Vibration Issues in Facility Refurbishing

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Abstract

Vibration is a major source of contamination in any Fab facility and can have disastrous effects on plant output. When a Fabrication plant is needed to be updated, the existing structure of the buildings may require extensive alteration to meet the new criteria of future operation. The sources of vibration both external and internal to the facility are examined in detail and appropriate solutions described.

Introduction

Facilities for I.C. chip fabrication and development are designed, typically, with an economic "lifetime" of ten to fifteen years or more. Yet the technology of circuit fabrication develops at a rate that inevitably outpaces the plans and expectations of the facility owner. By current reckoning there are more than two thousand fabrication facilities in current use throughout the world. The majority of these are more than ten years old and many of them are attempting to push the technology "envelope" as manufacturing line widths continue to decrease to, and beyond, the 0.25 micron value. The cost of fabrication facilities is such that facilities are rarely, if ever, consigned to the scrap heap. Rather, they must be refurbished and often expanded, to handle new tool sets and processes.

By Fab refurbishing we mean the process of adapting an "old" facility to support new technology processing. Often the process of refurbishing will include expansion of the process area by utilizing adjacent spaces not originally intended for the purpose – such as office space and general support areas. Refurbishing might also include the construction of new building additions adjacent to the structure to support processing, process support and central plant systems, etc. Often refurbishing takes place during on-going production in other parts of the same building or in buildings closely adjacent to the area to be refurbished. Vibration disturbance due to construction must be controlled to acceptable levels.

The purpose of this paper is to discuss the issue of refurbishment as it relates to the vibration environments necessary for high yield advanced technology production. Vibration, of course, is only one of the several contaminants that affect the problem of facility ageing.

Vibration Criteria and Facility Performance

The vibration criteria [1, 2] used extensively throughout the industry are described in Figure 1 and Table 1. They were developed many years ago to provide a "generic" basis for the vibration performance of an operating facility. The criteria apply to the floor or rigid pedestals on which the sensitive fabrication tools are supported. For a floor, or pedestal, to comply with a particular performance category the measured one-third octave band velocity spectrum must lie below the appropriate criterion curve of Figure 1.

Many of the older facilities were designed to criterion curve VC-B which sets a vibration limit of 25 microns/sec in the 8 through 80 Hz frequency range. In recent years, as manufacturing line widths have moved downwards, tool requirements have become increasingly stringent. Now, modern fabs are typically designed to curve VC-D (6 microns/sec) or VC-E (3 microns/sec).

The first step in a refurbishing project must be to select the vibration goals to be achieved on the "new" process floor. The goals should be realistic but not overly conservative. The purpose of refurbishing is to extend the useful life of the facility, not necessarily to provide a new facility with all the future promise that a new facility can hold.

Site Ambient Vibration

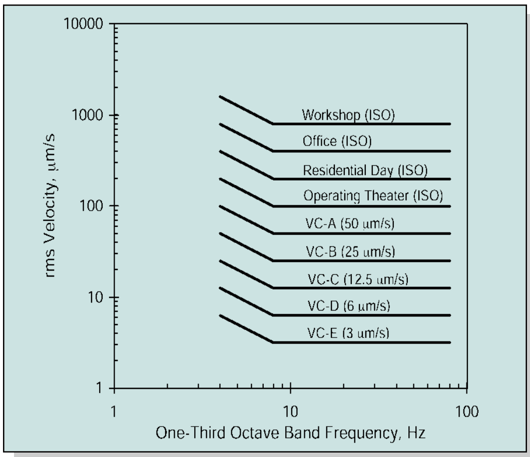
It is, generally, not possible to protect a building from the ambient vibration conditions on the site on which it is supported. It is important, therefore, to measure the ambient vibration conditions on the building site to update the data that may have been collected when the original building was set in place. Conditions on a site can change substantially over the years as land surrounding the site is developed, transportation (rail and auto) types and routings are changed and as the site owner develops his property.

