mtiinstruments

# Three Vibration/ Balancing Solutions for the Aviation Industry

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# Three Vibration/Balancing Solutions for the Aviation Industry

**Isaac Abbott, Lead Engineer, MTI Instruments**

Throughout the aviation industry, whether commercial or military, jet engine vibration is an everyday concern. Maintenance, repair, and overhaul crews worldwide are tasked with monitoring aircraft engine vibration to ensure flight safety and efficient service.

Gone unchecked, jet engine vibration can be the catalyst for any number of problems, from minor annoyances such as cabin noise to undue parts wear. In the most severe cases, an out-of-balance turbine could lead to catastrophic failure from metal fatigue or cracks in rotor structures.

Overall gas turbine engine vibration, however, is actually the summation of vibration contributions from a variety of moving parts within the engine. To correlate vibration magnitude with specific engine components, maintenance engineers rely on vibration analysis and trim balancing tools.

Vibration analysis detects discrepancies in rotational machine dynamics while trim balancing is used to reduce vibration amplitudes of gas turbine shafts. Together, they help engineers ascertain and correct individual sources of vibration within an engine.

# One: An Advanced Turbine Vibration Analyzer/Balancing System

A modern turbine engine will typically contain two or three concentric shafts containing compressors, fans, and turbines. These shafts are often referred to as “spools.” The spools are aerodynamically coupled, meaning each spool turns at rate that is variable to its fellow spool. Consequently, each spool contains a speed pickup or “tachometer” so that rotational velocity and the spool rotational angle can be known.

In addition, vibration sensors are affixed to one or more positions on the engine case, measuring the magnitude of physical shaking. These built-in tachometer and vibration sensors are intended to provide a means for measuring speed and vibration as the engine operates. Reliable detection of their signals, however, is no trivial task as the signals are extremely noisy. Complicating matters further, different engines feature different signal types.

To solve this problem, MTI Instruments has developed a turbine vibration analyzer/balancing system good for all engines. The “PBS 4100” is available as two different models. The test cell version (PBS-4100R+) is designed for use in a production or overhaul facility. A lightweight system (PBS-4100+) is used on the ground for installed engines. Both systems include proprietary tachometer signal conditioning technology, and both share the same principle of operation.

## How it works

The PBS-4100 Turbine Vibration Analyzer/Balancing System gives users the ability to check the vibration amplitude of an engine and balance that engine if necessary. It does this with a series of on-board digitizers designed to measure each spool's rotational speed and magnitude of vibration. Embedded logic assesses the 12 o'clock position of each engine spool to understand where on the spool an imbalance might be located.

A series of configurable "tracking filters" correlates vibration to the spools. These specialized computer algorithms measure the rotational speed of a given spool and then filter the vibration content outside of a narrow band of interest. The narrow band of interest is the characteristic frequency of vibration around each spool's rotational speed.

By using the tracking filter for each speed, the contribution of vibration of each spool can be separated. As vibration varies with engine speed, measurement data is stored and presented in vibration versus speed trend plots.

## Conduct a Turbine Engine Vibration Survey

In testing an engine, the operator will execute a vibration survey on the turbine engine. The survey is a slow cycling of engine speed from idle to maximum, then back down to idle again. As this occurs, the PBS-4100 will measure the vibration contribution from each of the spools and chart its findings on a series of plots. In addition, the overall vibration is also plotted.

Should pre-defined limits of vibration be exceeded, the operator is warned. By the conclusion of the vibration survey, the vibration profile is summarized for comparison against the OEM recommendations. If the vibration of any given spool exceeds an allowable limit, it is possible to add offset weights to bring the spool into balance, similar to the addition of lead weights by an auto mechanic onto an imbalanced tire.

Because the vibration magnitude and the angular position are known on the spool, a solution may be calculated with a variety of techniques using the highly-evolved algorithms within the PBS-4100. Such a solution would add one or more precisely defined weights onto designated locations/angular positions on the spool.

## Quick to Configure, Easy to Use

The elegance of the PBS-4100 series is the concealment of the science behind a simple user interface. The end-user is asked to identify the engine type and any traceability information (ID number, etc). The PBS-4100+ then retrieves the operating characteristics and the setup of the engine and provides guidance to the operator to execute an engine vibration survey. Subsequently, the reports are furnished to the operator, together with a balance solution, as needed.

