THE UNIVERSAL THEORY OF THE THREE-WAVE OZONOMETRIC MEASUREMENTS

H.G. ASADOV, M.M. ALIYEV, A.A. ISAYEV
Azerbaijan National Aircosmic Agency

In the paper "Universal theory of three-wave ozonometric measurements" the theoretical possibility of almost full compensation of sum error of three-wave ozonometer measurement, used for the measurement of the common ozone content in the atmosphere is shown. The algorithm of working of device is presented; the theoretical substantiation of compensation is given.

Key words: The common ozone content, aerosol error, ozonometer, optical density, two-wave technique.

As it is known [1], nowadays the base method for the common content of ozone in the atmosphere is the two-wave method of measurement, based on the reducing law of the radiation in the atmosphere - Buger law, which has the following form:

$$S_\lambda = S_{\lambda_0} \cdot 10^{-\left| \alpha_\lambda X \mu + \beta_{\lambda_0} m + \delta_\lambda m_1 \right|} \qquad (1)$$

where S_λ is the flux of the direct sun radiation on Earth surface; S_{λ_0} is the same flux on the top surface of the atmosphere; α_λ is the absorption index of the ozone radiation, to the wave length λ; X is the sum ozone in the atmosphere;, measured in atm/cm; β_{λ_0} is the optical density of the reley atmosphere; δ_λ is the optical density of the atmospheric aerosol for the wavelength λ; μ, m, m_1 are relative optical densities of the ozone layer of the reley atmosphere and aerosol layer, which are ratios of the considering optical densities in the gradient direction to the mentioned optical densities in the vertical direction.

The physical mean of the formulae (1) is that reducing of radiation in the atmosphere takes place because of: 1) absorption in the band; 2) stray radiation in the pure air; 3) reducing of the radiation in the aerosol.

Also, it is known [1], that common error of the measurement of the common ozone content (COC) by the two-wave method is defined as

$$\frac{\Delta X}{X} = \frac{(\beta - \beta')\, m}{(\alpha - \alpha')\, \mu X} + \frac{(\delta - \delta')\, m_1}{(\alpha - \alpha')\, \mu X} . \qquad (2)$$

In the ref [2] the three-wave ozonometer was given, allowing to increase the exactness of the ozonometric measurements. Before, that we consider the functional possibilities of the given ozonometer, we note the conventional signs, which will be used in the following explanations:

$\delta=\delta(\lambda)$ is the functional dependence of aerosol optical density on the radiation wave length. According to the ref [1], $\delta(\lambda)$ is the line function in the diapazon300-340 nm, practically:

$\beta=\beta(\lambda)$ is the functional dependence of the reley atmosphere optical density on the radiation wave length:

λ_1 is the first main wave length, where the first main calculation (measurement) S_{λ_1} takes place;

λ_2 is the second correct wave length, where the second auxiliary calculation (measurement) S_{λ_2} takes place;

D_1 is the operator of the calculation working S_1 and S_2 for the obtaining of the following calculated values:

1) Calculated value S_p, depending S_{λ_1} and S_{λ_2}, i.e. $S_p = f_1(S_{\lambda_1}, S_{\lambda_2})$;

2) Calculated value β_p, depending on β_{λ_1} and β_{λ_2}, i.e. $\beta_p = f_2(S_{\lambda_1}, S_{\lambda_2})$;

3) Calculated value δ_p, depending on δ_{λ_1} and δ_{λ_2}, i.e. $\delta_p = f_1(S_{\lambda_1}, S_{\lambda_2})$;

4) Calculated value length λ_p, defined or on δ_p or on β_p:

5) λ_3 is the third main wave length, where the third main calculation (measurement) S_3 takes place;

6) D_2 is the operator of λ_3 change;

7) D_3 is the operator of the operations carrying out under the exit values D_1 and D_2 for the calculation of the found value X.

The algorithm of the three-wave measurer working has the different form at the carrying out of the COC measurements in the dependence on the concrete given aim. That's why it is needed to consider the tasks, which are solved by the three-wave method step by step.

The algorithm of the three-wave COC measurer working generally has the following form (fig.1).

