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# Operating Characteristics and Performance Limitations of Circular Saws and Band Saws

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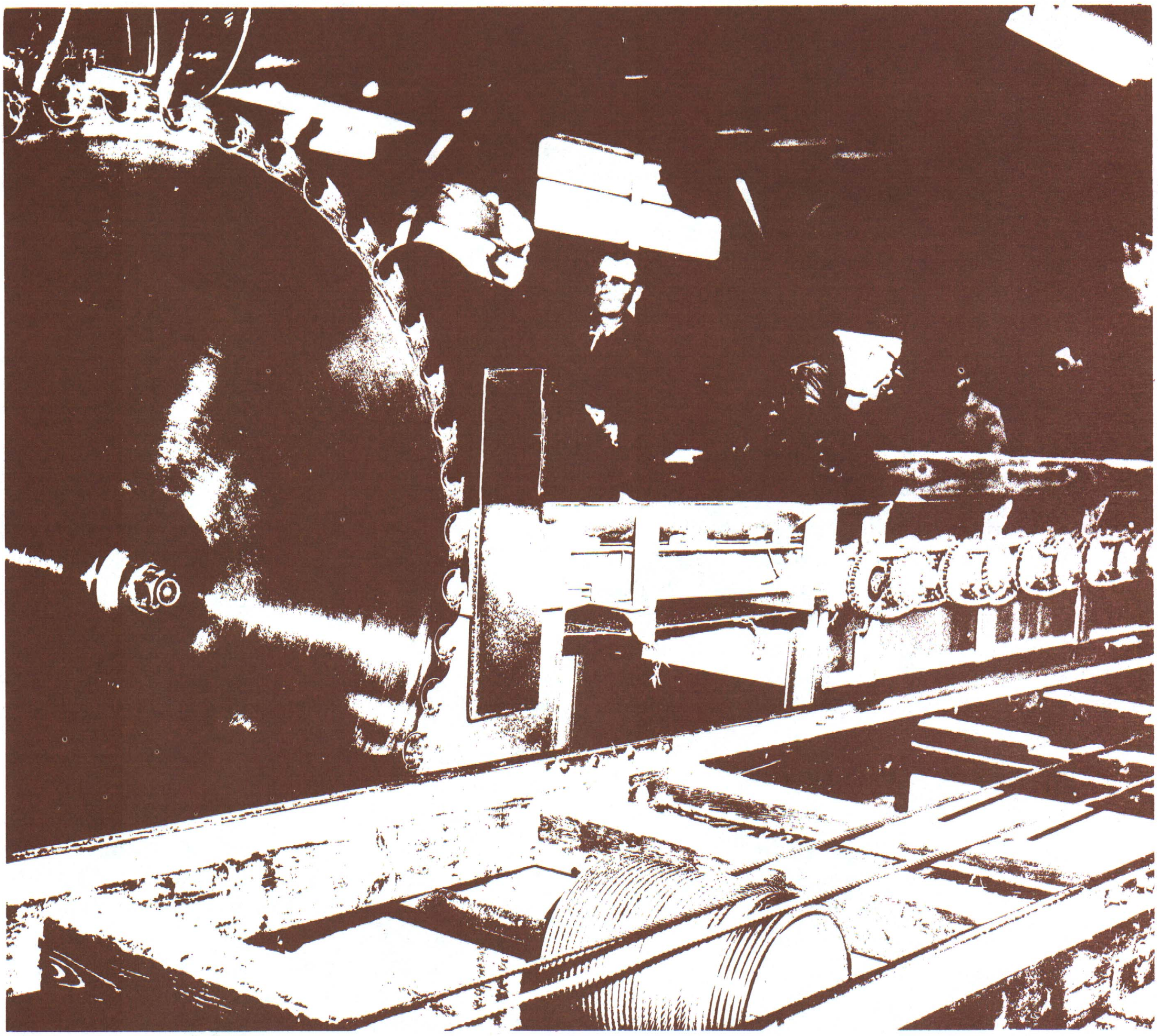

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Selection of saws is a critical decision for the sawmill operator. Saws for circular and band headrigs are manufactured for a variety of operating conditions, depending on such factors as size of sawing machine, size of logs, type of wood, and available power. Any saw is limited to a rather narrow range of conditions. Most sawmill operators learn from experience which saws to select for their particular mills and the type and size of timber normally cut.

