PART V.3

THE HANDLING OF EMULSIONS

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I would like to go back about two years in time. At this stage, when large collaboration stacks were envisaged, Professor Herz of Milan suggested the examination of each pellicle at Ilfords before the total stack was packed and sent to its destination. Dr. Dilworth and I went to Ilford to check the first stack of this kind.

By some confusion in the exchange of information with Ilfords, the stack we had come to check was in fact already packed. This proved to be extremely fortunate, because the people who had packed the stack were obliged to unpack it. At this time Ilfords had the habit of cutting their emulsions in pairs with the tissue paper already between them. In the unpacking they saw for the first time the tremendous difficulty there was in separating the tissue paper from the emulsion. Consequently the emulsions are now cut to size one at a time. Those of you who have been in this work for more than two years will probably have noticed that the emulsions now arrive with the tissue paper quite loose between them.

Another point which also amazed the packers was the amount of foreign matter that was stuck between, and into, the emulsions. In fact, of this stack of some 130 emulsions we were obliged to reject about 20%. This was largely due to the fact that the stack had already been packed and the foreign matter (e.g. silvers of glass, pieces of emulsions, etc.) had been really pressed into the emulsion. In a stack inspected recently (March 1962) less than 5% of the pellicles had to be rejected.

For the cutting of emulsions Ilfords have a simple guillotine. They have recently sharpened this device but unfortunately the emulsions always have some deformation at the edges and this is very noticeable when one makes a large stack. In a stack of 230 pellicles of 600μ

thickness, 20 cm long and 15 cm wide, that I made up recently, there was a gap at the centre of some 2 mm, as illustrated in Fig. 1. It is evident that a stack exposed horizontally in this condition would not be of much use, if one required the primary particles to pass through the length of the emulsion. I have suggested that a new cutting machine be made from stainless steel with a spring-loaded bar to hold the emulsion during the cutting operation (see Fig. 2). The spring-loaded bar would be of the order of 3 mm wide, so that any resultant pressure marking of the edge of the emulsion would be kept to a minimum. In most experiments measurements are not made in the region close to the edge of the emulsion.

When the emulsions arrive at the laboratory, each pellicle is re-examined during the stacking operation, and one sometimes still finds one or two emulsions that are not perfect. These are placed on top of the stack to act as a pressure buffer during tightening down.

Cleanliness is most important at this stage; the darkroom should be kept perfectly clean, like an operating theatre in a hospital.

The choice of stack holder is a problem. It depends on the experiment and exposure envisaged: whether the emulsions are to be horizontal, vertical, perpendicular, water soaked, loaded, or for use in a pulsed magnet. Let us consider first the type of stack holder used to expose emulsions horizontally.

For example, in the case of an experiment to investigate spurious scattering one requires the tracks to traverse the complete length of the emulsion. Therefore the emulsions have to be horizontal to within about 0.03 mrad. Figure 3 shows the type of holder we use in CERN for such exposures. It can also be used in certain cases for the kind of vertical exposures discussed yesterday. It is composed of a tufnol base 300 x 300 x 30 mm, a tufnol top piece 30 mm wide and about 3 mm all round smaller than the emulsions, plus four rather robust clamps to hold the emulsions in place. On the tufnol base we place a piece of black plexiglas 5 mm thick, cut to the stack size. This allows the milling cutter to pass the last emulsion without damaging the tufnol base and in this way the apparatus may be used many times.

The reason for making the apparatus in this form is because one needs some reference for gridding for most stacks. In addition, due to the distortion introduced at the edges by the cutting operation, one is obliged to mill all around the stack. Therefore we stack the emulsions in as neat a manner as possible on the plexiglas base, place the top piece of tufnol in position and tighten the clamps. The amount of pressure applied can be measured with a simple mechanical lever attached to the clamping screws, which are made long enough for this purpose. A known weight is then applied and the pressure on the emulsions can be calculated exactly.

The pressure applied to a stack of emulsions can be quite high without causing damage. A pressure that is quite reasonable is of the order of 300-350 g/cm^2.

