Pit Distribution Troubleshooting

Instructor's Copy

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[1] This exercise was developed and field tested under U. S. Bureau of Mines research contract no. H0348040. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies or recommendations of the Interior Department's Bureau of Mines or the U. S. Government.

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Appendix A: Problem booklet (duplicate this copy for use in class)

Appendix B: Answer sheet blank (print the answers on this)

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Introduction

This instructor's copy contains most of the materials needed to use the exercise. It tells how to use the exercise, presents the objectives, the master answer sheet, discussion notes to be used following the exercise, references, and the scoring key. The last part of this document is three appendices. Appendix A is the exercise problem booklet. This booklet can be duplicated locally. The booklets are reusable. One is needed for every person in the classroom. Appendix B is the answer sheet. Copies of this answer sheet must have the invisible ink answers that appear in Appendix C printed on them.[2] Answer sheets are consumable. One is needed for each group of 3 to 5 persons who work the exercise.

Exercise Summary

Read this section first. It determines if the exercise is appropriate for your classes. If you choose to use the exercise, examine the table of contents and review the remainder of this document.

Type:	Invisible ink
Audience:	Mine electricians
Length:	Five questions (20 minutes for administration and 20 for discussion)
Skills:	Electrical troubleshooting Safe work practices
Location:	Surface mine
Problem:	The surface mine where you work receives its power from a 138 KV utility line that is stepped down to 25 KV for pit distribution. Substations make further reductions to 4,160 volts for operation of smaller equipment such as drills. The pit electrical distribution system has worked well. Then a problem develops. Power leaving a portable substation goes through two boxes to a drill. A ground fault occurred in the system and tripped box A. The flag was reset and the system held for about a week. Then the ground monitor trips box B. Within a few days box A trips two more times. As a mine electrician you must find and correct the electrical problem so that production and safety can be maintained.

[2] You can do this yourself if you have the proper equipment, or you may obtain copies of preprinted answer sheets from MSHA, National Mine Health & Safety Academy, Dept. of Instructional Materials, 1301 Airport Road, Beaver, WV 25813-9426 phone 304-256-3257, fax 304-256-3368 or email to lord-mary@msha.gov.

How to Use This Exercise

1. Look at the performance objectives. Decide if the exercise is relevant for your mine training class.

2. Work through the exercise with the developing pen and score your responses.

3. Read the master answer sheet for the exercise. Look at all the answers.

4. Read the "Instructor's Discussion Notes" for the exercise.

5. Become thoroughly familiar with the problem so that you can present it to your class without reading it. Put the illustrations on an overhead projector so you can use these to help explain the problem.

6. When you present the exercise to the class:

   - Give each person an exercise booklet, and each group of 3 to 5 one answer sheet and a developing pen.

   - Demonstrate how to select and mark answers using the developing pen.

   - Go over the instructions for doing the exercise with the whole group.

   - Explain the problem making sure everyone understands the problem situation.

   - Have the class members work the exercise.

   - When the class members finish, have them figure up their score using the instructions at the end of the exercise.

   - When everyone has finished, discuss the exercise. Let class members discuss the merits of each answer. Add your own ideas.

Performance Objectives for Pit Distribution Troubleshooting

Objective number	Capability verb(s)	Description of the required performance and conditions under which it is to occur
1. ET[3]	Diagnose Select	Possible causes and locations of a ground fault in a surface mine electrical distribution system from a substation to a drill given a schematic of the system and a verbal description of the problem
2. SW	Recall Select	Safe work practices while troubleshooting and correcting electrical problems in high voltage electrical power distribution systems

[3] Skill and knowledge domain abbreviations:
ET = electrical troubleshooting
SW = safe work practices

Master Answer Sheet for Pit Distribution Troubleshooting

Use this answer sheet to mark your selections. Rub the developing pen gently and smoothly between the brackets. Don't scrub the pen or the message may blur. Be sure to color in the entire message once you have made a selection. Otherwise you may not get the information you need. The last part of the message will tell you what to do next.

Question A (Choose only ONE unless you are told to "Try Again!")

1. [Correct. This is very likely since cables frequently cause ground fault tripping]
   [of pit distribution systems. Since Box "B" has only tripped one time we can]
   [assume that it was a nuisance trip and can be ignored. Other possibilities do]
   [exist, however. Do the next question.]

