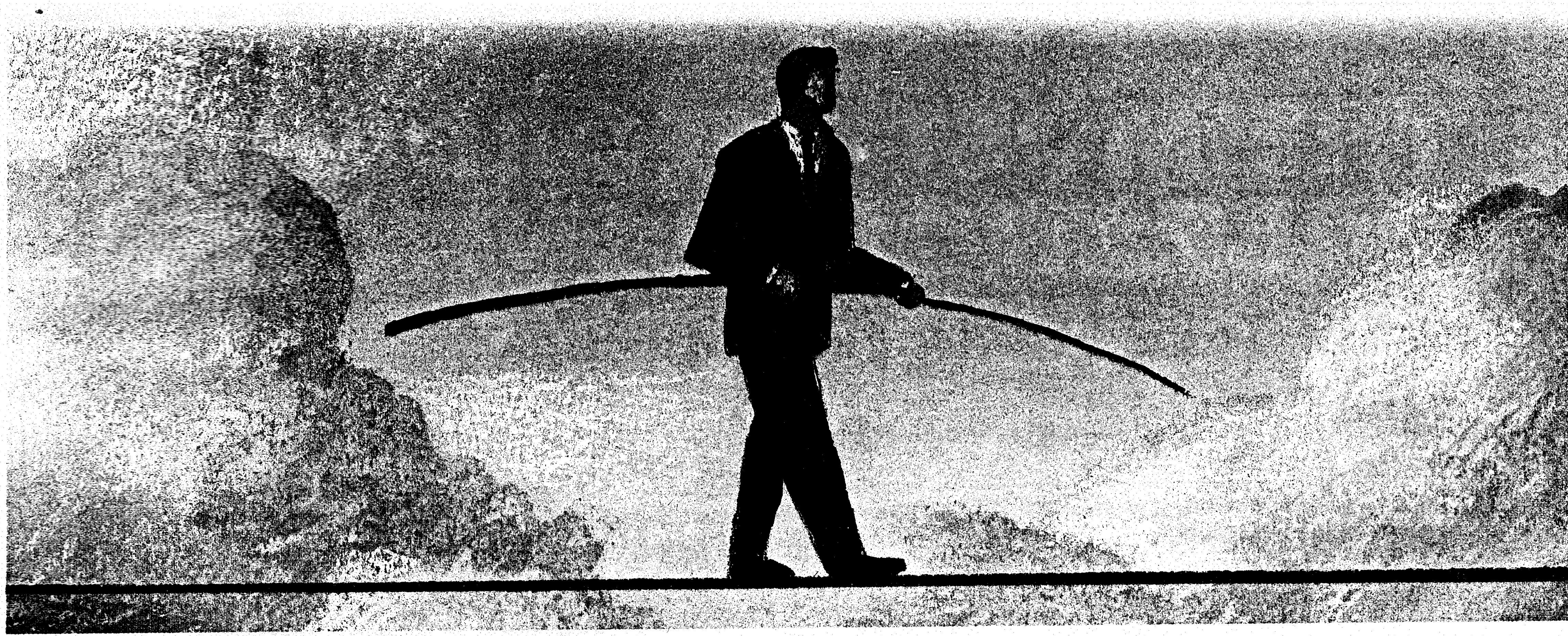

What Can Be Done When Balancing Is Not Working

By Victor Wowk

The following points explore some investigative steps you can take when balancing is not working.

1. Recognize when balancing is not working. Each correction-weight placement should produce at least a 50 percent reduction in vibration amplitude. Each correction-weight calculation should produce smaller weights, not larger ones. These are signs that the process is converging to a solution. If vibration is not quickly being reduced, and/or weights are getting larger, then something is wrong. It is time to stop the balancing process and investigate to understand the physical system better.

Set up a dial indicator and measure the runout of the shaft in as many places as are accessible along its length. Total indicator readings of less than .001" should be okay and balanceable. Larger runouts on a precision-machined portion of the shaft indicate that some distortion has occurred. It is possible to make some improvements with weights if the correction weights are placed in the plane of maximum bend. This improvement will only work at a single speed. The correction weights will turn out to be unusually large. For coupled machines, it is also possible to find a more favorable orientation, even with both shafts bent, by indexing the coupling; otherwise, the shaft will need to be replaced. The dial indicator can be used to measure for other mechanical conditions that affect balancing, like runouts on couplings and pulleys.

2. Another investigative step is to stop the machine and perform an impact test to measure the natural frequency of the bearings or other parts. The natural frequencies should be at least 20 percent away from the operating speed. If the speeds are close together, then a resonance condition is complicating the balancing process with nonlinear amplitude and phase response. The influence-coefficient method will need to be abandoned in favor of the four-run or seven-run method. Both of these methods work well near resonances. The four-run method is for single-plane balancing and the seven-run method is for two-plane balancing that properly corrects for couple unbalance and cross-effect.[1]

3. Remove all test weights and restore the rotor to its original condition as found. The amplitude and phase measurements should repeat. If they do not, then there exists instability or a roving unbalance. There is no point in proceeding with mass balancing until these conditions are corrected, and amplitude and phase repeat for multiple starts.

