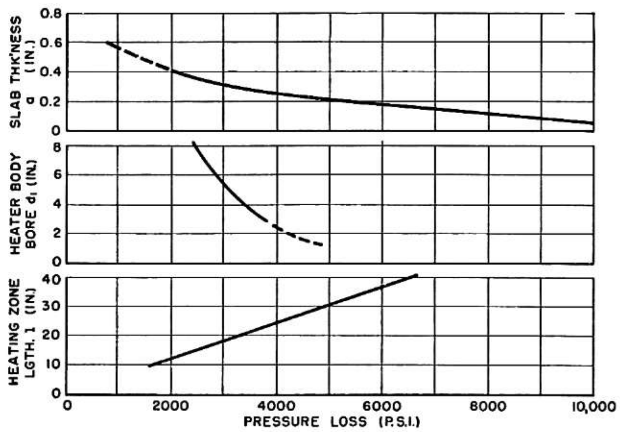

Fig. 8 Heating-Chamber Geometry Versus Pressure Loss

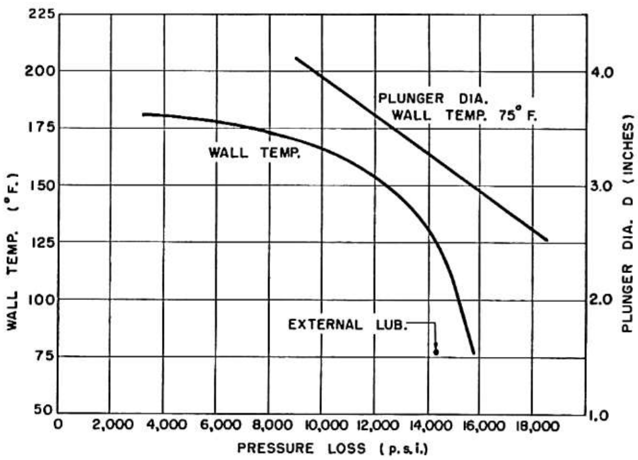

Fig. 9 Pressure Relationships in Cold Zone

in length results in a direct increase in pressure loss. A considerable change in heater-body bore has a negligible effect on the pressure loss. A small decrease in section thickness, on the other hand, produces a large increase in pressure loss.

Of even greater importance in analyzing the pressure losses is the cold zone. Here granules of material are compressed under very high pressure at temperatures so low they are not distorted appreciably. The result is an extremely high pressure loss.

The results of experiments in this regard have been published[6] and for static conditions the following relationship was found

$$\frac{F_a}{F_r} = e^{4\mu L_0/D} \quad [9]$$

For the maximum shot size of 14 oz, taken from Table 1, the cold zone would produce pressure losses as plotted in Fig. 9. Since it is assumed that the shot size is constant the effect is plotted in terms of plunger diameter only. The effect of wall temperature results because of the change in the coefficient of friction. An increase in wall temperature of 100 F is as effective in reducing the cold-zone pressure loss as increasing the plunger diameter by a factor of 2. The effect of an external lubricant is to reduce the pressure loss, as has been experienced by many molders.

[6] "Behavior of Granulated Polymers Under Pressure," by R. S. Spencer, G. D. Gilmore, and R. W. Wiley, *Journal of Applied Physics*, vol. 21, 1950, pp. 527–531.

Summary of Recommendations

It would be desirable to be able to specify an exact design incorporating a maximum heating rate and a minimum pressure loss. Since several assumptions have been made, particularly in regard to pressure losses, an exact specification cannot be drawn. There are, however, indications as to the approach to be taken. These, together with suitable experiments designed to establish the reliability of any assumed conditions, should provide sound engineering design information. Experiments of this type have been successful.[7]

Considering the specifications as listed in Table 1, the maximum heating rate with minimum pressure losses is approached in the following design changes:

1 Increase the heater-body bore. This actually increases the inventory and results in a smaller pressure loss.

2 The heating-zone length also may be increased and the section thickness decreased. These should be held to a minimum since they increase the pressure loss.

3 The spreader construction is very important, for by the use of an internal heater the heating rate can be increased 50 per cent.

4 Pressure losses may be considerably lowered by proper attention to the cold zone. A high wall temperature in the cold zone is desirable. Even a change in plunger design to accommodate its working against partially melted material should be attempted. Further decrease in pressure loss can be obtained by an increase in the plunger diameter.

These design changes, within limits, should greatly improve the heating chamber discussed. They also would apply to other specific designs patterned after the Gastrow unit.

Discussion

W. R. McLain.[8] Conclusions of the paper as to the large pressure losses that are possible in the cold zone would indicate that this particular zone would be an excellent place to consider design changes. Several questions are obvious. Would it not be possible to add another controlled heating zone extending from the rear of the present heating cylinder to the point of the withdrawn end of the injection plunger? This could be insulated from the sleeve to the rear and if necessary the rear sleeve could be water-cooled. This would provide a certain amount of preheating of material which feeds in front of the piston during the time of the cycle that the injection piston is in the reversed position.

If this were possible then the pressure drop in the cold zone should be minimized as shown in Fig. 9 of the paper. Pressure loss also should be reduced in the rear of the cylinder as the viscosity would tend to drop faster in the rear ranges than in a case where no preheating is done.

This might involve certain design difficulties, but it would seem to be a possible approach to greater capacity of plasticization, as well as better preserved injection pressures.

One other question relates to several factors mentioned in the paper. Experiments possibly have been made along this line, but it still seems to present a good basis for discussion and further study. Would it be possible to alter the spreader design so that it tapered on a gentle slope for most of the length of the heater and passed through a thinner wall section at the forward end? One factor entering the functioning of the cylinder would then be a larger over-all inventory providing more contact time. If the rear slope could be plotted so that it was based on a minimum pres-

[7] "Basic Features Influencing the Performance of Injection Moulding Machines," by E. Gaspar, a paper delivered at the British Plastics Convention, 1951.

[8] President, Kusan, Inc., Plastics Division, Nashville, Tenn. Mem. ASME.

sure loss due to wall thickness and a progressive decrease in viscosity resulting from heat absorption, then some losses of the rear zone might be reduced.

The thicker rear-slab thickness would, of course, pick up heat more slowly, but would eliminate entry to a thin slab section of relatively low-temperature material. The front-slab thickness could possibly then be even less than at present because of the fluidity of the material by the time it reached this point. It seems that present design with almost uniform slab thickness from rear to front introduces a higher friction and lowers inventory with a resulting shorter contact time. Such design also would increase inventory of material in the heater without increasing its size.

These are questions which may have been answered, but if not satisfactorily, it would seem that work along these lines to determine precise effects would be of considerable value.

The authors indicate that each dimension is changed independently for plotting in Fig. 8. It is assumed that spreader diameter is varied with heater-body bore, so as to maintain constant slab thickness, but this is not stated clearly.

Authors' Closure

Mr. McLain's comments are greatly appreciated. He has raised some interesting points on which the authors can be of little assistance except to agree that further study is needed.

The addition of another controlled heating zone, wherein the plunger would operate, has excellent possibilities of increasing plasticization and decreasing pressure losses.

It would also seem that there must be an optimum design which would involve a tapered spreader. Such an analysis requires clarification of assumptions already made in this paper. Pressure losses through straight sections, where temperature variations exist, is only one to be considered. As was pointed out in the paper, the knowledge of pressure requirements is limited to equilibrium conditions.

Mr. McLain's assumption is correct, in that the spreader diameter is varied with the heater-body bore while maintaining a constant slab thickness, in plotting Fig. 8. While this was implied, the authors agree that it should have been clearly stated in the paper.