Cold Weather Applications of Gas Mixture (SF_6/N_2, SF_6/CF_4) Circuit Breakers: A User Utility's Perspective

By

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Emission Reduction Strategies

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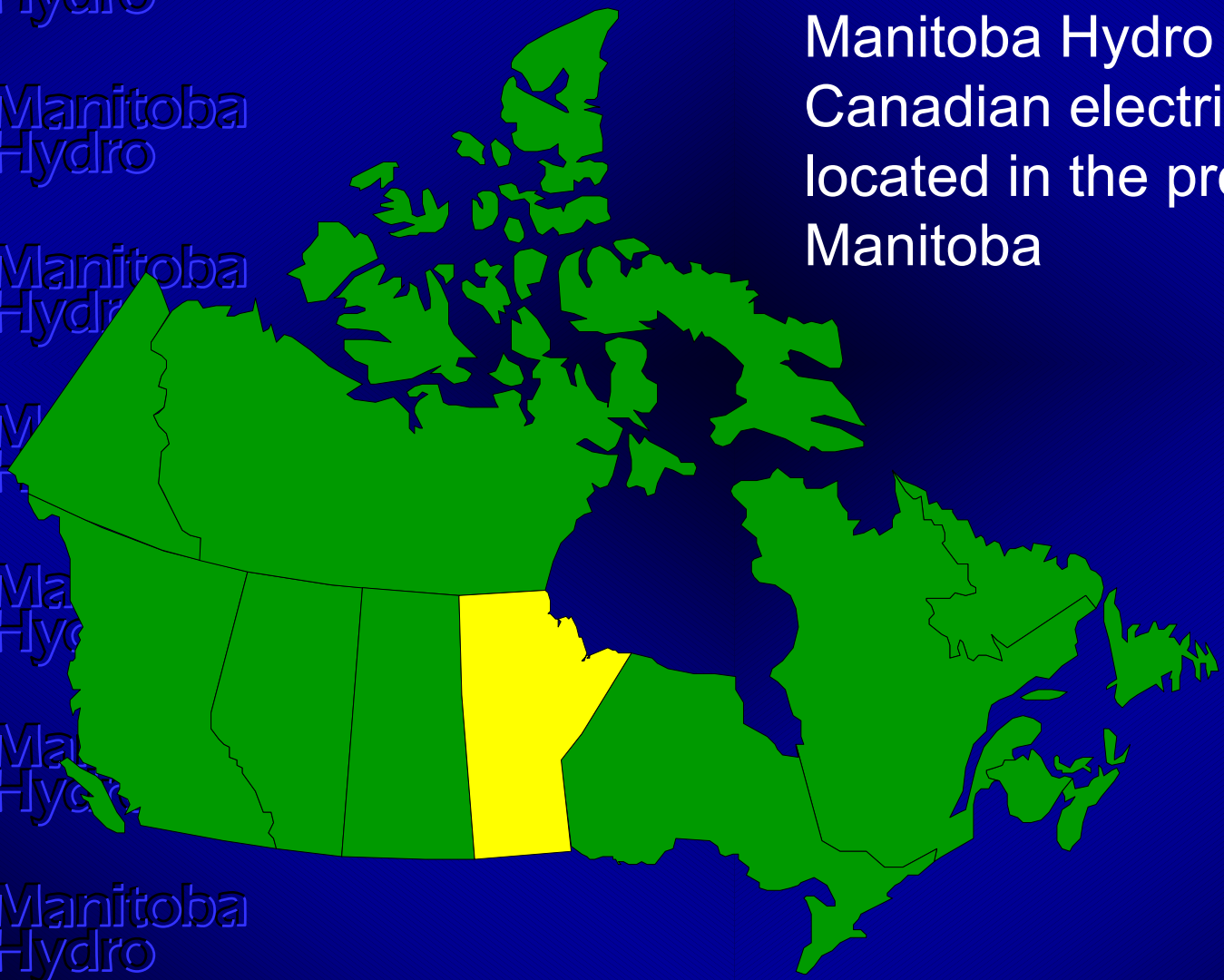
Mixed Gas Circuit Breakers Presentation Outline

- Overview of Manitoba Hydro system
- Technical considerations for -50ºC operation:
  - Gas mixtures and dielectric testing
  - Low temperature cycle test
  - Leakage rate
  - Circuit breaker tank designs
- Handling of gas mixtures

Where Are We?