Now the stack is ready for the milling operation. The whole idea of this apparatus is that one can mill and expose without disturbing the stack. In this way the milled edges of the stack give an excellent reference line for gridding. Further, by milling away the distorted edges, one has done the best one can to make the emulsions flat in the horizontal plane.

The technique of milling the stack is quite important. We have had a special cutter made which is 20 cm long and 5 cm in diameter (see Fig. 3). A length of this magnitude can be tolerated because the emulsion is a rather soft material. This cutter has a very fast helix angle so that it slices rather than shears. The shearing action tends to weld together the edges of the emulsion, but the slicing action of this type of cutter gives a smooth finish, and the emulsions separate quite easily after exposure. The recommended speed of a cutter of this type and diameter for milling emulsions, is of the order of 125-150 turns per minute, and the feed should be of the order of 50 mm per minute. During the whole of the milling operation compressed air should be applied to the cutter to clear away the cut emulsion and to keep the cutter cool. To avoid contaminating the emulsions with any oily matter it is better to filter the air supply.

This milling operation can be quite safely carried out in daylight. Immediately the edge of the emulsion becomes black it provides its own protection and the blackening penetrates to less than 0.5 mm. When one has a large stack (e.g. 200-250 600μ emulsions) it is necessary to divide the stack in half, mill each separately, put the two halves together and remill the complete stack. The reason for this is to avoid light entering due to the gap that can occur in large stacks, caused by edge distortion as is illustrated in Fig. 1.

Figure 4 shows a much smaller stack, in exactly the same fixture; this gives some idea of the flexibility of this type of holder. One can, in fact, hold up to 250 x 600μ emulsions in it. For very small emulsions, say 10 cm x 3 or 4 cm, only two of the clamps may be used. With this holder one has the possibility of stacking emulsions of all sizes up to a maximum of 30 cm long by 15 cm wide.

The only specialized types of stack holders that I shall discuss here are those required for pulsed magnet work (see Fig. 5). The pulsed coils constructed in CERN by our workshop have a central tube giving a working diameter of about 6.5 cm. The problem was to hold the emulsions in the centre of this coil. We have therefore developed the two holders seen in Fig. 5. The right-hand holder, which is made completely of plastic, was constructed for straight-forward vertical exposures. The emulsions are held between two pieces of black plexiglas cut to the required shape, and the whole stack is held together by scotch tape. The stack is then inserted into the circular holder and is ready for exposure. The left-hand holder was designed for the Σ^+ experiment and is, in fact, two stacks in the same holder. The two stacks are at $\pm$ 10° with respect to the beam. The side of the emulsions facing the beam was milled to present a radius of 3 cm to the target. This holder is held together by stainless steel screws and no movement of it was noticed in magnetic fields of up to 200 kgauss in magnitude.

Many other types of stack holders have been made for specialized purposes. For example, several groups (e.g. University College, London) have made some very elegant pieces of apparatus to hold water-soaked emulsions.

After the exposure comes the problem of how to keep the emulsions until it is convenient to do the development, etc. Dr. E. Dahl-Jensen remarked in his talk that it is not very good to keep emulsions at low temperatures after exposure. This is not true, however, if one seals them in polyethylene before putting them in the refrigerator, so that the relative humidity remains of the order of 50-60%.

Perhaps the most delicate part of the whole operation is the demounting, marking, thickness and/or density measurements, and the gridding of the emulsions. For this work we employ a team of four or five people, each with a specific job, which avoids confusion and mistakes.

Demounting

If the milling technique outlined above is used, the best approach is to take a stainless-steel knife, and run it up the corner of the stack. In this way the emulsions will then separate from each other quite easily.

Marking

Figure 6 shows the manner in which most stacks developed in CERN are marked. All the writing, which is done with a hard lead pencil, is on the bottom edge of the emulsion; this avoids resting the hand on the emulsion while writing.

