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Foreign Material Exclusion Process and Methods

Supersedes 1016315



Foreign Material Exclusion Process and Methods

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REPORT SUMMARY

This report organizes the thinking and execution of activities known to prevent foreign material intrusion. An organized approach is necessary because the sources of foreign material are essentially infinite and the possible preventive methods are numerous and unique to particular plant configurations in most cases. This report emphasizes the importance of protecting the nuclear fuel in accordance with the industry's "Driving to Zero" initiative, while simplifying the consistent application of station resources in support of the front line worker to prevent foreign material intrusion.

Background

Foreign material exclusion (FME) is vital to the safe and reliable operation of nuclear power plants. Foreign material intrusion into primary or secondary plant systems, equipment, and components can cause fuel damage, safety equipment inoperability or degradation, lost generation, high radiation, and increased contamination levels. Rework associated with foreign material intrusion increases operations and maintenance costs and replacement energy costs due to extended outage times. Single instances of foreign material intrusion have cost hundreds of millions of dollars due to damage to plant equipment and complicated recovery requirements.

Therefore, FME is a plantwide initiative that requires the involvement of all station personnel, permanent and supplemental, in order to be effective. The potential sources of foreign material, basic FME work practices, the need for preplanning systematic measures to prevent foreign material intrusion, and the consequences of foreign material intrusion should be clearly understood by all station personnel.

The Electric Power Research Institute (EPRI) published the first *Foreign Material Exclusion Guidelines* (TR-106756) in 1997. TR-106756 was revised and reissued in 2005 (1009707). The guidelines were revised again in 2008 (1016315). The current report replaces all previous versions.

Objectives

- To describe an FME process that can be applied to each work activity. The FME process organizes the selection of available tools, materials, and practices that prevent foreign material intrusion into systems and components for each work activity.
- To describe interfaces to the FME process in other programs and processes needed to support overall FME success. These interfaces include the work control process, especially preplanning activities; procurement, supply chain, and vendor practices; operations, chemistry, health physics/radiological protection, security, and oversight activities; the corrective action process; management processes such as performance indicators and performance improvement; training processes; and the housekeeping, chemical control, and lubrication processes.

- To improve the identification of potential foreign material by anyone planning or conducting work, to list methods known to be effective in preventing foreign material intrusion, and to recommend general FME methods appropriate to particular work activities or work on major components.
- To suggest the use of the corrective action process to document the loss of FME integrity, control the development of recovery plans when necessary, and support tracking and eventual recovery of unrecovered foreign material, especially when unrecovered foreign material can adversely affect fuel integrity.

Approach

This report and its previous versions are the result of work performed by the FME Industry Working Group, which is composed of active FME coordinators and supported by the Institute of Nuclear Power Operations (INPO) and EPRI. Within the Industry Working Group, a technical advisory group was formed to provide input on the report's content, organization, and end-use applications. Plant FME procedures were solicited and reviewed, and from them, a draft report was developed. The draft report was disseminated for review and comment to members of the Technical Advisory Group, Industry Working Group, and INPO. Comments and suggestions were incorporated to produce the final draft, which was reviewed in-house at EPRI before publication.

Results

This report provides a comprehensive overview of technical considerations related to work activities, sources of potential foreign material, and types of major plant equipment needing protection from foreign material intrusion. This report presents a process-driven approach to the planning, preparation, and performance of plant operations, maintenance activities, outages, and other plant programs from an FME perspective. The focus of this FME process is prevention. The FME process provides a way to evaluate prospective work tasks and activities against standardized criteria in order to identify the appropriate level of FME controls. The appendices give examples of FME equipment and documents that can be used in the development of specific plant information.

Application, Value, and Use

This report will be useful to utilities in implementing and engaging station resources in a consistent, trainable process that supports the worker's fundamental desire to prevent foreign material intrusion.

Keywords

Foreign material
Foreign material exclusion
Foreign material intrusion
Fuel reliability
Work control process
Work practices

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1
INTRODUCTION

Foreign material exclusion (FME) is vital to the safe and reliable operation of nuclear power plants. The entry of foreign material into primary or secondary plant systems, components, and equipment can cause equipment degradation or inoperability, lost generation, fuel cladding damage, high radiation, and contamination levels that could spread throughout the plant; it can also increase operations and maintenance (O&M) costs and degrade nuclear safety.

Foreign material can enter components, equipment, and systems through a variety of plant activities. Although the most common circumstances for introduction of foreign material involve systems being opened for maintenance, other sources include the following:

- Operational activities (such as venting and draining, system lineups, flushes, refueling operations, and routine surveillance and inspections)
- Supply chain (warehouse) activities (such as material receipt, material storage, and issued/returned item activities)
- Engineering activities (such as testing, inspections, and walkdowns)
- Chemistry, security, health physics activities (such as rounds, chemical additions, and surveys)



Key O&M Cost Point

The entry of foreign material into primary or secondary plant systems, components, and equipment can cause equipment degradation or inoperability, lost generation, fuel cladding damage, high radiation, and contamination levels that could spread throughout the plant; it could also increase O&M costs and degrade nuclear safety.

Foreign material–related events have caused major damage to plant equipment, and recovery from them can be very complicated and expensive. The following are typical examples of foreign material–related events in which equipment damage, increased cost, or both have been incurred:

- A single small machining chip—and even a single bristle from a wire brush—has caused fuel cladding damage that resulted in forced outages to replace leaking fuel.
- Machining dust and small Stellite™ particles from valve seat lapping have become activated as they passed through the reactor core, resulting in hot spots in piping and high contamination levels.
- Foreign material has resulted in main turbine failures, causing major damage to the main turbine, main generator, and steam generator (S/G) and resulting in a loss of generation capability.
- Foreign material debris in electrical devices and panels has led to personnel injuries.

As a result, utilities establish an FME program to ensure that ongoing attention is paid to avoiding the introduction of foreign material into plant systems and components. The FME program is a plant-wide initiative that requires the involvement of all station personnel, permanent and supplemental, in order to be effective. The program is described from a high level perspective of the Institute of Nuclear Power Operations (INPO) 07-008 guidelines [1] (and its various revisions from time to time). This report accepts the definitions, principles, and program elements described by the INPO guidelines and in general does not repeat, redefine, or interpret INPO guidance. Occasionally, common sense will require using or referring to the definitions and principles in the INPO 07-008 guidelines to provide context for the methods or practices described in this report.

Industry experience shows that effective FME programs emphasize prevention versus mitigation and recovery methods, and the remainder of this report is consistent with that attitude. This report is undertaken to capture and organize the many details of effective FME control practices that should be clearly understood by all station personnel if a "prevention attitude" is to consistently drive "prevention action."

1.1 Purpose

This report describes a process that engages station resources to apply prevention methods as appropriate throughout the work control process. The process emphasis is intended to provide positive controls before and during work rather than relying on mitigation and recovery after foreign material enters systems or components. This approach provides methods for management, supervisors, and craft (including supplemental personnel) to think through activities before performing them.

In addition, the process approach describes interfaces with other well-defined station processes such as design and systems engineering, supply chain, corrective actions, and training. This process is therefore one way to establish FME controls that protect components and systems from being degraded.

Like all processes, this one requires good human performance practices, such as a questioning attitude, self-checking (for example, stop, think, act, and review), peer checking, and prejob and postjob briefs. In addition to these conscientious efforts, the following key principles and expectations underlie all work to be performed in the plant:

- Housekeeping is the cornerstone of an excellent FME program. Based on industry experience and feedback, an effective FME process requires station personnel to be familiar with FME concepts, FME process requirements, and the consequences of a loss or failure of housekeeping and/or FME controls.
- FME methods are applicable whenever systems or components are opened; therefore, planners, supervisors, and workers should be alert to the potential for the introduction of foreign material at all times.
- Managers, planners, supervisors, and workers should recognize when an activity will generate potential foreign material. The FME process addresses any drilling, cutting, grinding, machining, filing, lapping, and other such activities that generate small particles of foreign material and provides methods for reducing and containing the foreign material to reduce the risk of plant or component damage.

- Activities should be planned appropriately to ensure that foreign material is captured or otherwise contained as it is created or introduced. Action should be taken to prevent the possibility of spreading the material. The traditional concept of cleaning up the job site afterward is not sufficient to meet this objective; rather, foreign material prevention requires a clean-as-you-go approach.
- Immediate reporting is required when FME controls are deemed lost during work task performance. Reporting enables a systematic approach. The systematic approach accounts for the accumulation of foreign material and evaluates both the impact of leaving foreign material in the short term and the recovery of the foreign material over time. These decisions should be raised to a level of authority commensurate with the potential risk to nuclear safety, personnel safety, and equipment reliability.
- The process and methods used to prevent foreign material intrusion should be applied by all station personnel, supplemental personnel, and off-site vendor organizations performing activities that present the potential to introduce foreign material into a system or component.
- The process and methods apply to all maintenance, modification, operation, and testing activities, whether safety related or not, that involve open plant systems, equipment, or components that could be adversely affected by the introduction of foreign material.
- The planned introduction of materials, such as leak-sealing compound, chemicals, or lubricants, requires additional controls to ensure compatibility with the system and to prevent inadvertent spreading of the material that could become foreign material if excessive amounts were used. Often there are separate station processes to control the purity and destinations for such materials, but it is often not the purpose of those programs to limit the amount of material used; instead, work plans should address such limits.
- Finally, the proper management of foreign material in a nuclear power plant is extremely important. It is based on common-sense methods to keep unwanted material out of the systems, equipment, and components and to properly deal with it when detected or inadvertently introduced. A repeatable thought process carried out in advance of work supports the well-trained, knowledgeable, proactive, and responsible workers in preventing a potentially expensive and damaging event.

1.2 Scope

This report provides station personnel with a process, methods, and actions that together can prevent the introduction of foreign material into plant systems, equipment, and components. The process steps, methods, and actions can be applied commensurate with the risk of foreign material adversely affecting equipment reliability or compromising nuclear safety. The report covers suggested training for permanent plant employees and supplemental personnel brought on site to work on outages and other tasks. The report presents various work practices to assist personnel from all disciplines who perform manual labor and nonlabor activities, along with general guidance covering the more common FME considerations. It provides details regarding activities on major equipment, components, and systems.

1.2.1 Responsibilities

Responsibilities are assigned by utility management to meet the objectives of the FME program. This report does not assign tasks to job positions except to differentiate among management tasks, planning tasks, supervisory tasks, and worker tasks.

1.3 Overview of the FME Process

The overall FME program and associated performance objectives and criteria are described by INPO [1].

The process described here is one part of implementing an overall program. Figure 1-1 provides an overview of the process. This process is based on experience collected to support foreign material exclusion coordinator training since approximately 2007. The utility instructors who have participated with EPRI in providing this training are hereby acknowledged for their contribution and expertise.

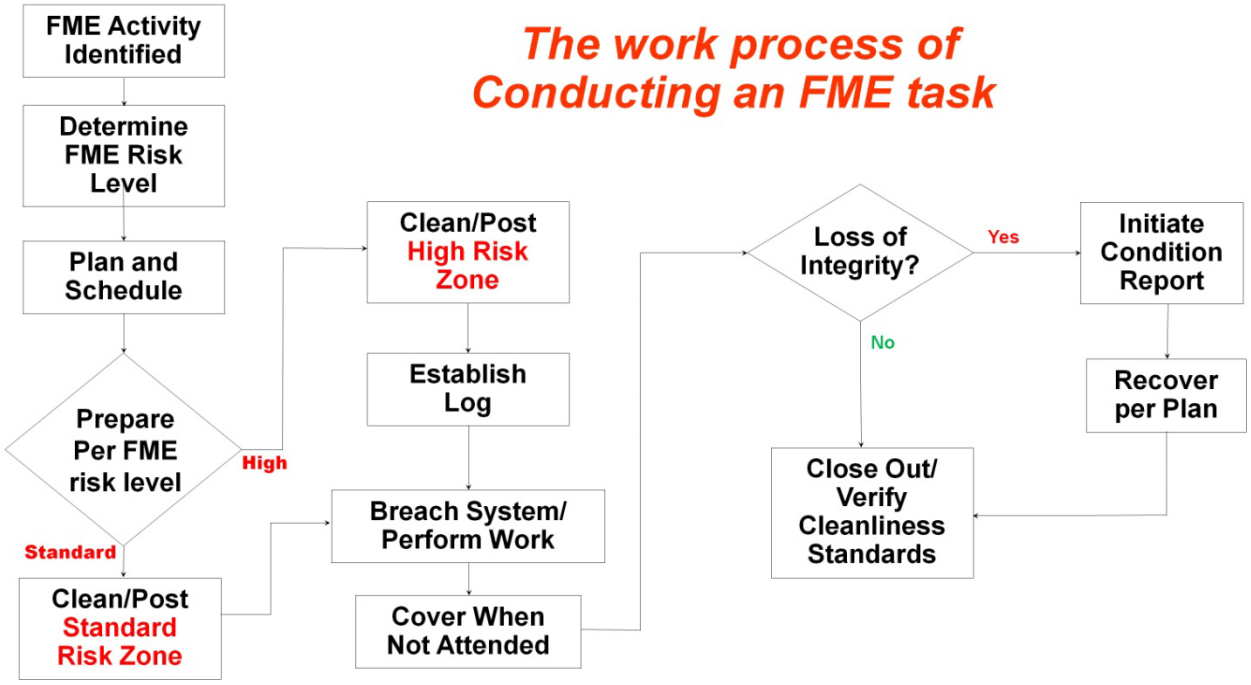


Figure 1-1
The FME process

The process described here interfaces with other station programs and processes, such that those programs and processes should support the needs of the FME process if the FME process is to succeed. In such cases, those programs and processes are a supplier of services or information needed by the FME process. Additionally, the FME process should support other station programs and processes with certain services and information if those processes are to succeed. In such cases, the FME process serves as a supplier to those customers.

1.4 Organization of This Report

Section 2 describes the sequence of the FME process shown in Figure 1-1, considering the sequence of events recommended to carry out a single FME-related activity.

Section 3 describes preventive actions that help reduce or eliminate the possibility of foreign material intrusion or that help reduce the consequences of foreign material intrusion. These actions include team practices such as effective use of FME zones and effective logging practices, effective personal practices expected of all workers, design and use of FME devices, and specific practices that are useful to prevent specific sources of foreign material from having adverse consequences.

Section 4 describes the key interfaces with other station processes and programs necessary for overall station success.

Section 5 provides methods and practices associated with major plant equipment and common plant configurations of electrical, instrumentation and control, and mechanical components.

The appendices provide examples of FME process tools and information that can be developed to support the FME process. The examples are generic and, if used, should be revised to meet the plant's needs and requirements.

1.5 Responsibility for Implementation: Shall, Should, and May

Nothing in this document supersedes the responsibility of local management and of each individual worker to adhere to applicable regulations and requirements. It is not the purpose of this guideline to tell local management or individuals what to do; instead, the document simply provides a basis for comparison so that local management and individuals can decide for themselves whether they are doing what is best for them. Therefore, the force of this document is the force of advice. In cases where there was a choice between the words shall, should, and may, the word *should* is generally used, and when it does not erode the coherence of the process described in the guideline, the less forceful word *may* is often used instead. The word *shall* is out of keeping with the advisory nature of the guideline.

However, in considering their own programs, utilities do need to recognize the following fact: In order to achieve reliable results, utilities should impose the force of *shall* in setting clear requirements at their plants.

1.6 Key Points

Throughout this report, key information is summarized in Key Points. Key Points are bold-lettered boxes that succinctly restate information covered in detail in the surrounding text, making the Key Point easier to locate.

The primary intent of a Key Point is to emphasize information that will allow individuals to act for the benefit of their plant. Electric Power Research Institute (EPRI) personnel who reviewed this report assisted in the selection of the information included in these Key Points.

The Key Points are organized into three categories: Human Performance, O&M Cost, and Technical. Each category has an identifying icon to draw attention to it for the benefit of readers who are quickly reviewing the report. The Key Points are shown in the following way:



Key Human Performance Point

Denotes information that requires personnel action or consideration in order to prevent personal injury, prevent equipment damage, and/or improve the efficiency and effectiveness of the task.



Key O&M Cost Point

Emphasizes information that will result in overall reduced costs and/or an increase in revenue through additional or restored energy production.



Key Technical Point

Targets information that will lead to improved equipment reliability.

Appendix L of this report contains a listing of all Key Points in each category. The listing restates each Key Point and provides a reference to its location in the body of the report. By reviewing this listing, users of this report can determine whether they have taken advantage of key information that the writers of this report believe would benefit their plants.

1.7 Acronyms and Abbreviations

ALARA	as low as reasonably achievable
CANDU	Canadian deuterium/uranium
EPRI	Electric Power Research Institute
FME	foreign material exclusion
I&C	instrumentation and control
INPO	Institute of Nuclear Power Operations
MOV	motor-operated valve
O&M	operations and maintenance
OE	operating experience
PHT	primary heat transport
RCS	reactor coolant system
SFP	spent fuel pool
S/G	steam generator

2
FME PROCESS DETAILS

The FME process is primarily a thought process that produces foreign material intrusion preventive actions applicable to particular maintenance tasks. The value of the thought process is that it reduces the vast number of possible methods to the few that will work well for this job, this time.

Related thought processes are applicable to procurement tasks, design change tasks, operational tasks, and tasks normally performed by support personnel such as health physics and quality assurance. Each of these supporting tasks can result in foreign material intrusion if preventive actions are not in place. The treatment of these other tasks are discussed in detail in Section 4 as process interfaces.

2.1 Identify FME Activity

New activities arise daily in the plant. Routine work by operators, chemistry, inspectors, observers, and health physics personnel are all activities. Preventive maintenance, shop activities, moving material around the world, corrective maintenance, and design changes are also plant activities. Most of these activities are prioritized and scheduled per the work control process or plant procedures.

Whether an activity is an FME activity or not comes down to only a few possibilities: Is there an open system involved with the activity or nearby? Does the activity generate debris? Is there a possibility that debris exists inside the system that the activity may discover? A yes answer to any of these initiates the FME process.

A yes answer to any of these questions when nuclear safety is involved—in a system communicating with the reactor core, a fission product barrier, or an emergency safeguard function system—should be a matter of management awareness and increased formality, planning, and supervisory involvement.



Key Technical Point

Whether an activity is an FME activity or not comes down to only a few possibilities: Is there an open system involved with the activity? Does the activity generate debris? Is there a possibility that debris exists inside the system that the activity may discover? A yes answer to any of these initiates the FME process. Everyone should understand these few possibilities so that they can be alert to ensuring that their personal influence builds good FME practices.

2.1.1 Open Systems

Some systems are open all the time. The spent fuel pool is a good example. Any activity near the open system needs to be planned and executed in a way that will prevent foreign material from getting into the open system, if the consequences of the foreign material cannot be tolerated. Spent fuel pools are normally designated high-risk FME zones (see Section 3) because fuel damage is not tolerated. On the other hand, for example, some plants have circulating water outfalls that are open to the sky. It is not likely that plant damage would occur if foreign objects were introduced to the river. However, the site's operating permits may not allow the introduction of certain materials into the environment via this path, and perhaps such a configuration would warrant treatment as a standard-risk FME zone for some activities.

Many maintenance activities require the opening of a door, flange, casing, enclosure, and so on to gain access to the components. This is the most common consideration, where access has been provided via a preplanned path that can be controlled. When the system is open, any foreign object smaller than the opening could intrude, and if not removed, could cause damage later. Therefore, these openings need to be protected by the appropriate preventive practices based on the details of the work.



Key Human Performance Point

If a system is open or you will open it, it is possible to put a foreign object in the system. Therefore, an open system always warrants application of good FME practices. This can be said without considering the importance of the system or the consequences of the potential damage that could ensue. Later it will be seen that the consequences of damage and the difficulty of retrieving potential foreign material are considerations in determining the FME risk level.

2.1.2 Generating Debris

Many work activities generate debris (loose materials) of various kinds. The only difference between simple debris and foreign material is whether it got into an open component. Therefore, if we are generating debris of any kind, we should plan how we are going to prevent the debris from becoming foreign material that could be left in the component.

Therefore, everyone needs to be quick to understand what activities generate debris. The following is a short list:

- Taking something apart (generates loose parts like screws, nuts, washers, bits of gasket material, and flanges). If you take something apart, something is now loose and could be lost or left in the wrong place to cause damage later.
- Breaking tools (for example, drill bits can break off, dead-blow hammers can fail releasing shot, wire brushes can wear, and filaments can break off to travel down pipes).
- Grinding, welding, cutting, sawing, drilling, machining, filing, and sand or grit blasting.
- Painting can cause airborne particles if spray painting, or drips can be generated by brush painting. Paint chips are a common debris from preparation activities.
- Windborne or waterborne dirt, contamination, sticks, stones, sand, and so on.

2.1.3 Finding FM

Although debris that is the result of corrosion or component degradation is possibly unrelated to FME control practices, it is still foreign material, as defined in industry guidance. It does not belong in the system. It is possible that debris could exist in essentially any system, and the worker who opens the system and looks is likely to be the first person aware of this foreign material. The FME process accommodates this possibility and provides the worker with appropriate action when such debris is found. Note that the notion of "what to do with foreign material that we find in a system" is really only triggered when we open a system and look. In that respect, it is not really a new category of FME activity that stands alone.

2.2 Determine FME Risk Level

Experience shows one of the attributes of plants with few FME issues is to have well-defined FME risk levels. In general, two different FME risk levels are sufficient to address most plant situations. Level determination should consider the possible consequences of foreign material intrusion, the probability of foreign material intrusion, and the difficulty of foreign material detection and recovery.



Key Technical Point

High-performing plants (with respect to FME) have two well-defined FME levels. For consistency with other industry documents, this guide names these two levels "high risk" and "standard risk." When neither an open system nor the potential to generate debris is present, good housekeeping practices are used.

The possible consequences of foreign material intrusion should be considered before and separately from the probability of foreign material intrusion. This is because nuclear safety is paramount. The consequences of foreign material also need to be considered in the long term: foreign material is known to migrate via any available flow path, and the worst possible location that any particular foreign material could migrate to should be considered. Generally accepted practice is to protect the integrity of fuel cladding; therefore, any foreign material that could migrate to the core is highest prevention priority. In addition, foreign material could damage important safety systems. These safety systems are needed to prevent the release of radionuclides to the environment in the event of a design basis accident and should also be the highest priority.

After nuclear safety, it is also true that foreign material could adversely affect industrial safety or economic performance. For example, foreign material intrusion consisting of a roll of paper towels has destroyed a turbine generator, costing millions of dollars to replace. It is up to local management to determine exactly which criteria are used to determine whether an activity is possibly high risk.

After considering whether the possible consequences of foreign material intrusion warrant treating the activity as high risk, there may be justifiable reasons to reduce the risk level to standard risk. It is at this point that the probability of foreign material intrusion might be considered. For example, if the opening in the system is configured in such a way that gravity would not allow a free-falling object to get in, then the risk level could be reduced to standard risk.

It is also possible to allow work to proceed as standard risk if detecting and removing foreign material is relatively trivial. This is largely determined by the configuration of the system or component and the opening itself. For example, if the opening is into a cavity that is shallow and uncontaminated and there are no outlets from that cavity to deep holes, long pipes, or narrow crevices, then it may be determined that any foreign material that is dropped into the cavity could be simply picked up by the worker before proceeding. This is essentially an economic consideration and does not override (reduce) the priority that should be given to nuclear safety considerations.



Key Technical Point

Care should be exercised when considering the ease of detecting and removing foreign material as a reason to reduce the risk level. Very small particles can damage hydraulic or lubrication systems and be nearly undetectable to the naked eye. Chemical contaminants may require special tests to detect the undesirable chemical residue.

Industry practice has evolved to provide two methods for reducing error in selecting the appropriate risk level. Consistency among all workers, supervisors, managers, and observers in selecting the risk level is vital; therefore, each station should choose one of the two methods and apply it consistently. If a station desires to use one method in some cases and the other method in other cases, it is important to clearly specify the criteria used to decide which method everyone will use for each case.

One method of selecting the appropriate risk level is to specify in procedures which systems and components are high risk and which systems and components are standard risk. This method requires the criteria of Section 2.2 be evaluated for each system or component on a one-time basis, and the results documented in procedures signed by the competent authority. This method has the advantages of being simple to implement during most activities, and the effort to complete the analysis is essentially once-and-done (subject to mid-course correction using the corrective action process or continuous improvement process). It has the disadvantage of being somewhat inflexible in the rare cases when truly unique and unanticipated conditions arise. Table 2-1 provides examples of designated high-risk zones applicable to PWRs and BWRs.

Table 2-1
Typical high-risk FME zones

PWRs	BWRs
Reactor coolant system (RCS)	RCS
Residual heat removal	Reactor circulation
Shutdown cooling	Residual heat removal
Chemical volume control	Shutdown cooling
Safety injection system, high and low pressure	High-pressure coolant injection/spray
Pressurizer	Low-pressure coolant injection/low-pressure core spray
Refueling water storage tank	Reactor water cleanup
S/Gs (primary and secondary sides)	Reactor core isolation cooling/isolation condenser
Spent fuel pool (SFP)	Main steam
SFP cooling	Control rod drive
SFP purification	Feedwater and condensate
New fuel storage racks (fuel installed)	BWR6 suppression pool
Ice condenser	Condensate/refueling water storage
Primary water and storage	SFP
Refueling floor and cavity (head removed)	SFP cooling
	New fuel storage racks (fuel installed)
	Drywell
	Refueling floor and cavity

The other method of selecting the appropriate risk level is to use a flowchart to guide the decision. The flowchart or matrix should be provided in a procedure signed by competent authority. Figure 2-1 is an example of a flowchart.

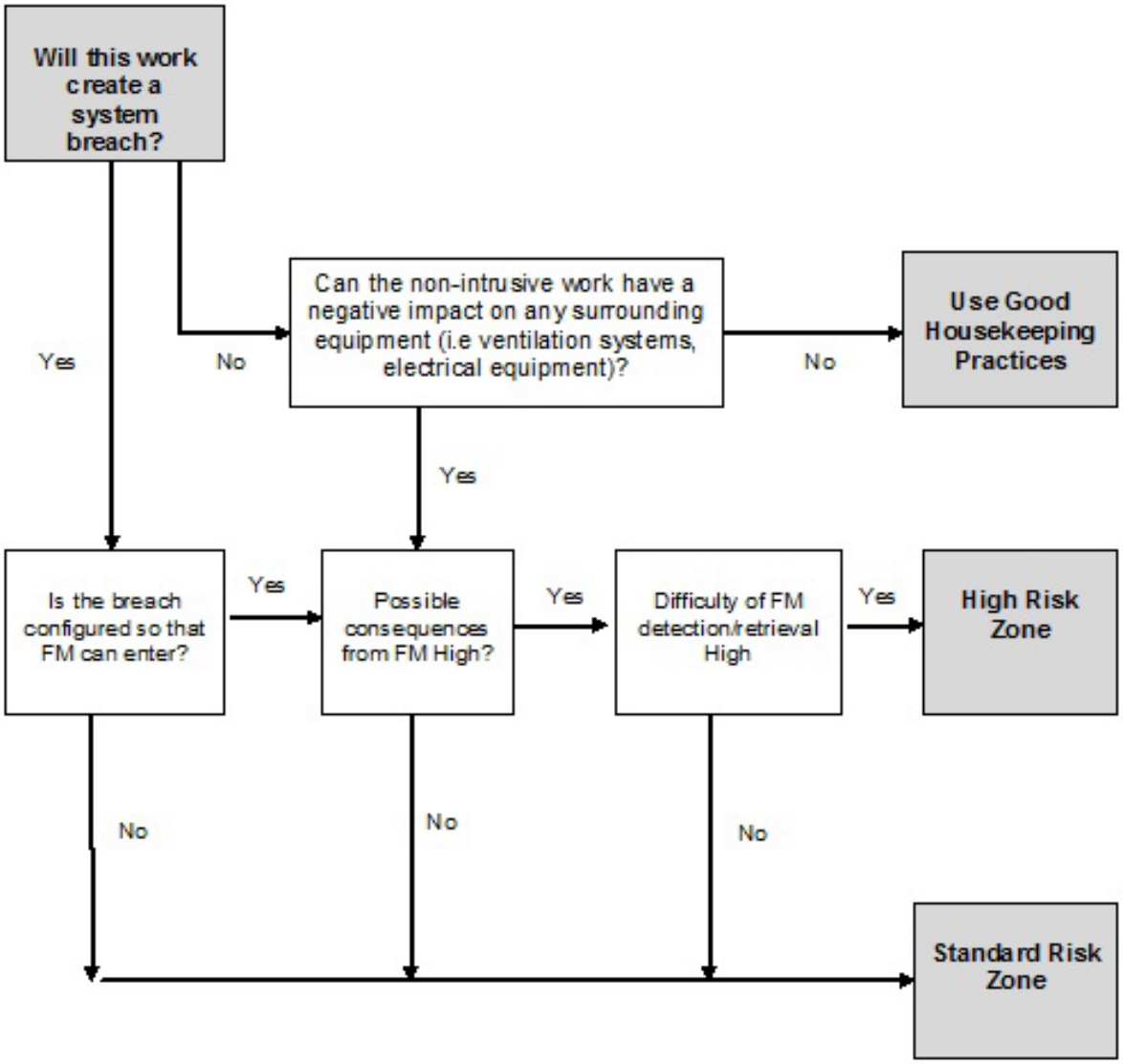


Figure 2-1
Sample flowchart for zone determination

2.2.1 Using the Zone Determination Flowchart

The use of the sample flowchart requires each user understands the subtle nature of some of the questions, such as the following:

- "Will this work create a system breach?" includes cases where the breach already exists, for example, in the spent fuel pool area.
- "Can the nonintrusive work have a negative impact on any surrounding equipment (such as ventilation systems and electrical equipment)? This includes cases where the nonintrusive work is in the vicinity of other open systems during maintenance. For example, if welding/grinding in an area around a normally closed sump or tank would not negatively affect the sump or tank, the answer would be different if the sump or tank were opened for maintenance during the welding/grinding.
- "Is the breach configured so that foreign material can enter?" might cause the user to assume the potential foreign material moves of its own accord, for example, falls gravitationally. But what if the nature of the work is that workers might have to reach up and place equipment, tools, and cleaning devices in the breach?
- "Possible consequences of foreign material high?" needs to be assessed in terms of the worst possible outcome, not the likelihood of that outcome. For example, if working in a system that feeds the RCS, the worst possible outcome is that something is left in the breach that could be pumped to the core through the fuel inlet nozzles and wedged in a grid strap.
- "Difficulty of foreign material detection/retrieval high?" needs to be assessed in terms of the worst possible outcome, and the most brain-dead causality. For example, if opening a check valve in a horizontal run of a feedwater pipe, it might seem simple to retrieve something the worker drops. But what about the possibility that the worker fails to notice a washer falling into the valve body while the disk is removed, and the washer rolls upstream, out of sight? What about the possibility of grinding debris from another activity entering the breach when the workers are otherwise occupied? Once the disk is reinstalled, and the final inspection is being performed before the bonnet is replaced, these things are hard to detect.



Key Human Performance Point

The bottom line of using a flowchart is that these methods place a burden on the worker conducting the evaluation to have an appropriate questioning attitude, a high degree of knowledge about the task, and a high degree of knowledge about the system interconnectivity. Applying a flowchart is a knowledge-based activity, known to be more error-prone than rule-based activities or skill-based activities.

The purpose of determining the FME risk level in advance is to give the planners and workers a starting point for understanding the specific actions and controls that are needed to ensure that foreign material is not left in plant systems or equipment. These specific actions and controls need to be called out by the next steps in the FME process, or the selection of appropriate action and controls will be left to the worker as a last line of defense.

2.3 Plan

The main purpose of planning is to reduce the vast list of possible FME methods to the few effective FME methods for the job at hand, given the specific plant equipment, work scope, and sources of debris that must be controlled. The purpose of planning in advance and writing down the plan is to reduce the mental burden for the workers on the day of execution. A side benefit of a written plan is that it aligns the entire team and any observers to the sources of foreign material that must be controlled and the methods used to control them. By providing this clarity, the situational awareness of the workers is improved so that they can use their skills to detect errors or potential weakness in the approach to the job. In short, with planning clarity comes a better questioning attitude for the physical things that matter at the job site.

Plans should vary in complexity and formality. It is appropriate that a graduated response to planning be used so that higher management attention is provided for highly complex or high-risk FME activities, while routine supervisory involvement with standard work management process controls be trusted to properly support routine activities. There may be cases where simple or repetitive FME activities can be effectively controlled on a skill-of-the-craft basis. It is up to local management to have clear criteria in the FME program to align everyone as to when a formal FME project plan is required, what scope of planning is to be accomplished by the work planning organization, and when plans should be complete relative to milestones in the overall planning and scheduling process.

Planning involves making decisions and documenting the decisions, so that others getting involved in the work later do not have to start from scratch. When the plan is complete and approved in accordance with whatever work management process is used, the plan establishes requirements that have been selected to fit the work in accordance with the general requirements. These approved decisions are now specific requirements for this job. By following this plan, all workers, supervisors, and managers involved will understand the positive controls and contingencies selected for this activity that together protect the equipment from the consequences of foreign material intrusion.



