A New Type of Self-Driven Vibrating Roller and its Effect on Press Performance

by John MacPhee *

Abstract: A novel patented mechanism for use in self-driven vibrating rollers is described. The uniqueness of the basic concept is highlighted through a review of the various types of mechanical drives that have been used over the past 90 years in prior art rollers. The capability of such rollers to favorably affect press performance is illustrated through the presentation of quantitive results of tests run on a web press printing unit under four conditions: standard roller configuration, vibrating roller in last ink form position, vibrating roller in dampening form position, and vibrating rollers in both dampening form and last ink form positions. Performance characteristics that were measured through the use of a special test form were degree of mechanical ghosting, on-press dot gain, ink lay or print mottle, and water feed rate.

INTRODUCTION

Inking systems for lithographic and other types of printing presses require that some of the rollers be oscillated or vibrated in the axial direction to eliminate ridging and to minimize mechanical ghosting (Hull, 1968). Normal design practice is to vibrate most of the hard surfaced inking rollers at a rate that is in the range of one vibratory cycle for every two plate cylinder revolutions on sheetfed presses, and five plate cylinder revolutions on web presses. In addition, many dampening system designs on lithographic presses employ one or more vibrating rollers.

To generate this vibratory motion, press designers generally utilize worm gear drives or some type of crank mechanisms. Such drives are external to the rollers, are an integral part of the press, are installed during manufacture, and have proven to be rugged and reliable.

In order to further improve press performance, additional vibrating rollers are sometimes incorporated into a press after it has been installed and operated for some time. Due to space limitations it is often necessary for such rollers to have self-contained or self-driven mechanisms for generating the vibratory motion. Because of those same space limitations, however, none of the self-driven mechanisms developed in the past has proven to be reliable at high press speeds, because of excessive mechanical wear.

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The first purpose of this paper is to describe a completely new mechanical drive concept that has promise for solving this problem of excessive wear, by virtue of an inherent feature. A second and equally important purpose is to present data that illustrates the improved press performance that can be achieved through the use of rollers equipped with this capability. In order to show that the subject mechanism is indeed totally new, a section has been included that describes and categorizes prior design concepts. This is followed by a section that explains the new concept, hereinafter referred to as the Baldwin VBR-2 design. Subsequent sections describe the press tests run to demonstrate the benefits achievable with such rollers, present the test results, and summarize the findings to date.

PRIOR DESIGN CONCEPTS

The best source of information on existing types of self-driven vibratory mechanisms was found to be the U.S. Patent Office. A search of its files turned up a total of sixteen patents, the earliest dated December 16, 1902. Appendix A lists these patents by number, inventor, date of issue, and title. Self-driven vibrating rollers are sometimes referred to as McKinley rollers and it is interesting to note that the origin of this name was the inventor granted a U.S. Patent in 1912 (McKinley, 1912). In general, all of these prior art devices can be said to utilize a rotary cam mechanism, defined here as follows:

> **Rotary cam mechanism** A mechanical device for converting a uniform rotary motion into a linear periodic oscillatory motion. Basic elements are a rotary cam, that imparts an oscillatory linear motion to a follower, by means of an edge or groove cut in the cam surface. Rotary cams are categorized as being either of the radial type or of the cylindrical type. Radial type cams generate linear motion along a line perpendicular to the cam axis whereas cylindrical cams generate linear motion along a line parallel to the cam axis as shown in Figure 1.

Based on this definition, it can be said further that all previous self-driven mechanical designs utilize some form of a cylindrical cam and that they can be classified into three broad groups, according to the type of cam configuration used. This system of classification defines four groupings or types as illustrated in Figure 2. The most straight-forward type is the simple cylindrical cam shown in Figure 1(b) and identified as "single revolution lead, high relative speed" in Figure 2. This type is impractical at today's relatively high press speeds because the changes in direction of travel are sudden enough to produce printing disturbances, e.g., streaks (Beisel, 1982). One solution to this problem is to use some form of gearing to reduce the relative speed of cam and follower, i.e., the "single revolution lead, low relative speed" type of Figure 2. However, this and the other two types identified in Figure 2 are much more complex in design. This can be seen in Figure 3, that shows examples of each of the four types taken from the patent literature.

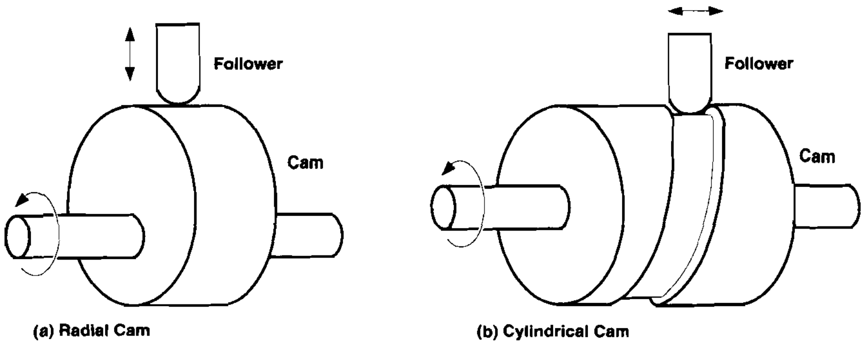


Figure 1 Classification of Continuous Rotary Cam Mechanisms

The excessive mechanical wear at high roller speeds, that is also a characteristic of prior design self-driven rollers, stems with one exception from a paramount undesirable feature:

> The sliding mating surfaces (i.e., the interface between cam and follower) that transmit the "high" loads necessary to produce vibratory roller motion travel at a "high" speed relative to one another. The "high" loads were measured to be as great as two pounds per inch of roller length (MacPhee and Wirth, 1989) while the "high" speeds are slightly lower than the surface speed of the roller. Both these loads and speeds are described as "high" because they are greater in combination than found or used in normal design practice.

The exception to this general condition is found in the reduced speed class of mechanism where gears are employed to reduce the speed of the follower, relative to the cam. The use of gears is no panacea however, because the problem of wearout at high speeds is transferred to the gears, which must travel at relatively high rotational speeds.

