The Formation of Microjets in Liquids under the Influence of Impact or Shock

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III. The formation of microjets in liquids under the influence of impact or shock

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[Plates 10 to 12]

If a small cavity or bubble in a liquid is subject to impact or to shock, tiny Munroe jets may be formed on its concave surface. The velocity of these microjets may be high. A short film illustrating the formation of these small jets in cavities and in coalescing drops was shown.

Previous experiments (Bowden & Brunton 1961) have shown that a shock wave falling on the concave surface of a cavity in a liquid may produce a tiny Munroe jet. Some early work of Sir Geoffrey Taylor, Professor Birkhoff and their colleagues (Birkhoff, MacDougall, Pugh & Taylor 1948) has given a quantitative explanation of the formation of these Munroe jets in shaped explosive charges. Typical microjet formation at the surface of a curved liquid surface is shown in figure 1, plate 10. In these experiments a small amount of water was held in a strong steel container with a small hole (*ca.* 2 mm diameter) in it. A sudden pressure could be applied to the water through the rubber plug P (e.g. by firing a bullet at it) so that the water was forced out of the hole at high velocity. If the water surface in the hole was flat the water emerged as a small cylinder moving at uniform velocity. If, however, the water surface was concave (as in figure 1) the main cylinder of water was preceded by a tiny Munroe jet moving at much higher velocity. The velocity of this jet depended on the curvature of the liquid surface. In this experiment the liquid surface was approximately spherical and it might perhaps be regarded as a 'half bubble'.

The successive high speed camera photographs show the jet moving forward and striking a Perspex target. Its velocity is *ca.* 1900 m/s and it is moving about three times as fast as the main body of water. The impact pressure of such a jet might be *ca.* 1000 Kg/mm^2 ($1\cdot5 \times 10^6$ Lb./in.^{2}) and this pressure is, of course, sufficiently great to cause deformation and permanent damage of the hardest solid. Its effect is to fracture the Perspex plate but in the frames shown there has not been time for this to occur.

If the target is a metal which is plastically deformed the micro jet will punch a small deep hole or crater in it. Subsequently the arrival of the main body of liquid will produce a much larger but shallower crater.

A crater in stainless steel which illustrates this pattern of behaviour (Bowden & Brunton 1961) is shown in figure 2, plate 11. The main crater is *ca.* 4 mm diameter. Near its centre a deeper but smaller crater only 0·3 mm in diameter has been formed. This small crater may be attributed to the presence of a microjet. It might be of interest to examine individual craters formed by cavitation or by rain or turbine erosion to see whether this duplex deformation is ever observed.