4. Start over from the beginning, placing the test weight in a different location 90° away from the first attempt location. The influence-coefficient method is sensitive to test-weight placement even though theoretically it should not be.[2] The influence-coefficient matrix may also be ill-conditioned. When ill-conditioned, the equations are not entirely independent and the mathematics do not converge to a proper solution. One procedure to utilize is to make a change in test weight plane and/or test weight angular location. It is very possible that the plane, or planes, initially chosen for balancing, missed the true heavy spot plane, as illustrated in Figure 1, and the rotor may be partially flexible. The only way to recover from this is to try a different plane for test weights and gauge the response. This trial-and-error procedure attempts to "feel out" the heavy-spot plane.

5. Make a load change or speed change and attempt rebalancing under the new conditions. It is possible that some other root cause, such as aerodynamic effects, is confusing the process. Mass balancing can partially compensate for other effects with some phase cancellation of synchronous vibrations.

(NOTE: This is the second half of a two-part article on balancing. The first part, "The Trouble with Balancing," was published in the June 2005 issue, and can be found on www.energy-tech.com)

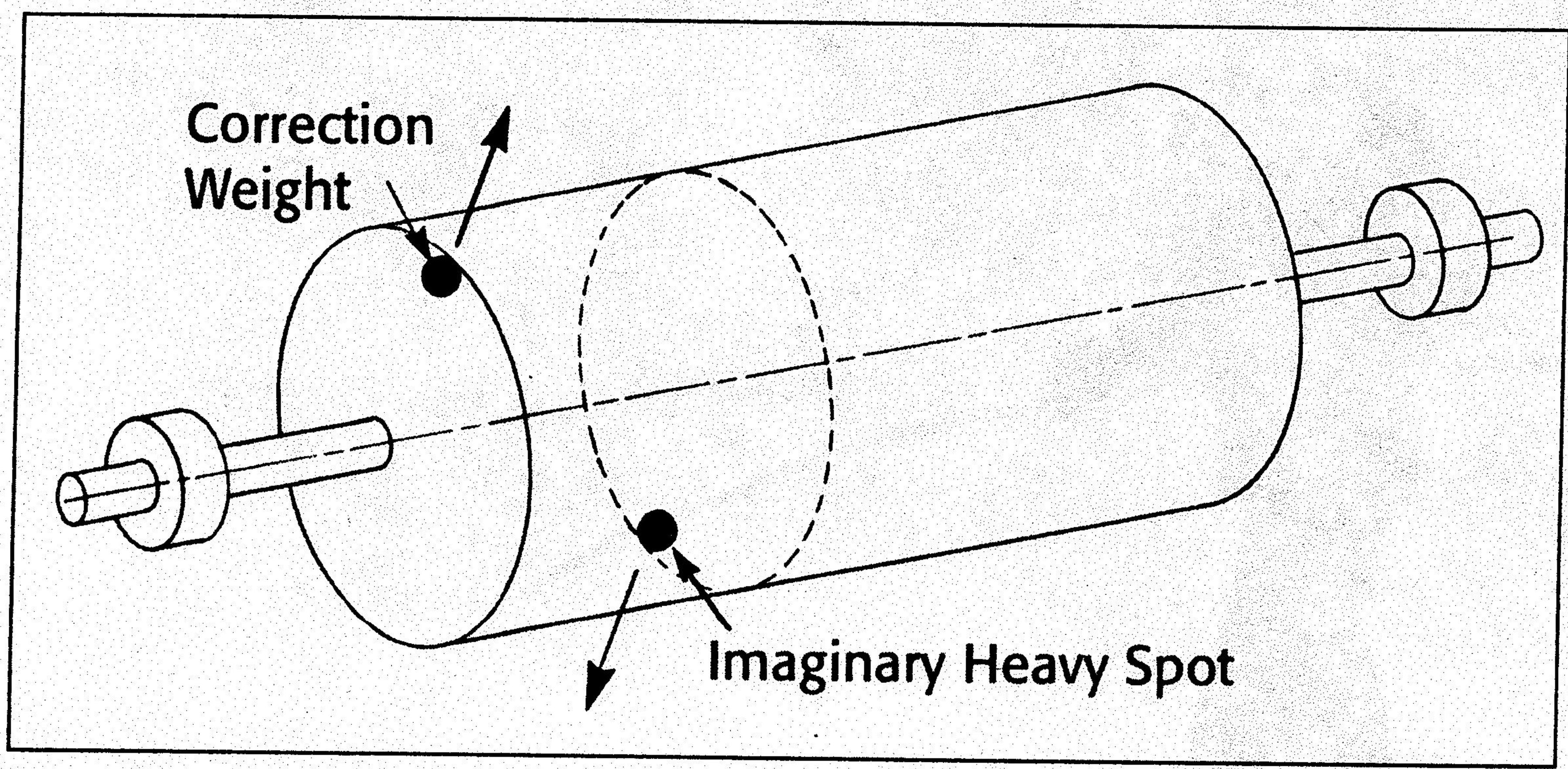

Figure 1: The correction weight plane is offset from the heavy spot plane, creating a couple unbalance condition.

