TEST PROCEDURE	TP 251
Title	Page Number
Heavy-Duty Engine Dynamometer Speed and Torque Calibration	1 of 20
Originator	Supersedes
Lou Oleszkiewicz	NA
Responsible Organization	<b>Computer Program</b> Speed and Torque Calibration Report
Type of Test Report	Data Form Number
Computer	Form 251-01
Report Distribution	Implementation Date
Calibration and Maintenance File	12-19-94

# **Implementation Approval**

Test Procedure Authorized by EPCN #136

**Note:** Specific brand names in EPA/EOD procedures are for reference only and are not an endorsement of those products.

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## 1. Purpose

The purpose of this procedure is to ensure accurate dynamometer calibration by adjusting the torque measuring equipment to a known value introduced by hanging National Institute of Standards and Technology (NIST) -traceable weights on a lever arm. The resulting calibration is verified over the typical measurement range of the dynamometer.

This procedure also contains a verification of the speed measurement system, made by comparing readings from the speed signal and data acquisition system to a frequency counter used as a reference.

#### 2. Test Article Description

Electric Engine Dynamometer, General Electric Model 42 G 408 AD

## 3. References

- 3.1 "Code of Federal Regulations," Title 40, Part 86, Subpart N, Sections 86.1308, 86.1316, and 86.1318
- 3.2 "Digalog Cellmate Toolbox User Manual"

## 4. Required Equipment

4.1 Electric Engine Dynamometer

Equipment used: General Electric Model 42 G 408 AD

4.2 Weights and hangers, certified traceable to NIST

Equipment used: Weights manufactured to Engineering Operation Division (EOD) specifications

4.3 Balanced shaft-torque lever arm, 60.0 inches in overall length with an effective lever arm of 30.0 inches

Equipment used: Torque lever arm manufactured to EOD specifications

4.4 Case-torque lever arm with an effective lever arm of 36.0 inches

Equipment used: Torque lever arm provided with General Electric Model 42 G 408 AD dynamometer

4.5 Dynamometer Controller

Equipment used: Digalog Model Cellmate II

4.6 Speed and Torque Signal Conditioners

Equipment used: Daytronic Models, 9178A, 9140 ("Daytronic")

4.7 Digital Multi-Counter

Equipment used: Fluke Model 1900 Multi-Counter

4.8 Computer

Equipment used: Macintosh with Excel® application

- 4.9 Protractor level
- 4.10 Hydraulic lift
- 4.11 Form 251-01, "Heavy-Duty Dynamometer Speed and Torque Calibration" (Attachment A)

## 5. Precautions

- 5.1 Personnel handling the weights must wear protective footwear.
- 5.2 Never place feet or hands under hanging weights.
- 5.3 Always turn the power off to all three GE Cabinets, #2, #3 and #5, before opening their access doors.

## 6. Visual Inspections

All visual inspections are included as part of the test article preparation and procedure.

## 7. Test Article Preparation

- 7.1 Assemble the required weights, lever arm, digital multi-counter, hydraulic lift and Form 251-01. Inspect the calibration sticker on the digital multi-counter to ensure that it is in calibration.
- 7.2 Arrange for the test cell air handling unit to be turned off. Air currents will cause the weights to swing, making the readings unstable.
- 7.3 Disassemble the driveshaft from the dynamometer shaft.
- 7.4 Assemble the shaft-torque lever arm to the dynamometer shaft.

Align the bolt holes in the lever arm with those on the dyno shaft; insert three bolts and tighten them securely. Do not overtighten the bolts, as this may damage the aluminum arm.

- 7.5 Assemble the dyno lock to the rear of the dynamometer shaft. Use two bolts to secure the lock to the shaft. The legs of the lock have adjustable feet to secure it in place and prevent the shaft from rotating.
- 7.6 Using a protractor level, ensure that the arm is secured in a horizontal position, approximately 5 degrees higher on the side to which the weights will be added. The arm will deflect downward as the weights are added.
- **Note:** The dyno is typically calibrated for engines that rotate in a clockwise direction. The weights will be added to the right side of the lever arm (facing the dyno from the position of the engine.)
- 7.7 For ease of handling, arrange the weights in the order listed on Form 251-01. All weights are stamped with an identification number.
- 7.8 Ensure that the AC power is switched to Dyno 2. To verify or change power to the dynos:
  - 7.8.1 Turn the rotating switches on the front of G.E. Cabinet #2 labeled "AC DISCONNECT" and G.E. Cabinet #3 labeled "LINE SWITCH" to "OFF." Switch the circuit breaker on the side of G.E. Cabinet #5 to "OFF."

This step must be completed as a safety requirement to ensure that the power is off when opening the cabinet.

TP 251		Heavy-Duty Engine Dynamometer Speed and Torque Calibration	Page 6 of 20
	7.8.2	Open Cabinet #3 and check the position of the knife swite	hes.
	7.8.3	When the switches are to the right side, Dyno #1 is energiner are to the left side, Dyno #2 is energized. Move them to the if necessary.	zed. When they ne proper position,
	7.8.4	Close the cabinet and switch the circuit breaker (Cabinet # turn the rotating switches "AC DISCONNECT" (Cabinet # SWITCH" (Cabinet #3) "ON."	5) "ON" and then #2) and "LINE
7.9	Activate	e the Cellmate II:	
	Note:	The symbols <> are used to indicate a key on either the C Computer Control System or Macintosh computer keyboa	ellmate II rds.
		Example: Press <return> to enter. This means that you n key labeled "Return" to enter information typed on the con</return>	eed to press the mputer screen.
	7.9.1	Press the yellow power button on the Cellmate II front par illuminate when the power is "ON."	nel. It will
	7.9.2	Press <caps lock="">. Ensure that the LED on this key is ill</caps>	uminated.
	7.9.3	The Cellmate II will prompt "hi." Respond by typing "HI Return>.	" and press
		The Cellmate II will now load its programming. A red lig the screen will blink while it is performing any operation. made until it has completed this operation. The "TESTIN appear on the screen when the loading sequence is finished	ht to the right of No entries can be G MENU" will d.
	7.9.4	Press <2> <return>. This will display the "TEST SEQUE</return>	ENCES" screen.
	7.9.5	Press <2> <return>. This will display the "TRANSIENT</return>	TESTS" screen.
	7.9.6	Press <4> <return>. This will display real-time measurer parameters.</return>	ments of test
	7.9.7	Hold down <ctrl> and press <next disp=""> (upper left A new display will appear. Repeat <ctrl> <next dis<br="">next screen which will display the shaft torque, case torqu</next></ctrl></next></ctrl>	of keyboard). P> to move to the e, and speed.