Thickness and Density measurements

Due to the accurate milled edges, the size of the stack can be easily measured and the volume calculated, provided that a sensitive balance is used for weighing the emulsions. Thickness measurements can be made in various ways. Figure 7 shows the apparatus currently used at CERN. The micrometer clock gives a precision of 1 micron, enabling accurate shrinkage factor determinations to be made.

Gridding

Figure 7 also shows the apparatus used at CERN for gridding. The box-like structure is about 2 metres high at the back and 1 metre in front. An ordinary microscope bulb is placed centrally at the top; at the bottom two mirrors are fixed at 90° to one another, resulting in nearly parallel light illuminating the plexiglas top of the front of the assembly. The grid negative is fixed on to this plexiglas top. On the right-hand side of the box is a time switch giving a choice of exposure time of 1-30 seconds. On the front panel there is a micro-ammeter which is operated by a selenium cell giving a measure of light intensity.

Figure 8 shows the square used for positioning the emulsions during gridding, with three-pin location that can be changed according to the emulsion size. Also shown is an enlarged section of the Berkeley-type grid that is normally used at CERN. Many other types of grid exist and can be used with our apparatus.

After the development of the emulsions, to facilitate the quick positioning of plates on the microscope it is desirable to cut the edges of the glass with reference to the grid. This can be done, with the aid of a simple glass-cutting machine, provided that the print of the grid on the bottom of the emulsion can be seen clearly with a hand microscope.

Transport of undeveloped emulsions

After exposure, emulsions which will not be processed at CERN have to be transported as quickly as possible to their destination for development. As I have already mentioned, providing that the emulsion stack is sealed in polyethylene it can be kept at a low temperature, e.g. $-5° \rightarrow -2°$, to avoid fading and the accumulation of extra background. Therefore we pack the stack in specially made strong wooden boxes, with a layer of at least 3 cm of styrofoam all around the inside, and construct appropriate compartments of styrofoam to hold the stack, plus sufficient dry ice to keep it cool during transit. This arrangement is illustrated in Fig. 9.

Suitable labels are then attached to the box indicating that it must be kept away from radioactive materials and in a cool place. A telegram is sent advising the recipient of the airway bill number, flight number and the date of arrival.

Whenever possible it is desirable to come to some agreement on procedure with your nearest Customs officials, so that the passage through the Customs of undeveloped emulsions is subject to the minimum of delay.

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DISCUSSION

Sichirollo : I should like to emphasize that the thickness measurement is useful for measuring the shrinkage factor, for example for precise angular measurements, and you can see where the measurement has been made as the friction causes a dot on the emulsion surface.

Roberts : Yes, the point would make a dot on the emulsion surface, which is easy to find afterwards, but we have rather a large foot on the CERN micrometer clock, so I emphasized that the position must be measured very accurately and written down.

Doble : Would you like to comment on the fact that we are interested in the average thickness and the average shrinkage factor? What are the objections, therefore, to a parallel plate condenser consisting of stainless-steel plates connected to a bridge circuit and moving one plate relative to the other until the bridge is balanced? This should be highly reproducible and would give an average thickness over the emulsion placed between the plates.

Nikolić : I am interested in the manner in which Ilfords produce the large emulsions. Do they make them one by one, or do they cut up a large sheet?

Lock : I shall anser Doble's point first. I made such a piece of apparatus fifteen years ago for a different purpose. I am not sure of the accuracy one could achieve, perhaps to 1 micron. However, even if you made thickness measurements at two or three standard points, and determined the shrinkage factor at these standard points, the assumption made afterwards would be that the

Lock (cont.) : shrinkage factor is constant over the whole emulsion. If you are interested in a particular event at a particular event at a particular point, I do not think that there is any difference between assuming an average thickness, or from a measurement at another point assuming an average shrinkage factor.

Doble : I agree with this. The idea was to eliminate the danger of pressing too hard and compressing the emulsion at that point, or not pressing hard enough, when the inclusion of air pockets would lead to too high a value for the thickness.

