STANFORD UNIVERSITY
W.W. HANSEN EXPERIMENTAL PHYSICS LABORATORY
GRAVITY PROBE B, RELATIVITY GYROSCOPE EXPERIMENT
STANFORD, CALIFORNIA 94305-4085

RE-INSTALL PROBE VACUUM CAN

GP-B SCIENCE MISSION PROCEDURE

2 June, 1999

PREPARED _____ _____
D. Bardas, Integration Manager Date

APPROVED _____ _____
D. Bardas, Integration Manager Date

APPROVED _____ _____
J. Janicki, Safety Engineering Date

APPROVED _____ _____
D. Ross, Quality Assurance Date

APPROVED _____ _____
S. Buchman, Hardware Manager Date

TABLE OF CONTENTS

1 SCOPE 4
1.2 Acronyms 4
2 REFERENCES 4
2.1 Plans and Procedures 4
2.2 Drawings 4
3 GENERAL REQUIREMENTS 5
3.1 Environmental Requirements 5
3.2 Integration and Test Personnel 5
3.3 Safety 6
3.4 Quality Assurance 6
3.5 Red-line Authority 6
4 REQUIRED EQUIPMENT 8
4.1 Flight Hardware 8
4.2 Ground Support Equipment 8
4.3 Tools and Miscellaneous 8
5 VERTICAL ALIGNMENT OF PROBE 9
5.1 Initial Probe Preparation Operations 9
5.2 Install Alignment Frame on PM; Center Probe 9
5.3 Precision Alignment of QBS Axis 12
5.4 Section 5 Completed: 14
6 INSTALL THE PROBE VACUUM SHELL 15
6.1 Position Vacuum Shell 15
6.2 Lower Probe into Vacuum Shell 17
6.3 Remove Vacuum Shell Stand 18
6.4 Section 6 Completed: 18
7 PROCEDURE COMPLETION 19
8 DATA BASE ENTRY 19

1 SCOPE

This procedure describes the method used for installing the Probe Vacuum Shell after the SIA has been integrated into the probe. This procedure assumes that the Probe is mounted on the Precision Manipulator (PM), horizontally following integration of the readout hardware and caging assemblies. This procedure begins with turning the probe vertical and finishes with the tightening of the vacuum can bolts at STA200. The Vatterfly valves can be installed on the Top Hat and the X-Flange P-040 before of after this procedure

1.2 Acronyms

The following acronyms are used in this document

PM	Precision Manipulator
SIA	Science Instrument Assembly
VS	Probe Vacuum Shell
ITD	Integration and Test Director

2 REFERENCES

2.1 Plans and Procedures

P0059	GPB Contamination Control Plan
P0057	Stanford Magnetic Control Plan
P0419	Operations Manual for the Precision Manipulator
P0205(SM)	Mount Probe in Precision Manipulator

2.2 Drawings

1C34111	Probe-C Phase IV-C Installation
1C34204	Quartz Block Structure
1C34146	Vacuum Shell
1C34124	Vacuum Shell assembly
1C34103	SIA/Probe Interface Drawing

3 GENERAL REQUIREMENTS

ONR representative, QA and Safety to be notified prior to beginning this procedure

3.1 Environmental Requirements

This procedure will be conducted in the Stanford Class 10 CLEANROOM in the HEPL facility.

3.1.1 Cleanliness

The Class 10 clean room where this integration takes place shall be maintained at the cleanliness levels per GPB Contamination Control Plan P0059. Certified Class 10 cloth garments shall be worn in the Class 10 clean room.

3.1.2 Particulate Contamination

All parts and tools shall be cleaned at least to the cleanliness levels of the rooms where they are used for assembly or testing. In addition, all flight parts shall be maintained at level 100 cleanliness per GP-B Contamination Control Plan (P0059). Take all necessary precautions to keep tools and handling equipment free of particulate contamination.

To the maximum extent possible, personnel shall keep their bodies and garments downstream of the SIA, relative to the HEPA wall.

3.1.3 Magnetic Contamination

All parts and tools shall be screened per Procedure P0057. All parts and tools shall be cleaned using methods consistent with achieving Mil Spec Level 100 cleanliness. In addition, all parts shall be maintained at level 100 cleanliness per GP-B Magnetic Control Plan, P0057. Take all necessary precautions to keep tools and handling equipment free of particulate contamination. Tools to be cleaned with Ethyl Alcohol prior to use, or when contaminated.

