Limiting SF6 Gas Emissions by Optimization of Design and Handling over the Life Cycle of HV Switchgear

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Introduction

Introduction

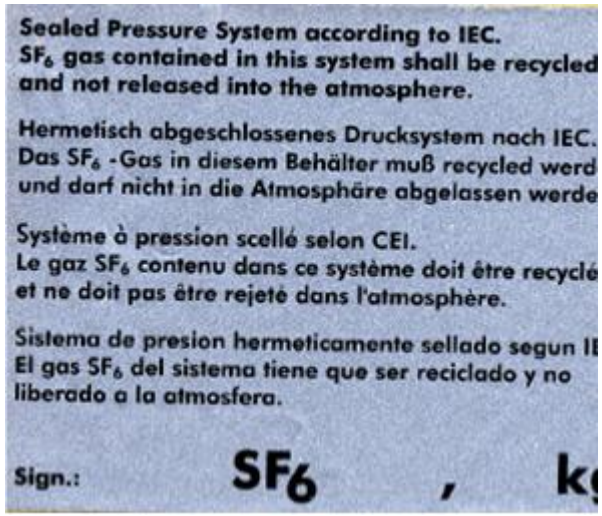
- **Technologies advances makes that emissions was averaged 4.5% per year of volume installed, now is reduced to 1% per year for older circuit breakers.**
- **Today emission objective is less than 0.5% per year.**
- **Need maintaining of all life cycle phases in particular during**
  - **Maintenance**
  - **End of life.**
- **Disposal of used SF_6 at the end of life: now recycled (99%) or disposed by burning it (1%).**

SF_6 gas is now never released to the atmosphere.

SF_6 Management During Development of Products and Manufacture

Management of SF_6 gas

- **SF_6 storage and Distribution in R&D and Manufacturing workshops**
  - **Example of Medium voltage switchgear.**
  - **Example of HV and EHV switchgear.**
  - **Shipment of additional gas in bottles or containers.**



CAPIEL is recommending proper management of SF6 Gas

- GL31x series manufacturing (HV & EHV)

Semi-Automatic tightness test facility for High-Voltage circuit breaker

SF_6 Gas Tightness

SF_6 Tight Design

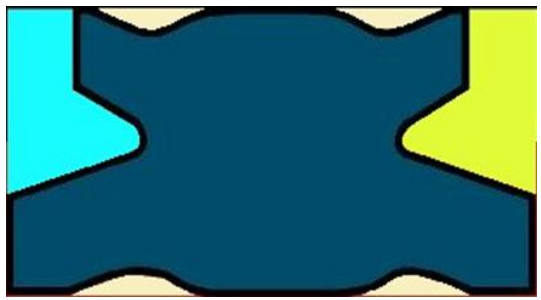
- **Aging effect is due to:**
  - **Hardening of the gaskets**
  - **Chemical attack**
  - **Corrosion**
- **Decrease in the mechanical, chemical and physical characteristics of the gasket material.**

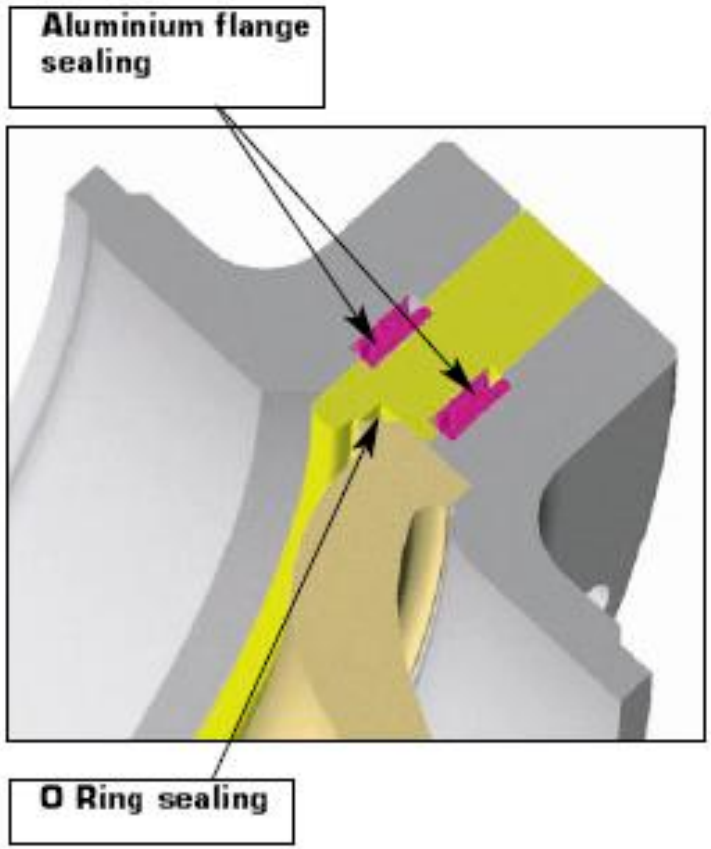
Historical development

SF_6 Tight Design

The one-O-ring seal and the two-O-ring.

