SEMI-AUTOMATIC COMPARATOR FOR EVALUATION OF STEREOPHOTOGRAPHS OF TRACK CHAMBERS

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INTRODUCTION

The use of reprojectors of different kinds makes it possible to evaluate stereophotographs quickly and with high precision. However, this method has serious difficulties in evaluating stereophotographs taken in bubble chambers. These difficulties arise due to the necessity to take into account the refraction effect of the liquid used in the bubble chamber. The difficulties arise also if the chambers are used in a magnetic field, when it is necessary to measure the curvature of spiral lines arbitrarily oriented in space and angles between them.

The use of electronic computers allows one to obtain higher productivity in making calculations. This makes it feasible to use methods based on calculation of curvatures and angles from co-ordinates of separated track points. It is natural that making the analytical calculations faster cannot solve completely the problem, as the process of taking the track co-ordinates with the aid of ordinary microscopes or stereocomparators requires a great amount of time.

The development of automatic devices [1, 2] permits a sharp increase in the productivity of taking and recording the co-ordinates. However, such devices are rather complicated and expensive. One of their drawbacks is that the reconstruction of the space co-ordinates of a track, making the appropriate optical corrections, takes about half the time necessary for calculation of the kinematics of the event. By means of automatic devices it is difficult also to measure photographs obtained under conditions of high background or high particle density.

There follows a description of a semi-automatic stereocomparator which makes it possible to measure simultaneously three co-ordinates (x, y, z) with automatic punching of them on tape, and with which one observes directly the image of the tracks in space.

DESIGN

The principle of operation of the comparator is that a reference mark is projected on to each of the two stereo views of the track chamber through the same optical system as was used to take the photographs and observed through a stereomagnifier [3]. The mark can move in space along the x, y, z axes. Co-ordinates of any track point are determined from the mark location in object space after superimposing its image seen through the stereo viewer with a track point. The optical diagram of the device is given in Fig. 1. The application of the same optical system which was used in photography permits automatic compensation for optical distortions and, thus,

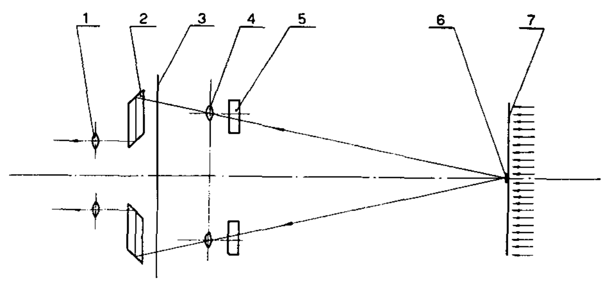

Fig. 1 Optical diagram of the device.
1. The eye piece of the stereomagnifier.
2. The periscope prism.
3. The film.
4. The camera objective.
5. The compensation glass.
6. The reference mark.
7. The screen.

saves one from the necessity of introducing the corresponding corrections (*). The advantage of the method is that the measurements are made in the object space and the accuracy requirements of the measuring system are ten times lower than those needed when measurements are made on the film.

The device is schematically shown in Fig. 2. The main parts of the device are: 1) The screen with mechanisms which move it along the x, y, z co-ordinate axes and digitizer systems to measure the displacement; 2) the front panel of the device with a camera, stereomagnifier, buttons and direction control handle; 3) electrical and electronic systems for reading out the co-ordinates and punching them on tape as well as for necessary switching of the electric circuits.

The screen (11) with the reference mark is mounted on a movable stage (16) which can move along the x axis within $\pm$ 180 mm. The guides of the stage are fixed on the other carriage (18) which can move along y within the same limits. The smooth movement of the carriage is achieved by using bearings mounted on rails. The screen weight and the parts (16) and (18) are balanced with the aid of a load operating by means of a cable and a block (19).

