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MODIFICATION OF GRADATION CURVES OF ICC PROFILES FOR IMPROVING THE QUALITY OF COLOR SEPARATION DEPENDING ON THE SUBJECT OF THE ORIGINAL

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The article studies the problem of optimal color reproduction of images with specific color content by means of offset printing. The limitation of universal ICC profiles from the ECI organization for reproduction of monochrome images and portrait photography with skin tones is substantiated. It is revealed that standard profiles with medium black generation do not ensure optimal reproduction of all types of digital color originals. An approach to creating specialized profiles is proposed by modifying the gradation curves of color and black ink generation of the standard ISO Coated v2 (ECI) profile using the ProfileEditor software. Profiles with heavy black generation for monochrome images and profiles with skeleton black generation for portrait photography have been developed while maintaining the colorimetric characteristics of FOGRA39. The possibility of an individual approach to prepress preparation of images with different subjects is demonstrated. The choice of technological parameters for color separation is substantiated: early start of black ink, maximum black content and reduction of yellow ink in shadows for monochrome originals; late start of black and dominance of triadic inks for portrait images. The proposed approach ensures improved color reproduction quality while maintaining standardized printing process parameters.

Keywords: *color separation, print profiles, offset printing, GCR color separation technology, standard, prepress preparation, digital original, gradation curves.*

Problem statement. The main task of printing technologies is high-quality printing of color images, as close in color as possible to the original. Based on current realities, a large number of customers choose prepress centers and printing houses by the criterion of price. However, there are also those for whom high-quality prepress preparation, individual approach and assurance of color reproduction quality according to the target values of ISO 12647 standard are important.

The key stage of the technological process of prepress preparation of illustrative material is color separation. To ensure correct conversion of the image to the CMYK color model, it is necessary at the prepress stage to comprehensively take into account the set of factors that affect the quality of color reproduction in the process of polygraphic reproduction of the color original. This task should be solved by ICC profiles. Profiles describe the relationship between RGB and CMYK signals that control devices and the specific colors reproduced using these signals. Profiles define the values of CIE XYZ and

CIE L*a*b*, corresponding to a given set of RGB or CMYK numeric values. Standard profiles are developed by specialized research institutes and organizations (ECI, Fogra), which carry out development, standardization and implementation of technological norms in the printing industry [1, 2].

However, there are originals with special subjects. For their mass printing it is not possible to achieve high quality of color reproduction using universal profiles.

To ensure optimal color separation in specific cases, specialized profiles are needed: with enhanced black ink generation for monochrome images and neutral tones, profiles with skeleton black generation for reproduction of skin tones in portrait photographs. However, the organization ECI.ORG provides only universal profiles, which do not take into account the specifics of certain categories of images.

Analysis of recent research and publications. The use of printing system profiles that can be customized in the Color Setting/Custom CMYK palette of Adobe PhotoShop program for one's needs by changing the main parameters of color separation is problematic, because they are based on color characteristics that do not correspond to the real printing parameters standardized by Fogra. The use of profiles with non-standard color characteristics from Adobe leads to unpredictability of color reproduction and significant deterioration of the quality of printed products [3].

In study [4] the possibilities of using XCMYK and eciCMYK color spaces with an extended range of reproducible colors are analyzed, which confirms the need for a differentiated approach to prepress preparation of images depending on their color features. The authors substantiate the expediency of using profiles with extended color gamut for images where green, yellow and red shades dominate, which indicates the dependence of the choice of technological parameters of color separation on the specifics of the subject and the color palette of the original.

The ECI organization expanded the Fogra characteristic data base, including FOGRA48 for offset on improved newsprint, as well as FOGRA49 and FOGRA50 for standardized offset printing with additional surface finishing with matte and glossy films EciWordpress. A profile for printing on supercalendered paper SC-B (FOGRA54) was also published.

The main profile PSO Coated v3.icc is characterized by medium black generation (GCR: Medium), maximum black ink content 96%, black generation start from 10%, and total average covered (TAC) 300%. The profile PSO Uncoated v3.icc for printing on uncoated paper has similar parameters with TAC 300%, maximum black 96% and medium GCR with black generation starting from 10% [5].

The ECI strategy is focused on creating profiles for different paper-printing process combinations, but the organization does not develop profiles with differentiated black generation for images with specific subjects.

