CHANNELING IN BLEACH TOWERS

AND

FRICTION LOSSES IN PULP STOCK LINES

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Production people are continually plagued with pump suctions plugging, with plugging broke pulpers, with high density lines plugging and jumping so badly they can hardly be anchored, with stock pumps that are not properly sized, and with chlorination towers and high density towers channeling. The remedy in some cases is to cut the impeller; however, if the line is a very long line the pump probably would not be large enough so one has to lower the consistency further than desired. It is possible to pump 5% stock inremittently through a one inch line without plugging and it is practical to pump any consistency stock up to 18% bone dry through any reasonable sized lines without encountering pumping problems.

To eliminate plugging and channeling problems one must exceed a critical velocity; the velocity at which the internal shear of the stock exceeds the wall friction, or else a diameter velocity relationship, Pseudo Reynolds number, must be large enough so that the stock plug is beginning to break up around the outside edge of the plug. Stock flow will never be turbulent above 2% at normal pumping rates.

The attached charts show friction losses on the ordinate as feet of water per 100 feet of pipe at a particular pipe diameter. The horizontal coordinate is gallons per minute. Note the enclosed region labeled "Pulsing and Plugging". Any time the flow gets into that region due to high consistency or low flows, the flow will either plug or start pulsing if one is pumping high consistency stock. When low or medium consistency stock is being pumped too slow the line will either plug in a pump suction or in a turn where gravity and centrifugal force compliment each other such as the outside of an elbow. In many cases stock pump suctions have been made too large. Stay out of the "Pulsing and Plugging" region. The lower right hand portion of the curves are labeled "semi-turbulent", this is a safe region as is the upper portion labeled "plug flow". Note the line labeled critical velocity and F = 1 and F = .8 then critical Ré and F = 1 and F = .8. Both these lines shift slightly with the type stock, pH, and temperature. In most cases if one stays outside either band on low flow he is safe. In a critical case one can calculate F.

The same comments apply to the chart for channeling in tile lined towers except that the vertical coordinate is for consistency and the bottom coordinate is for both velocity and diameter times velocity. For critical velocity read the horizontal ordinate as velocity and for the critical pseudo Ré read the horizontal ordinate as $D_F V$ when the diameter is in feet. Stay in the semi-turbulent flow or plug flow region. Note that consistency is quite critical if channeling is to be prevented and that consistencies of 6 to 9 per cent are most dangerous. In plug flow enough shearing must occur at the sidewalls to create a dewatered zone. This shearing occurs in the stock. The other type flow which one encounters that is stable is semi-turbulent flow, or mixed flow. As the velocity increases, shearing occurs further in from the outside edges and forms a turbulent annulus but the center still travels as a plug. Since for stable non-turbulent flows, stock shear is the failure point, a formula can be developed for stock consistencies from 2% to 18% bone dry. This formula is:

$$\Delta H = \frac{5.4\ FC^{2.5}V^{.15}}{D}$$

or

$$\Delta H = \frac{4.72\ F\ Q^{.15}C^{2.5}}{D^{1.3}}$$

UPFLOW TOWER

C = % Cons. BD
D = Diameter (inches)
Q = GPM
V = Velocity ft/sec.
$F = F_1 \times F_2 \times F_3$ where
F_1 = Factor for type stock
F_2 = Factor for pH
F_3 = Factor for temperature (100^oF = 1.0)

If stock flow is not in semi-turbulent flow at low consistencies a line will plug or a tower will channel. Note that both diameter and velocity are important in determining whether the stock flow is semi-turbulent or not. These charts indicate that 5% stock can be readily pumped through a relatively long one inch line containing several standard elbows, as far as 50 feet, if the velocity is high when the stock is moving. The author has pumped stock under these conditions inremittently such as to a sampler without flushing the line and without plugging over a period of six years, whereas a similar line regularly plugged when stock was metered through the line with a positive displacement pump because of the low velocity. The data indicates that most chlorination towers and some bleach towers channel. It indicates that the consistency must be kept high to keep bleach towers from channeling and that hardwood will channel worse than pine. The data also indicates that stock will eventually plug any line at any consistency if the velocity is continuously kept relatively low. Conversely it indicates that any consistency up to about 20% can be safely pumped in almost any size line if an adequate velocity is maintained, and it indicates that stock pump suction sizes should be reduced to a size equal to or only slightly larger than the discharge size because most stock lines plug in the pump suction.

Preliminary correlations of Brecht and Heller data were first published in 1952(1). Later this data was published as the Gould's curves. Unfortunately the diameter range of this experimental work covered only 6 and 7 inch pipe. Durst and Jenness continued their investigations under TAPPI Research Grant No. 64 and published another paper in 1954(2) and in 1955(3). These papers indicated that the Gould's curves were correct only in a narrow range for a pipe near a 6 inch diameter. Figure 1 indicates the deviation of several stock curves from the actual data.

Durst and Jenness proposed that internal shear values be determined with a simple rotor for various pulps and that these shear curves be used instead of the original curves. The test was simple but the presentation required considerable work to extract friction losses. Since the Gould's curves seemed to fit closer than any other data, the industry continued to use these curves because in many applications pipe friction is only a small portion of the system friction.

As stock lines became longer and pipe diameters increased, discrepancy began to become more apparent. The writer was involved and sold pulp through one 6 inch line about 2300 feet long and another 12 inch line about 1300 feet long. Since stock was measured wet the flow and consistency had to be known such that the total monthly billing error was less than 1/4 per cent. These systems were sampled with two rather long one inch lines containing standard elbows and valves. It was obvious from these data that the standard curves were off as much as threefold in certain areas, and in fact they would have predicted that 5% consistency stock would not flow through a one inch line, yet even though the flow was inremittent, the one inch line never plugged. At the 1968

TAPPI Engineering Conference, a paper was given[4] suggesting that another company had found the standard curves in error 100 per cent. The writer began to review his data and other data in an effort to correlate friction losses. Robertson and Mason presented a paper[5] in 1957 in which they found that stock flowed in lines either as a plug flow, as a mixed flow or semi-turbulent flow, and under some conditions as turbulent flow. At one per cent consistency the velocity had to exceed 5.7 feet/second to be turbulent; therefore, the industry would not encounter turbulent flow at consistencies above 2% under any normal conditions because it would require flows faster than 12 feet per second.

After reviewing all available data, it became obvious that there was a critical velocity at which the sidewall friction or the stock to wall friction exceeded the internal shear. At higher velocities stock to stock shear became greater and at lower velocities stock to wall friction became greater. When the stock to wall friction exceeded the internal stock shear the stock would not shear along the walls but away from the walls; when the stock sheared low consistency stock formed along the shear plane thus dewatering stock on both sides away from the shear plane. This higher consistency stock near the wall was even harder to shear and thus shearing moved more toward the center of the pipe or tower with the annulus of high consistency stock on the outside of the pipe increasing in consistency until the consistency reached about 20% then the hole began to get smaller until in a bleach tower channeling occurred. It was evident that channeling was worse on hardwood pulp and at lower consistencies in high density stock. If the slow flowing stock was in a pipe line at high consistency the stock would start to pulse causing the line to pound severely and in numerous cases the line eventually plugged. This critical velocity seemed to fit the formula:

	$C^{1.5}V^{.15} = \frac{9.05}{F}$	for tile lined towers
and	$C^{1.5}V^{.5} = \frac{15.17}{F}$	for stainless steel pipe

CRITICAL VELOCITY

$\left(\frac{C^{1.5} F}{15.17}\right)^2$

where

C = % consistency bone dry
V = velocity (ft/sec)
$F = F_1 \times F_2 \times F_3$
F_1 = Factor for type of stock
F_2 = Factor for pH
F_3 = Factor for temperature ($100^\circ F = 1$)

At low consistencies, around 3 per cent, it seemed that stock channeled worse as the consistency rose and worse on pine stock. This required another term or a Pseudo Reynolds Number. This is a critical diameter time velocity when the plug starts breaking or shearing at the edges and semi-turbulent flow results. No normal pumping conditions above 2% consistency will be found to be turbulent under mill operating conditions. The formula for this critical Pseudo Reynolds seems to fit the following formula above 2%:

$$\text{Critical } R\acute{e} \cong F12{,}900\ C^{1.22}$$

where $R\acute{e} = 1488 D_F V \rho$

C = % consistency bone dry
$F = F_1 \times F_2 \times F_3$
D_F = Diameter (feet)
V = Velocity (ft/sec)
ρ = Density ($\#/ft^3$)

The following fittings have approximately the loss listed below.

