Frederick Taylor

Following in Frederick Taylor's footsteps with Alcoa ergonomics

Various solutions show changing behavior is the key step toward a safer workplace

By Timothy Pottorff

I learned about Frederick Taylor, the founder of scientific management, while studying ergonomics at Kansas State University in Manhattan, Kansas, under the late Stephan Konz. After graduate school, I accepted a position as plant ergonomist at Alcoa's Warrick Operations facility in Newburgh, Indiana, in February 1992. As Taylor had gotten his start in the primary metals industry, I was in the "thick of things" with nearly 4,000 employees and, in a way, walking in Taylor's footsteps.

Warrick was a sight to behold, located on thousands of acres in southern Indiana with its own coal mines north of the plant and an on-site coal-fired power plant it shares with the local electric utility. The facility itself comprises more than 140 acres under one roof. Upon starting, I was given a site map and assigned an electric scooter. I quickly learned that ergonomics was not going to be exactly by the textbook there, nor were some of my other experiences. In this place, we had to go back to Taylor's basics.

Born in 1856 in Philadelphia, Taylor is less well-known for a book about concrete than for his study of the science of work. He was the first to study work methods scientifically and believed control of work should be in the hands of management, not labor. He determined through the study of shoveling materials that the optimal productive load was about 21 pounds. He designed shovels based upon the material to be moved, and increased productivity. He also modified the piece-rate system, which originally paid workers less the more they accomplished, and instead correctly paid them more for accomplishing more work.

Moving forward by going sideways

One of my first projects at Alcoa was with the manual handling of small, specifically alloyed aluminum "pigs" in the smelter. The task was pretty straightforward: To achieve the correct alloy, externally sourced pigs had to be introduced into batches of aluminum produced by the facility. The choice was between a higher frequency of handling 8-pound pigs or a lower frequency of handling 20-pound pigs, which was the task design at the time. Given the task characteristics and capital restraints, our solution was to go to the lighter pig and increase the frequency. While this specific project was less about efficiencies and more about energy expenditure and physical demands, at the very beginning of my career as an ergonomist, I had been given the opportunity to practically follow in Taylor's footsteps.

By using the smaller pigs, the department was able to lessen the physical demands on employees, which reduced risk for injuries and illnesses. The lighter pigs also allowed more people physical access to the task, particularly those with lifting restrictions.


Roll Shop reaches LWD milestone

Safety program improves ergonomics

The Roll Shop reached a safety milestone this week, achieving a half million hours without a lost work day accident.

And, in a job that requires regular heavy lifting, plans are in place to extend the streak.

John Orr, safety committee chairman in the Roll Shop, said Feb. 28 marked the fourth year without a lost work day accident.

It is not a small achievement.

Using cranes, Roll Shop Alcoans move loads that weigh anywhere from 6,000 pounds to 90 tons. They install, remove and repair parts that weigh about 20 pounds each. It requires a lot of lifting and the application of torque.

"In the past we've had a history of back problems and elbow strain," Orr

A key part of the Roll Shop's safety program is moving tools and parts on to specially designed hand trucks to improve lifting postures.

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An article in Alcoa's newspaper celebrates the roll cart designed by production line employees to ease access to tools.

Thus, the department was able to make a simple change in procurement and had the option of using job rotation if needed. It seemed to be a successful intervention; I never had to address the issue again, and in this facility, employees, supervisors, managers and engineers were never afraid to voice their opinions or let me know when something was amiss.

At the time the "new" National Institute for Occupational Safety and Health lifting equation had not been widely circulated, so we were using the 1981 version. The 1991 revised equation uses several key components of the lifting task, a predetermined algorithm, a load constant and a set of multiplier tables to help safety and ergonomic professionals determine a "safe" amount of weight a person can lift under certain circumstances. The task components included the frequency and duration of the lifting task, the starting and ending horizontal and vertical positions of the hands from the center of gravity of the body and the standing surface, the vertical travel distance, twisting experienced and the handhold on the object lifted. It also uses the average and maximum object weights. The algorithm calculates multipliers (or use a multiplier table) then multiplied by a "load constant" of 51 pounds, the weight researchers believed could be handled by healthy people in specific circumstances. Once the recommended weight limit is calculated, the weight of the object can be used to calculate a lifting index by dividing the actual weight by the RWL. The larger the lift index, the greater the risk for injury.

The data says what? Friends in high places

One issue that drove many decisions was the electromagnetic forces created by the immense electrical currents running through the giant smelting pots in the potrooms, which affect the ferrous steel tools being used. This was the most challenging department in the plant, where ambient temperatures seemed to be 100 degrees Fahrenheit in winter and even hotter in summer.

