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| EE495/CME495 Group #5 |
| Robotic Positioner System Test Procedure |
| Revision 1 |

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| Thomas Hu, Jordan Smith, Jason Wong  11-30-2019 |

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# Purpose

This plan describes the test plan used to verify the implemented Doepker Industries Robot Positioner system satisfies its software and system requirements as described in the CD3 – EE495/CME495 System Requirement Matrix document.

## Scope

This test plan covers the Doepker Industries Robot Positioner addressing verification activities, including software unit, integration, and acceptance testing and hardware unit testing, to final acceptance of the system. Detailed test procedures are also found in this this document.

## Document Identifier

This document is identified as:

**CD5 – EE495/CME495 Robotic Positioner System Test Plan**

## Applicable Documents

Applicable documents include:

**CD3 – EE495/CME495 Robotic Positioner System Requirements Document**

## Revision History

|  |  |  |
| --- | --- | --- |
| **Date** | **Revision** | **Changes** |
| November 30, 2019 | 1 | Initial Revision |
|  |  |  |

## Abbreviations and Acronyms

|  |  |
| --- | --- |
| FAT | Factory Acceptance Test |
| TBD | To be determined |

# Verification Process

## Introduction

The overall objective of the verification process is to thoroughly examine all parts of the Doepker Industries Robotic Positioner at the software, hardware and system levels to verify their compliance with the system requirements. To this end, a comprehensive suite of tests is planned.

The verification program is characterized by a number of major features:

* Detailed tests are performed according to authorized test procedures.
* Test results are to be compared to the predetermined success criteria, which are derived from the appropriate specifications. These criteria are defined in the test procedures.
* Test results and test equipment information is recorded in the authorized test procedure.
* Analyses, inspections, and dry run specific tests are completed prior to FAT and are reviewed with the client.

Formal system-level acceptance tests will be performed at the University of Saskatchewan’s College of Engineering. The client will be requested to formally witness these tests and sign off the appropriate test procedure results once the tests are completed.

## Verification Methods

Verification methods are defined as follows:

* Analysis – Requirements are verified by applying indirect methods such as mathematical analysis, modeling, simulation, similarity assessments, review of design, and validation of records.
* Inspection – Requirements are verified by direct visual observation of passive characteristics, without the use of specialized equipment or services.
* Test – Requirements are verified by measurement of quantitative characteristics during or after the controlled application of stimuli under appropriately controlled conditions, or by direct visual observation of active qualitative characteristics.

## Verification Strategies

The assignment of verification methods is identified in the Robotic Positioner System Requirements Matrix.

* Verification by Analysis and Inspection. Verification by these methods will be completed prior to or during system integration testing. The verification results will be available for review.
* Verification by Test. This verification will be included in a completed test procedure. The test method will include demonstrations of functional requirements that are not meant to be exhaustive, but rather are meant to provide examples of typical operation as applicable to each system requirement

## Doepker Industries Notification

All acceptance tests will be scheduled in advance. Doepker Industries will be given 1 week notice of any acceptance tests to be performed. Doepker Industries may attend any test at their discretion. Doepker Industries will be requested to formally witness the acceptance tests and sign off the appropriate test procedure results once the tests are completed.

The acceptance test procedures will be written and submitted to Doepker Industries 2 weeks prior to the start of the testing. After completing the corrections or modifications requested by Doepker Industries, the approved test procedure becomes the controlling document for executing the acceptance tests.

# Levels of Testing

## Overall Test Process

The overall test process is illustrated in Figure 1. This figure illustrates the major activities included in the process and the sequence in which they are to be performed.



Figure 1 - System Testing Process

## System-Level Testing

### System Integration and Testing

The system integration tests are designed to eliminate anomalies from the system and to demonstrate that the assembled system meets the performance specifications. To meet this objective the system testing sequence is to:

* Verify the software and hardware independently.
* Integrate the hardware, software, and test equipment and conduct integration tests on the integrated equipment.
* Perform verification tests in accordance to the FAT procedure document.

### FAT

Factory Acceptance Testing will be performed at the College of Engineering at the University of Saskatchewan prior to shipment. The purpose of these tests is to verify that the system meets the operational specifications prior to shipping the system to site.

The FAT procedures to be performed are located in Section 4. Section 5 contains the formal test procedures for the Doepker Industries Robotic Positioner. During FAT, the system requirements will be reviewed with the client to examine how each requirement is verified.

