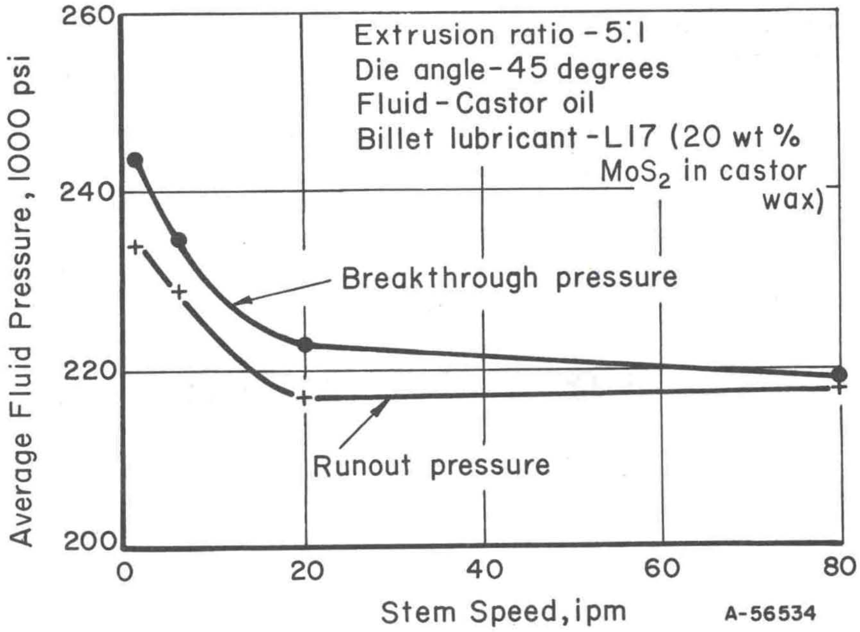

FIGURE 18. EFFECT OF STEM SPEED ON FLUID PRESSURES FOR COLD HYDROSTATIC EXTRUSION OF AISI 4340 AT AN EXTRUSION RATIO OF 5:1

Die Design

The effect of die angles on extrusion pressures was explored at ratios of 5:1 and 6:1. The results taken from Tables IX and X are summarized below in Table XIV.

TABLE XIV. EFFECT OF DIE ANGLE ON EXTRUSION PRESSURES AT TWO RATIOS

Fluid - Castor oil   Billet Lubricant - L17   Stem Speed - 20 ipm

Extrusion Ratio	Die Angle (included), degrees	Average Fluid Pressure, 1000 psi Breakthrough	Runout	Number of Trials
5:1	30	--	--	1
	45	220.5	216.3	6
(no billet	60	230.0	227.0	2
coating)	90	--	--	2
6:1	45	231.0	231.0[a]	1
(phosphated billets)	60	236.5	233.5	2

(a) Diminishing stick-slip occurred on runout.

It is seen that at both extrusion ratios minimum extrusion pressures were achieved with the 45-degree die angle, though the requirements for a 60-degree angle were only marginally higher (about 4.5 percent at 5:1 and 1.5 percent at 6:1). In trials at 30- and 90-degree angles at 5:1, breakthrough was not achieved even at pressures greatly in excess of those needed for dies with angles of 45 and 60 degrees. Therefore, it is concluded that a die angle of 45 degrees is close to the optimum for processing AISI 4340 steel at these high ratios. At the low ratio of 2:1 it was shown in previous work[1] that a die angle of 30 degrees gave lower pressures than were required for a 45-degree angle. But the converse was true at 3.3:1 ratio. These general observations are consistent with the findings for several other materials by other research workers that the optimum die angle decreases as extrusion ratio decreases[11, 12].

It is of interest that vestiges of the original machining marks on the billet were noted on the extrusions made with the 45-degree-angle die but not with the 60-degree-angle die. Apparently, sufficient distortion or burnishing of the surface occurs with the 60-degree die to obliterate the machining marks.

Hydrostatic Extrusion of AISI 4340 Steel at Elevated Temperatures

The essential aims of the study at elevated temperatures were:

(1) To determine the effect of elevated temperatures on pressure requirements and product quality

(2) To develop lubrication systems and sealing techniques which would function successfully up to 500 F, the maximum temperature design capability of the hydrostatic extrusion tooling.

Table XI gives data obtained in the evaluation of several lubrication systems (billet lubricants + fluids) at three temperature levels. Most of those systems operated efficiently by giving smooth runout conditions and producing good quality extrusions.

Extrusion at 140 F

Studies at 140 F were an extension of experiments which were initiated in the earlier study[1] with this material. The use of slightly elevated temperatures was explored as a possible means of reducing fluid-pressure requirements. The main purpose here was to prevent an excessive increase in viscosity or solidification of the system resulting from increasing pressure. In these trials, only the fluid was heated to 120 or 140 F. The billet, container, and die were at room temperatures. Data from Tables X and XI and from earlier work[1] are summarized in Table XV.

TABLE XV. COMPARISON OF PRESSURES OBTAINED IN THE HYDROSTATIC EXTRUSION OF AISI 4340 STEEL AT 80, 120, AND 140 F

Fluid – Castor oil Extrusion Ratio – 5:1

Lubrication	Stem Speed, ipm	Nominal Fluid Temperature, F	Average Fluid Pressure, 1000 psi: Breakthrough	Average Fluid Pressure, 1000 psi: Runout	Number of Trials
C1 + L17	20	80	215.5	212.3	4
C1 + L17	20	120	211.0	207.0	1
C1 + L17	20	140	210.5	206.5	2
C1 + L17	6	80	220.0	215.6	3
C1 + L17(a)	6	120	214.6	213.0	3
C1 only(b)	20	80	229.0	215.5	2
C1 only(b)	20	140	222.0	210.0	1

(a) Data from Reference (1). (b) Stick-Slip before smooth runout.