

installation when different trades are vying for the same space and during validation when deadlines are tight.

System Design

There are several documents^{4 5} that identify how best to design a particle monitoring system. Considerations include selection of sample points, which hardware to use for each application, and the relationship between risk versus instrumentation. Figure 2 shows a typical system designed to monitor the environmental conditions within a clean room.

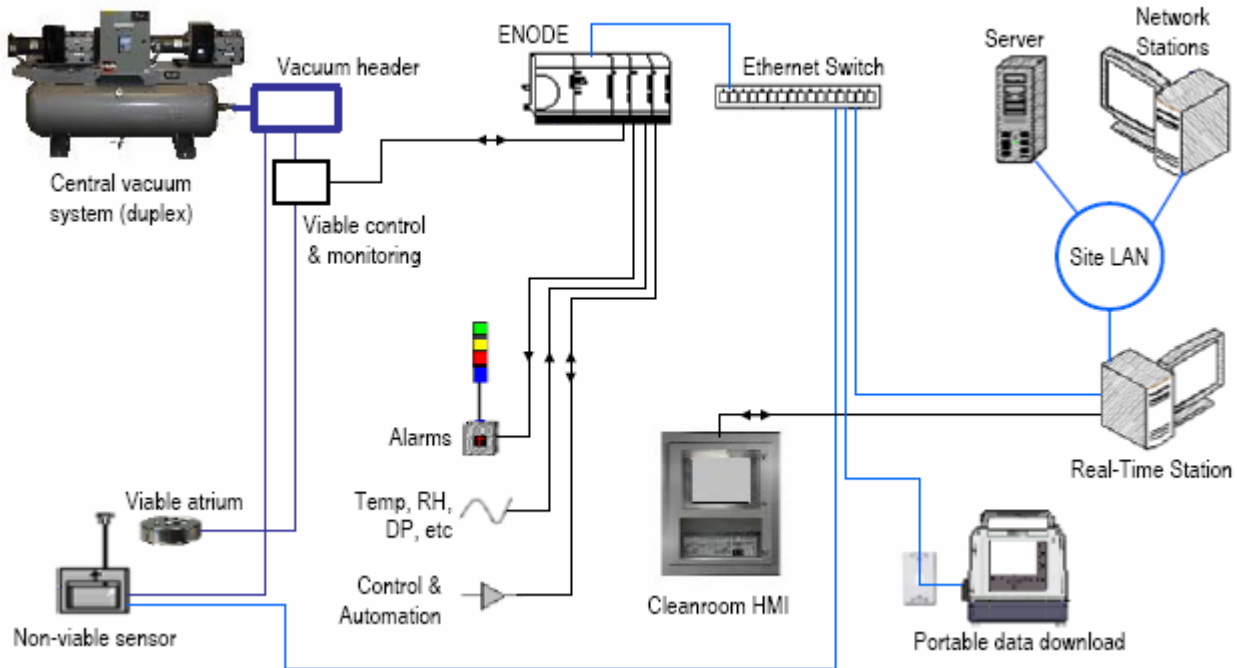


Figure 2 Facility Monitoring System Schematic

The driving factors in designing a monitoring clean room should be defined in the User Requirement Specification (URS), the contents and format of which is fully described in the GAMP guidance documentation. Any changes required to a system that makes it user friendly should be incorporated as early in the project as possible to avoid costly changes to project scope later. When the speed required to implement a system does not allow sufficient time for the generation of a 'perfect' URS it can be subcontracted to a design company for preparation. It is important to ensure the end users or system owners review the document as the liability of using a system lies with them.

System Installation

As can be seen from Figure 2 there are many components to the installation of a monitoring system. These include:

- **Wiring:** The infrastructure of wiring includes power cables (24VDC, 120-240VAC, and 3 phase), signal wiring 4-20mA analog, Ethernet and RS485 data communications, and I/O connections for process controls, starting stopping of vacuum pumps and the integration of functional hardware switches for state changes, etc. The choice of wire

depends on load, fire hazards, length of runs, and signal speed. Cables are normally run in either cable tray or conduit specific for a location, where existing support infrastructure can be incorporated; this reduces redundancy in the installation.

- **Tubing:** There are primarily two types of tubing: one that draws a sample to the sensor (sample tubing) and one that enables a sensor to operate (vacuum tubing). Particle counter tubing should not exceed 2 m due to excessive losses of large particles⁶. It is also important to ensure that any bends are maintained at the largest possible radius to reduce losses through transportation.

If the sensor does not have an integrated vacuum pump and requires an external vacuum source, the pump should be installed at a distance from the sensor in a technical space (mezzanine) and the tubing run via a manifold header and a tubing drop to the sensor. The design of the manifold is site specific. It is desired to install a loop manifold as this reduces differences in pressure drop across the system. The limitation of distance and installation criteria for the vacuum system is different than for sample tubing, as airflow is now post measurement. Figure 3 shows a loop manifold design and independent drops down to each individual sensor.