Manitoba Hydro is a Canadian electric utility located in the province of Manitoba



Manitoba Hydro

- 100% owned by the Province of Manitoba
- 4th largest electric utility in Canada
- 99% of our energy is generated from hydro
  Capacity:
  - 4900 MW (hydro)
  - 237 MW (thermal)
- Peak demand: 3500 MW

Manitoba Hydro

- Revenue - $1081.6 million
- Assets - $7865.9 million
- Customers – 398,863
- Number of employees – 3,277
  (plus 836 construction)
- 30% of our revenue from exports
- 80% of our energy is produced by the five generating stations on the Nelson River

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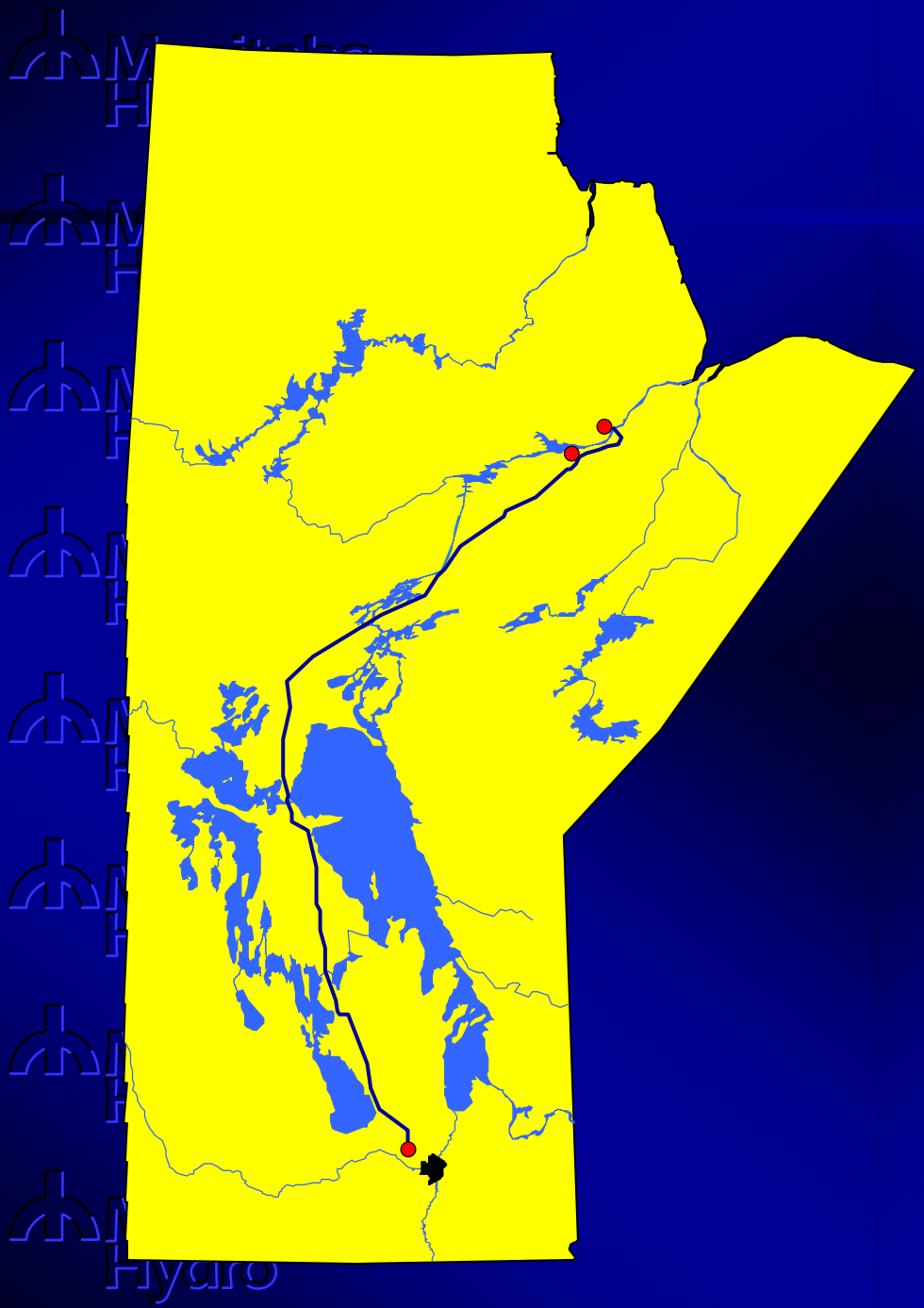