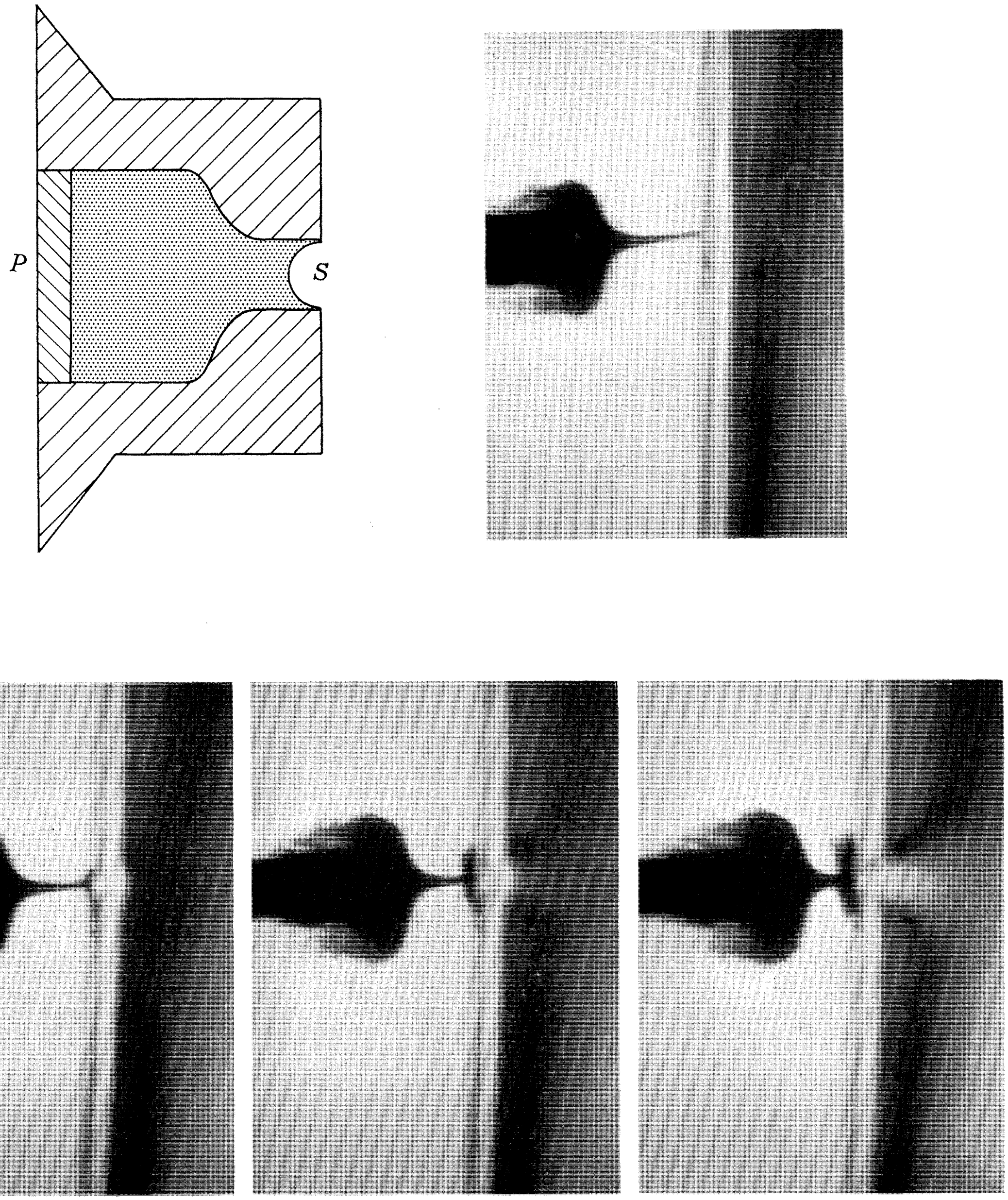


FIGURE 1. Formation of micro-Munroe jet when a shockwave falls on the concave surface S of a liquid. Velocity of main jet *ca.* 650 m/s, of microjet *ca.* 1900 m/s. Interval between frames, 0·8 μs. (Magn. ×5.)

