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Light Water Reactor Sustainability Program

ION Work Reduction Opportunity Realization Demonstration

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ION Work Reduction Opportunity Realization Demonstration

Advanced Training Modernization

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ABSTRACT

The purpose of this research was to realize one of the advanced training work reduction opportunities first presented in the Idaho National Laboratory (INL) report, "Process for Significant Nuclear Work Function Innovation Based on Integrated Operations Concepts" (INL/EXT-21-64134) [1], with a nuclear power plant (NPP) research partner. Researchers modernized two trainings: (1) an accredited instructor-led training (ILT) overview course on Westinghouse DS 480-volt (V) circuit breakers to a multimedia-focused computer-based-training (CBT) learning module, and (2) an on-demand chaptered video on how to properly rack and un-rack a Westinghouse DS 480-V circuit breaker. These modernized work products were developed and implemented in a manner consistent with the industry guidelines found in Institution of Nuclear Power Operations (INPO) Teaching and Learning 23-001 [2].

Researchers calculated that the modernized accredited training course reduced the time necessary to prepare and deliver the training material by a factor of 8:1. The amount of time learners spend in class could be reduced by this same factor. In other words, if a course took 8 hours to deliver a class, the new CBT instruction would take just over 1 hour. The researchers noted that the requirement for any practicum training by the learners with the instructor(s) would remain in place. But through interviews with new and experienced learners, the researchers discovered that the confidence of these learners in performing the racking and un-racking of the circuit breaker improved as a result of using the new modernized CBT process. Additionally, the learners who tested the modernized work products enjoyed the modernized CBT and the learning video significantly more than current in-class learning methods.

These are encouraging results for the nuclear industry, as this modernization of training can be applied to other classes and is scalable across the industry. In line with the Integrated Operations for Nuclear (ION) model, positive workload analysis supports the investment of resources in modernizing NPP training processes and infrastructure. Implementation of the advanced training technologies in this report is likely to result in substantive long-term workload benefits to instructors and learners and result in hard-dollar savings on contractor spends. Additionally, investment in these modernized training processes will result in improved learner proficiency. The results of this research can be applied to additional operator, technical, and general training topics to provide additional workload and learning benefits in addition to what was explored.

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ACRONYMS

AI	artificial intelligence
AR	augmented reality
AT	advanced training
CBT	computer-based training
CEWD	Council of Energy Workforce Development
COVID-19	coronavirus disease of 2019
DNP	Delivering the Nuclear Promise
EIA	U.S. Energy Information Administration
EPRI	Electric Power Research Institute
I&C	instrumentation and control
I&L	instructor and learner
IIJA	Infrastructure Investment Jobs Act
ILT	instructor-led training
INL	Idaho National Laboratory
INPO	Institute of Nuclear Power Operations
ION	Integrated Operations for Nuclear
IRA	Inflation Reduction Act
IRENA	International Renewable Energy Agency
LMS	Learning Management System
LWRS	Light Water Reactor Sustainability
ML	machine-learning
MMBtu	million British thermal units
NEI	Nuclear Energy Institute
NPP	nuclear power plant
NPV	net present value
OE	operating experience
OEM	original equipment manufacturer
PPE	personal protective equipment
PTTC	person-talking-to-camera (PTTC)
T&L	teaching and learning
U.S.	United States
V	volt
VR	virtual reality
WRO	work reduction opportunity

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ION Work Reduction Opportunity Realization Demonstration

1. INTRODUCTION

1.1 Cost Pressures of U.S. Operating Nuclear Power Plants

Current market forces emanating from the United States (U.S.) economic environment surrounding the nuclear industry are now applying an intense level of competitive pressure on electricity generators using nuclear power plants (NPPs), which threaten the long-term viability of nuclear power [3]. These forces include, among others, market restructuring, the increasing penetration of renewables into electricity markets, and public perception. This market restructuring introduced a change in incentives that drive outcomes today [4,5]. The intermittent nature of renewables creates challenging dispatch issues for baseload generation like nuclear [5], and the cost declines in renewables have further created challenging economics for nuclear generators [6].

Advancements in natural gas extraction techniques contributed to these market forces, causing a significant drop in natural gas prices where the monthly Henry Hub national gas price dropped from approximately $6/ million British thermal units (MMBtu) in January 2014 to less than $2/MMBtu by March 2016, which has challenged the cost-competitiveness of nuclear energy in electricity bidding markets and threatened the economic viability of U.S. commercial nuclear facilities. In response to these challenges, industry leaders launched the “Delivering the Nuclear Promise® (DNP)” initiative in 2015. This long-term strategy aimed to transform the nuclear energy industry by prioritizing safety, reliability, and efficiency while advocating for regulatory and market reforms to enhance the economic recognition of the value of nuclear energy [7].

As part of this initiative, there was a notable reduction in workload and labor costs considered to be “low-value work” across NPPs, particularly those affecting training processes and workload crucial for maintaining operational standards. Despite these workload adjustments, little improvement was made in enhancing existing training approaches. The emphasis shifted towards streamlining operational processes without concurrent advancements in modernizing training methodologies and approaches.

The most common response to addressing the economic challenges under DNP included implementing more efficient processes without sacrificing the industry’s commitment to safety, which consisted of reducing or eliminating positions, reducing dependency on contract services, reducing spending on excess materials, and improving focus on cost-management principles.

With the recent legislative changes imposed by the Infrastructure Investment and Jobs Act (IIJA) in 2021 and the Inflation Reduction Act (IRA) in 2022, the U.S. Government has recognized the unique operating characteristics of nuclear power and the vital role it plays in decarbonizing the electric grid. In spite of the economic challenges faced by NPPs, these plants have continued to achieve safe, reliable, and efficient operations, and are taking advantage of the new financial incentives that further the industry.

While the industry’s response to the cost-competitive challenges described above resulted in undertaking DNP, the industry has been able to sustain these more efficient processes and reduced workload, as well as continuing to deliver on its mission of safe, reliable, carbon-free electricity, as demonstrated by increased capacity factors greater than 91% over the past 10 years [8]. However, the industry is now largely comprised of an aging workforce, whose approaching retirement includes nuclear professional roles with significant operating experience. The in-depth knowledge, skill-of-the-trade, and operating experience that is departing with the retiring workforce must be captured to help educate and maintain the operating excellence currently seen in today’s nuclear energy industry.

1.2 Energy Industry Workforce Trends

Over the past decade, the generational makeup of the energy industry workforce has shifted to younger workers. While many workers from the Baby Boomer Generation have been retiring, this trend has only increased during the recent coronavirus disease of 2019 (COVID-19) pandemic. Millennial and Generation Z workers are replacing the retiring generations. As such, care must be taken to preserve the experiential knowledge of this retiring workforce before they leave permanently. Figure 1 shows the makeup of the current energy industry workforce by age group, which is taken directly from the "Center for Energy Workforce Development (CEWD) 2023 Energy Workforce Survey Results: Executive Summary" [9]. This document also asserts, "Survey data shows that 56% of workers overall have less than 10 years of service. This number is even higher in certain key job categories. Engineers and line workers were both above 60%" [9].

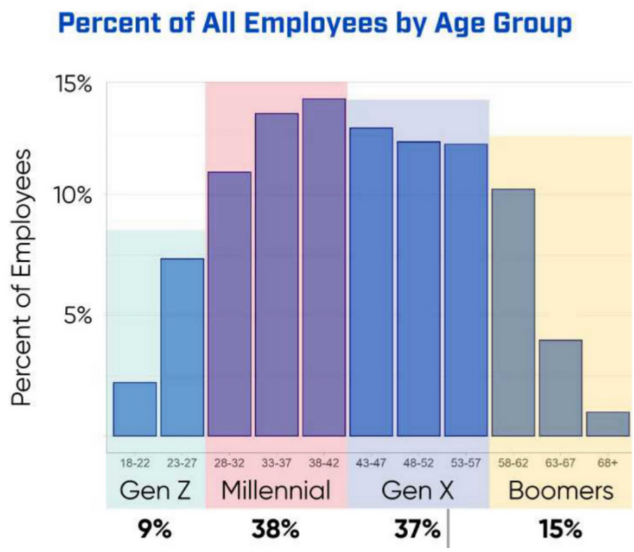


Figure 1. Precent of all NPP employees by age group [9].

The NPP industry has identified the need for improving knowledge transfer from experienced workers to younger workers through industry white papers and operationalizing this knowledge transfer through procedures and checklists. Knowledge transfer refers to the process of transferring an awareness of facts or practical skills from an experienced worker to an inexperienced worker. However, in the nuclear industry, knowledge transfer results have been variable at best. Additionally, the industry has been able to weather the storm of retired workers through financial incentives (e.g., signing bonuses, retention bonuses, benefit/pension enhancements, contract work, etc.) which have helped retain experienced workers. Overall, the implications of recent nuclear industry staff reductions will need to be addressed to preserve the retiring workforce's expertise and effectively encourage this retiring workforce to teach their skills to younger generations without interrupting retirement plans or overburdening them with the complicated task of knowledge transfer.

1.3 COVID-19 Impact on Learning for the Existing Workforce

While there were certainly negative consequences for the existing workforce during the COVID-19 pandemic, the transition to remote work forced many companies to significantly digitize their processes if they had not already, and the organizational benefits reaped from these changes are now standard in most industries. Before COVID-19, remote work was a sparse occurrence in most industries other than technology. But by the end of 2023, with COVID-19's impact subsiding, it is still common to see remote or hybrid work positions in all industries across the U.S. Most have recognized the benefits of remote work and online learning, and the existing workforce makeup of Millennials and Generation X had no trouble adapting to this new work environment.

The main benefits still ongoing that have been reaped post-COVID-19 are that workers have more options when it comes to how they decide to complete their work. This improved accessibility to work through online resources allows workers with more choices to live where they want and to prepare or work at any time they please. These benefits still apply even for industries with in-person work, as improved accessibility to work resources allows significantly faster and less wasteful methods of accessing documents, finding information, doing research, hosting meetings, and more recently, providing options to automate repetitive tasks.

Overall, Gen Z, Millennials, and Gen X have responded very positively to the digital transition. Based on the relationship younger generations have with technology it is likely these changes would have been encouraged even without the catalyst of the COVID-19 pandemic. These technological improvements have become so popular that there is no chance of companies that have implemented them reverting to the comparatively inefficient nature of physical file systems as they provide no options in terms of version control and have many drawbacks relating to accessibility, data analysis, distribution, integration, and collaboration. Gen X has been a driving force in optimizing work through digitization, as they have witnessed the wide adoption of the internet and co-evolved their work approach with advancements in digital technology. While Millennials and Gen Z are considered as more technologically savvy generations, it is important to note that the advancements of digital technology in the workplace would not be where they are today without the early support of Gen X individuals.

1.4 Training the New Generation of Workers

While an inexperienced workforce has been entering the nuclear industry in the last decade, online learning has also been evolving rapidly. Most members of Generation Z have had a lot of experience with online learning, whether on their own or as part of a curriculum. It is with that combined experience, as well as their technological skills, that they are prepared well for online learning as they rapidly enter the NPP workforce [9].

By the end of the COVID-19 government restrictions/guidance restricting in-person classes, instructors conducted their training sessions in a manner where important learning resources were still accessible through online portals. This approach allowed students to continue learning independently, while in-person classes were reserved for synthesis, questions, and teaching more complex topics. In all fields of study, it is now the standard in higher education to digitize all necessary resources and assignments, as it is a much more efficient method of delivery for students today. In any case, Generation Z employees are used to learning independently and are adept at using online learning technology.

In industries like nuclear power, utilities must adapt training approaches to efficiently teach the new generation of workers accustomed to independent online learning. While digitization of learning resources has been a hallmark of education in the last decade, industries like nuclear power have lagged in their approach to training for a variety of reasons. It is vital for the nuclear industry to digitize training before the experienced talent retires and are no longer contractually required to share their intangible knowledge with new learners. Given this unique overlap in the multi-generational workforce, the goals of this effort is to showcase modernized training methods that capture the skills of the experienced workforce before they retire and provides that content to the new generation of workers in a familiar format.

1.5 Training Approach of Other Regulated Industries

The use of video and multimedia is present in the training of other regulated industries, such as Internet Service Providers, airlines, oil and gas, etc., however, the use of these tools is still generationally stuck in the 1990's and 2000's mindset. For example, it is common to watch a training video that largely consists of a person talking directly to the camera with a greenscreen behind them. On the greenscreen are typically bulleted lists of what the speaker is outlining. This style does not properly capitalize on the inherent strengths of the visual medium and learning potential of video. In many ways, this type of video is inferior to Adobe PDFs and Microsoft PowerPoint slides. This is because videos excel at *showing* the learner exactly what is being discussed whether that be an object (such as a breaker), or a technique (such as racking the breaker). When the video is mostly comprised of only a person talking to the camera, the learner is deprived of seeing the subject of discussion.

While other regulated industries are experimenting with the more advanced approach used in this work reduction opportunity demonstration, most of their training content is comprised of this Person-Talking-To-Camera (PTTC) approach. This is likely because the PTTC approach is both familiar, and therefore understood to the creator, as well as easier to produce, since it does not require the situational awareness needed to record a video of live work. Recording live work often requires a familiarity with the subject matter and therefore requires the person operating the camera to process what is happening and adjust in real-time. Add the fact that most of this work can only be done one time (i.e., you only get one take) which is intimidating for many creators causing them to opt for the easier PTTC approach.

2. OVERVIEW

2.1 Background

Since training modernization was identified as a high-level work reduction opportunity (WRO) in earlier research [1,10], this project was intended to showcase how the nuclear industry could realize workload and qualitative benefits from modernizing their training programs using commercially available technologies. As the experienced workforce retires from the industry, capturing their expertise on video and including it in training programs is an efficient way to make learning completely accessible to the new workforce and bring knowledge transfer to life.

In 2023, the Institute of Nuclear Power Operations (INPO) released their "Guidelines for Advancing Teaching and Learning in the Nuclear Power Industry" [2], which provides a framework for understanding how new training methods could be integrated while preserving industry standards.

Some nuclear operators have begun experimenting with videos to teach specific content—both in a laboratory environment and in the plant during real-time work activities—but the finished products are rarely used by the workforce for learning as they are difficult to digest for the learner. An example of content filmed in the past is outage jobs, but the videos had a generally poor user experience (e.g., poor audio, jumpy camera angles). There has also been experimentation using virtual reality (VR) and/or augmented reality (AR) technologies, but the use cases for these technologies are still under development and the business case for these methods is yet to be determined. Considering the recent advancements, use, and practical applications of online learning in other industries, utilizing commercially available technology and tools offers a promising opportunity to realize training WROs in the nuclear power industry. Online learning through CBT also allows for scalability across the industry and provides the option to integrate new digital technologies in the future.

2.2 Scope

The scope of this research has two parts. The first was to create a video-based learning resource demonstrating the proper way to rack and un-rack a Westinghouse DS 480V circuit breaker. The second was to convert an accredited initial training class of the Westinghouse DS 480V circuit breaker to a multimedia-formatted computer-based training (CBT) consistent with the INPO 23-001 guidelines. In both training creations, the researchers then validated the new material with the nuclear operator's experienced and inexperienced participants.

2.3 Objective

The objective of this project was to identify the workload reduction benefits to a non-fleet nuclear operator by converting an accredited instructor-led training (ILT) course to a multimedia CBT. This research was undertaken to prove the applicability of modernization in the technical and general training programs for nuclear operators by studying the benefits of modernized training in comparison with traditional training methods (i.e., instructor-led and classroom-based). Additionally, this research was undertaken to identify any constraints needing to be alleviated with future guidance and lessons learned regarding this type of training.

3. SUPPORTS ION METHODOLOGY

3.1 ION Work Reduction Opportunities

This research supports the Integrated Operations for Nuclear (ION) WROs AT-02 (Technical Training Modernization) and AT-03 (General Training Modernization), as identified in previous research [1,10], by showing the modernization descriptions contained herein are possible to realize and how they can be implemented successfully to achieve meaningful workload reduction for nuclear operators. This research is a practical example of the benefits of modernized nuclear training, and the topic chosen for this work product is representative enough of the complexity of this type of training topic to be a good use case for estimating the potential benefits of this strategy being applied to an entire training program, operating fleet, or even as a possible industry standard. The evaluation of this work product displayed the quantitative and qualitative benefits of using the ION suggestions for modernized training on a practical example to build a business case for applying the methods to an entire training program.

3.2 Technical Training Modernization

This work product follows the suggestions proposed in AT-02 and demonstrates how these suggestions can be specifically implemented for a training topic that is complex to learn and time-consuming to teach. The workload for the technical training organization consists of developing or updating classroom instruction content, as well as delivering classroom instruction, demonstrating the learnings in a laboratory or dynamic-learning environment (including setup and cleanup), evaluating the progress of the learners, and overseeing any accreditation requirements. The AT-02 WRO proposes how to reduce or eliminate work for all of these issues except for the INPO accreditation process. Using the suggestions here have the potential to reduce the burden on instructors who have been assigned large groups of learners. This technical instruction team oversees the accreditation training for maintenance, chemistry, radiation protection, and engineering learners, all of which would benefit from having their learning methods modernized for independent learning.

