ESTIMATING FORCE AND POWER REQUIREMENTS FOR CROSSCUT SHEARING OF ROUNDWOOD

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This paper describes a procedure for estimating the force and hydraulic power required to crosscut shear frozen and unfrozen roundwood of various specific gravities. The designer of prototype equipment can use this method to rapidly estimate the effects of numerous combinations of blade thickness, cutting speed, and hydraulic pressure on the selection of cylinder size, pump delivery, and motor horsepower requirements. Or, if the prime mover has already been selected, the portion of the available horsepower and pump delivery required to effect the cut can be estimated. This is particularly important if other job functions are being performed at the same time as the shearing operation. If maximum component sizes are limited, the designer can determine whether a mechanical advantage between the cylinder rod and shear blade will be required. The owners of existing shear-blade harvesters can estimate the maximum log diameter for each species that can be sheared with their equipment.

The procedure for estimating the force and power requirements is described in the following steps. It is based on a shear study conducted on several northern forest species having specific gravities between 0.30 and 0.65 (Arola 1971). Log diameters in the study ranged from 5 to 10 inches, shear blade thicknesses from ⅛ to ½ inch, and shearing speeds from approximately 2 to 12 inches per second. The effects of shear blade dulling and internal wood temperature on crosscut shearing were also incorporated. A worksheet is provided for the convenience of the estimator.

Step 1.—Determine the following.—

G=specific gravity (based on ovendry weight, green volume) of the species to be crosscut sheared. (Values tabulated in the *Wood Handbook* (USDA Forest Service 1955) can be used for estimating purposes.)

t=shear blade thickness (inches)

D=maximum log diameter to be sheared (inches)

P=desired hydraulic pressure (psi)

V=desired shearing speed (ips) (Recommended range is 2 to 12 inches per second.)

T=estimated lowest temperature of operation (°F.)

Step 2.—Determine the total shear force requirement F_m.—Enter nomograph 1 at the appropriate wood specific gravity *G* and follow this value up to the selected blade thickness *t* (see example). At this intercept follow a horizontal line to intercept the maximum log diameter *D* to be sheared and then along a vertical line to determine the total shearing force F_m required to effect the cut.[1] Based on a previous shearing study (Arola 1971), shearing force values in nomograph 1 have been adjusted to approximate the 95-percent upper confidence limits on a single estimate plus a 15-percent increase in force due to moderate blade dulling (approximated by a 1/32-inch flat along the entire cutting edge).

Step 3.—Correct the shear force for temperature $F_{c/t}$.—The total shearing force as determined in Step 2 is for an approximate temperature of 60°F. This value must be corrected for shearing at lower temperatures—particularly for frozen wood. Increases in force for aspen, white spruce, and hard maple sheared at temperatures down to 0°F. range from 10 to 32 lbs./in. width of cut per °F. drop in temperature (Arola 1971). An average unit value of 20 lbs./in. width of cut per °F. is recommended as a multiplier of the anticipated temperature drop and maximum log diameter. Though not reported in the same manner, this estimate of the effect of low temperatures compares favorably with those of other investigators (Johnston 1968.[2] Thus,

$$F_{c/t} = F_m + 20\,(60\text{-}T)\,D.$$

Step 4.—Determine the cylinder size d.—Locate the maximum shearing force $F_{c/t}$ from Step 3 on nomograph 2 and the desired operating pressure *P*. Place a straight edge along these two values to find the intercept that

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[1] *Shear force requirements for blade thicknesses greater than ½ inch and log diameters in excess of 10 inches were extrapolated from experimental data.*

[2] *M. Wiklund. Temperature measurement in the living tree. Paper presented at IUFRO Meeting, Madison, Wis. 1971.*

determines the piston diameter d. If this is not a standard cylinder size select the next higher diameter. This selection procedure assumes a direct relationship between the maximum force requirement and the hydraulic cylinder. If a mechanical linkage is provided that voids this assumption, the force on the cylinder must be adjusted accordingly.