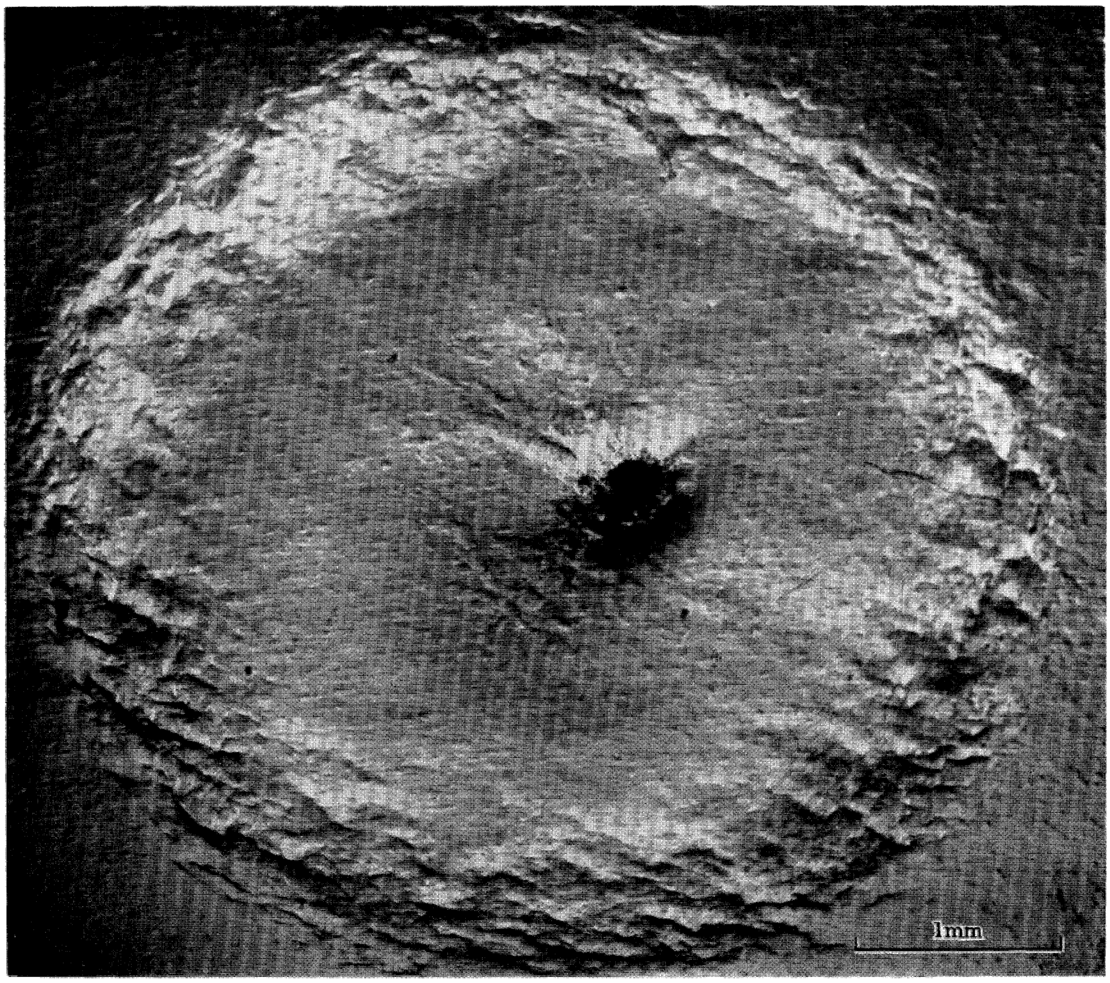
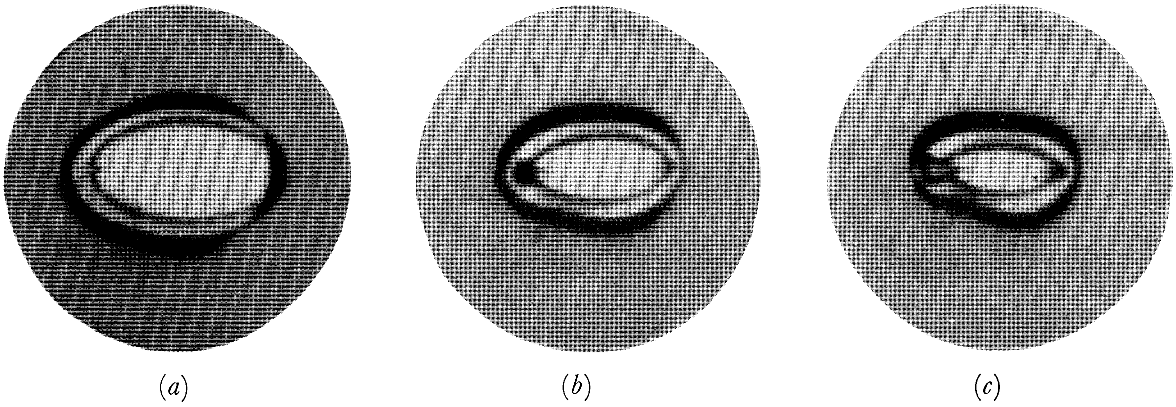
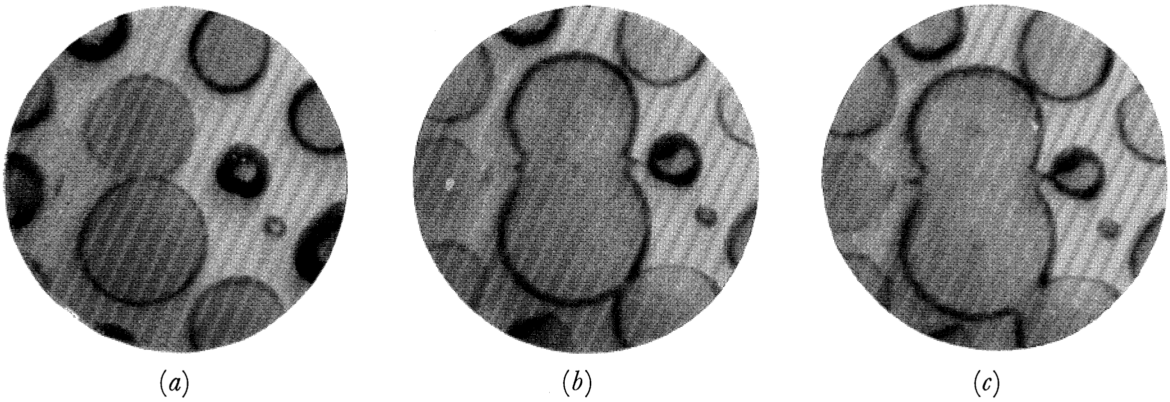