Optimum cutting conditions for a given saw can also be derived mathematically (1), and the results of such calculations have been tabulated (2). However, the relationships between the principal variables are complex enough to make it difficult to visualize the blade operating characteristic. Showing these relationships graphically in Figures 1-7 is intended to reduce these difficulties and to assist the operator in the selection and the efficient and safe use of saws.

## SAW CAPACITY

Figure 1 shows a band saw cutting a log of diameter d. The simultaneous movements of saw and log result in each tooth removing a thin slice of wood containing volume $V_t$:

$$V_t\,(\text{in.}^3) = t \cdot d \cdot k \quad (1)$$

where t = tooth bite (in.)
d = depth of cut (in.)
k = kerf width (in.)

The gullet chambers and removes the broken up slice from the cut. When the saw operates at the limits of its capacity, the gullet emerging at the bottom of the log is just filled to a degree that will not cause undue friction in the kerf. Feeding the log faster at the given depth of cut would exceed the gullet capacity. This maximum feed speed (gullet capacity) is determined as:

$$f_g\,(\text{ft./min.}) = \frac{a \cdot c \cdot 0.70}{p \cdot d} \quad (2)$$

where a = gullet area (in.²)
c = speed of tooth (ft./min.)
p = saw pitch (in.)
d = depth of cut (in.)

For a given saw this simplifies to

$$f_g = \frac{C}{d}, \text{ where } C = \frac{a \cdot c \cdot 0.70}{p} = \text{constant.}$$

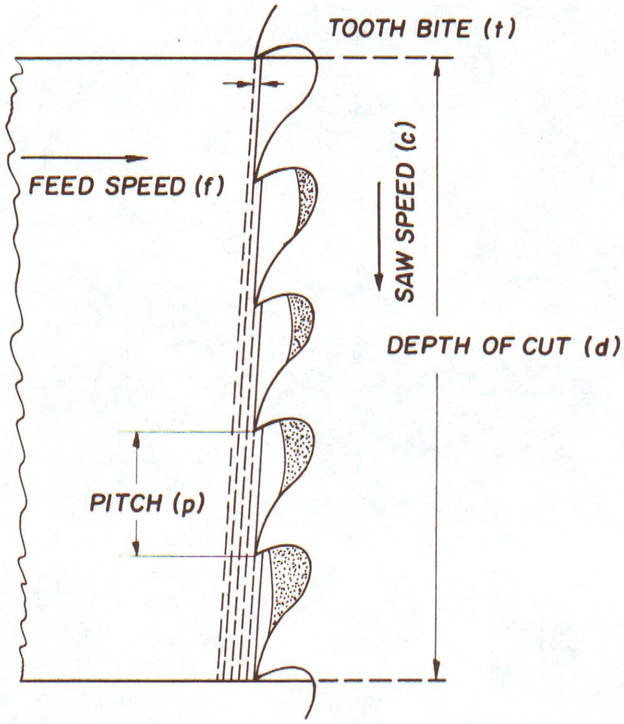


Fig. 1—Cutting Action of band saw.

