

**tecnar**

**cold spray meter**

**User Manual**

**CSM eVOLUTION**

Edition 1, 2013

## 1. NOTICES

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### 1.1 USER MANUAL PART

CSM eVOLUTION

### 1.2 EDITION

- Edition 1, January 2013

The material contained in this document is provided “as is” and is subject to change without notice in future editions.

### 1.3 OVERVIEW

Orientation:

- Table of contents at the front of the manual
- Index at the rear of the manual

This manual contains the following sections:

- “Safety”
- “Product description”
- “Installation”
- “Maintenance”
- “Operation”

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## 2. SAFETY SUMMARY

The following safety precautions should be observed during all phases of operation of the CSM eVOLUTION.

Tecnar Automation Ltd. assumes no liability for customer's failure to comply with these precautions or with specific warnings elsewhere in this manual.

### 2.1 GENERAL PRECAUTIONS

- Do not use a noisy or overloaded power line
- Supply cooling / cleaning air at 2.0 – 2.8 bar (30 – 40 psi) to sensor head
- Use only original spare parts

### 2.2 AUTHORIZED USE

CSM eVOLUTION is intended for use solely for Cold Spray process monitoring and control. Any other use is regarded as unauthorized.

Also, this manual should be read before the use of the CSM eVOLUTION is authorized and a copy of it should be kept near the equipment.

CSM eVOLUTION has been designed and manufactured according to state of the art technology and recognized safety regulations. However, unauthorized use can result in danger to the operator or third parties' body or even life and/or in damage to the product itself or other machinery.

### 2.3 SAFETY SIGNS

Signs such as the two examples below indicate particular hazards or risks to consider when operating the CSM eVOLUTION.

**WARNING**

**CAUTION**

*The danger sign denotes a hazard. It warns about dangers which could result in serious personal injury or even death.*

*The caution sign denotes a hazard. It warns about dangers which could result in minor personal injury or equipment damage.*

### 3. PRODUCT DESCRIPTION

The CSM eVOLUTION is an optical sensing device used in the field of cold spray processes. Based on a patented technology developed by the National Research Council of Canada, this system uses a dual slit optical device in order to perform in-flight diagnostics on individual particles. The CSM eVOLUTION system provides simultaneous & precise velocity and diameter measurements of up to 800 individual particles/s depending on spraying conditions. Values of these parameters averaged over an adjustable measurement period are continuously recorded and displayed.

The reproducibility of coatings obtained by spraying processes strongly depends on the ability to monitor and control key variables of the process. Present state of the art technology is based on the control and monitoring of torch zone variables such, powder temperature feed rate, powder carrier gas flow rate. Some of those variables simply cannot be monitored. However, the CSM eVOLUTION provides real-time monitoring of parameters proper to the particle plume itself. Those parameters (velocity & diameter of particles, and also particle flow rate) are among the most critical ones in the projection zone, and up to now, they could not be continuously measured and controlled in a typical industrial production environment; the CSM eVOLUTION offers that possibility.

The characterization of individual particles during the projection, as performed by the CSM eVOLUTION, is the most relevant tool to ensure rapid detection of problems during the process and consequently, to improve reliability and reproducibility of the thermal coatings obtained. Based on results and analysis provided by the CSM eVOLUTION, various feedback strategies for the torch zone parameters can be developed, leading to significant cost reduction in terms of test pieces and wasted production.

### Note

The Main controller contains all necessary optical & electronics components. It also features an industrial, touch screen computer.

The Fiber Cable carries light from the particles to the pyrometer inside the Main Controller for analysis.

The XY Scanning unit allows for computer-controlled, 2D cross-sectional mapping of the spray plume.



### 3.1 MAIN COMPONENTS

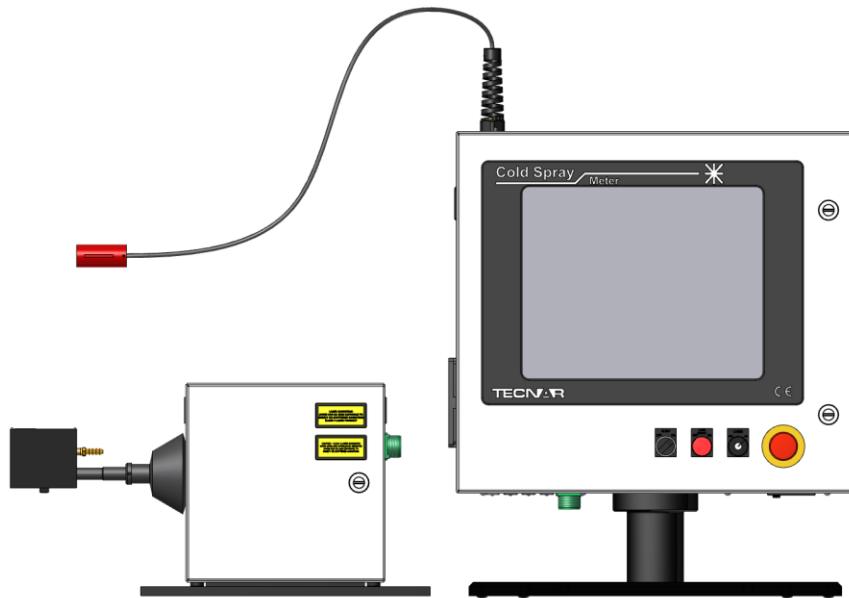


FIGURE 1 CSM EVOLUTION MAIN COMPONENTS

#### 3.1.1 THE SENSING HEAD

The optical sensor consists of a special multi-elements IR relay lens corrected for both geometrical and wavelength aberrations. A protective window is installed at the front of the lens (the closest to the plume). The lens is coupled to an optical fiber bundle consisting of one 400 $\mu$ m fiber surrounded by 2 other fibers used for alignment purposes. An optical two-slits photomask (schematically shown in Figure 2: Two-Slits mask) is inserted between the lens and the central fiber, in contact with the latter. Because of this photomask, a particle passing in front of the sensor will generate a twin-peaks signal as illustrated in Figure 2: Two-Slits mask.

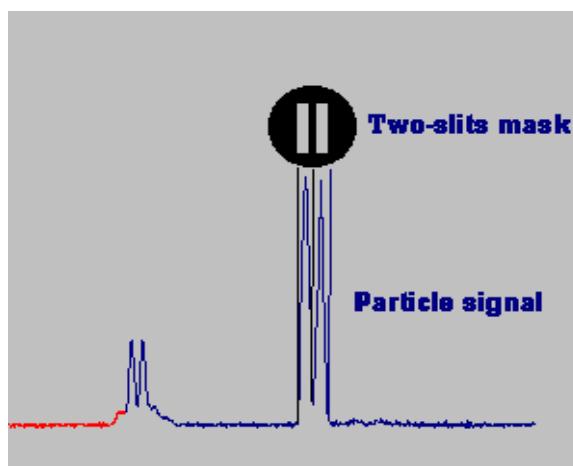


FIGURE 2: TWO-SLITS MASK

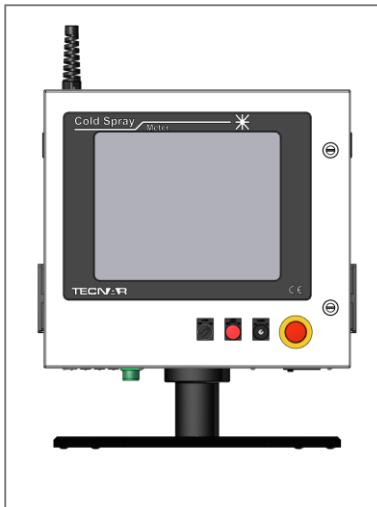
A particle will generate a valid signal only when its trajectory is totally included within the surface of both slits and the depth of field of the relay lens. We refer to the product (slit area)\*(depth of field) as the *measurement volume* of the



### 3.1.2 THE DETECTION MODULE

The signal collected by the lens from the laser illumination of the particles near the spray is transmitted through the optical fiber bundle to the Detection Module. The optical cable splits before entering the detection module. One end of the cable contains the alignment fibers while the other one contains the central 400 $\mu$ m fiber. Light transmitted through the central fiber is imaged on a *Si* photodetector. Signal from the photodetectors are linearly amplified and filtered. Finally, the signal is send to the acquisition card of the computer to be analysed.

Another fiber is added to the bundle with the CSM (Cold Particles Sensor). The fiber is used for illumination of the particles.



### 3.1.3 THE CONTROL MODULE

Signals from the photodetectors are transmitted to the Control Module to be digitized and analyzed by the software (described in section 6. *Operation*). The control module consists of an industrial grade PC equipped with a touch screen display and a high speed digitizing board for data acquisition.

#### Front panel

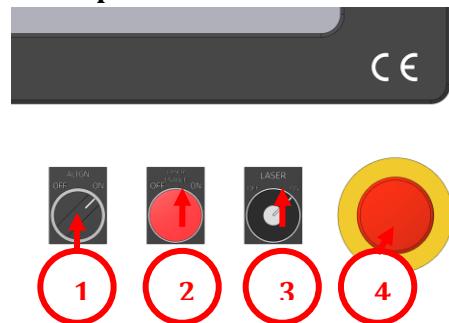


FIGURE 3 CONTROL MODULE FRONT PANEL

#### ■ Alignment switch (1)

The alignment switch is used to control the alignment LED. When the switch is in the ON position, the alignment LED is activated and two low power (<5 mW) laser beams are emitted from the end of the sensing head. These beams indicate the positions where the CSM measurements are taken (position of the measurement volume). See section 3.1.1 The sensing head for more details.

#### ■ Laser Control (2)

This push button is used to control the laser source used for cold particles characterization experiments. Pressing the button will activate or deactivate the laser. The laser is active when the button's light inside is ON. When an interlock is open the laser automatically shut downs and it needs to be re-armed.

#### ■ Laser safety switch (3)

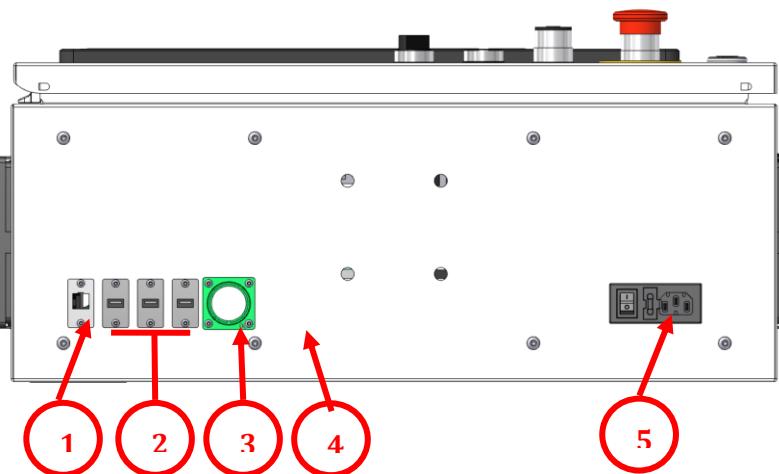
The laser safety switch is a safety component. The laser source can only be activated when the key is inserted and in the ON position. When not in use, it is

recommender to remove the safety key, thus preventing anyone that has not been properly trained from using the laser.

■ **Emergency stop (4) *CSM OPTION ONLY***

For CSM-0050 to CSM-0055, the emergency stop button is a laser safety feature only. Pushing on the emergency stop will immediately stop the laser source. Starting with CSM-0056, the emergency stop button will stop both the CSM laser (if option is purchased) and will interrupt any movement of the XY scanning unit.

**Connections panel**



**FIGURE 4 CONTROL MODULE CONNECTIONS PANEL**

■ **RJ45 Ethernet connector (1)**

The RJ45 allows the user to connect the CSM evolution to any network.

■ **USB connectors (2)**

The USB connectors allow the user to connect any USB peripherals to the CSM eVOLUTION such as USB sticks, keyboard or mouse.

■ **Scanning module connector (3)**

The connector is used to connect the XY scanning module to the control module.

■ **Interlock connector (4)**

The external interlock is a laser safety feature. This connector allows the user to remotely stop the laser source. It is the operator's responsibility to use the input to setup laser safety procedure at the location where the CSM eVOLUTION will be used. See diagrams below for more details.

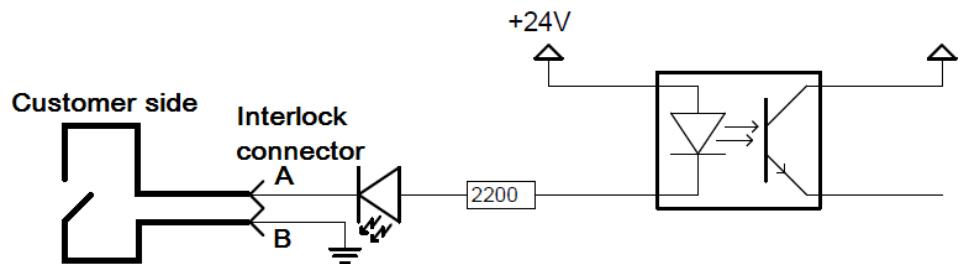


FIGURE 5 INTERLOCK CIRCUIT

- Power connector (5) and main switch  
120Vac 50/60Hz or 220Vac 50/60Hz. Must be configured at factory.

