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SOVIET SPECTROGRAPHIC EQUIPMENT

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Abstract- Standard Soviet spectrographic equipment is reviewed, and the properties of newer Soviet spectrographic instruments are briefly discussed.

Owing to a centrally administrated production, there is a relatively small variety of standard spectroscopic instruments in the U.S.S.R. However, the standard equipment must not be changed with the apparatus recently developed. The Soviet research in this field is carried out on an immense scale, and the author may claim that no spectroscopic instrument exists that could not be labelled "Made in U.S.S.R.".

Standard Prism Spectrographs

ISP-4, and USP-1 are small dispersion spectrographs using prisms of synthetic sylvine (1) (2).

ISP-28, and its older version, ISP-22 are typically Cornu quartz instruments comparable, e.g., to the Hilger E 498 (2) (3) (4) (5). Chromatic aberration is eliminated by employing a spherical mirror instead of the usual collimator lens (Fig.1). The photographic plate need not be curved to follow the focal surface of the camera lens. Also, the spectral lines are but slightly curved of relatively great focal lengths of the camera lens, and

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the collimating mirror (830, and 600 mm resp.). The high spectrum quality is achieved at the expense of some speed, however. The instrument is equipped- as most apparatus to be discussed - with a three-lens system of slit illumination. In the Russian instruments, the first two lenses of the system are achromatically corrected so that the analytical gap can be easily controlled at the intermeditate image diaphragm. Quartz prism, and quartz camera lens may be replaced by a glass Rutheford prism and a glass lens, i.e., this standard instrument can be used for work in the wavelergh range over 3 500 Å with a more convenient dispersion (Table I). As in Central Europe, the popularity of medium dispersion spectrographs is very high in the U.S.S.R., and the ISP-22 (ISP-28) is probably the most widely used intrument in Soviet spectrographic laboratories.

The optical scheme of the newer ISP-28 is essentially the same (Fig.1); however, the ISP-28 is built in order to attain a much better ease of handling.

KSA-1 is the usual Littrow instrument, comparable, e.g., to the Hilger E 492 (2) (Fig.2). In order to overcome an inherent defect in most Littrow spectrographs - the reflection of light from the spherical lens to the plate - a concavo-convex lens is used instead of the usual plano-convex condensor. The first surface of the lens is curved so that the reflections from it are screened by the camera case, while the reflection from the second surface is blocked out by means of a "point" screen. This is achieved at the expense of the quality of the slit images; however, the somewhat less perfect image as formed by the concavo-convex lens is said (2) to be not critical. The instrument is equipped with an interchangeable glass prism and glass collimator-camera lens. Three wavelength-selecting adjustements are combined in one operation for either quartz and glass optics; however, the glass prism and lens must be changed for the quartz optics by hand. In place of the usual total-reflecting prism, a plane mirror is used to refract light path within the

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light-tight spectrograph case. The wavelength range of 2 000 - 8 000 Å can be photographed on three lengths of the 24 cm plate (quartz prism and lens), and the range from 3 600 Å to 8 000 Å covers two lenths of the plate (glass optics). There are no essential differences in the dispersion of the KSA-1, and the Hilger E 492 (Table I).

The third standard prism instrument is the ISP-51. This is a three prism glass spectrograph the Fösterling's prism train of which enables attaining a reciprocal dispersion of 1 Å/mm at the wavelength of 3 600 Å (2). The instrument is equipped with four cameras; the respective focal lengths do not essentially differ from those of the known Zeiss three prism glass spectrograph.

Newer Prism Instruments

Besides the standard instruments mentioned (i.e., the ISP-28, the KSA-1, and the ISP-51), a fluorite spectrograph has been developed (6) (7) suitable for work in the far ultraviolet. The surfaces of the simple (achromatically uncorrected) lenses are curved parabolically so that a high spectrum quality is achieved.