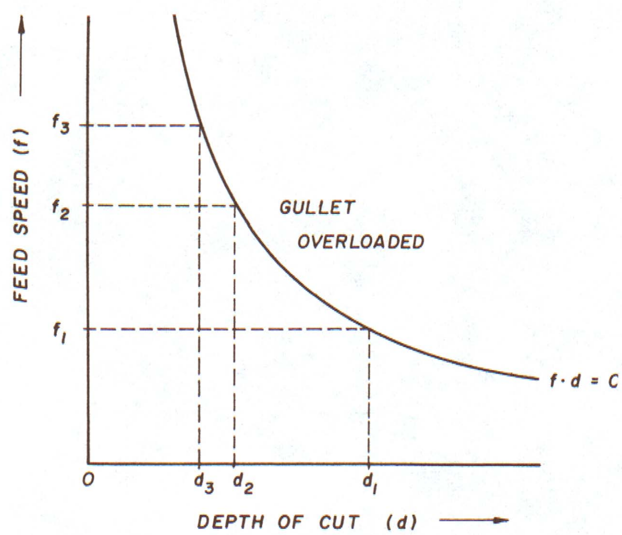


Fig. 2—Characteristic curve of saw indicates relationship between feed speed and depth of cut at gullet capacity.

Thus, in order to cut larger logs (wider faces), the feed speed must be reduced and, conversely, when sawing smaller logs (narrower faces) the feed speed can be increased according to the above relationship. This is illustrated in Figure 2.

At any point along the curve $f_g \cdot d = C$ the saw operates at gullet capacity. Any point to the right of the curve would indicate a feed speed-depth of cut combination that would result in overloading the saw. At any point along the curve, each tooth removes the same volume of wood. At the upper end of the curve, the slices are shorter since $d$ is smaller, but the tooth bite (t) is bigger. At the lower end of the curve, the slices are longer, but the tooth bite is smaller because of the slower feed. There are, however, both upper and lower practical limits to the tooth bite which restrict the optimum operating characteristic of the particular saw to only a portion of the curve.

The upper limit is reached when the tooth bite equals the gauge (g) of the saw (band) or 0.125 in. (circular). Larger tooth bites would subject the teeth to excessive strain. The lower limit is reached when the tooth bite equals the amount of side clearance (set)(s). Smaller tooth bites would generate saw dust particles small enough to spill out of the gullet into the narrow space on each side of the blade. This situation causes crowding and overheating of the saw rim.

$$f_{max}\,(\text{ft./min.}) = \frac{t_{max} \cdot c}{p} \quad (3)$$

$$f_{min}\,(\text{ft./min.}) = \frac{t_{min} \cdot c}{p} \quad (4)$$

where $t_{max}$ = max. tooth bite (in.)
= gauge (g) for band saws
= 0.125 in. for circular saws

$t_{min}$ = min. tooth bite (in.)
= set(s)

c = speed of saw (ft./min.)
p = saw pitch (in.)

## BAND SAWS

Figure 3 shows the operating characteristic of a specific band saw based on specifications listed in (2) and is designated here as saw "A" (see Table 1 on page 4). Gullet and tooth dimensions are shown in Figure 6. The characteristic curve (feed speed at gullet capacity) was calculated according to Equation 2 with one slight modification: d was replaced by $d' = d - .75p$. This is based on the observation illustrated in Figure 4: saw dust is being released from the gullet before the tooth point reaches the bottom of the cut. Therefore, this last part of the depth of cut (.75p) does not contribute to the loading of the gullet and can be subtracted from d (2):

$$f_g\,(\text{ft./min.}) = \frac{a \cdot c \cdot 0.70}{p \cdot (d - 0.75p)} \quad (5)$$

The shaded area in Figure 3 indicates acceptable operating conditions. Feed speed is limited to a range from 230 ft./min. to 360 ft./min. At feed speeds below 230 ft./min., saw dust spills out of the gullets, and the saw rim overheats. At feed speeds above 360 ft./min., the tooth bite exceeds the saw gage and will cause excessive strain on the teeth. At gullet capacity the minimum tooth bite limits the width of the face that can be handled, namely 16.7 in. This saw cannot continuously cut logs of larger diameter without exceeding gullet capacity or spilling saw dust. Both conditions result in overheating. At gullet capacity, the maximum tooth bite controls the minimum size log, namely 11.2 in. diameter. Smaller logs may be cut within the shaded area, but the gullet capacity would be underutilized.