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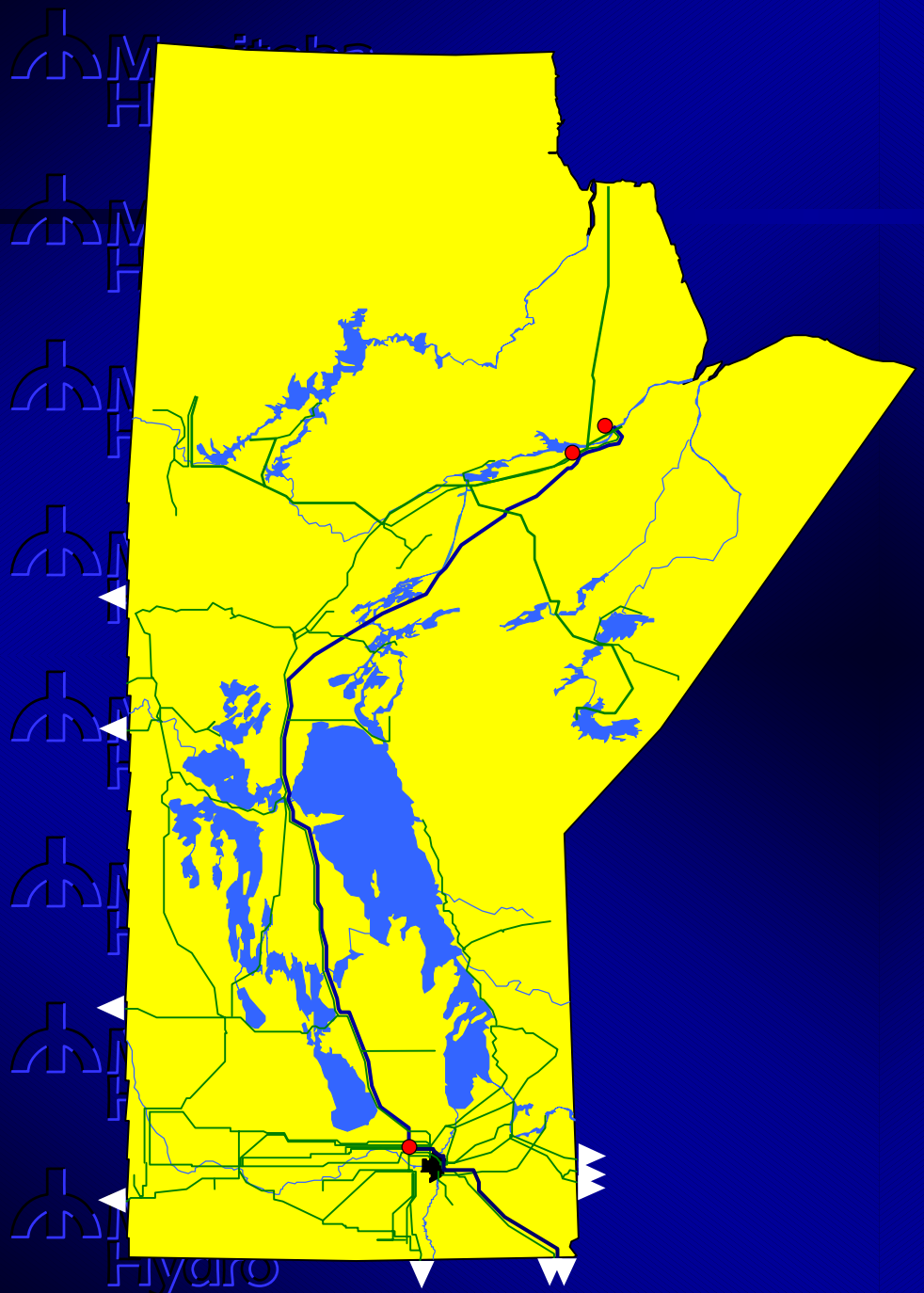

