POLANDS EXPERIENCE IN ACQUIRING REMOTE SENSING DATA WITHIN THE OPEN SKIES INTERNATIONAL TREATY

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ABSTRACT:

Open Skies Treaty /OS/ is one of a few international agreements giving base to a created cooperative security system. Each member country has the right to conduct a mission over the other countries and take airborne photos of selected objects. The main requirements of the Treaty concern the max resolving power that may be achieved by means of photographic (30cm), thermal (50cm), video (30cm) or radar (3m) sensors. The paper presents the Polish experience concerning photographic recorders application to the Treaty realization. The presented results of sensitometric and resolvometric study of films applied during OS missions enable determination of maximum resolving power for each of them as a function of exposure and processing..

1. INTRODUCTION

Film is the main medium for imagery information during the OS missions. Miscellaneous types of airborne films are applied to acquire photographic imagery information. Currently, eight types of films are applied: KODAK SO-050, 3404 and 3412, AGFA PAN-200, Russian TYP 42L and 38, Ukrainian TYP42 and Czech FOMA AIR 200. The study was additionally extended on: AGFA PAN 80 and 400. These films are different with respect to photosensitivity and contrast. Depending on the type of the exposed films, specific processors, solutions and temperature and time regimes are recommended to be applied. Sensitometric study is conducted both during the aircraft homologation phase and the mission to assess the quality of the airborne photosensitive materials.

To simplify the acquisition of research data for determination of the basic sensitometric quantities /ISO and GOST photosensitivity, mean gradient, contrast/ the member countries developed their own computer programs.

There is, however, no database enabling results comparison of the processing of films used during OPEN SKIES missions in miscellaneous processors and solutions and there is no correlations between them.

Sensitometric programs and databases concerning films processed in various conditions are necessary for controlling the correctness of the Treaty tasks realization.

To meet the requirements, Poland realized the following tasks:

1. Developed widely available software program enabling easy input of data and calculation basic sensitometric quantities according to the OPEN SKIES Treaty /ISO and GOST/
2. Conducted sensitometric and resolvometric study of air-borne photosensitive materials used during the OPEN SKIES missions and processed in solutions and processors of miscellaneous regimes of work. /PM-32, VERSAMAT, /
3. Created sensitometric databases for films used during the OPEN SKIES missions taking into account the processing.
4. Developed software program enabling the database management.

2. SENSITOMETRIC STUDY. EXPOSURE PARAMETERS SELECTION

Samples of photosensitive materials used for the determination were exposed by means of Avisense 2000 sensitometer with 21-step tablet (Fig.1a.). The exposure time was 1/1000 s , and the luminance was controlled by means of replaceable gray carbon filters. The values of the exposures for each of the filters are presented in table in Fig. 1b. The light source was a xenon lamp of flash type with spectrum corresponding to day light according to ISO 7829 norm.

$$\log H_F = \log(\int E(t)dt) - D_F - D_m$$

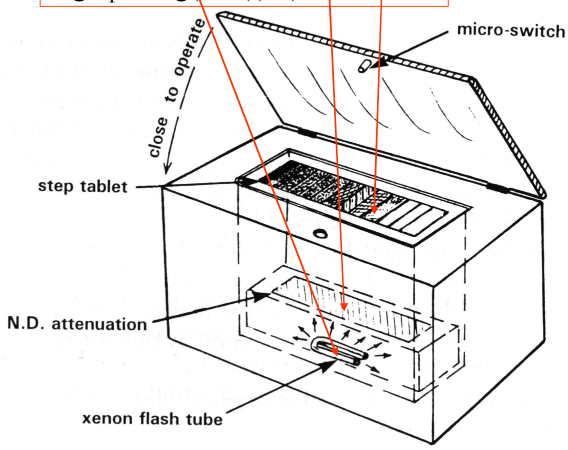


Fig. 1. Diagram of flash type sensitometer /Avisense2000/. [5]

Table 2 – characteristics of carbon filters set and exposure conditions.

Filter code	D_F	H_F [Lux s]
F005-800	0,2	5,20
F005-400	0,48	2,13
F005-200	0,8	1,0
F005-100	1,13	0,38
F005-50	1,46	0,15

The exposure conditions for specific materials were determined on the basis of their exposure under various filters. An example of exposure selection is presented in Fig. 3.