Step 5.—Determine the hydraulic oil flow rate Q.—The intercept for hydraulic oil flow rate Q is determined from nomograph 3 by placing a straight edge on the piston diameter d determined from Step 4 and the desired shearing speed V.

Step 6.—Determine the theoretical motor horsepower requirements HP_t.—To determine the theoretical horsepower of the motor to drive the hydraulic pump (assuming 100-percent overall efficiency of the pump), the straight line intercept on the horsepower scale (nomograph 4) is found by connecting the flow rate Q from Step 5 and the desired hydraulic pressure P from Step 1.

Step 7.—Adjust the motor horsepower for the overall efficiency of the pump HP_e.—The horsepower requirement (Step 6) must be adjusted for the overall efficiency e of the hydraulic pump (product of volumetric and mechanical efficiencies). The manufacturer's performance curves for the particular pump should be consulted. However, in lieu of the actual performance curves, the approximate values of overall pump efficiency from table 1 can be used for estimating purposes (Kaufman 1968). For mobile equipment applications the balanced vane pump having fixed displacement has become the most universally accepted because of high operational speeds and pressures. The adjusted motor horsepower is determined as follows:

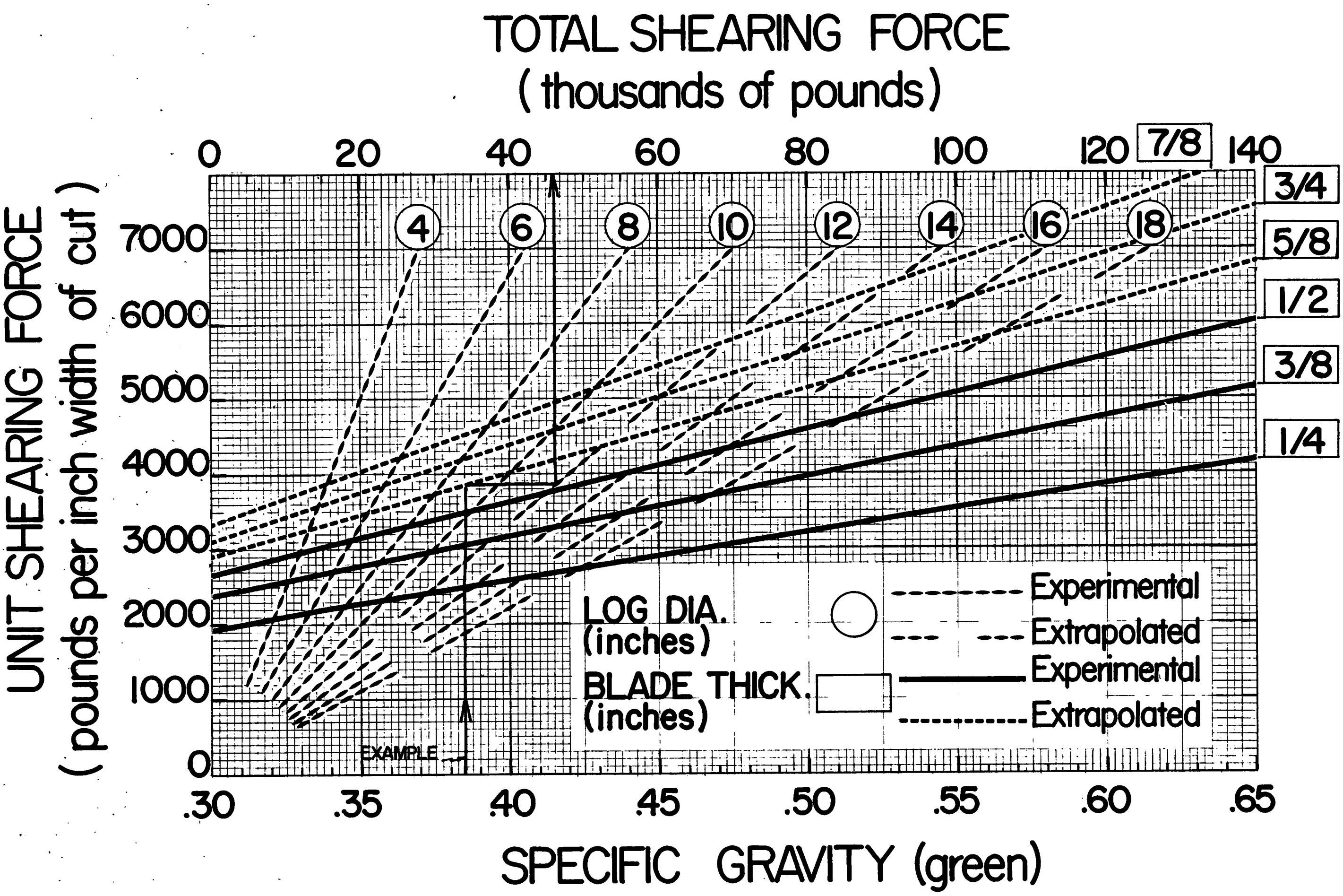
$$HP_e = \frac{HP_t}{e}$$

The estimator should be aware that line losses from the pump to the cylinder may decrease the usable hydraulic pressure in the cylinder by 10 to 25 percent (Anonymous 1967).

Table 1.—*Pump comparison*

Pump type	Pressure rating (P)	Overall efficiency (e)	Weight	Rated speed
	psi	Percent	Lbs. per HP	rpm
External gear	2,000 - 3,000	80 - 90	0.5	1,200 - 2,500
Internal gear	500 - 2,000	60 - 85	.5	1,200 - 2,500
Vane	1,000 - 2,000	80 - 95	.5	1,200 - 1,800
Axial piston	2,000 - 10,000	90 - 98	.25	1,200 - 3,600
Radial piston	3,000 - 10,000	85 - 95	.35	1,200 - 1,800

