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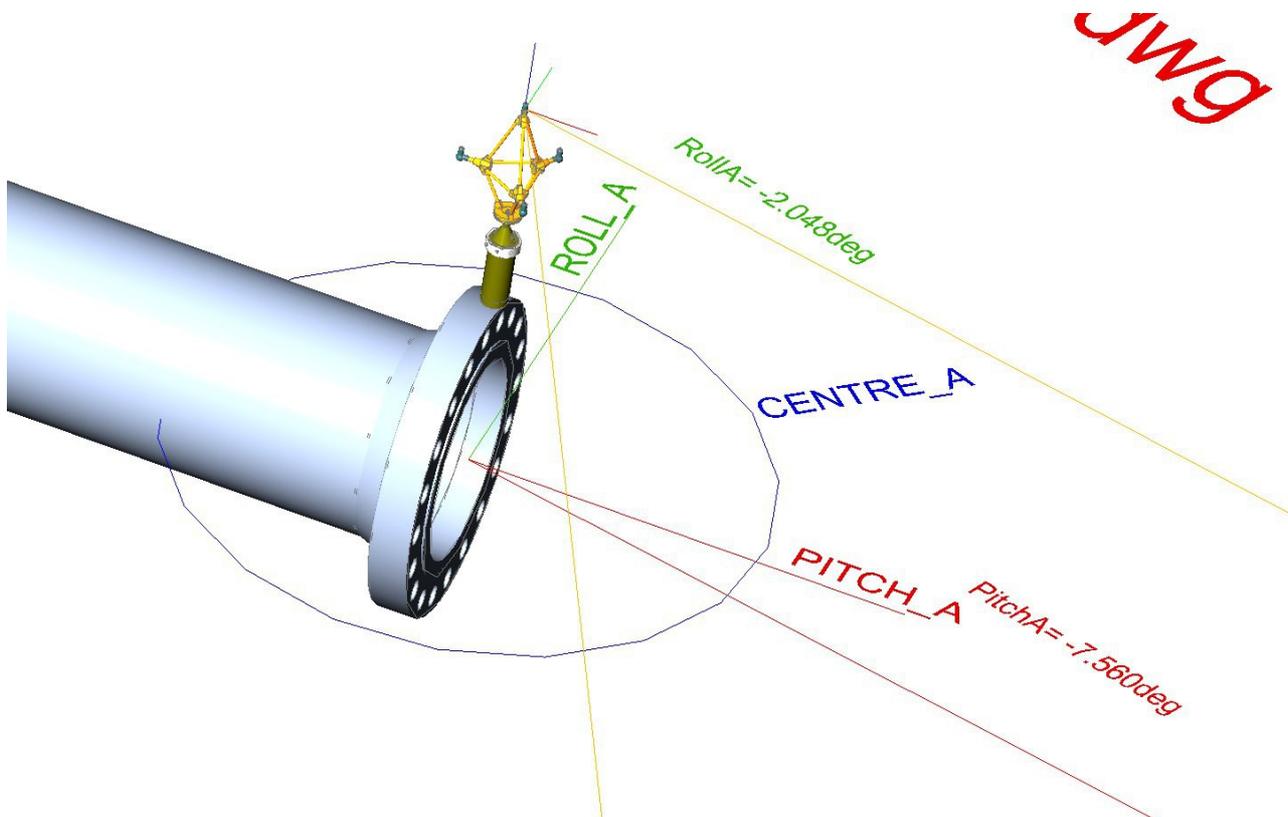
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AQUA-METRE R3000-NG

for

Spool Piece Metrology

“How to” Manual for surveyors



Document history

Document ref.	Modifications
0114-804-001	First issue
0114-804-002	Description of optional automatic measurement added to the metrology script (from AQUA-CAD version 6.00Beta20)
0114-804-003	minor update
0114-804-004	Update with AQUA-CAD 9.xx and AQUA-METRE R3000-NG version

SUMMARY

1 AQUA-METRE R3000-NG Metrology Configuration.....	4
1.1 Direct flange to flange configuration.....	4
1.2 Mid Base configuration.....	5
2 Spool piece metrology step by step.....	6
2.1 Prior to the metrology.....	6
2.2 System set-up.....	6
2.3 Launching AQUACAD.....	7
2.4 CM link activation.....	9
2.5 Reduce the CM unit squelch if necessary.....	10
2.6 Select and start the Log file.....	11
2.7 U/W Units Wake up and initialisation.....	12
2.8 CAD link activation.....	14
2.9 Metrology Script.....	15
2.10 Replay mode.....	19
2.11 Measurement Quality Check.....	20
2.12 Gravity referenced result.....	22
3 How to define a mechanical interface drawing.....	24
3.1 Centres and Axis for advanced measures:.....	26

1 AQUA-METRE R3000-NG Metrology Configuration

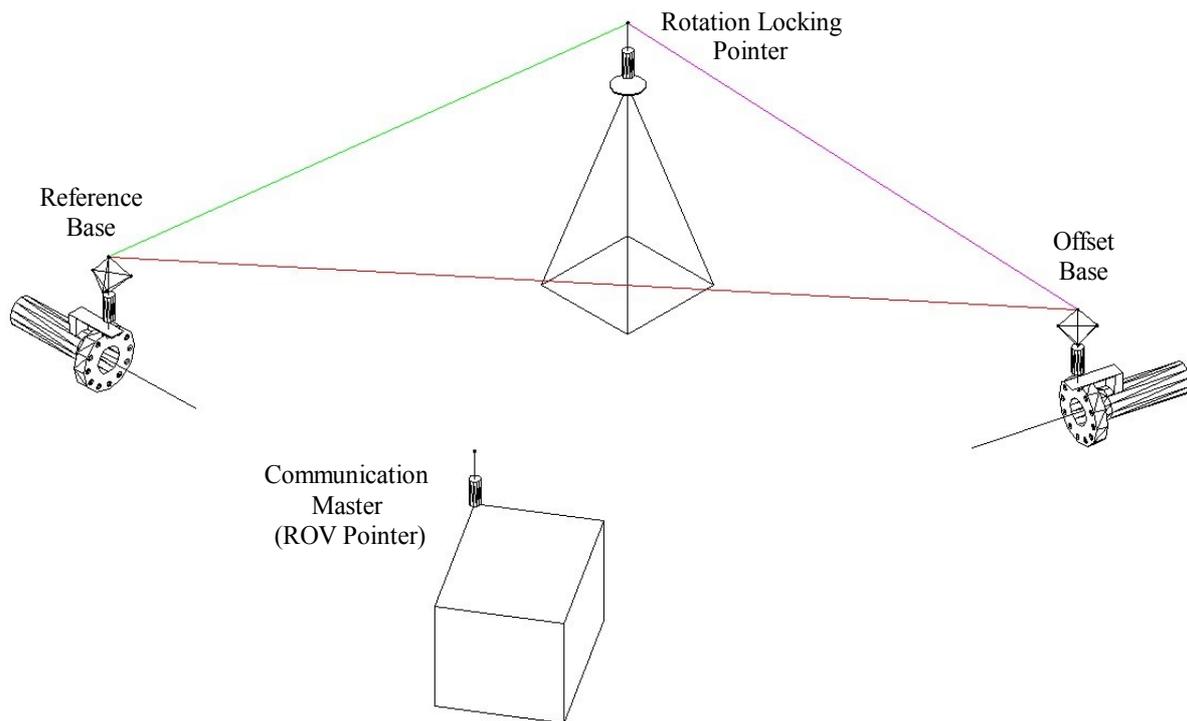
There are two AQUA-METRE R3000-NG configurations expected depending on flange-to-flange distance.

When the distance is less than about 80 metres with a clear flange-to-flange path, then a direct flange to flange metrology can be set up.

Distance greater than 80 metres may be affected by multipath due to seabed proximity, in this case a middle Base is recommended to split the metrology into two steps. This is also recommended when a clear path between flanges cannot be guaranteed (direct path masked by a large steel structure for instance).

1.1 Direct flange to flange configuration

The AQUA-METRE configuration in this case appears below:



Direct Flange-to-Flange Spool piece Metrology

One Base is set up on each flange, the first one is called the Reference Base and defines the relative coordinate system, all results will be output according to this Base coordinate system (which is defined by the interferometric frame), the other Base is called the Offset Base and attached to the second flange. One Pointer is set up on a seabed support in order to create roughly an isosceles triangle (see sketch), this Pointer is named Rotation Locking Pointer (RLP), it is used to solve the undetermined rotation around the Base-Base axis.

Each Base to flange mechanical interfaces have to be defined in a CAD drawing (.dwg) prior to starting the metrology (see in later chapter how to define this interface).

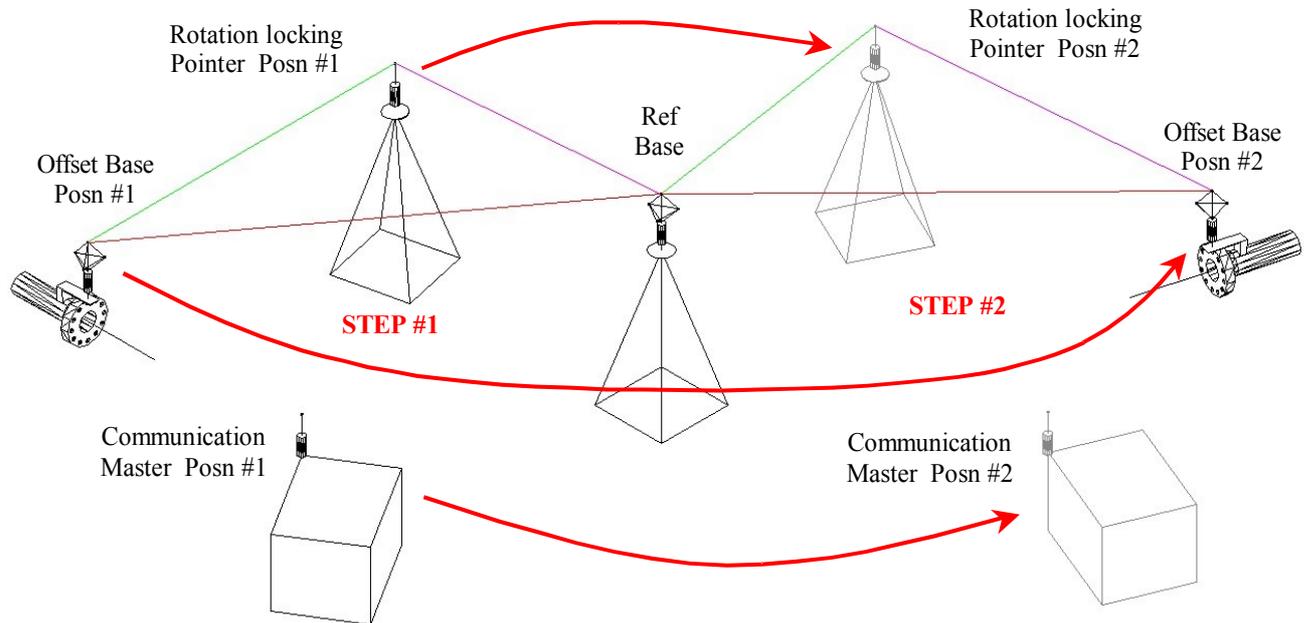
A Pointer attached to and preferably powered by the ROV is linked up to the survey room through a bi-directional RS232 channel and acts as the Communication Master, thus sending commands to and receiving results from the others units working on batteries (2 Bases and one RLP Pointer)

The metrology consists of four measurement steps:

- Step #1: Measurement of Offset Base location from Reference Base,
- Step #2: Measurement of Rotation locking Pointer from Reference Base,
- Step #3: Measurement of Reference Base location from Offset Base,
- Step #4: Measurement of Rotation locking Pointer from Offset Base,

All these acoustic measurements (four times Azimuth, Elevation and Distance) are processed by AQUACAD to produce a final drawing of the metrology including the mechanical interfaces, subsequently getting direct access to the flange-to-flange dimensions.