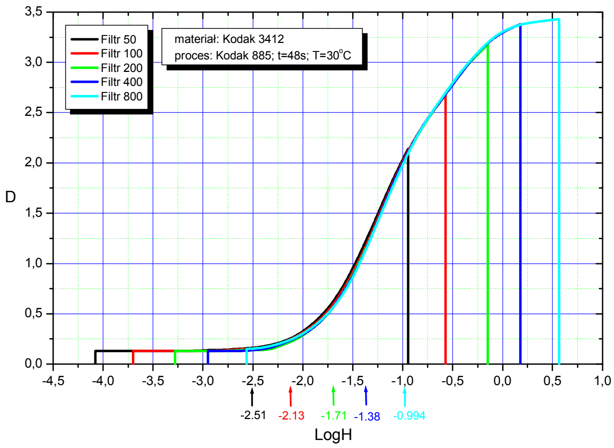


Fig. 3. Characteristic curves of Kodak 3412 material obtained using a set of five filters. In this case, the exposure of H=2,13 lux s (LogH=-1,38) was selected.

For every test the tested material was exposed three times using 21-step tablet. The values of the exposure under each of the log H fields were calculated according to the formula in Fig. 1a. The prepared materials were then processed in Kodak Versamat 1140 and Russian PM-32 processors. The processing was conducted in solutions listed in Table 4.

Table 4. Listing of films processing in Versamat 1140 and PM-32 processors.

FILM	Filtr	UP -5	UP -6	UP B1	AGFA A 74c	885
Typ 38	F/2,13		x	x		x
Typ 42	F/1	x		x	x	x
Typ 42L	F/1	x		x	x	x
Kodak 3412	F/2,13		x	x	x	x
Kodak 3404	F/1	x		x	x	x
Kodak SO-50	F/1	x		x		x
Agfa Pan 80	F/2,13	x	x	x	x	x
Agfa Pan 200	F/1	x		x	x	x
Agfa Pan 400s	F/1	x		x		x
Foma 200	F/1	x	x	x	x	x

3. STUDY OF THE KINETICS OF THE DEVELOPMENT PROCESS AND DETERMINATION OF THE BASIC SENSITOMETRIC QUANTITIES

Development was conducted in various temperatures 24 °C - 40 °C. To study the kinetics of the development of the specific photographic materials in each of the processes, the speed of the film transportation in the processor was changed which resulted in the change of development, fixing and drying time for the processed material. Sensitograms obtained due to exposing and processing were subject to densitometric measurements by means of a Macbeth densitometer and as a result the values of optical density for the specific fields were obtained. Using the measured values of optical density and absolute values of exposures for the specific fields, the characteristic curves were obtained (Fig. 5).

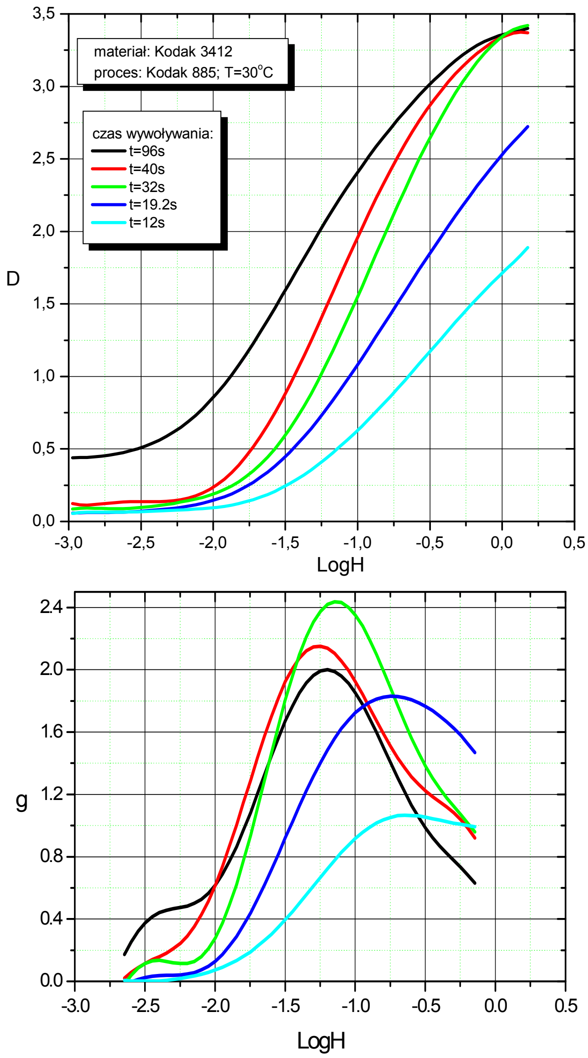


Fig. 5. Impact of the development time on the shape of the characteristic curve and distribution of the local gradient for Kodak 3412 material processed in Kodak 885 (T=30°C) process.