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- The transmission of power on HVDC power lines requires converter stations at either end
- These stations convert electricity from alternating current to direct current, and send the power at 500 kV
- From here, power is distributed all over the province or sold to neighbours, including the United States

MIXED GAS CIRCUIT BREAKERS

Manitoba Hydro has approximately 160 mixed gas circuit breakers on its system at various transmission and sub-transmission voltage levels

SYSTEM VOLTAGE	SF_6/N_2	SF_6/CF_4
500 kV	--	2
230 kV	5	62
138 kV	--	7
115 kV	2	46
66 kV	19	16

MIXED GAS CIRCUIT BREAKERS

- SF_6/N_2 mixture:
  - First breakers purchased (1988 – 1990) were supplied with SF_6/N_2 mixture
  - 60/40 mixture
  - Filling pressure (at 20ºC):

    0.31 Mpa SF_6

    +

    0.2 Mpa N_2
  - Alarm pressure (20ºC):

    0.45 Mpa
  - Blocking pressure (20ºC):

    0.43 Mpa

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MIXED GAS CIRCUIT BREAKERS

- SF_6/CF_4 mixture:
  - This mixture first became available in 1991; since then Manitoba Hydro has standardized on this mixture for all new breakers
  - 50/50 mixture
  - Filling pressure (at 20ºC):

    0.36 MPa SF_6

    +

    0.34 MPa CF_4
  - Alarm pressure (20ºC):

    0.62 Mpa
  - Blocking pressure (20ºC):

    0.60 MPa

MIXED GAS CIRCUIT BREAKERS

- ABB Type ELF SP7-4
- 550 kV, 4000A, 40 kA, SF_6/CF_4 circuit breaker at our Dorsey Converter Station
- Line to ground insulation 1800 kV BIL
- Grading capacitors 1500 pF
- Closing resistor:
  - 450 ohm
  - Energy rating 13000 kJ
  - Pre insertion time 8 +/- 2 ms

TECHNICAL CONSIDERATIONS

- We specify that circuit breakers must be able to operate down to ambient temperatures of -50ºC without the use of heaters

- To meet this requirement manufacturers must:
  - Provide a gas mixture to avoid liquefaction of the SF_6 gas at low temperatures
  - Test the mechanical operation of the circuit breaker at -50ºC according to the low-temperature cycle test defined in IEC 56

TECHNICAL CONSIDERATIONS

- Mixed gas:
  - Gas mixture of SF_6 and N_2 or SF_6 and CF_4 required to avoid liquefaction of the SF_6 gas at low temperatures
  - Filling with SF_6 and N_2 deteriorates the dielectric and thermal capacity
  - Manufacturers compensate for this reduced performance by:
    - A slightly higher operating pressure (dielectric)
    - De-rating the breaker under SLF conditions (thermal)

TECHNICAL CONSIDERATIONS

- If de-rating of the circuit breaker is unacceptable then grading capacitors have to be connected across the circuit breaker contacts to limit the rate-of-rise of the recovery voltage