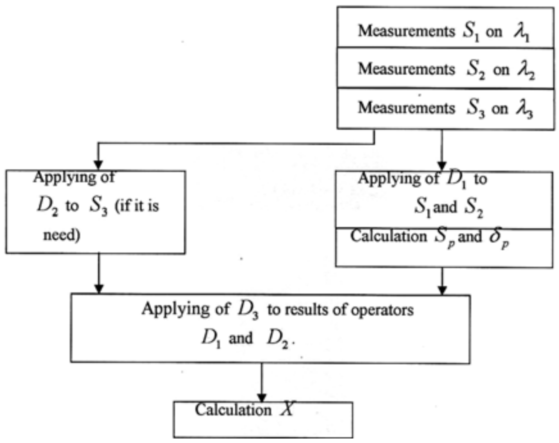

Fig.1. Common algorithm of three-wave oozonometric measurements.

By words, the algorithm of the device working can be expressed in the form of the following consequence of the carried out operations:

1) Carrying out of the measurements S_i on λ_I (i=1,2,3)

2) Applying of D_1 to S_1 and S_2

3) Applying of D_2 to S_3

4) Applying of D_3 to the exit values D_1 and D_2

The private algorithms of the device are differ from the general algorithm, i.e. in this case operators D_1, D_2, D_3 have the concrete mathematic meaning.

1. USING OF THREE-WAVE METHOD FOR THE DECREASE OF THE AEROSOL ERROR.

As it is known [1], the relative aerosol error in the two-wave ozonometer is calculated as

$$\frac{X - X'}{X} \cdot 100\% = \frac{(\delta - \delta') \cdot 100\%}{(\alpha - \alpha')X} , \qquad (2)$$

where the first three of parameters (X, δ, α) are equal to the wave length л1, but second three parameters (X', δ' α') are equal to the wave length λ_2.

The operator D_1 for the three-wave ozonometer has the meaning of the following consequence of the mathematic operations

$$D_1 = M \cdot R$$

where M is multiplication operation; R is

The operator D_2 in the given case has the shift meaning $S_3(\lambda_3)$ till the value $S_3'(\lambda_3 \pm \Delta\lambda_3)$.

The cases, when the applying of D_2 isn't necessary, are possible. The operator D_3 in the given case has the meaning of the fission and logarithmic of the D_1 and D_2 results.

Thus, the algorithm of the three-wave ozonometric measurements with the aerosol error compensation has the form (fig.2).

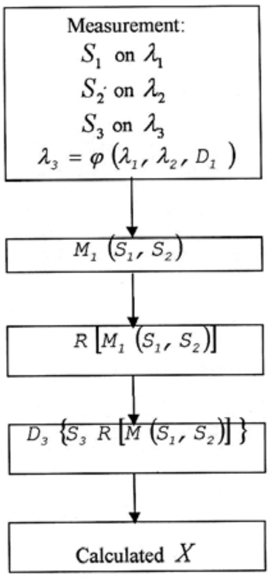

Fig.2. The algorithm of three-wave ozonometric measurements with compensation of aerosol component.

In the device in the given case the equality δ_{λ_3} and δ_{λ_p}, where δ_{λ_p} is the aerosol density of the considering to the calculated wave length λ_p, takes place.

As it was mentioned earlier, λ_p can be defined on the base λ_1 and λ_2, on the dependence $\delta(\lambda)$ or on dependence $\beta(\lambda)$ (in the dependence on the given aim). In the considered case

$$D_1 = M \cdot R ,$$

where M is the multiplication operation; R is λ_p is calculated by the formulae

$$\lambda_p = \frac{\lambda_1 + \lambda_2}{2}$$

Moreover, ideally the condition $\lambda_3 = \lambda_p$ should be kept. However, there are set of reasons, because of which $\delta_{\lambda_3} \neq \delta_{\lambda_p}$. They are:

1) Error of λ_p calculation
2) Error of $\delta(\lambda)$ nonlinearity.

For the clearing of the given error, the measurer algorithm is changed by the way of the input of the operator R (fig.3) regulation possibility.

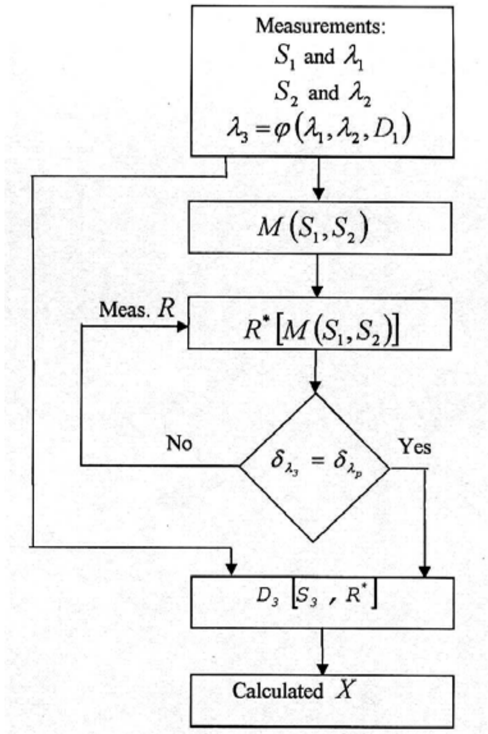

Fig. 3. Correction of error by the way of R^* regulation.