The characteristic curves were used to obtain the basic sensitometric properties (according to ISO 7829 and the Russian GOST norms).
Examples of the results obtained during the study are presented on the graph of $g_{śr}=f(S_{ISOA})$ in Fig. 6.

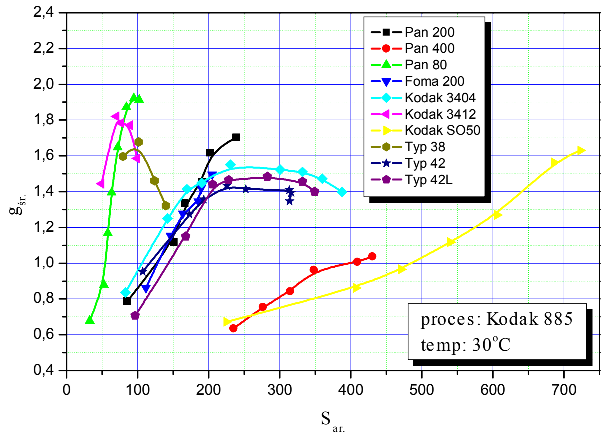
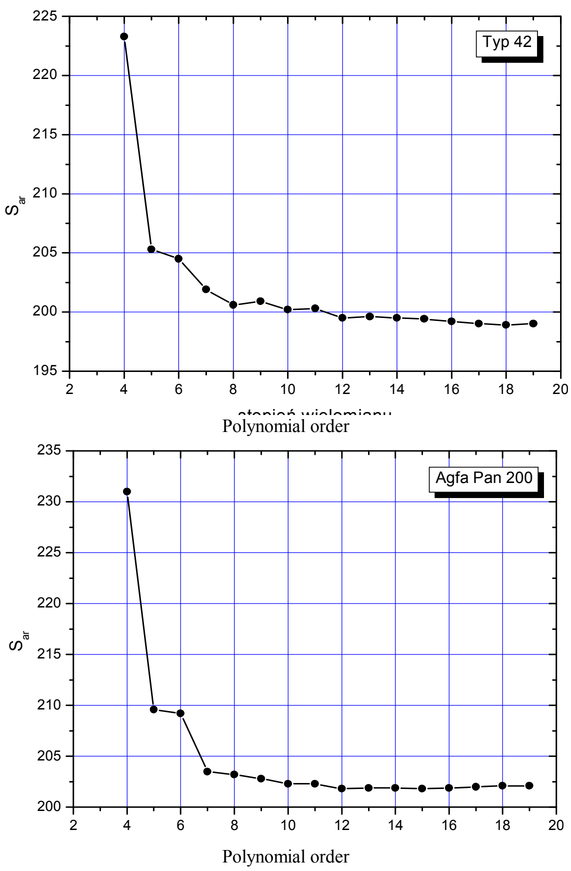


Fig. 6. Graph of relation $g_{śr}=f(S_{ISOA})$ for films processing in solution 885 at T=30°C in Versamat processor.

4. APPROXIMATION OF THE CHARACTERISTIC CURVE BY MEANS OF A POLYNOMIAL

The quality of the obtained characteristic curve is crucial for sensitometric study. It is frequent that the characteristic curve graph is of even stepwise shape or uneven. For the purpose of the study, the characteristic curves were smoothed by means of a polynomial approximation. The degree of the polynomial was appropriately selected to approximate the characteristic curve. It was proved that the best approximation of the curve shape for a 21-step tablet was achieved by a polynomial of 9th degree and further increasing of the degree has no impact on the quality of the results.

Examples of the calculation results are presented in Fig. 7.



