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# MEMORANDUM

**DATE:** 29 JUNE 2012

**TO:** BRIAN RUPP
UPTOWN NEWPORT LP

**FROM:** JAMES T. NELSON

**SUBJECT:** NOISE AND VIBRATION IMPACT MITIGATION
UPTOWN NEWPORT PROJECT

# INTRODUCTION

Uptown Newport LP (Uptown) proposes to construct a high density residential mixed-use development on land surrounding the existing TowerJazz semiconductor fabrication plant (Building 503). The Uptown Newport project will include redevelopment of the 25-acre property into a high-density mixed use residential project. Up to 1,244 residential units, 11,500 square feet of retail, and 2 acres of park space are planned as part of the project. Uptown Newport is anticipated to be developed in two primary phases. Phase 1 will include demolition of the existing single-story office building at 4311 Jamboree, and development of the westerly portion of the property, including the frontage along Jamboree Road. Phase 1 will include up to 680 units and up to 11,500 square feet of retail. Phase 2 will include demolition of the existing semiconductor fabrication building, and development of up to 564 units on the easterly portion of the property. This memorandum addresses potential noise impacts resulting from the continued operation of the TowerJazz on the Phase 1 development, and the vibration impact on TowerJazz due to Phase 1 development and construction.

# MECHANICAL EQUIPMENT NOISE IMPACT ON PHASE 1

## EXISTING NOISE LEVELS

Existing 24-hour noise levels were measured by The Planning Center at various positions about Building 503 and 501, and include noise from Jamboree Road, roof-top equipment on Building 503, cooling tower noise, and miscellaneous ground-level equipment. The site layout is shown in Figure 1.

Additional noise measurements were conducted by Wilson, Hiring & Associates (WIA) on the roof of Building 503 and at several positions at grade level west of Building 503, along the north side of Building 501, and south of Building 503. These latter measurements were intended to assess the contribution of the most significant noise sources. The measured A-Weighted sound levels are indicated in Figure 2.

The roof top mechanical equipment is contained behind a parapet wall/screen of nominal height 30 feet above the roof deck along the southern and western wall. Thus, the roof top equipment noise is largely contained by the screen, though most of the mechanical equipment is at a height of 8 to 10 feet above the roof deck. Some joints exist in the screen, through which noise energy may pass, but these are relatively small in relation to the overall area of the screen. Also, the screen is made of light-weight corrugated sheet metal. While the screen provides substantial noise reduction, its light weight may allow some sound to be transmitted directly through the sheet metal and contribute to the sound transmitted over the top.