NOMOGRAPH 1

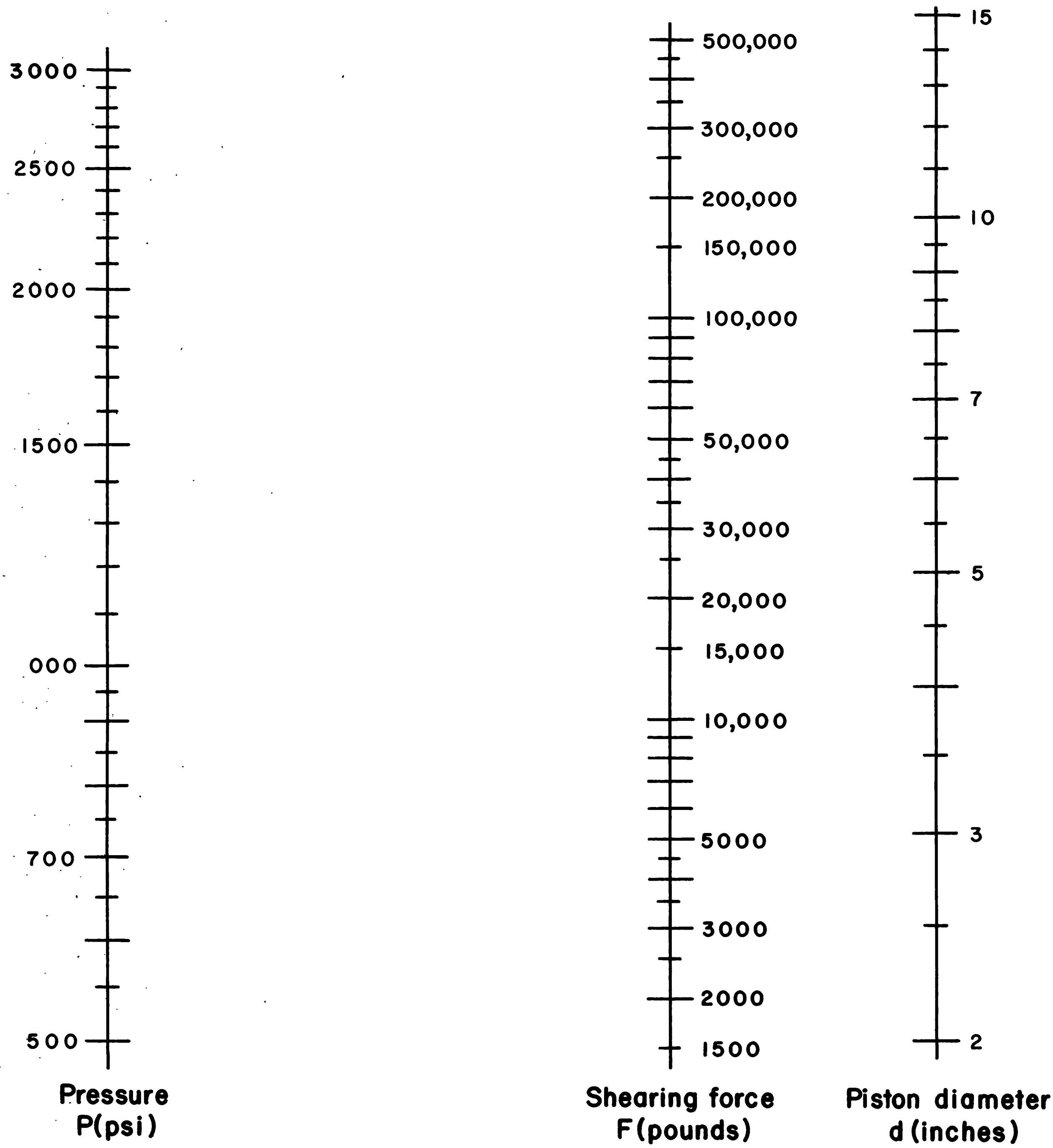


TOTAL SHEARING FORCE
(thousands of pounds)
0
20
40
60
80
100
120
140
7/8
3/4
5/8
1/2
3/8
1/4
4
6
8
10
12
14
16
18
UNIT SHEARING FORCE
(pounds per inch width of cut)
7000
6000
5000
4000
3000
2000
1000
0
EXAMPLE
LOG DIA. (inches)
BLADE THICK. (inches)
Experimental
Extrapolated
Experimental
Extrapolated
.30
.35
.40
.45
.50
.55
.60
.65
SPECIFIC GRAVITY (green)