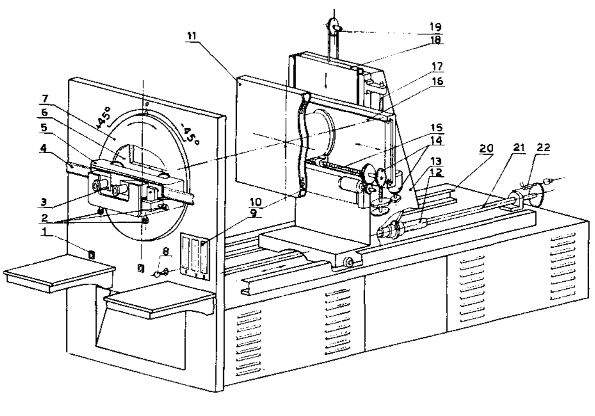

Fig. 2 Diagram of the comparator.
1. Recorder button.
2. Regulating screws for adjusting the film
3. Stereomagnifier.
4. The film.
5. Camera.
6. Compensation glass.
7. Rotating head.
8. Control handle.
9. Co-ordinate counter panel.
10. Luminescent lamps.
11. Screen.
12, 15, 17. Lead screws.
14. Digitizer.
16, 18. Movable carriages for driving a screen along the x and y axes.
22. Photodiode.

The system of screen motion along the x and y axes is mounted on the carriage (13) moving on rails along z within $\pm$ 75 mm.

The carriages move with the aid of screws (12), (15) and (17). The z co-ordinate screw can be fixed at any part of the shaft (21). This allows the measurement of photographs taken at 400-1000 mm distance. The screws are rotated by electric motors. To exclude the possibility of inertial motion of the carriages after the motors are cut off, brake electromagnets are automatically switched on. All the motors of the device are controlled with the handle (8) allowing the motors to be started in any combination. The speed of the motors is changed by a foot pedal.

The use of a split-nut makes it possible to use a lead-screw in a digitizing reading system as in this case it is possible to remove completely the back-lash in the lead-screw system. The lead screws are directly coupled with disc-type rotary digitizers modulating the light falling on the photodiode (22).

The reference mark is projected from the screen on the film by means of a camera (5) mounted on a rotating head (7). The rotation of the head with the camera is provided to turn the co-ordinate system, if necessary, with respect to track images, i.e. to direct one of the axes along a track chord, thus providing fast determination of the track curvature by measuring three track points.

The photograph, together with the projection of a reference mark, is examined with a stereoscopic viewing system with a magnifier (3). A film (4) is fixed to a glass plate supplied with spring clamps which provide close fitting of the film to the objective glass of the camera. For the rapid and perfect adjustment of the film in the camera the glass plate with the film fastened on it can be moved with the aid of screws (2). To obtain the uniform illumination of the film, the reference mark is viewed against a uniformly illuminated transluscent glass surface.

A frame is illuminated with 13 green luminescent lamps mounted behind the transluscent glass of a

(*) This method may be used in evaluating stereophotographs obtained in bubble chambers. The reference mark in this case must move along the z-axis in a vessel with liquid of the same index of refraction as that used in the chamber.

screen (11). The use of a lamp with green light makes it possible to work in a spectral region which is the most favourable for observation.

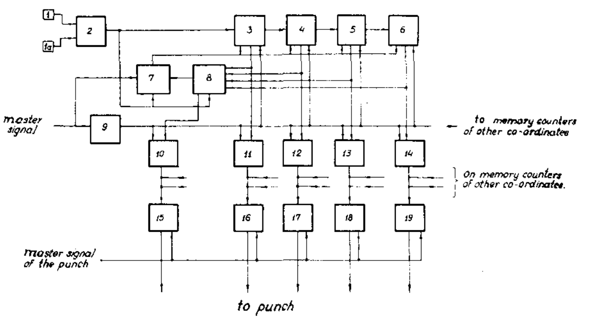

Fig. 3 Block diagram of counting and recording device of the stereocomparator (for one co-ordinate).
1, 1a. Photodiodes.
2. Pulse shaper determining left or right hand rotation.
3, 4, 5, 6. Dekatron recording units.
7. Unit determining whether pulses are to be added or subtracted in the scaler.
8. Device determining the sign of the number.
9. Recording punch generator.
10. Sign memory.
11, 12, 13, 14. Counters of the intermediate memory.
15, 16, 17, 18, 19. Register for input of the data into the punch.

