



DIAGRAMS DRAWN BY COMPUTER



An operator demonstrating the picture on the face of the cathode ray tube. In normal operation this tube is in the vertical position.

AWRE ALDERMASTON

By Dr. J. G. T. Jones

COMPUTER output printers currently in use are generally of the electro-mechanical type, limited in speed by the inertia of mechanical moving parts to about 1,500 lines per minute. Impressive though this speed may be, it is completely inadequate compared with the speed at which output can be created by present day computers capable of performing millions of operations each second.

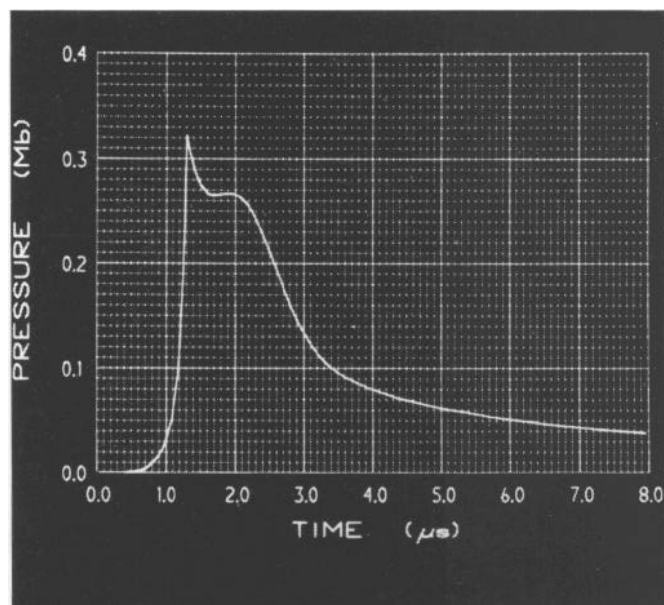
In order to achieve higher speeds, electronic printing devices have been developed in which mechanical moving parts are almost entirely eliminated. The Stromberg-Carlson 4020 is a device of this type, the only one of its kind in this country being at A.W.R.E. Data is input to the 4020 in the form of coded information on $\frac{1}{2}$ in. magnetic tape. Consequently the 4020 can be used with any computer which uses IBM compatible tape including the IBM 7090 and 7030 (Stretch), ICT Atlas and English Electric-Leo-Marconi KDF9 computers used in U.K.A.E.A. establishments.