7.10 Press the green "START" button above the "MG SET" label. The button will illuminate when the motor/generator (MG) set is operating. Operating the MG set ensures that the dyno armature is floating on a film of oil.

#### 8. Test Procedure

#### **100** Shaft-Torque Daytronic Calibration

- 101 On Form 251-01, in the box labeled "Prev. Shaft Torque Shunt Value," record the shunt value that is displayed on the sticker adjacent to the "Shaft Torque" Daytronic.
- 102 Adjust the "Shaft Torque" Daytronic signal conditioner display to exactly 0.0 by rotating the "Fine Balance" potentiometer.
- 103 Hang all the calibration weights on the shaft-torque lever arm. Refer to Form 251-01 for the weights to be used. Weights must not swing on the lever arm during calibration.
- 104 Adjust the "Shaft Torque" Daytronic so the display matches the total moment created by the lever arm. To do this, adjust the span potentiometer so the display reads 1237.0. The Daytronic is adjustable to  $\pm 0.5$ .
- Note: All weights hanging on the lever arm will equal 494.74 lb x 2.5 ft = 1236.8 ft-lb.
- 105 Using the hydraulic lift, raise the weights and the hanger off the lever arm clevis to recheck the zero calibration. Adjust the "Shaft Torque" Daytronic signal conditioner display to exactly 0.0, if necessary, by turning the "Fine Balance" potentiometer.
- 106 Repeat Steps 102-105 for zero and span until the "Shaft Torque" Daytronic readings are correct and repeatable.
- 107 Press the "-CAL" button on the "Shaft Torque" Daytronic. The value that is displayed will be the new shunt calibration value. On a new adhesive sticker, record this value, your initials, and the date. Remove the old sticker and post the new sticker next to the display.
- 108 On Form 251-01, record the new shunt calibration value in the box labeled "New Shaft Torque Shunt Value." This value should not differ by more than 5 percent from the "Prev Shaft Torque Shunt Value" unless repairs have been made or new equipment has been installed.

If it does differ by more than 5 percent, notify the Calibration and Maintenance (C&M) supervisor.

- 109 Remove the weights from the hanger, and set the weights and hanger aside.
- 110 Verify that the Cellmate II display for "SHAFT TORQUE" agrees exactly with the Daytronic reading for zero. Press the "-CAL" button on the "Shaft Torque" Daytronic, and again, ensure that the readings on the two displays agree exactly.

If the readings do not agree, proceed with Section 200.

If the readings agree, proceed with Section 300.

## 200 Cellmate II Shaft-Torque Calibration

This section should only be used if the "SHAFT TORQUE" readings on the Cellmate II display did not agree with the "Shaft Torque" Daytronic readings for the zero and span as observed in Section 100.

- 201 Press <MENU>. This will display the "TESTING MENU" screen.
- 202 Press <1><Return>. This will display the calibration screen.
- 203 Using <PAGE<sup>(1)</sup>>, scroll to the calibration screen that displays "TORQUE."
- 204 Using  $\langle \uparrow \rangle$  or  $\langle \downarrow \rangle$ , scroll to "TORQUE." It will become highlighted.
- 205 Press <Return> on the Cellmate II keyboard to enter the calibration mode.
- 206 Enter your initials and press <Return>.
- **Note:** If at any point you do not want to change an entry on the Cellmate II, press <Return> and the entry currently on the screen will be retained.
- 207 Enter the transducer serial number and press <Return>.
- **Note:** This number only needs to be changed if the transducer is replaced.
- 208 With the weights raised off the clevis, and the "Shaft Torque" Daytronic display reading 0.0, press <Return> to enter the zero calibration into the Cellmate II.
- 209 Enter "0.0" and press <Return> to enter the appropriate value in the "Low Engineering Value" field.

- 210 Press and hold the "Shaft Torque" Daytronic "+CAL" button to display the new shunt value. With the "Shaft Torque" Daytronic reading the shunt value, press <Return> to enter the high value of the calibration into the Cellmate II.
- 211 Type the shunt value displayed on the "Shaft Torque" Daytronic in the "High Engineering Value" field. Hold down the Daytronic "+Cal" button and press <Return>.
- 212 The Cellmate II will prompt: "Comments?" Enter comments as necessary.
- 213 The Cellmate II will prompt:

"Do you wish to review or change any answers? (Y/N)" Press  $\langle Y \rangle \langle Return \rangle$  to review or change, or  $\langle N \rangle \langle Return \rangle$  to end the shaft torque calibration.

- 214 When the Cellmate II calibration has been completed, press <MENU>, this will display the "TESTING MENU" screen.
- 215 Press <2> <Return>. This will display the "TEST SEQUENCES" screen.
- 216 Press <2> <Return>. This will display the "TRANSIENT TESTS" screen.
- 217 Press <4> <Return>. This will display real-time measurements of test parameters.
- 218 Hold down <CTRL> and press <NEXT DISP> (upper left of keyboard). A new display will appear. Repeat <CTRL> <NEXT DISP> to move to the next screen which will display the shaft torque, case torque, and speed.

#### **300** Shaft-Torque Linearity Verification

- 301 Place the hanger on the lever arm clevis and add Weights 2R and 4R. The weights must not swing on the lever arm during verification.
- 302 On Form 251-01, record the value displayed on the Daytronic, on the line labeled "Hanger, 2R, 4R," and the column labeled "Daytronic Shaft Torque."
- 303 On the same line under "Cellmate Shaft Torque," record the shaft-torque value displayed on the Cellmate II.
- Add weights 5R, 6R, and 7R on the hanger.

On Form 251-01, record the shaft-torque values displayed on the Daytronic and Cellmate II in the corresponding lines and columns.