Large aperture instruments have also been manufactured (7) such as ISP-66. The linear aperture ratio of this spectrograph is 4.6. Parabolic curvature of the collimating mirror is chosen because of attaining higher spectrum quality with a collimating mirror of such a short focal length.

Still more effective is the ISP-26 whose linear aperture is 0.7. (7)

Another three-prism glass spectrograph has been developed (7) the plate factor of which is 0.88 Å/mm at 4 000 Å. A plenty of other prism instruments have been developed in the U.S.S.R., and the interested reader should consult the original papers (7) (8); however, these apparatus are not yet comprehended into the "standard equipment".

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Steeloscopes

In Soviet Russia, a relatively great variety of steeloscopes exists. One of them is the steelometer ST-7 equipped with a three-prism Föstor-ling's train the reciprocal dispersion of which is 8 Å/mm at 4 000 Å. Standard and sample spectra can be observed simultaneously, so that the direct visual estimation of metal percentages may be carried out. The steeloscope SL-12 (8) is equipped with a wedge the transmission of which can be varied from 3 to 100%; consequently, the direct visual estimation of the metal percentages may be carried out in a more exact manner. The steeloscope SL-11 employs a single prism (9) (10), and the SLP-4 is a portable field spectroscope.

Grating Instruments

Great advances have been made in this field during the past five years. Gratings are claimed to have been ruled in the Soviet Union that seem to meet the highest requirements: 600, and 1 200 lines per mm, resolving power 400 000, no Lyman ghosts perceptible, very weak Rowland ghosts, 75 - 80% light extent with gratings ruled on an aluminium-on-glass surface are said (11) to have been obtained. Gratings with 1 200 lines per mm attain their maximum concentration of light at 2 700 Å in the first order (12).

The following grating instruments have been described, and manufactured on a small scale:

DFS-2 is a 2 meter concave grating spectrograph employing the Paschen-Runge mounting (7) (12). Two gratings are built in the instrument one above the other; the lower grating is one with the standard 600 lines per mm, and the standard 1 200 lines per mm are engraved on the upper grating. Each of aluminium-on-glass gratings has its own slit and camera so that, as a matter

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of fact, two spectrographs are combined in the DFS-2. The whole spectrum (2 000 - 10 000 Å) covers the length of 1 meter or 2 meters according to which grating is used. The reciprocal dispersion attains 8.3 Å/mm (600 lines per mm), and 4.2 Å/mm with the doubled number of lines per mm. The resolving power of the 600 lines part is 42 000, that of the 1 200 lines part 84 000. Step filters are set immedaitely in front of the emulsion because of the astigmatism of the mounting. The spectrograph is equipped with cameras enabling to photograph as much as 0.5 meter spectrum length at one setting. The linear aperture of the DFS-2 is 30.

DFS-3 (7) (12) is a large stigmatic spectrograph. Interchangeable plane gratings (the standard 600, and 1 200 lines per mm) are employed in connection with a concave mirror whose radius of curvature is 4 meters. Autocollimating principle is employed, the slit, the camera, and the grating being mounted on the opposite side to the collimator-camera mirror. The 24 cm plate covers the range of some 500 or 1 000 Å according to the grating used; consequently, the grating must be correspondingly turned at each wavelength selecting. The plate factor is 2 Å/mm (1 200 lines per mm grating), the resolving power being 144 000. Hyperfine structure of mercury lines may be seen on the plate when higher orders employed (for the reproduction of the spectrogram, see the original paper (11)). The linear aperture ratio of this instrument is 42.

DFS-4 (7) is built as a large aperture instrument (linear aperture ratio = 7.3). It employs two interchangeable plane gratings (the standard numbers of lines) the dimensions of which are 150 x 150 mm. Reciprocal dispersions of 13.5 , and 6.5 Å/mm are obtainable. The spectra can be photographed, or, alternatively, the instrument may be used in connection with the direct-reading attachment originally furnished as a complement to the ISP-51 (see, Direct Reading Instruments). DFS-5 (8) is a large vacuum spectrograph designed for work in the range of 500 - 2 000 Å. A concave grating (1 200 lines) is employed; the medium [illegible] the mounting: Paschen-Runge.

