer make a good combination.

Fine register can be obtained with the least difficulty in the plant without controlled air by printing the first color on paper giving a sword-hygrometer reading corresponding to no. 21 or 31 in figure 5. The humidity should be measured at the start and no subsequent colors printed unless the relative humidity in the pressroom is approximately the same as when the first color was printed. The paper should be protected from humidity changes between printings by moistureproof covers. If this procedure is followed, the most serious disadvantage of not conditioning the air will be the inability to print on the days when the humidity varies too widely from the condition under which preceding colors were printed. Various instruments for measuring relative humidity and temperature are described in a publication by R. F. Reed.[8]

V. SUMMARY AND CONCLUSIONS

The results obtained in printing papers varying as regards hygrometric condition at the start of the first-color print have indicated that practically all dimensional changes affecting register of prints are caused by changes of moisture content.

Commercial papers remain most nearly constant with respect to moisture content and dimensional changes and give best register when conditioned to equilibrium with relative humidity 5 to 8 percent above that of the pressroom prior to start of the first-color printing and printed under constant conditions.

Where facilities are not available for conditioning paper to the higher relative humidity, the moisture content should be adjusted at the mill and protected during transit and storage, so that it will reach the printing plant with a moisture content 0.5 to 1.0 percent above equilibrium with the pressroom air.

[8] Handbook of Air Conditioning for Lithographers, Lithographic Tech. Found., New York.

For the printing plant without controlled humidity, attention to the relationship between moisture content of paper and the relative humidity of the surrounding air is equally important. Paper with high moisture content should be required and no color printing should be started on paper that is dry relative to the surrounding atmosphere.

The sword type of hygrometer is a most convenient tool for determining whether paper is in proper condition for the first-color printing in multicolor work. It is in best condition when the sword reading taken in the pile of paper is "wet" relative to the pressroom air by an amount equivalent to 0.5 percent of moisture content. In plants without controlled humidity, the relative humidity should be measured at the time of the first printing and no subsequent printings started when the humidity is widely different. It is particularly important not to print subsequent colors when the humidity is higher than it was for the first-color printing.

WASHINGTON, November 12, 1935.