The meaning of that correction is in the some shifting of λ_p, in order to obtain $\delta_{\lambda_3} = \delta_{\lambda_p}$.

Such correction also can be obtained by the shifting of λ_3, however this would need the applying of set of filters with the nearest pass bands (set of bands), that is connected with the technical difficulties.

2. EFFECT OF FULL COMPENSATION OF SUM ERROR IN THE THREE-WAVE OZONOMETER.

As it was also mentioned, the full error of the two-wave ozonometer at the absence of the external impurity in the atmosphere is calculated by the formulae (2). In general case

$$\chi_{\Pi} = \chi_1(\beta) + \chi_2(\delta) \quad ,$$

where χ_{Π} is the full error of ozonometer; $\chi_1(\beta)$ is error component because of the scattering of pure atmosphere; $\chi_2(\beta)$ is error component because of aerosol influence.

The common conception of the mutual compensation of components $\chi_1(\beta)$ and $\chi_2(\beta)$ is in the such choose of the calculated wave length λ_p, that χ_1 and χ_2, calculated on the results of measurements in λ_3 and λ_p, would have the opposite signs and equal values on the absolute value. For the achieving of the given condition, the two ways can be used:

1) The regulation of operator R^*, i.e. the regulation in the calculated device, in the result of which λ_p will be differ from $\frac{\lambda_1+\lambda_2}{2}$ on the value $\pm\Delta\lambda^*$, i.e. $\lambda_p = \frac{\lambda_1+\lambda_2}{2} \pm \Delta\lambda^*$

2) λ_3 regulation by the way of using of many optical filters with the band in λ_{3i}; $i=\overline{1,n}$. However, as it was mentioned earlier, this way unpractical and too difficult.

Block is circuit of algorithm working of device is shown on the fig.4.

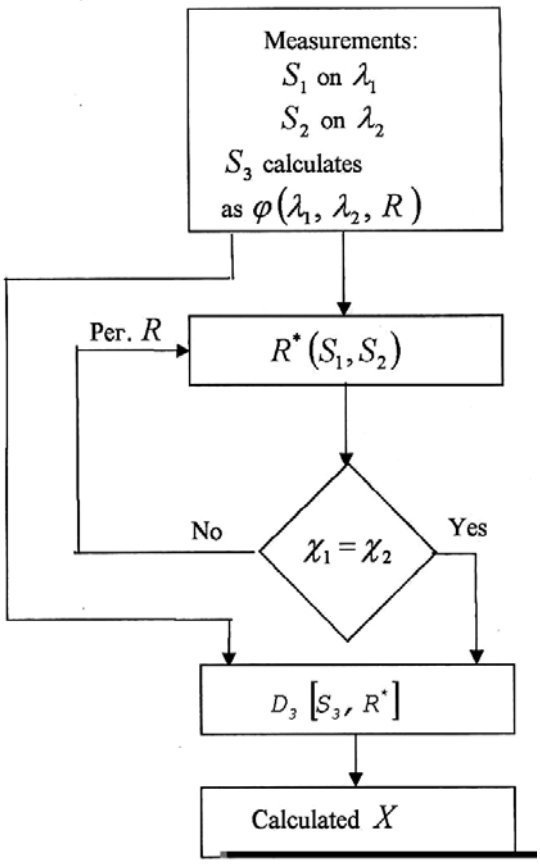

Fig.4. Block is circuit of algorithm of working of device.

The condition of practically full mutual compensation of error components χ_β and χ_δ can be expressed by the following way:

$$|\chi_\beta| = |\chi_\delta|$$

or

$$|\beta(\lambda_3^*) - \beta_p^*|\, m = |\delta(\lambda_3^*) - \beta_p^*|\, m_1 \quad . \qquad (4)$$

Thus, the meaning of the full compensation of sum error of three-wave ozonometer is in the carrying out of regulation λ_3^* or β_p^* with the aim of the carrying out of the condition (4).

Let's give the graphic interpretation of the mutual compensation of the above considered error components.