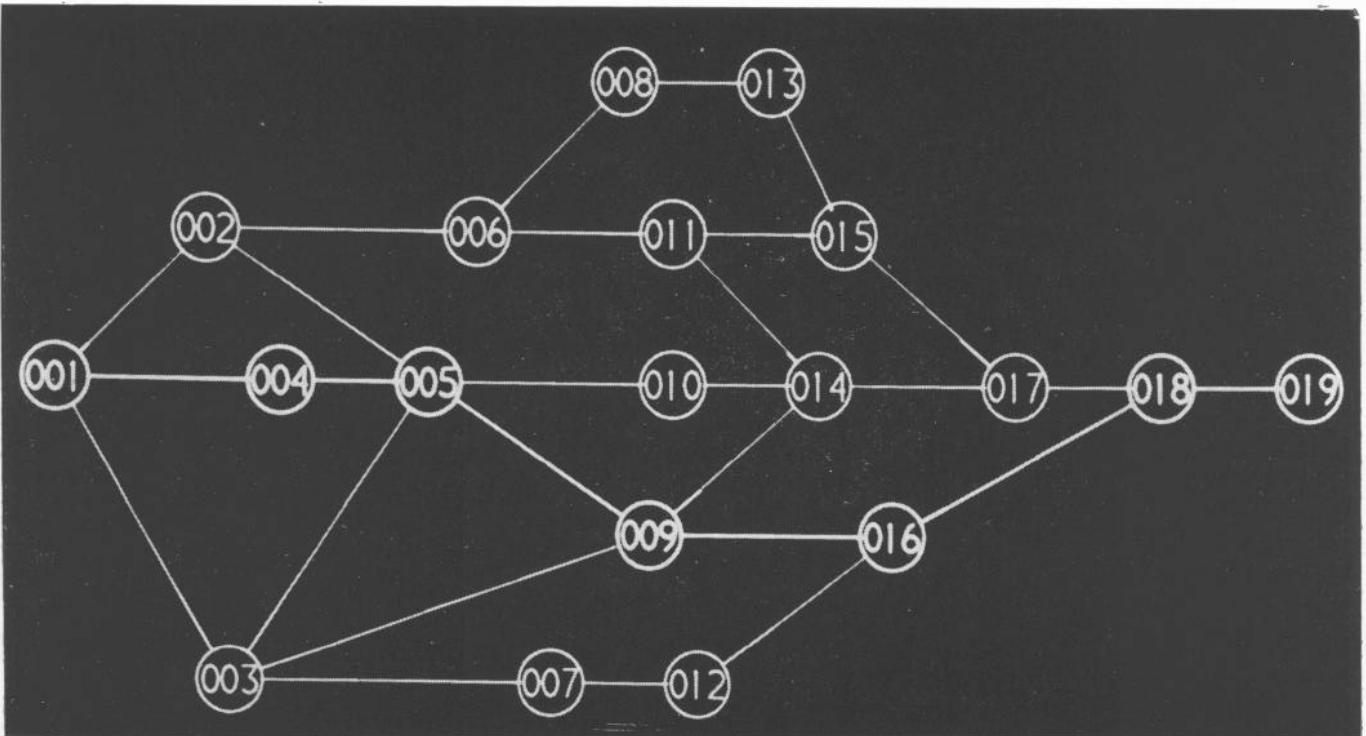
The 4020 generates characters using a cathode ray tube containing a small plate in which are cut sixty-four character-shaped apertures. An electron beam directed at a selected aperture is extruded into the form of the character and the shaped electron beam is then deflected to a selected position on the tube face. Character images so formed on the tube face can be recorded on 35 mm. film and/or sensitized paper which are subsequently developed photographically. Sixty-four lines each containing up to one hundred and twenty-eight characters can be printed on each frame. The only mechanical moving parts in the device are those required to advance the film or sensitized paper a page at a time so that extremely high printing speeds are possible, over 7,000 lines per minute when recording on microfilm only.

The speed of present day computers poses a human problem also in that the computer user has to assimilate the output before he can make any deductions from it. The printed numbers shown top right, an example of the 4020 printed output, will convey very little to the average reader and it is quite probable that the computer user will plot a graph of the results in order to understand them fully.

The 4020 can make a large contribution to the solution of this human problem. By panning the electron beam through the dot aperture a straight line trace can be made on the tube face. With a combination of dots

	TIME	PRESSURE	ENERGY	DENSITY
1	0.423724	0.	0.	1.800000
2	0.467674	0.000077	0.000017	1.808756
3	0.511624	0.000322	0.000071	1.817944
4	0.555574	0.000763	0.000167	1.827615
5	0.599524	0.001431	0.000311	1.837628
6	0.643474	0.002367	0.000512	1.848656
7	0.687424	0.003622	0.000779	1.860184
8	0.731374	0.005259	0.001123	1.872518
9	0.775324	0.007359	0.001561	1.885767
10	0.819274	0.010031	0.002112	1.900153
11	0.863224	0.013415	0.002801	1.915825
12	0.907174	0.017708	0.003664	1.933073
13	0.951124	0.023182	0.004750	1.952256
14	0.995074	0.030229	0.006126	1.973866
15	1.039024	0.039441	0.007894	1.998599
16	1.082974	0.051745	0.010209	2.027476
17	1.126924	0.068687	0.013324	2.062082
18	1.170874	0.093050	0.017681	2.105040
19	1.214824	0.130398	0.024135	2.161107
20	1.258774	0.193719	0.034591	2.240135
21	1.302724	0.321971	0.054400	2.367425
22	1.346674	0.307281	0.052207	2.354330
23	1.390624	0.294430	0.050274	2.342614
24	1.434574	0.283918	0.048682	2.332839
25	1.478524	0.275795	0.047445	2.325162
26	1.522474	0.270029	0.046564	2.319643
27	1.566424	0.266477	0.046019	2.316214
28	1.610374	0.264857	0.045771	2.314642
29	1.654324	0.264732	0.045751	2.314521
30	1.698274	0.265505	0.045870	2.315271
31	1.742224	0.266432	0.046012	2.316170
32	1.786174	0.266664	0.046048	2.316395
33	1.830124	0.265320	0.045842	2.315092
34	1.874074	0.261579	0.045267	2.311448
35	1.918024	0.254802	0.044222	2.304780
36	1.961974	0.244649	0.042647	2.294620
37	2.005924	0.231168	0.040542	2.280799
38	2.049874	0.214834	0.037965	2.263502