In terms of classroom training, the industry standard mainly relies on Microsoft PowerPoint slideshows with pictures, occasional video and audio recordings, and summary academic questions. What little video used is typically lacking in quality, both in terms of substantive content and editing polish, which results in a work product that is seldom used to effect. For example, action cameras have been used to record field activities but because of the wide-angle lens, but the viewer typically cannot see any detail, such as unscrewing a screw. Because the people in the video rarely wear microphones, the viewer cannot hear what the individuals are saying either. Finally, because these videos are rarely edited, the videos are overly long and make poor use of the learner’s finite attention span, resulting in minimal learning impact.

This project demonstrates the completed use case of this WRO by being an interactive multimedia CBT. It shows an extremely detailed and realistic tutorial of the training topic that is visually comprehensive and provides synced audio of the trainer completing the task while describing their actions. Augmenting or replacing the classroom training with this new method would significantly reduce the time required in class if the organization chose that option. Further, this approach would also empower learners to learn on their own time, or at the very least be able to prepare for each class. This will enable the time spent in a classroom to be significantly more productive, because the learners will always have access to the important content on their devices. In addition, since the multimedia CBT are comprehensive and reviewed meticulously, the learners will feel confident in answering most of their own questions. This approach can be even more effective than in-person training sessions, because while in-person training sessions will always be necessary, this work product provides a timeless and accessible version of those sessions in a standard format with no variation. Additionally, the behavioral questions allow for the learners to consider what they would do differently in real situations that can and will happen when they are on-the-job, so it instills the importance of those decisions and helps the learners understand when and why they should make a particular decision.

The traditional PowerPoint questions frequently asked in a classroom training have been largely academic rather than behavioral in nature. An academic question would be something like, “Identify the cell switch actuator,” as the PowerPoint question tests material retention in language form but does not necessarily relate to the operational skill being taught. In contrast, the multimedia CBT incorporates videos, so the questions that are asked are behavioral in nature. An example of this type of behavioral question that is shown after the learner watches a video is, “What happens if the cell switch actuator does not come back to its 30% position?,” as this type of question encourages the learner to think about the task in terms of a possible scenario. Overall, the combination of videos and behavioral questions helps learners prepare themselves for onsite demonstrations by presenting realistic scenarios.

Standardizing training using modernized training products as a knowledge base will reduce the routine work that instructors must prepare every cycle. Further, since the material will rarely require a change from the original film, it will be easier to build a knowledge base of questions and answers and document those that are frequently asked. Also, given that the most experienced instructors are used for the CBT videos, this allows for the tutorial to be of the highest standard, so there would be no variation in the level of instruction that becomes possible if some instructors are less experienced or they themselves did not learn the task at the highest level during their training.

In a laboratory setting, this type of modernized training work product would help learners gain visual familiarity with components before arriving, so the in-person laboratory training sessions would be more hands-on. The learners would arrive at the training session more prepared and aware of what they will see and how they will use the available tools. This helps the experience become less about learning new skills as a beginner but more about assisting the learners to test out and demonstrate their knowledge from the CBT of the components in a real setting. Additionally, better preparation will be helpful to reduce the amount of setup and cleanup, in addition to the more general sessions that would be required for a learner to become adept and comfortable in performing a task, thus increasing learner confidence and skill while reducing instructor workload.

3.3 General Training Modernization

In reference to WRO AT-03, the benefits of modernized training work products are like those of the technical training described above. Since these tasks are outside the accredited training programs, they will be even easier, faster, and broader to convey in modernized training work products and may require less oversight and compliance on content conversion to a new learning work product. Either way, the benefits are still a significant reduction on the required tasks of the instructors, with more efficient use of classroom time, and in some cases, fully online evaluations. For non-accreditation tasks, having modernized training work products that are immediately accessible through a knowledge base allows for learners to always review information they might want to brush up on. This supports the learner in using their time effectively and staying prepared for whatever task they are required to complete. Some of the general training work topics could include the use of training on how to use Maximo to reserve parts or how to properly plan a maintenance corrective work order package.

3.4 Improvements for Trainers and Learners

While traditional methods of classroom and on-the-job trainings have been essential and contributed to high levels of performance of the current nuclear fleet, online learning is a valuable opportunity to empower the younger workforce to learn online, which they are already well accustomed to. Online learning in video form also provides an effective method to capture the skills and expertise of older generations without requiring anything of them other than to describe their job on camera.

This approach significantly reduces the time and effort that successful knowledge transfer takes and creates a comprehensive virtual knowledge base that is easily accessible for younger, tech savvy learners into the future. Creating modernized training work products in this way allows learners to pay better attention and be present during in-person training without having to interpret, memorize, and perfectly understand the knowledge conveyed by the trainers immediately, because they can prepare and study effectively on their own. This will help the trainers and learners use their time effectively, as prepared learners will only need to ask informed questions because they are able to access organized and comprehensive tutorials beforehand and just-in-time on-the-job. Preserving the expertise of the retiring workforce is paramount, and the most efficient way to capture and deliver this content to learners is in visually comprehensive videos with multiple angles that provide as much detail as could be absorbed in-person.

4. APPROACH

4.1 Identifying the Topic

The NPP Director of Training suggested the ideal training topic to modernize was a topic that had the following four criteria:

- Broad applicability to the industry
- Challenging to learn
- Mastered by few
- A significant amount of instructor workload when teaching initial learners.

The general overview initial training class for the Westinghouse DS 480V circuit breaker was chosen because it is currently an instructor-led course that relies on a Microsoft PowerPoint presentation in a classroom setting, as well as an experienced instructor to provide an excellent overview of the training content. The Microsoft PowerPoint presentation in its current form can be seen in Appendix A.

One additional consideration that was identified after selecting this topic was any benefits realized from modernizing this topic that could be applied to additional initial technical training topic courses. During the process of identifying a topic to modernize, the NPP Director of Training identified a need to boost the knowledge of operators and maintenance craft on how to rack and un-rack the circuit breakers. This task was selected due to its difficulty, commonality across the industry, and regularity in plant activities.

4.2 Identifying the Team

The core project team consisted of two Idaho National Laboratory (INL) researchers, seven NPP resources, and a vendor partner. The NPP supplied resources consisting of the following, with the number of resources in parenthesis (x):

- Director of Training (1)
- Director of Innovation and Strategy (1)
- Electrical Maintenance Manager (1)

- Electrical Training Instructor (2)
- Instructional Technologist (1)
- Innovation Project Manager (1).

4.3 Storyboard Sessions

Storyboarding sessions were conducted to identify critical operating experience (OE), key steps of the task, and common areas of knowledge that less-experienced individuals should learn in the modernized training work products. The storyboarding sessions were used to align on key questions the core team hoped to have answered after project evaluation. The content of these key questions related to the benefits of the modernized training work products for the site and the fleet, improvements in the experience of the learners, the benefits for other operators, and any constraints INPO could alleviate to allow this method of training to be applied widely across the industry. Also, critical OE was discussed so that the team's knowledge of the tasks would be used to decide the most effective angles to film the tasks with the utmost detail and as realistic as possible. Additionally, personal protective equipment (PPE) was discussed, as well as what must be used by the instructors and operators who were going to be captured on camera performing the tasks.

These sessions allowed for the team to agree upon specific details of the modernized training work products to make sure the final product was up to their standard and that it functioned in the NPP's learning management system (LMS).

These decisions resulted in an outline of items needing to be captured during the content capture sessions. This allowed the training operator describing the tasks on camera to complete their jobs within the standard time it takes to complete the task and not take up unnecessary amounts of time to film.This allowed the instructors to complete the class normally and teach as comprehensively as they would in person.

4.4 Capturing the Content

Content was captured in a laboratory setting with two instructors discussing the training content captured the existing PowerPoint slides. Content was also captured in a field setting so that it was as realistic as possible. One of the instructors had over 35 years of experience with the circuit breakers being discussed, while the second had about eight years of experience using the circuit breakers. The instructors walked through the directions based on the original PowerPoint content and described the actions they took in that context while being filmed.

The instructors discussed the correct ways to perform specific tasks and discussed common errors or confusion points they had experienced over the years or where learners from past classes had difficulty comprehending specific elements of operations of the 480v Westinghouse DS circuit breakers. The storyboard outline from the previous step was referenced throughout to ensure that all key elements of their knowledge were captured during the training time.

During the content capture sessions, one experienced operator demonstrated how to don appropriate PPE, how to rack and un-rack a Westinghouse DS 480V circuit breaker, and the key areas or components of the breaker during the 480V racking and un-racking process.

The instructors captured additional content about how to perform refurbishment and maintenance of a Westinghouse DS 480V circuit breaker. This extra content can be finished and included in a future modernized training work product, since it was not contained in the PowerPoint slides. This extra content could be used as a knowledge transfer training work product.

The duration of the content capture session lasted two days for approximately eight hours per day (including setup and clean up) in the laboratory and another day in the plant to capture the racking and un-racking of the circuit breakers in the field.

One lesson learned from this process was the importance of requiring the operator who is showcasing the skill to use the proper type of PPE. Even though just filming a tutorial might not actually require this PPE, for safety reasons, it is important to show learners how to perform this work with the proper PPE. This way the learners do not perpetuate any error in the future believing it to be correct. It is crucial to identify these mistakes in the module as mistakes, because even something as simple as improperly adjusting a PPE outfit could be extremely dangerous if the behavior was replicated in the field. Making these distinctions in the modernized training work products is especially important, because new learners might just directly mimic operators when learning in-person and not be able to distinguish between a habitual error and the correct procedure.

4.5 Developing the Modernized Training Work Products

The next step in the approach involved editing the audiovisual content and organizing it so that it could be used in modernized training work products. Commercially available software was used to edit and create these CBT learning work products.

Upon completion of the draft work products, review sessions were conducted with the project core team to incorporate feedback and make sure the final product illustrated the operational standards of the NPP. This was an easy process as the training software used to make the modernized training work products allowed the instructors to comment on their feedback exactly where they would like an edit to be made.

4.6 Evaluating Effectiveness and Lessons Learned

To test the effectiveness of the modernized training work products, a combination of experienced and recently hired electricians were “trained” through the modernized work products. The electricians (independent of the development process) completed the module, and their insights about the multimedia CBT and videos were received through a survey. The survey questions focused on four key areas:

1. The length of time it took them to complete the multimedia CBT.
2. The baseline self-assessment of the participant’s confidence at performing the tasks.
3. Any changes in the participant’s self-assessment of confidence after taking the CBT module.
4. Any feedback or comments the participant had about the modernized training work products.

These questions were used to compare the learners understanding from the modernized work products vs. the current classroom training content. Screenshots of this format are contained in Appendix B.

4.7 Incorporating Finished Modernized Training Work Products into NPP Operator Infrastructure

The final step of the project was uploading the chaptered video of racking and un-racking the circuit breaker into the nuclear power plant’s intranet site. Once there, the learning module can be easily accessed by current and future learners from any onsite computer location. Secondly, the multimedia CBT was uploaded to the nuclear power plant’s LMS for testing and eventual use by future electricians during initial training. Also, the plant’s LMS will provide user data about the learners’ progress, helping instructors pinpoint any frequently asked questions to address as well as tracking the time it takes learners to complete the course. This data will be used to improve the training process as a whole and helps the instructors keep the learners on track as they progress through the course.

5. RESULTS OF WORK PRODUCTS

5.1 Work Product Description

The CBT module was made to replicate the exact PowerPoint content but in a new modern medium using commercially available CBT software. To elucidate the differences the medium had in the effectiveness of training, the CBT was created to directly copy the words straight from the PowerPoint training, so that there would be no chance of inadvertently introducing any potential errors or discrepancies into the CBT. Every PowerPoint slide from the traditional training's textual content was copied word for word when making the CBT. This PowerPoint content was then expanded upon with additional videos, pictures, GIFs, interactive diagrams, and realistic behavioral questions. All visual content in the CBT was added to supplement the words copied from the PowerPoint to allow for a deeper understanding of the same exact concepts. Example screenshots in Figure 2, Figure 3, Figure 4, Figure 5, Figure 6, and Figure 7 show the PowerPoint form of the content on the right with the corresponding CBT content for comparison on the left.

As shown in Figure 2, Figure 3, Figure 4, Figure 5, Figure 6, and Figure 7, the CBT videos are edited to include overlaying visual cues assisting the learner in understanding the details of the components. These visual cues include arrows, highlighted areas displaying components, magnifications to allow closer camera shots within larger frames, and overlayed words describing important facets of the tutorial at appropriate times. When explaining the components in terms of the diagrams the learners will need to utilize, the diagram and angle of the camera are shown in the same frames so the learner can avoid having to shift focus between a separate diagram and the CBT. The diagrams also have visual cues overlayed on them to show the corresponding parts of the diagram while the instructor manipulates the component on video in real-time. This feature allows learners to seamlessly associate the diagram with the component in the same visual context. Figure 3 provides an example of the behavioral questions included in the CBT. This example asks the learner an important question about what angle the actuating lever must be in to achieve specific results. Behavioral questions like the one in Figure 3 help solidify the learner's understanding of how components will react to their operation and impart realistic knowledge relating to the consequences of specific decisions.

Moreover, during the recording of the videos, additional insights were shared from the instructor performing the tasks. For example, it was common for the instructor to share the "why" behind a typical action, such as why the actuator lever inside the breaker housing should return to approximately 30° when performing the inspection. This is important because prior OE showed that if the lever did not return to roughly this degree, the breaker could potentially still show as being in-position even after being removed. OE was a frequent source of additional insights that were shared in the videos but were typically absent from the slides. In addition, the instructor and his assistant replicated some of the question-and-answer discussions that would typically take place during in-person instruction. This was intended to answer, in a natural conversation, typical questions that the learner may have.

Figure 2. Cubicle inspection from the CBT screenshots (left), cubicle inspection from the PowerPoint slides (right).

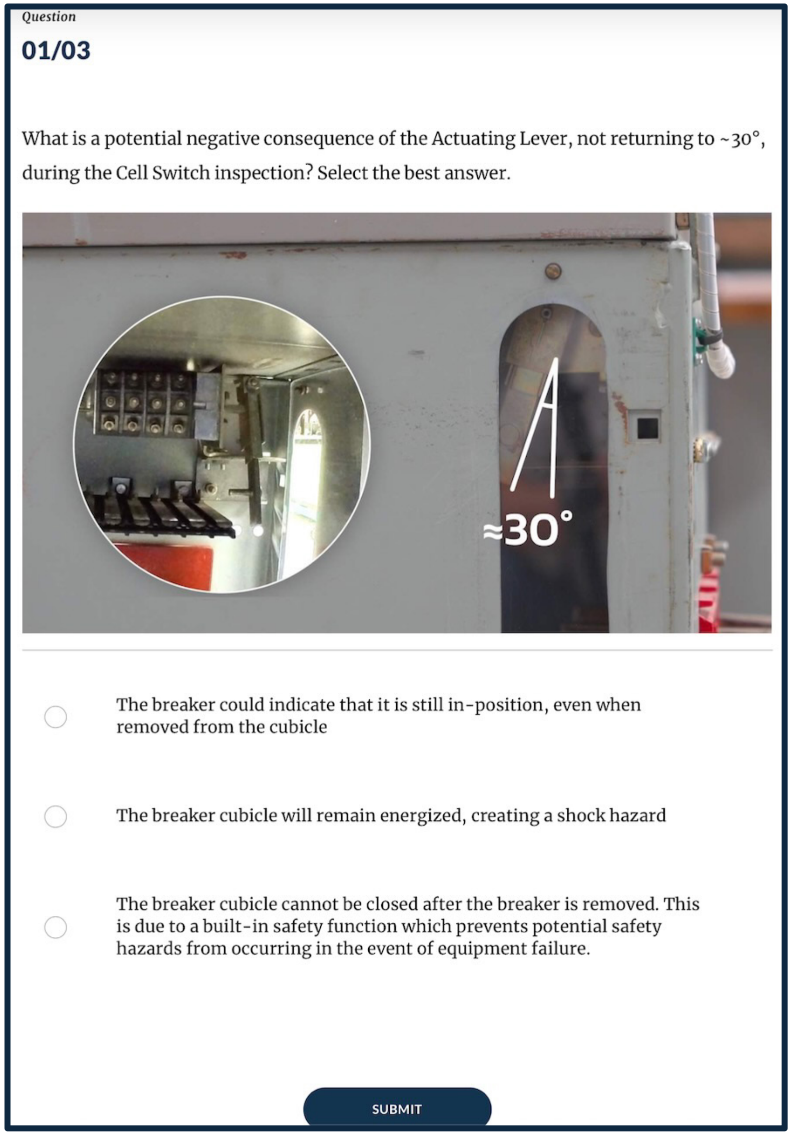


Figure 3. CBT Behavioral question based on cell switch inspection video.

