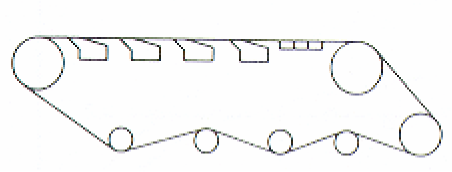


Maximizing Flat Box Performance

John D. Eames

Drag and drainage of a single flat box and a bank of flat boxes are investigated in relation to the applied vacuum, vacuum distribution among boxes, and the number of flat boxes employed.

Guidelines are established for distributing vacuum among the flat boxes and methods are suggested for maximizing or controlling drainage and minimizing drag in the flat box section of the paper machine.

Drainage on the forming table of the fourdrinier steadily decreases with increased sheet consistency to a point where self-inducing vacuum devices such as hydrofoils and table rolls are no longer effective. External vacuum must then be applied to the sheet to increase its consistency to a level where its strength is sufficient for transfer to the first press. Primarily flat boxes have performed this task for decades.

The simplicity of the flat box and the ease at which its performance can be adapted to various production requirements has made the flat box a universally accepted piece of equipment. However, there are shortcomings inherent to the flat box such as continuous abrasion of the forming media and covers, drag load created by the boxes, problems with drainage uniformity, pinholing and wire marking.

While all of the above problems can be associated more or less with the application of vacuum, this paper is limited to an investigation of the drag and drainage characteristics of the flat box as the level of vacuum applied and the distribution of vacuum among a bank of flat boxes directly affect them.

TEST EOUIPMENT AND PROCEDURE

The tests were performed at the Huyck Research Center in Rensselaer, N.Y. on their experimental fourdrinier with a FORMEX forming fabric at a machine speed of 1500 fpm. A 32 lb. newsprint sheet (18" wide) was formed on a 45-foot table equipped with 45 hydrofoil blades and 8 flat boxes. The flat box covers were made of HUYLIFE, an ultra-high molecular weight polyethylene, and had a staggered pattern of 1/2" diameter holes with 40% open area. The first four "wet" boxes and the following four "dry" boxes were mounted on separate frames. Each frame was connected to a load cell that allowed independent measurement of drag load on the wet and dry boxes.

Vacuum on each box was independently controlled and was measured with mercury Monometer gauges.

Drag readings, sheet consistency samples and white water samples were taken at the various locations in the flat box section during each test. Drainage from the various flat boxes was calculated from the sheet consistency differential across the boxes and white water data, employing mass balance equations.

The sheet sampling technique consisted of directing a high velocity air jet toward the sheet from the underside of the forming media, thus lifting it off and collecting it in a container. White water samples were obtained directly from the boxes by disconnecting the drainage hose and collecting a sample immediately before collecting consistency samples.

TEST RESULTS

Drainage, white water consistency and drag were the criteria with which flat box performance was evaluated. Measurements were taken at various vacuum levels, ranging from 0 to 8" Hg.

Results were first obtained for a single flat box with various incoming sheet consistencies, and then for a bank of flat boxes where total applied vacuum and the vacuum distribution among the boxes was varied.

DRAINAGE PERFORMANCE OF A SINGLE FLAT BOX

Drainage of a single flat box depends primarily upon the level of applied vacuum and the consistency of a sheet entering the box. Figure I shows drainage of a single flat box with applied vacuums of 0 to 8” Hg. and with entering sheet consistencies of 3.0%, 9.2%, and 11.6%. In all cases, drainage of the flat box increased proportionally with the level of vacuum applied. Drainage from the "wet" sheet (3.0%) was substantially greater than from the dryer sheets due to the increased availability of water.

At the high sheet consistency of 11.6%, a threshold vacuum level of 4" Hg. exists, below which no drainage was achieved.

The concept of threshold vacuum at the dryer sheet positions is important and plays a prominent role in optimizing the performance of a bank of flat boxes for maximizing drainage.