In the potrooms, it was all about the tools: Big and small tools, tools handled by cranes and by people and tools used inappropriately. Tools were strewn around the department, and (sometimes specialized, expensive) tools were frequently crushed by earth mover-sized crucible carriers. The tools issued were enormous. Departments had around 400 employees working in extreme conditions – temperatures frequently exceeded 120 degrees in the smelting pots.

A cross-functional potroom ergonomics team learned how many injuries and illnesses were simply due to employees not using the correct tools, damage to the tools and by tools not being easily available. In fact, tools at times were being manually transported up to what seemed to be the length of a football field.

In addition, steel tools were subject to the electromagnetic forces that increased employees' exertion and made their use unpredictable as they could be pulled in various directions. The electromagnetic forces were such that analog watches would not function, and if one brought credit cards into the potrooms, they likely would be turned into useless plastic by the magnetic forces.

This was the challenge. Ultimately, instead of reducing forces, as done with the pigs, we opted to use a unique stainless-steel alloy not subject to the electromagnetic forces, though significantly heavier than steel tools (traditional stainless steel will rapidly dissolve in molten aluminum.) With these tools, employees in the potrooms would be better able to predict what they were up against and magnetic forces would no longer be an issue. We also made various other changes to tools; at times, we had to try several variations before we found something just right.

Once the tools were improved, the next step was what to do with them. We knew tools were being crushed unnecessarily; broken or not, tools would be thrown down once no longer needed. One finding from the data was that since employees were using inappropriate tools due to lack of access to the correct ones, a tool management system was needed. We requested funding, then implemented such a system. The tool management system cost about $20,000 and included a set of customized carts for moving tools around and a series of storage boards at various locations accessible to both the services department and to employees in each room. The system included a protocol for damaged tools to be placed in a designated spot for repair to keep them from being destroyed.

The supervisor of the services department initially fought the changes, but after a few months, he was practically banging on the door at the ergonomics team meetings to see what else he could help with. The supervisor quickly realized that by employees having this simple system, tools in need of slight to moderate repair were fixed instead of being crushed, and working tools were protected. This system saved his department about $10,000 per month. As a bonus, the potroom employees no longer had to conduct "search and rescue missions" to find appropriate tools. (This was before many people had heard of 5S.)

The lessons learned were that sometimes we had to walk sideways or a bit backward before we could succeed, and that the support of senior management was not just important but critical.

In 1987, when Paul O'Neill took the reins as Alcoa CEO, the company's lost workday case rate per 100 employees was 1.86. Soon afterward, he shocked business investors with this excerpt from his speech: "Our safety record is better than the general American workforce, especially considering that our employees work with metals that are 1,500 degrees and machines that can rip a man's arm off. But it's not good enough. I intend to make Alcoa the safest company in America. I intend to go for zero injuries." (Reinhardt Krause, *Investor's Business Daily*, May 21, 2001.)

By the time O'Neill retired in 1999, the Alcoa lost workday case rate had dropped to 0.2. I would like to say I had a part in that, and in my consulting work I continue to tell stories and anecdotes from those days, as the lessons learned are still applicable.

Listen well and be respectful

The greatest test during my time at Warrick Operations came at the beginning of an all-day training course. I was scheduled to provide an ergonomics course to a group of 15 or 20 employees and supervisors. As we were doing introductions, we came around to "Junkyard Dog," who in the U-shaped table layout was sitting directly across from me. He proceeded to denounce the purpose and science of ergonomics as simply an attempt to take his job away and give it to others.

Dead silence fell over the room. As I listened to the tirade, I knew this moment would make or break me at the plant, within Alcoa and possibly my career. JYD was testing my mettle. I quickly realized he was just trying to see how I would respond. I let him finish, tried to listen and realized he was probably more scared than anything. In recent months, the plant had experienced cutbacks. The former Soviet states were dumping aluminum onto the commodity markets, sinking prices. JYD was no dummy, and he incorrectly saw the science of ergonomics as another thing to potentially upset his world.

I acknowledged his concerns about change and stated that our goal was to improve operations so people could work without getting hurt and to have jobs a wide variety of the workforce was physically capable of performing. The goal was not to allow other people to take his job, but rather to provide a safer work environment for those already there and for those to come.

At our first break, one of the supervisors in the class took me aside to thank me for how I had handled the situation, saying he "would have punched him," and that I had handled it as well as possible. We all survived the day, and in the end JYD became an integral part of the ergonomics effort in his maintenance department, as well as a great colleague. He just wanted to vent his fears that day.

That was a good lesson. Sometimes people just need to talk, and we need to listen. In my years of consulting, I have learned that the more opportunities I have to listen to clients and their front-line employees, the more successful they are. Whether with an office workstation evaluation or a manufacturing process, taking a few moments to close my mouth and listen enables the client to help me better understand the situation. When I do talk with a client, particularly on the job site, I do my best to help them understand where they want to be from both short-term and long-term ergonomics perspectives. I help them identify risk factors that affect not only human safety and performance, but which also impact quality, productivity and profitability, then work with them.

