WHITE PAPER

Site Preparation Service

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Today's TEM instruments are reaching ultra-high resolution in the sub-Angstrom range, so a site's environmental requirements are much more demanding than even a decade ago. A stable environment is critical in applications such as EELS and data reconstruction in a cryo-TEM with autoloader that runs for hours collecting data. This white paper discusses the environmental design requirements of a high-end TEM facility. This is a general discussion, as each site is unique and features its own set of issues.

Environmental factors

There are many environmental factors that can affect the performance of a TEM, for both imaging and long-term stability. For example, vertical vibration of the specimen holder will cause focus changes and result in a loss of resolution. Horizontal disturbances will cause "image flags" in STEM images, which can smear the edges and directly affect resolution. Temperature stability is paramount for applications in which the system collects thousands of images over a long period of time for post-processing. Any temperature drift outside the system specifications may cause loss of data. For cryo-TEM labs, humidity control is also critical.

For a cryo-TEM facility, the goal is to isolate the lab such that these disturbances are minimized and are within the system site specifications (or better) to avoid unforeseen problems in the future. There are four types of environmental disturbances which can affect the system: floor vibration, acoustic noise, electromagnetic interference (EMI), and temperature. To some extent, barometric pressure changes can also cause vibration or drift problems. All manifest themselves as "image noise or drift."

Vibration sources

1. Internal vibration sources
   - Mechanical systems such as HVAC equipment and air handlers
   - Foot traffic caused by people walking
   - Chillers, pumps, and fans or other machinery
   - Building resonances, especially if location is on a higher floor (not recommended).

2. External vibration sources
   - Seismic vibrations due to the nature of the soil structure
   - Traffic, such as cars, buses, trams, trains, subways
   - Heavy construction activities

Acoustic noise sources

- Mechanical systems such as HVAC equipment and air handlers
- Chillers, pumps, fans, or other machinery
- Other nearby laboratory equipment (fume hoods, centrifuges, etc.)
- People talking

EMI sources

EMI is classified in two ways: AC EMI, which is line frequency related, and Quasi-DC EMI, which is the change in the Earth's magnetic field caused by the movement of a large magnetic object like a car or a truck. A subway train produces very large Near DC interferences.

1. AC EMI sources
   - Power lines
   - Transformers
   - Power conduits
   - Power supplies
   - Improperly grounded wiring
   - Faulty wiring with imbalanced currents

2. Quasi-DC EMI sources
   - Subways
   - Trams, trains, cars, trucks
   - Elevators
   - Other transient events, such as equipment turning on or off
   - Furniture in the room
   - Metallic doors opening and closing

Temperature

Temperature control is important in all TEM/SEM labs. However, for cryo-TEM labs, it is especially critical, as the acquisition times are very long. Temperature specification for the Thermo Scientific™ Krios™ Cryo-TEM is 0.80oC p-p per 24 hours. Also, the humidity in the cryo lab or sample prep area must be maintained at around 20%. (Each lab may have its own different requirements.)

Barometric pressure

Heavy doors opening and closing cause pressure changes in the lab, thus causing the sample holder to shake. Additionally, temperature changes due to doors opening and closing can cause image drift. Thus, it is advisable to have non-metallic sliding doors in TEM labs.

Solutions

Now that the sources have been identified, what can be done? Remember that our goal is to keep these sources away from the lab and mitigate the sources that are in the lab or the building. We prefer an "integrated design approach" such that all mitigation measures are designed in before the site is built or modified.

Hence, an initial site survey is critical to determine what needs to be done and should be performed as soon as possible. Only site surveys performed by Thermo Fisher Scientific personnel are used to determine site pass/fail.

Design requirements for a state-of-the-art TEM lab

Vibration

The instruments are most sensitive to frequencies from 1 to 10 Hz.

- Build the lab as far away from heavy road traffic areas as possible. House the microscope in the basement. Vibration levels are typically lowest in the basement. It is not advisable to install high-precision systems on a higher floor. Build the lab away from subways.
- Install all chillers, motors, and HVAC equipment as far away from the lab as possible.
- Make sure all mechanical equipment is on the isolators provided or recommended by the manufacturer.
- Reduce the amount of foot traffic near the lab.
- Make sure that all mechanical systems are mechanically well-balanced. Unbalanced machines cause vibration.