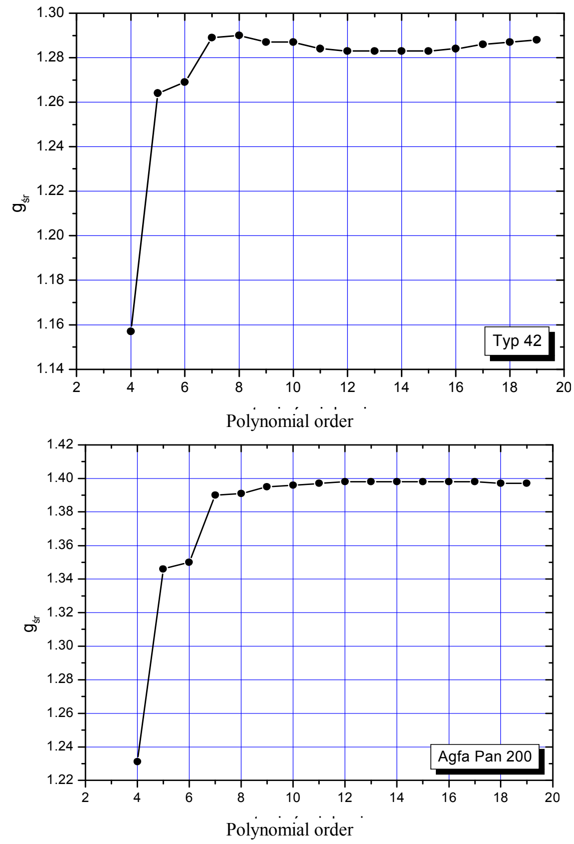


Fig. 7. Dependence of arithmetic photosensitivity (S_{ar}) and mean gradient ($g_{śr.}$) values on the degree of the polynomial for the Ukrainian material Typ 42 and Agfa PAN-200.

The developed sensitometric program uses the above described curve and enables automatic determination of the basic sensitometric quantities according to ISO A and GOST. The quantities obtained by means of other determination methods were very close.

5. EXPOSURE DETERMINATION FOR ACHIEVING MAXIMUM RESOLVING POWER

From the point of view of photographic information acquisition during the OS missions, it is important to determine the exposure for which the maximum resolving power is achieved.

Optimum exposure conditions for which the maximum resolving power is achieved may be determined in a traditional way by means of a series of exposing test stripes of various contrast. For a test of a given contrast, the dependence of the resolving power on the luminance is determined graphically. The maxima of the relations indicate the optimum level of the film exposure for which the information capacity is the greatest. This method is extremely laborious and time consuming. Additionally, the precision of subjective assessment of the resolving power in the specific fields of the sample plays an important role here. Therefore, to obtain reliable results, it is required that a few appropriately trained and experienced persons are involved. The changes of the resolving power R=f (log H) are similar to the changes of gśr =f(logH) in the obtained results while maxima of the values occur for the same exposure..

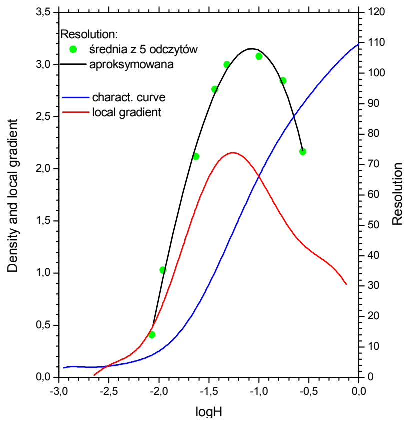


Fig. 8. Graphs of relations R=f (log H) and g_{max}=f(logH) for the USAF 1951 test exposure of 0,78 contrast and Kodak 3412 film processed in Versamat 1140 processor, AGFA 74, v=10 ft/min, T=30°C

Substituting the relation D=f/log H/ for a polynomial enables additionally easy determination of local gradient (Fig. 5b and Fig. 8). Using the local gradient, the maximum gradient for the characteristic curve and exposure logarithm at the maximum gradient was determined.

Determination of luminance conditions for optimum resolving power by means of application of the characteristic curve and Modulation Transfer Function (MTF) is much simpler. Determination of the MTF is presented in [1, 2]. Distribution of the local gradient of the characteristic curve presented in Fig. 7 is obtained by means of differentiating the characteristic curve.

Multiplying the specific values of the local gradient of the characteristic curve by the MTF, the Contrast Transfer Function (CTF) for the specific spatial frequencies is obtained. It is expressed as the number of pairs of lines per millimeter (Fig. 10).

CTF = MTF · g

where:

CTF Contrast Transfer Function,
MTF Modulation Transfer Function,
g local gradient of the characteristic curve.