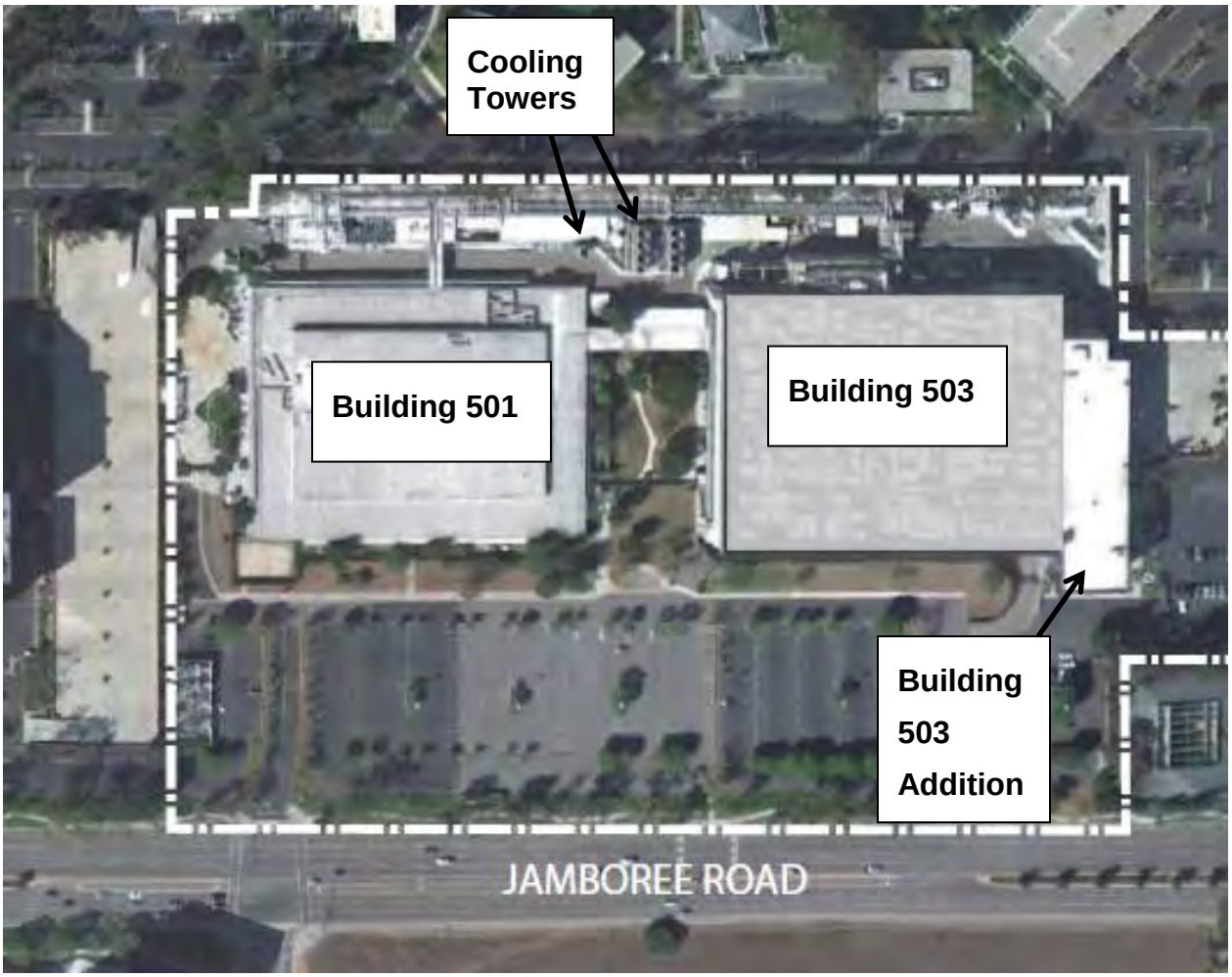


**Figure 1 Site Layout of TowerJazz Buildings**

**Figure 2 Rooftop Mechanical Equipment Noise Levels – dBA re 20 Micro-Pa**

## Exhaust Fans

The principal roof top noise sources include five exhaust fans located at the southern side of roof of Building 503, roughly 40 to 50 feet from the southern screen, and two exhaust fans located at the western side of the roof, about 10 feet from the screen and possibly reaching a few feet above the crown of the screen. A photograph of one of the exhaust fans is provided in Figure 3. The noise levels measured at about 5 feet in front of the screen directly opposite the exhaust fans are approximately 85dBA.

Noise was measured at the ground level at the south side of Building 503, towards the east end of the building. The roof-top exhaust fans were clearly audible and dominated the noise environment. Evidently, noise is transmitted through small gaps in the screen as well as diffracted over the top of the screen. The screen is relatively light-weight corrugated sheet metal. While this provides substantial noise reduction, it might not entirely control the exhaust fan noise transmitted through the screen.

## Other Roof-top Equipment

Numerous other roof-top equipment exist on the roof and produce noise. These are distributed over the surface of the roof. For the most part, they are relatively quiet, but taken together, produce substantial noise. The minimum noise level measured at the southwest corner of the roof, inside the screen, was about 70dBA. While this position was exposed to the exhaust fan noise, this position represents a worst-case estimate of the noise produced by other equipment. Some pressure doubling of noise existed at these roof-top measurement points, due to reflection of noise from the screen. A reasonable estimate is that without the screen, the roof-top noise along the southern and western edges of the roof would be about 67dBA.

## Cooling Tower Noise

Eight cooling towers are located north of the northern corner of Building 501, midway between Building 501 and Building 503, as shown in Figure 1. A ninth cooling tower is located directly opposite the northern corner of Building 501. A photograph of the cooling towers is shown in Figure 4. The height of the towers is approximately 25 feet.

The noise form the cooling towers consists primarily of propeller fan noise, most of which is likely radiated through the cooling coils. Waterfall noise was not apparent above the fan noise. Some unidentified motor or pump noise was also apparent in the background. Measure noise levels are shown in Figure 5. The noise level at the northern corner of Building 501, roughly 60 feet from the nearest cooling tower, was 81 dBA. This noise level would be representative of the noise at the façade of the Phase 1 development without noise control. The noise levels decrease with increasing distance from the cooling towers. At 50 feet to the southwest of the corner, the noise level is about 78 dBA. At 100 feet from the corner, the noise level declines to 77dBA. Some channeling appears to be occurring, due to reflection from the wall of Building 501. Other mechanical equipment within the TowerJazz site also contributes to measured noise levels. The level under the rack between the mechanical equipment and Building 501 was 74dBA. The level drops to 67 dBA at the gate at the end of the drive isle between Building 501 and the mechanical equipment along the northwest boundary of the site, roughly 350 feet from the cooling towers. At the western end of Building 501 the noise level decreases to 63dBA.