### 3.2 CALCULATION PRINCIPLES

The following explains the basic principles used by the CSM eVOLUTION to provide velocity measurements.

**Velocity** is obtained by dividing the distance between the image of the two slits in the measurement volume (real distance between the slits on the photomask multiplied by the magnification factor of the lens) by the “time of flight” between the two peaks of the particle signal (illustrated in Figure 2: Two-Slits mask), as estimated by the computer through waveform analysis. Velocity is the most precise of the CSM eVOLUTION’s measurements limited only by the frequency drift of the scope card’s crystal oscillator. Re-calibration is therefore not necessary.

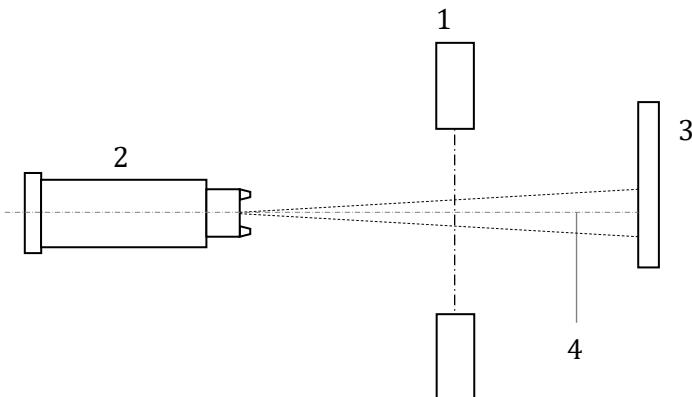
### 3.3 TECHNICAL DATA

<p><b>System including</b></p> <ul style="list-style-type: none"> <li>- CSM eVOLUTION controller</li> <li>- CSM eVOLUTION scanning unit</li> <li>- CSM eVOLUTION optical sensor and cable (10m) - Lens holder</li> <li>- Power cables</li> <li>- Scanning unit cables (10m)</li> <li>- Reusable carrying case</li> <li>- Photomask</li> <li>- Spare windows</li> <li>- Keyboard and mouse</li> </ul>	<p>Carrying case dimensions Length 95 cm Width 95 cm Height 98 cm</p>
<p><b>Main component 1: CSM eVOLUTION control module</b></p> <p>Dimensions</p> <p>Width 580 mm</p> <p>Height 770 mm</p> <p>Length 305 mm</p>	
<p><b>Main component 2: Scanning module</b></p> <p>Dimensions</p> <p>Width 152 m,</p> <p>Height 300 mm</p> <p>Length 615 mm</p>	
<p><b>System specification:</b></p> <p>Working distance (lens to spray) 100mm (60mm on old system)</p> <p>Diameter measurement range</p> <ul style="list-style-type: none"> <li>• From 10 to 300 <math>\mu\text{m}</math></li> </ul> <p>Velocity measurement range</p> <ul style="list-style-type: none"> <li>• From 50 to 1200 m/sec</li> </ul>	

## 4. INSTALLATION & SET-UP

**Step 1.** Mount sensor head (1) on the scanning unit. The sensor head can be set on either side of the spray plume after the spray gun (2). In case you are trying to characterize while a part or substrate is in space (3) please keep in mind that the measurement could be affected by multiple rebounds.

Left



Right

**Step 2.** Connect the scanning unit to the control module.

**Step 3.** Switch on controller main switch.

**Step 4.** Acknowledge Windows user password window by pressing the [ENTER] key. Windows boots and the desktop will be displayed.

Enter password if required.

**Step 5.** Start CSM eEVOLUTION software by double-clicking the corresponding icon on the desktop. After system communication check out is completed, the graphical user interface (see section 6.2 CSM eEVOLUTION software) will be displayed.



**Step 6.** Calibrate the scanning unit by pressing the “Center Slide” icon on the home page of the software. Once the calibration is completed the unit will stay calibrated until the software is shut down.

*Do not attempt to calibrate the scanning unit if the spray torch is active.*

*Dry & clean air must always be fed to the air purge connector at 1.7-2.7 bar (25-40 PSI)*

### WARNING

### CAUTION

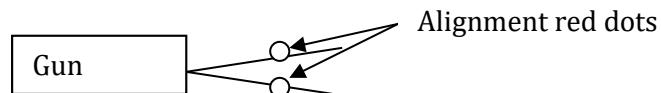
**Step 7.** Position sensor head **100 mm** (8) (60mm on old system) from the plume axis (4).

**Step 8.** It is not necessary to take the reference measurements at the exact same stand-off you use for coating, as long as you keep the reference distance (6) constant over time. See Figure 8 CSM eEVOLUTION installation drawing.

**Step 9.** If monitoring is required while spraying, set measuring point within measuring area (7), away from the substrate because of flow perturbation phenomena as the spray hits the substrate. Could be validated by

spraying without the substrate and compare the measurement with the substrate.

**Step 10.** Turn ON the alignment switch and position the 2 red dots perpendicular to the plume direction, in the middle of the plume.



**Step 11.** Load the appropriate (if already developed) setup file by clicking on the folder icon and choose *load setup* option.

**Step 12.** Start the spray torch.

**Step 13.** Once everything is stable (cold spray) Press the "Auto center" icon. The CSM will scan the plume and find its center.

**Step 14.** The CSM is now ready.

See section 6.4 for parameters optimization

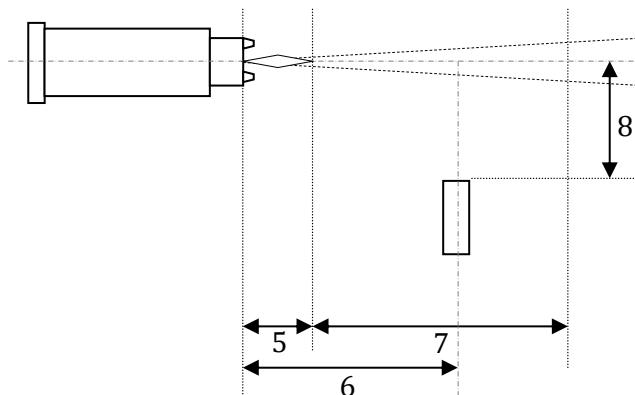


FIGURE 8 CSM EVOLUTION INSTALLATION DRAWING

## 5. MAINTENANCE

### 5.1 WHEN AND HOW TO CHANGE THE PROTECTIVE WINDOW

In order to prevent the expensive relay lens from any damage, a disposable protective window is installed between the spray plume and the lens. The window should be replaced when non-removable (either by air or lens paper) deposits or scratches are observed.

Use a spanner wrench to remove the blocking ring at the front end of the lens. Carefully remove the dirty window and replace it by a clean one. DOING SO, BE CAREFULL NOT TO PUT ANY GREASE ON THE NEW WINDOW. Insert and gently tighten the blocking ring.

Note that CSM eVOLUTION is delivered with one protective window installed, and two (2) spare ones. If you run out of disposable windows, CONTACT TECNAR (we keep them in stock at all times).

## 6. OPERATION

Here is a list of precautions concerning the use of the CSM-eVOLUTION unit & its related modules:

To avoid dirt penetration, the main cabinet doors should be kept closed at all times except for punctual access to the DVD-RW or for hardware verification as per TECNAR instructions.

### CAUTION

When the optical cable has to be manipulated & rolled up, the main precaution is to avoid small radius of curvature (keep radius of curvature above 15 cm) and brutal shape changes. When rolled-up on top of the cabinet, optical cable should in some way be attached (clamped) to the cabinet's roof. The lens should be covered with a plastic bag to avoid potential deposits.

Never hold the lens by the optical cable.

Make sure that the lens temperature is maintained below 75°C. To do so, apply proper air cooling. At all times, avoid drastic temperature change.

### WARNING

Keep the alignment LED diode OFF when you do not use it.

If your CSM-eVOLUTION was delivered with a power transformer, always use this particular transformer with the system. Do not use this transformer for any other equipment of yours.

If you have to carry the CSM-eVOLUTION from your facilities to any other facility and that the unit is exposed to temperatures below 10°C during transportation let it come back to room temperature (At least 6 hours) before turning it ON, otherwise condensation could occur on the different optical components.

When you move the sensing head with the XY scanning unit (in manual mode, or during an automatic scan), **MAKE SURE THAT THE LENS HAS NO CHANCE TO ENTER THE SPRAY PLUME ITSELF!**

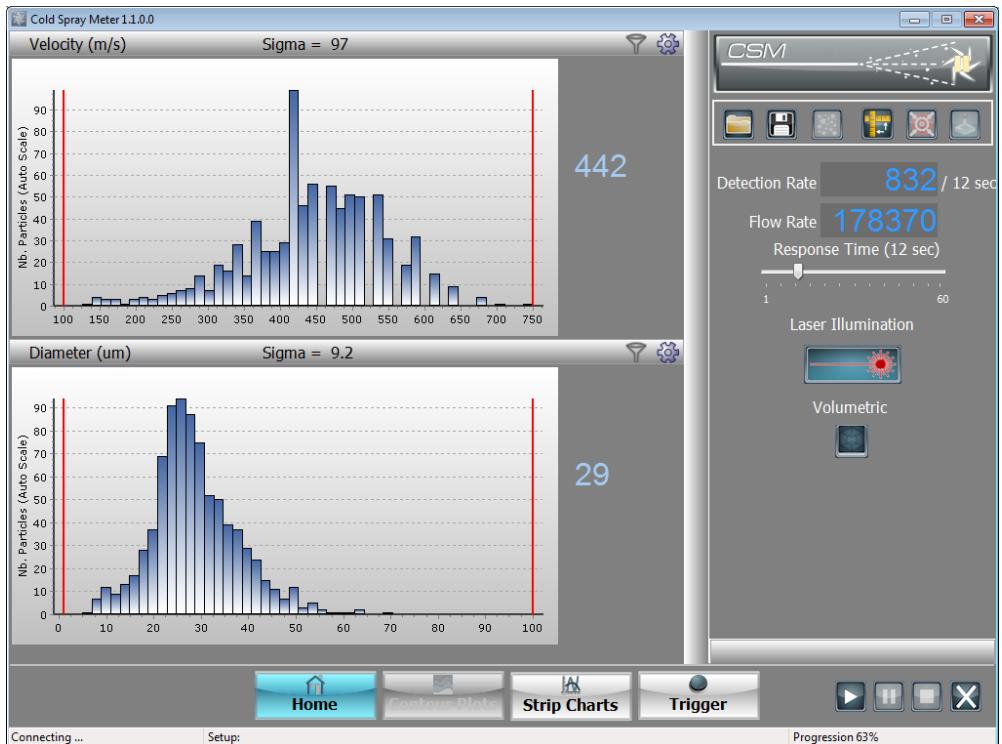
### CAUTION

### 6.1 TURNING-ON THE CSM-2000

Turn-on the CSM-2000 at least 30 minutes before starting the experiment in order to allow the acquisition boards, the photodetectors and all the electronic to stabilize. **In fact, it is a good habit to keep the CSM-2000 ON all the time unless you won't use it for a long period (2 days or more).**

### 6.2 CSM EVOLUTION SOFTWARE

The CSM eVOLUTION software is divided into 5 main tabs. Navigating between the tabs is accomplished by clicking on the icons at the bottom of the software window. The software is designed to be used with a mouse or a touch screen monitor. The different functions of the tabs are explained in details below.



**FIGURE 9 CSM EVOLUTION SOFTWARE**

### 6.2.1 HOME TAB

This section explains in detail the operation of the CSM eVOLUTION software Home tab.

#### 6.2.1.1 HISTOGRAM

There are two histograms on the home tab. From those, the user can monitor the particles distribution analyzed by the CSM during a given amount of time (user adjustable). Two histograms (1) are available providing velocity and diameter statistics. The different components of the histograms are explained below. Note that on the right-hand side of each histogram, the mean value of the distribution is displayed. On top of each histogram the standard deviation is displayed. The vertical axis represents the population (number of particles) for each class (histogram bar). By default, the vertical axis of the histogram is automatically scaled to fit the entire window.

