Particles in Cooling Liquids

Particle Detection in Cooling Liquids for Data Centers

The Application of Dynamic Imaging to Detect Particles in Cooling Liquid Systems

Heer Mehta

J.M. Canty

In data center cooling systems, maintaining liquid quality is critical for reliable thermal performance and long-term infrastructure protection. Particulate matter in cooling liquid can compromise system efficiency and integrity, making accurate measurement and quantification essential for assessing cleanliness and stability as advanced liquid cooling architectures are adopted.

Continuous particle monitoring provides real-time insight into particle size and concentration, enabling informed decisions on filtration, maintenance, and operational control. This paper examines the application of the CANTY InFlow™ analyzer, a dynamic imaging technology that detects solids, droplets, gas bubbles, and other foreign materials directly within cooling liquid flow.

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PROCESS TECHNOLOGY

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Introduction

Dynamic imaging involves flowing cooling liquids through an inline analyzer that captures microscopic images of the fluid and analyzes those images to detect the presence of particles. These particles may include droplets, gas bubbles, or solid materials. Because the acquired images are two-dimensional and these materials exhibit distinct physical appearances, dynamic imaging analyzers are capable of simultaneously detecting, sizing, and measuring the concentration of each material independently

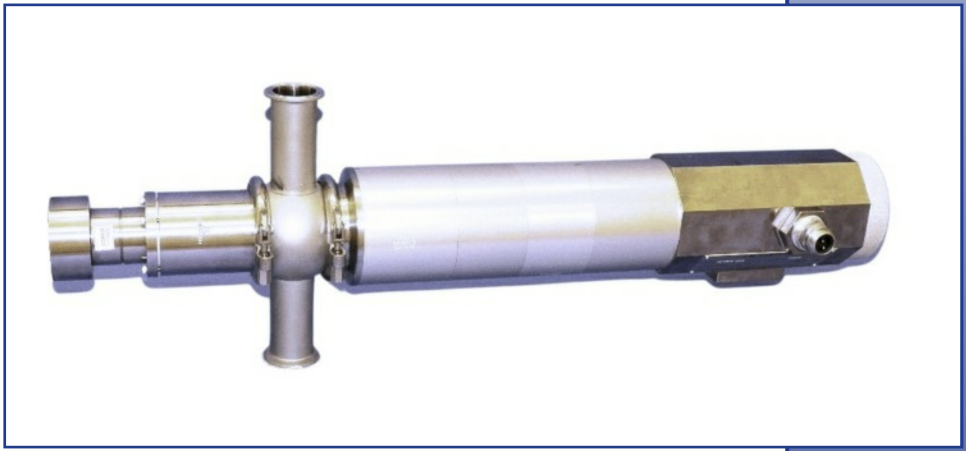
When the CANTY Inflow™ analyzer is installed inline within a data center cooling loop, the analyzer is capable of detecting solid particles at the micron scale and above. When detected, the analyzer outputs signals corresponding to particle size, count, concentration, providing continuous visibility into cooling liquid quality without interrupting system operation.

These outputs allow the cooling system to respond more quickly than conventional monitoring methods, such as conductivity sensors, florescent tracing chemicals, or pH sensors. By monitoring particles in real time as they pass through an inline analyzer, operators can accurately assess cooling liquid quality without taking separate samples. Since particle concentration in well-maintained cooling loops are usually low, relying on manual sampling can lead to uncertain results, and small sample volumes increase the chance of contamination from handling or containers. Real-time particle data can help determine when a line requires filtration maintenance, flushing, or cleaning, ensuring consistent system performance.

Overview of Cooling Liquids in Data Centers

Cooling liquid is an important part of data center operations, the equipment generates significant heat that must be efficiently removed. Poor liquid quality can reduce heat transfer efficiency, allowing equipment to overheat, which can lead to hardware damage, or system shutdowns. Particles in the liquid can cause scaling, corrosion, or clogging in pipes, further reducing cooling performance and increasing the risk of downtime. To prevent these issues, cooling liquid is typically managed through filtration, chemical treatment to monitor pH, and recirculation, with continuous monitoring to ensure that particle levels remain within safe operating limits.

Maintaining high-quality cooling liquid is essential for stable and efficient data center operation. Properly treated liquid enhances heat transfer performance, allowing cooling systems to operate within design specifications while minimizing energy demand. Good liquid quality also reduces corrosion, fouling, and particulate deposition on heat exchangers, pumps, and piping, extending equipment lifespan and reducing maintenance requirements. Consistent control of liquid quality parameters supports reliable system performance, lowers the risk of unplanned downtime, and helps maintain overall cooling system efficiency as thermal loads increase.



