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**Buildings for Advanced Technology Workshop II**
Mesa, Arizona

# Mechanical Systems Noise Issues - Case Studies

**January 22, 2004**

## Environmental Control for High Technology

Control of mechanical systems noise is essential to operation of advanced technology buildings

- Providing pleasant working environment for the building users (scientists, researchers, etc.)
- Allowing research equipment to operate as specifications require
- Maintain good relationship with adjoining properties

In particular, Acoustic criteria are getting more stringent

- Background noise levels of NC35 (teaching environment) versus NC 50 (standard design)
- Vibration limits of 0.75 to 3 μmeters/sec (30 to 120 μin/sec) are not unusual for nanotechnology buildings[1,2]
- Maximum noise level of 55db (31 Hz) specified by an E-Microscope Mfg.
- Zoning noise restriction of 45dBA (Nighttime)

Sources: [1] "NanoTech is BIG at NIST", Nano Fronteir, Vol. 1, Issue 1, HDR, www.nanobuildings.com/news
[2] Murray, Thomas, David Allen, and Eric Ungar, "Floor Vibrations Due to Human Activity", Steel Design Guide Series 11, American Institute of Steel Construction, Inc., 1997, p. 46.

## Acoustic Control for High Technology

Primary source of mechanical systems (HVAC) noise and vibration:

- Equipment operation (fans, chillers, boilers, pumps, cooling towers)
- Air movements through duct systems (regenerated noise due to aerodynamic forces)

Mechanical noise is most often controlled through duct silencers and vibration isolators

Best mitigation methods for duct-generated noise:

- Good aerodynamics design of duct systems
- Predicting and avoiding duct/equipment system effect during design process



## Presentation Outline

Case studies on dealing with objectionable mechanical noise and vibration caused by poor aerodynamic design – Author's experience

Noise Impact on Vibration Sensitive Equipment

- Case Study 1: Electron Microscope
  Not being able to meet manufacturer's criteria

Noise Impact due to Poor Mechanical System Design "System Effects"

- Case Study 2: 3 Different Fan Systems
  Not being able to meet specified mechanical duties

Mechanical Plant Noise Impact on the Neighboring Communities

- Case Study 3: Large Induced Draft Fan
  Causing noise impact on the neighboring homes

## Case Study 1: Electron Microscope

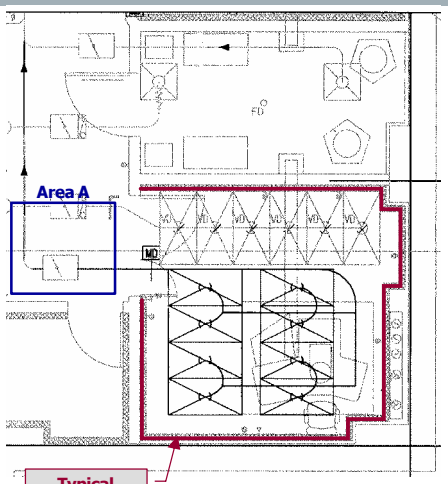
Duct noise impacts on operation of electron-microscope

Mfg. Specification requirements

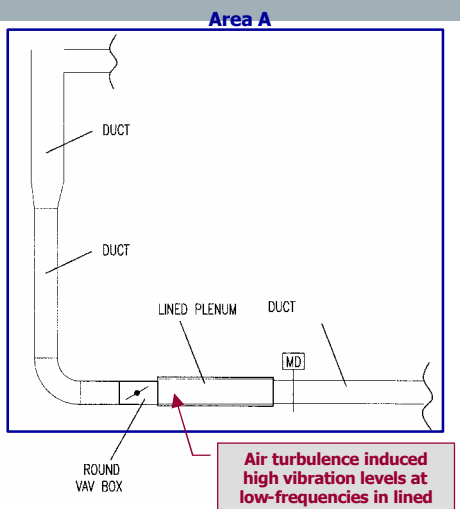
- Ambient noise at 0.5 meters around the EM is not to exceed
  - **55 db** per individual third octave frequency band
  - For the frequency range between **10 hz and 10 khz**
- Client's request: meet mfg. Criteria minus 5 db, or approximately NC 15