The read-out devices of the comparator are the reversible electronic counters which count the number of pulses from the digitizer photodiode. The block diagram of the device for the reading out of one co-ordinate is given in Fig. 3.

The counter is the four-stage reading circuit assembled on dekatrons 10-SG-I(OE-I). Their maximum stable counting rate (5-8 kcs) is quite sufficient for the selected speed of the screen displacements. Each dekatron is controlled by two univibrators, one for addition and the other for subtraction (Fig. 4). To determine the direction of the carriage motion, two photodiodes are used in each digitizer. The second diode is placed in such a way that its pulse is displaced in phase with respect to the first diode by half the pulse width. The circuit diagram of this assembly is shown in Fig. 5. The counter is supplied with a device determining the sign of a number (Fig. 6 and 7). This allows the counting to start at any point and if this point can be chosen to be at the point of interaction, it makes the analytical calculation rather easier, since the purpose is to calculate spiral lines coming from the origin. Besides, the superimposing

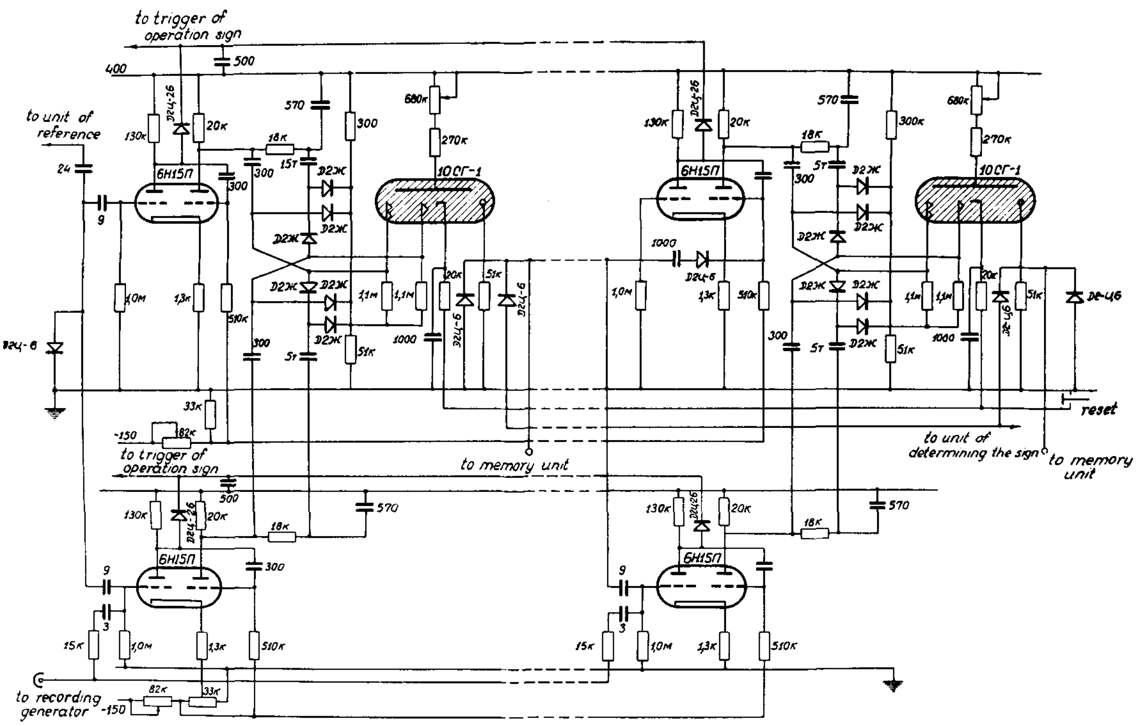

Fig. 4 The circuit diagram of 1 and 4 type reversible dekatron counter.