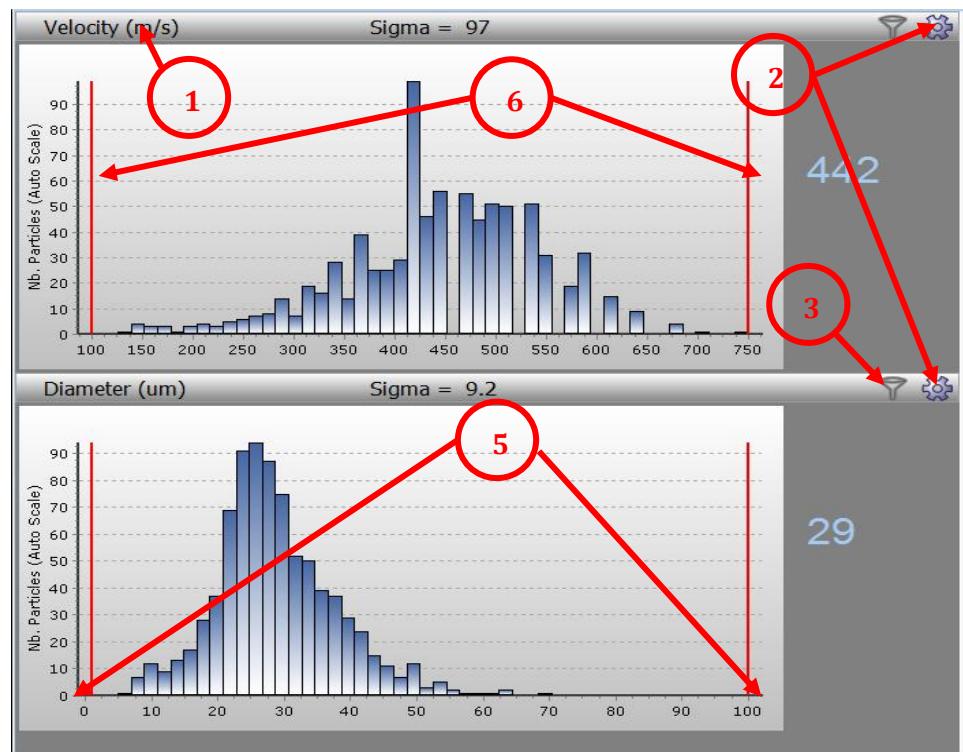


FIGURE 10 VELOCITY HISTOGRAM SETTINGS

One can configure the display and the option by clicking on the Histogram settings (2) icon. Use this icon to access the histogram settings menu.

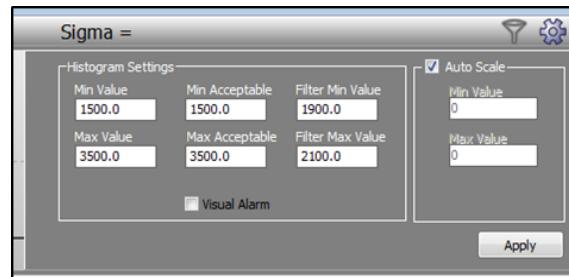


FIGURE 11 HISTOGRAM SETTINGS

#### 6.2.1.2 GENERAL ADJUSTMENT FOR HISTOGRAM:

- Min Max Values

The x-axis (horizontal) (5) can be adjusted using [Value] fields. Adjusting this parameter will affect the display range on the horizontal axis.

- Min Max acceptable values

The red lines (6) show the [Acceptable] values for each of the measurements. When the mean value of a measurement is outside the Acceptable range, the corresponding histogram section turns red.

- Filtered Min Max values

Filters can be applied in order to study a small population of particles. When a filter is activated on a particular histogram (3) a green rectangle will appear in the background indicating the range covered by the filter. On the other histograms, the particles that fall within the range of the filter will appear as green columns. The range of the filter can be adjusted using the [Filter Value] fields.

#### **6.2.1.3 PARTICULAR ADJUSTMENT FOR HISTOGRAM**

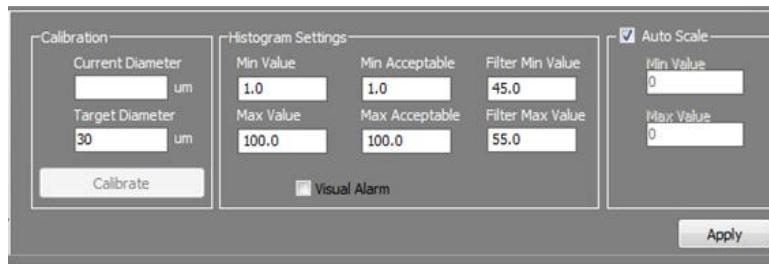
- Velocity histogram settings

Mask width should be adjusted depending on the velocity & diameter ranges you expect for a given process. The CSM-eVOLUTION is delivered with 1 photomask. Be sure that G2/coldspray is selected in the dropdown menu.

- Diameter histogram settings

For the CSM eEVOLUTION to provide accurate measurements of particles diameter, the particle's average diameter (typically you should use the D-50 as supplied by the powder manufacturer) has to be entered in the software. The following steps must be used in order to calibrate diameter for a given material:

1. Start the spray process & wait until powder injection is stable
2. Run an auto-centering so to find center of the spray plume
3. Enter the particles nominal diameter in the field [Target Diameter] then clicks the calibrate button.
4. Click Apply Changes so that the new calibration becomes active



**FIGURE 12 DIAMETER HISTOGRAM SETTINGS**

#### 6.2.1.4 HOME TAB - RIGHT PANEL

Here is a description of the right panel of the Home tab.

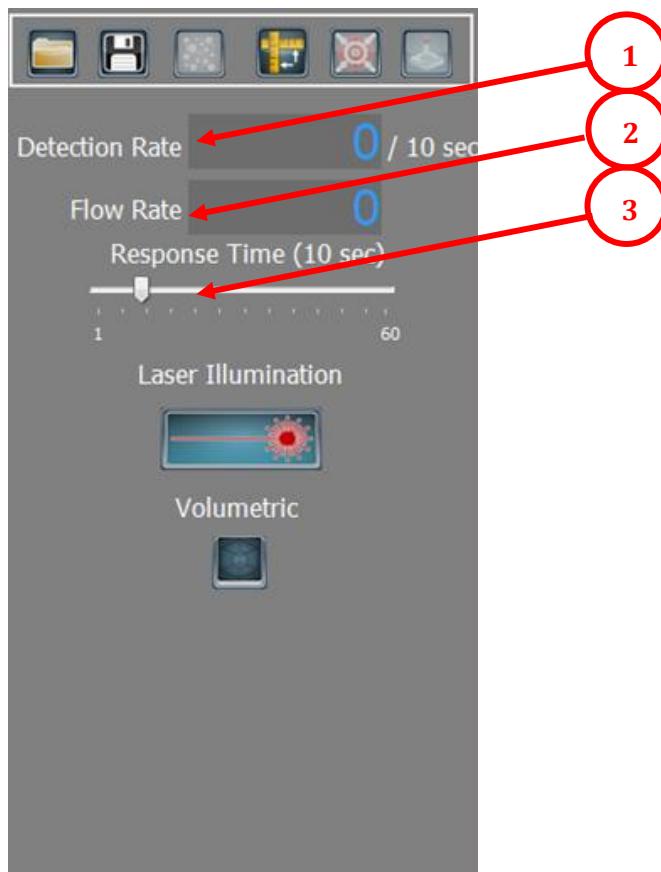


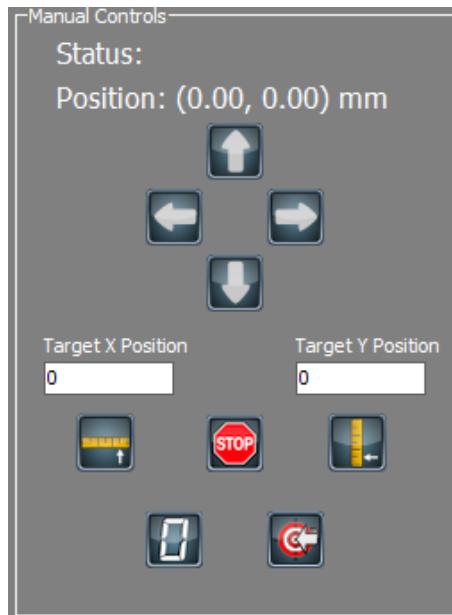
FIGURE 13 HOME TAB LEFT PANEL

Saved experiments and setups can be reloaded/replayed using the icon.

Experiments and setups can be saved using the icon.

The CSM eVOLUTION software can record a pre-specified number of particles using the icon. Before the recording starts, the user is prompted by the software to choose how many particles should be recorded.

It is necessary to calibrate the scanning unit before it can be used. Click the icon to calibrate the unit. The calibration will be valid until the software is closed. Once calibrated the scanning module can be used to automatically scan the plume or manually move the sensor. Manual controls are accessed by clicking the icon. Once the scanning unit is calibrated, you can hit the [autocenter] button so to find center of the plume (point of maximum mass flow rate).



**FIGURE 14 SCANNING UNIT MANUAL CONTROLS**

The scanner can be moved manually using the arrows or sent to a particular position using the [Target Position] field and clicking the icon or to initiate the movement.

If you press the stop button the scanner will stop moving.

By pressing the zero button you will reset to 0,0 your actual position. This gives you a new relative reference.

If you move your scanner and you want to return to the last autocenter position you can press on this button:

The DETECTION RATE [1] displayed corresponds to the effective performance of the system, that is how many GOOD particles were detected and analyzed per unit of time (a GOOD particle is one that successfully passed all the pattern recognition criteria).

The software also provides a measurement proportional to the number of particles passing by the measurement volume per unit time; this number is called FLOW RATE and it is displayed in the left panel of the screen [2]. Knowing the size distribution of the sprayed material and the size of the measurement volume, the FLOW RATE can be related to mass flow or density of particles.

The RESPONSE TIME [3] slider is used to set the period over which the rolling average is calculated. For example, if RESPONSE TIME is set to 5 sec, it will take 5 sec before a change in the input parameters is fully reflected in the particle measurements.

By default, the CSM software displays frequency-type histograms, but the user can as well generate volumetric-type histograms by clicking the VOLUMETRIC

button on the screen. The major difference between the two types of histograms is that volumetric ones take into account the size of the particle. This means that a 30 $\mu\text{m}$  particle would contribute 27 times more to the histogram than a 10 $\mu\text{m}$  particle.

**Finally, the laser Illumination button must be clicked when you are looking at cold particles. Be sure to click that button and to activate the laser, by turning the laser to enable key to on position and by pressing the laser button (the button becomes red when the laser is activated), prior to take cold particles measurements.**

**6.2.1.5 HOME TAB - ACQUISITION CONTROL SECTION****FIGURE 15 ACQUISITION CONTROL BUTTONS**

-  The [pause] button is used to pause the acquisition or the playback of a recorded experiment
-  The [play] button is used to resume the acquisition or resume playback of a recorded experiment
-  The [stop] button is used to stop recording an experiment
-  The [close] button is used to stop playing a recorded experiment and return to live mode

## 6.2.2 CONTOUR PLOTS

Thanks to the XY scanning unit, cross sectional mapping of the spray plume is possible. Results of the scans can be plotted under the form of contour plots has shown on Figure 16 Contour plots.

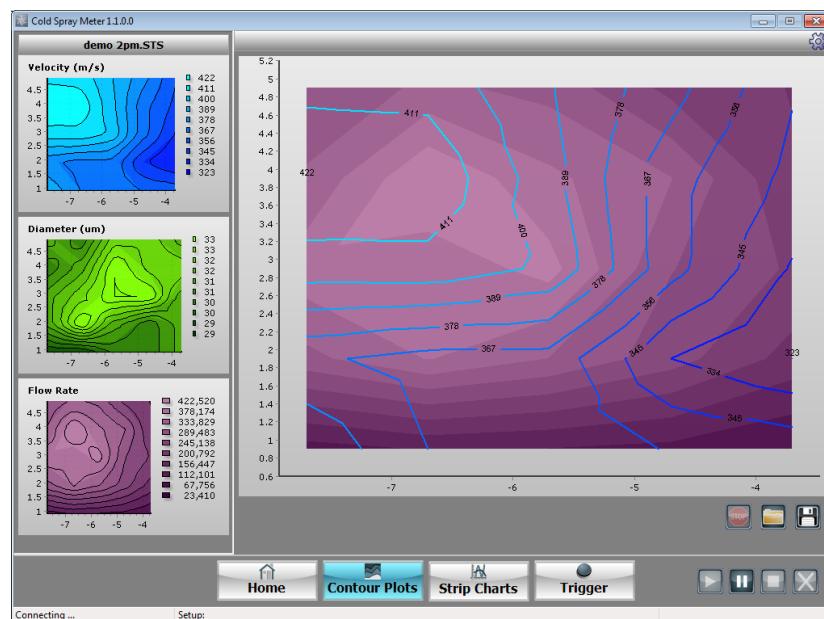


FIGURE 16 CONTOUR PLOTS

The first step to achieve a contour plot is to determine you grid of scan. To set the grid you need to press the setting icon at the top right of the screen. The following window will appear.