**Figure 3 Exhausst Fan at Western End of Roof**

The cooling tower noise level at about 360 feet southeast of the cooling towers, at the flag poles located between Building 501 and 503, was about 58dBA. Closer in, at the fence at about 250 feet from the cooling towers, the level was about 61dBA.

The cooling tower noise was measured on the roof of Building 501 by The Planning Center with long term monitoring instrument. The reported CNEL was 73.8dBA, at about 100 feet south of the cooling towers. This level is considerably less than the CNEL of 88dBA that would be inferred from the data collected at grade level. Reflections from the walls of Building 503 and from the ground may have elevated the noise measurement obtained by this writer. The measured level at 300 feet south of the cooling towers would suggest a CNEL of about 68dBA at this position. Scaling for distance at a rate of 6 dB per doubling of distance would give a CNEL

of 77 dBA at 100ft. Assuming reflections during the measurement at 300 feet, the estimated CNEL would be 74dBA at 100 feet, essentially equivalent to that obtained on the roof of Building 501. These data suggest that most of the fan noise is being radiated through the cooling coils.

**Figure 4 Cooling Towers**

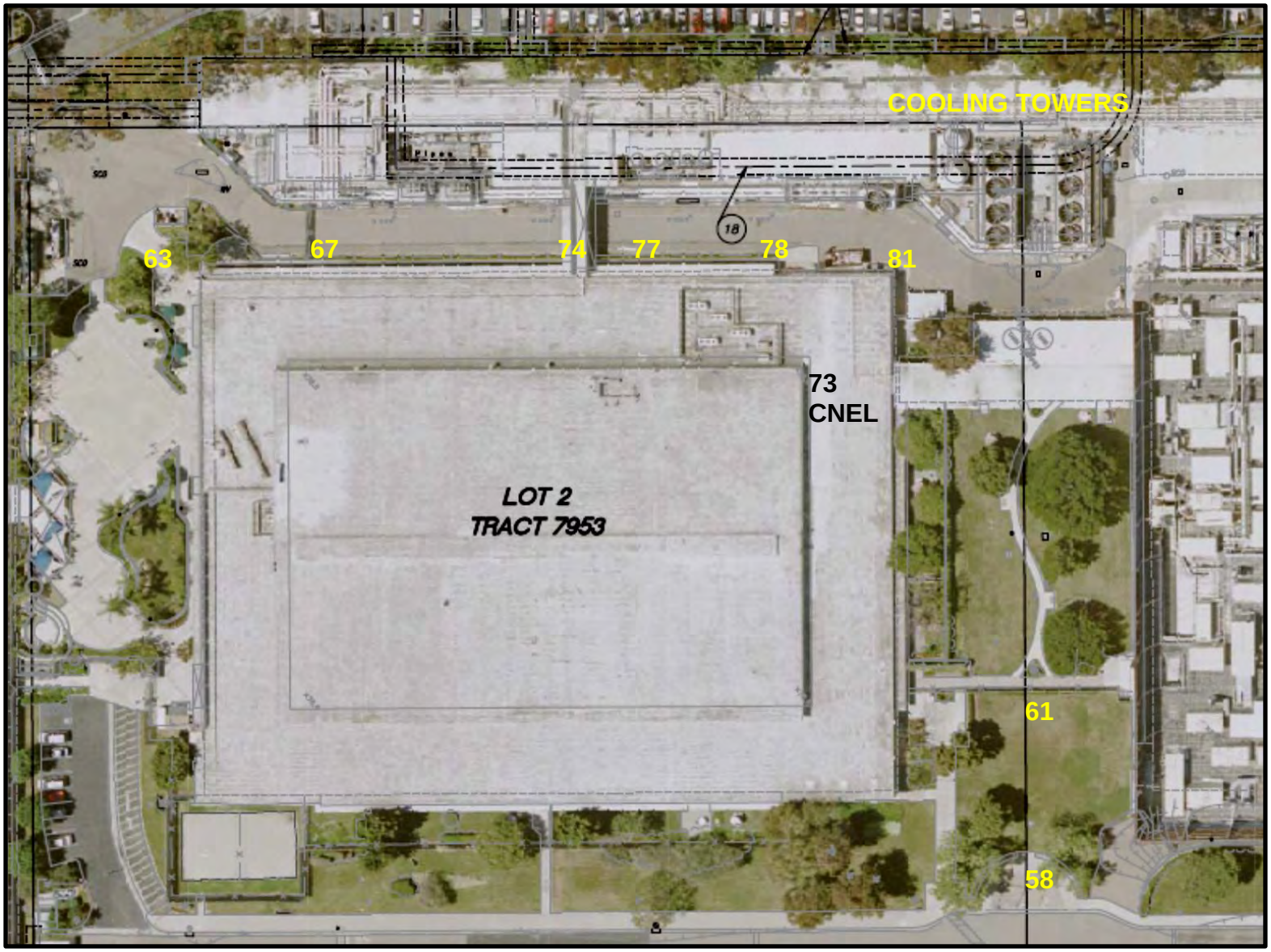


**Figure 5 Cooling Tower Noise**

## ROOF-TOP MECHANICAL EQIPMENT NOISE CONTROL

### Exhaust Fan Noise Control

The exhaust fan noise can be most effectively controlled by constructing noise barriers around three sides of each of the exhaust stacks, such that the barriers would be located between the stacks and the future Phase 1 development. The barriers should extend several feet above the top of the stacks, and extend down the below the decks, encompassing the motor and blower located below.

A practical approach would include construction of structural steel framing extending to the required barrier height, from which barriers consisting of 2 pound per square foot lead or barium loaded vinyl and glass fiber acoustical absorption of density 1.5pcf and thickness two inches. The acoustical absorption would be applied to the side of the barrier facing the stack and fan. Examples of this include "TL-blankets", that provide approximately 25dBA of noise reduction. Other commercial products that can be used include Industrial Acoustics Company Soundshield barriers or Empire Acoustics barriers.

In addition to a barrier, sound levels can be reduced by modifying the exhaust stack and fan. Stack modification would include enlarging the stack and placing a splitter baffle in the duct to absorb noise. Also, the discharge crown at the top of the duct might be enlarged and lined with acoustical absorption. The noise reduction effectiveness of the treatment would likely be about 10dB, but the modification might adversely affect the plume height if not properly designed. Modification of the fan discharge cut-off and/or fan blades or replacement of the fan can be considered.

