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# MODEL INVESTIGATION OF SEAMLESS STEEL TUBE MAKING

by

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PHYSICAL METALLURGY DIVISION

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## SUMMARY OF RESULTS

Colour laminated modelling clay was used for work pieces in a 1/8 in. scale investigation of portions of a steel tube making process in an attempt to increase the yield by eliminating tail end defects.

From tests made it was concluded that, in general, the devices suggested to reduce tail end defects are likely to cost as much in steel billets as in steel tubes saved. One upsetting technique suggested by others is the most likely approach to any savings.

While not part of the original plan of the investigation, an interesting sliver defect sometimes found in tubes was reproduced. This defect might be caused by large non-metallic inclusions or by shrinkage cavities.

Recommendations are made for full scale tests on steel billets.

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## INTRODUCTION

In a letter dated June 27, 1962, assistance was requested by Mr. C.F. Anderson, President, Page-Hersey Tubes, Limited, 100 Church Street, Toronto, Ontario, in seeking means of reducing tail end defects occurring in their seamless tube mill. Details were discussed with Mr. William Simpson, Chief Metallurgist, Welland, Ontario.

Reference was made by Page-Hersey staff to work done on scale model, colour laminated wax models by others and a similar approach was requested(1). The Mines Branch chose to use "Plasticine" modelling clay instead of wax because of familiarity with the material in previous forging investigations. Approximately 130 model tubes were processed. This is not considered adequate for the job as originally planned.

## THE TUBE MAKING PROCESS

This process, the only one of its kind on this continent, uses a semi-finished round cornered square billet which is pierced to a "bottle" in a vertical press, using a cylindrical punch. In the example studied, the billet was 6 1/8 in. square or 8 1/8 in. on the diagonal. The latter dimension is the same as the press container bore so that the billet is accurately centered for piercing.

Following piercing, the billet is forged in a rotary mill to a longer and smaller round section.

The elongated billet is next placed over a spring steel mandrel and pushed through a series of paired, undriven rolls which extend and thin the forging into a tube. The machine which performs this operation is known as a push-bench.

The complete sequence of operations is as follows:

1. Heat the billet to forging temperature.
2. Rectify diagonal dimensions and break heating scale.
3. Pierce to a bottle in a vertical press.
4. Reheat.
5. Elongate the bottle in a rotary mill.
6. Thin out wall on a push-bench.
7. Reel to expand the tube and extract the mandrel.
8. Reheat.
9. Reduce the tube to commercial sizes.

## DEFECTS

A number of tubes were showing longitudinal cracks and internal seams at one end. In an investigation, it was found that these defects were mainly the result of earing in the bottle piercing operation and not due to billet quality as previously suspected[(2)]. Ears or cusps are the lobes formed at the bottle mouth from material at the billet corners.

These occurred on the upper end of the bottle which formed the trailing end of the tube. Figure 1 shows the tail end of a steel tube with typical fish tails and cracks formed by further deformation of the ears.

The elongated bottle of operation No. 5 is illustrated in Figure 2. This is the intermediate step between the pierced bottle and Figure 1.

The four cracks or folds so clearly indicated are located between the four cusps produced during the bottle piercing operation, No. 3. It seems obvious that to eliminate or reduce the seams in the finished tubes, it would be necessary to reduce the height of the cusps or to distribute the steel more uniformly about the mouth of the bottle.

## PIERCING

The bottles are made by pushing a flat end punch into the end surface of a standard round cornered square billet while the piece is enclosed in a cylindrical, closed bottom container*, whose inside diameter is equal to the diagonal dimension of the billet. The steel is pierced almost to the bottom. It is significant that the cross sectional area of the punch is equal to the sum of the cross sections of the four empty segments between the square billet and the container bore. The designers of the process must have felt that neither upsetting nor backward extrusion were desired and chose punch diameter to avoid these conditions. No attempt has been made to alter this relationship in the experimental work.

(a) During the initial stages of the piercing, there is a tendency for the four corners to extrude upward and opposite to the punch direction and for the four sides of the billet to draw in toward the punch. This is thought to be due in part, to the volumetric distribution of the billet outside the punch circle and in part to the frictional restraint to outward motion by the flat face of the punch.

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*The word "container" is used here instead of "sleeve" as in the Company's plant.

