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COVER

Our cover shows a group of Crystal Instruments CoCo-80 FFT-analyzer/data-collectors being simultaneously stress tested on a 50 kN Sentek Dynamics shaker. The ruggedized hand-held CoCo-80 is used to monitor machinery condition by collecting vibration signatures. It acquires mission critical data in harsh conditions for demanding customers including the United States Navy. Following burn-in and prior to shipment, each CoCo-80 is subjected to stress screening while it operates. Critical performance parameters such as measurement precision and recording speed are monitored during and after the vibration test. The 100 g, 11,000 lb force, 2 inch stroke Sentek Dynamics shaker permits time efficient gang-testing of multiple units using a robust fixture on its 17.5 inch diameter load table. The air-cooled shaker can be rotated 90° to drive the 32 x 32 inch slip plate which shares its isolated mono-base. (Cover photo courtesy of Crystal Instruments, Santa Clara, CA.)

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What's Required to Bring Vibration Testing In House?

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So the question is on the table. Should we use an external laboratory to do our vibration tests or purchase equipment and do the work in-house? Clearly, using an outside facility avoids the capital costs to build and equip our own testing laboratory. We avoid all of the facility running costs and testing equipment maintenance and we don't need to cultivate our own vibration testing expertise. But having our own equipment would give us far better control of scheduling, avoiding repetitive packing and transport issues and providing us with far better security. Further, having such equipment at hand and people who know how to work with it will likely be a big advantage if a new (or revised) product exhibits quality problems detected by vibration testing.

What's involved in setting up a new vibration-testing laboratory? First off, you will need to select the right equipment to run the test or tests you are planning to execute. Most people start with a vertical-only shake capability and select an air-cooled shaker in the low- to-medium force range. As shown in Figure 1, this system will include a vibration controller, a shaker, an amplifier and a blower.

The controller is the "brain" of the system. It uses an accelerometer on the shaker table (occasionally on the tested specimen) to measure the vibratory motion during a random, swept-sine or shock test. The required details of the test are loaded into the controller from a personal computer. The controller continuously compares the measured Control signal to the desired reference Profile specified for the test and computes the necessary Drive signal for the shaker to force the Control to match the Profile. The controller also can perform a myriad of analytical support functions, including pre-test feasibility analysis and protective limit measurements during the test.

The amplifier is the closed loop's "power broker and operational cop." Its fundamental mission is to power amplify the low-voltage Drive signal from the controller and apply a high-current version of it to the shaker's voice coil. But it also provides a strong constant DC current to the shaker's field coils and three-phase electrical power to the cooling blower. The amplifier's control module constantly monitors that all high-power system components are operating safely with all voltages, currents, temperatures, airflow and vibratory stroke within specified allowable values.

The shaker provides the system's "brawn," the electromechanical muscle needed to provide enough force to move the device under test (DUT) at the vertical acceleration level required. To do this, it must have sufficient force, stroke and acceleration capacity. It must also have a frequency bandwidth that meets or exceeds the test's specification. Further, it needs the capacity to statically support the device under test and must have a large enough load table to properly attach and support the DUT. In some instances, shaking the DUT horizontally is essential. In this case, the shaker is rotated to the horizontal and used to drive a slip table through a driver bar. The slip table and shaker may be purchased as separate freestanding components or in a common mono-base for easier conversion from horizontal to vertical operation (see Figure 2).

The blower cools the shaker by drawing cool laboratory air in through the shroud surrounding the load table. The air flows down over the voice coil and the field coils, past the iron magnetic pole pieces and into an air chamber that is evacuated by a flexible hose leading to the blower. The heated air exits the blower through a silencer. For small systems, the blower may be located in the shaker space. To avoid recirculating the hot air, the blower's outlet should be vented to the outdoors. For large systems, the blower itself is located outside, reducing both noise and recirculated heat.

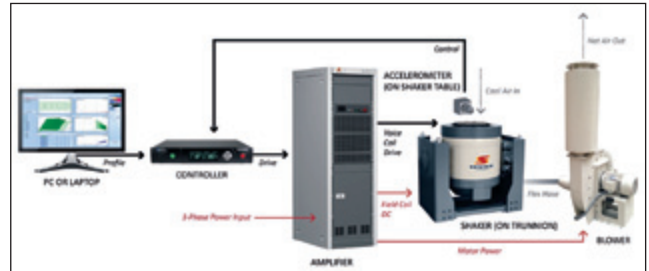


Figure 1. The basic elements of a vertical-only vibration testing system and their inter-relationships.



Figure 2. Advanced vibration testing system including horizontal slip table and large vertical/horizontal tip-over shaker sharing foot-isolated mono-base.

