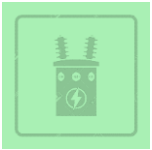
Experiences with retro-filling 11kV distribution transformers

Cigre UK A2/D1 R&D Dissemination Day

Manchester University

27th November 2024



Background

Princess Street, Edinburgh

Both incidents resulted in smoke damage claims from retail shops above

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Background – Motivation to change Policy

Edinburgh embedded substation incidents

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Research (TRC headed by Manchester University)

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Policy change in SP Energy Networks (SPEN)

SP ENERGY NETWORKS

SUBSTATION FIRE PROTECTION POLICY — **SUB-01-012 Issue No. 2**

1. SCOPE

This document defines the policy for the protection of persons and property against fire in all SP Energy Networks ("SPEN") Substations.

2. ISSUE RECORD

This is a Controlled document. The current version of Controlled and Reference documents is held on the Energy Networks Intranet Document Library.

It is your responsibility to ensure you work to the current version.

Issue Date	Issue No.	Author	Amendment Details
September 2013	1	John Russell	Initial issue:
October 2015	2	Lee Speakman	Updates including revision to fire resistance, fire detection and fire risk assessment requirements.

3. ISSUE AUTHORITY

Author	Owner	Issue Authority
Lee Speakman Lead Engineer	David Neilson SPD Distribution Network Manager Malcolm Bebbington SPM Distribution Network Manager	Jim McOmish Head of Distribution Networks pp Date: ..30/10/15.....

Transformers are a potentially significant source of combustible material.

An option to minimise the associated risks of secondary oil filled power transformers within existing embedded basement substations would be either to replace the existing transformer with a less flammable insulating fluid (Synthetic Ester Insulant) unit, or to retro-fill the existing transformer with less flammable insulating fluid, replacing the conventional insulating (mineral) oil.

Balgrayhill High-rise Estate - Glasgow

- 6 Multistorey blocks
- 200 homes in each block
- 26-storey Balgrayhill high-rise estate in Springburn has the tallest domestic buildings within the Glasgow city boundary
- 78 meters tall (256 feet)

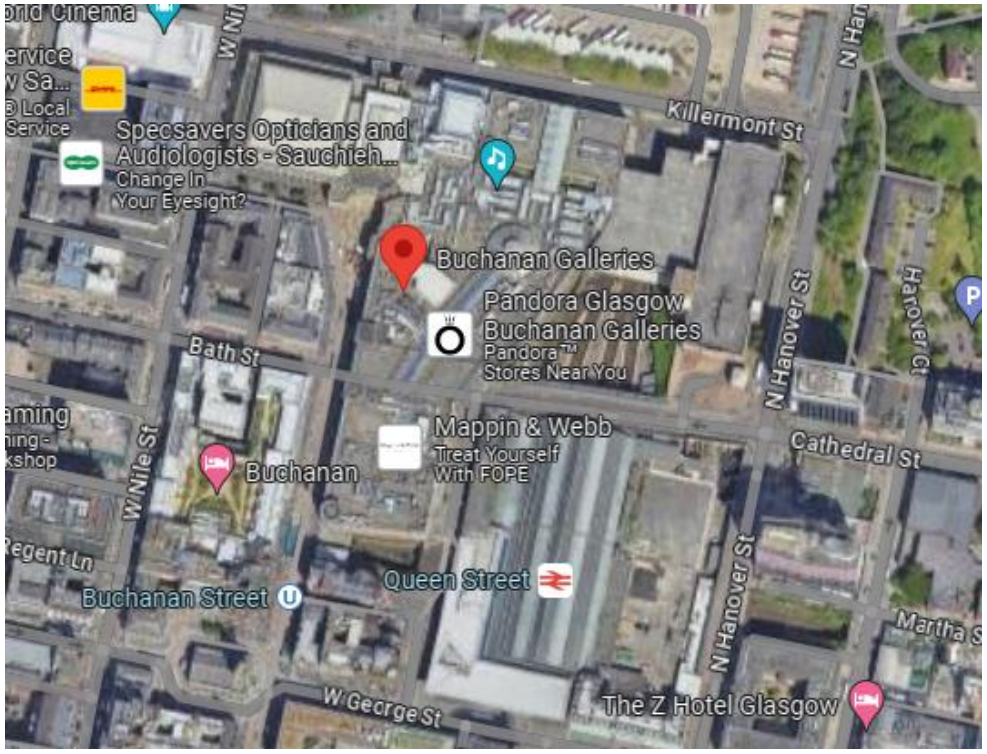
Substations located on bottom corner of buildings with Steet access.

Commercial Union Building – St Vincent Street, Glasgow

- Modern classical 7-storey and basement commercial business on corner site.
- Designated as a listed building and scheduled monument.