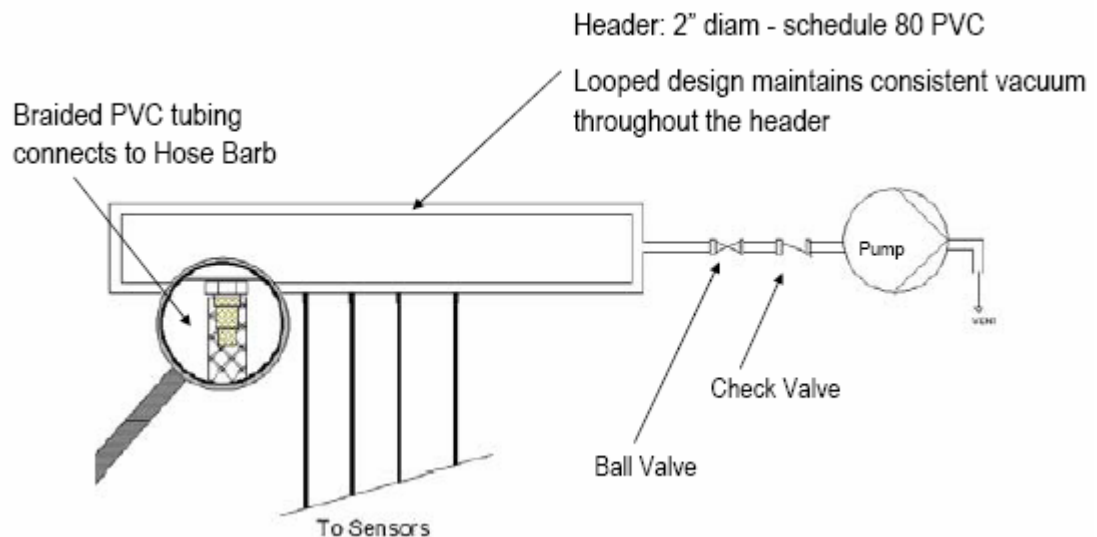


Figure 3 Vacuum manifold Schematic

- **Sensors:** The installation of measurement sensors is either mounted inside the filling equipment, on the filling equipment with sample tubing to draw a sample to the sensor, on/in the wall of the background room, or mounted on a supply/exhaust duct. The services, wiring, and tubing are run to the sensor via local conduit or service runs through equipment. These services are then taken back to a central location where the vacuum system and data cabinet reside.
- **Data Cabinet and Vacuum Pump:** Central to the system is the control data cabinet and vacuum system pump(s). They are typically mounted in the technical space as access for maintenance is required on a routine basis. The size and type of cabinet and vacuum pump depend on the size of the system, number of sensors, voltage

requirements, etc. Figure 4 shows two example data cabinets installed in technical spaces.



Figure 4 Data Cabinets

- **Computing and Network:** All sensors report to a centralized monitoring system. Control and reporting occurs here. The location of this system is flexible; all sensors are on an Ethernet network, therefore only a single connection is required to the central computer. If displayed or reported data is required at remote locations, a classic network architecture can be designed. Connections to site networks can be made via system routers, gateways, or other bridging means. A suitable desk in an office is used for the central computer and remote terminals can be installed into the fabric of the cleanroom using suitably compatible computer terminals or HMIs.

System Validation

The validation of the installed system follows the Good Automated Manufacturing Practices Guide. This continues from the initial URS and the design documents. A matrix of key components identified in the URS are linked to suitable tests to prove the robustness of the system, including error reporting and data archiving. This allows a traceable link between the requirements and the finished system, relative to the risk of the system. The testing proves that the installation of all the system components has been done in accordance with standards and as per the detailed design document (IQ) and that the system operates in accordance with the expectations made of it (OQ), i.e. when it exceeds a preconfigured threshold and alarm annunciation is activated.

Validation typically takes a few weeks depending on the size and complexity of the design. Once the validation testing is completed it can be turned over to the end user to begin the process of integration. This is an additional layer of validation to prove that it does what it was intended to do, i.e.: support the release of a batch through proof of control over the manufacturing environment (PQ).

System Implementation

This final stage causes the most concern with many new users of systems as the volume of data generated is much greater than that historically generated using a portable solution. The data can no longer be seen as a single page of data. A single particle counter can generate 5-10 pages of data per day, if this is extrapolated to a 10 sensor system, 50 -100 pages can be reported – so how do you deal with this volume of data?

System training provides the users with the skills they need. Training is in two parts; part one shows users how to use the system, change alarm limits, create new reports, add and disable user accounts, modify configuration variables (change control permitting of course). Part two of the training occurs after the system has been in use for several months. This second part of training is the key to a successful implementation, reading the data to deliver information relative to proving environmental control, necessary for compliance to the current standards.

Summary

Strong planning, following GAMP guidelines, and proper training to understand how to interpret the system data are essential for an effective monitoring program. A successful implementation requires planning, implementation, testing, and training to understand the results. Particle Measuring Systems provides services for all these steps.

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¹ EC Guide to Good Manufacturing Practice, Revision to ANNEX 1, European Commission, Enterprise Directorate General, September 2003.

² EC Guide to Good Manufacturing Practice, Revision to ANNEX 1, European Commission, Enterprise Directorate General, September 2003.

³ GAMP Guide for validation of Automated Systems; December 2001, published by the ISPE.

⁴ Choosing the most suitable non-viable sample point locations, Technical Note 79, M Hallworth, Particle Measuring Systems 2007.

⁵ Particle monitoring requirements in Pharmaceutical Cleanrooms, Application Note 41, M Hallworth, Particle Measuring Systems 2005.

⁶ An Analysis of Acceptable Particle Losses in Tubing, Application Note 81, M Hallworth, Particle Measuring Systems 2007.



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