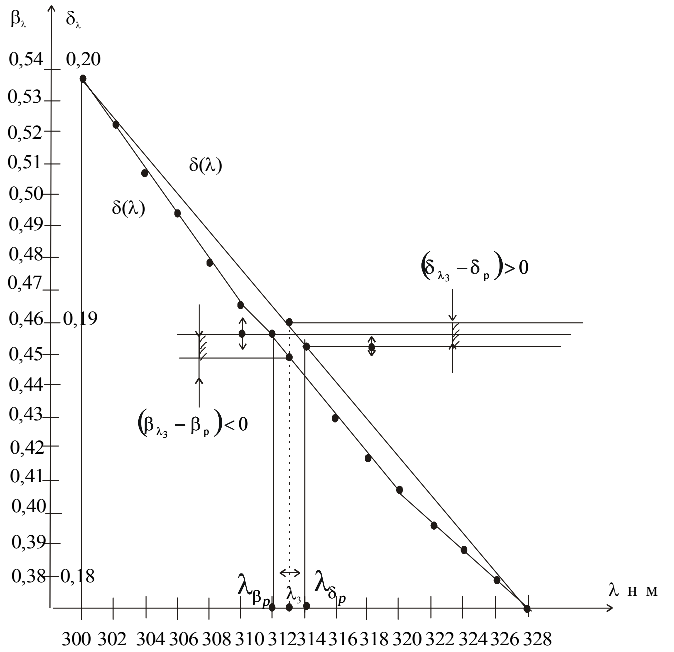

Fig.5. The graphics of dependencies β_λ and δ_λ on wave length λ.

The graphics of the dependencies β_λ and δ_λ on the wave length λ are shown on the fig.5. Taking into consideration $m \approx m_1$, effect of the mutual compensation from the graphic statements can be expressed by the following way:

$$|\beta_{\lambda_3} - \beta_p| = |\delta_{\lambda_3} - \delta_p|,$$

where β_{λ_3} is the value of reley scattering of atmosphere on the wave length λ_3; δ_{λ_3} is aerosol optical density on the wave length λ_3; β_p is the calculated value of β component, calculated on the curve $\beta(\lambda)$, from the condition $\beta_p = \frac{\beta_{\lambda_1}+\beta_{\lambda_2}}{2}$; δ_p is the value of δ component on the calculated wave length λ_{p_δ}, calculated on the curve $\delta(\lambda)$ from the condition $\delta_p = \frac{\delta_{\lambda_1}+\delta_{\lambda_2}}{2}$.

In the end we note, that revealed additional possibilities of later increase of the three-wave ozonometer clarity are realized by the famous technical means and don't present any difficulty in the practical realization plan.

[1] *G.P. Gushshin, N.N. Vinogradov*. Summarniy ozon v atmosphere. Leningrad, Gidrometeoizdat, 1983. (in Russian).
[2] Polojitelnoye resheniye № a20030134 ot 23.06.03 o vidache Patenta Azerbaijanskoy Respubliki na izobreteniye "Tryekhvolnoviy ozonometr"avtorov*: Kh.G. Asadova, A.A. Isayeva*. (in Russian).
[3]

H.H. Əsədov, M.M. Əliyev, A.A. İsayev

ÜÇDALĞALI OZONOMETRİK ÖLÇMƏLƏRİN ÜMUMİ NƏZƏRİYYƏSİ

"Üçdalğalı ozonometrik ölçmələrin ümumi nəzəriyyəsi" məqaləsində atmosferdə ozonun ümumi miqdarının ölçülməsi üçün istifadə edilən Dobson spektrofotometrinin üçdalğa modifikasiyasının jəm ölçmə xətasının tam kompensasiyası imkanının nəzəri mümkünlüyü göstərilmişdir. Ölçmə qurğusunun iş alqoritmi və kompensasiya şərtlərinin nəzəri əsasları verilmişdir

Х.Г. Асадов, М.М. Алиев, А.А. Исаев

ОБЩАЯ ТЕОРИЯ ТРЕХВОЛНОВЫХ ОЗОНОМЕТРИЧЕСКИХ ИЗМЕРЕНИЙ

В статье "Общая теория трехволновых озонометрических измерений" показана теоретическая возможность почти полной компенсации суммарной погрешности измерения трехволнового озонометра, используемого для измерения общего содержания озона в атмосфере. Приведен алгоритм работы устройства, дано теоретическое обоснование условия компенсации.

Received: 25.12.03