SF_6 Tight Design





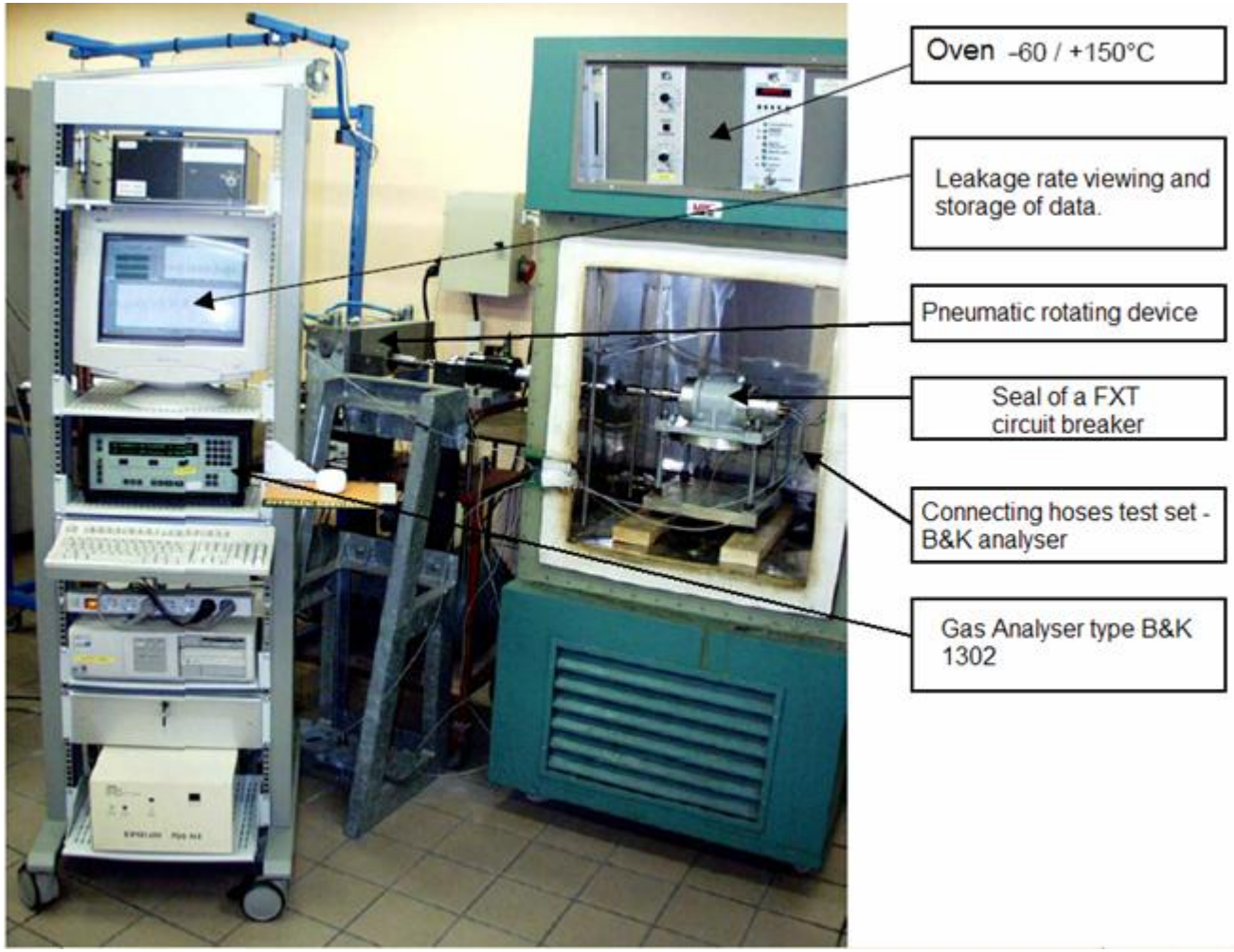
The Three-O-ring seal

SF_6 Tight Design

1. ***Electro-Chemical corrosion: Study of various compounds and it was noted the importance of a low electrochemical couple between the seal material, the aluminum alloy flanges and outdoor rain water.***
2. ***The selection of gasket was also crucial in decreasing the difference of potential. A compound of EPDM was selected that comply with all the above requirements.***
3. ***Many tests were performed in the 1980's and 1990's.***