### Other Equipment

Other specific pieces of roof-top equipment can be investigated and inventoried. Those that are judged to contribute significantly to the noise at the Phase 1 building set back line can be treated with barriers lined with acoustical absorption. Ducts that radiate significant noise can be treated by adding mass to the duct walls, or possibly lagging with 1" thick 3pcf glass fiber acoustical absorption and 1psf lead loaded vinyl. Noisy pipes can be lagged with 1" thick glass fiber and 22-gauge sheet metal or lead loaded vinyl.

### Screen

The performance of the existing sheet metal parapet wall/screen can be enhanced by treating the upper 8 feet of the screen with acoustical absorption, consisting of 3-inch thick 1.5 pcf glass fiber or mineral wool, faced with a perforated metal screen. Industrial Acoustics Company or Empire can provide prefabricated panels specifically for this application. The expected additional noise reduction provided by acoustical absorption is approximately 3 dB.

Joints between the sheet metal panels of the screens can be sealed or caulked. Openings in the screen should be sealed up, specifically the opening at the northern end of the western screen wall, though which a pipe runs.

### *Architectural Treatment*

Additional sound attenuation for balconies in close proximity to TowerJazz can be provided with glass or plexiglass barriers to reduce noise levels on the balconies. Acoustical absorption would

be needed to absorb sound in the balcony to allow the barriers to work. The surfaces above the balcony and/or walls can be treated with acoustical absorption, consisting of 2-inch thick 3-pcf glass fiber panels. Panel providers should be consulted for acceptable finishes and texture that would provide an acceptable architectural look.

Doors and windows should be acoustically rated. An STC 35 glazing should be adequate, and would consist of insulating glass such as 3/16 inch laminated x 1/2 inch air space x 1/8 inch light. Larger air gaps would require larger mullions than normally provided. Assuming an exterior noise level of 65dBA for noise incident at the façade of the Phase 1 development, the interior noise just inside the window or door would be about 30dBA with an STC 35 glazing. The interior Day Night Level, Ldn, would be about 37dBA, well within generally recognized criterion of 45 DNL for residential spaces.

## Cooling Towers

The cooling tower noise would have to be reduced by at least 10 dB to achieve a 65 CNEL measured at 100 feet from the cooling towers. Alternatives for achieving this noise level include several options such as: relocating the cooling towers away from the Phase 1 development; adding additional cooling towers to reduce the demand on the existing units; replacing the existing cooling towers with new units that operate at lower noise levels; modifying the fans, coils, blades, or motor drives, and; installing acoustical absorption barriers.