Figure 1

FLAT BOX DRAINAGE

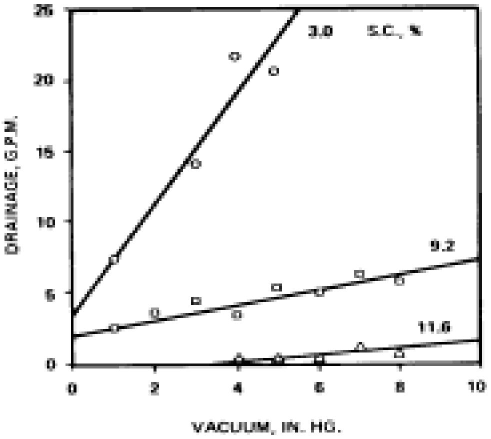
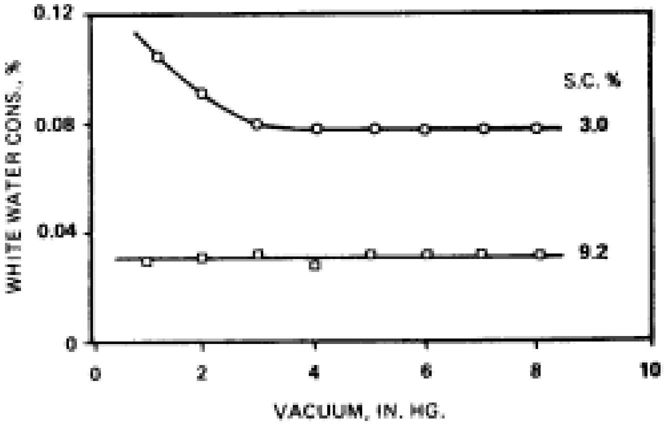


Figure 2

FLAT BOX WHITE WATER CONSISTENCY



WHITE WATER CONSISTENCY OF A SINGLE FLAT BOX

The effect of flat box vacuum on white water consistency was measured for a "wet" box and "dry" box with sheet consistencies of 3.0% and 9.2%, respectively.

Figure 2 shows the results of this test. The consistency of the white water from the "wet" box is significantly higher than from the "dry" box. However, compared with consistencies of 0.1 to 0.3%, common to the forming zone, flat box white water consistencies are relatively low (0.030.10%).

White water consistency from the flat boxes was found to be dependent on vacuum at the wet position only, and a significant decrease in consistency was observed with increased vacuum. At the wet position, it is believed that at the low vacuum levels, only the lower water level is removed from the bottom of the sheet. However, at the higher vacuum levels, additional water is filtered through successive layers of the sheet resulting in a leaner total mixture, thus the reduction in effluent consistency with increased vacuum.

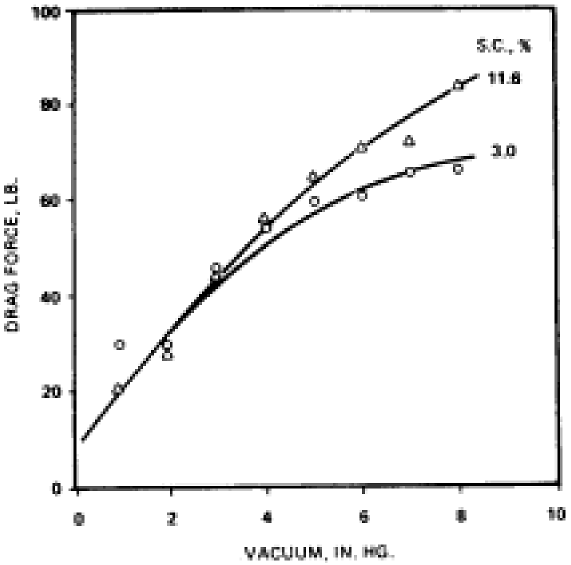
DRAG OF A SINGLE FLAT BOX

The movement of the forming media over the stationary flat box covers creates a drag force. Its magnitude is greatly influenced by the level of vacuum applied to the boxes. This drag, or friction from the flat box cover, constitutes a significant part of the overall power consumed by the fourdrinier drive motors and also adversely affects the life of the forming media.

