# Image Processing of Narrow Gap GMA Welding†

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**Abstract**

*In narrow gap GMA welding, welding locus of arc weaving, sidewalls of narrow gap and wire extension, etc. are detected successfully by image sensing and processing. Algorithm for detection is described.*

KEY WORDS: (Narrow Gap Welding) (Image Processing) (Arc Weaving Welding) (Direct Arc Monitor) (Wire Tip Weaving Locus) (Seam Tracking)

## 1. Introduction

In the narrow gap GMA welding process (NGW), the welding behavior of arc has great influence on the welding quality. The most important problem of NGW is how to keep the weaving of welding arc within a correct range in the narrow and deep groove to fuse both groove sidewalls and to build up the deposit metal adequately. There are some reports[1),2)] about the seam tracking system employing optical means in NGW. Recently, arc sensor has been applied to NGW[3)]. However, there are several types of NGW[4)] and arc sensor can be applied to not all of them. Moreover, according to the principle of arc sensor, the deviation of arc weaving is determined from the change of welding current during weaving action indirectly, it may be affected by irregular curve of wire or welding current disturbance under certain condition. For this reason, it is desirable that the position of weaving arc is detected directly and kept proper with a servo system.

On the other hand, it is also important to investigate various welding phenomena produced in arc weaving.

The purpose of this study is to develop the method of detecting the locus of weaving arc, locus of wire tip, other necessary information by means of image processing technique during narrow gap GMA welding. The influence of the arc weaving on the pattern of welding current and sound is also investigated by using this image prosessing result.

Only the former, detection by image processing, is described in this report (Report 1). The latter will be described in the next one.

## 2. Welding Process

The welding method used in this study, as schematically shown in **Fig. 1**, is BHK type narrow gap arc weaving device developed by BABCOCK-HITACHI K.K. The feature of this process is that the arc weaving is produced by feeding the wire which is preformed into wave shape with using the flapping plate and the feed rollers as shown. The process is very popular now, because it has advantages of simple design and low cost, but it is difficult to apply the arc sensor technique owing to its principle when necessary to keep the position of weaving arc proper.

It is one purpose of this study to develop an automatic monitoring system and to obtain higher reliability. The studying work was done by processing and analyzing the recorded data of welding experiments. General welding parameters used in these experiments are listed below:

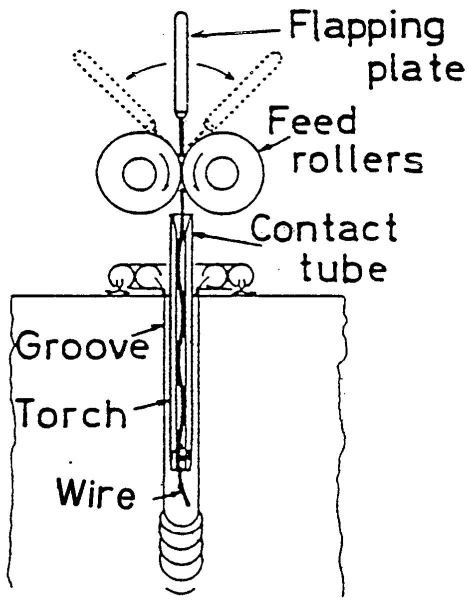


**Fig. 1** Schematic diagram of BHK type narrow gap GMA welding method

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Transactions of JWRI is published by Welding Research Institute of Osaka University, Ibaraki, Osaka 567, Japan

| | |
|---|---|
| Welding current: | 270 – 280 (A) |
| Arc voltage: | 29 (v) |
| Wire extension: | 13 – 20 (mm) |
| Shielded gas: | 20%$CO_2$ + Ar |
| Welding wire: | MGS – 50, $\phi$1.2 (Kobe steel Ltd.) |
| Width of groove gap: | 9 – 14 (mm) |

## 3. Recording and Processing System

**Figure** 2 shows the block diagram of the data recording and processing system. In the welding experiments, the imag of welding region is picked up with a CCD camera, and then recorded with a video recorder. At the same time, the welding current and the arc sound are measured respectively with a current detector and a microphone and recorded with a data recorder. The timing pulse from the pulse generator is also fed and recorded with both of the video recorder (in its audio side) and data recorder at the same time. The image signal from video recorder digitized in 6 bits, saved in video memory and processed by a microcomputer. The processed signal, for example, the locus of wire tip weaving, etc., is fed to a FFT analyzer as an analogue signal through DAC.