1.2 Mid Base configuration



Mid Base Spool piece Metrology

The Reference Base is set up on the seabed support and defines the relative coordinate system, all results will be output according to this Base coordinate system (which is defined by its interferometric frame).

THIS REFERENCE BASE MUST REMAIN STABLE AND AT THE SAME LOCATION DURING THE METROLOGY.

The metrology is then split in two steps corresponding to the two flanges:

- 1) The Offset Base is attached to the first flange. The rotation-locking Pointer is set up on a seabed support in order to create roughly an isosceles triangle with the two Bases (see sketch).
- 2) The second step consists of moving the Offset Base to the second flange and the rotation locking Pointer in order to create another isosceles triangle with the two Bases (see sketch)

A Pointer attached to and preferably powered by the ROV is linked up to the survey room through a bi-directional RS232 channel and acts as the Communication Master, thus sending commands to and receiving results from the others units working on batteries (2 Bases and one Pointer)

Like the direct flange-to-flange configuration, each Base to flange mechanical interfaces have to be defined in a CAD drawing (.dwg) prior to starting the metrology (see later how to define this interface).

Each step requires the same type of 4 acoustic measurements and output the same type of results like the direct flange-to-flange metrology.

2 Spool piece metrology step by step

This chapter describe all the steps required to make a spool piece metrology:

2.1 Prior to the metrology

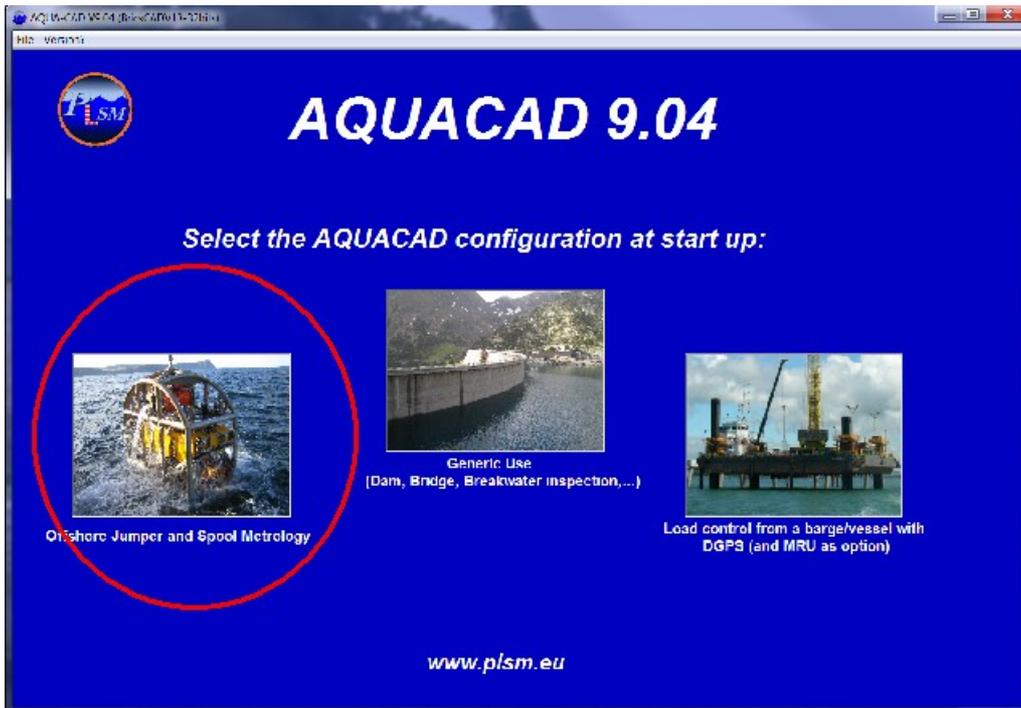
- The CM (Communication Master) Pointer must be installed on the ROV and the RS232 communication link up to the survey room checked (just use hyperterminal software or similar to check it, 9600,8,N,1), CM serial COM port must also be identified,
- The mechanical interface drawings must be prepared (see later how to define these interfaces)

2.2 System set-up

- Underwater Units (2 Bases and one Pointer) must be prepared (charged, interferometric frame mounted on each Base), **DO NOT FORGET TO IDENTIFY THE ADDRESS OF EACH UNIT**,
- If required, protection frame may be mounted on each housing,
- Plug an On/Off plug on each Underwater Unit (check the two short beeps that means “unit initialisation OK, sleeping now”, one long beep means warning encountered, two long beep means Error detected, unit can not operate),
- Bring the Underwater Units down and install them at the right location according to the chosen metrology configuration (see chapter 1 for the description of these configurations), check that each Underwater Unit is inserted at the right location.
- Ask the ROV to lay down at the proper location (one must pay attention that the ROV is orientated in order to get all Underwater Units in front of it in order to avoid any mask between the CM and Underwater Units.

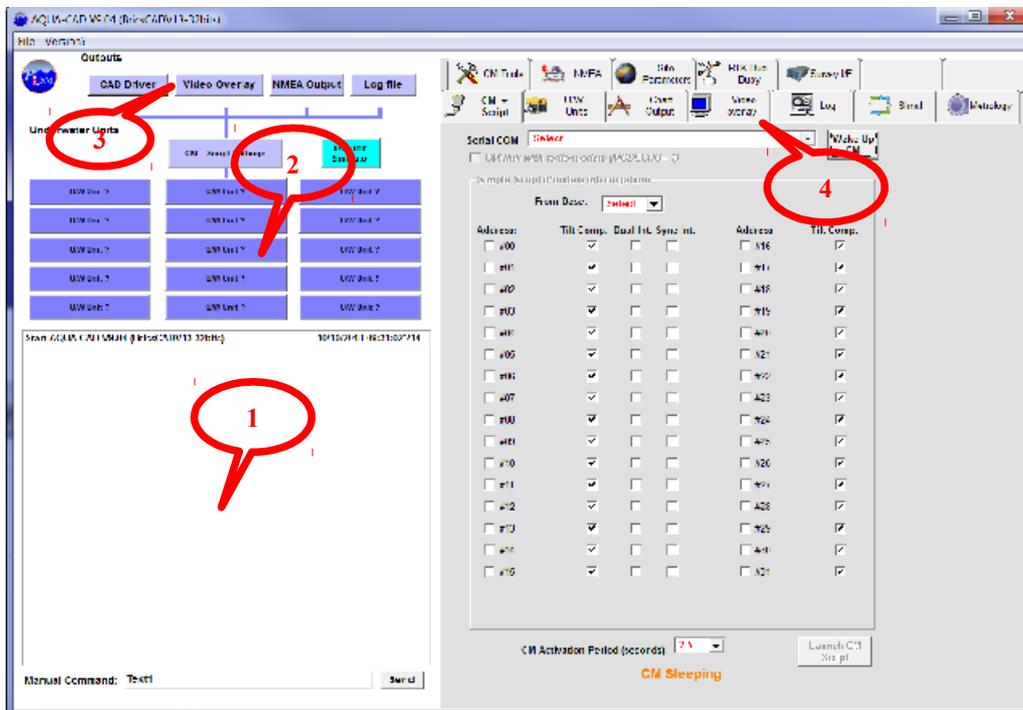
2.3 Launching AQUACAD

Launch AQUACAD software (version 9.02 or higher), choose the metrology mode:



AQUACAD start-up window (mode selection)

the user may be prompted first to activate a log file, then, the main window appears:



AQUACAD Main windows

The left part of the main window displays:

- The Log windows (1) where all incoming and out going Communication Master (CM) messages are displayed, this may help checking the system state.

- The Underwater Units frame (2) with 15 buttons, each corresponding to an underwater unit (could be a Base or Pointer), a CM & script button that corresponds to the CM settings.
- The Outputs frame (3) that groups the main software outputs: CAD/chart Output, Video Overlay output, NMEA output and Log file output.

The right part of the window displays sub-windows that may be:

- The CM & Script setting window,
- The Underwater Units setting window,
- The CAD/chart output setting window,
- *The Video Overlay output setting window (normally not used for this work),*
- The Log File output setting window,
- *The Environment setting window (not used for this work, may be used for sound speed estimation),*
- *The NMEA output setting window (normally not used for this work),*
- *The CM Tools setting window (normally not used for this work),*
- The Metrology setting window,
- The Simulation setting window (may be used for training surveyor prior to real task),

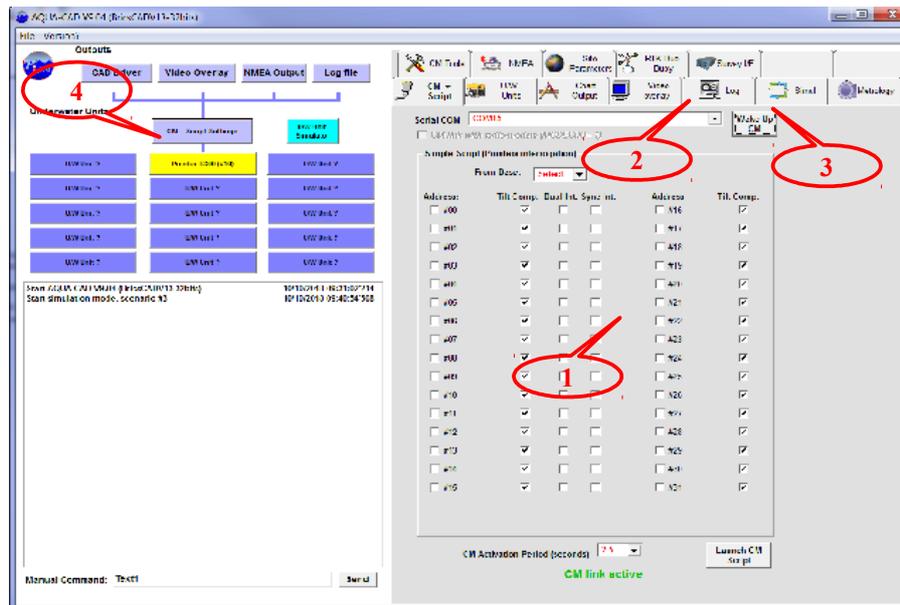
To display and then access these sub-windows, just click on the corresponding tab (4) on the top.