Third-party developers, in particular ColorLogic, created an alternative profile PSOcoated_v3_GCR_ColorLogic.icc, which applies maximum black generation in neutral colors to prevent instability of gray balance in printing, and medium black generation in skin tones to avoid grayness of skin in case of excessive black ink printing [6].

Purpose of the article. To perform analysis of technological parameters of color and black ink generation in the process of building ICC profiles and to develop an approach for creating specialized color separation profiles for specific categories of images by modifying the gradation curves of the standard ISO Coated v2 (ECI) profile while keeping the colorimetric characteristics of FOGRA39.

Presentation of the main research material. Printing system profiles contain individual settings for specific printing conditions. The process of creating ICC profiles involves setting a group of technological parameters of color separation, which determine the conditions of image conversion at the prepress stage.

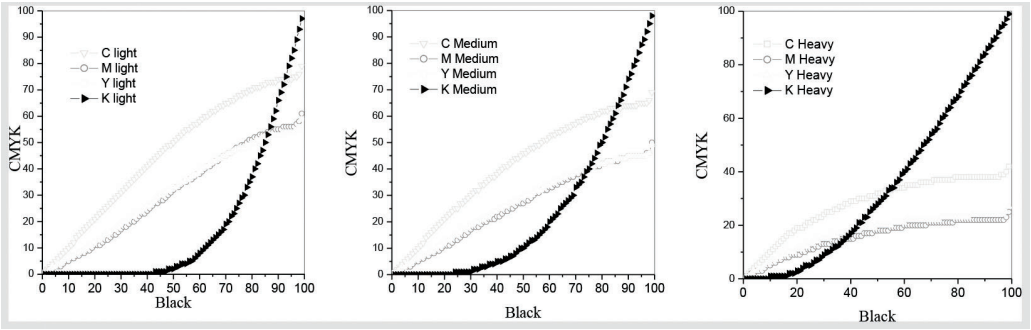
One of these parameters is the maximum total amount of ink that can be applied at the same time to an image area during printing: Total ink limit (TIL), Total dot area, Total Area Coverage (TAC). For offset printing profiles on coated paper, in many cases the optimal value for this parameter is 300%. Higher TIL values do not lead to expansion of color gamut and to an increase in contrast in shadows. There is also a risk of set-off during printing and contamination in the last in order color units of the printing press, especially the yellow one. With total ink percentage less than 300, coverage in deep shadows decreases. ISO 12647-2:2013 [7] for coated paper and sheet printing sets the limit very high – not less than 330% but not more than 350%; for web press with heatset drying – up to 300% on coated paper and 270% for other types of paper.

The parameter Black Start in printing system profiles defines the tone value in percent from which the addition of black ink (K) begins during color separation. It affects the moment when black ink is added to the CMY mix: at a low value (for example, 0–10%) black starts being used already in light tones, and at a high value (for example, 50%) – only in dark areas of the image. Choosing the optimal value of Black Start is important for keeping color balance, printing stability and correct reproduction of shades.

"Early" start means that the Black Start parameter is set close to zero on the percent scale. With an early start, black ink begins to appear in the color separated image already in light tones. Standard ECI color separation profiles developed based on Fogra data usually assume quite early start (about 10%). However, for example, in color separation of portrait images, the presence of black ink in light skin tones is undesirable, because on the print an unattractive rash may appear on skintone. For such images it is reasonable to set a late black start in the profile. At the same time, black start from zero is appropriate in color separation of monochrome and achromatic files.

The parameter Black curve allows setting the shape of the gradation curve of black ink and defines how much or how little of it will be in the color separated images compared to color inks. In the printing process, two technologies are known for minimizing color inks during color separation: Under Color Removal (UCR) and Gray Component Replacement (GCR). They allow to adjust the black ink curve – how much or how little of it will be in the separations relative to the color ones. It should be noted that color separation using the UCR technology is not used in practice. Professional programs for creating profiles Color Toolbox (Heidelberg) and i1Profiler (X-Rite) do not offer this outdated method and abbreviation. In these programs, even if in highlights and midtones a light generation of black is used, in shadows a heavy GCR is still created.