The authors developed a synchro-system which is composed of a timing pulse generator and a pulse counter for synchronizing the current signal or the arc sound signal with the image signal.

**Figure** 3 shows an example of timing pulse from timing pulse generator, the trigger pulse outputs from the timing

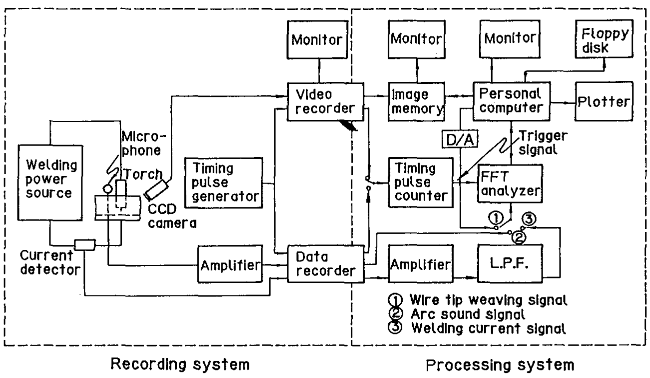


**Fig. 2** Block diagram of data recording and processing system

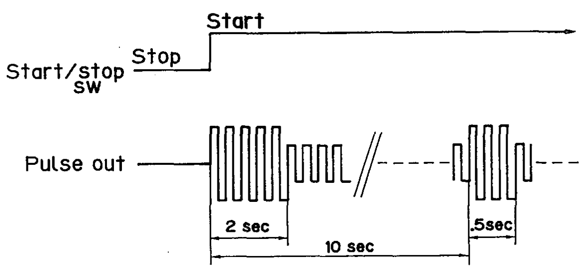


**Fig. 3** Example of timing pulse

pulse counter when the counting number of timing pulse, generated at the tape play-back, becomes the preset value during processing. The processed image signal or the welding current signal or the arc sound signal can be fed to FFT analyzer by this trigger pulse, and its processed result is saved in a floppy disk or figured in a graph with a plotter, which are connected to a microcomputer.

## 4. Image Processing

### 4.1 Outline of processing

**Figure** 4 shows schematic of image processing region. All processings are carried out to binary images which were thresholded to original images at suitable levels.

Items list below are detected: locus of weaving wire tip (Wi), both ends ($W_L$, $W_R$) of weaving locus, both sidewalls ($G_L$, $G_R$) of groove, center (C) of end of contact tip.

**Figure** 5 shows the flowchart of image processing. First, the instantaneous position of wire tip A is detected by horizontal search and it is chosen as an original point. Horizontal line L which is below m rows (of a pixel unit) of point A is chosen as a standard line to detect boundary $A_{li}$, $A_{Ri}$ of arc region. Horizontal line Lw which is over n rows of point A is chosen as standard to detect the weaving wire tip (Wi). The location ($W_L$, $W_R$) of both ends of locus of wire tip weaving can be determined from Wi. The location ($G_L$, $G_R$) of groove can be calculated by $A_{Li}$ and $A_{Ri}$. Finally, the center (C) of end of contact tip is detected.