For some sub-windows like U/W Units for instance, it is also possible to access them by clicking on an underwater unit button on the left.

2.4 CM link activation

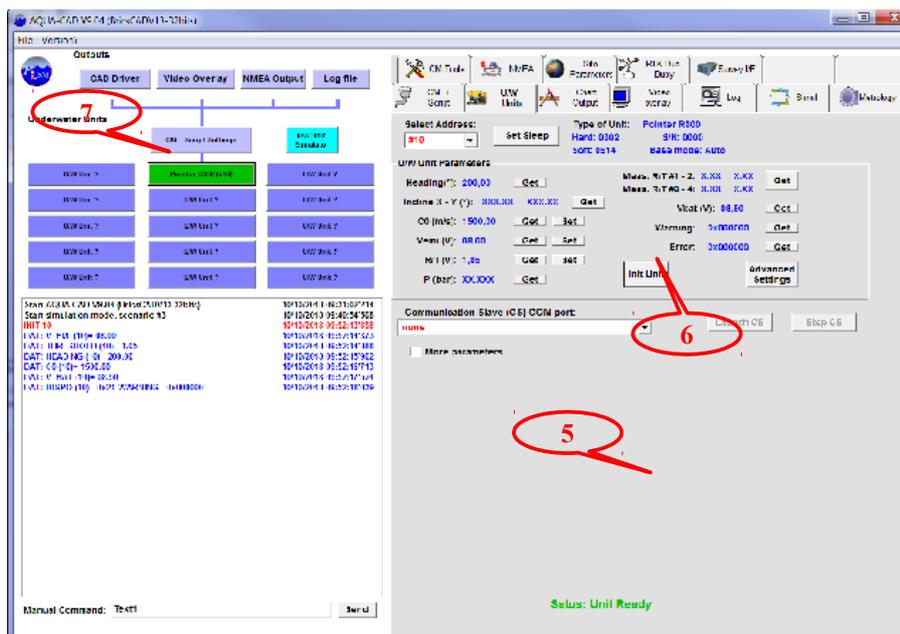
The first task to do is to activate the CM link.

- Open the “CM+Script Settings” sub-window (1) (it is normally the default one at start up), select the COM port associated with the CM Pointer on the ROV (2), make sure that the CM Pointer is powered,
- Click the “Wake Up” button (3), and wait for CM wake up (may last up to about one minute)
- When the CM link is activated, AQUACAD automatically check which type of unit and associated address acts as the CM and fills in the associated U/W Units button (4) (yellow colour means the unit is wake up but not yet initialised), the windows then appear as follow:



CM link activated, CM Unit wake up, identified but not initialised (button in yellow)

- Then click the yellow button of the CM unit to open the U/W Unit sub-window (5) and initialise it (init button 6), after few seconds it will change to green, which means it is ready for operation (7),

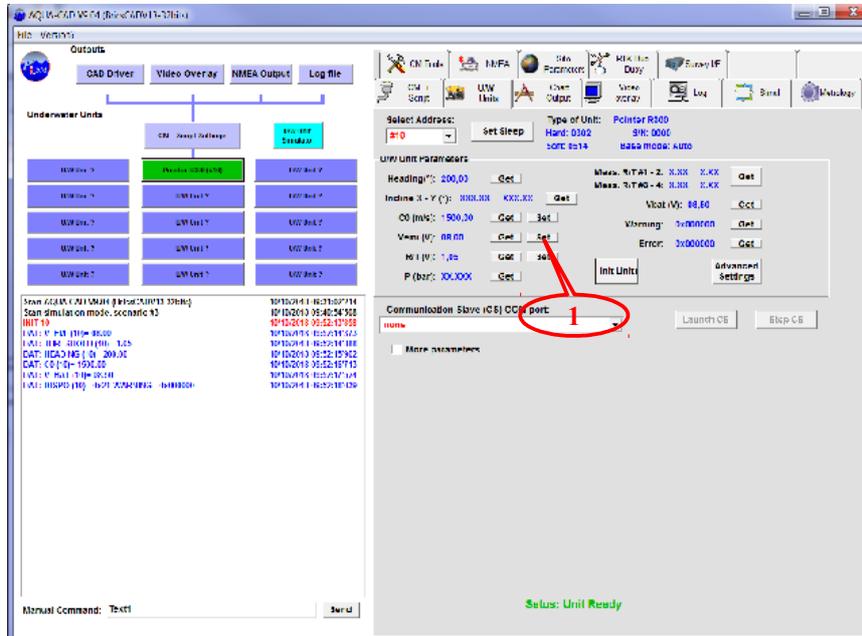


CM link activated, CM Unit initialised ready to operate (button in green)

2.5 Reduce the CM unit squelch if necessary

(this action is normally no longer required when using the R3000-NG version with better noise rejection)

The CM Pointer attached to the ROV may be affected by the ROV's noise or other acoustic devices, in this case the message “**NOISE/DEMOD ERROR**” may appear too frequently in the Log windows on the left. To avoid that, it is necessary to increase the receiver threshold level (squelch), designated as R/T in AQUACAD (Receiver Threshold). To do that:



Setting the Receiver Threshold level (R/T (V))

- Click the “Set” button on the right of R/T parameter (1), a prompt window invites you to enter the new setting, try to set it at 1.1, check that the new value has been taken into account (may differ slightly because the displayed value is actually the measured value),
- If noise persists, try to set the R/T to 1.2, avoid a level greater than 1.4 as it may affect the data link range.

Incoming «**NOISE/DEMOD ERROR**» messages at a rate of one per second do not dramatically affect the CM link. Noise like hammer on steel structure for instance will always induce noise (broadband noise), in this case, the «**NOISE/DEMOD ERROR**» messages assure proper receiver state.

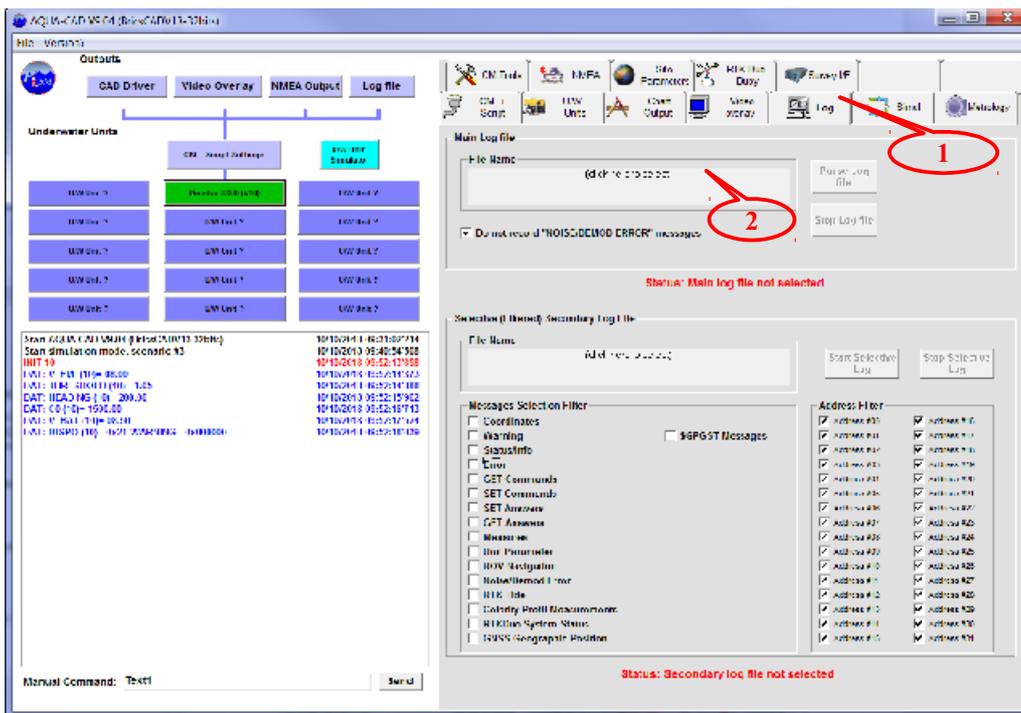
2.6 Select and start the Log file

(the log file is normally open at start-up when choosing the Metrology mode)

All commands and replies sent to/from the U/W Units are displayed in the Log windows on the left-bottom of the AQUACAD window. All commands sent appear in red, replies from U/W Units in blue, specific AQUACAD reported activities in black, and reported measures in green. The log window is not saved automatically, the user must select a file for that and start the Log (the Log file can be paused and resumed).

AQUACAD prompts user to select a Log file when launched, if not done at start-up the user can select and start a Log file later:

- Display the Log window by clicking on the “Log” tab (1).
- Click on the main Log file name area (2) and select a folder and file name, the log is then started.



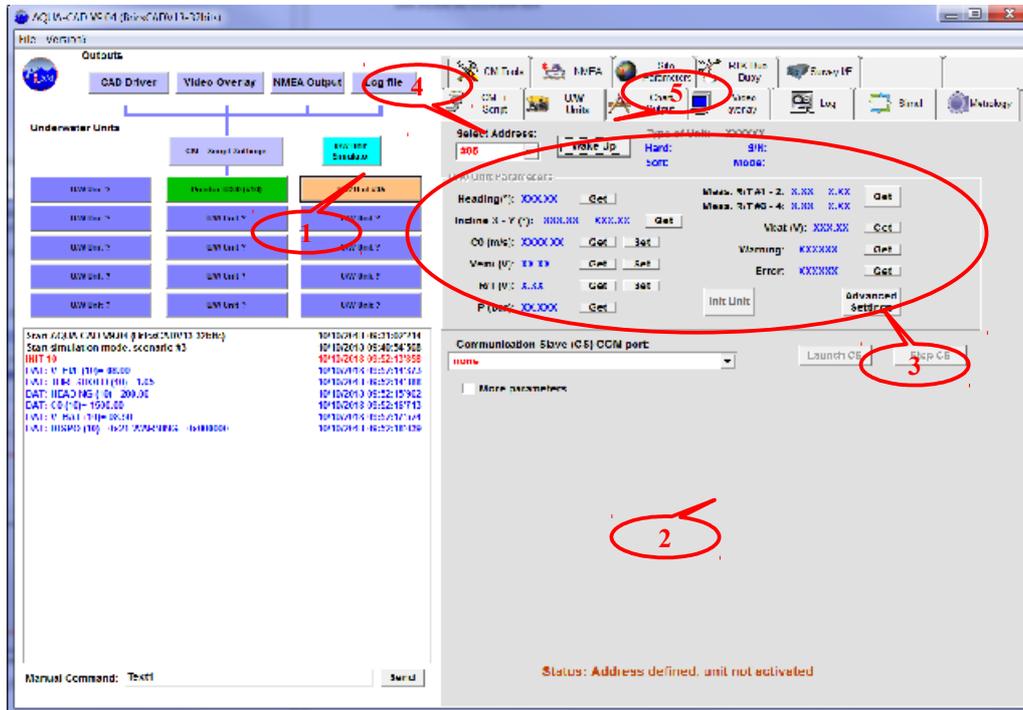
Main Log file name selected and Log started

Note: no need to activate the Selection Log file which is a secondary log file with filtered data only (data related to one address only,...)