In addition to experiencing excessive wear at high press speeds, prior art designs that improve printing are complex and thus relatively costly to manufacture.

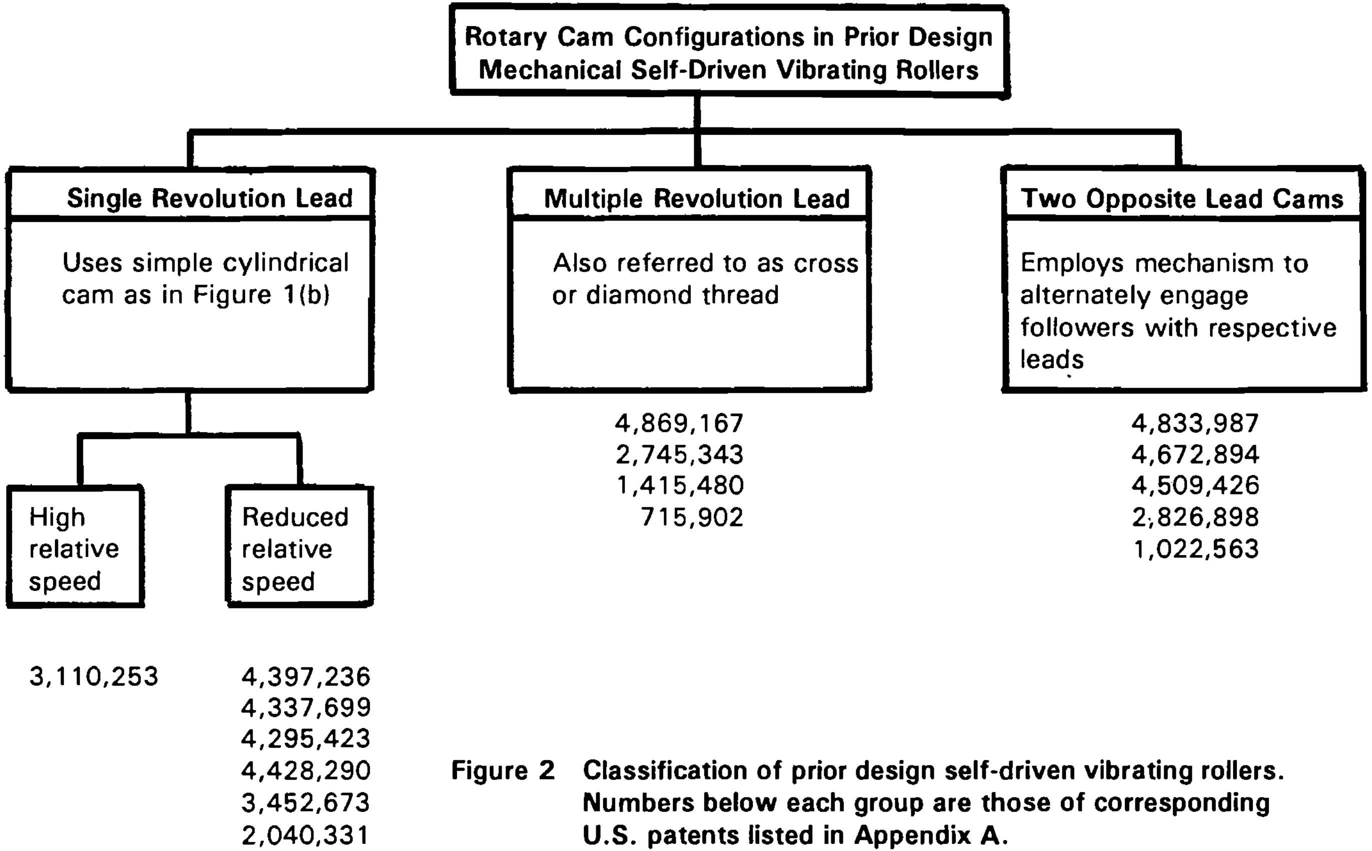
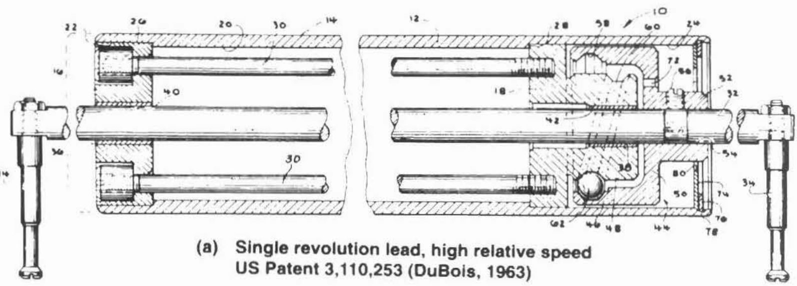
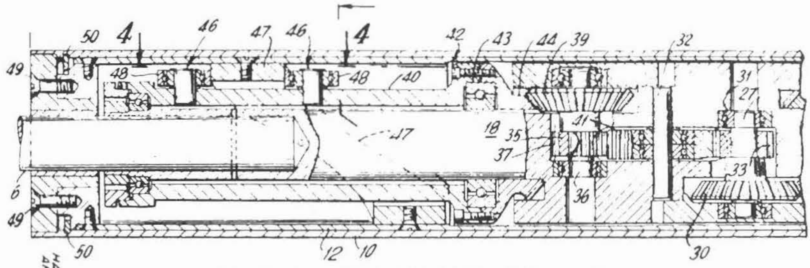


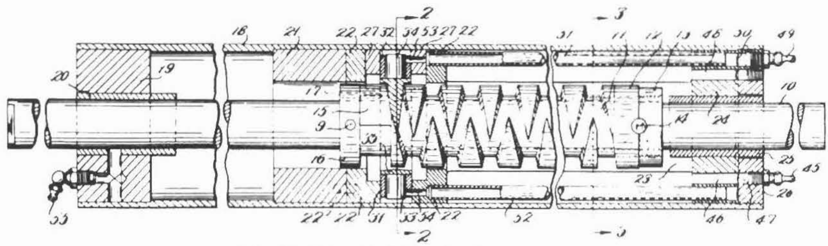
Figure 2 Classification of prior design self-driven vibrating rollers. Numbers below each group are those of corresponding U.S. patents listed in Appendix A.



