Fig. 1 shows experimental results obtained with a wide range of flowrates and of the ratio of the vessel diameter D to the outflow diameter d. It is clear that Gardner and Crow's relation fits the results for $(h_c/R) > 0.23$ but that there is a trend towards Harleman, Morgan and Purple's relation for smaller values of (h_c/R). This is not unexpected since the flow pattern towards the outflow might be expected to become more axisymmetric with respect to outflow at low liquid levels. It is noted that the outflow diameter does not appear to be a significant parameter.

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LITERATURE CITED

Gardner, G. C. and I. G. Crow, "Onset of Drawdown of Supernatent Fluid in Surge Tanks," *Chem. Engng. Sci.*, **26**, 211 (1971).

Gardner, G. C., I. G. Crow, and P. H. Neller, "Carryunder Performance of Drums in High Pressure Circulation Boilers," *Pro. Inst. Mech. Engrs.*, **187**, 207 (1973).

Reply:

Gardner's letter provides quite a fitting supplement to my paper. It might be concluded from his letter and related references for drains of cylindrical tanks with horizontal axes that there are two downflow regimes for H/D ratios above those producing simple weir flow (D = drain diameter). The first of these is for the lower range of H/D values. It is one in which the controlling flow is in the drain itself. The second is for the higher range of H/D values (and Froude numbers). There the flow is limited to a maximum critical horizontal Froude number, $Fr_c' = V/\sqrt{g'h} = 1.0$, where h is the height of the liquid in the horizontal flow channel.

It can be shown that a critical horizontal Froude number also exists for radial inflow at the base of a cylindrical tank with a vertical axis as well (see Figure 1). At any radius, r, the total head, H_T, is

$$H_T = \frac{V^2}{2g'} + h \qquad (1)$$

where V is the radial fluid velocity toward the axis of the cylinder. At a critical maximum horizontal Froude number, $Fr_c' = V/\sqrt{g'h} = 1.0$, the situation is such that inflow to a smaller radius must be accompanied by an increase in liquid height, h. It follows

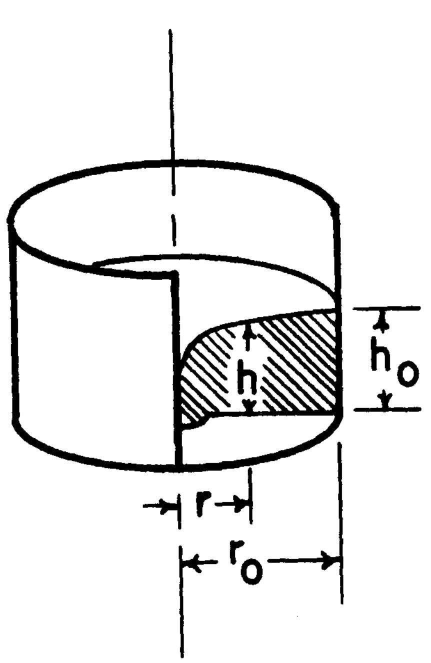

Fig. 1. Downflow system for cylindrical tank with vertical axis.

that, for the general case of horizontal inflow, at any radius, r,

$$\frac{3}{2} h_o \geq h \geq \frac{2}{3} h_o \qquad (2)$$

assuming that V can have nonzero values at $r = r_o$ and that the horizontal Froude number at this boundary is equal to, or less than the critical value of 1.0. If this condition of choked horizontal inflow occurs at the edge of the drain, where $r = D/2$, the maximum superficial Froude number within the drain is given by the relationship,

$$Fr = \frac{V}{\sqrt{g'D}} = 4.0\left(\frac{h}{D}\right)^{1.5} \qquad (3)$$

This equation fits my data at drain Froude numbers above 4.0 better than the Kalinske, or the Harleman equation. The concept of a choked horizontal flow condition can also be invoked to explain the fact that in my experiments the liquid downflow rate could not be increased beyond a given value at any one liquid height, even with increasing vessel pressure and air flow rate through the drain. With the incorporation of this third type of flow limit the equations best fitting my data are:

Flow Type	H/D	Equation
Weir	$\frac{H}{D} \leq 0.4$	$Fr = 2.36(H/D)^{1.5}$ (Souders)
Drain Limited	$0.4 < \frac{H}{D} \leq 1.0$	$Fr = 4.28(H/D)^2$ (Kalinske)
Choked Horizontal Radial Inflow	$1.0 < \frac{H}{D}$	$Fr = 4.0(H/D)^{1.5}$

where $H = h$ at $r = D/2$. I would not recommend any revision of the design equations suggested in my paper to fit this three-regime concept. The complexity is not justified for design.

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Errata

In "A Simple Method for Safety Factor Evaluation" by Ygàl Volkman [*AIChE J.*, **23**, 203-20 (1977)], the illustration for Figure 2 should appear as follows:

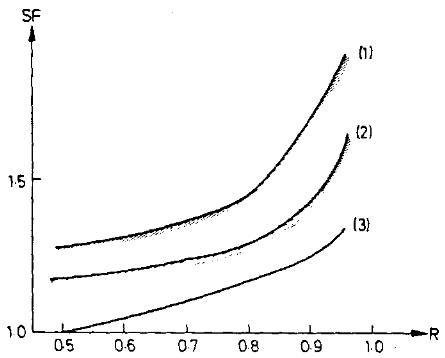

Fig. 2. Sample calculations of safety factors: $(\sigma_c/\bar{c} = 0.2)$.
(1) General (bound)
(2) Unimodal symmetrical (bound)
(3) Normal distribution

In "A Generalized Expression for the Effectiveness Factor of Porous Catalyst Pellets," [*AIChE J.*, **23**, 208-210 (1977)] by S. W. Churchill, a factor of τ_1 is missing from an entry in both Tables 1 and 2 and $2\tau_1^*$ from an entry in Table 1. These entries under *Infinite Cylinders* should read

(after η): $2I_1\{\tau_1\}/\tau_1 I_0\{\tau_1\}$
and $I_1\{2\tau_1^*\}/\tau_1^* I_0\{2\tau_1^*\}$

$$\left(\text{after } \frac{1}{\eta}\right): \frac{\tau_1^2}{2Bi} + \frac{\tau_1 I_0\{\tau_1\}}{2I_1\{\tau_1\}}$$

This error does not influence the balance of the paper.

The second term on the left side of Equation (6) should read $(C_s/C_b)_\infty$ and the second term from the right of Equation (7) should read $k_c(C_b - C_s)/s$.

It should have been noted that the results of this paper can also be interpreted as the effectiveness factor for heat transfer by fins and spines.