- Disadvantages of grading capacitors:
  i) Makes the breaker more expensive
  ii) Can lead to other problems not directly associated with the circuit breaker (e.g. Ferro-resonance)

TECHNICAL CONSIDERATIONS

- Mixed gas filling with SF_6 and CF_4 results in practically unchanged thermal and dielectric breaking characteristics

- Circuit breakers filled with an SF_6/CF_4 mixture often retain their breaking capacity down to the lowest ambient temperatures

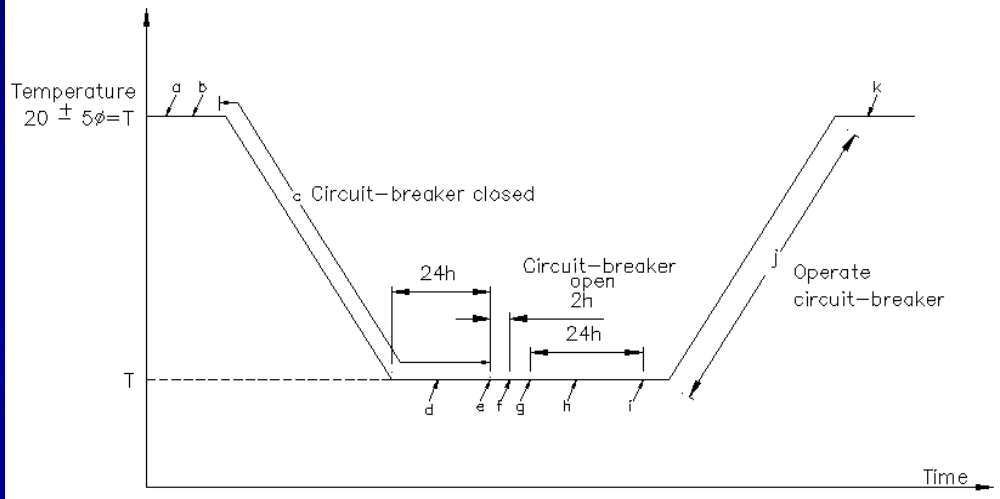
TECHNICAL CONSIDERATIONS

- It is not necessary to repeat all the type tests for the mixed gas version if the circuit breaker has been fully type tested as a pure SF_6 version

- Tests typically repeated to confirm the switching capability of the mixed gas circuit breakers:
  i) Cold performance test (for capacitive and small inductive current switching cases)
  ii)Terminal fault tests
  iii) Short line fault test

- Tests performed at 20ºC are valid for -50ºC

TECHNICAL CONSIDERATIONS



a Erection and adjustments

b Characteristic measurements, leakage test in 'closed' and 'open' states

c Circuit breaker cools down in the 'closed' state

d Leakage test whereby leakage <3*F_p (F_p=guaranteed leakage rate at 20 deg C)

e Circuit breaker 1 * 'O', 1 * 'C' at U_n; characteristic measurements

f Mechanism heating switched off for 2 hours followed by 1 * 'O'

g Circuit breaker in open state for 24 hours

h Leakage test whereby leakage < 3 F_p

i Characteristic measurements at 1 * 'C' and 1 * 'O', 3 * 'CO' with minimum reversing time, 50* (-'C'-ta-'O'-ta-)ta=1.5 min.

j Heating up at approx. 10 deg/hour and with the following simultaneous operation: -'C'-ta-'O'-ta-'C'-30 min. -'O'-ta-'C'ta-'O'-30min.-

- Low-temperature cycle test:
  - Based on IEC 56, Clause 6.101.3.3
  - This test is done to confirm that travel characteristics, operating times, and gas tightness are not compromised by low temperatures

MIXED GAS CIRCUIT BREAKERS TECHNICAL CONSIDERATIONS

- Gas leakage rate:
- < 0.5% per year at 20ºC
- At -50ºC the IEC standard allows a leakage rate of 3 x the rate at normal temperatures

