In designing automatic measuring systems incorporating various optical and mechanical sensing devices, a problem frequently arising is that of converting the primary information in the image plane of the object into a time-varying electrical signal. This problem is of course solved by means of various scanning devices. Although a number of photoelectric systems using scanning devices have been described in the literature, insufficient attention has been paid to scanning methods and techniques in the photoelectric recording of lined objects. In this paper we shall consider some slit scanning devices used in the reading of scales (angular and linear); in these the information required is the relative position of the scale divisions and the pointer or other reading indicator.

Let us consider the idealized form of the optical part of the measuring system (Fig. 1). The various units of the measuring system are shown schematically in a plane section passing through the optical axis. The scanning unit is either an optical component of the measuring system or a mechanical component containing a slit fashioned in a specific manner.

Scanning is effected by moving the scanning unit 5 in the plane 4, as a result of which either the slit moves relative to the image plane or the image plane moves relative to the slit. Then the photoreceiver accepts the light energy passing through the measuring system and converts it into an electrical signal varying in time. The value of the measured quantity may be judged from the electrical signal.

Depending on the relative motion of the slit and image plane of the object of measurement, slit scanning devices are classified thus:

1) devices involving the motion of the slit relative to the image plane;
2) devices involving the motion of the image plane relative to the slit;
3) devices with an electron-optical converter and scanning of the image with an electron beam.

Devices Involving Motion of the Slit. In the present case the motion of the scanning unit must be made up of linear and rotational motion or else linear motion alone. It is well known that the slit may then have the shape of a straight line, an Archimedes spiral, an evolute, or a helical line. Let us consider these in more detail.

Straight Line. It is clear that for scanning by a linear slit this must move uniformly relative to the object of the scanning. Two cases are possible.

1) The slit is parallel to the OY axis. In this case (Fig. 2a) the slit moves along the OX axis. The image of the scale division and pointer is projected on the same axis.

2) The slit is inclined at an angle $\alpha$ to the OX axis (Fig. 2b). In this case the motion of the slit is effected in a direction perpendicular to this axis. As indicated in Fig. 2b, for measuring the interval a the slit must move through a distance equal to $b = a \times \tan \alpha = ak$, which for $\alpha > 45^\circ$ increases the scale of the measured quantity by $k$ times and reduces the relative error of the system.

The motion of linear slits is usually effected by means of cam or screw couplings. However, this restricts the scanning frequency, and also causes error owing to the wear of the cams and screw couplings. Scanning devices with linear slits have become most widespread in practice [1-3].

Fig. 1. 1) Plane of the scale divisions on the graduated circle; 2) plane of indicator (pointer); 3) generalized optical system; 4) plane of the image of the object of measuring (scanning plane); 5) scanning unit; 6) photoreceiver; 7) amplifier.

Archimedes Spiral. The arrangement of a scanning device with a slit fashioned as an Archimedes spiral is shown in Fig. 2d; it works as follows. When the disc is turned at a constant angular velocity around the center O, the center of the spiral, the slit moves at a constant velocity along the line OX coinciding with the ray of the spiral. It should be noted that the image of the scale marking and pointer must be projected on the line of the ray of the spiral (the line OX).

Evolute. The arrangement of a scanning system with an evolute is shown in Fig. 2e. We see from this that on rotating the disc at a constant angular velocity \( \omega \) around the center O, coinciding with the center of the scanning circle, the slit moves at a constant velocity along any of the radii of curvature of the evolute. The images of the scale marking and pointer are projected on a line coinciding with the radius of curvature of the evolute.

Helical Line. The arrangement of the scanning device is shown in Fig. 2c. We see from this that on rotating the cylinder around the ZZ axis at a constant angular velocity the slit moves at a constant linear velocity along this axis. The images of the scale marking and pointer are projected on a line parallel to the ZZ axis. It should be noted that axial backlash of the cylinder leads to measuring error.

The scanning devices considered usually operate within the limits of a single scale division [4].

Devices with Motion of the Scanning Plane. The operation of devices of this group is based on the fact that on moving the optical units the rays passing through them are displaced and hence so is the image. The motion of the image takes place relative to a stationary slit, through which the photoreceiver "sees" successive parts of the scanning plane. The slit is usually arranged in the focal plane of an optical unit of the measuring system.

System with a Plane-Parallel Plate. The passage of a ray through a plane-parallel plate is illustrated in Fig. 3a. The displacement of the light ray in passing through the plate is determined from the formula

\[
z = \frac{d}{\cos i_1} \sin (i_1 - i'_1),
\]

where \( i_1 \) is the angle of incidence of the ray, \( i'_1 \) is the angle of refraction, and \( d \) is the thickness of the plate.

Hence when the plane-parallel plate moves around the center \( O_1 \) the image will move in the plane \( F \). A slit placed in this plane will pass the light energy to the photoreceiver.

The whole range of operation of the system is \( 2d \). This result is obtained from (1) with \( i = \pm 90^\circ \). In practice only part of the full range is used, since the plate cannot be deflected by \( 90^\circ \) from its middle position.

The advantages of this system are