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STUDY ON CORROSION FEATURES ANALYSIS FOR VISUAL INSPECTION & MONITORING SYSTEM: AN NDT TECHNIQUE

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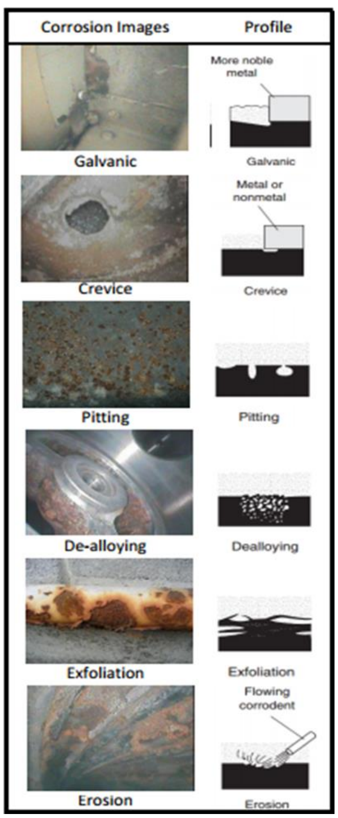
Graphical abstract



Abstract

These days, utilization of camera as inspection tools has been expanded. The flexibility functions of camera is good to get different kind of information. This research work is focusing on developing a robust visual inspection system for NDT corrosion detection. An investigation on corrosion types based on appearance features is simulated to identify the profiling of each corrosion types. The result found that each corrosion types has different features that can be used for classifying the corrosion. By identifying the type of corrosion, we can understand the pattern of attack, thus early prevention can be done. It is expected that the output of this research will be a new method of corrosion detection and improve vision inspection as the pioneer in NDT method for corrosion inspection. Furthermore, the system is able to adapt to the unrefined environment, thus, making the proposed system robust and useful for other detection applications.

Keywords: Corrosion; vision inspection; Non-Destructive Testing (NDT)

Abstrak

Hari ini, penggunaan kamera sebagai alat pemeriksaan semakin meluas. Fleksibiliti fungsi kamera yang baik boleh mendapatkan pelbagai jenis maklumat. Kerja penyelidikan ini tertumpu kepada pembangunan sistem pemeriksaan visual untuk mengesan kakisan secara ujian tanpa musnah. Siasatan ke atas jenis kakisan berdasarkan penampilan dijalankan secara simulasi untuk mengenal pasti profil setiap jenis kakisan. Hasil mendapati bahawa setiap jenis kakisan mempunyai ciri-ciri yang berbeza dan boleh digunakan untuk mengklasifikasikan kakisan. Dengan mengenal pasti jenis kakisan, corak serangan dapat difahami dan pencegahan awal dapat dilakukan. Hasil penyelidikan ini akan menjadi satu kaedah baru pengesanan kakisan dan sebagai perintis dalam kaedah NDT untuk pemeriksaan karat. Sistem ini dapat menyesuaikan diri dengan pelbagai persekitaran menjadikan sistem yang dicadangkan berguna untuk aplikasi pengesanan lain.

Kata kunci: Kakisan; pemeriksaan penglihatan; ujian tanpa musnah

1.0 INTRODUCTION

Corrosion can cause major losses to industry. One of the industry that has high impact due to the corrosion is oil and gas. This is because, oil and gas use pipeline to transfer goods between places. In a case study by Pure Technology, a deteriorated Bar Wrapped Pipe (BWP) due to corrosion was detected during schedule inspection [1]. However due to the pipe useful life is nearer to the end, the pipes section were replaced. Yet, by replacing BWP earlier then its expiry, the cost compare to the usage is increasing.

Corrosion inspection and monitoring are key activities in ensuring asset integrity and control of corrosion. Management choices on gear condition, expectation of leftover life and necessities for synthetic treating are just in the same class as the information input provided from field experience. Corrosion inspection and monitoring includes assessment of [2]:

a. In-line systems - corrosion coupons, bio-studs
b. On-line monitoring techniques
c. Off-line monitoring - Non-Destructive Testing

Non-destructive testing (NDT) techniques are used extensively to monitor corrosion. One of the advantages is that equipment usually need not be taken out of service. In Cawley review on NDT that presented in 2001, radiography, ultrasonic, eddy current, magnetic particle, and penetrant testing were top five techniques dominating the NDT market [3] yet visual inspection is the most widely applied in NDT technique, but due to the accuracy issues, it is often used together with others method. However due to the advancement of technology, we believe that visual inspection can be used for corrosion inspection without any assistance of other methods. Therefore, this research work is discussing the application of visual inspection system to be used as primary equipment for NDT corrosion inspection.

