Proper Table Harmonics is Key to Improved Sheet Formation Program

Drainage element spacing on forming table can be set to control sheet pulse frequency to achieve the best formation possible

By Arnold Giles

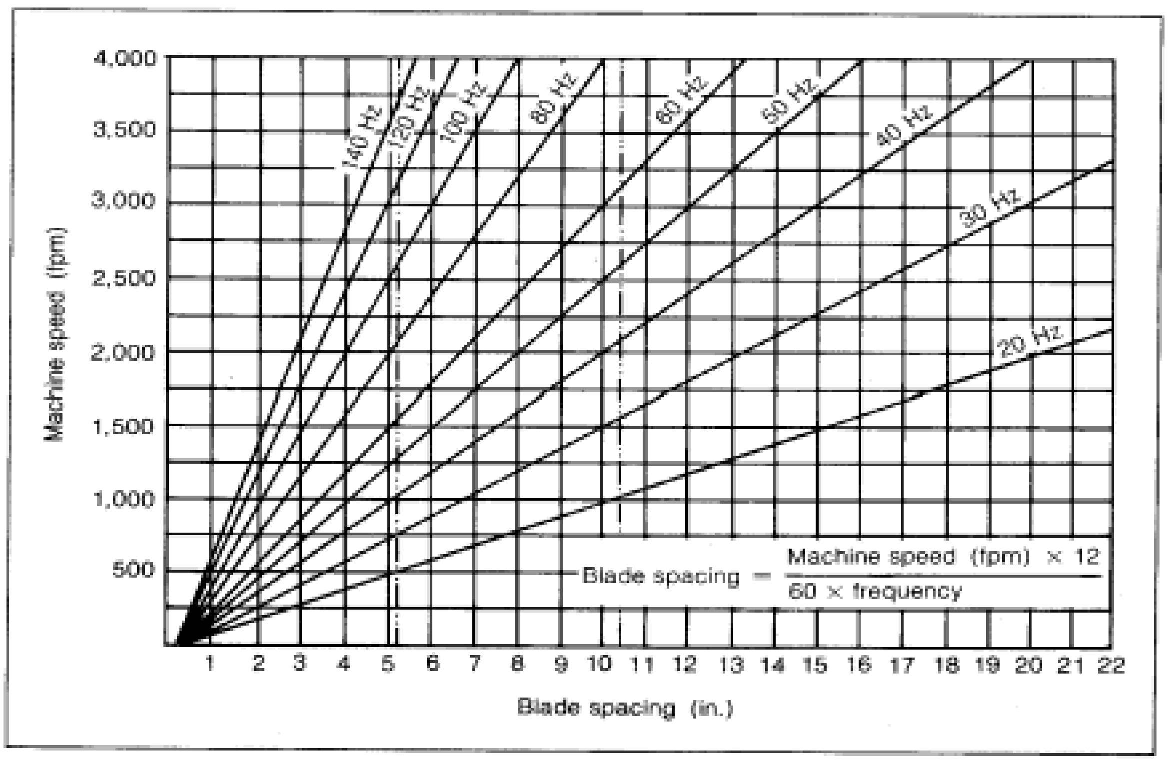
In papermaking, “harmonics” is a term that refers to the effect of turbulence regeneration. In this sense, it is not related to guitar or violin strings and the different sound frequencies obtained by tightening or loosening them.

It is well known that turbulence can affect sheet formation. Micro-turbulence in the right amount can improve sheet formation, whereas macro-turbulence (stock jump) can destroy a good sheet. Harmonics is a way of obtaining the best micro-turbulence and controlling it down the table to ensure that very little, if any, reflocculation takes place. This article discusses pulse frequency, which is the number of uniformly spaced dewatering elements (hydrofoil blades) hit by a part of the fabric at a given speed as the fabric and stock travel down the wire.

HARMONICS. A five-blade hydrofoil with a blade spacing of 5.25 inches and a fabric speed of 1,000 fpm gives a pulse frequency of 38/second or 38 Hz. Harmonics occurs when the positioning and blade spacing of the next unit are correct. A typical forming table can be made up of the following units:

- Forming board – lead blade plus three trailing on 5.25-inch centers.
- Hydrofoils – three blades each on 14 inch centers
- Hydrofoils – four blades each on 10.5 inch centers
- Hydrofoils – five blades each on 7 inch centers
- Vacufoils – five blades each on 5.25-inch centers.

