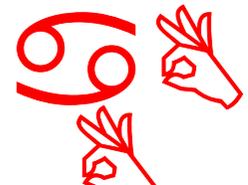


**CIGRE GUIDE FOR SF₆ GAS MIXTURES:
APPLICATION AND HANDLING IN ELECTRICAL POWER EQUIPMENT**

Lutz Niemeyer

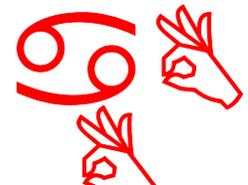
ABB Corporate Research Ltd.
Baden-Dättwil / Switzerland



WHAT IS THE PROBLEM?

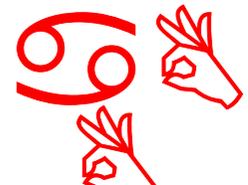
- SF₆ is a strong greenhouse gas
- There is no functionally equivalent substitute
- “Second best” gas: air
 - > Larger design --> higher cost
 - > More materials
 - > More environmental impact

As we cannot substitute SF₆ in T&D equipment we must minimize its emission



MINIMIZATION OF SF₆ LIFECYCLE EMISSION

- **Reduce leakage in-service**
 - Repair or retrofit leaking (old) equipment
 - Early leak detection
- **Implement responsible handling/recycling**
- **Minimize SF₆ per function**
 - Compact design (cost driven)
 - **Synergetic dilution of SF₆ by N₂**



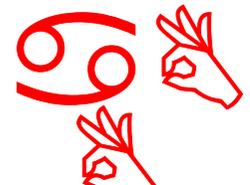
CIGRE

INTERNATIONAL CONFERENCE ON LARGE POWER NETWORKS

Working Group 23 - 02, Task Force 01: SF₆

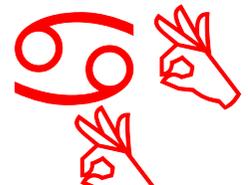
Mission:

**PROMOTE RESPONSIBLE SF₆ HANDLING IN THE
ELECTRIC INDUSTRY**



ACTIVITIES OF CIGRE SF₆ TASK FORCE

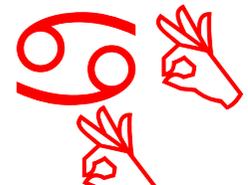
- **Assessing the environmental features of SF₆**
- **Proposing standards**
- **Preparing SF₆ handling documents**
- **Distributing SF₆-related information**



CIGRE SF₆ INTERNET SITE

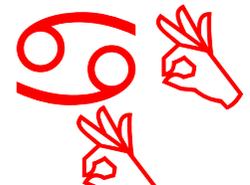
www.cigre-sc23.org/sf6/

- SF₆-related CIGRE documents
- Other SF₆-related documents
- (Links to SF₆ service providers)



SF₆ IN THE ELECTRIC INDUSTRY, STATUS 2000:

- **Handling processes, criteria, standards, and equipment have been developed**
- **On-site handling equipment is commercially available**
- **Services for further treatment off-site are available**
- **Responsible care practice is progressively implemented**



SUCCESS OF SF₆ RECYCLING EFFORTS?

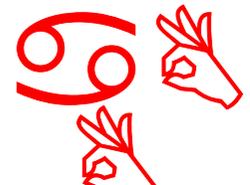
Max Planck Institute for Chemistry:*

“...annual emissions of SF₆ have declined by 27% from 1995 to 1998.”

“...a major part of the reduction must come from magnesium industry and electrical applications.”

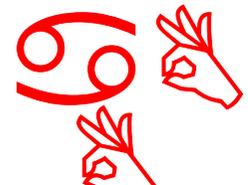
* M. Maiss and C.A.M. Brenninkmeijer, “A reversed trend in emissions of SF₆ into the atmosphere?” (Proc. 2nd Int. Symp. on Non-CO₂ Greenhouse Gases, Noordwijkerhout, Sept. 1999)

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WHY SF₆ MIXTURES IN T&D?