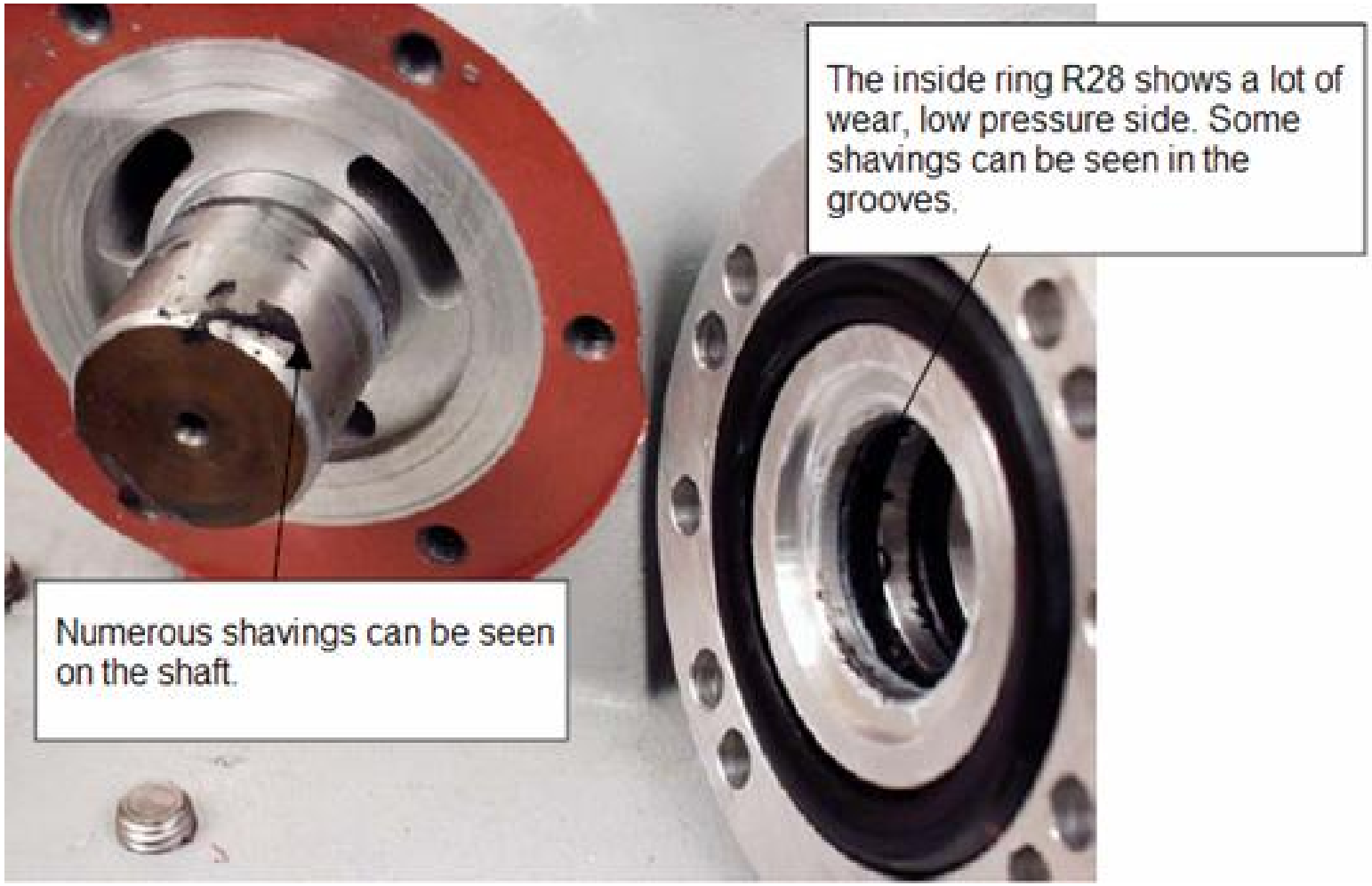
The Electrochemical corrosion

SF_6 Tight Design



The Tests

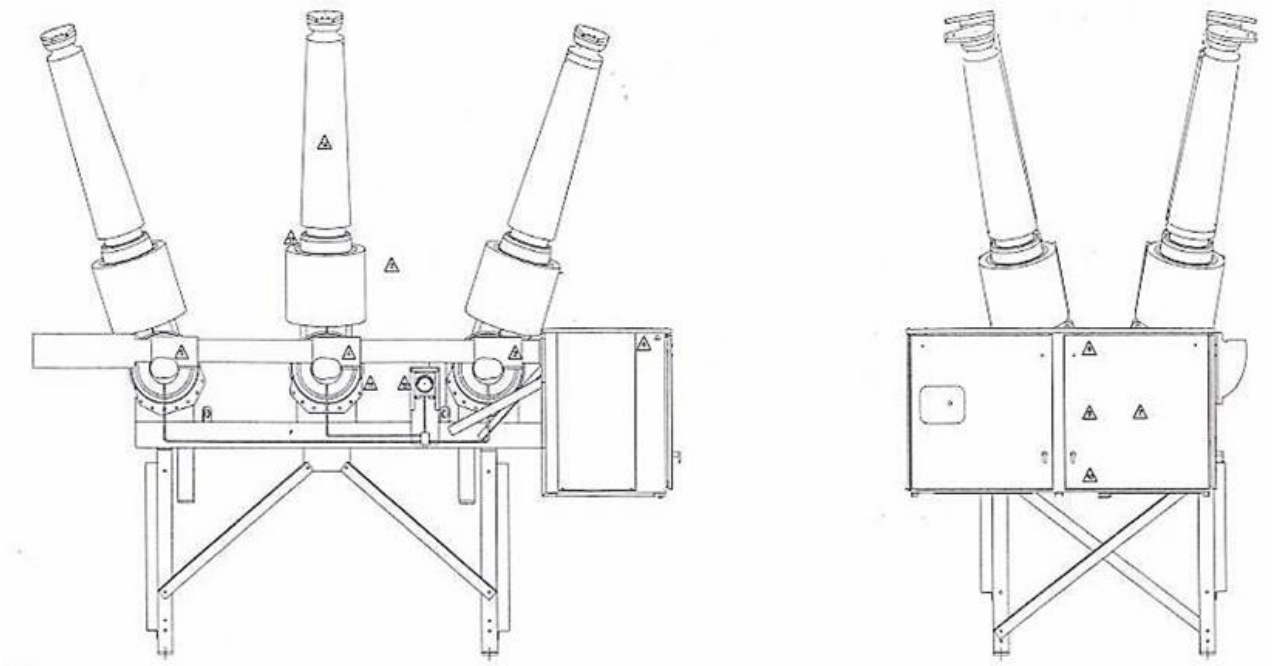
SF_6 Tight Design



The Tests

SF_6 Tight Design

» ***Application to dead tank circuit breakers***



Typical 245 kV dead tank circuit breaker

SF_6 Tight Design

Low temperature leakage test

Maintenance

Maintenance

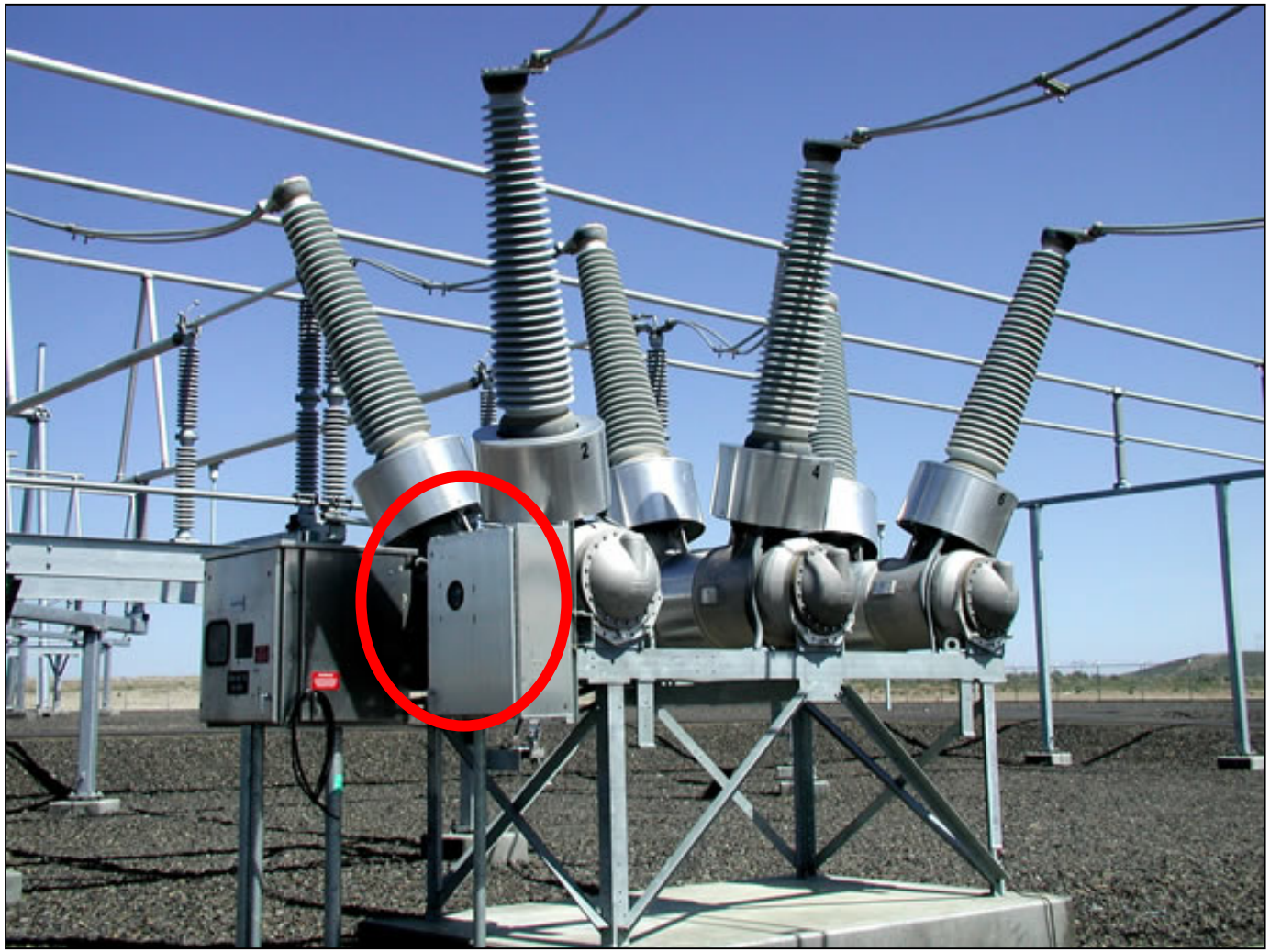
1. ***Work on circuit breaker : temporary store and re-use the SF_6 gas during service and maintenance.***
2. ***Ensure that there is adequate ventilation (natural or mechanical).***
3. ***Do not agitate SF_6 decomposition by-products unnecessary.***
4. ***Remove SF_6 decomposition by-products immediately after opening the circuit breaker to prevent moisture combination with by-products.***
5. ***Neutralize SF_6 by-products (arc products) with desiccant and used cloths, soak them in 3% soda solution for 24 hours (effervescence).***