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DFS-6 is a grazing incidence spectrograph (plane grating ruled on glass) (7), and DFS-8 (8) employs a plane aluminium-on-glass grating (600 lines per mm, 120 x 60 mm). Autocollimating principle is employed the collimating mirror being of the focal length = 2.6 meter. Reciprocal dispersion of 6 Å/mm is attainable, and the wavelength-range of 1 000 Å is taken on a plate 18 cm long.

Direct Reading Instruments

Direct reading instruments are not yet produced on a commercial scale. However, several apparatus have been designed. The photoelectric steelometer FES-1 (8) (13) consists of a three-prism glass spectrograph, an a.c. source with an electronic control (see, Excitation Sources) in connection with two antimony-cesium photocells (noise current of the order 10^{-15}A). One of the cells registers the light reflected from the first surface of the prism, the other registers the spectral energy of the line of the element to be determined. The photocurrents charge the condensers, the undispersed light having the function of an internal standard.

Photoelectric spectrometer DFS-10 employs a 2 meter Paschen mounting grating spectrograph (1 200 lines per mm variant of the DFS-2); 36 exit slits are placed along the Rowland's circle transmitting the monochromatic light on the standard antimony-cesium cells SCV-9. The instrument is suitable for work in the range 2 300 - 5 400 Å; 12 lines are registerable simultaneously (14).

DFS-12 (8) is a plane grating apparatus (600 lines per mm, Ebert mounting); it is designed to work in the 2nd grating order, and either single or double monochromatization may be used. The photomultiplier FEU-17 with a d.c. amplification serves as the registering device.

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Direct-reading attachment is manufactured for the glass prism ISP-51 (8).

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It consists of a telescope FEP-1, and of the multiplier FEU-17; the photocurrents are amplified and enregistered by means of the recorder EPP-09; the attachment may be used in connection with the DFS-4 as well.

Many other apparatus are being developed such as the SP-61 designed for work with light sources of very short duration, and the SP-64, another high-speed recording instrument (8). No further details can be given because of lack of information, however, on the electrical circuits.

Microphotometers

Several types of microphotometers have been described and manufactured, but the non-recording MF-2, similar in function and design to the Zeiss "Schnellfotometer I" (2), and the self-recording MF-4 (7) are used. The optical scheme of the MF-4 is essentially that of the MF-2, but the latter may be used either as non-recording and self-recording microphotometer.

Accessory

Rotating sectors are rarely used; platinum and similar step filters are manufactured instead of sectors (2). As a rule, three or eight steps are employed the latter having proved to be useful in the method of the photometric interpolation (15), very popular in the U.S.S.R.

Vertical projectors PS-18, and DSP-1 have formerly been furnished with the spectrographs ISP-28, and KSA-1. The former is a simple lantern projector, the latter is a device enabling comparing sample and master spectra (2); more recently, a special projector has been designed (7) the optical system of which enables suppressing the graininess of the emulsions.

Excitation Sources

No special d.c. arc unit has been produced on a large scale, although one

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type of an original d.c.arc unit with an impulse discharge has been suggested by Levintov (16).

The a.c.units are the DG-1, and the newer DG-2. In these standard sources, use is made of the circuit of Sventitski (17) (18) (19). It consists of a high frequency circuit in addition to a normal (50 cycles in Europe) circuit with an adjustable output (Fig.3a). The unit can serve as a low voltage spark source as well (Fig. 3b). The high frequency igniting the 220 volts a.c.arc can be taken out independently, so that three different sources are combined in this simple and inexpensive unit.

The desings of spark sources, the IG-2, and IG-3 are due to Rajski (20) (21). In these units, use is made of an auxiliary gap (Fig.4). The analytical gap is coupled in shunt with a coil choke releasing the low frequency currents only. When putting charge on the concenser C (Fig.4), no potential drop rises at the analytical gap, but the potential drop at the auxiliary gap grows until a high frequency discharge breaks out that is not released by the choke R (Fig.4) and must, consequently, go through the analytical gap. Very reproducible results are said (22) to be obtainable with this source.