- (1) Enabling equipment operation at low ambient (arctic) temperatures**
- (2) Saving SF₆ in large insulation systems (cost and environmental impact)**



ARCTIC ENVIRONMENT

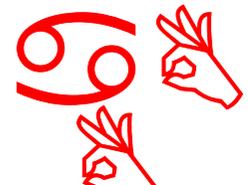
- **Avoiding SF₆ liquefaction**
- **Reducing SF₆ pressure**
- **Compensation by adding non-liquefying gas**

N₂

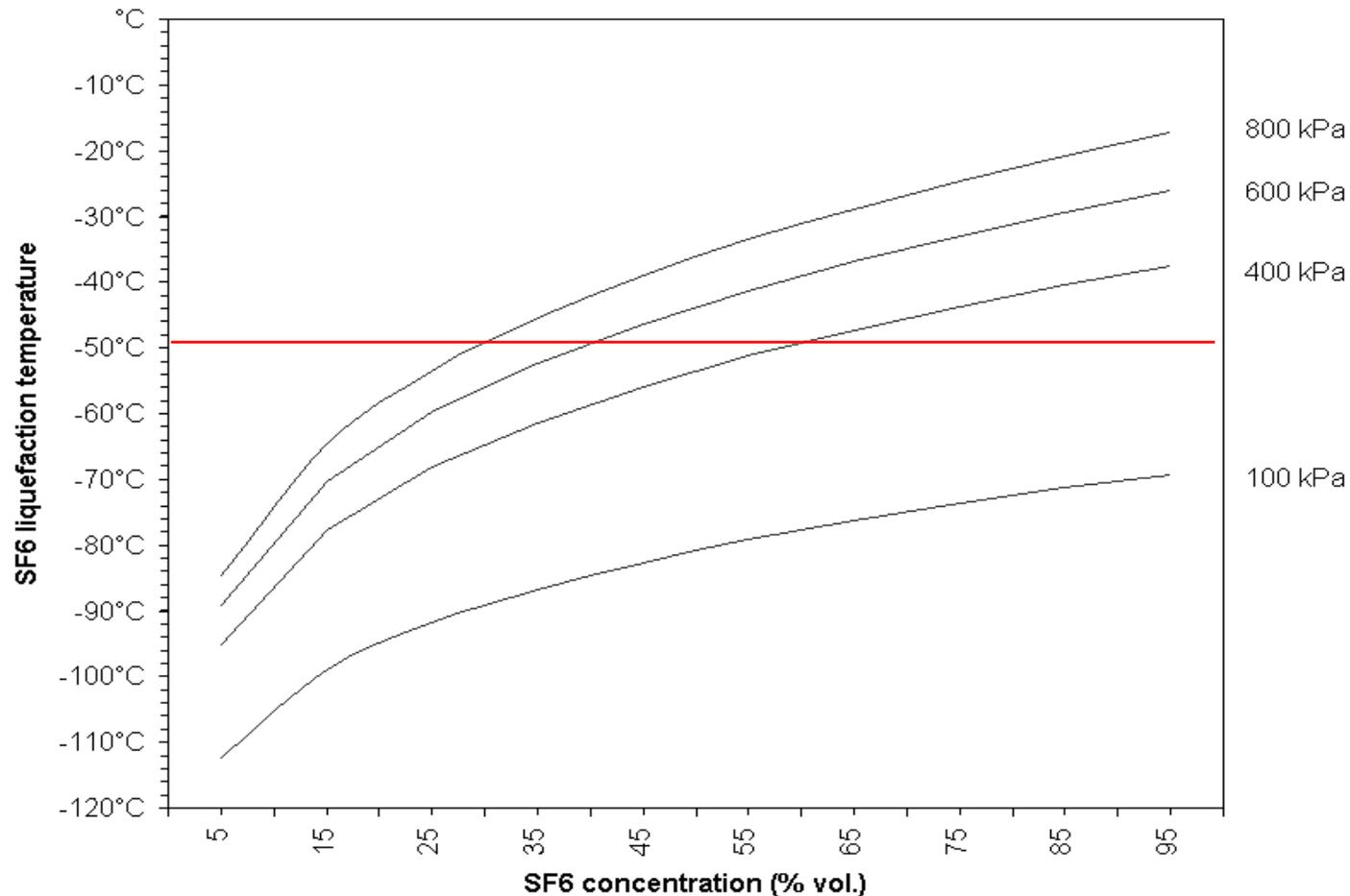
**High insulation synergy
Low switching performance**