Key Technical Point

When the plan is complete and approved in accordance with whatever work management process is used, the plan establishes requirements that have been selected to fit the work in accordance with the general requirements. These approved decisions are now specific requirements for this job. By following this plan, all workers, supervisors, and managers involved will understand the positive controls and contingencies.

Responsibility for developing FME plans will vary from site to site. This report uses the word “planner” to describe the person doing the planning for a given activity, regardless of whether that person is assigned to the planning department or has other responsibilities. The first-line supervisor or work planner might be responsible for the development of the FME plan. Responsibility should be designated in site procedures. Regardless of who does the FME planning for a job, there are inputs to the plan, a thought process to develop the plan, and an output (the plan itself).

The action steps needed to plan the FME aspects of a work activity are described in the remainder of this section.

2.3.1 Identify Detailed Scope of FME Work

As stated in Section 2.1, whether an activity is an FME activity or not comes down to only a few possibilities: Is there an open system involved with the activity? Does the activity generate debris? Is there a possibility that debris exists inside the system that the activity may discover? The "detailed scope of FME work" is the answer to these three questions, given the inputs to the planning process.

Inputs: Before the detailed planning stage begins, work activities are originated (for example, a corrective action, a work request, preventive maintenance task). These activities are generally well described enough (equipment identification and the symptom or description of the deficiency or necessary activity) so that it is obvious which systems, equipment, or components must be opened or accessed in connection with the scheduled activity.

Other critical input to the plan is the knowledge, skills, and experience of the person doing the planning.



Key Technical Point

The planner is the first to know the detailed scope of work. His or her first contribution to preventing foreign material intrusion is to clearly document which systems, equipment, or components must be opened or accessed in connection with the scheduled task. The planner also clearly documents which subactivities will generate debris (for example, grinding, cutting, lapping, welding).

Given these inputs, as a planner starts detailed investigation of an activity, it is possible that the planner will identify additional debris-generating actions or additional components that need to be opened to conduct the work. Once the scope of work is fully understood, the planner should validate the initial risk determination assigned to the activity and/or determine the risk level for the new subactivities that are now part of the scope of work.

For most common activities addressed by planners, the work package should be used to document the initial risk determination so that downstream users can review and understand. Stations may find it useful for the planner to write a short narrative about the FME risk level into the work package notes, especially if transitions in the risk level are anticipated as the work progresses (see Section 4).

For other activities, the planner may call out procedures applicable to the scope of work. When this is done, the responsibility of the planner to identify the scope of work and determine the FME risk level is at risk of being inappropriately transferred to the procedure writer (for example, new procedure development, procedure revisions, procedure-based instructions, technical manuals).

When calling out procedures, technical manuals, or other pre-existing guidance, planners should exercise a questioning attitude to ensure the procedure, technical manual, or other guidance was produced to include the correct FME risk level, preventive actions, and controls. If those documents do not include the correct FME preventive actions and controls, then the work plan should drive the necessary actions and controls.

Note: At this point in the process, we proceed under the assumption that an opening of some sort is involved in the activity. Given that, the person doing the planning now evaluates the potential sources of debris.

1. Sources and types of foreign material
   a. The planner's knowledge of the task and the job site are used to identify sources of potential foreign material. A disciplined thought process that considers in turn environmental sources, sources associated with this job, and sources associated with nearby jobs is one effective way of listing the relevant sources of foreign material that must be controlled.
   b. Section 3 provides numerous examples of sources and types of foreign material. Planners should have a detailed awareness of sources and types of foreign material in order to exercise the requisite questioning attitude in each activity they plan. Not all sources or types of foreign material are applicable to any individual activity. A checklist such as that shown in Appendix D can be used to focus the planner's thinking.



Key Human Performance Point

A checklist is not a plan. A checklist that has been properly filled out with due consideration based on the knowledge and skills of the preparer may be an adequate plan for some routine jobs. Passing blank checklists to the worker to be filled out on the day of execution add an unnecessary burden to the worker and impede the efficient conduct of work.

2. Planning aspects related to the possibility of foreign material being discovered when opening the system
   a. The basic principle of dealing with found foreign material is to look for it every time you open something because it is always possible that something will be there. If we find something, we want to say something as soon as possible. Whether this needs to be explicit in the plan is up to local management to decide, based on the knowledge and skills of the workers, the willingness of workers to use the corrective action process to communicate and resolve issues, and the like.
   b. The benefit of placing a specific "initial breach inspection" action step in the work plan is that it helps the worker remember to do this task.
   c. The action necessary for the worker who finds foreign material in a system is not difficult and need not interfere with the progress of work in most cases. Based on the FME risk level and the complexity of the task, simply notifying supervision may be sufficient. In other cases, writing a condition report for the corrective action system is warranted.

2.3.2 Identify Specific Controls to Be Used to Control Potential Foreign Material

Once the nature of the opening is understood and the nature of the sources of potential foreign material is understood, the person doing the planning can select effective methods of control for each source. Whether a given method will be effective depends on a mix of the following considerations and can only be assessed by a thoughtful person exercising judgment:

1. Orientation of system or component breaches
2. Duration of system breach
3. Number of personnel involved
4. Amount of material involved
5. Consider the need for preventive cleaning of the area before the scheduled work start date
6. Complexity of the work, for example, the number of tools necessary, the complexity of the tools
7. Duration of debris-generating activities and size of the affected area when debris is being generated
8. Protecting the operability of equipment when using FME devices. During the planning stage, consider the possible dangers that might result from closing off ventilation routes when fitting covers, plugs, caps, or seals on tanks, vessels, or other structures. Temporary modifications might be required. See Section 3.4.3 for other cautions and limitations regarding the use of FME devices.

Sections 3 and 5 of this report provide many preventive methods that are known to be effective at controlling potential foreign material. Many of the methods are quite specific to the type of activity or the equipment involved.

If it is to be left to the worker to identify the FME controls to be used, planners and/or first-line supervisors should include appropriate checklists or attachments in the work package as needed to assist the workers in making this decision. Examples include FME briefing forms, FME accountability log forms, and FME area signs to be posted at the job site.



Key Human Performance Point

If it is to be left to the worker to identify the FME controls to be used, station management should ensure that the workers are appropriately trained to make this decision.

Possible dangers from the use of FME devices include the following:

- Creation of a confined space, triggering additional work planning considerations
- Depletion of breathable atmosphere
- Accumulation of hazardous products (for example, noxious gases or fumes)
- Plant or equipment damage
- Implosion of hermetically sealed vessels (for example, storage tanks)
- Impaired cooling system efficiency

In such cases, consider alternative methods of ensuring FME control, such as the use of fine-mesh screens.



Key Technical Point

During the planning stage, consider the possible dangers that would result from closing off ventilation routes when fitting FME covers, plugs, caps, or seals on tanks, vessels, or other structures.

2.3.3 Insert the Selected FME Controls in the Work Plan

Having assessed what preventive methods should be used, the methods should be written down in the work package or the FME project plan, if used. This will communicate to all personnel what decisions have already been made. It is especially important that the work plan specify the extent of the FME zone for the task at hand.

2.3.4 Appropriate and Relevant Internal/External Operating Experience

Operating experience (OE) should be included in the work package and used during prejob briefs to reinforce existing expectations and to ensure that sites learn from others and do not repeat similar occurrences. Relevant OE can be found through INPO, the World Association of Nuclear Operations, the U.S. Nuclear Regulatory Commission, owners groups' websites, and the site's corrective action program.

2.3.5 When to Use Formal FME Project Plans

Many high-risk FME activities involve large zones, many work groups, long durations, and extensive movement of materials into and out of systems. As such, these activities would benefit from having an FME project plan developed before the start of work. The plan might identify specific FME vulnerabilities, FME vulnerability contingencies, and how to recover from a loss of foreign material control.

When determining whether an FME project plan is required, ask whether existing procedures lack specific FME controls for each breaching, opening, or removal evolution to be performed during the activity. Also, is the work to be performed in a continuously exposed area where highest level FME standards are continuously in effect (for example, the SFP)? If the answer to either of the preceding questions is "yes," a specific FME project plan should be developed for the activity.

An FME project plan should be considered whenever a benefit would be derived. FME project plans should consider the following:

- Inclusion of FME discussion during prejob/postjob briefings
- Work package closeout requirements and responsibilities
- Flushing requirements
- Instructions on how to recover from a loss of foreign material control.
- Use of FME devices

- Prevention of eating, drinking, and use of tobacco products inside FME areas
- Periodic housekeeping inspections
- As-found and as-left FME zone inspections
- Tooling preuse inspections
- Tooling and/or material controls (such as lanyards and drop cloths)
- Tool and material accountability logs
- Personnel badges, coverall requirements, and dosimetry bags that might contain wire
- Removal of all personal articles, including any jewelry, shirt pocket contents, and key chains, that could fall off while in the area
- Access to confined spaces and requirements; after entry, consider ventilation, air quality, and lighting
- Cutting, burning, and grinding operations
- Control of filler materials used in welding

An example of how an FME plan can be developed and topics that should be considered are provided in Appendix A, FME Project Plan Elements.

2.4 Prepare for Job Execution

On the day of execution, the FME preventive actions and controls have already been determined, and it is clear whether the work is being controlled as high risk or standard risk. Also planned are the specific preventive actions and controls expected to be used.

2.4.1 Prejob Briefs

Prejob briefs are an effective tool in task performance, especially for FME tasks because FME tasks rely on the skills, knowledge, and awareness of the particular worker. The prejob brief primes the worker for success by informing the work team of the results of all the prior planning, on a just-in-time basis. As a result, FME should be an element of these briefs when the activity has FME-related tasks.

The prejob brief provides an opportunity to do the following:

- Ensure that FME issues, practices, and consequences are communicated to all participants of the activity
- Heighten the awareness of participants to the FME aspects of the activity just before performance
- Sensitize participants to critical FME steps or tasks expected during the activity and the FME practices that will be implemented to prevent foreign material intrusion
- Communicate OE and lessons learned and their application to the activity

Prejob brief behaviors that should be avoided include the following:

- Talking about FME in general terms; speak to specific FME concerns, practices, and consequences related to the task at hand
- Allowing activity participants to leave a brief without knowing and understanding their FME roles and responsibilities
- Performing an activity for which the FME deficiencies from past performance have not been resolved
- Failing to solicit feedback from all activity participants
- Failing to document and resolve identified FME deficiencies

2.4.2 Ensure Cleanliness of Work Areas

Housekeeping is a cornerstone of the FME process. Providing a clean work area both inside and around the work area/FME zone will minimize the potential for foreign material intrusion. Inspect the work area and adjacent area for loose debris that could become foreign material. Preclean the work area/FME zone and adjacent areas to provide the required level of pretask cleanliness according to the cleanliness program.



Key Human Performance Point

Housekeeping is a cornerstone of the FME process. Providing a clean work area both inside and around the FME zone will minimize the potential for foreign material intrusion.

2.4.3 Post the Standard- or High-Risk FME Zone

FME zones are established to help prevent the introduction of foreign material into systems, equipment, or components contained within the boundary. An FME zone is a vital preventive measure on its own. Various FME zones are fully described as a preventive measure in Section 3 of this report. The FME plan should specify the extent of the zone. Often, it is appropriate for the zone to be as small as possible. However, it may help prevent foreign material intrusion by creating a stand-off distance around the opening to minimize the threat that untrained or uninvolved passersby could introduce foreign material.



Key Technical Point

FME boundaries should be established before breaching a system/equipment/component. Site-specific FME controls should also be established before breaching.

As the work progresses, survey the surrounding work area for other work in progress. Additional FME controls might be required as conditions change, for example, an overhead cover can be installed if other work is being performed overhead.

2.4.4 Establish FME Log If Logging Is an Appropriate Preventive Measure

Normally, logging is used for high-risk FME zones, but may be appropriate for standard-risk zones if many components, tools, or large numbers of people are involved in the standard-risk task.

2.4.5 Station the FME Monitor and Establish FME Zone Accountability

Maintain control of the FME zone by discouraging nonessential personnel from entering the FME zone, especially if they have not previously taken all the necessary precautions with respect to worker preparations for entering an FME zone.

Worker Accountability. Consider making individual workers accountable for certain items, such as personal tools, that they introduce into the FME zone. The use of separate daily FME accountability logs for each worker authorized to enter the area can increase individual accountability and enhance maintaining the FME accountability log. The FME accountability log should be used for general use even if individual work FME accountability logs are used.

2.5 Perform FME-Related Work

Because work could last a long time, during the work window, Sections 2.5.1 through 2.5.6 are applicable at all times.

2.5.1 Initial FME Inspection

After a system or component is opened for maintenance, an inspection should be performed immediately to inspect accessible internal areas for foreign material. If any abnormal or excessive amounts of corrosion or erosion or any broken or missing parts from equipment degradation are identified, consider this to be a loss of FME integrity (refer to Section 2.6). Inspections should also evaluate gasket integrity. Inspection results should be documented in the work package, and any deficiencies should be documented in the corrective action program.

2.5.2 Clean as You Go

One of the most effective ways to minimize the opportunity for foreign material intrusion is to maintain a neat and clean workplace by cleaning as you go, removing tools and excess consumable materials and their containers immediately after use, and removing all cleaning materials used to maintain the work site after each use. Shipping and packaging materials should not be brought inside the FME zone unless they are necessary for the protection of the equipment or components. New components and equipment should be thoroughly inspected before entry into the FME zone to ensure that packing materials, vendor paperwork, and vendor-installed FME devices and internal plugs have been properly removed. Likewise, cleaning the work area after completing the work task at the end of a shift or work day helps to ensure that foreign material is not inadvertently spread to other adjacent areas where they could become a potential FME concern during the performance of other unrelated work tasks.

2.5.3 Cover Openings When Unattended or Work Is Idle for a Long Period

Use FME devices appropriately. FME devices and criteria for use are listed in Section 3.

2.5.4 FME Accountability Log Reconciliation

Log reconciliation frequency can be based on work scope, the quantity of items entering the FME zone, or job duration. In general, it is recommended that reconciliation of the FME accountability log be performed each shift. For long-duration FME zones where little activity is in progress, reconciliation might be performed at least once every seven days as a minimum. For long-duration FME zones with long periods between work activities, reconciliation might be performed before recommencement of work and on completion of the work. Consider establishing appropriate hold points during component reassembly or before sealing major sections to reconcile outstanding items on the FME accountability log. If work is suspended or stopped for a period, log reconciliation during that period is not required. However, before stopping or recommencing work, an FME accountability log reconciliation should be performed.

Periodic performance of a reverse log review is recommended. This is accomplished by performing an inventory of the FME zone and comparing the results to the FME accountability log.

If the log reconciliation process shows control is lost, stop all work in the FME zone, notify the responsible work supervisor, and use the corrective action program to track and resolve the issue.

2.5.5 Deviations from the FME Plan

Implement all FME requirements specified in the work package. If on-the-job circumstances arise that make one or more of the work package FME requirements impractical, or if changes in the work environment make additional requirements advisable, notify and obtain the advance concurrence of the work supervisor, or elevate the issue to more senior management as expected by station policy.

Allow deviations only in cases where the consequences of foreign material intrusion are found to be acceptably low.

2.5.5.1 Document All Deviations

Deviations can be logged in the FME plan or other appropriate work document. Include the time and date, a brief discussion of the basis for the deviation, and the names of those supervisory personnel (for example, the FME coordinator, system engineer, shift manager, first-line supervisor) who reviewed and approved the deviation.

2.6 Loss of FME Integrity

Loss of FME integrity is a condition deemed to exist when material enters an open system or FME zone and is not controlled. Loss of FME integrity also exists when any of the following events occurs:

- Unexpected foreign material is found within a system, equipment, or component.
- Material is logged into an FME zone that cannot be accounted for during FME log reviews or closure activities.
- Material is found within an FME zone that was not logged while material logging was required.

- Foreign material that cannot be immediately retrieved has been introduced into the system, equipment, or component.
- Internal barriers fail or external covers become damaged or missing while the FME zone is unattended.
- An assembled or disassembled component used within the FME zone is found to have missing parts.
- An FME monitor is required (for example, when a system or component is open) but not present.
- Foreign material is found within an open-air system (for example, fuel pool, open tank, or flooded reactor cavity).

Any person who identifies a loss of FME integrity should immediately stop work progress, place the system or component in a safe or secured status, and notify supervision.

If the foreign material intrusion is associated with systems or equipment that connect with the reactor coolant system (RCS)/primary heat transport (PHT) or SFP cooling system, also notify the operations shift supervisor and the refueling floor senior reactor operator if manned.

Do not attempt to recover the foreign material until a recovery plan has been completed and instructions have been received from supervision, unless not acting would obviously make the situation worse. Management and engineering should develop a recovery plan and determine the appropriate time to retrieve the foreign material.



Key Human Performance Point

On realization that foreign material intrusion has occurred or FME integrity is lost, immediately stop work progress, place the system or component in a safe or secured status, and notify appropriate supervision.

2.6.1 Documentation and Incident Reporting

When a foreign material intrusion incident occurs, the work supervisor should be notified along with the FME monitor, if applicable. The incident should be documented in the site's corrective action program. Information might include the following:

- Date and time of occurrence
- Date and time of discovery, if different from those of the occurrence
- Steps necessary to secure the system or component before the stop-work order
- Date and time that the stop-work order was initiated
- The discoverer's name and title
- Initial estimates, including foreign material type and extent of intrusion
- Potential for continuation of foreign material intrusion

- The recognized or potential impact on the system or component
- Names of the supervisory personnel who were notified
- Steps taken to prevent reoccurrence

2.6.2 Condition Assessment

In the case of foreign material intrusion, each incident should be evaluated individually. Before acting, consider not only the mechanical impact that the foreign material intrusion incident might have on the system or equipment, but also any possible effects that it might have on water chemistry, instrumentation, or the electrical or radiological systems.

For foreign material such as welding slag, cutting debris, filings, grit, dirt, or other debris determine the best means available for carefully inspecting the affected system or component. Take special care not to further increase the severity of the foreign material intrusion incident by doing any of the following:

- Causing the subject foreign material to become less recoverable
- Introducing additional foreign material into the system or component
- Allowing inspection tools or materials to become part of the problem

After any foreign material is found or recovered from the RCS/PHT or attached system, add instructions to document findings in an attempt to identify the material composition and possible sources of the material. Particularly for items found in or near the core, the degree of irradiation can be used to estimate the age of the material. This will provide for proper classification as to current or legacy debris. These findings should be documented in the plant's corrective action process.

Begin formulating a foreign material recovery plan to address the incident. Notify the station supervisory personnel, as required, and initiate a condition report detailing that a foreign material intrusion incident has occurred where the foreign material in question is not easily retrievable or that FME controls have been lost and are not immediately recoverable. A determination is required as to whether the foreign material can be immediately recovered before recommencing work activities. If the foreign material will not affect work activities, will by itself not be disturbed by work activities, or will pose any additional problems while remaining in the system or equipment, it might be desirable to develop the plan and perform retrieval just before system or equipment closure. If items are left for future recovery, they should be documented and tracked until recovery has been completed.

2.6.3 Recoverable Foreign Material

Document the recovery plan, including the various considerations taken into account before the recovery operation began. Record the following additional information connected with the incident:

- The name and title of the person making the recovery
- The recovery plan
- The name and title of the management personnel approving the recovery plan

- The time it will take to accomplish recovery
- Post-recovery details
- Post-recovery inspection of foreign material to ensure intact recovery

Include the recovery plan as part of the corrective action package.

2.6.4 Unrecovered Foreign Material

When foreign material cannot be recovered and the system must be returned to service, begin by determining the probable extent of foreign material intrusion, based on all readily available plant information related to the incident. Review internal and external industry OE. Establish a central administrative mechanism to track nonrecoverable items. Tracking might include the approximate material location(s), the conditions necessary for material recovery, the material subsequently recovered, the material remaining in system, and the potential impact on system components or plant operations.

When foreign material might have been introduced into the plant's primary system or might migrate into that system over time, notify the appropriate departments, such as operations, engineering, chemistry, fuel services, and radiation protection. A technical evaluation should be performed for any nonrecoverable items that fall into or are discovered in the reactor vessel, reactor internals, SFP, transfer canal, or other systems that provide a direct path to the reactor vessel (for example, shutdown cooling, spent fuel cooling, or in other safety-related systems).

Provide or obtain a justification for system or equipment return to service and operation. Review the particulars of this incident and existing FME controls to develop recommendations to prevent future similar occurrences from taking place. The foreign material should be monitored at the next and subsequent system or equipment openings to detect any changes or movement of the foreign material.

2.6.5 Recovery Equipment and Tools

If visual equipment or recovery tools are used in the foreign material recovery process, every effort should be made to ensure that the equipment or tools or any parts of the equipment or tools do not introduce additional foreign material into the system or equipment, causing additional foreign material problems.

If foreign material cannot be located by line of sight, a variety of camera and lighting systems are commercially available for use under water and in high-radiation fields. The following types of equipment are among those available:

- Boroscopes
- Remotely operated video cameras
- Radiography
- Infrared thermography
- Mirrors
- Fiberoptics

When foreign material is not readily retrievable by hand, special tools might be required individually or in combination. Available tools include the following:

- Grapple-, disk-, or cone-equipped snakes
- Adhesives
- Magnets
- Reach rods
- Vacuum systems
- Flushing systems
- Temporary screens and strainers

2.6.6 Recovery Plan Formulation

Contact the responsible authority to request an engineering and operational impact analysis and to solicit input on alternative retrieval options. Document all physical site conditions and personnel actions as they pertain to the foreign material intrusion incident and recovery of FME controls. Some elements that any recovery plan should include are the following:

- Personal and nuclear safety
- As low as reasonably achievable (ALARA) issues
- Subsequent analysis of recovered materials
- Determination of source, quantity, and location of foreign material
- Measures to limit further spread of the materials
- Subsequent inspection requirements or equipment disassembly
- The process for material location and recovery as it concerns plant procedures for safety, ALARA, confined space, and so on
- Evaluation of possible equipment damage already sustained
- Assessment of potential impact of material not yet accounted for that remains in the system or component
- Monitoring methods to identify unacceptable consequences of foreign material intrusion on a return to service
- Measures to prevent recurrence, further equipment damage, or degradation

2.7 Removal of FME Devices

It is possible to forget that foreign material intrusion can actually occur when removing devices previously installed to prevent the intrusion of foreign material. Before removing an installed FME device, thoroughly inspect the local area surrounding the device to ensure that no foreign material has built up on the device or around its edges. Clean the FME device as necessary before removal to minimize this problem. After removing the device, document its removal, as required, in the FME accountability log.



Key Human Performance Point

Clean the FME device and the adjacent area before removal to minimize the potential for foreign material intrusion.

2.8 As-Left Closeout Inspections

The as-left closeout inspection is the final barrier for detecting foreign material intrusion. It should consist of the following steps:

1. Ensure that tools and materials have been removed from the FME zone and adjacent areas upon overall work task completion.
2. Ensure that FME accountability logs are reconciled.
3. Perform a closeout inspection of the system or equipment.
4. Ensure that all internal FME barriers that were installed have been removed. Document removal in the work document or other tracking document. If new or refurbished equipment was installed, particular attention should be given to ensure that any internal barriers installed by the vendor have been removed.



Key Human Performance Point

The as-left closeout inspection is the final opportunity for detecting foreign material intrusion.

2.9 Close the Breach

1. Perform a postmaintenance inspection of the FME zone, with the appropriate personnel inspecting the FME zone and adjacent areas before closing out the work order. This inspection should include checking for missing fasteners or parts in the vicinity of the opening that may have been lost during the work activity and so are potential foreign material.
2. Document the inspection results in the work document.
3. Remove and account for all barriers used in establishing and maintaining FME controls and the FME zone boundary, and return the area to its premaintenance state.
4. Properly store reusable barriers, and dispose of all consumable items removed.
5. For permanent or long-term FME zones, ensure that the area is left clean and that the inventory or accountability log is up to date.
6. Items found that were not on the accountability log should be documented in the corrective action program and their source determined and resolved.

3
PREVENTIVE METHODS AND CRITERIA FOR USE

3.1 Preventive Methods

An effective FME process focuses on preventing foreign material intrusion. Some preventive measures are quite general; for example, the notion of establishing an FME zone around an opening is applicable to a wide variety of situations. Other preventive measures are quite specific to limited circumstances; for example, the notion of tracking individual welding rods is not applicable to most work activities. To help readers find appropriate preventive methods to apply, this section is arranged to first discuss general team practices such as the use of FME zones, logging practices, and inspections; next to discuss individual work practices such as tethering tools, controlling personal items such as jewelry and contents of pockets, and use of personal protective equipment; then to discuss proper design and use of FME devices; and finally to discuss specific methods associated with particular sources of potential foreign material such as airborne foreign material, deliberately introduced foreign material, wire brushes, and gaskets.

3.2 General or Team Methods to Prevent Foreign Material Intrusion

3.2.1 FME Zones

3.2.1.1 General Options for FME Zones

There are many varieties of FME zones. In general, we describe high-risk FME zones and standard-risk FME zones. The main difference between the two risk-level zones is that logging is generally used for high-risk FME zones. Many stations provide for transitioning some FME zones from high risk to standard risk or back again based on criteria intended to balance preventing foreign material intrusion with allowing efficient conduct of work when the probability of foreign material intrusion is known to vary during long work windows.

Some FME zones are permanent, some are established during specific work windows during outages encompassing many tasks on many different components, and some are established only for particular activities on specific components.

3.2.1.2 Establishing an FME Zone

Each plant should have an FME program that details the plant's FME risk levels and the controls required for each level. It is essential to determine whether FME controls (for example, boundaries, signage, restricted access, accountability) are required and the extent to which they should be applied.

Before establishing an FME zone, the area should be inspected to ensure that loose debris and other potential foreign material is removed. This inspection should include checking for missing objects, fasteners, and so on that later may be questioned as to when they were lost. Any missing items should be logged. Areas that will be adjacent to the FME zone should be inspected also. Overhead areas, including work or equipment platforms, scaffolding, stairways, and overhead cranes or hoists, should be inspected. Overhead cranes should be restricted from passing over an FME zone. Some plant designs make the use of overhead cranes over FME zones unavoidable. When this occurs, the overhead crane should be controlled as part of the FME zone (this should include rigging materials and the load).

An overhead cover can be installed if other work is being performed overhead.

Before actually breaching a system, equipment, or component, establish FME zone boundaries in accordance with procedural requirements. Often, the FME zone may be as small as practical so as not to impede or restrict work activities. The FME boundary and the system breach might be the same. In other cases, to establish a stand-off distance from the breach to reduce the probability of inadvertently introducing foreign material, a large zone could be established.

Figure 3-1 provides an example of the use of signs and barriers at a work site. An example of an FME zone sign based on foreign material intrusion risk is provided in Appendix E, FME Accountability Log (Example).







Figure 3-1
FME signs and barriers

Install boundary markers and remove or log all items within the boundary before activating the FME zone. If logging is required, assign responsibility for tool and material control. To ensure accountability, items logged into the FME zone should be logged with sufficient detail (for example, description of the item, quantity, and any missing or damaged pieces/parts).



Key Human Performance Point

The criteria for selecting the appropriate classifications and establishing the level of controls that will be imposed should be based on the consequence of foreign material intrusion, the difficulty of foreign material detection and recovery, and the probability of foreign material intrusion.

3.2.1.2.1 High-Risk FME Zone

Determination of the FME risk level associated with any activity is performed in accordance with Section 2.2 of this report. The FME process described in Section 2 results in a high-risk FME zone being established when a loss of FME integrity could result in any of the following:

- A nuclear fuel failure
- Personnel injury
- Reduced safety system or station availability
- An outage extension or significant cost of recovery (define site specific)

A high-risk FME zone should also be established whenever a final visual inspection of internal cleanliness before system closure is not possible (for example, ALARA, system or equipment configuration). Additional high-risk FME zone controls might be applied for systems or equipment where the consequences of foreign material introduction are irreversible.

General characteristics of a high-risk FME zone include the use of boundaries/signs, buffer zones, an FME monitor and FME accountability log, and tool/material/personal items control.

The high-risk FME zone area should be demarcated with a continuous boundary and signs placed at appropriate intervals. The entrance to the high-risk FME zone should be limited and clearly marked. The high-risk FME zone boundary should be made as small as practical so as not to inhibit the work activity. The FME boundary and the system breach might be the same. If possible, a buffer zone outside the high-risk FME zone should be established to aid in further reducing the potential for foreign material intrusion.

An FME monitor is established to control personnel and material access to the high-risk FME zone whenever work is in progress. The FME monitor helps ensure only necessary personnel and material should be allowed inside the high-risk FME zone (see Section 3.2.3 for more details on the FME monitor).

Tools and materials taken into the high-risk FME zone should be controlled. They should be failsafe or provided with a lanyard. Tools and materials entering the high-risk FME zone should also be inspected for foreign material.

Sites should establish a high-risk FME zone for systems, equipment, or areas where there is a high potential for the introduction of foreign material to the fuel. Table 2-1 provides a sample list of systems, equipment, or areas that provide a path for foreign material intrusion into the RCS. These should be designated high-risk FME zones and identified in site procedures and work documents. Table 2-1 is not all-inclusive; site designs, needs, requirements, or physical arrangement (for example, ice condenser plants) can affect this list.

3.2.1.2.2 Standard-Risk FME Zone

A standard-risk FME zone should be established for system, equipment, or component breaches that do not meet the high-risk FME zone requirements. Other criteria can be established depending on site needs. Criteria could include the size of the breach (for example, the breach is failsafe), orientation of the breach (for example, horizontal vs. vertical), or whether an inspection or recovery of foreign material can be made before final closure. General characteristics of a standard-risk FME zone include the use of boundaries/signs, limited access, and control of tool/material/personal items (for example, failsafe or provided with lanyards).

3.2.1.3 Permanent FME Zone Considerations

When considering basic FME work practices, a plant might have certain areas designated as ongoing or permanent FME zones. This is especially true if maintenance-related activities are performed in the vicinity. Examples of the areas where plants should consider instituting at least an increased level of FME control are presented in this section. Permanent or long-term FME zones might be established where systems are normally open and subject to potential foreign material intrusion (for example, the SFP, BWR drywells, PWR containment sumps, and the Canadian deuterium/uranium (CANDU) emergency core injection flow path). A permanent FME zone can be a high-risk FME zone or a standard-risk FME zone, based on the level criteria established. These FME zones should be inspected and cleaned periodically. Any deficiencies noted during these inspections should be placed in the corrective action program.

3.2.1.3.1 Fuel Storage Pools

Unless appropriately marked and previously approved, clear plastics or other such materials should not be used in and around fuel pools where they could become transparent when submerged in the pool. Pay particular attention to liquids used in the area such as lubricants and solvents that could be introduced into the pool during an inadvertent spill or line (hose) break. Materials placed into the SFP should be chemically compatible with the environment. Arrange to protect the pool with mesh or other suitable barrier to prevent the introduction of foreign material when work is occurring overhead or in the immediate vicinity and warrants such action. Also, emphasize the importance of tool and material FME controls. Light fixtures located in or over pools should have protective covers in the event of a light bulb breaking.

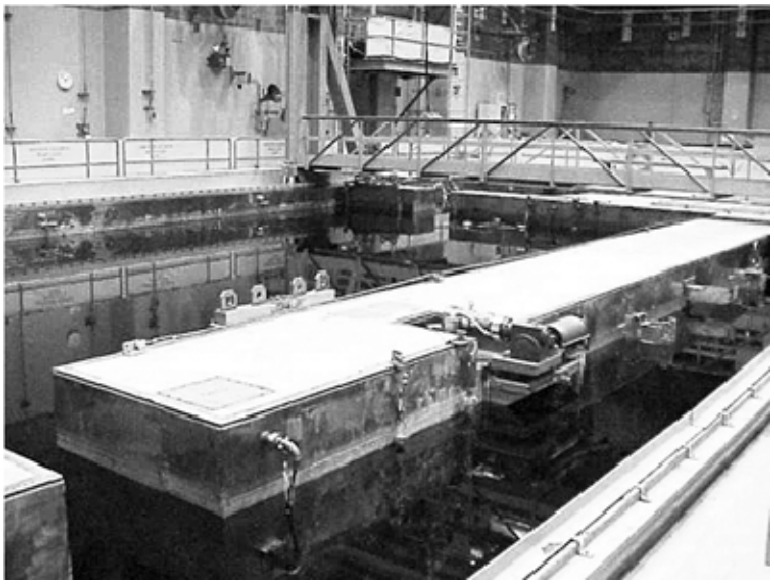


Figure 3-2
SFP FME zone

3.2.1.3.2 Fuel Handling for CANDU Reactors

CANDU reactors perform online fueling. A permanent FME plan or fuel-handling procedure should be developed to assist in controlling the inspection process and movement of fuel during the fuel loading and unloading process. Similar maintenance procedures should be in place when work is being performed on the fueling machine assemblies and reactor vessel.

3.2.1.4 Outage-Related FME Zones

In order to improve the consistent application of FME controls, many plants have designated certain critical areas as outage-related FME zones. Any activities within these zones will fall under the plant FME process controls. Areas to be considered include the following:

- Specific areas on the refueling floor, including the fuel pool, dryer separator pit (BWRs only), and the open reactor cavity with head removed
- Torus or suppression chamber hatches, main vent headers, and downcomer region (BWRs only)
- The drywell under the vessel area drywell sump (BWRs only)
- The turbine generator when opened
- The S/G
- The diesel generator
- The condenser

- The ice condenser (Ice condensers might not be an FME zone, but they should have established FME controls for ensuring that foreign material is not introduced or left in the ice condenser during work activities.)
- Feedwater heaters/moisture separator reheaters
- Emergency core injection (in CANDU units)

3.2.1.5 FME Risk-Level Transition Requirements

During the course of work activities, it might be necessary or desired to change the FME risk level for an FME zone. This can be done either to increase the awareness and controls for the current scope of the activity or to enhance the efficiency of an evolution without compromising FME requirements.