Figure 3 is a plot of drag (lbs.) vs. vacuum (Hg.) for a single flat box with entering sheet consistencies of 3.0% and 11.6%.

Figure 3

FLAT BOX DRAG



Drag of a flat box was found to be primarily a function of applied vacuum and the sheet consistency entering the box. Drag of the "dry" box is higher than the "wet" box, particularly at the higher vacuum levels. The existence of a thicker lubricating water film between the forming media and stationary cover surface is most likely the reason for lower drag on the wet cover. However, the influence of vacuum on drag is very pronounced in both cases, with drag increasing proportional to the square root of the vacuum. This fact will also be important in establishing an optimum relationship between drainage and drag for a bank of flat boxes.

PERFORMANCE OF A BANK OF FLAT BOXES

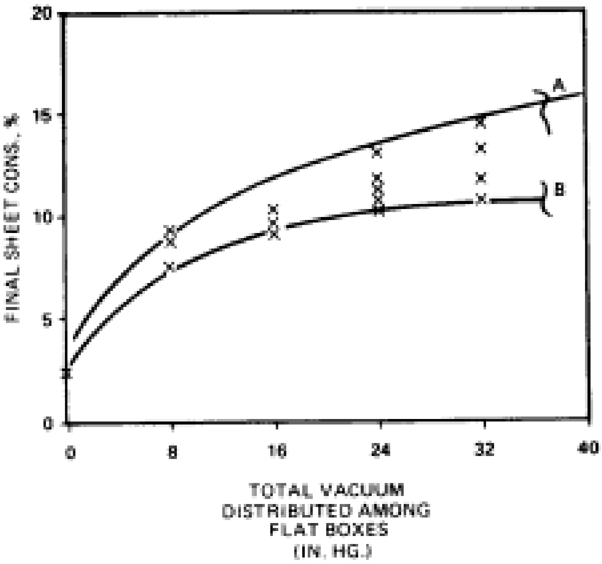
Drag and drainage of a bank of flat boxes was investigated in regard to the total cumulative vacuums applied to the boxes, the manner or schedule in which the vacuums were distributed among the boxes, and the number of flat boxes utilized.

DRAINAGE

Figure 4 shows the sheet consistency leaving the last of eight flat boxes when 8, 16, 24 and 32 in. Hg. were distributed among the eight boxes in turn.

Figure 4

DRAINAGE PERFORMANCE OF A BANK OF FLAT BOXES



As expected, the sheet consistency leaving the last flat box increased with an increase in cumulative vacuums applied to the 8 flat boxes. The range of sheet consistencies obtained at each cumulative vacuum in Figure 4 is the result of the different vacuum schedules employed. The higher sheet consistencies (Curve A) were obtained when vacuum on the flat boxes was graduated in such a manner as to increase from the wet to the dry end. The lowest sheet consistencies (Curve B) were the result of a decreasing vacuum schedule from wet to dry end, and intermediate sheet consistencies were obtained when the same vacuum was applied to all flat boxes.

Table 1 shows typical vacuum schedules employed and sheet consistencies leaving the eight flat boxes when 24" Hg. was distributed among the eight flat boxes.

It is seen that not only does an increasing vacuum schedule from wet to dry end result in a higher sheet consistency leaving the flat boxes, but the steeper the graduation in vacuum from wet to dry end, the higher the sheet consistency leaving the bank of flat boxes.

The concept of threshold vacuum displayed in Figure 1 plays a dominant role in achieving maximum drainage from a bank of flat boxes. When decreasing vacuum schedules are applied, the vacuums on the "dry" flat boxes are likely to fall below the threshold vacuum level of the sheet and result in no additional drainage from those boxes.