## Case Study 1: Electron Microscope

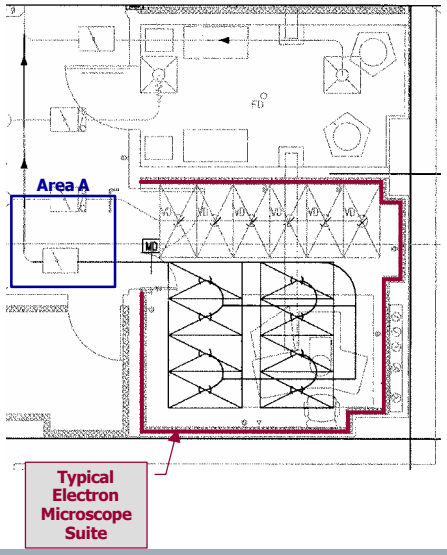



Typical Electron Microscope Suite




Air turbulence induced high vibration levels at low-frequencies in lined plenum, producing 59 dB noise level at 31.5 Hz

## Case Study 1: Electron Microscope




31.5 hz noise impact generated by air turbulence at the duct components

Noise mitigation measures

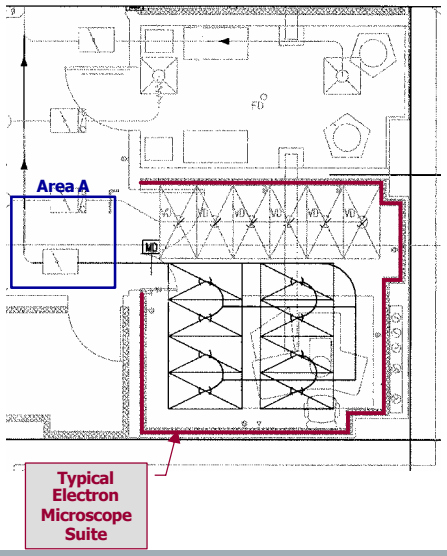
- Move VAV box and silencer further away from the EM suite
- Replace lined plenum with a circular silencer
- Reduce air duct velocity
- Use external lagging on all ductwork serving EM suite

Reduce reverberation time

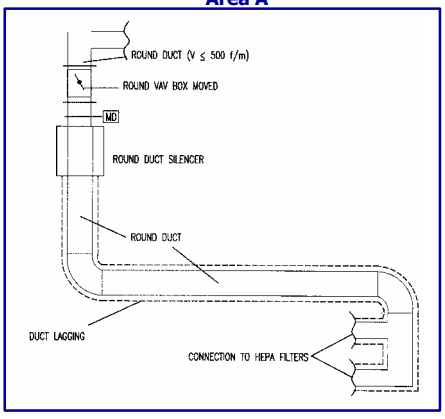
- Add acoustical treatment to walls of EM suite
- Replace reflective EM doors with acoustical transparent curtains



## Case Study 1: Electron Microscope




Area A



## Case Study 2: 3 Different Fan Systems

Less than "ideal" airflow conditions at the fan inlet and outlet (system effects) causing:

- Non-uniform airflow entering fan inlet (centrifugal backward fans)
- Swirling of air at fan inlet (vane axial fans)
- Sudden change in duct dimension at air outlet opening (centrifugal forward curve fan)

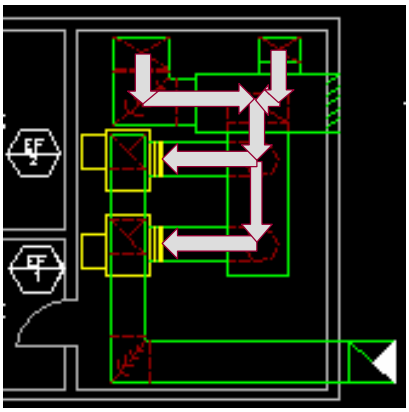
Fan deficiencies due to system effects:

- Reduced airflow rate
- Increased static pressure
- Increased speed
- Increased motor horsepower



## System Effect: Non-uniform flow at fan inlets

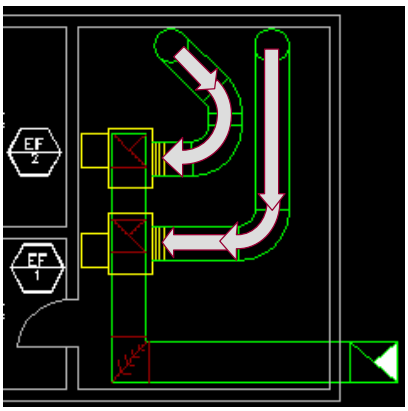
| | Spec. | Actual (Before Modification) |
|---|---|---|
| Airflow (cfm) | 6850/ 6850 | 5218/ 6218 |
| Static Pressure (in. $H_2O$) | 3.4/3.4 | 5.6/5.4 60% |
| Fan Speed (rpm) | 1510/ 1510 | 1880/ 1890 <1,150> |



**Ductwork Layout Before Modifications**

## System Effect: Non-uniform flow at fan inlets

| | Spec. | Actual (Before Modification) | Actual (After Modification) |
|---|---|---|---|
| Airflow (cfm) | 6850/ 6850 | 5218/ 6218 | 5877/ 5877 |
| Static Pressure (in. $H_2O$) | 3.4/3.4 | 5.6/5.4 60% | 3.0/3.2 |
| Fan Speed (rpm) | 1510/ 1510 | 1880/ 1890 <1,150> | 1510/ 1700 |




**Ductwork Layout After Modifications**

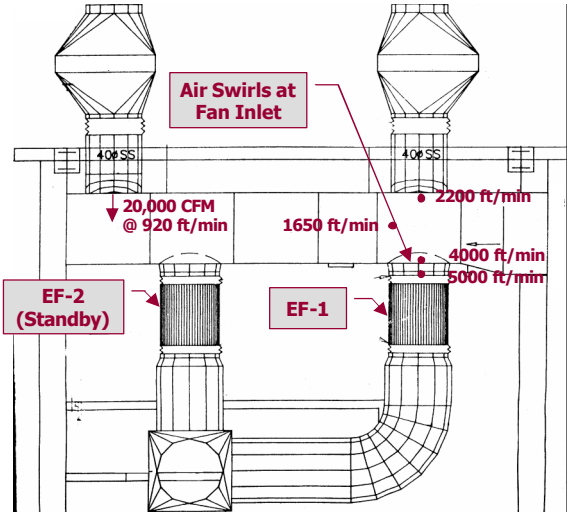
Amir Yazdanniyaz | Arup

## System Effect: Swirling air at inlet to vane axial fan

Exhaust fan specifications

- 42" Vane Axial Direct Drive
- Airflow: 40,000 cfm
- Static Pressure: 5 in. $H_2O$
- Fan Speed: 1770 rpm