3.2.1.5.1 Transition from a High-Risk FME Zone to a Standard-Risk FME Zone

The transition should include the following:

- The first-line supervisor should ensure that all system/equipment/component openings have been covered/plugged and that FME devices have been logged, including their location.
- The first-line supervisor should ensure that the FME monitor has balanced the FME accountability log and that it reflects an accurate listing of all items in the FME zone.
- Suspend logging activities and secure the log for later use.
- Change the posted FME signs to reflect the new risk level.
- Maintain all FME zone requirements for the lower risk level as noted on the FME control plan.

3.2.1.5.2 Transition from a Standard-Risk FME Zone to a High-Risk FME Zone

The transition should include the following:

- The first-line supervisor should ensure that the FME barrier around the high-risk FME zone is re-established.
- The first-line supervisor should ensure that the housekeeping zone is appropriate for the high-risk FME zone and that all unnecessary materials, parts, tools, and so on are removed from the FME zone, as previously noted.
- The first-line supervisor should perform housekeeping activities in the external area around the high-risk FME zone, as previously noted.
- The FME monitor should inventory and log all remaining items inside the high-risk FME zone using the existing log.
- Post the area as a high-risk FME zone.
- Maintain the FME zone requirements for a high-risk FME zone as noted in the FME control plan.

3.2.2 FME Logging

FME accountability should be implemented as required by work instructions, the FME plan, or whenever it is deemed appropriate based on work conditions. Accountability requires logging of items entering an FME zone to maintain an accurate inventory of what is in the FME zone. For a sample log, see Appendix E, FME Accountability Log (Example).

An FME accountability log should be implemented as soon as the FME zone is established. Items that remained inside the FME zone at the time it was established should be logged. In addition, items that are discovered missing within the FME zone before establishing the zone should be logged as missing so that if they are noted later, it will be clear that this is not a case where the missing item is suspected of being lost inside the breach.

Whether personnel are tracked entering and leaving the high-risk FME zone is a site-specific determination. However, personnel entering a high-risk FME zone should be inspected for any personal or carried items. Personal items should be secured, and carried items should be logged in the FME accountability log. If personnel are going into the high-risk FME zone and not carrying any items requiring logging, the logging of personnel on the FME accountability log might be optional. Personnel access to the high-risk FME zone should be limited to essential personnel.

Loose parts should be logged. During system/equipment/component disassembly, as-found conditions should be inspected carefully. Be sure that items removed during maintenance, especially renewable items, such as gaskets, are inspected for completeness. Account for all loose parts, such as fasteners and washers, by logging them on the FME accountability log. When and if they are reinstalled, log them out as installed. Implement loss of FME integrity for unaccounted-for parts/materials when encountered.

3.2.2.1 Guidelines for Logging Items in an FME Zone

- When logging is required for items taken into an FME zone, the level of detail should be sufficient to account for items removed from the FME zone and to identify any items remaining in the FME zone.
- The FME accountability log should provide a clear description of items entering the FME zone to ensure accountability of tools and equipment. Items with missing parts or damage could result in questionable accountability.
- Personnel should perform an initial inventory of the area before implementing an FME zone. Unnecessary items should be removed from the area.
- The log should include all items that were left inside the FME zone at the time it was established, and personnel should continue to log all items that enter or leave the FME zone.
- To the extent practical, take all possible steps to minimize the introduction of tools, materials, and spare parts into the FME zone.
- Tools, equipment, and material should be logged before entry into the FME zone.
- All tools, materials, and equipment that enter an FME zone and are not failsafe should be secured by a lanyard or other approved means or recorded on the accountability log.

- Some items might require multiple log entries (for example, nitrile gloves, cable ties/wraps, FME devices that will be removed from the FME zone separately from the component that they protect, and tools that can be disassembled in multiple pieces).
- Each tool in the toolbox should be logged as an individual item. It is unacceptable to log a toolbox full of tools as a single item.
- A standardized method for logging in bulk material and consumables, such as rags, tape, smears, and replacement gloves, should be developed.
- Rags should be numbered or counted. Finding each numbered rag may produce a contamination control problem if they are placed in contaminated waste containers, in which case, it may be more appropriate to count them.
- Boxes containing multiple items should have the items removed and counted. Unnecessary items should not be taken into the FME zone.
- Items that are worn into the FME zone and subsequently removed (for example, life jackets) should be secured and logged if removed. The item should be removed on exiting the FME zone.
- Permanent plant parts brought into an FME zone should be logged. After installation, they should be logged as installed on the accountability log.
- Ensure that subcomponents are logged (for example, a tool with lanyard attached). The quantity of subcomponents should be minimized.
- Document any installed FME devices by quantity and location.

3.2.2.2 Items Exempt from Logging

Items that might be exempted (site-specific) from entry into the FME accountability log include the following:

- Special nuclear material (fuel) that can be otherwise tracked
- Dryer and/or separator storage pit plugs and keyway plugs
- New and/or irradiated fuel channels and control rod blades
- Blade guides and dummy assemblies
- Drywell head, insulation, and/or associated piping, reactor head, and internals
- Any other large, obvious item that would be conspicuous by its absence

3.2.3 FME Monitors

Trained FME monitors are effective at reinforcing worker accountability expectations and zone-specific requirements for material control. In addition, they help the flow of work by performing logging activities.

An FME monitor is established to control personnel and material access to the high-risk FME zone whenever work is in progress. Only necessary personnel and material should be allowed inside the high-risk FME zone. Physical plant arrangements might require more than one entrance into the high-risk FME zone. If this is necessary, an FME monitor should be positioned at any additional entrances to the high-risk FME zone. The FME monitor should maintain an FME accountability log that tracks all personnel and any materials, consumables, tools, and so on taken inside the high-risk FME zone. The FME accountability log should be reconciled as required.

3.2.4 Housekeeping



Key Human Performance Point

General FME guidance should always take into account OE, housekeeping, and pre-job briefings as the basis for establishing levels of risk for control and inspection.

If the plant is maintained clean and free of loose objects, the chance of loose objects causing foreign material intrusion is reduced. Therefore, general housekeeping at all times is a preventive action.

3.2.4.1 Preventive Cleaning

Routinely inspect an FME zone for evidence of dirt, debris, or other potentially undesirable materials before opening a system or component. Evidence of lapping-compound residue, metal dust, paint chips, and so on suggests that further cleaning should be performed in and around the proposed FME zone. Consider using vacuums, magnets, wipes, or other cleaning aids as appropriate for the material being cleaned. Remember to check overhead for similar materials and objects that could become loose or dislodged and subsequently be introduced into the open system or component below. Inspect the area for potential sources of foreign material intrusion that might occur infrequently and that could occur during work task performance; examples include overhead cranes, ventilation ducts, drains, vents, and relief valves. Consider how best to plan for each specific occurrence.

3.2.4.2 Clean As You Go

Housekeeping is also a subtask of every FME activity. If an FME zone is to be used, before posting the FME zone, housekeeping is checked or specifically improved to reduce the potential for loose objects to become foreign material.

Whether a FME zone is posted or not, before breaching a system, good craftsmanship demands that the area around the breach be cleaned.

During work, clean-as-you go is a preventive action, effective in the plant, shop, warehouse, or bench work.

To the extent practical, do not keep trash cans or other general refuse containers within the FME zone. Collect and remove all dirt, debris, and other refuse as it accumulates. Remember to log out all trash, as applicable, in the appropriate FME accountability log.

During cutting, grinding, lapping, welding, painting, cable installations, wire stripping, or other particulate-producing activities, precautions should be taken to prevent material intrusion into any open systems or equipment. The erection of barriers might be required around these particulate-producing activities before they are performed.

3.3 Individual Work Practices to Prevent Foreign Material Intrusion

3.3.1 Securing Personal Items

The preferred method is to remove all personal items (for example, jewelry, contents of pockets, and other potentially loose objects) before entering an FME zone. Items such as clothing buttons, glove tops, and bootie tops should be taped over to ensure that they do not become dislodged during work task performance.

Secure eyeglasses, safety glasses, hard hats, hearing protectors, and similar items in such a fashion that they cannot become lost if they are dislodged while worn within the FME zone. See Figure 3-3 for examples of methods used to secure safety glasses and hard hats.

Key Human Performance Point

The preferred method of ensuring that personal items do not become foreign material is to remove them before entering an FME zone.



Figure 3-3
Typical method for securing safety glasses and hard hats

3.3.2 General FME Worker Practice

Do not use clear plastic in an FME zone, especially if there is a possibility of its entering a water-filled system or component, because detection and retrieval of clear plastic from water is very difficult.

Rags, gloves, and other similar materials should not be stuffed inside piping for use as FME devices. Only approved devices should be used.

FME devices should be installed on any opening that is subject to foreign material intrusion during periods when work is stopped or suspended.

FME barriers should be installed to prevent items from falling into or being dropped from above into open systems or equipment if work is conducted on, above, or under open gratings.

All workers should be aware that the following items are not allowed inside an FME zone:

- Any transparent material (for example, visors, clear plastics, clear tubing) (see Section 3.5.3, Use of Transparent Materials)
- Wire wheels/brushes inside an FME zone associated with the RCS/PHT or systems that directly connect with the RCS/PHT (see Section 3.6.8, Using Wire Wheels and Brushes)
- Cable ties/wraps with metal fasteners
- Tags, bags or tarps with metal grommets
- Wire twist ties
- Because housekeeping is a cornerstone of FME performance, eating, drinking, spitting, and chewing within the boundaries of an FME zone should be strictly prohibited

If it becomes necessary to use transparent material inside an FME zone, it should be distinctively marked to improve visibility, and it should receive previous review and approval before use. Similarly, if wire brushes must be used on the systems previously mentioned (Table 2-1), previous review and approval should be obtained. Wire brush use should also require the installation of FME devices to prevent foreign material intrusion, and a cleanliness inspection before closure should take place (see Section 3.6.8, Wire Wheels and Brushes).

In addition to being an FME risk, dropped items can be a safety hazard. The following are good work practices to prevent items from being dropped:

- Workers should remove all items from their person/pockets that are not necessary for the activity when traversing the plant or the work area, where items could be dropped.
- Scaffolds should meet the following requirements:
  - Be constructed with netting to the mid-rail whenever scaffolding is directly over passageways or over personnel.
  - Have toe boards installed on decks where personnel might be working or traversing under the scaffolding.
  - Be constructed so the scaffold deck is as close to a vertical surface as possible.
  - Have a lift system attached for raising and lowering equipment if the scaffold is in a high-traffic area.
- When personnel are passing material, ensure that there is positive control of material so that items are not dropped, that is, the receiver must have control of the load before the send releases the load.
- Where equipment and material are stored on grating, sheet metal, Visqueen®, or other approved material can be used to prevent small items from falling through the grating.
- Do not lean over handrails/railings or open holes where items could be dropped.
- Pay special attention to items normally carried on your person (for example, radios, phones, cameras, clipboards, battery compartments) that could be dropped. Lanyards should be used as appropriate.

3.4 Design, Types, and Use of FME Devices

3.4.1 Design of FME Devices

An FME device should have the following characteristics:

- Fire resistant or retardant.
- Nonbrittle, nonsplitting, and nonmelting under the environmental conditions that it might be exposed to.
- Tear resistant (materials such as paper, plastic wrap, and polyethylene film should not be used).
- Unlikely to deteriorate or decompose with time (for example, compatible with its environmental conditions).
- Inert (chemically compatible); unable to cause any type of chemical reaction.
- Highly visible. It is recommended that FME devices be brightly colored to minimize the chance that they will be left installed. Note that many stations have improved FME performance overall by standardizing (branding) FME colors and device styles to make the FME function more consistently visible and commonly understood
- Allows for venting if applicable.
- Nonconductive to electricity.

The following are additional desired features for covers, plugs, caps, seals, and other FME devices:

- They should be installable and securable in such a manner as to prevent accidental removal, including accidental displacement by wind, equipment movement, ventilation systems, and so on.
- They should not mark or mar the system or component hardware.
- They should not result in galvanic or other corrosion at the point of contact with the system or component hardware.
- They should be easy to install and remove.
- They should not affect system/equipment/component structural condition.
- They should not obstruct design functions if they are installed with equipment in service.
- If intended for use inside systems or components, an appropriate telltale is provided to reduce the risk that it will be left in the system.

Types of materials that can be used for FME devices include the following:

- Rubber, metal, and rigid plastic (not clear).
- Wood used to cover large openings, if adequately covered with Herculite or a similar material.

- Soft material covers, if pressure/vacuum is not an issue.
- To cover asymmetrical components or irregular equipment openings (for example, pump or turbine casings) where a rigid cover might not be practical, sponge plugs or other suitable material can be used. Ensure that these devices have telltales or other devices to ensure that they are not left in a system or sucked into a system from pressure fluctuations.
- Generally, tape and wood should not be used as an FME device. Wood can splinter and create foreign material. Although tape can be used to hold and secure FME devices in place, if tape or adhesives are used to secure an FME device, they should be chemically compatible with the material they are used on. Tape should be accounted for in a manner that ensures complete removal from the FME zone before closeout.

FME device design considerations might include the following:

- FME devices should be capable of being securely attached to the equipment or component and be of such a design that no loose parts can fall into the system during installation or removal. If the design of an FME device prevents this, lanyards should be attached until installation/removal is complete.
- The design of large FME devices in horizontal positions should take personnel and industrial safety into consideration, such as measures to prevent personnel from stepping on or falling through the device.
- FME devices that are used in harsh environments (for example, sunshine, rain, wind, heat, steam, water) should be inspected periodically to ensure their structural integrity. The operating environment of the FME device should be taken into account before installing the device.

3.4.2 Types of FME Devices

This section contains information on several general categories of FME protective devices that can assist station personnel in properly selecting and using each type of item.

3.4.2.1 Tents/Tarps/Barriers

A tent, an example is shown in Figure 3-4, is a covering that completely encloses a work area or entire FME zone, as indicated by individual circumstances. Its purpose is to protect the open equipment, system, or component by preventing the introduction of foreign material that might be generally present in the local area, such as dust or debris from adjacent maintenance operations or foreign material that might be on overhead sources, such as cranes, gratings, walkways, vents, and drainpipes. Tarps can be used as barriers to prevent foreign material intrusion into a system or equipment or as a barrier to prevent debris-producing activities from spreading debris to plant areas.



Figure 3-4
Tent completely enclosing an FME zone

Tarps used as barriers might have grommets attached. Before introducing these items into or near an FME zone, they should be inspected to ensure that the grommets are in place and securely attached. If admitted to the FME zone, any deficiencies should be noted in the FME accountability log. On removal of these items from the FME zone, they should be inspected to ensure that all grommets are intact. Any deficiencies should be noted in the FME accountability log and the corrective action program used for resolution. Some stations have installed tie wraps through grommet eyes to keep grommets in place. Not cutting the ends of tie wraps provides for a way to lift the item and prevents generation of foreign material.

3.4.2.2 Access Covers and Closure Devices

Access covers and other closure devices are meant to prevent the introduction of foreign material directly into equipment, systems, or components. Keep all system or component openings covered whenever possible, except when in use during maintenance activities or when system or equipment inspection or testing makes it impractical. FME devices should be inspected before installation to ensure that they are intact and have no loose parts. FME devices should not allow the introduction of foreign material into the system or component as a consequence of the cover's installation or removal. Examples of pipe caps and covers are shown in Figure 3-5. The cover itself should be clean, sturdy, and free of debris. Secure the cover so that it cannot be dislodged by sudden pressure drops or surges in the system.

3.4.2.3 Pipe Caps and Plugs



Figure 3-5
Some examples of pipe caps and plugs

3.4.2.4 Pipe Dams

Pipe dams are generally internal blocking devices, such as inserted plugs, that effectively limit the distance to which foreign material can be introduced into an open piping system. Pipe dams should meet the requirements of an FME device, as established in Section 3.4.1.

Pipe dams, as shown in Figures 3-6 and 3-7, are used to seal off pipes to isolate the system or component opening. Pipe dams should be installed during grinding, lapping, filing, or brushing activities. General considerations for the use of pipe dams or plugs include the following:

- They should be secured to prevent them from being sucked in or blown away by pressure drops or surges in the system.
- Secure pipe dams external to the pipe whenever possible to avoid their inadvertent loss into the system or component.
- Where possible, attach a tail or lanyard to pipe dams that extend outside the pipe to provide a highly visible warning, or use additional methods to ensure that the pipe dam is easily detectable and retrievable.
- Record pipe dams in the FME accountability log or appropriate work document when they are used as an FME barrier.

- When it is not possible to keep the dams or devices tied off, such as welding or lapping valve seats, they should be constantly attended.
- When unattended, they should be logged and externally tied off (tattle-tailed) or removed.



Figure 3-6
Inflatable pipe dam

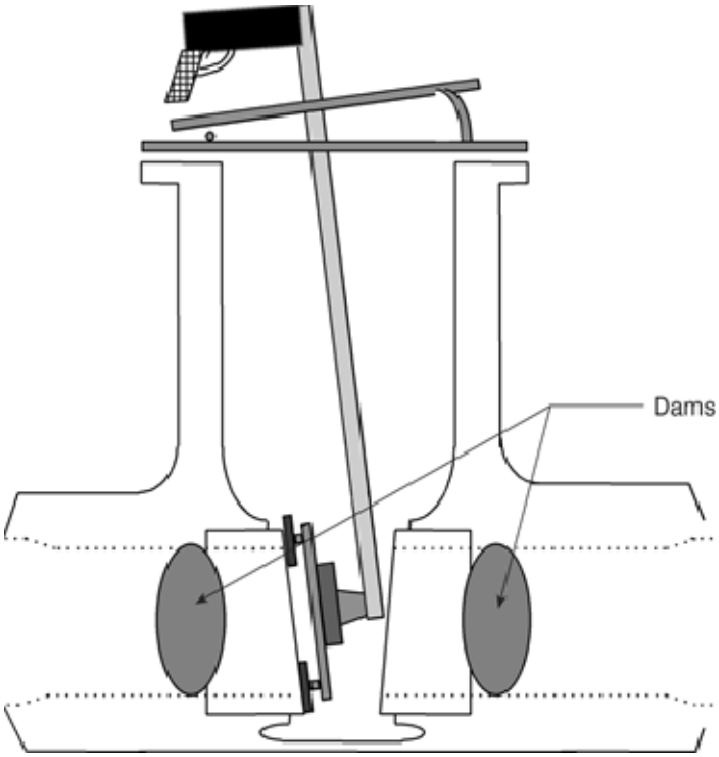


Figure 3-7
Pipe dams installed during a valve-lapping operation

- Always inspect for internal dams when receiving equipment from the warehouse or vendors.
- Use closures made of appropriate material and design rating for their intended application. As an example, never use paper pipe dams, clear plastic bags, or cloth FME devices.
- Always exercise caution when removing pipe dams. Valve leakage into a piping system can cause a pressure buildup behind such devices.



Key Technical Point

Exercise caution when removing pipe dams. Valve leakage into a piping system can cause a pressure buildup behind such devices.

3.4.2.5 Lanyards

Lanyards should be considered for high-risk FME zone jobs, work over open water, deep holes, and high elevations. If the system or component contains areas that cannot be easily inspected or areas where foreign material could go unnoticed without additional disassembly (for example, valves in vertical piping runs), materials should be secured using lanyards or other suitable means to prevent loss. Alternatively, the opening can be sealed off. Lanyards or a suitable means to secure, capture, or retain tools and materials are required when working in areas where dropped tools or materials could do any of the following:

- Cause personnel injury
- Enter operating systems (for example, the reactor cavity, spent fuel storage, condensers)
- Cause damage to the plant equipment
- Hit and break into multiple parts that might be hard to find or recover

Failsafe and readily retrievable items do not require lanyards. The following precautions should be considered when using lanyards:

- All material/tools used over open water or fluids should be attached by a lanyard or other acceptable retention method.
- Use lanyards in such a manner that they do not constitute a personnel safety hazard.
- Personnel should exercise special care when using lanyards to prevent snagging the lanyard on equipment, thereby causing an injury or allowing the attached item to fall loose.
- Select lanyards that are made from materials that do not chip, flake, or peel. Tape should not be used as a lanyard.
- Lanyards should be strong enough to resist the breaking force that would result when the free-falling object is caught by the lanyard. Nylon, rubber tubing, or corrosion-resistant steel wire is recommended. Stainless steel wire is recommended for long-term exposure in harsh environments.
- Size lanyard lengths so that they are short enough to minimize the dropping distance and limit the possibility of the dropped object causing damage, yet long enough to not impede or restrict use of the tool or item. Normally, the shortest possible length of lanyard should be used.

- Inspect and test lanyards to ensure that they are securely attached and not likely to become detached during use.
- Lanyards should be attached in such a manner as to prevent loss from the anchoring point, such as a handrail or personnel.
- Lanyards are intended to provide a backup method for preventing loss of materials within an FME zone. Do not suspend items by their lanyard where lanyard failure might result in the loss of the item. Never use power cords or air hoses as lanyards.



Key Technical Point

Never use power cords or air hoses as lanyards.

3.4.3 Use of FME Devices

Appropriate FME devices are used to cover unattended system breaches or open equipment to reduce the potential for foreign material intrusion. SFPs and other areas where it is not practical to cover the opening may be exempted; other FME controls such as FME zones should be used.

When a system or equipment is breached and must be left unattended during the performance of the work activity, FME devices should be installed. If the work task is not being actively performed, ensure that the FME devices are securely installed and rigorous enough for the entire duration. FME devices should be available in appropriate plant locations, in the warehouse, and in training laboratories. Specific devices can be designed for special applications (for example, breakers, large equipment openings, manways, manholes). FME devices might need to consider potential requirements, such as ventilation, drainage, ingress/egress, or passage of electrical or other service supplies. Vent or drain openings typically do not require additional FME devices when oriented downward (for example, between the four-o'clock and eight-o'clock positions).

FME devices should not obstruct the designed function of vents for tanks while the system or component is in-service, and they should not obstruct confined space ventilation needs. The use and design of FME devices should be consistent with required cleanliness of the system or equipment breach.



Key Human Performance Point

Covers should not allow the introduction of foreign material into the system or component as a consequence of the cover's installation or removal.

Use only approved covers, caps, plugs, and so on that are made of materials that enable them to perform their FME function without causing any detrimental effects to systems, equipment, or components.

FME devices should be used appropriately. Personnel should be able to recognize when and where the use of a protective device is warranted and understand the implications and limitations relating to its use based on station-provided training.

A convenient method to store these protective equipment devices and have them readily available is to strategically locate FME carts, cabinets, and bins throughout the plant. The cart would contain covers, pipe dams, lanyards, signs, log sheets, and procedures. An example of an FME cart is shown in Figure 3-8. A method should be in place to dispose of soiled or damaged FME devices.



Figure 3-8
FME cart

When an internal plug is used that will allow reassembly without removing the plug, a label should be affixed to the pipe noting the installed plug. The plug should be recorded in the FME accountability log, and a second verification of removal is required. Removal should require a concurrent verification of removal by a qualified FME person.

3.5 Methods to Prevent Foreign Material Intrusion from Particular Sources

3.5.1 Control of Airborne FM

Sources and Consequences: Activities such as spray painting, sandblasting and/or grit-blasting, grinding, insulating, chemical cleaning, welding, and cutting generate airborne foreign material. Airborne dust, debris, or chemical fumes could be introduced into operating plant equipment, such as motors, switchgear, control panels, ventilation intakes, floor drains, and electrical cabinets. Airborne foreign material is extremely likely to enter plant equipment that is out of service for maintenance because those systems are often open.

Control measures: Airborne foreign material may be controlled by containing the source activity within tents, tarps or other barriers erected around the generating activity. This method has the advantage of limiting the impact on in-service or operating equipment. This method also eases the effort involved in clean-as-you go because the exposed area is limited.

Airborne foreign material may be prevented from entering open systems by proper use of FME covers, pipe caps or dams, plugs, and so on. Care should be exercised before choosing to install covers on operating equipment. An engineering evaluation may be needed because the openings in motors, switchgear, ventilation systems, drains and electrical cabinets often have a function such as cooling, flow control or pressure control.

If the ventilation in the area can cause dirt and debris to be introduced into the system/equipment, consider securing or redirecting ventilation, installing temporary filters on supply and exhaust ducts, or installing clean enclosures, such as glove bags or tents (with or without self-contained ventilation systems) at the work site or in adjacent areas.

3.5.2 Control of Deliberately Introduced Foreign Material

Sources and consequences: Activities such as injection method leak sealing, chemical cleaning, valve seat lapping, welding, grinding or grit-blasting inside components, certain nondestructive evaluation methods, inert gas blankets, and decontamination introduce foreign material into systems to meet a particular need.

It is particularly important to control debris from valves with hard facing. Stellite debris from activities such as valve grinding or lapping is of particular concern because those particles can represent a risk to fuel clad integrity. In addition, the particles can become highly radioactive after passing through the reactor and can subsequently increase radiation and contamination levels.

Control measures: The amount of leak-sealing compound injected should be planned and controlled. Experience has shown that if excess leak-sealing compound is needed to seal a leak, the excess leak-sealing compound is migrating to where it should not be. Engineering and supplemental personnel coordinators (contract coordinators) should perform or review any analysis prepared for leak sealant injections. The evaluation should include verification that the leak sealant will not enter systems (that is, the volume of the space being sealed vs. the amount of sealant being injected) and the potential impact on a system if breached. If the planned amount of leak-sealing compound is reached, work should stop and the condition should be re-evaluated.

Grit, welding/grinding debris, and lapping compound can be limited in extent by use of pipe dams or plugs to eliminate transfer to inaccessible regions. Experience has shown that vacuuming alone is not always sufficient to ensure material removal, especially in the case of lapping-compound residue. Wipes, flushes, or similar methods should be used to be sure that all grit and debris are removed to prevent their intrusion into the area, system, or component.

Chemical cleaning compounds and decontamination debris can be removed by flushing. The use of chemical cleaning should be limited to flushable areas, that is, the flush boundary.

When used to remove grit, lapping debris, decontamination products, or chemical cleaning compounds, flush considerations should do the following:

- Ensure that proper filters are installed
- Minimize the amount of piping required within the flush boundary
- Maintain an awareness of equipment in the flush path that is trapping debris

3.5.3 Use of Transparent Materials

Do not allow the use of transparent materials, such as visors, clear plastics, and tubing, within an FME zone unless they are conspicuously marked to improve visibility and tracking. Clear material entering a system is very difficult to detect and retrieve, especially if the system is water filled. Special evaluation and consideration should be given for the lenses of flashlights, cameras, binoculars, and so on before use around pools.



Key Technical Point

Do not allow transparent materials, such as visors, clear plastics, and tubing, to be used within an FME zone unless they are conspicuously marked to improve visibility and tracking.

3.5.4 Overhead Cranes

Overhead cranes travel over open systems and equipment, routinely creating the potential for foreign material intrusion. Good FME work practices should be used during overhead crane operations that are operated over or near FME zones. An inspection of the overhead crane, including crane rails, should be performed before its operation. It is recommended that the requirements of the FME zone that will be traversed should be implemented by the crane operator before its use. Appendix B, Overhead Crane FME Preoperational Inspection, provides an example of an overhead crane inspection checklist that should be used before crane operation over or near FME zones.

Maintenance work or other activities (for example, coating inspections on overhead cranes) should not be performed over an uncovered open reactor vessel or SFP. Loads that traverse an FME zone should be inspected to ensure that they are free of loose debris. If it becomes necessary to use overhead cranes over the reactor vessel or SFP, access should be controlled and the crane inspected for foreign material before use, and access of personnel, tools, and materials should be controlled as a high-risk FME zone.

Overhead crane controls should apply also to the refueling machine, spent fuel machine, and overhead hoists that are used in fuel-handing operations. An overhead crane inspection is recommended before use of this equipment. The overhead crane inspection should apply also to the turbine crane when it is being used to support turbine overhaul.

3.5.5 Water Sources During Outages

Filtered water sources for PWR, BWR, and CANDU units should be used during outages. Ensure that debris mitigation strategies are addressed when the water management plan changes.

Additional filtration strategies for BWRs can be used to minimize the potential for fuel fretting failures. These strategies include installation of filters on feedwater lines in close proximity to the reactor vessel. Strainers at the pump suctions for pump-forward heater drain systems can also reduce debris.

3.5.6 Documents in Work Areas as a Source of Debris

Secure all sheets of paper, such as procedures, work packages, drawings, and signage, used in and around open systems and components. Pages should be accounted for and secured by an approved method (for example, with a clipboard, notebook, colored plastic sleeves). Be aware that staples and paper clips have the potential to become foreign material.

3.5.7 Control of Welding Rods

Weld rods should be accounted for in the FME accountability log (when in use) before being brought into the FME zone. On job completion, be sure to account for each unused welding rod and used rod stub that was introduced into the FME zone. Collecting rod stubs in a bag or other suitable container immediately upon rod changes during the welding process helps to ensure that a stub is not accidentally introduced into the system or component. Store any special clothing (such as welding masks, goggles, welding gloves, and aprons) and other specialized supplies in an appropriate container in the FME zone when not in use.

3.5.8 Tools and Materials

Tools and materials are a major source of potential foreign material.

3.5.8.1 Staging Tools and Materials

Whenever practical, tools and materials should be staged outside the FME zone. Whenever possible, schedule tool, material, and spare parts requirements in advance and prepare a separate staging area for these items that is convenient to, but outside, the designated FME zone. The suitable staging area should be established outside of the FME zone to allow tools and materials to be staged when they are not actively being used in the FME zone, and activity in the staging area should not disturb or interfere with other concurrent work task performance. To the extent possible, introduce items into the FME zone only as required to support current work activities. Equipment/components should be inspected for loose, broken, or missing parts and foreign material before installation. On completion of use, collect these items and return them to the staging area as soon as practical. Minimizing the quantity of items available inside the FME zone reduces the potential for foreign material intrusion.

Ensure that an adequate supply of FME devices, including lanyards, is staged for use. Before creating a system breach, workers should verify that an FME device is ready and available to be installed before entering the area.

3.5.8.2 Inspecting and Securing Tools and Materials Used in FME Zones

Inspect tools for excessive wear or damage, loose parts, and parts that might fall off (for example, loose brush bristles, mushroomed chisel or punch heads, hammer heads, bolting, moving parts). Replace worn or damaged tools. Loose parts should be tightened, and parts that might fall off should be secured (for example, covered with tape or secured by other appropriate means). Tools and equipment that contain lead, steel, or other types of shot (for example, shielding, diver weight belts, dead blow hammers) that could come loose and become foreign

material should not be used in FME zones. Clean all tools entering the FME zone of all dirt, debris, and excess lubricant that could be introduced into the system or equipment. Portable tools, equipment, or hoses used in the transfer of material should have all openings covered when not in use to prevent entry of foreign material.

Tarps used as barriers and lead shielding might have grommets attached. Before the introduction of these items into an FME zone, they should be inspected to ensure that the grommets are in place and securely attached. If admitted to the FME zone, any deficiencies should be noted in the FME accountability log. On the items' removal from the FME zone, they should be inspected to ensure that all grommets are intact. Any deficiencies should be noted in the FME accountability log and the corrective action program for resolution. Some stations have installed tie wraps through grommet eyes to keep grommets in place. Not cutting the ends of tie wraps provides for a means of lifting the item and prevents the production of foreign material.

As required, secure all tools, materials, and equipment before introducing them into the FME zone through lanyards or other acceptable means. All tools used over open water or fluids should be attached by a lanyard or other acceptable retention methods. All installed tooling over open water should be secured using redundant methods, including appropriate knots and fastening systems that will ensure that if the primary lanyard loosens, the device will remain controlled. Figure 3-9 shows methods that can be used to secure tools. Tools, materials, or other items that are dropped should be documented in a drop log for tracking and resolution.



Figure 3-9
Methods for securing tools

3.5.8.3 Accounting for Tools and Materials

Include material and tool accounting within the work document or turnover process. When an FME accountability log is being used, tools and materials should be logged in and out of the FME zone in accordance with the plant's FME procedure. An example of an FME accountability log is shown in Appendix E, FME Accountability Log (Example).

3.5.8.4 Unpack Items Before Entering the Work Zone

Packaging and similar materials should not be taken inside the FME zone unless absolutely necessary. As a general rule, unpack and properly dispose of unnecessary packaging and shipping materials before transporting the items to the work site if such action does not expose delicate or fragile items to increased risk of damage. Likewise, where packing and shipping materials need to remain intact to protect such items while at the work site, remove such packaging before introducing the items into the FME zone. Where some packaging must remain to contain or protect small or delicate items until their point of use, collect and remove that packaging from the FME zone as soon as practical. Packaging that serves as protection for extremely sensitive components or containers for small items that might otherwise easily become lost is considered acceptable inside the FME zone.