2. [This is not likely. A poor ground connection would cause a low level of ground]
   [fault current and mean that tripping of the ground relay would be difficult,]
   [even with a true fault. Try again!]

3. [This is not likely. An open grounding resistor would prevent any ground fault]
   [current from flowing, even with a true ground fault. The ground relay would]
   [never trip with an open resistor. Try again!]

4. [This is possible but should not be the problem if the pit system is set up]
   [properly. The system should be coordinated so that the box nearest the fault]
   [trips. If the ground fault was in the drill, pit box "B" should have tripped.]
   [Try again!]

Question B (Choose only ONE unless you are told to "Try Again!")

5. [This might be of some help, especially if the faults had all occurred when the]
   [machine was moving. Since box "A" was tripping instead of box "B", it is]
   [doubtful that the problem is associated with the machine. Try again!]

6. [This would be a logical answer, but since box "A" was tripping rather than]
   [box "B", the trailing cable is probably okay unless box "B" ground detecting]
   [circuits are not working. Try again!]

7. [Correct. Since cables frequently cause this type of problem, this would be a]
   [logical step. Do the next question.]

8. [Nice thought, but not right. Try again!]
   [ ]

Question C (Choose only ONE unless you are told to "Try Again!")

9. [This may seem logical, but remember that box "A" was tripping, not box "B".]
   [Replacing this cable will take time and may not correct the problem. Try again!]

10. [If the problem is with the cable, this could cause a phase-to-phase condition]
    [which would make this action very dangerous. Try again!]

11. [Correct. Isolating the system into smaller parts and testing each part with the]
    [megger will locate the problem. Even though this will take more time, it will]
    [allow you to locate the problem precisely and avoid wasting time and energy]
    [changing a cable that was okay. Do the next question.]

12. [Since box "A" is tripping out, it is doubtful that this cable is the problem.]
    [Cutting open the cable will probably waste time and not locate the problem.]
    [Try again!]

Question D (Choose only ONE unless you are told to "Try Again!")

13. [This might be your first instinct, but it may waste time and energy if cable "A"]
    [is not the problem. Try again!]

14. [This is logical and should be part of your next step. Try again!]

15. [This is logical and should be part of your next step. Try again!]

16. [Correct. Completely isolate cable "A" and use the megger to check all three]
    [phases. When walking from one end to the other, you may want to check the]
    [cable for damage as suggested in answer 15. When you unplug the distant]
    [end it is a good idea to check for dirt and moisture as is suggested in]
    [answer 14. Do the next question.]

Question E (Choose only ONE unless you are told to "Try Again!")

17. [Actually, the secondary of current transformers should be grounded for safety reasons. Even short circuited transformers will not cause leakage between the phase conductor and ground. Also, each current transformer is used with only one phase wire and, therefore, would affect only one phase; not two. Try again!]

18. [Potential transformers are connected from phase-to-phase; not phase-to-ground. Try again!]

19. [An open phase in the OCB would have caused the drill to single-phase and many other problems would have occurred. It is not likely that this is the problem. Try again!]

20. [Correct. Since the control power transformer is a single-phase transformer it has only two primary terminals. These would be connected to two of the phase conductors of the system and not the third. It is likely that this is the problem. Moisture may have gotten into the transformer through condensation or from rain leaking into the pit box. It also is possible that the primary has developed an arcing fault to the transformer iron core or that an insulating bushing on the primary is defective. Color in the box below.]

[You isolate the control power transformer by removing both primary leads and again use the megger to test the transformer and verify the problem. You find a low resistance reading on both transformer primary terminals to ground. There are no visible indications on the outside of the transformer that it is defective, but your tests indicate low internal resistance. You replace the CPT and the system is back in service by the end of the shift. Good job! **End of problem.**]

Finding your score

Number of "Correct" answers you colored in = (1)_____

15 minus number of incorrect answers you colored in = (2)_____

Add blanks one and two to get your total score = (3)_____

Highest possible score = 20

Discussion Notes for Pit Distribution Troubleshooting

Use the information presented on the master answer sheet, your own ideas and experience, and those of the miners in your class, to discuss the exercise after it is completed. Group discussion can strengthen knowledge and skills, correct errors, and relate the exercise content to the experiences of the miners. After they have worked the exercise, miners enjoy discussing the problem. They also frequently think of better ways to respond to a problem than those listed among the answers. The purpose of the exercise is to help miners think about and remember basic knowledge and skills they may someday need to deal with an emergency. The discussion following the exercise can contribute to this goal and tailor the exercise content to the needs of the group you are training.

