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**A ROTATING STEP SECTOR FOR USE WITH A C OR OTHER
INTERMITTENT SPECTROGRAPHIC LIGHT SOURCES**

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A ROTATING STEP SECTOR FOR USE WITH AC OR OTHER INTERMITTENT
SPECTROGRAPHIC LIGHT SOURCES

by

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May 9, 1955

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at
Iowa State College
F. H. Spedding, Director
Contract W-7405 eng-82

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This report is distributed according to the category Chemistry-
General as listed in M-3679, October 15, 1954.

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ABSTRACT

The calibration of the response of photographic emulsions using rotating step-sectors may lead to erroneous results when intermittent spectrographic light sources are used. These errors arise through partial synchronization between the periodicity of the light pulses and the passage of sector apertures in front of the spectrograph slit. A design for a rotating step sector which should overcome synchronization possibilities has been conceived and some actual sectors have been tested. This sector essentially consists of a series of stepped apertures randomly spaced about the periphery of a rotating disc. Data are presented to show that the random spacing of the sector apertures eliminates the possibilities of introducing errors through synchronization effects when conventional intermittent discharges are used.

INTRODUCTION

The convenience, simplicity and general applicability of the step-sector technique (1) have made it one of the most popular methods of photographic emulsion calibration for emission spectrography. Some objections to this technique have been raised but its validity has been proven when used under proper

(1) G. Scheibe, Ber. 58, 586 (1925).

experimental conditions (2). When intermittent spectrographic light sources such as the ac arc or spark and the Multisource (3) are used with these sectors, erroneous results may be produced by partial synchronization between the passage of the sector apertures in front of the spectrograph slit and the periodicity of the light pulses. It is therefore necessary to photograph auxiliary dc arc exposures for emulsion calibration purposes when intermittent discharges are used for the excitation of samples, even though it would be more convenient, and, in principle, more accurate to employ the sample spectrograms themselves.

Several techniques have been suggested to eliminate the possibilities of synchronization. Thus, it has been proposed that by continuously changing the sector speed, or by allowing the sector to run down during each exposure, or by adjusting the sector speed so that an integral number of flashes occur during the passage of each step in front of the slit (4), the synchronization possibilities would be eliminated. None of these techniques are convenient in practice and all of them have been shown to lack dependability.

Several other methods have been proposed which eliminate the use of a step-sector and thus eliminate synchronization effects. One of these is the use of neutral step filters, but

(2) R. E. Thiers, J. Opt. Soc. Am. 41, 273 (1951); E. H. Amstein, J. Soc. Chem. Ind. 62, 51 (1943).

(3) M. F. Hasler and H. W. Dietert, J. Opt. Soc. Am. 33, 218 (1943).

(4) R. Schmidt, Rec. trav. chim. 62, 437 (1943).

these are not without their disadvantages. The metal films are fragile and not strictly neutral. Thus, transmission calibrations should be made for all wavelengths of interest and these should be checked at intervals since the calibrations may change with time. Also, step filters must be made from very thin prisms to prevent the occurrence of interference patterns. These interference patterns may not be readily apparent under visual observation but they may produce imperfect line images. Another solution is to employ groups of spectral lines whose relative intensities are known and invariant (5), but the large amount of preliminary experimental work that has to be done greatly limits the applicability of this technique.

Thiers (6) has described a focal-plane step-sector consisting of a continuous band of jet black film in which stepped apertures were punched along the length of the film. This film was then passed rapidly in front of the photographic emulsion along the length of the focal plane. Thiers pointed out that if these sector shapes were punched at random intervals along the band, the sector had no frequency of its own and thus would allow a random sampling of the discharge. Thiers showed experimentally that this was true and that this sector could be used with intermittent light sources. The only observed synchronization occurred when 60-cycle critically damped discharges were used for short exposure periods.

(5) G. H. Dieke, Study of Standard Methods for Spectroscopic

Analysis, Report No. W-54, WPB Research Project NRC-525.

(6) R. E. Thiers, Spectrochim. Acta 4, 467 (1952).