(b) Figure 3 illustrates the polar distribution of metal volume in the unpierced billet outside of the punch circle. In the first inch or so of piercing, it is this volume which forms the open end of the bottle. It is not surprising that four cusps appear with this distribution. The metal from the extreme end of the billet is displaced downwards under the flat face of the punch and helps later to force the billet flats out against the container wall, but the damage at the top of the bottle has already been done.

## EXPERIMENTAL PUNCHES

Referring to paragraph (a) preceeding; in one series of tests the punch end was heavily lubricated with vaseline to lessen side "draw-in" due to the frictional effect suspected. It was hoped that if some improvement could be shown here, lubrication of the steel billet end could be accomplished with a pad of glass fibre or other lubricant(3). However, no difference in cusp height or volume could be seen whether the punch was lubricated or not.

To improve the condition described in paragraph (b), an experiment was made with punches shaped to force the billet flats against the container wall from the earliest moment of contact between punch and billet. The obvious shapes were a truncated conical and a hemispherical tip, both of which it was hoped, would move the central billet material aside rather than carrying it downwards.

A large number of samples made with the three punch designs, (Figure 4), showed no improvement in earing. The conical punch did cause less "drag-in" of the billet flats at the open end of the bottle and by this token a less extreme distribution pattern than Figure 3 would be expected. The hemispherical punch caused intermediate "drag-in" between the cylindrical and conical punches (Figure 5). Left to right, the bottles were made with conical, hemispherical and flat punches. While it is not evident from the photograph, the distance down the bottle from the top showing a residual billet flat was as follows:-

| Punch Style | % of Total Bottle Length |
|---|---|
| Conical | 6 |
| Hemispherical | 12 |
| Cylindrical | 20 |

Figure 6 shows vertical cross sections through bottles made with the three punch profiles. Note that the conical punch does very little forging work in the bottle bottom. It is possible that this lack of work, particularly in the billet, centre, might be responsible for end push-outs on the push bench (Operation No. 6), particularly with cast billets, unless the elongator introduced sufficient work to refine the cast structure.

Based on parallel experience in another process, it might happen that punch wear would be greater with the conical than the standard punch.

Should the conical punch prove to make better tubes in respect of reduced length of tail end seams, it should be noted that any improvement at the tail end might have to be paid for at the expense of a heavier bottle bottom. Assuming that all three punch designs would pierce to the same bottom thickness, the differences in displaced volumes have been calculated and expressed as length of tube unrealized at the push bench. The tube size chosen was 3.75 in. OD by 0.180 in. wall. Punch size was 4.25 in. dia.

<u>Loss in tube length due to punch shape</u>

| | |
|---|---|
| Conical Punch | 6.8 in. |
| Hemispherical Punch | 6.0 in. |
| Cylindrical Punch | 0.0 in. |

This means that any improvements realized would have to be greater than the above amounts to justify changes.

## BILLET SHAPING

In a brief experiment, the upper end of the billet was handicapped by removing the four corners at 45° for a distance of $1\frac{1}{4}$ in. (full scale equivalent) down the corner of the billet. This device resulted in eight cusps of reduced height. The volume of metal removed was $2/3\ a^3$ where a is the vertical distance down the billet corner. The equivalent length of full scale tube loss was about one inch.

## BILLET UPSETTING

Following a suggestion made by a forging consultant, Page-Hersey made an initial upset or rounding of the upper end of the billet by interposing a disc tool between billet and punch prior to piercing. This technique reduced tail-end seams from about 21 in. to 7 in., a worthwhile saving[4].

In order to avoid a two step piercing operation, the Mines Branch pierced a number of model billets using a co-axial sleeve to restrain earing and promote upsetting simultaneously with the piercing operation. The sleeve was held against the billet by only a gentle finger pressure and produced flat topped bottles. In full scale, a separate ram or spring or hydraulic cushioning from the main ram would be needed to operate the sleeve.

## ELONGATOR MODEL

To assess the tendency of the bottle cusps to close together and form seams, a large number of plasticine bottles were made using all three punch designs and the "rounded" billets described above. The upper surface was coated with a thin layer of colour contrasting plasticine and the bottles elongated in a scale model of the Page-Hersey equipment (Figure 7).

The machine made very good cylinders with deformations resembling the full size work but no seams could be induced to form from the most exaggerated bottle defects. It must be admitted that the model elongator was a failure in this respect.