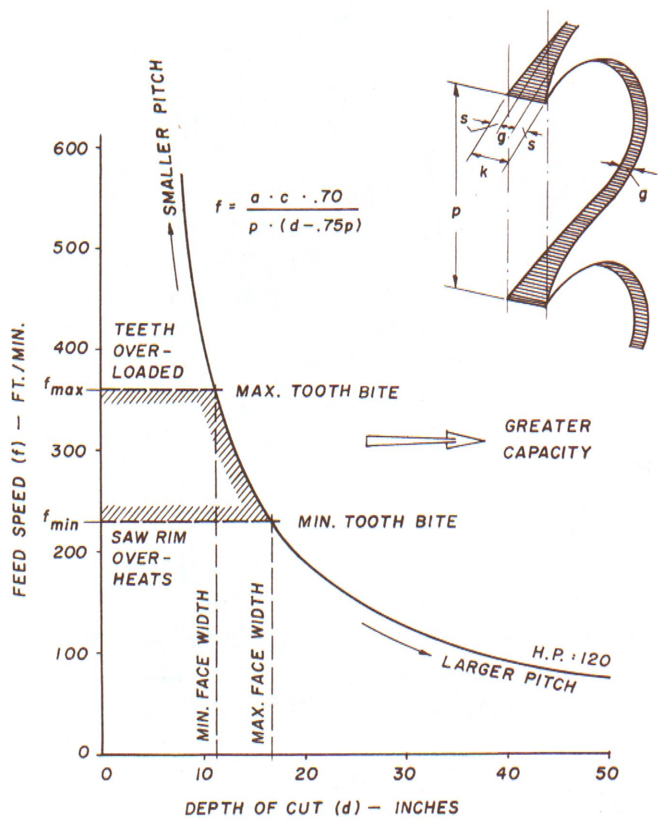


Fig. 3—Operating characteristic of band saw "A".

**Table 1—Specifications of selected band and inserted circular saws. Band saw specifications from Quelch (2).**

| Item | Band saws | | |
|---|---|---|---|
| **Style** | **"A"** | **"B"** | **"C"** |
| Wheel diameter (in) | 72 | 96 | 108 |
| Width of blade (in) | 10 | 15 | 16 |
| Saw speed (ft/min) | 10,000 | 10,000 | 10,000 |
| Gauge (in) | .072 | .095 | .120 |
| Side clearance (set)(in) | .046 | .060 | .065 |
| Kerf (in) | .165 | .217 | .250 |
| Pitch (in) | 2.0 | 2.5 | 4.0 |
| Gullet area (in²) | 1.0 | 1.7 | 3.4 |
| | **Circular Saws** | | |
| **Style** | **"2½"** | **"F"** | **"D"** |
| Blade diameter (in) | 54 | 54 | 54 |
| Number of teeth | 56 | 50 | 36 |
| RPM | 637 | 637 | 637 |
| Rim speed (ft/min) | 9,000 | 9,000 | 9,000 |
| Gauge | 7×8 | 7×8 | 6×7 |
| Side clearance (set) (in) | .058 | .058 | .082 |
| Kerf (in) | .281 | .281 | .344 |
| Gullet area (in²) | 1.5 | 2.0 | 4.0 |

The surface area sawn per minute is about constant along the curve. Therefore, the curve represents a line of constant horse power requirement (2).*

$$H.P. = \frac{0.003 \cdot a \cdot c \cdot 12}{p} \cdot \frac{k}{0.250} \qquad (6)$$

For saw "A":

$$H.P. = \frac{0.003 \cdot 1.0 \cdot 10{,}000 \cdot 12}{2.0} \cdot \frac{0.165}{0.250} =$$

$$= 118.8 \sim 120$$

If the mill was regularly sawing logs of less than 12 in. in diameter, it would be desirable to move the operating range of the saw upward along the curve. This could be done by selecting

*These horse power calculations are based on timber of medium specific gravity. For more specific information on calculating power requirements consult Lunstrum (3) and Williston (4).*