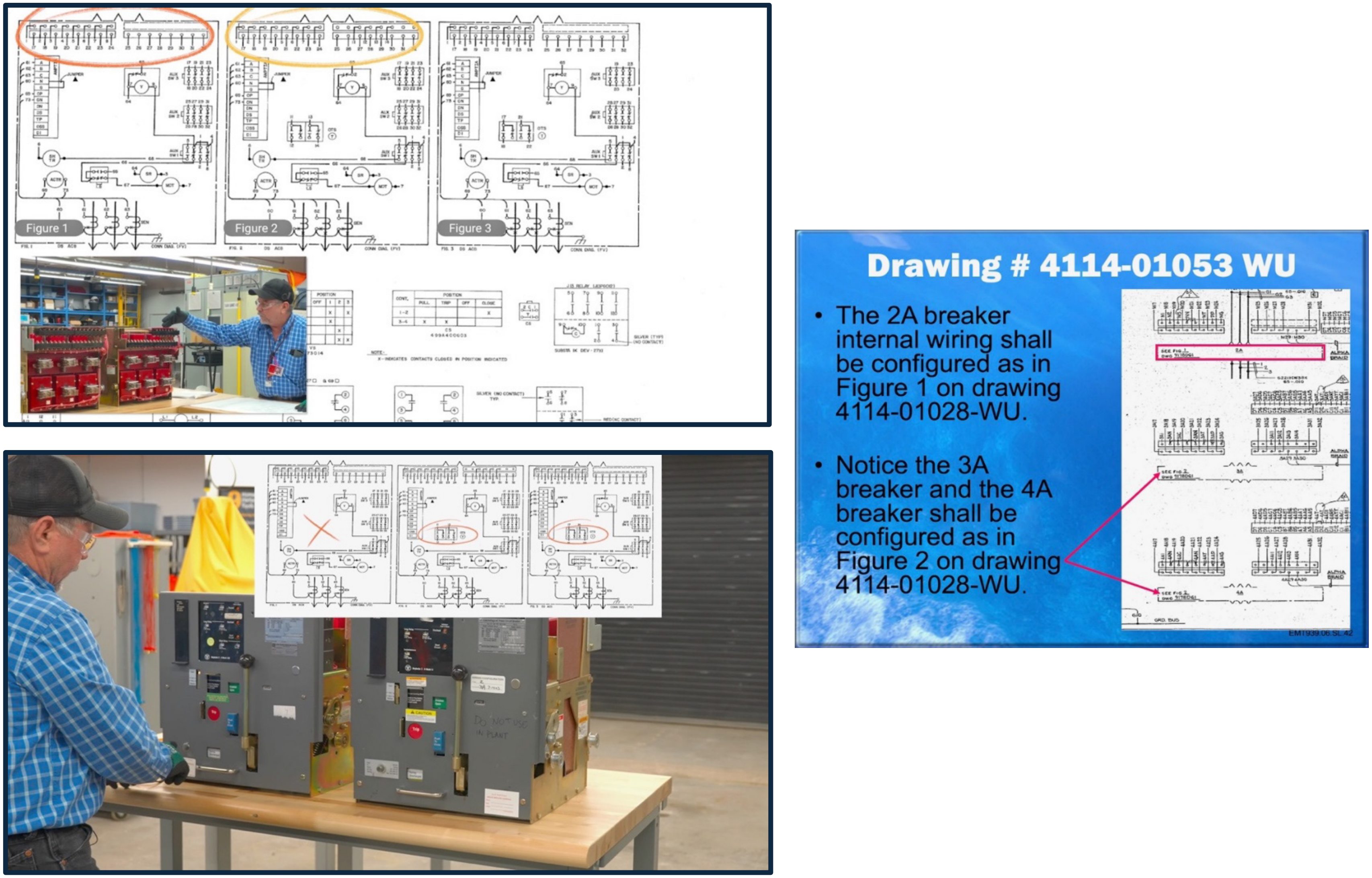
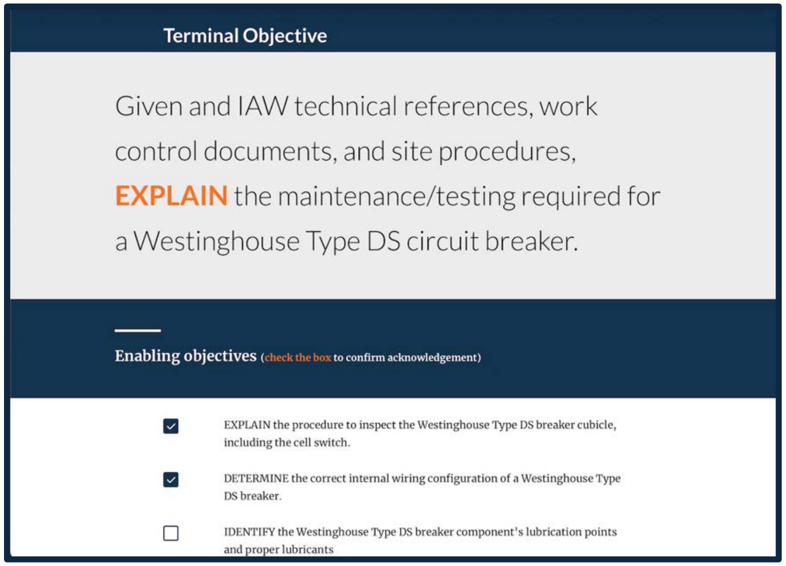


Figure 4. Breaker configuration from the CBT screenshots (left), breaker configuration from the PowerPoint slide (right).



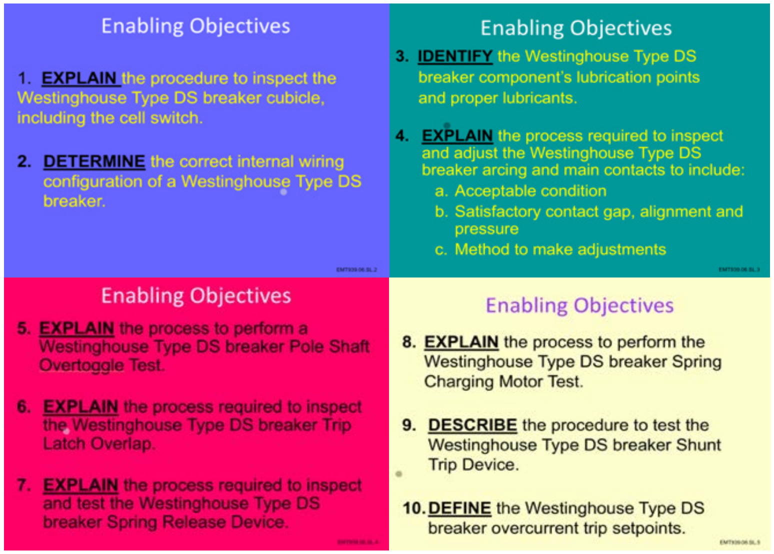


Figure 5. Terminal objective for the Westinghouse type DS circuit breaker from the CBT screenshot (left), terminal objective for the Westinghouse type DS circuit breaker from the PowerPoint slides (right).

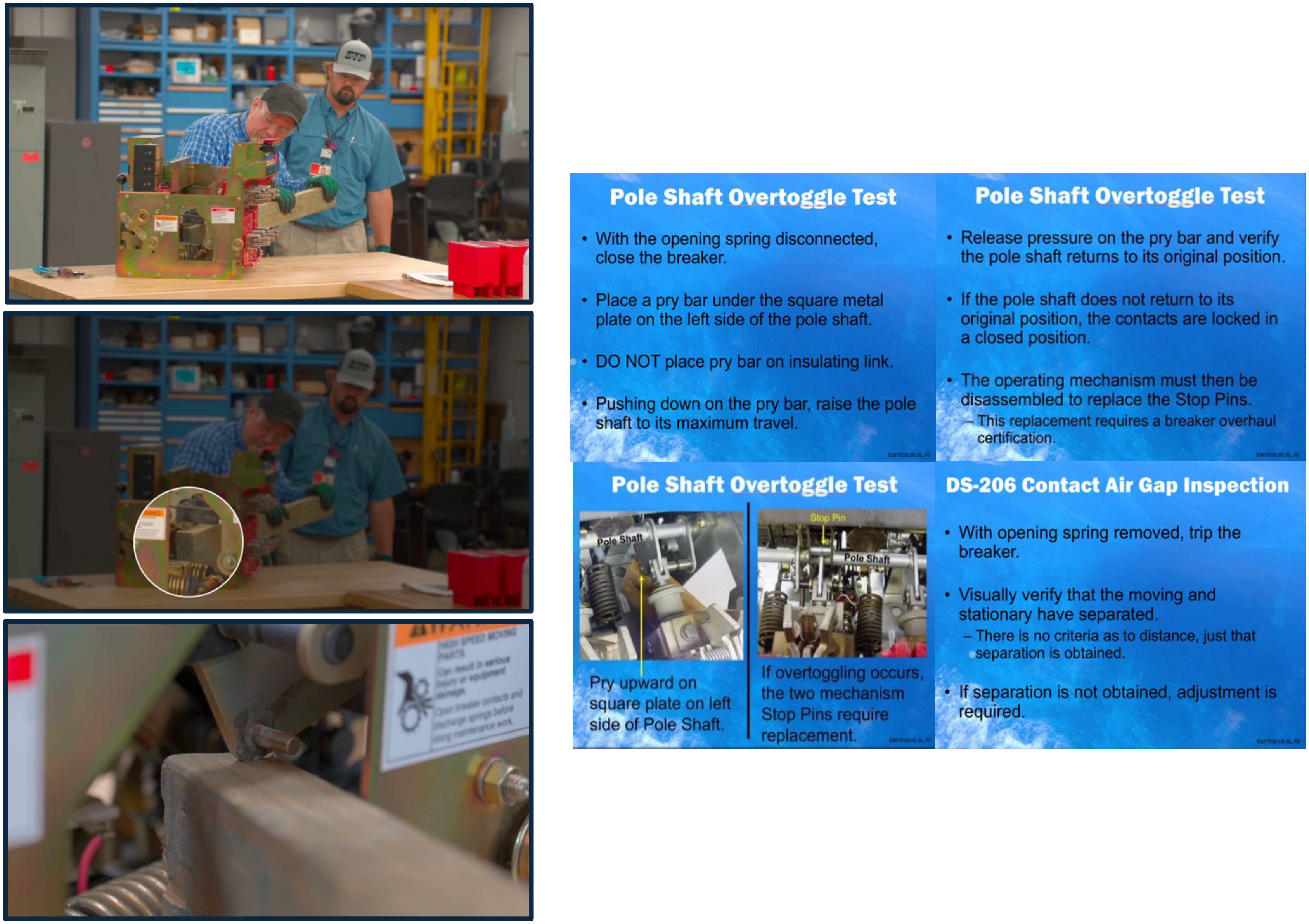


Figure 6. Pole shaft overtoggle test from the CBT video screenshot (left), pole shaft overtoggle test from the PowerPoint slides (right).

Figure 7. Use of special effects and graphics to enhance understanding. CBT video screenshot of testing (left), on-demand video screenshot of racking the breaker (right).

5.2 Overview of On-Demand Video

The on-demand video tutorial showing the racking and un-racking of the circuit breaker was filmed with an experienced operator instructor who was near retirement. This instructor was chosen to capture his expertise from his long career, and to preserve his knowledge virtually post-retirement. This concise video tutorial was filmed in a laboratory setting, where he referred to the procedure as he acted it out on camera in detail and at a speed similar to the actual time it takes to complete the task for real. This comprehensive tutorial consisted of three chapters and an introduction, with the chapters being time-stamped for easy navigation throughout the tutorial. After the introduction, the chapters consisted of inspecting and putting on PPE, how to rack in the circuit breaker, and finally how to un-rack the circuit breaker, all together under 15 minutes in duration. The OE was captured in the video in detail, and the experienced operator instructor explained important things to note in detail. Visual indicators were used in the tutorial as well (after editing) to signify what he was explaining visually, so that he could explain the task as he completed it and the operators in training could follow along to the video without unnecessary confusion. These special effects help to guide someone unfamiliar with the component to understand the effects of certain actions on the state of the different parts of the component so they can learn what is and what should be happening as the task is performed. In addition, auditory information was conveyed in the videos realistically because listening for certain sounds is an important part of confirming the validity of one's operations on certain plant components. Captions were also used to make distinctions about counterintuitive facts an operator would need to be aware of, such as when the operator instructor removed his gloves. This is important because this practice is unacceptable when working on a real component, but it was entirely appropriate for the laboratory tutorial.

5.3 Intended Use of On-Demand Video

This on-demand video tutorial is intended to be used as a job aid, a pre-job brief, or as a just-in-time reference before completing an evolution. Operators in training would be well equipped to have these videos on-demand and accessible on mobile devices, as they can even repeat the video, skip around in it, or speed the video up or down to match whatever learning style they prefer, as well as to have an example analogous to observing the task being performed in-person.

5.4 Approach to Measure Impact of Training

To understand subjective opinions regarding the effectiveness of the CBT module, three short surveys were provided to the groups of experienced and inexperienced learners to complete both before and after seeing the PowerPoint slides and then the modernized training work products. The survey respondents first took a baseline asking how confident and prepared they felt they were in performing this work. Answers to these questions were provided on a scaled number format from 1–10, with 1 indicating they did not feel ready and 10 indicating they felt confident to complete the task. Next, the learners went through the traditional PowerPoint slides used in the classroom training and took another survey that asked the same questions using the same response mechanism. The researchers used the same questions to compare the effectiveness of the PowerPoint method against the initial baseline test. At this point, the groups were asked to take the modernized training work products. Afterward, they completed the final survey. This third survey consisted of the questions from the first two surveys as well as an additional three questions. The additional questions asked how many minutes it took them to complete the CBT module, if they would like to adjust their previous scores on the previous surveys, and how much they would like to change their previous choices by if so. Finally, they were asked to add any comments or feedback they might have had about the modernized training work products or survey process.

The survey consisted of obtaining responses from some experienced and some relatively new electricians who have passed the circuit breaker course previously, and who have been trained on racking and un-racking circuit breakers. Three electricians were surveyed using MS forms, as contained in Appendix B, and according to the surveys, the CBT took between 65 and 75 minutes to complete.

5.5 Survey Results of CBT

There were several results from the subjective survey of the CBT vs. PowerPoint trainings. First, the survey respondents indicated that it took between 65 and 75 minutes to complete the CBT vs. the original 10 hours it took to complete the traditional PowerPoint training. This is not to imply that classroom training is less effective than the CBT because it takes longer, but there is a notable difference in the time it took to complete the same training using the two different formats.

Next, the survey respondents indicated their subjective competency level had increased after taking the CBT, as compared to their first survey response after only having taken the PowerPoint. A potential bias that was noticed with the survey was the fact that respondents could be hesitant to rate their score as higher on the second survey than on the first, as they believed that it could possibly reflect on their training instructor who used the PowerPoint slide training to teach them.

To date there have not been any significant lessons learned from the implementation of this WRO.

6. BUSINESS CASE

6.1 Previous Training Modernization Business Case Results

In INL/RPT-22-68671 [10], the business case results illustrated a 37% chance of achieving a net present value (NPV) of $7.7M by committing to an investment between $22.6M and $33.7M and an ongoing investment of between $1.8M and $850,000 annually. This investment was to support the successful implementation of the following six training technologies:

1. Digital simulator with auto-update software.
2. Dynamic training modules.
3. Modern LMS.
4. VR or AR headsets.
5. Mobile worker software.
6. Digital documents handling software.

These investments were intended to help reduce the workload of the following areas in operations, technical, general, and training records learning opportunities.

The business case for this research focused on modernizing the dynamic training modules. As discussed in INL/RPT-22-68671 [10], the investment to modernize these training modules identified between $4M and $5M per plant to modernize the existing ILT modules. The INL report also identified an ongoing investment of $100,000 to $200,000 per year to maintain the modules.

6.2 Analysis Approach Summarized

The business case results for implementing this type of training were based on data from the survey and validation sessions. These findings elucidated the implications of the training modernization being implemented on a large scale. One consideration was how this new training approach could be applied to all maintenance training classes onsite, as it is reasonable to assume the quantitative WROs would show similar proportions of work reduction for tasks of similar complexity. To account for any workload reduction by instructor role, benefits were categorized by maintenance discipline to ensure workload benefits by expertise were maintained.

The benefits of this modernized training approach being implemented across a fleet were also considered, as a centralized training program would be very beneficial for fleets teaching the same skills and using the same technology and protocols in different facilities. This approach would also be beneficial if implemented across the industry, as the modernized training work products allow for significant WROs and would standardize benefits across the industry. If this process became the standard approach to training in the next few years, it would be a solution for the knowledge transfer issues caused by the large amount of experienced talent retiring. This solution would provide opportunities of scalability and would communicate OE and skill-of-the-craft better than PowerPoint training, all in a format the incoming workforce is accustomed to.

6.3 Workload Reduction Results for the Nuclear Operator

The initial maintenance electric class used a ratio of 1 instructor to 8 learners. This class takes about 10 hours to deliver on average and is taught once every three years. In contrast, the modernized CBT converted from the PowerPoint slides took 65–75 minutes to complete. The CBT would be an effective supplemental learning option for training, and its realistic videos and interactive scenario questions helped keep learners prepared both during and after their training. Allowing the learner the opportunity to access all training content on their digital devices at any time helps them solidify their knowledge independently and effectively prepare for in-person training. The competency-based questions serve to help the learner become knowledgeable about the task, while the detailed videos show a realistic version of the hardware they are learning to operate.

6.4 Investment to Modernize Training Module

The investment in external support to develop these two work products was significantly less than the estimated proportion of the investment identified in INL/RPT-22-68671 [10]. Moreover, the investment in hours to modernize the content in this research was significantly less than the annual workload savings from the instructor and learner (I&L), as outlined in Table 1 and Table 2. In addition, there is no ongoing marginal cost or support needed for the NPP as the finished work products are incorporated into the NPP's existing LMS and intranet site to use going forward.

Note that this WRO estimation implies a reduction of 4032 instructor hours and 504 learner hours, annually.

Table 1. Current annual I&L hours by discipline.