## INTERNAL SLIVERS

While it is beyond the purpose of this report, it is worth mentioning that an incipient internal sliver or roke was produced in one bottle by injecting 400 mesh alumina powder into the billet with a hypodermic syringe. It was intended that the powder would represent a void or an inclusion. This defect is illustrated in Figure 8.

Other attempts to introduce larger inclusions of alumina resulted in catastrophic ruptures of the bottle in the elongator and these samples were considered to be unrepresentative of reported experience.

## CONCLUSIONS AND RECOMMENDATIONS

To quote another: "Deformations of the same kind appear in piercing wax and steel but differ in magnitude as a consequence of the difference in properties of the two materials"(1).

This investigation confirms Mr. Holmquist's thoughts. One should note in particular the inability to reproduce tail end seams in the model elongator. It is suggested therefore, that some of the model experiments may be worth attempting in full scale in spite of negative results of model work.

Further model work on punch forms seems to be unjustified, but the tools are being preserved in the event that some other detail of the process may require examination.

The author feels that a heavily lubricated punch face with complete removal of mill scale from the billet end is worth trying. A glass wool pad heavily saturated with graphite, oil and mica mould wash would be a likely candidate. Please note that in recommending glass wool, the use of glass is not meant to conflict with Sejournet patents but merely to retain the other components conveniently. The best oil to use is a "Bentone" type high temperature grease similar to "Plastilube No. 2" made by Wakefield Oils, Canada Ltd.

Further it is recommended that the truncated conical punch be tried, with and without lubricant.

## REFERENCES

1. J.L. Holmquist, "Tube Mill Practice", Association of Iron & Steel Engineers 1953 - pages 25-40.

2. Atlas Steels Ltd., Report on tube quality as related to "Concast" and rolled billets.

3. Refer to Can. Patents 473265, 455327 and others.

4. Page-Hersey Internal Metallurgical Report No. 62 - 51.

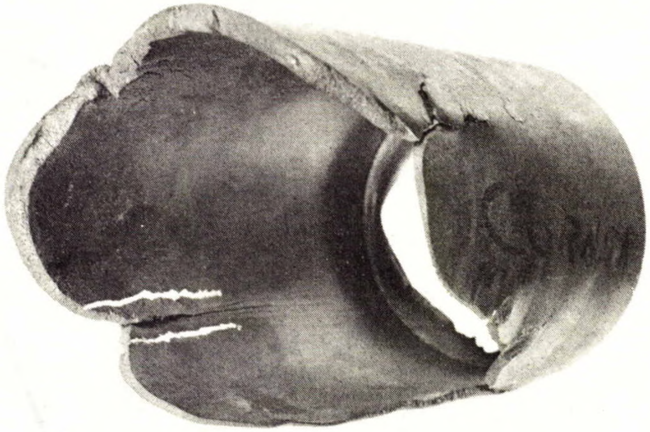

Figure 1. Tail end seams in push bench tube.

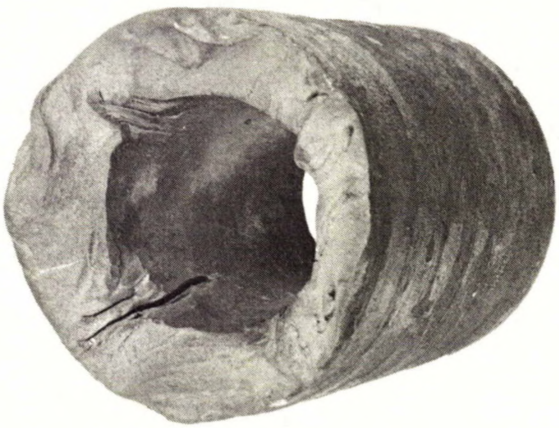

Figure 2. Enfolding of cusps to form seams in elongated bottle.

