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A STUDY OF WELD DEFECTS OF GAS METAL ARC WELDING WITH DIFFERENT SHIELDING GASSES

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ABSTRACT

Welding is the preferred joining method of two or more parts into one piece and it has been developed depending on the combination of temperature and pressure. In Gas Metal Arc Welding (GMAW) process, shielding gas selection has a great influence on the quality and the strength of a welded joint. Shielding gas is very important and therefore any changes in gas mixture or flow parameter affects the arc transfer characteristics and resultant weld quality. Shielding gas systems is rather problematic as mixed cylinders are expensive and gas mixers are often inaccurate, therefore more efficient and alternative shielding gas technology is of interest. The aim of this study isto determine the weld defects by using different gasses which are Carbon Dioxide and Argon. The Visual Inspection, Dye Penetrant Inspection (DPI) and Ultrasonic Testing were used and the data from the inspection were analyzed and measured according to the ISO 5817 and ASTM E164/E165 standard. The findings defined the weld defects of the specimen of the Carbon Dioxide was less than the specimen of the Argon. The findings also identified the Carbon Dioxide shielding gas has a great potential to produce stronger weldment compared to Argon due to the oxidizing potential of CO_2 and CO_2 has a higher thermal conductivity level than Argon.

Keywords: welding, welding defect, A36 low carbon steel, shielding gas.

INTRODUCTION

Welding is a fabrication or sculptural process that joins materials, usually metals by causing coalescence. Md. Ibrahim Khan (2007) stated that the joining of the two or more parts becoming one piece is called welding process. [8] There are types of welding process such as Gas Metal Arc Welding (GMAW), Gas Tungsten Arc Welding (GTAW), Manual Metal Arc Welding (MMAW) and etc. In this study, Gas Metal Arc Welding is used and two different gasses which are Carbon Dioxide (CO_2) and Argon (Ar) are used in the welding process. In Gas Metal Arc Welding (GMAW) process, shielding gas selection has a great influence on the quality and the strength of a welded joint. [9] The primary function of all shielding gases is to protect the molten weld puddle and electrode from the oxygen, nitrogen and moisture in air. Shielding gases flow through the welding gun and exit the nozzle surrounding the electrode, displacing the air and forming a temporary protective pocket of gas over the weld puddle and around the arc. [7] Shielding gas is very important and therefore any changes in gas mix or flow parameter affects the arc transfer characteristics and resultant weld quality. Carbon dioxide and argon respond in different ways under the heat of the arc. Argon is an inert gas and does not react with other compounds or elements and it is about 1.4 times heavier than air and not sustainable. In GMAW process, argon does not provide the chemical to the molten pool and it only shields the molten from the contaminant.

However, Carbon Dioxide (CO_2) is a reactive gas, which is about 1.5 times heavier than air and its relatively high oxidizing potential can be countered by the use of GMAW wires which is higher in alloying elements such as silicon and manganese. The aim of this study is to determine the weld defects by using different gasses which is Carbon Dioxide and Argon. Both gasses are used to produce the sample of specimen for welding inspection and analysis.

METHODOLOGY

The material is prepared according to the code and standard. The A36 Low Carbon Steel is used for material of the specimen plates which is stated in the American for Testing and Material (ASTM) as A36 or A36M. [2] The sample size of specimen plate is 100mm x 300 mm x 10mm per piece. The material properties of the low carbon steel are 400-550 MPa (Mega Pascal) for ultimate Tensile Strength and Shear Modulus is 79.3MPa. [12] The Single v-butt joint is used for welding joint configuration has been chosen for 10mm thickness plates (included angle is 60º and without root gap). [1] Preparation of the welding joint requires a special beveling machine or cutting torch, which makes it more costly than a square butt joint. Even though it requires more filler material than square joint. The joint is stronger than square butt joint. Figure 1 shows the schematic line diagrams of the joint design for different plate thickness according to AWS D1.1 standard. [11]

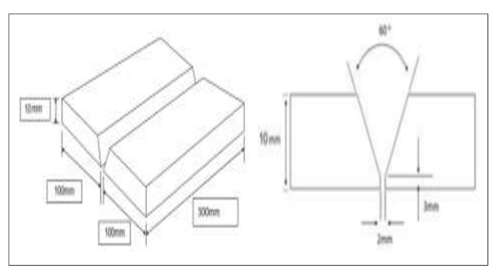

Figure-1. Base metal marking.