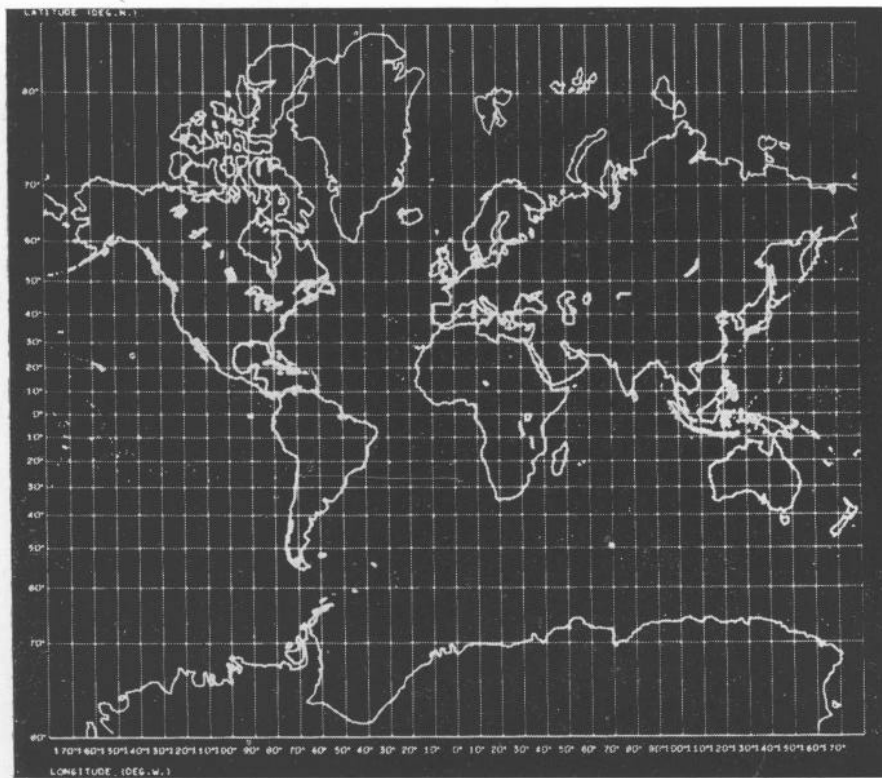


and straight lines a drawing can be created, a technique which can be used in almost every computer application to present results in visual form, quickly assimilated by the computer user. All the illustrations in this article, with the exception of the first, were drawn in this way and show a few of the many uses of the 4020.