3.1.4 Electrostatic Discharge Control

To prevent electrostatic charge buildup, until the vacuum can is fully on the QB/T the particle ionizer shall always be upstream of the QB/T relative to the fan wall and the PM and the QB/PM shall be grounded.

3.2 Integration and Test Personnel

3.2.1 Integration and Test Director

The Integration and Test Director (ITD) shall be Dr. Doron Bardas or an alternate that he shall designate. The ITD has overall responsibility for the implementation of this procedure and shall sign off the completed procedure and relevant sections within it.

3.2.2 Integration Engineers and other personnel

All engineers and technicians participating in this procedure shall work under the direction of the ITD who shall determine personnel that are qualified to participate in this procedure. Participants in this procedure are expected to be D. Bardas, G. Asher, C. Gray with assistance from LMMS (particularly G. Reynolds) at certain times.

3.3 Safety

3.3.1 General

Personnel working in the Class 10 Cleanroom must be cognizant of the base of the Precision Manipulator, and take special care to avoid tripping or bumping into it.

3.3.2 Hardware Safety

Extreme care must be taken to avoid bumping or scratching the QB/Telescope. Also now that the SIA is fully integrated into the probe, care must be taken to avoid snagging any cables, wires, or plumbing connections. (See also preparations prior to taking the probe vertical (section 5.1)

3.3.3 Maximum Number of People in Cleanroom

Under normal operating conditions, there shall be no more than 5 people in the Class 10 Cleanroom. This is to avoid violating legal make up air requirements, and to provide an efficient workspace. Exceptions must be for short periods only, and approved by the ITD.

3.4 Quality Assurance

Integration shall be conducted on a formal basis to approved and released procedures. The QA program office shall be notified of the start of this procedure. A Quality Assurance Representative, designated by D. Ross shall be present during the procedure and shall review any discrepancies noted and approve their disposition. Upon completion of this procedure, the QA Program Engineer, D. Ross or her designate, will certify his concurrence that the effort was performed and accomplished in accordance with the prescribed instructions by signing and dating in the designated place(s) in this document. Discrepancies will be recorded in a D-log or as a DR per Quality Plan P0108.

3.5 Red-line Authority

3.5.1 Authority to red-line (make minor changes during execution) this procedure is given solely to the ITD or his designate and shall be approved by the QA Representative. Additionally, approval by the Hardware Manager shall be required, if in the judgment of the ITD or QA Representative, experiment functionality may be affected.

3.5.2 Procedure Computerization Special Requirements

Because of cleanliness requirements in the Class 10 room, and to conveniently record data directly into the procedure thus generating the "as-built" document, the procedure will be handled in a paperless fashion until completed. A Laptop computer containing an electronic version of this procedure will be operated by the ITD or QA Representative and data shall be recorded by typing directly into the electronic file.

"As-Built" Procedure

Following completion of the procedure, a hard copy of the "as-built" procedure shall be printed ***and signed off by all the designated parties***. It shall then be filed, including an electronic copy into the data base. The electronic editing of this document shall be as follows:

Data will be inserted into the document using normal font, i.e. non-bold, non-italic

"Signatures" shall be designated by **BLACK CAPITAL BOLD LETTERS**.

"Redlines" shall be in ***RED BOLD ITALICS*** to make them distinguishable both on the Laptop screen and on the hard copy printout.

If available, digital pictures shall be inserted into the document where appropriate.

4 REQUIRED EQUIPMENT

4.1 Flight Hardware

Hardware	Part Number	Quantity	Serial # or LDC
SIA Kit	23170-101	1	
Probe-C Assembly, Without Sunshade	1C34115-102	1	
Vacuum Shell Assembly	1C34124-101	1	
Screw, Socket Head, Locking	1C34465-101	30	
Belleville Washer	1C34360-103	150	
C-seal, Vacuum Shell	1C34313-105	1	

4.2 Ground Support Equipment

- Precision Manipulator (PM)
- PM Alignment Frame
- Probe Vacuum Shell Stand
- Delrin Cup for Stand
- 2" elevation spacer under cup

