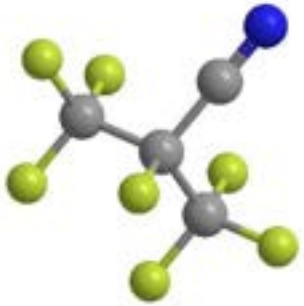
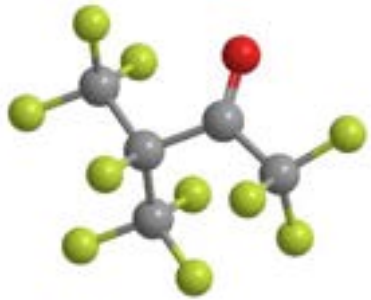




Mixing of Alternative Gases

Corey Ratza

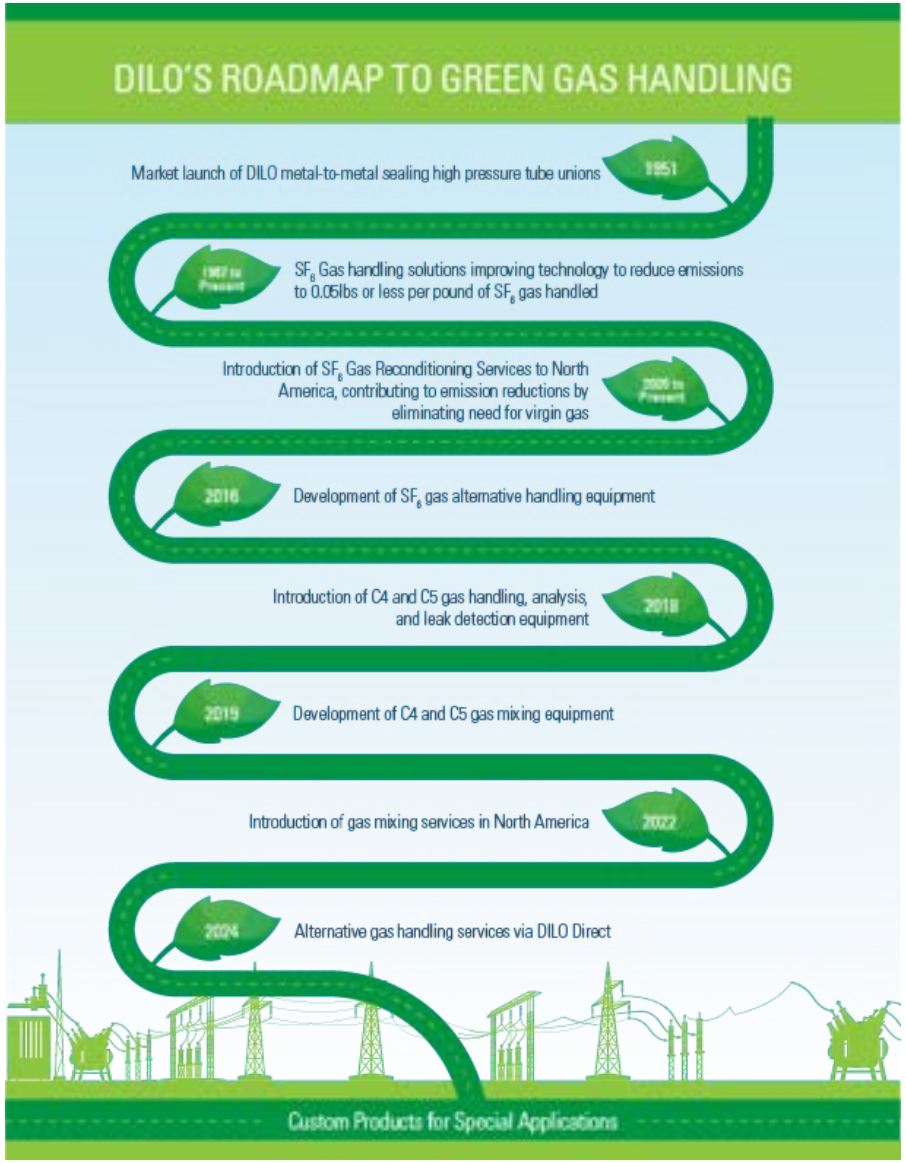
Chris Barrett

- Review of DILO's Green Gas Handling Roadmap
- Alternative Gas Theory review
- Storage (C4, C5)
- Mixing on-site
- Preparation and Creating a Mixture
- Measuring a mixture
- Alternative Gas Cylinder information
- Gas Mixture - End of Life
- Closing Remarks

Learning Outcomes

- Review the characteristics of Novec mediums
- Identify the ratios for mixtures of alternative gases
- Understanding the importance of liquid vs. vapor storage of C4/C5 mixtures
- Prevention methods of cross contamination

DILO's Green Gas Handling Roadmap



Mixture Procurement: Past & Present

- End-users previously only allowed to purchase from 3M
  - A distribution agreement has been struck between EPA and DILO for the US Market in 2022
- Cylinders of Novec used to have to be sent to the DILO factory in Germany to be mixed and sent back to customer in either gaseous or liquid storage containers
- DILO Florida will have all of the equipment to perform mixing in the US by Q1 2023
  - C4/C5 gas mixing plant & associated handling/testing equipment
  - Novec-specific vessels
  - Supporting carrier gases
  - Factory-trained technicians
- Stock of filled cylinders based on OEM mixtures will be available

DILO's History With Insulating Gases

7TH ANNUAL SF_6 GAS MANAGEMENT SEMINAR 2022

DILO has over 70 years of experience, providing high-pressure fitting solutions for industrial and specialty gases and liquid applications. And, over 50 years of knowledge, experience and expertise in engineering, production and service of gas handling, field analysis, leak detection and gas management solutions for gas insulated equipment.