VOL. 12, NO. 6, MARCH 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

Selection of the proper filler metal requires an understanding of the material properties and welds appearance considerations. The welding wires must contain less carbon than the base material and more of the alloying elements, manganese and silicon, in order to achieve the required strength. [1] In this process, the selection of filler wire is used according to AWS specifications; such an AWS 5.18 ER70S-6 with diameter 1.0mm is recommended. [2] The ER70S-6 usually used in an indoor area with no wind. Carbon dioxide and Argon are used as shielding gas.

The distance of the nozzle between the workpiece i.e. 15-16mm is maintained and the welding position of the weldingis 1G groove. Five of the specimen plates (low carbon steel) are prepared for both Carbon Dioxide and Argon in welding process. The parameters of welding for five specimen plates are remained for specimen plate 1 to 5. Table-1 and Table-2 shows the welding parameter for Carbon Dioxide and Argon.

Table-1. The shielding gas flow rate (Liters/min) of carbon dioxide (CO_2).

Specimen No.	Plate Thickness (mm)	Voltage (Volts)	Current (Ampere)	Shielding Gas Flow Rate (Liters/min)	Electrode Extension	Work Angle (°)	Travel Angel (°)	Marking
1	10	18.6/19.2	80/90	15	Normal	90	5 to 15	/
2	10	18.6/19.2	80/90	15	Normal	90	5 to 15	/
3	10	18.6/19.2	80/90	15	Normal	90	5 to 15	/
4	10	18.6/19.2	80/90	15	Normal	90	5 to 15	/
5	10	18.6/19.2	80/90	15	Normal	90	5 to 15	/

Table-2. The shielding gas flow rate (Liters/min) of Argon (Ar).

Specimen No.	Plate Thickness (mm)	Voltage (Volts)	Current (Ampere)	Shielding Gas Flow Rate (Liters/min)	Electrode Extension (Stickout)	Work Angle (°)	Travel Angel (°)	Marking
1	10	18.9/19.3	90/110	15	Normal	90	5 to 15	/
2	10	18.9/19.3	90/110	15	Normal	90	5 to 15	/
3	10	18.9/19.3	90/110	15	Normal	90	5 to 15	/
4	10	18.9/19.3	90/110	15	Normal	90	5 to 15	/
5	10	18.9/19.3	90/110	15	Normal	90	5 to 15	/

The welding inspection and testing were used in this study. The Visual Inspection, Dye Penetrant Inspection (DPI) and Ultrasonic Testing (UT) were used to define the weld defects in specimen plates of the Carbon Dioxide and Argon. Visual Inspection is an inspection that requires an inspector to look closely and check for defect at a welded part. The single V-Butt joint sample had been welded through GMAW process which is consists of the three layers weld bead sequence and the inspection only focused on three types of defect such as porosity, undercut and crack.[3] The result in Visual Examination is projected the weld imperfection and then analyzed according to the ISO 5817 Standard. Dye Penetrant Inspection (DPI) is a low-cost inspection method used to locate surface-breaking defects in all non-porous materials (metals, plastics, or ceramics). DPI is used to detect casting, forging and welding surface defects such as cracks, surface porosity, and leak in new products.

The red dye penetrant, remover and developer were used as tools during DPI process. Ultrasonic Testing (UT) is used to measure the time for high frequency pulses of ultrasonic sound travel through the inspection material. It is sensitive to crack and porosity at various orientation and able to penetrate thick section. [9] Its also can measure depth through wall extent. If a discontinuity is present, the ultrasonic reflect the probe in a time other that appropriate to good material.

ANALYSIS AND RESULT

The Visual Inspection, Dye Penetrant Inspection (DPI) and Ultrasonic Testing were used and the data from the inspection were analyzed and measured according to the ISO 5817 Standard and ASTM E164/165 Standard. The direct visual examination method is used and performed on the surface condition of the weldment. The single V-Butt joint sample had been welded through GMAW process that consists of the three layers weld bead sequence.