Measurements should be taken on the footings of the building, if these are accessible, or on grade slabs or other structures close to the footings. In this way one can be assured that the measurement represents the vibration to which the building structure is exposed. If the process floor of the building is supported on grade, rather than above one or two levels of sub-fab, then measurements should be taken at a number of locations on the slab. Measurements of this sort can often indicate the condition of the slab in terms of the uniformity of grade support. Old on-grade slabs can become separated from the ground as differential settlement occurs due to time, uneven load distribution, flooding, etc.

Table 1. Application and interpretation of the generic vibration criterion curves of Figure 1

Criterion Curve (See Figure 1)	8-80Hz Limit μm/s	Detail Size Microns	Description of Use
Workshop (ISO)	*800*	*N/A*	*Distinctly feelable vibration. Appropriate to workshops and nonsensitive areas.*
Office (ISO)	*400*	*N/A*	*Feelable vibration. Appropriate to offices and nonsensitive areas.*
Residential Day (ISO)	*200*	*75*	*Barely feelable vibration. Appropriate to sleep areas in most instances. Probably adequate for computer equipment, probe test equipment and low-power (to 20X) microscopes.*
Operating Theater (ISO)	*100*	*25*	*Vibration not feelable. Suitable for sensitive sleep areas. Suitable in most instances for microscopes to 100X and for other equipment of low sensitivity.*
VC-A	*50*	*8*	*Adequate in most instances for optical microscopes to 400X, microbalances, optical balances, proximity and projection aligners, etc.*
VC-B	*25*	*3*	*An appropriate standard for optical microscopes to 1000X, inspection and lithography equipment (including steppers) to 3 micron line widths.*
VC-C	*12.5*	*1*	*A good standard for most lithography and inspection equipment to 1 micron detail size.*
VC-D	*6*	*0.3*	*Suitable in most instances for the most demanding equipment including electron microscopes (TEMs and SEMs) and E-Beam systems, operating to the limits of their capability.*
VC-E	*3*	*0.1*	*A difficult criterion to achieve in most instances. Assumed to be adequate for the most demanding of sensitive systems including long path, laser-based, small target systems and other systems requiring extraordinary dynamic stability.*

Figure 1
Generic vibration criterion curves for vibration-sensitive equipment, see Table



Measurements should be taken both vertically and horizontally, in a format consistent with the vibration criterion selected for the refurbished facility. One would wish the site conditions – including steady-state and intermittent sources – to lie below the criterion by some reasonable margin.

Structural Design and Performance

Notwithstanding the acceptability of the site ambient vibrations, the structure of the building, especially that of the process floor which supports the manufacturing tools, must be able to resist the vibration-generating effects of the many sources of vibration associated with operation of the building in full production. Such sources include mechanical systems (pumps, fans, chillers, etc.), process support systems (house vacuum, ultra-pure water, process cooling water, etc.), certain production tools (ion implanters, certain photolithography tools, etc.), material movement systems and the movements (primarily walking) of personnel.

The single most important parameter in determining the vibration performance of a structural floor is the floor stiffness – its ability to resist applied forces with small resultant deflections. Both vertical and horizontal stiffnesses are important. Vertical stiffness is controlled primarily by the on-center spacing of the columns supporting the process floor and the depth of the process floor. Horizontal stiffness decreases as the length of the supporting columns increases. Stiffening elements such as shear walls and diagonal braces are beneficial.

If the facility was originally designed to a criterion that is much less stringent than the one which the refurbished facility must achieve, it is likely that the stiffness of the structural floor supporting the process is inadequate. In this case, it will be necessary to increase the floor stiffness. There are various ways in which this can be done including addition of columns and shear-walls, installation of additional beams, extension of beams and thickening of topping slab.