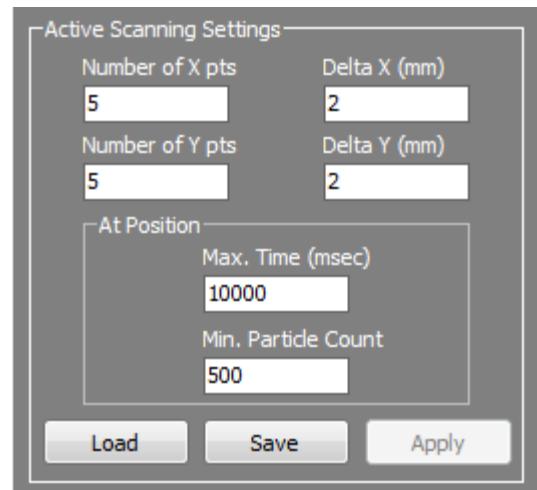


FIGURE 17 CONTOUR PLOTS ACTIVE SCANNING SETTINGS

In that window, you need to set the number of points per axis you want and the distance between two points. The center of your grid is the current position of the scanner. The second step is to determine the number of good particles acquire per point. 500 particles usually give a good statistical analysis. If the scanning position is out of the spray of course the CSM will not be able to see

particles. In such cases you need to tell the software how long it must wait until the scanner moves to the next point. To change the time, you need to edit the field name Max. Time (msec).

You can save or load your settings by pressing the corresponding button in the active scanning settings window.

When you are ready to start you scan you press the floppy icon at the right of the screen. You enter the name of the file you want to save, and the scan will automatically start after you press the save button.

You can stop a scan by pressing the stop button.

You can also recall a contour plot by pressing the folder icon. The recorded contour plot can be found in the folder statistics inside the root folder of the CSM.

### 6.2.3 STRIP CHARTS

Strip charts give you the average value over time of the measurements of the CSM.



**FIGURE 18 STRIP CHARTS**

- This icon returns to live mode when you have loaded a previous run.
- This icon clears and resets the graphic.
- The folder icon recalls a previous run of strip charts
- The floppy disk icon saves the strip charts on screen in a CSV file.

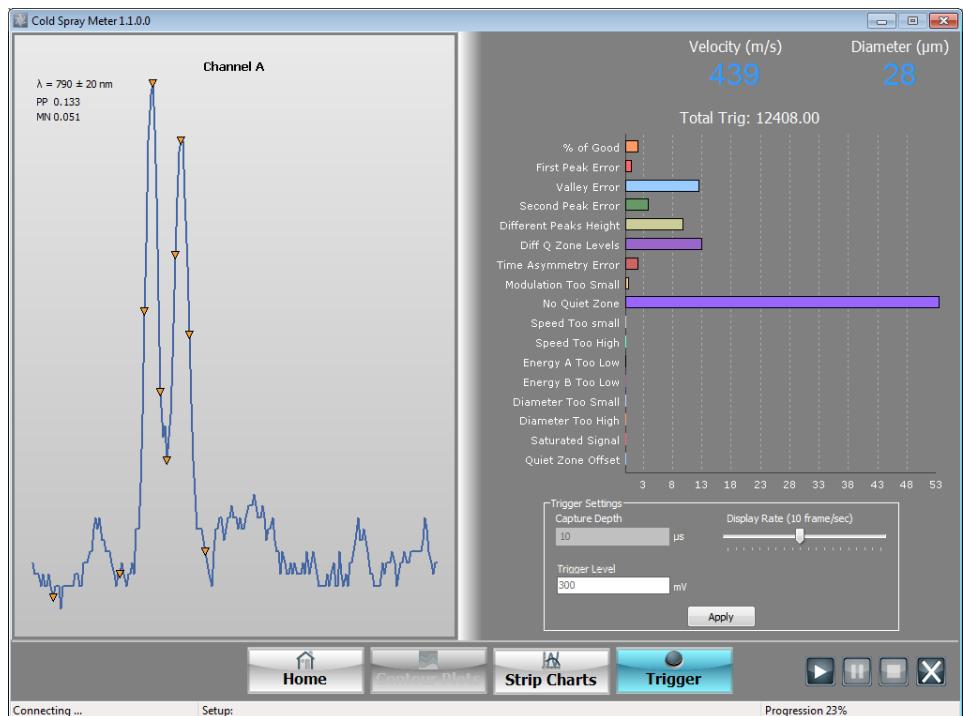
You can zoom by dragging on the Y axis or the X axis

You can move the charts by dragging in the graphic.

#### 6.2.4 TRIGGER

This screen has been designed to help the operator with analysis adjustments. It basically transforms your screen into an oscilloscope. The operator can look at the different signals collected from the process and then adjust the input range, the trigger level, etc. that will best fit the ongoing spraying conditions. This screen has been also designed to allow for on-line adjustment of the particles rejection criteria.

This screen is also very useful to detect abnormalities. For example, one can rapidly see if the noise level is of the same order of magnitude as it usually is. Figure 19 Trigger screen is an example of the trigger screen.



**FIGURE 19 TRIGGER SCREEN**

The window on the left of this screen displays raw signals coming out of detector. In the top left corner of the window, three values are displayed: the wavelength band, the peak-peak amplitude (PP), which corresponds to the difference between the point of maximum and the point of minimum voltage within the acquisition window, and the Mean value (MN), which indicates the average level of the signal within the acquisition window. You can notice the presence of cursors identifying the peaks, the half-heights, the valley & the quiet zones (for matter of baseline establishment, the system will identify two relatively flat regions, one on each side of the signal; we refer to those regions as QUIET ZONES).

The top right part of the screen shows the means values measured by the CSM:

- Velocity

- Diameter

The Total Trig label shows the number of trigger events that took place during the integration period set in the Home tab.

The particles analyzed are categorized into 19 sub-categories:

- Good
- No First peak
- No valley
- No second peak
- Different peaks height
- Different quiet zone levels
- Time Asymmetry Error
- Insufficient Modulation
- Missing quiet Zone
- Low speed
- High speed
- Low temperature
- High temperature
- Low Energy on channel A
- Low Energy on channel B
- Low Diameter
- High Diameter
- Saturated
- Quiet zone offset

All those sub-categories are shown on Figure 20 Trigger screen- Analysis result section. The graphic shows the percentage of particles in each sub-category.

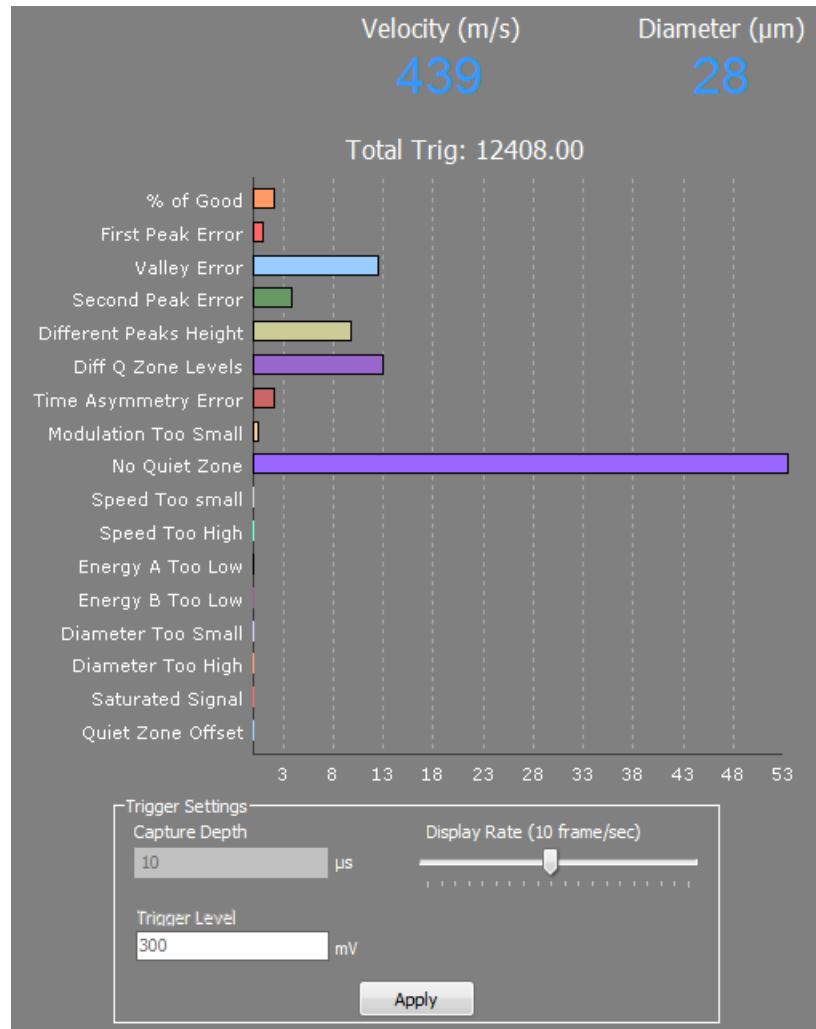


FIGURE 20 TRIGGER SCREEN- ANALYSIS RESULT SECTION

#### 6.2.4.1 TRIGGER SETTINGS

Let's now move to the bottom right part of the screen, which is used for optimization of data acquisition. The operator can adjust CAPTURE DEPTH (the width of the acquisition window) depending on the duration of a typical event.

The last parameter is TRIGGER LEVEL. It must be set with great care. Its value ranges from 0mV to 5000mV. The general idea is to set the TRIGGER LEVEL high enough to avoid triggering on noise or undesired signals (this will increase the detection performance of the system), but not so high that you miss a significant portion of the low energy particles (the small and/or cool ones).

See section 6.3 for parameters optimization

**WARNING**

### 6.3 PARAMETERS OPTIMIZATION FOR A TYPICAL EXPERIMENT

First make sure that the X&Y slides are about in the middle of their travel; to do so, calibrate the scanning unit by pressing the “Center Slide”  icon on the home page of the software. Once the calibration is completed the unit will stay calibrated until the software is closed. Insert the sensing head into the sensing head holder of the XY Scanning Unit. Turn-on the ALIGNMENT button on the CSM-eVOLUTION; red light will then be injected backward in the optical fiber bundle. Use a piece of paper, hold it right in the axis of the torch and then manually move the hole Scanning unit box in the X direction until you obtain a relatively sharp (in focus) image of the two optical fibers on the paper in the middle of the plume position. Vertical rough alignment can be done by moving the torch until the mid-point between the two alignment fibers aims at the torch axis. AUTO-CENTERING routine will take care of the fine alignment.

One last detail to pay attention to: thermal spray plumes are rarely horizontal. This means that velocity measurements could be more or less affected since they assume that particles are traveling perpendicular to the 2-slits photomask. Therefore, we recommend that you evaluate the angle of the thermal spray plume. Knowing this angle, you can compensate for it by giving a slight inclination to the sensing. This being said, keep in mind that the velocity measurement will be affected as the COSINE of the angle. As you know, for angle 10 degrees and less, the COSINE is pretty much “1” so not much error introduced on the velocity.

Do not forget to release the ALIGNMENT button/key when the procedure is over.

Before starting the spray process, DO NOT FORGET TO CONNECT THE AIR COOLING LINE to the sensing head holder; usually, 20 to 40 PSI airflow is sufficient to keep the lens clean & cool.

You are ready to start spraying and optimizing your parameters.

#### 6.3.1 TRIGGERS SETTINGS

Get to the Trigger Screen and look at the particle signals. The first parameter to adjust is the TRIGGER LEVEL. Values range from 0mV to 5000mV. If you set the TRIGGER LEVEL too low, your particle counting rate will also be low because you will often trigger on noise, and consequently getting valuable statistical samples will take more time. On the other hand, if you set the TRIGGER LEVEL too high, your particle counting rate will also be very high because you start looking only at signals of large amplitude (this means that you are discriminating in favor of large particles). We found out that a TRIGGER LEVEL between 150 & 160 does not cause any size discrimination in the majority of the processes.

Adjust CAPTURE DEPTH in such a way that typical particle signal can be totally included within the acquisition window and that quiet zones can be correctly

established on both side of the signal. BEWARE! If you set Capture Depth too low, you might lose the biggest, slowest particles.

### 6.3.2 FINAL CENTERING

To activate the fully automated computer controlled auto-centering routine,

Press the “Auto center”  icon. The CSM will scan the plume and find its center (in terms of mass flow).