3.6 Methods to Prevent Foreign Material Intrusion During Particular Activities

3.6.1 Grit-Blasting Surfaces

Before beginning grit-blasting operations, inspect the general area, especially any system, component, or equipment openings into which foreign material generated from the operations could be introduced. Pay particular attention to the location of any vents, drains, gratings, or intakes where foreign material entry could occur.

Use covers and covering materials as necessary to contain foreign material in the immediate area and to protect specific equipment and components from foreign material contact.

Upon completing grit-blasting operations, thoroughly clean the local area of remaining foreign material, using appropriate means. Be sure to wipe down all equipment, equipment access covers, and flanged and other system openings that might have contacted grit-blasting residue to reduce the chance of foreign material intrusion when the system, equipment, or component is next operated or opened.

3.6.2 Pipe Cutting

For pipe cutting on vertical runs where grit and cutting debris might be difficult or impossible to remove, consider using the blue line or roller-cutting method. In this method, shown in Figure 3-10, a ring of pipe wall circumference is progressively ground away, but not completely so. Eventually, the pipe wall becomes so thin that heat generated by the grinding operation turns the metal blue in color. At this stage, the remainder of the pipe wall is cut using a chisel to prevent any cutting debris

from entering and getting lost inside the vertical run of pipe. Once the pipe has been cut, install an FME device to prevent foreign material from entering the system. When two cuts in a vertical run need to be made, cut the lower one first, and then install a sheet metal cover over the opening to the pipe below before cutting the upper cut.

For pipe cutting on horizontal runs, grinding or band-saw cutting is acceptable, provided that filings and other generated debris can be contained or removed upon completion of the cutting task. Before subsequent pipe end preparation (for example, weld end preparations), use suitable covers, plugs, caps, or seals to prevent entry of foreign material.

Use of these methods will minimize entry of debris into the system, but a complete FME plan should provide detailed cleanup of residual debris, inspections, and flushes as necessary to capture everything.

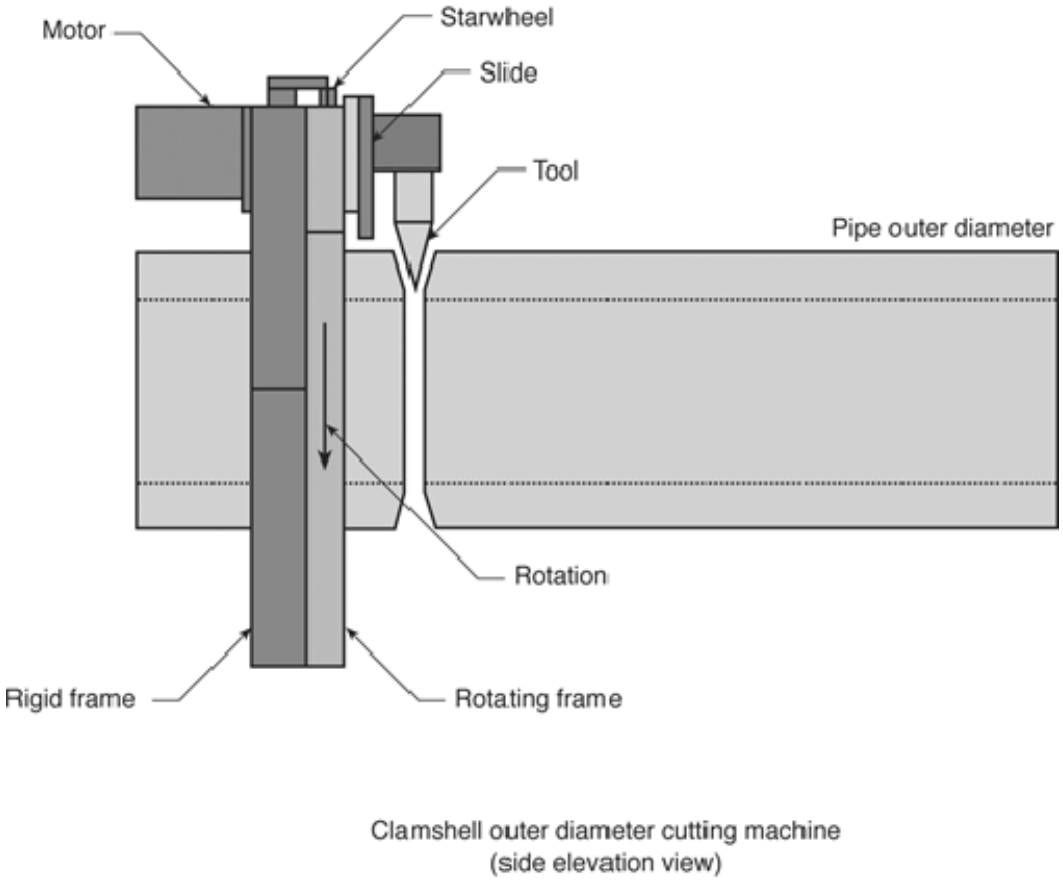


Figure 3-10
Pipe roller cutting method

3.6.3 Compliance with the Chemical Control Program

Make certain that all chemicals or chemical compounds introduced into the FME zone comply with plant guidelines and the plant chemical control program, if applicable. Consider alternative chemicals, such as water in lieu of metal cutting coolants, to avoid the introduction of unapproved materials into systems. Unapproved chemicals and oils can become foreign material in a system.

Inspect hoses and hose fittings for foreign material during bulk chemical deliveries (for example, acid, caustic, biofouling chemicals, diesel fuel oil, and so on) before connecting to plant systems. Fitting covers or FME devices should be installed on hoses when not in use. Bulk chemical deliveries should also be sampled and analyzed to ensure that they are acceptable for plant use.

3.6.4 Work on or Near Hydraulic Fluids

Hydraulic systems are vulnerable to contamination from three distinct sources. Sources of contamination include the following:

- Built-in contamination that is the result of the initial fabrication and assembly, in the form of weld slag, pipe thread burrs, machining chips, and assembly lubricants. Other contaminants, such as coatings and thread sealing tape, might become evident after many years of service. Proper filtration is needed to remove some of the particles to minimize this effect.
- Contamination that enters the system during maintenance and service or is introduced into the system from the surrounding environment. The most common ways are during fluid replacement or from within the fluid storage vessels. Clean hoses with adequate filtration should always be used during the filling process. If a hydraulic system is opened, appropriate pipe sealers should be used. Reservoir access covers should be cleaned with a suitable agent before removal and replacement. Breather caps should be inspected to ensure that they include air filters and moisture separator components.
- Internally generated contamination that is the result of the moving parts of the system. This contamination results from wear and abrasion. Proper filtration is needed to remove some of the particles to minimize this effect.

Workers should do the following:

- Preclean the area and exercise caution when removing fill or sample ports and sight glasses.
- Ensure that all sample equipment is free of dirt and debris when taking oil samples.
- Ensure that containers and hoses are free of debris before use.

3.6.5 Bulk Material Receipt

A typical nuclear site receives a variety of bulk liquids to support plant operations. These products include fuel oil, hydraulic oil, and various chemicals. These products might arrive on site in barrels, tanks, or tanker trucks that transfer their contents to an on-site tank or other holding facility. Receipt of these materials could be a potential source of foreign material to systems, equipment, and components that use them. FME controls should exist to ensure that systems/ equipment/components are not contaminated. The following points should be considered:

- The incoming material should be checked that it is being added to the correct tank to prevent undesired chemical reactions which could be dangerous.
- Bulk material itself might contain debris that entered at the source.
- Vendor-supplied hoses might contain debris.
- Hoses might be contaminated if FME controls (for example, FME caps, covers, plugs) are not installed.
- Pump skid rigs could contain debris if not properly maintained with FME devices.

Bulk materials received from vendors should be sampled to ensure that they meet site specifications before being pumped into the holding tank. Materials that are received in barrels or other containers should be sampled before their use in the plant. Water standing on barrels could be introduced into the fluid as the barrel breathes with changes in environmental conditions. These materials should also be stored properly to prevent possible foreign material intrusion, with their covers, caps, or plugs in place.

3.6.6 Equipment Lubrication or Greasing

The FME considerations when lubricating or greasing are to use the correct material and not use excessive amounts. If the amount is excessive, the lubricant is likely migrating to the wrong location and will be foreign material.

Monitor lubricant application to ensure that the amount of lubricant dispensed is generally within the expected range for the particular application. Inspect equipment, where possible, after lubrication or greasing to ensure that any excess lubricant has not passed beyond its intended point of application and will not do so when the lubricated equipment is subsequently operated.

3.6.7 Coolant and Solvent Use

Make sure that chemical handling procedures are in place to control material usage. Limit the use of cutting coolant fluids and solvents to ensure that fluids do not become foreign material or a safety hazard.

3.6.8 Using Wire Wheels and Brushes

Wire (metallic) wheels and brushes in the past were widely used for routine maintenance activities for many years. Wires/filaments from wire wheels and brushes can separate from these tools during normal use and during inappropriate use. The wires/filaments have been known to cause fuel failures (and other failures such as valve damage) when they are transported to the reactor and become lodged in a fuel assembly. Over time, the wire filament, which undergoes flow-induced vibration, wears through the fuel cladding and results in a small fuel leak.

Research has identified good alternatives that avoid generating debris from wire wheels and brushes [2, 3].

Special consideration should be made before using wire wheels and wire brushes. The wire strands can separate from the wheels and brushes and might become a source of foreign material that migrates into adjacent FME zones if proper controls are not maintained. Wire wheels and brushes should not be used in high-risk FME zones (see Section 3.2.1.2.1, High-Risk FME Zone). Wire wheels or wire brushes should not be used on the RCS/PHT or any of its components, unless specifically approved and controlled. Their use should also be prohibited on any systems that interface with the RCS, unless specifically approved and controlled.

Nonmetallic (polymer) brushes should be used instead of wire brushes. Sites are encouraged to evaluate and consider the use of nonmetallic brushes to reduce the probability of wire brush filament-related fuel failures. Polymer brushes do have temperature limitations, and their cleaning effectiveness is limited in some applications.

In the event that wire wheels or brushes must be used, the following should be discussed in the FME plan:

- The use of wire wheels and brushes on the RCS, related components, and systems that connect to the RCS should be evaluated and approved before use.
- FME devices should be installed to prevent foreign material intrusion from bristles.
- Thorough closeout inspections should be performed following their use.
- If wire wheels or brushes are used in areas adjacent to high-risk FME zones, barriers or tents should be used to capture brush filaments or wires.

The following are general operating practices to follow when using wire wheels or brushes:

- Inspect wire brushes and wheels for loose bristles before use.
- Operate the wheel or brush with light pressure. Let the tips do the work. Heavy pressures cause overflexing of the wire, which shortens its life and causes loss of wire/filaments.
- Wire wheels are generally designed to be used in one direction only. Wheels should be used as designed as an additional measure to prevent loss of wires or filaments.
- Vacuuming directly in the area of wire brush use during wire brushing can assist in controlling debris generated and loss of wire bristles.
- The maximum wire extension should be no longer than 3/8 in. (9.5 mm) to minimize wire flexing.
- Use the face of the brush. Applying pressure to the side or the edge of the brush will result in wire/filament breakage and shorten its life.

3.6.9 Installing and Removing Gaskets

Extra care should be exercised when removing gasket material. Depending on the type of gasket, removal could create a debris problem. A metallic crush-style gasket is made of thin, accordion-like plates that could break into lengths of wire-like material. If a gasket is overcompressed, incorrectly sized, off center, pinched, or unevenly compressed, the tack welds that hold the wire wraps together might fail and release into the system. Composite material gaskets, such as asbestos, are fibrous and can break down into small pieces. Care should always be exercised to remove the gasket in as large a piece as possible.

When gaskets are replaced in piping systems, the use of wire-wound gaskets that have a high potential to degrade and release wire debris should not be used. Do not use wire-reinforced gaskets or packing. When the wire-wound spiral gasket is used, it should be of the type that has both the inner centering ring and the outer ring. Gaskets with inner and outer rings are less susceptible to radial buckling and prevent the release of gasket material if the gasket degrades. Figure 3-11 provides an example of a spiral-wound gasket with both inner and outer rings.

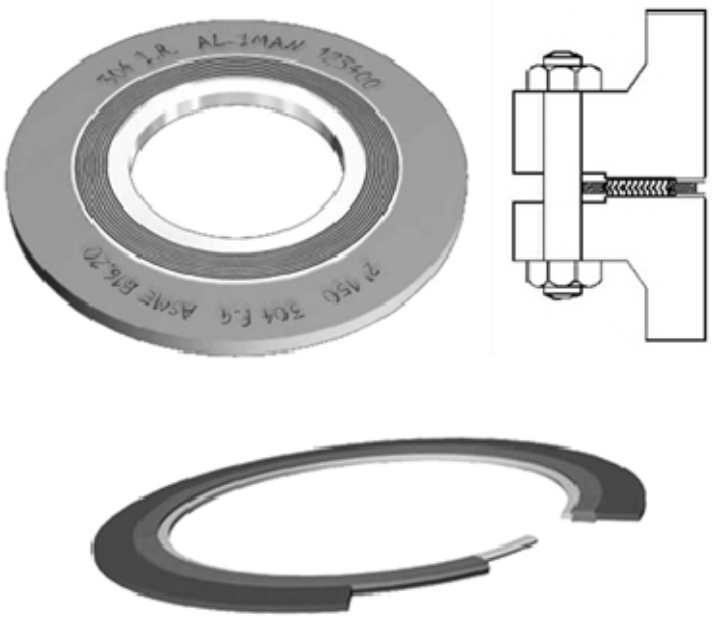


Figure 3-11
Spiral-wound gasket with inner and outer rings

The use of wire wheels is promoted by gasket sheeting materials that have a tendency to strongly adhere to mating surfaces. Stations should consider gasket materials that release easily from surfaces during replacement activities.

If temporary systems are used during outage periods and the temporary systems have a direct connection to the RCS/PHT or steam generators, proper gaskets should be used.

3.6.10 Working on Bearings, Journals, and Seals

Bearings, journals, and seals are all items that operate under tight clearances. Even the smallest foreign material can easily affect these close tolerances. Because of this, it is important to exercise excellent FME practices when working with components containing these items. When greasing bearings, preclean grease fittings and ensure that the grease gun injection tip is free of grit and debris.

3.6.11 Flushing Systems or Components

System cleanliness should be a plant lifetime evolution, through design, operation, and maintenance. The prevention of debris or chemical contamination and the maintenance of system cleanliness are essential to long-term system/equipment/component reliability. A tool for accomplishing this goal is the flush. Flushes can be performed on a variety of systems/ equipment/components, transporting a wide range of fluids (for example, oil, air, water, steam, chemicals). The objective of the flush is to remove all detectible foreign material from a system/equipment/component.

The most efficient method of maintaining system/equipment/component cleanliness is effective implementation of the FME process by precluding foreign material intrusion into system/equipment/components during work activities. These methods are described throughout this report (for example, FME devices, housekeeping, work practices). The success of a flush depends on the efforts taken to keep debris and foreign material out of the system/equipment/component and the proper conduct of the flush itself. A successful flush will meet cleanliness acceptance criteria with minimum time and effort.

Maintenance personnel routinely replace equipment, components, and parts. Maintenance personnel should not assume that new equipment, components, and parts or vendor-overhauled equipment, components, and parts are free from debris. Both pre- and postinstallation inspection and flushing should be evaluated and used as necessary.

General guidelines for flushing include the following:

- Flushing can be performed on equipment before installation (bench flushing) or after installation, depending on requirements and configurations.
- Bench flushing should be performed on equipment for which it is difficult or impractical to determine internal cleanliness without complex disassembly or complex plant flushing operations.
- Flushes should take place before system operation.
- The pump (the motive force for the flushing agent) should provide sufficient flow to ensure turbulence.
- Depending on the system/equipment/component, the flushing medium might be heated to enhance flush performance (for example, oil system flushes).
- Vibration techniques can be used to loosen solids attached to pipes, tanks, or other components.
- Flushing times will vary based on system/equipment/component size and the level of cleanliness required.

3.6.12 Working in Shops or Fabrication Areas

The clean-as-you-go concept should extend to all plant facilities, shops, and offices. Shop and bench practices should follow FME concepts and practices. When materials are received in the shop from warehouses or storage, FME devices should be present and installed. Pay particular attention to identifying internal FME devices and applying an external identification device as appropriate. If these devices are not present, the equipment or component should be completely inspected to the extent practical, and FME devices should be installed on completion of the inspection before installation in the plant. When items are returned to the warehouse, FME devices should be routinely installed. When equipment and components are stored in the shop, they should be protected with appropriate FME devices. FME devices should remain intact on the equipment or components during transport. The FME devices should not be removed until just before installation. It is preferred that the FME devices be removed outside the FME zone to prevent the devices from becoming foreign material. It is also important to note that some FME devices are internal to the equipment or component and require a second verification of removal. A thorough inspection of possible internal FME devices should be performed to prevent future equipment damage.

If an FME zone is established, verify that the level of controls specified in the work order or FME plan is correct.

3.6.13 Working in Electrical Cabinets

Ensure that all electrical enclosures are free of foreign material at the end of each work task. Such obvious materials could include wire strippings, wire connectors, mounting screws, and tie wraps. Electrical cabinets should be closed when there is no work in progress. Cabinets should not be used as storage space for spare parts (for example, fuses, light bulbs, rags) or drawings.

3.6.14 Preventing Your Job from Creating Foreign Material Intrusion into Other Areas

When working on or above gratings, work platforms, or scaffolds, use suitable precautions to prevent the introduction of foreign material into other work areas. The use of Herculite or a similar approved material can be used for this application. Stairways that traverse over or adjacent to work areas should have tarps suspended beneath them or other suitable barriers to prevent foreign material intrusion. If cable tray work is occurring above or near FME zones, precautions should be taken to prevent foreign material from entering the FME zone (see Section 3.2.1).

3.6.15 Protecting Adjacent Equipment

Take precautions to avoid affecting other permanently installed material or equipment in or near the work area from possible foreign material intrusion by covering it as necessary. Protect any openings in which welding slag, cutting/grinding debris, grit, dust, inclement weather, or other conditions would affect cleanliness during work activities. Ensure that the FME device does not affect the safe operation of adjacent equipment.

3.6.16 Working with Bulk Storage Tanks

Storage tank access openings should be covered with an FME device when the tank is unattended. Consider the need to erect a tent over an opening in the top to prevent rain, leaves, or other airborne foreign material from entering. If FME devices are installed on tank vents, it is recommended that they be made of mesh material to provision for the possibility that they will be left installed inadvertently. This will prevent a tank implosion if the internal pressure drops (for example, from a temperature decrease in the tank fluid). Figure 3-12 shows damage to a storage tank caused by the tank vent being blocked.



Figure 3-12
Storage tank damage

Tanks and their liners and bladders should be inspected on some periodic basis. Tanks might have coatings, liners, bladders, or other items or materials that over time become a source of foreign material. Even the material or substance stored in the tank could become a source of foreign material. Maintenance inside tanks has the potential for foreign material intrusion. Foreign material can come from coatings, sandblasting activities, tools, materials, and so on. During maintenance activities inside storage tanks, FME devices should be installed on all penetrations (for example, inlet, outlet, drains, vents, instrument taps). Bottoms of tanks should be inspected for unexpected debris buildup when opportunities exist.

FME devices installed on storage tanks when personal access for internal maintenance activities will be required should consider mesh covers to prevent the buildup of harmful gases. Ensure that FME practices do not compromise confined space requirements. If FME devices are installed on tank vents, it is recommended that they be made of mesh material to provide for the possibility that they will be left installed inadvertently.



Key Technical Point

If FME devices are installed on tank vents, it is recommended that they be made of mesh material to provide for the possibility that they will be left installed inadvertently.

The FME considerations previously provided should be applied rigorously to tanks, pools, or other water sources that interface with the RCS (PHT). These tanks include the following:

- Refueling water storage tank
- Primary water tank
- Demineralized water tanks (demin tanks)
- Safety injection tanks
- Borid acid makeup tanks
- Volume control tank
- Condensate storage tank/pool
- Boric acid holding tanks (if boric acid is reclaimed)

4
KEY INTERFACES WITH OTHER STATION PROCESSES AND PROGRAMS

Among the key interfaces are the following:

- Work control process (including outage planning, scheduling, and work prioritization). For maintenance and design change activities, the FME process is entirely embedded within the work control process, and the FME process works best when the steps in the FME process are coordinated in advance of the day of execution in parallel with the normal planning and scheduling activities in the rolling 26-week (or outage planning) schedule.
- Procurement, supply chain and vendor practices controls (including purchasing, inspection, warehousing, transport).
- Operations, including chemistry, health physics/radiological protection, security, oversight, and other activities.
- Corrective action process (notification and assessment of loss of FME control or improvement opportunities, prioritization, recovery planning).
- Management processes (FME process performance indicators, tracking of system degradations, management support).
- Housekeeping processes, chemical control processes, and lubrication processes.

4.1 Procurement, Supply Chain, and Vendor Practices Controls

Warehouse FME practices should be developed to support in-plant FME practices. Warehouse FME practices should emphasize prevention and not rely on inspection and removal of FME at the time of material issuance. Materials supplied by vendors and manufacturers should be ordered with contracts that specify that FME requirements be used. The procurement engineering group should develop FME specifications for various types of equipment/components or vendor activities that might be performed on their site. When materials are delivered to the plant, they should be inspected to ensure that FME requirements are met and that FME devices are installed. Receipt inspections should be performed using site FME program guidelines. If materials arrive without installed FME protection, appropriate FME inspection and controls should be put in place. Failure to meet FME requirements should be documented in the corrective action program and the vendor/supplier should be notified.

Additional warehouse considerations that should be observed by supply chain personnel include the following:

- General housekeeping in the warehouse should meet site standards. The warehouse should be kept free of debris and other foreign material. Inspections for cleanliness should be conducted on a continuing basis to ensure that program requirements are being met. Trash should not be allowed to accumulate in receipt or material storage areas.
- Materials should be properly stored and maintained until installed or returned to the warehouse. Materials that are returned to the warehouse should have the proper FME devices installed after a thorough inspection.
- Ensure that materials in storage have all required FME devices installed and intact. If it is necessary to remove an FME device for internal access or inspection, remove the device, perform an inspection, and reinstall the FME device immediately.
- FME devices used should be consistent with plant requirements (see Section 3.4, Design, Types, and Use of FME Devices).
- If an internal plug is used that will allow reassembly without removing the plug, a label should be affixed to the pipe noting the installed plug. The plug should be recorded in the FME accountability log, and a concurrent verification of removal is required.
- Before sending equipment off site for service or repair, proper FME controls should be considered. Ensure that the equipment is properly packaged for transportation, FME devices are installed, FME considerations are in place for transit, and controls are in place while the equipment is at the service facility.

4.1.1 Equipment Protection During Transit

Review the equipment handling and transportation methods against the plant FME program, and resolve any FME concerns and special considerations with the freight company. Work with them to identify potential sources of FME concern and to develop an off-site FME management plan acceptable to both the freight company and the utility.

4.1.2 Instructions for Service Companies

Review the equipment maintenance plan, plant FME program, and any FME concerns with the service organization or vendor responsible for servicing or repairing the equipment. Work with them to develop an off-site FME management plan acceptable to both parties. During quality assurance assessments of approved vendors and suppliers, FME practices should also be assessed.

4.1.3 Preservice/Postservice Inspections

Consider implementing a preservice and postservice inspection of the equipment. This should ensure that there was no foreign material intrusion into the equipment while it was off site.

4.1.4 State FME Instructions in Service Contracts

In the purchase order or contract, consider implementing FME control requirements that specifically address FME expectations.

4.2 Design Engineering FME Considerations

Good engineering design can enhance the ability to control foreign material or mitigate the consequences of an FME event. FME considerations should be incorporated into the design process. This will typically occur in the design modification process, but it should also be incorporated into future plant designs. Engineered design controls might be hardware, software, and equipment items that could affect people's behavior, choices, and attitudes.

Engineering design controls can be active or passive. An active control would involve a design in equipment that typically has moving parts. This could involve pumps or valves with better materials that would be less prone to degradation through wear or corrosion. A passive engineering design might include pipes or vessels. An example is a sump design that prevents the introduction of foreign material to the suction of safeguard pumps. Passive engineering designs are typically the most reliable because they require little to no operational or maintenance support to be effective.

Examples of how engineering design can benefit the FME process include the following:

- Incorporate potential FME impact on systems and equipment into engineering design packages.
- Prepare design equivalent documents to use components that are of less foreign material intrusion concern.
- Provide engineered FME controls to FME plans when required.
- Prepare procurement specifications that include FME requirements for vendor-supplied equipment/components and services.
- Review PM requirements and ensure that they take FME principles into account, especially with respect to system/equipment/component wear and degradation.
- Review FME trends of equipment degradation for potential design changes.
- Establish a performance-based fuel fabrication inspection/audit program to verify that FME standards and sound manufacturing practices are maintained.
- Establish a thorough and comprehensive fuel receipt inspection program.

4.3 Operations Including Chemistry, Health Physics/Radiological Protection, Security, Oversight, and Other Activities

For operational activities, the FME process should be embedded in the operational guidance provided to personnel. For example, if an operational need places operators in the vicinity of an open system (for example, the spent fuel pool during routine rounds), then the operational procedures and practices should recognize the FME risk level and provide appropriate preventive actions to preclude the operators from introducing foreign material.

Because operations and chemistry personnel often add chemicals or lubricants to operating systems, procedures for such activities should also address FME requirements.

This need to provide guidance to personnel extends, of course, to nearly anyone who can enter the plant and perform activities. Quality assurance personnel need to understand the requirements for entering FME zones in the conduct of their work. Health physics personnel need to follow good FME practices when conducting surveys near open components or systems. Managers conducting observations need to remove personal effects before entering FME zones and secure their personal protective equipment and badges just like the supplemental workers they are observing.

4.4 Training

Because the FME program is a site-wide program, training plays a key role supporting FME process effectiveness. Based on local management's allocation of FME tasks to different people, those people need to understand and be capable of correctly executing their assigned tasks. The systematic approach to training should be applied to produce this outcome. It is not likely that maintenance department personnel assigned FME coordinator tasks are also training professionals; therefore, most stations will find that the highest quality training will be achieved by using the training department appropriately, with priority given to FME training balanced with other management objectives via line-driven curriculum review committees or similar function.

This guide does not prescribe any particular training for any particular individual or group. The systematic approach to training, if applied correctly, will establish training requirements, including who gets trained, on what content, using which training techniques. Once the training for FME is first established, FME process monitoring and using the corrective action process will inform FME process owners (typically, FME coordinators) when to change or improve training requirements.

Many stations have established a qualification requirement for particular FME roles, ensuring that individuals filling those roles are qualified. Use of the learning management system to track and control individual qualifications is also a common training department process that may be used to allow FME process owners to improve process performance over time.

Appendix K, FME Training Elements Based on FME Process Roles, contains common practices regarding how stations have assigned different training to different groups of people, typical training program content, and suggested training methods specific to particular skills and knowledge.

4.5 Corrective Action Process/Performance Improvement Process

The corrective action process/performance improvement process is fundamental to any process owner's tool kit. Like the training function, these functions generally are well understood, and it is not the purpose of this guide to reproduce those functions in detail. Instead, it is important for FME process owners to use the corrective action process effectively.

4.5.1 Use of the Corrective Action Process When FME Integrity Is Lost

As stated in Section 2.6.1, any person who identifies a loss of FME integrity should stop work progress, place the system or component in a safe or secured status, and notify supervision. It is at that point that a graded approach to the next steps can be applied. Writing a condition report at that point initiates an appropriate thought process that considers the risks involved with the condition, and responds appropriately. Importantly, because the precise circumstances of an event cannot be predicted in advance, the corrective action process involves the correct people, at the appropriate level of management, in ensuring the actions to be taken from that point on are positively controlled.

FME process owners should then ensure that the actions taken to correct the particular instance preserve the goals of the overall FME process, while preventing future similar events as appropriate. This is a management judgment involving a graded approach to prioritize nuclear safety, while preserving efficient use of limited resources.

4.5.2 Use of the Corrective Action Process/Performance Improvement Process for Continuous Improvement

Any process flaw short of a loss of FME integrity may be documented using a condition report or similar input into the corrective action process. The advantage of this for FME process owners is that data on process quality can be collected and trended over time. Use of a standard form for collecting these data is easy to remember for most personnel. The resulting trends act as a leading indicator of process effectiveness (see performance management section).

FME process owners should also use the station's performance improvement process to provide opportunities for continuous improvement. Generally, peer or management coaching programs, benchmarking opportunities, and self-assessments are tools that can rapidly identify useful improvements and drive change. Participation in the FME industry working group is strongly advised for FME coordinators and FME process or program owners.

4.6 Management Processes: Performance Monitoring

As with any successful program, a mechanism to consistently measure program health is essential. In addition, the program should have a mechanism to identify program weaknesses or deficiencies. This is accomplished through performance monitoring. Performance monitoring involves collecting data, analyzing the data, and then responding to the resultant information. The corrective action program should be used as the vehicle for gathering data on the FME process. The ultimate goal is to establish continuous program improvement. Appendix J, FME Program Health, provides additional information related to program refinement.

4.6.1 Metrics

Key performance indicators are metrics used to quantify objectives to reflect the health or performance of an organization. Metrics are based on and defined by significant events and vulnerabilities to a program's health. When choosing metrics, make sure that they are specific, measurable, achievable, results oriented, and time based.

Industry standard metrics are specified in INPO 07-008 and are not repeated here.

4.6.2 Assessments

Periodic assessments should be performed to determine the overall health of the program. The assessment of the program should be performed on both programmatic attributes as well as behaviors. A typical assessment should include the following areas:

- Program, ownership, and expectations
- Maintenance work practices
- Management and supervision
- Training
- Supplemental personnel
- Self-assessment and benchmarking

Typical questions that support the listed areas are provided in Appendix I, Typical Assessment Questions to Support Continuous Improvements.

4.6.3 Trending

Corrective action program trends can provide a valuable source of information with regard to the ongoing health of the FME process. As a minimum, trend codes should be developed around FME metrics (see Section 4.6.1). The results should be evaluated and trends developed on a periodic basis. This constitutes an accurate lagging indicator of program performance.

FME trending can be performed on other data sets. Coaching or observation data and low-level corrective action reports prioritized “trend only” or cause coded per the below criteria have been used effectively to produce a sort of leading indicator of process effectiveness. Additional areas might include the following examples:

- FME causation group trending (for example, housekeeping, logging, dropped items)
- FME events by equipment type (for example, turbines, valves, motors)
- FME events by organizational responsibility

Examples of these trends and other trends that can be used are provided in Appendix J, FME Program Health.

4.6.4 Observations and Coaching

A well-implemented coaching (observation) program is a valid component for determining the overall health of a program. Evaluation of trends through the corrective action gauges program health over a relatively long period. An observation program, on the other hand, can reveal subtle behavioral shortfalls that occur during work task performance on a nearly real-time basis. The observation program should have specific guidelines describing the proper behaviors to the observer to ensure that effective coaching can be provided when required. Observation results should be trended to identify subtle program performance problems and drive continuous improvement. The results should be used to improve procedures and training.

4.6.5 Off-Site Vendors

Work performed by vendors off site should adhere to the same FME standards as those expected to be used on site. Material suppliers should also possess FME programs that meet or exceed site FME standards. During the procurement process, vendors/suppliers should be informed of site FME standards and expectations; these should be included in the procurement documentation/ contract. During receipt inspections, supply chain personnel should perform thorough inspections that include FME controls. Any deficiencies identified should be placed in the corrective action program and the vendor/supplier should be notified of the deficiency. Quality assurance personnel should also assess vendor/supplier FME programs during inspections and audits performed on approved suppliers.

4.6.6 FME Program Health

FME program health reports can be an effective tool for determining overall FME program effectiveness. The FME program health reports can also serve as an effective communications vehicle of site FME program implementation to station personnel. In addition to trending information related to FME program attributes, other information related to the FME program can be disseminated. Items that might be included are the following:

- Significant events or conditions, categorized either by frequency (for example, those that occur at the site in a given quarter or year) or by type of activity (for example, refueling outages)
- Recent FME improvements (for example, FME program expectations, procedure changes, engineered FME barriers)
- FME training (for example, training schedules, lessons learned)
- FME steering committee/working group/peer team activities
- New FME products or tools available for use
- Pending FME issues or activities (for example, upcoming refueling outages, self-assessments, equipment issues, program issues)

4.7 Housekeeping Process, Chemical Control Process, Lubrication Processes, and Other Processes

The common-sense understanding of what foreign material is (anything that does not belong inside a system, structure, or component) includes dust and leaves blown into the turbine building, putting the wrong bulk chemical in a bulk storage tank, or the wrong fuel in an engine, the wrong grease in a bearing. Traditionally in the United States, utilities have defined separate processes to control these issues, and deficiencies in these processes have not necessarily been tracked as FME issues. Elsewhere in the world, cleanliness and purity criteria of all kinds have been grouped closer together and FME has been an allied subset of these cleanliness controls.

What matters is that plant activities should be carried out to prevent the wrong stuff from being in the wrong place. It does not matter fundamentally whether we call contaminating the lube oil in an emergency diesel generator an “FME issue” or a “lubrication” issue. The terminology is a matter for local management to decide, and as long as there are no substantial gaps at the

interface between “what foreign material is in the lube oil” and “what contamination is in the lube oil,” we can be assured that if something is wrong with the lube oil, we know about it and will fix it appropriately. FME process owners should keep these interfaces in mind when benchmarking because other stations may have a different (maybe better!) way of tracking the issues.

