BATTELLE PRACTICES

THE SAFE CONDUCT OF RESEARCH

Preface

Research by its nature explores the unknown, constantly pushing the boundaries of our experience. It is work best performed by those with deep curiosity and natural skepticism, capable of intense focus. On the cusp of a new discovery, matters that seem ancillary to the task at hand can easily be overlooked.

The safe conduct of research, however, must never fade into the background of scientific endeavor.

Great science increasingly requires complex and powerful equipment, materials that pose substantial risk if mishandled, specialized operations, and teams of researchers supported by very capable technicians and craftsmen. Just as sound scientific conclusions rely upon a shared understanding of scientific disciplines, successful operations in a research environment require a shared code of conduct.

The Safe Conduct of Research was produced through a collaborative effort across Battelle-affiliated laboratories and has been informed by our own experiences as well as those that have gone before us. The purpose of this booklet is to codify the principles and practices that we believe ensure our science is performed without unnecessary risk and is sustained without operational disruption. In short, the principles outlined here form the underpinnings of the strong safety culture we embrace.

This booklet cuts through regulations specific to particular laboratories or institutions that, while important, don't always crisply articulate our basic approach to working safely. While of particular benefit to graduate students and others beginning their careers, the principles articulated here apply equally to scientists, engineers, and the multitude of other staff necessary to accomplish research.

The practices outlined here are endorsed by the Battelle Operations Council.

Juan Alvarez
Chair, Battelle Operations Council

Battelle Operations Council		
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A Note on Using This Booklet

This booklet has one primary goal: to make clear that accidents and injuries can be avoided through a set of purposeful actions.

It is not enough for an institution to simply have a "safety program" or a list of procedures. Rules and regulations cannot adequately protect you or your colleagues engaged in research and development (R&D).

Safety in your facilities depends on each researcher, each operations person, and each manager recognizing the need to conduct work safely and understanding how to achieve that nonnegotiable goal.

This booklet is not designed to replace your institution's safety program but rather to explain the ideas and approaches undergirding our safety processes, procedures, and standards of behavior.

This booklet can serve as . . .

- A quick read to orient new employees;
- A template for scientific leaders and managers to drive discussion and set expectations, and;
- A tool to help you and your colleagues organize peer reviews focused on safety.

The ideas that follow underscore your personal responsibility for safety—for yourself, your colleagues, and your staff. This booklet should encourage you to keep safety constantly in mind as you go through your day, and it should empower you to intervene before unsafe activities occur.

Take a few minutes and read this publication.

Then conduct yourself according to these standards.

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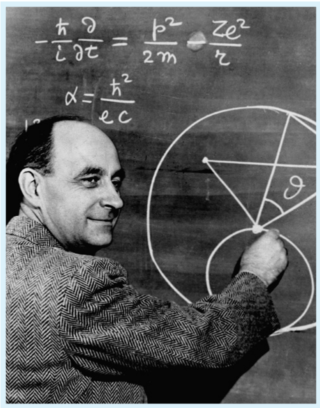


Introduction

In the early 20th century, the government maintained limited public research capabilities and provided minimal support for academic research. This all changed with the advent of World War II, as national security considerations drove dramatic increases in federal research investment. Today's federal research budgets are sustained by the recognition that investments in institutions such as national laboratories ensure our national security, underpin our economy, and provide essential tools for meeting national needs.

Nothing is more important to our institutions than the safe conduct of our research mission. In some areas, seminal discoveries can still be made without recourse to laboratories or large scientific instruments and facilities. However, to an increasing degree, basic and applied research requires the cooperation of individuals across a broad range of disciplines and the use of a wide variety of materials and equipment, many of which present unique hazards.