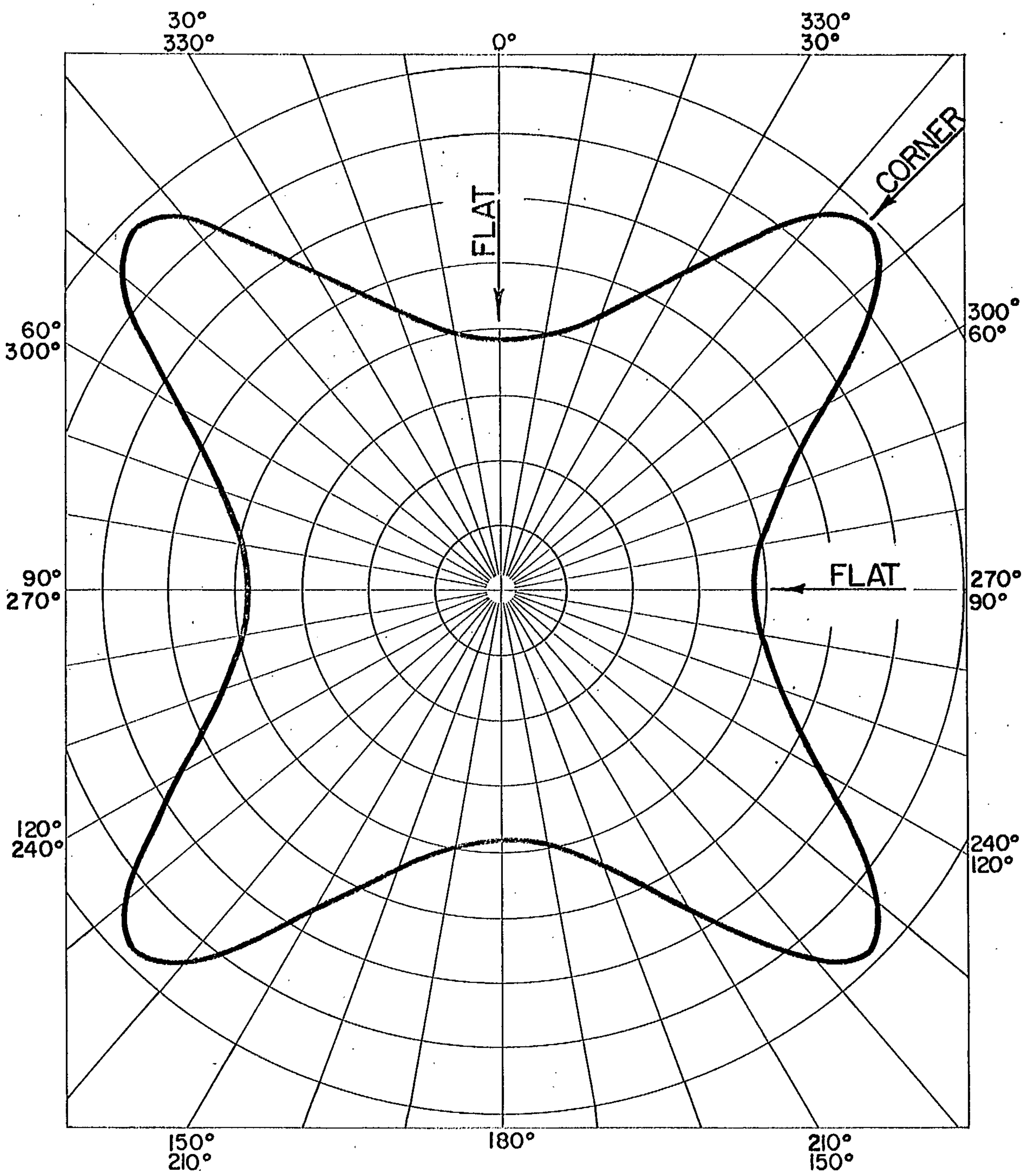


Figure 3

Polar Distribution of Metal in Un-Pierced Billet Outside of Punch Circle.