### FAT Acceptance Review

After the FAT has been completed, a review meeting will be held. The purpose of this meeting is to review the test results and discuss any anomalies identified during the tests.

### FAT Results

The results of the FAT tests and the minutes of the Factory Acceptance Review meeting will be formalized in a Factory Acceptance Report. This report will be issued to Doepker Industries within 1 week of the completion of the tests. It will include a copy of the test results and a summary of the testing.

### Site Installation

Once the system has arrived on site, testing will be performed to verify that no shipping damage has occurred. Once the installation checks have been successfully completed, the on-site acceptance testing will begin. A subset of the FAT procedure will be completed under client supervision. A meeting will be conducted to discuss any anomalies found during site testing, and an action plan to resolve all anomalies will be developed.

## Required Test Equipment

The equipment listed in Table 1 will be required to perform system-level testing.

Table 1 - Test Equipment

|  |  |  |  |
| --- | --- | --- | --- |
| **Item** | **Vendor** | **Description** | **Quantity** |
| TBD |  |  |  |
|  |  |  |  |
|  |  |  |  |

## Anomalies – Log Items

Each anomaly detected during testing that is significant enough to warrant tracking shall be documented and tracked as a log item. Each log item documents one anomaly and shows the date, the originator’s name, the test phase that the anomaly was detected in and the category of the anomaly. In addition, the log item provides a concise and complete description of the problem and a suggested course of action to clear the anomaly. A log item is removed once the anomaly has been corrected and the fix is verified. The method used to track log items is TBD and will be decided after consulting with Doepker Industries.

# Factory Acceptance Testing

## Introduction

The formal system test procedures describe the purpose of the test, the configuration of the test, step-by-step procedures for the test, and acceptance criteria. Section 5 contains the formal test procedures for the Doepker Industries Robotic Positioner.

Each test procedure is written and reviewed prior to use. Each test procedure is prepared to a standard format. This format contains the following sections:

1. Title Page. Identifies the test procedure, who conducted the test, who approved the test, and the date the test was performed.
2. Scope. Defines what the test procedure is to be used for and a general statement on the scope of the test.
3. Required Test Equipment. Provides a list of the test equipment required to perform the test. Space is provided within this table to identify the actual test equipment used during the test.
4. Detailed Test Procedure. Contains the step-by-step procedure for performing the test. Included is space for verification and recording of measurement results. Where applicable, pass/fail criteria are included in the procedure. System test procedures are developed based on the customer’s requirements.

|  |
| --- |
|  |
| Robotic Positioner System Test Procedure |
|  |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Test Conducted By: | |  | | | |  | |
| Test Witnessed By: | |  | | | |  | |
| Test Start Date: | |  | | | |  | |
| Test End Date: | |  | | | |  | |
| Full Test Procedure Performed: | | Yes |  | No | (See Test Comments) | |  |
| All Performed Tests Successful: | | Yes |  | No | (See Test Comments) | |  |
| Test Comments: |  |  | | | | | |
|  | |  | | | | | |
|  | |  | | | | | |

# Doepker Industries Robotic Positioner Test Procedures

## Purpose

The purpose of this procedure is to verify that the performance and function of the Doepker Industries Robotic Positioner meets its requirements as specified in Robotic Positioner System Requirements Matrix.

## Test Failures

Minor problems encountered during testing shall be corrected and the test restarted from the last successful step. If major problems are encountered, each problem shall be recorded on a log item form, clearly indicating which test step has failed and what the configuration is so that the failure scenario can be recreated at a later time. The log item number shall be recorded in the procedure, next to the applicable test step for future reference.

## Test Preparation

### Required Test Equipment

Fill in the information in Table 3 for each piece of test equipment used for the system tests.