Exactly in Color Toolbox from Heidelberg all current color profiles for offset printing according to the international standard ISO 12647-2 were built, which are published on the ECI website [1]. Thus, in the standard profiles from ECI a combined technology is used, which is not purely GCR or UCR: in shadows intensive black generation is applied, while in highlights and midtones – moderate.



a) b) c)

Fig. 1. Generation curves under Eurostandard (Coated), 9%, GCR:
a) Light; b) Medium; c) Heavy

For a clear presentation of the difference between the shapes of the curves, which show the degree of replacing color inks with black in the GCR technology, graphs were built (Fig.1), under conditions of Eurostandard (Coated), 9%, GCR, which were chosen in Adobe PhotoShop. From the graphs one can evaluate the distribution of inks across the tonal intervals of the image. The maximum amount of ink is in the shadows (on the right), the minimum – in the highlights (on the left). The growth of the amount of triad inks in the shadows is smaller, but there the amount of black ink grows exponentially.

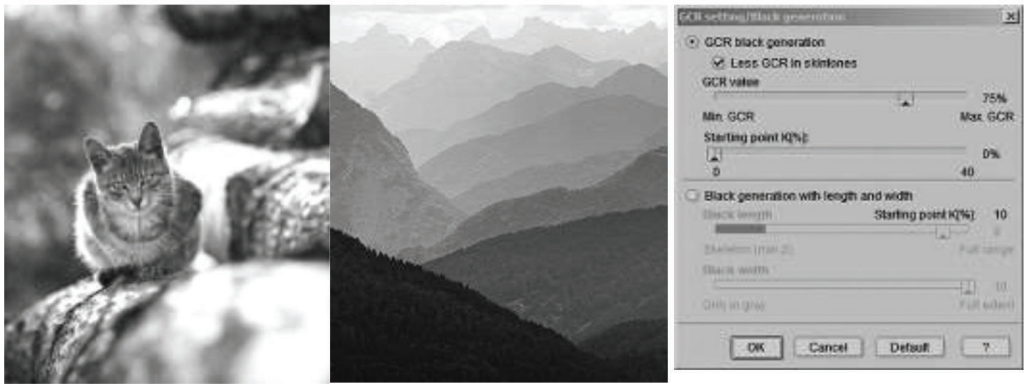
When generating the gradation curve of black ink under heavy GCR conditions, a significant advantage is that the stability of offset printing increases. The option heavy and heavy+ when generating black by GCR technology in profile settings should be chosen for color separation of monochrome and achromatic images (Fig.2).

When building print profiles, it is also necessary to set Maximum black – the limit of black ink, Black width – the width of black, and some other parameters that do not significantly affect the quality of color separation of color originals with different subjects.

The limit of black ink can be set below the value of 100%, but there are no technological reasons to limit black below 100 percent for coated paper in offset printing.

The setting of the Black width parameter (black width) determines the amount of black ink in the separations when saturation increases: with small width black is present only in neutral shades with low saturation; with medium width (about 50) – it appears in shades with medium saturation, except grays; with maximum width (100) – black ink is present even in shades with maximum saturation. It is recommended to set maximum black width (100) in all cases. Small width reduces the color gamut in deep saturated shadows, because the profile does not add neutral black ink to such shades; instead, the

opposite color ink is used, which leads to a change of shade not only in lightness, but also in saturation. Large black width does not distort saturation of shades, affecting only their lightness.



a) b) c)

Fig. 2. Different types of originals and settings when creating profiles:
a) achromatic image; b) monochrome image; c) settings window of Color Toolbox

To study the possibility of changing the parameters of universal profiles to the specifics of the color content of particular originals, one of the most common standard ICC profiles from ECI was chosen – ISOcoated_v2_300_eci.icc. This profile is based on the characteristic data of FOGRA39 (standard ISO 12647-2:2004).

Technological parameters included in the profile:

Paper: coated glossy (coated paper)

Type of printing: sheetfed offset

TAC (Total Area Coverage): 300%

Black generation: Medium GCR

Maximum black ink: 96%

Black Start: about 10%

New profiles will be based on the same Fogra 39 data, on the basis of the same colorimetric measurements, but with the use of other separation methods, optimized for different types of images. For this, the ProfileEditor program from the ProfileMaker package will be used, where it is possible to edit the curves of individual channels: Cyan, Magenta, Yellow and Black.