As data centers continue to increase in size and power density, maintaining consistent cooling liquid quality becomes more challenging and more critical. Higher thermal loads place greater demands on cooling infrastructure, making systems more sensitive to even small changes in liquid quality. Fluctuations in particle concentration or chemical balance can quickly impact heat exchanger performance and system stability. As a result, reliable and continuous monitoring of cooling liquid is necessary to detect early signs of contamination, assess treatment effectiveness, and ensure long-term operational reliability.

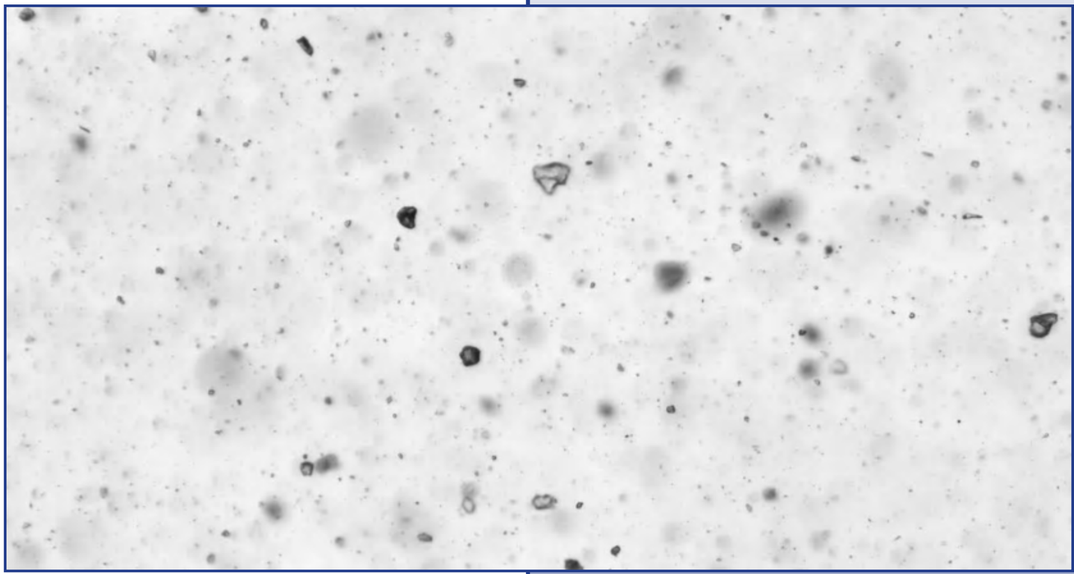
Current liquid Testing Techniques

Some common methods for detecting and measuring particles in cooling liquid are (1) Conductivity and pH sensors, (2) Blowdown reuse analysis, and (3) Manual analysis. Conductivity sensors are used to identify leaks by measuring the liquids electrical current in µS/cm. This is dependent on the concentration of ions in the solution. To determine if there is a leak, the sensors are placed in between the possible source to locate a difference in conductivity. The pH sensors are used to identify contaminant levels, which depending on the coolants pH (on average 7.5-9), it is likely the process is contaminated with dissolved solids when fluctuated. Although they provide useful information about overall liquid chemistry, they do not directly detect or measure particulate matter.

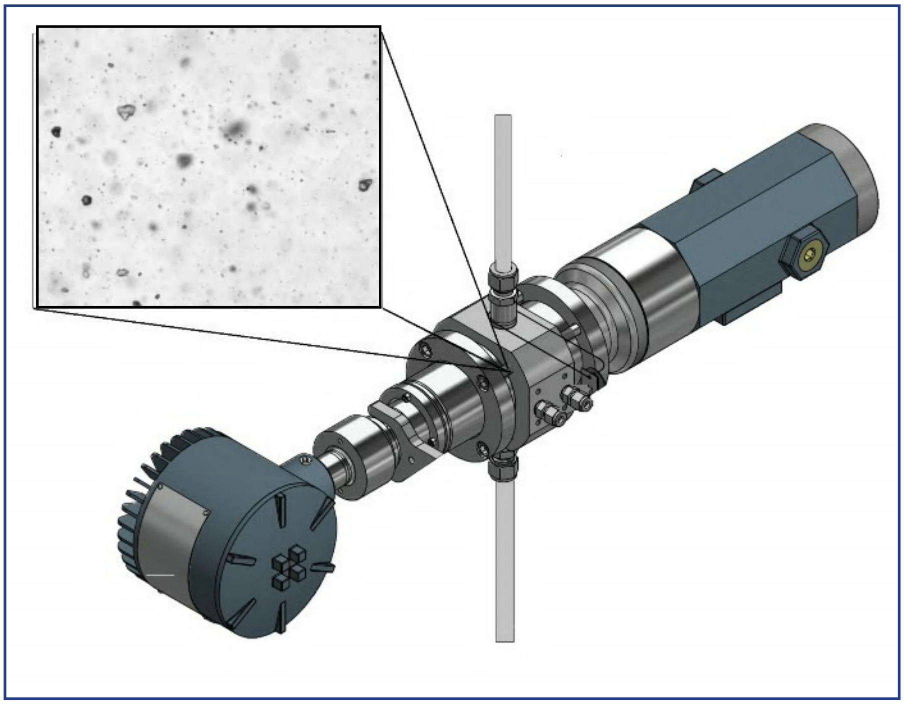
During blowdown reuse, the concentrated liquid is periodically removed to control the buildup of contaminants and total dissolved solids (TDS) to protect the system health. This needs to be properly calibrated otherwise problems may arise. Excessive blowdown wastes large volumes of liquid and energy and insufficient blowdown can lead to scale buildup and chemical instability. Since blowdown only represents a small portion of the system, it may not reflect particle activity occurring in other areas of the cooling loop.