Current	Electrical	I&C	Mechanical	Maintenance	Annual Hrs
Instructor	297.7	176.7	71.7	30.0	576.0
Learners	2381.3	1413.3	573.3	240.0	4608.0

Table 2. Future annual I&L hours by discipline.

Future	Electrical	I&C	Mechanical	Maintenance	Annual Hrs
Instructor	37.2	22.1	9.0	3.8	72.0
Learners	297.7	176.7	71.7	30.0	576.0

If a nuclear operator wished to modernize existing initial and continuing operations, update technical and general training content, and achieve the benefits outlined in INL/RPT-22-68671 [11], the operator would need to commit to a significant project to modernize content. However, there also would be significant economy of scale to modernizing this content as part of one project. In addition, a proportion of the modernization effort may be able to be achieved by internal resources, provided the knowledge, skills, and abilities to modernize the content consisted with the expected level of quality. However, this degree of knowledge, skills, and ability would need to be developed over time and must be achieved through repetition and experience.

6.5 Potential Workload Benefits If Approach was Expanded to Additional Initial Classes and Topics

To infer the possible results of expanding this approach to all classes at an NPP, the ratio of class duration to CBT duration was used to estimate time reductions. One of the classes was not a good candidate to create a multimedia CBT for, but the other 70 initial maintenance classes were good candidates for this training optimization strategy (see Appendix C). When categorizing the initial classes by discipline, they were grouped as electrical, instrumentation and control (I&C), mechanical, and maintenance. Applying the 8:1 ratio from the Low Voltage Air Circuit Breaker modernization example between the durations of the CBT and classroom trainings, the 576 trainer hours and the 4608 learner hours per year could be reduced to 72 trainer hours and 576 learner hours, as shown previously in Table 1 and Table 2.

6.6 Potential Benefits of Expanding to Entire Industry

It is reasonable to assume these benefits would be applicable for sites with similar training programs, and especially for sites and fleets that have the same equipment. For sites using the same equipment hardware and teaching the same skills, the CBT could be shared between them to aid in learning and reduce training staff burdens. There also would be no need to repeat the process of creating a CBT for a single component, as each require the same information taught in the classroom training. If there are any discrepancies in the information being taught regarding the same components at different sites, the CBT easily could be adjusted to fit the standard of any site protocol.

Three considerations for the industry that must be mentioned before expanding this modernized CBT and on-demand chaptered video sessions are that these options would not work: (1) if the operator leadership team must see their procedural and management expectations/standards shown in the content (e.g., PPE), and (2) if the nuclear operator must showcase their personnel and/or site, and (3) if the content would be restricted by copyright or export control regulations/laws.

7. ALIGNMENT WITH INPO GUIDANCE

7.1 Alignment with Teaching and Learning (INPO 23-001)

From the beginning of this research, care was taken to keep the work product aligned with the accreditation goals and factors described in INPO 23-001 [2]. While it might be feasible in the future to replace current training methods with modular video tutorial learning, this work product is currently intended to be a supplemental resource to augment standard classroom training methods. This product will also be an effective resource to support just-in-time training, as maintenance staff with just-in-time training and an organized online knowledge base will be able to access needed information in real-time. These video tutorials also will help learners visualize and mentally simulate tasks learned in a classroom setting, solidifying knowledge and allowing the classroom instructor to use class time more efficiently.

This technology would help learners be comfortable and familiar with seeking out needed information and assist them in answering most of their own questions. The ability to access a detailed and organized knowledge base will prepare them for independence once they finish their training. These work products were created to augment traditional classroom training so that the overall training process becomes more efficient and so that individual differences in learning ability, teaching ability, or communication style can be overcome without burdening the trainer or learner while removing any barriers to effective training.

During the research a representative from INPO was updated on the progress of the advanced training modernization and reviewed the final versions of the modernized training work products. At the conclusion of the meeting with INPO, their representative was supportive to have the industry research utility demonstrate their modernized training work products at a future industry Teaching and Learning meeting, where utilities showcase their work products and learnings from conducting these types of modernization to other utilities to accelerate learning.

At the beginning of this demonstration project, INL researchers reached out to EPRI to discuss how to collaborate in the training area. Due to workload limitations, EPRI was not able to attend the filming of the breaker demonstration but did provide useful insight into various methods of implementing computer-based training. Near the end of this project, a demonstration of the final work products was conducted with two training leaders from EPRI who provided positive feedback and encouraged further industry engagement.

7.2 Alignment with Proficiency (INPO 24-001)

The modernized CBT aligns with INPO 24-001[11] by addressing core elements of proficiency: knowledge, skill, familiarity, understanding, currency, and teaching and learning (T&L). Detailed instructional modules provide comprehensive knowledge accessible on-demand, while realistic views of tasks from multiple camera angles enhance skill development. The CBT allows learners to build familiarity with tasks before and after classroom training, and competency-style questions foster deep understanding by challenging learners to apply knowledge in various scenarios. Additionally, the up-to-date content ensures that learners maintain currency in their skills, and that there are no barriers to studying the material. This comprehensive approach also prepares learners to respond to challenges such as unexpected equipment states, aligning with the emphasis given in INPO 24-001[11] on mitigating risks and maintaining high-proficiency levels.

8. Additional Advanced Training Technologies

In addition to CBT, there have been many other innovative training solutions formulated for the NPP industry to help improve the efficiency of the training process. In “Modernizing Training in the Nuclear Power Industry: A White Paper” [12], the advancements in training technologies are explored from VR and AR to artificial intelligence (AI) and machine-learning (ML)-driven personalized training and even gamification strategies to improve learner engagement. Tailored learning approaches and dynamic-learning analytics show great promise for tracking the success of learners and training programs and helping learners efficiently choose the career paths and learn the skills they want. These various new training approaches allow companies to reduce the barriers to learning and create accessible training programs to help learners efficiently learn new skills [13]. The framework used to decide which technologies are suited to which training programs is focused on providing long-term sustainability and continuous optimization to achieve the best results for I&L.

8.1 Gamification + VR

Earlier in this report, the changing generational makeup workforce was discussed. The younger workforce comprised of Generation Z and Millennials have very high rates of technological savviness. Video games are a very popular pastime for these young generations, and these games have been successfully designed to reward users as they progress through them. This is the very idea of gamification as the skills a user is rewarded for improving in a game are arbitrarily specific for the game, but the system of entertainment and rewards is a successful way to increase engagement and enjoyment of the game. There are many games that simulate real life skills as well—especially in the VR industry, such as surgery or car repair simulation games. For people training to become airplane pilots, there are very advanced training (AT) simulation games that help pilots learn how to use the controls in a safe but very realistic learning medium. These games, most of which are purely created for fun, exemplify the potential that computer games have for keeping users engaged in learning new skills, while the technology today is well enough advanced to create enjoyable and entertaining training simulations for almost any skill. Even game-like features implemented in a training program helps bring learners novel simulations of situations they will eventually perform in and help them decide which skills they need to pursue for their careers.

9. CONCLUSION

9.1 How Modernized Training Creates WROs

The overall goal of this report was to document the process used in this pilot project to show the attractive WROs imparted by modernizing the approach to training in the nuclear industry. Given the significant reduction in hours required to complete the training material, and the fact that it can be taken anywhere on any mobile device, demonstrates that this approach is a promising step in improving the effectiveness of nuclear training programs. Instead of long hours of viewing slideshows in a classroom setting, learners can prepare themselves and the instructor can get through the material significantly faster than in the slideshow format, leaving extra time for questions and hands-on laboratory training, which is often more engaging and fun. While it might seem like a daunting task, using this approach to modernize training promises a more accessible experience that is not contingent on the conformity of individual teaching or learning styles.

9.2 How Accessible Training Supports Knowledge Transfer

Equipping learners with a virtual knowledge base will help them accept responsibility for their own learning and allow them to control their learning experience to best fit their preferences and schedules. Instead of frantically scrolling through quickly scribbled notes from hours of PowerPoint trainings, the learners can quickly open their digital devices and rewatch a video of what they are going to practice in-person. Being able to prepare this way for any task would be a significant benefit in implementing this approach because the requirements and deadlines for learning certain skills can be made clear. Furthermore, while the instructors aid in the learning process and answer questions, it becomes the learner's complete responsibility to prepare themselves to use the tools they have and ask for help if they need it. The accessibility of a knowledge base such as this also will remove any discrepancies between learned information, such as if two recently trained learners are unsupervised and disagree on the proper procedure for a task they both only have in memory from long hours of class. The knowledge base solves this problem because instead of relying on memory, learners can access the information quickly as knowing where to find the information one needs is a much more important and effective skill than trying to force oneself to remember textual information from a PowerPoint slide exactly, and also mentally convert that information into a correct course of action. People learn from real experience. Allowing these learners to have the knowledge base resources they need in the moment will let them verify their memory of procedures until they solidify their habits.

9.3 Skills for Continuously Improving Training

Investing time and staff who already have onsite experience in learning how to create these modernized training work products is the most efficient way to receive the most benefits. This way there can be an active role by the instructors in the formation of training content and they can predict and respond to the learners' questions better. In the same way that creating digital presentations, using online file systems, and utilizing the internet have become expected skills in most industries even outside of the technology arena, so too will the skills of modernizing training to capture and present content digitally. Making these skills the industry standard will create an environment that reduces workload in all training and learning processes and will be applicable to teach any skills required in the future. Camera and software capabilities have progressed to the point that if they are not utilized, there will be intense stagnation in the future ability to teach and learn complex skills. So, if those processes are taken advantage of, the effects will benefit the entire industry. As the level of skill required to operate modern NPP technology increases, optimizing the training and learning process to make it as easy as possible will allow more novice learners to spend less time and effort to gain the same level of expertise in a task that once took significant time and resources to teach. There is no reason to not take advantage of the modern capabilities improving training and learning. As in every other discipline, making learning easier allows learners to learn more skills in a shorter amount of time by reducing the effort and experience required to become adept at tasks. At this point in the evolution of training technologies the difference between modern training methods and those employed at many NPPs is a compelling reason to make the switch and realize improvements in knowledge retention, afford greater information accessibility, and appeal to next generation workforce preferences. Companies that embrace innovative training methods will give themselves more options for current and future WROs and will reduce the strain on instructors responsible for training, preparing content for, and evaluating large groups of learners.

9.4 Expansion of Training into Work Packages and Field Activities

Developing training content in this way, that is, archivable, chaptered video with meta-tags to identify specific procedure steps or key-points has value beyond the classroom. This work product can feasibly be included as part of an electronic work package and accessible while the workforce is performing field activities. The on-demand video could be cut to show the specific parts of the work to enable easier reference by the learner or field performer.

These on-demand videos were identified to offer a variety of use cases to support field activities, including pre-job briefs, and self-directed learning by the field worker prior to executing work. These videos when integrated seamlessly into procedural content provide a realistic on-demand resource, so that field workers can feel confident in their understanding of the skills they are expected to perform. While it is already standard in other industries, the method of using on-demand resources in the field should be a topic for future research and has the potential to benefit field workers and improve procedural integrity.

Further research should be performed to quantify the workload and qualitative benefits of incorporating these on-demand training work products into electronic work packages. Having these measures and making them accessible to the industry could prompt further adoption of advanced training methods supporting greater industry success.

9.5 Benefits to Train the Workforce on Obsolete Equipment

During the research, the project team identified the benefits of modernized learning work products to accelerate learning for the workforce when operating, training, or troubleshooting obsolete and aging equipment. The nuclear industry has been facing obsolescence challenges with aging equipment or equipment that is no longer manufactured or available to train a workforce regarding how to operate, maintain, and troubleshoot. With original equipment manufacturers (OEMs) no longer being able to supply rare or significantly older equipment for training purposes, the benefits of capturing multimedia content on this type of equipment in the NPP can be beneficial to educating the workforce of the future. For example, if a three-way safety-related valve is no longer available due to the original manufacturer going out of business years ago, the nuclear operator could capture how to operate and maintain that three-way valve during an outage when it is placed out of service.

This is a potential area of future research to identify the qualitative benefits of developing on-demand training work products to train the workforce on how to operate, maintain, and troubleshoot aging equipment such as the three-way valve.

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Appendix A

Low Voltage Air Circuit Breakers

Westinghouse Type DS Circuit Breakers

EMT939.06

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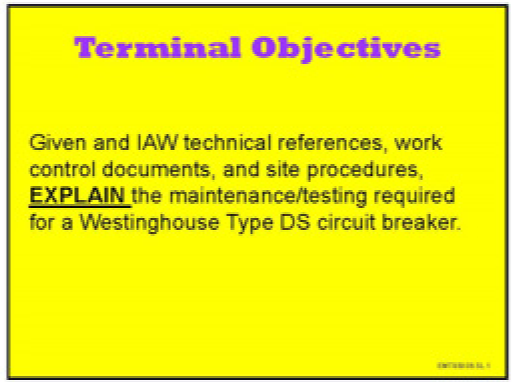
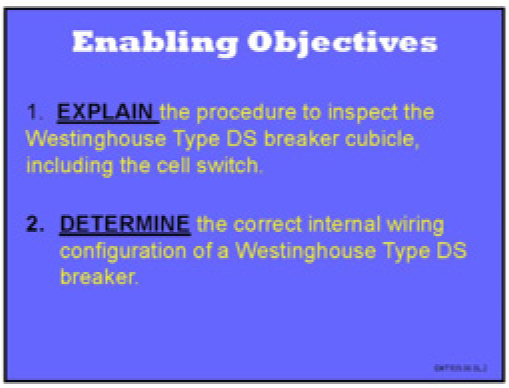
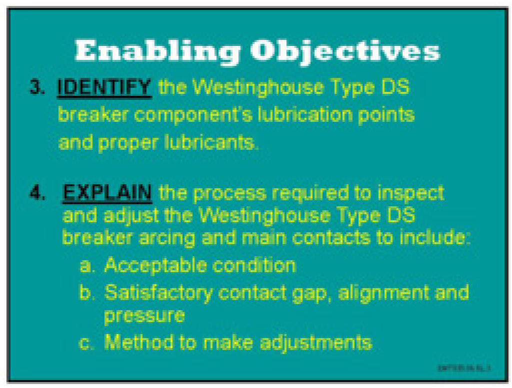
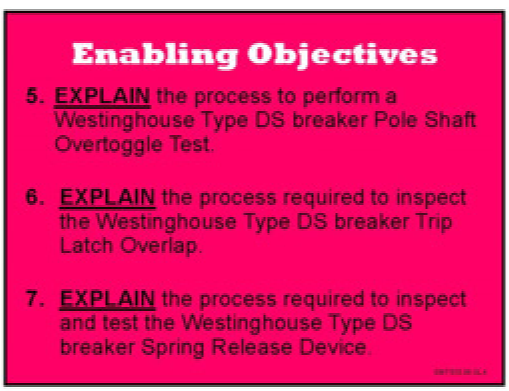
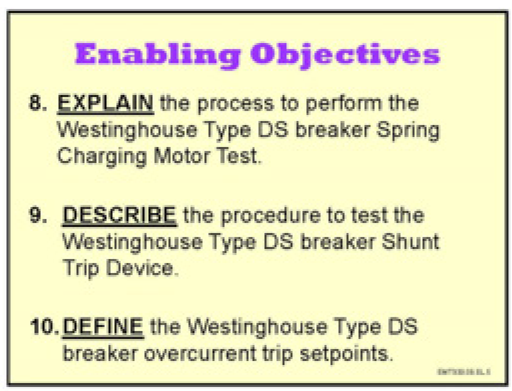
Appendix A
Low Voltage Air Circuit Breakers
Westinghouse Type DS Circuit Breakers
EMT939.06



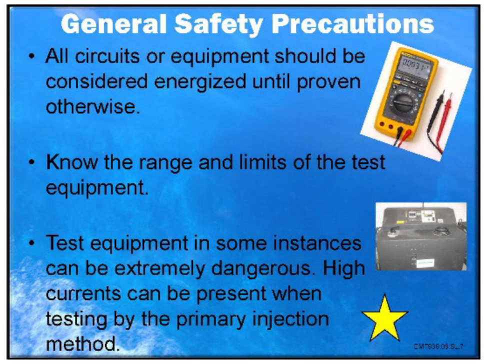


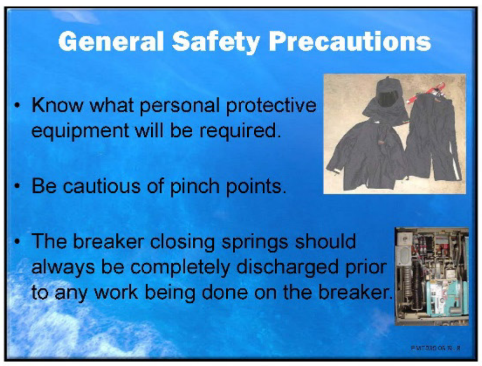


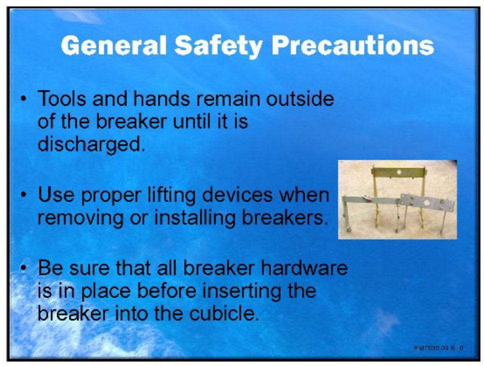


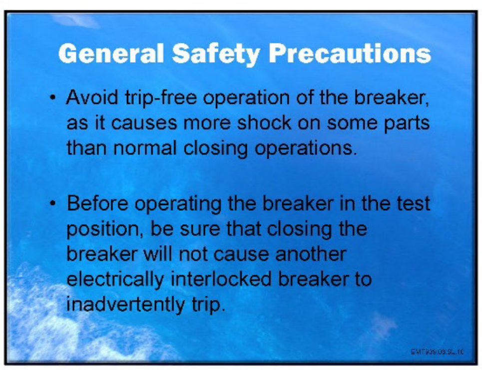



Safety Moment


General Safety Precautions
• All circuits or equipment should be considered energized until proven otherwise.
• Know the range and limits of the test equipment.
• Test equipment in some instances can be extremely dangerous. High currents can be present when testing by the primary injection method.