### CAUTION

NOTE THAT POWDER INJECTION TAKES A CERTAIN TIME TO REACH DYNAMIC EQUILIBRIUM DEPENDING ON THE SETUP YOU USE. IT IS THEREFORE STRONGLY RECOMMENDED TO WAIT FOR A STABLE PLUME BEFORE STARTING THE AUTO-CENTERING ROUTINE. A message will appear on the screen to indicate that centering is finished

### 6.3.3 ADJUSTING REJECTION CRITERIA

Valid particles are identified according to specific criteria that may be adjusted in the Trigger Screen. The CSM software analyses each acquisition. First the CSM software tries to do pattern recognition, if some test failed the particle is rejected. After that, the CSM software checks if the particle met the rejection criteria. If any of the rejection criteria is met, the particle is rejected and categorized into one of the 18 sub-categories. To adjust the rejection criteria or to see the particles rejected you simply click on the graphic bar for which you want to obtain details in the trigger screen. All the parameters are described in the sub-section below. Note that when you click on a parameter what you see on the oscilloscope section are only the particles referring to that parameter. By example, if you click on the GOOD horizontal bar you see on the oscilloscope section only the good particles; in that case those particles are used to calculate CSM measurements.

#### 6.3.3.1 GOOD

The sub-category “GOOD” shows the particles that are considered for the calculations (Velocity and diameter). The graphic shows the percentage of the good particles relative to the total number of triggers received. No specific action can be achieved in that sub-category.

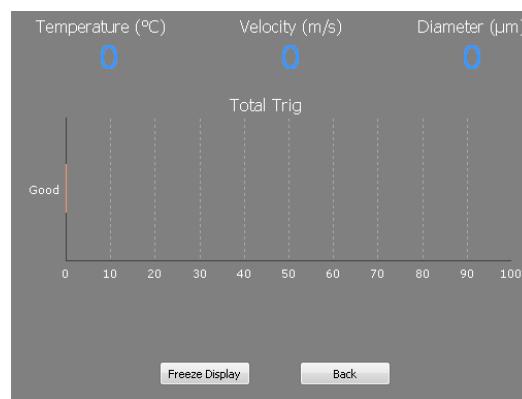


FIGURE 21 TRIGGER SCREEN- GOOD PARTICULES SECTION

### 6.3.3.2 NO FIRST PEAK

The sub-category “NO FIRST PEAK” shows the particles rejected because they show characteristics that are not within the acceptable range. The graphic shows the percentage of rejected particles showing no first peak during the acquisition. No specific action can be achieved in that sub-category.

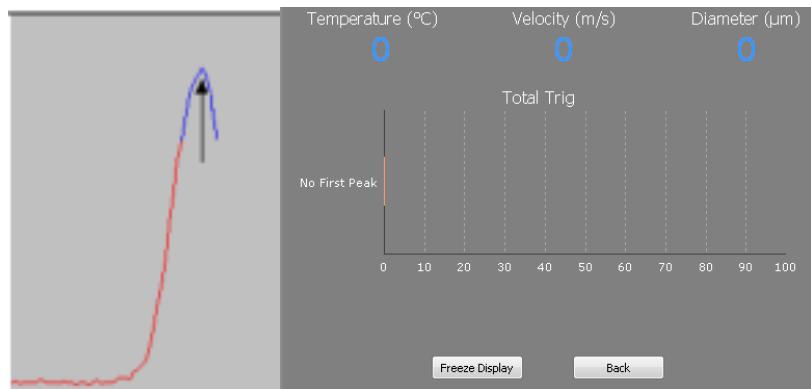
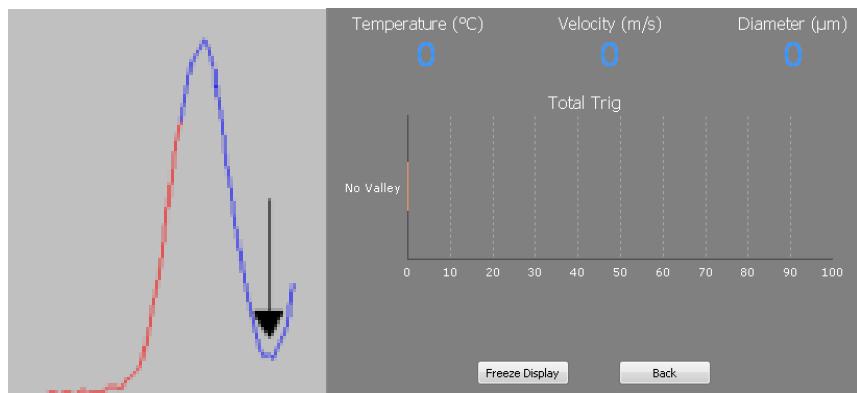


FIGURE 22 TRIGGER SCREEN- NO FIRST PEAK

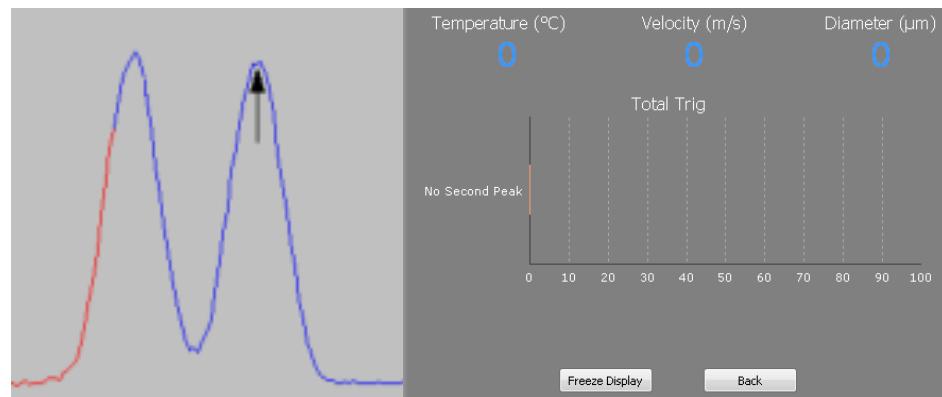
### 6.3.3.3 NO VALLEY

The sub-category “NO VALLEY” shows the particles rejected because they show characteristics that are not within the acceptable range. The graphic shows the percentage of rejected particles showing no valley during the acquisition. No specific action can be achieved in that sub-category.



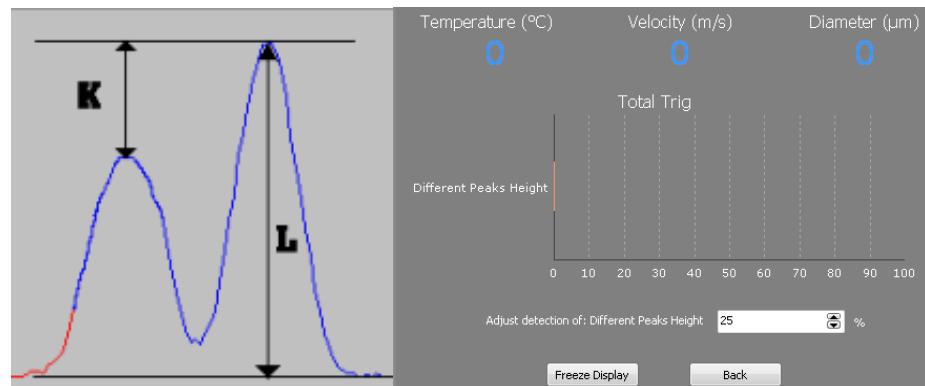
### 6.3.3.4 NO SECOND PEAK

The sub-category “NO SECOND PEAK” shows the particles rejected because they show characteristics that are not within the acceptable range. The graphic shows the percentage of rejected particles showing no second peak during the acquisition. One possible cause to obtain only 1 peak if an incorrect orientation of the sensor head/photomask assembly (a 90 degrees error would translate into seeing only 1 peak).



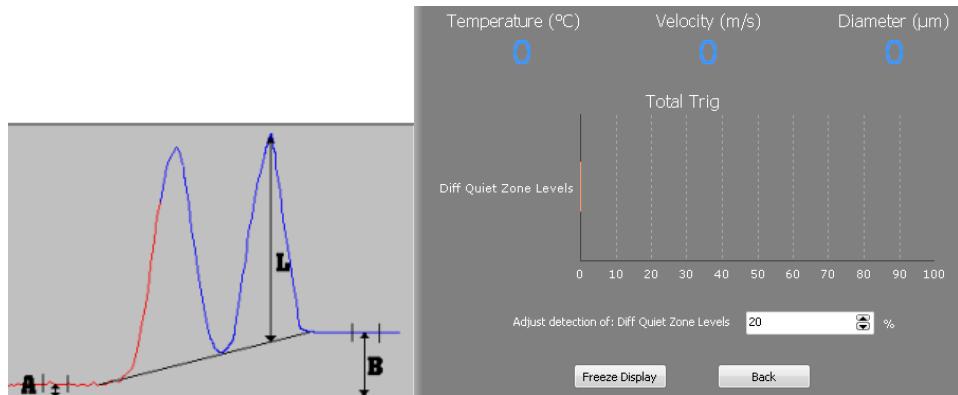
#### 6.3.3.5 DIFFERENT PEAKS HEIGHT

The sub-category “DIFFERENT PEAKS HEIGHT” shows the particles rejected because they show characteristics that are not within the acceptable range. The graphic shows the percentage of rejected particles showing different peak height during the acquisition. You can modify the acceptable criteria by changing the percentage of difference between the 2 peaks height. K/L must be smaller than the percentage chose in the “DIFFERENT PEAKS HEIGHT” panel. 25% covers the majority of the processes.



#### 6.3.3.6 DIFFERENT QUIET ZONE LEVELS

The sub-category “DIFFERENT QUIET ZONE LEVELS” shows the particles rejected because they show characteristics that are not within the acceptable range. The graphic shows the percentage of rejected particles showing different quiet zone level during the acquisition. You can modify the acceptable criteria by changing the percentage of difference between the 2 peaks height.  $|B-A|/L$  must be smaller than the percentage chose in the “DIFFERENT QUIET ZONE LEVEL” panel. 20% covers the majority of the processes.

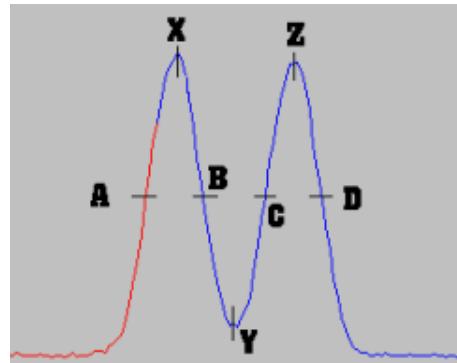


#### 6.3.3.7 TIME ASYMMETRY ERROR

The sub-category “TIME ASYMMETRY ERROR” shows the particles rejected because they show characteristics that are not within the acceptable range. A time asymmetry error can arise from 2 particles of similar sizes, out of focus and slightly shifted in time. Each particle will show a peak on the oscilloscope and since they are slightly shifted in time it will look like 2 peaks on the screen. The way to validate that this is not a real particle is by looking at the symmetry of the peak in time.

Here are the 4 equations used to verify this criterion (time position is used in the equations):

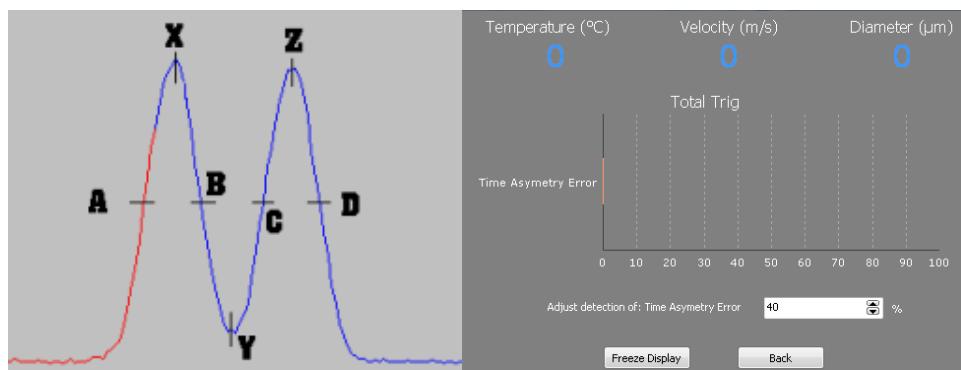
- $\frac{||X-Y|-|Z-Y||}{|X-Y|} < J$
- $\frac{||X-Y|-|Z-Y||}{|Z-Y|} < J$
- $\frac{||A-B|-|C-D||}{|A-B|} < J$
- $\frac{||A-B|-|C-D||}{|C-D|} < J$



Where J is the Maximum time asymmetry.

When J is higher than the percentage written in the “TIME ASYMMETRY ERROR” section, the particle is rejected.