1.1 Corrosion Inspection & Monitoring

In the petroleum industry, the internal corrosion in oil and gas production operation is often monitored with hydrogen probes. Hydrogen probes measure hydrogen permeation and provide information on the rate of corrosion [4]. Other on-stream corrosion-monitoring techniques that are used in the petroleum and chemical industries, include the following:

a. Electrical resistance and linear polarization methods
b. Ultrasonic thickness measurement

The costs of corrosion vary considerably from one industry to another industry. However, substantial savings are achievable in most industries. The first step in any cost reduction program is to identify and quantify the present costs of corrosion [5]. Based on this analysis and a review of the present status of corrosion control in the industry, priorities can be determined and the most rewarding cost-reduction projects pursued [6]. Corrosion can be classify based on one of the following three factors [7]:

a. Nature of corrode: either as "wet" or "dry"
b. Mechanism of corrosion: either electrochemical or direct chemical reactions
c. Appearance of the corroded metal: either uniform or it is localized

With the ability to classify the corrosion type based on visual, the inspection system will able to make suitable decision based on expert system database. Corrosion is either uniform which the metal corrodes at the same rate over the entire surface, or it is localized, in which only small areas are affected. The detection of the corrosion "areas" will be detected by means of visual sensor, using camera or video that is able to determine and analyze the sensed areas. Thus the corrosion detection on the inspection system using visual, proves to be validated.

1.2 Visual Corrosion Classification

Camera or vision sensor capabilities are able to execute various inspections such as dimension inspections, character inspections, positioning, and defect inspections. The images obtained from the vision sensor provide different kinds of information. For example, H. Seiji et. Al. use vision sensor to detect color and pattern of the object for their inspection system [8]. Another use of vision sensor for inspection was demonstrated by H. M. Haniff, using shape data to inspect defects on a glue process [9]. With different data extracted from a single image, visual inspection can be used on various processes of inspection.

Classification by appearance, which is particularly useful in failure analysis, is based on identifying forms of corrosion by visual observation, either with naked eye or magnification. The morphology of attack is the basis for classification. Nine forms of wet (or aqueous) corrosion that can be identified based on appearance of the corroded metal [5] is shown in Figure 1. However in NDT visual inspection system, macroscopic localized corrosion type is suitable for classification as macroscopic size defect is large enough to be detected in ordinary visible sense.

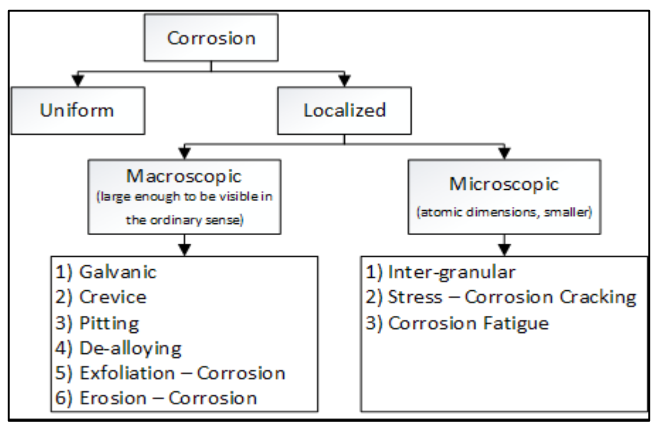


Figure 1 Characterization based on appearance.

1.3 Corrosion Features

In visual inspection, the corrosion level identification requires expert who can clearly determine the corrosion based on experience as well as types of corrosion, with red rust as a common experience. Usually, the corrosion process produces rough surfaces, and image analysis based on textural features that can be used for quantification and discrimination of corrosion extent [10]. Additionally, color progression of metallic surfaces is also used for the detection of corrosion because of different metal oxides and other corrosion products [11].