We will proceed from the fact that the print profile contains six reference tables for direct and reverse conversion according to each of the three Rendering Intents (Relative Colorimetric, Perceptual and Saturation). By direct it means the conversion of the color reproduced by the device into the LAB color space (conversion tables AToB), and reverse conversion means the tables for recalculation from LAB into the color reproduced by the device (conversion tables BToA). Thus, conversion LAB→CMYK and CMYK→LAB is carried out by different tables in the color profile. Programs build these tables colorimetrically mirrored, so when editing profiles, if necessary, one should not forget to edit

both tables. Otherwise, visualization by profile on the screen, the so-called Soft Proof, or on the CMYK→LAB proof print will not correspond to the LAB→CMYK color separation. ProfileEditor allows separately editing all profile tables.

In the ProfileEditor program window, we choose the "One ICC profile" editing mode and load the source ICC profile ISO Coated v2.icc (Fig.3). ProfileEditor supports selective color correction with the possibility to apply edits to one profile, with extended channel control in the CIE LCH and LAB spaces.

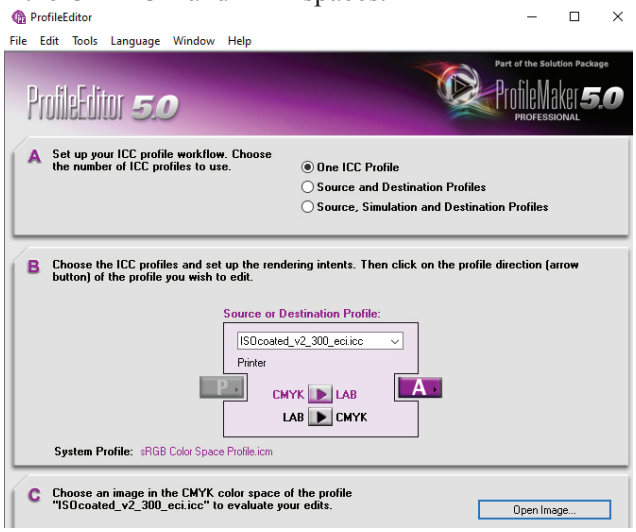


Fig. 3. Window of the ProfileEditor program

For monochrome and achromatic images, the most appropriate is the use of "heavy" black generation GCR. Then black ink will dominate over color inks when reproducing the gray scale even in high highlights at zero start.

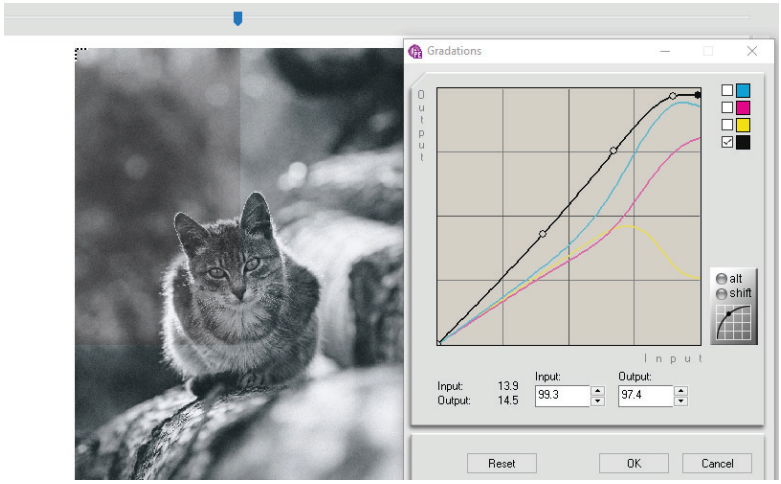


Fig. 4. Creation of a new profile for color separation of achromatic and monochrome images (based on ISOcoated_v2_300_eci.icc)

In Figure 4 the settings of generation curves of the profile for color separation of achromatic and monochrome images are shown, which will be identical in colorimetric characteristics to the ISOcoated_v2_300_eci.icc profile. Early (zero) start of black ink will ensure heavy black generation across the entire tonal range and in large volume. This will guarantee high contrast and stability of printing of the whole run. In deep shadows the amount of yellow ink is significantly reduced to avoid lightening of black, since yellow ink is printed last.