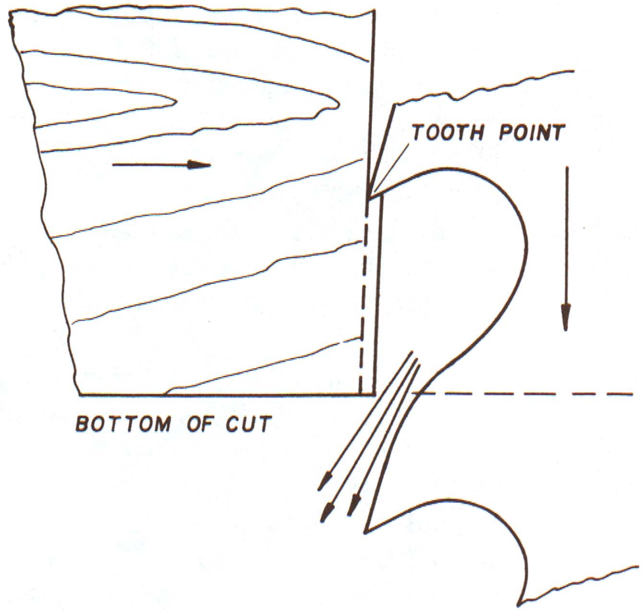


**Fig. 4—Schematic illustration of saw dust release from gullet before tooth point reaches bottom of cut. From Quelch (2).**

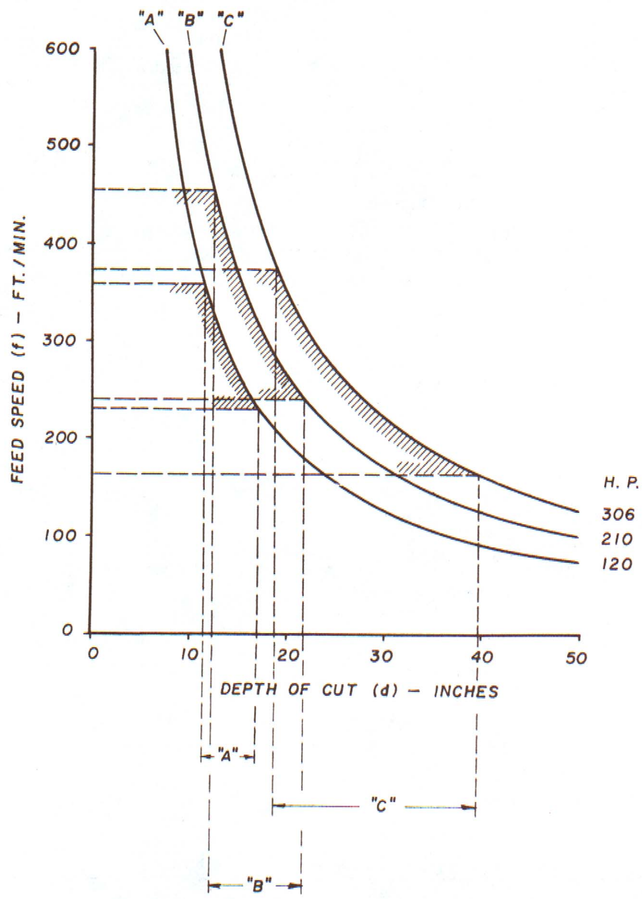


**Fig. 5—Operating characteristics of selected band saws "A", "B", and "C".**

a saw with a smaller pitch which would reduce the tooth bite. If, on the other hand, the mill was shifting towards logs of larger diameters than 17 inches, a saw with larger pitch should be selected. This would increase the tooth bite at decreasing feed speeds.

In order to saw larger logs at high feed speeds, the entire curve would have to shift to the right. That would require larger gullet capacities and more power.

In Figure 5, operating characteristics of saws "B" and "C" are added to that of "A". Gullet dimensions are shown in Figure 6, and other specifications are listed in Table 1.