Figure 2 shows the corrosion image features profile identified for localized macroscopic corrosion that able to differentiate various classes of corrosion. Each type has different features that can be differentiated with either texture, color or shape. The experiment conducted is to identify the profile developed using vision inspection corrosion system on each type of corrosion inside the Nickel Tube for classification of corrosion.

Figure 2 Corrosion image with profile.

2.0 EXPERIMENTAL SETUP

There are five types of corrosion (erosion, galvanic, crevice, pitting and exfoliation) artificially generated on the test bed for simulation purpose. Figure 3 shows the experimental setup of the test bed that is to be used in order to obtain simulation images of corrosion based on appearance types. The images use in this experiment would be obtain by the USB boroscope. The boroscope would acquire images and videos of the corroded pipe in order to let the visual inspection system to classify the detected corrosion.

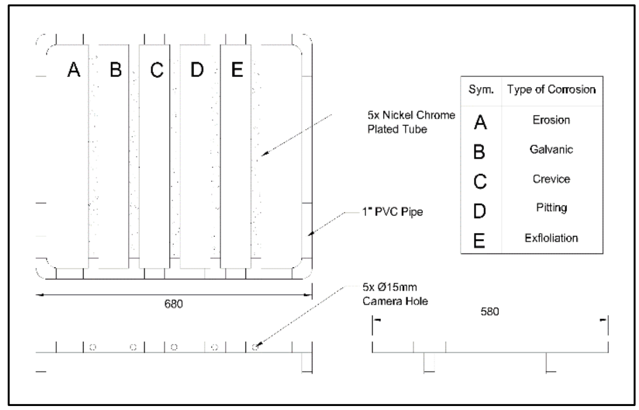


Figure 3 Experimental setup to obtain simulation images of the corrosion

2.1 Sample Preparation - Erosion

Erosion corrosion is an acceleration of the rate of corrosion, attacked on metal due to the relative motion of a corrosive fluid and a metal surface. To generate erosion corrosion inside the nickel tube, a solution H_2O (96-97%) + NaCl (3%) (seawater) is used as a corrosive fluid. The seawater then, is agitated using motion flow agitation system to make sure for the relative motion of the corrosive fluid inside the metal tube. The appearance of erosion corrosion most likely exhibits grooves, gullies, waves rounded holes and usually a directional pattern based on the fluid flow.

2.2 Sample Preparation - Galvanic

Galvanic corrosion exist due to electrochemical process, in which one metal corrodes preferentially to another when both metals are in electrical contact during the presence of an electrolyte. This same galvanic reaction is exploited in primary batteries to generate an electrical voltage. Therefore what galvanic corrosion required to be appear is the conjunction between dissimilar metals and an electrolyte, which means a substance that conducts an electric current (seawater). Hence, to generate the galvanic corrosion, an electrolysis experiment between corrode metal (nail) with the sample (nickel plated chrome) are conducted. The appearance of galvanic corrosion most likely display a spot area of uniform corrosion.