Manual inspection involves collecting liquid samples and examining them for visible particles and discoloration, this can also be taken for sampling to provide detailed particle size and concentration. This method is time-consuming and limited to what can be seen with visual inspection or basic magnification. This may not represent the particles within the cooling system. With low particle concentrations, individual samples may not reflect intermittent particle activity, and small samples are more likely to be contaminated during collection.

The CANTY InFlow™ eliminates many limitations associated with sampling-based monitoring, including inconsistent results, reduced fluid clarity, increased viscosity, and interference from gas bubbles. The analyzer can be installed directly inline within a cooling loop or used in a laboratory configuration and operates fully automatically, providing continuous data without operator intervention. It captures images in real time and measures particle size, two-dimensional shape, and concentration as particles pass through.



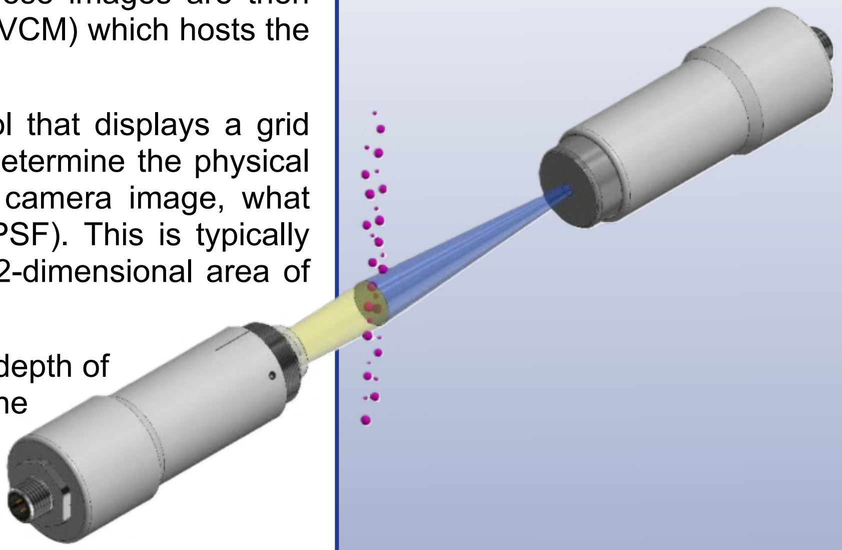
Integrating this technology inline eliminates the need for sampling, manual counting or observation to detect particles. Real-time particle detection provides a representative view of cooling liquid quality across the system, rather than a single point-in-time sample. This data allows operators to spot abnormal particle levels, confirm filtration performance, and determine when cleaning or flushing is necessary. Tracking particle size and concentration over time helps prevent cooling issues and protect hardware reliability.



How Dynamic Imaging Works

Dynamic imaging makes use of image analysis on a video stream of microscopic images. CANTY's InFlow™captures images of the process fluid and potential contaminants. These images are then transmitted back to a Vector Control Module (VCM) which hosts the software that performs the analysis.

The analyzer is calibrated by installing a tool that displays a grid pattern on the camera. This grid is used to determine the physical distance that each pixel represents on the camera image, what CANTY refers to as the pixel scale factor (PSF). This is typically reported in μm/pixel. Knowing the PSF, the 2-dimensional area of each frame can be calculated.



The lens utilized in an InFlow™ has a known depth of field (DOF). The DOF is a measurement of the depth in which subjects, such as the particles in a fluid, are in focus. This now allows CANTY to measure the volume of each image taken in which particles are in focus.

