

IN-VITRO ACCELERATED FATIGUE TESTING PROTOCOL

THIS IS A TEST PLAN FOR ACCELERATED FATIGUE TESTING OF **CUSTOMERS** DEVICES. THE DURATION OF THIS TEST SIMULATES **X** YEARS OF IMPLANTATION LIFE.

AUTHOR: CUSTOMER

DOCUMENT ID:

APPROVED BY:

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- d) Keyence LS-5000 series Laser Head and Controller
- e) Computer, $\geq 400\text{MHz}$ CPU
- f) Required number of devices – provided by Company
- g) Balloon Catheters – provided by Company
- h) Mock Latex Arteries $x.xx$ mm ID with wall in the range of $.xx$ to $.xx$ mm $n=x$
- i) Mock Latex Arteries $x.xx$ mm ID with wall in the range of $.xx$ to $.xx$ mm $n=1$
- j) Isotonic Saline Solution (PBSS) :
 - (1) Water
 - (2) Sodium Chloride 0.85% w/v
 - (3) Dihydrogen Potassium Phosphate - trace
 - (4) Sodium Dihydrogen Phosphate Monohydrate - trace
 - (5) Ethylene Glycol Monophenylether – trace
- k) Associated Paper Work
 - (1) SGT Test Set Up Checklist
 - (2) Test Tube Mapping Sheet
 - (3) Physiological Set Up
 - (4) Test Deployment Form
 - (5) Daily Data Sheets (Template 99126)

5.0 **MOCK ARTERY INSPECTION**

Inspect the thick walled mock arteries and the physiological mock artery for uniform color, general appearance, and ID and wall thickness.

6.0 **THICK WALLED MOCK ARTERY CONDITIONING**

- a) Flush the thick walled mock arteries with saline water and install on the tester. Fill the tester with saline via an elevated pressure head and rid the tester of air bubbles.
- b) Start the tester at the **projected test frequency** adjusting the pressure head and tuning terms to achieve a stable sine wave.
- c) Adjust displacement levels to achieve a %OD radial strain between 1% - 2%. Cover the tester to prevent UV damage to the latex arteries and condition the tubes for a minimum of 2 hours.
- d) Map the OD (mm) and %OD of the empty mock arteries. Recording data at each cm along the length of the artery on the Artery Mapping data sheet.
- e) Analyze the data: The radial strain (%OD) of each position on every artery must be within 1% of each other. If an artery is not within this range, remove it and replace it with a new test artery. Repeat the conditioning/mapping procedure.
- f) Mark the mock artery with position on the tester and left and right reference marks.

7.0 **PHYSIOLOGICAL COMPLIANCE**

- a) **Use the customer supplied compliance information ($x\%$ - $x\%$)** to identify a physiological artery. (Example: At the indicated area of use the measured healthy vessel compliance is 3% - 5% at 160/80mmHg)

- b) Remove the thick walled test artery at the pressure transducer position by stretching it off of the fitting to preserve original length for re-installation.
- c) Install the physiological artery on the tester in the position with the pressure transducer.
- d) Measure OD along the length of the artery under static conditions in desired pressure range (typically 160/80)
- e) Record the data on the physiological compliance data sheet and spreadsheet.
- f) Calculate the compliance of the physiological artery.

Calculations:

Equation 1: $\%ID/\%OD \text{ strain ratio} = (1 + a^2/b^2 - \nu * (1 - a^2/b^2 + 2 * \nu))/2/(1 - \nu^2)$

a= OD radius of artery
 b= ID radius of artery
 ν= Poisson Ratio (.47)

Equation 2: $\%ID = \%OD * \%ID/\%OD \text{ strain ratio}$

Equation 3: $\%Compliance = [(ID_{max} - ID_{min})/ID_{min}] / \Delta P] * 100$ if $\Delta P = 100\text{mmHG}$

Equation 4: $\%Compliance = \%ID\text{strain} = ((ID_{max} - ID_{min})/ID_{min}) * 100$

* AAMI Draft Standard 25539-2. Cardiovascular implants – Endovascular devices – Part 2: Vascular Stents. 2006.

- g) If the compliance is within the accepted range proceed to the Accelerated Test %OD Target Calculation. If the compliance is not within range repeat the Physiological Compliance procedure with a new physiological artery.