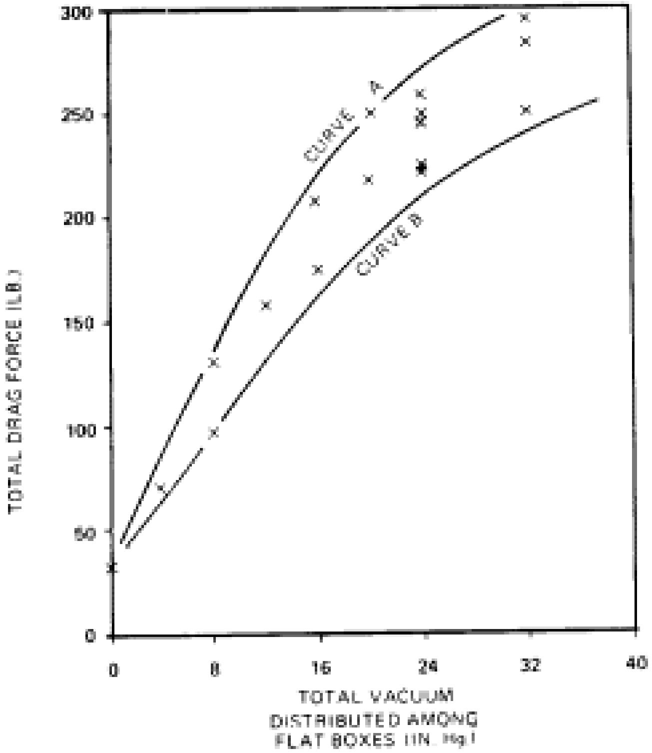
The highest sheet consistency and thus maximum drainage is obtained from a bank of flat boxes by applying the steepest vacuum schedule to the flat boxes from wet to dry end.

DRAG

Figure 5 shows the total drag load (lbs.) produced by eight flat boxes when total vacuums of 8, 16, 24 and 32 in. Hg. were distributed among the boxes.

Figure 5

DRAG OF A BANK OF FLAT BOXES



Drag, like drainage, of a bank of boxes is seen to increase with an increase in the total vacuums applied, but is highly dependent upon the vacuum schedule employed. The highest drag loads (Curve A) were obtained when vacuums were increased on successive boxes from wet to dry end and the lowest drag (Curve B) resulted when decreasing vacuum schedules from wet to dry end were used. Thus, those vacuum schedules, which resulted in the highest drainage from the 8 flat boxes, also resulted in the greatest amount of drag load.

OPTIMIZATION OF FLAT BOX PARAMETERS FOR MINIMUM DRAG AND MAXIMUM DRAINAGE

Successively dropping flat boxes and redistributing their vacuums among those boxes remaining achieved maximum drainage and minimum drag.

Figure 6 shows the drag load of the bank of flat boxes and the sheet consistency leaving the last flat boxes.

Table 1

Vacuum Trend	Flat Box No. Wet 1	2	3	4	5	6	7	Dry 8	Final Sheet Consistent %
Decreasing	4	4	4	4	2	2	2	2	10.6
Constant	3	3	3	3	3	3	3	3	11.8
Increasing	2	2	2	2	4	4	4	4	12.1
Increasing (Steeper)	1	1	1	2	3	4	6	6	13.1