It is helpful to show overhead transparencies of the master answer sheet during the discussion while the miners look at their problem booklets. This allows you to lead the group through the exercise and to disclose and discuss all the answers to each question. Information about why particular answers are correct or incorrect is given on the master answer sheet.

References

Morley, L. A., et. al. (1977). Coal mine electrical system evaluation. Volumes 1-7. University Park, PA: Pennsylvania State University. (USBM OFR 61-78).

Morley, L. A. (1982). Mine power systems. University Park, PA: Pennsylvania State University, Department of Mineral Engineering. (USBM OFR 178-82).

Stanek, E. K., et al. (1979). Mine electrical power systems. Transients protection, reliability investigation, and safety testing of mine electrical power stems. Morgantown, WV: West Virginia University, Engineering Experiment Station. (USBM OFR 6-81).

Scoring Key for Pit Distribution Troubleshooting Exercise

The correct answers are marked with an asterisk.[4]

Question	Answer Number			
A	1*	2	3	4
B	5	6	7*	8
C	9	10	11*	12
D	13	14	15	16*
E	17	18	19	20*

[4] This page may be duplicated and used as an overhead transparency.

Appendix A: Problem Booklet

Duplicate this copy of the problem booklet for use in your classes. **Booklets should be printed on only one side of the paper.** Each person in your class should have a problem booklet while they are working the exercise. The problem booklets are reusable.

You may obtain a copy of the problem booklet from MSHA, National Mine Health & Safety Academy, Dept. of Instructional Materials, 1301 Airport Road, Beaver, WV 25813-9426 phone 304-256-3257, fax 304-256-3368 or email to lord-mary@msha.gov.

Pit Distribution Troubleshooting Exercise

Problem Booklet

Instructions

Read the problem situation described on the next page. Then study Figure 1. Next answer each of the 5 questions. Do them one at a time. Don't jump ahead but you may look back to earlier questions and your answers.

After you have selected a choice to a question look up the number for that choice on the answer sheet. Select your answer to the questions by rubbing the developing pen between the brackets on the answer sheet. A hidden message will appear and tell you if you are right or wrong and why. The best score is obtained by selecting the one correct answer for each question. However, if you select a wrong answer, try again. This will help you learn the correct answer to each question. When you finish you will learn how to score your performance.

Background

The mine is a surface mine located in hilly country with two operating pits. Utility power is brought to the mine at 138 KV and reduced to 25 KV for primary pit distribution. Further reductions are made to 4,160 volts to power smaller equipment such as drills.

You are an electrician assigned to the south pit area. You have 12 years total electrical experience with 8 of those years at this mine.

The weather has been bad for the past three months with quite a bit of rain. Winter is approaching and temperatures have been cold enough recently to produce frost in the mornings.

You completed electrical retraining in June and this year had an excellent class in troubleshooting.

Problem

In your pit 25 KV power feeds a large dragline. A substation located on the south end of the pit drops the line voltage to 4,160 to power a drill. Power leaves the portable substation and goes through two boxes before reaching the drill. We'll call these boxes "A" and "B". The system has a good past history with few problems. All boxes in this pit were recently tested and calibrated to give a good coordinated distribution system.

Two weeks ago a ground fault occurred in the system and tripped box "A". The flag was reset and the system held. Then the ground monitor tripped box "B". After the monitor was reset the system held for a few days. During the past week box "A" has tripped at least two more times, also because of a ground fault. Study Figure 1 on page 4, then answer the first question.