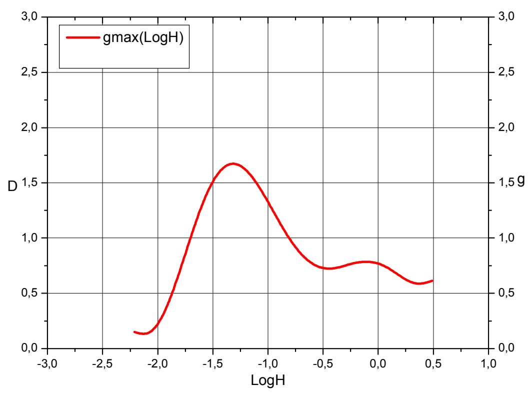


Fig. 9. Distribution of the local gradient g =f(Lo,gH) for Agfa Pan 80 film

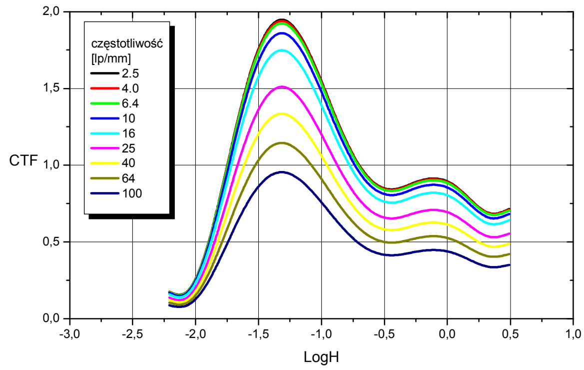


Fig. 10. Contrast Transfer Function graph for spatial frequencies ranging from 2.5 lp/mm to 100 lp/mm determined for the Agfa Pan 80 material

The maximum of the CTF obtained in this way for the specific spatial frequencies determines the value of the exposure logarithm at the maximum resolving power which coincides with the maximum of local gradient of the characteristic curve.

On the other hand, CTF value is defined as the difference between the optical densities that the human eye can distinguish as separate details:

CTF = Dmax - Dmin

where:

Dmax – optical density of the image,
Dmin – optical density of the background,

Values of the Dmax and Dmin are obtained for the luminance values equal LogHmax and LogHmin. It is obvious that during exposing a resolvogram for a test of a given contrast, increasing luminance (e.g. by increasing the exposure time) causes increase of LogHmax and LogHmin values but the difference between them is still constant (LogHmax - LogHmin = const.). Therefore, knowing the course of the characteristic curve for a material and using the above mentioned relation it is possible to determine the dependence of the CTF on exposure logarithm for specific contrasts of the test. Such relations determined for a few contrasts of the test are presented in Fig. 11.

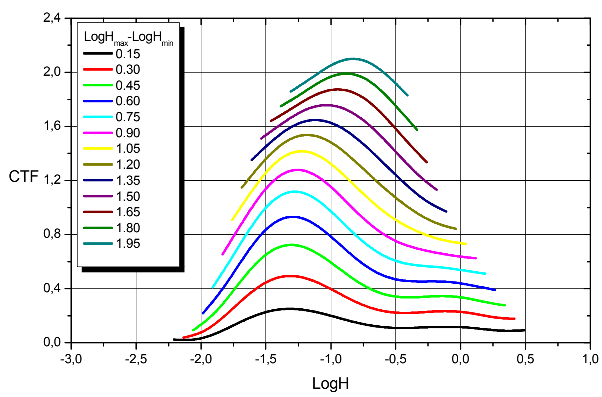


Fig. 11. Courses of Contrast Transfer Function for various values of contrasts of the test ranging from 0.15 to 1.65 determined for Agfa Pan 80 material.

Maxima of the specific curves occur for various values of the exposure logarithm. Optimum contrasts of the photographed objects are determined by the curves whose maxima occur close to the exposure logarithm value for which the maximum resolving power was previously determined.

6. CONCLUSIONS

The results of the sensitometric study enable quick selection of processing parameters independently of the used processor type and solution for any film used during the OS missions.
The presented method of local gradient determination enables relatively easy assessment of exposure for which the maximum resolving power is obtained for any parameters of processing.
The sensitometric software program with the database as well as the basic sensitometric quantities and resolvometric study results for ten films mentioned above with respect to: processor type, developer type, exposure conditions, temperature, development time, storage time of unexposed and exposed films will be presented during the seminar organized in POWIDZ /Poland/ in December 2004.

7. REFERENCES

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