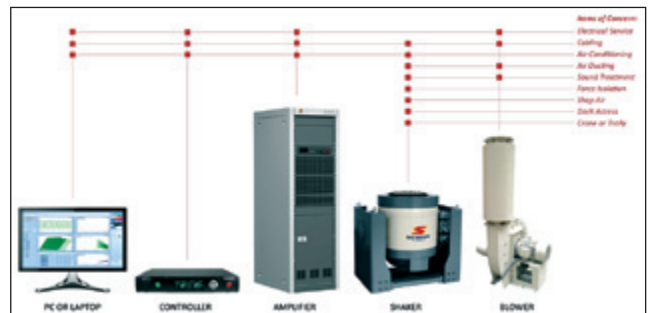


Figure 3. Twenty-one what (vertical) and where (horizontal) considerations for shaker installation.

Planning Laboratory Space

There are a lot of things to be considered in planning a new vibration laboratory beyond what equipment to buy. The dots in Figure 3 denote 21 what-and-where considerations that you don't want to overlook. Clearly you need to know the size and weight of everything your lab will house as a start point. You need enough floor space to house everything comfortably, allowing equipment to be used and serviced efficiently. You should plan for at least one meter clearance between the shaker, amplifier, blower and walls, benches or other obstructions. The floor needs to be level and strong enough to tolerate any equipment you need to use to move the test equipment initially and test items thereafter. You'll also need cabinet and shelf space to store fixtures and tools and supplies of all sorts.

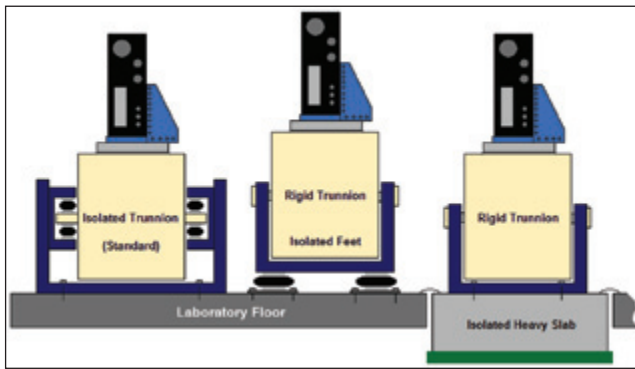


Figure 4. Three alternative shaker isolation configurations.



Figure 5. Wiring considerations at various locations in the system.

You need enough ceiling height to get large items in and out. If you are going to test large items, you will need an overhead crane near the shaker and possibly trolley access. You're going to need three-phase electrical power for the amplifier rack and single phase outlets for work lights and power tools near all elements of the system. There will be a lot of wiring, and you need to plan for its orderly arrangement in protective wiring troughs allowing maintenance access. You will need clean shop air (ISO 8573-1: class 1.7.1, 0.01 micron particle size, 0.01 ppm oil content) at the shaker. There will be a flexible duct between the shaker and blower. It needs to be safely routed and preferably sound insulated. The blower (or at least its discharge) should be outside the work area. You will need air conditioning – your shaker system will impose a significant added heat load on the workspace.

Your lab floor will need to be strong and level, since it will be supporting a lot of heavy items. Unfortunately, that strong floor can make your activities very unpopular with other inhabitants of the building. It can transmit the reaction forces of the shaker throughout the building, causing noise and even resonant vibration. Unless properly dealt with, this can be a real source of annoyance. The ideal answer is to situate your shaker on a separate floor slab, isolated from the remainder of the building. When this is not possible, our standard isolated trunnion or air-spring isolators under the feet of your machine can help enormously. Figure 4 illustrates these options.

Wiring Considerations

Wiring is always an issue that deserves careful planning (see Figure 5). You should plan separate conduits or troughs for signal cables to minimize electrical noise injection. You will need both three-phase and single-phase electrical service. It is likely that these will be separate. In the United States, the most common industrial three-phase supply (480/277 VAC 4-wire wye) provides a line-to-line voltage of 480 VAC; this is what you want to power your shaker amplifier and blower. However, many industrial buildings then use the resulting 277 VAC line-to-neutral voltage for lighting circuits. That may be fine for your overhead lighting, but you are still going to need 120 VAC single-phase outlets for the controller, other test instruments, trouble lights and power tools. You can only get that from a 240/120 VAC split-phase, a 208/120 VAC 4-wire wye three-phase drop or a purchased 408/277-to-120 VAC transformer.

It is extremely important to provide proper grounding of the system, both for operational safety and to preclude line-fre-



Figure 6. Installation of cooling blower external to laboratory space.

quency ground loop signal problems. The main ground lead should be applied to the amplifier and the shaker and controller should derive their ground connections from this point using no smaller than 12 AWG copper wire. Signal cables deserve special attention. To minimize noise injection and ground-loop problems, analog signal leads should be kept to minimum length. Note that the controller accepts the Control acceleration signal from the shaker and may also need to accept other measured accelerations (Monitor and Limit signals) from the shaker-mounted DUT. So the controller should be near the shaker. The controller Drive output connects to the amplifier, which connects to the shaker. Clearly, the shaker, amplifier and controller need to be close to one another. This does not imply, however, that the PC and the system operator need to be near the shaker.