### 4.2 Detection of wire tip A as a standard point

First, as shown in **Fig.** 6, vertical scanning starts from

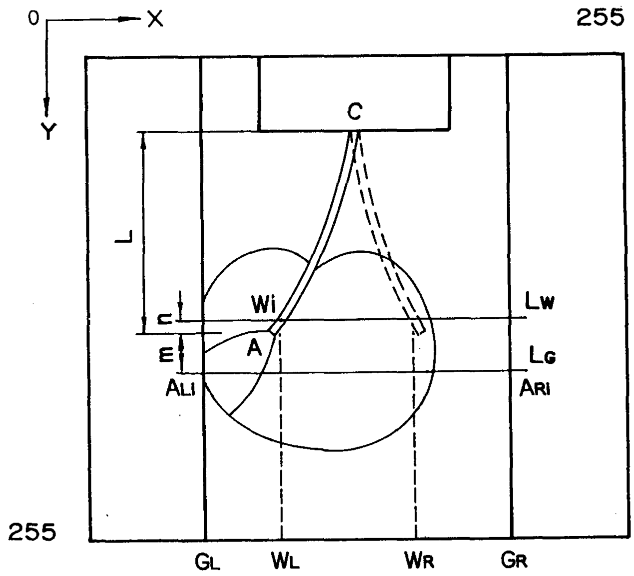


**Fig. 4** Illustrating of image processing region and values to be measured

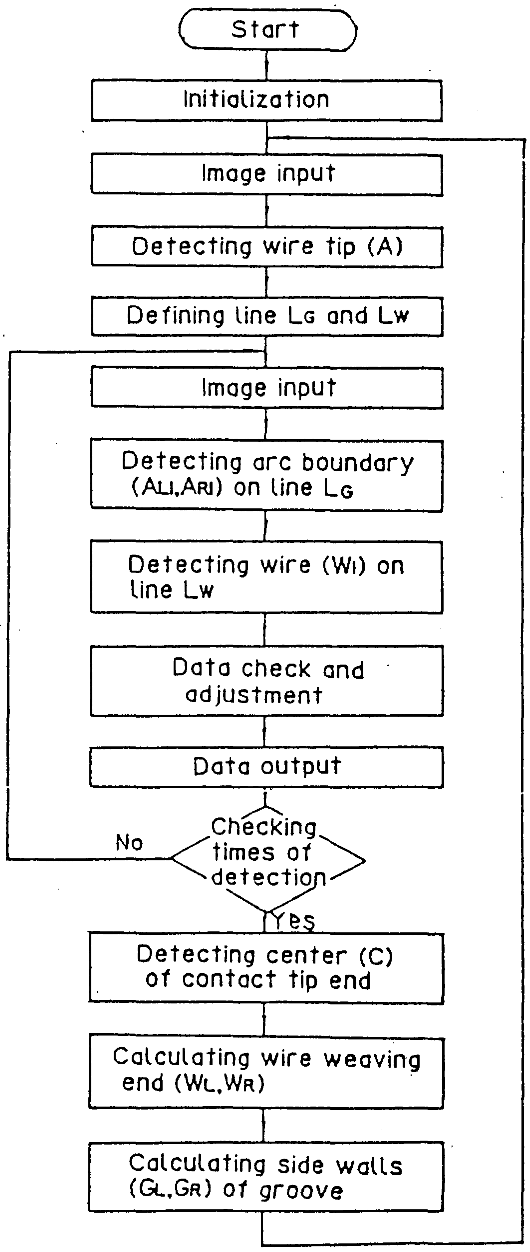


**Fig. 5** Flowchart for image processing

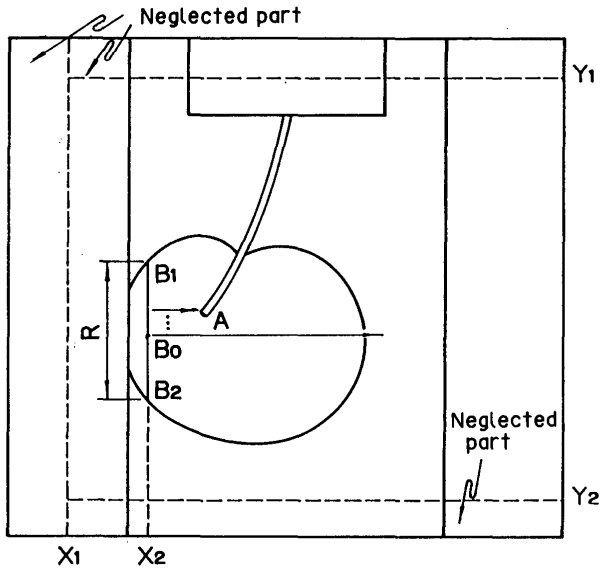


**Fig. 6** Detection of wire top point (A)

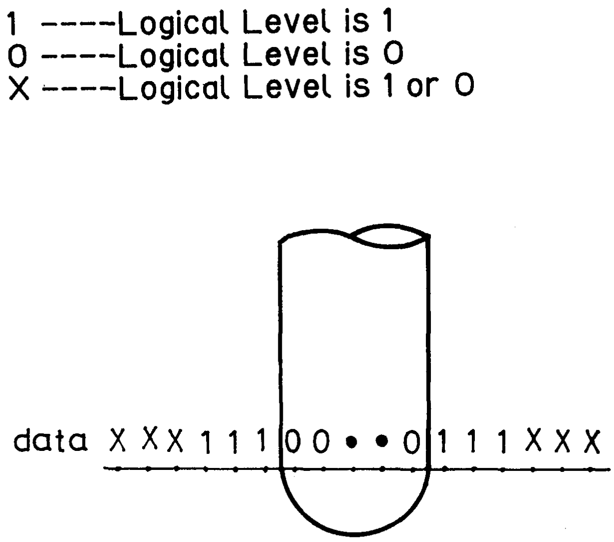


**Fig. 7** Template for detecting wire image

left side of image frame $x_1$ and moves to right, until the arc region is detected at $x_2$, which can be checked by relation expressed in **Eq. (1)**

$$L_i = \sum_{Y=Y_1}^{Y_2} f(X_i, Y) \geqslant R \qquad (1)$$

where $f(X, Y)$ is equal to 1 or 0, represents the logical level of a pixel $(X, Y)$ of a binary image. $L_i$ represents the length of the arc region on the vertical line at $X_i$. R is the value which is preset according to the image condition.

Next, if $L_i = R$, then two crossing points of the arc defined as $B_1$ and $B_2$ (see Fig. 6). The mid point of $B_1$ $B_2$, $B_0$ is used as a starting point of horizontal scanning. The scanning is going on with scanning width of s, which is also preset according to the image condition, until the wire tip A is detected. The template shown in **Fig. 7** is used to detect the welding wire correctly. The width of wire is specified by 3 ~ 5 of pixel unit, whose logical level are 0, and can be regulated suitably according to the magnification of the image.