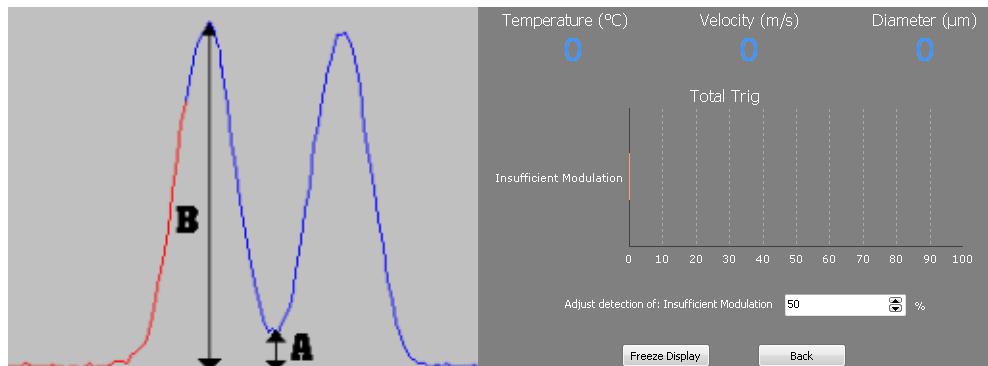
The graphic shows the percentage of rejected particles showing time asymmetry error during the acquisition. You can modify the acceptable criteria by changing the percentage of J. J must be smaller than the percentage chose in the “TIME ASYMMETRY ERROR” panel. 40% covers the majority of the processes.



#### 6.3.3.8 INSUFFICIENT MODULATION

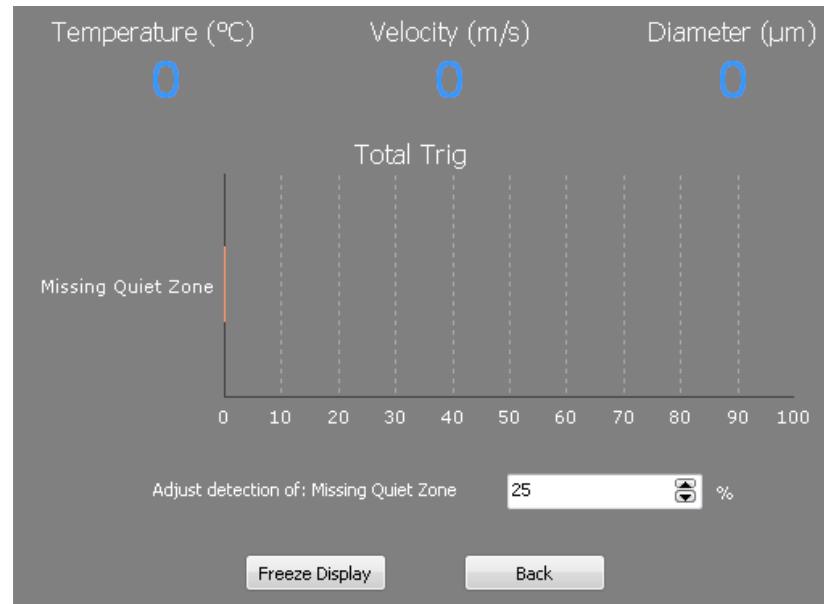
The sub-category “INSUFFICIENT MODULATION” shows the particles rejected because they show characteristics that are not within the acceptable range. An insufficient modulation particle rejection occurs when the particle is not at the focal point. In such case the valley will not return near the noise level. You can modify the acceptable criteria by changing the percentage of minimum acceptable modulation.  $1 - \frac{A}{B} \geq \text{Minimum acceptable modulation}$

50% covers the majority of the processes.



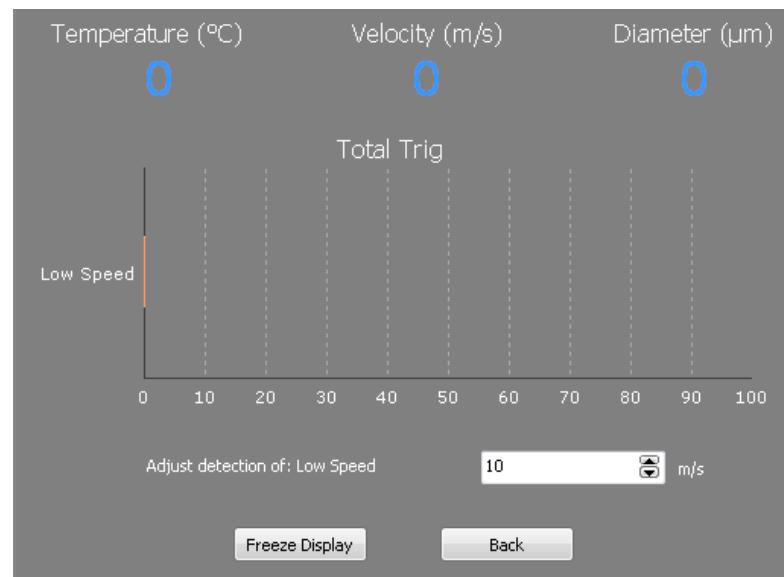
#### 6.3.3.9 MISSING QUIET ZONE

The sub-category “MISSING QUIET ZONE” shows the particles rejected because they show characteristics that are not within the acceptable range. A Missing quiet zone particle rejection occurs when you can observe signal in the noise zone. The CSM software computes the mean voltage in the noise zone. If the peak value in the noise zone is higher than X% of the mean value the particle (buffer) is rejected. Another reason to explain Missing Quiet Zones is a Capture Depth that is set too narrow. You can modify the acceptable criteria by changing the percentage of Missing quiet zone. 25% covers the majority of the processes.



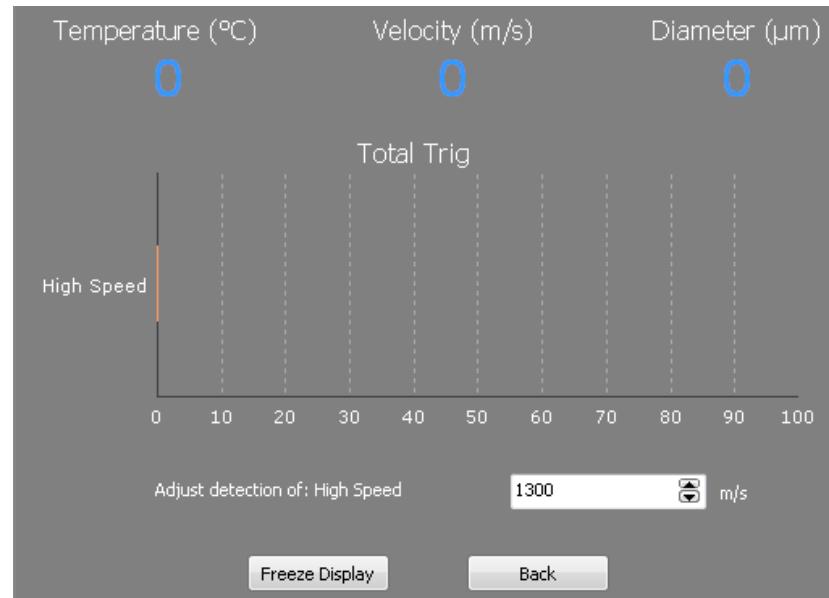
#### 6.3.3.10 LOW SPEED

The sub-category “LOW SPEED” shows the particles rejected because they show characteristics that are not within the acceptable range. A low-speed particle rejection occurs when the particle speed is lower than the value entered in that setting. You can modify the acceptable criteria by changing limit of low speed. 10m/s is the default value.



#### 6.3.3.11 HIGH SPEED

The sub-category “HIGH SPEED” shows the particles rejected because they show characteristics that are not within the acceptable range. A high-speed particle rejection occurs when the particle speed is higher than the value entered in that setting. You can modify the acceptable criteria by changing limit of high speed. 1300m/s is the default value.



#### 6.3.3.12 LOW TEMPERATURE

**Not used in CSM**

#### 6.3.3.13 HIGH TEMPERATURE

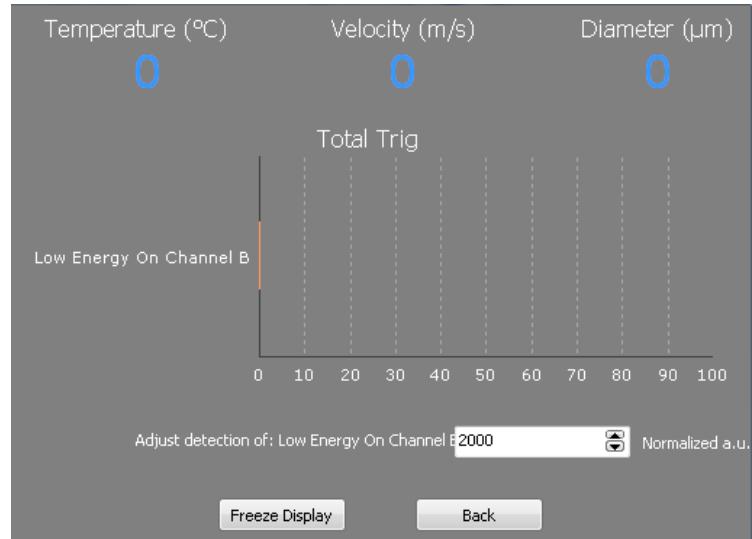
**Not used in CSM**

#### 6.3.3.14 LOW ENERGY ON CHANNEL A

**Not used in CSM**

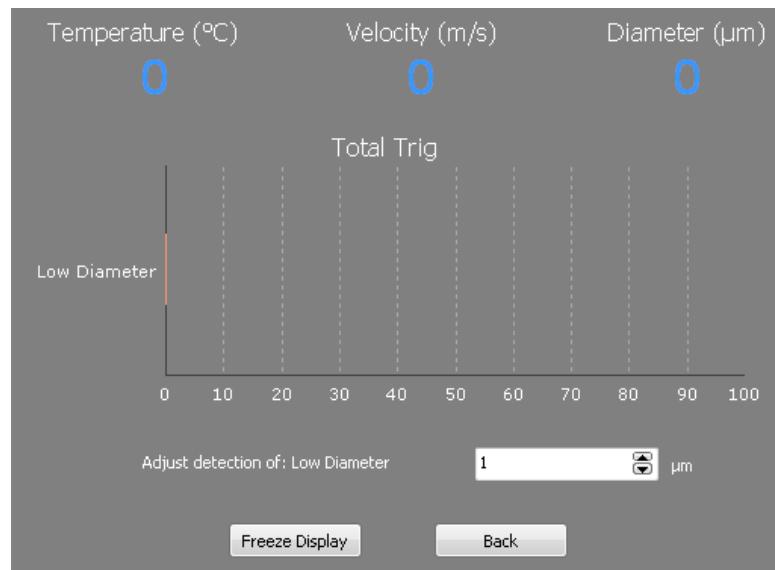
#### 6.3.3.15 LOW ENERGY ON CHANNEL B

The sub-category "LOW ENERGY ON CHANNEL B" shows the particles rejected because they show characteristics that are not within the acceptable range. A LOW ENERGY ON CHANNEL B particle rejection occurs when the particle energy is lower than the value entered in that setting. Basically, it means that there is not enough signal. You can modify the acceptable criteria by changing limit of low energy on channel B. 2000 is the default value.



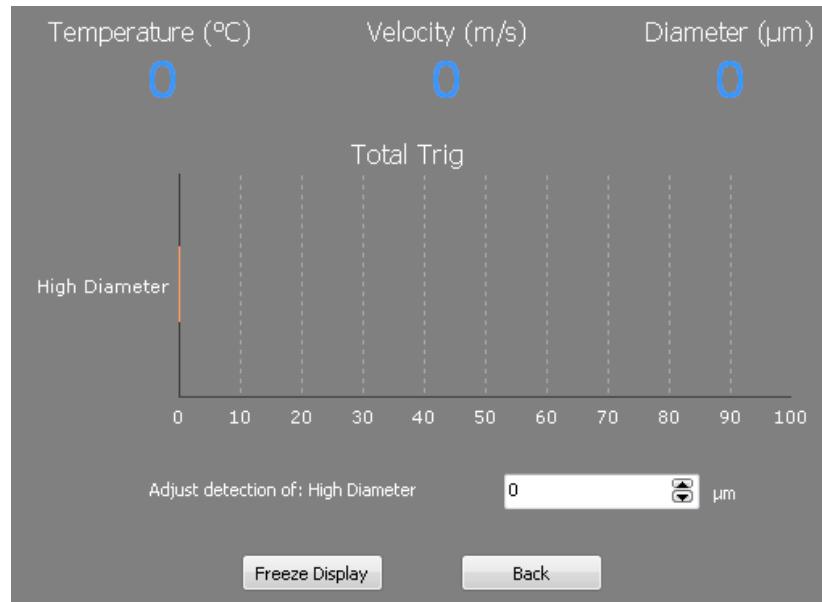
#### 6.3.3.16 LOW DIAMETER

The sub-category “LOW DIAMETER” shows the particles rejected because they show characteristics that are not within the acceptable range. A low diameter particle rejection occurs when the particle diameter is lower than the value entered in that setting. You can modify the acceptable criteria by changing limit of low diameter. 1um is the default value.