General Safety Precautions
• Know what personal protective equipment will be required.
• Be cautious of pinch points.
• The breaker closing springs should always be completely discharged prior to any work being done on the breaker.


General Safety Precautions
• Tools and hands remain outside of the breaker until it is discharged.
• Use proper lifting devices when removing or installing breakers.
• Be sure that all breaker hardware is in place before inserting the breaker into the cubicle.


General Safety Precautions
• Avoid trip-free operation of the breaker, as it causes more shock on some parts than normal closing operations.
• Before operating the breaker in the test position, be sure that closing the breaker will not cause another electrically interlocked breaker to inadvertently trip.


Operating Experiences
OE21963
OE25143
OE25160
SOER-98-2
OE22447
OE22867
OE22505
OE19278
OE22442
OE18056
OE22447
OE21026
OE19812
OE21597

Westinghouse Type DS

General Information

- Used in Class 1E and Non-Class 1E 480 volt loadcenter applications at STPEGS.
- The solid state trip unit is an Amptector trip unit.
  - It has adjustable dial settings.

- Also used as Motor Generator output breakers and Reactor Trip breakers (no Amptector on the Reactor Trip breakers).

Typical DS Breaker Sizes (STPEGS)

- DS-206
  - The frame rating is 800 amps.
  - Used for loads such as small motor supply breakers.
- DS-416
  - The frame rating is 1600 amps
  - Used for loads such as MCC feeder and large motor breakers.
- DS-420
  - The frame rating is 2000 amps.
  - Used for loads such as loadcenter feeder and tie breakers.

Breaker Racking

Breaker Removal

Use the proper breaker lifting device

Fully extend the cubicle rails

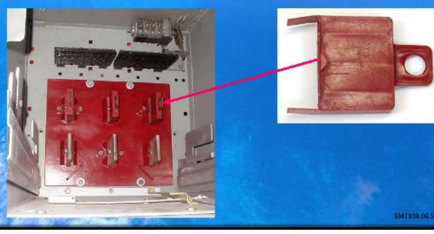
Objective 1

<u>EXPLAIN</u> the procedure to inspect the Westinghouse Type DS breaker cubicle, including the cell switch.

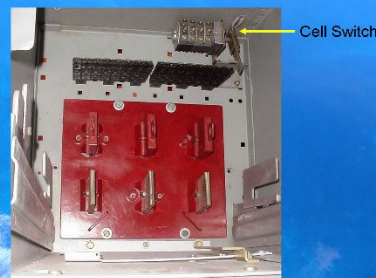
3

Cubicle Inspection

- Install insulating boots over all exposed energized bus connections.



Cubicle Cell Switch



Cubicle Cell Switch

- The cell switch identifies breaker position in the cubicle.
- The contacts are identified as a "33" contact on the electrical drawings.
- The cell switch operating arm is actuated as the breaker moves from the "TEST" position to the "CONNECT" position when racking the breaker in and between the "CONNECT" position and the "TEST" position when racking the breaker out.

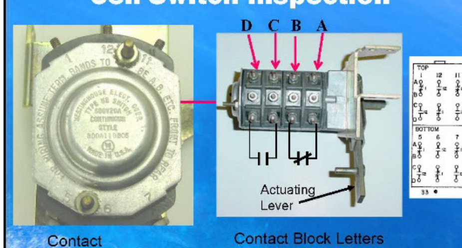
Cubicle Cell Switch

- Electrically the contacts are usually used as a permissive contact in the electrical scheme.
- They are commonly used to enable or disable the control switch located at the cubicle and also the remote control switch (Control Room and/or at the device).

Cubicle Cell Switch

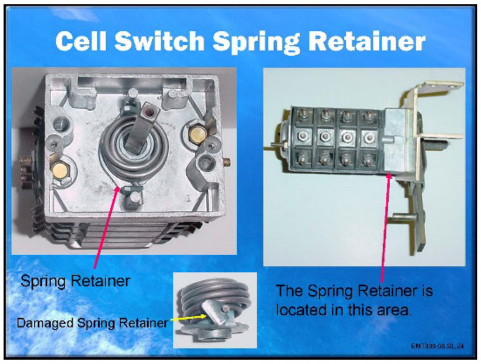
- Usual configuration:
  - When the breaker is in the "TEST" position, the <u>cubicle</u> control switch is <u>operable</u> and the remote control switch is disabled.
  - When the breaker is in the "CONNECT" position, the <u>remote</u> control switch is <u>operable</u> and the cubicle control switch is disabled.

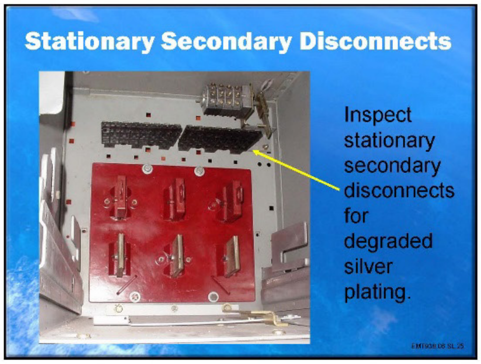
Cell Switch Inspection

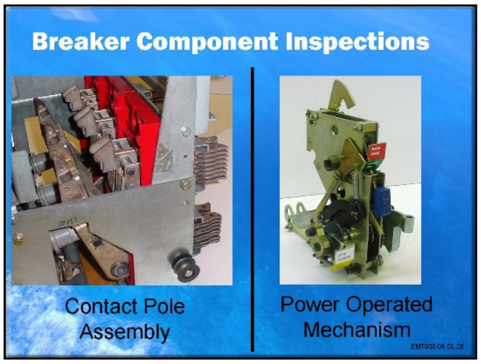


The contacts should change state when the actuating lever is operated.

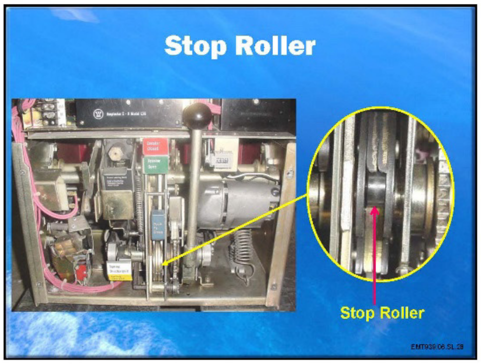
4

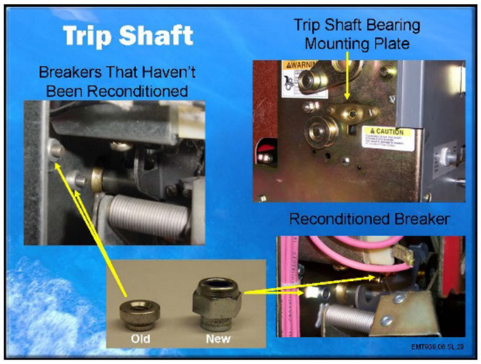

Cell Switch Spring Retainer
Spring Retainer
Damaged Spring Retainer
The Spring Retainer is located in this area.


Stationary Secondary Disconnects
Inspect stationary secondary disconnects for degraded silver plating.


Breaker Component Inspections
Contact Pole Assembly
Power Operated Mechanism


Spring Release Latch Lever
Check for metal distortion, fatigue and cracks
Verify this area is clean of dried lubricants
New Style Spring Release Latch Lever

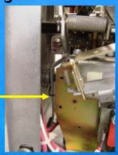

Stop Roller
Stop Roller

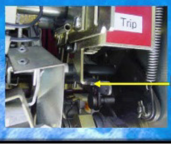

Trip Shaft
Trip Shaft Bearing Mounting Plate
Breakers That Haven't Been Reconditioned
Reconditioned Breaker
Old
New

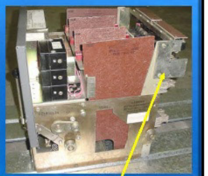
5

Breaker Component Inspections

Interlock Linkages







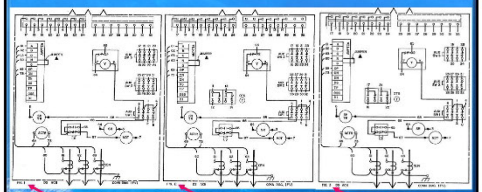
Objective 2

DETERMINE the correct internal wiring configuration of a Westinghouse Type DS breaker.

DS Wiring Configurations

- At STPEGS, Westinghouse DS breakers can have three different internal wiring configurations.
- Breaker internal wiring diagrams are shown on STP vendor drawing 4114-01028-WU (Unit 1) and 8114-01046-WU (Unit 2) - Internals and Miscellaneous Diagram.

Drawing 4114-01028-WU



DS Wiring Configurations

- To determine which wiring configuration is appropriate for your breaker, refer to 0PMP05-NA-0015, Calibration of Westinghouse Amptectors, Addendum 1 – Connection, Internals and Misc. Diagrams.
  - Contains a table for Unit 1 and a table for Unit 2.
  - Lists the Internals and Misc. drawing.
  - Lists drawings for Connection Units A, B, C, D, E and F.

0PMP05-NA-0015 – Addendum 1

Connection, Internals and Miscellaneous Diagrams – Unit 1

Load Center	1J	E1A	1K	E1B	1L	E1C
Internals and Misc.	4114-01028	4114-01028	4114-01028	4114-01028	4114-01028	4114-01028
Connection Unit A	4114-01053	4114-01059	4114-01066	4114-01072	4114-01078	4114-01084
Connection Unit B	4114-01054	4114-01060	4114-01067	4114-01073	4114-01079	4114-01085
Connection Unit C	4114-01055	4114-01061	4114-01068	4114-01074	4114-01080	4114-00086
Connection Unit D	4114-01056	4114-01062	4114-01069	4114-01075	4114-01081	4114-00087
Connection Unit E	4114-01057	4114-01063	4114-01070	4114-01076	4114-01082	4114-01088
Connection Unit F	4114-01058	N/A	4114-01071	4114-01077	4114-01083	N/A

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Typical Loadcenter Design

- The Connection Units are the columns of loadcenter cubicles.
- The rows are numbered numerically from top to bottom

Conn. Unit 1A	Conn. Unit 1B	Conn. Unit 1C	Conn. Unit 1D	Conn. Unit 1E	Conn. Unit 1F
Conn. Unit 2A	Conn. Unit 2B	Conn. Unit 2C	Conn. Unit 2D	Conn. Unit 2E	Conn. Unit 2F
Conn. Unit 3A	Conn. Unit 3B	Conn. Unit 3C	Conn. Unit 3D	Conn. Unit 3E	Conn. Unit 3F
Conn. Unit 4A	Conn. Unit 4B	Conn. Unit 4C	Conn. Unit 4D	Conn. Unit 4E	Conn. Unit 4F

DS Wiring Configurations

- Notice that the Internals and Misc. drawing is the <u>same</u> for all the Connection Units (per Unit).

Connection, Internals and Miscellaneous Diagrams – Unit 1

Load Center	1J	E1A	1K	E1B	1L	E1C
Internals and Misc.	4114-01028	4114-01028	4114-01028	4114-01028	4114-01028	4114-01028
Connection Unit A	4114-01053	4114-01059	4114-01066	4114-01072	4114-01078	4114-01084
Connection Unit B	4114-01054	4114-01060	4114-01067	4114-01073	4114-01079	4114-01085
Connection Unit C	4114-01055	4114-01061	4114-01068	4114-01074	4114-01080	4114-00086
Connection Unit D	4114-01056	4114-01062	4114-01069	4114-01075	4114-01081	4114-00087
Connection Unit E	4114-01057	4114-01063	4114-01070	4114-01076	4114-01082	4114-01088
Connection Unit F	4114-01058	N/A	4114-01071	4114-01077	4114-01083	N/A

DS Wiring Configurations

- Notice that the different loadcenters and each Connection Unit in each loadcenter has a <u>different</u> drawing number.

Connection, Internals and Miscellaneous Diagrams – Unit 1

Load Center	1J	E1A	1K	E1B	1L	E1C
Internals and Misc.	4114-01028	4114-01028	4114-01028	4114-01028	4114-01028	4114-01028
Connection Unit A	4114-01053	4114-01059	4114-01066	4114-01072	4114-01078	4114-01084
Connection Unit B	4114-01054	4114-01060	4114-01067	4114-01073	4114-01079	4114-01085
Connection Unit C	4114-01055	4114-01061	4114-01068	4114-01074	4114-01080	4114-00086
Connection Unit D	4114-01056	4114-01062	4114-01069	4114-01075	4114-01081	4114-00087
Connection Unit E	4114-01057	4114-01063	4114-01070	4114-01076	4114-01082	4114-01088
Connection Unit F	4114-01058	N/A	4114-01071	4114-01077	4114-01083	N/A

DS Wiring Configurations

- To determine the appropriate internal wiring diagram, start by selecting the appropriate drawing for your Connection Unit cubicle.
- This drawing is also listed in 0PMP05-NA-0008, Westinghouse 480 Volt Breaker Test, Addendum 13 – Breaker Locations and Specifics.

0PMP05-NA-0015 – Addendum 1

Assume our breaker is located in loadcenter 1J, cubicle **2A**. The drawing we need is 4114-01053.

Connection, Internals and Miscellaneous Diagrams – Unit 1

Load Center	1J	E1A	1K	E1B	1L	E1C
Internals and Misc.	4114-01028	4114-01028	4114-01028	4114-01028	4114-01028	4114-01028
Connection Unit A	4114-01053	4114-01059	4114-01066	4114-01072	4114-01078	4114-01084
Connection Unit B	4114-01054	4114-01060	4114-01067	4114-01073	4114-01079	4114-01085
Connection Unit C	4114-01055	4114-01061	4114-01068	4114-01074	4114-01080	4114-00086
Connection Unit D	4114-01056	4114-01062	4114-01069	4114-01075	4114-01081	4114-00087
Connection Unit E	4114-01057	4114-01063	4114-01070	4114-01076	4114-01082	4114-01088
Connection Unit F	4114-01058	N/A	4114-01071	4114-01077	4114-01083	N/A

0PMP05-NA-0008, Addendum 13

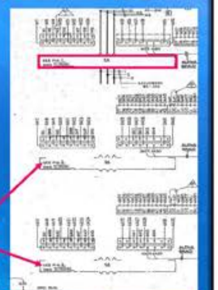
Location	Load	Frame/Trip	Trip Unit	Figure	Vendor Drawing
1J1B	MAIN CH WTR	600/300	LT-I	2	4114-01054 WU
1J1E	MCC 1J3	600/600	LT-ST	1	4114-01057 WU
1J2A	MAIN	2000/2000	LT-ST	1	4114-01053 WU
1J2C	TIE	2000/2000	LT-ST	1	4114-01055 WU
1J2E	MCC 1J1	600/600	LT-ST	1	4114-01057 WU
1J2F	MAIN	2000/2000	LT-ST	1	4114-01058 WU
1J3A	HC HEATER	600/400	LT-ST	2	4114-01053 WU
1J3B	MAIN EX FN	600/400	LT-I	2	4114-01054 WU
1J3C	PRESS HTR	600/600	LT-ST	2	4114-01055 WU
1J3E	RCB H-PURG	600/200	LT-I	2	4114-01057 WU
1J3F	HC HEATER	600/400	LT-ST	2	4114-01058 WU
1J4A	FHB HTR	600/600	LT-ST	2	4114-01053 WU
1J4C	MAIN STMFW	600/400	LT-I	2	4114-01055 WU
1J4E	RAD ANU	600/300	LT-ST	2	4114-01057 WU

This drawing number can be validated in Addendum 13 of 0PMP05-NA-0008.

7

Drawing # 4114-01053 WU

- The 2A breaker internal wiring shall be configured as in Figure 1 on drawing 4114-01028-WU.
- Notice the 3A breaker and the 4A breaker shall be configured as in Figure 2 on drawing 4114-01028-WU.



0PMP05-NA-0008, Addendum 13

Location	Load	Frame/Trip	Trip Unit	Figure	Vendor Drawing
[illegible]	MAB CH WTR	300/300	LT-I	2	[illegible] WU
[illegible]	MCC 1D	800/400	LT-ST	1	[illegible] WU
[illegible]	MAIN	2000/2000	LT-ST	1	[illegible] WU
[illegible]	TIE	2000/2000	LT-ST	1	[illegible] WU
[illegible]	MCC 1E	800/600	LT-ST	1	[illegible] WU
[illegible]	MAIN	2000/2000	LT-ST	1	[illegible] WU
[illegible]	HC HEATER	800/400	LT-ST	2	[illegible] WU
[illegible]	MAB EX FN	800/400	LT-I	2	[illegible] WU
[illegible]	[illegible]	800/600	LT-ST	2	[illegible] WU
[illegible]	RCB H-PURG	300/300	LT-I	2	[illegible] WU
[illegible]	HC HEATER	800/400	LT-ST	2	[illegible] WU
[illegible]	PRS HTR	800/600	LT-ST	2	[illegible] WU
[illegible]	MAB SUPFN	800/400	LT-I	2	[illegible] WU
[illegible]	EAB AHU	300/300	LT-ST	2	[illegible] WU

This figure number can be validated in Addendum 13 of 0PMP05-NA-0008.