2.7 U/W Units Wake up and initialisation

The batteries operated U/W Units are normally sleeping after switch on and first initialisation. They must be wake up and initialised again before starting the metrology acoustic measurements, to do that:

- Select a free U/W Units button (1) and click it (the Underwater Unit sub-windows (2) is then displayed on the right with all blank parameters (3)),
- Select the address (4) of the Unit to be wake up (it is why it is very important to identify the addresses of each U/W Unit before they are brought down), the U/W Unit button will then change colour,

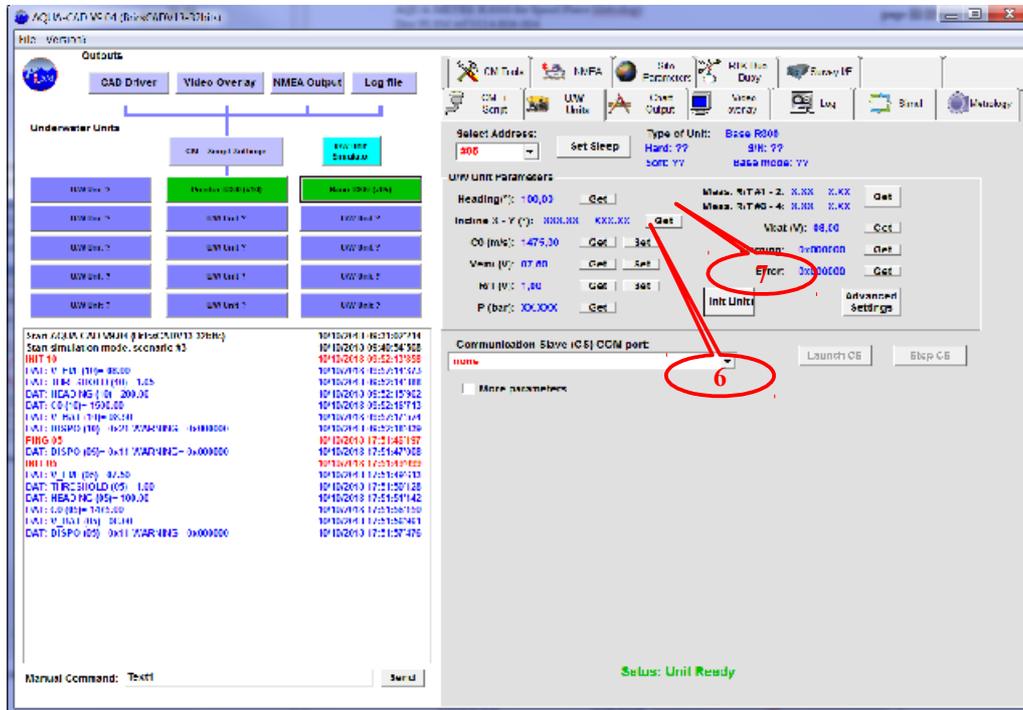


Introduction of a new Underwater Unit, address selection

- Click the “Wake Up” button (5) of the Unit, the CM will then transmit “PING” messages every second to the address selected until it receives an answer (a sleeping unit opens a listen windows for 2 seconds every 45 seconds, then a wake up may last up to 45 seconds), the button of the unit becomes yellow.
- If necessary (no automatic initialization at wake up), click then on the “Init” button in order to initialise the unit, after completion the button of the unit becomes green,

Note: during an initialisation of a Base, a lot of «NOISE/DEMOD ERROR» messages will be reported by the CM, this is normal and corresponds to the sound speed measurement performed by the Base using acoustic pulses, it may last up to 20 seconds.

- **Important!:** after initialisation, force the sound speed (celerity) of each Base with the value given by the CTD sensor by clicking the “Set” button (6) on the right of C0 (m/s) parameter,
- It is recommended to check the inclination of each unit by clicking the “Get” button associated to inclination (7), then the measured inclination will appear on the Log window and be stored in the Log file if defined and may be used for a later check (this is highly recommended in the case of a seabed supported Base that must remain stable and at the same location during the whole metrology),

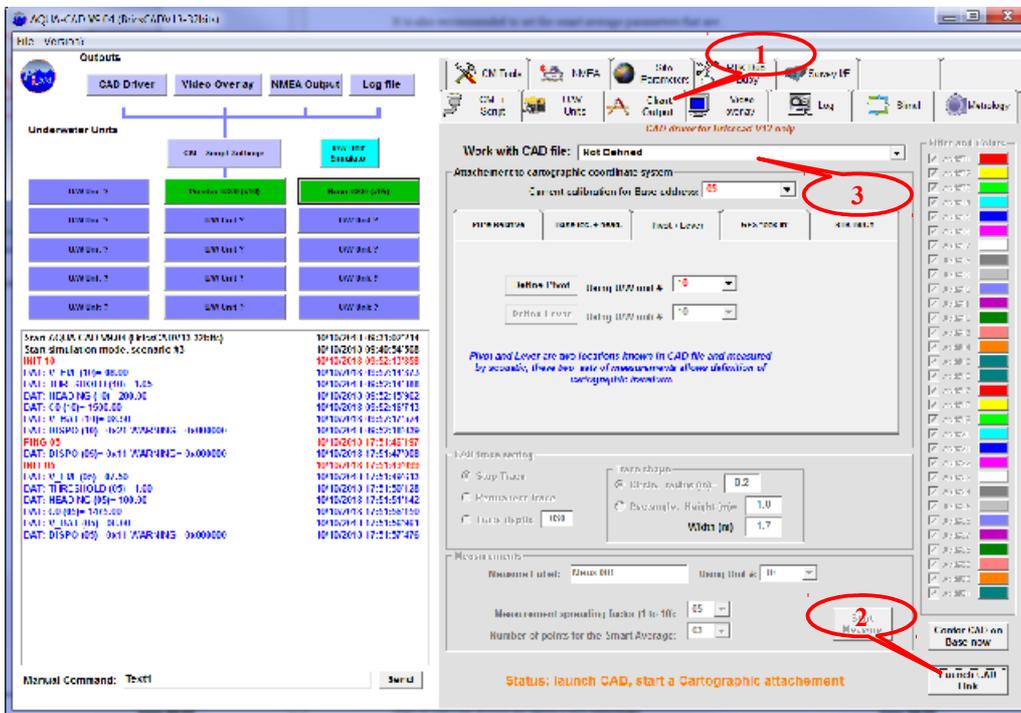


Setting sound speed of Base and checking inclination

2.8 CAD link activation

To link AQUACAD with the BricsCad CAD software:

- Display the “Chart Output” windows by clicking on the “Chart Output” tab (1).
- simply activate the link with BricsCad by clicking the button “Launch CAD Link” (2),
- in metrology mode, the CAD coordinate system is exactly the same as the reference Base coordinate system,



CAD ready: Pure relative mode, CAD launched, smart average parameters settled

User can launch BricsCad prior to activate the link with AQUA-CAD, if not, AQUA-CAD will automatically start BricsCad. Only the version 13 of BricsCad can be linked with AQUA-CAD.

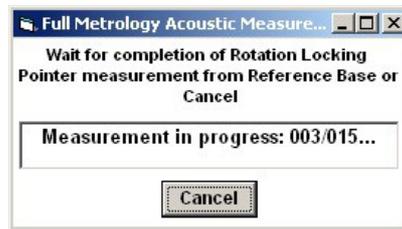
Since AQUA-CAD version 8.0, it is possible to open several drawings in BricsCad, but AQUA-CAD is still linked to a single drawing, it may be selected by user with the scroll-down list (3).

In any case, do never close the drawing linked to AQUA-CAD, but user can use the “Save As“ function instead (it will close the previous drawing, AQUA-CAD will be linked to this new drawing name).

2.9 Metrology Script

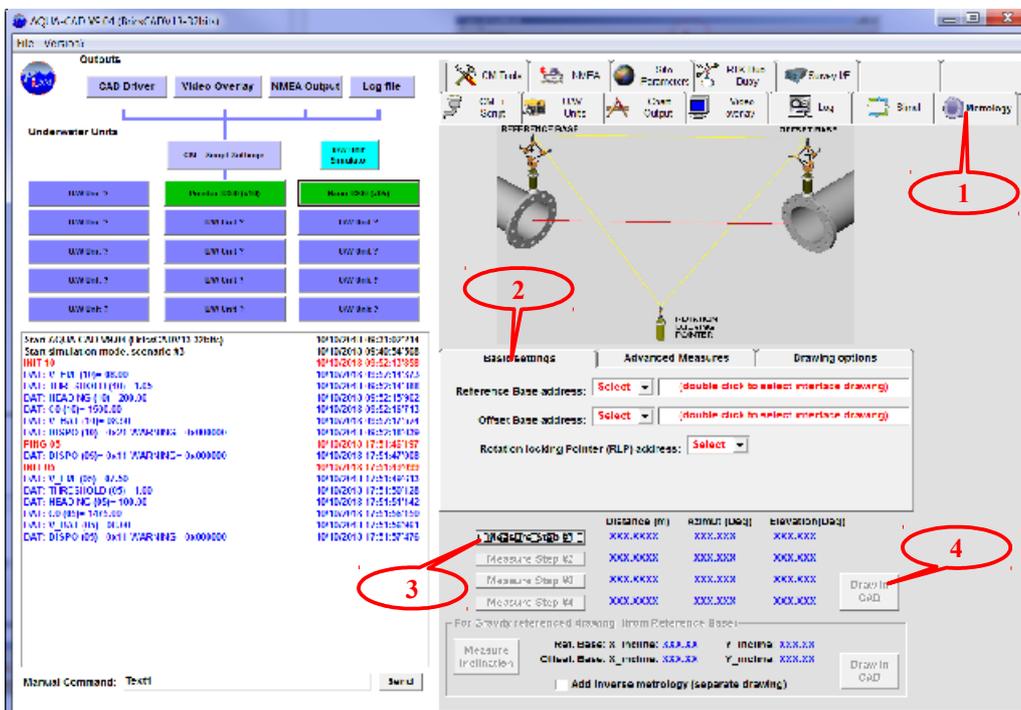
The Metrology Script will perform all required acoustic measurements and automatically draw the metrology result in the CAD drawing. To do that:

- Display the “Metrology Script” window by clicking on the “Metrology Script” tab (1),
- Select the Basic Settings tab (2) in order to enter addresses and mechanical interfaces definitions,
- Select the address and associated mechanical interface definition drawing of the Reference Base (the seabed supported Base for Mid Base Metrology configuration),
- Select the address and associated mechanical interface definition drawing of the Offset Base,
- Select the address of the rotation locking Pointer,
- Start Step #1 (3) (Offset Base from Reference Base) and wait for measurement completion, a specific window is displayed showing measurement progress as follows:



Measurement progress windows

- Start Step #2 (Rotation locking Pointer from Reference Base) and wait for measurement completion,
- Start Step #3 (Reference Base from Offset Base) and wait for measurement completion,
- Start Step #4 (Rotation locking Pointer from Offset Base) and wait for measurement completion,
- After step #4 completion, all raw acoustic measurements are output in the Log file, click then on the “Draw in CAD” button (4) to draw the metrology results CAD drawing in BricsCad.