Recently, an a.c. source has been designed with an electronic control (23) that is considered useful for using in connection with the self-reading instruments. A low voltage spark has newly been described (24), but the standard units remain the DG, and IG.

Table I

Reciprocal dispersion of the ISP-22, and the KSA-1

Wave-length, Å	Dispersion, Å/mm			
	ISP		KSA	
	Quartz	Glass	Quartz	Glass
2 000	3.5	-	1.2	-
3 000		-	2.5	-
4 000	39	10	11.5	3.6
5 000			21.0	12.5
6 000	110		34.0	21.5
7 000				33.0
8 000				

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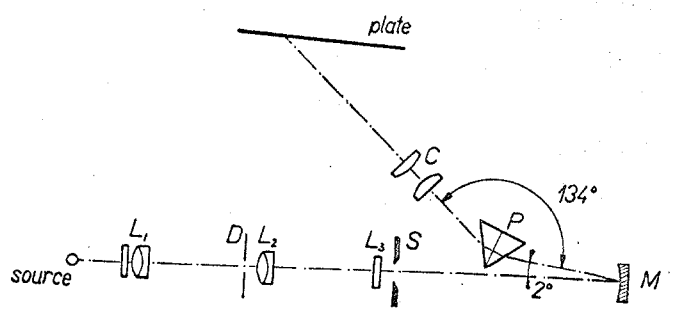

Fig.1

Schematic diagram of the medium dispersion ISP-22

L_1 L_2 L_3 ... lenses of the three-lens system of slit illumination
D ... diaphragm of the three-lens system
M ... collimating mirror
C ... camera-lens

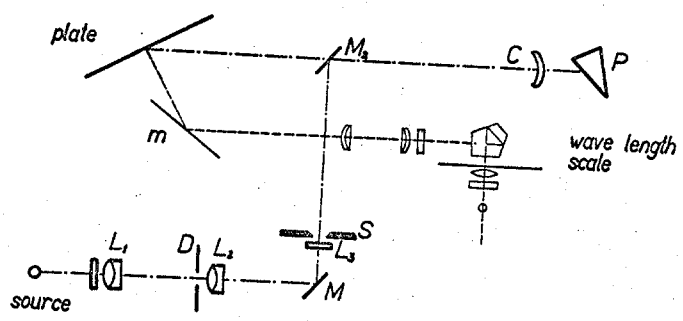

Fig.2

Schematic diagram of the autocollimating KSA-1

L and D ... see Fig.1
S ... slit
M_1, M_2 ... plane mirrors
C ... collimator-camera lens
m ... plane mirror of the wave-length projection system

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Fig.3

a b

Simple circuit diagram of the DG arc (a) and spark (b)

R_1 ... resistance of the 50 cycles circuit
R_2 ... resistance of the high frequency circuit
C_1 ... condenser of the high frequency circuit
C_2 ... condenser of the 50 cycles circuit
A.G. ... auxiliary gap
T ... transformer of the high frequency circuit

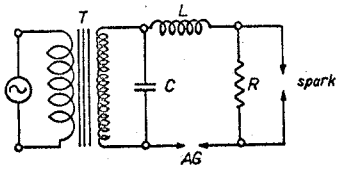

Fig.4

Simple circuit diagram of the IG spark

T ... transformer
C ... capacitance
L ... inductance
A.G. ... auxiliary gap
R ... resistance not releasing high frequency currents

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SOVIET SPECTROGRAPHIC EQUIPMENT

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Abstract- Standard Soviet spectrographic equipment is reviewed, and the basic properties of Soviet spectrographic instruments are briefly described.

Owing to a centrally administrated production, there is a relatively small variety of spectroscopic instruments in the U.S.S.R. Each type of instruments has its own representative, but in no more than two different models.