For color separation of images where skin tones dominate, the opposite task arises. It is necessary to provide skeleton black generation with late start to preserve the naturalness and softness of skin. Unlike monochrome images, here it is critically important to minimize the amount of black ink in light and mid tones, because excessive black leads to grayness and loss of natural skin shade. Black generation should begin at about 30% of the tonal range, ensuring its use mainly in shadows to support image depth. At the same time, the main role in reproducing skin tones is placed on the triad inks (CMY), which guarantees smooth gradations, natural color and absence of unwanted gray shades. In deep shadows an increase of black ink content is allowed to provide the needed contrast, but the balance of color components must be preserved to avoid loss of details in shadows and to maintain detail in dark areas of the portrait.

The profile for color separation of portrait images (Fig.5) is also based on the characteristic data of Fogra 39. Late start of black ink. The distribution of color inks in the shadows differs significantly from the settings of the ISOcoated_v2_300_eci.icc profile. To increase the print contrast in deep shadows, the influence of yellow ink on color formation is reduced.

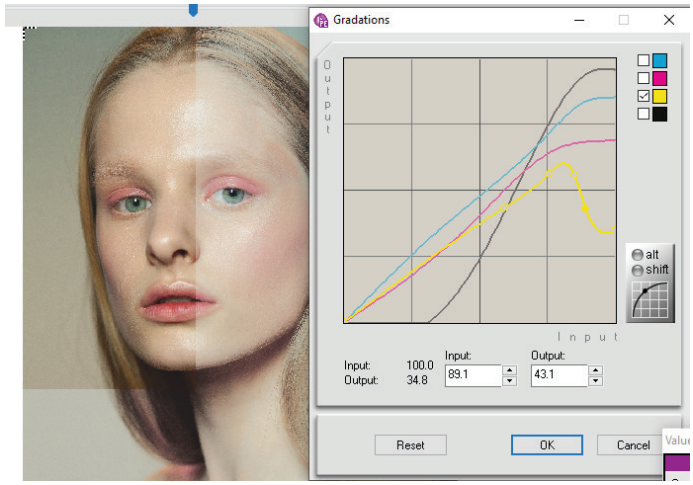


Fig. 5. Creation of a new profile for color separation of portrait images (based on ISOcoated_v2_300_eci.icc)

To illustrate the flexibility of settings in the ProfileEditor program, we perform editing of the ISOcoated_v2_300_eci.icc profile for color separation of a portrait photograph on a gray background. The new profile is colorimetrically identical to ISOcoated_v2_300_

eci.icc, but it has fundamental differences in the strategy of black generation. Heavy black generation with early (zero) start is implemented, which ensures maximum use of black ink in neutral and gray tones (Fig.6).

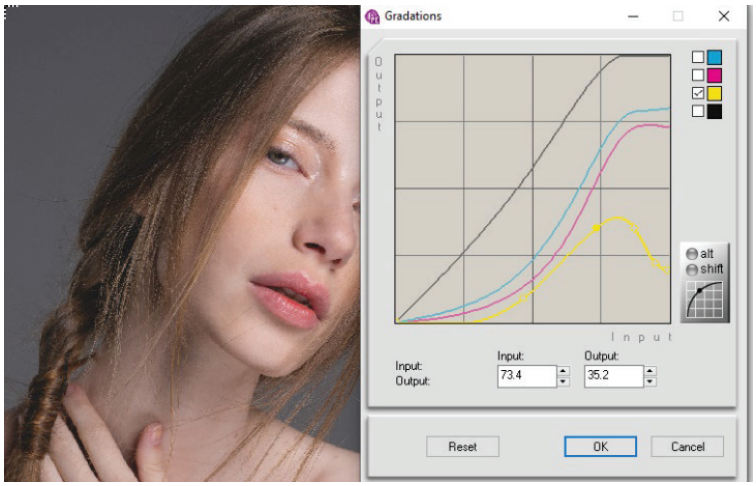


Fig. 6. Creation of a new profile for color separation of portrait images on a neutral background (based on ISOcoated_v2_300_eci.icc)

When performing color separation in the PhotoShop program using the created profiles, it is advisable to use the following settings from the Convert to Profile palette.

The choice of Rendering Intent Relative Colorimetric method (Fig. 7) is well suited for most images, because it allows to achieve the maximum possible colorimetric similarity of the colors of the original and the print, as well as visual similarity, since the colors of the original are recalculated relative to the white point of the output device, which will ensure the color relations between the white and the rest of the colors of the original, and the white and the rest of the colors of the print. At the same time, as in the previous case, the colors that do not fall within the gamut of the output space are replaced with the nearest by color tone.