Vibration mitigation

Some measures can be taken to mitigate vibration problems:

- Isolation blocks
  - Isolation blocks work best if they can be detached completely from the building and attached firmly and directly to the grade. This will avoid disturbances from the building and building resonances. Isolation blocks that are not attached to the grade will not work well for low frequencies. Floating blocks are also not recommended due to low natural frequencies associated with TEM.
  - If seismic vibrations are present in the grade, the isolation block may not work, as seismic activity is independent of the mass and affects the whole area. For example, Mexico City has a 4 Hz peak at almost all locations since it is built on a lake bed, and so isolation blocks will not work there.
- Active isolation systems
  - If there is high seismic vibration present, we typically recommend an active vibration isolation system, as these have excellent low-frequency performance. There are several manufacturers of such systems. These systems are very versatile and work well.
  - If such a system is to be used for a TEM, the decision should be made before any substantial site modifications are performed, as these systems normally require a "pit" to house them. This may also affect the ceiling height requirements. This is a good insurance policy because

these systems are active and will continue to cancel vibration if site conditions change in the future, such as nearby construction.

– For a SEM or DualBeam™ system, no special consideration has to be made for the site. These systems are installed under the instruments, do not affect the height requirements, and do not need a pit.

Acoustic noise

Acoustic noise is insidious and perhaps the most difficult to mitigate, since the instruments are sensitive to low-frequency noise, which is quite challenging. Some of our high-end SEMs and TEMs have specially designed acoustic enclosures (AE) that work quite well. Thermo Scientific TEMs (such as the Krios, Spectra, Themis, and Metrios) all have the AE standard. It is an option for select SEMs and small DualBeam (SDBs). Sometimes, the AE is the only way to reduce the noise such that it is within specifications. The instruments are most sensitive to frequencies between 50 to 500 Hz.

As noted above, HVAC-related noise is the most common type of acoustic problem. This comes from the placement of the HVAC equipment very close to the lab, unbalanced motors, non-isolated equipment, higher harmonics in the ducts, and exhaust fan noise.

Acoustic mitigation

Several measures can be taken to mitigate HVAC noise:

- Use chilled water panels for heat management. This approach has the advantage of being “almost” noiseless, as the HVAC requirements are low. Only a small amount of air is needed for personnel. This is the preferred solution and is not very expensive to implement, while providing excellent temperature control. Below is a picture of such an installation.

Chilled water panels

- Place all mechanical systems as far away as possible. If not possible, then isolate the equipment chase mechanically, acoustically, and electrically.
- Balance the HVAC loads properly. This may take several days.
- Use acoustic wall treatments to reduce reverberations in the room.
- Use fabric ducts, such as DuctSox, to reduce the noise from the air inlets in the room.
- Place the air inlets along the walls so the air flows down, reducing air drafts.
- Use acoustically rated drywalls, like Quiet Rock.
- Use heavy duty insulation in the walls.
- Avoid windows in the lab.

While none of these measures may completely eliminate the noise from the lab, they will certainly help. Acoustic mitigation starts with the design phase.

EMI mitigation

As mentioned above, EMI can emanate from a variety of sources. It is best to mitigate EMI at the source by placing all EMI-generating equipment about 30 feet from the lab. This equipment includes chillers, UPS, transformers, and HVAC equipment, among others.

Sometimes, it is not possible to mitigate EMI at its source (such as with traffic or subways). For these cases, EMI must be mitigated at the lab. For GIF applications, the EMI requirement is 10nT p-p. This is only repeatedly achievable with a passive Al shield around the entire lab. The Quasi DC EMI is not attenuated by passive shielding, so ACS (automatic cancelling systems) are used. Several manufacturers produce such systems. The type of EMI shielding is dependent on the lab environment and the system specifications.

Summary

Whether you have a new lab design or an existing facility, our team of experts can help to ensure the lab is within environmental specifications so that installations proceed smoothly.

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Notes

Find out more at
thermofisher.com/emserviceandsupport

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