Lock : What we do is to remove the spring, and just use the weight of the dial micrometer pointer to measure the thickness. In this way we obtain enough pressure without including air gaps, or denting the emulsion.

Key : We combine the density method and this method. We weigh the whole stack and then each pellicle, and then on every tenth pellicle throughout the stack we make thickness measurements at ten or twelve points. This gives a good idea of the variation throughout the stack and in each pellicle. Combined with the density measurement we feel this probably gives quite a good value.

Roberts : It is probably true to say that the shrinkage factor is reasonably constant over any individual emulsion. In answer to Nikolić, I really am not qualified to comment. It probably depends on the size ordered. Perhaps they produce one metre square of emulsion, pour it onto glass, and cut it afterwards.

Nikolić : This is the usual assumption, but recent information suggests that they are produced one by one. I feel this is important for precision measurements.

Dahl-Jensen : We are interested in this for our next exposure. I asked Ilfords, and they said that for 4" by 4" pellicles, they produce a 9" by 9" sheet, then put away the surplus, and cut it into four.

Roberts : I will check on this next time I am at Ilfords. You mentioned pouring onto the glass, and this reminded me of our examination in London of the first stack. We did, in fact, find convex bumps as well as concave indentations due to foreign matter. These bumps were due to chips in the glass, and I believe that Ilfords immediately changed all their pieces of glass.

Allen : For the recent K^- exposure, we examined the pellicles and rejected 16 out of 360, which is about 4%. We were quite critical, and some pellicles could have been used if absolutely necessary. Ilfords always manufacture more emulsion than is actually ordered, but are not prepared for a rejection of more than 5%.

Roberts : Yes, after the first examination when we rejected about 20%, Ilfords have been prepared to accept a rejection of up to 5%.

Gottstein : What is the present standard of uniformity in emulsion thickness at Ilfords? A few years ago fluctuations of as much as 10% occurred in a given stack.

Roberts : This is still so, even in one pellicle, but it varies from stack to stack and probably depends on the levelling of the glass plate onto which they pour the emulsion.

Dahl-Jensen : Do you measure the thickness at Ilfords when you check the plates?

Roberts : No, we do not have time.

Dahl-Jensen : We have had pellicles which varied from 640μ to 570μ down one edge. How can one avoid this? If you had examined this, it would have been rejected.

Roberts : If we used this criteria, we would probably throw out up to 50%. The Milan stack of 130 pellicles dipped by about one millimetre at one edge.

Harmsen : How many milimetres are lost when the stack is milled?

Roberts : I normally mill off at least three millimetres from all sides. Another point: with a big stack it is advisable after each cut to take up the slack gently on the screws.

Evans : How do you mill the edge of the stack which is by the screw rods?

Roberts : I just mill the front edge until completely flat, and then take it into the darkroom, and turn the stack round and mill the other three edges.

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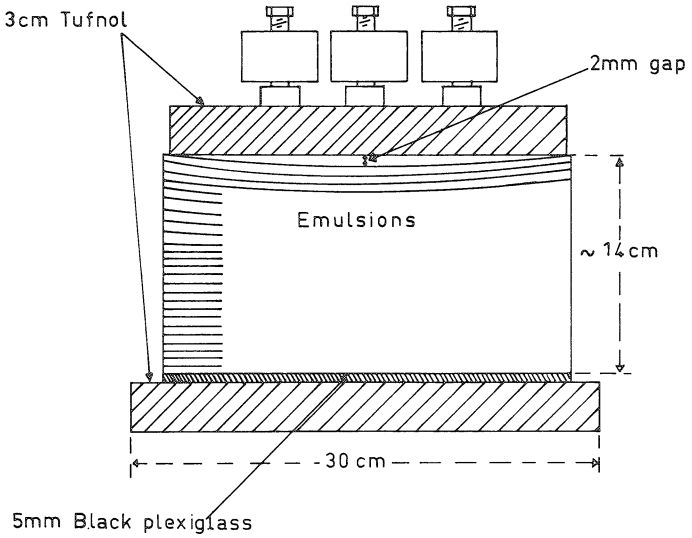


Fig. 1

Schematic diagram of clamped emulsion stack showing effects of edge thickening.