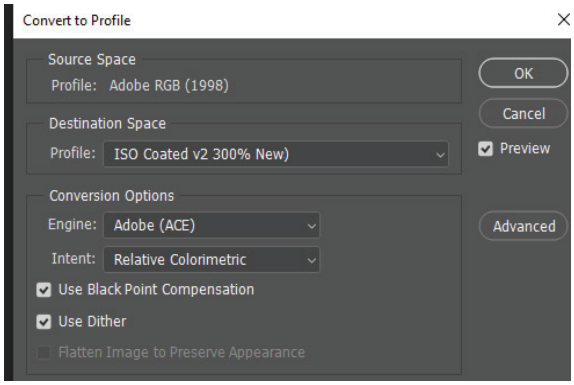


Fig. 7. Color separation settings in Adobe PhotoShop program

By understanding the specifics of reproduction in offset printing of different digital originals by content, it is possible to flexibly adjust the gradation curves of color inks and black ink for specific needs and at the same time keep the colorimetric characteristics of standard ECI profiles. The checkbox Use Black Point Compensation is better to turn on. The black point in different profiles may be different in lightness. The non-linear algorithm Black Point Compensation is useful for matching the black point.

Conclusion. To solve the problem of color reproduction of images with specific content, a method of modification of the standard ISO Coated v2 (ECI) profile using ProfileEditor software is proposed. The method is based on preserving the original colorimetric characteristics of FOGRA39, which guarantees compliance with the ISO 12647-2 standard, with simultaneous change of the generation curves of color and black inks according to the content features of a specific digital original. Such an approach makes it possible to create specialized profiles with enhanced (Heavy GCR) or skeleton black generation for monochrome images, portrait photography and other categories of originals, while keeping the standardized parameters of the printing process.

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МОДИФІКАЦІЯ ГРАДАЦІЙНИХ КРИВИХ ICC-ПРОФІЛІВ ДЛЯ ПІДВИЩЕННЯ ЯКОСТІ КОЛЬОРОПОДІЛУ ЗАЛЕЖНО ВІД СЮЖЕТУ ОРИГІНАЛУ

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У статті досліджено проблему оптимального кольоровідтворення окремих типів зображень засобами офсетного друку. Виконано аналіз основних параметрів для кольороподілу, закладених в стандартних ICC-профілях від Європейської ініціативи з кольору (ECI) та вказано на недоліки, які виникатимуть за умови їх використання при відтворенні монохромних зображень та портретної фотографії. Встановлено, що стандартні профілі PSO Coated v3 та ISO Coated v2 з середньою генерацією чорного, максимальним вмістом чорної фарби 96% та стартом генерації чорного з 10% не можуть бути універсальними для кольороподілу різних за колірним вмістом цифрових оригіналів.

Запропоновано підхід до створення спеціалізованих профілів шляхом модифікації градаційних кривих генерації кольорових і чорної фарб базового профілю ISO Coated v2 (ECI) з використанням програми ProfileEditor (ProfileMaker). Методика базується на збереженні у профілі колориметричних характеристик FOGRA39 при зміні параметрів генерації фарб відповідно до сюжетно-колористичних особливостей оригіналу. Розроблено профіль з важкою генерацією чорного (Heavy GCR), раннім стартом та зменшеним вмістом жовтої фарби в тінях для монохромних зображень, що забезпечує високий контраст та стабільність друку. Створено профіль зі «скелетною» генерацією чорного з пізнім стартом (30%) та домінуванням тріадних фарб для портретних зображень, що гарантує природність відтворення тілесних відтінків. Продемонстровано можливість створення комбінованого профілю для портретів на нейтральному фоні з одночасним забезпеченням стабільності балансу за сірим та природного вигляду кольору шкіри. Результати дослідження підтверджують ефективність диференційованого підходу до кольороподілу та демонструють практичну можливість адаптації стандартизованих профілів під специфічні завдання додрукарської підготовки. Запропонований підхід дозволяє підвищити якість кольоровідтворення при збереженні відповідності стандарту ISO 12647-2.

Ключові слова: *кольороподіл, профілі друку, офсетний друк, технологія кольороподілу GCR, стандарт, додрукарська підготовка, цифровий оригінал, градаційні криві.*

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