CF₄

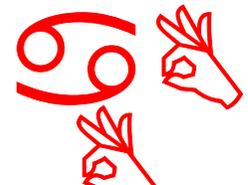
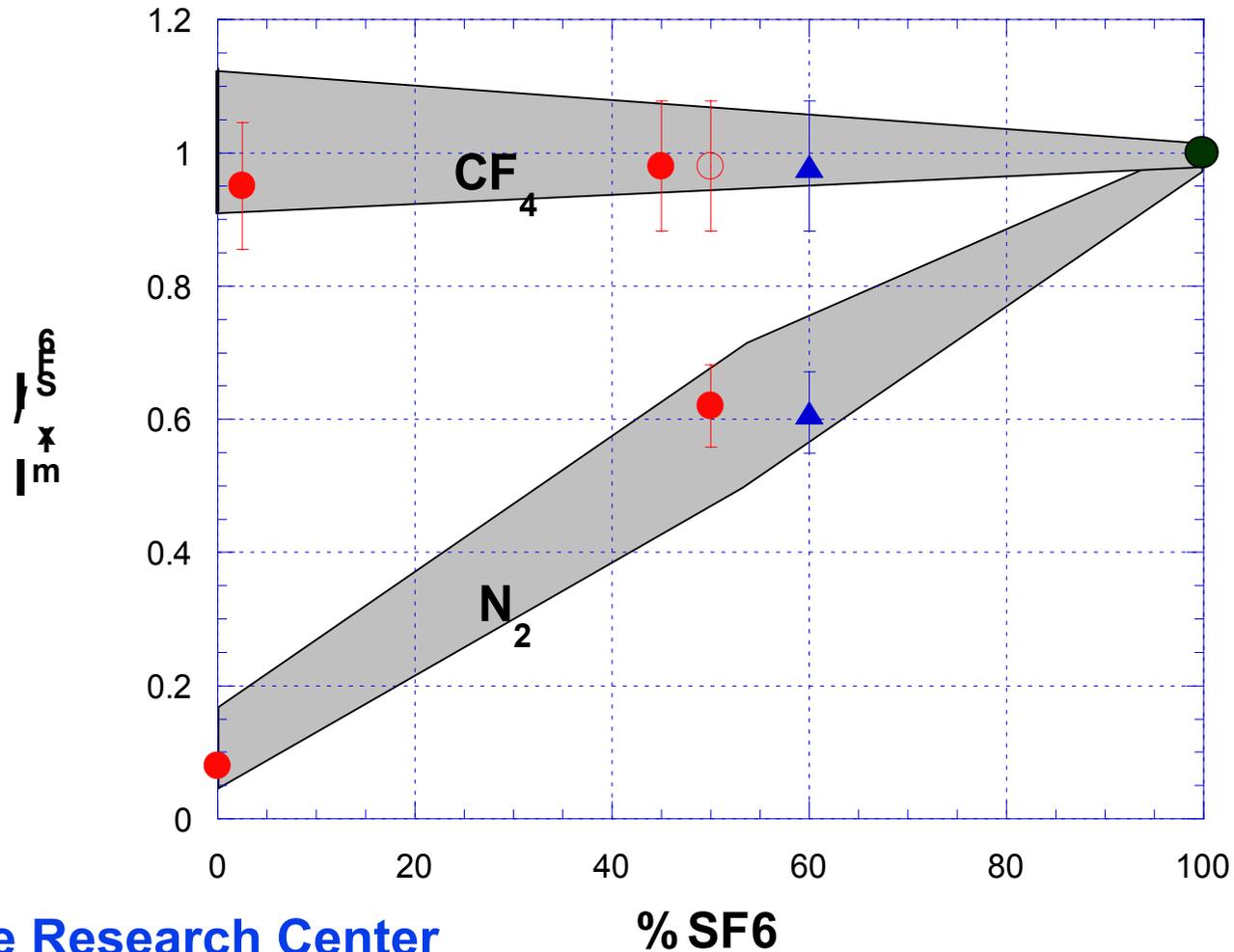
**High switching performance
Low insulation synergy**