- 305 Continue adding weights on the hanger, and recording the values on the corresponding lines on Form 251-01, until the complete set has been added.
- After all the weights have been placed on the hanger, and the readings have been recorded, remove the top two weights (this should be weights 23S and 24S).
- 307 On Form 251-01, record the shaft torque values from the Daytronic and Cellmate II on the corresponding lines.
- 308 Continue removing weights and recording the values until no weight remains on the lever arm.
- 309 Verify that the shaft-torque values displayed on both the Daytronic and Cellmate II are  $0.0 \pm 0.5$ .

If this tolerance is not met, repeat Steps 102 through 309.

- 310 Remove the lever arm and dyno lock from the dyno shaft.
- 311 Again, verify that the shaft-torque values displayed on both the Daytronic and Cellmate II are  $0.0 \pm 0.5$ .

If this tolerance is not met, investigate possible lever arm imbalance and repeat Steps 102 through 309.

If this tolerance still cannot be met, notify the C&M supervisor.

#### 400 Case-Torque Daytronic Calibration

- 401 On Form 251-01, record the shunt value that is displayed on the adhesive sticker adjacent to the "Case Torque" Daytronic, in the box labeled "Prev Case Torque Shunt Value."
- 402 Adjust the "Case Torque" Daytronic signal conditioner display to exactly 0.0 by rotating the "Fine Balance" potentiometer.
- 403 Hang all the calibration weights to be used on the case-torque lever arm. Refer to Form 251-01 for the weights to be used.

Remove hysteresis from the load cell by tapping its base with a rubber mallet after adding or removing any weight.

- 404 Adjust the "Case Torque" Daytronic, so the display matches the total moment created by the lever arm. To do this, adjust the span potentiometer so the display reads 1484.0. The Daytronic is adjustable to  $\pm 0.5$ .
- Note: All weights hanging on the lever arm will equal 494.74 lb x 3.0 ft = 1484.2 ft-lb.
- 405 Using the hydraulic lift, raise the weights and the hanger off the lever arm clevis to recheck the zero calibration. Adjust the "Case Torque" Daytronic to exactly 0.0, if necessary, by rotating the "Fine Balance" potentiometer.
- 406 Repeat Steps 402-405 for zero and span until the "Case Torque" Daytronic readings are correct and repeatable.
- 407 Press the "+CAL" button on the "Case Torque" Daytronic. The value that is displayed will be the new shunt calibration value. On a new adhesive sticker, record this value, your initials, and the date. Remove the old sticker and post the new sticker next to the display.
- 408 On Form 251-01, record the new shunt calibration value in the box labeled "New Case Torque Shunt Value." This value should not differ by more than 5 percent from the "Prev Case Torque Shunt Value" unless repairs have been made or new equipment has been installed. If it does differ by more than 5 percent, notify the C&M supervisor.
- 409 Remove the weights from the hanger, and set the weights and hanger aside.
- 410 Verify that the Cellmate II display for "CTORQUE" agrees exactly with the Daytronic reading for zero. Press the "+CAL" button on the "Case Torque" Daytronic and ensure that the readings on the two displays agree exactly.

If they do not agree, proceed with Section 500.

If the readings agree, proceed with Section 600.

#### 500 Cellmate II Case-Torque Calibration

This section should only be used if the "CTORQUE" readings on the Cellmate II display did not agree with the "Case Torque" Daytronic readings for the zero and span as observed in Section 400.

501 Press <MENU>. This will display the "TESTING MENU" screen.

- 502 Press <1> <Return>. This will display the calibration screen.
- 503 The first "CAL SCREEN" will display "CTORQUE."
- 504 Using  $\langle \downarrow \rangle$ , scroll to "CTORQUE." It will become highlighted.
- 505 Press <Return> on the Cellmate II keyboard to enter the calibration mode.
- **Note:** If you do not want to change an entry on the Cellmate II, press <Return> and it will retain the entry currently on the screen.
- 506 Type your initials and press <Return>.
- 507 Type the transducer serial number and press <Return>.
- **Note:** This number only changes if the transducer is replaced.
- 508 With the weights raised off the clevis, and the "Case Torque" Daytronic display reading 0.0, press <Return> to enter the zero calibration into the Cellmate II.
- 509 Enter "0.0" and press <Return> to enter the zero value in the "Low Engineering Value" field.
- 510 Press and hold the "Case Torque" Daytronic "+CAL" button to display the new shunt value. With the "Case Torque" Daytronic reading the shunt value, press <Return> to enter the high value of the calibration into the Cellmate II.
- 508 Type the shunt value displayed on the "Case Torque" Daytronic in the "High Engineering Value" field. Hold down the Daytronic "+Cal" button and press <Return>.
- 509 The Cellmate II will prompt: "Comments?" Enter comments as necessary.
- 510 The Cellmate II will prompt:

"Do you wish to review or change any answers? (Y/N)" Press  $\langle Y \rangle \langle \text{Return} \rangle$  to review or change or  $\langle N \rangle \langle \text{Return} \rangle$  to end the case torque calibration.

- 511 When the Cellmate II calibration has been completed, press <MENU>, this will display the "TESTING MENU" screen.
- 512 Press <2> <Return>. This will display the "TEST SEQUENCES" screen.

- 513 Press <2> <Return>. This will display the "TRANSIENT TESTS" screen.
- 514 Enter <4> <Return>. This will display the real-time measurements of test parameters.
- 515 Hold down <CTRL> and press <NEXT DISP> (upper left of keyboard). A new display will appear. Repeat <CTRL> <NEXT DISP> to move to the next screen which will display the shaft torque, case torque, and speed.

#### 600 Case-Torque Linearity Verification

- 601 Place the hanger on the lever arm clevis and add Weights 2R and 4R. Weights must not swing on the lever arm during verification.
- 602 On Form 251-01, record the value displayed on the Daytronic, on the line labeled "Hanger, 2R, 4R," and the column labeled "Daytronic Case Torque."
- 603 On the same line under "Cellmate Case Torque," record the case-torque value displayed on the Cellmate II.
- Add weights 5R, 6R, and 7R on the hanger.

On Form 251-01, record the case torque values displayed on the Daytronic and Cellmate II in the corresponding lines and columns.