AI Functionality

On each image, the CantyVision software determines what might be a "particle" from what is the background fluid. At this stage, the "particle" could be anything, a solid, rouge, biofilm, or bubble. Using classical image processing techniques, the software first identifies potential particles based on contrast, edges, and segmentation from the background.

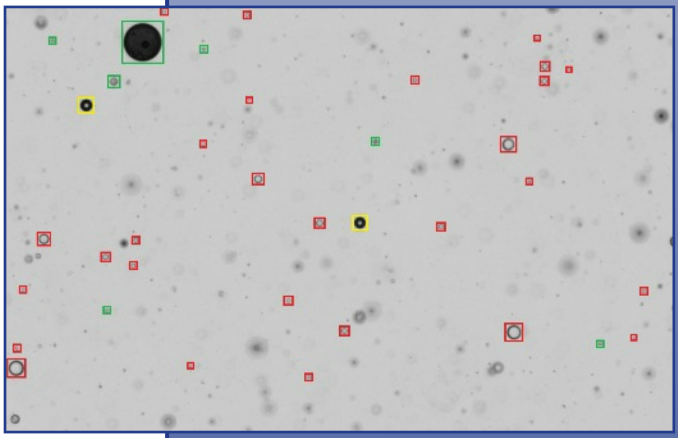


Figure shows a variety of particles detected and differentiated through our CantyVision software.

The software next makes a measurement that grades whether or not the particle is in focus. If it is in focus, then this particle is within the depth of field of the lens used and should be included in the analysis. If a particle is not in focus, it is disregarded.

Each particle looks morphologically different from one another. These differences are captured numerically through various measured shape factors. The CantyVision platform combines these classical measurements with AI-based classification, where the software is trained to recognize trends in these shape factors belonging to each particle type. This allows the system to distinguish between different kinds of particles captured in the same analysis and quantify each class independently.

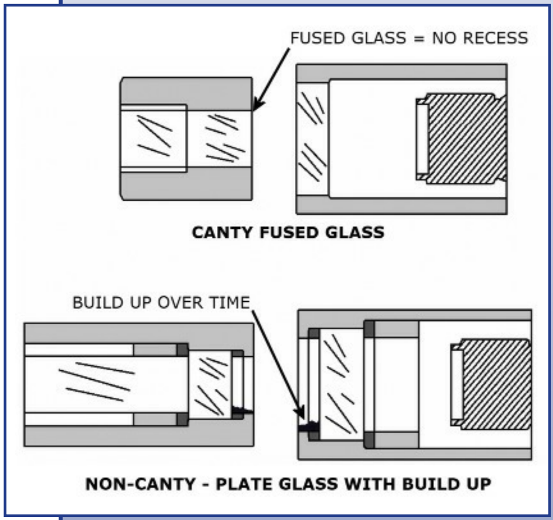
The software then calculates a volume of that particle based on its classification. Since the volume of each image being analyzed is known, the concentration of any given class of particle can be calculated on a volumetric basis and converted into a mass concentration using the bulk density of the particle class.

By averaging over hundreds of images, the InFlow™ system provides a representative concentration and particle size distribution for each particle class analyzed.

InFlow™ Hardware

The hardware involved in CANTY's InFlow™ includes 4 main key technologies: the flow cell, lighting, camera optics, and Vector Control Module (VCM).

The flow cell on an InFlow™ is designed to mount directly inline with standard sizes up to a pipe size of 3". (Custom units may be provided for line sizes greater than 3". Consult the factory for details.) The flow cell is designed to orient particles such that the analyzer is always able to capture an image of the longest side of each particle. This is key to accurately sizing each particle seen. Critically, the flow cell seals the light and camera from the process using CANTY's fused glass technology. This fused glass barrier, unique to CANTY, can sustain extremely high temperatures and pressures while still allowing for a view into the process. Unlike other analyzers, this fusion of metal to glass creates a hermetic seal eliminating the need for gaskets or O-rings at the glass interface where the camera views and light shines through. The smooth, crevice-free viewing surface makes it difficult for contaminants to adhere or accumulate, which is extremely important for mining slurries.



CANTY says that there are three keys to a perfect image: lighting, lighting, and lighting. CANTY has been leading the industry and innovating in process lighting since the 1970's and applies all of that knowledge in the InFlow™ analyzer. The LED light used is the brightest in the industry with a guaranteed lifetime of 5 years. Unlike many other analyzers, the light in the InFlow™ back-lights the process, resulting in sharp, crisp images of each in-focus particle.