4.3 Tools and Miscellaneous

- Allen Wrench, various
- Seekonix 30 in-lb torque wrench Calibration date _____
- Seekonix 48 in-lb torque wrench Calibration date _____
- Variable setting torque wrench Calibration date _____
- Fluke 77 Multimeter or equivalent Calibration date _____
- Starrett No.25-441, 1 mil resolution dial (2 per ring, 4 total) for measuring alignment
- SPI Protracto Level Calibration date _____

5 VERTICAL ALIGNMENT OF PROBE

Started: _____ at:_____ Signed: _____
date time ITD or QA Representative

5.1 Initial Probe Preparation Operations

5.1.1 Ensure that no items protrude beyond the QBS and that the vacuum can will not impact on the cables especially in the Spider region. This envelope, including that when it is cold should be verified by direct measurement of the location of the vacuum can, according to LMMS drawing 1C34103 rev D. (SIA/Probe Interface Drawing)

5.1.2 If problems are noted in 5.1.1, redressing of cables, wires, FOs etc., shall take place if determined by the ITD with the concurrence of the QA Representative.

Disposition./.sign-off: _____ Date _____
ITD

Concurrence: _____ Date _____
QA Designated Representative

5.1.3 Rotate the Probe from horizontal to vertical, using the socket wrench on the Hex Nut on the Probe Yoke Ring Collar.

5.1.4 Use the SPI Protracto level and the STA200 yoke alignment mechanism to align the QBS vertical in the plane parallel to the HEPA wall to within ± 0.2 degree. (Goal ± 0.1 degree)

5.1.5 Use the SPI Protracto level and the PM tilt alignment mechanism to align the QBS vertical in the orthogonal plane to that of 5.1.2 to within ± 0.2 degree. (Goal ± 0.1 degree)

5.1.6 Raise the probe up high enough to clear the brackets, located on each side of the of the PM, for the alignment frame to be installed without endangering the spider hardware.

5.2 Install Alignment Frame on PM; Center Probe

Started: _____ at:_____ Signed: _____
date time ITD or QA Representative

5.2.1 Slide the arms of the Alignment Frame into the Alignment Frame slots on the PM. Align the 4 bolt holes of the Frame and slots and bolt down snug but not tight, to allow adjustment.

5.2.2 Use the SPI Protracto level to level Frame arms to horizontal within approx. 0.3 deg., while maintaining approximate center of the half-arcs around the projected probe axis.

5.2.3 Attach the upper semicircular arcs and the lower semicircular arcs onto the arcs of the main fixture with a bolt, washer and wing nut on each side. *Be sure that all the dial indicators and micrometers are retracted.* Recheck Frame alignment to horizontal.

5.2.4 Lower the probe QBS into the rings, carefully adjusting the frame, with all dial indicators and micrometers retracted, so that the QBS is concentric to within approx. 0.1 inch radially with the rings.

5.2.5 After adjustments, tighten the four bolts holding the alignment frame to the PM and check the concentricity again. Iterate 5.2.4 and 5.2.5 until the QBS is concentric to within approx. 0.1 inch with the rings.

5.2.6 Lower the Probe until the contact points of the dial indicators are approximately 2" below the bottom of the yoke worm gear housing.

5.2.7 Rotate the probe that no dial indicators or micrometers (when extended) will interfere with the any structures and will slide along the smooth parts of the when the probe is raised and lowered.