	Equivalent Length
Elbow short radius	12 diameters
Elbow medium radius	10 diameters
Elbow long radius	7 diameters
Tee	12 diameters

For elbow or tee where the turn is more vertical double the equivalent length.

There are three factors that markedly affect the flow properties of pulp stock. These are type of pulp, pH of pulp, and temperature of the pulp. Freeness also has a fairly large effect at the extreme end of the spectrum. Coarse fiber bundles resistance goes up and very low freeness stock, perhaps 100 freeness, goes down. The first factor F_1 is a factor for the type stock. These factors are the best available at present.

Type Stock	Factor F_1
Bagasse	.70
Bleached Sulfite	.75
Unbleached Sulfite	.80
Hardwood Sulfate	.80
Bleached Soda Pulp	.90
NSSC Pulp (below 700 CSF)	.90
Unbleached Soda Pulp	1.0
Pine Sulfate bleachable grades	1.0
Pine Sulfate coarse grades (refined)	1.0
(700 CSF)	1.2
Waste paper (chemical)	1.1
Newsprint	1.1
Chemical Groundwood	1.1
NSSC Pulp (above 700 CSF)	1.1
Canadian Kraft Liner (unrefined)	1.3
Groundwood Pulp (unscreened)	1.5
(screened)	1.2

The second factor F_2 refers to pH.

pH Range	Factor F_2
pH above 8.5	0.7
pH below 8.5	1.0

The third factor, F_3, refers to stock temperature and all curves are based on 100°F.

$F_3 = 1.6 - .006T$ $\qquad$ T = Temperature °F.

Example:

Pine Pulp in tile towers

at 12% consistency and V = .0001 ft/sec.

pulp will channel

at 12% consistency and V = .008 ft/sec.

pulp will flow as plug and not channel but note hardwood velocity must be .00115 ft/sec. or higher to prevent channeling.

at 4.3% consistency

if $D_F V$ is greater than 0.49 ft/sec. pulp will not channel. If it is below 0.49 ft/sec. pulp will channel.

Pine Pulp in Stainless Steel Line

at 12% consistency if V is less than .04 ft/sec. the line will plug. If it is greater than .04 ft/sec. stock will flow as a plug.

at 8% Consistency

if $DV > 1.77$ ft/sec. flow is semi-turbulent

if $DV < 1.77$ and $V > 2.5$ ft/sec. flow will be plug flow with no plugging.

if $DV < 1.77$ and $V < 2.5$ ft/sec. the line will plug.

at 2% consistency

if $DV > .315$ ft-ft/sec. flow is semi-turbulent

if $DV < .315$ ft-ft/sec. stock will plug in the line

at 5% Consistency

in a one inch line $D = 1/12$

DV must be greater than 1

or V must exceed 12 ft/sec. to prevent plugging; however, pumping may be inremittent.