The Safe Conduct of Research describes the essential attributes of conducting research safely. The content of this booklet has a strong basis in past laboratory events. Rather than prescribing a specific program or implementing methods, basic principles are addressed. These principles, associated roles, and attributes—when embraced—will influence values, assumptions, experiences, behaviors, beliefs, and norms that describe what it is like to work at one of our laboratories and how all work is to be concluded. These are the collective traits that must lead us as individuals and organizations to emphasize safety over competing priorities.

This document is complementary to and should be used in conjunction with your institution's Integrated Safety Management program or other published policies and procedures for conducting work safely.

These principles, roles, and attitudes are similar to the three categories of safety culture in the DOE Integrated Safety Management Guide (DOE 450.4-1c, Attachment 10) and in International Nuclear Safety Advisory Group (INSAG)-4, Safety Culture.

Battelle's Philosophy of Simultaneous Excellence

Across our institutions, we are committed to simultaneous excellence in three critical areas: science and technology; laboratory operations, and corporate citizenship. This means we expect our teams to deliver outstanding results that meet the critical needs of our sponsors and customers; to operate our facilities effectively, efficiently, and in full compliance with all applicable laws, regulations, and client expectations; and to set an example of outstanding corporate citizenship and community service.

The Safe Conduct of Research will help you achieve operational excellence. Our research can be outstanding only if it is conducted with the highest regard for safety. The communities in which we work and live rightly expect us to demonstrate our corporate responsibility by preventing accidents and avoiding environmental incidents in research and all of our other activities.

The Importance of Culture

Bottom line:
Stop when unsure.
Protect yourself and be your brother's keeper

Organizational culture is DEFINED BY the shared assumptions that develop as an organization learns from problems and achieves success. Basic assumptions that have worked well enough to be considered valid are taught to new members of the organization, either explicitly or through demonstration, as the correct way to perceive, think, and act. Culture is the sum total of a group's learning. Culture is for the group what character and personality are for the individual.

Because of the special characteristics and unique hazards of R&D, the organizational culture of research facilities must incorporate a healthy safety culture, founded on a collective commitment to put safety first. This commitment applies to everyone in the organization, from the laboratory director to the individual contributor. No one is exempt from the obligation to ensure protection of people, the environment, and the facility.

We have articulated a set of principles that shape our behavior and form the basis for a strong safety culture. Whether you are a principal investigator, visiting scientist, group leader, project manager, program manager, senior scientific leader, or craftsman, your behavior creates our culture.

1. **Everyone is personally responsible for ensuring safe operations.**
   - As a research staff member or as a guest researcher, you are accountable for safety. Your organization has safety professionals available to support you. Use them.
   - You should know the hazards that your work activities create better than anyone else. If you don't, ask questions until you do.
   - Human error is inevitable, but you can reduce its likelihood and consequences.
   - Anyone can stop work, and you are expected to use that authority when there is uncertainty about the safe conduct of work.
   - Safety requirements and processes are there to protect you, your co-workers, facility, and the environment. Working around those requirements and processes is never a good idea.
2. **Leaders value the safety legacy they create in their discipline**
   - Leaders exhibit behaviors that set the standard for safety.
   - Being in research areas and engaging staff is the best way to understand whether your staff are prepared to work safely; coach, mentor, and reinforce expectations about safety during such engagements.
   - Expectations for safe performance are communicated often and in many forums.
   - Science leaders strive to keep safety at the forefront by being conscious of the complexity of the research, the preparedness of their staff, and the pressure to perform.
3. **Staff raise safety concerns because trust permeates the organization.**
   - You can't fix what you don't understand; staff are encouraged to raise concerns and report problems.
   - Science leaders create an environment of inquisitiveness as the norm to counteract the tendency of students, postdoctoral fellows, and junior staff to view uncertainty as a sign of professional weakness.
   - Anyone can respectfully challenge unsafe behavior regardless of his or her position in the organization, and these challenges are accepted graciously as an opportunity to improve.

> In this document, safety includes personnel safety, industrial safety, radiological safety, and, especially, nuclear safety, when applicable.