Safety comes first

Minimizing the maintenance needs to avoid unnecessary SF_6 handling.

Hydro One – Belleville substation

Minimizing the maintenance needs to avoid unnecessary SF_6 handling.



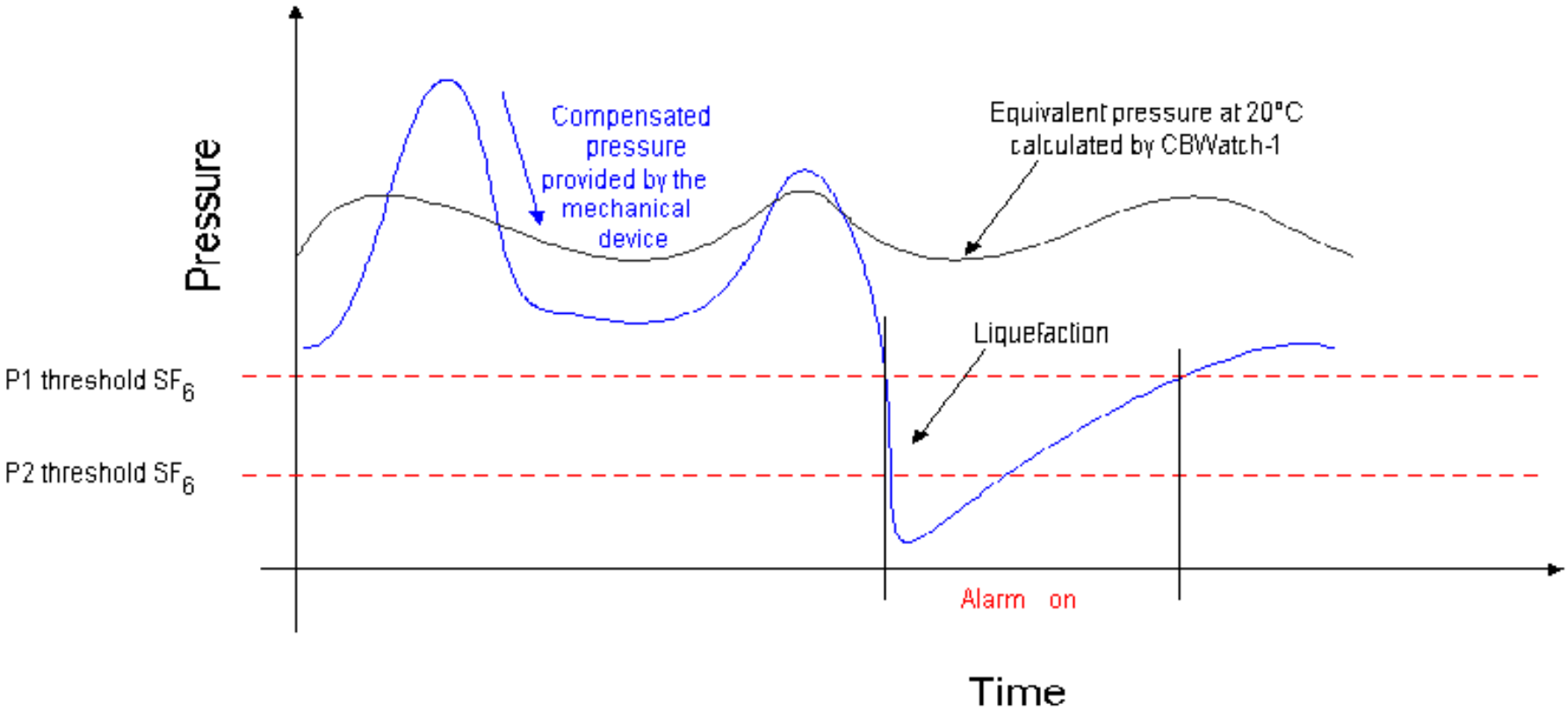
Grand County Public District Typical Monitoring

Minimizing the maintenance needs to avoid unnecessary SF_6 handling.