The result shows that only one type of the weld defects detected in Carbon Dioxide sample. The incomplete fusion occurs on the weld face of CO_2 Sample 2. Figure-2 shows the weld defect on CO_2 Sample 2 and Table-3 shows the result of Visual Inspection for CO_2(five specimens).


(a) (b)

Figure-2. The incomplete fusion occurs on the weld face (a) and weld root (b) for CO_2 sample.

However, there are two types of weld defects found in Argon samples such as excessive weld metal and intermittent undercut. The length and height of the excessive weld metal is 5 mm and 2 mm and the length and depth of intermittent undercut are 150 mm and 2 mm which is out of the range of defect measurement.

VOL. 12, NO. 6, MARCH 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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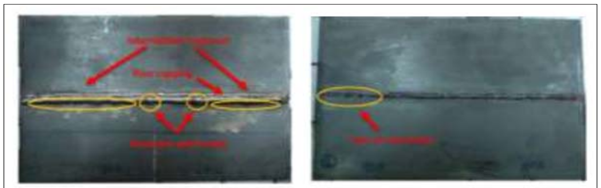
Table-3. The result of the visual inspection for carbon dioxide.

EXTERNAL VISUAL INSPECTION (According to ISO 5817 Standard)						
Specimen (5 Samples) for Carbon Dioxide (Co^2)						
Specimen No.		Thickness (mm)	Type of Defect	Measurement of Defect (mm)	Max. Allowance (mm)	Result Accept / Reject
1	Weld Face	10	Excessive Weld Metal	L=5, H=4	H=5	Accepted
	Weld Root		-	-	-	Accepted
2	Weld Face	10	Incomplete Fusion	L=25	Not Permitted	Rejected
	Weld Root		Excess Penetration	L=23, H=3		Accepted
3	Weld Face	10	-	-	-	Accepted
	Weld Root		Excess Penetration	L=10, H=4		Accepted
4	Weld Face	10	-	-	-	Accepted
	Weld Root		Lack of root fusion	L=15	L=25	Accepted
5	Weld Face	10	-	-	-	Accepted
	Weld Root		-	-	-	Accepted

The excessive weld metal, poor capping and intermittent undercut occur on the weld face of Argon sample. Intermittent undercut is a groove cut at the toe of the weld and left unfilled. It's caused by high amperage, electrode angle, long arc length and rust. [6] Figure-3 shows the weld defects on Argon samples and Table-4 shows the result of Visual Inspection for Argon for five specimens.



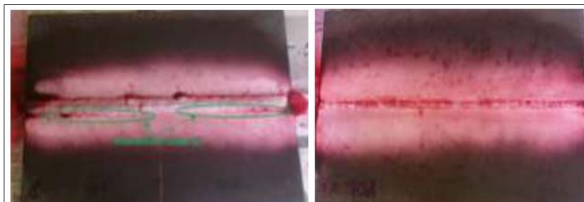
(a) (b)

Figure-3. The excessive weld metal and Intermittent undercut occurs on the weld face (a) and Weld root (b) for Argon (Ar) sample.

Table-4. The result of the visual inspection for argon.

EXTERNAL VISUAL INSPECTION (According to ISO 5817 Standard)						
Specimen (5 Samples) for Argon (Ar)						
Specimen No.		Thickness (mm)	Type of Defect	Measurement of Defect (mm)	Max. Allowance (mm)	Result Accept / Reject
1	Weld Face	10	Excessive Weld Metal	L=2, H=2	H=5	Accepted
			Intermittent Undercut	L=130, D=2	L=20, D=1.5	Rejected
	Weld Root		Lack of Root Fusion	L=15	L=25	Accepted
2	Weld Face	10	Excessive Weld Metal	L=4, H=2	H=10	Rejected
			Intermittent Undercut	L=150, D=1	L=20, D=1.5	Rejected
	Weld Root		Lack of Root Fusion	L=15	L=25	Accepted
3	Weld Face	10	Excessive Weld Metal	L=8, H=3	H=10	Accepted
			Intermittent Undercut	L=100, D=2	L=20, D=1.5	Rejected
			Porosity	D=1	D=5	Accepted
	Weld Root		Excess Penetration	L=20	L=25	Accepted
4	Weld Face	10	Excessive Weld Metal	L=4, H=2	H=10	Accepted
			Intermittent Undercut	L=140, D=2	L=20, D=1.5	Rejected
	Weld Root		-	-	-	Accepted
5	Weld Face	10	Excessive Weld Metal	L=4, H=3	H=10	Accepted
			Intermittent Undercut	L=140, D=2	L=20, D=1.5	Rejected
	Weld Root		-	-	-	Accepted