4.8 Exempted Plant Activities

It might be useful to exempt some items from the FME process based on site-specific needs. When determining whether to exempt items from the FME process, the risk associated with the determination should be based on acceptable safety and performance judgments. The areas, activities, or processes exempted should be clearly defined, documented, and understood by all personnel associated with FME process activities (for example, items to be scrapped or disposed of).

5
GENERAL GUIDANCE FOR MAJOR COMPONENTS

This section contains general guidance covering FME considerations for several common major components found in most nuclear power plants. These guidelines are not meant to be specific because plants vary in design and layout. Rather, the intent of this section is to emphasize the use of prevention and recovery concepts during the formulation of a plan.

5.1 FME and Fuel Integrity

Key O&M Cost Point

Debris is a major cause of fuel element failure in both BWRs and PWRs. A single fuel element failure can cost millions of dollars in replacement energy costs, outage costs, and replacement fuel. Fuel element failure causes increased contamination and radiation levels that require additional O&M expense.

Loss of fuel clad integrity results in higher fuel costs (replacement or repair) and increased contamination and radiation levels that require additional O&M controls. An effective FME process, sound maintenance practices that reduce the introduction of foreign material into systems and equipment, and a dedicated commitment to remove debris that already exists in plant systems and equipment help prevent foreign material from entering the RCS with a resultant loss in fuel clad integrity. Figure 5-1 provides examples of fuel clad damage caused by fretting.

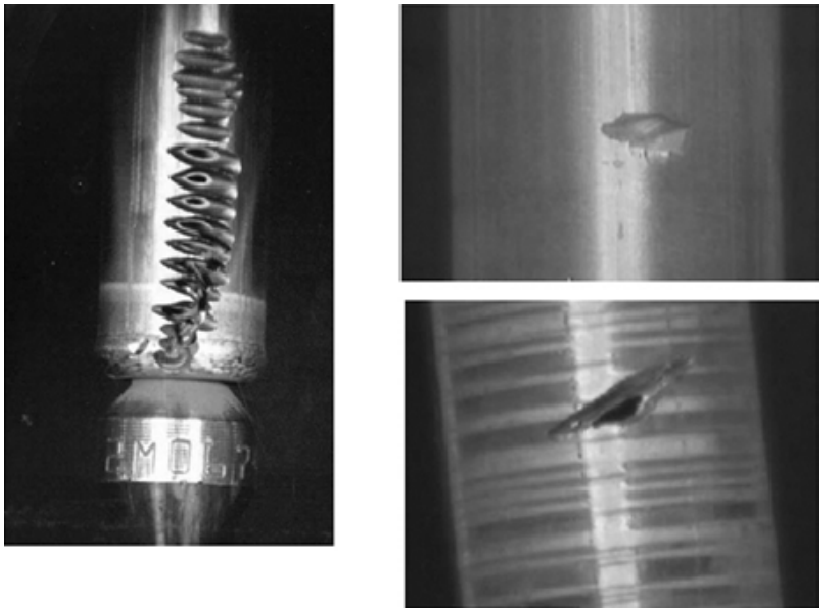


Figure 5-1
Fuel damage resulting from fretting

With respect to fuel performance, an effective FME program should do the following:

- Establish FME zones and accountability requirements for any work performed on the RCS/PHT or any systems that interface with the RCS/PHT.
- Allow only approved materials and chemicals for use on the RCS/PHT or systems that interface with the RCS/PHT.
- Establish standards of cleanliness and require inspections before and after work on the RCS/PHT and systems that interface with the RCS/PHT.
- Ensure the cleanliness of any new equipment/components installed in the RCS/PHT or systems that interface with the RCS/PHT.
- Use system flushes to prevent the transport of debris into the vessel after maintenance.
- Control any work that involves cutting, grinding, or other debris-generating activities over or near any fuel storage locations (for example, the SFP, new fuel storage).
- Develop work practices and engineered FME defenses to prevent foreign material intrusion during work activities.

5.1.1 Refueling Outage Activities

Refueling outage activities present the highest risk of foreign material being introduced into the primary systems of nuclear plants. This is because many systems are opened, and a complex array of activities are simultaneously taking place. PWRs, BWRs, and CANDU reactors have systems that provide a direct path to the RCS/PHT (for example, SI, residual heat removal, shutdown cooling). FME plans should include appropriate FME controls on all systems providing a direct path to the RCS/PHT. Maintenance on open systems or equipment that directly connect to the RCS/PHT should be designated high-risk FME zones (see High-Risk FME Zone section).

From the receipt inspection of new fuel to the last system walkdown, the nature of the refueling outage work results in many maintenance activities and inspections that are performed in a short period. Depending on the intrusiveness of the work, a wide variety of FME controls need to be established that are specific to preventing foreign material from entering the refueling cavity, pools, and primary systems during the conduct of refueling operations.

Plans for FME controls for refueling outages should be in place before starting the outage. These plans will ensure that appropriate FME controls are established and applied as different work groups move through the various stages of refueling activities. Arrangements should comply with general site FME requirements, or it might be necessary to develop unique material or personnel logs and establish personnel responsibilities applicable to the work to be performed.

Foreign material visual inspections and cleaning should be performed for areas that are not normally exposed during outages, when reactor internals become accessible. See References 5 and 6 for additional guidance regarding when to perform under-core support plate inspections in accordance with the overarching priority of preventing fuel failure due to debris.

5.1.2 Refuel Floor Activities

The concern on the refuel floor is protecting the reactor pressure vessel and reactor pressure vessel cavity, SFP, dryer separator pit, fuel transfer canals, and the fuel from adverse chemical and metallic foreign material intrusion. Historically, fuel fretting failures have been caused by ribbon- or wire-like metallic elements that get trapped in the fuel bundle and fuel bundle support arrangements. Because there is a high potential for foreign material intrusion into the areas previously listed, these areas should be designated high-risk FME zone. Laydown areas for major reactor components should also be designated high-risk FME zone if feasible. If it is not possible to designate these areas as high-risk FME zones because of physical restraints or impeding work activities, the reactor components should be thoroughly inspected before moving to the reactor area for reassembly.

Electrical or other work on fuel handling equipment may have special FME considerations (see Section 5.2.7).

Because fuel assemblies and other components might be returned to the reactor vessel, the SFP should be considered a high-risk FME zone. Some additional considerations to make with respect to the SFP are the following:

- Limit the amount of time that materials that generate debris (for example, filters) are stored in the SFP.
- Clean SFP and new fuel storage areas before commencing refueling outages.
- Visually inspect all items that are being returned to the reactor vessel for foreign material.
- Inspect the SFP for cleanliness periodically; make sure that the area is free of debris, that tooling and equipment are properly secured and logged, and that the area is free of any clear materials (for example, clear plastic). Any clear materials should be approved and clearly marked for easy identification and retrieval.

The following general guidance for refueling floor activities should be considered for inclusion in FME process:

- Complete FME plans for all work activities on the refuel floor before performing any work on equipment located above or within the area or zone of control. This plan identifies control requirements based on OE for access, conduct of activities within said area or zone, and egress from the area or zone. Work that can generate debris should be performed outside of high-risk FME zone when possible. If this is not possible, barriers or tents should be erected to capture or block any material generated from reaching a high-risk FME zone.
- Review pertinent OE for lessons learned, and incorporate them into the work plan.
- Keep the entire refueling area and all areas around and above it free of all debris before start of work and through final closeout. Use a clean-as-you-go methodology.
- Verify that no new debris is being introduced to the plant by completing a thorough new fuel receipt inspection.
- Wipe down all material entering the refuel floor area or zone to remove any dust or excess grease and oils as necessary.

- Sequence and control FME practice on the refuel floor by an individual or individuals delegated by management to coordinate the work. This person or team is responsible for implementing FME procedures on the refuel floor.
- Place the refuel support equipment in a controllable FME condition over solid floor space versus open pools or cavities before performing any maintenance and support activities. This will help prevent foreign material from entering the primary systems.
- Maintain and inspect cranes and fuel-handling equipment.
- Consideration should be given to minimizing the movement of irradiated fuel and core components over fuel that will go into the core. This minimizes the chance that debris will fall from these items.
- Overhead cranes should be inspected before their use during fuel activities. Cranes should be wiped down to ensure that grease or oil is not introduced into the refueling cavity.
- Identify an area or zone of material control that will prevent movement of personnel, equipment, tools, and materials to locations within this boundary and materials within the zone. The area or zone should be identified in a manner such that it is plainly apparent that this is an area where movement of personnel, tools, and materials (both in and out) is clearly controlled. Maintain accountability of personal items that are not restrained by a lanyard.
- Evaluate the importance and risk of the entry, and inspect the equipment and equipment components for loose parts and structural defects before allowing the entry of any personnel, tools, materials, or equipment into a refueling area or zone. These items should be inspected to verify integrity, cleanliness, and the potential for foreign material intrusion. Evaluate the potential for tooling failures and loss of tool pieces.
- Limit and control processes requiring the use of gas or generating gases, liquids, wire strips/wire brushes, wire ties with metal inserts, clear plastic, grinding and/or machining debris, nuts, bolts, and screws adjacent to or over the refuel floor FME zone. When these processes are required on the refuel floor, it should be demonstrated that the FME zone will be controlled so that the following apply:
  - Items will be easily identifiable and retrievable under water.
  - Items will not react with the components or other materials and tools in a manner that will be harmful to the fuel or reactor pressure vessel components.
  - Items can be attached to a lanyard so that they will not fall or be left within the FME zone.
- Consider the use of buoyant items (for example, cable ties/wraps or rags) that will float if they inadvertently enter the cavity, allowing for easy retrieval. Some tool lanyards have built-in flotation devices that make them easily identifiable and retrievable in the event that the tool is dropped into the cavity or SFP (see Figure 5-2 for an example).



Figure 5-2
Floating tool lanyard

- Establish standards for securing reactor cavity and SFP tools, lighting, and equipment. Locations for securing these items should be designated and should not be located near suction and discharge piping.
- Overhead or underwater lamps should have protective covers installed to contain material if bulbs break (explode).
- FME accountability logs should include all equipment, tools, refueling tools, and operator devices. Periodic inspections should be performed to verify full accountability and control.
- Maintain pool and material accountability and/or control for the FME zone.
- The upper cavity area should be inspected for debris before the cavity is flooded.
- The upper portion of the core should be inspected after removal of internals.
- Before reinstallation of the reactor internals, a visual inspection should be considered for the top of the fuel.
- Provide instructions on how to recover from a loss of foreign material control.

The handling of new fuel and fuel reload activities pose a high potential for foreign material intrusion. Good work practices related to fuel-handling activities include the following:

- New fuel should receive the highest level of FME controls. New fuel storage racks should be cleaned and inspected before storing new fuel in the racks. Some plants have placed FME devices over the new fuel vault deck plates to provide an additional assurance that debris will not be introduced into the fuel during storage.
- Preventive maintenance and surveillance activities for fuel-handling equipment (for example, cranes, hoists, tools) should be inspected to ensure that fastener integrity is maintained.

- When previously burned fuel is to be reloaded back into the core, it should be thoroughly inspected. Inspections should include the sides, top, and bottom of the assembly and a close examination of grid straps. A grid strap inspection is especially important for fuel assemblies that appear bent, bowed, or twisted (for example, grid straps might have been damaged during fuel movements).
- Mockups should be used to perform refueling activities training when available (for example, latching and unlatching of control rods).

5.2 Electrical Equipment Maintenance

As with other plant activities in which control of foreign material is a concern, the performance of electrical maintenance activities should require that work planners, supervisors, and workers consider whether any potential FME implications exist for each work task during both planning and performance. All electrical and instrumentation enclosures that have the potential for the introduction of foreign material during maintenance should be secured using proper FME controls.

Electrical components and electronic cabinets that have ventilation openings (for example, motors, generators, control cabinets) are subject to foreign material intrusion. When work activities are near or above this equipment, additional care and FME controls should be used to prevent dropping tools, parts, and materials (for example, wire clippings, wires from wire brushes). Netting or screen should be used to shield vent holes without blocking air paths.

In general, never leave electrical enclosures, cabinets, boxes, or conduits open and unattended unless specifically instructed to do so by procedure, operations, or the work task supervisor.

FME considerations for general types of electrical maintenance are as follows:

- When working in the vicinity of operating electrical equipment, consideration should be given to maintaining proper FME controls while maintaining required ventilation.
- Do not use electrical enclosures, cabinets, panels, boxes, trays, or conduits for equipment or material storage (for example, fuses, light bulbs, rags, tape, drawings, breaker lists, and rack-out tools).
- Cover cable trays before performing any work in the immediate area that could generate foreign material that might drop onto or into the tray.
- Use flame-resistant welding blankets to cover the cable trays when activities such as welding, burning, and grinding are taking place in the immediate area.
- Cable ties/wraps with a metal fastening tab have been an issue and have been banned at some plants. If the cable tie/wrap is overexerted, the metal tab can break free and become loose debris. Serious consequences could result if this were to occur within an electrical or instrumentation enclosure.
- Establish a boundary of plastic, Herculite, or other approved FME barrier.
- For activities such as cleaning contacts, a vacuum can be used to capture any debris.

The following sections describe several electrical maintenance activities with specific FME considerations.

5.2.1 Routine Electrical Activities

Rely on thorough precleaning, visual inspection, and parts accountability. During the performance of electrical maintenance activities, consider the possibility of introducing foreign material into the component or system being worked on, either from external sources or from the generation of incidental electrical waste, such as cable ties/wraps, wire strippings, banding materials, tape, and screws. Place waste material in an appropriate container immediately on generation (clean as you go) for later disposal. Before the installation or closure of electrical or instrumentation equipment, a thorough inspection should be performed to verify that no foreign material is present.

5.2.2 Large Electric Motors

Consider the appropriate level of FME control for the repair operations. If the motor must be transported to another location for repair, consider the possibilities for foreign material intrusion and establish precautions that address those possibilities through the contract or purchase order. Perform a thorough visual inspection of the motor before reassembling and testing. Look for indications of foreign material during testing, such as increased vibration, noise, and abnormal current signature.

If temporary screens or filters are installed on motors (for example, during outage periods) to prevent dirt, dust, and other debris from fouling the motor, the screens or filters should be installed in a way that they do not adversely affect the ventilation or cooling of the motor. When temporary screens or filters are installed, they should be inspected and changed on some basis to ensure that they do not adversely affect motor ventilation or cooling. Such temporary screens or filters installed on operating motors should be evaluated by engineering.



Key Technical Point

Perform a thorough visual inspection of the motor before reassembling and testing.

FME considerations for motor or generator work might include the following:

- Before opening an electric motor, visually inspect the surrounding area, overhead area, screens, and air filters for foreign material that could enter the motor. Preclean these areas.
- Disassemble the motor as necessary according to approved procedures and good working practices.
- On removal of the motor, cover the exposed motor-drive coupling area with an appropriate FME barrier, if necessary.
- Perform a thorough visual inspection of the motor to detect any obvious foreign material before disassembly.
- Clean or otherwise remove any debris using appropriate means, being careful not to inadvertently introduce material that could subsequently damage the motor during the cleaning process.
- Pay particular attention to any screens or filters that cover air intake or affect air intake and the function of the heaters on the motor.

FME considerations for motor or generator installation might include the following:

- Inspect the motor location before reinstalling the motor to ensure that no foreign material exists that might interfere with motor installation or subsequent operation.
- The area where the motor is to be set should be free of dirt and debris to minimize the impact on alignment and vibration.
- Remove the FME device from the motor coupling, inspect the motor, and reinstall it in its proper place.
- Before placing the motor back into service, perform a final visual inspection of the area, motor coupling, electrical connection junction box, and motor ventilation openings to be sure that no obvious foreign material has been introduced.
- Monitor lubricant application to ensure that the amount of lubricant dispensed is generally within the expected range for the particular application.
- Inspect equipment, where possible, after lubrication or greasing to ensure that any excess lubricant has not passed beyond its intended point of application and will not do so when the lubricated equipment is subsequently operated.

5.2.3 Electrical Enclosures/Cabinets/Boxes/Panels

FME considerations for work in electrical enclosures/cabinets/boxes/panels include the following:

- Before opening an electrical cabinet, visually inspect the surrounding area, particularly overhead, for potential sources of foreign material.
- Note any nearby system or equipment openings that could conceivably vent into the local area, thereby introducing unwanted foreign material into the electrical cabinet. Take necessary precautions to address potential foreign material sources.
- Wipe down the electrical cabinet exterior in the area around the cabinet opening to ensure that minor dust and debris present do not inadvertently enter the cabinet on opening.
- When working in electrical enclosures with multiple doors or access openings, only those doors or access areas required to perform the task should be opened.
- When work activities involve opening electrical enclosures, the enclosures should normally be closed when work is stopped. If the locking/blocking mechanism does not allow closure, the opening should have an FME device installed.
- Re-energized electrical cabinets should be cleaned, preferably from the top down, before reenergizing.
- While working in the electrical cabinet, make use of a nonconductive cover placed over the electrical components below to ensure that nothing is dropped into parts, such as operating transformers.
- Place all mounting screws, wire nuts, and other miscellaneous fasteners into a container immediately on their removal.

- Use special tools as necessary to minimize the chance of dropping screws or other fasteners on their removal. Internal catch bags can be used as a second line of defense.
- During the performance of activities that produce foreign material inside electrical or instrumentation enclosures, precautions should be taken to prevent the inadvertent entry of foreign material into the enclosure, equipment, or components.
- Whenever drilling into an electrical enclosure, determine what actions might be required to avoid intrusion of any foreign material generated by the drilling process into the enclosure.
- Place wire end stripping, cable tie/wrap ends, and other incidental debris immediately into a temporary trash container for removal from the work area when the work task is complete.
- Use good work practices to ensure that no loose parts are lost during the maintenance activity or remain in the cabinet on work task completion.
- Before closing an electrical cabinet, a thorough inspection should be performed to verify that no foreign material is present.
- Ensure that all parts are accounted for and that fasteners, such as mounting screws, are sufficiently tight so that they do not become loose and subsequently displaced.
- Ensure that nothing remains in the cabinet that does not serve an intended function of the cabinet.

When removing electrical components, such as circuit breakers, motor control center buckets, and load centers from their enclosures, as shown in Figure 5-3, ensure that appropriate FME devices are installed on the components to prevent foreign material intrusion.



Figure 5-3
Electrical breaker enclosure

In the past, incidental items have been found stored in electrical cabinets. Although such items might not have caused any serious problems, they nonetheless represent a form of foreign material and increase the potential for a subsequent problem. Remove any such items (for example, fuses, light bulbs, documents, drawings) found during routine cabinet inspections, and discontinue this practice.

5.2.4 Batteries

Station batteries are vulnerable to foreign material entering into the cells when the cell caps are off. Also, there is a potential for short circuits or shock as a result of metallic material coming in contact with the battery terminals.

FME considerations for work on and around station batteries should include the following:

- The battery top surfaces should be clean to prevent dirt and debris from entering the cells when the caps have been removed.
- All removed parts should be placed in a nonconductive container located away from the cells.
- Tools and materials should be controlled to prevent them from falling onto or coming in contact with the exposed electrical connectors or terminals.
- Ensure that sampling and test equipment is clean and in good working order. Equipment parts that might fall off into the battery should be properly secured.

5.2.5 Switchgear

When preparing to work on a switchgear, take FME measures similar to those identified in Section 5.2.3 for electrical cabinets. FME considerations include the following:

- Perform an effective precleaning.
- Perform a thorough visual inspection.
- Maintain parts accountability (removed and to be installed).

When removing electrical components (for example, circuit breakers, relays, motor control center buckets, and switchgear) from their enclosures, cover the components to prevent foreign material intrusion into the mechanisms.

- When breaker cabinet doors are opened, proper FME awareness to foreign material intrusion should be demonstrated (for example, control of personal items, control of any tools, verification that open cabinet doors are not unattended).
- Keep circuit breakers covered when in transit or stored.
- Place waste material in an appropriate container immediately (clean as you go) on generation for later disposal.

5.2.6 Transformers

When preparing to work on transformers, take measures similar to those identified previously for electrical cabinets.

FME considerations should include the following:

- Be aware of the possibility of air and water in-leakage. Tents or tarps should be considered to prevent air or water in-leakage.
- Transformer tank penetrations, such as instruments and access openings, should have FME devices installed when unattended or not in use.
- Perform thorough precleaning, visual inspection, and parts accountability.
- Place waste material in an appropriate container immediately on generation for later disposal (clean as you go).
- Establish a high-risk FME zone for any internal activities on or inspections of large transformers, such as station transformers. External insulators should be cleaned of all accumulated grime before they are returned to service.

5.2.7 Fuel-Handling Equipment

Another area of potential FME concern is any electrical maintenance activities performed on equipment that places personnel over the SFP, refueling pool, or reactor cavity (for example, work on a refueling crane or refueling machine). This is because there is a risk that personnel will accidentally drop materials, tools, parts, or other items into the pool. It is advisable to institute the most stringent FME control over the work area until work task performance is completed (see High-Risk FME Zone section). In addition to normal precautions and procedural requirements, it is advisable to erect a catch device (for example, netting, sheeting) beneath the work area to catch inadvertently dropped items. It is recommended that a requirement be established for independent postmaintenance inspections of the equipment on completion of the work task to ensure that no tools, spare parts, or other items are left that might subsequently drop into the pool during operation of the equipment. Small parts on chain falls or hoists should be secured with tape or otherwise secured appropriately to prevent them from becoming loose.

5.2.8 Connectors

Intrusion of dirt, moisture, and other contaminants is a common failure mechanism for electrical connectors; it causes short circuits and arcing or high resistance and false or erratic signals.

Periodic maintenance and equipment inspection procedures should include specific instructions to look for this type of condition [4].

5.2.9 Electrical Conduit

Electrical conduit should be protected from foreign material when stored and during maintenance activities. Appropriate FME controls and practices in the warehouse and during maintenance should be defined. Failure to have proper FME control in place might subject electrical conduit to foreign material intrusion from water, oil, dust, dirt, insects, or other debris.

Electrical conduit caps, covers, or other access points should be in place unless required to be removed for maintenance. Foreign material in electrical conduits can lead to the following:

- Corrosion
- Electrical grounds and shorts
- Damage to equipment to which the conduit is attached
- Insulation damage
- Excessive friction during cable pulls or possible insulation damage

5.2.10 Isophase Bus Duct and Fans

The isophase bus duct carries extremely high currents. FME controls should be considered any time this duct is opened for inspection or maintenance. Considerations should include the following:

- Proper FME controls should be in place for any cutting or grinding on the isophase duct to ensure that debris generated is not introduced inside the duct.
- Duct covers should be in place or an FME device installed when opened for maintenance.
- Openings should be covered with an appropriate FME device if left unattended.
- Bus links and hardware should be properly controlled if removed.
- Bus ducts should be inspected for any signs of water or oil intrusion when opened.
- Bus duct fans should be inspected for any loose, missing, or broken parts.

5.2.11 Air-Handling Units (Fans and Ducts)

FME controls should also be used when working on or around air-handling units or associated duct work or plenums. FME inside air-handling units or duct work can be a threat to the air-handling unit or the equipment or area to which it supplies air, cooling, or ventilation. FME concerns associated with air-handling units include debris and dirt that clogs coils, filters, drains, bearings, belts, and so on. Moisture and dust in air-handling units and filter trains that lead to microbial growth pose a threat to personal hygiene is another concern.

FME practices that can be used when working around air-handling units include the following:

- Do not perform activities that generate potentially hazardous fumes around air-handling units intakes.
- Areas near the air-handling units intake should be kept free of debris to prevent debris from being taken into suction.
- Do not perform grit-blasting activities near intakes of air-handling units.
- Access panels, doors, covers, penetration, and so on should remain closed and intact when not required to be open for maintenance.

- Do not open access panels to supply air or ventilation to areas without prior approval from engineering. Doing so could affect the functionality of the air-handling unit and could damage equipment or the areas it serves.
- Most ventilation systems are balanced with doors closed. Doors should not be propped open.

5.2.12 Motor-Operated Valve Actuators

FME controls should be considered when maintenance is performed on motor-operated valves (MOVs). When MOVs are opened for maintenance, numerous sensitive parts are exposed to the elements. Considerations when working on MOVs include the following:

- MOV internals should be covered if the MOV is left unattended.
- MOVs should be thoroughly inspected for loose, broken, or missing parts when opened.
- MOVs should be inspected for excess grease or any signs of water intrusion.

5.3 Instrumentation and Control Maintenance

As with electrical maintenance, performance of various instrumentation and control (I&C) activities within the plant requires thoughtful advance consideration of potential foreign material sources, OE, and contamination issues. In general, follow all applicable plant FME guidelines when planning or performing any I&C maintenance activity.

Because of the severity of the consequences that can be associated with I&C foreign material intrusion events, it is important to consider covering even the smallest system openings during maintenance activities.

The following are several common systems and components in the I&C area that can be significantly affected by foreign material intrusion. Good FME practices should also apply to measurement and test equipment. Any opening on measurement and test equipment should have FME devices installed to prevent foreign material intrusion into the device. Measurement and test equipment should be inspected to the extent possible for debris or foreign material before use on plant equipment.

5.3.1 Instrument Tubing

Appropriately sized FME caps or plugs should be used on instrument tubing whenever a component is disconnected or left unattended or when moving tubing between locations. Temporary instrument tubing used for performing response and functional testing or calibration should be cleared of all dust, dirt, oil, and so on before being connected to any plant instrumentation. Care should also be exercised when applying thread lubricants or sealants to piping or instrumentation tubing.

5.3.2 Reactor Vessel Level Indication System

Reactor vessel level indication system components are located in and around the reactor vessel cavity. Take adequate precautions so as not to drop tools, fittings, and loose parts onto the reactor head or into the cavity below, especially if refueling activities are in progress.

5.3.3 Air-Actuated Components

Be especially careful to collect debris generated by cutting or removing supply hoses, tubing, fittings, or piping connected to air-actuated components, such as valve operators and solenoid valves. Purge or flush tubing to dislodge and remove any particles that might have entered the hose, tube, or pipe. Direct the purge discharge in a safe direction.

5.3.4 Tank, Pool, or Sump-Mounted Level Instrumentation

Take adequate precautions not to drop tools, loose parts, and so on into tanks or sumps, especially when using a tool, such as a reach rod, to move the sump float in order to check instrument calibration and response. Dropped tools can be very difficult to retrieve, and in the case of sumps, they can cause sump pump damage or restricted flow.

5.3.5 Instrument Cabinets

FME considerations for work inside instrument cabinets should be similar to those used when working inside of electrical cabinets (see Section 5.2.3, Electrical Enclosures/Cabinets/Boxes/ Panels). FME considerations might include the following:

- Use good work practices to ensure that no loose parts are lost during the maintenance activity or remain in the cabinet on work task completion.
- Catch devices and drop screens should be used when removing screws.
- Vacuum accumulated dust and debris from card frames and cabinet bottoms.
- Power supplies are frequently located in the bottom of cabinets. Take care to prevent debris from entering the power supply case through case ventilation openings while maintaining proper air flow.
- Before closing an instrument cabinet, make certain that all parts and temporary covers are accounted for.
- Before closing cabinets, ensure that fasteners, mounting screws, and clips are sufficiently tight so as not to become loose and subsequently displaced.
- Ensure that nothing remains in the cabinet that does not serve an intended function of the cabinet.

In the past, incidental items have been found stored in instrument cabinets. Although such items might not have caused any serious problems, they nonetheless represent a form of foreign material and increase the potential for a subsequent problem to arise. Remove any such items found during routine cabinet inspections.

5.3.6 In-Line Flow Elements and Meters

Use appropriate FME devices (such as a cap and plugs) to prevent the intrusion of tools, loose parts, and so on into the exposed piping system during maintenance. Take particular care to inspect the system for any foreign material before removing the FME devices.

5.4 Mechanical Maintenance

As with other plant activities where control of foreign material is a concern, the performance of mechanical maintenance activities should also require that work planners, supervisors, and craft personnel consider whether any potential FME implications exist for each work task during both planning and performance. While maintaining proper FME controls, it is important to ensure that those controls do not negatively affect operating equipment (for example, by blocking ventilation, affecting heaters).

Special precautions should be taken when work tasks generate foreign material or plan to introduce foreign material into a system or equipment (for example, leak-sealing compounds, lubrication, chemical cleaning, decontamination compounds). Nondestructive evaluation residues should be cleaned after use.

Some of these activities and FME recommendations are listed in the following sections.

5.4.1 S/G (Primary Side)

Whenever the S/G manways are removed from the hot and/or cold legs of the S/G, the primary side should be designated a high-risk FME zone. Numerous activities occur in the S/G primary side when it is opened or breached. These activities might include the following:

- Nozzle dam installation
- Eddy current testing
- Tube plugging or staking
- Inspections

The highest level of FME control should be implemented during these activities because of the difficulty in inspecting S/G internals for foreign material intrusion. This includes a strict accountability for tools and materials (for example, eddy current probes and plugs). All tools, material, and equipment that enter the primary side of the S/G should be inspected before and on removal for any loose, broken, or missing parts (for example, nozzle dams, automated robot machines for eddy current testing and plugs operations). When access to the S/G primary side is not required, covers should be installed on the hot and cold leg openings.

Even with nozzle dams installed over the hot and cold leg pipe openings, covers should be maintained over the S/G primary manways when maintenance activities are not in progress. Manway covers should not be removed without authorization of the work permit holder who is responsible for S/G maintenance. The S/G should not be left unattended or unmonitored while primary covers are removed unless strict FME controls, physical barriers, access control, FME tools and a materials log, posted signs, and so on are in place. For ALARA considerations, monitoring of S/G activities can be performed through closed-circuit television or at low dose areas near S/G platform access.

When S/G maintenance activities are concluded and nozzle dams have been removed, a final closeout inspection should be performed. No material should be left inside the primary side of the S/G. Independent inspections can be useful; however, ALARA should also be considered. Personnel who are familiar with the S/G primary side internal should perform the closeout inspections. All work history documentation and FME accountability logs should be reviewed first to ensure that there are no discrepancies before final closure of the S/G.

5.4.2 S/G Secondary Side and Feedwater Systems in BWRs, PWRs, and CANDUs

For work inside the secondary side of an S/G, a high-risk FME zone should be established. Because of the difficulty in determining the existence of foreign material and retrieving foreign material in the secondary side of an S/G, strictly control personnel access to the area. Use physical barriers, implement an FME accountability log, post signage, and control all potentially loose items using lanyards or other appropriate methods. Perform a foreign object search and retrieval inspection of the tubesheet after all work above the tubesheet has been completed. Record this activity in the work document or barrier log. Immediately before closing the S/G, at least two people should perform a visual inspection through the opening and confirm that the log shows no items remaining inside the S/G.

Debris that can threaten fuel clad integrity can be introduced from BWR balance of plant systems. These systems include the turbine, moisture separator reheaters, main condenser piping, feedwater heaters downstream of the condensate polisher system, and portions of the heater drain system that do not return to the condenser. Internal inspections performed on large balance of plant replacement equipment have identified welding slag, grinding debris, fasteners, and so on after vendor closeout inspections. Receipt inspections should be performed on all equipment received to the extent practical.

Similarly for PWRs, debris introduced from balance of plant systems can damage steam generator tubes, causing primary-to-secondary leakage.

A high-risk FME zone should be established for PWR balance of plant systems to prevent foreign material intrusion that can affect the integrity of the S/G tubes, especially for initial opening and until appropriate FME devices have been installed.

5.4.3 Turbine

OE tells us that turbine components are considered highly susceptible to foreign material intrusion. Rotor blades are susceptible to various types of damage from foreign material intrusion. Flow paths upstream of the turbine blades need to be free of foreign material. Working near turbine bearings and coupling faces requires that the areas be controlled to prevent entry of foreign debris. Figure 5-4 illustrates controls and covers in place to prevent foreign material intrusion.

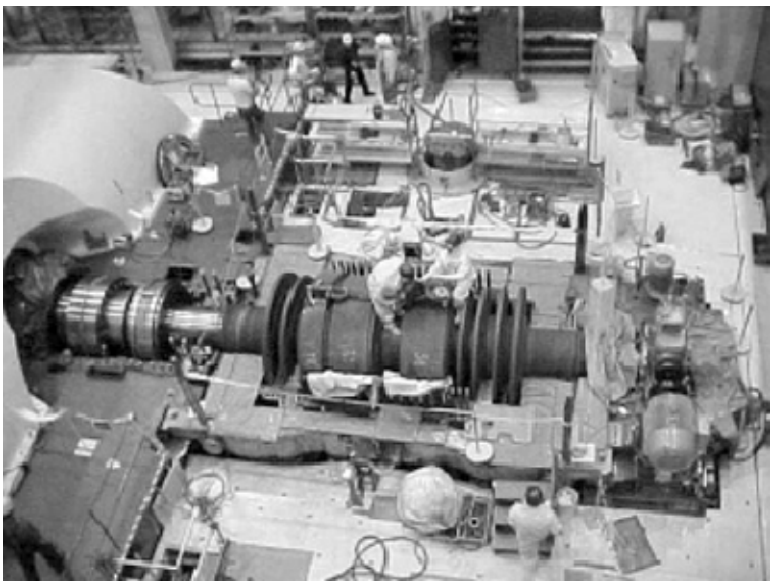


Figure 5-4
Turbine maintenance with covers and controls in place

In addition to the main steam paths of the turbine and the bearings, consideration should be given to FME requirements for work on the stop and control valves, steam chest, turbines, electrohydraulic components, seal oil, and lube oil components of the turbine systems. The controls put in place should include the completion of FME plans before the start of any work. These plans should reference pertinent industry OE to prevent the chance of foreign material intrusion.