Saws "B" and "C" have increasingly larger gullet areas, and particularly saw "C" with its large pitch of 4.0 inches is obviously designed for handling large diameter logs. Both gullet depth and pitch must be increased for greater gullet capacity. Increasing the pitch alone would lower feed speeds. Increasing the depth of the gullet weakens the teeth and requires heavier gauge saws for support. Heavier gauge band saws, in turn, need larger diameter wheels to hold bending stresses down. Large gullet capacities at constant saw speed allow the removal of more saw dust per minute. Therefore, as the characteristic curves move towards the right, saw gauge, wheel diameter, horse power, and potential productivity increase.

Table 2 lists potential productivity and horse power efficiency for the three saws. The decrease in efficiency is due to increased kerf. Thus, to consistently saw small logs with saw "C" would waste power and increase kerf losses.

Similar characteristics can easily be developed for any saw if the specifications are known.

**Table 2—Performance characteristics of selected band saws.**

| Characteristic | Band Saws (Style) | | |
|---|---|---|---|
| | "A" | "B" | "C" |
| Max. face width—$d_{max}$ (in) | 16.7 | 22.0 | 39.0 |
| Feed speed at max. face width — $f_{min}$ (ft/min) | 230 | 240 | 162 |
| Productivity at max. face width— $f_{min} \cdot d_{max} / 12$ ($ft^2$/min) | 320 | 440 | 526 |
| Horse power efficiency at max. face width— $f_{min} \cdot d_{max} / 12 / hp$ ($ft^2$/min/hp) | 2.67 | 2.09 | 1.72 |
| Max. feed speed—$f_{max}$ (ft/min) | 360 | 456 | 372 |
| Face width at max. feed speed—$d_{min}$ (in) | 11.2 | 12.3 | 19.0 |
| Productivity at max. feed speed— $f_{max} \cdot d_{min} / 12$ ($ft^2$/min) | 336 | 467 | 599 |
| Horse power efficiency at max. feed speed— $f_{max} \cdot d_{min} / 12 / hp$ ($ft^2$/min/hp) | 2.80 | 2.23 | 1.92 |
| Horse power at gullet capacity (hp) | 120 | 210 | 306 |

## CIRCULAR SAWS WITH INSERTED TEETH

Seven tooth styles are available for circular head saws. Size of gullet ranges from 1.5 $in.^2$ to

**Table 3—Performance characteristics of selected circular saws.**

| Characteristic | Circular Saws (Style) | | |
|---|---|---|---|
| | "2½" | "F" | "D" |
| Max. face width—$d_{max}$ (in) | 21.1 | 27.1 | 37.1 |
| Feed speed at max. face width — $f_{min}$ (ft/min) | 172 | 154 | 157 |
| Productivity at max. face width— $f_{min} \cdot d_{max} / 12$ ($ft^2$/min) | 302 | 348 | 485 |
| Horse power efficiency at max. face width— $f_{min} \cdot d_{max} / 12 / hp$ ($ft^2$/min/hp) | 2.31 | 2.23 | 1.76 |
| Max. feed speed—$f_{max}$ (ft/min) | 371 | 332 | 239 |
| Face width at max. feed speed—$d_{min}$ (in) | 11.4 | 14.2 | 25.4 |
| Productivity at max. feed speed— $f_{max} \cdot d_{min} / 12$ ($ft^2$/min) | 352 | 339 | 506 |
| Horse power efficiency at max. feed speed— $f_{max} \cdot d_{min} / 12 / hp$ ($ft^2$/min/hp) | 2.69 | 2.52 | 1.83 |
| Horse power at gullet capacity (hp) | 131 | 156 | 276 |