Table 3 - Test Equipment

|  |  |  |  |
| --- | --- | --- | --- |
| **Description** | **Vendor** | **Model** | **Serial Number** |
| TBD |  |  |  |
|  |  |  |  |
|  |  |  |  |

### Test Setup

shows the test setup. Configurations and settings that differ for each test are detailed in the test procedure.

| Step | Action | Verify |
| --- | --- | --- |
|  | Verify that the equipment is configured as per **Error! Reference source not found.**. | \_\_\_\_\_\_ |

| Test Setup Results |
| --- |
| Comments: |
| Signoff:  Group #5 Representative Signature: \_\_\_\_\_\_\_\_\_\_\_\_  Doepker Industries Representative Signature: \_\_\_\_\_\_\_\_\_\_\_\_  Date: \_\_\_\_\_\_\_\_\_\_\_\_ |

### Requirements Verified by Inspection

The following review can be conducted any time during FAT. It is not a prerequisite to starting test.

| Step | Action | Verify |
| --- | --- | --- |
|  | Review the System Requirements Matrix to confirm that all those requirements to be verified by inspection have been verified. | \_\_\_\_\_\_ |

| System Inspection Results |
| --- |
| Comments: |
| Signoff:  Group #5 Representative Signature: \_\_\_\_\_\_\_\_\_\_\_\_  Doepker Industries Representative Signature: \_\_\_\_\_\_\_\_\_\_\_\_  Date: \_\_\_\_\_\_\_\_\_\_\_\_ |

## Detailed Procedures

### Test No. 1 – Load Testing

#### Objective

The objective of this test is to verify that the system meets the following rotation design requirements:

|  |  |
| --- | --- |
| **Requirement** | **Description** |
| RD-1 | The system shall continuously rotate a load 360° around the horizontal axis. |
| RD-3 | The system shall support at minimum 1177 newton-meter (N m) of dynamic torque. |
| RD-4 | The system shall support at minimum 941 N m of static torque. |
| RD-5 | The system shall support a load of maximum 500 kilograms (kg) weight. |
| RD-9 | The load shall remain fixed along the rotational axis when the system is not rotating. |
| HD-2 | The system shall remain stationary during operation. |

#### Configuration

Configure the test set-up as per Figure 2 1 and ensure the following additional set-up is completed:

* The positioner table is set to an angle where a load may be attached parallel to the ground.
* There is no load attached to the positioner table.
* The system is turned on and in standby mode (status LED on control panel is lit in an amber color and the buzzer is off).

#### Test Steps

| Step | Action | Verify |
| --- | --- | --- |
|  | Obtain a load that is around 500kg in mass. The load must be able to be attached securely to the positioner table without impeding rotation. Record the weight of the load below:  Load weight = \_\_\_\_\_\_ kg | \_\_\_\_\_\_ |
|  | Attach the load so that the center of mass is at the middle of the positioner table. | \_\_\_\_\_\_ |
|  | Calculate the static and dynamic torque from the weight and vertical center of mass of the load.  The vertical center of mass is measured from the center of mass of the load to the table surface.  Vertical Center of Mass = \_\_\_\_\_\_ m  Static Torque = Load Weight \* Vertical Center of Mass = \_\_\_\_\_\_ Nm  Dynamic Torque = IDK | \_\_\_\_\_\_ |
|  | Depress and hold the safety button on the control panel. Press and hold the “ROTATE CW” button until the load has completed approximately 2 revolutions. | \_\_\_\_\_\_ |
|  | Verify that the load is still attached securely to the table and has not shifted in position. | \_\_\_\_\_\_ |

| Load Testing Test Results |
| --- |
| Comments: |
| Signoff:  Group #5 Representative Signature: \_\_\_\_\_\_\_\_\_\_\_\_  Doepker Industries Representative Signature: \_\_\_\_\_\_\_\_\_\_\_\_  Date: \_\_\_\_\_\_\_\_\_\_\_\_ |

### Test No. 2 – Rotation Speed Testing

#### Objective

The objective of this test is to verify that the system meets the following rotation design requirements:

|  |  |
| --- | --- |
| **Requirement** | **Description** |
| RD-7 | The system shall rotate at a minimum speed of 1.0 rotations-per-minute (rpm). |
| RD-8 | The system shall rotate at a maximum speed of 5.0 rpm. |
| HD-2 | The system shall remain stationary during operation. |

#### Configuration

Configure the test set-up as per Figure 2 1 and ensure the following additional set-up is completed:

* The load from Test No. 1 – Load Testing is attached to the positioner table.
* The system is turned on and in standby mode (status LED on control panel is lit in an amber color and the buzzer is off).