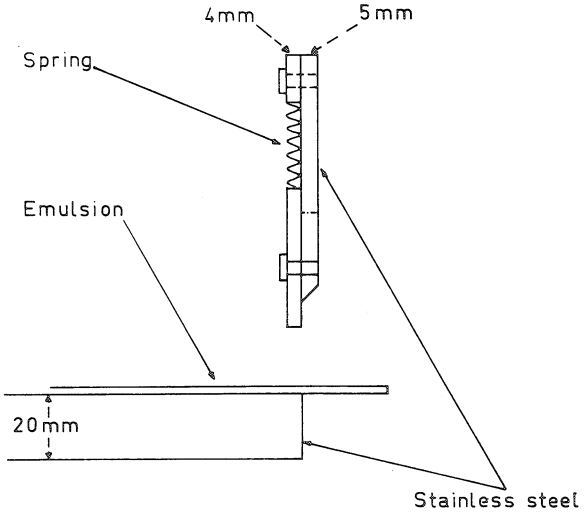


Fig. 2

Schematic diagram of proposed device for cutting emulsion

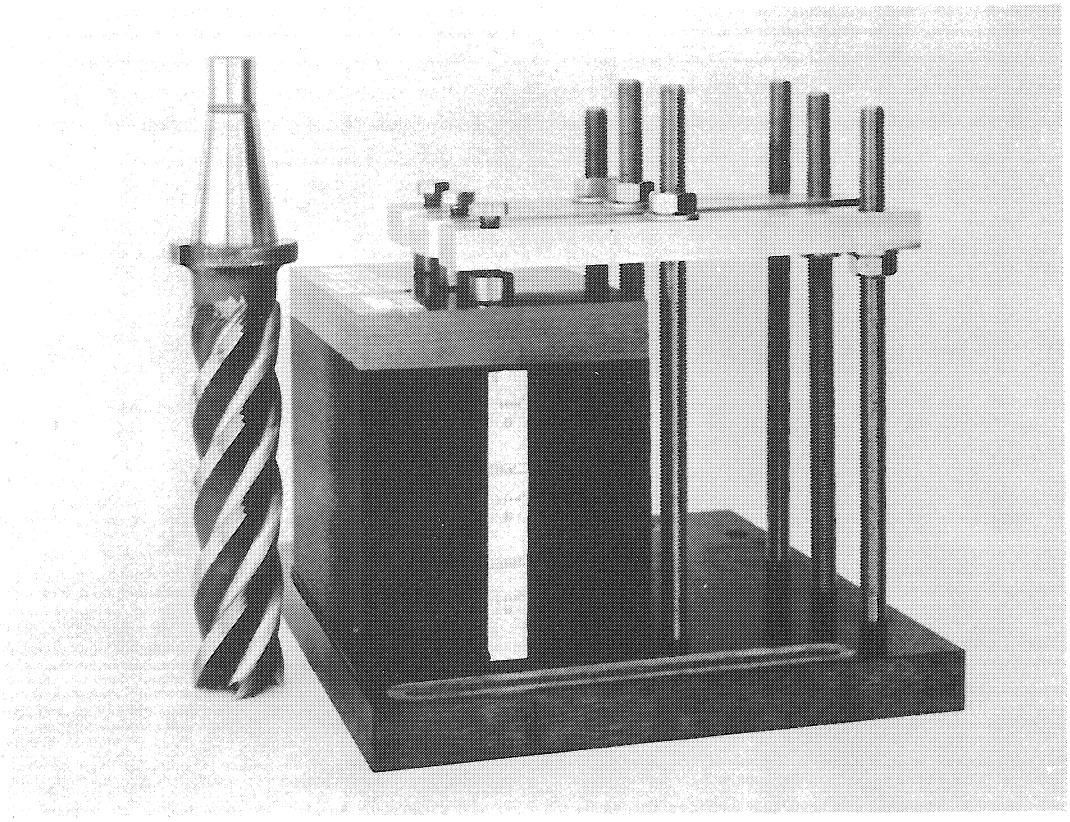


Fig. 3. Photograph of clamped emulsion stack with special milling cutter.