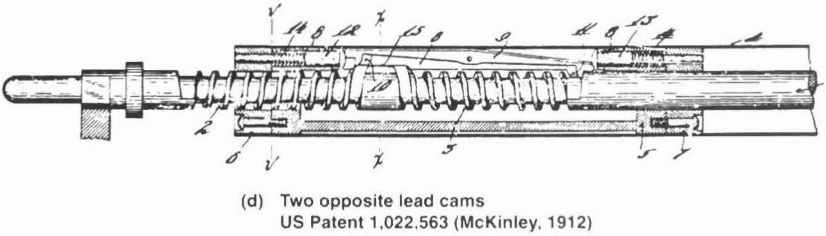
(a) Single revolution lead, high relative speed
US Patent 3,110,253 (DuBois, 1963)



(b) Single revolution lead, low relative speed
US Patent 3,452,673 (Gegenheimer, 1969)



(c) Multiple revolution lead
US Patent 2,745,343 (Davis, 1956)



(d) Two opposite lead cams
US Patent 1,022,563 (McKinley, 1912)

Figure 3 Examples of prior design mechanical self-driven vibrating rollers

THE BALDWIN VBR-2 DESIGN

The Baldwin VBR-2 design is unique in two respects as follows:

1. It employs a radial type cam instead of the cylindrical type found in all previous self-driven mechanical rollers.

2. The cam is integral to and driven by a novel worm gear type mechanism, consisting of an internal worm that meshes with a worm gear mounted inside the worm.

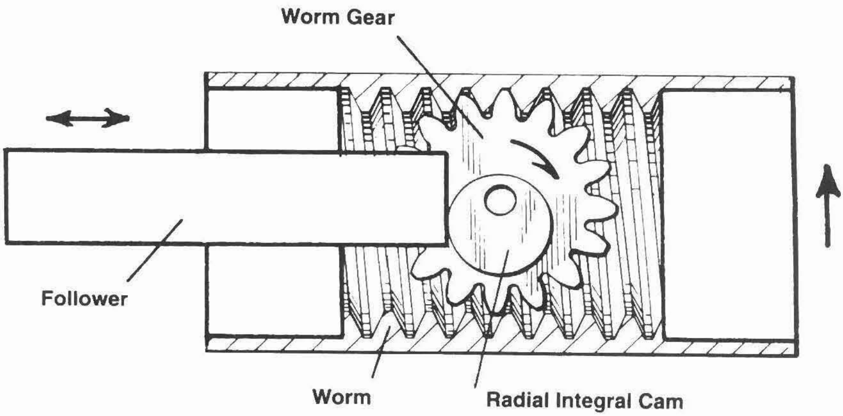


Figure 4 **Schematic showing arrangement of the unique elements of the Baldwin VBR-2 roller. In the actual design, the follower is part of the stationary roller shaft; thus the worm and worm gear move back and forth along the axis of the shaft. A fourth basic element, not shown, is a tubular bearing that supports the worm gear shaft and is free to slide back and forth along the roller shaft axis.**

Figure 4 illustrates these unique elements of the VRB 2 design. This combination eliminates the paramount undesirable feature of earlier designs. This comes about because the VBR-2 design has two pairs of sliding surfaces: one running at "high" speed, but with a low load, and one subjected to the "high" load but running at a low speed. That is, the load at the "high" speed interface of the worm gear and worm is equal to the vibratory load divided by a reduction factor equal to the ratio of the worm gear pitch diameter to the vibratory stroke. This reduction factor is equal to 3.8 in actual rollers built to date. Conversely, the relative speed of follower and cam, which transmit the "high" vibratory load, is equal to roller surface speed reduced by a factor somewhat greater than the number of teeth in the worm gear. (Gears used in rollers to date have sixteen teeth.) Figure 5 is a photograph of a model of the complete mechanism used in an actual VBR-2 roller. Portions of the model have been machined away for clarity. The uniqueness of the VBR-2 is attested to by the fact that a U.S. patent was granted on its design without opposition from the Patent Office (MacPhee, 1991).

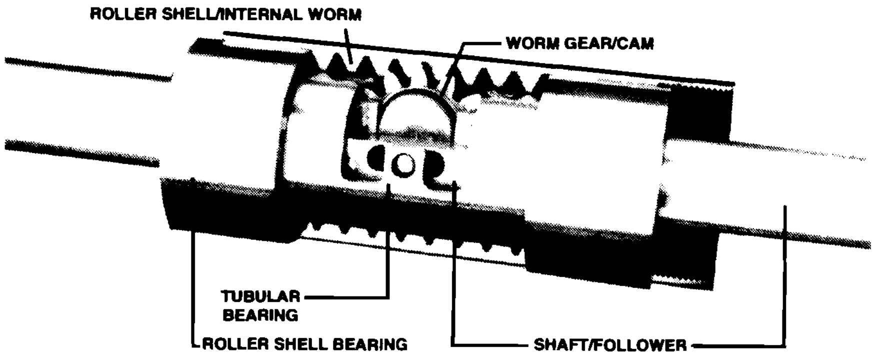


Figure 5 Cutaway model of the Baldwin VBR-2 vibrating roller that shows its three basic moving parts; the worm/roller shell, the worm gear/cam, and the tubular bearing. Both the roller shaft and tubular bearing are slotted to receive the worm gear. A second slot, perpendicular to the first, is also cut into the roller shaft so as to permit the worm gear shaft to slide back and forth along the axis of the roller shaft. The ends of the worm gear shaft are mounted in the tubular bearing; thus rotation of the roller shell about the tubular bearing causes the worm gear to turn. As the cam also turns, it pushes back and forth against a close fitting slot in the roller shaft. Because the roller shaft is fixed the worm gear shaft ends react against the tubular bearing, causing it and the roller shell to slide back and forth along the roller shaft.