LITERATURE CITED

1. Durst, R. E., Chase, Andrew J., and Jenness, Lyle C., _TAPPI_ 35, No. 12: 529-535 (1952).

2. Durst, Richard E., Jenness, Lyle C., _TAPPI_ 37, No. 10: 417-422 (1954).

3. Durst, Richard E., Jenness, Lyle C., _TAPPI_ 38, No. 4: 193-198 (1955).

4. Unpublished.

5. Robertson, A. A., Mason, S. G., _TAPPI_ 40, No. 5: 326-334 (1957).

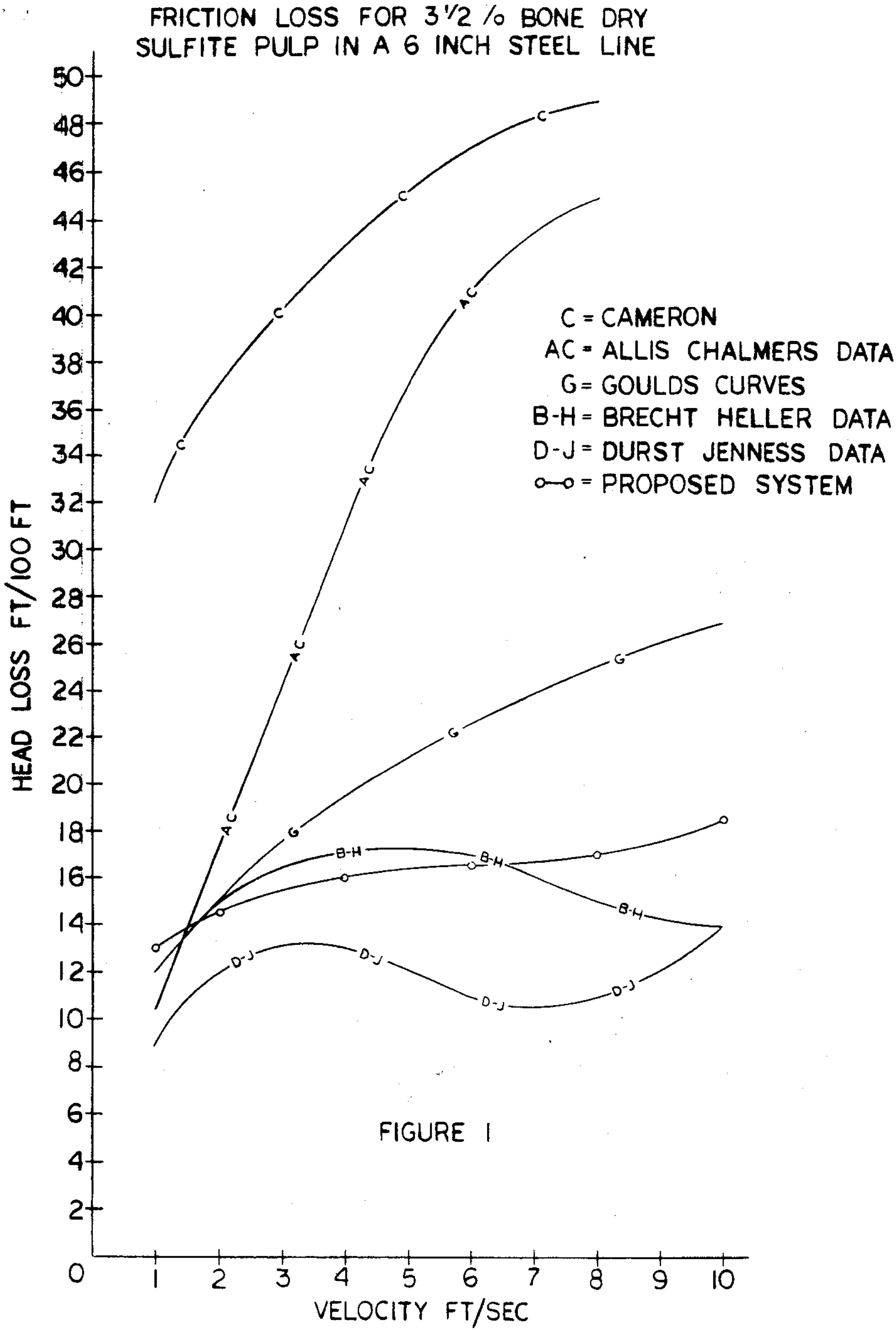
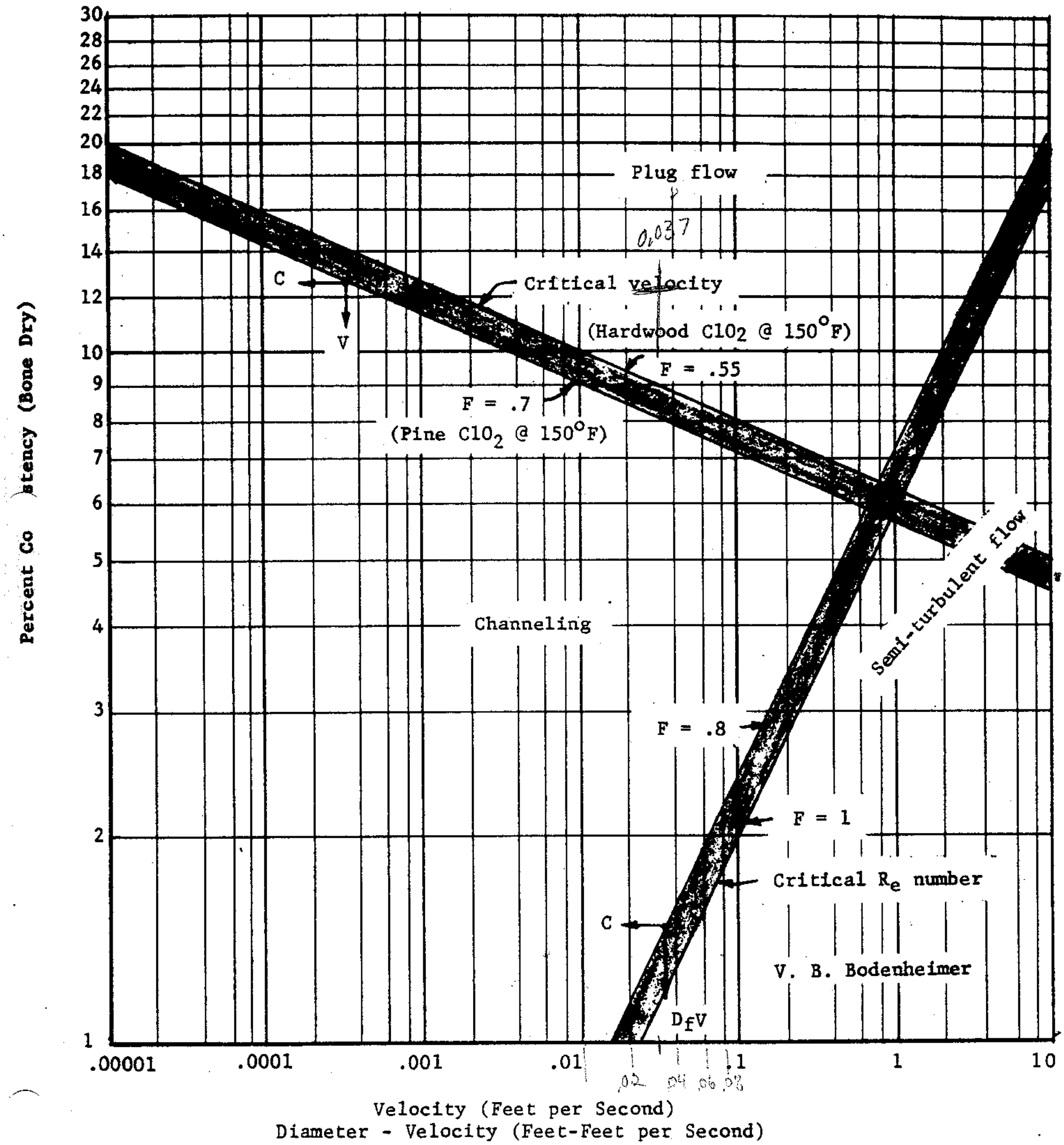
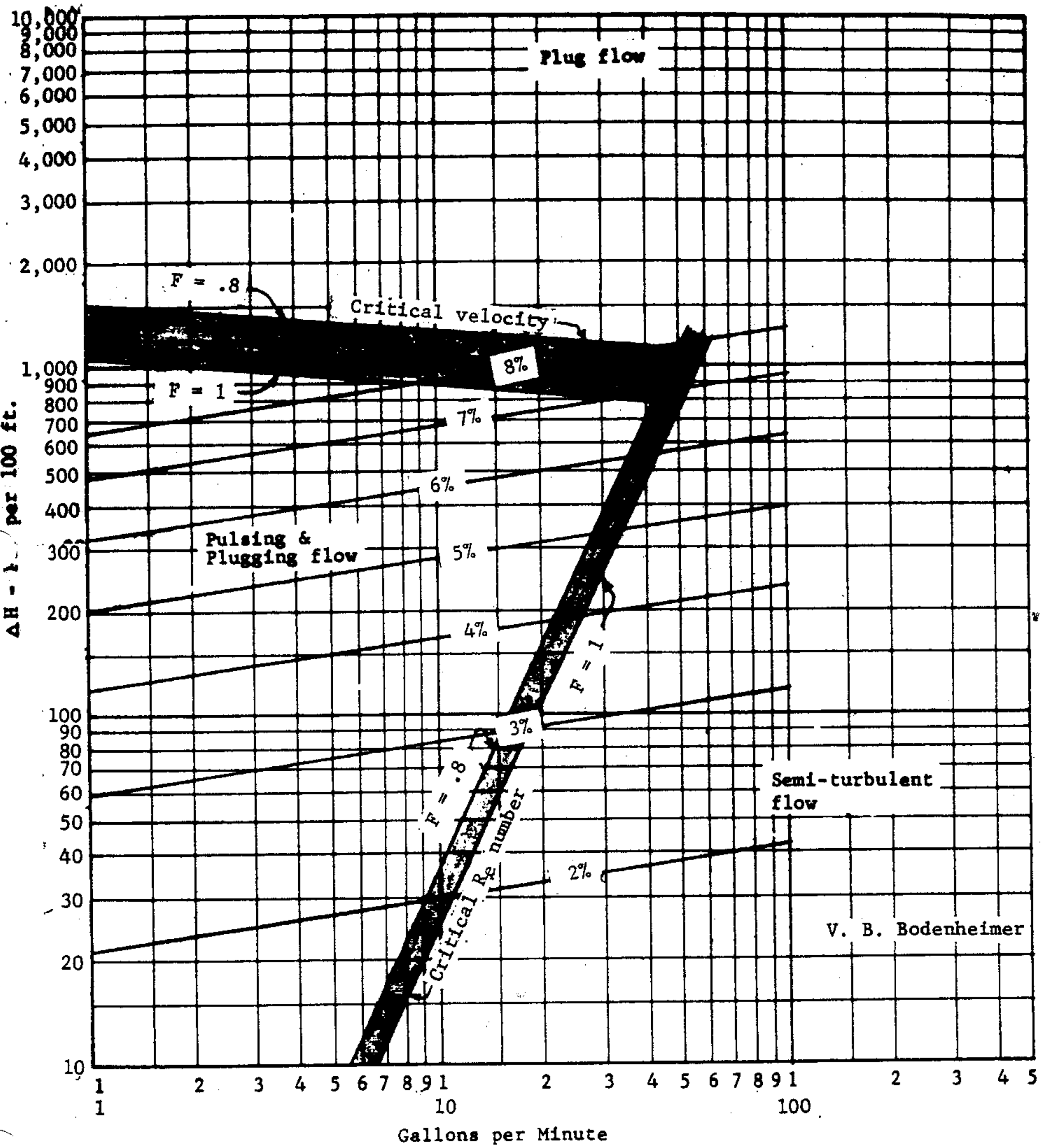

FRICTION LOSS FOR 3 1/2 % BONE DRY
SULFITE PULP IN A 6 INCH STEEL LINE
HEAD LOSS FT/100 FT
VELOCITY FT/SEC
C = CAMERON
AC = ALLIS CHALMERS DATA
G = GOULDS CURVES
B-H = BRECHT HELLER DATA
D-J = DURST JENNESS DATA
o—o = PROPOSED SYSTEM