Drawing 4114-01028-WU

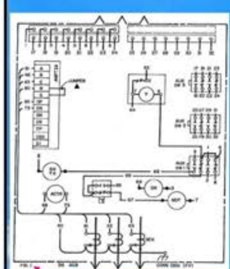


FIG. 1

- **Fig. 1 Components**
  - (3) 8 point secondary disconnects
  - Amptector terminal strip (AMPT1A)
  - Anti-Pump relay (Y)
  - (3) Auxiliary switches
  - Shunt Trip device (SH TR)
  - Direct Trip Actuator (ACTR)
  - Motor Cut-Off switch (LS)
  - Spring Release device (SR)
  - Spring Charging Motor (MOT)
  - (3) current transformers (SEN)

Drawing 4114-01028-WU

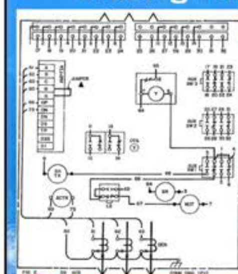


FIG. 2

- **Fig. 2 Components**
  - (4) 8 point secondary disconnects
  - Amptector terminal strip (AMPT1A)
  - Anti-Pump relay (Y)
  - (3) Auxiliary switches (AUX SW)
  - Overcurrent Trip Switch (OTS)
  - Shunt Trip device (SH TR)
  - Direct Trip Actuator (ACTR)
  - Motor Cut-Off switch (LS)
  - Spring Release device (SR)
  - Spring Charging Motor (MOT)
  - (3) current transformers (SEN)

Drawing 4114-01028-WU

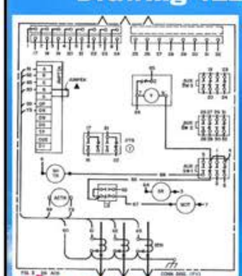


FIG. 3

- **Fig. 3 Components**
  - (3) 8 point secondary disconnects
  - Amptector terminal strip (AMPT1A)
  - Anti-Pump relay (Y)
  - (3) Auxiliary switches (AUX SW)
  - Overcurrent Trip Switch (OTS)
  - Shunt Trip device (SH TR)
  - Direct Trip Actuator (ACTR)
  - Motor Cut-Off switch (LS)
  - Spring Release device (SR)
  - Spring Charging Motor (MOT)
  - (3) current transformers (SEN)

DS Breaker Component Terminology

Sensors

Amptector

Direct Trip Actuator

Overcurrent Trip Switch

Motor Cut-Off Switch

Spring Release Device

Aux Switch & Anti-Pump Relay

Shunt Trip Device

8

Objective 3

IDENTIFY the Westinghouse Type DS breaker component's lubrication points and proper lubricants.

Approved Lubricants

- Molykote BR-2 Plus
  - Used on all pivoting and sliding surfaces.
  - NOT to be used on conductive, insulating or electrical parts.
- Westinghouse Graphite Grease 53071AN
  - Apply a thin film to the contact surfaces of the Auxiliary Switches.
- Apply lubricants sparingly.

CAUTION

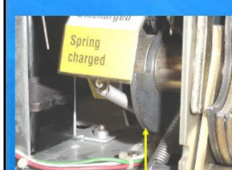
- When cleaning or lubricating a DS breaker, be very careful applying solvents such as isopropyl alcohol to the interior of the breaker. Some breaker parts that can only be lubricated during an overhaul are coated with a lubricating coating called Poxy-Lube. Solvents will remove the Poxy-lube, affecting the breaker operation.

DS Lubrication Points

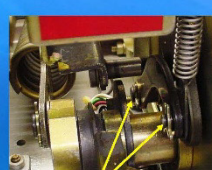
Spring Charge Indicator Surface Engaging the Cut-off Switch Link

Example of Poxy-Lube

DS Lubrication Points

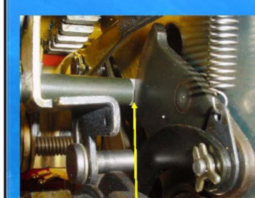


Cam Surface Operating the Cut-Off Switch Link
(Also Poxy-Lube)



Pins on Both Ends of the Constraining Link

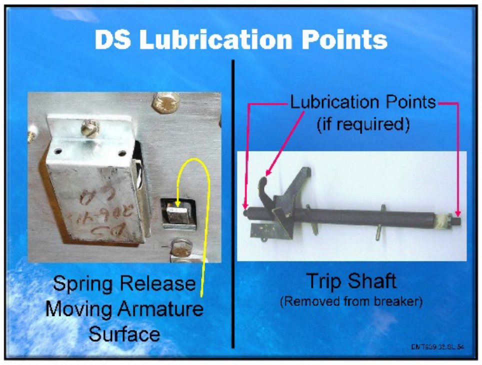
DS Lubrication Points

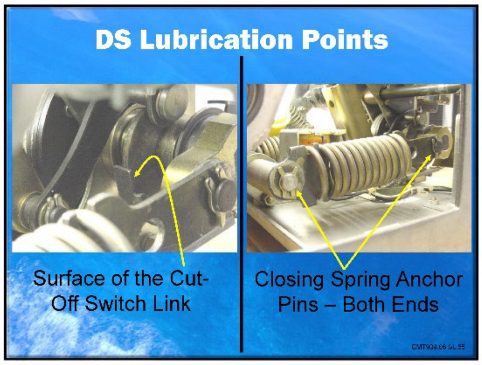


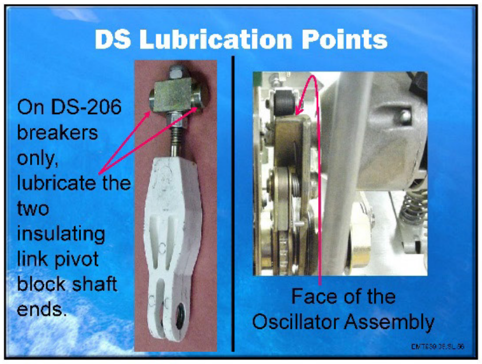
Curved Surface of the Trip Latch

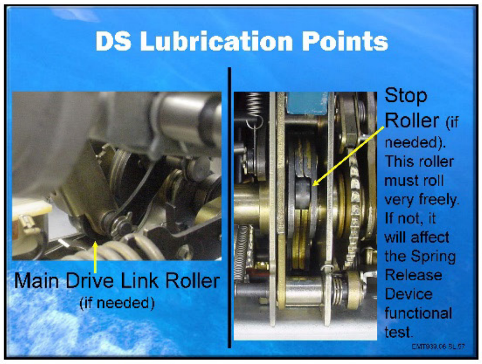
Shunt Trip Moving Armature Surface

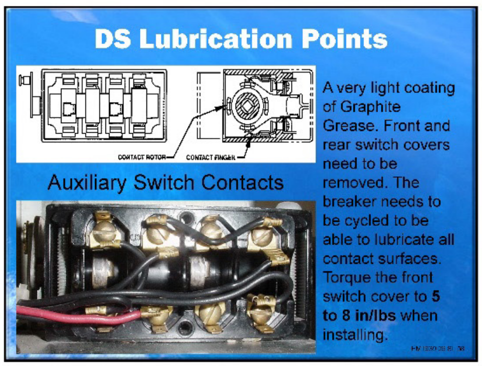
9

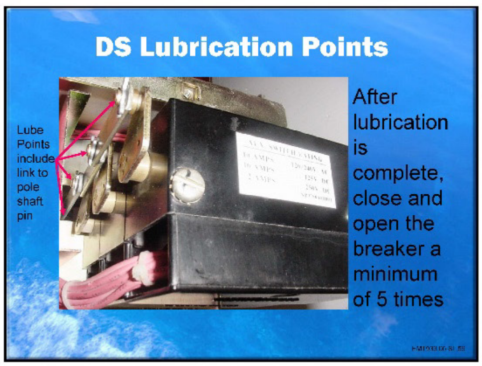

DS Lubrication Points
Spring Release Moving Armature Surface
Lubrication Points (if required)
Trip Shaft
(Removed from breaker)


DS Lubrication Points
Surface of the Cut-Off Switch Link
Closing Spring Anchor Pins – Both Ends


DS Lubrication Points
On DS-206 breakers only, lubricate the two insulating link pivot block shaft ends.
Face of the Oscillator Assembly


DS Lubrication Points
Main Drive Link Roller
(if needed)
Stop Roller (if needed). This roller must roll very freely. If not, it will affect the Spring Release Device functional test.


DS Lubrication Points
CONTACT ROTOR
CONTACT FINGER
Auxiliary Switch Contacts
A very light coating of Graphite Grease. Front and rear switch covers need to be removed. The breaker needs to be cycled to be able to lubricate all contact surfaces. Torque the front switch cover to 5 to 8 in/lbs when installing.


DS Lubrication Points
Lube Points include link to pole shaft pin
After lubrication is complete, close and open the breaker a minimum of 5 times

10

Objective 4

EXPLAIN the process required to inspect and adjust the Westinghouse Type DS breaker arcing and main contacts to include:

a. Acceptable condition

b. Satisfactory contact gap, alignment and pressure

c. Method to make adjustments

Arcing and Main Contacts

Contact Appearance

- Arcing Contacts may have a mottled, dirty appearance. This is normal.
  - Clean surface of the arcing contacts with Scotchbrite. Dress any slag/burrs with a fine file.
  - Follow the contour of the contacts.
  - Do not allow any filings to enter the mechanism or contact assembly.
- Main contacts should be clean without burns or pitting.
  - Clean the main contacts with a clean, dry cloth.

Dimension "C" Measurement

- With the breaker open and the closing springs discharged, measure the distance between the stationary arcing contacts.
- Functional criteria for this measurement is **0.34" – 0.50"**.
- Replace the arcing contacts if unable to meet this criteria.

Dimension "C" Measurement

(0.34" - 0.50")

Dimension "A" Measurement

- Ensure the breaker is open and close the arcing contacts by hand.
- Ensure the arcing contact surfaces align with each other.

Parallel and touch each other on initial contact over the 1/2" length.

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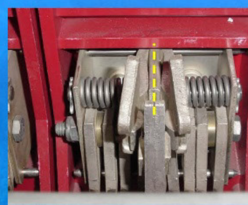
Dimension “A” Measurement

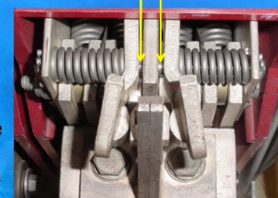
- The moving arcing contact centerline should visually align with the centerline of the stationary contact bar **± 1/16** inch.



Centerline should be within ± 1/16”

Dimension “A” Measurement

- Close the breaker.
- The gap between each stationary contact and the stationary contact bar is a minimum of **0.02** inches.



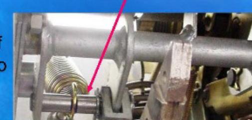
Dimension “A” Adjustment

- Loosen the contact assemblies and move to achieve correct centerline alignment.
- Torque moving arcing contacts mounting bolts in accordance with the Addendum.
- Redo the measurements.
- If unable to achieve functional criteria, replace the affected contacts.

Dimension “B” Inspection

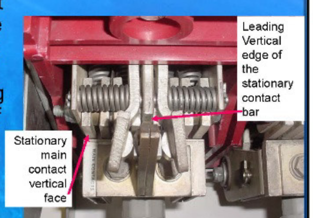
- <u>For DS-206 breakers only</u>, disconnect the opening spring from the pole shaft pin.

Note the orientation of the spring in relation to the pin. The spring hook should come up from the bottom.



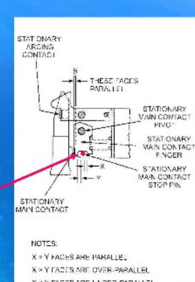
Dimension “B” Inspection

- Visually inspect the faces of the stationary main contact fingers with the leading vertical edge of the stationary contact bar.
- The two faces should be parallel.



DS-206 Dimension “B”

- DS-206 breakers have only two stationary main contact fingers – one contact finger mounted on each side of the stationary contact bar.
- When the stop pin is centered in the cutout of the stationary main contact finger, the faces are parallel.



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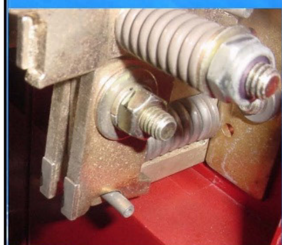
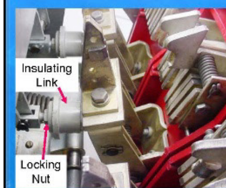
DS-206 Dimension "B"



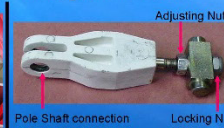
Contacts Open

Contacts Closed

Dimension "B" Adjustment



DS-416/420 breakers: loosen the locking nut, then turn the insulating link to bring the faces parallel.



DS-206 breakers: loosen the locking nut, then turn the adjusting nut to bring the faces parallel. It is critical that the insulating link remain square with the pole shaft to prevent binding for the Contact Air Gap Inspection.

Objective 5

<u>EXPLAIN</u> the process to perform a Westinghouse Type DS breaker Pole Shaft Overtoggle Test.

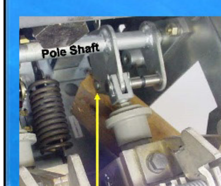
Pole Shaft Overtoggle Test

- With the opening spring disconnected, close the breaker.
- Place a pry bar under the square metal plate on the left side of the pole shaft.
- DO NOT place pry bar on insulating link.
- Pushing down on the pry bar, raise the pole shaft to its maximum travel.

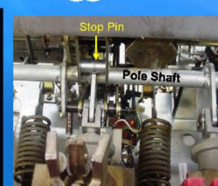
Pole Shaft Overtoggle Test

- Release pressure on the pry bar and verify the pole shaft returns to its original position.
- If the pole shaft does not return to its original position, the contacts are locked in a closed position.
- The operating mechanism must then be disassembled to replace the Stop Pins.
  - This replacement requires a breaker overhaul certification.

Pole Shaft Overtoggle Test



Pry upward on square plate on left side of Pole Shaft.



If overtoggling occurs, the two mechanism Stop Pins require replacement.

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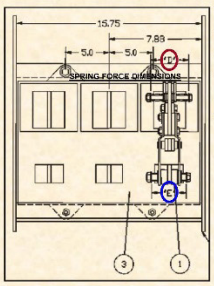
DS-206 Contact Air Gap Inspection

- With opening spring removed, trip the breaker.
- Visually verify that the moving and stationary have separated.
  - There is no criteria as to distance, just that separation is obtained.
- If separation is not obtained, adjustment is required.

DS-206 Contact Air Gap Adjustment

- Measure the distance between the flat washers for the arcing contact springs.
  - Dimension "D" = **3.12" – 3.14"**
- Measure the distance between the flat washers for the moving contact arm hinge springs.
  - Dimension "E" (Original Design) = **2.95" – 2.98"**
  - Dimension "E" (New Tapered Spring Design) = **2.51" – 2.54"**

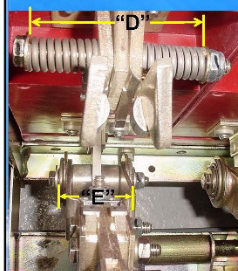
DS-206 Contact Air Gap Adjustment



"D" - Arcing Contact:	3.12" to 3.14"
"E" - Hinge Spring	
Original Design	2.95" to 2.98"
New Design (Tapered Spring):	2.51" to 2.54"

- Verify the contact insulating link is not binding on the Pole Shaft.
- Connect the opening spring to the Pole Shaft.

DS-206 Contact Air Gap Adjustment



"D" - Arcing Contact:	3.12" to 3.14"
"E" - Hinge Spring	
Original Design	2.95" to 2.98"
New Design (Tapered Spring):	2.51" to 2.54"

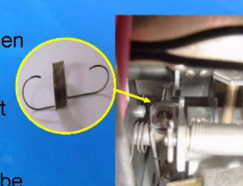
Both measurements are from the inside surfaces of the washers on the springs.

Objective 6

EXPLAIN the process required to inspect the Westinghouse Type DS breaker Trip Latch Overlap.

Trip Latch Overlap Check

- With the breaker open and the closing springs discharged, inspect the trip shaft return spring.
- Extreme care must be used when removing or installing this spring as it can be over stretched very easily.



One end of this spring is attached to the Direct Trip Actuator bracket, the other end to the trip shaft.