PRESS TESTS RUN

On November 12, 1991, printing tests were run on an eight-unit Didde VIP web press at Tempo Graphics in Carol Stream, IL to evaluate the effectiveness of using vibrating rollers in both the dampening form and last ink form positions. A single-color, cyan, was printed on 50 pound enamel stock in the last press unit, using the form shown in Figure 6.The primary purpose of the tests was to

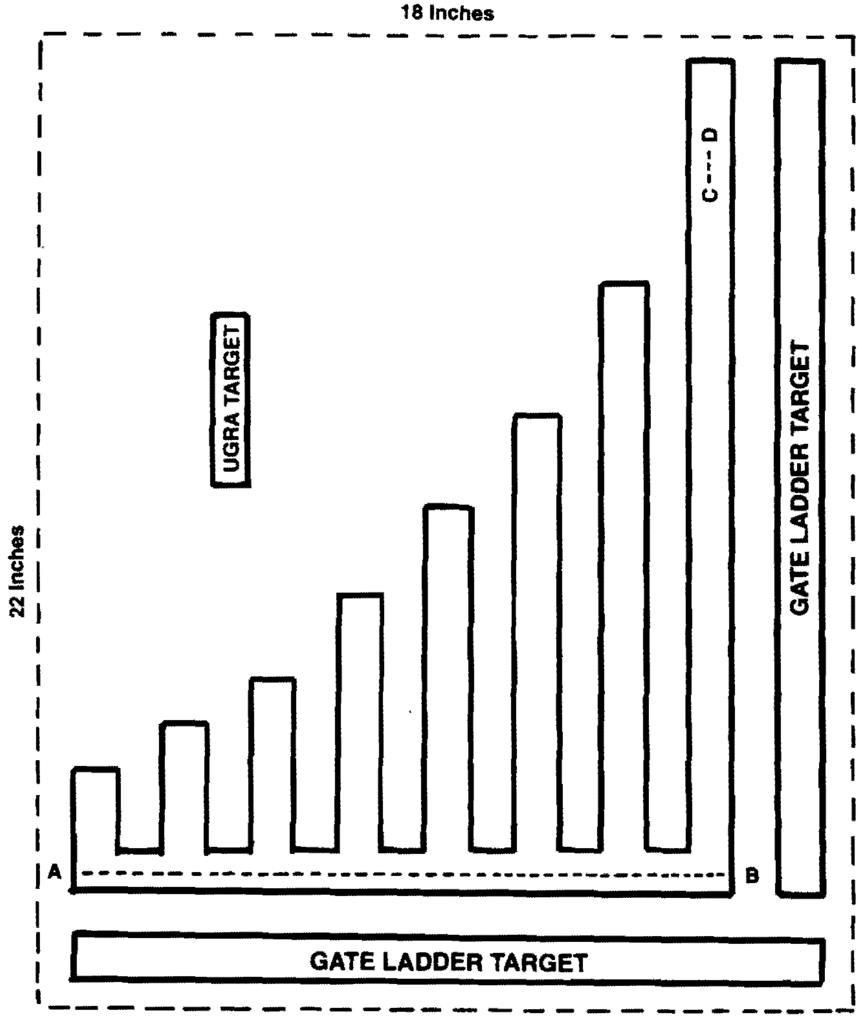


Figure 6 Test form used to evaluate effectiveness of vibrating rollers. Densities were measured along line A-B to evaluate ghosting and along line C-D to evaluate ink lay. UGRA target was used to evaluate dot gain and slur.

evaluate the effectiveness of the rollers to reduce mechanical ghosting; however, data was obtained on the effects of ink lay, water feedrate, and dot gain. In addition, the effect of higher ink density on ghosting was observed.

The Didde VIP used is 20½ inches wide and has a 22 inch cutoff or repeat length. As shown in Figure 7, the press inker has three form rollers; and vibrating rollers were fabricated to fit the first (dampening) and last (second ink) form positions. The test rollers had a total stroke of 7/16 inches and had a cycle rate of one per 7.6 plate cylinder revolutions for the dampening form and 7.3 plate cylinder revolutions for the second ink form roller.

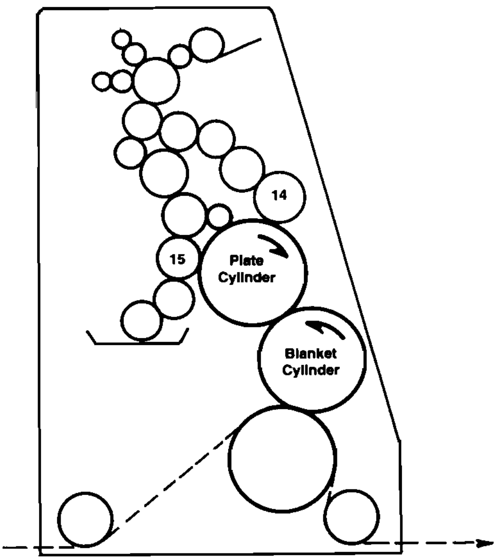


Figure 7 Roller diagram of Didde VIP Press on which tests were run. Vibrating rollers were tested in positions 15 (dampening form) and 14 (last ink form).

The design of the test form, shown in Figure 6, is similar to forms used on pervious ghosting tests by Baldwin and to the GATF ghosting form (Prince, 1988). It consists of one inch wide solid bars, of various lengths, running in the direction of paper travel. Along the bottom of the form these bars are joined by another solid bar, at right angles to them. The degree of ghosting is judged by the extent to which density discontinuities, corresponding to the edges of the vertical bars, can be observed along the horizontal bar, i.e., along line A-B in Figure 6. Two GATF ladder targets and an UGRA target were also included to make it possible to measure dot gain and to more readily detect streaks.

The test comprised six runs, under the various conditions given in Table I. Runs 1 and 2 were designed to reveal the effect of high vs normal or standard print density; runs 3 - 5 were to show the effect of different combinations of vibrating rollers; and Runs 6 (when compared with Run 2) was to confirm that press performance was repeatable.