Flushing of oil systems and inspections of sumps for foreign material after maintenance should be performed. During flushes, filters and screens should be inspected and cleaned often. For further information on FME considerations during turbine overhauls and inspections, see *Guidelines for Reducing the Time and Cost of Turbine-Generator Maintenance Overhauls and Inspections–2012* [7].

5.4.4 Generator

Because of the size of the component and the large number of people involved in generator maintenance, the electrical generator is extremely susceptible to foreign material intrusion during maintenance operations. Cases have been reported where plastic bags, metal-handled brushes, and even large items, such as the skid tray used in extracting the generator rotor for maintenance, have been left inside on completion of the maintenance activity. Assignment of strict FME control is indicated for the main generator area whenever the generator is open for maintenance.

For major maintenance involving several work groups or exposing the generator internals, establish physical barriers and restrict access of nonessential personnel. Some plants erect metal cages to restrict access to the unit.

Establish a requirement for postmaintenance inspections immediately before closing the generator. Consider flushing cooling and lubrication systems (for example, stator cooling water system, mail lube oil, control oil [electrohydraulic], and so on) to ensure that they are free of debris.

For both turbine and generator maintenance, FME controls for overhead cranes, hoists, and other lifting devices should be implemented.

5.4.5 Cross-Under Piping

Cross-under piping comes from the bottom of a high- or intermediate-pressure turbine cylinder casing. The diameter of cross-under piping is large enough for items to be dropped into it.

Before working in the areas of cross-under pipe openings, FME devices (for example, the cover, dam, or seal) should be installed to prevent foreign material intrusion. After the completion of the work, remove the covers, dams, or seals and inspect the cross-under piping visually. Use a video probe or boroscope, when available. Use of an FME accountability log should be considered during work in these areas, and an FME plan should be considered before beginning work.

5.4.6 Condensers

Condensers are common places to find foreign material. Any time a turbine, turbine component, or piping is opened, allowing access to the condenser, the shell side should be inspected before closing to ensure that no foreign material is present. Consideration should be given to covering the tubes under work areas, such as extraction lines and expansion joints.

The controls put in place should include the completion of FME plans before the start of any work. These plans should reference pertinent industry OE to prevent the chance of foreign material intrusion.

Where waterboxes, such as cooling water condensers or heat exchangers, have been opened for cleaning, ensure that a thorough waterbox and tubesheet inspection has been performed before closure. An FME plan should be considered before beginning work.

5.4.7 Moisture Separator Reheaters

Moisture separator reheaters are vessels common to nuclear power plant steam systems. Typically, they require inspection in every outage. Before allowing any major work inside a moisture separator reheater, FME boundaries should be established; before system opening, floor openings are to be covered or sealed to prevent foreign material from entering the system and later being carried into the low-pressure turbine blades. Consideration is to be given to the type of work being performed inside the moisture separator reheater. The use of ventilation systems is typically required for cutting, welding, and grinding operations. An FME plan should be considered before beginning work.

5.4.8 Drywell

BWRs have a large leak-tight pressure vessel that contains the reactor and some primary components. The drywell might be composed of a drywell, downcomer piping, and a torus or suppression pool. The drywell is located above the torus, and the two are connected from the bottom of the drywell to the top of the torus by downcomer piping. In BWR plants, the primary components, such as recirculation pumps, motors, valves, and piping, operate within the drywell. During refueling outages or instances of plant shutdown or low-power operation, the drywells are accessed by various personnel to perform inspections and repairs if necessary. All activities requiring access to the drywell are required to have tool and material controls in place to prevent foreign material from being left within the drywell during plant operation. It is recommended

that, before closing the system, one or more independent inspections of the drywell and downcomers be performed to ensure that no foreign material is present. It is also recommended that the downcomer piping be covered, dammed, or sealed during shutdowns and refuel outages to ensure that no foreign material is introduced.

5.4.9 Torus or Suppression Pool

At some BWR plants, a torus is part of the primary containment and is connected to the drywell through downcomers or large diameter pipes. This equipment is almost always partially filled with water. During refueling outages or instances of plant shutdown, these areas might be accessed by various personnel to perform inspections and repairs. All activities requiring access to these areas are required to have tool and materials controls in place to prevent foreign material from being left inside during plant operation. It is recommended that one or more independent inspections be performed before closing the equipment after work activities have been completed to ensure that no foreign material is present.

Nuclear plants have periodic inspection requirements that require divers or submersibles to inspect the inside surfaces of the suppression pool and other water areas. It is highly recommended that all work requiring access to these areas be scheduled for a time when divers and/or submersibles are present to ensure that no foreign material has been left.

5.4.10 Other Large Vessels That Enable Personnel Access

For maintenance in large vessels, use appropriate FME devices or materials to cover openings in the floor or lower quadrants to prevent foreign material from falling into a drainpipe or sump. Seal all openings (for example, inlet, outlet, instrument taps) from the inside to prevent items from entering the system. Once the openings are sealed internally, the controls inside the vessel can be relaxed.

If an internal plug is used that will allow reassembly without removing the plug, a label should be affixed to the pipe noting the installed plug. The plug should be recorded on the FME accountability log, and a second verification of removal is required.

Before removing any FME barriers, thoroughly clean and inspect the vessel. Once the vessel is clean and accepted, remove the covers before closing the system. Before system closure, perform two independent inspections to confirm that no foreign material is present. Where the risk of foreign material intrusion is significant, follow guidelines similar to those expressed in Section 5.4.7, Moisture Separator Reheaters. An FME plan should be considered before beginning work.

5.4.11 Working Over and Inside Sumps

Always implement tool and material control while working over open water. Use lanyards for tools, and maintain material control. Install covers over as much of the area as possible. Sump maintenance and repair activities are common at plant facilities. Sumps contain pumps, valves, piping, controls, and electrical power so that a wide variety of activities can be performed. Minimizing foreign material intrusion can be achieved by approaching sump work and sump designs in the simplest way. Arrange for access to the controls, power, and equipment from the outside with flexible electrical and control connections and/or manifold piping.

Underwater piping can be arranged in a manifold configuration to allow the entire assembly or component to be removed at one time. This allows you to perform the inspection or repairs in an area where the risk of losing a tool or part is eliminated.

When performing work inside containment on CANDU reactors, consideration should be given to housekeeping to maintain a clear flood plane in the event that emergency cooling injection is required.

5.4.12 Working Inside Open Valves

A typical nuclear plant contains thousands of valves. Improper valve operation could occur if foreign material blocks the valve-sealing surfaces, such as disks and wedges. When working on valves, pay attention to FME controls, particularly on those valves that are in a direct flow path to the fuel assemblies. Consider the following suggestions:

1. Before starting work, perform the following:
    a. Develop a planning sequence to incorporate FME concepts.
    b. Thoroughly clean the area around the valve.
    c. Set up the area around the valve to be an FME control area.
    d. Designate FME tool and material controls for the work area.
    e. Always cover the valve unless you are working on internals.
    f. Inspect new valves received from the warehouse for cleanliness before installation (for example, look for dirt, grease, desiccant).
2. While working on the valve, perform the following:
    a. Inventory (that is, bag and tag) bolting (taken off bonnet) and pressure seal parts.
    b. Install temporary blind flanges, plug drains, and cap nitrogen lines, as required.
    c. Install appropriate FME devices (for example, bladders, plugs) as required.
    d. If an internal plug is used that will allow reassembly without removing the plug, a label should be affixed to the pipe noting the installed plug, the plug should be recorded in the FME accountability log, and a second verification of removal is required.
    e. If allowed by procedure, at this point, the crew can relax FME controls on the valve.
    f. Keep a vacuum on hand.
    g. Use barriers and frequent cleaning when machining Stellite surfaces. Machining can generate sharp shards of metal that can damage fuel.
    h. Use measures as necessary to remove any Stellite residue on valves with hard facing. This residue might not be visible to the human eye.
    i. Maintain cleanliness according to housekeeping requirements.
    j. Inspect spiral-wound gaskets or wire-reinforced packing for structural integrity during valve disassembly.

3. While reassembling the valve, perform the following:
   a. Vacuum-clean valve internals and re-establish FME tools and materials controls before removing FME bladders.
   b. Perform a closeout inspection, and resolve tool and material control logs.
   c. Complete the reassembly of the valve.

5.4.13 Cutting Pipes, Valves, and Fittings

Saw-cutting, grinding, hot tapping, and machining processes produce debris that could be harmful to system or component internals. When flame-cutting or saw-cutting pipe, consider the following:

- Use flame-resistant welding blankets to cover the cable trays when activities such as welding, burning, and grinding are taking place.
- Care should be exercised during pipe cutting because it will produce a fine metal particulate from the part being cut. When cutting a pipe or tube, clean the particulate from the outer surface, the inner surfaces, the saw wheels and guides, and the blade before breaching or cutting through the material. The last stages of pipe cutting can introduce materials to the pipe interior. Usually when the pipe is positioned horizontally, as shown in Figure 5-5, the debris can be cleaned from the pipe after the cut is made. When the pipe is positioned in a line that rises or falls from horizontal, the debris can fall away from the cut area into the line and can no longer be easily reached.

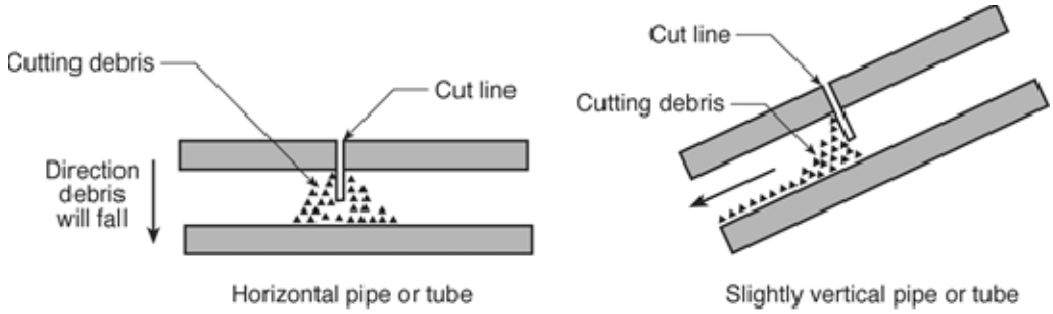


Figure 5-5
Examples of foreign material intrusion when cutting pipe

- Careful consideration should be given before the use of hot tapping. In general, it should be used only when absolutely necessary and not as a convenience or to save time. Hot tapping is not a debris-free practice. Although the process does flush away a large portion of the debris generated, the potential exists for some of the generated debris to enter the system being tapped. When hot tapping is used, foreign material techniques (for example, boroscope, flushing) should be used after the tapping process to ensure that the system is free of foreign material.
- Horizontal pipes can be cut with saws as long as the interior surfaces are dry and cleaned after the cut is made.

- Do not saw cut any vertically (slope >5°) positioned in-line pipe or pipe component whose interior system cannot tolerate the saw-cutting debris unless an in-line strainer exists downstream of the work area. This strainer should be capable of removing the material from the system during operation, or a temporary strainer should be installed downstream of the work area.
- It is important to consider flushing the system after cutting.
- Once completed, the interior area of the pipe where the cut is located can be plugged before starting pipe wall end preparation and cleaned after the cut is made.
- Piping components, such as valves, fittings, and hangers, can be removed from the closed welded system by using grinding wheels. Grinding particulate should be contained so that other equipment within the area is protected.
- Clamshell or outer diameter machine-cutting equipment is also used to cut in-line pipes. Most of the debris that is generated by these machines falls outside the pipe being cut. As the tool moves around the pipe, it strips off a layer of the pipe material in ribbons. Because of the tool design, the stripped layer rolls out of the slip or notch made by the cutting tool in the shape of a coil, curl, or spring. As this tool spirals downward into the pipe wall, the slip or notch material is removed and remains on the outside of the pipe until no more material remains to be removed. As the tool approaches the point of penetration, periodically measure the exact depth. Just before the tool penetrates the predetermined depth of the pipe wall, turn the machine off and use a chisel or rolling cutter to penetrate the pipe wall. The material remaining in the slip or notch turns blue at this point. This is sometimes referred to as blue lining. Blue lining is a cutting method that can eliminate the possibility of materials entering pipes during cutting operations.
- If two cuts are required on a vertical line (slope >5°), make the first cut as previously described on the lower side. By making the lower cut first, a piece of lagging or other material can be inserted through the pipe, allowing a more aggressive cutting method on the upper cut.
- Socket welds can also be removed with outer diameter cutting equipment. This machining process faces the old weld out back toward the fitting. The close-fitting joint fillet weld is released with little or no intrusion of foreign material into the system. Care should be taken to clean the cut area before separating the pipe from the fitting.

Other methods for cutting pipe include electrical discharge machining and metal disintegration. These methods are typically used for machining components. Their advantage is greater control over the debris particle size. Even with these methods, appropriate FME techniques should be used.

5.4.14 Torch Cutting, Air Arc, Plasma Arc, and Welding Activities

Flame cutting, air arc, plasma arc, and welding activities create molten metal and slag that can spatter about the work area. Consider constructing barriers to prevent these materials from migrating to an open system or spreading throughout a system. Use of well-placed weld curtains or fire-retardant blankets can protect systems, components, and cable trays.

Be sure to account for each unused welding rod and used rod stub that was introduced into the FME zone on job completion. Collecting rod stubs in a bag or other suitable container immediately on rod changes during the welding process helps to ensure that a stub is not accidentally introduced into the system or component. Store any special clothing, such as welding masks, goggles, welding gloves, or aprons, and other specialized supplies in an appropriate container in the FME zone when not in use.

Grinding activities are typically associated with burning and welding tasks. Grinding disks propel small metal bits away from the metal surface. These metal bits can be directed in a stream away from or into the work piece. Whenever grinding activities take place within or near open systems and components, barrier curtains and/or ventilation should be in place to protect open systems, components, and cable trays.

5.4.15 Diesel Maintenance

Diesel maintenance might require partial or complete disassembly. These activities are performed from either side of the engine or from above. Material and tool logs might be required for the side on which the work is being performed. Maintaining separate logs helps to easily identify and locate items on completion of the work. In instances where maintaining logs is not required, the use of special covers over openings is acceptable.

Exhaust and injector ports are typically opened during engine maintenance and inspection. These openings should be covered with appropriate FME devices when work is not in progress.

OE has shown that the use of rags or wipes as an FME device is a poor practice. They can easily be left inside the diesel, causing loss of cooling and lubrication. Solid tapered plugs, cut-to-fit covers, or oversized cut-to-suit magnetic sheeting material is suitable for standard-risk FME devices over fuel and lubrication lines or ports. Sized plugs are good for water and air lines.

Overhead hoists and monorails should be inspected and cleaned before opening the diesel for maintenance. Rags should be numbered for FME control purposes.

5.4.16 Ice Condensers

The ice condenser provides containment pressure suppression and a significant contribution to containment recirculation sump inventory during a transient. During the late 1990s, a number of problems were identified regarding maintenance and surveillance of ice condensers. Foreign material issues were identified (for example, missing or broken basket screws, debris in the ice). Foreign material issues in ice condensers can lead to containment sump clogging, insufficient quantities of ice, and improper operations of components (for example, door operation, drain blockage).

Maintenance activities (for example, ice making and blowing, ice weighing, and general ice condenser maintenance) associated with the ice condenser has the potential for foreign material intrusion into containment sumps. Because of the physical arrangement and access, it might be difficult to establish a specific level of FME control. However, FME requirements should be implemented for ice condenser work, including the following:

- General FME requirements, including tool and material accountability and cleanliness standards, should be implemented. (An FME monitor is not required.)
- Thorough inspections for loose and ice-trapped debris should be performed. This includes basket inspections for missing screws and broken screw heads.
- Loose debris that is recovered during inspections should be documented. (Use of a debris log is recommended.)
- Loose debris that cannot be retrieved should be documented in the corrective action program and evaluated. If the debris has previously been identified and evaluated, it need not be logged.

5.5 Other Conditions or Activities That Require FME Controls

Maintenance is not the only activity that can result in foreign material intrusion: additional activities or situations can cause material to get into systems or components. Routine activities performed by other station personnel, environmental conditions, normally open systems, equipment degradation and failures, and legacy items all have the potential of causing foreign material intrusion and should be considered in the FME process. Some stations can include these areas in separate programs, but as a minimum, these areas should be given consideration from an FME perspective to determine whether additional evaluations or controls are required.

Control of large FME work areas should be designated in-site procedures. Large FME work areas (for example, turbine work and refueling activities) might have several work disciplines involved. Consideration should be given to having a lead group responsible for general FME zone requirements (for example, FME monitor, FME accountability log). Individual work organizations might have their own specific FME requirements related to a given work task (for example, I&C personnel disconnecting reactor vessel level instrument lines). In this case, the responsible work organization should address the installation and removal of specific FME devices associated with their task within their work documents. Control of large FME work areas can be affected by the work activities to be performed, the number of work groups involved, or physical arrangement of the FME zone. Specific FME plans should be developed for these large FME areas, with well-defined FME responsibilities for all groups required to enter the FME zone.

Examples of applicable activities in the power plant boundaries or equipment are lubrication, chemistry additions, sampling, venting, filling, draining, radiation surveying, housekeeping activities, inspections, surveillances, testing, maintenance, refueling activities, and so on. The FME process applies to any group performing such activities.

5.5.1 Support Activities

Of particular concern are painting and coating activities. Both of these activities generate debris during application and removal that represents a potential for foreign material intrusion. During painting or coating installation activities, the potential exists for dropped paint or painting/coating equipment/components that affect their ability to function properly (for example, painting over MOV vent screens, coating over instrument penetrations). The method of application or removal can increase the risk of foreign material intrusion (for example, by producing spraying, chipping, sandblasting debris). When paint or coatings are applied or removed by one of the means previously described, the application or removal should be performed with a suitable barrier (for example, tents) to minimize the spread of the installed or removed material.

The installation and removal of insulation produce debris that can become airborne and be introduced into an open system/equipment/component as foreign material. Personnel who perform insulation activities should be aware of any FME zones that are in the immediate area of insulation activities. Barriers and/or filter systems to capture or minimize insulation dust should be used. If insulation activities are to be performed over grating, the grating should be covered with a suitable material to prevent insulation dust or particles from falling into lower elevations. Care should be taken in the selection of covering material used because insulation dust on some surfaces could pose a personnel slip hazard.

The assembling and disassembling of scaffolding also pose a foreign material intrusion risk. If scaffolding is being assembled or disassembled adjacent to or over FME zones, there is a potential for tools and scaffold knuckles or their components to be dropped or introduced into the FME zone. Scaffold workers should be made aware of any FME zones in the immediate area before beginning work. If scaffolds are being assembled or disassembled over an FME zone, the requirements for the control of tools, materials, and personal articles should be equivalent to those requirements of the FME zone affected. The use of lanyards on tools during scaffold assembly and disassembly is recommended for FME protection and personal safety of any personnel who might be working below.

Scaffolds can be erected over FME zones that are not associated with the work in the FME zone. If this is the case, the requirements of the FME zone affected should be in place for the workers on the scaffolds. The use of toe boards and protective sheathing is recommended for these scaffolds. (See Section 3.3.2 for additional guidance.) Tools, materials, or other items that are dropped should be documented in a drop log for tracking and resolution.

5.5.2 Nonmaintenance Personnel Activities

As with the performance of plant maintenance activities, many other routine activities can require the implementation of FME controls. These FME issues might fall into any of the metric performance indicators.

Vents and drains that are open and unattended should have an FME device installed to prevent foreign material intrusion. Vent or drain openings typically do not require additional FME devices when oriented downward (for example, between the four-o’clock and eight-o’clock positions). If the vent or drain has a drain line installed, FME devices are not required.

Foreign material could inadvertently be introduced through several different categories of activities, as follows:

- Operations activities, such as venting and draining, racking breakers in and out (proper implementation of FME controls), changing fuses, refueling, resin addition, operator rounds and/or inspections, surveillances, adding oil to pumps and motors, system flushes, housekeeping
- Engineering activities, such as walkdowns of operating plant equipment and equipment inspections
- Health physics activities, such as radiological surveys of plant equipment, monitoring operations activities within the plant, monitoring maintenance activities within the plant, monitoring refueling activities within the plant, monitoring radiological effluents
- Chemistry activities, such as chemical additions and sampling
- Supply chain (warehouse/procurement) activities, such as receipt inspection, material and component storage, vendor expectations for providing goods, warehouse periodic maintenance activities
- Security activities, such as training exercises and equipment searches

5.5.3 Environmental Conditions (Biofouling)

When environmental conditions result in the introduction of foreign material to plant systems or components, the event should be reported in the FME metrics; however, the cause of these events might be attributed to other plant programs. These cases do not necessarily constitute an indication of an FME process failure. Examples include the following:

- Zebra mussels
- Asiatic clams
- Jellyfish
- Grasses
- Algae
- Barnacles
- Kelp or seaweed
- Insects
- Ice or frazzle ice

Equipment that might be affected (during flushes) includes the following:

- Condensers
- Heat exchangers
- Building heating, ventilation, and air conditioning equipment

- Strainers
- Fire systems
- Traveling screens

5.5.4 Normally Open Systems

Each plant has unique design features that might incorporate open systems or partially open systems. The term *open systems* means that a portion of the system is open to the atmosphere or surroundings.

As part of their design function, these systems have an open access to the environment to provide cooling or evaporation. Regardless of the function, suitable consideration should be made to prevent the intrusion of foreign material. Housekeeping standards or engineered controls should be maintained to prevent equipment damage or degradation.

Examples of these systems include the following:

- Cooling water intake structures
- Circulation water cooling ponds
- Retention ponds
- Storm drains
- Floor drains
- Ventilation systems
- Reactor heat recovery reservoirs
- Cooling tower basins
- Open pools

5.5.5 System Degradation or Equipment Failures

Some systems or equipment showing signs of degradation from aging, environmental conditions, or design issues can cause the introduction of foreign material through the breakdown of components. Specifically, they involve events in which plant FME practices are not contributors to the introduction of foreign material. Examples would be the leafing of flex links, broken light bulbs, and pump impeller failure. However, as a minimum, these areas should be given consideration from an FME perspective to determine whether additional evaluations or controls are required.

5.5.6 Legacy Items

Foreign material might be found in plant systems or pieces of equipment that were introduced before plant startup or from maintenance activities that were performed before the implementation of FME industry standards. These items should be included in the appropriate FME performance metrics and evaluated but not necessarily considered failures of the current FME process.

If a site has experienced multiple occasions of debris-related fuel failures that are attributed to legacy debris, a program to identify, inspect, and recover legacy debris should be implemented. Measures for addressing legacy debris issues include the following:

- Foreign material that is recovered from the RCS/PHT or attached systems should be identified by material composition and source, if possible.
- Legacy debris should be properly classified within the corrective action program to effectively identify whether it is a threat to fuel integrity.
- Plans should be developed to search for sources of legacy debris.
- As-found conditions should be documented when systems or equipment are opened.
- System/equipment closeout inspection results should be documented in the work package.

6
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A
FME PROJECT PLAN ELEMENTS

The need for and specific development of an FME project plan will be site-specific. The following sample plan elements are provided for consideration based on possible circumstances, not all sections would be useful for all activities. Station procedures should provide for flexibility based on a graduated response to job complexity and overall risk.

A.1 Cover Sheet

The cover page should contain the name of the FME plan (for example, the task to be performed). The cover page might also contain a place to signify review, approvals, and an understanding of the FME controls and responsibilities of the plan. Typical reviews and approvals might include the following personnel, but only those approvals that would add value should be listed on any particular plan:

- Task manager
- Maintenance manager
- FMEC
- Contract coordinator
- Specific maintenance department heads (if applicable)
- Modifications manager
- Responsible engineer
- Responsible first-line supervisor
- Other personnel as applicable

A.2 Purpose

A general statement should be given that provides instructions for determining the need for the specific FME plan, gives guidance on the content of the FME plan, and establishes roles and responsibilities for the personnel who perform work within the scope of the plan.

The following is a sample purpose statement:

“This FME plan provides FME controls that will be used for:

_____

_____

_____

Site Procedure [[[insert your station's FME procedure here]]] describes the general approach and provides numerous possible methods to prevent foreign material intrusion into systems and components. This plan establishes requirements which are selected to fit the work in accordance with the general requirements. These approved decisions are now specific requirements for this job. By following this plan, all workers, supervisors, and managers involved will understand the positive controls and contingencies selected for this activity that together protect the equipment from the consequences of foreign material intrusion."

A.3 Executive Summary

The optional executive summary statement should be a short statement that describes the work activity covered by the plan, including the following:

- The overall scope of the work activity
- What open systems are affected
- What sources of potential foreign material have been considered
- An overview of FME zone level/risk categories to be used
- A description of the control of work when system/equipment/components are not at risk

A.4 References

This section provides a list of resources used to develop the plan, including the following:

- Procedures
- Technical manuals
- Drawings
- OE

A.5 Responsibilities

This section should describe the responsibilities of key owners and other personnel involved with the plan. Key responsibilities associated with the plan might include the following:

- Perform reviews and approvals.
- Lead development and implementation.
- Develop engineered FME methods or techniques to prevent foreign material intrusion.
- Ensure that appropriate work instructions or references are included.
- Ensure that personnel who perform the work are properly trained and understand the plan.
- Ensure adherence to the FME procedure and FME process expectations.
- Ensure adherence to FME practices and housekeeping.

A.6 FME Risk Level

Provide a short narrative of what the risk level is and any transition requirements. Include the basis or reason(s) this particular risk level is selected.

A.7 Potential Sources of FME and Preventive Strategy

Provide a discussion of the potential sources of foreign material. A standard format may be used for ease of use and completeness, for example the following:

This work [ ] creates an opening in a system or component.

This work [ ] occurs near an open system or component.

This work [ ] generates debris (grinding, cutting, welding, spraying, sandblasting, brushing, painting, and so on).

- Environment, airborne dust, and contaminants: (explain source and mitigation strategy)
- Other work activities: (explain source and mitigation strategy)
- This work activity: (explain source and mitigation strategy)

The specific requirements below are to prevent foreign material intrusion from these sources while enabling efficient access to conduct the necessary work.

A.8 General Requirements

This section provides general or specific FME requirements that should be established to prevent foreign material intrusion during the work activity. The "General Requirements" section might do the following:

- Provide preliminary work precautions or requirements prior to opening systems.
- Provide inspection and hold points for FME aspects of the project.
- Describe when to use FME devices.
- Establish an FME monitor.
- Provide for periodic housekeeping inspections.
- Provide for as-found and as-left inspections.
- Establish guidance as to when or if the FME risk classifications can be changed and the requirements for changing risk classification.
- Establish tooling controls.
- Define FME zone accountability log requirements (that is, any special requirements, reconciliation requirements, use of personal accountability forms, and so on).
- Define lanyard/tethering requirements (for example, tools, personal items, and so on).
- Define personal FME requirements (for example, removal/securing of personal articles, badges, thermoluminescent dosimeters [TLDs], and so on).

- Establish requirements for cutting, burning, and grinding and/or other particulate-generating operations.
- Describe the control of trash and material waste (for example, packing material, weld rod, cable ties/wraps, and so on).
- Establish briefing requirements.
- Establish FME zone requirements (for example, barriers, buffer zones, signs, access points, prohibited items, and so on).

A.9 Training for the Work Activity

This section should outline any training requirements needed to perform the work activity within the FME zone to prevent foreign material intrusion. Training might include the following:

- Use of any special FME methods or techniques
- Training requirements for workers, FME monitors, and management
- Mockup training (for example, use of DLAs)

A.10 Special FME Controls

This section should contain any special FME controls that are warranted during the performance of the work activity to prevent foreign material intrusion, such as the following:

- Pre-job briefings that focus on FME, as applicable
- Work order FME hold points
- Material cleanliness, inspection, and storage requirements
- Housekeeping clean-as-you-go expectations
- FME plan risk category (include any changes in risk anticipated and authorization to change risk)
- Work flow planning to minimize exposure to foreign material intrusion
- Use of tooling (for example, inspections, lanyards, and so on)
- Requirements for control of breaches and FME devices to be used
- Precautions associated with internal FME devices
- Inspections (for example, pre-inspections and post-inspections, flushes, final inspections, and so on)
- The role of the FMEC
- Reconciliation and closeout of the FME accountability log

A.11 FME Zone Access Control

This section should include any additional controls that should be applied to the FME zone, such as the following:

- The use of buffer zones around an FME zone
- Specific FME monitor requirements (for example, use of individual personal accountability sheets)
- FME zone entry and access controls
- Specific responsibilities required by work activity that might not be addressed by procedure

A.12 FME Contingency Plan

This section should provide any special instructions that should be considered in the event that foreign material intrusion occurs. This guidance might contain instructions to ensure that systems, equipment, and components are properly maintained or controlled in the event of foreign material intrusion. It can provide instructions for loss of FME accountability, and might do the following:

- Detail any equipment required to be available in the event of foreign material intrusion.
- Identify vendors and/or personnel who will be part of the plan to operate special investigative or retrieval equipment (for example, cameras, boroscopes, robots, and so on).
- Discuss the importance of FOSAR availability if FOSAR is required.

A.13 Material Storage Control

This section should describe any controls required to maintain material or tool cleanliness in the FME zone or buffer zone (if applicable). For example, the section might discuss control of packing material and storage locations.

A.14 Crane and Rigging Accountability

This section should describe any requirements that should be in place if overhead cranes, monorails, hoists, and so on are used by the work activity or by any anticipated or unforeseen activities in the immediate areas surrounding or above the FME zone. The requirements might cover the following:

- Inspections of cranes
- Inspections of rigging, chain hoists, and so on
- Anticipated movements of overhead cranes above an established FME zone

A.15 OE and Lessons Learned

This section should provide any available OE or lessons learned from past performance of the work activity. Describe how this experience is applicable to the work activity and the consequences of the foreign material.

A.16 Other Topics as Required

Additional topics should be considered depending on the work. The following are examples:

- Special FME controls
- Controls for removal and installation of components
- Engineered FME controls
- Visual exams
- Use of consumable containers
- Special control measures during breaches
- FME SME involvement
- FME attendant requirements
- Emergency response actions

A.17 FME Plan Closeout

This section should cover the following topics:

- Work package closeout requirements and responsibilities
- Who to notify and how to recover foreign material if there is a loss of tool or material control during the evolution
- Closeout inspections at completion of the work

B
OVERHEAD CRANE FME PREOPERATIONAL INSPECTION

The overhead crane FME pre-operational inspection, a sample of which follows, is required prior to each use of an overhead crane adjacent to or over an FME zone following periods when the crane is unmanned. A completed copy of this inspection should be kept with the work package.

_____ Inspect crane trolley, bridge, runways, and rails, and verify that they are clear of all
Init. loose debris or material.

_____ Verify that all crane cabinet or enclosure doors are closed and secured.
Init.

_____ Tools and/or materials should be removed from the crane cab. If they must remain
Init. on the crane, they should be made failsafe.

_____ Crane operators and other personnel on the crane should remove or secure any
Init. personal items. A suitable restraint or lanyard should be used to restrain personal items.

If work is being performed on an overhead crane that is adjacent to an FME zone(s), additional controls should be implemented to prevent FME from being introduced into the FME zone(s).

Additional Controls Required _____ Yes _____ No

1. _____
2. _____
3. _____
4. _____
5. _____

_____/_____/_____
Crane Operator Signature Initial Date

C
FME SIGN EXAMPLE

Figure C-1 is an example of an FME sign that might be located at an FME zone for which requirements are based on possibility of intrusion, recovery, and consequence. Similar signs could be developed based on risk, system, or other classification systems. Signs should be posted at FME zone entrances. Signs should also be made from a highly visible, colored material.