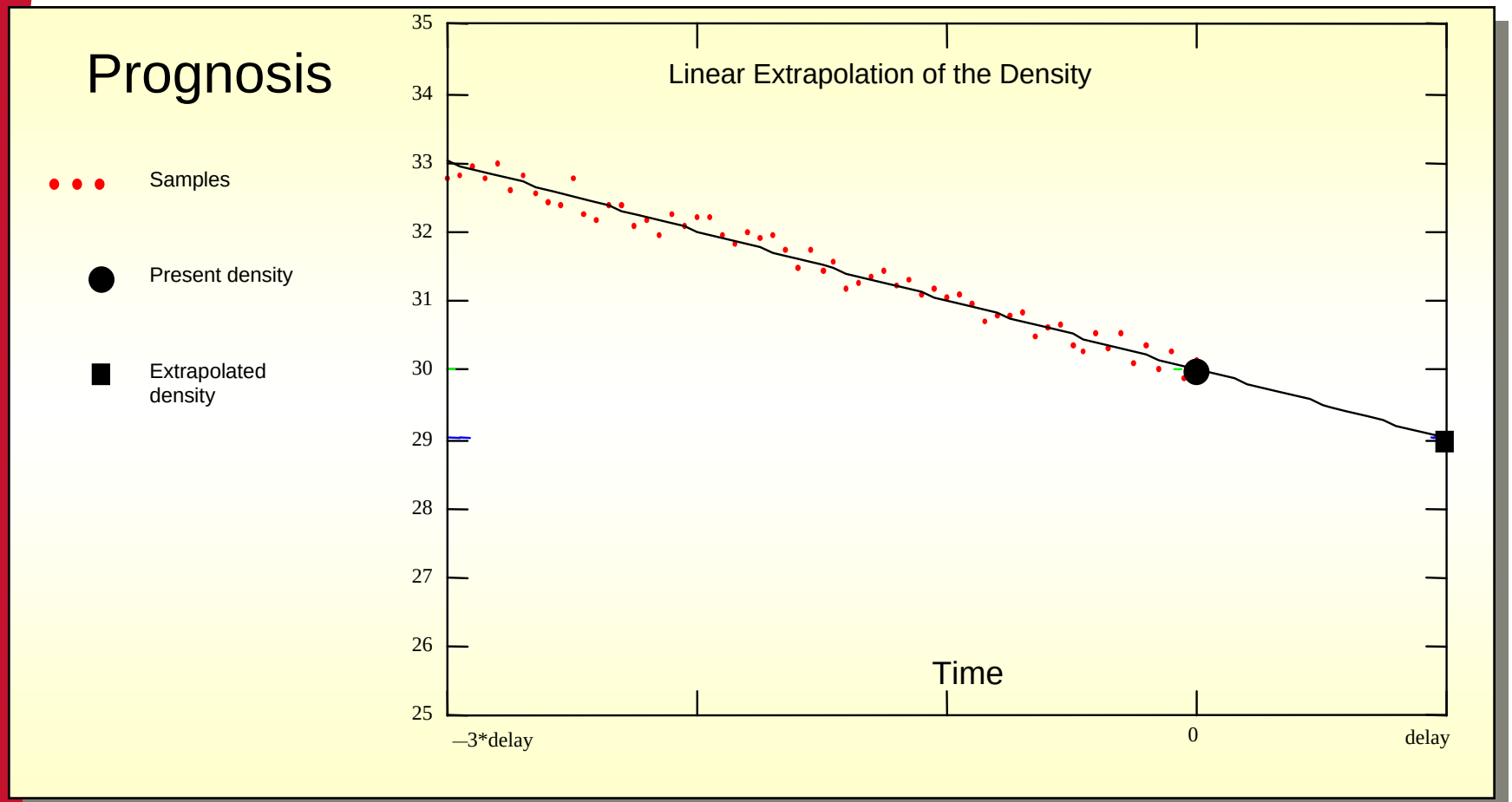
- **Why an electronic monitoring system for the SF_6 gas?**
- The conventional densimeter can be the origin of wrong alarms when a spread of temperature variation within a day is large.
- The use of an electronic allows the analysis of a rate of leakage and the generation of advanced alarms in addition to the computation of the density of the gas.
- The rate of Return On Investment (ROI) can be assured with only one false alarm (as liquefaction) in the life of the circuit breaker.

Minimizing the maintenance needs to avoid unnecessary SF_6 handling.

- Example: Breaker at James Bay (Northern Quebec)
- **When, exceptionally, temperature falls below the liquefaction point:**
- **A conventional densimeter will activate the P2 threshold (refilling required),**
- **CBWatch will send the message:** Temperature too low. Do not refill**.**



Minimizing the maintenance needs to avoid unnecessary SF_6 handling.



- Alarms are set within a range of 20 to 200 days before a topping up is required (20 mn to 20 hours before the locking pressure).

Minimizing the maintenance needs to avoid unnecessary SF_6 handling.

- System based on the state equation of the SF_6 gas developed by Beattie & Bridgeman.
- Internal range -40°C to + 60°C equivalent to -55°C to + 60°C ambient with heaters on the dead tank circuit breakers.
- Sensor send the information to the control board.
- Inhibits false alarms in the event of gas liquefaction, and indicates liquefaction.
- Calculates SF_6 leakage rates to:
  - Give advance warning
  - Lockout threshold levels

Minimizing the maintenance needs to avoid unnecessary SF_6 handling.