TABLE I Test Conditions

Run No.	Solid Density Specified	Blanket	Paper	Type of Roller: Ink Form Position	Type of Roller: Dampening Form Position
1	1.60	Old	Roll #1	Standard	Standard
2	1.30	Old	Roll #1	Standard	Standard
3	1.30	Old	Roll #1	Vibrating	Standard
4	1.30	New*	Roll #2	Vibrating	Vibrating
5	1.30	New	Roll #2	Standard	Vibrating
6	1.30	New	Roll #2	Standard	Standard

* Old Blanket was smashed during makeready for Run #4

The pressman was instructed to makeready by running minimum water and adjusting the ink keys to achieve the target density, $\pm .05$ density units, at points along line A-B corresponding to the center lines of the vertical bars. Once makeready was completed, a minimum of fifty sheets were run and collected for subsequent analysis. In general, five thousand or more impressions were run per makeready, as evidenced by the fact that almost two rolls of paper were consumed during the tests. Typically printing was carried at 14,000 impressions per hour or 438 fpm.

RESULTS OF PRESS TESTS

1. Ghosting. From visual examinations of sheets, made on the spot, the following was evident:

a) Ghosting was worse at the higher print density.
b) A single vibrating roller reduced ghosting somewhat.
c) A single vibrating roller was more effective in the second ink form position than in the dampening form position.
d) Two vibrating form rollers had a pronounced improvement on ghosting.

In the more detailed analyses made following the tests, abrupt density discontinuities were identified and compared as indicated by the "V's" in Figure 8. As can be seen, 14 such discontinuities, or all that might possibly occur, were visible in Run #6, with no vibrating rollers in place. In contrast only five such were visible with both vibrating rollers in place, which represents a substantial quantitative improvement. Alternately, the results represented by these observations can be expressed in the following way:

"The minimum length of the vertical bar required to generate a density discontinuity in an adjoining horizontal bar was greater than eight inches (but less than ten inches) with two vibrating rollers installed as compared to only two inches or less with no such rollers."

These results, while quantitative, are dependent on the observer and the viewing conditions and thus are somewhat subjective. For this reason alternative methods for gaging ghosting, independent of visual observations were explored. The first approach tried was to measure density at 1/8 inch intervals along line A-B of the test form using a Cosar Autosmart densitometer equipped with a 2mm diameter aperture (Cox, 1985). Figure 8 contains plots of such measurements on sheets from the last four runs. While these density plots do reflect the improvements achieved by using vibrating form rollers, they do not provide a readily apparent correlation with the degree to which ghosting occurred, as detected visually.

The second approach taken was based on the principle that a visual observation or detection of a ghost is the result of the observers eyes and brain responding to a density change where the change is defined by both the magnitude of the density difference and the distance over which the change occurs. For example an abrupt density change of 0.05 density units is readily detectable whereas a gradual change of 0.20 density units across a sheet is not. Thus it was theorized that a plot of the absolute changes in density, over each one eighth inch of traverse along line A-B of the form, i.e. density gradient, might correlate better with a human observer's response. Such plots, shown in Figure 9, do indeed appear to be a better indicator of ghosting and do provide a clear measure of the improvement in the performance due to the use of vibrating form rollers. The correlation with the visual observations (indicated by the V's) is reasonably good and suggests that the density change over one eighth inch must exceed 0.06 to 0.07 density units, for a ghost to be detected by the particular human

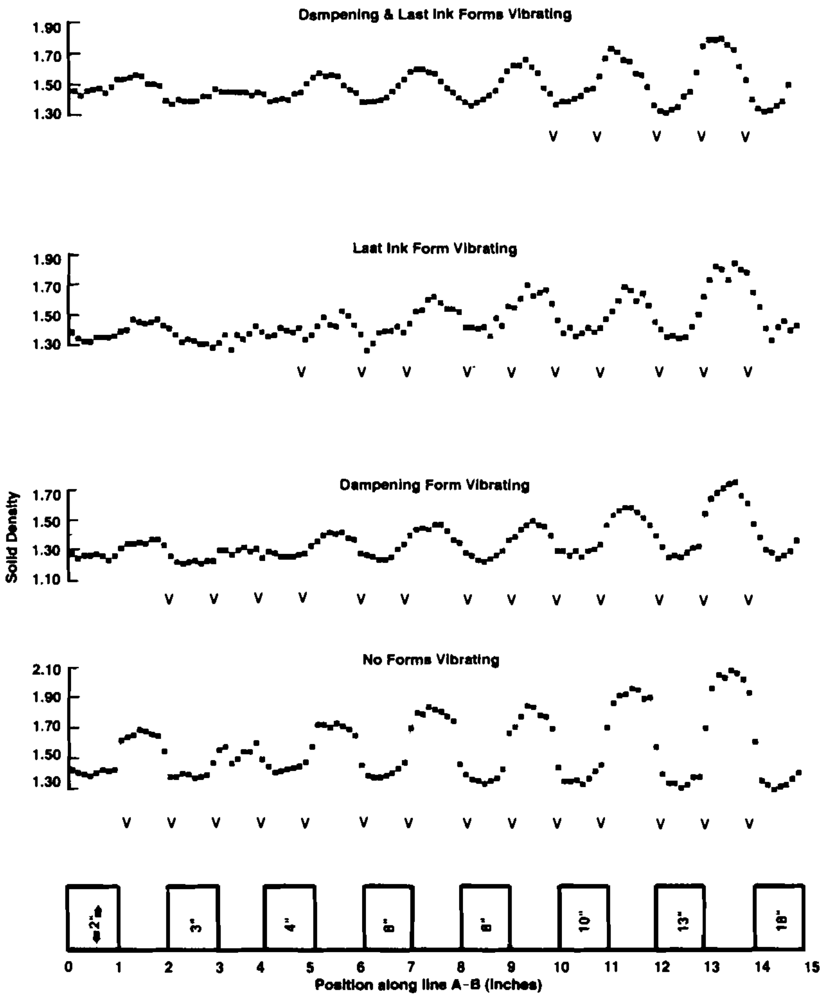


Figure 8 Density readings along line A-B on sheets from the last four runs.