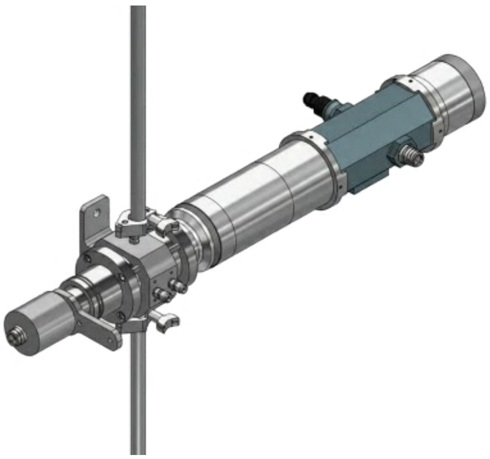
The high-resolution gigabit Ethernet CCD optics used in every InFlow™ undergo rigorous testing to ensure long-term durability and performance. Because imaging technology is always advancing, CANTY continually evaluates the latest cameras and lenses to deliver the highest-quality images without compromising the analyzer's quality and reliability. Optics used in any given analyzer are picked according to the requirements of the application. The latest generation of optics used in the InFlow™ utilize a 4K resolution camera that can pick up on particles as small as 1μm.

Obtaining a high quality image of a process is only half the battle. The magic happens when that image is processed on CANTY's VCM. The VCM platform is a series of powerful processors that host the CantyVision software. These machines are configured with the analyzers at the factory prior to shipping to make obtaining an image truly plug-and-play right out of the box. In an age of remote connections, the VCM have the ability for users to allow CANTY personnel to remotely access the unit to provide support and help troubleshoot the analyzers. These analyzers also provide the outputs to interface the data tags with a user's control system.

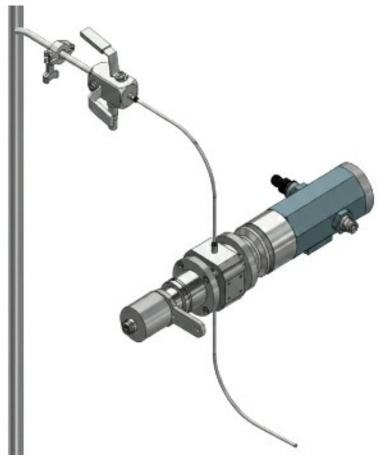
InFlow™ Hardware Cont'd & Configurations

CANTY InFlow™Analyzers can be configured multiple different ways, either in the field or in a laboratory environment. When mounted in the field the analyzer connects to two pieces of process tubing directly **inline or at-line** on a sample line. For either configuration vertical upward flow is preferred, flow rates and connection sizes determine if it is best to mount directly inline or on a sample line. Inline analyzer connection sizes range from 1/2" to 8" and the at-line system is a 1/2" sample line connection size.

Inline Unit



At-Line Unit



Although sampling is not recommended, these analyzers can also be configured for laboratory environments if a suitable location in the field can not be accommodated. The **Mini Lab InFlow™** can draw samples of fluid through the flow cell to analyze the sample and detect droplets, solids, rouge, or biofilm. Although sampling is not optimal, dynamic imaging is still being utilized which has many benefits above other methods such as laser light obscuration. Any lab configuration is fully automated, requiring limited operator intervention. When there are several streams that need to be tested and permanent installations on each may not be possible, the **Portable InFlow™** can be used. This system is easily moved from stream to stream to run short-term testing on each. This can also be a useful tool in situations where space is limited and monitoring is only needed occasionally.