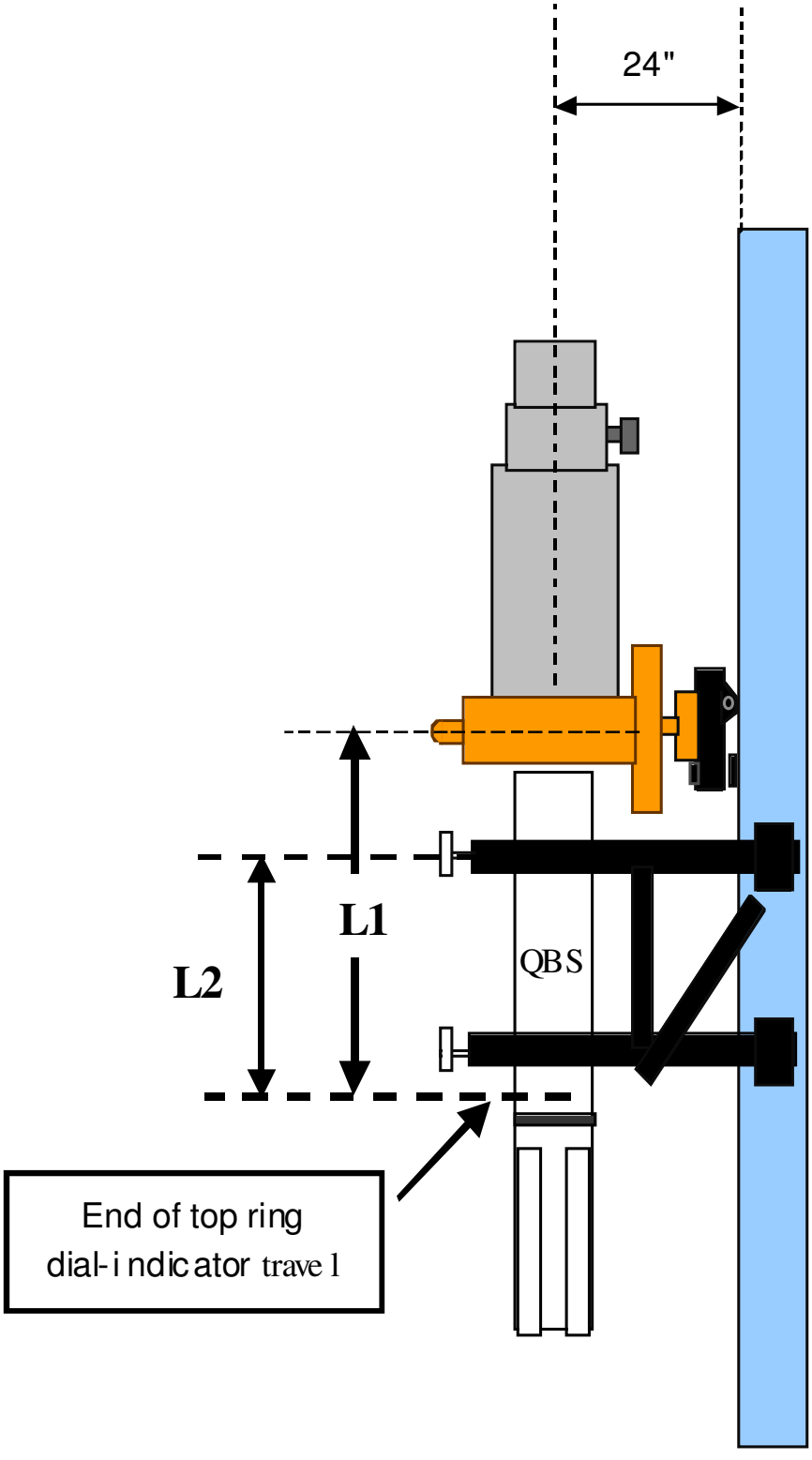

Figure 1. Alignment Setup Showing Essential Dimensions

5.3 Precision Alignment of QBS Axis

Started: _____ at:_____ Signed: _____
date time ITD or QA Representative

5.3.1 Remove the constraints holding the stems of the two dial indicators on the top ring only and ease them radially inwards so that their Delrin tips touch the QBS. Ensure probe rotation consistent with 5.2.7

NOTE: One of the dials reads displacement of the QBS due to tilt of the probe around the STA200 yoke axis, while the other dial indicator reads displacements due to tilt of the PM mounting plate in the orthogonal direction.

5.3.2 Turn the fiducial markers on each dial indicator's window to match the dial's fine scale pointer. Record the absolute complete reading (coarse plus fine) of each dial indicator. Record the actual complete reading of each dial indicator in mils as **N_d, M_d,** for DOWN Yoke tilt and PM plate tilt displacements .

Probe DOWN:
Yoke tilt = **N_d** = mils PM plate tilt = **M_d** = mils

5.3.3 Raise the Probe until the contact points of the dial indicators are approximately 1 in. above the bottom of the smooth cylindrical section of the QBS. Record the actual complete reading of each dial indicator in mils as **N_u, M_u**. for UP Yoke tilt and PM plate tilt displacements .