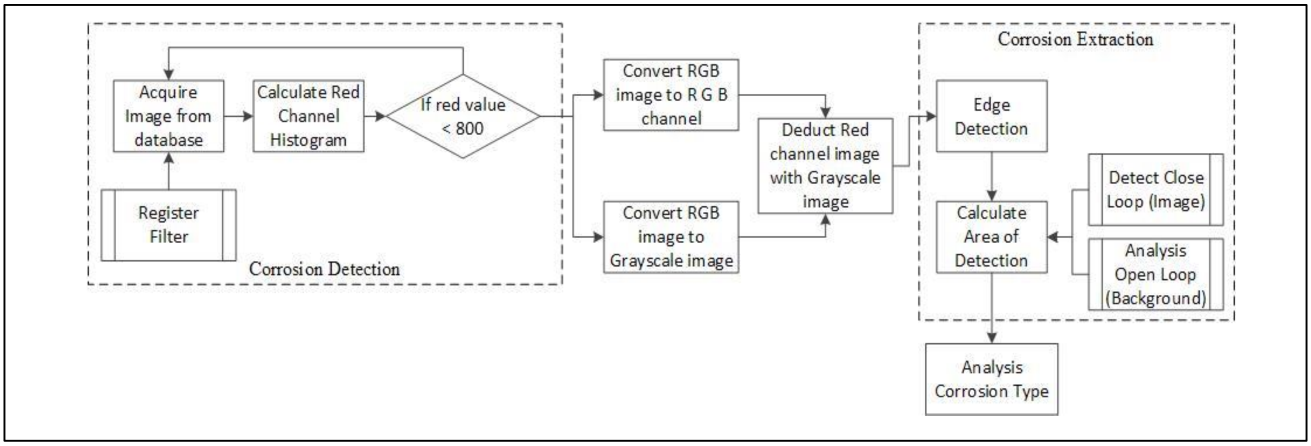


Figure 4 Flowchart for corrosion profile classification

2.3 Sample Preparation - Crevice

Crevice corrosion is encountered particularly in metals and alloys which owe their resistance to the stability of a passive film, since these films are unstable in the presence of high concentrations of Cl^- and H^+ ions. Therefore the crevice corrosion are generated by exposing the surface of nickel tube to the seawater [H_2O (96-97%) + NaCl (3%)]. Firstly the tube required to be cleaned from any anti-rust element coated for protection. Scratch using rust material on the surface would be able to expose the area and at the same time infected the surface with rust element. Next, the uncover area are encrusted with the seawater as a catalyzer for the corrosion process. The crevice corrosion appearance most likely display a spreading pattern which focus in the middle.

2.4 Sample Preparation - Pitting

Pitting corrosion is a form of extremely localized corrosion that leads to the creation of small holes in the metal. It is an autocatalytic process in which the corrosion products promote further corrosion reactions. This is shown for a metal in an oxygenated NaCl electrolyte. The pit is anodic and the metal surface is cathode. Pitting corrosion was formed inside the surface of nickel tube by sprinkled aqueous solution of NaCl using needle holes spray. The method involved electrolysis of nickel tube surfaces with the NaCl aqueous solution. The pitting corrosion appearance preview pattern of small dots corrosion inside the surface of nickel tube.

2.5 Sample Preparation - Exfoliation

Exfoliation corrosion usually occur along aluminum grain boundaries. These grain boundaries in both aluminum sheet and plate are oriented in layers parallel to the surface of the material, due to the rolling process. The delamination of these thin layers of the aluminum, with white corrosion products between the layers, characterizes exfoliation corrosion. In this research work, to obtain the layered corrode on nickel plated chrome tube appearance just like exfoliation corrosion would affect the materials, the tube would be exposed to seawater [H_2O (96~97%) + NaCl (3%)] to obtain the surface corrosion. After drying up the tube, the corrode area are coated with anti-rust paint without clearing the corrosion surface. The corrode nickel tube will display uneven layered surfaces just like the effect of exfoliation corrosion on the aluminum sheet.

3.0 METHODOLOGY

Images obtain from the test bed are filtered using image enhancement. Using filtered image obtain from image enhancement process, the image is converted into red, green and blue channel in the corrosion detection section. However, only red channel is used from this image as shown in flowchart in Figure 4. Then the value of red channel is extracted, and for the pixel which value is between level 16: 25 above 800, the system will considered that corrosion is present. And if the value is lower than 800, the system assumed that it is not corrosion. The value of red channel corrosion is determine during the experiment, using the image obtain from design and simulation stages.

Next, to display the detected area, the red channel image will be subtract with the grayscale image of corrosion. The display image will be in black and white image, in which white area is the detected corrosion are and the black area is the background image. Using the subtract image, edge detection algorithm is applied on the image, and the edge will detect close loop area, which is the corrosion. From the result of edge detection, analysis on pattern, texture and shape is conducted for corrosion classification process.