- 605 Continue adding weights on the hanger, and recording the values on their corresponding lines on Form 251-01, until the complete set has been added.
- After all the weights have been placed on the hanger and the readings have been recorded, remove the top two weights (this will be weights 23S and 24S).
- 607 On Form 251-01, record the case-torque values from the Daytronic and Cellmate II on the corresponding lines.
- 608 Continue removing weights and recording the values until no weight remains on the lever arm.
- 609 Verify that the case-torque values displayed on both the Daytronic and Cellmate II are  $0.0 \pm 0.5$ .

If this tolerance is not met, repeat Steps 402 through 609.

610 When the verification is complete, return the weights to their storage location.

#### 700 Speed Verification

The speed measurement system is typically very stable and does not require adjustment. If the equipment fails any part of this verification, it should be taken out of service and a possible equipment malfunction should be investigated.

- 701 Verify that the Cellmate II display for "SPEED" agrees exactly with the Daytronic reading for the zero.
- 702 Press and hold the "SPAN" button on the "SPEED" Daytronic. Verify that the Cellmate II display for "SPEED" agrees exactly with the Daytronic reading for span.
- 703 Unplug the rotary transformer speed sensor cable (the smaller of two cables) from the dynamometer shaft-torque transducer.
- 704 Connect the Fluke multi-counter to the transducer using the cable labeled "Dyno Cal," which is stored in the large tool box in the test cell.
- 705 Press the "Freq" and "Auto" buttons on the counter. The counter will automatically set itself to the correct scale to measure the dynamometer revolutions per minute.
- 706 Turn the "AUTO/MANUAL" switch on the Cellmate II to the "MANUAL" position.
- Turn the dyno "POWER" switch to the "ON" position.
- Turn the "FUEL/IGNITION" switch to the "ON" position.
- 709 Press the "RESET" button. This will cause the green "FUEL ON" light to illuminate.
- 710 Press the "DYNO ON" button. This will cause it to illuminate.
- 711 Turn the variable voltage power supply unit to "OFF."
- 712 Press the "MANUAL" button on the dyno control panel.
- 713 Control the dyno rpm with the "SPEED" potentiometer on the right side of the control panel. Speed will be set by observing the multi-counter display and adjusting the speed to exactly those speeds shown on Form 251-01.

714 Verify the accuracy of the "SPEED" Daytronic display and the Cellmate II display by operating the dynamometer at 200 rpm and then from 500 to 4500 rpm at 500 rpm increments. Compare the readings at each point to the readings on the multicounter display.

On Form 251-01, record the readings under the columns labeled "Daytronic Speed" and "Cellmate Speed."

Both the Daytronic and Cellmate II readings must be within  $\pm 2$  percent of the multi-counter readings.

- Turn the "POWER" switch on the dyno control panel to "OFF."
- 716 Turn the "FUEL/IGNITION" switch to "OFF."
- 717 Press the "MG SET" "STOP" button.
- 718 When verification is complete, reinstall the sensor cable into the transducer and return the multi-counter and connection cable to their storage areas.
- End the calibration procedure on the Cellmate II:

Press <MENU>. The "TESTING MENU" will appear on the screen.

Press <6> <Return>.

Leave the Cellmate II power "ON."

## 9. Data Input

- 9.1 The technician will enter all calibration and verification data required on Form 251-01.
- 9.2 For each Daytronic torque signal conditioner, the technician will put his/her initials, the date, and the new shunt calibration value on an adhesive sticker and post the sticker next to the signal conditioner.
- 9.3 The technician will enter all data from Form 251-01 into the Excel<sup>®</sup> spreadsheet upon completion of the calibration.
  - 9.3.1 Locate a Macintosh computer that has access to the Labrotory Network System (LNS).
  - 9.3.2 Sign on to the LNS Production Server.

- 9.3.3 Open the "C&M" folder, then open the "TP 251 (Dyno Cal)" folder.
- 9.3.4 Open the "Speed and Torque Cal Report" spreadsheet.
- 9.3.5 Transcribe the data from Form 251-01 to the spreadsheet. When it is complete, print the spreadsheet for review. Printing the spreadsheet creates the "Heavy-Duty Speed and Torque Calibration Report."
- 9.3.6 Save the completed file as "Speed and Torque Cal Report mm/dd/yy" with the date included in the title.
- 9.3.7 Close the file and the "TP 251 (Dyno Cal)" folder and sign off of LNS.

#### 10. Data Analysis

- 10.1 The technician will check Form 251-01 and the "Heavy-Duty Speed and Torque Calibration Report" for transcription accuracy.
- 10.2 The computer automatically compares the observed torque value to the theoretical or calculated value and calculates the percent deviation for each point. The technician will review the computer printout to ensure that all acceptance criteria have been met.

If all acceptance criteria have been met, the technician signs and dates Form 251-01.

10.3 A technician other than the technician who entered the data, reviews Form 251-01 and the "Heavy-Duty Speed and Torque Calibration Report" for transcription accuracy to ensure that all acceptance criteria are met. If this verification is successful, the technician signs and dates the "Heavy-Duty Speed and Torque Calibration Report."

If all acceptance criteria have been met, the equipment may be placed back in service.

If the acceptance criteria have not been met, the equipment must be taken out of service until it can be adjusted, repaired, or replaced and the verifications outlined in this procedure are completed successfully.

## 11. Data Output

The completed Form 251-01 and the "Heavy-Duty Speed and Torque Calibration Report" are filed in the C&M Department Calibration File.

## **12.** Acceptance Criteria

- 12.1 The torque values indicated on the Cellmate II and the Daytronic signal conditioners must be within  $\pm 3$  percent or 10 ft-lb of the calculated value, whichever is less, for each point.
- 12.2 The speed values indicated on the Cellmate II and the "Speed" Daytronic both must be within 2 percent of the Fluke multi-counter readings.
- 12.3 Final zero-point torque readings must be within  $\pm 0.5$  ft-lb on both the Cellmate II and Daytronic readouts.

## **13.** Quality Provisions

- 13.1 Weights must not swing on the lever arm during a calibration.
- 13.2 Speed and Torque calibrations on the dynamometer must be performed monthly or whenever any portion of the torque or speed measurement system is repaired or replaced.
- 13.3 Speed and torque signals are checked for accuracy and linearity throughout their entire working range.
- 13.4 The calibration weights must be traceable to NIST standards.