FIGURE 1

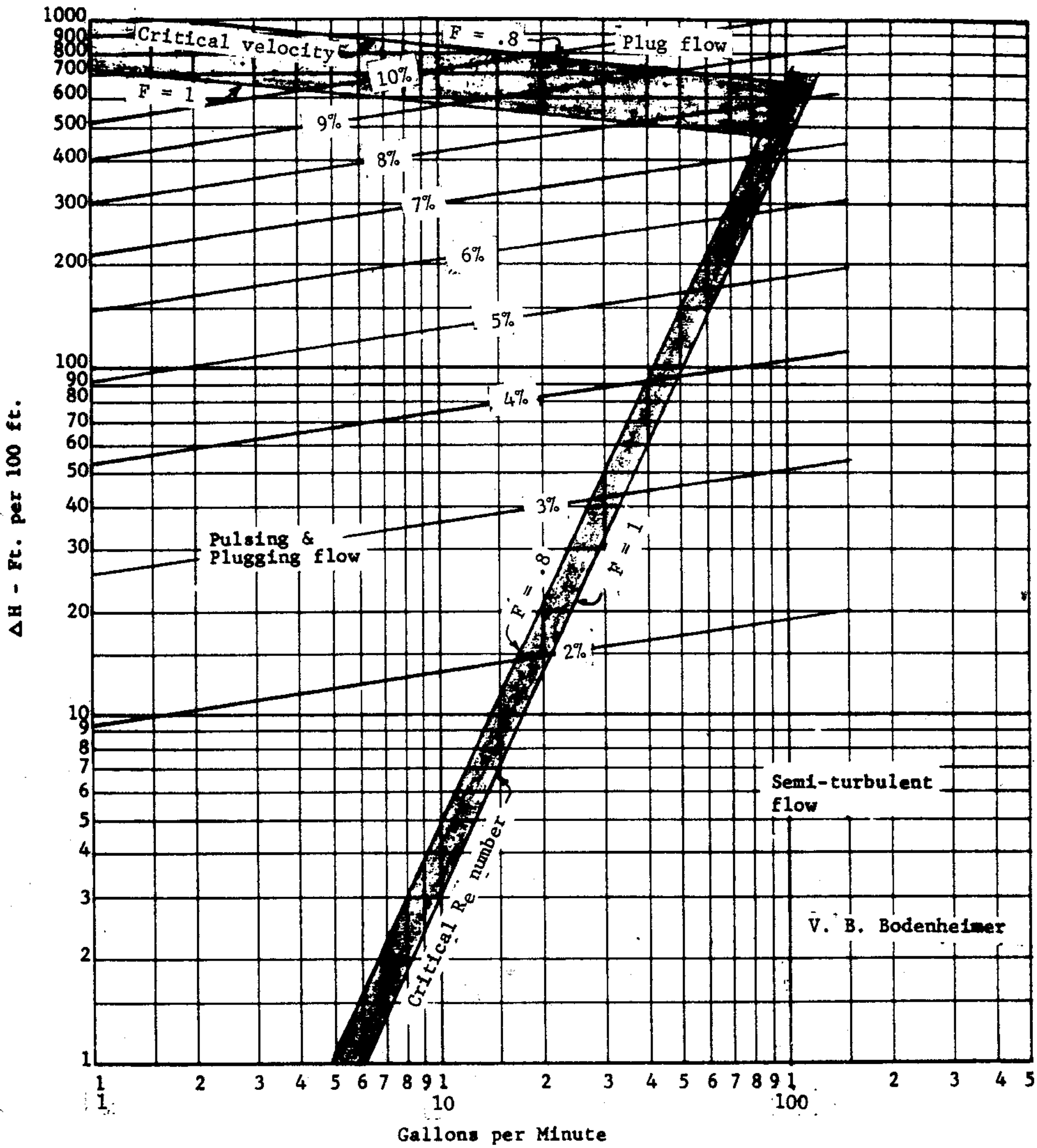
CHANNELING IN TILE LINED TOWERS



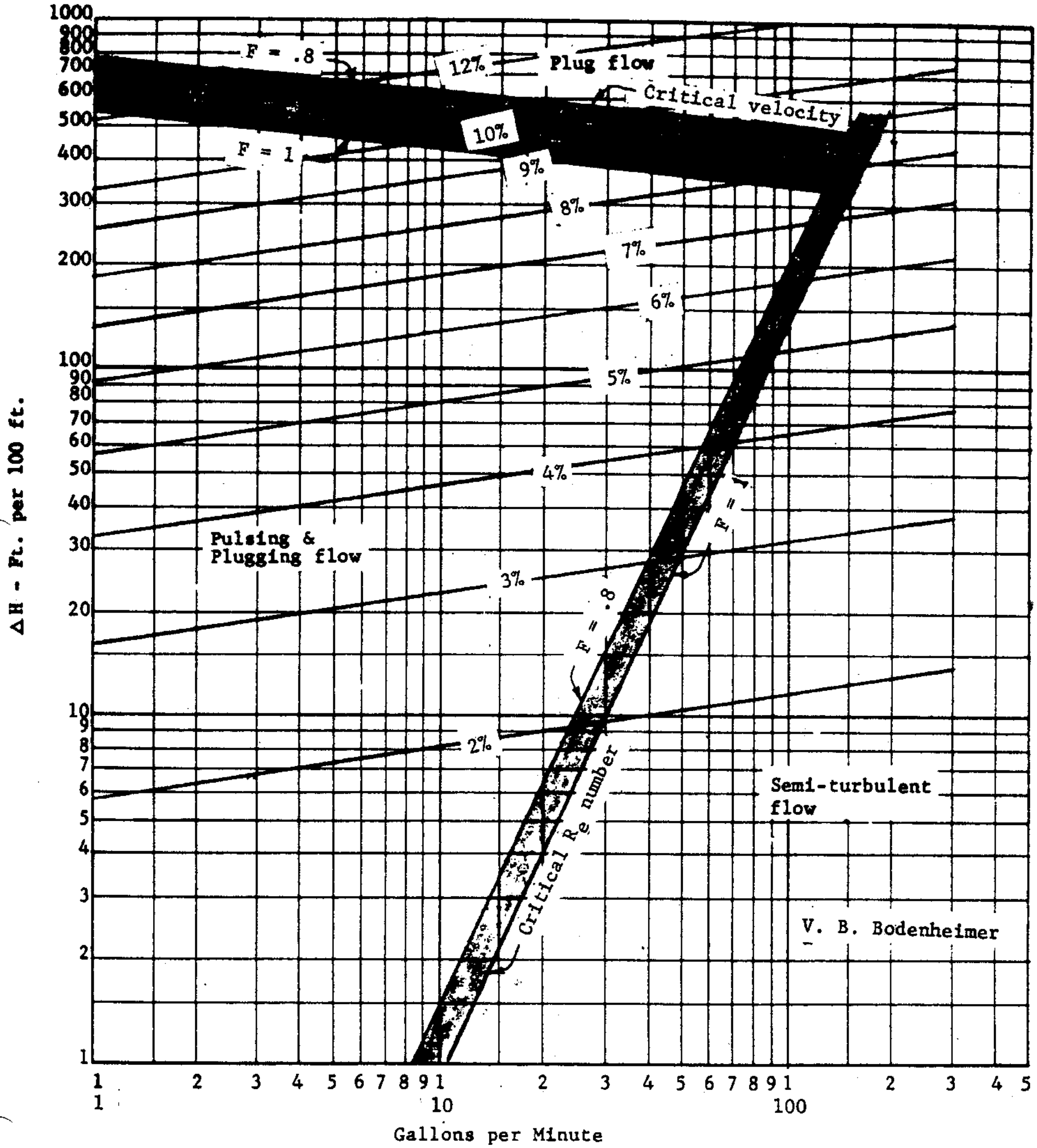
FRICTION LOSS IN 1.097" I. D. STAINLESS STEEL PIPE



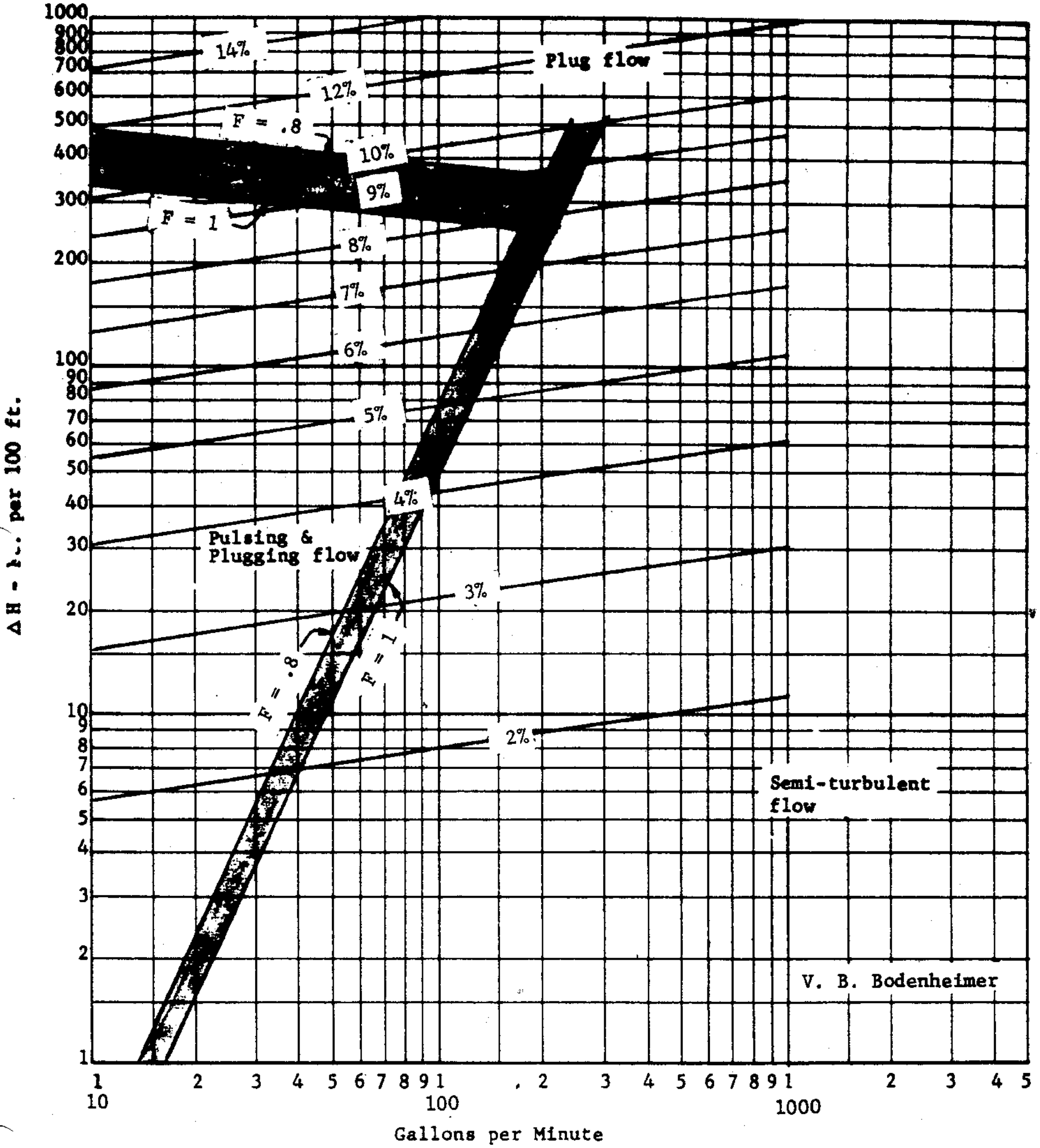
FRICTION LOSS IN 2.157" I. D. STAINLESS STEEL PIPE