This concept should apply just as well to a rotating step-sector placed at the slit (or secondary focus of astigmatic grating spectrographs), giving a much simpler and more convenient arrangement from an experimental standpoint. A rotating step-sector of this type is shown in Figure 1. As shown in the figure, the sector openings are divided into segments and these segments are combined into stepped apertures which are randomly spaced around the periphery of the disc. The spacing of these apertures was determined from a table of random numbers (7) and the circumference of the disc was adjusted to conform with the last number used in the selected series. It should be noted that this spacing is not perfectly random since only the first part of the series was used and a constant, corresponding to the width of the aperture, is added to each number. Thus, the random spacing should be measured from equivalent edges of the aperture, but this would immediately eliminate all random distances from 1 to 4 mm. since the widest step is 4 mm. wide, and these numbers occur frequently in the series. Finally, the sector rotation speed is not uniform since a synchronous motor was not used.

CONSTRUCTION OF SECTOR

The production of sectors of this type presents a few construction problems. The four apertures are segments of arcs, each segment having a different radius at the outside edge.

(7) M. G. Kendall and B. B. Smith. Tables of Random Sampling Numbers. Cambridge University Press, 1939.

Figure 1 Diagram of "Non-Sync" Step-Sector.

The leading and trailing edges of the apertures must be precisely parallel to the radius vectors, so that the aperture edges are parallel to the slit as they cross the slit. The sectors used in this study were prepared by punching the sector apertures in an aluminum disc, spacing the apertures with a dividing engine. The punch was made out of 4 segments, each corresponding to one of the 4 sector steps, and joining these segments to make one punch. In spite of the care taken in fabricating the punch, the weakest two steps produced spectrograms which showed intensity variations ($\pm 4\%$) along the length of each step. These steps were not used in this study because of the necessity to reduce errors of observation to a minimum.

The sector disc was mounted in a standard Jarrell-Ash sector housing and rotated at approximately 500 rpm. Under ideal conditions a synchronous motor should be used to insure a constant speed of rotation but in these experiments the universal motor supplied with the Jarrell-Ash sector was found satisfactory.

It should be noted that the large amount of closed time on this sector necessitates slightly longer exposure times than with a standard sector. However, this is not a major difficulty since longer exposure times tend to minimize the possibilities of synchronization. The minimum exposure time recommended with this sector is 20 seconds, even though no synchronization was found in cases where the exposure time was shorter.

EXPERIMENTAL

A series of experiments were designed to provide data on the degree of synchronization of various discharges with a standard sector and to show that this special design eliminates synchronization effects. Synchronization manifests itself as step-to-step intensity ratios which first of all do not agree with the step factor of the sector, and secondly, show variations in this value from exposure to exposure. Thus, the various discharges which were available were exposed through both sectors on a series of plates. On each plate a standard step-sectored spectrogram of a dc arc was included for emulsion calibration purposes, and on many of the plates a second dc arc spectrogram was exposed. The step-to-step ratios in the latter spectrograms were measured to determine the precision of step ratio measurements. The data obtained from these experiments are summarized in Tables I through IV. In these tabulations each value is the average step-to-step intensity ratio obtained from approximately 12 different spectral lines in the same wavelength region in a single spectrogram. The $\pm$ values indicate the average deviation from the mean. These data indicate that the standard step-sector definitely tends to synchronize with certain intermittent light sources and the error is quite large in some cases. However, no synchronization was observed when the "Non Sync" sector was used with the same discharges. Since the discharges selected for this study are representative of those commonly utilized for spectrographic analysis, this sector should be applicable under all conditions encountered.

An interesting result was obtained with the NSL "Spec Power" air-interrupted type spark source. Synchronization was definitely observed with the standard step-sector when 1 and 2 discharges per cycle were used but little or no synchronization was observed when the number of discharges per cycle was increased (Table I). No attempt was made to explain this observation since there were several variables which were difficult to correlate (e.g. sector speed, dead time between discharges, and duration of the discharge). However, there apparently was a decreasing tendency for synchronization to occur as the number of discharges per cycle was increased.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the valuable assistance of Mr. D. Borts in the production of the sector discs.