LIQUEFACTION TEMPERATURE OF SF₆ IN MIXTURES



SWITCHING SYNERGY OF SF₆ MIXTURES



SAVING SF₆ IN INSULATION SYSTEMS

Basic effect:

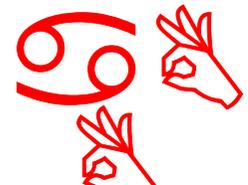
Strong insulation synergy in “diluted” SF₆-N₂ mixtures (~10% SF₆)

Typical applications:

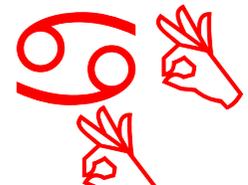
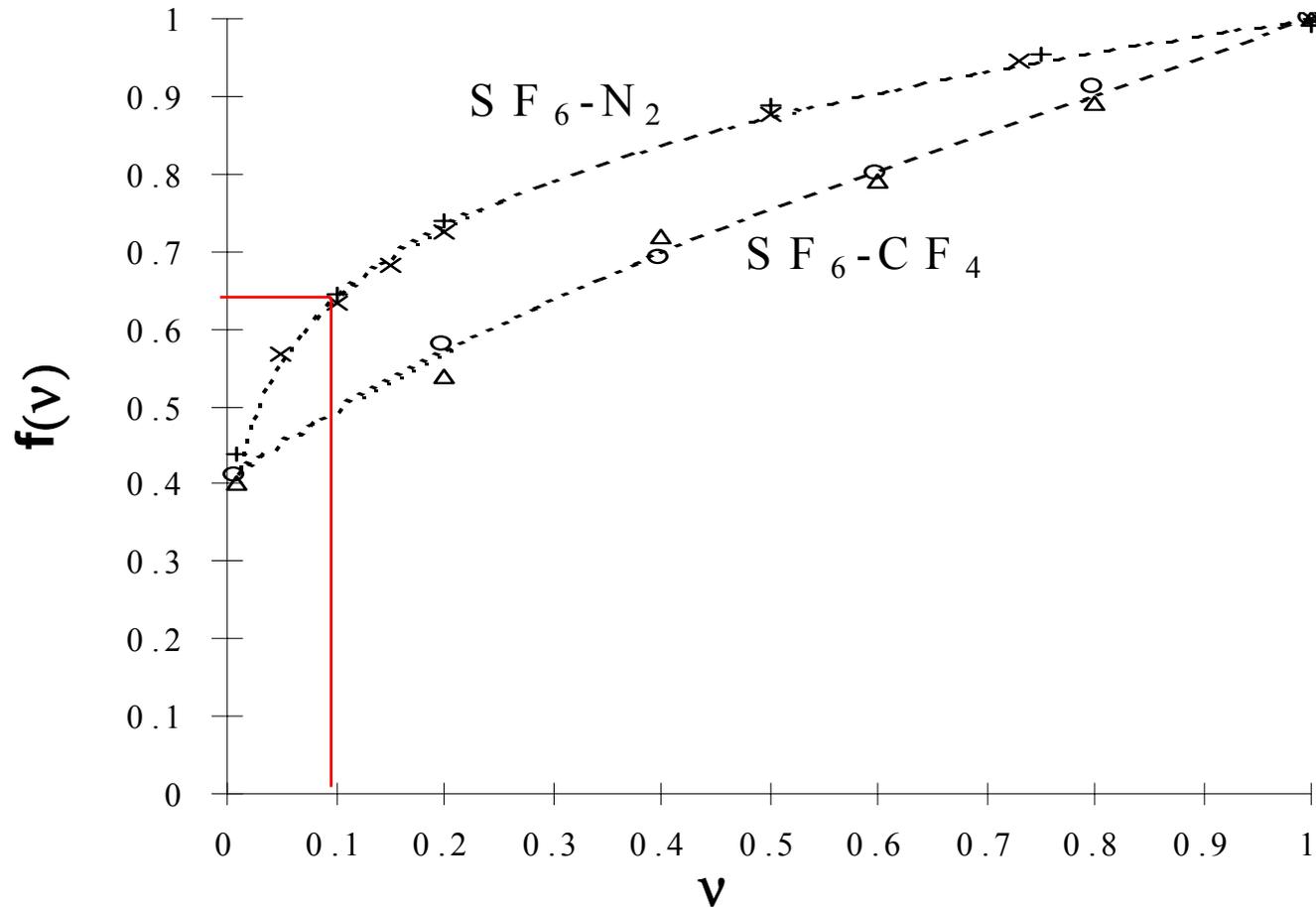
Gas-insulated lines (GIL)