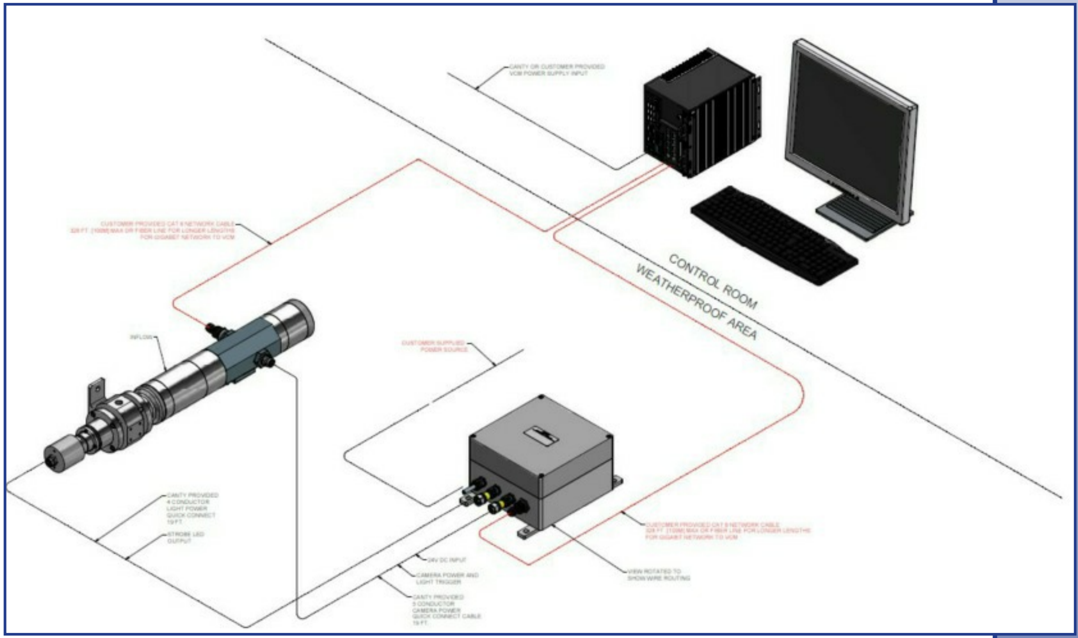
Portable InFlow™

Mini Lab InFlow™

Connectivity

Inline Connectivity

Due to the amount of data being transmitted between the InFlow™ and VCM, CANTY requires the use of CAT6 Ethernet running from the analyzer to it's power supply and from it's power supply back to the VCM. A typical layout of the components can be seen here. CAT6 Ethernet, however, has a distance limitation of 100m before there is signal loss that can interrupt analysis. In those situations, it is possible to convert the CAT6 Ethernet to fiber via CANTY's media converters. Refer to document TA11950-1024 if this situation applies.



Lab Connectivity

The Canty core unit powers and controls the analyzer. Once the Mini Lab InFlow™ and core unit are setup on a lab bench, connecting them is simple. There are unique pinned receptacles which only allow them to be connected one way with the provided cables allowing for easy straight forward wiring.

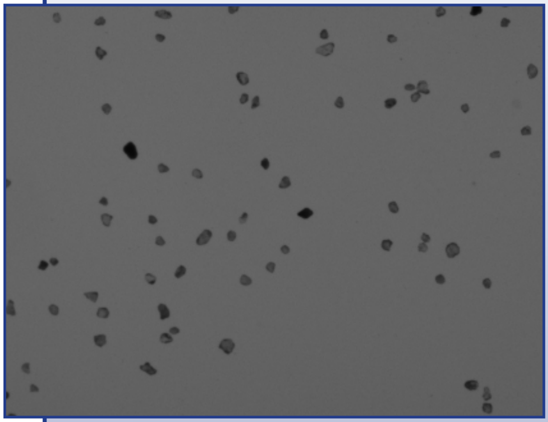
The Ethernet connections on the core unit and analyzer are connected to the VCM in the labeled Ethernet ports.

Connecting the USB from pumps in the Mini Lab InFlow™ system to any USB port on the VCM as well as connecting the USB dongle for the keyboard and mouse is simple.

The monitor comes pre wired from Canty's factory with the display cable and power cable wired through the mounting pole that slide into the core unit. Connecting the display cable to the VCM will allow for the CantyVision Software to be displayed on the monitor. Lastly, connecting the core unit and monitor to a standard wall outlet powers the system allowing for samples to be analyzed right away with data storing locally on the VCM.

Data Outputs For Particles in Cooling liquid

When a particle is detected in cooling liquid, it is critical to capture as much information as quickly as possible. Inline dynamic imaging analyzers provide the following key outputs:



- Count of suspended solids/rouge, biofilm, and counts of bubbles per unit volume of process fluid