Probe UP:
Yoke tilt = **N_u** = mils PM plate tilt = **M_u** = mils

5.3.4 As a result of the dimensions shown in Figure 1, a calculation based on nulling out both probe tilt angle misalignments, relative to the PM direction of travel, results in adjusting the tilt in each direction by (probe in UP position):

YTA_u =Yoke tilt adjustment(up): = $(N_d - N_u) \times (L1/L2)$ = mils
PMA_u = PM plate tilt adjustment(up): = $(M_d - M_u) \times (L1/L2)$ = mils

where **L1** and **L2** are as shown in Figure 1.

5.3.5 Adjust the tilts in both directions so that **N_u (new) = N_u (old) + YTA_u** and
M_u(new) = M_u (old) + PMA_u

5.3.6 Now let: **$N_u = N_u$ (new), and $M_u = M_u$(new)**

5.3.7 Lower the Probe until the contact points of the dial indicators are approximately 2" below the bottom of the yoke worm gear housing. Record the actual complete reading of each dial indicator.

Probe DOWN:
Yoke tilt = **N_d** = mils PM plate tilt = **M_d** = mils

5.3.8 As a result of the dimensions shown in Figure 1, a calculation based on nulling out both probe tilt angle misalignments, relative to the PM direction of travel, results in adjusting the tilt in each direction by (probe in DOWN position):

YTA_d =Yoke tilt adjustment(down): = $(N_d - N_u) \times [(L1-L2)/L2)]$ = mils
PMA_d = PM plate tilt(down): = $(M_d - M_u) \times [(L1-L2)/L2)]$ = mils

where **L1** and **L2** are as shown in Figure 1.

5.3.9 Repeat above steps (ending in the probe DOWN position) until the displacements **(N_d - N_u)** and **(M_d - M_u)** are less than 10 mils each (goal ≤ 5 mils each).

The longitudinal axis of the QBS is now sufficiently parallel to the direction of travel of the PM.

5.3.10 Upon completion of alignment, with the QBS in the down positions , turn in the 3 micrometers on each ring until they just contact the QBS then back them off by 0.001 inch, taking care not to disturb the readings on the dial indicators.

5.4 Section 5 Completed:

Integration Engineer(s) _____ Date _____

_____ Date _____

Discrepancies if any:

Disposition./.sign-off: _____ Date _____
ITD

Concurrence: _____ Date _____
QA Designated Representative

6 INSTALL THE PROBE VACUUM SHELL

Started: _____ at:_____ Signed: _____
date time ITD or QA Representative

6.1 Position Vacuum Shell

Calculate the theoretical difference between outer diameter (OD) of QBS and OD of VS, by looking up the ODs in Drawings 1C34146 and 1C34204.

Note: The OD of the QBS (disregard the bump) is approx. 9.55 inch. The OD of the Vac Can is approx. 9.948 inch. Thus the theoretical difference is 0.398 inch on dia. or 0.199 on radius.

6.1.1 Back off the micrometers on each ring by 0.250, note their readings and lock them.

Looking clockwise at +Z and starting with the upper micrometer facing the PM they are

micrometer (upper): 1) 2) 3)

The lower ring set is:

micrometer (upper): 4) 5) 6)

6.1.2 Remove the half arcs of the upper and lower rings

6.1.3 Raise the probe to almost touch the ceiling, so that there is ample room to work below.

6.1.4 Roll the Vacuum Shell in its Stand into positions in the Alignment Frame. Ensure that a new C-seal, P/N 1C34313-105, is in the vacuum can flange groove.

6.1.5 Replace the half arcs of the upper and lower rings and bolt securely. During this process loosen the clamp around the vacuum can so that the can becomes aligned approximately by the rings and their micrometers.

6.1.6 Raise the probe on its puck and suitable support box so that the top of the can is several inches above the top of the alignment frame. Lower the 3 stops on the VS Stand to stabilize the Stand in place.

6.1.7 Incrementally dial in each micrometer 5 mils at a time, for 40 mils. Then proceed at 2 mils at a time for another 10 mils and 1 mil at a time thereafter

6.1.8 When the Delrin tips of all the micrometers are snug against the can, (some shifting of the can may be necessary) back off each micrometer by 1 mil and record the value below.