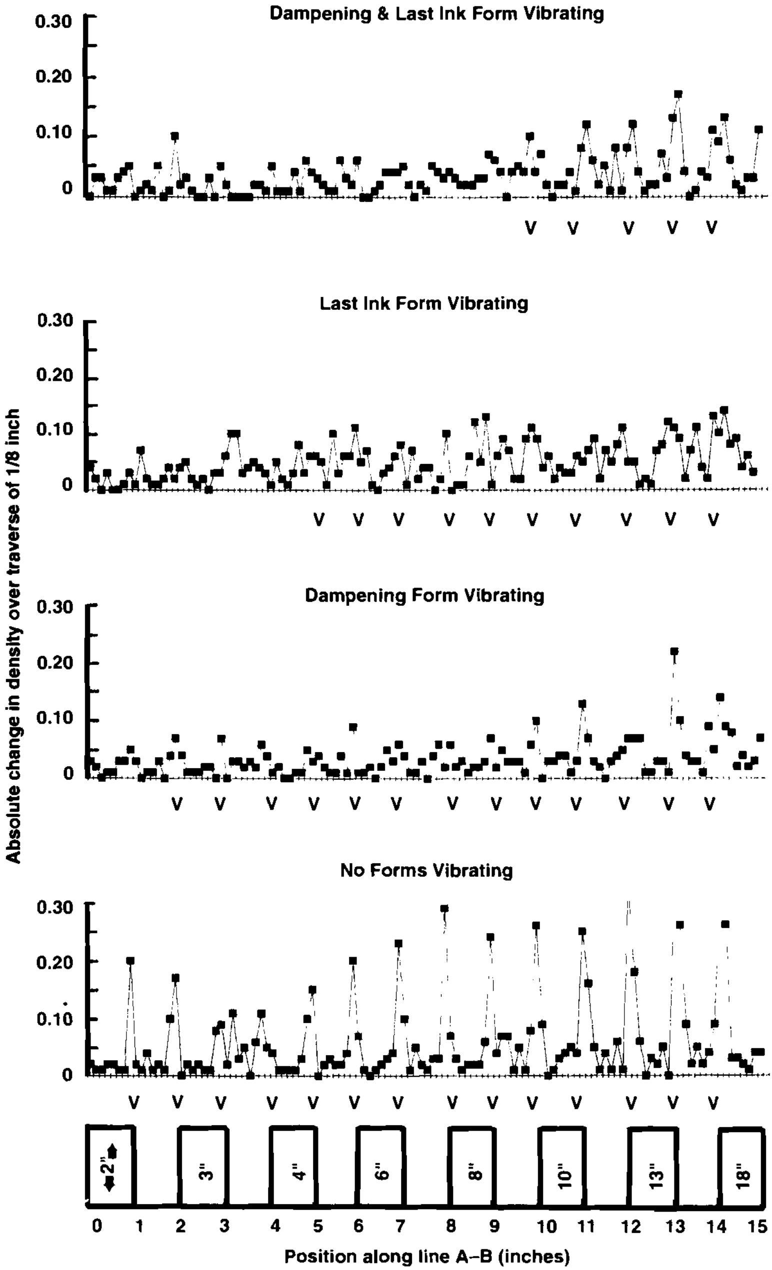


Figure 9 Absolute density gradient along line A-B

observer used, i.e., the author. The correlation is not perfect however because the plots in Figure 9 seem to indicate that a single vibrator roller performs better in the dampening position that in the ink form position; and this is contrary to the visual observations. Nevertheless, this form of density data presentation appears promising and should be explored further.

2. Ink Lay. While the tests were in progress, Bob Pechacek of Tempo pointed out that the use of a vibrating roller in the dampening form position had a marked improvement on ink lay. * Following the tests, three methods were used to quantify this observation. First a panel, made up of three GATF workers experienced in evaluating print quality, was asked to rank the quality of ink lay on sheets from Runs 2-6, in the region C-D of the form, as shown in Figure 6. The second method comprised making a series of 41 density measurements per inch over a one inch long line (C-D) in the same area on three consecutive sheets. The variance or standard deviation of these measurements on each sheet was then calculated to obtain a measure of ink lay. Figure 10 is a plot of one such set of measurements. This approach was based on work by Chet Daniels at RIT (Daniels, 1991) who found that a correlation exists between density variance and ink lay, i.e., the greater the standard deviation, the worse the visually observable variation in ink film thickness or mottle. The frequency of measurements recommended by Daniels is 40 per inch.

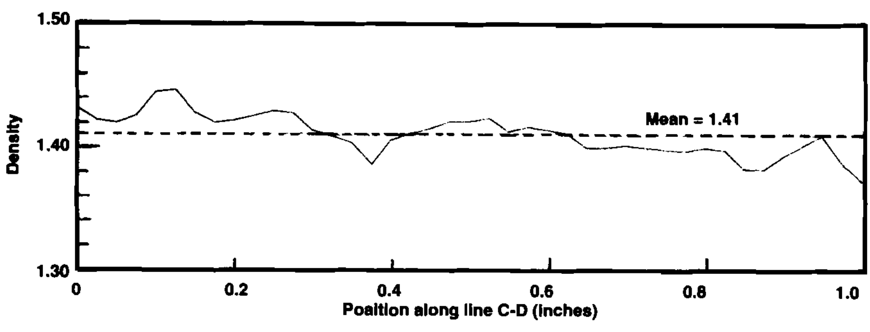


Figure 10 Density readings along line C-D, Run 4. Standard deviation of forty-one readings was 0.017.

The third method was suggested by similar considerations that led to the form of presentation shown in Figure 9.It also came about because of misgivings that density variance can be a misleading indicator of mottle.