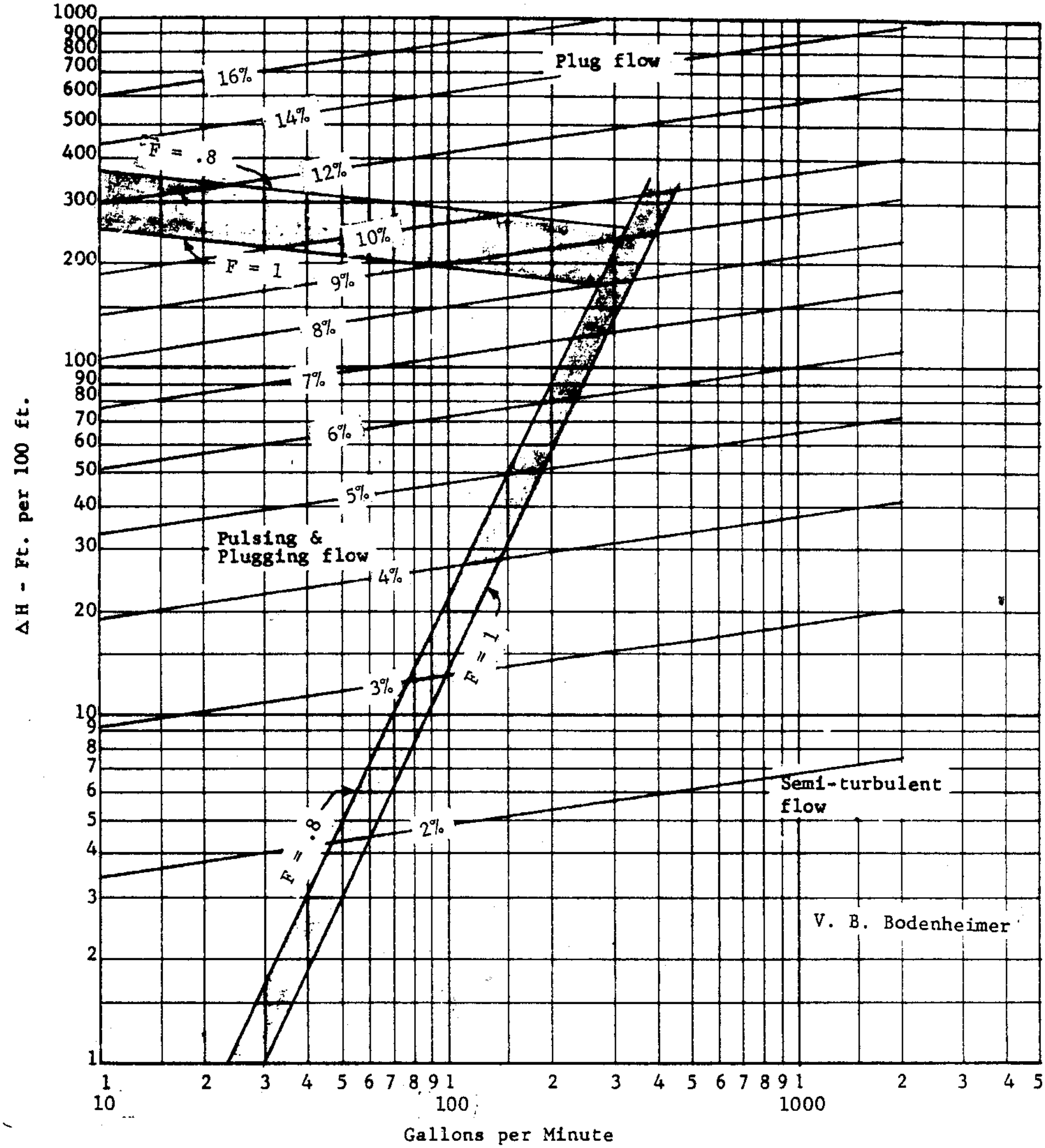
FRICTION LOSS IN 3.340" I. D. STAINLESS STEEL PIPE