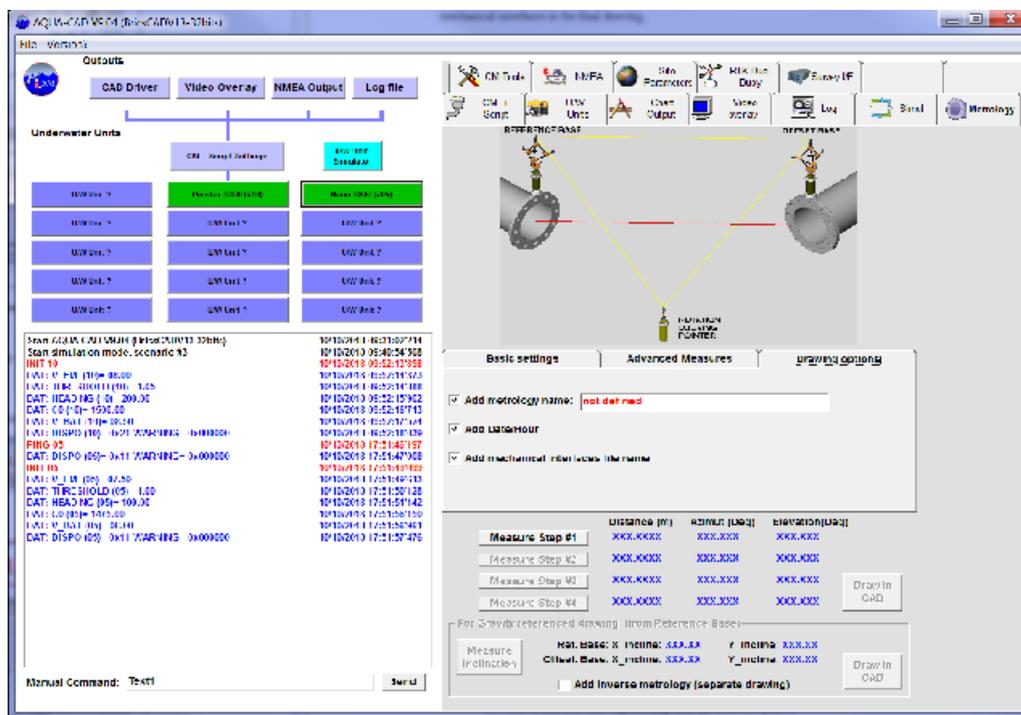
Metrology Script windows, metrology completed

Drawing options:

Since AQUA-CAD 6.0, user can have optional information being automatically added to the final CAD drawing.

To do that:

- Select the Drawing options Tab (1), the windows appears like that:



Metrology Script windows, setting drawing options

- Check the “Add Metrology Name” option, and enter the metrology name to be included in the final drawing,
- Check the “Add Date/hour” option to add the actual date and hour in the final drawing,
- Check the “Add mechanical interfaces file name” option to add the name of the selected file for the mechanical interfaces in the final drawing (important for traceability),

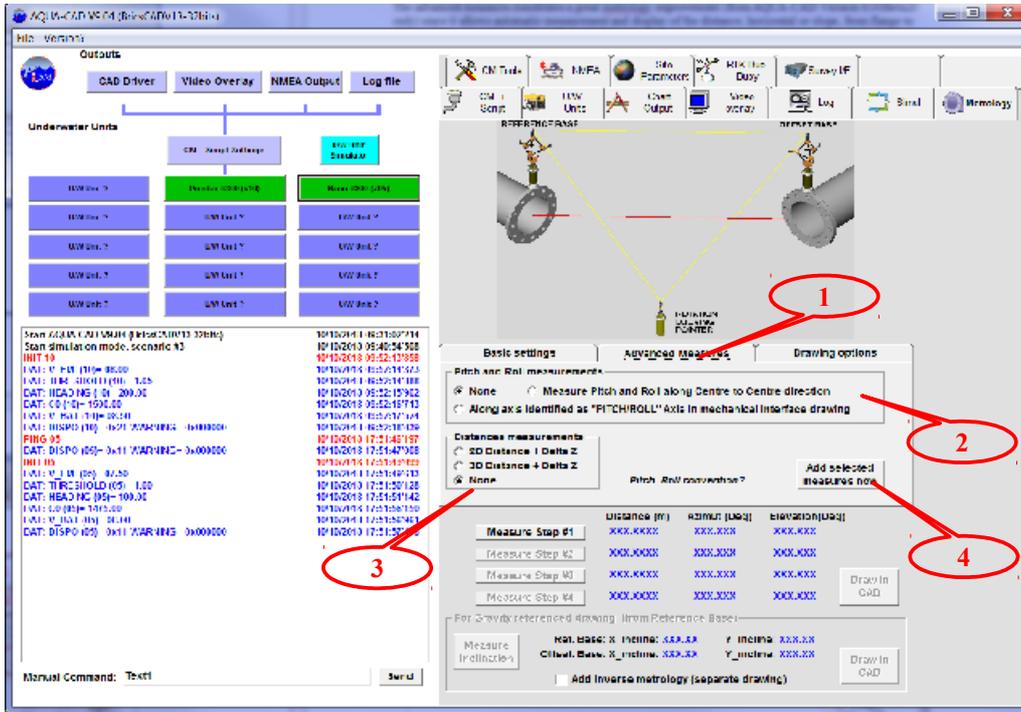
The drawing options must be settled before activating any of the “Draw in CAD” button.

Advanced measures:

The advanced measures constitutes a great metrology improvement (from AQUA-CAD Version 6.0 only) since it allows automatic measurement and display of the distance, horizontal or slope, from flange to flange, difference of height from flange to flange, and, last but not least, Pitch and Roll of user’s defined axes.

The way these advanced measures are added is explained hereafter:

- Select the Advanced Measures Tab (1), the windows appears like that:



Metrology Script windows, Advanced Measures options

- There are three Pitch&Roll measurement options (2):
 - o Pitch & Roll of each flange along user’s defined axis (these axis are defined in the mechanical interface drawing),
 - o Pitch & Roll of each flange along flange to flange axis (the user’s defined axis in the mechanical interface drawing defining then the reference plane),
 - o None to avoid any Pitch and Roll measurement.

All Pitch and Roll are positive when axis comes up.

Refer to mechanical interface drawing definition for an explanation regarding Pitch and Roll axis definition.

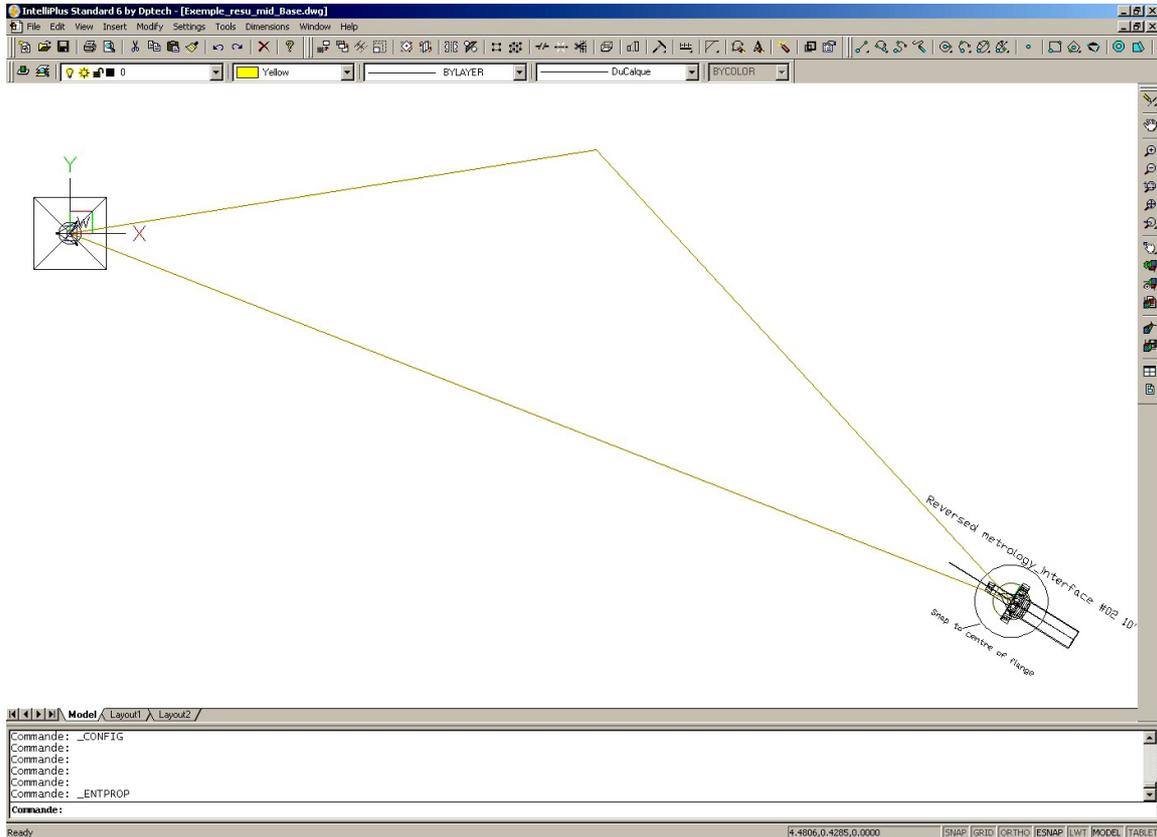
- There are three Distance measurement options (3):
 - o 2D distance (also named horizontal distance) from flange centre to flange centre,
 - o 3D distance (also named slope distance) from flange centre to flange centre,
 - o None to avoid any Distance measurement.

For the 2D and 3D distance measurement options, the difference of height (named DeltaZ) from flange to flange is also measured and display.

The flange centre is defined by Log file again in the mechanical interface definition drawing (please refer to the chapter dedicated to Mechanical Interface Definition).

The advanced measurements options are only valid when the user’s defined Pitch and Roll axis and flange centres are detected in the final drawing (then, these centres and axis must be included in the mechanical interface definition drawing).

The measurement are launched only when the user activate the “Add selected measures now” button (4).



Example of metrology result (first step metrology with Mid Base configuration)

Note that the Reference Base is identical to CAD coordinate system (pure relative mode)

In case of a flange-to-flange Metrology, it is finished, then check the flange-to-flange result.