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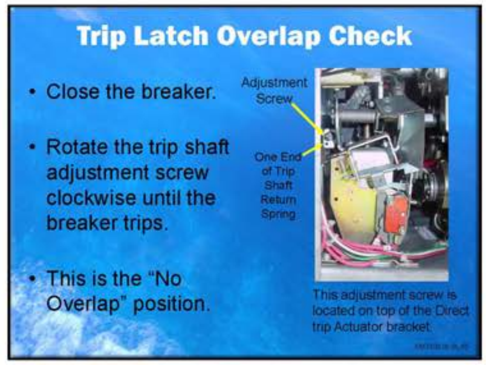
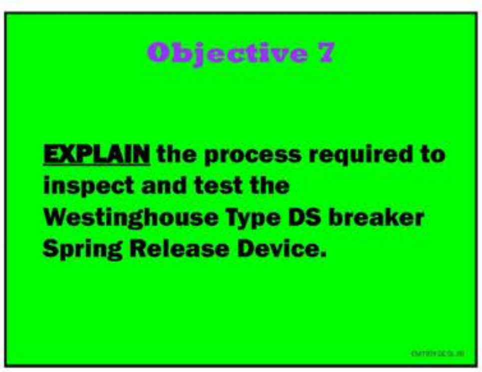
Trip Latch Overlap Check
• Charge the closing springs and verify there is a gap between the trip shaft and the trip latch.
• The gap will be extremely small.
• This gap is to ensure the trip shaft is fully reset.
Trip Shaft
Gap
Trip Latch


Trip Latch Overlap Check
• Close the breaker.
• Rotate the trip shaft adjustment screw clockwise until the breaker trips.
• This is the "No Overlap" position.
Adjustment Screw
One End of Trip Shaft Return Spring
This adjustment screw is located on top of the Direct trip Actuator bracket.


Trip Latch Overlap Check
• Rotate the adjustment screw 4 turns in the counter-clockwise direction.
• This is the proper position for the trip shaft.
• Cycle the breaker open and close 5 times without any trip-free occurrences.

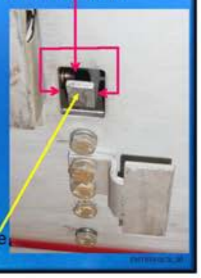

Trip Latch Overlap Check
• If the breaker does trip-free during one of the cycles, replace the Trip Shaft Return Spring.
• If the breaker cycling appears to vibrate the adjusting screw from its proper setting, readjust the overlap and apply torque seal to the adjusting screw threads.


Objective 7
EXPLAIN the process required to inspect and test the Westinghouse Type DS breaker Spring Release Device.


Spring Release Device Inspection
• The Spring Release Device lever (clapper) must have a minimum 1/32" clearance between the lever and the opening in the breaker baseplate.
• The lever must be moved as far forward as possible.
• Remove, inspect and reinstall the device, if necessary (torquing is required).

Spring Release Device Inspection

There shall be a minimum clearance of 1/32" when the clapper is moved through the breaker baseplate.



Apply pressure here…

…then push up here.

Spring Release Device Test

- With the breaker open and closing springs charged, apply 70 VDC to points 3(+) and 4(-) of the secondary disconnects.
- The breaker must close.
- Repeat this test a second time. The breaker must close each time.
- If the breaker fails to close, replace the Spring Release Device.

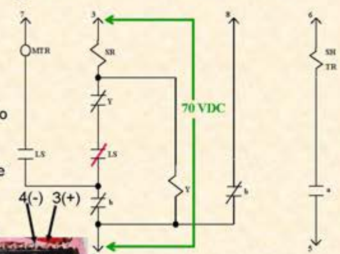
Spring Release Device Test

Important Note

If the breaker fails to close during this test, it could be an indication that the breaker may be experiencing lubrication issues and is in need of an overhaul. It is recommended that the Supervisor and System Engineer be contacted prior to replacing the Spring Release Device.

Spring Release Device Test

Secondary disconnect terminals are numbered left to right, top to bottom, when viewed from the breaker front.



Rear View Shown

Objective 8

EXPLAIN the process to perform the Westinghouse Type DS breaker Spring Charging Motor Test.

Spring Charging Motor Test

- With the breaker open, apply 125 VDC to secondary disconnect terminals 4(-) and 7(+).
- Verify the charging motor runs at the proper speed and fully charges the closing springs.
- Verify the motor cut-off switch shuts off the motor when the springs are fully charged.

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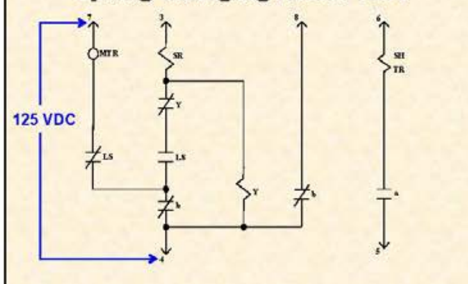
Spring Charging Motor Test



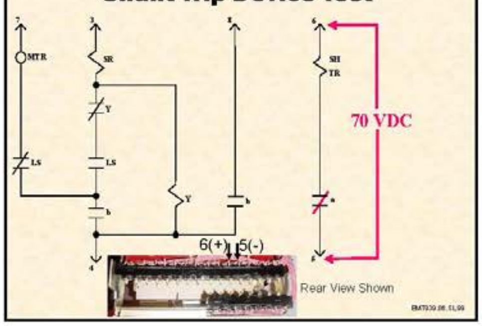
Objective 9

DESCRIBE the procedure to test the Westinghouse Type DS breaker Shunt Trip Device.

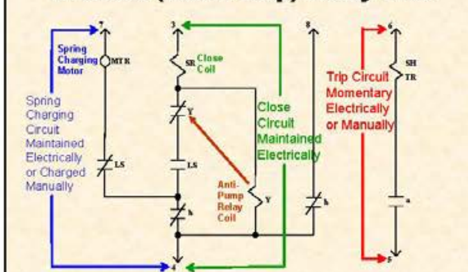
Shunt Trip Device Test

- With the breaker closed, apply 70 VDC to secondary disconnect terminals 5(-) and 6(+).
- The breaker should trip without hesitation.
- If the breaker fails to open, replace the Shunt Trip Device.

Shunt Trip Device Test



Lockout (Anti-Pump) Relay Test



Objective 10

DEFINE the Westinghouse Type DS breaker overcurrent trip setpoints.

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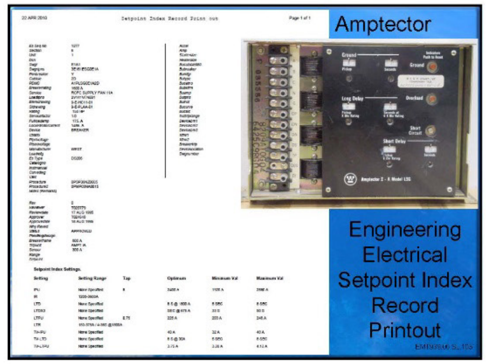
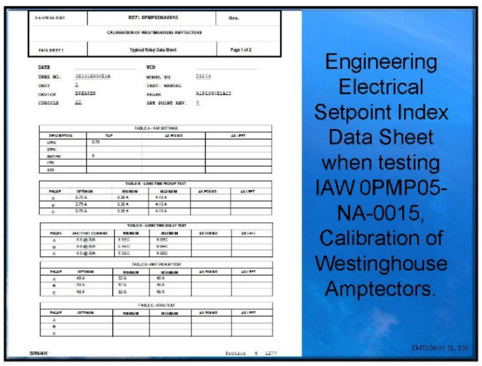
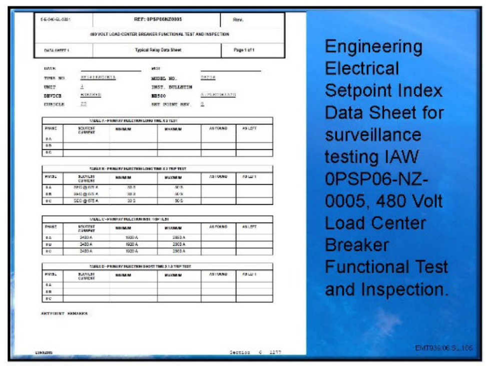
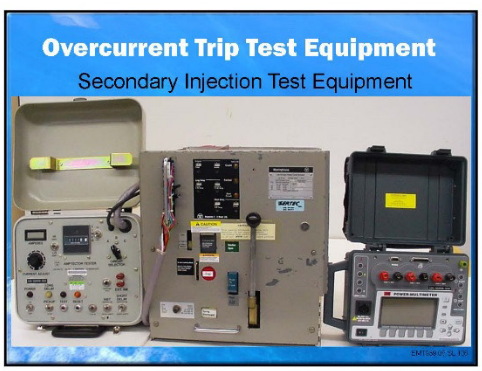
Overcurrent Trip Tests

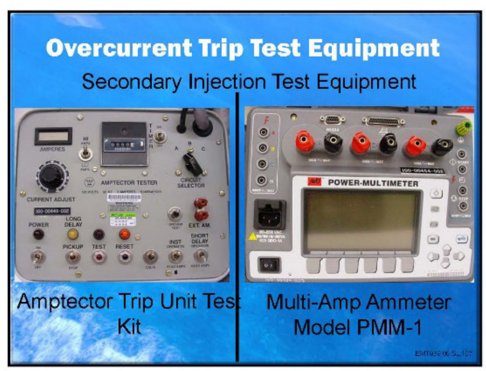
- Overcurrent trip test are performed in accordance with 0PMP05-NA-0015, Calibration of Westinghouse Amptectors and surveillance test procedure 0PSP06-NZ-0005, 480 Volt Load Center Breaker Functional Test and Inspection.
- Setpoints are obtained from the Engineering Electrical Setpoint Index (EESI).











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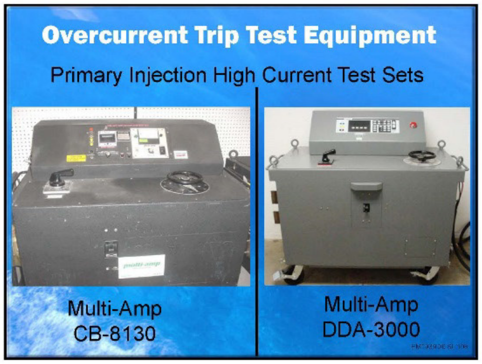
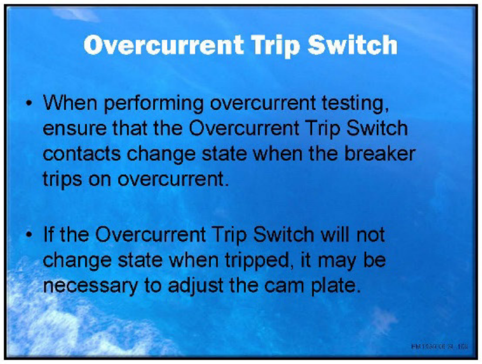
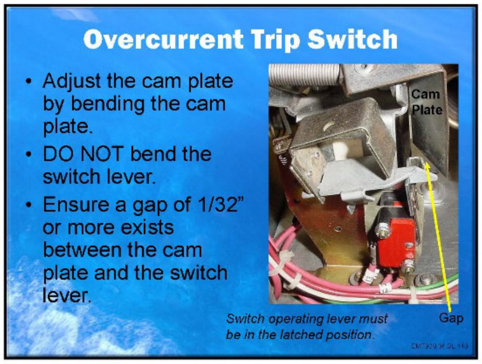

Overcurrent Trip Test Equipment
Primary Injection High Current Test Sets
Multi-Amp
CB-8130
Multi-Amp
DDA-3000


Overcurrent Trip Switch
• When performing overcurrent testing, ensure that the Overcurrent Trip Switch contacts change state when the breaker trips on overcurrent.
• If the Overcurrent Trip Switch will not change state when tripped, it may be necessary to adjust the cam plate.


Overcurrent Trip Switch
• Adjust the cam plate by bending the cam plate.
• DO NOT bend the switch lever.
• Ensure a gap of 1/32" or more exists between the cam plate and the switch lever.
Cam Plate
Gap
Switch operating lever must be in the latched position.


Questions?

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Appendix B
Survey Screenshots

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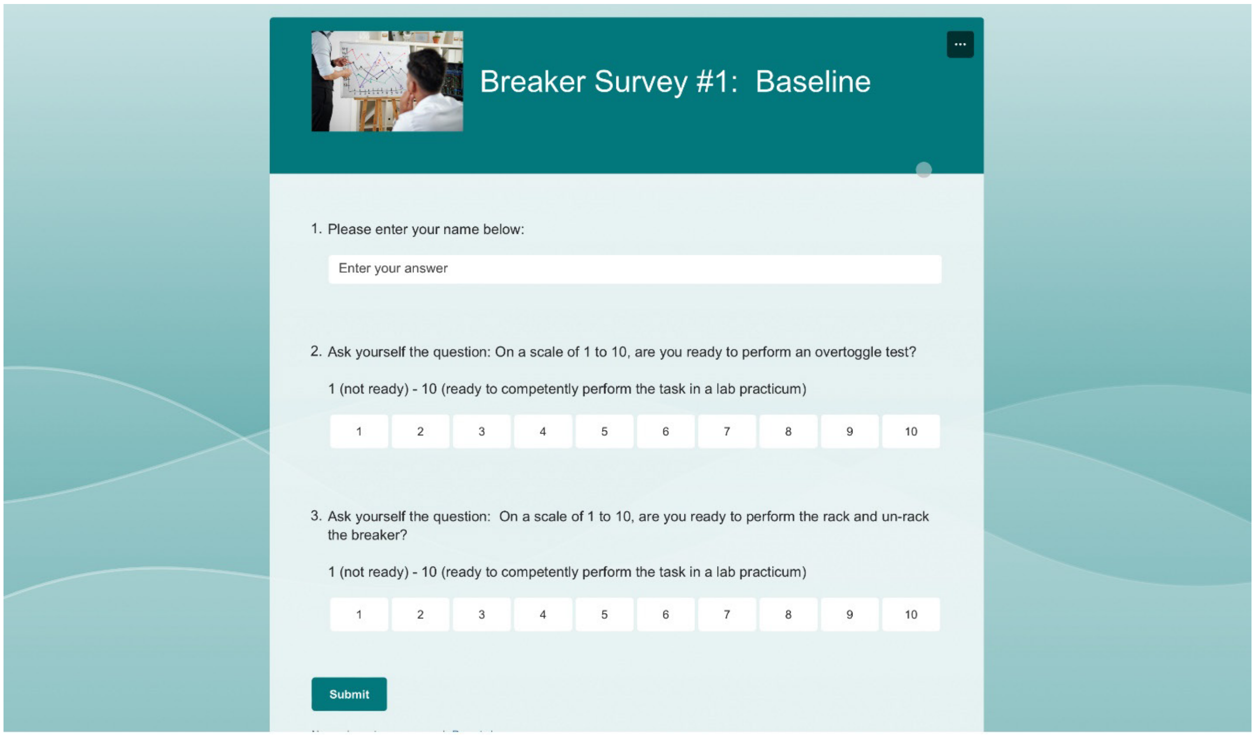
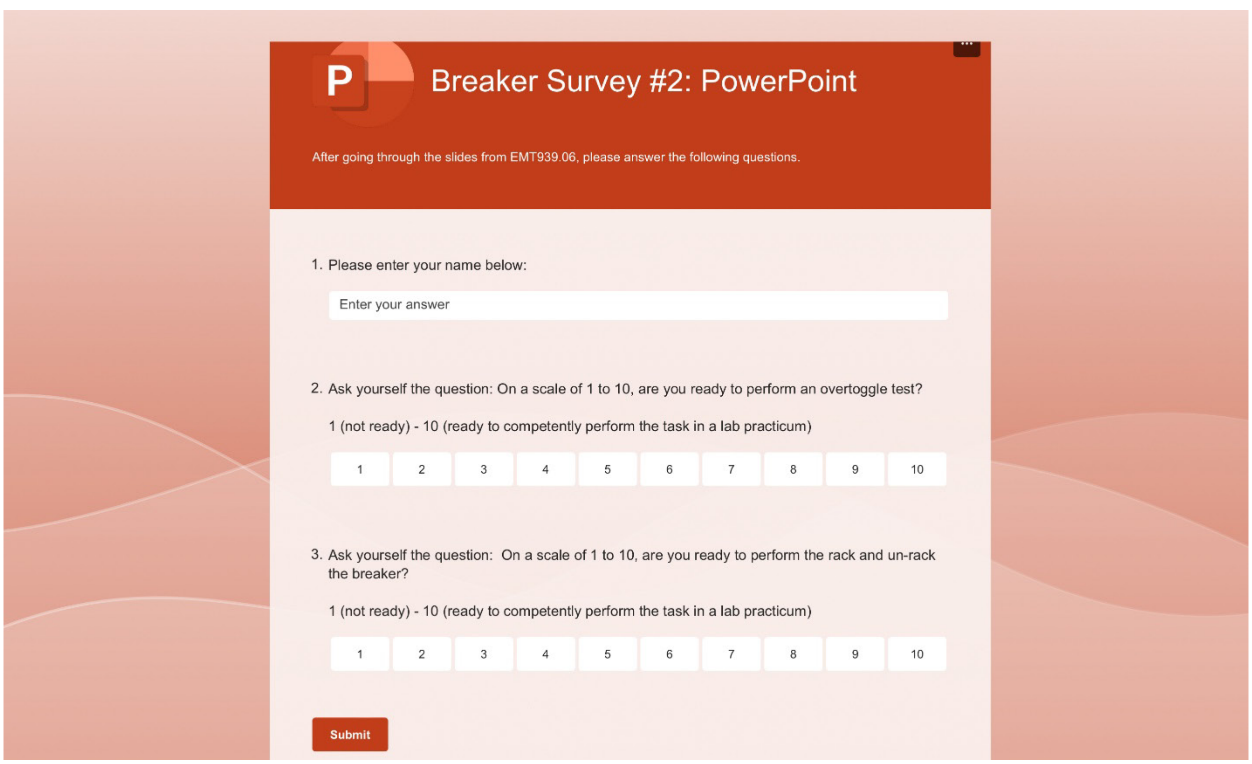
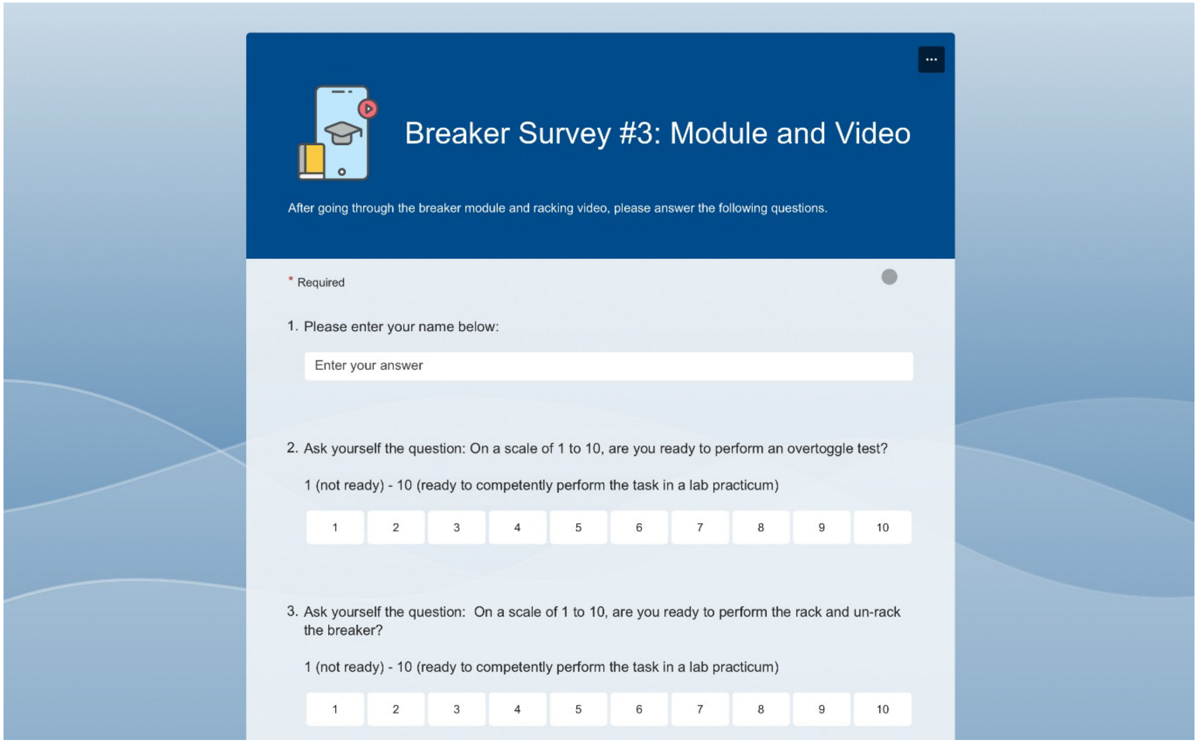
Appendix B