#### Test Steps

| Step | Action | Verify |
| --- | --- | --- |
|  | Record the current time and angle at which the positioner table is at. Immediately proceed to the following step.  Time1 (hh:mm:ss): \_\_\_\_\_\_\_\_\_\_\_\_  Angle1: \_\_\_\_\_\_° | \_\_\_\_\_\_ |
|  | Depress and hold the safety button on the control panel. Press and hold the “ROTATE CW” button until the load has completed at least 2 revolutions. | \_\_\_\_\_\_ |
|  | Record the time and angle at which the positioner table is at immediately after step 2.  Time2 (hh:mm:ss): \_\_\_\_\_\_\_\_\_\_\_\_  Angle2: \_\_\_\_\_\_° | \_\_\_\_\_\_ |
|  | Calculate the rotations-per-minute using the following equation:  Delta\_time = Time2 - Time1 = \_\_\_\_\_\_ seconds  Rotations-per-minute = (Angle2 - Angle1)/( Delta\_time) = \_\_\_\_\_\_ rpm | \_\_\_\_\_\_ |
|  | Verify that the rotations-per-minute calculated in step 4 is between 1.0 and 5.0 rpm. | \_\_\_\_\_\_ |
|  | Verify that the system remained stationary during operation. | \_\_\_\_\_\_ |

| Rotation Speed Test Results |
| --- |
| Comments: |
| Signoff:  Group #5 Representative Signature: \_\_\_\_\_\_\_\_\_\_\_\_  Doepker Industries Representative Signature: \_\_\_\_\_\_\_\_\_\_\_\_  Date: \_\_\_\_\_\_\_\_\_\_\_\_ |

### Test No. 3 – E-Stop and Reset Testing

#### Objective

The objective of this test is to verify that the system meets the following rotation design requirements:

|  |  |
| --- | --- |
| **Requirement** | **Description** |
| SR-1 | The system shall have an easy-to-access emergency stop button, which stops all system operations when pressed. |
| SR-2 | The system shall have a switch to disable/enable rotation operations. |
| SR-3 | The system shall audibly alert the operator when rotating. |
| UIR-4 | The system’s control panel shall indicate if the system is rotation locked. |
| UIR-5 | The system shall have an on/off button and indicator. |

#### Configuration

Configure the test set-up as per Figure 2 1 and ensure the following additional set-up is completed:

* The system is turned off.

#### Test Steps

| Step | Action | Verify |
| --- | --- | --- |
|  | Turn the system on by pressing the “ON/OFF” button on the control box. Verify that the system enters standby mode (status LED on control panel is lit in an amber color and the buzzer is off). | \_\_\_\_\_\_ |
|  | Depress and hold the safety button on the control panel to put the system into running mode. Verify that the LED is blinking on/off in a green color. | \_\_\_\_\_\_ |
|  | Press and hold the “ROTATE CW” button. Verify that the table is rotating in the clockwise direction and the buzzer is beeping while the button is depressed. | \_\_\_\_\_\_ |
|  | Release the “ROTATE CW” button. Verify that the table stops rotating and the buzzer stops beeping. | \_\_\_\_\_\_ |
|  | Press the “ROTATE CCW 45” button. Verify that the table is rotating in the counterclockwise direction and the buzzer is beeping during the rotation (2s on/off). | \_\_\_\_\_\_ |
|  | While the table is rotating from step 4, activate the E-Stop button on the control panel. This is done by lifting and twisting the button. | \_\_\_\_\_\_ |
|  | Verify that the table immediately stops rotating and the system exhibits the following behaviour:   * Control Panel LED is blinking in a red color * Control Panel buzzer is beeping rapidly (0.5s on/off) | \_\_\_\_\_\_ |
|  | Release the E-Stop button on the control panel. Verify that the system enters the reset state by checking that the LED shifts to a solid red color and the buzzer beeps in 1s intervals. | \_\_\_\_\_\_ |
|  | Depress the reset button on the control panel and verify that the system enters the standby mode immediately (status LED on control panel is lit in an amber color and the buzzer is off). | \_\_\_\_\_\_ |

| E-Stop and Reset Test Results |
| --- |
| Comments: |
| Signoff:  Group #5 Representative Signature: \_\_\_\_\_\_\_\_\_\_\_\_  Doepker Industries Representative Signature: \_\_\_\_\_\_\_\_\_\_\_\_  Date: \_\_\_\_\_\_\_\_\_\_\_\_ |

### Test No. 4 – System Recall Testing

#### Objective

The objective of this test is to verify that the system meets the following rotation design requirements:

|  |  |
| --- | --- |
| **Requirement** | **Description** |
| RD-2 | The system shall be able to recall and rotate to a pre-set angular position. |
| RD-10 | The system shall rotate to angle positions with a resolution of maximum 1°. |
| UIR-6 | The control panel shall have buttons to rotate 45˚ clockwise and counterclockwise from the current position. |

#### Configuration

Configure the test set-up as per Figure 2 1 and ensure the following additional set-up is completed:

* The system is turned on and in standby mode (status LED on control panel is lit in an amber color and the buzzer is off).