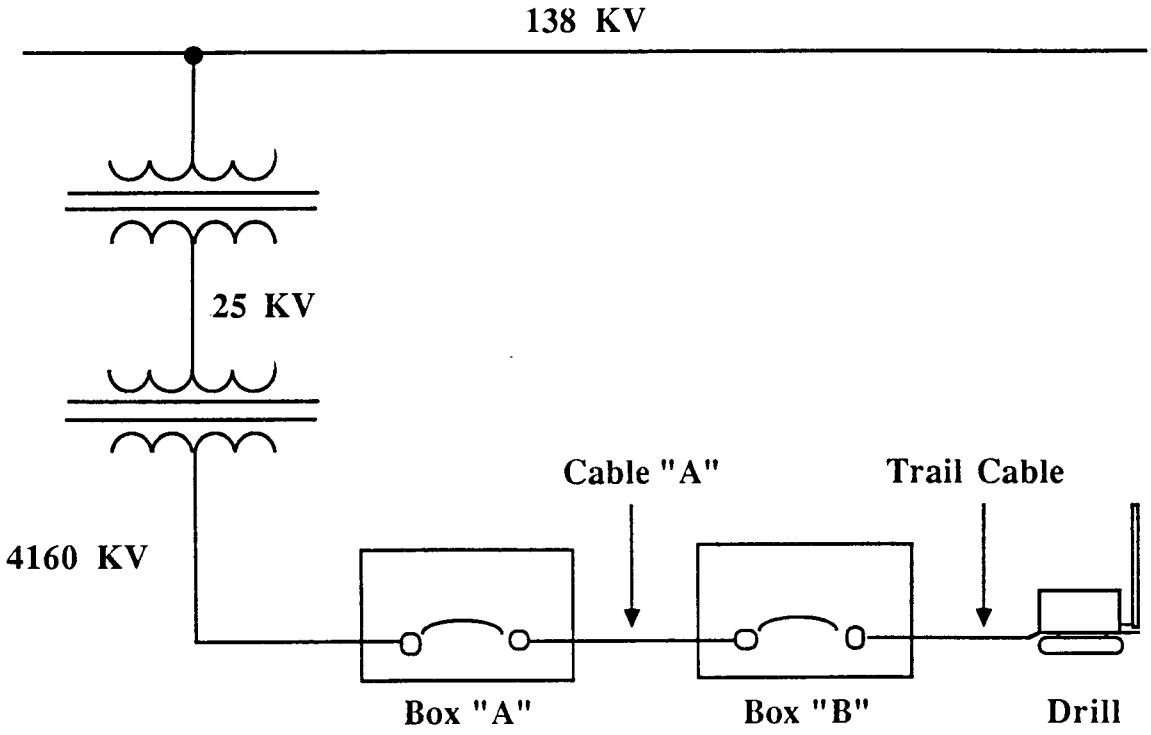

Figure 1: Schematic showing power distribution to the drill

Question A

A possible cause of these trips could be: (Choose only ONE unless you are told to "Try Again!")

1. Fault in the distribution system.
2. Poor ground connection at the 4160 volt substation.
3. Open grounding resistor at the 4160 volt substation.
4. Ground fault in the drill.

Question B

This week the ground fault tripping in box A has become so frequent that some action is needed to correct the problem. At 10:30, box "A" trips out again and you are assigned the task of fixing the problem. A possible action you might take is: (Choose only ONE unless you are told to "Try Again!")

5. Ask the machine operator if he was doing anything unusual when the power tripped off.

6. Assume that the problem is in the trailing cable feeding the drill, as it usually is, change it out, and hope for the best.

7. Walk out the cables from box "A" to the drill and look for damage.

8. Break for lunch, and hope something else comes up so second shift will have to worry about it.

Question C

You have walked out the cables and found no serious damage. There was one place in the trailing cable feeding the drill where the cable jacket had been cut by a rock, but it didn't look serious enough to cause this problem. You taped the cut and went on.

You decide that testing the system is the best approach and get your ohm meter from the truck. Next you lock-out and tag the oil circuit breaker (OCB), disconnect the cable feeding out of box "A", discharge any voltages from the cable and then check each phase-to-ground. All phases seem to be okay.

You remember seeing a megger in the truck and decide to give it one more test in hopes of finding the problem.

The megger is set to the highest voltage scale, 1000 volts, and each phase is tested. This time you find leakage to ground on all three phases, with resistance readings much lower than they should be.

Your next action might be: (Choose only ONE unless you are told to "Try Again!")