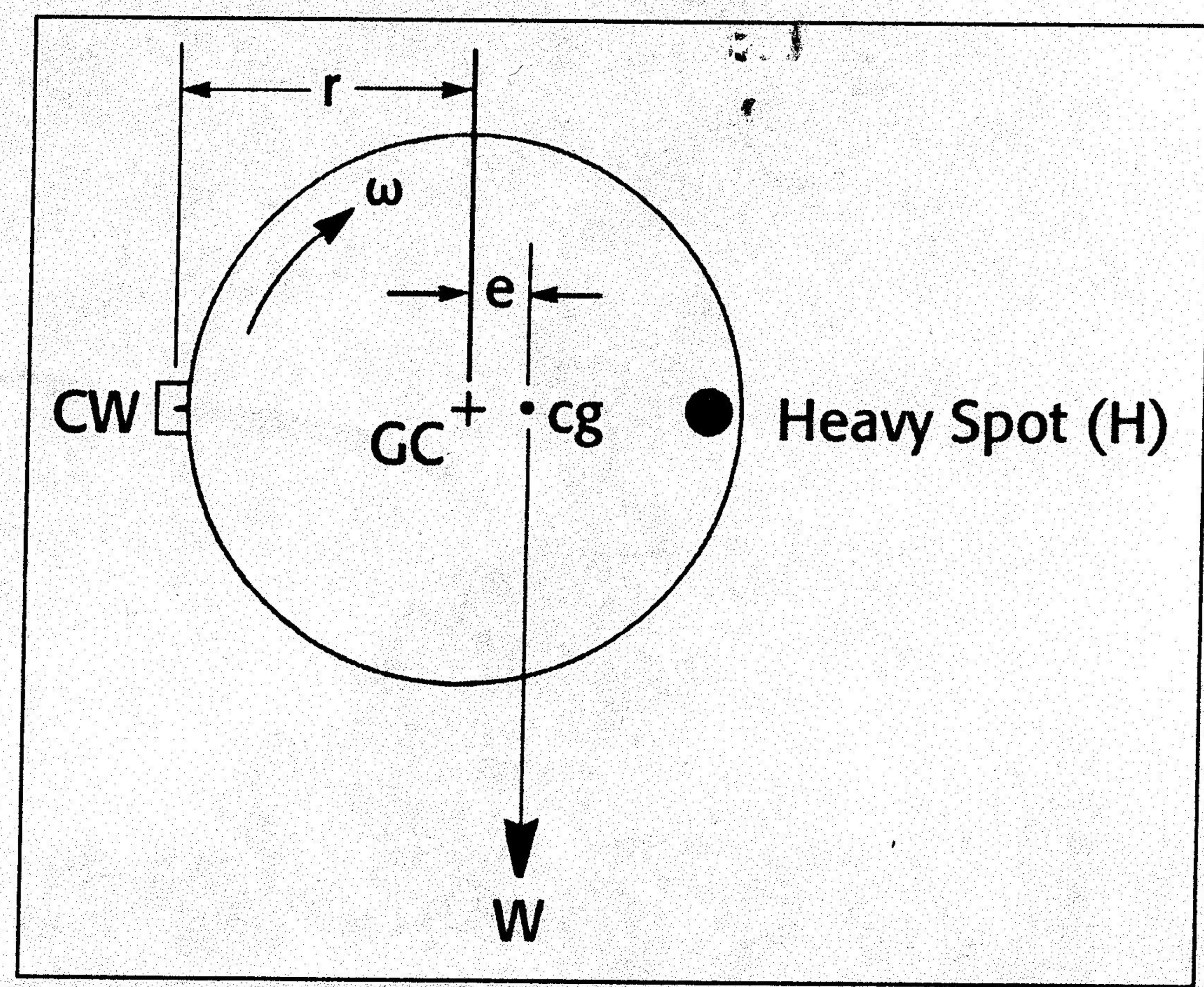

Figure 2: The mass of the rotor multiplied by the eccentricity equals the unbalance. M(e) = U.