* **As used here, ink lay refers to the visually observable nonuniformity of the printed ink film thickness.**

(For example, a print having a monotonic decrease in density from 1.40 to 1.20 density units over one inch would exhibit no mottle yet have a variance of 0.06 density units.) Specifically this third method comprised using the same 41 density measurements to calculate the mean absolute change in density over each traverse of 0.025 inches. (In the above example, this would yield a mean change of .005 density units.)

The results of all three methods are given in Table II and show the following:

(i) All three methods are in agreement with Pechacek's on-the-spot observation that vibrating the dampening form roller improved ink lay, i.e., reduced apparent mottle.

(ii) The rankings of the three observers overall were quite consistent and suggested that only a small difference separated both the two worst and the two best samples.

(iii) The rankings obtained from the density change method correlated better with the rankings of the three observers, compared to the rankings of the density variance method. In addition, this method showed small differences between the two best and two worst samples and thus seems to explain the relatively minor differences in the rankings of the three observers in this regard. Agreement between repeat readings was also somewhat better for this method.

3. Dot Gain. One of the projected advantages of using a self-driven vibrating roller in a form position as opposed to one driven by a press vibrator is that there will be no increase in gain - because a self-driven roller having a pure harmonic motion will not produce sudden changes in transverse roller speed. In order to check on this, gain in the 50 percent UGRA dot screen area was measured, along with solid density. For each run, ten consecutive sheets were measured and the mean values were calculated. These values are plotted in Figure 11(a) vs solid density. From this plot it can be seen that there was much more gain in Runs 4 and 5, in which the dampening form roller was vibrated. Further insight into the cause of this increase in gain was obtained by constructing similar plots of the UGRA slur targets, as in Figure 11(b). These two plots reveal that the gain seen in dots is due only to spread or slurring in the direction of paper travel. This is evidenced by the fact that the spread or gain in lines parallel to paper travel simply rises as density increased whereas the plot of gain in lines perpendicular to paper travel has the same two outlying points, i.e., Runs 4 and 5. The conclusions to be drawn from this information are as follows:

TABLE II Rankings of ink lay by three different observers and two different density measurements

Ranking Method	Run #2 Standard Press Rollers	Run #3 Vibrating Roller in #2 Ink Form Position	Run #4 Vibrating Roller in Damp. & #2 Ink Form Positions	Run #5 Vibrating Roller in Dampening Form Position	Run #6 Standard Press Rollers
Observer A	5 (1)	4	1	2	3
Observer B	5	4	1	2	3
Observer B	4/5	5/4	2	1	3
Density Variance	4	3	2	1	5
Mean Density	1.43 1.46 1.43	1.50 1.50 1.50	1.41 1.41 1.41	1.33 1.30 1.32	1.34 1.42 1.37
Std Deviation	.030 .032 .037	.016 .023 .036	.017 .016 .013	.013 .014 .016	.035 .033 .039
Density Change	5	4	2	1	3
Mean Value(2)	.015 .012 .018	.014 .014 .014	.0071 .0061 .0062	.0065 .0064 .0058	.014 .010 .011

(1) #1 is the best, #5 is the worst; (2) Equal to mean value of absolute changes in density over each traverse of .0025 inches

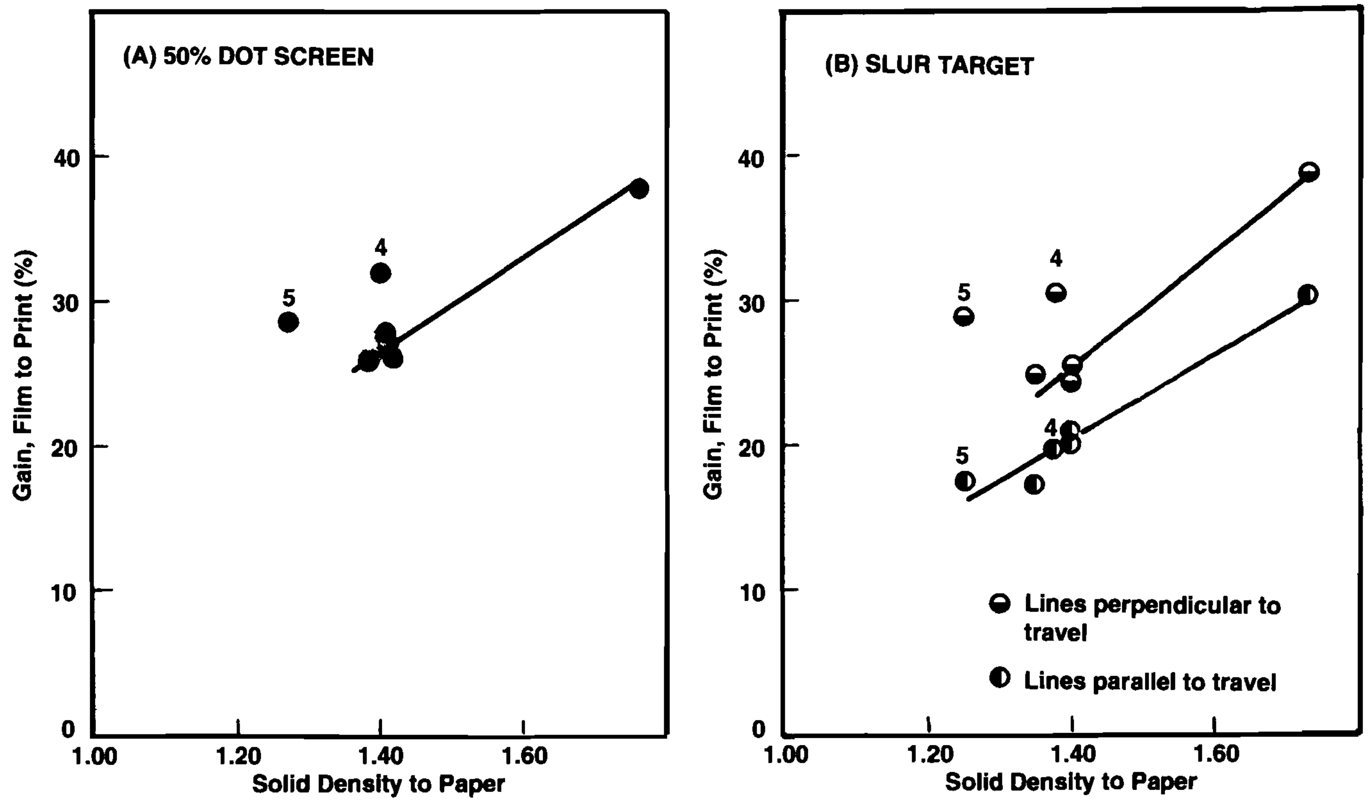


Figure 11 Plots of gain data which show that increase in dot gain that occurred with vibrating roller in dampening form positions (Runs 4 and 5) was not caused by vibratory motion

(i) There was an increase in dot gain in the runs (4 and 5) where the dampening form roller vibrated.