Figure 2. Crater formed by liquid impact on stainless steel. Near its centre a second small but deep crater (0·3 mm diameter) has been formed by a microjet.



(*a*) (*b*) (*c*)

FIGURE 3. A falling hammer has struck an annulus of liquid and trapped a single cavity containing air in the centre of the liquid film. These frames show the formation of tiny jets in the regions of maximum curvature and their ejection into the central cavity, as the cavity is compressed. Interval of 10 μs, between (*a*) and (*b*) and 5 μs between (*b*) and (*c*). (Magn. × 10.)



(*a*) (*b*) (*c*)

FIGURE 4. A falling hammer has hit hemispherical drops of liquid and is flattening them. (*a*) Two large drops coalesce; (*b*) two jets, formed at the highly curved region of contact; (*c*) one of the jets impinges on a neighbouring drop. Interval of 25 μs between (*a*) and (*b*) and 5 μs between (*b*) and (*c*). (Magn. × 7.)

Jet inside cavity

In another series of experiments (Bowden & McOnie 1965) the liquid was spread as an annulus on a flat glass anvil and struck with a flat glass hammer. In this way a 'bubble' or cavity containing air was trapped in the centre of the liquid film by the approaching surfaces and was rapidly compressed by the impact. The liquid in these experiments was nitroglycerine.

Various stages of the compression of the central cavity are shown in figure 3, plate 12. The cavity was elliptical, and it will be seen that a small jet is formed in the region of maximum curvature and is projected rapidly into the cavity as compression proceeds. At a later stage a second jet is formed at the opposite end of the cavity and in the final stages (not illustrated in the frames shown) these two jets collide.

Jet between coalescing drops

If the liquid is distributed over the surface as small drops, impact with another flat surface will cause them to coalesce. Under appropriate conditions microjets may be formed at the curved point of contact between the coalescing drops. This is illustrated in figure 4, plate 12. In figure 4 (*a*) two drops have just begun to touch. In the next frame a tiny jet has begun to form at each side of the highly curved region of contact (figure 4 (*b*)). As compression continues these jets increase in size and velocity and, in the last frame shown (figure 4 (*c*)), one of the jets is impinging on a neighbouring drop. The velocity of these microjets is, of course, dependent not only on the geometry of the liquid surface but also on the intensity of the shock or the velocity of impact.

We see that these microjets can readily be formed under a variety of conditions and that they can cause a marked increase in the velocity of the moving liquid and hence increase the impact pressure. We have evidence that they can play an important part in liquid impact experiments and also in the initiation of explosives (Watson & Gibson 1964; Bowden & McOnie 1965). It is of interest to inquire what role they can play in erosion and in cavitation processes.

References (Bowden)