FIGURE 1: **Pulse frequency chart.**



If machine speed is 1,500 fpm, each of the above units would generate the following pulse frequencies:

- Forming board trailing blades: 57 Hz
- 14 inch centers hydrofoil: 21.4 Hz
- 10.5 inch centers hydrofoil: 28.5 Hz
- 7 inch centers hydrofoil: 42.8 Hz
- 5.25 inch centers hydrofoil: 57 Hz

This mixture of pulse frequencies does nothing to enhance harmonics. Such a table would probably not perform well at all. Drainage would likely be good but formation would suffer. Figure 1 shows pulse frequency of any part of a hydrofoil table if blade spacing and speed are known.

EXAMINING THE PROBLEM. Why worry about harmonics? Why spend time examining this “problem?” The answer to these questions requires going back to basics. Originally, the table roll was the major drainage device on paper machines. The dewatering action of the

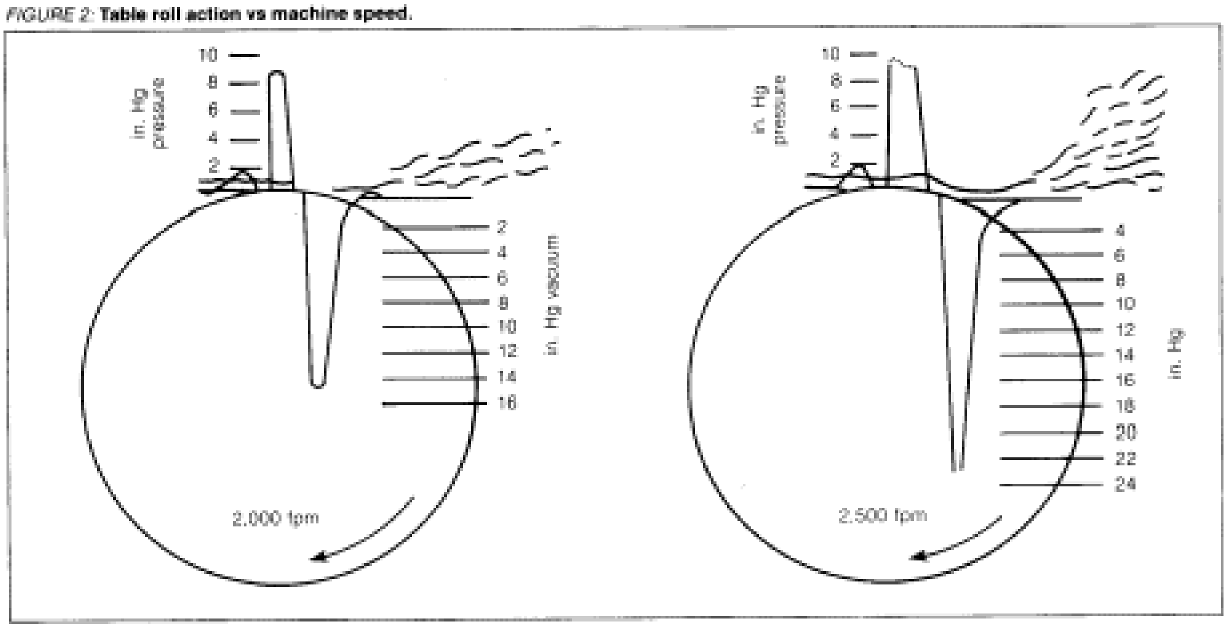


FIGURE 2: **Table roll action vs machine speed.**

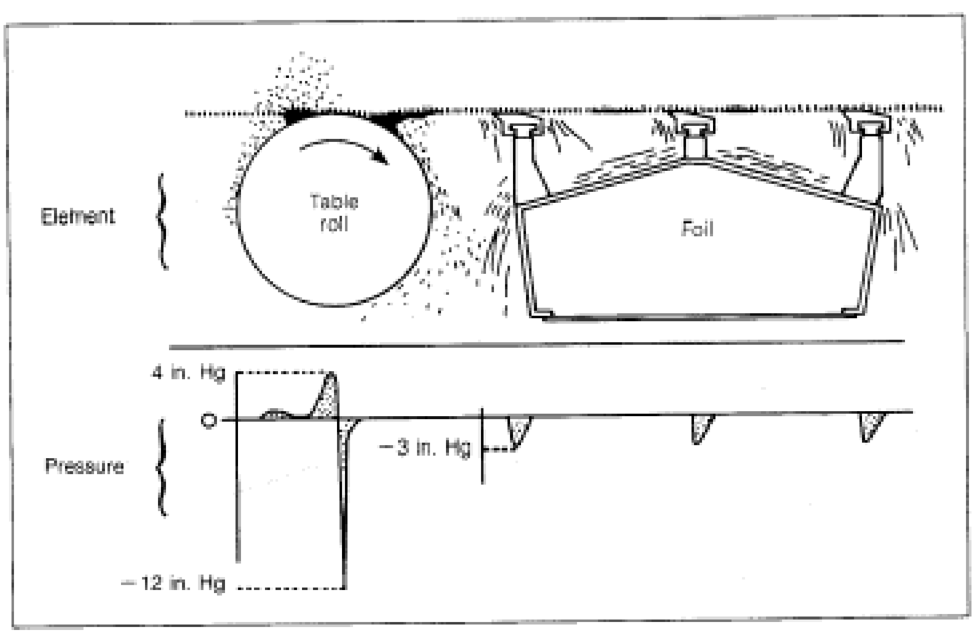


FIGURE 3: **Hydrofoil vs table roll dewatering action illustrating comparative pressure peaks and dewatering rates.**

roll produced the now well-known pressure/vacuum pulse (Figure 2). This combination was so violent at high speeds that the sheet was virtually destroyed. Amplitude of both the pressure and vacuum pulses was very high. A frequency check down the fourdrinier would show that rolls spaced on 14-inch centers at a speed of 1,000 fpm give 14.2 Hz (using Figure 1), which is like trying to break a nut with a sledgehammer.

The multi-blade hydrofoil that replaced the table roll gave smaller pressure/vacuum pulses (amplitude), but the frequency was higher because of the increased blade number (Figure 3). It is certainly not surprising that formation was improved.

PULSE FREQUENCY. Formation, in papermaking, can be defined as homogeneity of the sheet when viewed in transmitted light – "wildness," cloudiness, presence/size/frequency of lumps, and areas of thicker or thinner sheet. Formation is best under the following conditions:

- Slice discharge is as homogenous as possible (i.e., no flocculation).