Calibration
Torque
and
Speed
Dynamometer
Heavy-Duty

Numbers         (1)         Orque         Torque         Torque         Torque         Torque         Speed	Weight ID	NIST Weight	Daytronic Shaft	Cellmate Shaft	Daytronic Case	Cellmate Case	Multi- Counter	Daytronic	Cellmate
Hamper, 2R, 4R         0.00         0.0         200         1000         1000           5R, 6R, 7R         54.675         600         1000         500         1000         1000           95, 105         140.548         24.675         200         1000         1000         1000           95, 105         140.548         24.070         200         1000         1000         1000           153, 165         242.020         200         2000         1000         1000         1000           155, 165         292.802         444.378         243.250         444.378         3000         4000           175, 185         243.252         444.378         195.200         4000         4000           215, 225         444.378         195.200         444.378         5500         400           215, 225         444.378         194.739         100         100         100           215, 225         444.378         244.378         244.378         5500         106           215, 225         244.378         244.378         100         100         100           215, 225         244.378         244.378         105         100         106	Numbers	(11)	(all)	Torque (ft-1b)	Torque (ft-1b)	Torque (ft-1b)	Speed (rpm)	Speed (rpm)	Speed (rpm)
Hanger         28, 4R         24,675         500 <t< td=""><td></td><td>0.00</td><td><math>\left  \begin{array}{c} 2 \end{array} \right </math></td><td></td><td></td><td></td><td>200</td><td></td><td></td></t<>		0.00	$\left  \begin{array}{c} 2 \end{array} \right $				200		
5R, 6R, 7R         54,538         1000	Hanger, 2R, 4R	24.675					500		
8R. 85         89.792         1500	5R, 6R, 7R	54.538		V			1000		
95, 105     140,548     2000     2500     2500       115, 125     191,627     2500     5500     100       155, 165     232,2802     3500     5500     100       175, 185     343,282     444,378     544,378     5500     100       195, 205     393,757     444,378     544,378     544,378       215, 225     494,739     100     4000     4000       235, 245     494,739     100     100     100       235, 245     494,378     100     100     100       235, 245     494,379     100     100     100       235, 245     494,379     100     100     100       235, 245     494,379     100     100     100       235, 245     494,379     100     100     100       235, 245     494,379     100     100     100       215, 225     444,378     244,378     100     100       215, 225     244,378     244,378     100     100       215, 225     244,378     244,378     244,378     100       175, 185     245,38     141,577     101,657     100       155, 165     292,802     101,627     100     100	8R, 8S	89.792		$\searrow$			1500		
115, 125       191.627       24       2500       5000       5000         135, 168       242.020       530.282       530.00       5000       5000         175, 185       353.757       443.78       543.280       544.378       544.378         175, 185       353.757       444.378       544.378       544.378       544.378         215, 225       444.378       8       8       8       8         235, 245       494.739       8       8       8         215, 225       444.378       8       8       8         235, 245       494.739       8       8       8         215, 225       444.378       8       8       8         215, 225       444.378       8       8       8         215, 225       444.378       8       8       8         215, 125       144.378       18       18       18         155, 165       292.602       18       18       18         155, 185       292.302       19       18       19         155, 185       292.302       19       18       19         155, 185       292.302       19       10       10 </td <td>9S, 10S</td> <td>140.548</td> <td>/</td> <td></td> <td></td> <td></td> <td>2000</td> <td></td> <td></td>	9S, 10S	140.548	/				2000		
135       145       242.020       3000       3000       3000         175       165       292.802       4000       4000       4000         175       185       333.525       444.378       4000       4000       4000         195       215       2255       444.378       5       44.378       5       44.378         215       2255       444.378       5       5       44.378       5       5         235       245       494.739       5       5       5       5       5         235       245       494.739       5       5       5       5       5         235       245       444.378       5       5       5       5       5       5         235       245       444.378       5 <td>11S, 12S</td> <td>191.627</td> <td>07</td> <td><math>\sum</math></td> <td></td> <td></td> <td>2500</td> <td></td> <td></td>	11S, 12S	191.627	07	$\sum$			2500		
15s, 16s       292.802       5500       45000       5500       5500 </td <td>13S, 14S</td> <td>242.020</td> <td></td> <td></td> <td></td> <td></td> <td>2000</td> <td></td> <td></td>	13S, 14S	242.020					2000		
175, 185       343,282       4000       4000       4500       4500         195, 205       393,757       94,4378       844.378       844.378       844.378         235, 245       494,739       8       844.378       844.378       844.378         235, 245       494,739       8       844.378       844.378       844.378         235, 245       494,739       8       844.378       844.378       844.378         215, 225       494,739       8       844.378       844.378       844.378         215, 225       494,739       8       844.378       844.378       844.378         215, 225       494,739       8       844.378       844.378       844.378         215, 225       494,739       8       844.378       844.378       844.378         215, 225       494,739       8       844.378       844.378       844.378         175, 185       235,262       19       8       844.378       844.378         135, 145       245,282       19       8       844.378       844.378         15, 125       191,627       8       89,792       89,792       844.378         15, 125       191,627       9	155,165	292.802			<u> </u>		3500		
195, 205       393, 757       195, 206       393, 757       4500       4500         215, 225       444, 378       544, 739       5haft       7orque Shunt Value         235, 245       494, 739       7       7       5haft       7orque Shunt Value         235, 245       494, 739       7       7       5haft       7orque Shunt Value         235, 245       494, 739       7       7       5haft       7orque Shunt Value         235, 245       444, 378       7       7       5haft       7orque Shunt Value         195, 205       393, 757       7       7       6ase       7orque Shunt Value         175, 185       343, 282       7       7       6ase       7orque Shunt Value         175, 185       242, 020       7       7       6ase       7orque Shunt Value         155, 165       292, 802       7       7       6ase       7orque Shunt Value         155, 125       146, 7       7       7       6ase       7       7         155, 148       244, 05       7       7       7       7       7         155, 6R, 7R       54, 55       7       7       7       7       7         5R, 6R, 7R <td>175, 185</td> <td>343.282</td> <td></td> <td></td> <td></td> <td></td> <td>4000</td> <td></td> <td></td>	175, 185	343.282					4000		
215,225       444.378       215,225       444.378       215,125       144.378       215,125       144.378       215,125       144.378       215,125       144.378       215,125       144.378       215,125       144.378       215,125       144.378       215,125       144.378       215,125       144.378       215,125       144.378       215,125       144.378       215,125       144.378       215,125       115,125       125,165       222,802       New       New <td>195, 20S</td> <td>393.757</td> <td></td> <td></td> <td></td> <td></td> <td>4500</td> <td></td> <td></td>	195, 20S	393.757					4500		