There will always be some who will talk just to talk; however, the key is to stay on subject and focus on the specific needs identified. The next step I take, particularly in a nonoffice environment like manufacturing or processing, is to ask which metrics are most important. How do we approach the assessment and the collection of data so the best case may be made from a quality, productivity, performance and profitability standpoint? No client wants to see people injured, but sometimes reducing risk of injuries and illnesses by itself will not be enough to achieve approval to spend more capital.

Trust your gut – literally

At Alcoa, I had the opportunity to take Don Wasserman's NIOSH vibration course. This course went into depths about hand-arm and whole-body vibration, the causes and symptoms of vibration-related disorders and solutions. The practical concepts I learned have stayed with me.

When an object vibrates, it can be found to be constantly accelerating first in one then the other. Most vibration is measured by acceleration (meter per second squared) and accelerometers are used to measure this acceleration. Vibration frequency is measured in hertz.

In his book *8 Human Aspects of Occupational Vibration*, Wasserman states, "Probably during the time when ancient man (sic) first assembled his shelter and used rocks as a hammer he (sic) noticed the sting of vibration impacts ringing through his unprotected hands. Similarly, during the time ... when man (sic) took to the sea ... the debilitating and often incapacitating effects of low frequency vibration were most likely known."

There are two major types of vibration: Hand-arm, also called "segmental," where vibration is transmitted from a tool to one or both hands; and whole body, where vibration is transmitted to the body from operating a vehicle or piece of equipment through a seat or a standing surface.

Common symptoms of segmental vibration exposure include numbness, "coldness" and tingling in the affected areas. Blood circulation can be restricted by damage to blood vessels and a paling of the hands and fingers from this can result in what is called primary Raynaud's disease, or more commonly, "vibration white finger." This vibration can come from operating tools such as impact wrenches, chain saws, chippers and grinder. In extreme cases, gangrene might have set in before modern occupational medicine and workers' compensation insurance programs became ubiquitous.

Common symptoms of whole-body vibration include upset stomach and nausea as well as lower back pain, with the spine changed from being a supporting structure to a biological "shock absorber." With whole-body vibration exposure, early studies cited by Wasserman identified effects such as increased rates of "venous, bowel, respiratory, muscular and back disorders," plus the "combined effects of forced body posture, cargo handling, improper eating and whole-body vibration were factors contributing to back pain, spinal deformities, sprains, strains and hemorrhoid disorders."

Not long after I took the course, an issue arose in the ingot plant where certain operators were becoming nauseous. This was around the same time carbon monoxide poisoning stories were becoming prevalent in the news media. At one point, someone in the facility called in the Indiana Occupational Safety and Health Administration, which shut down part of the department, tented it off and conducted extensive air sampling with no conclusive evidence of air quality issues caused by CO or anything else.

The operation in question was one in which about 1 billion recycled aluminum cans per year were crushed, delacquered (coatings burned off,) steel washers removed by overhead magnets, lead fishing weights removed by a mesh shaking conveyor and the aluminum remelted and cast, along with the virgin metal, into 35,000-pound ingots.

Once it was determined air quality was not an issue, I brought up the possibility of exposure to whole-body vibration from the shaking conveyor that removes nonaluminum detritus recycling-minded people placed into cans to increase their weight and payout.

The affected employees were monitoring the delacquering process by watching a video feed in a booth near the shaking conveyor. Since air quality wasn't an issue, site management was at a loss, and the operation was literally on shaky ground. Taking my advice, engineers in the department brought in an outside consultant to test whole-body vibration exposure. It determined the operator's booth was literally "galloping" in place, and that it was not CO poisoning but rather vibration that made operators sick.

The same thing happens on a particularly turbulent aircraft ride or by operating a truck or piece of heavy equipment for extended periods. When the frequency and acceleration of the body intersect at a specific point, the health and safety of an individual may be at stake with exposure over time. High amounts of vibration can be tolerated for short periods, and low amounts of vibration can be tolerated longer. The aircraft example would likely present itself in the form of an "engaged sick bag"; however these situations are rare. Often, to counteract short-term exposure to whole-body vibration, the best thing to do is to tense the abdominal muscles. Unfortunately, in an industrial environment, tensing the abs for an entire work shift won't suffice.