It pays big productivity benefits to provide a comfortable environment for the staff that runs your vibration tests. This implies placing the PC in a clean, sound-treated and air-conditioned space adjacent to the shaker installation. The recommended Crystal Instruments controllers all use Ethernet® as the interface between the PC and the controller. Ethernet allows long distances between the PC and the controller with no loss of communication speed or system reliability. Of very special importance is the fact that Ethernet uses no ground-referenced signals. Because all of its digital signals are differential, an Ethernet connection cannot cause a highly problematic ground loop between the remote PC and the control system (as USB and older PC interfaces could).

Be aware that local electrical codes may influence the wiring of your laboratory. For instance, even though the amplifier powers the blower, city codes often require a three-phase disconnect near the blower. This is particularly likely if the blower is installed outside your building (Figure 6). Local building codes may also require a cage or barrier to prevent accidental contact with the blower.

Control Room Considerations

The ideal control room should be adjacent to the shaker room (see Figure 7), but separated from it by a sound-insulated wall (or double wall). It should be well ventilated and air conditioned. The control room should have excellent lighting and many 120 VAC outlets. It should provide desk space for the PC and related paperwork as well as ample storage space for office needs. It should have a double-glazed window at the operator's desk through which the shaker is visible and a passage door to that space. It should also provide a remote shaker amplifier system control unit (SCU) at the operator's desk. The SCU echoes all of the status readouts of the amplifier's control console and duplicates all of its control inputs. This unit (in conjunction with the PC) provides complete control of the shaker system from a comfortable location away from the noise and heat of operation.

Dealing with Heat

Heat is always an issue with an electrodynamic shaker installation, since a significant amount of electrical power is consumed in operation and converted to heat. It is essential to review the heat load survey for the proposed space; additional air-conditioning



Figure 7. Control room with view of shaker room; note remote SCU, controller, PC and large monitor on desk.

capacity is likely to be needed (see Figure 8). This should be brought online before the laboratory is commissioned. All Sentek Dynamics PA-series amplifiers are highly efficient class-D switching amplifiers. They have a thermal efficiency of 90%. Cooling efficiency is harder to characterize and varies significantly between systems. The “big picture” issue is that the total heat generated by the system (heat output) is essentially equal to the electrical power input to the amplifier. For the shaker at “full song,” the worst-case heat load (in BTU/hr) is equal to 3,412 times the amplifier’s kVA rating. System heat is given off by the amplifier, the shaker and the blower as well as the blower exhaust. Venting the blower’s exhaust to the outside dispels more than 50% of this heat.

Conclusions

Creating a new vibration testing facility will include equipment selection, and existing facility evaluation and upgrades. These upgrades will include electrical, HVAC, piping, partitions and

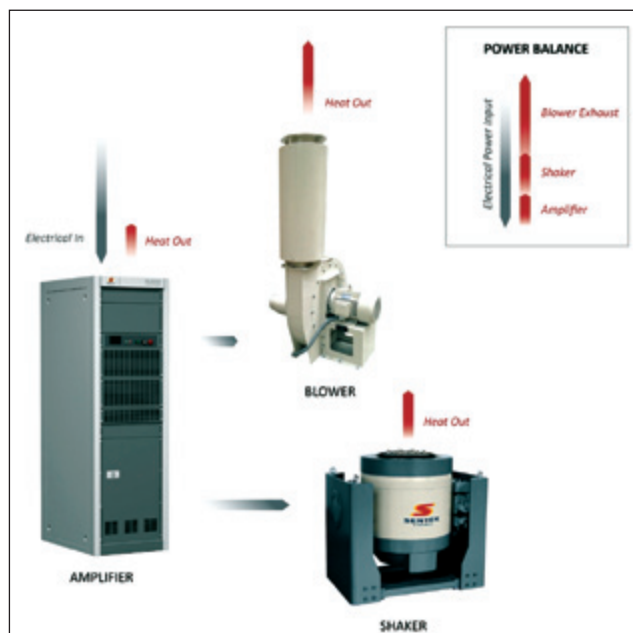



Figure 8. Balance of heat and electrical power within the vibration testing system.

passages and possibly building structural changes. Each of these upgrades must be accomplished and inspected in compliance with local codes and laws. Creating a new vibration test laboratory can appear to be a daunting task. But as with any sizable engineering project, breaking it down into a series of smaller tasks to be accomplished makes the effort manageable. This article should serve as your initial planning guide. 

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