235, 245       494.739       Shaft Torque Shunt Value         235, 245       494.739       Erevious       Shaft Torque Shunt Value         235, 245       494.739       Erevious       Erevious         215, 225       444.378       Erevious       New         155, 125       393.757       Erevious       New         175, 185       333.757       Erevious       New         155, 185       232.802       New       New         155, 185       242.020       New       New         155, 125       191.627       New       New         95, 105       140.548       New       New         15, 125       140.548       New       New         95, 105       140.548       New       New         95, 105       140.548       New       New         15, 125       140.548       New       New         16, 7R       54.575       New       New <t< td=""><td>21S, 22S</td><td>444.378</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></t<>	21S, 22S	444.378							
235, 245       494.739       Previous       Previous         215, 225       494.378       New       New         195, 205       393.757       New       New         175, 185       393.757       Previous       New         155, 165       294.728       New       New         155, 165       242.020       New       New         155, 145       242.020       New       New         95, 105       140.548       New       New         95, 105       140.548       New       New         95, 105       140.548       New       New         115, 125       191.627       New       New         95, 105       140.548       New       New         96, 105       140.548       New       New         115, 125       0.00       New       New         118       0.00	235, 24S	494.739					Shaft	t Torque Shun	it Yalue
235, 24S         494.739         New         New           215, 22S         444.378         New         Case Torque Shunt Value           195, 205         393.757         New         Case Torque Shunt Value           175, 185         343.282         New         New           175, 185         343.282         New         New           175, 185         343.282         New         New           155, 165         292.802         New         New           155, 145         242.020         New         New           8R, 85         89.792         New         New           8R, 85         89.792         New         New           Anger, 2R, 4R         24.675         New         <							Previous		
215, 225       444.378       1       1       Case Torque Shunt Value         195, 205       393,757       0       Case Torque Shunt Value         175, 185       343.282       0       0         155, 165       292,802       0       0         155, 165       292,802       0       0         155, 165       292,802       0       0         155, 165       292,802       0       0         155, 145       242,020       0       0         155, 145       242,020       0       0         95, 105       140,548       0       0         8R, 85       89,792       0       0         95, 105       140,548       0       0         115, 125       140,548       0       0         8R, 85       89,792       0       0         6R, 85       89,792       0       0         15, 128       140,548       0       0         48, 85       89,792       0       0         16, 6R, 7R       54,538       0       0         18, 85       0       0       0       0         18, 85       0       0       0 </td <td>235, 245</td> <td>494.739</td> <td></td> <td></td> <td>70</td> <td></td> <td>New</td> <td></td> <td></td>	235, 245	494.739			70		New		
195, 205         393.757         Case Torque Shunt Value           175, 185         343.282         Exercicle         Frevious         Exercicle           155, 165         292.802         Exercicle         Frevious         Exercicle           155, 165         292.802         Exercicle         Frevious         Exercicle           155, 145         242.020         Exercicle         Mew         Exercicle           95, 105         140.548         Exercicle         Exercicle         Mew           95, 105         140.548         Exercicle         Exercicle         Mew           95, 105         140.548         Exercicle         Exercicle         Mew           95, 105         140.548         Exercicle         Exercicle         Exercicle           115, 125         140.548         Exercicle         Exercicle         Exercicle           95, 105         140.548         Exercicle         Exercicle         Exercicle         Exercicle           95, 105         140.548         Exercicle         Exercicle         Exercicle         Exercicle           15, 125         140.548         Exercicle         Exercicle         Exercicle         Exercicle           16, 0.00         0.00         Exerc	215, 225	444.378							
175, 185         343.282         Previous           155, 165         292.802         New           155, 145         242.020         New           155, 145         242.020         New           95, 105         191.627         New           95, 105         140.548         New           98, 85         89.792         New           88, 85         89.792         New           98, 105         140.548         New           15R, 6R, 7R         54.538         New           Hanger, 2R, 4R         24.675         New           Inaccordance with TP 251.         New         New           Inaccordance with TP 251.         Date         New	19S, 20S	393.757					Case	Torque Shum	t Yalue
15S, 16S       292.802       New         13S, 14S       242.020       New         13S, 14S       242.020       New         91, 10S       191.627       New         95, 10S       1405.488       New         95, 10S       1405.488       New         95, 10S       1405.488       New         98, 88       89.792       New         98, 85       89.792       New         15R, 6R, 7R       54.538       New         18R, 85       89.792       New         18R, 85       89.792       New         199       0.00       New         1       0.00       New         1       New       Ne	17S, 18S	343.282				25	Previous		
13S, 14S       242.020       0       0       0         91,05       191.627       0       0       0         95,105       191.627       0       0       0         98, 85       89.792       0       0       0         8R, 85       89.792       0       0       0         98, 85       54.538       0       0       0         Hanger, 2R, 4R       54.538       0       0       0         Hanger, 2R, 6R, 7R       54.538       0       0       0         I have performed this calibration in accordance with TP 251.       Date       Date       Date	155,165	292.802					New		
115, 125       191.627       Comments         95, 105       140.548       Comments         95, 105       140.548       Comments         5R, 6R, 7R       54.538       Comments         5R, 6R, 7R       54.538       Comments         Hanger, 2R, 4R       24.675       Comments         I have performed this calibration in accordance with TP 251.       Date       Date	13S, 14S	242.020							
95, 105         140.548 <t< td=""><td>115, 125</td><td>191.627</td><td></td><td></td><td></td><td></td><td>Comments</td><td></td><td></td></t<>	115, 125	191.627					Comments		
BR, BS     89.792     B. 72       5R, 6R, 7R     54.538     D       Hanger, 2R, 4R     24.675     D       1 have performed this calibration in accordance with TP 251.     Date	9S, 10S	140.548							
5R, 6R, 7R     54.538        Hanger, 2R, 4R     24.675        0.00     0.00        I have performed this calibration in accordance with TP 251.     Date	8R, 8S	89.792							
Hanger, 2R, 4R       24.675       Low         0.00       0.00       Low         I have performed this calibration in accordance with TP 251.       Date         Technician Signature       Date	5R, 6R, 7R	54.538							
I have performed this calibration in accordance with TP 251. Technician Signature Date	Hanger, 2R, 4R	24.675							
I have performed this calibration in accordance with TP 251. Technician Signature		0.00							
Technician Signature Date	l have performed th	nis calibration ir	1 accordance 1	with TP 251					
	Technician Signatur	e.				Date			