(ii) The increase in dot gain was not caused by the vibratory motion of the roller.

(iii) The real cause of the gain increase is not known with any certainty. The most likely explanation is that the vibrating dampening form roller was set differently, thereby producing a change in the degree of slip between this roller and the plate.

4. Water Feedrate. A definite decrease in the minimum required water feedrate was observed when the dampening form roller was vibrated. The water settings used for the various runs were as follows:

Run 1:	7.0	Run 4:	6.0
Run 2:	6.5	Run 5:	6.0
Run 3:	6.5	Run 6:	8.3

5. Density Variation, Top to Bottom. As a matter of interest, the density change from the top to bottom of the form was measured by scanning densitometer measurements made along the 18 inch high bar at one half inch intervals. The differences between the averages of the first and last four readings were taken as the top to bottom density difference. Table III lists the average values of the density differences for three consecutive sheets from each run. No correlation with vibratory rollers motion appears to exist. The data do however show a small improvement in the last three runs which, if real, would be attributable to either the new blanket or the second roll of paper used in these runs.

Table III Top to Bottom Density Variations

Run No.	Form Rollers Vibrated	Density Variation
2	None	0.13
3	2nd Ink	0.14
4	2nd Ink & Dampening	0.07
5	Dampening	0.05
6	None	0.04

SUMMARY

1. Although self-driven vibrating rollers have been in use for over ninety years, the design described in this paper was shown to be new and unique through a review and categorization of the prior art.

2. Tests run on a three form roller offset web press demonstrated that the following benefits accrued from using self-driven vibrating rollers of this design in form roller positions:

   (i) A substantial reduction in ghosting was achieved when two form rollers were vibrated.

   (ii) Vibrating the dampening form roller by itself or in consort improved ink lay by a degree that was visually apparent and reduced the amount of water that had to be fed to the plate.

3. Although some dot gain was observed in tests where the dampening form roller was vibrated, this gain was not attributable to the vibratory motion and was most likely due to a difference in roller setting.

4. Quantification of absolute density gradient showed promise as a method for measuring both the degree of ghosting and of ink lay or mottle. A plot of density gradient, as in Figure 9, appeared to be most suitable for quantifying ghosting. A calculation of mean gradient, rather than a plot, appeared better for gaging ink lay.

5. For the test conditions reported here, ghosting was made worse by increasing print density.

ACKNOWLEDGEMENTS

Important contributions were made by Bob Gasparrini and Dave Wirth of Baldwin during the detailed design and fabrication of the basic VBR-2 rollers described in this paper. The test results presented were made possible through the cooperation and help of many people. Thanks go to John Howard at Didde for suggesting Tempo Graphics as a test site and for introducing the writer to Dick Lami. The advice and participation of Dick Lami, Bob Pechacek, and Bob Arco at Tempo were essential elements to the success of the press tests. Lloyd DeJidas, John Lind, and John Peters of GATF are to be thanked for giving of their time in ranking the prints. Bill Eisner of RIT has our gratitude for agreeing to the measurement of densities at his facility, as does Dan Clark who actually made the measurements. Finally, the work of Mohammad Chaudhry of Baldwin in plotting the density data shown in Figures 9 and 10 constitutes an important contribution, while the finished form of the paper is due to the good work of Vittoria Vavala.

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APPENDIX A
Prior Art U.S. Patents

Patent Number	Inventor	Issue Date	Title
4,869,167	Jose A. Villarreal	09/26/89	Variable Speed Oscillating Roller
4,833,987	Philip J. Hardin	05/30/89	Axially Oscillating Ink Distributing Roller having a Unitary Rocker Follower
4,672,894	Philip J. Hardin	06/16/87	High Rotational Speed Autoreversing Axially Oscillating Ink Roller
4,509,426	Philip J. Hardin	04/09/85	Autoreversing Dual AxialSpeed Ink Roller
4,428,290	Rudi Junghans Hermann Beisel	01/31/84	Device for Axially Reciprocating an Inking-Unit Roller of a Rotary Printing Machine
4,397,236	Harry M. Griener Roland Holl Klaus Neberle Paul Abendroth	08/09/83	Inking Unit with Traversing Ink Rollers
4,337,699	Hermann Beisel	07/06/82	Device for Axially Reciprocating an Inking-Unit Roller
4,295,423	Hans Johne Wolfgang Muller Arndt Jentzsch Ginter Schumann	10/20/81	Liquid Distributing RollerAssembly for PrintingMachines
3,452,673	Harold W. Gegenheimer Andrew N. Stad	07/01/69	Vibrating Roller

APPENDIX A (cont.)

Patent Number	Inventor	Issue Date	Title
3,110,253	Edgar H. Dubois	11/12/63	Oscillating Roller Mechanism for Printing Presses
2,826,898	Harold W. Gegenheimer Samuel Davis Robins	03/18/58	Ink Roller Vibrating Mechanism
2,745,343	Noel Davis	05/15/56	Automatic Vibrator Roller
2,040,331	Henri E. Peyrebrune	07/05/34	Vibrating Mechanism
1,415,480	William Jacob Ramsaier	05/09/22	Ink Distributor
1,022,563	Joseph S. McKinely	04/09/12	Ink-Distributor Roll
715,902	John Thomson	12/16/02	Changer