Circuit Breaker 145 kV Dead Tank with CBWatch1 (Hydro Québec-"Les Cèdres")

More than 400 units installed since 1998

Strategy for Applying Digital Monitoring in mixed gases
Minimizing the maintenance needs to avoid unnecessary SF_6 handling

Typical density monitor for SF_6/N_2 mix circuit breakers.

Ref: "Non Intrusive Method for the Assessment of SF_6/N_2 Gas Mixture Ratio"

Dallas, 2003

Minimizing the maintenance needs to avoid unnecessary SF_6 handling.

SF_6 monitoring: the CBWatch

Minimizing the maintenance needs to avoid unnecessary SF_6 handling. Sensors.

SF_6 monitoring the CBWatch:

typical pressure sensor and temperature probe.

Minimizing the maintenance needs to avoid unnecessary SF_6 handling. Communicate!!!

"Mobile Pad" on Pocket PC

- **No more need of drawings to find faulty sensor #FHG34, thanks to WiFi connection to the monitoring system, its location is displayed in your hand!**

SF_6 monitoring the CBWatch.

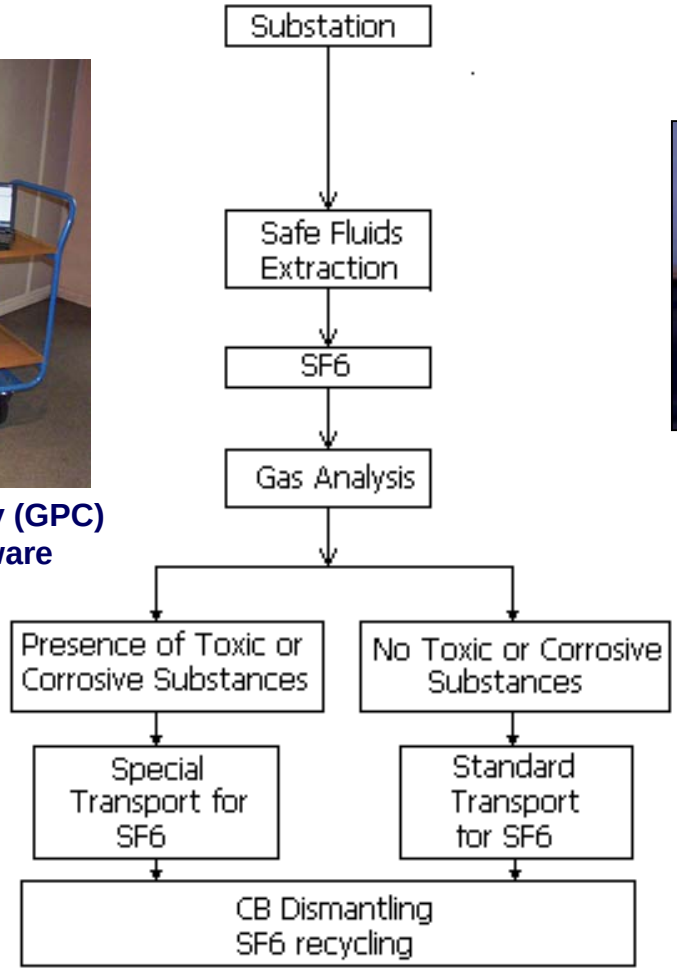
End of life

End of Life

Typical old SF6 circuit breakers

End of Life

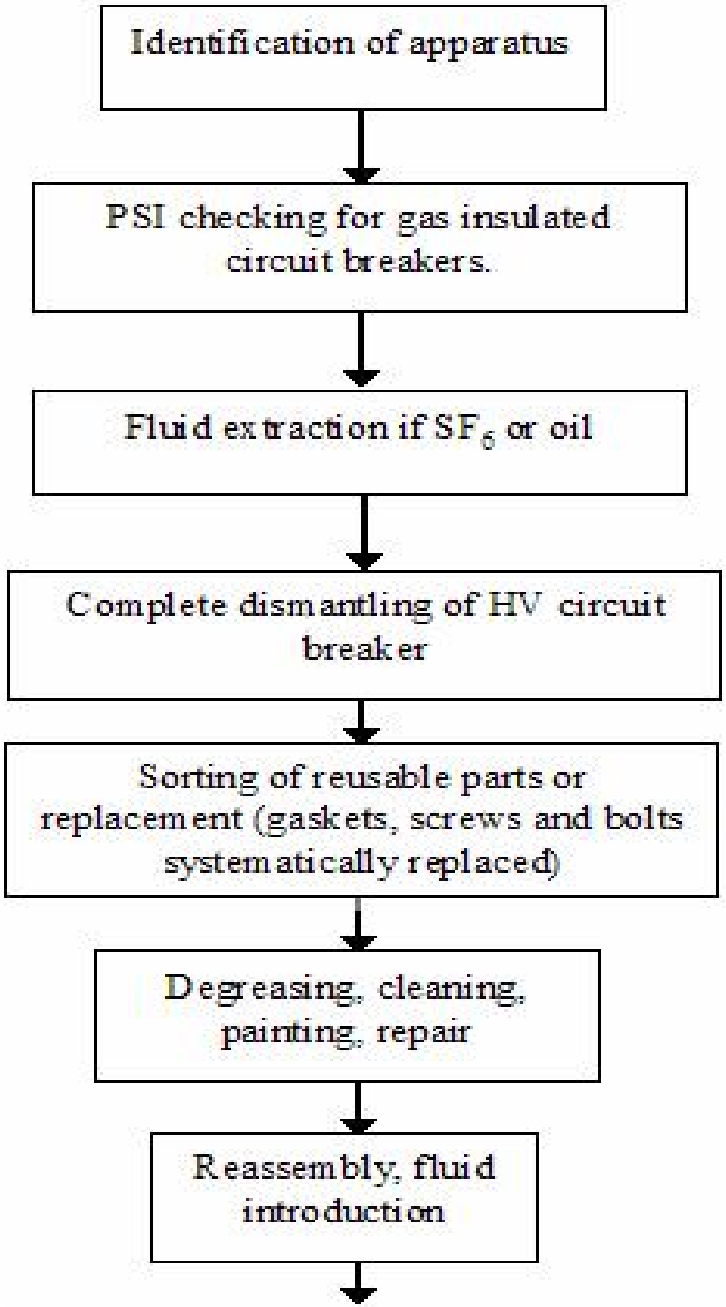
- **Gas Phase Chromatography (GPC) (Agilent P200) with software "Ezchrom 200".**

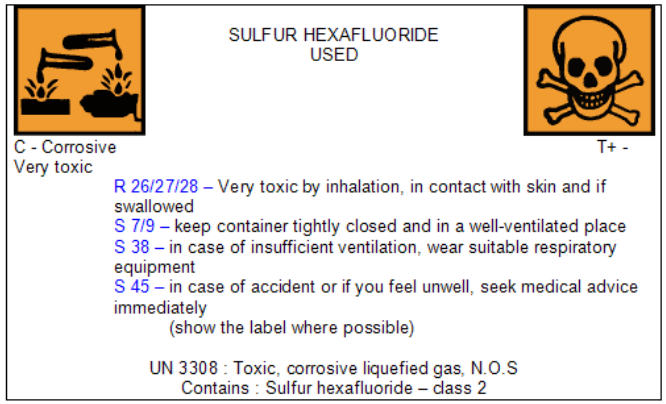


- ***Recovery container***

Typical old SF6 circuit breakers

Refurbishing





End of Life

Table 2. Different Waste Management subcontractors according to the material. The SF_6 gas is the last item.

Channels	Collection		Treatment	
	Sub-contractor	Receipt date for transport	Sub-Contractor	Regulation
Aluminum	EPUR	23/11/2001	EPUR	22/03/1982
Copper	SOBRAL	23/06/1998	SOBRAL	27/05/1994
Steel	CFF Recycling	Not available	CFF Recycling	02/09/1975
Bulky	SITA MOS	21/11/2003	SITA MOS	09/06/1982
Dangerous Industrial Wastes	SITA MOS	21/11/2003	LABO Services	23/09/2003