Large GIS

Several GIL projects ongoing



INSULATION SYNERGY OF SF₆ MIXTURES



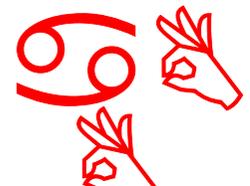
ENVIRONMENTAL ASSESSMENT

Relevant figure:

- The ***total*** environmental impact
- Of a **functional** system
- With specified power handling **performance**

SF₆ is only one contributor to environmental impact

Critical figure: SF₆ lifecycle emission

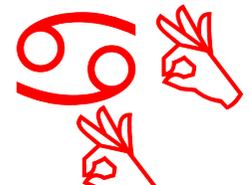


COMPARATIVE LIFECYCLE ASSERTION

Procedure: ISO 14040

Based on

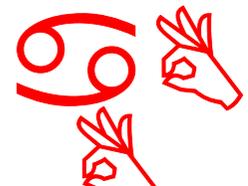
- **Detailed design**
- **Defined functional unit (bay, supply system)**
- **Defined power handling performance**



SF₆ HANDLING IS ESTABLISHED PRACTICE

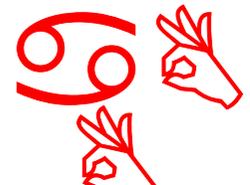
WHAT'S DIFFERENT FOR SF₆ MIXTURES?

- **Criteria**
- **On-site handling equipment**
- **Further treatment off-site**



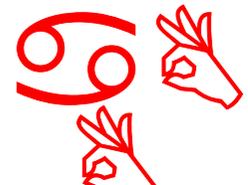
HANDLING CRITERIA FOR SF₆ MIXTURES

- | | |
|-----------------------------|--|
| (1) Criteria for reuse: | as for pure SF ₆
new: mixture composition |
| (2) Transport criteria: | as for pure SF ₆ |
| (3) Environmental criteria: | as for pure SF ₆ |
| (4) Safety: | as for pure SF ₆ |



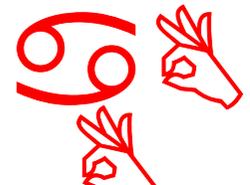
MIXTURE PREPARATION

- **Supplier - premixed gas**
- **Reused mixed gas**
- **Dynamic mixing at filling**
- **“One after the other” filling**