Prism spectrographs

The ISP-4, and USP - 1 are small dispersion spectrographs using prisms of synthetic potassium chloride[1,2].

ISP-28, and its older version, ISP-22 are typically Cornu quartz instruments, comparable, e.g., to the Hilger E 498[2-5]. Chromatic aberration is eliminated by employing a spherical mirror instead of the usual collimator lens (Fig.1). The photographic plate need not be curved to follow the focal surface of the camera lens. Also, the spectral lines are but slightly curved because of relatively great focal lengths of the camera lens and the collimating mirror (1830, and 600 mm resp.). The high spectrum quality is achieved at the expense of some speed, however. The instrument is equipped-as most apparatus to be discussed in this article- with a three-lens system of slit illumination with an intermediate image. In Soviet instruments, the first

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all wavelengths is easily obtainable[6]. Quartz prism and camera lens can be replaced by a glass Rutheford prism and a glass lens, i.e., this standard instrument may be used for work in the visible spectrum range as well as in Central Europe, the popularity of medium dispersion spectrographs in the U.S.S.R. is very high and, consequently, ISP-22 (ISP-28) is probably the most widely used instrument in Soviet spectroscopic laboratories.

[illegible]-1 or its older model [illegible]-55 are the usual Littrow instruments, comparable, e.g., with the Hilger E 492[2] (Fig.2). In order to overcome an inherent defect in most Littrow spectrographs - the reflection of light from the spherical lens to the plate - a concavo-convex lens is used as the collimator-camera lens instead of the usual plano-convex condensor. The radius of curvature of the first surface is approximately equal to the focal length of the collimator-camera lens, while the radius of the second surface is correspondingly smaller. The first surface reflects the image of the slit on the plate, but somewhat lower than the spectrum is placed, so that this reflection is automatically screened. The direct light reflection from the second surface is avoided by means of a small screen placed between the collimator-camera lens and the plate. The scattered light is thus minimized with considerable efficiency without having screened some parts of the collimating lens. This is achieved at the expense of some quality of the spectrum; the somewhat less perfect image formed by the concavo-convex lens is said[2] to be not critical (Fig.3). The instrument is equipped with an interchangeable glass prism and a glass collimator-camera lens. Three wave-selecting adjustements are combined in one operation for either quartz and glass optics; the glass prism and lens must be changed by hand, however. The wave-length scale can be projected in agreement with the drum reading automatically after the wave-selecting adjustements have been

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made by rotating the handwheel, but only a middle part of some 4 cm of the 24 cm plate is covered with it, so that an additional (millimeter) scale must be projected on the plate.

Because the optical bank is mounted parallel with the light path within the instrument (Fig.2), a plane mirror is placed at an angle of 45° to the light path immediately in front of the slit. In place of the total reflecting prism of the Hilger E 492, a plane mirror is used to refract the light path within the spectrograph being described (Fig.2). The wave-length range of 2 000 - 3 000 Å can be photographed on three lengths of the plate (quartz prism and lens), and the range from 3 600 to 8 000 Å is covered by two plate lengths (provided that glass prism and lens are employed). There are no essential differences in dispersion of the ASA-1 and the Hilger E 492 (Table I). The focal length of the collimator-camera lens is 1 700 mm, compared with 1 827 mm of, for example, Bausch & Lomb autocollimating spectrograph.

The remaining prism instrument to be mentioned is the glass three-prism ISP-[illegible]. This apparatus is equipped with four cameras whose respective focal length are 120, 270, 840, and 1 300 mm. With the latter, when used, autocollimating principle is employed. The Fösterling prism set used in this apparatus, together with the 1 300 mm camera lens, is able to attain a dispersion of 1 Å / mm at the wave-length of 3 600 Å [2,7].