To solve the issue, operators were moved to a booth in a different area and the monitor feeds and machine controls were moved. This relatively simple improvement addressed the vibration exposure; the problem was solved and operations resumed. Long term, the issues most likely related to improper

Federal safety agency to upgrade its standards

Growing concerns about health, safety and an aging demographic in the U.S. workforce has led NIOSH to update its research and service goals recently for the next four years. The effort directly addresses issues with more older workers employed and many employees facing longer hours or compressed work schedules. Two of the seven chosen goals are directly linked to ergonomics issues. Under the header, "Reducing Occupational Musculoskeletal Disorders (MSDs)," NIOSH recommends the following:

- In the agriculture, forestry and fishing industries, develop a better understanding of the impact of vibration and repetitive motion exposures.
- In manufacturing, construction and trade industries, study the impact of workers using robots and exoskeletons.
- In healthcare, evaluate the effectiveness of interventions aimed to reduce MSDs.
- In mining, better identify risk factors for MSD development.
- Among service industry jobs, increase the understanding of risks for back injuries.
- In wholesale and retail trade, improve ability to reduce MSDs among older employees.

NIOSH will fund much of the research required to examine these issues. More details can be found at *https://link.iise.org/NIOSHgoals*.

isolation of the conveyor, which would necessarily affect the long-term reliability and life of the equipment.

Trust, encourage and avoid paralysis of analysis

The last two facility examples exemplify what I struggled at the time to accept as successes, but which probably would not have happened had the incident with JYD not ultimately gone smoothly.

As a newly minted ergonomist, I needed to be involved with every improvement. But in retrospect, these next two examples showed that the skills and concepts I had been teaching and coaching to facility employees were not only being absorbed and implemented but were changing the safety culture and empowering front-line employees and supervisors to make simple, effective improvements.

The first project was in the roll shop. Traditionally, employees placed on the floor the various components needed to change the giant rolls used to turn 35,000-pound ingots into the aluminum for beverage containers, then bent over and lifted the parts as needed. The employees asked me to periodically consult with them on their new "roll cart" design, which looked like a skeleton with steel rods sticking out of a central spine.

We know much more now about forward bending postures than we knew then. Around 2003, Ohio State conducted research using "fresh frozen cadaver spines" in a flexion (forward-bending) study. The results showed that bending forward 45 degrees or more creates about a 20- to 50-time greater risk for a back injury than from standing in an upright posture ("Dissertation, Effects of Torso Flexion on Fatigue Failure of the Human Lumbosacral Spine," Sean Gallagher, 2003.) The researchers' definition of a "back injury" was about a one-centimeter shift between the spinal vertebrae and a disc.

The roll shop cart was ahead of its time. This simple cart created in 1993 allowed parts to be kept and presented about waist height, eliminating most forward bending by no longer placing items on the floor. This was a successful and simple project and featured in a facility newspaper article (see image on page 28), which also discussed some of the improvements being made to hand tools.

The other employee-led project was in the potrooms. One regular task was to use a jackhammer to remove excess insulation "crust" off nearly used-up anodes. When I arrived, I started widescale training to discuss various risk factors, including vibration. With the anodes, employees had to contend with heat and fumes. The carbon anodes were just removed from smelting pots at around 900 degrees Celsius and were emitting fumes that were no longer captured by the massive ventilation system. We had three issues: a potential air quality issue with the fumes, heat stress and vibration. At this point, given the work technique and the size of the jackhammers, it was both hand-arm and whole-body vibration.

Not long before I left to work for Zurich Services Corp., one of the many potroom supervisors asked me to meet him in the department so he could show me a prototype they wanted to try. On their own, potroom employees had attached a jackhammer to a Bobcat-style tractor and used its hydraulics to operate the hammer. This new arrangement better separated employees from the direct radiant heat and fumes and transferred most of the vibration from the human body to the tractor body. Employees discovered they could clean the anodes almost immediately after removal from the pots. This meant they could more effectively remove the crust, which saved more of the anode carbon. This reduced material costs, as the cleaned anodes were then crushed and recycled into new anodes.

Granted, employees still had some vibration exposure, which was not going to go away. However, the success did not require massive amounts of analysis. We knew the closer you were to the source, the worse the vibration.

By teaching employees not "what to do," but rather "this is our goal," it allowed them to start developing these simple yet effective solutions. When we intrinsically "know" something is an issue, do we trust our gut or second-guess ourselves? Do we try prototypes? Do we throw our hands into the air and give up in failure when a prototype does not work? Or do we try again? Obviously, we do not want to throw our hands into the air in failure to achieve a "perfect" improvement, but I do encounter this situation on a regular basis.

The tools and skill sets I developed and shared at Alcoa included setting up a simple decision matrix to force-rank possible solutions, teaching top-notch engineers on-site that it was OK not to solve 100 percent of the problem, and that "baby steps," including trial and error, were still better than no steps.

I also spent a good amount of time teaching my colleagues it was critical to get beyond the "paralysis of ergonomics analysis" many organizations still suffer from, as I encountered at Alcoa. Yes, analysis is important, but I find it critical that analysis does us no good if clients, internal and external, become confused and are unable to select improvements that improve their quality, productivity, performance and, ultimately, profitability. These are the concepts and skills I have shared with clients for my entire ergonomics career over more than a quarter-century. ❖

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