In case of Mid Base Metrology configuration, the Base on the first flange and the rotation-locking Pointer have to be moved to the next expected location (see chapter one for details). Then replay the metrology script (you can change the drawing file name) and check the flange-to-flange result.

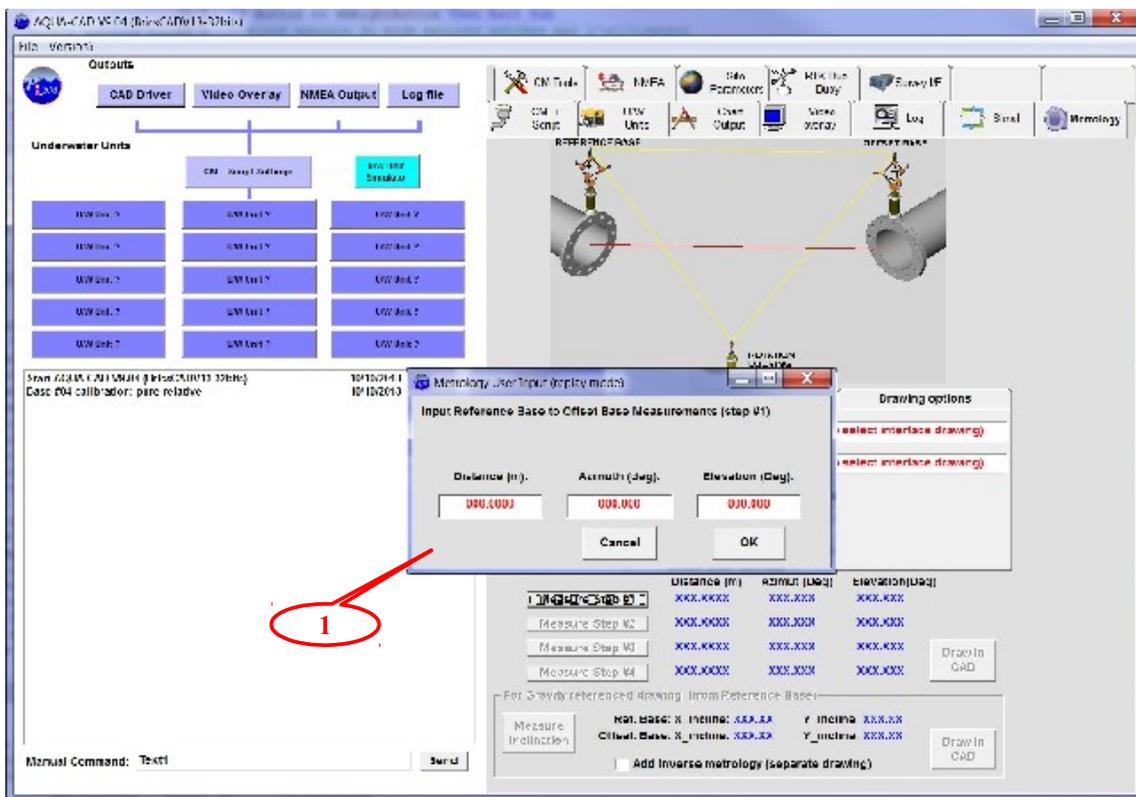
The Gravity referenced measurement option is explained in later chapter.

2.10 Replay mode

A Metrology script replay mode has been included from AQUACAD 6.0 version. This feature allows the user to redraw a drawing file with previous raw acoustic and inclination measurements and with modified or different interface definition for instance.

To activate this mode, no need to set up U/W units:

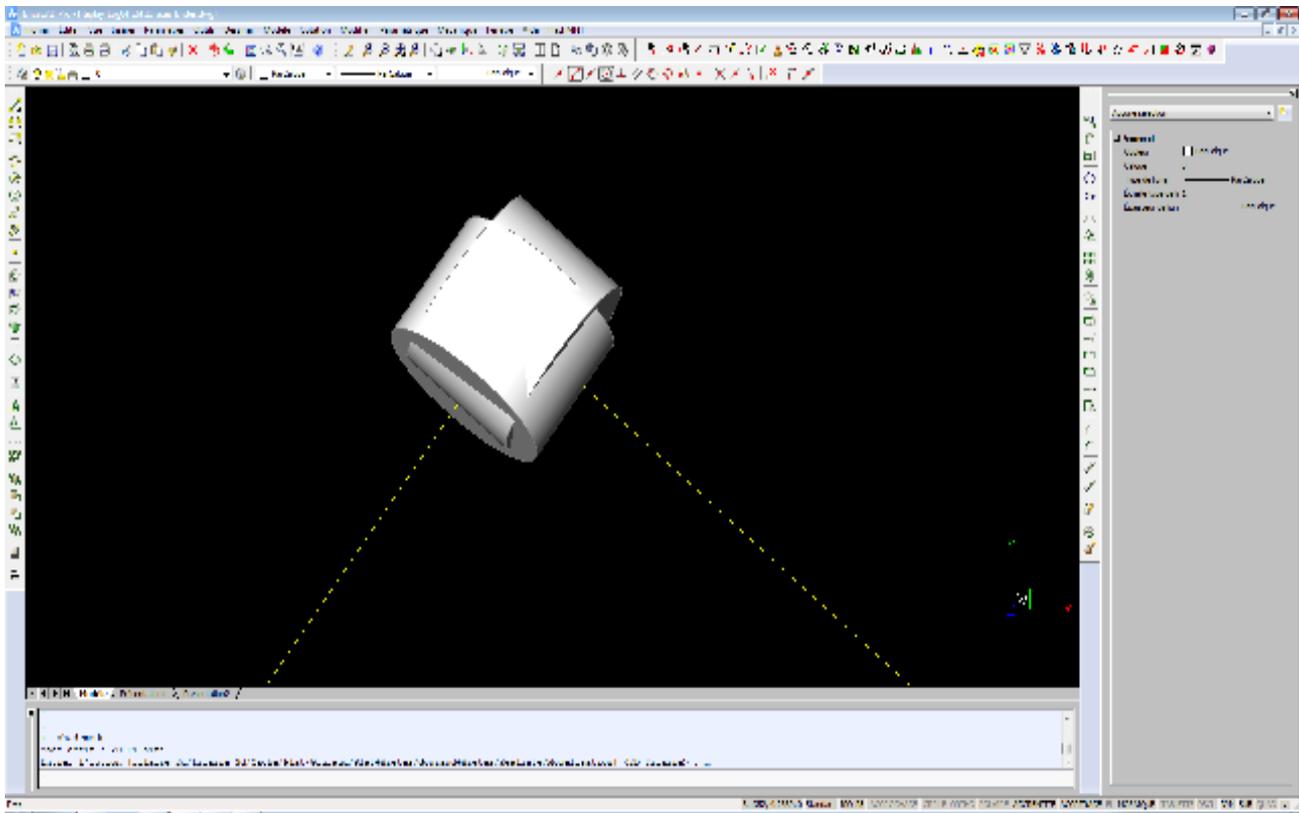
- Just activate the CAD link,
- Then switch to the Metrology window, select the addresses of Reference Base, offset Base, Rotation locking Pointer and mechanical interface definition associated to each Base,
- Then **RIGHT-CLICK** on the Step #1 button to start the replay mode, a window (1) will prompt user to input the first step measurements associated to Step #1 (may be found in Log file),
- Then click (simple click since you are now in replay mode) on step #2 button and so on up to Step#4 completion, and then draw the result by clicking the “Draw in CAD” button.
- It is also possible to replay gravity referenced drawing, click the “Measure Inclination” button to enter the measured inclination and draw the result.



Replay mode just after right-clicking on Step #1

2.11 Measurement Quality Check

It is possible to check the consistency of the metrology by looking how the measurements close together at the rotation locking Pointer location, if this portion of the CAD drawing is zoomed, it may appear like this:



Checking distance between the two Rotation locking Pointer measures

The ends of each measurements of the rotation-locking Pointer (from Reference Base and from Offset Base) are theoretically identical, but due to errors accumulated along the four measurements, these two ends of line are not identical. Note that the distance between this two points is due to distance errors AND angular errors. Also note that this only checks the acoustic part of the metrology, not the quality of the mechanical interfaces between the centre of the flange and Base (which will introduce further error, it is why the user must survey the mechanical interface in the yard prior to going offshore).

How to check the acoustic accuracy:

The distance and angular errors for each end line is the combination of both Base to Base and Base to Pointer measurements, the standard deviation for each is 2cm for distance (for distances less than 50m) and 0.1° for angle. Lets assume that Base-to-Base and Base to Pointer measurements error are not correlated. The resultant error is then the quadratic summation of the two errors:

Then for distance error:

$$\text{End_Line_Distance_Error} = \text{SQRT}(\text{Base_to_Base_Distance_Error}^2 + \text{Base_to_Pointer_Distance_Error}^2)$$

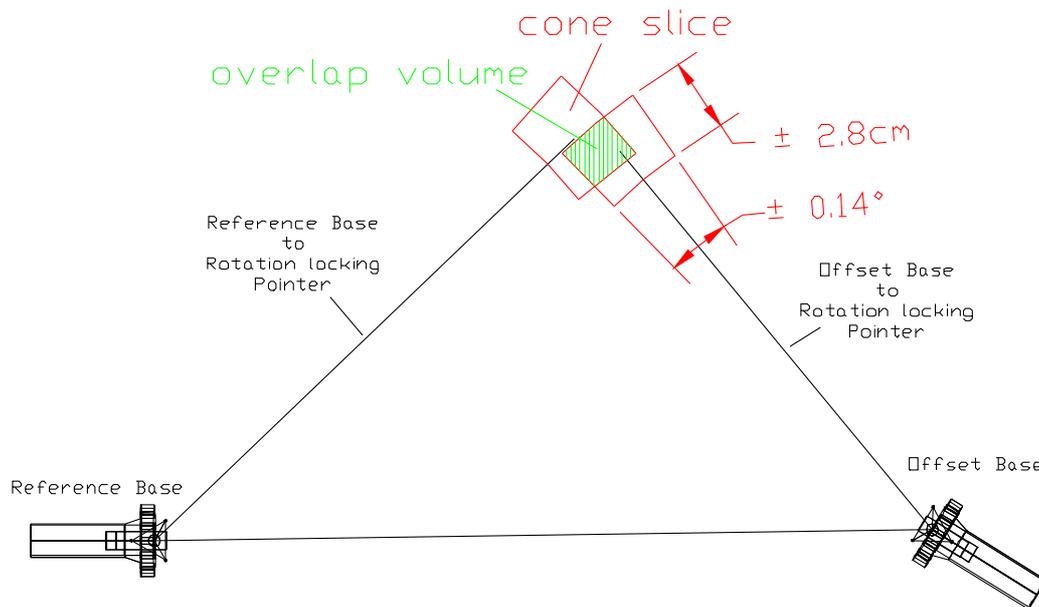
$$\text{End_Line_Distance_Error} = \text{SQRT}(2\text{cm}^2 + 2\text{cm}^2) = \mathbf{2.82 \text{ cm}}$$