			SCORI	Not available
Oils	SRRHU	Special agreement	SRRHU	16/10/1990
SF_6 gas	STML	16/02/2004	AVANTEC	14/06/2004

End of Life

Table 3. Recycling rates and qualitative considerations for end of life.

Materials	Recyclability rate (grinding)	Recyclability rate (dismantling)	Energetic valorization
Steel	**80%**	**~100%**	-
Aluminum	**80%**	**~100%**	-
Copper	**95%**	**~100%**	-
PTFE	**0%**	**15%**	**Good**
Oils	-	-	**Very good**
SF_6	-	**99%**	**Not recommended**

Consideration for End of Life

Conclusion

Conclusions (1)

1. ***Improve management of the gas in the electrical industry.***
2. ***Many efforts were done in the design, manufacturing, testing, to reduce and master to the lowest possible level emissions of gas.***
3. ***Objective is the life cycle of the equipment, mainly during maintenance and at the end of life of the equipment.***
4. ***One of the problem is leakage and we described at length the tests, material selection, various gaskets to prevent leakage due to corrosion.***
5. ***Maintenance is usually where some gas escape to atmosphere. Ways to improve leak detection, sensing and handling of SF_6 gas during operations and maintenance were described.***

Drastic reduction of emission of SF_6 gas in the atmosphere.

Conclusions (2)

6. ***Solutions are available for extremely low SF_6 emissions for conventional and low temperature countries.***
7. ***Recycling rate is very high.***
8. ***We recommend continuous monitoring of SF_6 gas.***
9. ***Management of the End of Life of a circuit breaker is discussed in particular the recycling of the gas from "cradle to cradle" (99%) and if the pollution is too high from "cradle to grave" (1%).***

Drastic reduction of emission of SF_6 gas in the atmosphere.