Controlling Assembly Variables

Mass Balancing compensates for less-than-perfect manufacturing. In fact, manufacturing precision and mass balancing are inseparable by the fundamental balancing equation (Figure 2). Some of the manufacturing variables are poorly controlled, such as density, while others are better controlled, like hole locations and sizing. The parts are assembled and balancing is a final correction on the assembly to compensate for the lack of perfection. Every mechanic knows that when things are disassembled, they never go back together the same as before; the balance condition changes. There are some field techniques that can minimize the disruption of balance:

1. Match-mark everything during disassembly.
2. Weigh all replacement hardware and attempt to distribute it evenly.
3. Measure the shaft size when using setscrew or eccentric locking bearings. These devices push the shaft to one side of the clearance in the bearing inner ring and can grossly affect balance. Self-centering bearings, such as taper adapters, do not affect balance as much when shaft sizes vary.
4. Be prepared to measure vibration on startup and rebalance if necessary. Rolling element bearings define the rotating center, and simply replacing bearings can affect the balance because of the tolerances of ABEC-1 bearings.

Shop vs. Field Balancing

Shop balancing on a balancing machine will generally produce a better balance, whereas field balancing in place results in lower vibration. These statements seem contradictory and need clarification.

A balancing machine is better at detecting unbalance and quickly determining correction weights. It is good at this task because of its known support stiffness free of nonlinearities (such as resonance) and its ability to separate planes cleanly. It is also usually calibrated with known sensitivities for various weights of rotors and their final service speeds. The rotor leaves the balancing machine in a well-balanced condition as a free rotor, but then control is lost of the installation variables, such as bearing fits, support stiffness, foundation resonances, housing distortion when bolted down, and shaft alignment.

Field balancing in-place can detect and correct for some of these other effects by adjusting the weight distribution from previous balancing. The resulting lower vibration is achieved because installation factors can be partially compensated for. The combination of both balancing procedures, first shop balancing with the rotor out, then field trim-balancing in-place, will guarantee the best final results.

There are three types of balancing machines: gravity balancing stands, soft bearing, and hard bearing. Gravity balancing employs twin roller stands, string suspension, or pendulum balancers. Commercially available twin roller stands are surprisingly sensitive, able to detect 1.0 gr-in. of unbalance in a 1.5-pound workpiece. This is equivalent to a balance quality grade of G1.0 at 500 rpm. Gimbal balancers are even more sensitive. Gravity balance methods are sensitive to static unbalance only. They cannot detect couple unbalance. For that, the rotor must be spun in a dynamic balancing machine.

The soft-bearing balancing machine with belt drive will produce the finest balance results. It is also safer in the shop because the rotor does not need to be spun at high speed. Equivalent balance results can be achieved at 600 rpm, even for a 3,600-rpm machine.

The hard-bearing balancing machine is less sensitive. The rotor must be spun at higher speed to achieve good results. It is used mostly for production operations because of its fast cycle time, especially with end drive.

The present balancing standards, ANSI S2.19 and the international counterpart, ISO 1940, are out-of-date and need to be revised. They are out-of-date because machines are in a more critical posture today than 65 years ago, and balancing machines are capable of achieving better balance in a shorter time. In addition, the standards are difficult to read and understand. The average balance technician is unaware of their contents. This is one of the troubles with balancing. If the standards are to be followed, a balance quality grade of G2.5 or less should be specified for everything. This is achievable. For a soft-bearing balancing machine, a final vibration reading of 1.0-mil peak-to-peak has been used as a standard goal to strive for in repair facilities for decades and has resulted in satisfactory performance for common utility equipment.

	Acceleration, g peak	Velocity, in/sec peak	Displacement, mil peak-peak
Good	0.1	0.1	1.0
Best	0.01	0.01	0.1

Table 1: Field Balance Guidelines

For field balancing in place, there are no standards, but the numbers in Table 1 provide some guidance.

Closing

With all of these complications, it is a wonder that balancing works at all. The facts are that it does work well most of the time. The influence-coefficient method works beautifully when it works. Balancing is done mostly by non engineers, and is not formally taught at universities or technical schools. In fact, most balancers learn their trade at workshops or by being apprenticed to another; few are self-taught.

Mass balancing is mostly science, but it's an art, too. The art is realizing when it is not approaching a solution and selecting another method. There are several known methods, not all equal, and some are better in specific situations. This is the most significant factor to successful balance results, i.e., choosing a method that is more likely to achieve results in each specific situation. The instrument used is the least significant factor. Balancing instruments achieved maturity 50 years ago. Modern digital instruments are no better at achieving results than a 1950s tunable filter balancer; they just do it with more lights and color.

The power utilities have led balancing technology since the 1890s because of the size and speed of machines, and the consequences of bearing failures. The installed rotating machines at power plants represent the state-of-the-art in engineering technology that the general public benefits from, but is not entitled to observe in person like a balancer does. **ET**

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