In the U.S.S.R., a relatively great variety of steeloscopes exist. One of them is the steelometer ST-7 equipped with a three-prism Fösterling set, the dispersion of which is 8 Å/mm at the wavelength of 4 000 Å [7]. Standard and sample spectra can be observed simultaneously, so that direct visual estimation of metal percentages may be made with this instrument. The remaining two instruments employ but one prism; the steeloscope SL-11 was developed according to a design suggested by Ivantsov [10], and Smirnov [10], while the steelo-

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Grating instruments

In this field, four different models have been developed, two of them being plane grating instruments, and two concave-grating instruments.

The plane-grating instruments are the 4 meter DFS-5, and the 2.6 meter DFS-3[10].

The DFS-2, and the DFS-9 are 2 meter grating spectrographs with Paschen-Runge mounting[10]. No further description can be given because of lack of information.

Direct-reading instruments

In the U.S.S.R., spectrographic methods are widely used and therefore prism, and grating instruments have been developed. It is probable that direct-reading instruments are being developed as well, but they are not produced on a commercial scale.

Microphotometers

Several types of microphotometers have been described and manufactured[2], but non recording MF-2, similar in design and function to the Zeiss "Schellfotometer", and the self-reading MF-4 are being used.

Accessory

Rotating sectors are rarely used; platinum filters[2] are manufactured instead of sectors. As a rule, three step or eight step filter are employed, the latter proving very useful in the method of photometric interpolation[11]. When properly calibrated, very exact emulsion calibrating can be carried out by means of these filters as no reciprocity law failure or intermittency effect occur.

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Vertical projectors PS-18 , and DSP-1 are employed, the former being a simple lantern projector, the latter being a device that enables comparing sample spectrum with that of a master plate.

Breakthrough sources

No special d.c.arc unit has been produced on a large scale, although one type of d.c.arc circuit with an impulse discharge has been suggested by Lovinton[12].

A.c.units are DG-1, and the newer DG-2. In these sources, use is made of the circuit of Evershed[13-15]. It consists of a high frequency circuit in addition to a normal 50 cycles circuit with an adjustable output (Fig.4 a). The unit can serve as a low voltage spark source as well (Fig. 4 b); the high frequency current igniting the 220 volts a.c.arc can be taken out independently, so that three different sources are combined in a simple inexpensive unit.

The design of spark sources, IS-2 , and IG-5, are due to Rajski[16,17]. In these units, use is made of an auxiliary spark gap (Fig.5). The analytical gap is shunted with a coil choke that releases low frequency currents only. When putting charge on the condenser C (Fig.5), no potential drop rises at the analytical gap, but the potential drop at the auxiliary gap grows until a high frequency discharge breaks out that is not released by the choke R (Fig.5) and must, consequently, go through the analytical gap. Very reproducible results are claimed to be obtainable with this source[18].

Recently, an a.c.generator has been designed with an electronic control[19], which is considered useful for employment in connection with self-reading instruments. A low voltage spark is newly used that has been built by Abramson[20] , and Dominov and co-workers[21].

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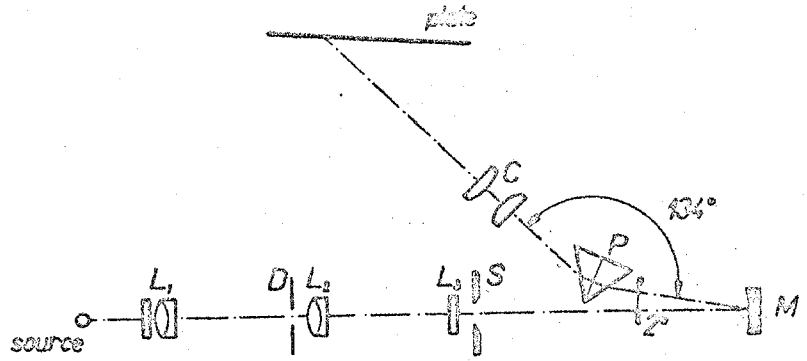
Table I

Linear dispersion of the ISP-28, and KSA-1 resp.