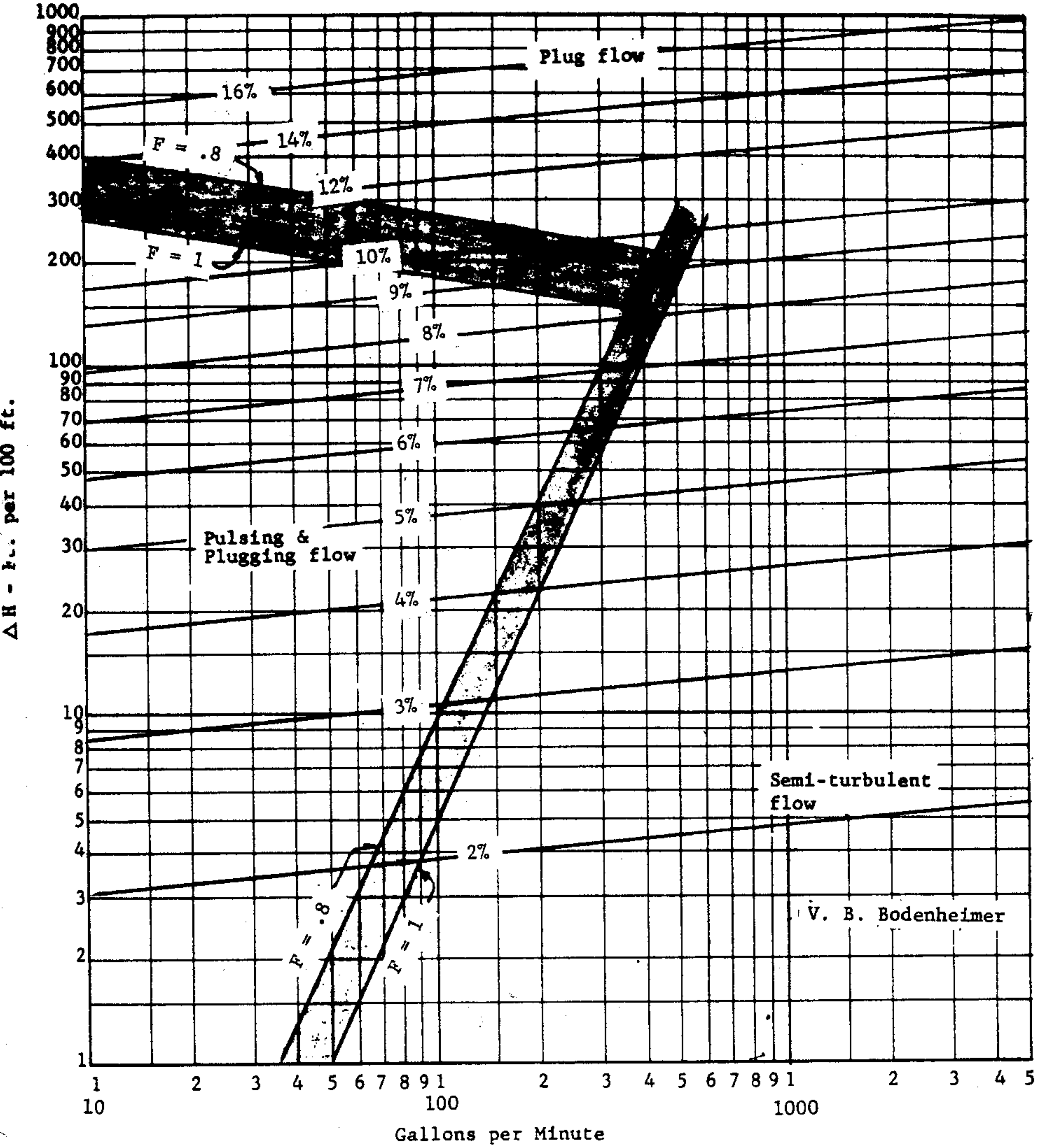
FRICTION LOSS IN 4.334" I. D. STAINLESS STEEL PIPE



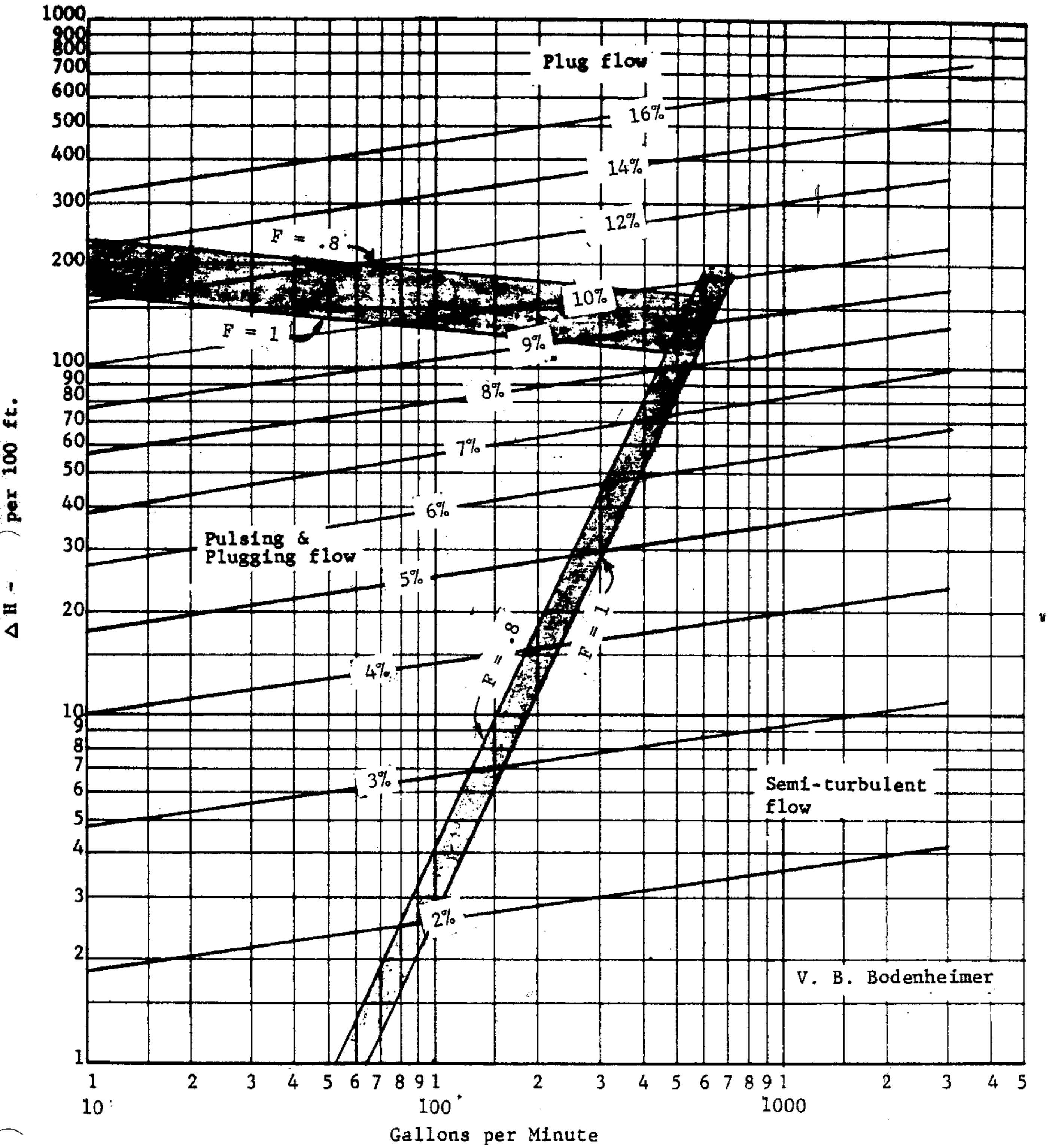
FRICTION LOSS IN 6.407" I. D. STAINLESS STEEL PIPE



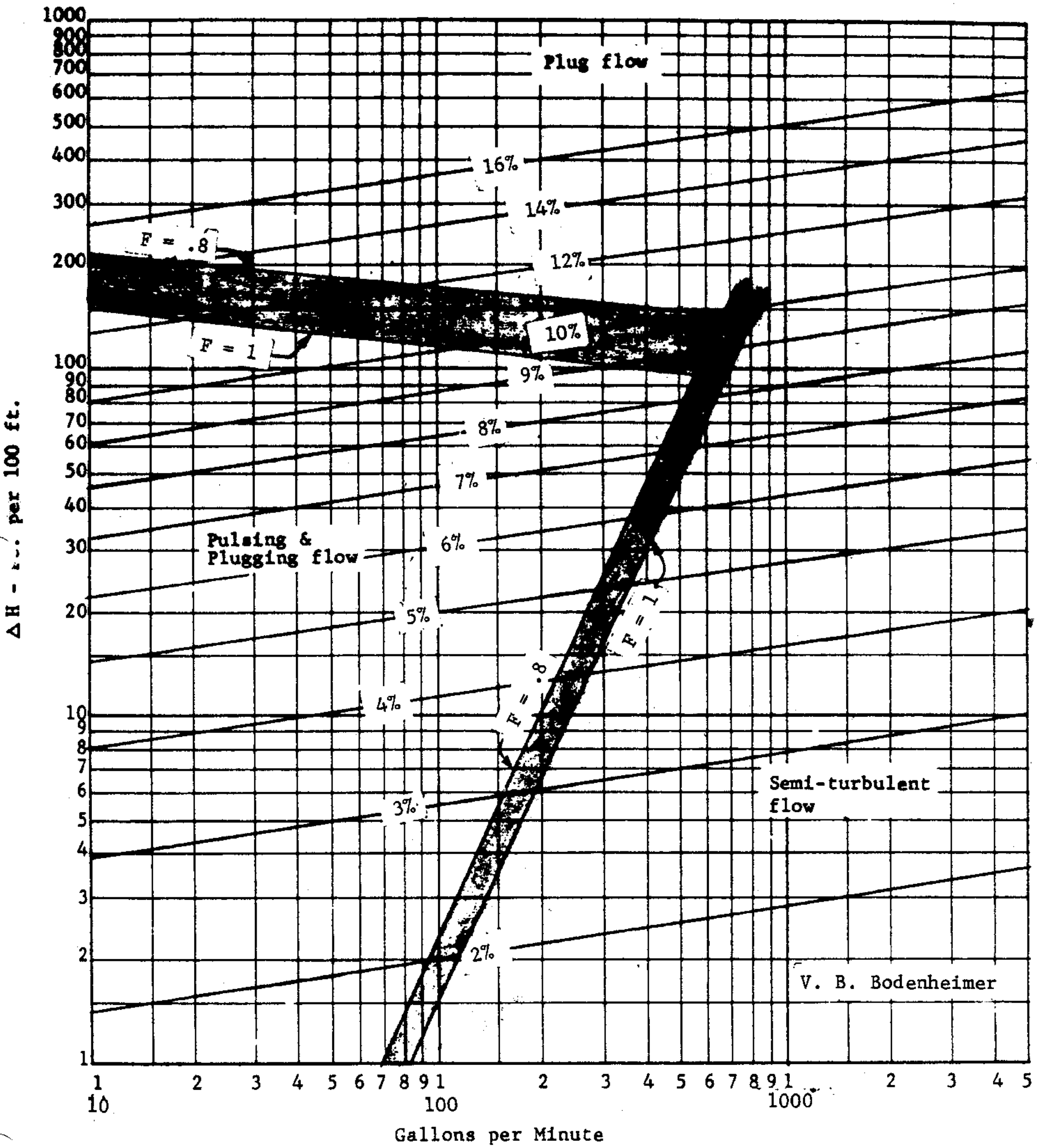
FRICTION LOSS IN 8.407" I. D. STAINLESS STEEL PIPE