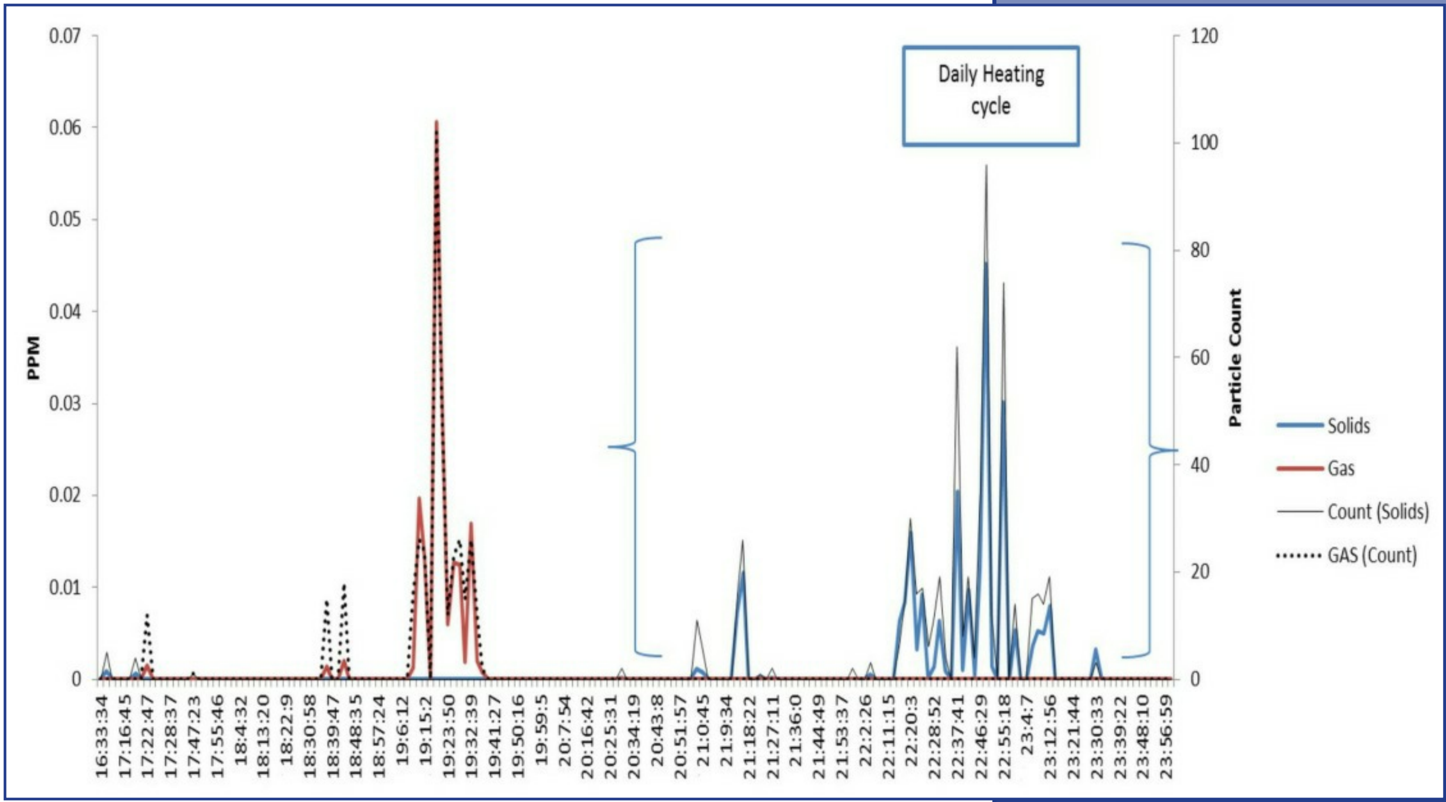
  Combined with size data, outputs of counts/mL in a size range output to match USP 788/1788.

- Shape and Size distribution of the solid particles

  The shape and size distribution of the suspended solids can give information on the type of solid and promote understanding of biological, chemical, and physical processes that form the solids.

In addition to particle-specific measurements, generic system health alerts monitor analyzer status, including camera temperature, signal integrity, and communication health.

All outputs can be trended over time in a data historian to track contamination patterns, evaluate filtration performance, and assess overall cooling system health. The analyzer supports standard communication protocols—including OPC UA, Modbus TCP/IP, Modbus RTU, and Analog (4–20 mA)—to integrate seamlessly with building or process control systems.



Conclusion

CANTY's InFlow™ analyzer is an effective tool for the automatic detection and measurement of particles in data center cooling liquid. Installed directly inline, they avoid the limitations of sampling-based methods, can detect very small particles, and provide multiple outputs that help evaluate filtration performance and overall system liquid quality. The analyzer captures two-dimensional measurements while filtering out gas bubbles, resulting in more accurate and detailed data. These measurements provide a reliable way to monitor particle levels, optimize cooling system performance, and protect critical hardware from particulate-related issues.