8.0 ACCELERATED TEST %OD TARGET CALCULATION

- a) The physiological artery is deployed with a test sample to experimentally determine the %OD target for the Accelerated Fatigue Test.
- b) Deploy the test device. Customer must supply the pressure and time if a balloon expanded device is being deployed, as well as the deployment configuration in the arteries and around the tester.

Example of a Balloon expanded

Place the device on the balloon catheter and position within the artery
 Pressurize the device to dictated pressure (**xx atm**) and maintain pressure for dictated time interval (**xx sec**)
 Release the pressure and remove the balloon

Example of a Self Expanding Device

Place the device in the end of the catheter and position within the artery
Expand the device to final diameter by releasing it from the end of the catheter

- c) Rid the tester of air bubbles.
- d) Measure OD along the length of the deployed device under static conditions in desired pressure range (typically 160/80). Generic devices positions include left end, center, and right end.
- e) Record the positions measured including the location on the device on the Physiological Set Up data sheets.
- f) Transfer the data to the Physiological Set Up spreadsheet. Formulas for calculating the target %OD radial strain for the accelerated fatigue test using thick walled vessels is built into the spreadsheet.
- g) Convert the measured %OD strain to %ID strain in the thin walled vessel. The mean %ID is the %ID strain required in the accelerated fatigue test. (Equation 2)
- h) Calculate the target %OD for the accelerated fatigue test using the mean %ID of the thin wall and the %ID/%OD strain ratio (Equation 1) for the thick walled vessel.

Equation 4: Accelerated Fatigue Test Target %OD = Mean %ID (for deployed devices in the physiological artery) / %ID/%OD strain ration for the thick wall vessels.

9.0 TEST SET UP VALIDATION: PHYSIOLOGICAL

- a) Test set up is validated by comparing the OD vs. pressure slope of the device deployed positions with an empty position along the physiological artery. The OD is evaluated throughout the full pressure range of the pending test; this indirectly ensures that the device is in contact with the artery wall under test conditions.
- b) Measure and record the OD (mm) at a single position along the deployed device throughout the range of pressures being measured (60, 80, 100, 120, 140, 160, 180, 200). Measure and record the OD(mm) at a single empty position throughout the range of pressures being measured (60, 80, 100, 120, 140, 160, 180, 200)
- c) Record the positions measured including the location on the device on the Physiological Set Up data sheets and the Physiological Set Up spreadsheet.
- d) Analyze the data by graphing the OD vs. Pressure of both positions. The slope of the device deployed position must differ from that of the empty position. If the set up is not valid, discuss the results with the Operations Manager.

10.0 ACCELERATED TEST DEVICE DEPLOYMENT

- a) Deploy the test device. Customer must supply the pressure and time if a balloon expanded device is being deployed, as well as the deployment configuration in the arteries and around the tester. High speed camera is available as an option to confirm deployment.
Example of a Balloon expanded

Place the device on the balloon catheter and position within the artery
Pressurize the device to dictated pressure (xx atm) and maintain pressure for dictated time interval (xx sec)
Release the pressure and remove the balloon

Example of a Self Expanding Device

Place the device in the end of the catheter and position within the artery
Expand the device to final diameter by releasing it from the end of the catheter

- b) Record the device deployment on the Device Deployment Form.
- c) Mark the left and right ends of the device on the outside of the artery, providing a reference point for migration monitoring.

11.0 ACCELERATED FATIGUE TEST START UP

- a) Determine Test command parameters. At the test frequency adjust the displacement controls to obtain a strain level close to the target radial strain calculated in 8.0 h. If necessary adjust the pressure head and PID terms to achieve a stable sine wave.
- b) Apply test parameters to the WinTest Control System.
- c) If test warrants, additional accessories may be utilized to achieve and maintain the test target %OD. These accessories include throttles, clamps, and devices approved by the Operations Manager.

12.0 TEST SET UP VALIDATION: ACCELERATED FATIGUE TEST

- a) Test set up is validated by comparing the max OD of the center of the device deployed positions with the max OD of the empty artery on either side of the device under dynamic conditions. This validation may not be possible for all device deployment configurations, for example devices deployed very closely to the fittings or the entire length of the artery. If the configuration limits this validation it will be discussed with the customer.
- b) Measure and record the OD (mm) and OD% radial strain at the center of each device and on the empty artery adjacent to the left and right ends of the device.
- c) Record the data on the Dynamic Mapping data sheet and transfer the data to the Dynamic Mapping spreadsheet. The spreadsheet contains the formula for calculating the max OD from the observed measurements.
- d) Calculation:
- e) $OD_{max} = OD_{avg}(1 + (.5 * \%OD \text{ strain})/100)$
- f) Analyze the data by graphing the OD (mm) vs. position. The max OD of the deployed device position must be greater than the max OD of the empty arteries. If the set up is not valid, discuss the results with the Operations Manager.