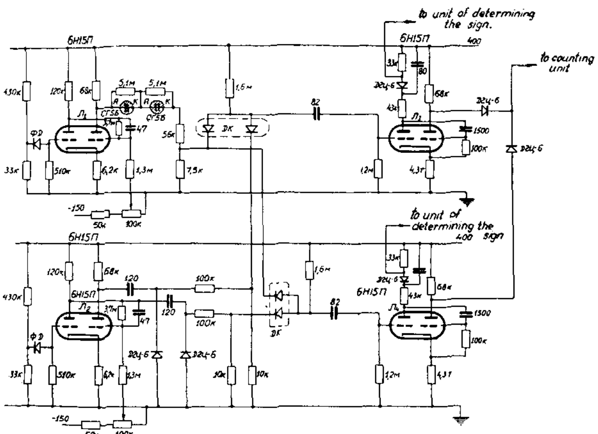

Fig. 5 The circuit diagram of the unit to determine the direction of the carriage motion.

dekatrons is carried out simultaneously with the aid of a generator giving 10 pulses (Fig. 9). In the course of this operation the carriage motion is blocked. From the memory unit the co-ordinates are fed successively to the tape punch through the punch register unit (Fig. 10), and punched on the tape in 1-1.5 sec. In putting the data into the punch register the counters of the memory device are reset to zero. The succession of the operations in automatic recording of co-ordinates is carried out by a relay circuit.

The electric part and electronic circuits are mounted in the frame of the device.

The general view of the device is shown in Fig. 11.

of the reference mark with interaction point after scanning every track permits a fast control of the circuit operation. The dekatrons are mounted on the front panel of the device (9 - Fig. 2). This makes it possible for an operator, if necessary, to make the reading directly.

To feed the data into the electronic computer " Ural " the information written on counters is automatically punched on tape in a binary-decimal code via the intermediate memory system (Fig. 8) composed of gas-discharge tubes MTH-90 [4]. The three co-ordinates are written into the memory unit in 0.1 sec. The recording of the data from all the

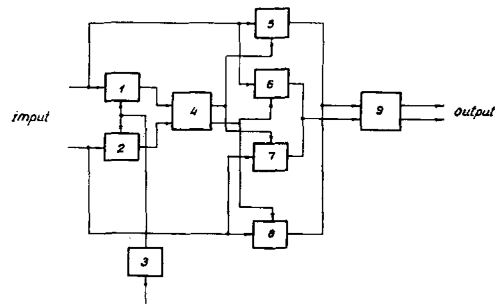

Fig. 6 Block diagram of the unit for determining the sign of a number and an operation.

1, 2. Gating circuit.
3. The indicator of dekatron zero state.
4. The counting direction trigger.

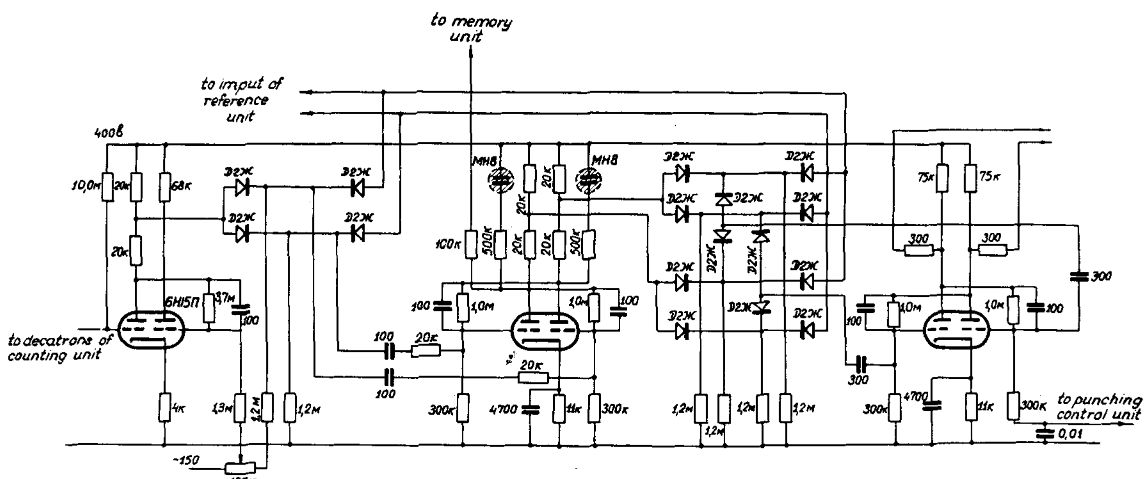

Fig. 7 The circuit diagram of the unit for determining the sign of a number and the counting direction.