4. Cutting-edge science requires cutting-edge safety

- A conservative posture is assumed when the impact of hazards is uncertain.
- Safety is viewed as integral to the research product and not simply as compliance.
- Opportunities to research improvements in hazard controls are encouraged.
- Safety-related information is included in research records and publications.

5. A questioning attitude is cultivated

- In the face of uncertainty, researchers do not proceed with work until potential impacts have been evaluated and controls are in place to mitigate them .
- Anomalies are thoroughly investigated and mitigated.
- Opposing views are encouraged and used to advance everyone's understanding
- Differing opinions are welcomed and respected, but debate doesn't paralyze sound decision making.

6. Learning never stops

- Every experiment, event, or project provides opportunities to improve safety.
- You know your issues better than anyone else, reflect on them and assess lessons learned.
- Mistakes are treated as opportunities to learn.
- When challenged by someone, you view it as a chance to get better.
- Safety techniques and lessons learned are routine topics in research discussions.

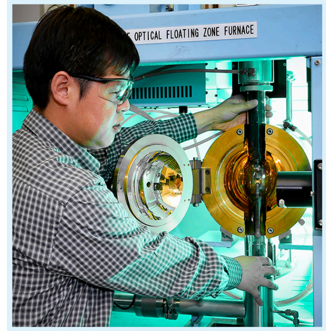
7. Hazards are identified and evaluated for every task, every time

- Research staff are expected to understand the hazards associated with their work, the controls necessary to do the work safely, and the rationale behind the selection of the controls used.
- Procedures and safety components are constantly reevaluated to ensure they still provide the protection assumed.
- "Work-arounds" are viewed as unnecessarily taking on risk and are avoided.
- Peer involvement is encouraged; it helps to avoid blind spots to new risks.

8. A healthy respect is maintained for what can go wrong

- Avoid complacency; routine tasks can result in serious injuries or operational upsets.
- Time pressure is a setup for mistakes; it is openly acknowledged when present and attention to safety is heightened during those times.
- Small failures and mistakes are seen as clues to more consequential failures and thus are highlighted and shared.
- External reviews and management engagement are viewed as opportunities to challenge assumptions and reinforce what is right.
- First-time operations are never conducted without thorough discussion of contingencies.

ELECTRICAL SHOCK FROM BOX FURNACE— DECISION MAKING WHEN FACING UNCERTAINTY



CASE STUDY

This case can be used to demonstrate a number of safety culture principles, one of which is the need for conservative decision making when faced with uncertainty. In 2011, a technician was asked to blanket a heating operation with argon gas; however, the oven routinely used for this type of operation was being repaired. He fashioned a purge line that he inserted under the door of the furnace, but the switch powering the heating elements would not fully engage because the line created a gap in the door. He placed a small block in front of the switch, which provided enough pressure to engage the switch and power the heating elements. He successfully completed the task, leaving the block in place.

Days later, a junior technician was assigned a similar task. The furnace of choice was still pending repair. The senior technician explained his modified approach to the junior technician. As the junior technician held the purge line in place while lowering the door to the furnace, he experienced a mild electrical shock. Subsequent investigation found that the shock occurred when the metal purge line contacted an energized heating element. The element would have normally been de-energized when the door was raised, but the block in front of the switch allowed electricity to continue flowing to the heating elements, bypassing a safety control.

In this case, both technicians proceeded without sufficient knowledge when faced with uncertain conditions. The senior technician, faced with an inoperable furnace, modified his process without fully understanding the consequences. He did not understand the conductivity of the heating elements or the safety function of the switch. The junior technician followed the direction of the senior technician without questioning the modification or understanding the changed functionality of the equipment.