NOMOGRAPH 2

CYLINDER SIZE

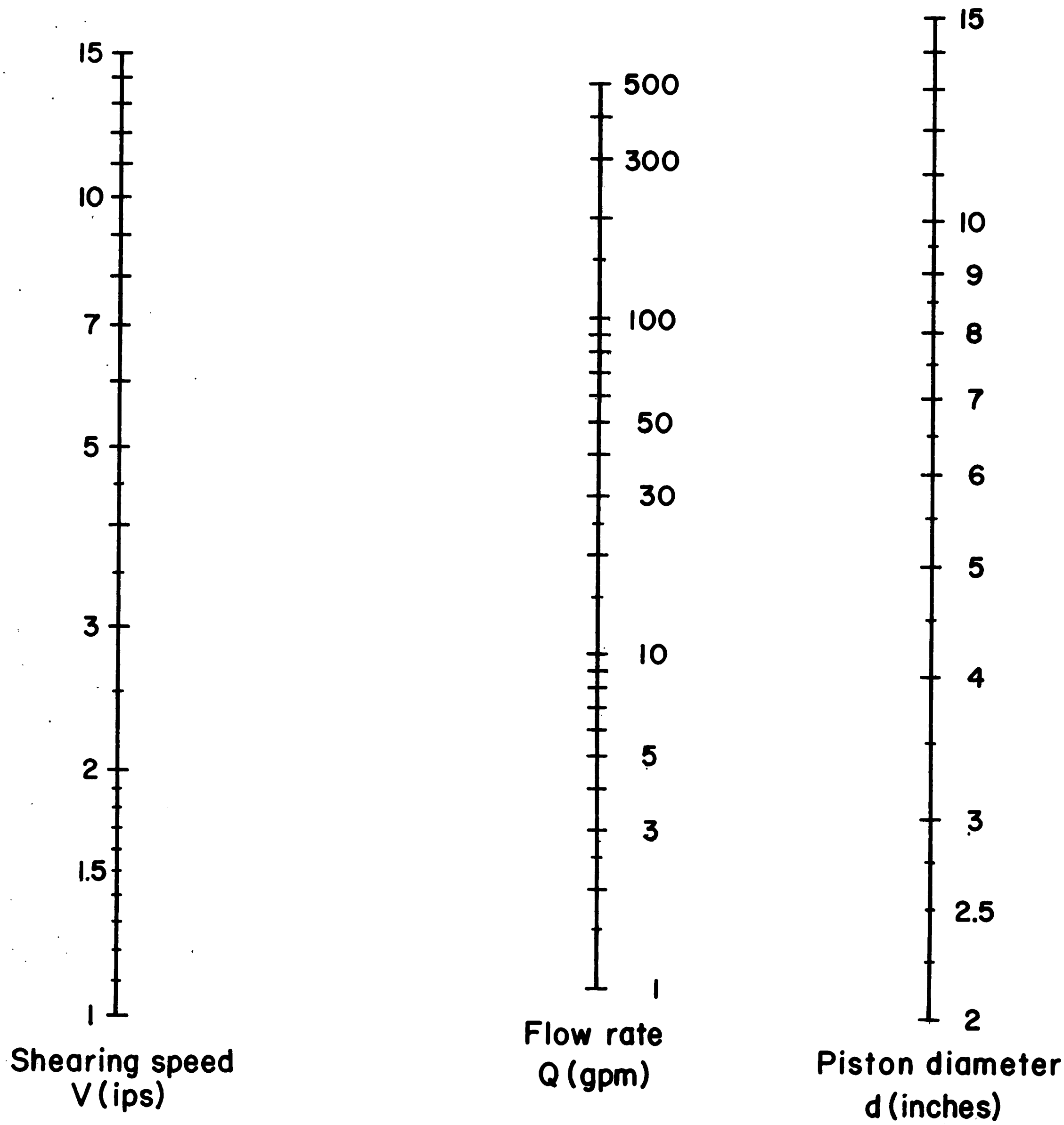
SOLVES: $d = 2\sqrt{\frac{F}{P\pi}}$



NOMOGRAPH 3

FLOW RATE

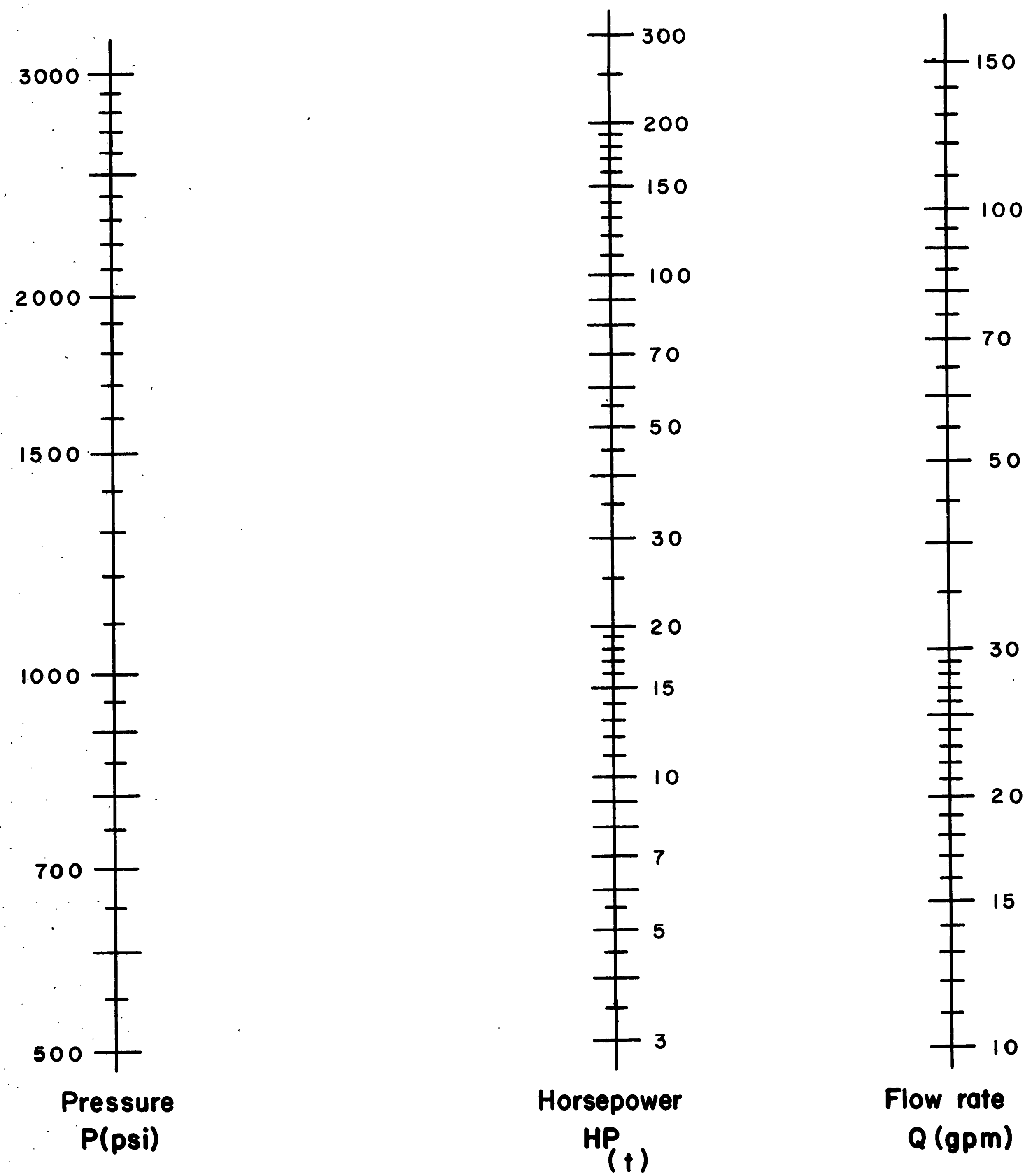
SOLVES: $Q = 0.204\, V d^2$



NOMOGRAPH 4

THEORETICAL PUMP OR MOTOR HORSEPOWER

SOLVES: $HP_{(t)} = \frac{PQ}{1714}$



SHEAR FORCE AND POWER REQUIREMENT WORKSHEET

STEP 1. Determine advance requirements:

Specific gravity of wood to be crosscut sheared (based on ovendry weight, green volume) $G=$ ______________

Shear blade thickness $t=$ ______________ inches

Maximum log diameter to be sheared $D=$ ______________ inches

Hydraulic pressure $P=$ ______________ psi

Desired shearing velocity $V=$ ______________ ips

Estimated lowest wood temperature to be encountered $T=$ ______________ °F.

STEP 2. Determine total shear force requirements:

From Nomograph 1
Total shear force $F_m=$ ______________ pounds

STEP 3. Correct shear force for low temperature:

From Formula $F_{c/t} = F_m + 20(60-T)D$
Total shear force corrected for temperature $F_{c/t}=$ ______________ pounds

STEP 4. Determine hydraulic cylinder size:

From Nomograph 2
Piston diameter $d=$ ______________ inches

STEP 5. Determine hydraulic oil flow rate:

From Nomograph 3
Flow rate $Q=$ ______________ gpm

STEP 6. Determine theoretical motor HP requirement:

From Nomograph 4
Theoretical motor HP $HP_t=$ ______________

STEP 7. Adjust motor HP for overall efficiency of pump:

From formula $HP_e = \frac{HP_t}{e}$

Adjusted motor HP $HP_e=$ ______________

LITERATURE CITED

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