

TRANSFORMER, OIL-FILLED REACTOR and 3PHASE REGULATOR INSTALLATION PROCEDURE

SP-TRF-INST

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TRANSFORMER INSTALLATION PROCEDURE

1 Scope

The scope of this procedure is to provide guidelines for receiving, installation, and commissioning tests prior to energizing all relocated and new substation class transformers, shunt reactors, large 3 phase voltage regulators and other similar oil filled devices. Throughout this procedure, the term transformer is used in the generic sense and is meant to include all the equipment types listed above. For most of these devices, the installation activities are essentially similar to that of an oil filled transformer. Exceptions to this are for example: specific testing requirements and items that may not apply to a particular device, such as the testing of a load tap changer, which is not present on some transformers or on any reactors.

This procedure may not cover all types of transformers and/or accessories. Most transformer manufacturers require specific tests for validation of warranty. The manufacturer's guidelines may include additional tests or procedures that exceed this guideline. Obtain the manufacturer's installation guidelines before work is begun. If there is a conflict between the PacifiCorp procedures and the manufacturer procedures, PacifiCorp/Owner procedures shall prevail unless specifically otherwise agreed to by PacifiCorp's substation technical services.

2 Purpose

The purpose of this procedure is to ensure that PacifiCorp-owned transformers are properly installed, tested and the test results approved by PacifiCorp prior to placing them in service.

Specific instructions for transformers that are to be stored as spares, or for those for which the final installation is deferred temporarily, are listed in section entitled "*Spare transformers or transformers installed in a temporary section*" at the end of this document.

Completion of PacifiCorp form SF-TRF-INST is required as part of the transformer receiving, installation and commissioning work scope. Commissioning procedures and forms are listed in sections 3 & 4 of this document.

Refer to the Equipment Commissioning Summary document for a complete list of required commissioning forms and procedures for each transformer commissioning.

No installation and testing forms with failed test results shall be submitted to PacifiCorp. The technician shall contact PacifiCorp to determine an appropriate course of action when acceptable test results cannot be achieved.

3 References

- 3.1 Equipment manufacturer instruction / maintenance manuals;
- 3.2 PacifiCorp Equipment Commissioning Summary spread sheet;
- 3.3 Confined space entry procedure;
- 3.4 PacifiCorp procedure SP-INSRES Insulation Resistance Testing;
- 3.5 PacifiCorp procedure SP-OIL-QUAL Oil Quality Analysis Sampling;
- 3.6 PacifiCorp procedure SP-TTR Transformer Turns Ratio (TTR) Test;
- 3.7 PacifiCorp contractor procedure SPC-TRF-OILPROC Transformer Vacuum Processing;
- 3.8 PacifiCorp procedure SP-OIL-DGA Dissolved Gas Analysis (DGA) Sampling;

3.9 Exhibit X – substation testing and commissioning specifications.

4 Required documentation

The forms and electronic test results listed below shall be completed and submitted to PacifiCorp for review and acceptance of the installation work. Refer to section 10 for submittal instructions.

- 4.1 PacifiCorp form SF-TRF-INST Transformer Installation;
- 4.2 PacifiCorp form SF-OIL-DGA Dissolved Gas Analysis (DGA) Sampling, (form used only for lab requirements/use, NOT sent in as commissioning data);
- 4.3 Laboratory generated DGA and oil quality test report;
- 4.4 PacifiCorp form SF-TTR Transformer Turns Ratio Test;
- 4.5 PacifiCorp form SF-INSRES-XXX Insulation Resistance Test, where XXX is substituted with the letters corresponding to the specific form for the specified winding configuration.
- 4.6 PacifiCorp form SFC-TRF-OILPROC Contractor Vacuum Processing Log(s);
- 4.7 Field Sweep Frequency Response test reports generated from the Doble M5000 test set, in both PDF test report and electronic raw data file format;
- 4.8 Power factor and excitation test results in both PDF test reports and in electronic raw data files from Doble M4000 software; and
- 4.9 Impact recorder print-out or electronic recorded data file and impact data report, if applicable.