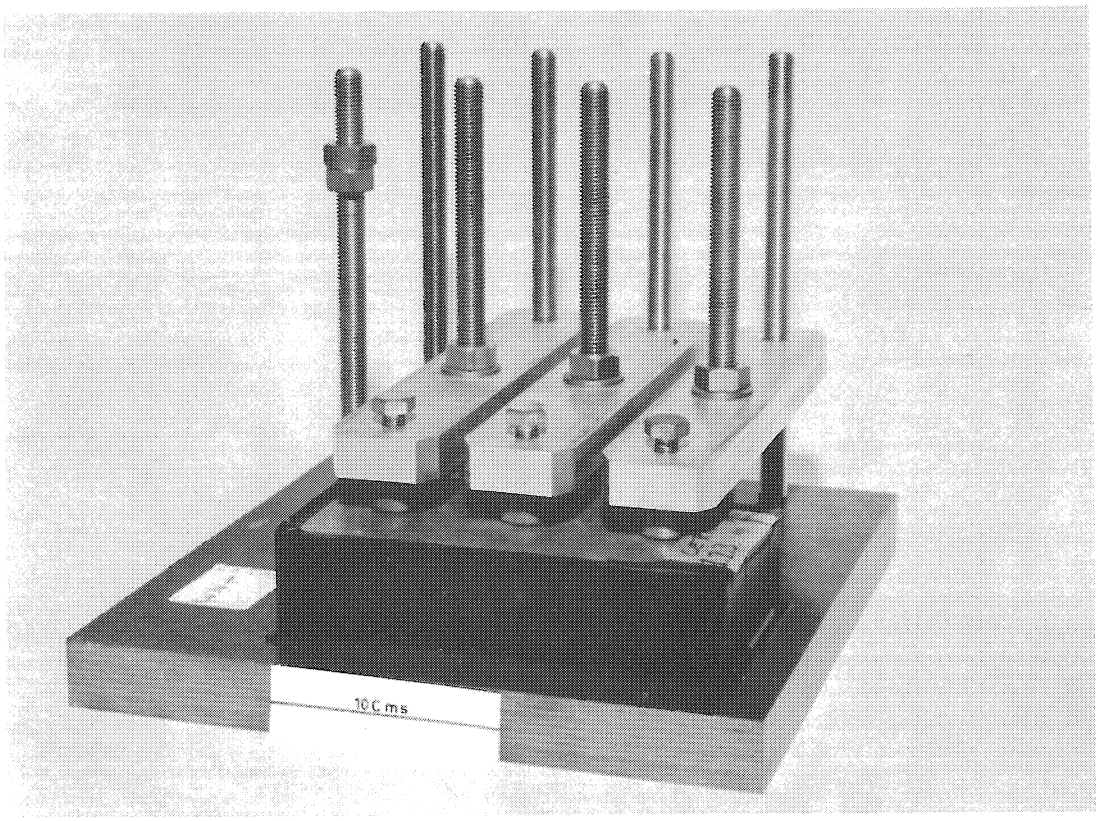


Fig. 4. Photograph of small emulsion stack in special holder

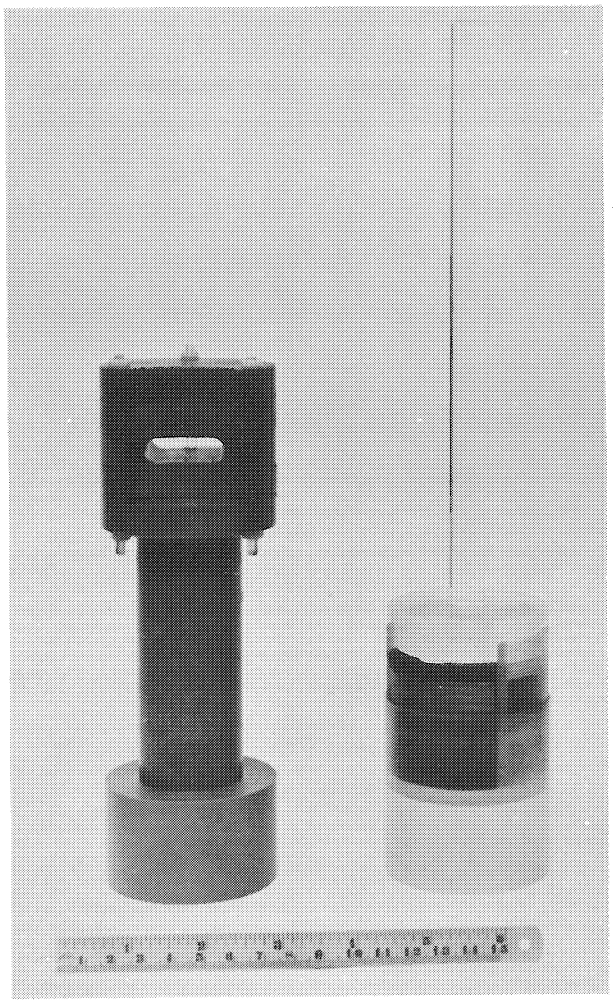
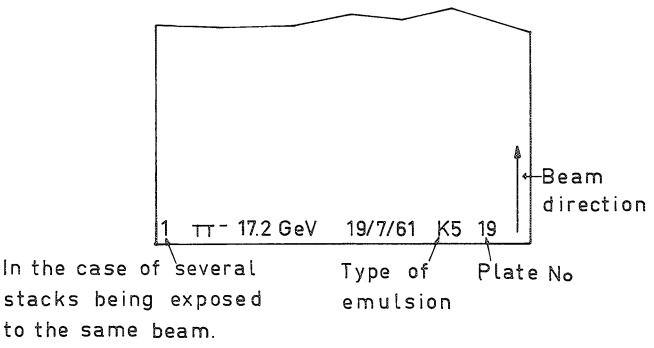


Fig. 5. Photograph of two types of stack holders for exposure in pulsed magnets.

Fig. 6

Diagram illustrating the CERN Emulsion Group's method of marking plates and pellicles.