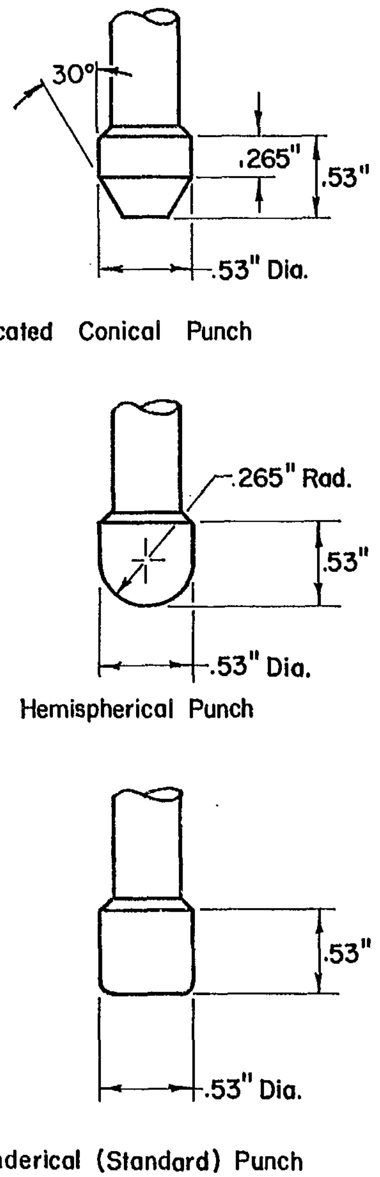


Figure 4

Model Punch Designs

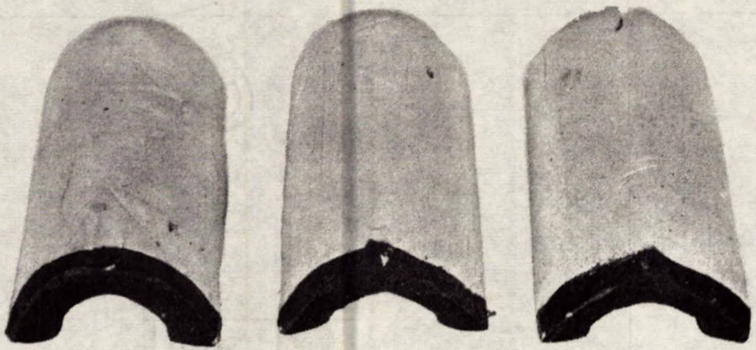

Figure 5. Relative top rounding resulting from use of conical, hemispherical and cylindrical punches, left to right.

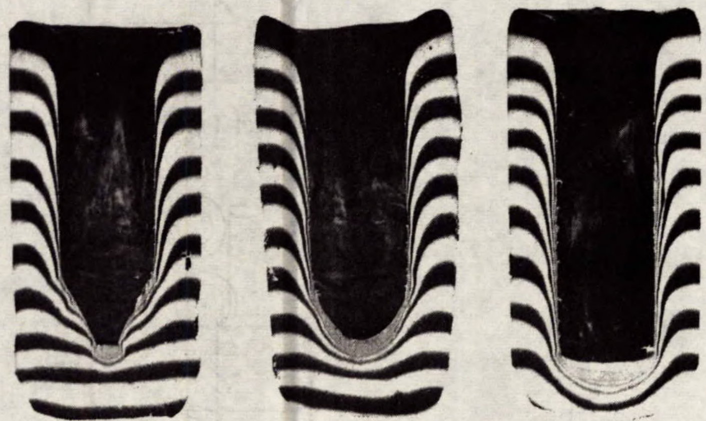

Figure 6. Corner to corner sections of bottles made with three punch designs: conical, hemispherical and cylindrical, left to right.

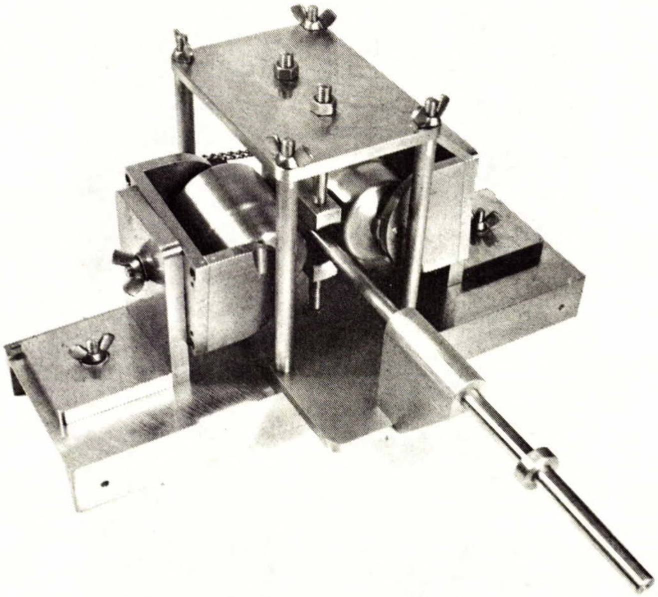

Figure 7. Model elongator.

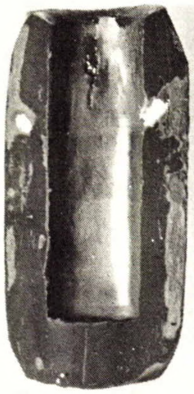

Figure 8. Alumina inclusions in plasticine bottle. Right inclusion has broken through inside surface.