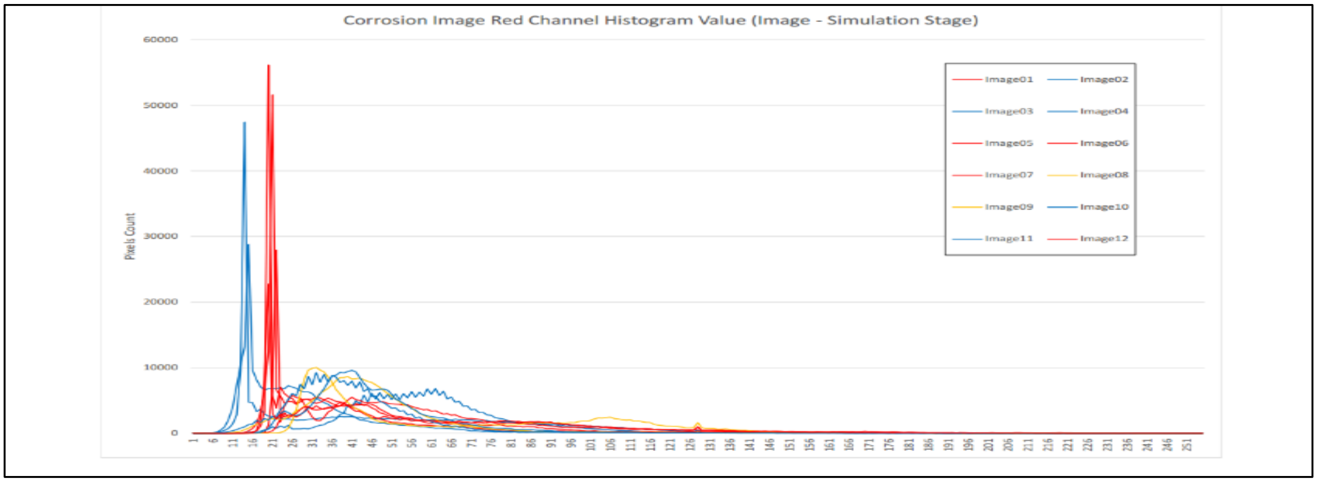


Figure 5 Corrosion Image - Red Channel Histogram Value

4.0 RESULTS AND DISCUSSION

4.1 Results

Classification by appearance, which is particularly useful in failure analysis, is based on identifying forms of corrosion by visual observation. The morphology of attack is the basis for classification. 5 forms of wet (or aqueous) corrosion can be identified based on the appearance of the corroded steel metal [2]. However, in order to understand the corrosion profile for classification, the detection of corrosion is required.

As illustrated in Figure 5, the corrosion image on red channel histogram are represented by red line. As for non-corrosion image, blue line is use as the indicator and orange line is for representing small scale corrosion area. The x-axis represent the value of intensity for the red channel histogram and the y-axis shows number of pixel on that intensity. From the figure, the corrosion area are located between 16 -21 intensity and the number of pixel can be set at 800. The method used to detect corrosion which is based on red channel histogram is limited for medium size of corrosion as small scale corrosion can be ignored in this research work.

Couple of images were run on the Vision Inspection Corrosion System, and Table 1 presents corrosion images detected. The corrosion images are classified based on their type of corrosion and the extraction of corrosion is shown in column corrosion profile for each type of corrosion. From the images in corrosion profile, the white area indicates the corrosion pattern detected for vision inspection corrosion system.

Five types of corrosion is simulated to identify the corrosion appearance features. From the result of corrosion extraction, based on all corrosion types, the appearance texture developed are significantly different between each other. Table 2 presented the appearance features, possibly developed for each corrosion in order to compare with the images obtain from the experiment.

Table 1 Result for corrosion image inside a Nickel Tube with corrosion profile

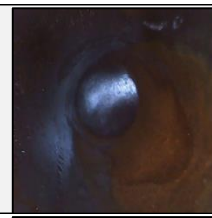
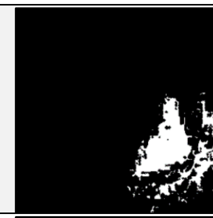
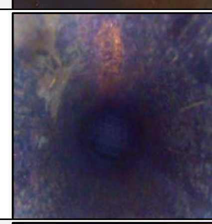
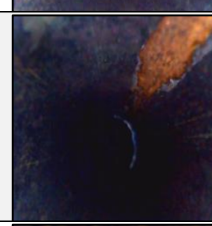
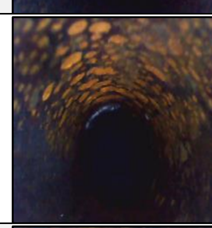
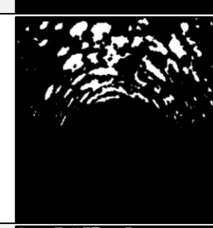
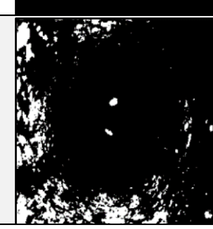
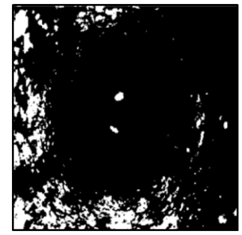
	Corrosion Images	Corrosion Profile
Erosion		
Galvanic		
Crevice		
Pitting		
Exfoliation		