### Relocation

Moving the cooling towers away from the Phase 1 development would be an effective approach to noise control. Possible locations include areas along the northern side of Building 503, possibly extending into the parking lot at the eastern side. Unfortunately, moving the cooling towers would entail substantial plumbing relocation as well. Engineering costs and labor would be substantial.

### Additional Cooling Towers

Additional cooling towers would reduce the cooling demand on individual units, allowing the fans to operate at lower speed. The level of the noise produced by the cooling tower fans is roughly proportional to 50 times the logarithm (base 10) of fan tip speed. Thus, a reduction of fan speed by a factor of two would reduce the cooling tower noise by about 15 dB to 59 CNEL, as measured at the roof of Building 501. However, doubling the number of cooling towers would increase the water fall noise and fan noise by 3 dB, so that the net reduction might be limited to 12 dB, unless the additional cooling towers could be positioned at greater distance from the Phase I development, perhaps along the northern side of Building 503. Again, considerable additional plumbing and costs would be required.

### Replacement

Replacement of the existing cooling towers can be considered, as new towers would have new coils with improved air flow and efficiency. This may allow reduced fan speed, and, combined with other noise control provisions, could achieve the desired noise limit at the facades of the Phase 1 buildings. The cooling requirements should be reviewed and manufacturers consulted to determine if replacement of the cooling towers would be a viable option. Sound power level data would be required for any candidate cooling towers to determine viability. Replacement of

the towers with more efficient units might pay for the noise control effort by reducing operating costs.

## Fan Noise

The cooling tower fans appear to be the primary noise source. The fan noise emanates from the top of the cooling towers and from the coils. Water fall noise, though not readily apparent, also transmits through the coils to the exterior. As noted above, most of the noise measured at ground level is probably transmitted through the coils. The facades of the upper levels of the Phase 1 development nearest the cooling towers would likely be in view of the coils as well as discharge cones.

Following below are provisions that might be applied to the existing cooling towers to reduce cooling tower noise. Of these, a reduction of fan tip speed is a primary goal, as noise levels produced by the fan are roughly proportional to 50 times the logarithm of tip speed.

The recommendations given below for reducing fan and waterfall noise of the existing cooling towers should provide a 10dB noise reduction, and a 15 dB noise reduction can be contemplated, reducing existing noise levels at the Phase 1 development nearest the cooling towers to perhaps 70 to 75dBA. Additional noise reduction would likely be needed to reach 65 DNL.

### *Coil Replacement*

The existing coils appear to be partially blocked by salts or other deposits. Replacement of coils may improve flow through the coils and thus improve cooling capacity of the towers. Improved cooling capacity would allow reduction of fan speed and would thereby reduce noise levels.

### *Variable Frequency drives*

Variable speed drives can be provided to allow low speed operation at night when cooling requirements are less. This, combined with improved flow through the coils, may yield substantial benefit in achieving an acceptable Day Night Level of 65 Len.

### *Tip Seals*

A large gap between the tip of the fan blade and the circular shroud surrounding the fan causes low fan efficiency and noise. Commercial tip seals can be provided that reduce the gap to perhaps 1/8”, thereby maximizing fan efficiency, and allow lowering of fan speed.

### *Aerodynamic Fan Blades*

Aerodynamically designed fan blades provide greater efficiency than simpler blades not designed for noise control. Commercial blades are available that, combined with tip seals, may maximize fan efficiency.

### *Discharge Stack*

The interior walls of the discharge stack could be treated with 4-inch thick 3-pcf glass fiber acoustical absorption or mineral wool to absorb sound before it escapes over the top of the cone. The elevation charge cone can be raise to increase the path length difference between the fan and receiver. The noise reduction would increase with increasing height. Ideally, the height of the cone above the fan should be three fan diameters. However, a lower height might be sufficient.

The discharge cone can also be flared by 15-degrees to provide some static regain and further improve fan efficiency. The Industrial Acoustics Company also provides attenuators that can be placed over the discharge stack opening to absorb sound.

### *Acoustical Louvers*

Both fan noise and water fall noise are radiated from the cooling coils. Placement of a barrier in front of and close to the coils would be impracticable, as this would restrict air flow. However, louvers with acoustical absorption can be provided at the face of the cooling towers exposed to the Phase 1 development.

### *Sound Barrier*

A sound barrier lined with acoustical absorption can be interposed between the cooling towers and Phase 1 Buildings. The barrier would have to be high enough to interrupt the line of site between living units and the top of the cooling towers.