Get more information!
Website: https://www.jmcanty.com

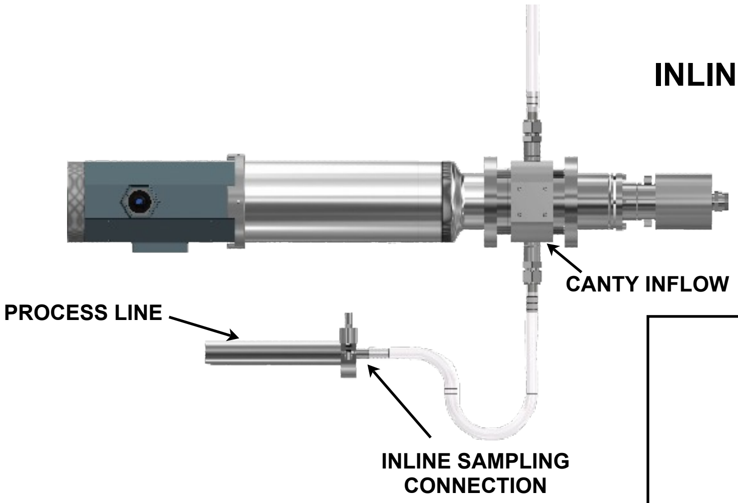
North America
JM Canty, Inc.
6100 Donner Road
Buffalo, NY, United States
+1 (716) 625-4227
sales@jmcanty.com
techsupport@jmcanty.com

EU & International
JM Canty International, Ltd.
Ballycoolin Business Park
Blanchardstown
Dublin 15, D15 KV02, Ireland
+353 (1) 882-9621
+353 (1) 882-9622
Sales.ie@jmcanty.com
Techsupport.ie@jmcanty.com

Thailand Office
JM Canty Thailand Office
Phuket, Thailand
+66 83 9689548
Sales.ie@jmcanty.com
Techsupport.ie@jmcanty.com

Sampling Ports

INLINE Sampling

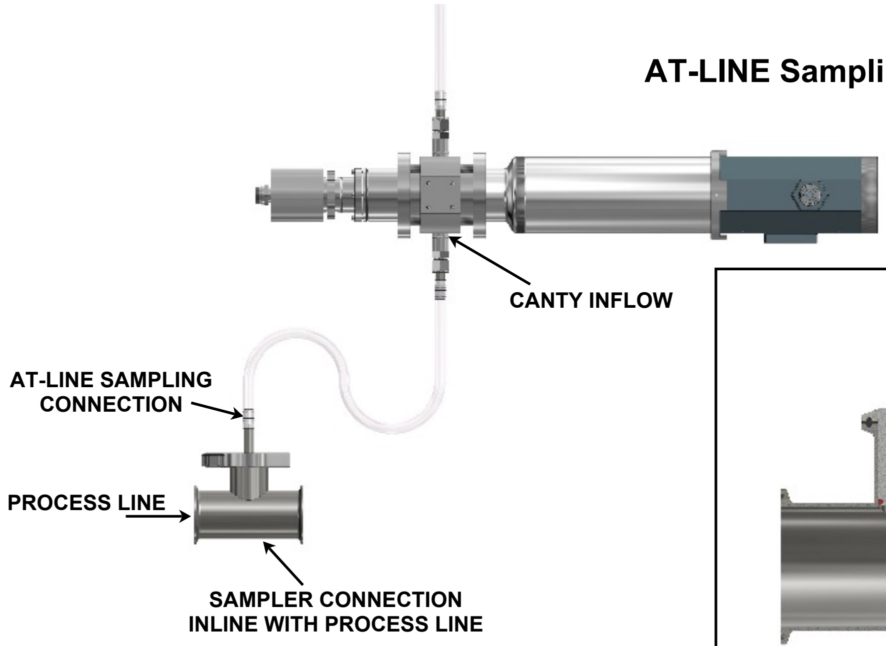


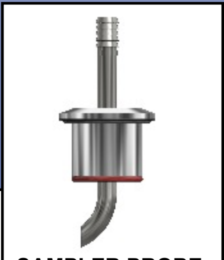
BARB FITTING

INLINE SAMPLING CONNECTION

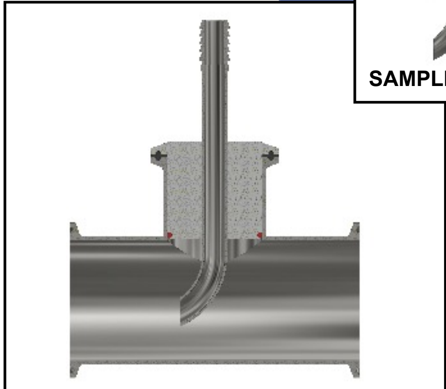
The inline sampler mounts at the end of the customer’s process line to draw a sample. The tri-clamp connection is available in ½”, ¾”, 1”, and 1.5” sizes to match the customer’s process line, and the barb fitting on the outlet connects directly to the Inflow analyzer.

AT-LINE Sampling





SAMPLER PROBE



SAMPLER CONNECTION
INLINE WITH PROCESS LINE

The At-Line sampler installs directly into the customer’s process line using two end connections. The center sampler probe then draws the product stream directly into the Inflow Analyzer. Tri-clamp connections are available in 2”, 2.5”, 3”, 4”, and 6” sizes to match the customer’s process line.