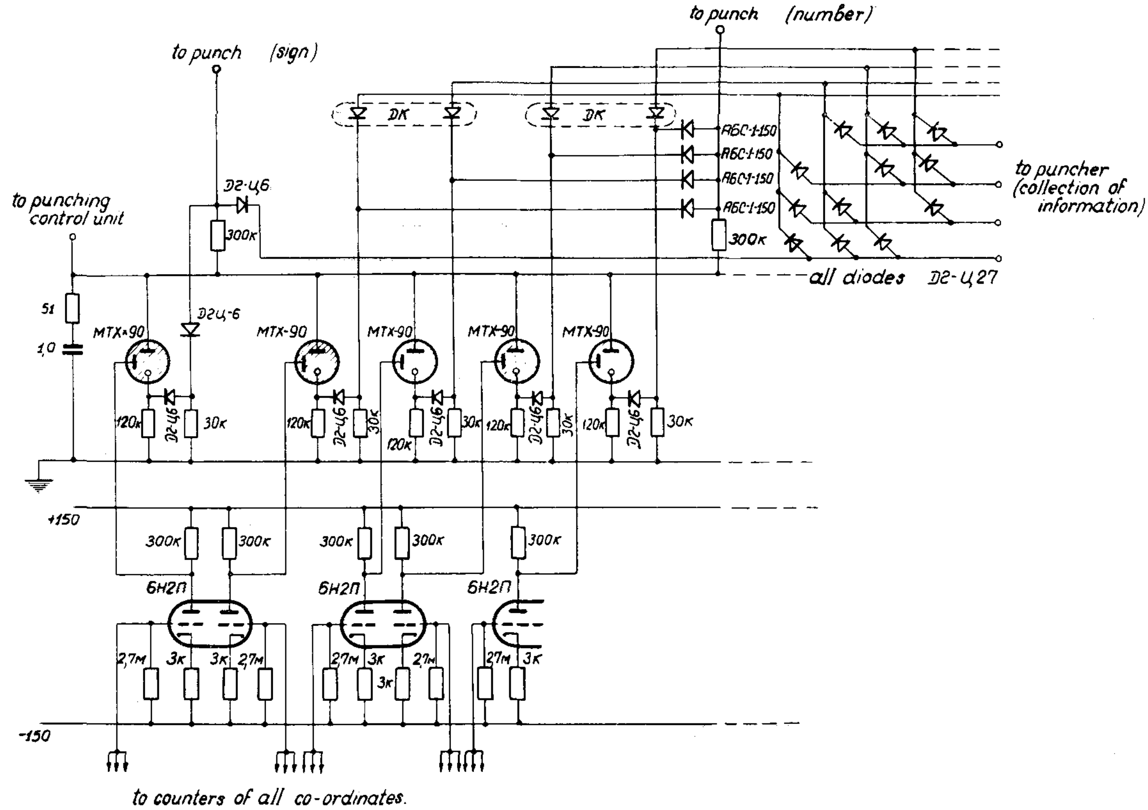

Fig. 8 The circuit diagram of the memory for a number and its sign.