13.0 MONITORING

- a) Set and apply the pressure limits, displacement limits, and pressure underpeak to prevent damage to the tester due to fluctuations.

- b) Create a new job folder on the server. C:/Data Files/ WinTest Data/ JOB#. This data is backed up on the server. All data concerning the current test should be stored here.
- c) Set autolog function: daily journal of the tester and data. Save in the new job folder.
- d) Determine the daily monitoring positions. Generic positions include the left end, center, right end of a device, and an empty artery position. These positions may be modified to include overlapping positions or other positions dictated by the protocol. Record the positions on the Daily Data Sheet.
- e) Daily Monitoring
 - (1) Record cycle count, temperature, pressure, and displacement levels on the Daily Data Sheet
 - (2) Observe devices for migration.
 - (3) Observe and record the %OD and ODmm for each pre-determined position.
 - (i) WinTest software measures the %OD strain using the calculation: $\text{Strain\%} = \frac{\Delta\text{OD}}{\text{ID}_{\text{avg}}} \times 100$; however, the draft standards* for determining %OD strain define it as: $\text{Strain\%} = \frac{\Delta\text{OD}}{\text{ID}_{\text{min}}} \times 100$. Medical Device Testing Services compensates for this discrepancy by recording the WinTest measurement and calculating the correct standard %OD Strain during data entry ($\text{WinTest \%OD strain} / (1 - (.5 * \text{WinTest \%OD strain} / 100)) = \text{Strain\%} = \frac{\Delta\text{OD}}{\text{OD}_{\text{min}}} \times 100$).
 - *ASTM Draft WK4370: Standard Test Methods for in vitro Pulsatile Durability Testing of Vascular Stents. ASTM Committee FO4. June 2006
 - (4) Save daily scope capture to the appropriate job folder.
 - (5) Enter the data into the electronic Data spreadsheet.
 - (6) Calculate the %OD average. If necessary adjust the displacement levels to maintain the target %OD.
- f) If an abnormal data point is observed, continue with the list below until the situation has been addressed:
 - (1) Check that the laser micrometer is positioned correctly, re-measure the data point.
 - (2) Purge the system and re-measure the data point.
 - (3) Notify a senior lab technician or Operations Manager to assess the situation:
 - (a) Analyze the trend in data
 - (b) If necessary inspect the device endoscopically
 - (c) If there is a suspected failure the Lab Technician, Operations Manager or Director of Testing will contact the customer.
- f) Prepare a weekly Customer Update including strain, temperature, pressure, and number of cycles to be emailed once a week, or per customer's protocol.

14.0 TEST SHUTDOWN: PROTECTIVE LIMITS OR MALFUNCTIONS

- a) Retrieve the history from the show menu, record notes regarding shut down and contact the Operations Manager or senior lab personnel.
- b) The operations manager or lab personnel may resume the test and/or contact the customer at their discretion, based on the shut down specifications.

15.0 TEST COMPLETION

- a) Document the date of test cycle completion.
- b) Inspect the devices while still on the instrument. Carefully place the 30x/10x endoscope within the artery and while looking through the optic coupler thread the scope through the center of the device. Video inspections are also available as an option.
- c) Inform the customer of the test completion and inspection results.
- d) Remove the test arteries from the instrument per customer's protocol. Generally this step is accomplished by stretching the latex off of the fittings, or cutting the arteries from the instrument with a snub nose scissor.
- e) Return the test samples, physiological samples, and any remaining samples to the customer.
- f) If requested complete a test report within 2 weeks of test completion. Send the report for revisions. Once the report has been finalized send a signed cover sheet along with a cd containing all of the customer's raw data.
- g) If no report was requested, send the cd containing all of the customer's raw data within 2 days of test completion.

16.0 PROJECTED SCHEDULE FOR TESTING.

SAMPLE NUMBER	CYCLES	FREQUENCY
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CYCLE START DATE:

PREDICTED CYCLE END DATE:

These times reflect an estimate for the time to complete the various stages of the testing. As the test proceeds, more definitive dates may be established to account for set up, artery adjustments, data acquisition, problems, etc.

Revision History:

Version	Change	Date