Wave-length, λ	Dispersion, Å/mm			
	ISP		KSA	
	Quartz	Glass	Quartz	Glass
4,000	9.5	-	1.2	-
4,500		-	2.5	-
4,800	39	10	11.5	3.6
5,000			21.0	12.5
5,500	120		34.0	21.5
6,000				33.0
6,500				46.0
7,000				64.5
7,500				85.0

Fig. 1 - Schematic diagram of the medium-dispersion ISP - 28



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L_1 L_2 L_3 ... lenses of the three-lens system of slit illumination

D ..... diaphragm of the three-lens system

S ...

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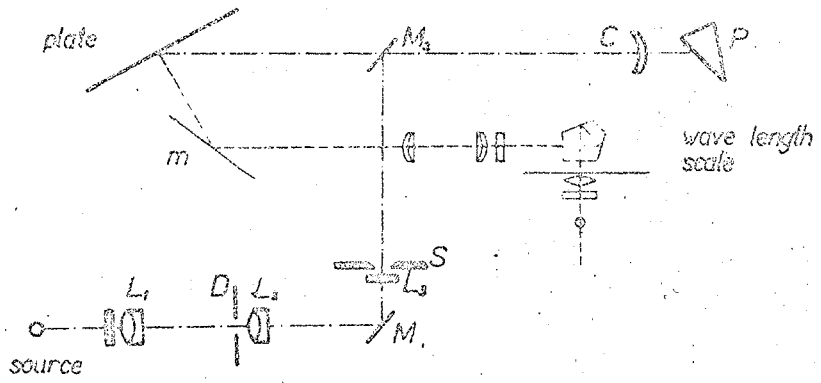

Fig.2

Schematic diagram of the large-dispersion KSA-1

L_1 L_2 L_3	... lens of the three-lens system with an intermediate image
D	... diaphragm of the three-lens system
S	... slit
M_1 , M_2	... plane mirrors
C	... collimator-camera lens
m	... plane mirror of the wave-length projection system

Fig.3

The triplet [illegible] photographed by the KSA-1

(With a usual 3 step platinum filter placed before the slit)

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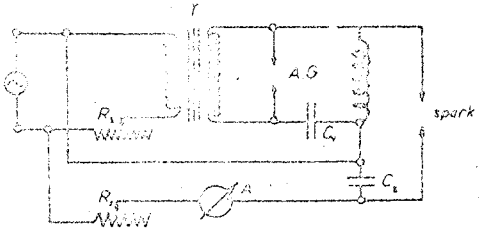

Fig.5 a

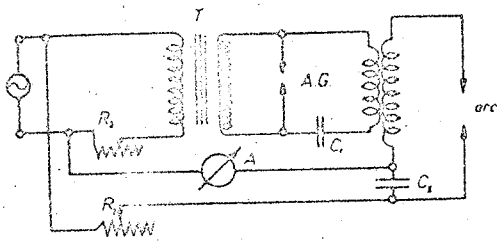

Fig.5 b

Fig.5

Simple circuit diagram of Arenitski's a.c.arc (a), and spark (b).

R_1 ... resistance of the 50 cycles circuit
R_2 ... resistance of the high frequency circuit
C_1 ... condenser of the high frequency circuit
C_2 ... condenser of the 50 cycles circuit
A.G. ... auxiliary gap
A ... ammeter of the 50 cycles circuit
T ... transformer of the high frequency circuit

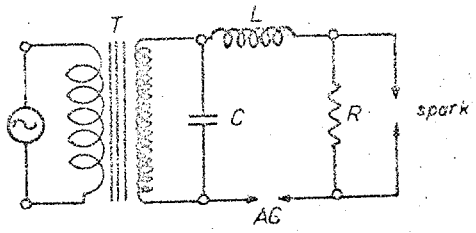

Fig.6

Simple circuit diagram of Rajski's condensed spark

T ... transformer
C ... capacitance
L ... inductance
A.G. auxiliary gap
R ... resistance not releasing high frequency currents

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