### 4.3 Detection of boundary ($A_{Li}$, $A_{Ri}$) of arc region

As shown in **Fig. 8**, the points specified as $A_{Li}$ and $A_{Ri}$ are boundary of the arc region, i.e., the juncture points of region whose logical level is 1 and 0 on the line $L_G$.

The point $X_A$ which is a projection of the standard point A on the line $L_G$ is chosen as a starting point of horizontal scanning. The scanning goes to left first along the line $L_G$ until the point $A_{Li}$ is detected and then to right until the point $A_{Ri}$ is detected.

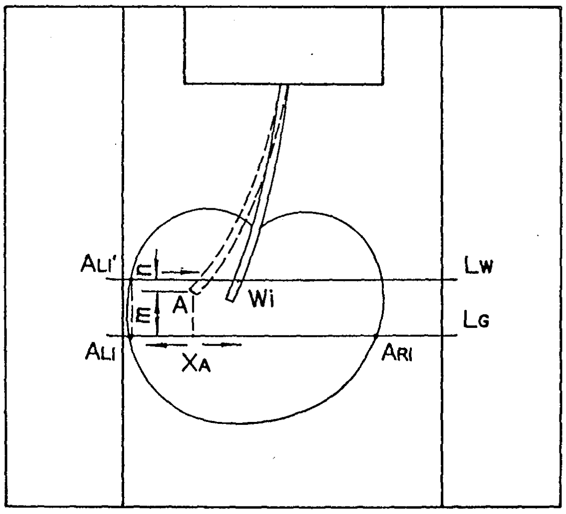


Fig. 8 Detection of boundary of arc region ($A_{Li}$, $A_{Ri}$) and weaving wire tip (Wi)

### 4.4 Detection of weaving wire tip (Wi)

The weaving wire tip is represented approximately by the point Wi that is the cross point of wire and the line $L_W$. As shown in Fig. 8, horizontal scanning starts from the point $A'_{Li}$ which is a projection of $A_{Li}$ on the line $L_W$ to right until the point Wi is detected or scanning length is equal to (G-r), where G is the distance between $A_{Li}$ and $A_{Ri}$, r is also preset value. The template shown in Fig. 7 is still the standard for judging wire pattern.

The steps described in section **4.3** and **4.4** of the image processing are repeated. As the scanning range is small, the number of pixels to be processed is quite small in every scanning, hence the frequency of detection reaches the level of 20 – 30 Hz. It is quick enough to meet the requirement for judging the locus of weaving arc in practical welding.