% diff.		-1.11%	0.48%	0.18%	-0.01%	0.32%	0.41%	0.21%	-0.04%	-0.15%	9 1 2 0	-0.18%	-0.14%	%60°0	0.34%	0.32%	0.19%	0.32%	0.85%	-0,30%														age 1 of 2	·
Daytronic Shaft Torque Offset (ft-Ib)	0.0	-0.7	√.0 -0.5	0.6	-0.1	2.0	3.0	8.5	4.0-	<b>1</b> 00	đ	0 6 	4.1-	0.8	2.5	2.0	0.0	1.1	u di	-0.2					ſ	J								Ľ	
Cellmate Case Torque (ft-1b)	0.0	74.2	769.5	421.4	575.2	728.1	881.3	0.1601	1332.2	1481.7	1 481 7	1332.4	1182.2	1031.2	882.0	727.2	575.6	422.2	164.9	74.0 0.0					nolo Data Only	ווחום המומ כוווא									
Daytronic Case Torque (ft-Ib)	0.0	74.0	269.5	421.5	575.0	728.0	881.5	1030.5	1332.0	1481.5	1481 5	1332.5	1182.0	1031.0	881.5	727.0	575.0	422.U 360.5	164.5	73.5					Evar										
Cellmate Shaft Torque (ft-lb)	0.0	61.4	224.3	351.5	479.3	607.1	735.5	860.1	1109.7	1235.1	1 2 3 5 2	1109.8	983.3	859.1	734.6	607.1	479.9	936.4	137.4	61.4															
Daytronic Shaft Torque (ft-1b)	0.0	61.0	224.0	352.0	479.0	607.0	735.0	800.U	1109.5	1235.0	1235.0	1109.0	983.0	859.0	734.5	607.0	480.0	0.900	137.5	61.5 0.0															
Catc. Shaft Torque (ft-Ib)	0.0	61.7	224.5	351.4	479.1	605.0	732.0	7.000	1110.9	1236.8	1236.8	1110.9	984.4	858.2	732.0	605.0	479.1	4.100	136.3	61.7 0.0		<u>Weight ( b)</u> 25.52237	24.87054	25.56443	25.21751	25.28046	25.20028	25 2220E	25.47852	25.14300	25.17076	25.18945			
Calc. Case Torque (ft-1b)	0.0	74.0 162 6	269.4	421.6	574.9	726.1	8/8.4	1181.3	1333.1	1484.2	1484.2	1333.1	1181.3	1029.8	878.4	726.1	5/4.9	269.4	163.6	74.0	IGHTS	<u>Weight ID</u> 13S =	14S =	155 =	165 =	175 =	= 091 1801		215 =	22S =	23S =	24S =			
Totel NIST Weight (1b)	0.0	24,675 54,530	89.792	140.548	191.627	242.020	292.802	793.25F	444.378	494.739	494.739	444.378	393.757	343.282	292.802	242.020	191.62/ 140 548	89.792	54.538	24.675 0.0	NIST CERTIFIED WE	<u>Weight (Ib)</u> 09.68644	05.00871	09.97989	10.01902	09.84235	10.00126	26 32673	25.25314	25.50234	25,48440	25.59476			
NIST Weight (Ib)	0.0	24.675 29 863	35.255	50.755	51.079	50.393	78/'nc	50.474	50.622	50.360	50.360	50.622	50.474	50.481	50.782	54 070	8/0.16 50.765	35.255	29.863	24.675 0.0		<u>Weicht ID</u> Hanger =	2H =	4R =	= H2	= 49 64		- v	- <u>~</u> Se	10S =	115 =	12S =		/94	
Weight ID	:	Hanger, 2H, 4R 5B 6B 7P	8R, 8S	9S, 10S	11S, 12S	13S, 14S	133, 163	19S. 20S	21S, 22S	23S, 24S	23S, 24S	21S, 22S	19S, 20S	17S, 18S	155, 165	135, 145	021 101	50, 100 8R. 8S	5R, 6R, 7R	Hanger, 2R, 4R														Version 1.0:5/26	