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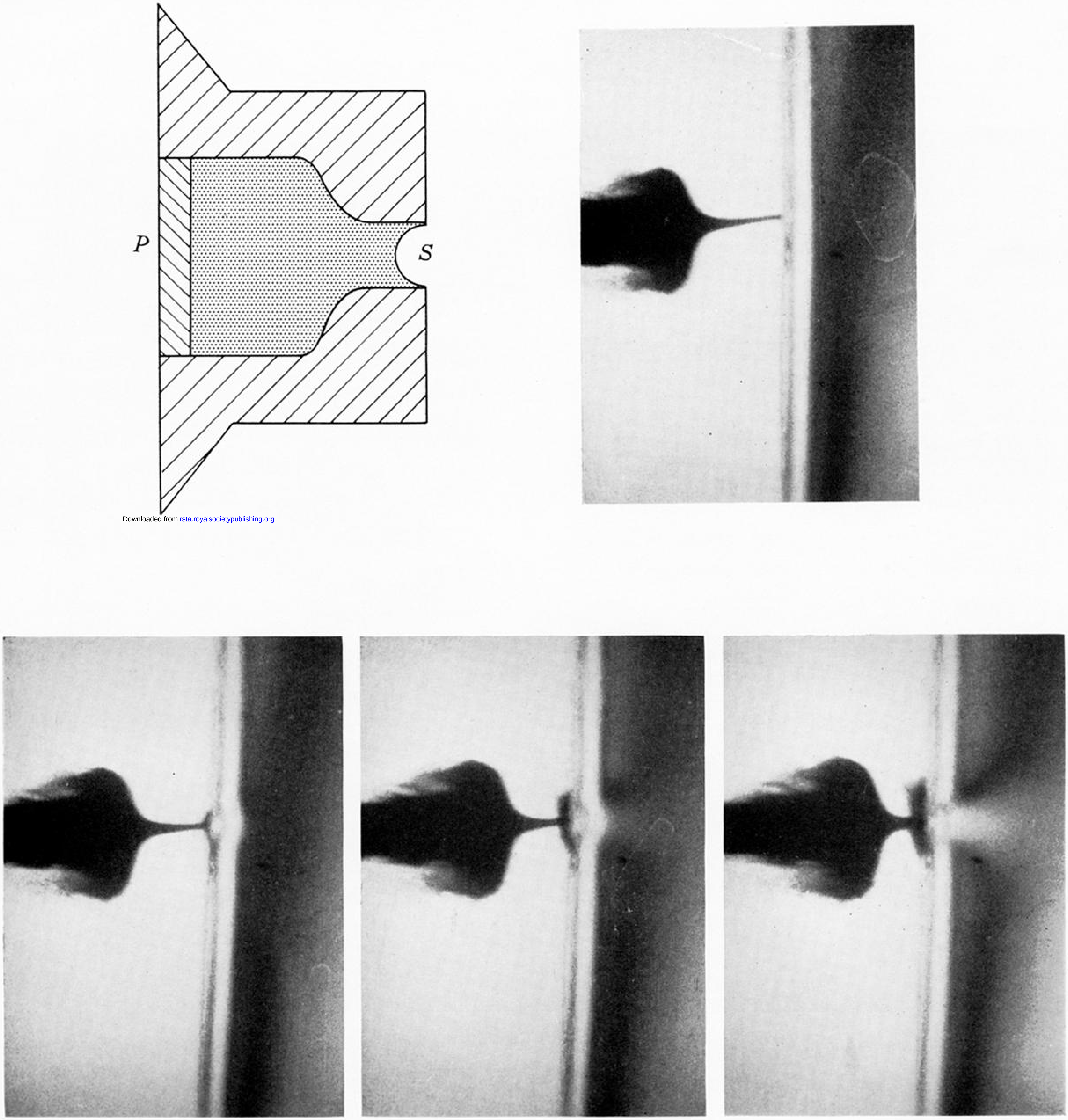