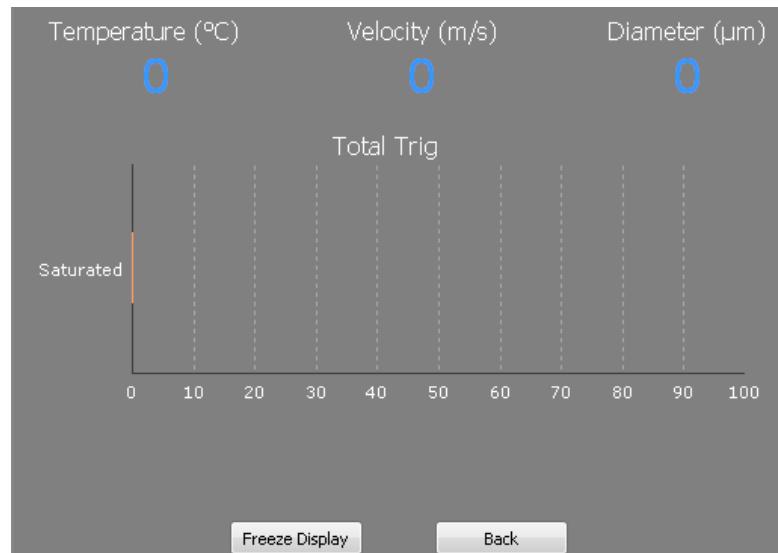
#### 6.3.3.17 HIGH DIAMETER

The sub-category “HIGH DIAMETER” shows the particles rejected because they show characteristics that are not within the acceptable range. A high diameter particle rejection occurs when the particle diameter is higher than the value entered in that setting. You can modify the acceptable criteria by changing limit of high diameter. 500um is the default value.



#### 6.3.3.18 SATURATED

The sub-category “SATURATED” shows the particles rejected because they show characteristics that are not within the acceptable range. A saturated particle rejection occurs when the particle signal saturate the acquisition card. You cannot modify this setting.



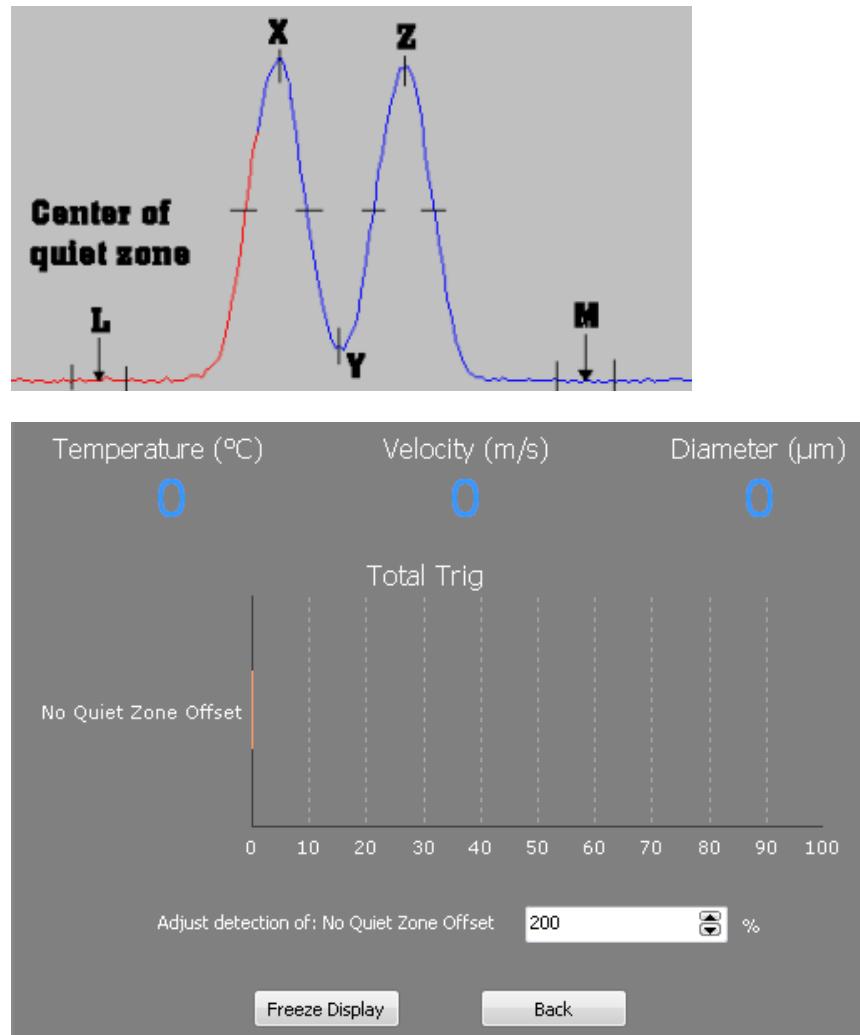
#### 6.3.3.19 QUIET ZONE OFFSET

The sub-category “QUIET ZONE OFFSET” is used to set the position where to analyze the noise section (L and M). The quiet zone location will be

$$L = X - 200\% | X - Y |.$$

$$M = Z + 200\% | Z - Y |.$$

The number entered as to be higher than 100%



NOTE THAT adjustments will probably be different for different materials or different thermal spray processes. It is therefore a good idea to create a library of setup files.

Depending on the spray process/powder/gun you are looking at, different parameters will have to be adjusted, such as DIAMETER COEFFICIENT, MASK WIDTH, Display scales, temperature calibration, etc.

When you feel your set of parameters is pretty much optimal for a given process/powder, you **SAVE** a setup file in the home tab.

Then, when coming back to this process in the future, all you will have to do is **LOAD** the corresponding setup file and your system will be configured exactly the same way it was before.

PLEASE NOTE THAT YOUR CSM IS DELIVERED WITH A SET OF PATTERN RECOGNITION PARAMETERS THAT HAS BEEN FOUND APPROPRIATE FOR

THE MAJORITY OF THE SPRAY PROCESS/CONDITIONS TYPICALLY  
ENCOUNTERED IN THERMAL SPRAY.

## 7. ABOUT CALCULATION OF VELOCITY & DIAMETER USING THE CSM-EVOLUTION

The objective of the present section is to establish some definitions as well as to explain in greater details the basic principles behind measurement of velocity & size as performed by the CSM-2000.

### 7.1 DEFINITIONS & HYPOTHESIS

TOF ≡ Time of Flight of the particle between the two slits

$V_p$  ≡ velocity of the particle

$s$  ≡ center to center distance between the slits

$A_a$  ≡ Area under the two peaks curve of channel a (corresponds to  $\lambda_1$ )

$A_b$  ≡ Area under the two peaks curve of channel b (corresponds to  $\lambda_2$ )

Energy ≡ Time integral of the two peaks curve normalized by velocity & corrected for difference in peak heights. Values are logged to \*.PRT files under

Columns "ENERGYA" and "ENERGYB"

$E(\lambda_1)$  ≡ Theoretical energy that particle irradiates at  $\lambda_1$

$E'(\lambda_1)$  ≡ Energy measured at  $\lambda_1$ , and corrected for peak height

difference (equivalent to ENERGY A as logged to the .PRT file)

$E(\lambda_2)$  ≡ Theoretical energy that particle irradiates at  $\lambda_2$

$E'(\lambda_2)$  ≡ Energy measured at  $\lambda_2$ , and corrected for peak height

difference (equivalent to ENERGY B as logged to the .PRT file)

$d$  ≡ diameter of the particle

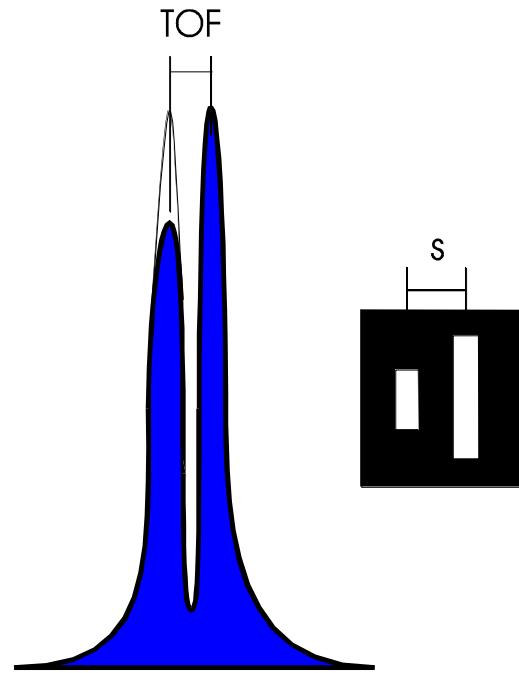
$K$  ≡ grouped constants taking into account optical properties of the system

$K_2$  ≡ constant

$K_3$  ≡ constant

$R \equiv E(\lambda_1) / E(\lambda_2)$

### 7.2 REFERENCE SCHEMATIC



- The blue area represents  $A_a$  or  $A_b$
- The clear area on top of the first peak represents the correction (extrapolated additional surface) required to take into account the fact that this particle could not be totally seen in both slits.

### 7.3 VELOCITY CALCULATION

The velocity measurement is the most simple & precise one carried out by the CSM-2000. The particle velocity  $v_p$  is defined as

$$v_p = \frac{s}{TOF} \times \text{Optical magnification of the lens} \quad (1)$$

Since the two-slits photomask is fabricated using microelectronics techniques,  $s$  is known at  $1\mu\text{m}$  precision. Furthermore, TOF is measured by a high-speed, high precision scope board, and it is as precise as the crystal on the board is. Finally, both  $s$  & Optical magnification are passive characteristics that can not drift with time. The precision on velocity is on the order of 0.5%.

### 7.4 DIAMETER MEASUREMENT

Using Planck's law & Hyp2, one can write that the diameter of a particle,  $D_p$ , is

$$D_p \propto \sqrt{\frac{E(\lambda_i)}{K_3 \epsilon(\lambda_i)}} \quad (6)$$

where  $i$  is 1 or 2.  $\varepsilon(\lambda_i)$  being extremely difficult to measure on-line, we define a new coefficient which includes both  $K_3$  &  $\varepsilon(\lambda_i)$ :

$$DC = K_3 \varepsilon(\lambda_i) \equiv \text{Diameter coefficient}$$

We then rewrite (6) as

$$D_p = \sqrt{\frac{E(\lambda_i)}{DC}} \quad (7)$$

Since diameter is calculated based on energy at ONE wavelength (one channel) only, we must here take into account the fact that some particles will not have perfectly horizontal trajectories. The two-peaks signal shown on the schematic is a typical example of a particle partially seen through slit #1 and totally seen through slit #2 ( $A_i \neq E_i$ ). If no correction is applied, this results in a systematic underestimation of the energy radiated by the particle, and consequently, based on (7), this leads to a systematically underestimated diameter value. For all particles showing different peak heights but still accepted because the difference is inferior or equal to the criteria MAXIMUM PEAK HEIGHTS DIFFERENCE, an ENERGY correction is automatically applied in order to minimize the error on diameter due to the fact that most of the particles do not travel on horizontal trajectories. We then rewrite (7) as

$$D_p = \sqrt{\frac{E'(\lambda_i)}{DC}} \quad (8)$$

where, again,  $E'(\lambda_i)$  is the MEASURED energy CORRECTED for peak height difference.

The correction is of the form

$$E'(\lambda_i) = A_i \left[ 1 + \frac{(P_1 - P_2)}{2P_1} \right] \quad (9)$$

where  $P_1$  &  $P_2$  are the first and second peak amplitude respectively. Note that values of  $P_1$  &  $P_2$  are generally different at  $\lambda_1$  as compared to  $\lambda_2$ , leading to a

slightly different correction factor for the two wavelengths.

It is clear from the above that emissivity  $\varepsilon(\lambda_i)$ , and thus DC, is an unknown at the beginning of the experiment. In order to obtain precise ABSOLUTE  $D_p$  values, one must follow, for each different material, the calibration procedure described in the reference manual in section 3.5.

When this calibration step is performed, we consider that precision on  $D_p$  is between 7 & 15%, and that it is greatly dependent on the validity of the initial hypothesis, specifically Hyp3 concerning sphericity of melted particles.

## 8. LASER SAFETY

The risks related to lasers are highly variable depending on several laser emission characteristics such as wavelength, energy, mode of delivery, pulsed or continuous operation, etc... The American National Standard (ANSI) has developed a laser classification table to indicate rapidly the level of hazards pertinent to a given laser. The table defines four general classes:

CLASS I: Lasers presenting no danger in all reasonable foreseeable condition of use.