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Table I

Step-to-Step Intensity Ratios for Standard Sector
NSL "Spec Power" Discharges

Step Ratio = 1.585

DC Arc from Multisource	Spark Discharges/Cycle					AC Arc
	1	2	4	8	12	
1.59±.02	1.46±.02	1.51±.02	1.59±.02	1.63±.02	1.59±.02	1.48±.02
1.60±.03	1.63±.01	1.63±.01	1.61±.03	1.62±.01	1.60±.02	1.54±.02
1.58±.02	1.66±.01	1.63±.01	1.61±.03	1.58±.02	1.61±.02	1.52±.01
1.57±.02			1.60±.02	1.60±.01	1.59±.02	
1.59±.01			1.60±.02	1.62±.03	1.58±.03	
			1.57±.01	1.62±.02	1.63±.03	

Electrodes: Fe

Sector RPM: 800

Exposure Periods: 110-120 seconds

Spectrograph: Jaco 3.4 Meter Wadsworth

Sector Aperture: 2nd and 3rd strongest steps

Table II

Step-to-Step Intensity Ratios for Standard Sector
ARL "Multisource" Discharge

Step Ratio = 1.585

DC Arc	Type of Discharge			
	Oscillatory	Critically Damped	Overdamped	30 Cycle Overdamped
1.59 $\pm$ 0.02	1.37 $\pm$ 0.03	1.44 $\pm$ 0.02	1.39 $\pm$ 0.02	1.72 $\pm$ 0.03
1.60 $\pm$ 0.03	1.43 $\pm$ 0.02	1.40 $\pm$ 0.01	1.47 $\pm$ 0.03	1.51 $\pm$ 0.02
1.57 $\pm$ 0.02	1.61 $\pm$ 0.03	1.65 $\pm$ 0.02	1.63 $\pm$ 0.03	1.53 $\pm$ 0.02
1.59 $\pm$ 0.01	1.58 $\pm$ 0.01	1.55 $\pm$ 0.02	1.50 $\pm$ 0.03	

Electrodes: Fe

Sector RPM: 800

Exposure Periods: 15-30 seconds

Spectrograph: Jaco 3.4 Meter Wadsworth

Sector Apertures: 2 strongest steps

Table III

Step-to-Step Intensity Ratios for "Non Sync" Sector
NSL "Spec Power" Discharges

Step Ratio = 1.51 ± 0.02

DC Arc from Multisource	Spark Discharges/Cycle				AC Arc
	1	2	4	12	
$1.50 \pm .03$	$1.51 \pm .02$	$1.51 \pm .02$	$1.52 \pm .03$	$1.52 \pm .02$	$1.51 \pm .03$
$1.50 \pm .03$	$1.51 \pm .02$	$1.51 \pm .01$	$1.51 \pm .02$	$1.50 \pm .01$	$1.51 \pm .01$
$1.52 \pm .02$	$1.52 \pm .02$				$1.52 \pm .01$
$1.52 \pm .02$					
$1.51 \pm .02$					

Electrodes: Fe
Sector RPM: 600
Exposure Periods: 200-222 seconds
Spectrograph: Jaco 3.4 Meter Wadsworth
Sector Aperture: 2 strongest steps

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Table IV

Step-to-Step Intensity Ratios for "Non Sync" Sector
ARL "Multisource" Discharges

Step Ratio = 1.51 ± 0.02

DC Arc	Oscillatory	Type of Discharge		30 Cycle Overdamped	Rectifier Discharge
		Critically Damped	Overdamped		
$1.50 \pm .03$	$1.52 \pm .02$	$1.53 \pm .01$	$1.52 \pm .02$	$1.51 \pm .04$	$1.54 \pm .02$
$1.50 \pm .03$	$1.50 \pm .03$	$1.51 \pm .03$	$1.51 \pm .02$	$1.52 \pm .02$	$1.52 \pm .04$
$1.52 \pm .02$	$1.51 \pm .03$	$1.51 \pm .01$	$1.54 \pm .03$	$1.51 \pm .02$	$1.50 \pm .03$
$1.52 \pm .02$	$1.51 \pm .02$	$1.53 \pm .02$	$1.51 \pm .03$	$1.53 \pm .03$	$1.52 \pm .02$
$1.51 \pm .02$	$1.54 \pm .05$	$1.53 \pm .01$			$1.52 \pm .01$
	$1.53 \pm .02$	$1.52 \pm .02$			$1.53 \pm .02$
	$1.52 \pm .02$	$1.52 \pm .02$			
	$1.52 \pm .02$				
Electrodes: Fe					
Sector RPM: 600					
Exposure Periods: 15-30 seconds					
Spectrograph: Jaco 3.4 Meter Wadsworth					
Sector Aperture: 2 strongest steps					