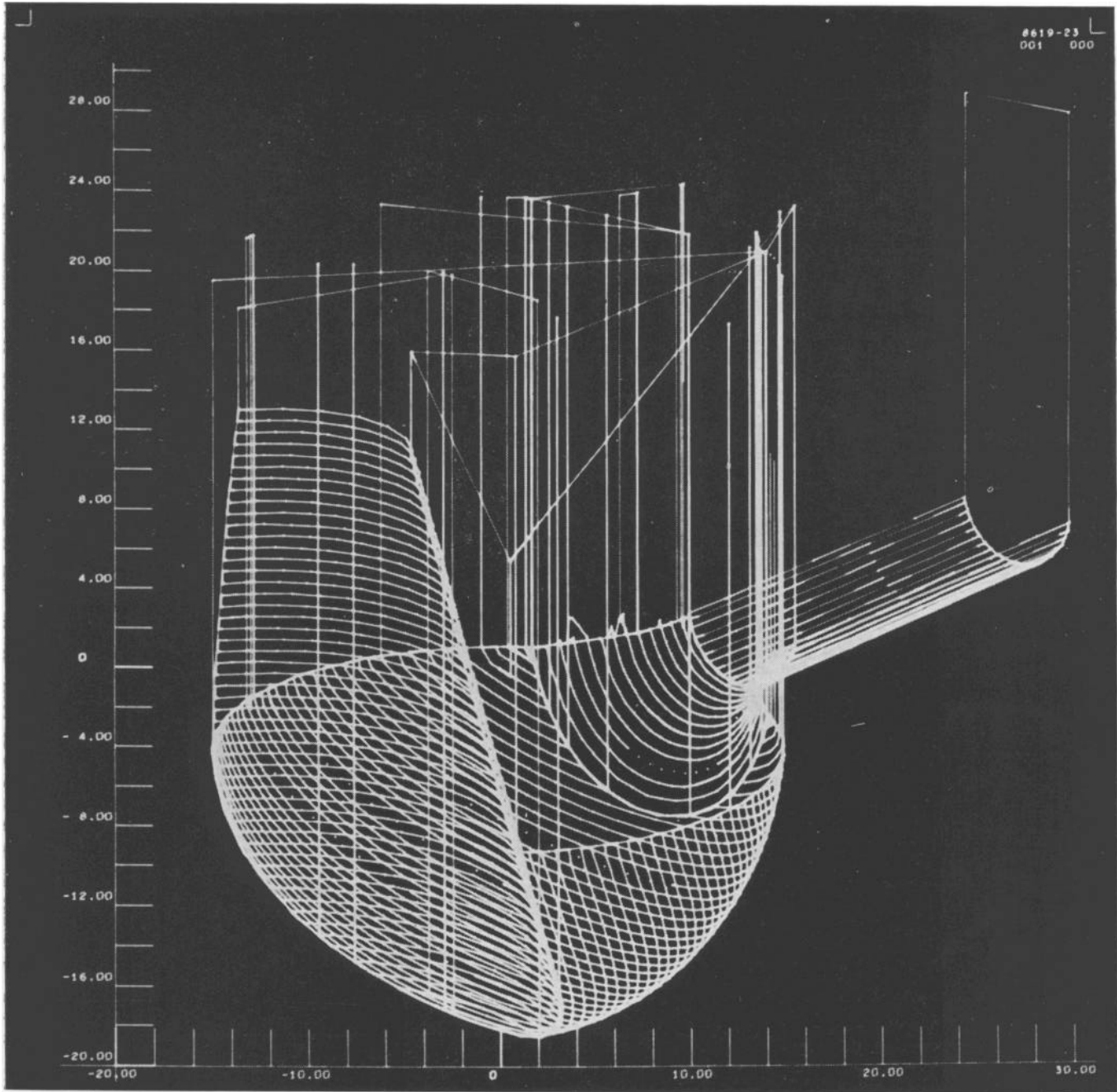
The graph at the bottom of the first page is a plot of the pressure/time values printed above it. The essential features of this graph can be assimilated by the computer user almost at a glance, certainly much more quickly than can the printed numerical values. A graph of this type can be drawn on the 4020 in a fraction of a second.

Critical Path or PERT techniques are being used extensively to plan large engineering and research pro-

jects. In these projects some activities cannot start until other activities have been completed, e.g. in building projects the roof cannot be put on until the supporting walls have been built. This ordering of activities is represented by a directed network. The time required for each activity is then estimated and a computer is used to analyse the network to determine the total time required for the project and to draw the attention of the project manager to the critical activities, i.e. those activities which prevent the project from being completed in a shorter time. Project networks can be drawn on the 4020, the diagram above shows a simple network produced automatically by a critical path analysis program. Attention is drawn to the critical path by emphasising the critical activities.