5 Equipment used

- 5.1 Handheld digital multi-meter, 4.5 digit or better resolution;
- 5.2 Power factor / exciting current, Doble M4000;
- 5.3 Sweep frequency response analyzer, Doble M5000;
- 5.4 Transformer turns ration, (TTR) tester;
- 5.5 Insulation resistance tester;
- 5.6 Oil quality sample containers;
- 5.7 DGA sample syringes;
- 5.8 Oil processing equipment, including cold trap unit; and
- 5.9 Any other specific equipment required to complete the equipment commissioning.

6 Precautions

- 6.1 Follow all applicable manufacturer, federal, state and PacifiCorp safety precautions and procedures.
- 6.2 Follow all applicable department of transportation and oil handling requirements.
- 6.3 Follow all testing precautions in referenced manuals, standards and procedures.
- 6.4 Follow all required confined space entry procedures.

Note: When internally inspecting equipment, verify that all loose items (bolts, nuts, tools, etc.) on top of the transformer tank are removed or away from any open manhole. Tie off any tools or equipment used in the inspection.

Ensure that all personal belongings (keys, pocket change, jewelry, etc.) are removed prior to entering equipment tank.

Never allow rain or snow to enter transformer.

7 Assembly and acceptance testing

The activities listed in section 7.1 and 7.2 shall be performed shortly as possible after the transformer has been placed on the foundation pad or defined storage location.

7.1 External visual inspection

7.1.1 Verify that the transformer main tank has a positive pressure. If pressure is not positive, contact PacifiCorp substation technical services or project manager immediately.

7.1.2 Verify that there are no oil leaks.

7.1.3 Inspect for signs of impact or any other damage such as broken tie downs, equipment movement, etc.

7.1.4 Inspect the load tap changer for shipping damage, and follow manufacturer guidelines to complete any model specific installation tasks.

7.1.5 Verify that the bushings are not damaged or leaking and have correct oil levels.

7.1.6 Inventory and inspect the auxiliary components (bushings, radiators, radiator fans, surge arrestors, device supports and braces, grounding materials, etc.). Refer to the manufacturer's parts list to inventory parts shipped separately from the transformer.

7.2 Impact recorder

7.2.1 Verify recorder is operational and recording.

If the equipment did not record or is not operational, contact PacifiCorp substation technical services. The electronic impact report must define or explain what has taken place during the transit of the transformer. Submitting only the electronic impact recorder spread sheet print outs will not be acceptable. A final impact recorder report with the electronic spread sheets must be submitted to PacifiCorp in an Adobe Acrobat formatted report for review.

7.2.2 Obtain, inspect, and review the impact recorder data, paper/charts or electronic recorder data.

7.2.3 For mechanical chart-type impact recorders, it is preferable for a PacifiCorp representative to witness the impact recorder inspection. Contact the project manager to make arrangements for a PacifiCorp representative to witness the impact recorder inspection.

- 7.2.4** For electronic impact recorders for which the data can be interrogated remotely, copies of the data recording shall be compiled and submitted to PacifiCorp for review.

The electronic Impact recorder report must include:

- PacifiCorp equipment identification number and Transformer serial number.
- The time entry with the start and finish dates for shipment.
- What are the speed, etc. parameters programmed into the recorder for impact data.
- At what value or impact the recorder will show an impact.
- Three gravities (3 G's)
 - If impacts greater than 3 (G's) are discovered on the impact recorder data, PacifiCorp may require more acceptance testing. Contact PacifiCorp substation technical services for determination of additional acceptance tests.
- Five gravities (5 G's)
 - Stop work and contact PacifiCorp substation technical services immediately if impacts of greater than 5 G's are noted. An internal inspection shall be performed unless express permission from PacifiCorp has been received.

7.3 Transformer nameplate

All of the data and diagrams on the nameplate attached to the transformer must be compared with the data and diagrams from the Manufacturer final as-built nameplate drawing. This action is to ensure that all data on the transformer nameplate and the final as-built nameplate drawing match.