The second testing is Dye Penetrant Inspection (DPI). DPI method is used to locate surface-breaking defects in all non-porous materials (metals, plastics, or ceramics). DPI is used to detect casting, forging and welding surface defects such as cracks, and surface porosity. The procedure of analysis and testing are according to American Society for Testing and Material (ASTM) E164 and American Society Mechanical Engineer (ASME) V Article 5. [5] The type of weld defect detected on Carbon Dioxide samples is only Porosity. The porosity detected on the Weld Face of CO_2 Sample 1, Sample 2 and Weld Root of CO_2 Sample 3. Porosity is gas pores found in the solidified weld bead. In this case, the possible causes of porosity are atmosphere contamination and excessively oxidized workpiece surface. Atmosphere contamination can be caused by inadequate shielding gas flow and excessive shielding gas, this can caused aspiration of air into the gas stream. [5] Figure-4 shows the weld defect on CO_2 Sample 1, 2 and Table-5 shows the result of Dye Penetrant Inspection (DPI) for CO_2 in Sample 1 to Sample 5.



(a) (b)

Figure-4. The porosity occurs on the weld face (a) and weld root (b) for CO_2 sample.

Table-5. The result of the dye penetrant inspection for carbon dioxide.

DYE PENETRANT INSPECTION (According to ASTM E164 Standard)			
Specimen (5 Samples) for Carbon Dioxide (Co^2)			
Specimen No.		Thickness (mm)	Type of Defect
1	Weld Face	10	Porosity
	Weld Root		-
2	Weld Face	10	Porosity
	Weld Root		Porosity
3	Weld Face	10	-
	Weld Root		-
4	Weld Face	10	-
	Weld Root		-
5	Weld Face	10	-
	Weld Root		-

Meanwhile, there are two types of weld defects detected on Argon samples which are undercutting and porosity. The undercutting detected on the weld surface of Argon (Sample 1 to Sample 5). Undercutting is a defect that appears as a groove in the parent metal directly along the edges of the weld. For Argon samples, Undercutting is caused by improper welding parameter particularly the travel speed and arc voltage. When travel is too high, the

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ARPN Journal of Engineering and Applied Sciences

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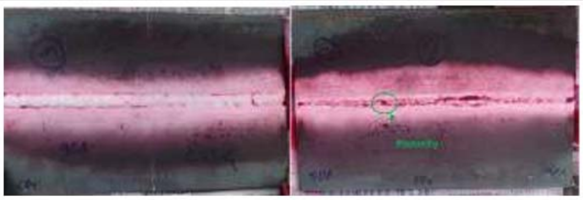
weld bead will be very peaked because of its extremely fast solidification. [4] The forces of surface tension have drawn the molten metal along the edges of the weld bead and piled it up along the center. [5] The second defect is porosity which is detected on the Weld Face of Argon Sample 1 and Sample 3. This occurs when gases are trapped in the solidifying weld metal. Figure-5 shows the weld defect on Argon Samples and Table 6 shows the result of Dye Penetrant Inspection (DPI) for Argon in Sample 1 to Sample 5.



(a) (b)

Figure-5. The undercutting and porosity occurs on the weld face (a) and Weld root (b) for CO_2 sample.

Table-6. The result of the dye penetrant inspection for argon.