Table 2 Appearance Features for each corrosion types

Erosion	Galvanic	Crevice	Pitting	Exfoliation
				
Exhibits grooves, gullies, waves rounded holes and usually a directional pattern based on the fluid flow	Display a spot area of uniform corrosion	Display a spreading pattern which focus in the middle. (contour)	Preview pattern of small dots corrosion inside the surface of nickel tube.	Display uneven layered surfaces just like the effect of exfoliation corrosion on the aluminum sheet

4.2 Discussion

From the result, each corrosion type display different appearance profile respectively. This profile can be used to classify the corrosion. However, for galvanic corrosion and crevice corrosion the profile have slight similarity compare to others. These similarity may confuse intelligent system in classify the corrosion. In order to differentiate between galvanic and crevice corrosion profile, the histogram pattern is analyze in Figure 6.

From the graph in Figure 6, the histogram of red channel graph on crevice corrosion displays a peak pattern at 21 intensity compare to galvanic corrosion which present range pattern between 11 through 100 intensity. Crevice red channel histogram pattern shows the existing of contour on its appearance features, where the contour represents the spreading pattern. As for galvanic corrosion, the range pattern explained on the characteristic of galvanic, which are spot area of uniform corrosion.

5.0 CONCLUSION

This paper discussed the potential of vision system to be used for primary equipment on NDT corrosion inspection. The visual inspection system is to be conducted during monitoring stage in the preliminary inspection. Visual inspection system would be able to gather data and at the same time process and analyze the collected data.

Through the result, the analyzed data is able to classify the corrosion type and by identifying the type of corrosion, we can understand the pattern of attack, thus early prevention can be done. Using image as inspection data, issue on analogue signal loss due to the communication interference can be eliminated, as the image data is able to recover the required feature based on other features.

Furthermore, by enhancing the image capture, the limitation of inspection environment can be lifted and the accuracy of the inspection can be increase. Additionally adding the ability of the system, able to adapt the unrefined environment make the proposed system robust and able to use in others application.

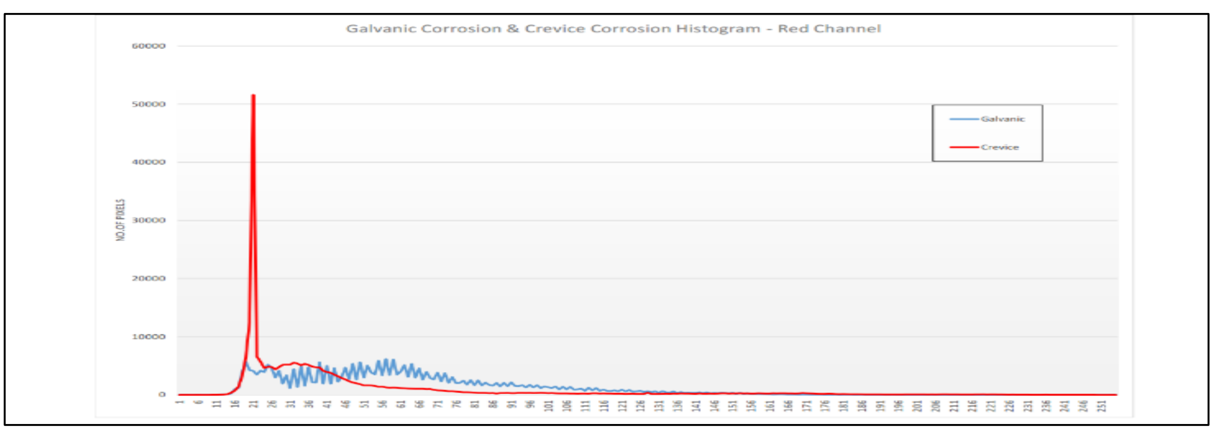


Figure 6 Histogram - Red channel pattern for Galvanic and Crevice Corrosion

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