A readable photo of the attached transformer nameplate will be submitted with the final field installation documentation package.

7.4 Transformer anchoring

Anchor transformer main tank to foundation pad according to manufacturer design/drawing.

7.5 Internal inspection

An internal inspection shall be performed on all transformers shipped without oil unless waived by PacifiCorp. Contact PacifiCorp substation technical services at least five (5) business days before performing an internal inspection to verify whether a PacifiCorp representative will witness the internal inspection.

- 7.5.1** Verify acceptable breathing atmosphere and that a constant dry air purge is in place to prevent atmospheric air from entering transformer tank.

Follow all precautions outlined in the "Precautions" section of this document.

- 7.5.2** Visually inspect the inside of the transformer for any foreign materials such as metal filings, dirt or other abnormal conditions.
- 7.5.3** Determine if any shipping blocks or braces were used during the transportation of the transformer. Verify that all shipping blocks or braces were removed; follow manufacturer's instructions.
- 7.5.4** Visually inspect all accessible internal components for damage incurred during loading, shipping and off-loading of the transformer.
- 7.5.5** List name of PacifiCorp representative that witnessed the internal inspection in PacifiCorp form SF-TRF-INST.

If a PacifiCorp representative is not present for the inspection, notify the project manager and or PacifiCorp substation technical services immediately if any abnormal conditions are found in the transformer.

- 7.5.6** If the transformer will be left overnight or for any period longer than twelve (12) hours without oil inside, care should be taken to prevent moisture from entering the transformer. Fill the transformer with dry air or nitrogen to a minimum of two to three psig of pressure.

7.6 Assembly

- 7.6.1** Follow the manufacturer's assembly instructions with particular emphasis on the steps outlined below.
- 7.6.2** Clean the top and bottom insulator surfaces and draw-lead tubes on all bushings prior to installing in the transformer.
- 7.6.3** Install components (radiators, radiator fans, surge arresters, oil pumps, device supports and braces, grounding materials, temperature and monitoring devices, etc.) in accordance with manufacturer instructions and layout diagrams.
- 7.6.4** If applicable, note the bushing draw lead condition and length. Draw lead slack should not be greater than two (2) inches.
- 7.6.5** Surge arresters that are made up of stacked units shall be checked to ensure the correct serial numbers are used in each phase stack and that they are properly assembled with each unit in the correct location relative to other units in the stack.
- 7.6.6** Verify that surge arrester expulsion vents face away from the transformer bushings
- 7.6.7** Verify that ground grid leads and or bus bar connections are installed as designed to transformer tank connections, all surge arresters and if applicable, transformer neutral bushing connection.
- 7.6.8** Do not re-use radiator, bushing or manhole cover gaskets used for shipping. Use new gaskets at all times.
- 7.6.9** Verify that all radiator valves are functional with no leaks. If applicable, verify that all valve packing nuts are tight.

7.7 Oil processing and filling

The contractor is required to follow PacifiCorp procedure SPC-TRF-OILPROC for oil processing of transformers. The transformer shall be dried out using the “Hot Oil Circulation Dry-out with Vacuum Fill” process, which will include the use of a moisture trap (also known as a cold trap). Taking a dew point measurement to determine dryness in lieu of this dry-out method is not acceptable. Any substantial deviation from the PacifiCorp procedure shall be pre-approved prior to the contractor’s mobilization to the work site.

Use PacifiCorp form(s) SFC-TRF-OILPROC to record all pertinent data as described in PacifiCorp procedure SPC-TRF-OILPROC. Data must include the time lines used during the oil processing. Pertinent data shall include:

- 7.7.1 The conclusion for the vacuum leak tests for processing equipment and transformer.
- 7.7.2 The transformer vacuum readings for each hour.
- 7.7.3 The amount of oil in gallons or volume used for the hot oil recirculation process.
- 7.7.4 Recirculated oil temperatures entering the oil processing equipment and transformer main tank, (oil temp IN & OUT).
- 7.7.5 Start and finish time when recirculated oil was added and removed.
- 7.7.6 Start and finish time for deep vacuum pull process of transformer.
- 7.7.7 Time and amount of moisture removed for each moisture (water) collection reading.
- 7.7.8 The oil processing logs must provide a clear picture of the tasks and activities used to complete the oil processing.
- 7.7.9 After filling the transformer with oil, check that all valves are in their normal operating position (radiators, conservator, nitrogen, etc.).