Questions

1. Did the senior technician assume too much risk when making modifications to the experimental equipment?
2. What is the threshold for seeking help or performing additional safety reviews when an experiment cannot be executed as originally planned?
3. What steps should have been taken by the senior technician when he realized that the box furnace could not be used as designed?
4. If the junior technician was unsure or uncomfortable with the safety modifications, how could he raise his concerns without making the senior technician defensive?
5. How could the senior technician have created an environment that encouraged the junior technician to raise concerns?

CASE STUDY

ARC FLASH FROM RESEARCH EQUIPMENT—DECISION MAKING WHEN FACING UNCERTAINTY

Researchers are problem solvers with varying skill sets that serve them well in research. There are situations, however, when that combination can present a risk to balanced, comprehensive decision making. During preparations for an experiment, a researcher found that engaging the control button on an experimental device did not initiate the equipment's standby mode. He went to an electrical equipment room and found that the breaker that fed the equipment had tripped. He donned personal protective equipment (PPE) and reset the breaker. Returning to the equipment's control panel, he removed the PPE and tried the standby button again. After the standby button failed to respond again, he opened a door on the equipment without donning appropriate PPE to check the internal 480-volt breaker and found that it was also tripped. He reset the internal breaker and immediately heard a loud noise from behind the lower equipment panel door located to his right. Thankfully, the researcher was not contacted by the arc flash, although he did experience temporary tinnitus.

This researcher was a qualified electrical worker who was very familiar with the design and operation of the research equipment. The laboratory's electrical safety training sets the expectation that a breaker should not be reset unless there is an obvious cause for the trip. If the reason is unknown, electricians are to be called to investigate. This expectation is set to prompt conservative decision making when conditions are uncertain. Because this researcher did not comply with that expectation, he focused on the wrong electrical hazard within the second panel. His focus on the 28-volt downstream feed to the control panel caused him to overlook the 480-volt upstream hazard. Had he stopped and called for an electrician to assist in the troubleshooting, the second set of eyes, ears, and skill set could have avoided both a procedural violation and exposure to a potentially deadly situation.

Questions

1. Why is troubleshooting one of the most risky activities in a laboratory setting?
2. What steps can be taken to reduce risks during troubleshooting activities?
3. Researchers face uncertainty and changing conditions in the laboratory every day. When is it okay to use an alternative method to perform a task if the normal procedure cannot be used as intended?

Key Roles in Safely Conducting Research

Because hazards associated with research can change with little or no warning, Battelle employs a layered defense strategy to ensure the safety of staff and facilities. This strategy relies on three layers, or defense in depth, for the safe conduct of research.

Layer 1: Research staff

Research staff performing laboratory experiments have the best understanding of the work they are performing. As a result, researchers should have the greatest knowledge of hazards associated with the work, and they are best positioned to understand both the unknowns and the potential energies involved in experiments. Their competence, expertise, and attention to experimental conditions form the first layer of defense.

Research staff are encouraged to use subject matter experts, peers, and support staff to delve into areas where their personal knowledge could be lacking.

Layer 2: Space managers, instrument scientists, and support staff in key roles

At Battelle, the second layer of defense is provided by individuals who become responsible space managers (RSMs) or instrument scientists.

- Battelle assigns RSMs to most laboratory spaces or high-bay areas in which research is conducted. The RSM maintains cognizance of all work being done in their space, any hazards that could be introduced, and collective or cumulative hazards associated with multiple laboratories that could challenge a facility's safety systems.
- Instrument scientists support the operation of scientific instruments or test stands at user facilities and participate in the research. Many user facilities are equipped with unique instruments and experimental capabilities, so instrument scientists play a critical role in ensuring safe and effective operation of these facilities. The instrument scientist is tasked with assisting users with experiment setup; data collection; data reduction and analysis; and safe operation of a particular instrument or test stand.
- Support staff and ES&H professionals are critical resources available to add knowledge and ideas when planning and executing work.

The expert knowledge of RSMs and instrument scientists and their dedication to ensuring safe operation of laboratories and user facilities form the second layer of defense. To be effective, the RSMs and instrument scientists must understand the work being conducted in their assigned spaces.