FIGURE 4: **KMW Periformer—constant pressure drainage.**

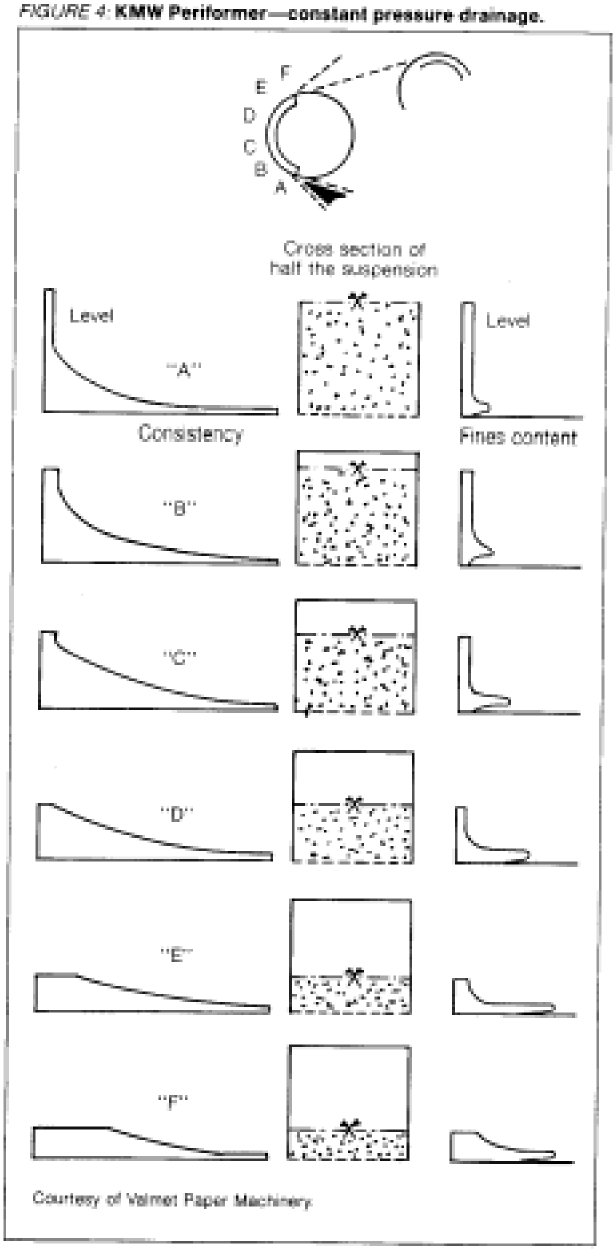
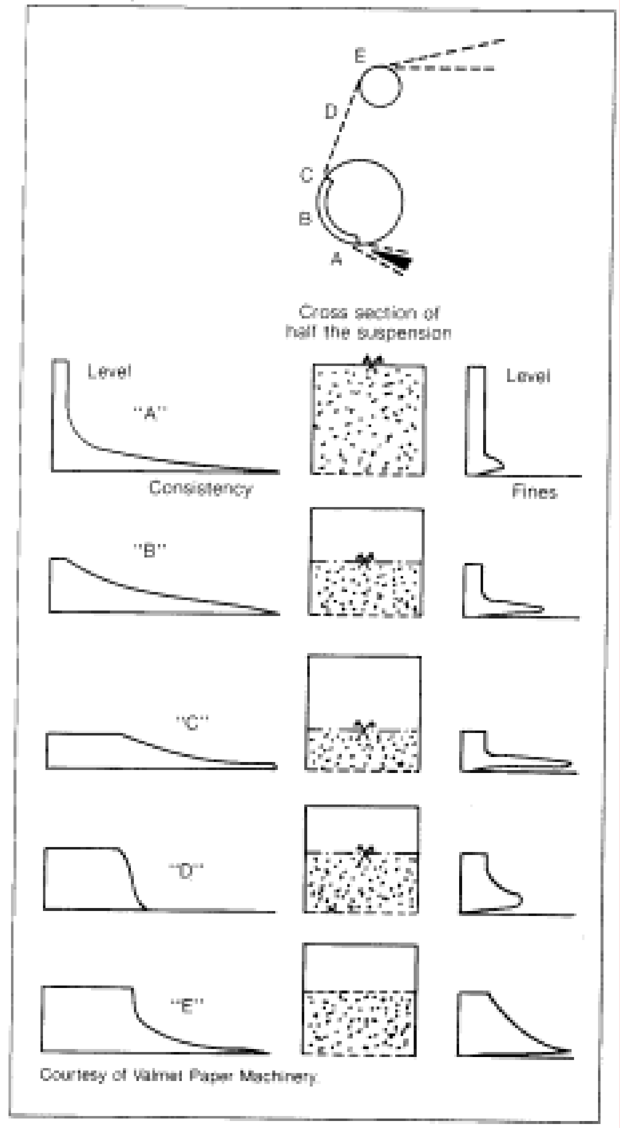


FIGURE 5: **KMW Periformer-MW—constant pressure drainage with one expansion.**



- Impact of jet on fabric is not disruptive.
- Small-scale agitation is sufficient to continue a non-flocculated state until the fibers are set into a mat.

How does the pressure/vacuum pulse impact sheet formation? A twin-wire roll former, under vacuum, gives constant drainage forces two ways: one inward due to the vacuum and one outward due to centripetal forces. Figure 4 shows fines buildup on both sides of the sheet with less buildup in the middle. Figure 5 shows a similar former with an "expansion zone" that improves fines distribution by reversing the constant pressure in an area between the two rolls. This has the effect of stirring up the sheet.

The curved shoe in a blade former (Figure 6) creates a varying pressure pulse from blade to blade (Figure 7). This type of former (Beloit's Bel Baie II) is well known for its quality of formation. An analysis of this phenomenon shows the pressure variation and its spacing (Figure 8). Blade spacing on the Bel Baie is approximately 15 cm or 6 in. If the machine runs at 3,000 fpm, the pulse frequency (using Figure 1) would be 100 Hz.

A recent visit to a fine paper mill in the South showed superior formation on a 90-lb. sheet at 3,200 fpm. The table has 24 ceramic hydrofoil blades spaced at 5.25-inch blade centers. This gives 122 Hz (using Figure 1). Stock jump is controlled by low blade angles (0° to ½° to 1°). Putting things in perspective, the pulse frequency obtained on this machine is twice that experienced when a finger is stuck into an electrical outlet (60 Hz).