THE 4020 is being used elsewhere to draw maps, the map of the world on the left being an example of this use. In order to draw these maps it is necessary to specify the positions of a large number of points on the desired outlines, but once this has been done a large variety of maps can be drawn. Any desired projection can be easily obtained, the map shown here is a Mercator projection. Also any part of the map can be selected and expanded under computer control and additional information such as cloud density, radiation intensity, temperature, population, etc., can be superimposed.



IN the last few years numerically controlled machine tools have been introduced to industry. Instead of being controlled by a human operator these machine tools are automatically controlled by coded instructions, read sometimes from punched cards but usually from either magnetic or punched paper tapes, which define the path to be followed by the cutting head and even the cutting head to be used for each section of the path.

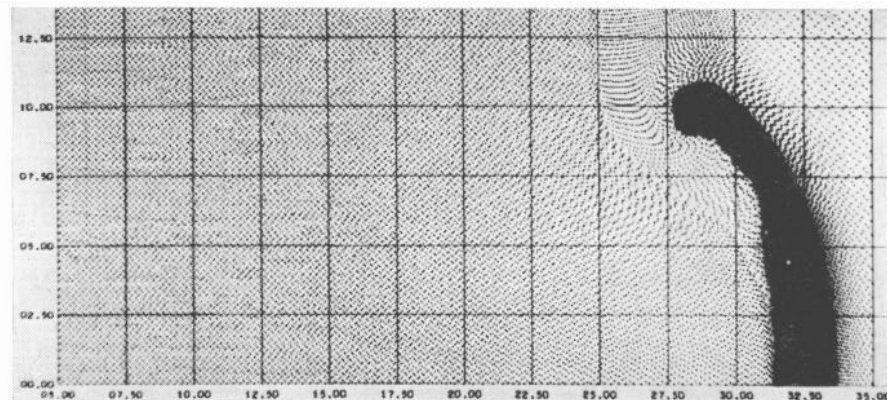
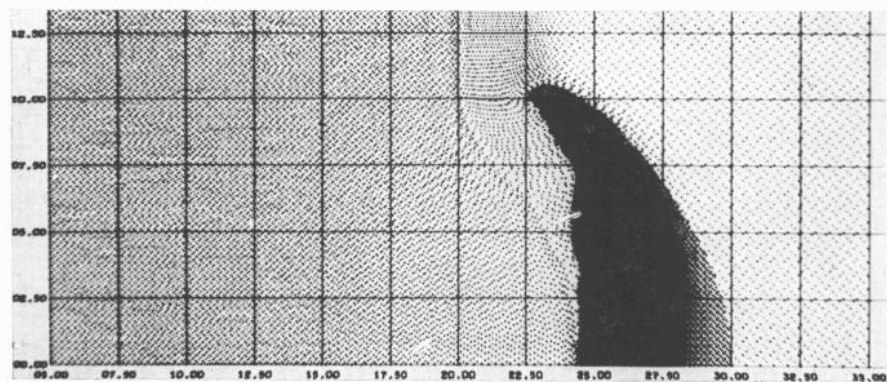
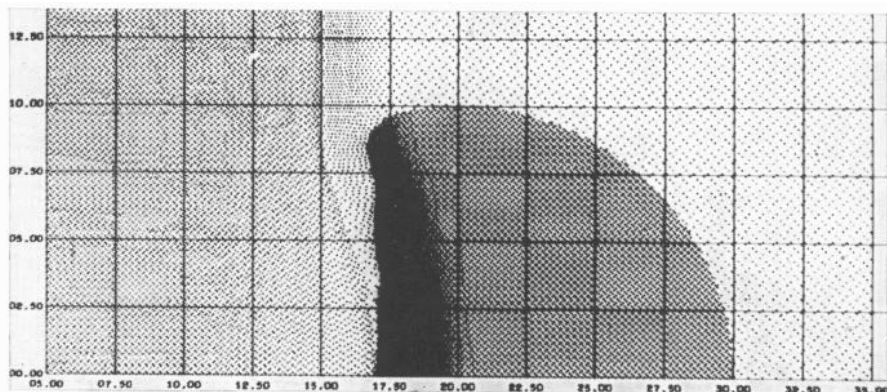
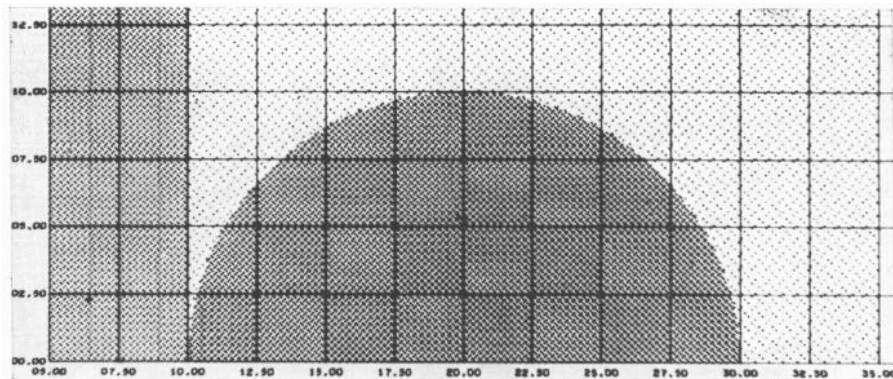
To produce these control tapes a complete programming system known as APT (Automatically