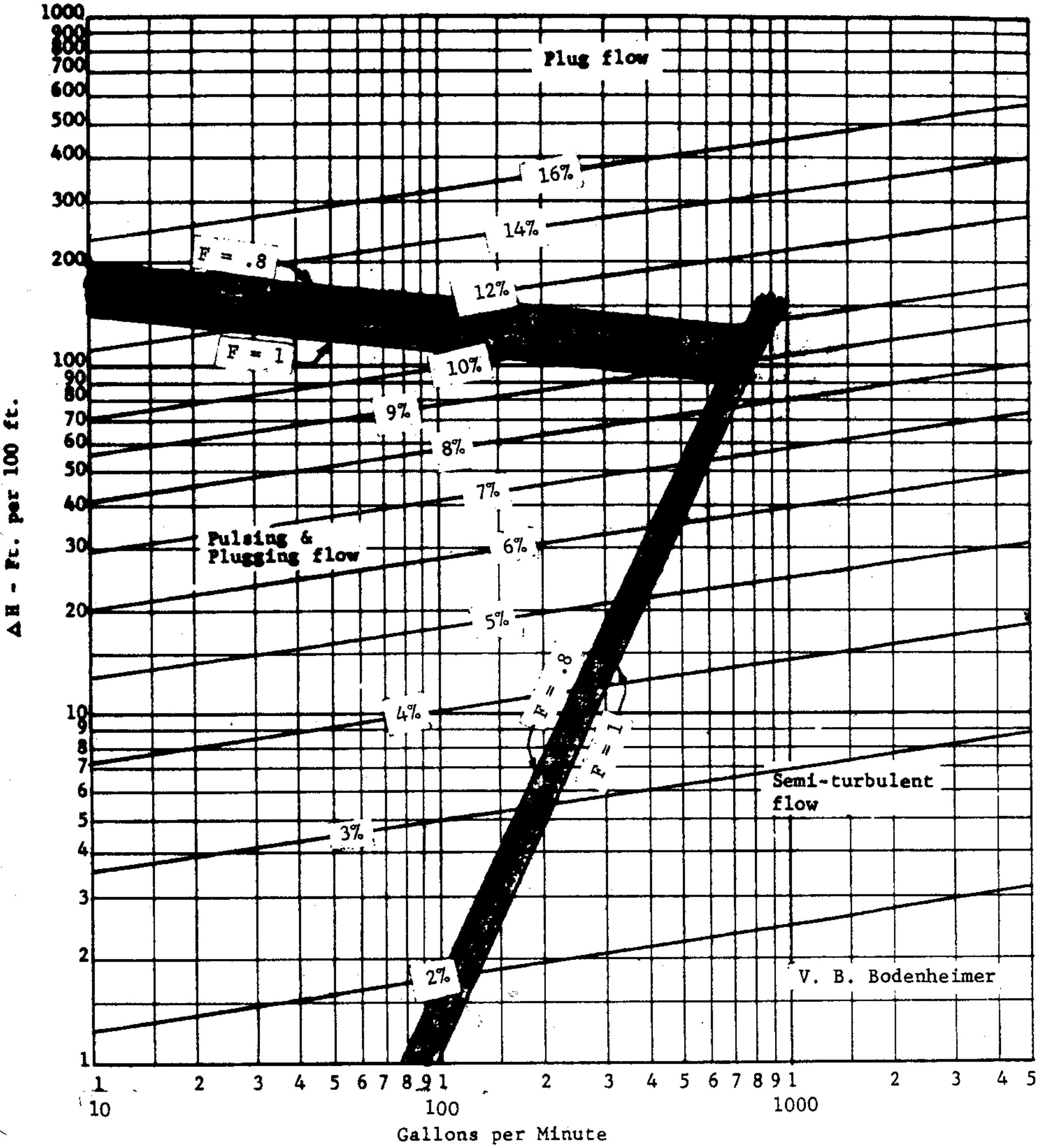
FRICTION LOSS IN 10.532" I. D. STAINLESS STEEL PIPE



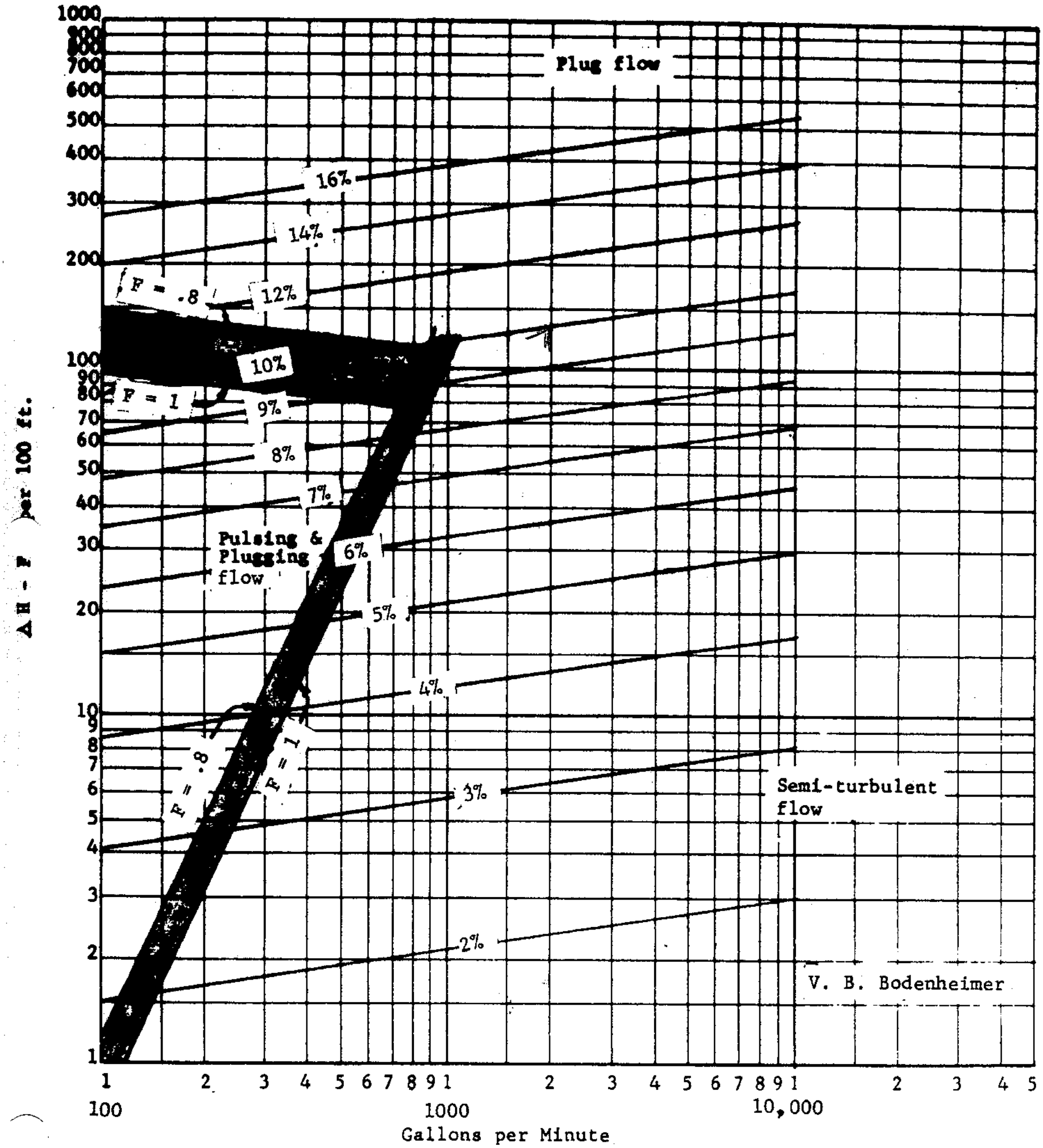
FRICTION LOSS IN 12.53" I. D. STAINLESS STEEL PIPE



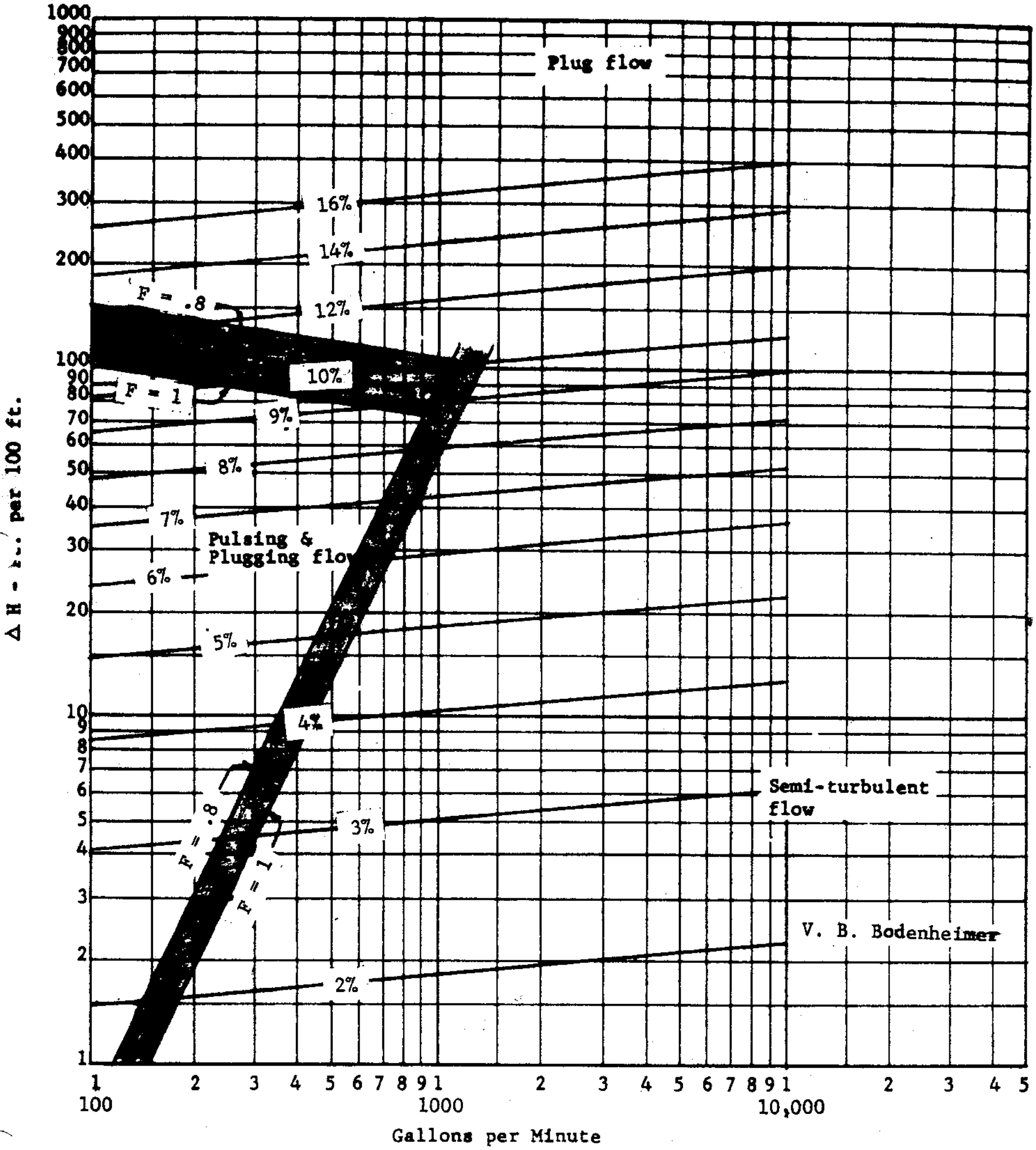
FRICTION LOSS IN 13.75" I. D. STAINLESS STEEL PIPE