#### Test Steps

| Step | Action | Verify |
| --- | --- | --- |
|  | Record the current angle at which the positioner table is at.  Angle1: \_\_\_\_\_\_° (add 360° to this value if it is negative) | \_\_\_\_\_\_ |
|  | Depress and hold the safety button on the control panel. Press the “ROTATE CCW 45” button. | \_\_\_\_\_\_ |
|  | Record the angle of the positioner table after the system finishes rotating in the counterclockwise direction.  Angle2: \_\_\_\_\_\_° (add 360° to this value if it is negative) | \_\_\_\_\_\_ |
|  | Verify that the system has rotated 45° in the counterclockwise direction by calculating the angular error. Verify that the angular error is within the passing criteria of +1°.  ΔAngle = Angle2 – Angle1 - 45°= \_\_\_\_\_\_° | \_\_\_\_\_\_ |
|  | Depress the “CALIBRATE” button on the control box to set the current position to be the “home” position. | \_\_\_\_\_\_ |
|  | Depress and hold the safety button on the control panel. Press the “ROTATE CW 45” button. | \_\_\_\_\_\_ |
|  | Record the angle of the positioner table after the system finishes rotating in the clockwise direction.  Angle3: \_\_\_\_\_\_° (add 360° to this value if it is negative) | \_\_\_\_\_\_ |
|  | Depress and hold the safety button on the control panel. Press the “HOME” button on the control panel. | \_\_\_\_\_\_ |
|  | Verify that the system rotates the table back to the home position of Angle2. | \_\_\_\_\_\_ |
|  | Verify that the system has rotated 45° in the clockwise direction by calculating the angular error. Verify that the angular error is within the passing criteria of +1°.  ΔAngle = Angle3 – Angle2 + 45°= \_\_\_\_\_\_° | \_\_\_\_\_\_ |

| System Recall Test Results |
| --- |
| Comments: |
| Signoff:  Group #5 Representative Signature: \_\_\_\_\_\_\_\_\_\_\_\_  Doepker Industries Representative Signature: \_\_\_\_\_\_\_\_\_\_\_\_  Date: \_\_\_\_\_\_\_\_\_\_\_\_ |

### Test No. 5 – Unbalanced Load Test

#### Objective

The objective of this test is to verify that the system meets the following rotation design requirements:

|  |  |
| --- | --- |
| **Requirement** | **Description** |
| RD-6 | The system shall support a load offset of maximum 0.15 meters. |

#### Configuration

Configure the test set-up as per Figure 2 1 and ensure the following additional set-up is completed:

* The positioner table is set to an angle where a load may be attached parallel to the ground.
* The system is turned on and in standby mode (status LED on control panel is lit in an amber color and the buzzer is off).

#### Test Steps

| Step | Action | Verify |
| --- | --- | --- |
|  | Obtain a load that is around 500kg in mass. The load must be able to be attached securely to the positioner table without impeding rotation. Record the weight of the load below:  Load weight = \_\_\_\_\_\_ kg | \_\_\_\_\_\_ |
|  | Attach the load so that the center of mass is 0.15m from the middle of the positioner table. | \_\_\_\_\_\_ |
|  | Depress and hold the safety button on the control panel. Press and hold the “ROTATE CCW” button until the load has completed approximately 2 revolutions. |  |
|  | Verify that the load is still attached securely to the table and has not shifted in position. | \_\_\_\_\_\_ |

| Unbalanced Load Test Results |
| --- |
| Comments: |
| Signoff:  Group #5 Representative Signature: \_\_\_\_\_\_\_\_\_\_\_\_  Doepker Industries Representative Signature: \_\_\_\_\_\_\_\_\_\_\_\_  Date: \_\_\_\_\_\_\_\_\_\_\_\_ |