Buchanan Galleries – Buchanan Street, Glasgow

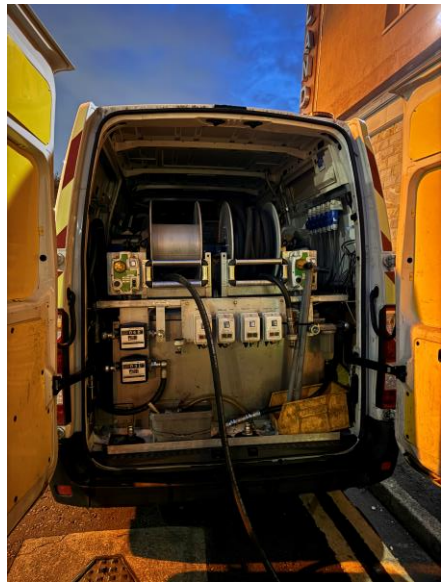
- Located in the heart of **Glasgow** and fronting onto the city's premier shopping thoroughfare, **Buchanan** Street
- Mall housing department store plus 90 fashion, electrical and gift outlets, and restaurants.

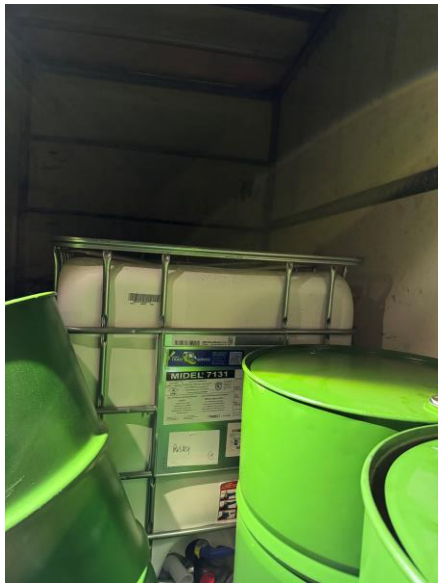


Glasgow District 2023 Synthetic Ester Retro-fill Programme

Substation	Manufacturer	Size kVA	Voltage	Year of Manufacturer
Viewpoint Place 22	Bonar Long	1000	11/0.433	1965
Viewpoint Place 42	Bonar Long	1000	11/0.433	1964
Balgrayhill Road 178	South Wales	800	11/0.433	1987
Balgrayhill Road 198	South Wales	800	11/0.433	1987
Edgefauld Road 250	Bonar Long	500	11/0.433	1967
Croftbank Street	Parsons	500	11/0.433	1967
Commercial Union	Babcock	800	11/0.433	1992

SPEN Retro-fill Procedure





SP ENERGY NETWORKS

Procedure for Retro-filling and Topping up Distribution Transformers with Synthetic Ester (Midel 7131) Liquid — **TRAN-04-008 Issue 1**

1. SCOPE

This document details the procedure required to retro-fill or top-up distribution transformers with a primary winding of 33kV or below and maximum size of 1500kVA with synthetic ester (Midel 7131) liquid.

This document also includes the guidance on suitability of a transformer for retro-fill with synthetic ester liquid.

Work undertaken includes retro-filling in line with SP Energy Networks Substation Fire Protection Policy SUB-01-012, specifically for embedded substations, where there is a requirement to mitigate fire risk.

This document replaces EPS-12-005 which has been withdrawn.

2. ISSUE RECORD

This is a Reference document. The current version is held on the EN Document Library.

It is your responsibility to ensure you work to the current version.

Issue Date	Issue No.	Author	Amendment Details
August 2020	1	D Walker	Initial version. Supersedes EPS-12-005.

3. ISSUE AUTHORITY

Author	Owner	Issue Authority
David Walker Lead Engineer Engineering Design and Standards	Fraser Shaw Substations Manager Engineering Design and Standards	Fraser Ainslie Head of Engineering Design and Standards Date:

4. REVIEW

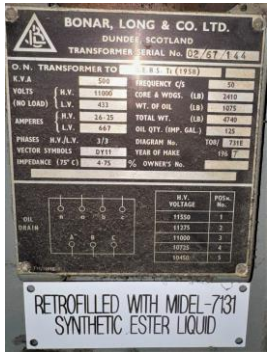
This is a Reference document which has a 3 year retention period after which a reminder will be issued to review and extend retention or archive.