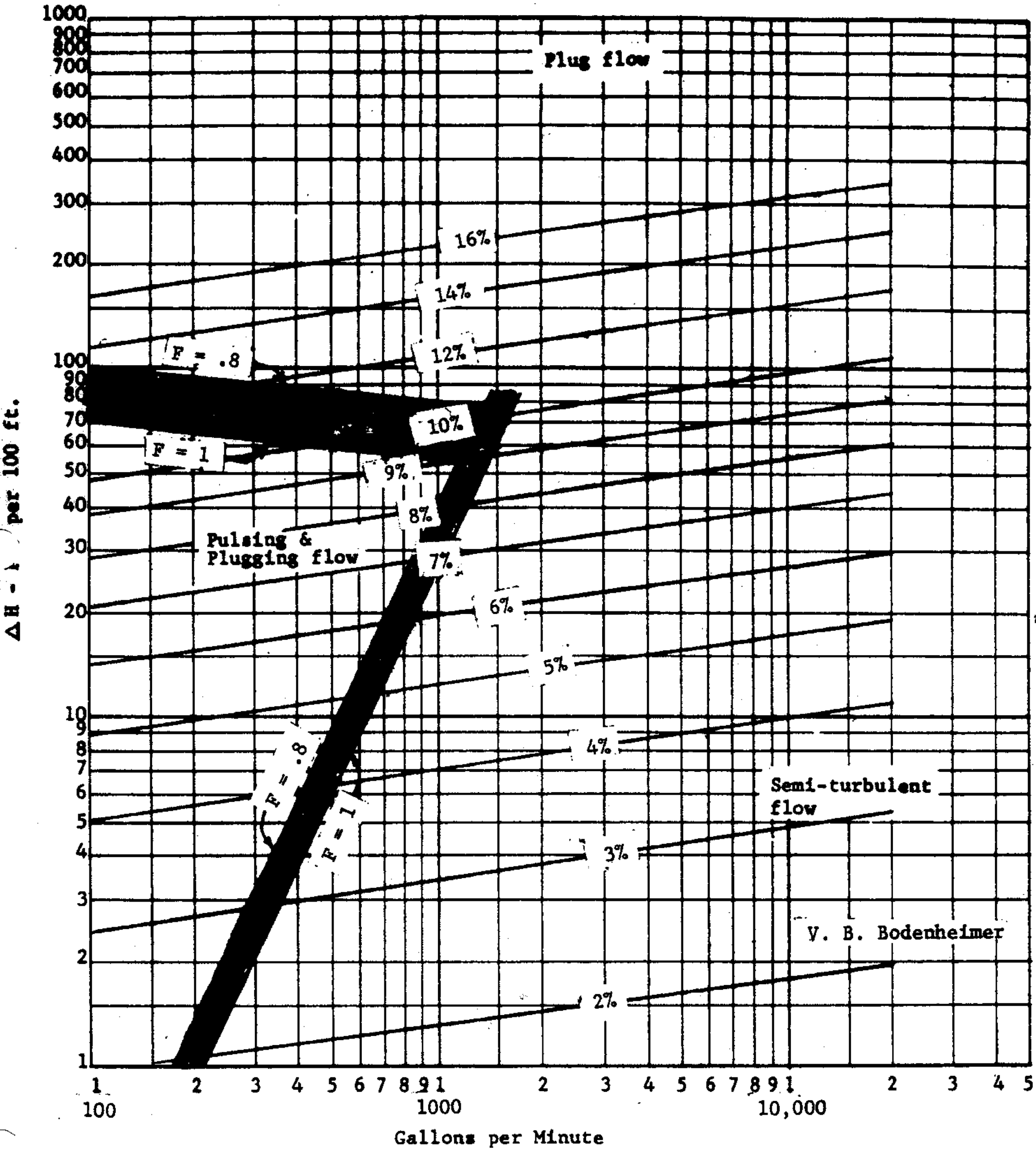
FRICTION LOSS IN 15.75" I. D. STAINLESS STEEL PIPE



FRICTION LOSS IN 19.72" I. D. STAINLESS STEEL PIPE



FRICTION LOSS IN 23.72" I. D. STAINLESS STEEL PIPE



FRICTION LOSS IN 29,72" I. D. STAINLESS STEEL PIPE