To improve the reliability of detecting Wi, there are some check and modification routines in the program. They are listed below:

1) The detection result Wi obtained in every scanning is compared and checked with the result of just previous scanning in order to modify miss-detection if it appears.
2) If the point Wi can not be detected within the scanning range, the threshold level for binarization of image is adjusted a little and the original image is processed again.

### 4.5 Calculation of both ends ($W_L$, $W_R$) of wire tip weaving locus

Then points $W_L$ and $W_R$ is obtained by calculation of Eq. (2):

$$\left.\begin{aligned} W_L &= \mathrm{Min}\,(Wi) \\ W_R &= \mathrm{Max}\,(Wi) \end{aligned}\right\} \cdots\cdots\cdots\cdots (2)$$

### 4.6 Calculation of both side walls ($G_L$, $G_R$) of groove

The points $G_L$, $G_R$ is also obtained by calculation of Eq. (3):

$$\left.\begin{aligned} GL &= \mathrm{Min}\,(A_{Li}) \\ GR &= \mathrm{Max}\,(A_{Ri}) \end{aligned}\right\} \cdots\cdots\cdots\cdots (3)$$

### 4.7 Detection of center point (C) of end of contact tip

As shown in **Fig. 9**, the line $L_W$ is chosen as a starting line of horizontal scanning. The horizontal scanning which is symmetrical with respect to the mid point of $W_L$ and $W_R$ moves upward gradually within the region which is a little broader than the width (w) of the image of the contact tip until the end of contact tip is detected by the algorithm explained below.

The length of dark part (logical level of the pixel is equal to 0) is obtained by one horizontal scanning. The contact tip can be recognized when the length is equal to W approximately. The center of dark part of this horizontal scanning is considered to be the center (C) of the end of the contact tip.

The threshold value for binarization to detect C must be a little smaller than the value to detect the weaving wire tip (Wi) and boundary ($A_{Li}$, $A_{Ri}$), because grey level of the scanning region for detection of C is darker than that of the arc region.

**Figure 10** shows photo illutrating of each step of image processing.

**Figure 11 (a)** shows the locus of the wire tip weaving and both sidewalls of groove obtained by the image processing mentioned above in the case without any modification for every detection result.