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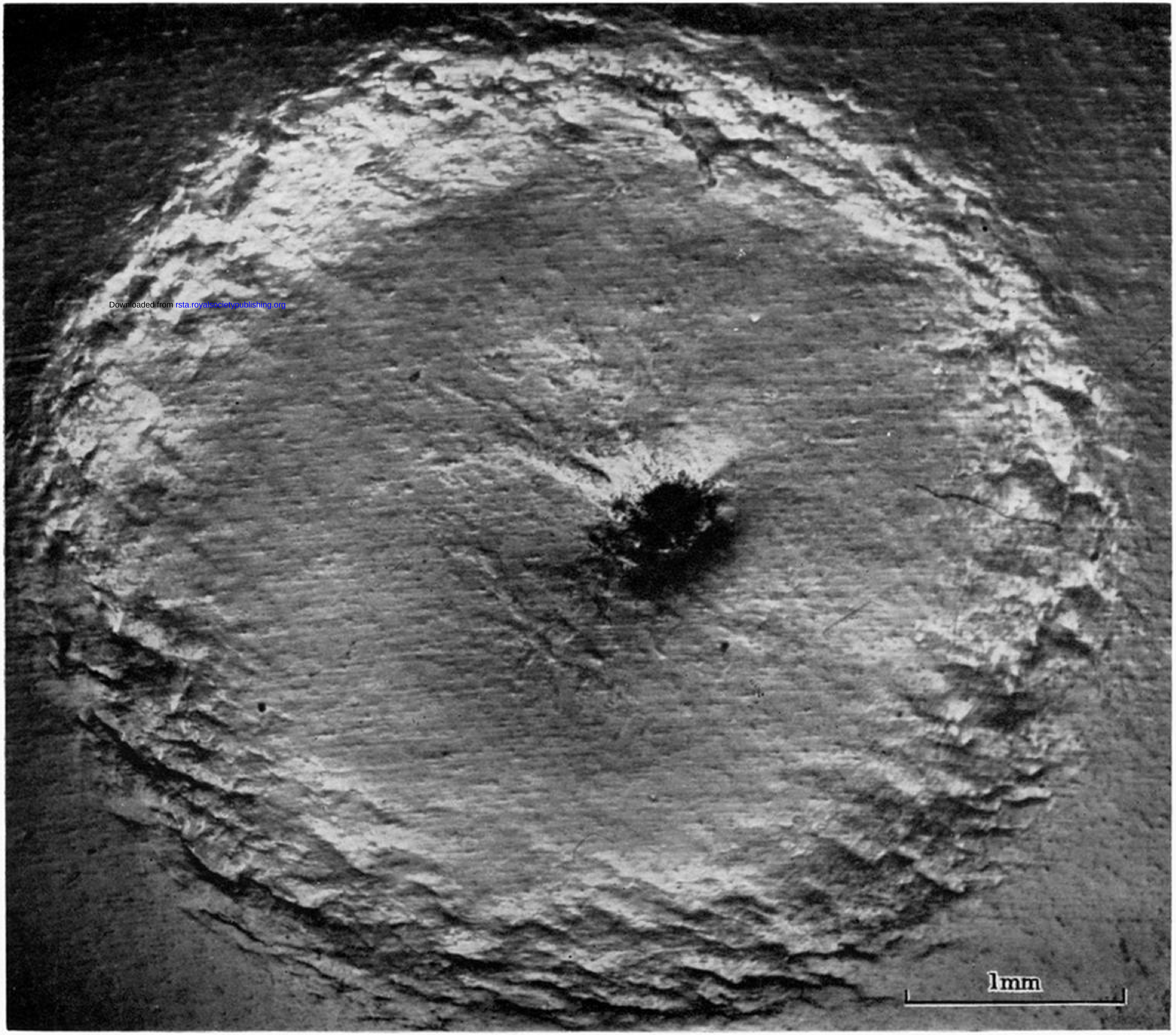