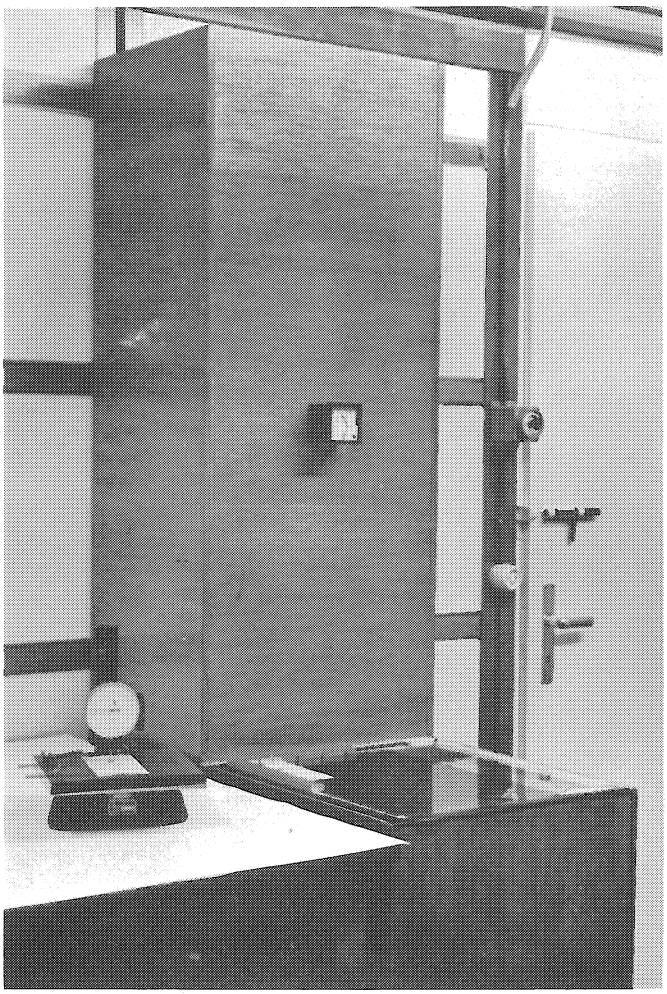


Fig. 7. Photograph of CERN Emulsion Group's gridding and thickness measuring apparatus

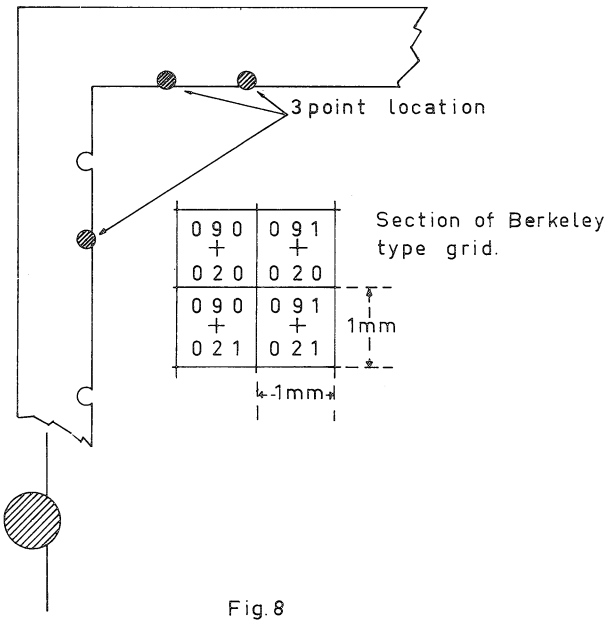


Fig. 8
Schematic diagram of locating device for gridding emulsions plus a section of Berkeley type grid.

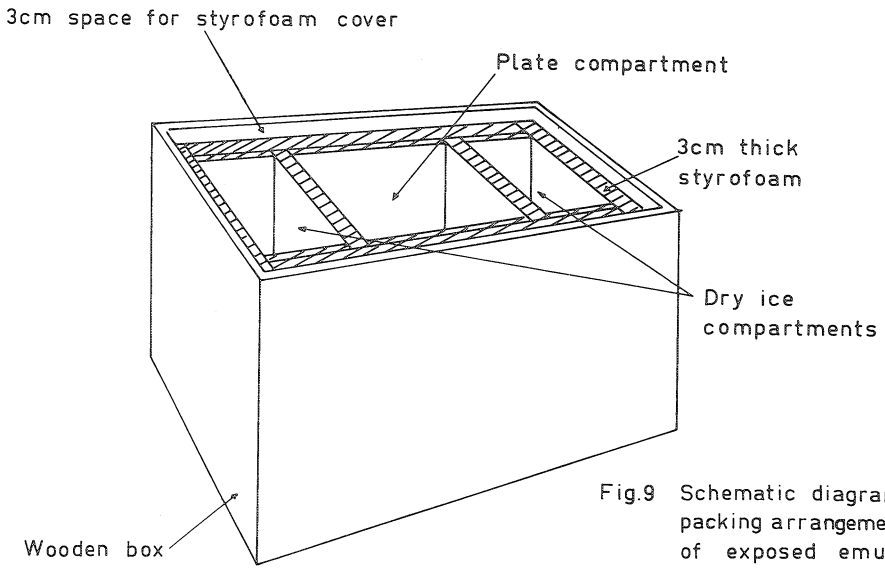


Fig. 9 Schematic diagram of typical packing arrangement for transport of exposed emulsions.