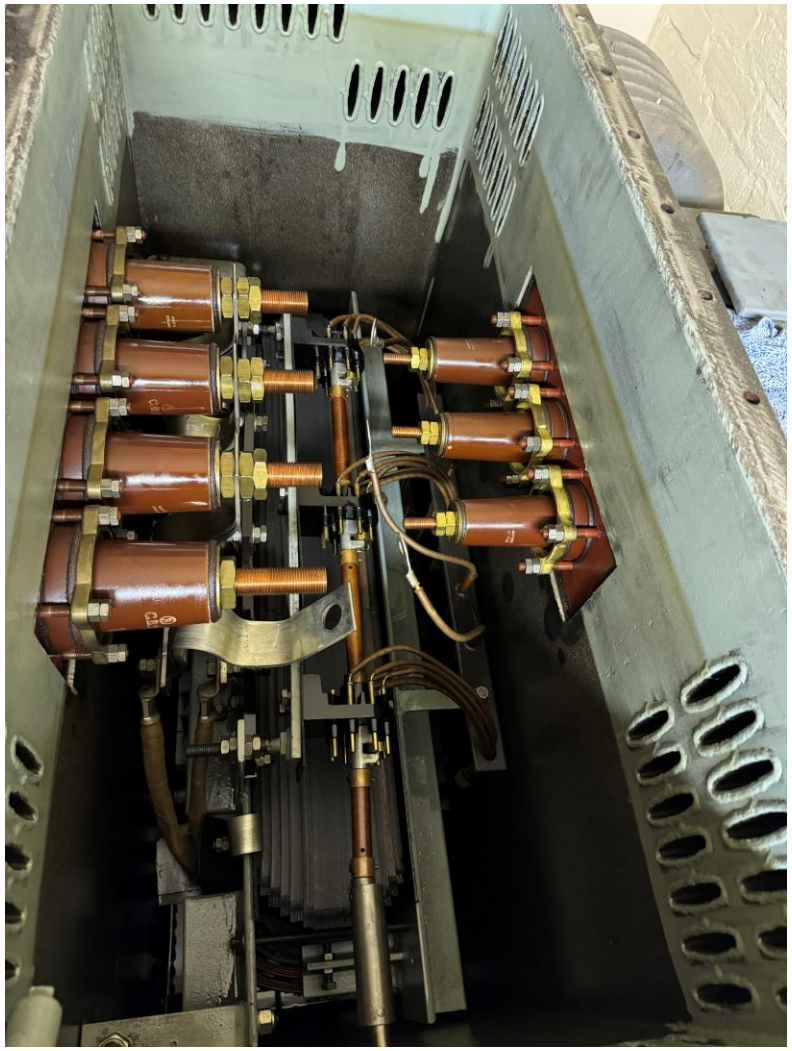
5. DISTRIBUTION

This document is not part of a Manual maintained by Document Control and does not have a maintained distribution list.

SPEN Detailed Retro-fill Procedure

- Initial checks
- Oil Sampling and Analysis
- Visual Inspection
- Electrical Tests
- Mineral oil Draining
- Flushing the active part and radiators
- Prepare for refilling
- Fill with Synthetic Ester Liquid
- Fit new liquid data plate
- Repeat electrical tests
- Take liquid sample for analysis
- Update corporate systems
- After 3 months take second sample
- After 2 years check Fire Point





Liquid Analysis Data – Pre and Post Retro-fill

	Mineral Oil (Pre Retro-fill)			Synthetic Ester (Post Retro-fill)		
Substation	Water Content	Breakdown Voltage	Acidity	Water Content	Breakdown Voltage	Acidity
Viewpoint Place 22	35	53	0.261	112	45	0.025
Viewpoint Place 42	25	43	0.323	153	60	0.026
Balgrayhill Road 178	19	41	0.051	121	72	0.016
Balgrayhill Road 198	17	36	0.132	124	62	0.022
Edgefauld Road 250	23	55	0.267	76	63	0.029
Croftbank Street	30	52	0.391	139	73	0.019
Commercial Union	68	34	2.053	N/A	N/A	N/A

	Synthetic Ester (Post Retro-fill)			Synthetic Ester (Post Retro-fill 3 Months)		
Substation	Water Content	Breakdown Voltage	Acidity	Water Content	Breakdown Voltage	Acidity
Viewpoint Place 22	112	45	0.025	461	65	0.068
Viewpoint Place 42	153	60	0.026	429	70	0.089
Balgrayhill Road 178	121	72	0.016	204	>75	0.029
Balgrayhill Road 198	124	62	0.022	190	74	0.041
Edgefauld Road 250	76	63	0.029	204	73	0.05
Croftbank Street	139	73	0.019	291	72	0.086
Commercial Union	N/A	N/A	N/A	N/A	N/A	N/A