And for angular error:

$$\text{End_Line_Angular_Error} = \text{SQRT}(\text{Base_to_Base_Angular_Error}^2 + \text{Base_to_Pointer_Angular_Error}^2)$$

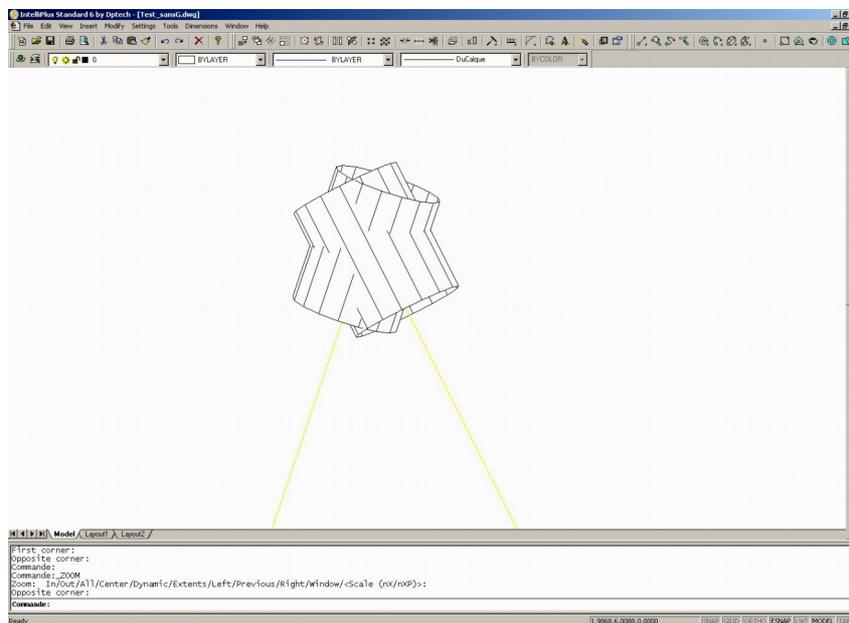
$$\text{End_Line_Angular_Error} = \text{SQRT}(0.1^\circ^2 + 0.1^\circ^2) = \mathbf{0.141^\circ}$$

The method to check the consistency of the metrology just consists of drawing the error volumes, which are slices of cone, at the end of each Rotation Locking Pointer measurement and to check that they overlap, if they overlap it assures the user that the flange to flange accuracy is consistent with the nominal system accuracy (2cm for distance when distance is less than 50m, 0.1° for angles measurement).



Metrology QC by checking error volumes overlapping

AQUACAD automatically add these measurement error volumes in the CAD file, but they are simplified as cylinders instead of portion of cone (which is quite acceptable for distance greater than 5 metres), it is user responsibility to check that they overlap.



Example of QC: passed because error volumes overlap

2.12 Gravity referenced result

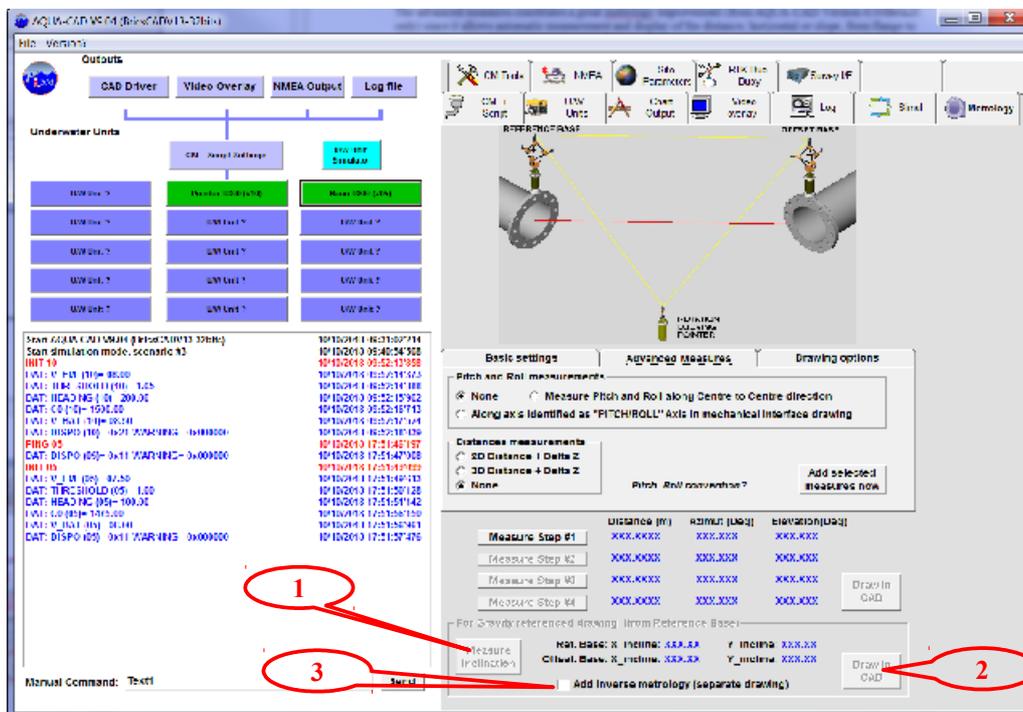
The metrology process described in previous chapters is purely acoustic and does not take into account any inclination. The result is a pure relative flange-to-flange measurement. Thus it does not indicate how this set of two flanges is orientated in the local terrestrial coordinate system. Even if each Base includes a compass, it is difficult to rely on it due to the proximity of large steel structures. Regarding the inclination, it is possible to use the inclinometer of the reference Base in order to measure the inclination along X and Y-axis of the Base and rotate the result according to this measurement. The final result will then be gravity referenced, and it will be possible to get each flange inclination (pitch&roll) and also flange-to-flange difference of height.

To do that:

- One must have completed Step #4 of metrology script,
- Measure the inclination of reference Base by clicking on “Measure Inclination” button (1), this will also activate the measurements of the inclination of the offset Base,
- After measurement completion, inclinations and standard deviation are added in the Log window,

Important note: gravity reference will not be enabled if the inclination of the reference Base is greater than 45° from vertical and standard deviation greater than 0.25° in order to check the stability (a warning message will be displayed).

- then just click on the “Draw in CAD” button (2) within the Gravity reference drawing frame,



Getting a gravity referenced drawing

The gravity reference process will not affect the flange-to-flange results. But the projection of flange alignment angles on the horizontal plane may differ slightly depending on inclination value (the 3D angle is still the same).

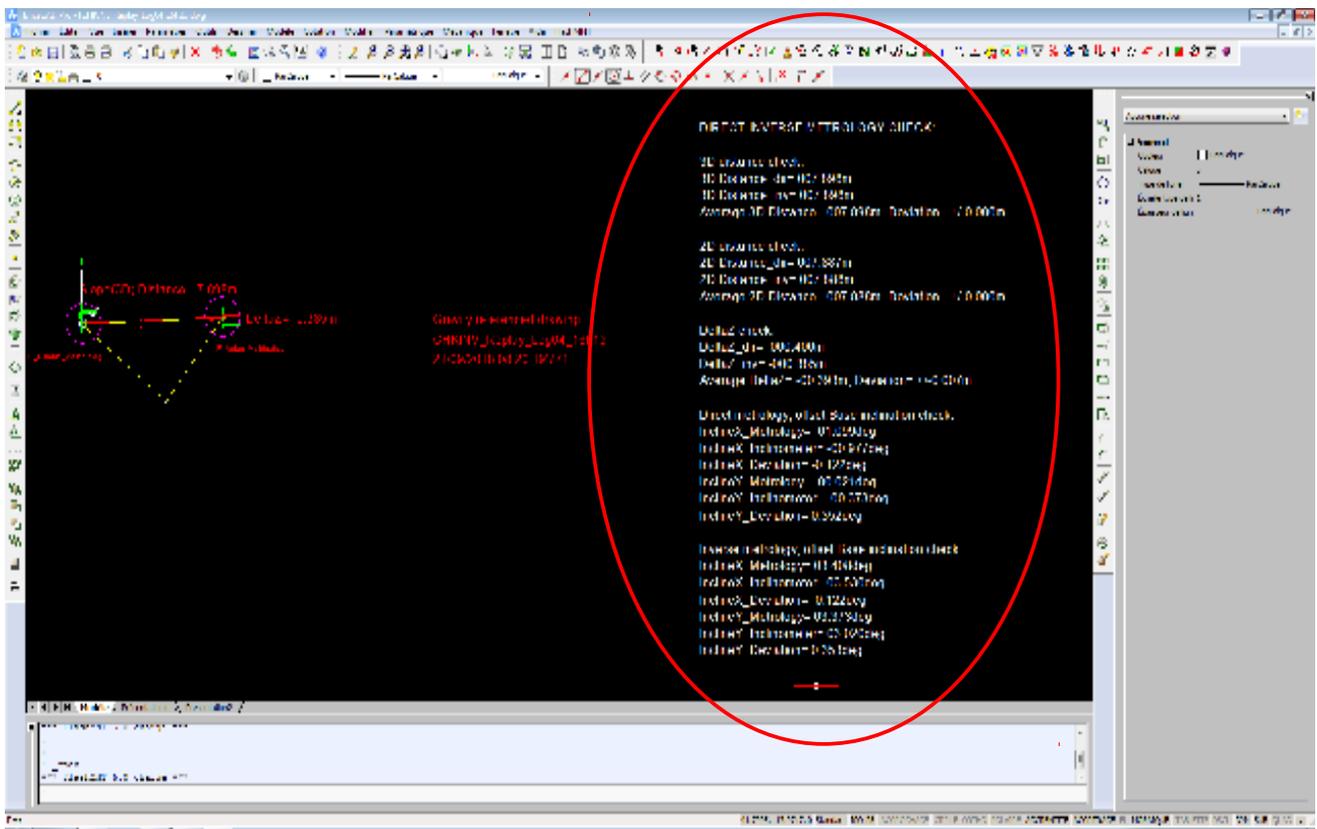
Advanced QC using direct-inverse Metrology result

The Pitch&Roll of the offset Base that can be extract from the CAD result is a combination of the acoustic measurements and inclination measurement of the reference Base (here, the results of the inclinometer measurements are named inclination and the pitch&roll are the result extracted from the CAD file). Thus, it is possible to compare the pitch&roll of the offset Base with the direct inclination measurements (from the offset Base inclinometer).

After doing this comparison, it is also possible to swap the reference and offset Base and replay the metrology and again proceed to the same comparison.

In the same way, it is possible to secure the DeltaZ measurement.