CLASS II: Laser that emits laser radiation in the visible spectrum (400 nm to 700 nm wavelength. In such case, eye protection is normally ensured by automatic reflex of the human eye.

CLASS III: Laser that emits laser radiation for which direct eye contact is dangerous, under any circumstances. Diffuse reflection of the laser source presents no danger.

CLASS IV: Laser that emits laser radiation for which even diffuse reflection is dangerous.

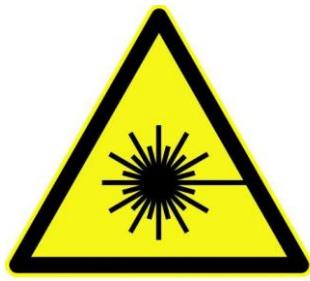
***The COLDSPRAY METER is a CLASS 4 type laser***

### 8.1 GENERAL SAFETY GUIDELINE

***The COLDSPRAY Meter emits an invisible laser that can cause irreparable damage to the naked eye. Never view directly and/or indirectly the laser light emitted from the COLDSPRAY Meter without proper eye protection.***

When using the *Coldspray meter*, operator should ***strictly*** adhere to the following procedures:

- Only personnel trained in laser safety should operate the *Coldspray meter*.
- Operators should never look directly into any output optical fiber of the *Coldspray meter*, nor point any output fiber into the eye of another person.
- The *Coldspray meter scanner (not the controller)* is installed into a close room with a door that can be closed.
- It is recommended that all doors and accesses leading to the area where the *Coldspray meter* is located be mounted with safety interlocks connected to the external interlock link of the *Coldspray meter*. With such safety interlocks, unexpected entry will automatically deactivate the unit. Once deactivated, the *Coldspray meter* must be manually restarted before laser firing can be resumed.
- It is recommended that warning signs be placed on all doors and accesses leading to the area where the *Coldspray meter* is used, indicating the presence of a class IV laser.
- An emergency stop (E-STOP) button is located on the front panel of the



*Coldspray meter*. Pressing the E-stop will immediately disable the laser. It will not, however, cut the electrical power to the unit.

- The operating procedures include steps for verification of the safety systems at start-up of the PDL and before resuming the firing of the PDL.
- The operator is required to use a removable key to arm the lasers.
- Safety features, risks, procedures and precautions are described in the training session when installing the *Coldspray meter*.
- Any personnel present inside the area where the *Coldspray meter scanner* is used is required to wear laser safety goggles when the *Coldspray meter* is activated. The laser safety goggles are meant to provide adequate protection considering the *Coldspray meter*' wavelength, maximum output power and waist.

## 8.2 LASER SAFETY LABELS

The *Coldspray meter* has safety labels identifying areas of potential hazard. The following figures show the different labels present on the *Coldspray meter* scanner. During training, the maintenance personnel and operators will be advised of the location of these labels and their significance. All safety labels must be kept clean and at all times.

The following describes the safety labels present on the *Coldspray meter scanner*.



FIGURE 23 UNIVERSAL LASER LABEL (LABEL 1)

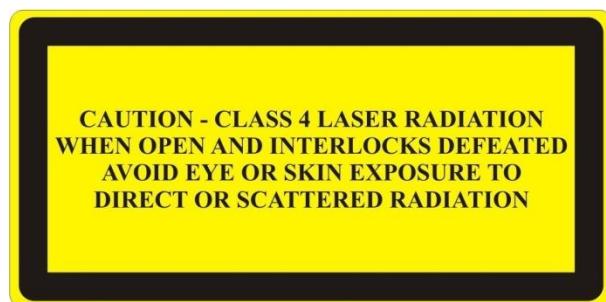
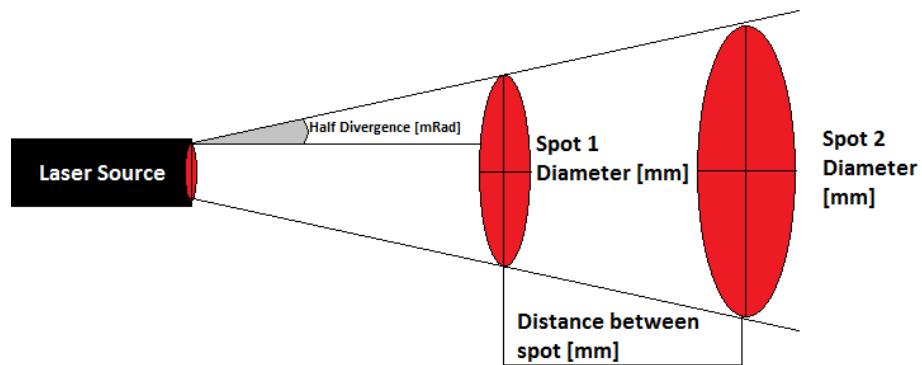


FIGURE 24 LASER SAFETY INTERLOCK DOOR (LABEL 2)

## 8.3 LASER BEAM DIVERGENCE AND LASER POWER

The Beam divergence explains the angular propagation of a laser ray. The unit of the divergence is the milliradian. When the divergence is high, the laser spot will grow faster.

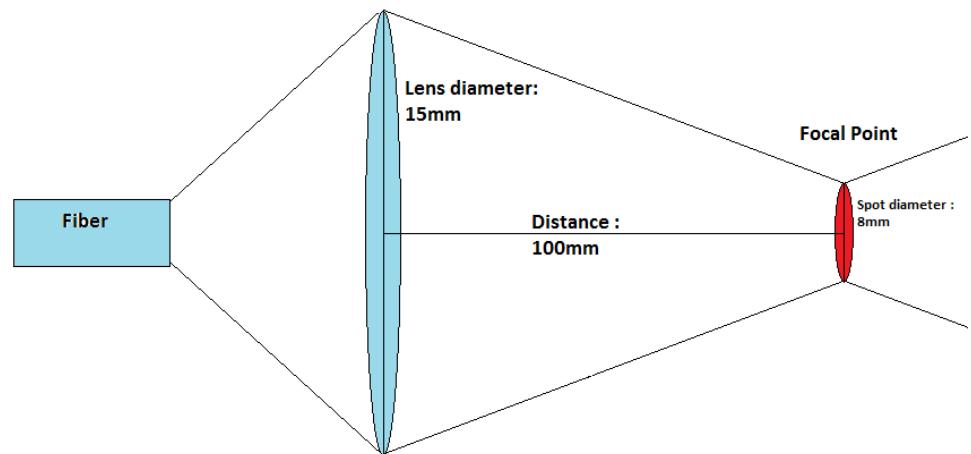


The calculation of the divergence is:

$$\text{Divergence[mrad]} = 2 \times \left( \tan^{-1} \left( \frac{\text{Radius2} - \text{Radius1}}{\text{Distance}} \right) \right)$$

In the Coldspray meter, the light is coupled into an optical fiber before being focused at the working distance. The nominal power of the laser source is 3.3W at the output of the fiber. The divergence after the fiber-lens system is determined by the same calculation.

$$\text{Divergence[mrad]} = 2 \times \left( \tan^{-1} \left( \frac{7.5\text{mm} - 4\text{mm}}{100\text{mm}} \right) \right) = 70\text{mrad}$$



The power density at the focal point is  $6.57\text{W/cm}^2$

The Wavelength of the CSM laser is 810nm.

## 9. TROUBLESHOOTING

### 9.1 HOW TO GET RID OF THE PHANTOM VELOCITY PEAK

It is possible for two out of focus identical particles to cross the measurement volume with such a time shift that they will look like a very symmetrical, lower velocity particle; we refer to this phenomenon as the “phantom velocity peak”. This phantom peak will be more or less important depending on the process. You have two choices here: either you reject particles in post treatment, or you adjust the LOW SPEED parameter (in the Detection Tuning Screen, see section 1.5.3) high enough to discard those particles right before acquisition.

## 10. GLOSSARY / ACRONYMS

CSM	Cold Spray Meter
Item 2	Definition 2
Item 3	Definition 3

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## 12. SERVICE & SUPPORT

Below are the points of contact for questions and/or service-support on CSM-2000/eVOLUTION systems.

TECNAR Automation Ltd (The original manufacturer)

1021, Marie-Victorin Street,

St-Bruno, Qc, Canada J3V 0M7

Phone: 450-461-1221

Contact:

service@tecnar.com

**E C Conformity  
Declaration**

Herewith the company:

**TECNAR Automation Ltd.**

**1321, Hocquart Street, St-Bruno, Qc, Canada, J3V 6B5**

Declares that the products:

**ColdSprayMeter**

Meets all the requirements as defined in the following standards:

CISPR 11: 2009 A1 : 2010  
EN 61000-4-3: 2006 A1: 2008 A2 : 2010  
EN 6100-4-6 : 2009  
EN 6100-4-2 : 2009  
EN 6100-4-4 : 2012  
EN 6100-4-5 : 2006  
EN 6100-4-11 : 2004

St-Bruno, March 1st, 2014



Francois Nadeau  
President

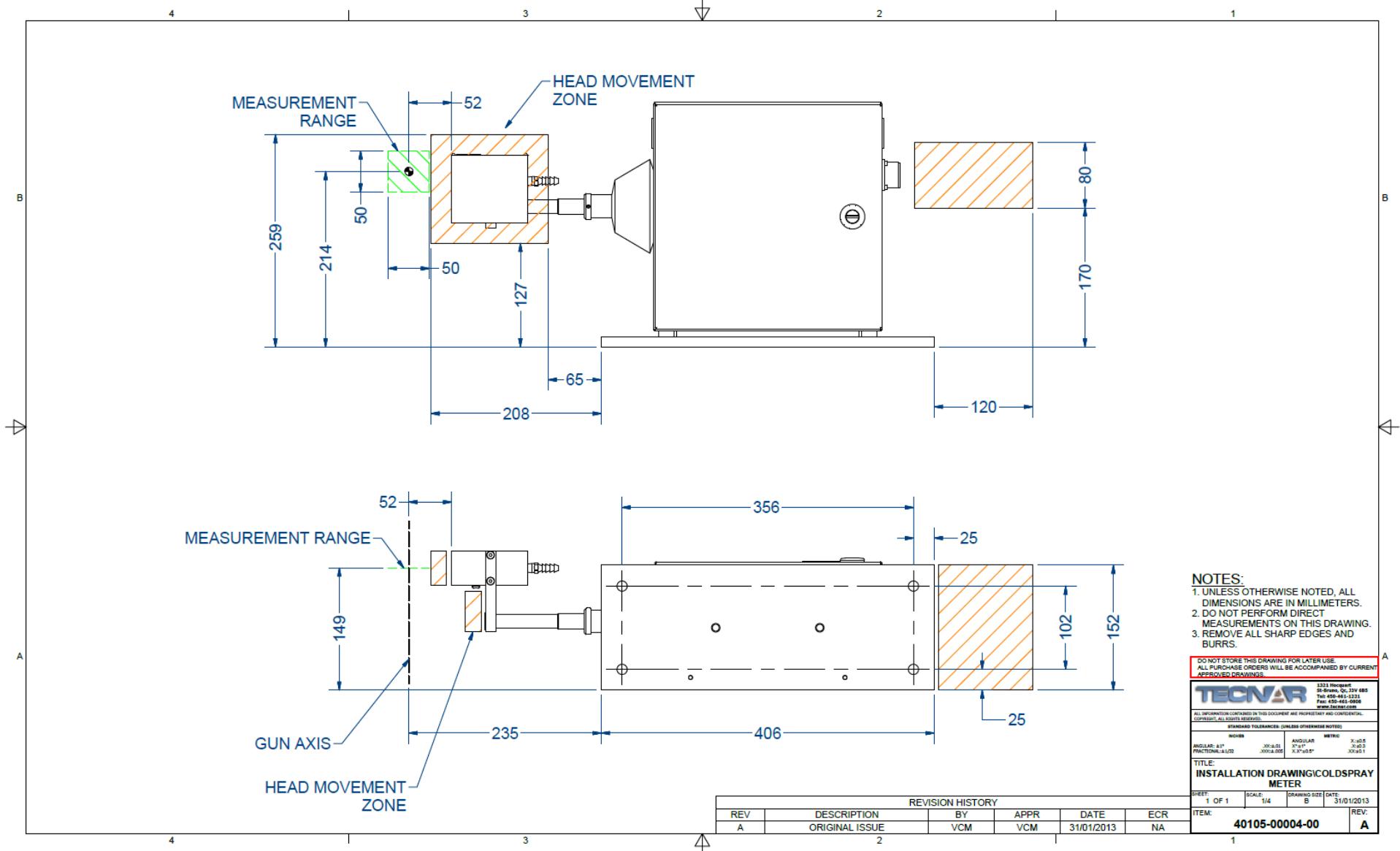


FIGURE 25 CSM EVOLUTION INSTALLATION DRAWING