9. Go ahead and replace the drill cable, since it had a cut in it and is probably the problem.

10. Turn the power back on and kick the trailing cable at the location where the cut was located.

11. Try to isolate more parts of the system and find the problem, even though this will take more time.

12. Go back to the cut in the trailing cable, open the cable at that point, and look for trouble.

Question D

From past experience you feel that the cut in the trailing cable is the source of the problem. Isolating various parts of the system and testing them is the logical next step. You unplug the trailing cable at both ends and again use the megger. Much to your surprise, all three phases read okay to ground. The system is now broken into three parts; the trailing cable that you just tested, the drill itself, and cable "A" and box "B" connected together. You decide to start over at the beginning of cable "A" since box "A" had tripped most of the time. This time the megger reads lower on two phases to ground than it does on the third phase.

Your next step is to: (Choose only ONE unless you are told to "Try Again!")

13. Change-out cable "A".

14. Unplug cable "A" and check both cable ends for dirt, moisture, or damage.

15. Carefully walk-out cable "A", again looking for damage.

16. Unplug cable "A" and again use the megger to check it.

Question E

You have unplugged both ends of the cable and checked for dirt and moisture. Everything looks good so you connect the megger to the cable and find all three phases check okay. This is a surprise, but one final check will tell the story. You go to box "B" and use the megger on the input connector. Here you again find two phases that read lower than the third.

Some possible causes of this are: (Choose only ONE unless you are told to "Try Again!")

17. A current transformer (CT) has shorted it's secondary winding to ground, thus reflecting this low resistance to the phase wires.

18. One fuse has probably blown on the potential transformer (PT) primary, thus giving a higher reading on one phase.

19. The OCB has one phase open thus giving a higher reading on that phase.

20. The control power transformer (CPT) may be defective causing a high amount of leakage from its input terminals to ground.

Scoring your performance

1. Count the total number of responses you colored in that were marked "correct". Write this number in the first blank on the answer sheet.

2. Count the total number of incorrect responses you colored in. Subtract this number from 15. Write the difference in the second blank on the answer sheet.

3. Add the numbers on the first and second blanks. This is your score.

The highest possible score is 20.

Appendix B: Answer Sheet Blanks

These are the answer sheet blanks. Copies of these blank answer sheets may be duplicated in the normal fashion. However, the answers that are found within the brackets must be printed on these blank answer sheets in invisible ink. These answers are found in Appendix C. If you have the capability to print invisible ink, make copies of the blank answer sheets. Make a master of the answers that appear in Appendix C. Then print the invisible ink on the blank answer sheets, being careful to make sure all pages print and that the appropriate answers line up with the appropriate blanks. The Master Answer Sheet shows all the answers in their proper places.

Most companies and trainers prefer to obtain copies of the preprinted answer sheets from MSHA, National Mine Health & Safety Academy, Dept. of Instructional Materials, 1301 Airport Road, Beaver, WV 25813-9426 phone 304-256-3257, fax 304-256-3368 or email to lord-mary@msha.gov.

The exercise is designed to be used in small groups. You will need one answer sheet for each group of 3 to 5 persons in your class. The answer sheets are consumable. You will need a new set for each class.

A developing pen is also needed by each person who marks an answer sheet.

Answer Sheet for Pit Distribution Troubleshooting

Use this answer sheet to mark your selections. Rub the special pen gently and smoothly between the brackets. Don't scrub the pen or the message may blur. Be sure to color in the entire message once you have made a selection. Otherwise you may not get the information you need. The last part of the message will tell you what to do next.

Question A (Choose only ONE unless you are told to "Try Again!")

1. [ ]
   [ ]
   [ ]
   [ ]

2. [ ]
   [ ]
   [ ]

3. [ ]
   [ ]
   [ ]

4. [ ]
   [ ]
   [ ]
   [ ]

Question B (Choose only ONE unless you are told to "Try Again!")

5. [ ]
   [ ]
   [ ]

6. [ ]
   [ ]
   [ ]

7. [ ]
   [ ]

8. [ ]
   [ ]

Question C (Choose only ONE unless you are told to "Try Again!")

9. [ ]
   [ ]

10. [ ]
    [ ]

11. [ ]
    [ ]
    [ ]
    [ ]

12. [ ]
    [ ]
    [ ]

Question D (Choose only ONE unless you are told to "Try Again!")