Programmed Tools) has been developed. The programmer describes the component to be machined in terms of its geometric forms, e.g. straight lines, circles, parabolas, ellipses, etc., in the English-like APT language. A digital computer is then used to translate this description and other relevant information to produce automatically a control tape which then directs the machine tool to produce the required component.

The 4020 is being used to check the accuracy of these control tapes.

Before the component is machined the control tape can be read and the machine tool path drawn on the 4020. An example of such a tool path drawing is shown above. This particular component is 3-dimensional so that the drawing illustrates the projection of the tool path onto a plane from one view point. It is possible to obtain a projection of the tool path from several view points. These drawings are checked for errors prior to manufacture, thereby eliminating the costly machining of incorrectly designed components.

ONE further capability of the 4020 merits special mention. It was said earlier that the output could be obtained either on 35 mm. film, which is very suitable for long term storage, or on sensitized paper, which is more convenient for everyday use. However, the 35 mm. film output can be run through a 35mm. cine projector: thus if a series of slightly changing sequential events is recorded on film, this can be projected and viewed as a cine film giving a time scale sequence. Cine projectors run at 24 frames/second so that even a short film would require a large number of frames. To reduce the computer time required to produce an adequate number of frames the 4020 has a facility for repeating each frame up to thirty-two times. Titles can be added using characters formed from vectors, characters formed in this way were used to annotate the graph on the first page, so that a complete film can be made using the 4020. Such films are ideal for the presentation of results of time dependent computer calculations and a few films have been made in the Mathematical Physics Divisions at A.W.R.E. The sequence of photographs shown on the right have been taken from one of these films illustrating the interaction of a plane shock wave with a spherical bubble of helium in neon. The computation was done by a 2-dimensional unsteady hydrodynamics program using the Particle-in-cell method. In this method elements of fluid are represented by particles, shown in the photographs as dots: to distinguish the helium from the neon the helium particles are shown as larger dots. The program computes the motion of the particles through a fixed reference grid of cells in which hydrodynamic variables, such as pressure, are evaluated, hence the name Particle-in-Cell. The photographs show a section through the centre of the bubble perpendicular to the shock. In the top photograph the shock-



is touching the left of the bubble, behind the shock the neon is compressed to a higher density, this increase in density showing as an increase in the number of particles per unit area. In the sequence of photographs the shock propagates from left to right, travelling faster in

the helium bubble than in the neon outside and also compressing the helium more. In the bottom photograph, the last of the sequence, the helium bubble has been compressed into a meniscus shape.



Changing the hard copy magazine.

There are vacancies in the Mathematical Physics Divisions for staff with qualifications ranging from an Honours Degree to a General Certificate of Education at "O" level in four subjects, including English Language and a Mathematical or Scientific subject.

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