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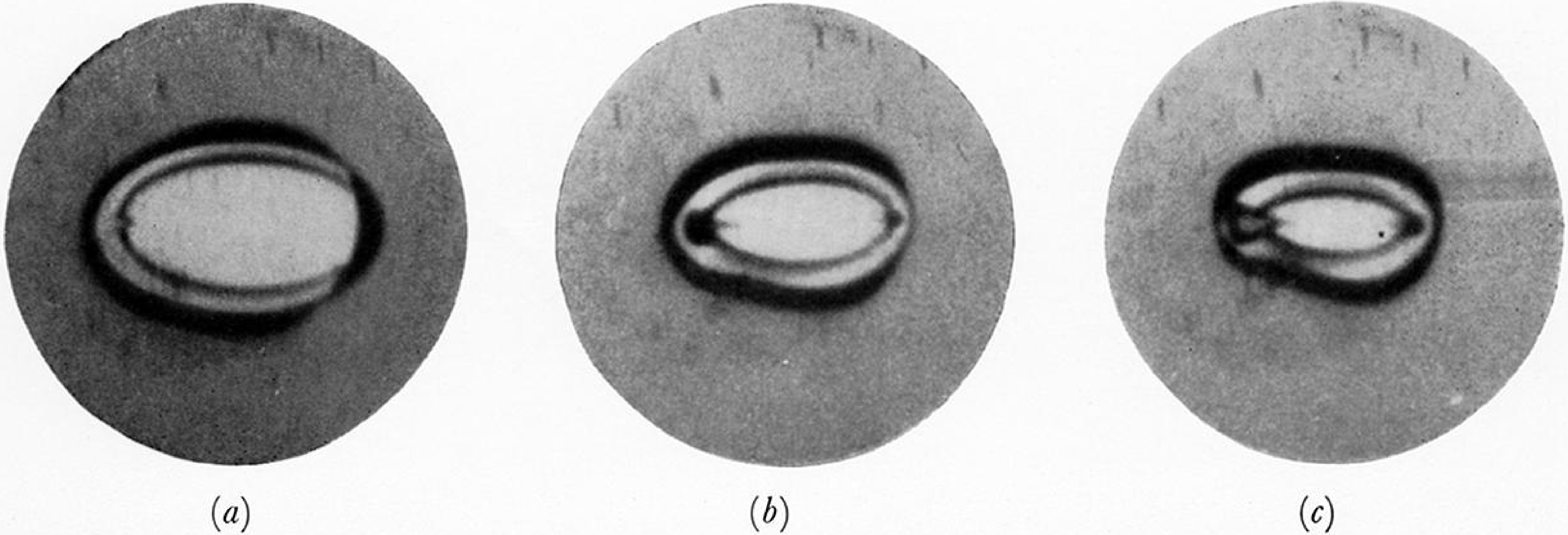

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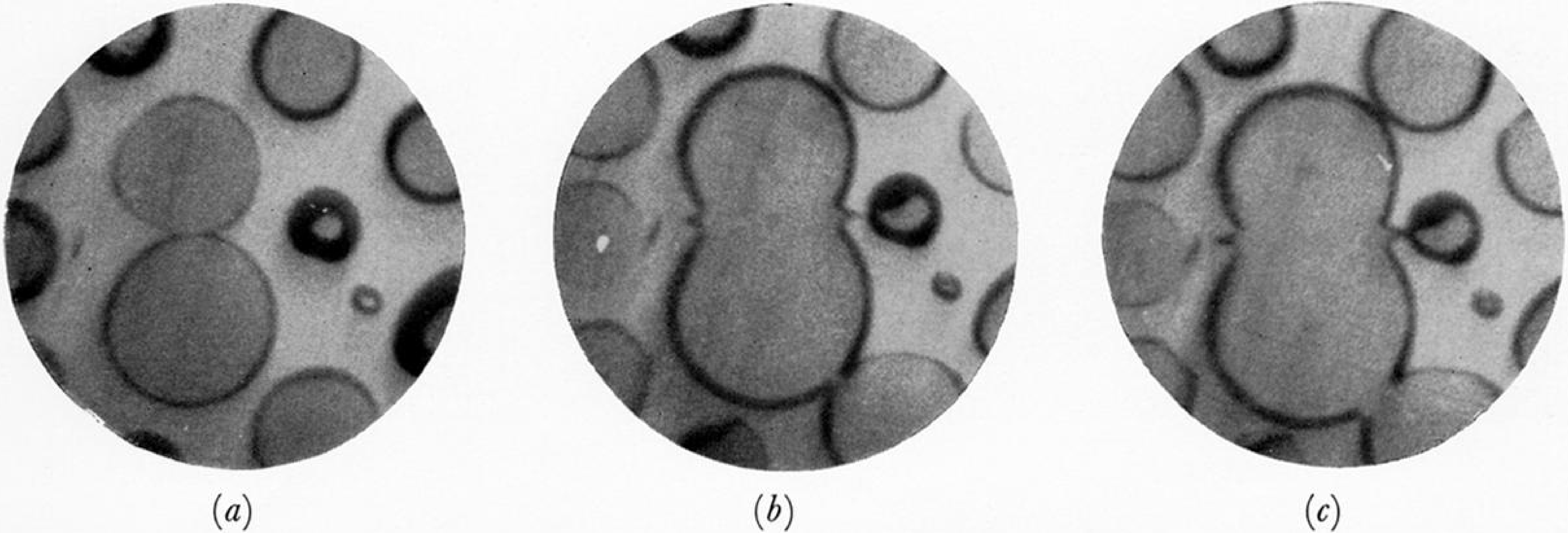
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