Major structural changes can be difficult to engineer and construct, and inevitably one has to deal with problems of interference and space constraints. The addition of columns will generally require new column footings which must be set in place within an enclosed space (the sub-fab) with the constraint of limited head room. New columns must be adequately stiff and must rigidly support the process floor to which they are attached. Properly designed and installed they can be very effective.

Floor stiffness can be calculated with some precision. It can also be measured using a shaker or impact hammer. It can also be inferred from the measured performance of the floor as an operating facility. When the possibility of a refurbishing project is being considered it would be well to determine the floor stiffness and to compare this with the stiffness that will be required to achieve the new performance criterion. This exercise will, immediately, indicate the "scale" of the structural problem and perhaps lead to reconsideration of the goals for the refurbished facility.

Facility Layout

Even with an entirely adequate structural system, the vibration performance of a facility is affected by its layout – particularly the location of major vibration sources relative to the vibration-sensitive process floor. Vibration sources include mechanical systems in the central utility plant, recirculation air and make-up air handlers, exhaust systems, process cooling water systems and ultra-pure water systems. They also include emergency generators and certain UPS systems. Nitrogen plants are also a major source. Material handling activities associated with truck deliveries to the facility and material movements within the facility can also be a significant source of vibration. Finally, tools and processes can also generate significant vibration. Implanters are a known source of vibration. CMP processes appear, increasingly, to pose vibration problems. Sensitive tools themselves, such as stepper scanners, currently in development, can prove to be their own "worst enemy", as it were, since they can generate vibration as reticle and wafer stages are moved between exposures.

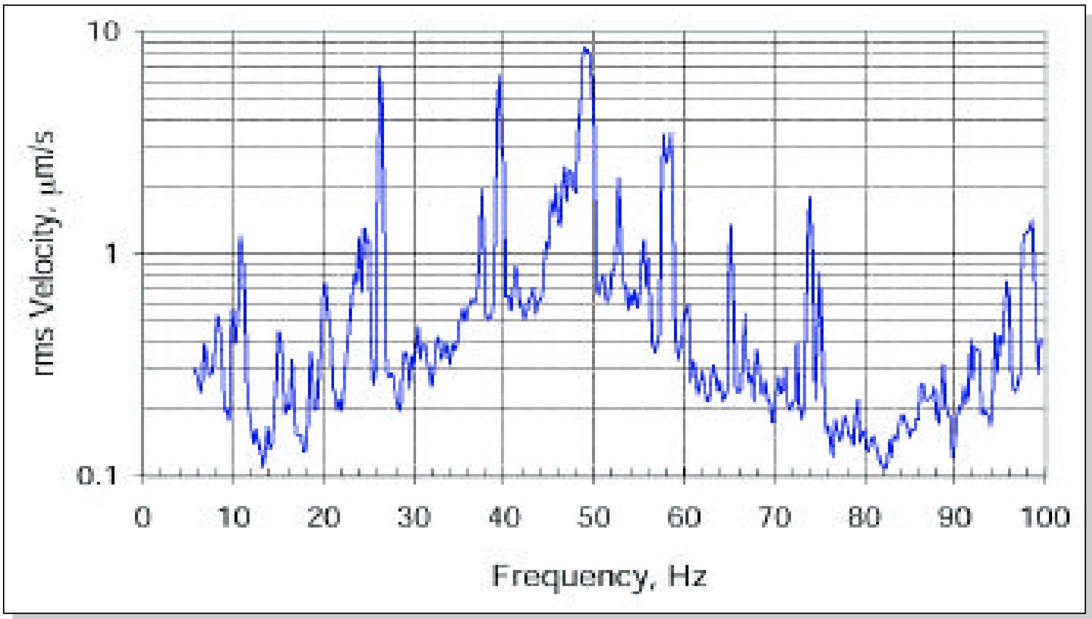


Figure 2
Narrowband spectrum showing effects of poorly specified or isolated mechanical systems

It is important, therefore, in any refurbishing project, to be aware of the importance of layout as a design parameter. It may be hard to believe, but in some early facilities the energy center was placed in a basement directly below the process floor. Even today, it is not unusual to find central utility systems immediately adjacent to critical floors. And, of course, in the process of tool hook-up we inevitably must cope with the fact that the sub-fab will be replete with pumps, chillers and scrubbers of significant mechanical power.