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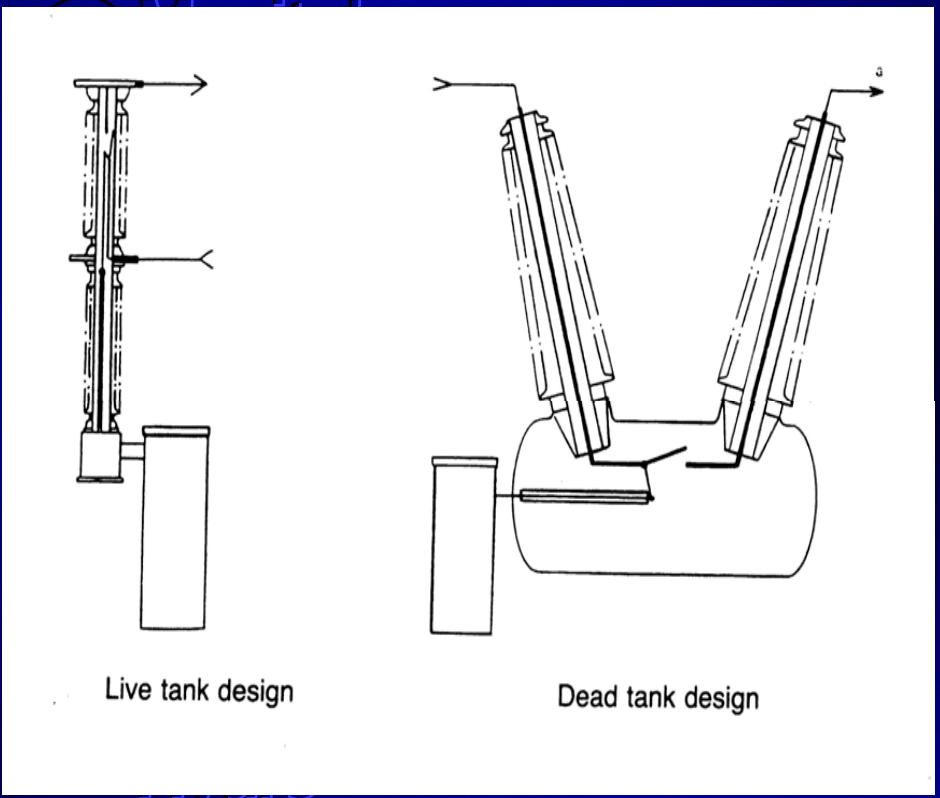
TECHNICAL CONSIDERATIONS



- Until recently only the live tank design was supplied with a gas mixture
- It is only recently that some manufacturers can offer mixed gas dead tank designs up to 145 kV, 40 kA; previously, dead tank designs relied on the use of tank heaters to keep the SF_6 gas above its liquefaction temperature

GAS HANDLING CONSIDERATIONS

- Manitoba Hydro owns and utilizes three gas handling carts
- The carts are manufactured by DILO Company Inc.
- Capable of handling SF_6, CF_4, and N_2 in either the gaseous or liquid form

GAS HANDLING CONSIDERATIONS

- A diaphragm compressor evacuates the gas containment compartment to an absolute pressure of 50 MBAR
- The scavenged gas is accumulated in an “empty” gas bottle, located on the cart
- A vacuum pump is then used to evacuate to an absolute pressure of 2 MBAR

GAS HANDLING CONSIDERATIONS

- In-line filtering is used to:
  - Absorb moisture from the gas
  - Cleanse unwanted gaseous particles from the gas (SF_4, SO_2F_2, HF, SO_2, and WF_6)
  - Collect solid particles which are created as the SF_6 decomposes after exposure to an electric arc (WO_3, CuF_2)

CONCLUSIONS

- Manitoba Hydro was the first North American utility to install mixed gas circuit breakers on its system
- Our mixed gas circuit breaker population continues to grow with over 170 presently in-service
- These circuit breakers have performed flawlessly and have provided the cold weather performance and reliability demanded by our company

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