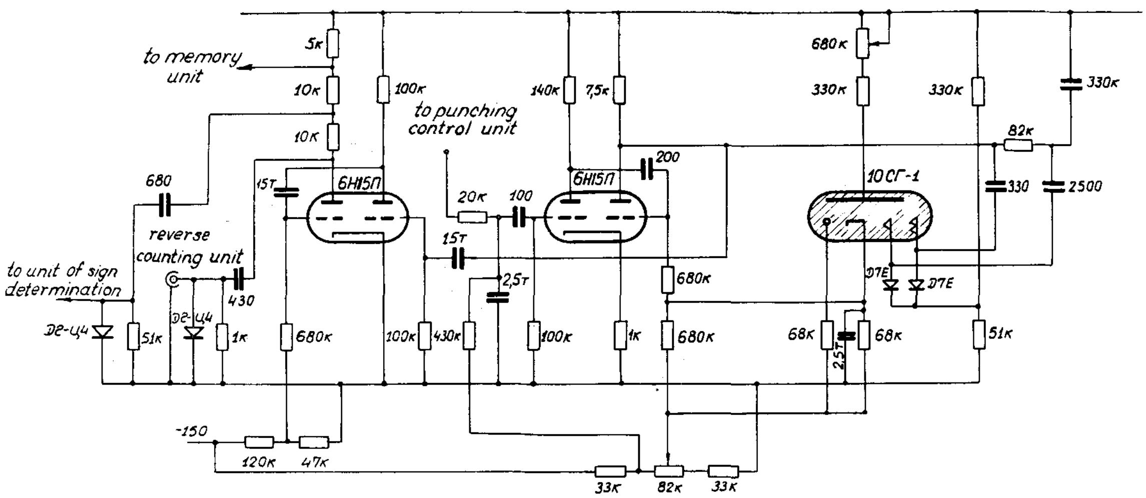

Fig. 9 The circuit diagram of the recording generator.