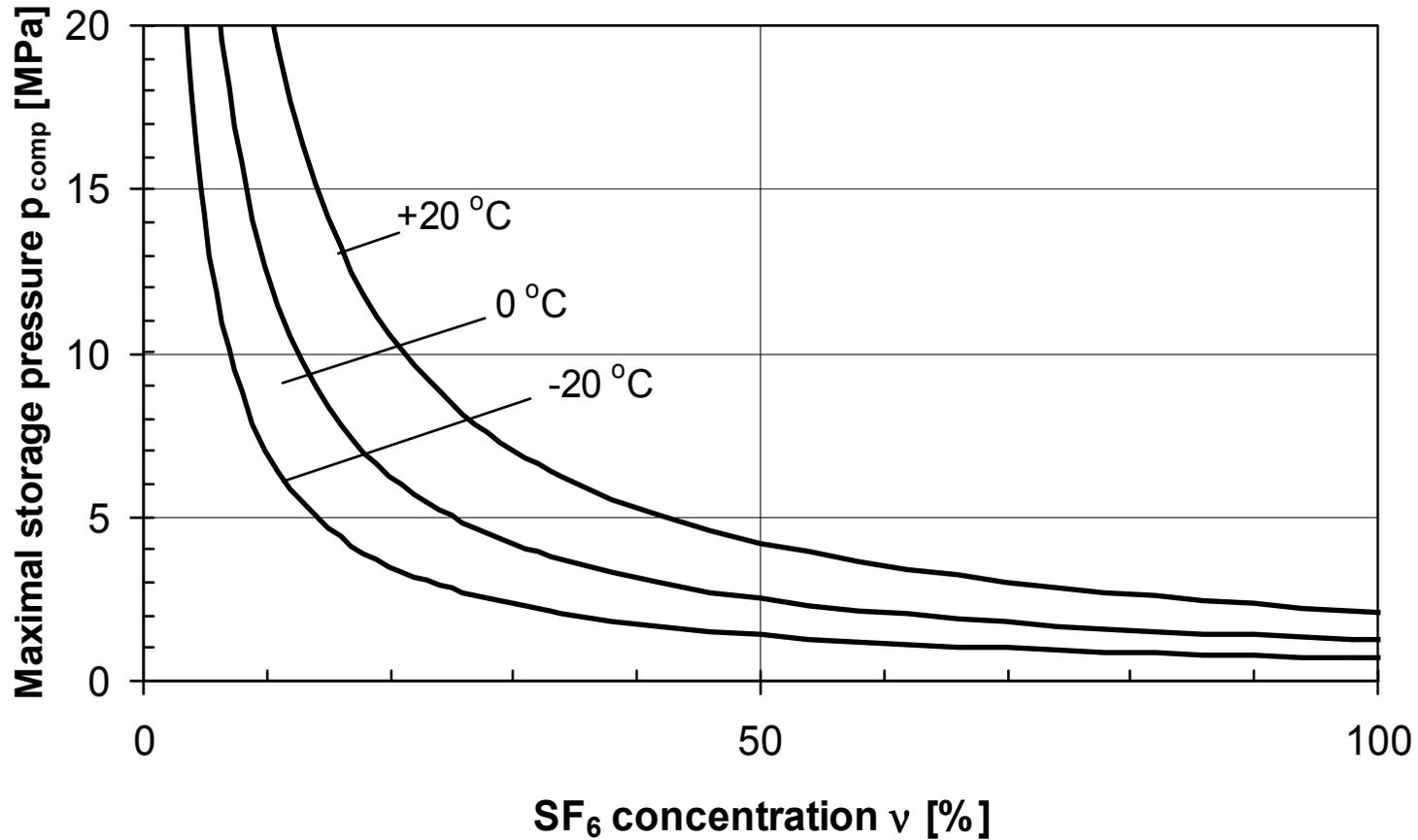


REUSE OF SF₆ MIXTURES ON-SITE

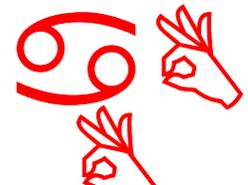
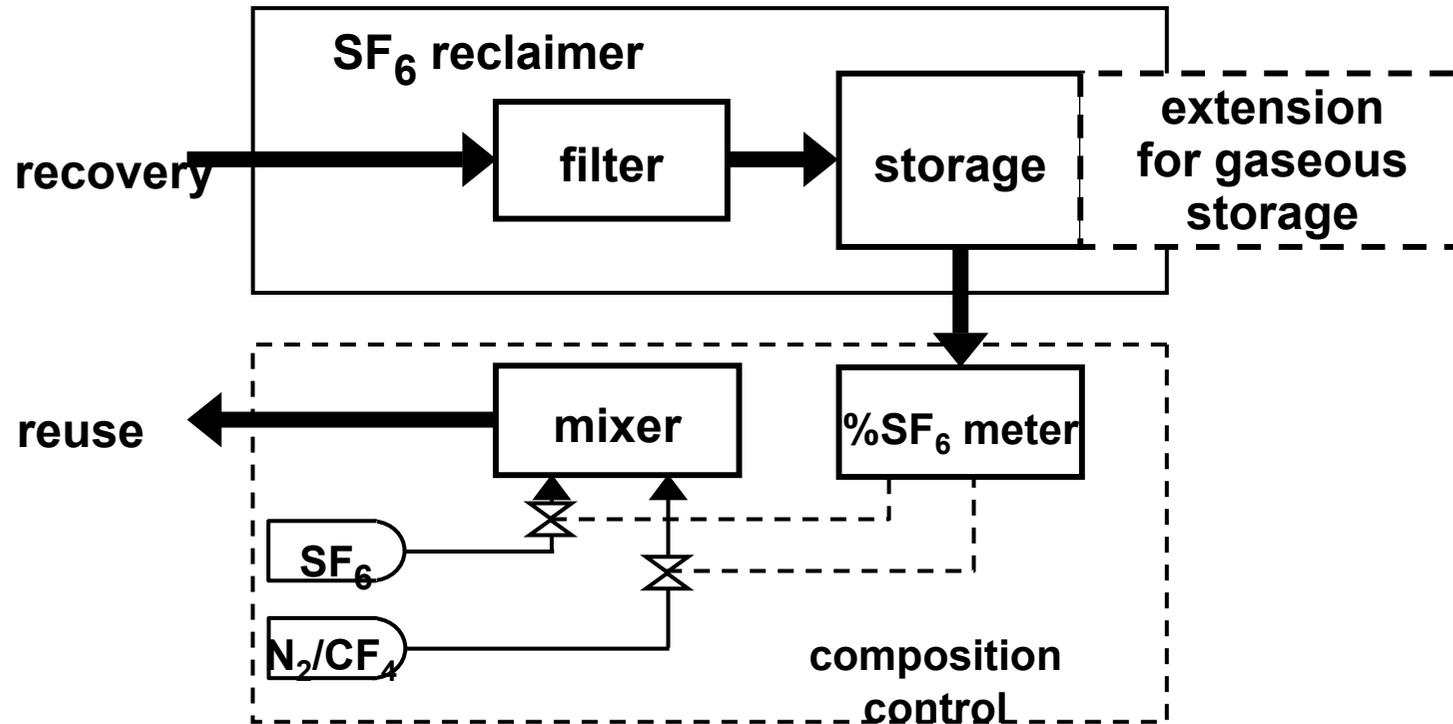
- **Mixtures can normally be reused on-site without separation**
- **Conventional SF₆ reclaimers cannot handle mixtures but can be upgraded for this function**
- **Mixtures must be stored without SF₆ liquefaction**