7.8 Oil tests - baseline

Draw an oil quality sample and dissolved gas analysis sample from the transformer and if applicable, load tap changer, per procedures SP-OIL-QUAL and SP-OIL-DGA. Use form SF-OIL-DGA for both samples and submit samples and form to a PacifiCorp-approved laboratory for analysis. The results of these oil samples shall be included in the final field installation documentation package.

Note: The sample form will not be part of the final field installation documentation package, only the laboratory test reports are required to be submitted as part of the documentation package.

7.9 Core ground test

For all accessible core grounds, a core ground test of each individual core ground connection shall be performed on the transformer.

Perform the test per the “Core Ground Test” section located in PacifiCorp procedure SP-INSRES. Record values on PacifiCorp form SF-TRF-INST.

Contact PacifiCorp's substation technical services immediately if the reading is below 1,000 megohms for new equipment or below 100 megohms for existing equipment. The test voltage shall be 1,000 VDC, unless the transformer manufacturer specifies a different test voltage.

7.10 Transformer turns ratio (TTR) test

Testing results shall be recorded on PacifiCorp form SF-TTR or if an electronic TTR test set is used, the test set generated data file together with a printout of the electronic test results (in PDF format) shall be attached to form SF-TTR. Filling out the calculated and measured results on form SF-TTR is not required if electronic test results are attached.

Any test values that are not within the acceptable criteria as specified in the PacifiCorp procedure SP-TTR shall be brought to the attention of PacifiCorp substation technical services.

7.10.1 Perform TTR tests on all five de-energized tap changer (DETC) positions. Transformers equipped with a Load Tap Changer (LTC), perform DETC tests with the LTC on the neutral tap position. Record test results on PacifiCorp form SF-TTR.

7.10.2 Perform TTR tests on all LTC tap positions, 16 Lower through 16 Raise. These tests shall be completed with the DETC in the tap position that the transformer will use during normal in-service operation. Follow the protection and control relay settings sheet. Contact the project manager to determine the final operational position of the DETC before performing the tests. If the final in-service DETC is unknown. These tests will be performed with the DETC in the full winding/highest DETC winding tap position.

7.10.3 Document the final as tested DETC tap position on PacifiCorp form SF-TRF-INST.

7.11 Power factor/exciting current test

7.11.1 Power factor testing shall be done in accordance with the test equipment manufacturer's published data. Perform an overall test on all transformer windings.

Perform an overall power factor test on all windings in accordance with the test equipment manufacturer's published data.

Perform bushing C1 and C2 power factor tests on all bushings that have potential test taps.

Exciting current testing shall be performed in accordance with the test equipment manufacturer's published data.

7.11.2 Perform exciting current tests on all de-energized tap positions (DETC). If the transformer is equipped with a load tap changer (LTC), place the LTC in neutral tap position while testing all the DETC positions.

7.11.3 Perform exciting current tests on all LTC tap positions from 16L-16R with the de-energized tap changer on the final normal in-service de-energized tap position (DETC) according to the protection and control relay settings sheet.

If final in-service tap position is unknown, these tests will be performed with the DETC in the full winding/highest tap winding position.

Any test results that deviate from the manufacturer's published acceptable values shall be brought to the attention of PacifiCorp substation technical services. It is also the responsibility of testing technician to submit the deviated testing data to the test equipment manufacturer for review and determination of results.

In addition to a printed PDF report, the original electronic test file in original Doble software raw data format will be included with the PDF report together with the rest of the final field installation documentation package for PacifiCorp review.

7.12 Sweep Frequency Response Analysis (SFRA)

A sweep frequency test is required once the transformer is installed in its final or stored location.