Survey Screenshots







Breaker Survey #3: Module and Video

After going through the breaker module and racking video, please answer the following questions.

* Required

1. Please enter your name below:

Enter your answer

2. Ask yourself the question: On a scale of 1 to 10, are you ready to perform an overtoggle test?

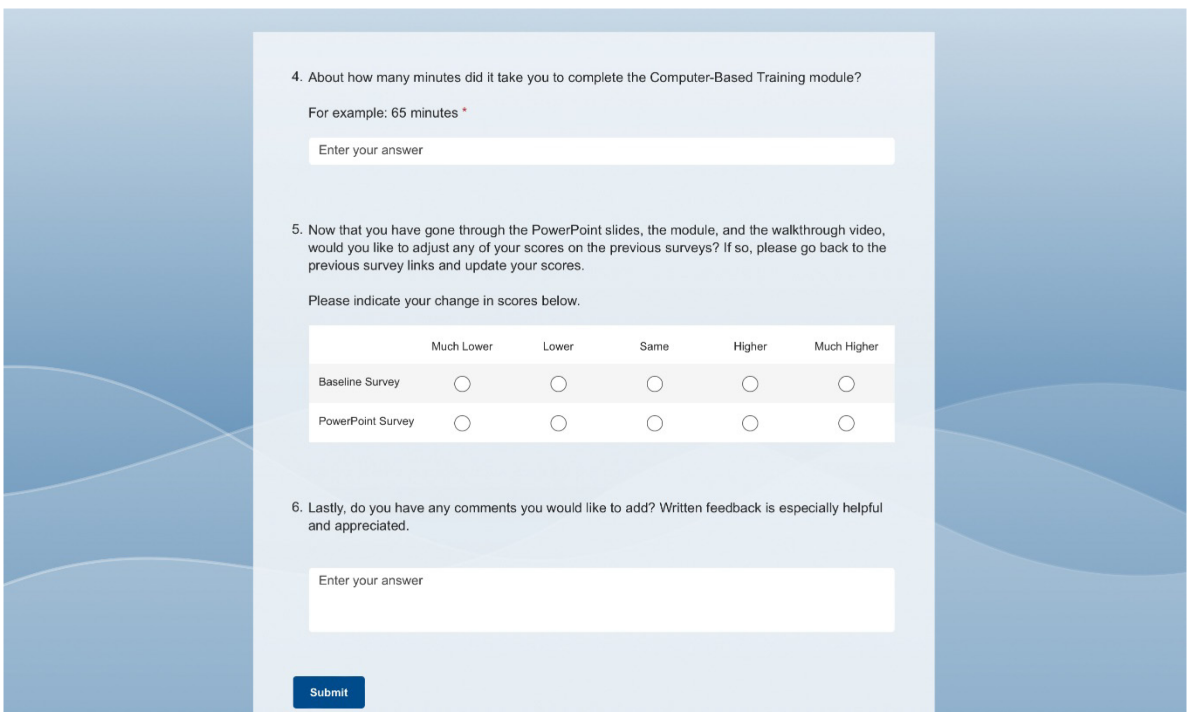
1 (not ready) - 10 (ready to competently perform the task in a lab practicum)

1	2	3	4	5	6	7	8	9	10

3. Ask yourself the question: On a scale of 1 to 10, are you ready to perform the rack and un-rack the breaker?

1 (not ready) - 10 (ready to competently perform the task in a lab practicum)

1	2	3	4	5	6	7	8	9	10



4. About how many minutes did it take you to complete the Computer-Based Training module?

For example: 65 minutes *

Enter your answer

5. Now that you have gone through the PowerPoint slides, the module, and the walkthrough video, would you like to adjust any of your scores on the previous surveys? If so, please go back to the previous survey links and update your scores.

Please indicate your change in scores below.

	Much Lower	Lower	Same	Higher	Much Higher
Baseline Survey	○	○	○	○	○
PowerPoint Survey	○	○	○	○	○

6. Lastly, do you have any comments you would like to add? Written feedback is especially helpful and appreciated.

Enter your answer

Submit

Appendix C
Initial Maintenance Training Classroom Based List

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Appendix C

Initial Maintenance Training Classroom Based List

#	Class Name	Course Number	Training Function	Discipline	Initial/ Cont'd	Accredited or General	# Instructors	Approximate # Learners	Duration (Hours)	Frequency
Pilot Proj.	Low Voltage Air Circuit Breakers - Westinghouse DS206 CBs	EMT939.06	Maintenance	Electrical	Initial	Accredited	1	8	10	Once every 3 years
2	Shop Tools	GMT020	Maintenance	Maintenance	Initial	Accredited	1	8	20	Once every 3 years
3	Hand Tools	GMT021	Maintenance	Maintenance	Initial	Accredited	1	8	20	Once every 3 years
4	Power Tools	GMT022	Maintenance	Maintenance	Initial	Accredited	1	8	20	Once every 3 years
5	Basic Measurement Tools	GMT023	Maintenance	Maintenance	Initial	Accredited	1	8	30	Once every 3 years
6	Battery Maintenance	EMT205.02	Maintenance	Electrical	Initial	Accredited	1	8	30	Once every 3 years
7	Battery Maintenance - Theory of Operation	EMT205.03	Maintenance	Electrical	Initial	Accredited	1	8	15	Once every 3 years
8	Battery Maintenance - Theory of Operation	EMT205.04	Maintenance	Electrical	Initial	Accredited	1	8	13	Once every 3 years
9	Motor Control Center Bus and Cubicle Maintenance	EMT210.01	Maintenance	Electrical	Initial	Accredited	1	8	5	Once every 3 years
10	AC and DC Motor Controller	EMT210.02	Maintenance	Electrical	Initial	Accredited	1	8	10	Once every 3 years
11	Electrical Distribution Equipment Cleaning and Inspection for Contract Personnel	EMT210.03	Maintenance	Electrical	Initial	Accredited	1	8	20	Once every 3 years
12	Portable Power Tools	EMT213.02	Maintenance	Electrical	Initial	Accredited	1	8	5	Once every 3 years
13	ESF DG Initial Training - Operational Characteristics	EMT909.01	Maintenance	Electrical	Initial	Accredited	1	8	60	Once every 3 years
14	Electrical Safety	EMT962.01	Maintenance	Electrical	Initial	Accredited	1	8	10	Once every 3 years
15	Ametek Chargers and Inverters	EMT950.14	Maintenance	Electrical	Initial	Accredited	1	8	30	Once every 3 years
16	Basic Test Equipment	EMT917	Maintenance	Electrical	Initial	Accredited	1	8	100	Once every 3 years

#	Class Name	Course Number	Training Function	Discipline	Initial/ Cont'd	Accredited or General	# Instructors	Approximate # Learners	Duration (Hours)	Frequency
17	Conduit Bending and Simple Cable Pull	EMT973	Maintenance	Electrical	Initial	Accredited	1	8	30	Once every 3 years
18	Battery Maintenance	EMT205.02	Maintenance	Electrical	Initial	Accredited	1	8	30	Once every 3 years
19	MCC and Cubicle Maint; AC and DC Motor Controller	EMT210	Maintenance	Electrical	Initial	Accredited	1	8	15	Once every 3 years
20	Splices, Terms, Soldering	EMT904	Maintenance	Electrical	Initial	Accredited	1	8	40	Once every 3 years
21	Raychem	EMT915	Maintenance	Electrical	Initial	Accredited	1	8	100	Once every 3 years
22	Cathodic Protection	EMT920	Maintenance	Electrical	Initial	Accredited	1	8	10	Once every 3 years
23	Test/Calibrate Transformer Instruments	EMT924.05	Maintenance	Electrical	Initial	Accredited	1	8	20	Once every 3 years
24	Testing Electric Cables and Busses	EMT959.01	Maintenance	Electrical	Initial	Accredited	1	8	30	Once every 3 years
25	Testing Electric Motors	EMT959.02	Maintenance	Electrical	Initial	Accredited	1	8	30	Once every 3 years
26	Testing Transformers	EMT959.03	Maintenance	Electrical	Initial	Accredited	1	8	20	Once every 3 years
27	Testing Generators	EMT959.04	Maintenance	Electrical	Initial	Accredited	1	8	20	Once every 3 years
28	Molded Case Circuit Breakers	EMT939.01	Maintenance	Electrical	Initial	Accredited	1	8	40	Once every 3 years
29	Control Relays	EMT930.01	Maintenance	Electrical	Initial	Accredited	1	8	30	Once every 3 years
30	Transducers and Transformers	EMT930.02	Maintenance	Electrical	Initial	Accredited	1	8	30	Once every 3 years
31	Meters	EMT930.03	Maintenance	Electrical	Initial	Accredited	1	8	30	Once every 3 years
32	Automatic Transfer Switch	EMT930.05	Maintenance	Electrical	Initial	Accredited	1	8	30	Once every 3 years
33	Motor Maintenance	EMT957.01	Maintenance	Electrical	Initial	Accredited	1	8	80	Once every 3 years
34	Lubrication	MMT105.01	Maintenance	Mechanical	Initial	Accredited	1	8	10	Once every 3 years
35	Pulleys and Drive Belts	MMT109.01	Maintenance	Mechanical	Initial	Accredited	1	8	10	Once every 3 years
36	Piping Characteristics	MMT203.01	Maintenance	Mechanical	Initial	Accredited	1	8	25	Once every 3 years
37	Hangers and Restraints	MMT204.02	Maintenance	Mechanical	Initial	Accredited	1	8	10	Once every 3 years
38	Filters and Strainers	MMT204.03	Maintenance	Mechanical	Initial	Accredited	1	8	10	Once every 3 years
39	Gauge and Sight Glass Maintenance	MMT207.01	Maintenance	Mechanical	Initial	Accredited	1	8	10	Once every 3 years
40	Oxyacetlyne Torch Use	MMT211.02	Maintenance	Mechanical	Initial	Accredited	1	8	10	Once every 3 years
41	Bearings	MMT302.01	Maintenance	Mechanical	Initial	Accredited	1	8	10	Once every 3 years

#	Class Name	Course Number	Training Function	Discipline	Initial/ Cont'd	Accredited or General	# Instructors	Approximate # Learners	Duration (Hours)	Frequency
42	Fans, Blowers and Dampers	MMT304.03	Maintenance	Mechanical	Initial	Accredited	1	8	10	Once every 3 years
43	Heat Exchanger/Condenser Maintenance	MMT402.02	Maintenance	Mechanical	Initial	Accredited	1	8	20	Once every 3 years
44	Rigging and Flagging	MMT900.01	Maintenance	Mechanical	Initial	Accredited	1	8	20	Once every 3 years
45	Overhead Gantry Crane Operations	MMT900.04	Maintenance	Mechanical	Initial	Accredited	1	8	10	Once every 3 years
46	Valve Packing	MMT904	Maintenance	Mechanical	Initial	Accredited	1	8	20	Once every 3 years
47	Hydraulic Systems and Components	MMT908	Maintenance	Mechanical	Initial	Accredited	1	8	20	Once every 3 years
48	Tubing and Fittings	IMT201	Maintenance	Mechanical	Initial	Accredited	1	8	20	Once every 3 years
49	Introduction to Soldering	IMT203.01	Maintenance	I&C	Initial	Accredited	1	8	20	Once every 3 years
50	Triaxial and Coaxial Connectors	IMT206.01	Maintenance	I&C	Initial	Accredited	1	8	10	Once every 3 years
51	Low Voltage Rachem	IMT208.01	Maintenance	I&C	Initial	Accredited	1	8	10	Once every 3 years
52	Multi-pin Connectors	IMT209.01	Maintenance	I&C	Initial	Accredited	1	8	10	Once every 3 years
53	Valve Lineups/Filling and Venting	IMT211	Maintenance	I&C	Initial	Accredited	1	8	10	Once every 3 years
54	I&C Test Equipment	IMT213	Maintenance	I&C	Initial	Accredited	1	8	30	Once every 3 years
55	Process Measurement Fundamentals	IMT301.01	Maintenance	I&C	Initial	Accredited	1	8	20	Once every 3 years
56	Pressure Measurement	IMT302.01	Maintenance	I&C	Initial	Accredited	1	8	40	Once every 3 years
57	Level Measurement Fundamentals	IMT303.01	Maintenance	I&C	Initial	Accredited	1	8	40	Once every 3 years
58	Flow Measurement	IMT304.01	Maintenance	I&C	Initial	Accredited	1	8	40	Once every 3 years
59	Temperature Measurement	IMT305.01	Maintenance	I&C	Initial	Accredited	1	8	40	Once every 3 years
60	Smart Transmitters	IMT307.01	Maintenance	I&C	Initial	Accredited	1	8	10	Once every 3 years
61	Pneumatic Instruments	IMT401.01	Maintenance	I&C	Initial	Accredited	1	8	30	Once every 3 years
62	Solenoid Valves/Target Rock Non-Modulating Valves/Crosby SPORV's	IMT402.01	Maintenance	I&C	Initial	Accredited	1	8	10	Once every 3 years
63	Control Valves	IMT402.02	Maintenance	I&C	Initial	Accredited	1	8	40	Once every 3 years
64	Pneumatic Controllers	IMT404.01	Maintenance	I&C	Initial	Accredited	1	8	40	Once every 3 years
65	Pneumatic Process Control Loops	IMT405.01	Maintenance	I&C	Initial	Accredited	1	8	40	Once every 3 years
66	Electronic Devices	IMT501.01	Maintenance	I&C	Initial	Accredited	1	8	10	Once every 3 years

#	Class Name	Course Number	Training Function	Discipline	Initial/ Cont'd	Accredited or General	# Instructors	Approximate # Learners	Duration (Hours)	Frequency
67	Programmable Recorders	IMT502.01	Maintenance	I&C	Initial	Accredited	1	8	10	Once every 3 years
68	Analytic Instruments	IMT503.01	Maintenance	I&C	Initial	Accredited	1	8	10	Once every 3 years
69	Electronic Process Control Loops	IMT504.01	Maintenance	I&C	Initial	Accredited	1	8	10	Once every 3 years
70	Programmable Logic Controller Fundamentals	IMT718.09	Maintenance	I&C	Initial	Accredited	1	8	50	Once every 3 years