The whole comparison is done automatically by checking the “Add inverse Metrology” option (3), the direct and inverse metrology result will be drawn in separate drawings, and the result of the comparison printed in the inverse drawing like this:

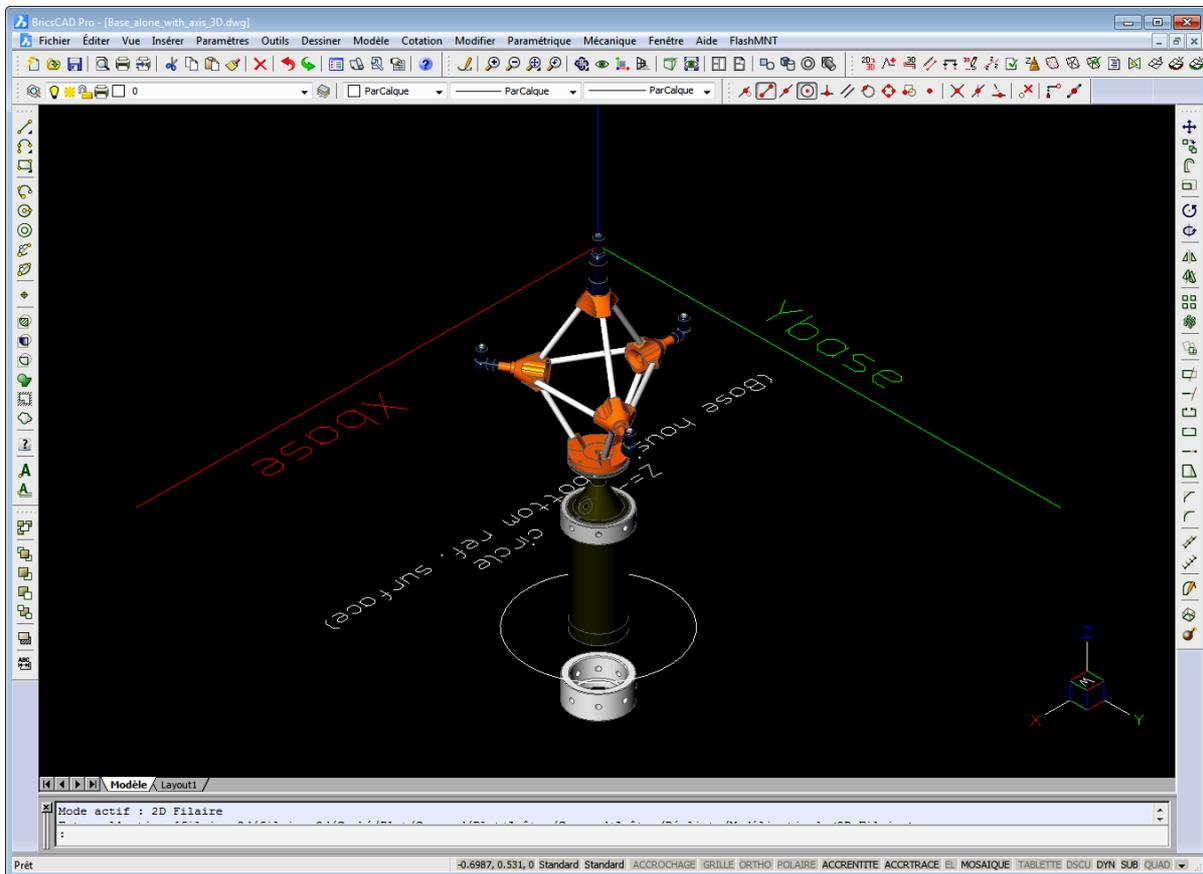


Inverse Metrology with direct-inverse comparison

3 How to define a mechanical interface drawing

The mechanical interface drawing defines the way each Base is attached to the Flange. This is a very important file because it will be inserted in the final metrology drawing and allows the user to directly get the flange-to-flange distances and angles. This chapter describes how to draw this mechanical interface and gives some useful tips in order to speed up drawing process.

First of all, use the mechanical interface drawing template that include the Base orientated in the right direction.



Mechanical interface drawing template

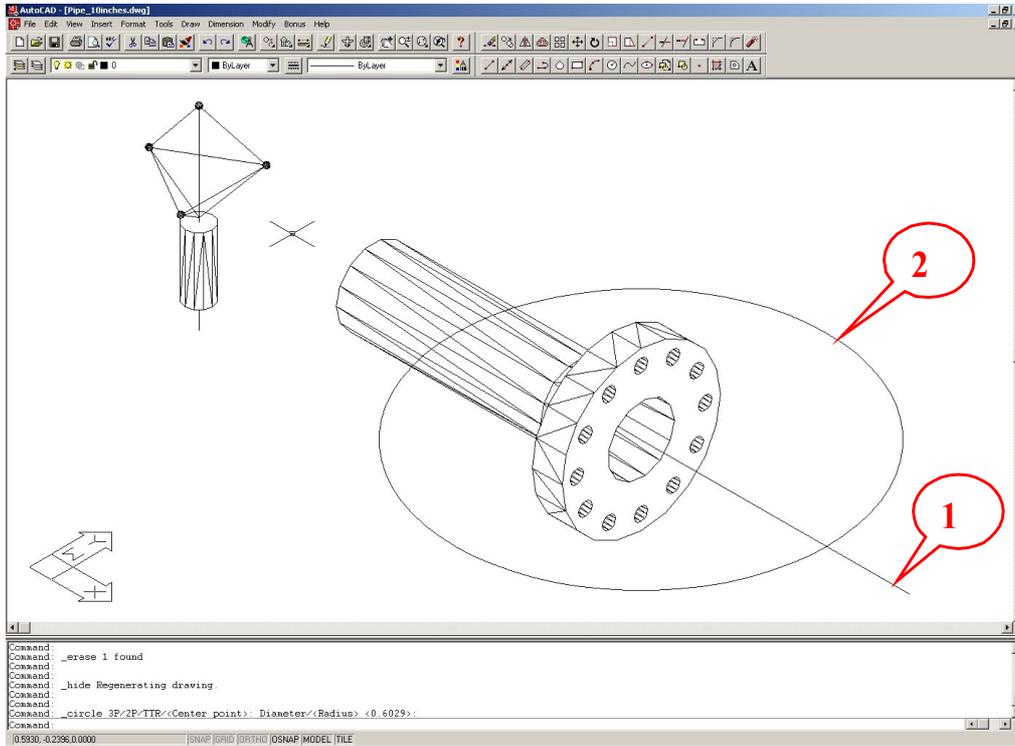
In this template, the X, Y and Z axis of the Base are orientated just as X,Y and Z axis of the CAD drawing. The origin of acoustic measurement (top hydrophone) is at location $\{0,0,0\}$. A vertical axis which length is 727.0mm represents the distance from top hydrophone to the bottom housing reference plane. This reference plane is used to attach the Base to the mechanical interface with the flange.

THE BASE LOCATION AND ORIENTATION MUST NOT BE CHANGED, just build the interface and flange from the bottom of the Base (it is recommended to lock the Base layer).

Then identify the flange shape and size and build a 3D model of it (must be a 3D solid or just an axis and circle that represents the flange face).

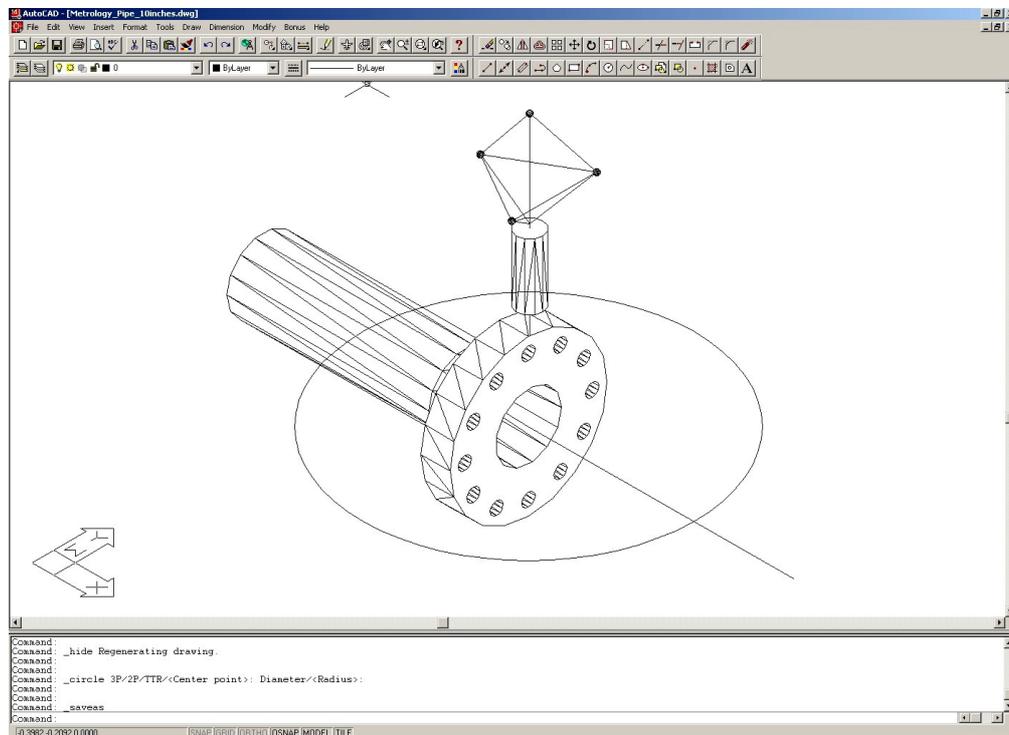
It is recommended to build a line (1) from the centre of the flange up to 3metres in front of the flange. This line will be used at the end of the metrology to facilitate identification of flange angular alignment.

It is also recommended to create a horizontal circle (2), where its centre is in the centre of the flange. It may be used later to easily snap on centre of the flange.



Flange construction (note axis in front of the flange and circle to snap on flange centre)

Then, just move and rotate the flange according to the mechanical interface that attaches the Base to the flange (the mechanical interface has to be “as built” surveyed before), always remember to not change Base location nor orientation. Then the final mechanical drawing should appear like this:



Example of Mechanical interface definition drawing

It is highly recommended to add a text describing the flange in order to avoid any mistake, and to allow checking at a later date.

3.1 Centres and Axis for advanced measures:

In order to allow distance and pitch and roll advanced measurements, user must embedded the centre of flanges and reference axis for pitch and roll.

The centre of flange must be **CAD circles** and placed in layers named “**CENTRE_A**” and “**CENTRE_B**” (CENTRE_A for the mechanical interface attached to the reference Base, CENTRE_B for the offset Base). Only these names and entity type circle will be detected and validated for distances measurement. The distance measurement will be made from circle centre to circle centre.

The pitch and roll axis must be **CAD lines** and placed in layers named “**PITCH_A**” and “**ROLL_A**”, “**PITCH_B**” and “**ROLL_B**” (PITCH_A/ROLL_A for the mechanical interface attached to reference Base, PITCH_B/ROLL_B for the offset Base). Only these names and entity type line will be detected and validated for pitch and roll measurement. The pitch and roll measurement will be positives when these lines go up.