13. [ ]
    [ ]

14. [ ]

15. [ ]

16. [ ]
    [ ]
    [ ]
    [ ]
    [ ]

Question E (Choose only ONE unless you are told to "Try Again!")

17. [ ]
[ ]
[ ]
[ ]
[ ]

18. [ ]
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19. [ ]
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20. [ ]
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Finding your score

Number of "Correct" answers you colored in = (1)_____

15 minus number of incorrect answers you colored in = (2)_____

Add blanks one and two to get your total score = (3)_____

Highest possible score = 20

Appendix C: Invisible ink Answers

These pages contain the answers that must be printed in the blanks of the answer sheet in Appendix B. These answers are spaced and sequenced correctly so that they exactly match up with the appropriate blanks on the answer sheet blank.

Once the answers have been printed in the answer sheet blanks, the developing pen reveals the formerly invisible printed message.

You may obtain preprinted answer sheets or you may prepare your own copies. To learn more about these options, and to determine how many answer sheets and developing pens you will need, see the introductory section of the Instructor's Copy.

Correct! This is very likely since cables frequently cause ground fault tripping of pit distribution systems. Since Box "B" has only tripped one time we can assume that it was a nuisance trip and can be ignored. Other possibilities do exist, however. Do the next question.

This is not likely. A poor ground connection would cause a low level of ground fault current and mean that tripping of the ground relay would be difficult, even with a true fault. Try again!

This is not likely. An open grounding resistor would prevent any ground fault current from flowing, even with a true ground fault. The ground relay would never trip with an open resistor. Try again!

This is possible but should not be the problem if the pit system is set up properly. The system should be coordinated so that the box nearest the fault trips. If the ground fault was in the drill, pit box "B" should have tripped. Try again!

This might be of some help, especially if the faults had all occurred when the machine was moving. Since box "A" was tripping instead of box "B", it is doubtful that the problem is associated with the machine. Try again!

This would be a logical answer, but since box "A" was tripping rather than box "B", the trail cable is probably okay unless box "B" ground detecting circuits are not working. Try again!

Correct! Since cables frequently cause this type of problem, this would be a logical step. Do the next question.

Nice thought, but not right. Try again!

This may seem logical, but remember that box "A" was tripping, not box "B". Replacing this cable will take time and may not correct the problem. Try again!

If the problem is with the cable, this could cause a phase-to-phase condition which would make this action very dangerous. Try again!

Correct! Isolating the system into smaller parts and testing each part with the megger will locate the problem. Even though this will take more time, it will allow you to locate the problem precisely and avoid wasting time and energy changing a cable that was okay. Do the next question.

Since box "A" is tripping out, it is doubtful that this cable is the problem. Cutting open the cable will probably waste time and not locate the problem. Try again!

This might be your first instinct, but it may waste time and energy if cable "A" is not the problem. Try again!

This is logical and should be part of your next step. Try again!

This is logical and should be part of your next step. Try again!

Correct! Completely isolate cable "A" and use the megger to check all three phases. When walking from one end to the other, you may want to check the cable for damage as suggested in answer 15. When you unplug the distant end it is a good idea to check for dirt and moisture as is suggested in answer 14. Do the next question.

Actually, the secondary of current transformers should be grounded for safety reasons. Even short circuited transformers will not cause leakage between the phase conductor and ground. Also, each current transformer is used with only one phase wire and, therefore, would affect only one phase; not two. Try again!

Potential transformers are connected from phase-to-phase; not phase-to-ground. Try again!

An open phase in the OCB would have caused the drill to single-phase and many other problems would have occurred. It is not likely that this is the problem. Try again!

Correct! Since the control power transformer is a single-phase transformer it has only two primary terminals. These would be connected to two of the phase conductors of the system and not the third. It is likely that this is the problem. Moisture may have gotten into the transformer through condensation or from rain leaking into the pit box. It also is possible that the primary has developed an arcing fault to the transformer iron core or that an insulating bushing on the primary is defective. Color in the box below.

You isolate the control power transformer by removing both primary leads and again use the megger to test the transformer and verify the problem. You find a low resistance reading on both transformer primary terminals to ground. There are no visible indications on the outside of the transformer that it is defective, but your tests indicate low internal resistance. You replace the CPT and the system is back in service by the end of the shift. Good job! **End of problem**.