DYE PENETRANT INSPECTION (According to ASTM E164 Standard)			
Specimen (5 Samples) for Argon (Ar)			
Specimen No.		Thickness (mm)	Type of Defect
1	Weld Face	10	Undercut
	Weld Root		-
2	Weld Face	10	Undercut
	Weld Root		-
3	Weld Face	10	Porosity and Undercut
	Weld Root		-
4	Weld Face	10	Porosity and Undercut
	Weld Root		-
5	Weld Face	10	Undercut
	Weld Root		-

The third testing is Ultrasonic Testing (UT). Ultrasonic testing uses high frequency sound energy to conduct examinations and make measurement. In this study, Ultrasonic Testing (UT) is used to measure the time for high frequency pulses of ultrasonic sound travel through the inspection material. It is sensitive to crack and porosity at various orientation and able to penetrate thick section. The result shows the different path of CO_2 Sample 1 and Argon Sample 1. The path means the distance at the plate from weld bead to the probe of the testing. If the distance of the path does not tally with or similar to the actual distance, it means that the sample has a defect. [11] The tolerance of the path is ±1mm. For Ultrasonic testing, only two samples from Carbon Dioxide (CO_2) and Argon (Ar) were being inspected. The procedure of analysis and testing was according to the American Society for Testing and Material (ASTM) E165 and American Society Mechanical Engineer (ASME) V Article 4. The result of CO_2 samples shown, the porosity was detected in the distance of X (34.64mm), Y (150-180mm); the path reading is 77.08mm and X (34.64mm), Y (240-270mm); the path reading is 77.64 and it is rejected because the path reading is higher than the constant path measurement (69mm ±1mm). This might be extremely fast weld solidification rates and erratic arc characteristics. When solidification rates are extremely rapid, any gas that would normally escape is trapped. Figure-6 shows the Ultrasonic testing for CO_2 samples and Table-7 shows the overall result of Ultrasonic Testing (UT) for CO_2 sample.

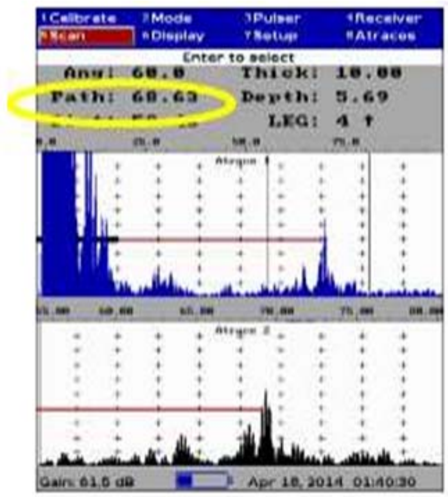


Figure-6. Ultrasonic testing result of CO_2.

Table-7. The result of ultrasonic testing for carbon dioxide (CO_2) samples.

ULTRASONIC TESTING (According to ASTM E165 Standard)						
Specimen Sample for Carbon Dioxide (Co^2)						
X (mm)	Y (mm)	Type of Defect	Length (mm)	Constant Path (69.00 mm ± 1 mm)	Path (mm)	Result Accept / Reject
34.64	0 - 30	-	-	69.00 mm ± 1 mm	68.63	Accepted
34.64	30 - 60	-	-	69.00 mm ± 1 mm	68.39	Accepted
34.64	60 - 90	-	-	69.00 mm ± 1 mm	69.12	Accepted
34.64	90 - 120	-	-	69.00 mm ± 1 mm	69.44	Accepted
34.64	120 - 150	-	-	69.00 mm ± 1 mm	69.77	Accepted
34.64	150 - 180	Porosity	3	69.00 mm ± 1 mm	77.08	Rejected
34.64	180 - 210	-	-	69.00 mm ± 1 mm	70.13	Accepted
34.64	210 - 240	-	-	69.00 mm ± 1 mm	69.26	Accepted
34.64	240 - 270	Porosity	3	69.00 mm ± 1 mm	77.64	Rejected
34.64	270 - 300	-	-	69.00 mm ± 1 mm	69.42	Accepted

For Argon samples, there are two types of weld defects detected which is crack and porosity. The cracks was detected in the distance of X (34.64mm), Y (30-60mm); the path reading is 53.14mm.The second measurement in the distance of X (34.64mm), Y (120-150mm); the path reading is 53.32 and the third measurement in the distance of X (34.64mm), Y (210-240mm); the path reading is 32.33mm and the fourth measurement, the distance of X (34.64mm), Y (240-270mm); the path reading is 33.78mm. The cracks occur