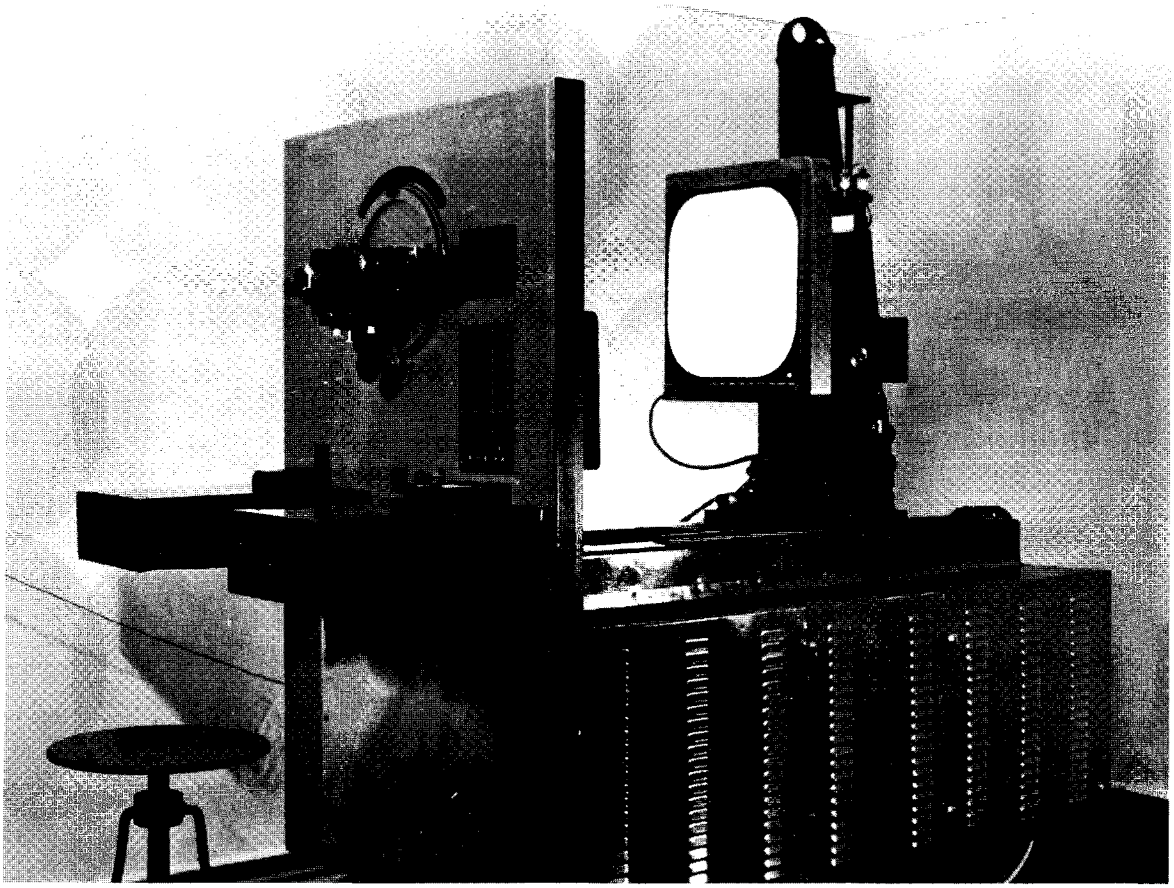

Fig. 11 General view of the semi-automatic comparator.

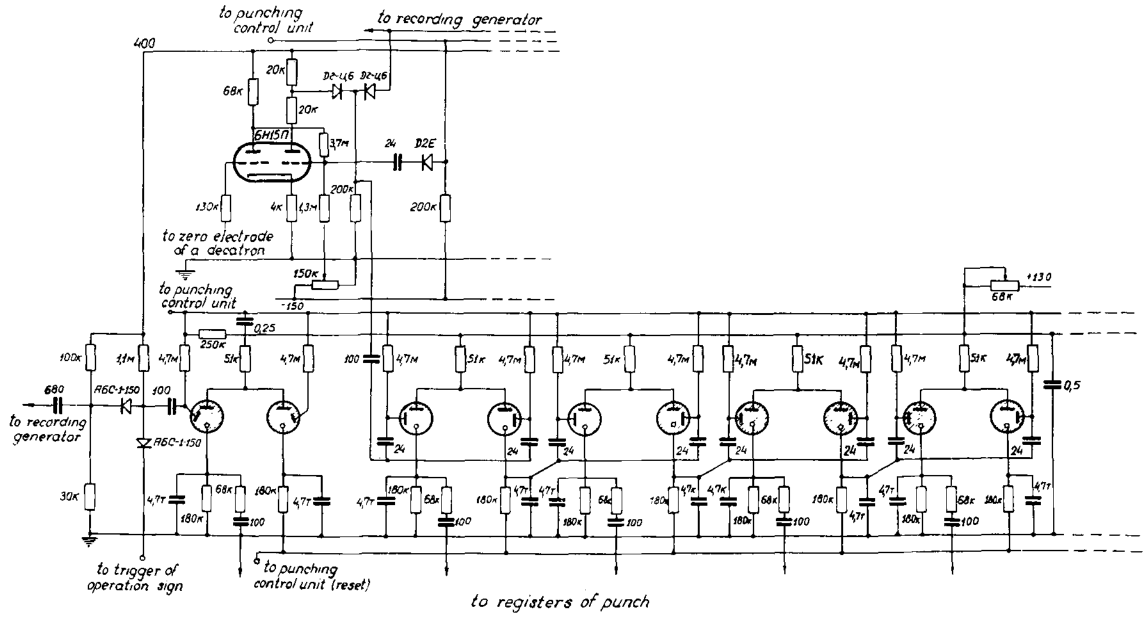

Fig. 10 The circuit diagram of the register for input of the number and sign into the punch.

THE MAIN CHARACTERISTICS OF THE DEVICE

In the model described, the linearity of the lead-screws was better than 1 micron in 200 mm length and the back-lash in the lead-screw system did not exceed 0.01 mm. This value is equal to 20 per cent of the basic resolution of 0.05 mm obtainable with the lead-screw and digitizer system and so does not affect the accuracy of measuring the co-ordinates. More important errors are introduced in the superimposing of the reference mark upon a track. These errors depend upon the magnification of the stereo-viewing device (in our case 5 times), the quality of the track image, speed of the reference mark displacement and so on, as well as upon the skill of the operator.