Insulation Resistance Tests – Pre and Post Retro-fill

	Insulation Resistance					
Substation	HV-LV Pre	HV-LV Post	HV-E Pre	HV-E Post	LV-E Pre	LV-E Post
Viewpoint Place 22	227 MΩ	170 MΩ	196 MΩ	279 MΩ	97 MΩ	169 MΩ
Viewpoint Place 42	199 MΩ	268 MΩ	235 MΩ	353 MΩ	91 MΩ	168 MΩ
Balgrayhill Road 178	519 MΩ	1.06 GΩ	596 MΩ	1.12 GΩ	283 MΩ	317 MΩ
Balgrayhill Road 198	437 MΩ	603 MΩ	463 MΩ	612 MΩ	209 MΩ	203 MΩ
Edgefauld Road 250	340 MΩ	381 MΩ	401 MΩ	423 MΩ	131 MΩ	82 MΩ
Croftbank Street	145 MΩ	253 MΩ	192 MΩ	247 MΩ	90 MΩ	155 MΩ
Commercial Union	N/A	N/A	N/A	N/A	N/A	N/A

If the unit is compliant with all checks detailed above, the following electrical tests should be carried out before proceeding with the retro fill to confirm the insulation condition of the transformer:

- HV side windings. Insulation resistance test, with a 5kV Megger for 1 minute. Expected values for newer transformers shall be c500 MΩ, and for older transformers c100-200 MΩ, where values are below 100 MΩ they shall be reviewed, and further action taken as required.
- LV side windings. Insulation resistance test, with a 1kV Megger for 1 minute. Expected values for newer transformers shall be c500 MΩ, and for older transformers c100-200 MΩ, where values are below 100 MΩ they shall be reviewed, and further action taken as required.

Pre and post insulation test results should be consistent with a slight improvement typical. Where the post test results are significantly poorer further investigation may be required.

Buchanan Galleries Liquid Analysis Data – Pre and Post Retro-fill

	Mineral Oil (Pre Retro-fill)			Synthetic Ester (Post Retro-fill)			
Substation	Water Content	Breakdown Voltage	Acidity	Water Content	Breakdown Voltage	Acidity	Fire Point
Buchanan Galleries East	Not Known	Not Known	Not Known	59	74	0.026	
Buchanan Galleries South T1	24	68	0.173	65	52	0.023	
Buchanan Galleries South T2	23	74	0.149	97	56	0.021	
Buchanan Galleries West T1	15	60	0.016	35	66	0.019	
Buchanan Galleries West T2	20	73	0.206	38	68	0.021	
Buchanan Galleries West T3	22	54	0.131	57	48	0.029	

	Synthetic Ester (Post Retro-fill)			Synthetic Ester (Post Retro-fill >3 Months)			
Substation	Water Content	Breakdown Voltage	Acidity	Water Content	Breakdown Voltage	Acidity	Fire Point
Buchanan Galleries East	59	74	0.026	120	67	0.155	299
Buchanan Galleries South T1	65	52	0.023	101	61	0.062	
Buchanan Galleries South T2	97	56	0.021	184	72	0.057	
Buchanan Galleries West T1	35	66	0.019	88	>75	0.04	311
Buchanan Galleries West T2	38	68	0.021	130	72	0.102	
Buchanan Galleries West T3	57	48	0.029	137	70	0.125	

Liquid Analysis Data – Pre and Post Retro-fill

The results for the East S/S samples did not meet the IEC 61203 requirements for fire point. The colour of these samples was orange and much darker than expected. The fire point and density of the samples further indicate that there is residual mineral oil remaining in the sample. K classification is not met for these samples.

The results for the West S/S liquids tested met IEC 61203 requirements. The flash points of these samples were measured at 244°C and 242°C. These values are lower than expected for pure MIDEL 7131 however the flash points are expected to diminish with residual mineral oil content.

The flash point of the liquid is more sensitive to contamination and has lower repeatability/reproducibility than fire point measurement. Therefore, the fire point measurement of a sample can be used for in-service samples, as stated in IEC 61203. The fire point of the liquids was 314°C and 308°C indicating that residual mineral oil remaining in the sample was low. K classification is met for these samples

East S/S Transformer

West S/S Transformer

Key Points / Conclusions

- Results highlight the importance of carrying out a good retro-fill procedure and draining as much mineral oil as possible out of the asset.
- The Buchanan Galleries project was impeded by the outage times available due to the shopping centre not wanting to go off supply. Therefore, the whole retro-fill process was carried out in a shorter period than we would normally allow.
- This inevitably was a major contributor with the draining and flushing of the residual oil not being adequate for the Buchanan Galleries East transformer.
- Our experience and test regime indicate that when carried out correctly there is an improvement in insulation resistance test values. Typically, after 3 months following retro-fill the breakdown value improves but there is a rise in both water content and acidity.