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when the weld bead in the final stage of solidification has sufficient strength to withstand the contraction stresses generated as the weld pool solidifies. Meanwhile, the result of Argon samples shown, the porosity was detected in the distance of X (34.64mm), Y (0-30mm); the path reading is 61.00mm, X (34.64mm), Y (90-120mm); the path reading is 62.83mm and X (34.64mm), Y (270-300mm); the path reading is 62.74mm. These measurements are rejected because the reading is lower than the constant path measurement (69.00 mm ± 1 mm). Figure-7 shows the Ultrasonic testing for Argon samples and Table 8 shows the overall result of Ultrasonic Testing (UT) for Argon sample.

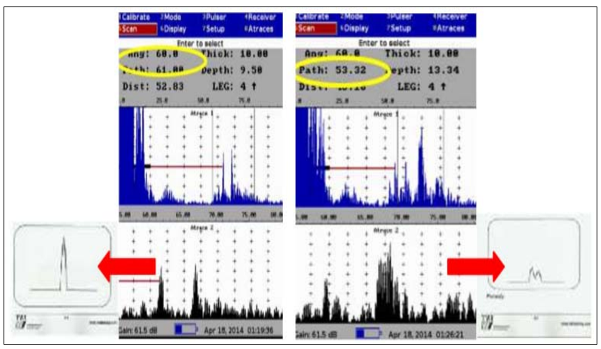

Figure-7. Ultrasonic testing result of Argon (Ar).

Table-8. The result of ultrasonic testing for Argon (Ar) samples.

ULTRASONIC TESTING (According to ASTM E165 Standard)						
Specimen Sample for Argon (Ar)						
X (mm)	Y (mm)	Type of Defect	Length (mm)	Constant Path (69.00 mm ± 1 mm)	Path (mm)	Result Accept / Reject
34.64	0 - 30	Porosity	4	69.00 mm ± 1 mm	61	Rejected
34.64	30 - 60	Crack	5	69.00 mm ± 1 mm	53.14	Rejected
34.64	60 - 90	-	-	69.00 mm ± 1 mm	69.11	Accepted
34.64	90 - 120	Porosity	3	69.00 mm ± 1 mm	62.83	Rejected
34.64	120 - 150	Crack	2	69.00 mm ± 1 mm	53.32	Rejected
34.64	150 - 180	-	-	69.00 mm ± 1 mm	69.05	Accepted
34.64	180 - 210	-	-	69.00 mm ± 1 mm	70.05	Accepted
34.64	210 - 240	Crack	3	69.00 mm ± 1 mm	32.33	Rejected
34.64	240 - 270	Crack	3	69.00 mm ± 1 mm	33.78	Rejected
34.64	270 - 300	Porosity	3	69.00 mm ± 1 mm	62.74	Rejected

Based on the welding inspections and testing, the Carbon Dioxide (CO) shielding gas shown the low of the weld defect compared to the Argon shielding gas. There are only two type of the weld defects found in CO_2 samples such as incomplete fusion and porosity. For Argon samples, there are five types of the weld defect detected such as intermittent undercut, excessive weld metal, porosity, undercutting and crack. These defects occur because of several factors. For example, excessive weld metal, its caused of the travel speed too slow and amperage current too low during welding. The amperage current must be increased, the appropriate wire sticks out maintained and the root angle on torch must be correct to avoid the weld defect. [10]

CONCLUSIONS

In this study, the weld defects of gas metal arc welding using different shielding gasses are explained in order to determine types of weld defects occur in the visual inspection, dye penetrant inspection and ultrasonic testing. The findings defined the weld defects of the specimen of the Carbon Dioxide was less than the specimen of the Argon. There are only two type of the weld defects found in CO_2 samples such as incomplete fusion and porosity. The findings also identified the Carbon Dioxide (CO_2) shielding gas has a great potential to produce stronger weldment compared to Argon (Ar)due to the oxidizing potential of CO_2 and CO_2 has a higher thermal conductivity level than Ar, this affects the mode of transfer, shape of the arc, weld penetration and temperature distribution within the arc. Shipyards also generally prefer to use CO_2 because its arc characteristics have proven a greater ability to burn off primer on the base material.

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