### Receiver Noise Control

Windows and doors facing the cooling towers should be acoustically rated. Depending on the noise control reductions achieved, windows and doors rated with an STC-45 can reduce interior noise levels just inside the windows and doors to 40dBA. The noise levels further inside the rooms would be about 35dBA. The corresponding Day-Night Level would be about 42 DNL, adequate for interior residential spaces. The needed STC ratings of the windows and doors would depend on the noise reductions achieved by source controls.

## Conclusion

Based on the existing noise levels and available alternatives for reducing sound levels from the TowerJazz operation on Phase 1 of Uptown Newport, feasible controls are available that can reduce exterior sound levels to 65dBA and interior noise levels to below 45dBA.

**Table 1 Summary of Noise Sources and Sound Attenuation Alternatives**

| Noise Source | Noise Control Provision | Noise Reduction - dB - | Notes |
|---|---|---|---|
| Exhaust Fans | Sound Barrier | 10 | |
| Exhaust Fans | Modify exhaust stack and fan | 6-10 | |
| Miscellaneous Rooftop Equipment | Existing Screen/Parapet Wall | 10 | For receivers below elevation of screen |
| | Add acoustical absorption material to existing screen | 3 | |
| | Acoustical absorption and/or lagging to noisy pipes | 10-15 | Depends on nature of noise |
| | Air-cooled condenser fans | 5 | |
| Cooling Towers | Replacement with new units (all or in part) | TBD | |
| Cooling Towers | Exhaust Fan Cone with Acoustical Absorption, aerodynamic blades with tip seals, acoustically lined inlet louvers | 10 | Depends on air flow loss limitations. |
| All | Architectural treatments (transparent barriers for balconies) | 3 | Un-enclosed |
| All | Architectural treatments ( High STC glazing and frames for doors and windows) | 15dBA | Relative to typical glazing |

## CONSTRUCTION VIBRATION IMPACT ON JAZZ OPERATIONS

Vibration is a major consideration for TowerJazz, as they are actively engaged in manufacturing of sub-micron geometry semiconductors, using very high resolution photo-lithography. Vibration-sensitive equipment is located within the TowerJazz building, and construction practices to limit vibration and reduce the potential for vibration impacts to sensitive equipment should be taken. This section summarizes possible impacts by construction equipment and steps that may be taken to avoid such impacts.

### Criteria for Floor Vibration

Three sources of information can be used as a basis for selecting appropriate floor vibration criteria. These include generic criteria employed in the industry for building construction, vibration tolerance specifications for manufacturing equipment, and the existing background vibration.

#### IES Recommended Practice

The Institute of Environmental Sciences[i] has published guidelines for floor vibration in sensitive manufacturing facilities such as TowerJazz. These guidelines are listed in Table 2. The guidelines are stated in terms of 1/3 octave band vibration velocity levels for various types of

equipment, such as scanning electron microscopes, photo-lithography systems, etc., and are used almost universally for design of floor systems in semi-conduct manufacturing facilities.

Floor vibration limits are roughly proportional to the semi-conductor line widths. Semiconductor tool manufacturers today employ active vibration cancelation systems and servo-feedback focusing systems to reduce sensitivity to vibration, and one must rely heavily on specific equipment vibration tolerance specifications. The IES vibration criteria curves are probably conservative in this respect.

### Manufacturer's Specifications

Manufacturer's specifications are usually provided for vibration sensitive semi-conductor manufacturing tools. These specifications are stated in a variety of ways, and there is little uniformity between manufacturers. The vibration tolerance curves may be stated in terms of 1/3 octave band vibration velocity or acceleration, peak displacement, power-spectral density, etc. Often, these can be restated as 1/3 octave band root-mean-square velocity limits, as used by the IES. These can be easily measured with commonly available sound level meters and analyzers.

### Existing Vibration

The TowerJazz building is susceptible to vibration from existing sources surrounding the site, but more notably from existing equipment and operations located within and on the roof of the TowerJazz building. The 1/3 octave band vibration velocity on the second floor of Building 503 has been measured at about 6 to 25 μm/sec (240 to 1,000 μin/sec) velocity, largely due to roof-top equipment. This corresponds to IES criterion curves of VC-D and VC-B, respectively. TowerJazz has reinforced the floor for selected photolithography tools to reduce floor vibration. In any case, the velocity level may vary considerably from point to point within the building.

Appropriate floor vibration criteria for TowerJazz must necessarily be based in part on the background vibration at specific pieces of equipment with some margin of safety. A criterion that is substantially below the background vibration does not make sense. The background vibration is probably less than the tool's tolerance to vibration, judging from existing floor vibration levels and the apparent successful operation of the production tools. Some safety factor may be incorporated into the tolerance specifications of various tools.