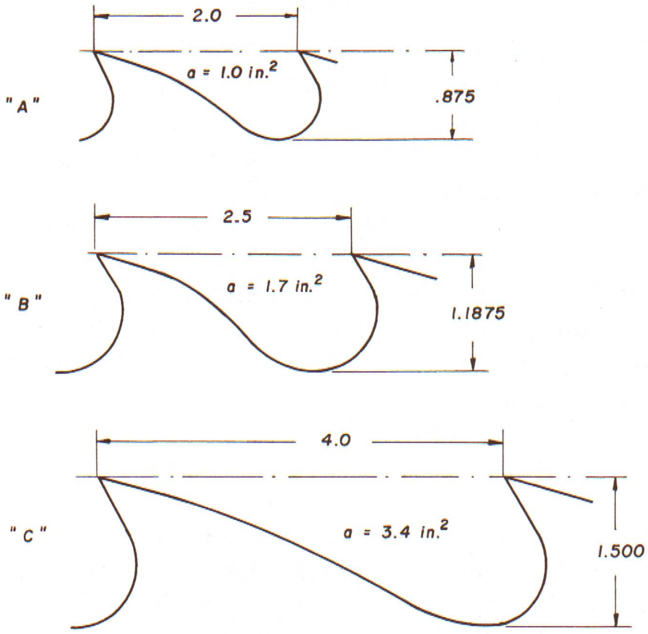


**Fig. 6—Gullet space and tooth dimensions of selected band saws "A", "B", and "C".**

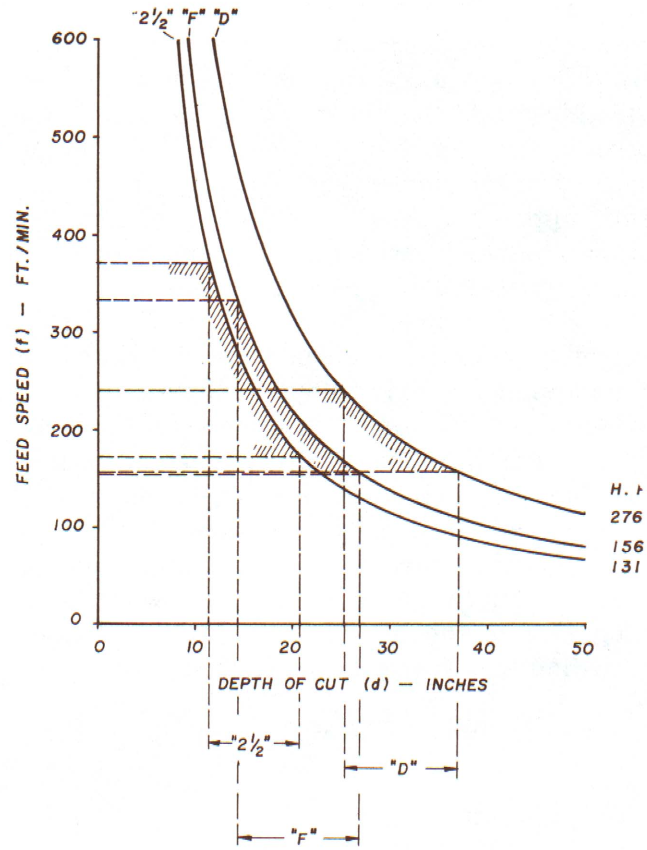


**Fig. 7—Operating characteristics of three standard inserted tooth circular saws.**

4.0 in.² The pitch varies somewhat within each style, depending on saw diameter and number of teeth per saw.

The relationships between saw plate or tooth specifications, log size, and feed speed are the same as those for band saws, except that the maximum tooth bite is considered to be constant (.125 in.) for all tooth styles. The minimum tooth bite is equal to the amount of side clearance (set) as is the case with band saws. The effective depth of cut (d′) in the case of circular saws is equal to d−3.0 rather than d−.75p. Thus, the characteristic curves are calculated as follows (2):

$$f_g\,(\text{ft./min.}) = \frac{a \cdot c \cdot 0.70}{p \cdot (d - 3.0)} \qquad (7)$$

The characteristic curves of three of the seven tooth styles are illustrated in Figure 7. Blade and tooth specifications are listed in Table 1. Feed speeds at maximum and minimum tooth bites were determined according to equations 3 and 4. Horse power was calculated according to equation 6.

Style "D" is clearly identified as a large log diameter saw. The "2½" style is a high feed small log tooth. "F" assumes an intermediate position.

Productivity and horse power efficiency for the three styles are listed in Table 2.

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