Looking clockwise at +Z and starting with the upper micrometer facing the PM they are

micrometer (upper): 1) 2) 3)

The lower ring set is:

micrometer (upper): 4) 5) 6)

Comments:

6.2 Lower Probe into Vacuum Shell

6.2.1 Lower the Probe until the bottom of the CBS's spider hardware is just above vacuum can.

6.2.2 Attach one lead of the Digital Multimeter to the vacuum can and the other on the QBS to check for shorts. Move the multi-meter lead on the QBS as necessary, as the probe is lowered.

6.2.3 Slowly lower the probe while watching for shorts. Should a short circuit be indicated, adjust the can position to eliminate the short, and reset the micrometers equally.

6.2.4 Continue lowering the probe until the Station 200 ring is approximately 3 inches above the top of the Vacuum Shell.

6.2.5 Adjust the vacuum can clocking as necessary to line up the 30 bolt holes between the Vac Can flange and the Station 200 ring.

6.2.6 Connect the three intermediate connectors, P/N 1C34145-102, to their mating connectors on the Station 200 ring. These connect two vac can heaters, H-8P and H-9P, and the two VS Silicon Diodes, T-13P and T-14P.

6.2.7 Continue to slowly lower the QBS until its flange enters the STA200 ring on the QBS

5.2.8 Using one screw and its stack of bellevilles lower the QBS very slowly until the screw head begins to push back about 0.2 in.

6.2.7 Install 2 other socket head screws, P/N 1C34465-101, with five preinstalled Belleville washers, P/N 1C34360-103, approximately equidistantly around the vacuum can, into the Station 200 ring. Hand tighten all three screws.

Note All 5 bellevilles for these screws are installed on the screw s concave upwards.

6.2.8 Install the remaining 27 mounting screws, to hand tightness.

6.2.9 Lower the QBS until the depth of the flange relative to the STA200 surface (accounting now for the C seal) is approximately 0.700, or when resistance of the C seal becomes evident, whichever comes first.

Note: In P0376 the results were: +X* =0.649, +Y* = 0.655, -X* = 0.651, -Y* = 0.650

6.2.10 Now tighten the bolts in a star pattern using Seekonix 30 in-lb torque wrench and the Seekonix 48 in-lb torque wrench to tighten the screws to a maximum of 48 in-lb. Alternatively use a variable torque wrench for the value provided by LMMS. (Note the above numbers assume 6 lb of running torque from the locking pellet .

6.2.11 Verify that the depth of the "sealed " Vac Can flange is approx. 0.650 below STA200. This plus the torque should provide for a good seal.

6.3 Remove Vacuum Shell Stand

6.3.1 Back off the six micrometers completely, and ensure that the dial indicators are retracted.

6.3.2 Remove the upper and lower semicircular arcs of the Alignment Frame.

6.3.3 Raise the probe approximately 4 inches so the vac can clears the Delrin cup on the Stand.

6.3.4 Raise the 3 stops on the vac can Stand to lower the Stand onto its wheels, and roll it out to a corner of the room, or to the Class 1000 room.

6.3.5 Raise the probe high enough so that the bottom of the vac can clears the alignment rings.

6.3.6 Remove the rest of the PM alignment frame from the PM, by unbolting at PM.

6.4 Section 6 Completed:

Integration Engineer(s) _____ Date _____

_____ Date _____

Discrepancies if any:

Disposition./.sign-off: _____ Date _____
ITD

Concurrence: _____ Date _____
QA Designated Representative

7 PROCEDURE COMPLETION

The results obtained in the performance of this procedure are acceptable:

Integration Engineer _____ Date _____

Integration Engineer _____ Date _____

ITD _____ Date _____

The information obtained under this assembly and test procedure is as represented and the documentation is complete and correct:

QA Representative _____ Date _____

QA Program Engineer _____ Date _____

Copy discrepancies to D-Log and open Discrepancy Reports when required.

Hardware Manager _____ Date _____

8 DATA BASE ENTRY

The following data shall be entered into the GP-B Data Base:

- Name, number and revision of this procedure
- An electronic copy of this document
- A copy of the "as-built" procedure with data and pictures, when completed.