## Construction Vibration Sources

Vibration impacts on TowerJazz were evaluated for a variety of construction equipment prior to a seismic isolation retrofit of the TowerJazz building in 1997. Tests were conducted for hoe rams, jack hammers, front-end loaders, and a road header excavator. These data can be used in part to estimate ground vibration impact on TowerJazz. Other data have been documented for large scale construction projects. WIA has also conducted ground vibration tests of construction equipment for the LA Metro Red Line, which data can be employed for prediction of vibration due to loaders and the like.

Following below are construction vibration sources that might be of concern during development and construction of Phase 1.

## Pile Drivers

Pile drivers include impact pile drivers, vibratory pile drivers, and constant frequency pile drivers. Impact pile drivers produce the highest vibration, and would likely negatively impact the TowerJazz facility. Constant frequency pile drivers might conceivably be acceptable if not located in close proximity to the building. Auger piles are not anticipated to cause excessive vibration.

## Mobile Sources

### *Track-Laying Dozers and Loaders*

Track-Laying Dozers and Loaders can produce unacceptable ground vibration when operated in 2nd or higher gear at such speed that impulsive forces are created as the steel cog wheels traverse the steel treads.

### *Wheel dozers and loaders*

Wheeled dozers and loaders are often used in areas where vibration control is an issue. Specific cases include construction of cut-and-cover subways. Operation of wheeled dozers and loaders is not anticipated to cause excessive vibration. However, transient vibration can be generated if dozer blades or loader buckets are allowed to drop to the ground.

**Table 2 Vibration Criteria for Sensitive Equipment[i]**

| Criterion Curve | RMS Velocity[1] $10^{-6}$m/sec | Detail Size μm | Description of Use |
|---|---|---|---|
| | | | |
| | 100 | 25 | Bench Microscopes up to x100 magnification, laboratory Robots |
| 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 | Appropriate for inspection and lithography equipment (including steppers) to 3mm line widths. |
| VC-C | 12.5 | 1-3 | Appropriate standard for optical microscopes to 1000x, lithography and inspection equipment (including moderately sensitive electron microscopes) to 1mm detail size. |
| VC-D | 6.25 | 0.1-0.3 | Suitable in most instances for demanding equipment, including many electron microscopes (SEMs, TEMs) and E-Beam systems, aligners and steppers for 0.5 micron resolution, and wafer inspection systems. |
| VC-E | 3.12 | <0.1 | A challenging criterion to achieve. Assumed to be adequate for the most demanding of sensitive systems, including long path, laser based, small target systems, electron beam lithography systems working at nanometer scales, and other systems requiring extraordinary dynamic stability. Other equipment may include scanning transmission electron microscopes, and atomic force micro-scopes. A representative line width is 0.1micron. |

[1]As measured in one-third octave bands of frequency over the frequency range of 8 to 80 Hz (VC-A and VC-B) or 1 to 80 Hz (VC-C through VC-G)

[2]The detail size refers to line width in the case of microelectronics fabrication, the particle (cell) size in the case of medical and pharmaceutical research, etc. Detail size is not relevant to imaging associated with probe technologies, AFMs, and nanotechnology.

### *Vibratory Rollers*

Vibratory compactors operating on site would likely cause excessive vibration that would impact TowerJazz operations, especially within a range of about 200 feet.

### *Hoe Rams*

Hoe rams are often considered to produce excessive ground vibration. However, they are usually used to break up concrete, and thus much of their impact energy is dissipated in the concrete. The exception might the use of the hoe ram to break up a concrete grade slab.

## Vibration Control

### Piles

Piles are not anticipated for building construction, except for the high rise (> 75ft) buildings. Augured piles should be employed where practicable. Impact and vibratory pile drivers should not be used during construction unless TowerJazz is consulted to avoid excessive vibration during operation of sensitive equipment. Constant frequency pile drivers might be acceptable if operated at sufficient distance from TowerJazz and if demonstrated to not interfere with TowerJazz operations.

### Static Rollers

Static rollers should be employed where compacting is required. Vibratory rollers should not be used unless TowerJazz is consulted to avoid excessive vibration during operation of sensitive equipment and if ground vibration produced by such rollers is found to be acceptable to TowerJazz operations.

### Wheel Loaders and Dozers

Within 200 feet of Building 503, wheel loaders and dozers should be employed, rather than the track-laying heavy equipment. However, dozer blades and buckets may generate considerable transient vibration if dropped on the ground. Contractor training and notification should be conducted for wheeled equipment operated within 200 feet of the TowerJazz Building 503.