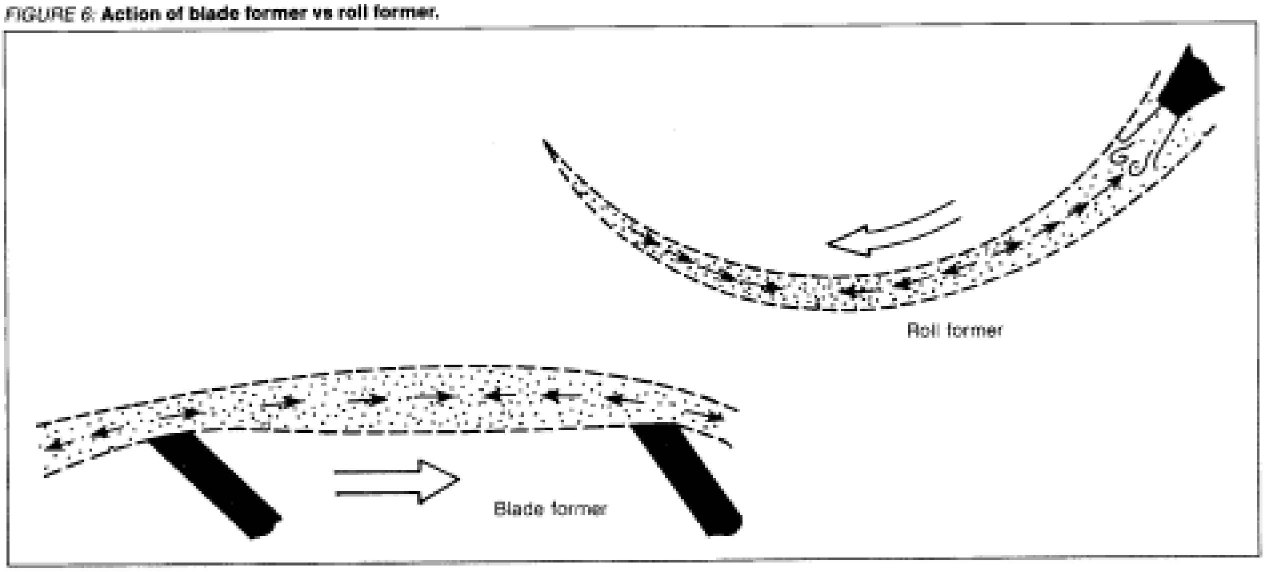
USING HARMONICS. Once the stock on the wire has started to vibrate due to the pulse frequency of the first few dewatering elements, succeeding elements must be positioned correctly, with the right spacing, to ensure that the vibration (turbulence) continues until sheet set time. The pulse frequency required will depend on many factors, including freeness, sheet weight, and consistency or mass on the wire. A heavy-mass linerboard sheet will not vibrate as easily as newsprint or writing paper. To get things moving on the wire, three basics are needed:

- Pulses
- Amplitude (energy)
- Continuation of pulse frequency (harmonics)

Pulse frequency is obtained by blade spacing and harmonics by meticulous attention to blade spacing on units and between units. Amplitude is obtained by blade angle and the now famous Turbo Blade. A simple guideline would be to get the pulse frequency as high as possible, along the order of 100 Hz. Control drainage and energy (amplitude) with size of blade and blade angle. If more amplitude and less drainage are needed, use the Turbo Blade. The frequency required should be in excess of the natural fiber mat setup time.

NATURAL FIBER MAT SETUP. It is well known that when water only is being run on a machine, it disappears through the fabric in a very short time, usually no later than the first hydrofoil unit. It is a function of fabric open area (measured in cfm). At 2,000 fpm, all the water is gone within 4 feet or 0.12 seconds. This means drainage of 8.33 headboxes/sec. If fiber is added, the initial drainage rate over the forming board would be similar to the water-only drainage rate. This rate would continue until a fiber mat had been formed. This mat would then dictate further drainage and it would be relative to sheet freeness.

FIGURE 6: Action of blade former vs roll former.



How much of the total flow is needed to form a mat – 50%, 20%, 10%? It is likely to be close to 10%. This means that a mat could be formed (as per the previous discussion) in 0.012 sec. or 83 times/sec. Therefore, if this table has a blade space pulse frequency of less than 83 Hz, a filter mat could be formed between each blade to be disturbed by the pressure pulse of the next foil blade. If the pulse frequency is kept above 83 Hz, then the stock has no time to build a filter and is kept constantly agitated until not enough water is left to allow agitation (total sheet set).