(H-b)         (H-b) <th< th=""></th<>
0.0         0.11         0.0
0.3         0.47%         0.0         0.03%         0.0         0.03%         0.0         0.03%         0.0         0.03%         0.0         0.04%         0.0         0.03%         0.0         0.03%         0.0         0.03%         0.0         0.03%         0.0         0.03%         0.0         0.0         0.03%         0.0         0.03%         0.0         0.03%         0.0         0.03%         0.0         <
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0.2 $0.035$ $0.1$ $0.035$ $0.1$ $0.035$ $0.1$ $0.055$ $0.0$ $0.055$ $0.0$ $0.055$ $0$
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
0.1       0.03%       0.03       0.03%       0.00%       0
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16       -0.13%       -27       -0.19%       25       -0.17%       4000       4001       0.00%       4001       0.01%       4500
16       -013%       27       -0.13%       25       -0.17%       4500 $\overline{4501}$ 0.0% $\overline{4500}$ 11       -0.11%       0.7       -0.06%       0.9       0.06%       0.9 $\overline{4500}$ $\overline{4501}$ 0.0% $\overline{4501}$ 0.0% $\overline{4501}$ 0.0% $\overline{4500}$ $\overline{4501}$ 0.0% $\overline{4500}$ $\overline{4501}$ 0.0% $\overline{4501}$ 0.0% $\overline{4501}$ 0.0% $\overline{4500}$ $\overline{4500}$ $\overline{4501}$ 0.0% $\overline{4500}$ </td
11       0.10%       0.6       0.05%       0.7       0.06%       0.0       0.00%       0.0       0.00%       0.0       0.00%       0.0       0.00%       0.0
11       -0.11%       0.7       0.06%       0.9       0.06%         0.8       0.10%       1.2       0.11%       1.4       0.13%       1.4         2.8       0.33%       3.1       0.13%       1.4       0.13%       1.4         2.1       0.34%       0.9       0.04%       0.6       0.13%       1.4         2.1       0.34%       0.9       0.03%       0.6       0.13%       1.4         0.8       0.17%       0.1       0.02%       0.6       0.13%       1.1         0.1       0.34%       0.1       0.02%       0.6       0.13%       1.1       0.14%         0.1       0.03%       0.6       0.13%       1.1       0.14%       0.13%       1.1         1.1       0.17%       0.3       0.13%       1.3       0.13%       0.13%       0.13%         0.1       0.10%       0.1       0.02%       0.0       0.13%       0.13%       0.06%       0.06%         0.1       0.17%       0.3       0.13%       0.13%       0.13%       0.06%       0.06%         1.1       0.17%       0.3       0.13%       0.03%       0.06%       0.03%       0.06%       <
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26       0.33%       3.1       0.13%       1.4       0.13%       1.4       0.13%       1.4       0.13%       1.4       Torque Shunt Values         21       0.33%       0.1       0.03%       0.5       0.13%       1.1       0.13%       1.1       0.13%       1.1       0.13%       1.1       0.13%       1.1       0.13%       1.1       0.15%       0.13%       1.1       0.15%       0.13%       1.1       0.15%       0.13%       0.11%       0.13%       0.13%       0.13%       0.13%       0.11%       0.11%       0.11%       0.11%       0.11%       0.11%       0.13%       0.11%       0
ZB       0.33%       3.1       0.33%       3.6       0.41%       Torque Shunt Values         0.1       0.13%       0.1       0.16%       1       10       0.13%       0.16%         0.1       0.17%       0.1       0.03%       0.6       0.13%       1       0.16%         1.0       0.23%       0.6       0.13%       0.6       0.13%       0.1       0.16%         1.1       0.17%       0.1       0.05%       0.6       0.13%       0.1       0.16%         0.2       0.17%       0.1       0.03%       0.6       0.13%       0.16%       0.119%         0.1       0.05%       0.33%       0.6       0.33%       0.6       0.33%       0.119%         0.3       0.77%       0.3       0.34%       1       0.03%       0.03%       0.06%         0.3       0.77%       0.3       0.03%       0.03%       0.03%       0.06%       0.06%         0.3       0.77%       0.3       0.03%       0.03%       0.06%       0.06%       0.06%         0.3       0.77%       0.3       0.03%       New       0.06%       0.06%       0.06%         0.3       0.77%
21     0.34%     0.9     0.13%     1.1     0.16%       10     0.17%     0.1     0.22%     0.7     0.13%       11     0.17%     0.1     0.05%     0.6     0.13%       11     0.17%     0.1     0.05%     0.6     0.13%       11     0.17%     0.1     0.05%     0.6     0.13%       0.3     0.17%     0.9     0.04%     1.3     0.13%       0.3     0.17%     0.9     0.05%     0.13%     Prov.       0.10     0.05%     0.13%     0.03%     Now     1106.0       0.01     0.03%     0.03%     0.03%     0.03%     0.06%       0.0     0.03%     0.03%     0.03%     0.06%     0.06%       0.0     0.03%     0.03%     0.03%     0.06%     0.06%       0.0     0.03%     0.03%     0.06%     0.06%     0.06%       0.00     0.03%     0.03%     0.05%     0.06%     0.06%       0.01     0.03%     0.03%     0.06%     0.06%     0.06%       0.01     0.03%     0.03%     0.06%     0.06%     0.06%       0.01     0.03%     0.03%     0.05%     0.06%     0.06%       0.01     0.03%
0.8         0.17%         0.1         0.02%         0.7         0.13%           1.0         0.29%         0.4         0.08%         0.6         0.13%           1.1         0.17%         0.1         0.05%         0.6         0.13%           1.1         0.17%         0.3         0.13%         0.6         0.13%           1.1         0.17%         0.9         0.05%         0.13%         New           1.1         0.17%         0.9         0.05%         0.13%         New           0.03%         0.13%         0.3         0.13%         New         1195.0           0.03%         0.00         0.03%         0.03%         New         1056.0         1195.0           0.0         0.03%         0.00         0.03%         0.05%         0.06%         0.06%           0.0         0.03%         0.03%         %         New         1056.0         1195.0           0.0         0.03%         0.00         0.03%         %         New         1056.0         1195.0           0.05%         0.05%         0.05%         0.05%         0.05%         0.06%         0.06%           0.11%         0.0         0.00%
1.0     0.23%     0.4     0.08%     0.6     0.13%     0.33%     0.6     0.13%       0.2     0.10%     0.1     0.05%     0.6     0.13%     0.33%     Peer     Ease Toque     Case Toque     Ca
0.2         0.10%         0.1         0.05%         0.5         0.23%         Prev.         Case Torque         Case Tordue         Case Tordue <thcase <="" td="" tordue<=""></thcase>
1.1       0.77%       0.9       0.54%       1.3       0.79%       Prev.       106.5.5       1195.0         0.3       -0.47%       0.5       -0.71%       0.0       -0.03%       New       106.5.5       1195.0         0.0       -0.47%       0.0       0.00       -0.03%       New       106.5.5       1195.0         0.0       0.0       0.00       0.03%       0.03%       0.06%       0.06%         0.0       0.01       0.03%       0.03       %. Difference       0.05%       0.06%         e performed this calibration in accordance with T.P. 251.       Date
0.3     0.47%     0.5     0.71%     0.0     0.03%     New 1066.0     1196.0       0.0     0.0     0.03%     0.00     0.03%     0.06%     0.03%       e performed this calibration in accordance with T.P. 251.     Date
0.0 0.05% 0.06% 0.08%
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