MAXIMAL STORAGE PRESSURE OF SF₆ MIXTURES

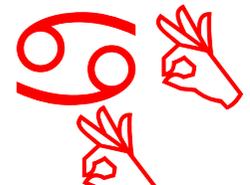


SF₆ RECLAIMER UPGRADING FOR MIXTURES

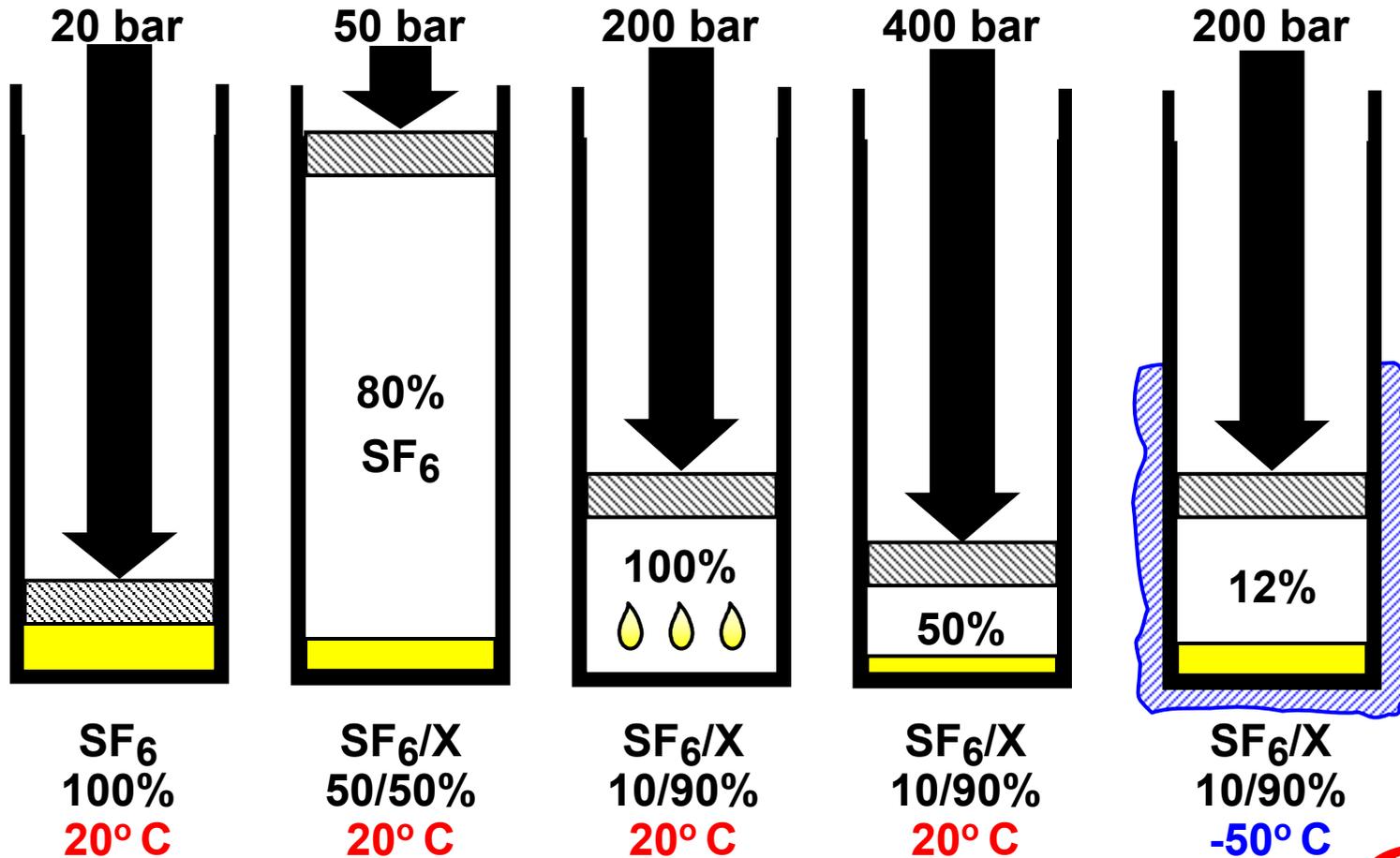


FURTHER TREATMENT OF SF₆ MIXTURES OFF-SITE

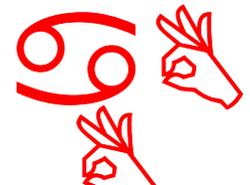
- (1) Purification of contaminated mixtures**
- (2) SF₆ separation**
- (3) Final disposal of SF₆ and CF₄**



SF₆ SEPARATION BY LIQUEFACTION



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FINAL DISPOSAL OF SF₆ AND CF₄

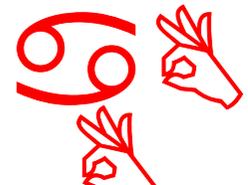
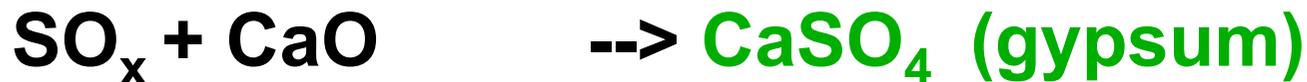
Thermal dissociation



Reaction:

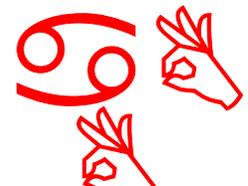


Flue gas treatment



CONCLUSIONS USE OF SF₆ MIXTURES

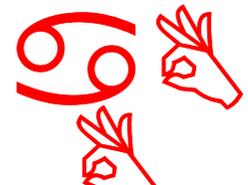
- **SF₆ mixtures enable equipment operation at low (arctic) ambient temperatures**
- **Diluted SF₆ nitrogen mixtures promise cost and environmental advantages**
- **Environmental advantages have to be assessed by comparative LCA (ISO 14040)**



CONCLUSIONS

MIXTURE REUSE ON-SITE

- **SF₆ mixtures can be reused on-site without separation**
- **Conventional SF₆ reclaimers can be upgraded for mixture reuse on-site**



CONCLUSIONS

CLOSING THE ECO-CYCLE

- **Non-reusable SF₆ mixtures can be further treated off-site:**
 - Purification
 - SF₆-separation
- **Closing the eco-cycle: SF₆ can be destroyed through re-transformation into natural substances**