Perform Sweep Frequency Analysis Test in accordance with Doble Engineering's guide titled "Power Transformer – Test Specification Transformer Sweep Frequency Response Analysis Test".

This guide is available from Doble Engineering.

The tests shall be performed using exactly the same test configurations and tap positions as those performed at the factory, if factory tests were performed.

Verify that the factory test configuration were performed according to the specific winding layout and Doble Engineering test specification.

If the factory tests were not performed correctly according to Doble Engineering test specification or there are no factory test results. A standard configuration tests for the specific winding layout must be performed in the recommended test positions as described in the Doble Engineering test specification, to obtain a set of standardized baseline tests for future reference.

The field test configuration and setup will be logged in the notes section in the SFRA test setup. The following items shall be recorded in the test configuration, if applicable:

- DETC position;
- Neutral point grounded or ungrounded;
- Tertiary windings: open; closed delta; buried; accessible; grounded or ungrounded; and
- LTC position.

These test results shall be compared to the equivalent tests performed by the manufacturer prior to shipping the transformer. If any discrepancies are found, contact PacifiCorp substation technical services representative immediately.

All test results shall be submitted in the original electronic Doble software raw data format, in addition to PDF test reports. If more than one set of tests were performed, each shall be clearly identified for the exact purpose both in the software comments and in the PDF final field installation documentation package submittals.

7.13 Insulation resistance test

Caution: Any DC test may magnetize the core.

Perform an insulation resistance (megger) test according to PacifiCorp procedure SP-INSRES.

Use PacifiCorp form SF-INSRES-XXX Insulation Resistance (where XXX represents the letters used for the specific winding configuration of transformer) to record the test results.

7.14 Auxiliary gauges and devices

Perform operational and calibration checks on all applicable auxiliary devices listed below. Verify all alarm, trip and seal-in relay logic is consistent with transformer output terminal blocks. This list may not include all transformer auxiliary devices installed on the transformer. Use the blank lines at the end of the auxiliary gauges and device section in PacifiCorp form SF-TRF-INST for any additional devices not listed that may need testing.

7.14.1 Fans

Each fan shall be checked for proper operation and fan rotation.

7.14.2 Pumps, if applicable

Each pump shall be bump tested for proper operation. Check each oil pump flow indicator to ensure proper operation and pump rotation.

7.14.3 Temperature gauges (electro-mechanical), if applicable

Record the transformer oil temperature as indicated on each gauge on PacifiCorp form SF-TRF-INST.

7.14.4 Gas accumulation relay (Buckholtz), if applicable. Test micro-switch contact(s) in the gas accumulation relay device for proper operation, alarm etc.

7.14.5 Liquid level gauges

By using liquid level comparisons and other references, verify that each liquid level gauge is reading accurately.

Record the liquid level as indicated on each gauge on PacifiCorp form SF-TRF-INST.

7.14.6 Pressure relief device

Inspect the pressure relief device(s) and assemble the yellow operate flag.

Each pressure relief device shall be inspected and its alarm contacts shall be checked for proper operation.

7.14.7 Nitrogen system, if applicable

The nitrogen system shall be tested to ensure the system regulates correctly and that there are no leaks.

Testing shall be done according to the manufacturer's testing procedures.

Record the pressures indicated on gauges on PacifiCorp form SF-TRF-INST.

7.14.8 Cooling loss of power

Each under-voltage alarm relay shall be tested for proper operation.

7.14.9 Load tap changer (LTC) failure, if applicable

The LTC failure indication alarm shall be tested for proper operation in accordance with the manufacturer's specifications.

7.14.10 Load tap changer (LTC) vacuum interrupter protection circuit, if applicable

Verify correct operation of the LTC vacuum interrupter protection circuit in accordance with manufacturer instructions.

7.14.11 Load tap changer (LTC) filter, if applicable

The LTC filter indication alarm shall be tested for proper operation in accordance with the manufacturer's specifications.