**Figure 11 (b)** is the modified result of (a) followed by the algorithm described in section **4.4**.

**Figure 11 (c)** is the smoothing processed result of (b)

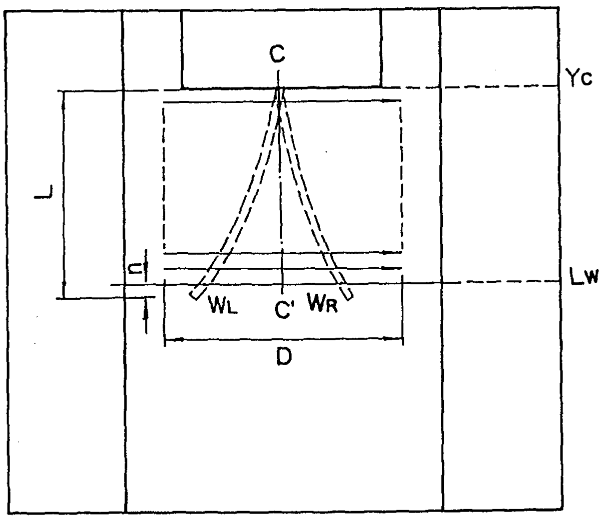


Fig. 9 Detection of center point (C) of end of contact tip

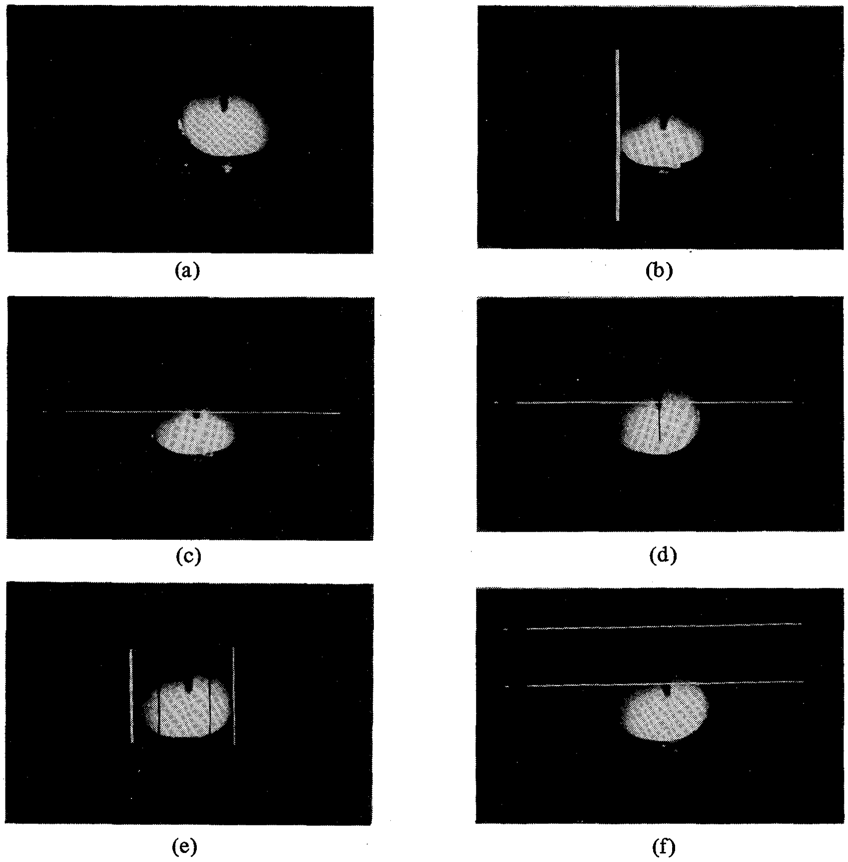


**Fig. 10** Example for each step of image processing
(A) Image input to image memory
(B) Detecting arc region
(C) Detecting wire tip and defining standard line
(D) Detecting wire on standard line
(E) Both ends of wire weaving and both sidewalls of groove
(F) Detecting end line of contact tip.

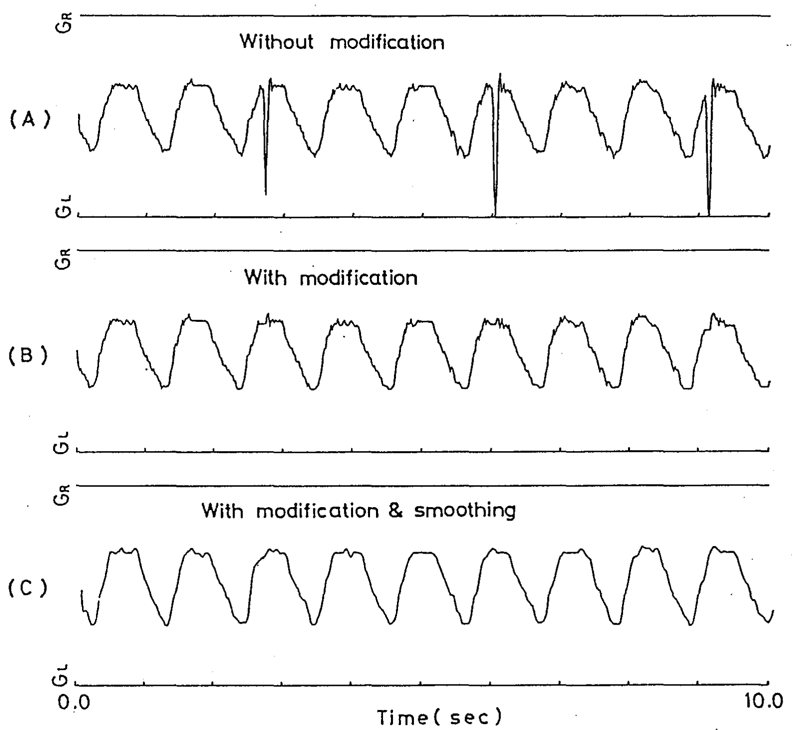


**Fig. 11** Detection result of wire tip weaving locus and both sidewalls of groove

with 5 Hz low-pass digital filter.

## 7. Conclusion

The locus of arc weaving, sidewalls of groove and wire extension, which are important information, are detected successfully by image processing technique. By using these results, correlations of arc current, welding sound and arc weaving can be analyzed. These will be described in the next report.

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