Figure 6

DRAG LOAD AND FINAL SHEET CONSISTENCY OF A BANK OF FLAT BOXES

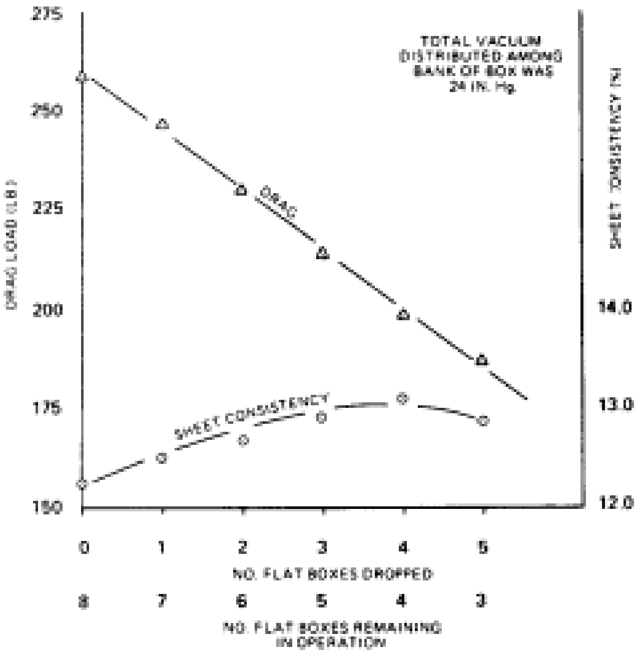


Table II

	Wet	Flat Box Number						Dry	
	1	2	3	4	5	6	7	8	
	Vacuum Schedules (In. Hg.)								Total Vac. (In. Hg.)
8 Boxes	2	2	2	2	4	4	4	4	24
7 Boxes	Dropped	2	2	2	3	4	5	6	24
6 Boxes	Dropped	Dropped	2	2	4	4	6	6	24
5 Boxes	Dropped	Dropped	Dropped	2	4	4	6	8	24
4 Boxes	Dropped	Dropped	Dropped	Dropped	4	5	7	8	24
3 Boxes	Dropped	Dropped	Dropped	Dropped	Dropped	8	8	8	24

When successive flat boxes were dropped and their vacuums redistributed among those flat boxes remaining in operation. In each case, the vacuums were distributed with an increasing schedule from wet to dry end and totaled 24 in. Hg.

With eight flat boxes in operation the highest drag (259 lb.) and a final sheet consistency of 12.2% were obtained.

When one flat box was dropped and its vacuum distributed among the remaining seven boxes the drag had dropped from 259 lb. to 247 lb. and the final sheet consistency increased to 12.5%.

With two boxes dropped, leaving six boxes in operation (total vacuum distributed among the six boxes still 24 in. Hg.), the drag load decreased further to 230 lb. and the final sheet consistency increased to 12.7%.

It is seen in Figure 6 that drag load continued to decrease linearly as each successive flat box was dropped and its vacuum redistributed among those boxes remaining in operation. Increases in final sheet consistency were realized up until the fifth flat box was dropped; at which time a slight decrease in final sheet consistency was noted.

Table II shows the vacuum schedules and the respective flat boxes dropped during these tests.

The reduction in drag loads noted when fewer flat boxes were used is a direct result of the decrease in flat box cover area in contact with the forming media. In order to realize the maximum reduction in drag load, it is important that the flat boxes be dropped completely from the forming medium and not merely turned off.

Higher final sheet consistencies were obtained, even with fewer flat boxes, because of the steeper vacuum schedules realized when the vacuum of the boxes which were dropped were redistributed among those remaining in operation.

CONCLUSIONS

A threshold vacuum exists on "dry" flat box positions below which no water is removed from the "dry" sheet.

Maximum drainage can be achieved from a bank of flat boxes by applying an increasing vacuum schedule from wet to dry end.

Drainage can be maximized and drag load minimized in a bank of flat boxes by reducing the number of flat boxes employed and redistributing vacuums on the remaining boxes using an increasing vacuum schedule from wet to dry end.

The extent of which these results may be utilized on commercial machines will depend upon many factors such as sheet quality and vacuum pump capacities. However, sheet consistency measurements are easy to make and total loads can be easily determined on a large number of machines

Hence, these findings can be implemented on many fourdriniers. The result can be increased production due to a drier sheet, lower total fourdrinier drag load and increased wire or fabric life due to lower total drag.