7.14.12 Desiccant/dehydrating breathers, if applicable

Verify that desiccant breathers for both the main tank and LTC compartment are assembled in accordance with the manufacturer's instructions.

Verify that the breathing cups are properly filled with oil, and that the desiccant containers are properly filled with new desiccant.

8 Spare transformers or transformers installed in a temporary location

Transformers that are designated to be stored as spares or that will be installed in temporary location shall be handled in the same manner as transformers that are to be installed ready to be energized, with the following additional requirements:

8.1 On a case by case basis, and only with specific prior approval from PacifiCorp substation technical services: Transformers that are already earmarked for installation in a substation and stored temporary for less than three (3) months may be exempted from oil filling, dress out and tested until they are moved to their final destination. Contact PacifiCorp substation technical services for approval and specific instructions before work is started.

8.2 Unless specific other instructions are provided by PacifiCorp, transformers shall be installed on suitable treated timbers. Timbers shall be of quality and size that they will withstand the weight of the transformer and they shall be treated to withstand years of outdoor exposure.

8.3 Unless specific other instructions were provided by PacifiCorp, transformer will be fully assembled according to Manufacturer instructions.

8.4 If PacifiCorp determines not to install the radiators and radiator fans the following in section 8.4 and 8.5 will be required.

Radiators shall be filled with nitrogen to keep moisture from coming in contact with the radiator internal walls.

- 8.5** Transformers that are filled with oil but without the radiators installed shall be overfilled to compensate for the oil that would normally be contained by the radiators. The purpose of this is to minimize or avoid the need for make-up oil once the radiators are installed at a later date.

Warning: Verify that sufficient expansion space remains in the overfilled transformer to prevent damage due to expansion of oil as a result of ambient temperature changes.

- 8.6** If make-up oil has to be added to a transformer it shall be added by following all the requirements of PacifiCorp procedure SPC-TRF-OILPROC. Oil that is added shall be processed by degassing and heating first.

Note: A vacuum shall not be pulled on an oil-filled transformer before adding oil. Contact PacifiCorp substation technical services for specific arrangements.

- 8.7** All equipment and accessories shall be installed and tested as described in this document, with the possible exception of the auxiliary devices, radiators, cooling fans and surge arresters. Refer to changes in 8.6 for temporary location testing requirements for auxiliary devices.

Note: If electrical power is not readily available for testing purposes, the installer shall make the necessary arrangements to provide power through the use of a portable generator.

- 8.8** After all testing has been completed, short all bushings together with suitable copper wire. The shorted bushings shall then be connected to the tank wall and ground, if possible.

- 8.9** If site AC power is available, connect the power source to the transformer to power the control cabinet heaters during storage.

- 8.10** Any miscellaneous parts associated with the transformer that are not installed on the transformer shall be clearly marked using a weather-resistant method and stored near the transformer.

This would include items such as radiators, fans, cooling pumps, surge arresters, arrester brackets, bushing cover plates, etc.

All such accessories shall be stored on pallets and covered with tarpaulins in a manner that will ensure they will not be damaged if stored for any length of time. The pallets shall be located to allow easy access so they can be ready for shipment in a short period of time.

9 Final documentation submittals

- 9.1** Document any issues that occur during installation or testing in the comments section of PacifiCorp form SF-TRF-INST.

- 9.2** Complete all required test reports, installation forms, electronic forms, electronic files and marked up drawings. Submit field copies, required test reports and files to Commissioning@PacifiCorp.com using the following naming convention.

SubstationName_EquipmentPositionNumber_PacifiCorpSAPNumber_FormName

OR

TestReportType_Date

The final field installation documentation package reports and test results may not be combined or scanned into one electronic Adobe Acrobat file or equipment test report. Each form or data set shall be included as a separate attachment contained in the one (1) e-mail submittal. The body of the e-mail shall list all the attachments contained in the e-mail by form or document name.

If the e-mail message size will exceed ten (10) megabytes, the data shall be divided into separate e-mails and clearly labeled with subpart numbers, for example: Part 1 of 3; Part 2 of 3; etc.