FME Zone

FME Zone Contact Information	
Work Order #:	Date Posted:
Job Supervisor	Phone:
Day Shift Contact	Phone:
Peak Shift Contact	Phone:
Night Shift Contact	Phone:
FME Zone Classification	
[ ] High-Risk FME zone [ ] Standard-Risk FME zone	
FME Zone Requirements (check all that apply)	
[ ] FME monitor	
[ ] FME Accountability Log. Reconcile log every _____ (day/week)	
[ ] FME Plan	
[ ] Pre-Job Brief Required Prior to Work	
Additional FME Considerations	

Figure C-1
Example of an FME zone identification sign

D
FOREIGN MATERIAL CONTROL REQUIREMENTS CHECKLIST

Work Order/Work Activity Description						Equipment ID	
A. FME Requirements							
FME Level Determination		□ High Risk		□ Standard Risk		Actions Performed	**Notes**
General Requirements							
FME plan		□ Yes □ No		Not Required		Init._____ Date _____	
Pre-job brief		Required		Required		Init._____ Date _____	
FME monitor		Required		□ Yes □ No		Init._____ Date _____	1,5
FME zone boundary		Required		□ Yes □ No		Init._____ Date _____	2
FME signs		Required		□ Yes □ No		Init._____ Date _____	2
Inspection Requirements							
Initial inspection		Required		Required		Init._____ Date _____	
Inspection following breach		Required		□ Yes □ No		Init._____ Date _____	6
Periodic inspection of adjacent areas		□ Yes □ No		□ Yes □ No		Init._____ Date _____	3
Reconciliation (frequency)		Required		□ Yes □ No		Init._____ Date _____	4
Unattended openings		Required		Required		Init._____ Date _____	7
Final/closeout		Required		Required		Init._____ Date _____	See Section C

Covers/barriers		Required		□ Yes □ No	□	Init._____ Date _____
Lanyards		Required		Not required		Init._____ Date _____
Plugs/dams		□ Yes □ No		□ Yes □ No	□	Init._____ Date _____
Accountability log		Required		□ Yes □ No	□	Init._____ Date _____
Tools		Required		□ Yes □ No		Init._____ Date _____
Material		Required		□ Yes □ No	□	Init._____ Date _____
Consumables		Required		□ Yes □ No	□	Init._____ Date _____
Personnel		□ Yes □ No		□ Yes □ No	□	Init._____ Date _____
Personal items		Required		□ Yes □ No	□	Init._____ Date _____
Other FME Considerations		**(As Required)**				
Ventilation		□ Yes □ No		□ Yes □ No	□	Init._____ Date _____
Overhead controls		□ Yes □ No		□ Yes □ No	□	Init._____ Date _____
Clean enclosure		□ Yes □ No		□ Yes □ No	□	Init._____ Date _____
Special clothing		□ Yes □ No		□ Yes □ No	□	Init._____ Date _____
System flush/cleaning		□ Yes □ No		□ Yes □ No	□	Init._____ Date _____
Vent path requirements		□ Yes □ No		□ Yes □ No	□	Init._____ Date _____

B. Initial FME Control Actions
Initial inventory and appropriate levels of FME controls exist _____/_____/_____ (Print) (Sign) (Date)
Work Supervisor/Designee
Initial internal foreign material inspection following system breach completed _____/_____/_____ (Print) (Sign) (Date)
Work Supervisor/Designee

FME Internal Device Configuration Control Record (All internal plugs, dams, and so on should be logged)					
Internal Device Description	**Location**	**Date Installed**	**Work Supervisor/ Designee Initials**	**Date Removed**	**Work Supervisor/ Designee Initials**

C. Reconciliation and System Closeout

If FME accountability log is used, reconciliation is complete.

_____/_____/_____

(Print) (Sign) (Date)

<table>
<tr><td colspan="2">FME Monitor</td></tr>
<tr><td colspan="2">System/component is verified free of foreign material and internal barriers prior to system closure.</td></tr>
<tr><td>_____/_____/_____
(Print) (Sign) (Date)</td><td>_____/_____/_____
(Print) (Sign) (Date)</td></tr>
<tr><td>Work Supervisor/Designee</td><td>Peer Check</td></tr>
<tr><td colspan="2">All foreign material deficiencies noted during work activity have been noted, corrected, and documented in the corrective action program. (This includes all programmatic failures of the FME program, both task-related and administrative.)

_____/_____/_____
(Print) (Sign) (Date)</td></tr>
<tr><td colspan="2">Work Supervisor/Designee</td></tr>
</table>

Notes:

1. A high-risk FME zone requires a continuous FME monitor when the system/equipment/component is open. High-risk FME zone or medium-risk FME zone can use either a working or independent FME monitor, provided that the worker is FME monitor-trained.
2. A high-risk FME zone boundary should be established with preferably one entry point. Signs and tool, material, and personnel accountability are required. Medium-risk FME zone typically does not require tool and material accountability. However, lanyards should be used on items that are smaller than the system/component breach.
3. Breaching a system/equipment/component requires inspection of adjacent areas (including above), including the removal of all debris and non-failsafe items.
4. A high-risk FME zone requires reconciliation of the FME accountability log. The log should be reconciled when foreign material is suspected of being introduced into system/component breach, when there is a loss of accountability control, during long periods of unattended work activities, prior to final closure of a system/component, and at the work supervisor's discretion. Any medium-risk FME zone accountability log should be reconciled similar to high-risk FME zone FME conditions.
5. For a high-risk FME zone, an FME monitor is required to inspect all equipment, personnel, material, consumables, and so on at the entry point. Personal items should be removed. If it is not possible to remove personal items, they should be secured by an effective means (for example, with tape).
6. The high-risk FME zone and medium-risk FME zone require inspection of components upon removal and before installation for any broken, missing, or loose parts. Any parts found missing, broken, or loose should be resolved prior to final system/component closure.
7. The high-risk FME zone and medium-risk FME zone require that unattended openings have temporary covers and signs installed.
8. For a high-risk FME zone, the quantity of consumables should be minimized to the extent possible. Consumables should be recorded on the accountability log. Personal work gloves that could be removed inside the FME zone should be recorded on the accountability log.

E
FME ACCOUNTABILITY LOG (EXAMPLE)

FOREIGN MATERIAL EXCLUSION LOG

Component or Location: _____

SWO No: _____ **Page** _____ **of** _____

Item Description	Quantity Log In	Taken in By (Name or ACAD #)	Date In	Logged In By (ACAD #)	Quantity Log Out	Removed by (Name or ACAD #)	Date Out	*Removal Code (R, I, E, T)	Logged Out By: (ACAD #)

REMARKS	
***REMOVAL CODES** R: Removed from FME Area I: Installed E: Exchanged T: Transferred to different SWO in same FMEA	**FILLING OUT THE LOG** Log in an item by completing the item description, quantity in, taken in by Name/ACAD, date in and loggers ACAD number. Note any discrepancies in the remarks. Log out items by completing the quantity out, removed by Name/ACAD, date out, and the removal code and loggers ACAD number. Items may be logged out on a separate line and reconciled later.
PROCEDURAL REQUIREMENT: Reconcile logs once per shift and prior to final closure. Report discrepancies to work group supervisor.	

Close out Inspection: __________ Independent close out inspection: __________

Signature Date Signature Date

When complete, return a copy of the form(s) to the FME coordinator.

F
FME PROGRAM TRAINING MATRIX

F.1 FME Program Training Matrix

Major Training Topic	Topic Subset	Site Personnel	FME Coordinator	First-Line Supervisor	Planners	Maintenance Workers	Supp. Maint. Personnel	FME Monitors	Operations	Engineering	Managers	Others (*)
FME Fundamentals		X	X	X	X	X	X	X	X	X	X	X
	What is FME?											
	Where does foreign material come from?											
	Why is FME important?											
	Define workers' responsibilities											
	Define FME terms											
	FME zone requirements											
	Classification of FME zones											
	FME tools											
	FME logs											
	FME housekeeping requirements											
	Items not to be used in or around FME zones											
	Permanent site FME zones											

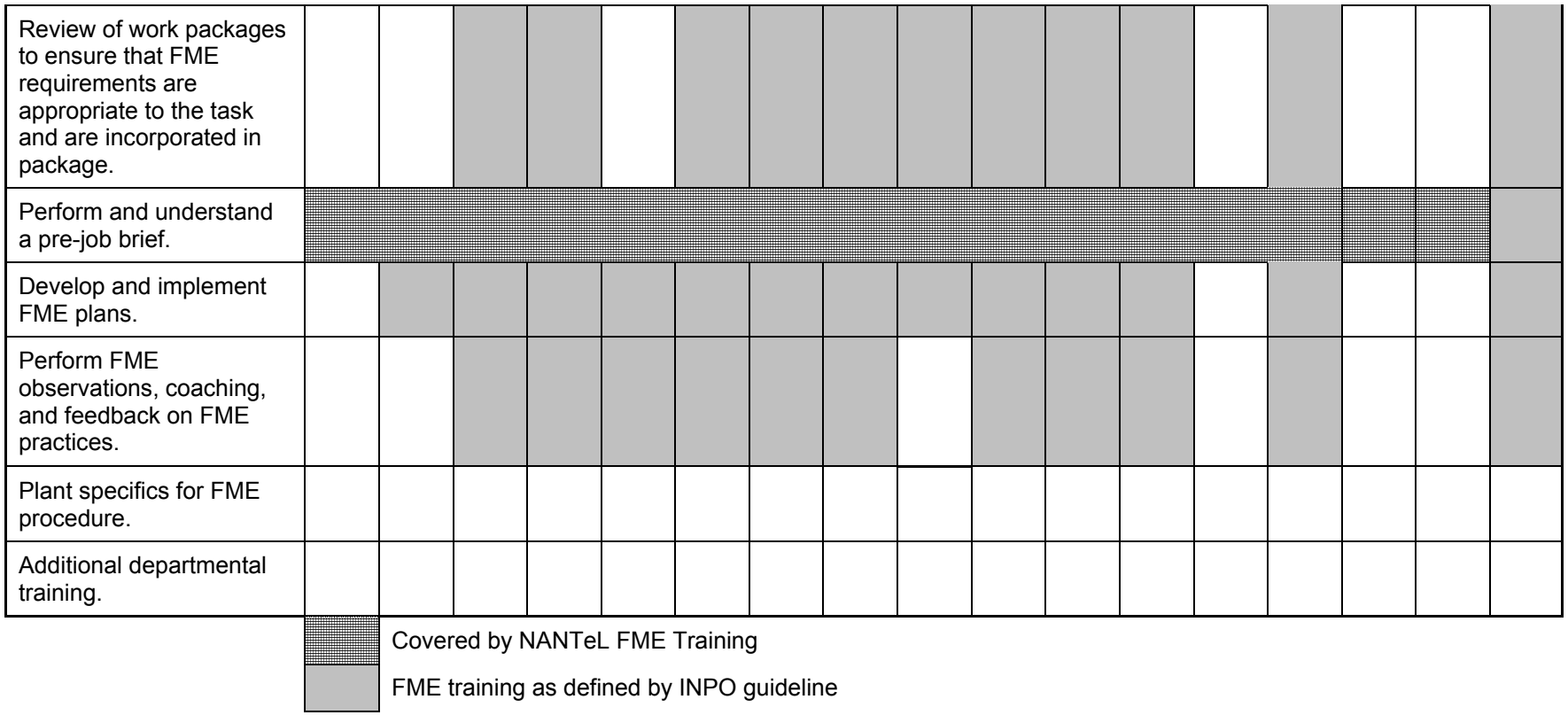
Major Training Topic	Topic Subset	Site Personnel	FME Coordinator	First-Line Supervisor	Planners	Maintenance Workers	Supp. Maint. Personnel	FME Monitors	Operations	Engineering	Managers	Others (*)
FME Trending			X									
	Use of the corrective action program (initiation)	X		X	X	X			X	X	X	X
	Performance indicators										X	
	Technological improvements			X						X		
Monitoring			X									
	FME assessments			X	X						X	
	Observations			X	X						X	X
	Benchmarking											
	Work site monitoring			X	X	X	X	X	X	X	X	X
	Feedback			X	X	X	X					X
	Work site inspections			X	X						X	X
FME Training			X	X							X	
	Communicating and reinforcing standards			X						X		
	OE			X	X							
	Lessons learned			X	X	X	X	X				
	OJT			X		X	X	X				

Major Training Topic	Topic Subset	Site Personnel	FME Coordinator	First-Line Supervisor	Planners	Maintenance Workers	Supp. Maint. Personnel	FME Monitors	Operations	Engineering	Managers	Others (*)
FME Devices/Tools			X									
	Use of FME devices/tools			X		X	X				X	
	Procurement of FME devices/tools				X							
FME Requirements												
	Implementation			X	X	X	X					
	Review			X		X	X	X	X	X		
	Pre-job briefs			X	X						X	
	FME zones										X	
	Initial FME zone classification				X							
	Establish FME zones			X	X							
	Review FME requirements					X	X	X				
	Logging requirements							X				
	Material and personnel control requirements				X	X	X	X				
	Loss of FME integrity	X	X	X		X	X	X				
	Foreign material recovery techniques								X	X		
	System pre-opening inspections			X	X	X	X		X			
	Final system closure			X	X	X	X		X	X		

Major Training Topic	Topic Subset	Site Personnel	FME Coordinator	First-Line Supervisor	Planners	Maintenance Workers	Supp. Maint. Personnel	FME Monitors	Operations	Engineering	Managers	Others (*)
	Work packages										X	
	Develop work packages (FME documents)				X							
	Work package reviews			X	X							
	Assign FME monitor			X	X							
	FME plans											
	Develop			X	X							
	Review			X							X	
	Implement					X	X					
	Housekeeping					X	X	X				
	Changing FME requirements											
	Recognize and notify supervisor					X	X					
	Approve				X							
	System flushing techniques and requirements								X	X		
	Design package reviews for FME consideration											
	Evaluation of FME capture devices									X		
	Evaluations of unretrievable FM									X		

F.2 FME Training (NANTeL to INPO Guideline Cross-Reference)

	NANTeL Covers	FME Monitors	QC/QA	First-Line and Supplemental Supervisors	Managers	Maintenance Workers	Planners	Supplemental Maintenance	Operations Personnel	Engineering Personnel	Fuel Handlers	Radiation Protection	Supply Chain	Security Personnel	All Plant Personnel	General Supplemental	FMEC
FME general program awareness.																	
Understand FME requirements and how to implement them.																	
Initiate corrective actions if FME requirements have not been met.																	
Understand changes in conditions or work scope and how they relate to changes in FME requirements.																	
Ensure system and component cleanliness before final closure.																	


Review of work packages to ensure that FME requirements are appropriate to the task and are incorporated in package.
Perform and understand a pre-job brief.
Develop and implement FME plans.
Perform FME observations, coaching, and feedback on FME practices.
Plant specifics for FME procedure.
Additional departmental training.
Covered by NANTeL FME Training
FME training as defined by INPO guideline

G
COACHING OPPORTUNITIES/JOB OBSERVATIONS FOR MONITORING FME PROCESS COMPLIANCE

The following are specific observations/coaching opportunities that should be considered:

- The pre-job briefing addresses specific FME activities and expectations.
- FME zone control is discussed and implemented.
- Personal items are secured or controlled to prevent introduction into systems.
- Tools in FME zones have been inspected and are serviceable.
- Lanyards are used as required or are failsafe.
- Laydown or disassembly areas are established as necessary.
- Appropriate barriers and signs are established.
- Work package FME documentation is completed as appropriate.
- An FME monitor and log are established.
- Tools are verified to be clean and serviceable.
- Area barriers and signs are in place.
- Openings are covered by appropriate barriers.
- Clear plastic in FME zones has been marked to ensure visibility.
- Tool and part controls are used (lanyards, failsafe tools, and so on).
- Material generated has been removed from the area.
- FME barrier devices or covers are removed.
- Internal areas have been cleaned as appropriate.
- Inspection is performed and documented.
- The tools and material log is reconciled, if required.
- Zone barriers and signs have been removed.
- The work area is clean.

These observations might be incorporated into plant procedures or formulated to provide quick and easy reminders of what to look for during pre-job briefings, implementation, and closeouts.

H
WARNING FLAGS DEPICTING AN FME PROGRAM WEAKNESS

If any of the following statements apply, an FME program weakness could be indicated:

- Management does not support the FME program sufficiently. Examples of this include bypassing FME controls to meet the schedule, not reinforcing FME boundaries, and not holding supervisors and workers accountable for identifying and correcting poor FME practices.
- Workers do not understand the expectations and standards for FME program implementation.
- Workers view FME controls as a burden.
- FME materials and/or tools are not readily available.
- Workers are not using available FME materials.
- The workforce demonstrates poor housekeeping practices.
- Supervisors tolerate poor housekeeping practices.
- FME is not considered a site-wide program (for example, only maintenance personnel are expected to implement the FME program).
- The FME procedure is unwieldy or unclear.
- Equipment-related failures are occurring as the result of foreign material intrusion.
- Debris is found in the systems and equipment.
- FME requirements are not included in the work packages.
- FME equipment and materials are not specified in the work packages.
- FME zones and/or FME boundaries are not enforced or are not clearly established at the work site.
- Oversight and coaching of worker FME practices are lacking.
- Warehouse and/or storage FME practices are not consistent with requirements in station areas (lower standards for FME controls in the warehouse areas).
- Workers are uncomfortable reporting FME issues.
- Pre-job briefings do not focus sufficiently on foreign material prevention and detection.
- Vendors and/or supplemental personnel are on the site performing work without being aware of and accountable to the site standards for FME.

- Situations arise in which site staff cannot verify the absence of foreign material in refurbished or preassembled parts and equipment coming from a vendor.
- Receipt inspections do not include an FME inspection.
- Concern for removing foreign material is weak during debris-generating activities, such as mechanical cutting and grinding.
- Insufficient initial training on FME expectations and requirements is identified in root cause reviews or self-assessments.
- Continuing training does not include recent industry or station FME experience.
- Training instructors do not reinforce FME practices during practical training sessions on mockups or on actual station equipment.
- Human performance simulators and equipment mockups lack FME covers, plugs, and other controls.
- FME is not integrated into training activities for which, if the same activity were to be performed in the station, FME controls would be expected.
- FME lessons learned are not captured following the work.

I
TYPICAL ASSESSMENT QUESTIONS TO SUPPORT CONTINUOUS IMPROVEMENTS

I.1 Program, Ownership, and Expectations

1. Does the site have a clear program owner to promote and improve the FME program?
2. Does the FME program include clearly defined FME levels based on risk, consequences, and/or systems?
3. Does the FME program include a clearly defined scope for plant systems and components?
   a. Definitions of FM?
   b. Levels of FME controls?
   c. Guidelines for FME requirements?
   d. Establishing FME boundaries?
4. Are roles and responsibilities clearly defined for each of the following?
   a. Site leadership
   b. Supervisors
   c. Planners
   d. Workers (including supplemental personnel)
   e. Contract coordinators
5. Does the FME procedure discuss actions to be taken when problems or concerns arise or when a loss of FME control occurs?
   a. Is there a clearly established criterion for reporting FME events?
   b. Are reporting requirements clearly understood by plant personnel?
6. Are there criteria for reporting FME events?
   a. Does the FME program have FME metrics for tracking performance?
7. Is procedural guidance for retrieval of foreign material from open systems and components clear?
8. Does the plant have an FME report that is generated on a regular basis and that documents plant condition reports of FME problems, trends, or FME observations from the site observation program?

9. Is FME considered when making design changes or modifications to plant systems or components?
10. Are all required items logged in an FME accountability log?
    a. Is the FME accountability log audited as part of work activity closeout processes to verify 100% accountability for all materials that entered the FME area?
    b. Does the FME accountability log provide for clear description and quantities of items taken in by a worker?
    c. Is performance of a closeout inspection documented on the FME accountability log or in a work package?
11. Does the site and/or utility look at non-traditional areas, like traveling screens, as potential foreign material intrusion points?
12. Where formal FME procedures exist, have they been evaluated for usability?
    a. Are they unwieldy or unclear?
13. Do site fuel receipt inspection instructions properly account for foreign material inspections?
14. If an FME steering committee is used to improve performance, has it been effective?

    Note: The use of these types of teams is a business decision for each site to evaluate. However, effectiveness of the committee should be evaluated to support this business decision.

I.2 Maintenance Work Practices

1. Do work package instructions contain adequate technical directions for applying FME controls to specific work situations?
    a. If so, do supervisors or workers provide backup by reviewing the work packages or perform walkdowns to ensure that proper FME controls will be established for the activity?
    b. Do work instructions incorporate the graded approach to planning?

    Note: Assessment of this question requires a review of other plant programs.
2. Do work plans include input from maintenance, engineering, and operations departments regarding past performance of maintenance or surveillances?
3. Do work instructions provide adequate guidance during maintenance closeout activities that appropriately document FME inspections and verification?
4. During pre-job briefings, do workers address FME requirements (including prevention, detection, and retrieving) and proper controls and practices?
5. To what extent are site and industry FME OE used in pre-job briefings?

6. FME materials and tools

   Do workers use available FME materials and tools (such as caps, plugs, and covers)?

   a. Are FME materials and tools readily accessible?
   b. Are FME tools in good, fair, or bad condition?
   c. Are parts and tools inspected before and after entering an FME zone to identify loose, missing, or broken parts?

7. Are workers using error-prevention techniques to reinforce proper work practices?

   a. Do they generally take ownership with respect to FME controls?

8. Are FME zone boundaries clearly established and enforced at the work site?

9. Do maintenance techniques include methods to prevent introduction of foreign material (such as grinding versus cutting) when breaching plant systems or components?

10. Housekeeping Practices

    a. Do workers have a mindset of system cleanup versus foreign material prevention?
    b. Do workers and/or first-line supervisors demonstrate and/or tolerate poor housekeeping practices?
    c. Are housekeeping problems identified during supervisory overviews (especially during outages and new fuel preparation)?
    d. Are site leadership expectations for housekeeping and cleanliness controls well communicated?
    e. Do workers know and understand site leadership expectations? (Are they part of the routine pre-job/post-job briefing discussions?)

11. Are workers encouraged to report FME issues, problems, or concerns to supervisors?

    a. Do workers feel comfortable reporting FME issues or concerns?
    b. Are there repercussions for workers who report a loss of FME integrity event?

12. Do workers understand site leadership expectations concerning FME?

13. Do workers view FME as a burden? If so, what assistance has been requested to assist in developing a change in attitude?

14. Supply chain (warehouse) policy. Do warehouse receipt inspection instructions include criteria for identifying and disposing of foreign material or debris?

    a. Are FME standards and practices in the warehouse consistent with plant standards?

I.3 Site Leadership and Supervision

1. To what extent are managers and supervisors involved in oversight of work activities, especially where the introduction of unplanned foreign material would have serious consequences?
2. Is FME considered a stationwide program?

   (For example, there might be a mindset that only maintenance personnel are expected to implement FME controls and practices.)
3. Do some supervisors have weaknesses in recognizing improper FME controls?
   a. Are they performing effective work observations?
   b. Do they provide timely intervention and coaching to correct and improve worker performance?
   c. What is being done to overcome such weaknesses?

   Note: Assessment of this question requires a review of other plant programs.
4. How often is site leadership observing work requiring FME controls?

   Note: Assessment of this question requires a review of other plant programs.
5. Are supervisors reinforcing the importance of using proper FME controls during pre-job briefs and field inspections?

   Note: Assessment of this question requires a review of other plant programs.
6. Can it be verified by both observation and interviews that site leadership, supervisors, and workers are in alignment in their understanding of the station FME procedure and expectations?

   Note: This question requires a review of other plant programs.
7. Are worker practices and behaviors for controlling foreign material and housekeeping routinely evaluated? If so, review documentation and verify that corrective actions were effective.
8. Regarding open vessel activities, are shortfalls in FME practices rigorously identified and corrected?

I.4 Training

1. Have site leadership expectations been incorporated into the training program(s)?
2. Is the adequacy of FME initial and continuing training for all site and supplemental personnel involved in adhering to proper FME practices being assessed?
3. If the site uses temporary personnel during outages as supervisors and/or to conduct pre-job/post-job briefings, what site-specific training concerning FME is provided prior to allowing them to perform these functions unmonitored?
4. Does FME training for supplemental personnel meet the same standards as the training for station personnel?

5. Is FME integrated into training activities for which, if the same activity were to be performed in the station, FME controls would be expected?
   a. Does training (classes, labs, and task performance evaluations) include reinforcement of FME controls as a passing criterion for the class?
   b. Does training use DLAs to reinforce FME controls?
6. Are personnel designated as FME monitors examined for their knowledge of site/utility FME requirements and expectations?
7. Are training instructors reinforcing FME expectations and requirements during practical training sessions on mockups or actual station equipment?
8. Do human performance and/or error prevention training simulators or mockups include FME devices (for example, covers, plugs, and so on) and other controls if such would exist at the work site or plant location?
   a. Do these simulators or mockups include FME-specific scenarios that reinforce prevention?
9. Does continuing training include recent industry or station FME OE?
   a. Are FME lessons learned included in training?
10. How often are station workers and supervisors who are responsible for site FME enforcement tested on their knowledge of the FME program?
11. Is training in basic FME practices provided to personnel who are involved in activities that can occur in or near FME zones?

I.5 Supplemental Personnel

1. Do supervisors increase the number of observations of supplemental personnel until they feel that site expectations have been met?

   (In normal station practice, use of FME monitors might accomplish the same purpose.)

   Note: Assessment of this question requires a review of other plant programs.
2. Do pre-job/post-job briefings of supplemental personnel address FME controls and practices?

   Note: Assessment of this question requires a review of other plant programs.
3. To what extent are site and industry FME OE used in pre-job briefings?
4. If the utility uses shared resources for supplemental personnel oversight during outages, what is done to ensure that these individuals understand the site FME program expectations and standards?
5. What is the level of site leadership's (such as first-line supervisors') involvement with in-processing and/or training of supplemental personnel?

I.6 Self-Assessment and Benchmarking

1. Are recommendations from self-assessments implemented in a timely manner?
   a. Are there contingencies in place while recommendations are awaiting implementation?
   b. Are self-assessments documented?

   Note: Assessment of this question requires a review of other plant programs.
2. How often are self-assessments dedicated to FME practices and training performed?
   a. Has the periodicity and/or areas of focus changed based on issues identified in corrective action program documents?

   Note: Assessment of this question requires a review of other plant programs.
3. Do assessments tend to be compliance-based rather than seeking comparison of station activities to the industry's best programs and practices?
4. Have warehouse storage and warehouse personnel FME practices been assessed to be consistent with station expectations?
5. Has benchmarking been used to improve FME performance?
6. Has the site evaluated the INPO warning flags, as applicable?
7. Have FME plans been developed for major projects (turbine generator overhaul, refueling floor, intrinsic internal inspections/repairs to equipment, S/G replacement, condenser bundle replacement, and so on)?
8. Have key personnel (FMEC, maintenance, engineering, operations staff) been involved in setting up plans for FME controls for construction of new plants?
9. Does your plant have an FME report that is generated on a regular basis and that consists of plant condition records concerning FME problems?
10. Does the site observation program incorporate FME control practices to allow tracking and trending of low-level situations?
11. Have FME plans been developed for big projects (turbine generator overhaul, refueling floor, intrinsic internal inspections/repairs to equipment, and so on)?
    a. Have maintenance, engineering, or operations staff been involved in setting up the plan?
12. Does your plant have an FME report that is generated on a regular basis and that consists of plant condition records concerning FME problems and FME observations from your plant's observation program?

J
FME PROGRAM HEALTH

J.1 FME Event Trending Example

Event trending is based on the metric definitions provided in Section 8.1. Table J-1 is an example of FME events by FME type (level). Data can be presented on a monthly basis, but they are best presented using a 12-month rolling average. This will avoid large swings in data and possible overreaction to small deviations.

Table J-1
Trending by FME event type

Number of FME Event Types per Month												
FME Event Type	**Jan.**	**Feb.**	**March**	**April**	**May**	**June**	**July**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
FME Significant Event	0	0	1	0	0	0	0	0	0	0	0	0
FME Threat	0	0	0	4	0	0	0	0	1	0	1	0
FME Condition	2	2	3	7	2	3	1	1	1	0	1	1
Total	2	0	4	11	2	3	1	1	2	0	2	1

It is difficult to distinguish trends when data are presented in chart form. The use of graphs aids in trend identification. Figure J-1 represents the data shown in Table J-1.

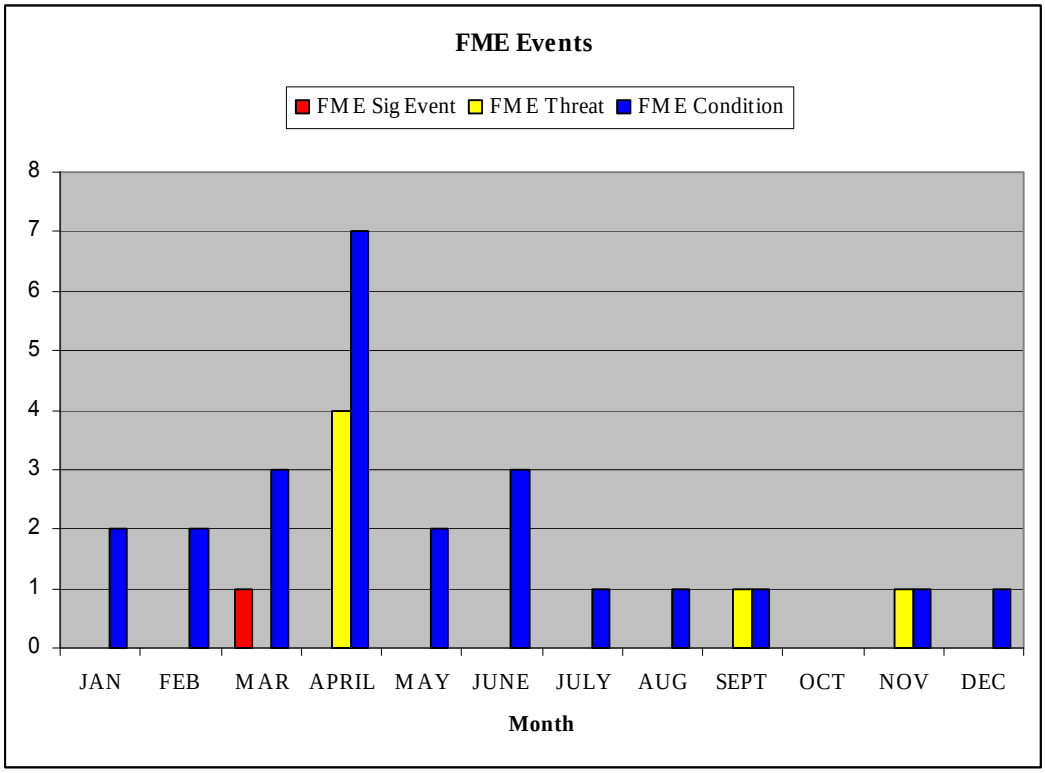


Figure J-1
Bar chart display of the data shown in Table J-1

J.2 FME Causation Group Trending Example

Table J-2 presents definitions of FME events by causation grouping. Groupings can be designated according to site needs or requirements. The definitions in Table J-2 can be used to look into specific areas of FME events to assist in understanding more about those events. Group definitions are further reduced to subgroup causations (for example, foreign material identified might be debris, parts, damage, tape, tools, and so on).

Table J-2
Definitions of FME events

Group Definitions	
FME Causation Group	Definition
	FME Causation Subgroups
Dropped Item	If an item is dropped, it is almost always a human performance worker practice issue. Associated with this group would be:
	Debris Tool Parts Tag Personal & Protective Equipment
Equipment	Typically, the equipment or component was affected by what happened during the work activity, such as loss of FME control. Associated with this group would be:
	Damage Degrading Design
Foreign Material Identified	These are items found upon opening the system or component. Associated with this group would be:
	Debris Parts Damage Tape Cover Tool
Housekeeping	Items found and are there because of worker practice. These items were not found when opening the system or component, rather they are found during or after the work. Associated with this group would be:
	Degrade Design Debris Tool
FME Accountability Log	An item was logged in but cannot be located in the FME zone, or the item was found in the FME zone and is not logged into the area. Almost always a human performance worker practice issue. Associated with this group would be:
	Tool Debris Housekeeping Misc. Tool
Program Issue	This grouping typically tracks program strengths, weaknesses, or improvements. Associated with this group would be:
	Procedure Personal Evaluation Enhance Administration Track Cover Work Order
FME Tools	Can be a worker issue, such as not inspecting the tool prior to use. Associated with this group would be:
	Degraded Broken

Table J-3 is an example of a chart that could be developed using FME causation groupings defined in Table J-2.

Table J-3
Number of FME events by causation groups by quarter

Group	Quarter/Year				
	4th/2006	1st/2007	2nd/2007	3rd/2007	4th/2007
Dropped Item	7	4	7	2	0
Equipment	6	0	2	2	1
Foreign Material Identified	6	8	6	3	1
Housekeeping	2	1	1	1	0
FME Accountability Log	1	1	1	0	1
Program Issue	2	3	3	1	3
FME Tools	0	0	0	0	0
Total	24	17	20	9	6

Figure J-2 depicts the information from Table J-3.