Layer 3: Management

Battelle managers provide the third layer of defense. We expect our first-line managers to be knowledgeable about the work being conducted by their staff, the competence of the staff executing the work, and the effectiveness of the assigned RSMs or instrument scientists in performing their roles. The only way of detecting failures in either or both of the first two layers of defense is management presence in the field and technical expertise. Management awareness, gained from active engagement with staff performing research and with RSMs and instrument scientists, forms the third layer of defense.

CASE STUDY

RESEARCHER INJURED FROM EJECTION OF MOLTEN SALT FROM REACTION VESSEL—IMPORTANCE OF MANAGEMENT PRESENCE IN THE FIELD

In 2013, a researcher and guest were testing the performance of a new steam sparging system for a chemical reaction vessel containing molten salt. The system was operated in an open configuration to allow researchers to observe steam bubbles rising from the salt bath. During the test, an unexpected release of built-up pressure within the chemical reactor vessel resulted in steam and molten salt being ejected through the top of the vessel, striking one of the researchers and injuring portions of one arm and shoulder, his chest, and the left side of his head.

In the subsequent investigation, conditions were identified that pointed to a lack of management involvement and presence in the work area as a root cause for this incident. The open configuration (an unsafe, unanalyzed condition) was used for two years during initial testing of the system without management awareness and oversight of the configuration. The system sat idle for two years from lack of funding. At the time of the incident, funding had been reinstated; however, the high-risk activity had not been authorized under work control documents that addressed the current system configuration. By their inaction and absence, managers allowed unsafe behaviors.

QUESTIONS

1. As experimental equipment increases in size and complexity, what additional reviews and risk mitigations are needed (design reviews, hazardous operations reviews, emergency plans, operational readiness reviews, etc.)?
2. What specific steps should managers take to assure themselves that the risks of new or changing experimental equipment are properly mitigated?
3. When visiting or conducting a tour of a laboratory, what types of questions can be used to probe the safety culture of the staff?

Working in a Safe and Environmentally Sound Manner

Although it is important, maintaining a strong safety culture and understanding the layered defense strategy alone isn't enough. Ultimately, specific tasks at the working level must be executed. In today's complex world, a plethora of laws, regulations, standards, and controls that must be integrated into daily work activities. Your institution has a system for capturing these inputs and distilling them into a set of operating procedures. This section outlines a simple concept that forms the foundation for all of our procedures and processes, regardless of institution. In addition, in times of uncertainty, this concept can be a useful tool in framing one's thinking about what to do next. This concept, known as "Integrated Safety Management," has five core functions consistent with the scientific method:

1. **Define the Work and Its Hazards.** Translate the work objectives into defined work activities that will meet those objectives and identify expectations for the performance of that work.

2. **Analyze the Hazards.** Identify and analyze the hazards, as well as safeguards and security issues associated with the planned work. This includes potential effects on workers, the public, and the environment.

3. **Develop and Implement Hazard Controls.** Identify the applicable standards and requirements that address the identified hazards and security issues, establish appropriate work controls to prevent and mitigate those hazards, implement those controls, and allocate resources to ensure that the controls are effective.

4. **Perform Work Within Controls.** Confirm readiness and perform the work safely in accordance with the established work controls.

5. **Provide Feedback and Continuous Improvement.** Assess and provide feedback on the adequacy of controls and continually improve the programs and processes that form Integrated Safety Management.

Principles for a Strong Safety Culture

1. Everyone is personally responsible for ensuring safe operations
2. Leaders value the safety legacy they create in their discipline
3. Staff raise safety concerns because trust permeates the organization
4. Cutting-edge science requires cutting-edge safety
5. A questioning attitude is cultivated
6. Learning never stops
7. Hazards are identified and evaluated for every task, every time
8. A healthy respect is maintained for what can go wrong

Notes:

Oak Ridge National Laboratory

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