Layout is important therefore. When undertaking a refurbishing project the issues of layout, coupled with the fundamental requirement for space to accommodate modern tools, may dictate the need for additional buildings to provide spatial separation.

MECHANICAL

Mechanical systems are the single, most dominant, source of process floor vibration. A typical state-of-the art microelectronics facility consumes about one-hundred times the mechanical energy, per unit area of cleanroom floor, than does a conventional commercial building. This fact, coupled with the fact that modern production tools can be one-hundred times more sensitive to vibration than the human occupant of a conventional building, explains why control of mechanical system vibration is such a critical element of successful facility design.

In a refurbishing project many items of the existing mechanical system may be reused. Often, however, they must be augmented or replaced by new, larger or more efficient systems. In the case of an existing system it is important that the condition of the equipment and of installed vibration isolation hardware be checked and corrected, if necessary. The rotating unbalance of equipment can often deteriorate as the equipment ages and alignments change. Certain equipment that was appropriate for older facilities, such as reciprocating compressors, may be entirely unsuitable for the vibration goals of the refurbished facility. Such equipment may have to be replaced. Vibration isolation systems, such as spring or neoprene mounts supporting the equipment, may have deteriorated and/or become misaligned. Pipe and duct isolation hangers may need to be replaced.

Vibration measurements on the process floor will generally show the effects of inadequately isolated mechanical systems. Narrowband spectrum analysis can often be used to positively identify faulty installations. An example of such a spectrum is shown in Figure 2.

New mechanical systems to be installed in the refurbished facility must be specified and isolated to the high standards required to meet the selected criterion. The required balance specification for fans (recirculation, make-up and exhaust) will probably preclude the use of belt-driven systems. Present day availability of variable frequency drives makes direct drives (non-belted) systems attractive in terms of vibration, noise and operating efficiency.

Often, in older facilities, major piping and ducting systems are supported directly from the underside of the process floor. Such supports, even in combination with spring hangers, may be incompatible with the revised goals. In this case a solution may be to support these and other systems from the sub-fab floor or from the process floor columns.

CONSTRUCTION CONTROL AND MONITORING

Construction activities involved in a refurbishing project can generate significant vibration. If refurbishing takes place close to on-going production, either in the same building or in an adjoining building, construction procedures must be selected so that vibration amplitudes are limited to acceptable levels. Product “yield” is one of the primary “drivers” of the microelectronics industry. Significant loss of yield is always unacceptable.

A number of steps can be taken to minimize the effects of construction on on-going production. These have been used successfully by the author on a number of projects.

- Construction Equipment and Methods: Work with the contractor to quantify the vibration affects of equipment options for the project. This generally entails measurements on site using the types of equipment – concrete breakers, excavators, compactors, etc. – that are candidates for the project. In this way, “areas of influence” of various equipment can be developed and alternative equipment or methods selected when acceptable areas of influence are exceeded. In one project for instance, construction of a small trench immediately adjacent to operating photolithography tools dictated that the trench be dug by hand and that small “pogo” compactors be used.