### Hoe Rams

Hoe rams should be not be used to break up concrete grade slabs within 100 feet of the TowerJazz Building. Concrete slabs can be sawed and lifted away to another location where they may be broken up by the hoe ram. However, the process of hauling away large pieces of concrete may involve transient ground vibration due to inadvertent dropping of the concrete. Thus, hoe rams should be used as much as possible to break up concrete before hauling away with a bucket.

### Scheduling/Coordination

Coordination of construction work with TowerJazz operations should be considered. However, TowerJazz manufacturing may be non-stop, 24-hours per day. Even so, semiconductor manufacturing equipment require maintenance from time to time, and windows of opportunity may present themselves during which certain construction with attendant high vibration potential might be scheduled.

### Haul Trucks

Ground vibration from haul trucks should not produce significant vibration if routed away from the TowerJazz Building 503.

### Lay-Down Areas

Lay-down areas include material storing areas. Such material may include piles, steel shapes, and other heavy items. Significant ground vibration transients may be produced by flipping or dropping large steel shapes or concrete pieces. Also, fork lifts would be operating frequently in the lay-down area. The lay-down area should be located in portions of the construction site that are at least 200 feet away from the TowerJazz Building 503.

## Vibration Monitoring During Construction

Vibration monitoring should be conducted at the TowerJazz building during development and construction of Phase 1. Existing ambient vibration can be measured at various points in the building, specifically at vibration sensitive production and inspection tools, to determine appropriate vibration limits. However, these should be correlated with foundation vibration. That is, construction vibration energy must enter the TowerJazz facility through the foundations of the building, so that the foundation should be the most appropriate location for vibration monitoring. Existing 2$^{nd}$-floor vibration at Building 503 is largely produced by HVAC equipment, production tools, and footfalls. These latter can produce substantial vibration, in excess of 25 μm/sec (1,000 μin/sec.) Thus, false indications of construction vibration can be expected if vibration is monitored at the second floor of Building 503, adjacent to sensitive equipment. The most appropriate location for monitoring would be at the building foundations nearest the construction area, where construction vibration would enter the building.

Previous measurements of basement floor vibration in the newer three-level "bump-out" building addition to Building 503 indicate that background third octave vibration velocity levels are less than 3 μm/sec (125 μin/sec), corresponding to a IES criterion of VC-E. Ambient floor vibration was only slightly higher than that at the basement floor, likely due to vibration from mechanical equipment located either on the roof of the bump-out or on the roof of Building 503. In any case, the appropriate point of monitoring would likely be at the building foundation, along the exterior sides of the building facing the construction work.

Recommended thresholds for vibration monitoring have been developed based on past vibration monitoring at TowerJazz during the seismic retrofit of the TowerJazz building and the vibratory characteristics of construction equipment that are anticipated to be used during construction of Phase 1. Recommended thresholds for vibration monitoring include the following:

- A vibration level of 3.16 μm/sec (125μin/sec) will trigger a warning that will notify the construction operator and TowerJazz of the condition;
- A vibration level of 6.3 μm/sec (250 μin/sec) will trigger a warning that will notify the construction operator and TowerJazz that excessive vibration is occurring and that the construction activity that is causing the excessive vibration should be stopped.
- Construction activity may recommence upon satisfactory assessment that the continued construction activity will not substantially affect the use of

vibration- sensitive equipment, or interfere with operations at the TowerJazz facility.

Higher thresholds than those listed above may be acceptable, based on the actual floor vibration response at various tools. The seismic isolators beneath Building 503 and the three-story addition may provide some vibration reduction at frequencies above 10 Hz, though floor resonance amplification may cancel any positive benefit achieved. Final protocol for notification to TowerJazz and construction equipment operators will be determined and documented in a vibration monitoring plan prepared prior to construction.

## Conclusion

The bump-out to Building 503 and seismic isolation of Building 503, involving considerable excavation and construction work beneath critical areas, apparently occurred without significant cessation of semiconductor manufacturing operations within Building 503. One may expect that ground vibration impact on Building 503 would be less than that which occurred previously, provided that impact or vibratory pile drivers and vibratory rollers are not employed, at least close to Building 503.

Based on the recommended vibration monitoring and various alternatives for reducing vibration from pile driving and the operation of heavy construction equipment, feasible vibration control provisions can be incorporated to reduce Phase 1 construction vibration to acceptable levels at TowerJazz. With implementation of vibration control measures, project construction would not cause vibration levels that would substantially affect the use of vibration- sensitive equipment, or interfere with operations at the TowerJazz facility.

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[i] Considerations in Clean room Design, IEST-RP-CC012.2, Institute of Environmental Sciences and Technology, Contamination and Control Division Recommended Practice 012.2, Arlington Heights, Illinois, 2007.