The speed of the screen motion along the x and y co-ordinates is 10 mm/sec, and along the z co-ordinate it is equal to 2 mm/sec. To increase the accuracy of superimposing the reference mark with a track point, the speed can be decreased by switching the foot pedal to 1 mm/sec and 0.2 mm/sec, respectively.

The measurements made showed that the root mean square error in recording the x and y co-ordinates is $\pm$ 0.1 mm, and in the z co-ordinate is $\pm$ 0.3 mm through the whole field of view. These results are from the photographs of the test objects taken with the stereocamera with the objectives "Jupiter 12", 120 mm base and parallel optical axes. The frames were taken from 450 mm through the 25 mm thick glass plate on "panchrom-X" film.

The recording of the co-ordinates of 30 points per three prong star takes on the average about 10 minutes including the time required for setting up the film in a camera.

The mathematical treatment of the data obtained on the electronic computer "Ural", consisting in determining, by the least squares method, the track curvature and angles between tracks, takes about 5 minutes.

The authors take the opportunity to express their gratitude to A. G. Potekhin, A. G. Zorin, V. F. Poenko, and V. P. Tokarskij for their help in assembling and adjusting the device, L. A. Kulyukina for working out the programme of calculation for interaction events, as well as M. S. Kozodaev for valuable advice.

LIST OF REFERENCES

1. International meeting on instruments for the evaluation of photographs. 15-16 Sept. 1958. CERN, Geneva. Summary of proceedings. CERN (*) 58-24, October, 1958.
2. Von Dardel, G., Goldschmidt-Clermont, Y. and Iselin, F. The present state of the instrument for evaluation of photographs and future developments. Nuclear Instrum., *2*, p. 154-63, 1958.
3. Groshev, L. M., Dobrotin, N. A. and Frank, I. Stereocomparator for work with the cloud chamber. Doklady Akad. Nauk. SSSR, *3*, p. 289-90, 1936. (in English).
4. Korablev, L. N. (New application of lamps with cold cathode in impulse apparatus). Moscow, Gostekhnika SSSR, 1956.

AN INSTRUMENT FOR AUTOMATIC BUBBLE CHAMBER PHOTOGRAPH EVALUATION

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In the Institute for Theoretical and Experimental Physics an instrument for automatic evaluation of bubble chamber photographs was built. This instrument allows the measurement of the co-ordinates of a number of points of the track on individual stereoscopic projections and the recording of these measurements in a form suitable for further handling by a computer.

The general scheme of the instrument is rather similar to that of comparable instruments built in CERN and in Berkeley.

The film containing one of the projections is fixed on the microscope stage, which is moved in two mutually perpendicular directions x and y by two servo-motors. The image of the photograph to be measured is projected on a screen viewed by the operator. Part of the image corresponding to an area of about 1 mm in diameter on the film is projected by means of a semi-transparent mirror on the light-sensitive screen of the automatic centring device.

The displacement of the microscope stage is measured by counting the number of Moiré fringes, produced by grating digitizers. Ten micron-gratings are used, viewed by four phototriodes. The electronic circuit used with these phototriodes gives a minimum count of one pulse per 2.5 μ displacement of the microscope stage. The pulses from the digitizers are counted by two reversible counters from the output of which they are fed via the intermediate memory to a tape perforator.

The centring device uses an orthicon tube; on the screen of this tube is displayed an annular illuminated region of width 0.5 cm and mean radius 1.25 cm. This is obtained by supplying the four deflecting coils with 400 cps sinusoidal voltage, superimposed upon which is a high frequency signal (Fig. 1a). When a track image is projected on this screen, two video signals are obtained during one revolution of the electron beam of the orthicon tube (Fig. 1b). These video signals are fed to one of the inputs of a double-input diode detector; to the other input of the detector a sinusoidal 400 cps reference voltage is applied. The phase of this reference voltage may be changed by means of a phase-rotator within 0-360°.

The amplitude of the output signal from the diode detector depends on the phase-angle of the sinusoidal reference voltage at which the video signal appears at the input of the detector, and is equal to the instan-

(*) See note on reports, p. 696.