For the technician to understand where to place the balance weights on an engine, the vibration/balancing system must know the engine speed and the phase of vibration.


MTI offers the PBS-4100 as two different models. A lightweight system (PBS-4100+) to be used on the ground for installed engines. A test cell version (PBS-4100R+) is intended for use in a production or overhaul facility. The principle of operation is identical for both systems.

# Two: A Modern Signal Conditioner for All Engine Types

For some aircraft engine MRO situations, vibration data and balancing are not necessary; only the tachometer signal conditioning functionality is needed. In such cases, MTI's TSC-4800A signal conditioning unit fills the bill. The TSC-4800A is the same tachometer conditioning technology used within the PBS-4100. As with the PBS-4100, it can accommodate all types of engine speed signals.

With the TSC-4800A, users can test engines with a long tooth or short tooth embedded N1 signal; engines with older high-voltage tachometer generators; or engines with the new offset tooth design.

In addition, the TSC-4800A can be configured to condition as many as three individual speed signals. Channels A, B, and C can be assigned to a different engine speed signal and each channel can be individually controlled and programmed to condition different types of speed signals. Because many engines have primary and secondary speed signals, the TSC-4800A also offers multiple input sources for each channel.

The bottom line: MTI's TSC-4800A provides useful output signals from all types of inputs. These include pulses coincident with the input signal, pulses coincident with the 1/revolution signal, and raw analog signals proportional to the input signal. The TSC-4800A can also condition signals from engine FADEC systems or other instrumentation. These signals can be square wave signals, triangle waves, and short-duration pulse type signals produced by magnetic sensors – as well as signals from optical and laser sensors.

## Advanced signal processing, Ethernet control interfaces

Each channel of the TSC-4800A utilizes a dedicated high-speed signal processor to ensure accuracy and performance. These processors independently sample speed signals 20 million times per second. This means the TSC-4800A can reliably detect critical amplitude and timing changes in the speed signal, maintain accurate phasing of the output pulses, and track rapid speed changes of the engine.

The TSC-4800A features a full Ethernet control interface for configuration, control, and testing of the unit. A Web style interface, moreover, gives users easy access to the unit from any computer running an Internet browser program. Other computers can directly control the TSC-4800A using a simple yet complete machine interface language.

Additional features that further enhance the TSC-4800A user experience:

- Pre-defined conditioner settings speed up configuration
- An automatic power-up self test ensures reliable operation
- The firmware based design makes for easy upgrades
- An optional Buffered Output card provides 20 additional output signals from each input channel


MTI's TSC-4800A signal conditioner generates useful output signals from all types of inputs.

# Three: Portability Streamlines Jet Engine Testing

Early analysis of turbine vibration can identify problems quickly, saving the time and cost of engine removal. Implementing such troubleshooting techniques, however, can prove difficult. Mechanical constraints under the engine cowls and the complex design of aircraft wiring harnesses can make the installation of accelerometers, charge amplifiers, and cables a time consuming and error-prone task.