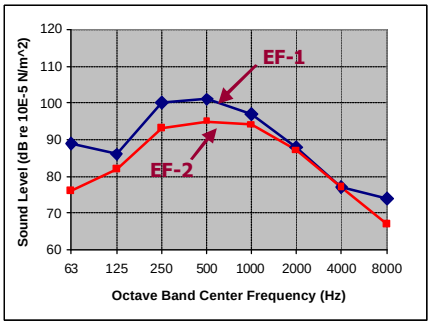
High level of vibration was measured




**Typical Lab Building Exhaust Air Duct Layout**

Amir Yazdanniyaz | Arup

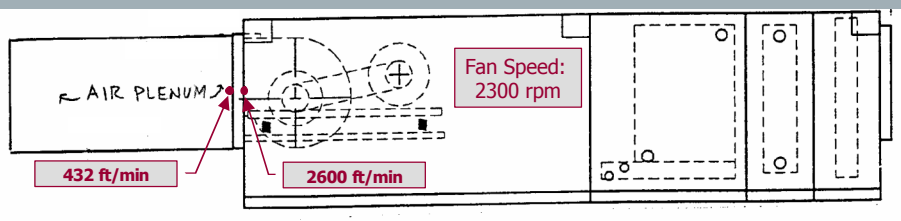
## System Effect: Swirling air at inlet to vane axial fan




**Note condition of flexible connection**
**Spec. diameter: 42.5" (4000 ft/min)**
**Flex diameter: 38.0" (5000 ft/min)**



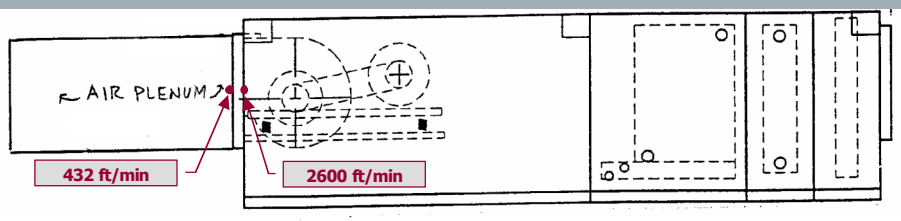
## System Effect: Sudden change in duct size



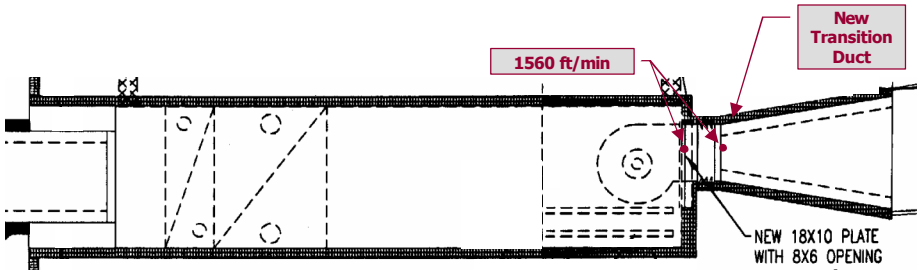

**AHU Outlet Design Before Modifications**

| | Specified | Actual |
|---|---|---|
| Airflow (cfm) | 530 | 540 |
| Static Pressure (in. $H_2O$) | 1.25 | 0.72 |
| Fan Speed (rpm) | 2600 | 2300 (2000) |

## System Effect: Sudden change in duct size



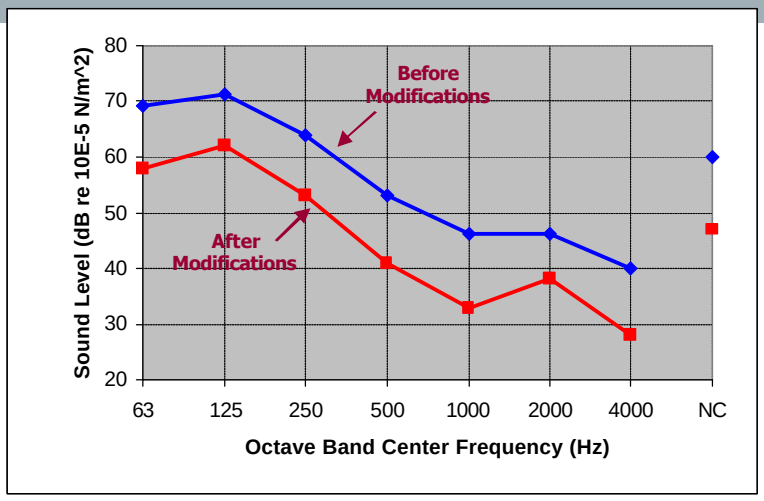

Section - AHU Outlet Design Before Modifications




Section - AHU Outlet Design After Modifications



## System Effect: Sudden change in duct size



## Case Study 3: Large Induced Draft Fan

Most advanced technology buildings have a large volume of mechanical equipment placed outside the building:

- Cooling towers
- Exhaust fans
- Scrubbers
- Pumps

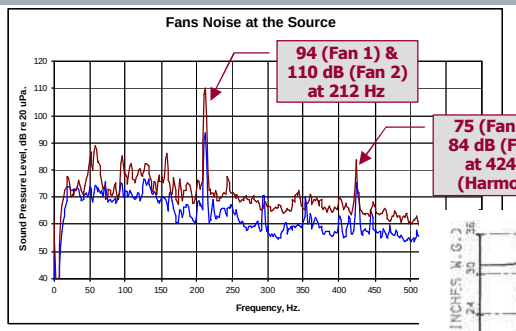
Particular issues to consider:

1. 24-hour plant operation
2. Local noise regulations
3. Noise source characteristics (i.e. tonal sound)
4. Adjacency to residential communities

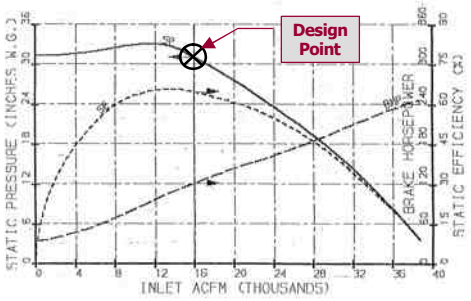


## Case Study 3: Large Induced Draft Fan

# Case Study 3: Large Induced Draft Fan



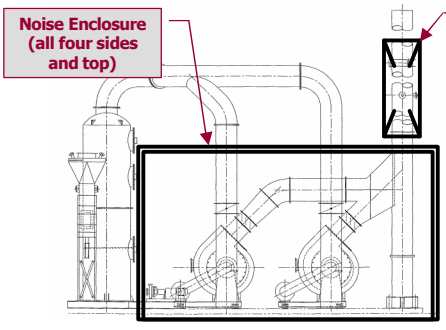

| ID Fan #2 | Specified | Actual |
|---|---|---|
| Airflow (cfm) | 15908 | 9500 |
| Static Pressure (in. $H_2O$) | 31 | 36 |
| Fan Speed (rpm) | 2088 | 2020 |



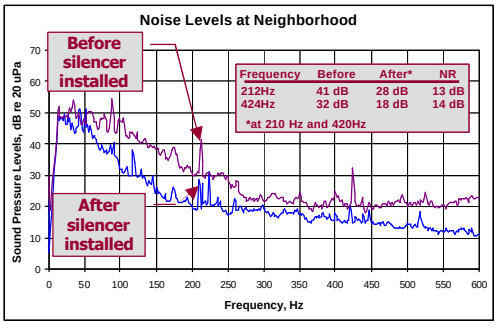

Induced Draft Fan's Performance Curve



# Case Study 3: Large Induced Draft Fan




Elevation – Induced Draft Fans 1 and 2



## Conclusions

- Building mechanical systems that support high-tech research facilities are complex and challenging in terms of acoustic design
- Conventional noise control solutions may not be compatible with the function of advanced technology buildings
- Thus, attention to ductwork design may prove beneficial both in terms of control of noise/vibration and conservation of energy
  - Design of duct systems should:
    - Avoid short lengths of duct and sharp elbow connections
    - Use inlet boxes and radius bends with turning vanes
    - Avoid using flex connections
    - Use inlet bell mouth and flex at maximum possible connection
    - Avoid sudden changes in duct area between fan outlet and duct connections
  - The system effect must be considered in noise level calculations