FIGURE 7: **Blade former creates varying pressure pulses from blade to blade.**

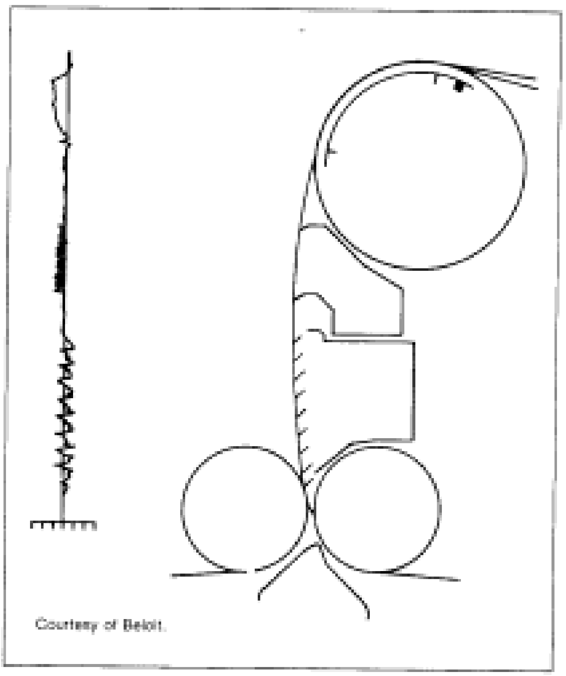
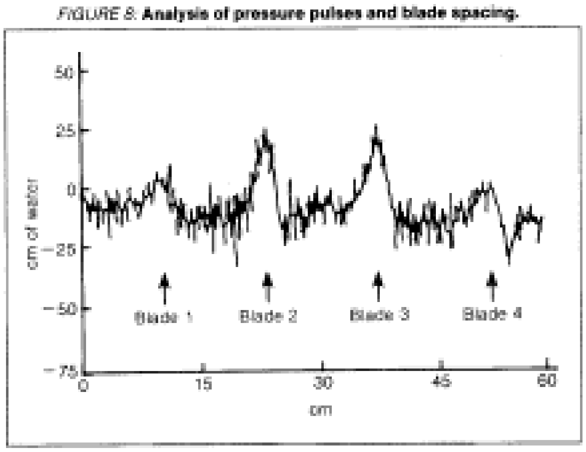


FIGURE 8: **Analysis of pressure pulses and blade spacing.**



Machine builders are trying to overcome the lack of good sheet formation on some hybrid twin-wire formers. Even totally new machines can have relatively poor formation. Machines with a long forming table prior to the top former are typically a problem. Due to the drainage capacity of the twin-wire unit, drainage prior to it is usually delayed, and thus machines with this type of former usually have wide-spaced foils (low frequency). This has a negative effect on formation. Some early table imperfections stay with the sheet and are still seen after the former. On other machines, to obtain early table formation, the sheet arrives too dry at the former, negating its prime purpose.

The latest range of paper machines brings the added former right down to the headbox (for example, Horizontal Bel Baie, Duoformer CF, Valmet HHS). Each of these machines uses a bladed shoe to obtain pulse frequency. The fine paper machine mentioned earlier is an example of this problem being overcome. Stock sampling shows that very little drainage is taking place, even with 24 foil blades and three Vacufoils.

If pulse frequency were high enough, with just enough amplitude, perhaps no sheet mat would be formed, the whole mass being held in suspension but drained slowly at the same time. It is like putting a high-consistency headbox just ahead of the former.

EXISTING MULTI-BLADE TABLE SETUP. The following are suggested guidelines for setting up an existing multi-blade table.

- Determine blade spacing of forming board trailing blades.
- Set the first hydrofoil blade at the same spacing or multiples of forming board trailing blade spacing.
- Set succeeding units at the same spacing or multiples of the previous unit.

It is obvious that if the table is made up of a multitude of odd blade spacing units, not much can be done. But collecting all those units that have uniform spacing or their multiples and placing them in one part of the table will give good pulse frequency and harmonics in that area. The other alternative is to consider a new table of foils.

As always, slower-speed machines are the most difficult. The stock is on the wire for longer periods, allowing more time for flocculation. The slow speed gives only a low pulse frequency number. In this case, it is critical to make sure that unit spacing is correct to enhance harmonics.

One problem must be watched for in setting up an existing table. If different width blades are mixed together on the same unit, setup becomes difficult. For example, a four-blade unit with “tee bars” at 10-in. centers would be a mixture of blade spacings if 2.5-in., 3.5-in., and 4.5-in. blades were used on the same unit. To maintain equal spacing between blades and to enhance harmonics, equal size blades must be used on each unit.