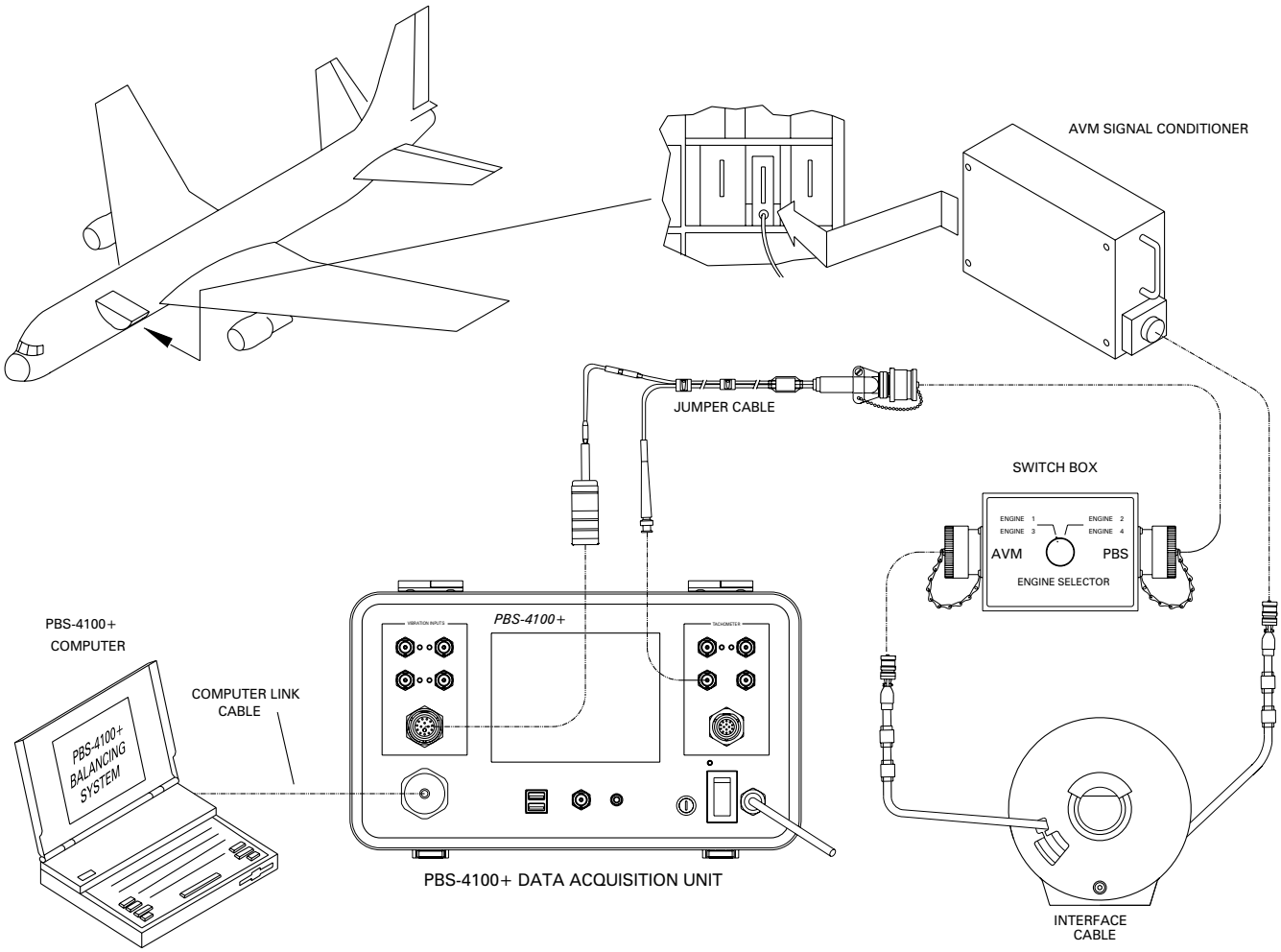
MTI's portable vibration analysis and engine trim balance instrument, the PBS-4100+, connects directly to the engine's built-in sensors to read necessary signals. Coupled with aircraft-specific accessory kits (AVM Systems), the unit simplifies balancing and vibration testing on almost any jet engine.

As with the larger test cell version, the portable instrument employs a series of on-board digitizers and configurable tracking filters. With these, the operator executes a vibration survey on the turbine engine. The survey is a slow cycling of engine speed from idle to maximum, then back down to idle again. As this occurs, the PBS-4100+ measures the vibration contribution from each spool and plots its findings. In addition, overall vibration is also plotted.

Compared with existing testing procedures, the PBS-4100+ portable vibration analysis and engine trim balance instrument is quick to configure and easy to use. The system is compatible with engines from all major manufacturers including GE, Pratt & Whitney, Rolls-Royce, and Honeywell.

# PBS-4100

## Advanced AVM




The PBS-4100+ swiftly pinpoints engine problems and eliminates avoidable engine removals. Cable sets and connection accessories are available for all engine and aircraft types.

# About MTI Instruments

MTI Instruments is a US-based manufacturer of highly-advanced balancing and vibration analysis systems. Specifically designed for aircraft engine/turbine manufacturers, our portable and test cell balancing solutions are backed by 50 years of industry service. Every day, leading names from commercial aviation, as well as the US Air Force and foreign militaries, use our systems to solve engine vibration problems. At MTI, we're obsessed with precision and with providing innovative vibration/balancing expertise to maintenance, repair and overhaul (MRO) organizations worldwide. MTI Instruments is also proud to be an ISO 9001:2015 certified company.

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