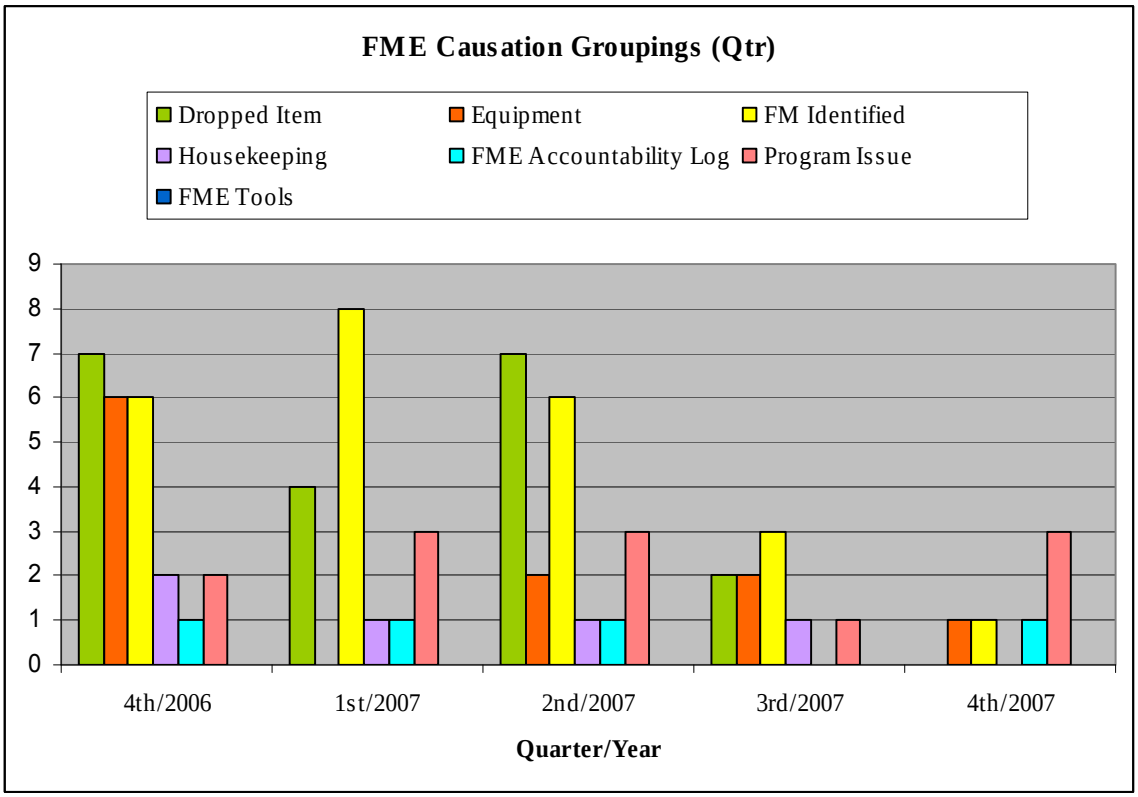


Figure J-2
Number of FME events by causation groups by quarter

J.3 FME Zone Related by Equipment Type Event Trending Example

Table J-4 lists FME-related events for FME zones related by equipment type. This can assist in understanding the types of equipment that have experienced an FME event. Information from this type of trending could result in program changes to enhance FME controls on certain types of work.

Table J-4
FME zone related by equipment type events by quarter

Component	Quarter/Year			
	1st/2007	2nd/2007	3rd/2007	4th/2007
Condenser	2	2	0	0
Diesel generators				1
Drains		1	1	0
Electrical cabinets	2	1	0	1
Filters	0	2	0	0
FME zone	0	0	0	0
Gaskets			1	0
Heat exchangers	0	0	4	0
Intakes: circulation water/service water	0	0	0	0
Miscellaneous	1	5	1	3
Motors	1	0	1	0
Pumps	0	1	1	0
Reactor building	0	2	0	0
Reactor cavity	1	4	0	0
SFP	4	1	0	1
S/Gs	3	0	0	0
Turbine	2	1	0	0
Valves	1	0	0	0
Total	17	20	9	6

Figure J-3 is a graphical representation of the information provided in Table J-4.

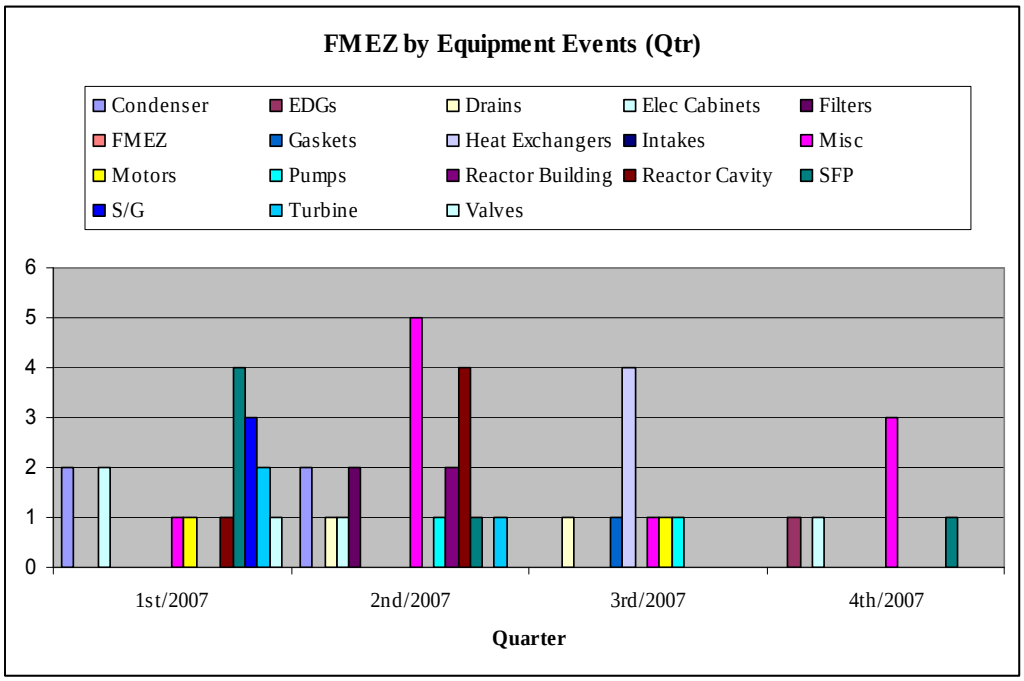


Figure J-3
FME zone related by equipment type events by quarter

J.4 FME Responsible Group Trending Example

Table J-5 lists FME-related events that have been trended to assist in understanding which organizations are involved in FME events. Information from this trending could assist in developing changes in FME training for affected organizations or an evaluation of FME practices by a particular group.

Table J-5
FME events by responsible organization by quarter

Responsible Organization	1st/2007	2nd/2007	3rd/2007	4th/2007
Chemistry	0	0	0	0
Electrical maintenance	1	1	2	1
Engineering	0	0	1	0
I&C	0	1	0	1
Maintenance services	0	1	1	0
Mechanical maintenance	2	1	0	0
Modifications	1	2	2	0
Operations	1	0	0	1
Radiation control	1	0	0	1
Reactor vendor	0	2	0	2
Turbine vendor	0	1	0	0
Unknown	5	5	2	0

Figure J-4 is a graphical representation of the information in Table J-5.

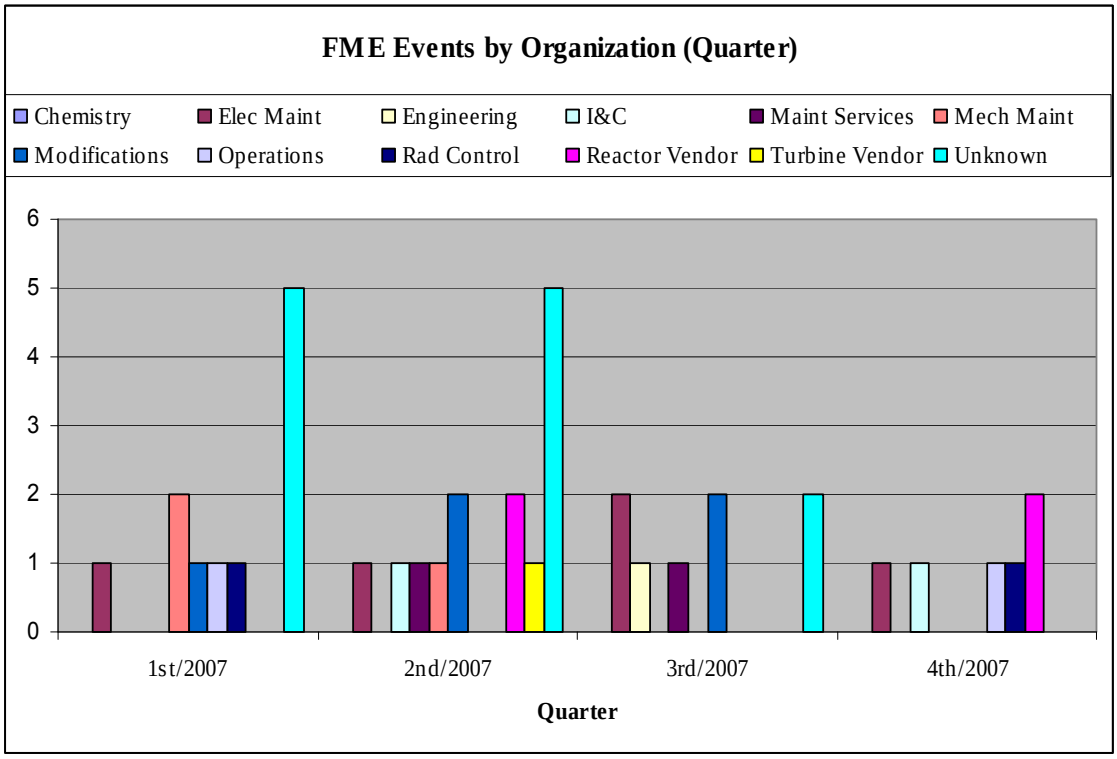


Figure J-4
FME events by organization by quarter

J.5 Other Trending

The preceding examples are but a few of the trends that could be developed to assist in monitoring overall FME program effectiveness. Other FME program attributes that could be trended might include the following:

- FME events caused by different work practices
- FME observations and monitoring performed
- FME event-free clocks

The information that is tracked and trended should be based on site-specific needs or requirements.

K
FME TRAINING ELEMENTS BASED ON FME PROCESS ROLES

The development of the FME training program should follow the systematic approach to training (SAT) process. Although the fundamental concepts of an FME process might be relatively straightforward, these concepts are applied to and affect a wide range of plant systems and equipment and are implemented by a broad spectrum of station personnel, each with his or her own responsibilities regarding the FME process implementation. The FME training program should be a site program touching all areas of the plant; therefore, it should be designed to include all on-site, station, and supplemental personnel.

K.1 Needs and Objectives

Key fundamental FME process concepts should be presented to all personnel. Specialized training should be provided to station personnel based on their FME process responsibilities. Personnel who perform operational, maintenance, or inspection activities on open systems and equipment or within FME zones should be trained to implement the requirements of site procedures. Alternatively, such personnel should be continuously supervised by personnel who have been trained to implement the requirements of the procedures. Personnel who perform FME zone monitoring activities and personnel who perform closeout inspections or verify that systems and equipment meet site cleanliness standards should receive specialized training related to these activities. Specialized training should also be provided to personnel who perform observations, inspections, or assessments of FME work practices, FME zones, and the FME process. In addition, FME practices should be incorporated into all other applicable training programs, such as maintenance and operations training. As with any training program, different groups have different needs, goals, and objectives. Appendix J, "FME Program Training Matrix," provides a matrix of key station personnel in the FME program and FME training topics. (The list is not all-inclusive.)

K.1.1 All Station Personnel

The introductory level of FME training should be provided to all station personnel, both permanent and supplemental. These personnel should be trained to recognize and respond to foreign material risks to plant systems and equipment. The training can be provided through a variety of training venues. Many plants use their general employee training (GET) programs as the venue to deliver FME initial training. Some plants employ the use of computer-based training (CBT) to deliver the program fundamentals. No matter what the venue or method of training used, the introductory course on FME should be involved enough to relay the fundamentals of the FME process, emphasize the program's importance to the site's goals and objectives, and provide for some demonstration of proficiency in FME knowledge and skills.

Security personnel should also receive basic FME process awareness training to take advantage of their field observations performed during their patrols. Security can be added to enhance the FME process.

K.1.2 Maintenance Workers

Workers/monitors are presented with situations that pose the greatest risk for the loss of foreign material control. Therefore, these groups should receive training to reflect the function they perform. Significant gains in an effective FME process can be accomplished through an effective training program built around the maintenance worker. An effective training program should include a combination of classroom training that is reinforced by lab activities that provide opportunities to demonstrate actual FME skills and expectations. Too often, workers understand the FME requirements but fail to implement the requirements in the field. Mockups and training scenarios should reflect actual field conditions as closely as is practical in order to achieve the maximum benefit from this training. FME cabinets and disposal barrels for soiled or damaged FME devices should be consistent with those in the station to foster expected FME practices.

Maintenance workers should receive FME fundamentals training and specialized training associated with their FME responsibilities. It is essential that workers understand the impact of poor work practices. In general, the specialized training should include training in the following areas:

- FME zone requirements (implementing and review)
- Proper use of FME tools/devices
- FME housekeeping expectations and requirements
- Implementation of FME plans
- Review and implementation of system opening and closure requirements
- Loss of FME integrity requirements
- Disposal of soiled or damaged FME devices

K.1.3 The FME Monitor

The FME monitor provides additional control to prevent introduction of foreign material into the FME zone. Similar to the maintenance worker, the FME monitor can have significant impact on the effectiveness of the FME process. In many cases, the FME monitor is a very junior person who might possess little or no work experience in a nuclear plant. FME monitors should clearly understand the importance of their FME responsibilities and the impact that poor FME practices can have on the plant, and they should receive FME fundamentals training similar to the maintenance worker. Mockups or lab scenarios can be particularly effective forms of training, providing hands-on skills in log reviews, turnovers, work site inspections, log reconciliation, identification of poor FME work practices, and other key responsibilities. In addition to FME fundamentals, the FME monitor should receive specialized training in the following areas:

- FME zone (requirements, logging requirements, and tool and personnel control)
- Loss of FME integrity requirements (including work stoppage)

- FME zone monitoring (which includes reconciliation, inspection, and reverse inspection)
- FME housekeeping expectations and requirements
- Inspection practices for FME devices and how to use them

The FME monitor should be required to shadow a qualified FME monitor before performing independent FME monitor responsibilities.

K.1.4 First-Line Supervisors

First-line supervisors should possess a solid working knowledge of FME requirements. The first-line supervisor is often relied upon to develop FME plans and determine requirements, to change FME requirements as field conditions change, to ensure the performance of system pre-opening and closure inspections, and to reinforce expectations at the working level through inspections and observations. Knowledge includes the following:

- FME zone classification and requirements
- The use of OE in FME work packages
- FME documentation for work packages

Therefore, first-line supervisors' training should encompass knowledge at the working levels in addition to the areas previously listed.

K.1.5 Planners

Many plants use their planners to develop FME plans and determine requirements, similar to the role of first-line supervisors. Therefore, planners should receive training equivalent to that of first-line supervisors. The planner has the first opportunity to establish FME controls.

K.1.6 Operators/Radiation Protection/Field Engineers

Many plants use these groups as a resource to ensure that FME requirements are being met and to identify possible shortfalls. Training requirements for these groups should be at a level for them to understand the overall program requirements and specific enough for their individual responsibilities. A successful program will train these groups to the same level as the hands-on workers.

K.1.7 Supplemental Personnel

Supplemental personnel often pose an increased risk for the FME process and are subsequently the greatest challenge for training. Plant needs peak during outages, and many supplemental personnel are in-processed in a short time. In addition, many of the supplemental personnel are new to the nuclear industry. One of the effects from this is a lack of focus on FME training. Supplemental personnel should be trained to the same standards as permanent employees. Additional reinforcements might include the use of dynamic learning activities (DLAs) or walk-through tutorials during training, along with a shortened classroom time, shorter-duration CBT, or not allowing them to work independently.

With the current trends in shorter outages and fewer core personnel, it is becoming increasingly difficult to ensure that supplemental personnel, who do not understand the station's FME culture, are supervised by experienced core personnel. Supplemental personnel are usually trained in their particular field, but they are generally untrained in the strict requirements of the nuclear industry's FME procedures. This is particularly true of contractors brought in for infrequent activities during outages.

K.1.8 Managers

In a strong program, management participates in FME training and clearly understands elements of a good FME process. This group requires the ability to assess FME in the field. Management should attend the same training as and along with workers to be able to perform this function. Some plants use a simple presentation for management to relay observation expectations. The use of field observation cards can be a very useful tool in increasing management effectiveness. For examples of job observation topics, see Appendix K, "Job Observations for Monitoring FME process Compliance."

K.1.9 The FME Coordinator

The FME Coordinator is the site champion for the FME process. This position is the single point of contact for the FME process. The FME Coordinator should be trained in and thoroughly familiar with every aspect of the FME process. In addition to FME training, the FME Coordinator should receive training that will enhance his or her ability to effectively communicate with station personnel and allow the FME Coordinator to drive the site toward excellence in FME performance. Training topics should include the following:

- Knowledge in all levels of the FME program
- Use of the corrective action program and the identification of trends
- Use and knowledge of OE sources
- Performance techniques and behaviors involved in assessments, benchmarking, and observations
- Training in any additional areas of responsibility that will improve the FMEC's overall effectiveness

K.1.10 Supply Chain (Warehouse/Procurement) Personnel

Supply chain personnel should receive training in station FME fundamentals and requirements. In addition, they should receive training in the application of FME requirements directly associated with their responsibilities. Topics should include the following:

- Use of FME devices
- Stocking and ordering of FME devices
- FME considerations during the performance of receipt inspections
- Types of foreign material and foreign material intrusion
- Supply-chain-specific OE

K.2 Key Training Elements

K.2.1 FME Training Content

Although training needs vary from site to site, the following key aspects should be included in every FME training program:

- Detailed program and procedure information. All site employees should receive training related to the FME program's standards and expectations, as well as FME program implementation requirements contained in site procedures. The information contained in these documents provides the trainee the key to understanding where the FME requirements and standards come from and how they are to be applied to employees' individual responsibilities. This information can be provided in a variety of training settings (for example, classroom, computer, required reading, and so on). Many sites include FME training as part of GET. Regardless of the training setting, the course should be involved enough to convey the FME message and its importance.
- Specific FME responsibilities. Because of the nature of the FME program and the diverse responsibilities of station personnel with respect to the FME program, it is necessary to provide training to key station personnel and personnel who have a high potential to influence the FME program's effectiveness. These personnel were presented in Section 3 of this report. The specific training for these personnel might be provided in specifically designed courses or included as part of other training programs (for example, operations, maintenance, and so on). The most significant lesson is best taught by example. An effective way to do this is by integrating FME expectations into other courses and as an area of evaluation.
- OE. OE is the best tool available to demonstrate the impact and consequences of poor FME work practices. The use of site-specific OE is preferable, but relevant industry OE should also be used. OE is a valuable tool for managers, supervisors, planners, and workers when it is relevant, practical, and timely with respect to the current situation. In addition to training, OE should be used in work packages, pre-job briefs, FME awareness posters, site outage goals, and so on. Too often, only the negative aspects or consequences of OE are presented. However, when positive occurrences of good FME practices are identified, they should be acknowledged, documented, and integrated into future training, procedures, work packages, and so on.

K.2.2 Training Settings/Venues

FME training is composed of knowledge and skills. To effectively communicate and enhance the comprehension and understanding of FME concepts and to enable trainees to demonstrate proficiency in the application of those concepts, one or more training settings should be used. In recent years, dynamic learning has been used to maximize the training experience. Dynamic learning employs a variety of techniques to make the training experience more effective. The key difference between regular or passive learning and dynamic learning is the interaction between the trainee and the classroom instructor, plant mockup, or simulator—even the computer in multimedia settings. The integration of concepts and tools is applied to situations where the student uses visual, auditory, kinesthetic ("doing" or motor skills), and emotions (learned or

acquired experiences) in a classroom (case studies), laboratory (mockups or simulators), or computer (multimedia presentations) to demonstrate understanding or proficiency of FME. Various training settings are available to communicate FME knowledge and skills. These include the following:

- **Classroom instruction**. The classroom is the traditional training setting. It is well suited for disseminating the programmatic and procedural aspects of FME. Instructors should be knowledgeable in all aspects of the FME program. If the instructor is not knowledgeable in all aspects of the program, an SME should be present during the instruction to ensure that FME fundamentals, standards, and management expectations are monitored and reinforced. This should be taught by the FME Coordinator or at least observed as part of the management observation program.
- **On-the-job training (OJT)**. Under some conditions, additional training might be required for a special or complex plan, project, or task. OJT provides an opportunity to practice and test key points and aspects of the activity and to demonstrate understanding and proficiency. This training setting is useful for FME monitors to demonstrate their understanding of the unique aspects surrounding the control of foreign material around FME zones and the FME zone itself.
- **FME labs (mockups or simulators)**. Plant mockups or simulators are a popular form of training and are an effective means to communicate plant expectations, incorporate new ideas, and demonstrate practical application of FME tools and devices. Mockup/simulators should resemble actual plant situations as closely as practical. This includes both physical arrangement and any associated controls (for example, radiation protective clothing, gloves, personal safety equipment, tools, and so on). Mockups/simulators might be permanent setups within the training center. Because they typically contain poor or bad practices or conditions, they should be clearly identified as areas that do not conform to plant standards. All mockups/simulators should be controlled using proper FME techniques, and FME expectations should be reinforced; however, some examples of poor FME practices should be incorporated into the training of station personnel to be sure that personnel are able to identify these deficiencies.
- **CBT**. CBT is a proven training setting that has been used to effectively communicate standards and FME fundamentals at a high level of initial understanding. Its effectiveness is enhanced when the program is monitored and proctored, allowing trainees to ask questions, promoting better understanding. Testing can also be administered through CBT. If this method of testing is used, it should be proctored, and test questions should be objective and randomly selected. INPO provides such training through its National Academy of Nuclear Training Electronic Learning (NANTeL) system.

K.2.3 Initial Training

Effective plants provide initial FME training to all station personnel. Many sites include initial FME training as part of the overall GET prior to plant access. This training is typically provided in the classroom or through CBT. To achieve the maximum benefit and effect, the training should accurately reflect plant conditions and include both internal and external OE. The use of mockups/simulators, OJT, and DLAs will enhance the trainees' learning experience. CBT has also been used for testing to validate knowledge retention. Initial training topics should include the following (based on site needs):

- FME program standards and expectations
- The definition, origin, and importance of FM
- Consequences and impact of poor FME practices (internal and external OE)
- Definition of FME terms
- Classification and requirements of FME zones
- Items excluded from use in and around FME zones
- Location of permanent site FME zones
- Loss of FME control/integrity
- Use of FME tools and devices
- Disposal of FME devices
- FME accountability log (personal accountability)
- FME housekeeping expectations and requirements

Depending on the responsibilities of certain station personnel or needs of the plant with respect to FME, additional training that is specifically directed at those responsibilities or needs should be provided. The groups include the following:

- Workers directly involved in the maintenance of the plant
- Workers responsible for monitoring FME controls
- Workers responsible for the development or review of FME plans or the classification or modification of FME zones
- Workers responsible for monitoring/observing FME program adherence (on-site or off-site)
- Workers responsible for procuring or receipt of materials or equipment
- Supplemental workers that perform maintenance activities on site (using either site or vendor FME procedures)
- Engineering working on station modifications who can affect the program by prescribing hardware that is prone to being dropped on removable items that must be removed during surveillances

- Contract coordinators who write scopes of work
- Contract coordinators who are overseeing a scope of work and who have the same responsibilities as first-line supervisors

K.2.4 Continuing Training

As the FME process changes, so do the expectations in the field. Refresher courses are valuable tools in maintaining a quality FME process. As plant goals change, so does the focus of its workers. In an effort to maintain the focus on FME, continuing training should be provided periodically, depending on plant needs. This training can be in the form of classroom instruction, CBT, mockups/simulators, required reading, and so on.

Continuing training topics could include any of the following:

- Weaknesses identified by the observation program
- A summary of FME-related items from the corrective action program database
- OE
- Lessons learned from outage critiques and normal plant operations
- Training for infrequent or difficult tasks
- Refresher training (FME fundamentals, FME device use, use of lanyards and tools, and so on)
- Reinforcement of management expectations
- Industry trends
- foreign material prevention and recovery techniques
- foreign material intrusion strategies that use FME devices (for example, barriers, dams, covers, and so on)
- Vulnerabilities of fuel to foreign material intrusion
- FME procedure review
- Flushing and cleanliness standards

K.2.5 Specialized FME Training

Additional FME training might be required for specific projects or activities, as determined by project or management personnel. Such activities could include new fuel receipt, refueling activities, S/G nozzle dam installation, main generator removal, or power repairs (Modes 1–4) inside containment. Many plants have found that group-specific training is a useful tool for areas such as the refuel floor or primary containment. These groups often encounter special FME needs that most station personnel would never come across. For this reason, it is a good practice to pay special attention to the training of these groups.

K.3 Training Department Responsibilities

For all aspects of FME training—initial, continuing, or special—the training department is responsible for designing, developing, and delivering FME training that meets the site's expectations and requirements. The training department is also responsible for maintaining lesson plans based on lessons learned and feedback, reviewing internal and external OE, and maintaining FME training facilities.

K.3.1 Training Center Facility Material Condition and Housekeeping

The conditions of the training center material, laboratories, and classrooms should be a direct representation of the high standards that are present in the plant. Methods and controls that are used in the plant should also be present in training scenarios. These include such items as work staging areas, FME zone use, housekeeping, material storage, tool control, radiation and contamination control, and so on. Each of these should be evaluated and reinforced during training scenarios. Managers and supervisors should be involved in training and should use the site observation program to reinforce the cleanliness and housekeeping expectations during all training activities.

K.3.2 Lesson Plans

Lesson plans should be kept current and reflect current site and industry standards and trends. Lesson plans should reinforce the primary focus of preventing foreign material intrusion. Although not a primary focus, lesson plans should also demonstrate when and how to use mitigation and recovery strategies. Historical events should be presented from internal and external OE.

K.3.3 Use of FME Devices in Training

The same FME devices that are used in the plant should also be used in training scenarios. Key considerations when incorporating FME devices in training include the following:

- Mockups/simulators should represent, as closely as is practical, actual plant situations.
- The scenarios should represent performance conditions (for example, lighting, clothing, and so on) to assist in the development of desired FME behaviors.
- Accuracy of FME scenarios should be evaluated and validated periodically by managers, supervisors, or the FMEC. Feedback should be captured and incorporated into future training scenarios.
- Actual plant designators, tools, signs, FME devices (for example, covers, plugs, dams, lanyards, and so on) should be used in the classroom, mockups/simulators, and dynamic learning activities.
- If the training scenario simulates work in an area that requires FME zone protection, an FME monitor, FME devices, and other FME protective devices should be used to enhance the learning environment.

K.3.4 Human Performance in FME Training

Human performance techniques should be incorporated into FME training to improve the overall effectiveness. FME controls should be part of the thought process when personnel are using the STAR self-checking technique. The peer-checking process should also be used to assist personnel in implementing proper FME controls and procedures. The pre-job brief provides an excellent forum for the identification of FME controls that might be required, potential foreign material problems at the work site, a discussion of relevant OE to the activity being performed, and the opportunity to increase an overall awareness to FME during the performance of the activity or task.



Key Human Performance Point

Human performance techniques should be incorporated into FME training to improve the overall effectiveness of training.

K.3.5 The DLA

Increasingly, the DLA is being integrated into the training process. The major difference between the DLA process over the normal or passive learning process is the interaction between the student and the facilitator. In the DLA environment, the student is required to use a broad spectrum of senses and skills. The DLA provides an excellent opportunity for the student to be observed and evaluated using acquired and learned skills and knowledge in an environment that simulates actual plant conditions as realistically and authentically as possible. The DLA is also a valuable tool that can be used to detect latent organizational weaknesses and improve work processes and procedures.

DLA approaches vary depending on the method of training delivery. The DLA is more commonly used in the mockup/simulator environment, but works well in the classroom (for example, case studies). Key components of the DLA include the following:

- Facilitator/observer pre-activity brief/review. This brief provides the DLA focus points. The precautions, limitations, expectations, activity scenario, and scenario faults are discussed. In addition, any other particular focus items can be presented (for example, housekeeping, FME, human performance techniques, and so on).
- Participant pre-brief. The participants are provided with the learning objectives and performance expectations (for example, perform as if in plant, use tools and procedures, and so on). Scenario termination criteria are also presented.
- Scenario performance. Participants should conduct the activity as if being performed in the plant, including such items as a pre-job brief, task performance, and post-job brief.
- Post-activity critique. Participants and facilitators/observers should discuss strengths (work process, individual and crew performance, organizational factors) and areas for improvement (work process, individual and crew performance, organizational factors), and they should assign action items (track and monitor in the corrective action program).



Key Human Performance Point

The DLA is a valuable tool that can be used to detect latent organizational weaknesses and improve work processes and procedures.

DLAs will vary from one organization to another.

L
KEY POINTS SUMMARY

The following list provides the location of Key Point information in this report.

L.1 Key O&M Cost Points



Key O&M Cost Point

Emphasizes information that will result in overall reduced costs and/or increase in revenue through additional or restored energy production.

Page	Key Point
1-1	The entry of foreign material into primary or secondary plant systems, components, and equipment can cause equipment degradation or inoperability, lost generation, fuel cladding damage, high radiation, and contamination levels that could spread throughout the plant; it could also increase O&M costs and degrade nuclear safety.
5-1	Debris is a major cause of fuel element failure in both BWRs and PWRs. A single fuel element failure can cost millions of dollars in replacement energy costs, outage costs, and replacement fuel. Fuel element failure causes increased contamination and radiation levels that require additional O&M expense.

L.2 Key Technical Points



Key Technical Point

Targets information that will lead to improved equipment reliability.

Page	Key Point
2-1	Whether an activity is an FME activity or not comes down to only a few possibilities: Is there an open system involved with the activity? Does the activity generate debris? Is there a possibility debris exists inside the system that the activity may discover? A yes answer to any of these initiates the FME process. Everyone should understand these few possibilities so that they can be alert to ensuring that their personal influence builds good FME practices.
2-3	High-performing plants (with respect to FME) have two well-defined FME levels. For consistency with other industry documents, this guide names these two levels “high risk” and “standard risk.” When neither an open system nor the potential to generate debris is present, good housekeeping practices are used.
2-4	Care should be exercised when considering the ease of detecting and removing foreign material as a reason to reduce the risk level. Very small particles can damage hydraulic or lubrication systems and be nearly undetectable to the naked eye. Chemical contaminants may require special tests to detect the undesirable chemical residue.
2-8	When the plan is complete and approved in accordance with whatever work management process is used, the plan establishes requirements that have been selected to fit the work in accordance with the general requirements. These approved decisions are now specific requirements for this job. By following this plan, all workers, supervisors, and managers involved will understand the positive controls and contingencies.
2-9	The planner is the first to know the detailed scope of work. His or her first contribution to preventing foreign material intrusion is to clearly document which systems, equipment, or components must be opened or accessed in connection with the scheduled task. The planner also clearly documents which subactivities will generate debris (for example, grinding, cutting, lapping, welding).
2-12	During the planning stage, consider the possible dangers that would result from closing off ventilation routes when fitting FME covers, plugs, caps, or seals on tanks, vessels, or other structures.
2-14	FME boundaries should be established before breaching a system/equipment/ component. Site-specific FME controls should also be established before breaching.
3-17	Exercise caution when removing pipe dams. Valve leakage into a piping system can cause a pressure buildup behind such devices.
3-18	Never use power cords or air hoses as lanyards
3-21	Do not allow transparent materials, such as visors, clear plastics, and tubing, to be used within an FME zone unless they are conspicuously marked to improve visibility and tracking.
3-33	If FME devices are installed on tank vents, it is recommended that they be made of mesh material to provide for the possibility that they will be left installed inadvertently.
5-7	Perform a thorough visual inspection of the motor before reassembling and testing.

L.3 Key Human Performance Points



Key Human Performance Point

Denotes information that requires personnel action or consideration in order to prevent personal injury, equipment damage, and/or improve the efficiency and effectiveness of the task.

Page	Key Point
2-2	If a system is open or you will open it, it is possible to put a foreign object in the system. Therefore an open system always warrants application of good FME practices. This can be said without considering the importance of the system or the consequences of the potential damage that could ensue. Later it will be seen that the consequences of damage and the difficulty of retrieving potential foreign material are considerations in determining the FME risk level.
2-7	The bottom line of using a flowchart is that these methods place a burden on the worker conducting the evaluation to have an appropriate questioning attitude, a high degree of knowledge about the task, and a high degree of knowledge about the system interconnectivity. Applying a flowchart is a knowledge-based activity, known to be more error-prone than rule-based activities or skill-based activities.
2-10	A checklist is not a plan. A checklist that has been properly filled out with due consideration based on the knowledge and skills of the preparer may be an adequate plan for some routine jobs. Passing blank checklists to the worker to be filled out on the day of execution add an unnecessary burden to the worker and impede the efficient conduct of work.
2-11	If it is to be left to the worker to identify the FME controls to be used, station management should ensure that the workers are appropriately trained to make this decision.
2-14	Housekeeping is a cornerstone of the FME process. Providing a clean work area both inside and around the FME zone will minimize the potential for foreign material intrusion.
2-17	On realization that foreign material intrusion has occurred or FME integrity is lost, immediately stop work progress, place the system or component in a safe or secured status, and notify appropriate supervision.
2-21	Clean the FME device and the adjacent area before removal to minimize the potential for foreign material intrusion.
2-21	The as-left closeout inspection is the final opportunity for detecting foreign material intrusion.
3-3	The criteria for selecting the appropriate classifications and establishing the level of controls that will be imposed should be based on the consequence of foreign material intrusion, the difficulty of foreign material detection and recovery, and the probability of foreign material intrusion.
3-9	General FME guidance should always take into account OE, housekeeping, and pre-job briefings as the basis for establishing levels of risk for control and inspection.
3-10	The preferred method of ensuring that personal items do not become foreign material is to remove them before entering an FME zone.

Page	Key Point
3-18	Covers should not allow the introduction of foreign material into the system or component as a consequence of the cover's installation or removal.
K-10	Human performance techniques should be incorporated into FME training to improve the overall effectiveness of training.
K-11	The DLA is a valuable tool that can be used to detect latent organizational weaknesses and improve work processes and procedures.

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