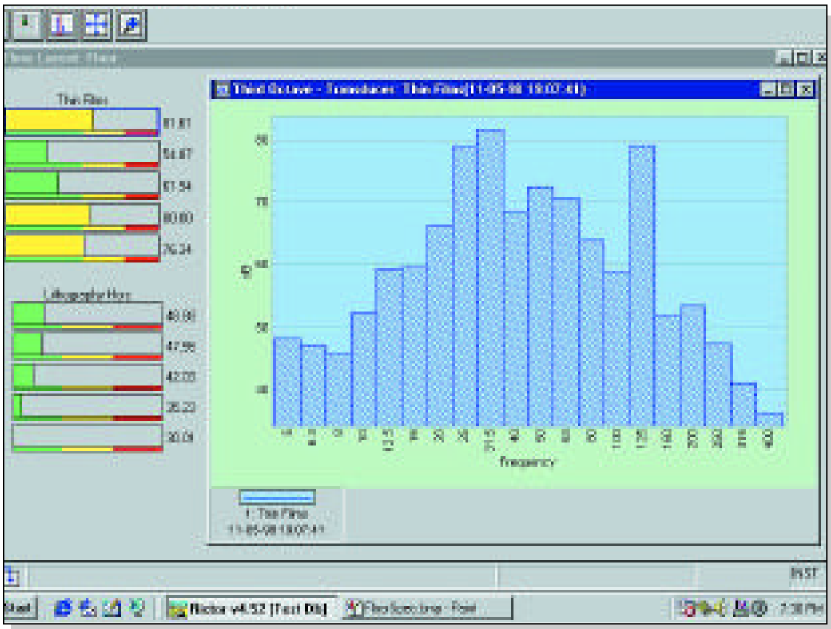


Figure 3
Screen capture from PC-based vibration monitoring system, (courtesy of Signalysis, Ohio)

- **Construction Guidelines: Prepare a guideline document for the contractor in which "good practice" methods for the control of vibration are set down to augment equipment-specific information. Such a document covers road maintenance, crane movements, concrete removal, etc.**
- **Construction Scheduling: Schedule construction so that the use of heavy vibration-generating equipment can be accommodated with minimal impact – perhaps during a down-period in the operating facility.**
- **Vibration Monitoring [3]: Install a single- or multi- channel PC-based Microvibration Monitoring System at critical locations in the operating facility. The "output" of the system should have a form that is compatible with the vibration requirements (criterion) for the operating facility. A screen capture from a monitoring system that accommodates up to eight data channels is shown in Figure 3. This system allows "yellow" and "red" alarm settings to be pre-set based on the vibration needs of the operating facility. A modem connection can be used to monitor and control the system remotely. The modem can also be used to alert the contractor in the event that alarm levels are exceeded. With this system, data are acquired and archived continuously over a period of months, or years, if necessary.**

CONCLUSIONS

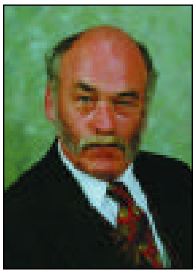
The growing cost of new fabrication facilities, coupled with the present state of the world economy, dictates the need for constant refurbishing of existing facilities. This paper has outlined some of the ways in which facility vibration can be controlled.

REFERENCES

[1] C.G. Gordon, "Generic Criteria for Vibration-Sensitive Equipment", SPIE Proceedings, Volume 1619, Nov. 1991.

[2] Institute of Environmental Sciences and Technology (IEST), "Considerations in Cleanroom Design", Recommended Practice RP012.1, 1993.

[3] Q.G. Holloter and C.G. Gordon, "Monitoring of Vibration in Vibration-Sensitive Facilities", SPIE Proceedings, Volume 2264, July 1994.



ABOUT THE AUTHOR

Colin Gordon is President and Principal of Colin Gordon & Associates with offices in San Mateo, California. Mr. Gordon has worked as a consultant and researcher in the field of acoustics and vibration and noise control for thirty-five years. Prior to establishing his present business, Mr. Gordon worked in a variety of roles with Bolt Beranek and Newman and with the Institute of Sound and Vibration Research at the University of Southampton, England.

Over the past twenty years, Mr. Gordon has worked extensively with the microelectronics industry and with the biotech, medical and research communities on the design of facilities to house vibration-and-noise-sensitive tools and instruments. He and his colleagues have published extensively in this area.

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