DILO is represented by over 80 agents globally. Including, 30 service locations worldwide and 3 main Service Centers of Excellence located in, Babenhausen Germany, three service centers and one production facility in the United States of America (Odessa FL, Casa Grande AZ & Portland OR) and a location in Singapore.

Visit dilo.com or scan the QR code for more information on DILO solutions for all your Gas Insulated Equipment fitting and gas handling needs.

DILO's Gas Supply Commitment

- New alternatives are certainly offering excellent benefits and the future will continue to allow the evolvement of the alternatives.
- We as an industry will continue make progress with equipment, resources, knowledge and training for alternatives
- As the alternatives improve and decisions to which alternatives will be used, considering and supporting reduction of global emissions can be realized at the local level by utilizing recycled and/or reconditioned SF_6 gas
- SF_6 gas continues to be a proven medium for GIE insulation and arc quenching at all voltage and current levels
- SF_6 gas handling techniques, processes and training has provided a great level of reduction in emissions during the gas handling process

DILO SF_6 Certified Gas Process

Intake & Analysis of Used SF_6

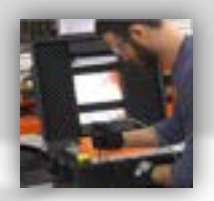
- Low Purity
- High H_2O*
- Presence of SO_2*

Account for weight of SF_6 analyzed and to be reconditioned

* CIGRE ; IEEE; ANSI; IEC; ASTM

Perform SF_6 reconditioning

Analysis of Reconditioned SF_6



Confirm analysis of reconditioned SF_6 meets/exceeds standards for re-use*

Request:	S-2975	Serviced:	0		Date:	1/20/2020	Pulled:	1
AssetTag Number	Cylinder Serial Number	Cylinder Certification Date	Purity (vol %)	Moisture	Decomp (SO_2/SOF_2)	Tare Weight	Gross Weight	SF_6 Weight
	SG852500Y	9/2014+	100.0%	<40 PPMv	PPMv	1,804.0 LBS	2,904.0 LBS	1,100.0 lbs
	6169-33	8/2014+	100.0%	<40 PPMv	PPMv	1,388.0 LBS	2,488.0 LBS	1,100.0 lbs
	4090-20	4/2015+	100.0%	<40 PPMv	PPMv	1,402.0 LBS	2,502.0 LBS	1,100.0 lbs
	4057-0	9/2014+	100.0%	<40 PPMv	PPMv	1,430.0 LBS	2,530.0 LBS	1,100.0 lbs
	4057-17	9/2014+	100.0%	<40 PPMv	PPMv	1,407.0 LBS	2,507.0 LBS	1,100.0 lbs

Fill into clean (non-contaminated) SF_6 storage containers

Account for weight of SF_6 analyzed and reconditioned

Introduce into SF_6 supply stream


BEHIND THE SCENES

Alternative Gas Review

		Sulfur-hexafluoride	Clean-Air	Carbon Dioxide and Oxygen	C4-Fluoronitrile	C5-Fluroketone
Base Gas	Chemical Formula	SF_6	80% N_2 + 20% O_2	70% CO_2 + 30% O_2	$(CF_3)_2CFCN$	$(CF_3)_2CFC(O)CF_3$
	$CO2_e$(GWP)	23,500	0	<1	2,210	1
	Boiling Point	-64°C	<-183°C	-50C	-5°C	+27°C
	Dielectric Strength	1.00	0.43	0.77	2.20	1.70
Gas Mixture	Background (gases)	Pure or with N_2 or CF_4	80% N_2 + 20% O_2	70% CO_2 + 30% O_2	~90% CO_2	~90% O_2 With N_2 or CO_2
	$CO2_e$(GWP)	23,500	0	<1	~380	<1
	Lowest Operating Temperature	-30°C *	-50°C	-50C	-30°C	0°C to +5°C -20°C possible
Internal Arc Reaction	Decomposition Products	HF, S_xF_y, SOF_x, F_2, SO_x, CF_4	If applicable: O_3, NO_x	CO, HF, O_3	CO, HF, C_nF_{2n+2}, other Fluorinated Compounds	CO, HF, COF_2, C_xF_y other Fluorinated Compounds
	Toxicity of Decomposition Products	Slightly toxic (Hodge-Sterner)	Typically None	Relatively harmless (Hodge-Sterner)	Practically non-toxic (Hodge-Sterner)	

Alternative Gas Review

Properties of the gas mixtures				
Common trade names		g³ (GE)	AirPlus (ABB)	CleanAir (Siemens)
Gas mixtures in use	Pure SF_6	C4: < 6.3 % with CO_2	C5: < 15 % in Synthetic Air	CA: ~ 20 % O_2 in N_2
	SF_6 with N_2 or CF_4	C4: < 6.3 % with O_2/CO_2	C5: < 15 % in O_2/CO_2	-
Minimum operating temperature	Pure SF_6: < –30 °C	Depending on the exact mixture:		< –50 °C
	SF_6 with N_2/CF_4: < –50 °C	–30 °C to –5 °C		-
Global warming potential	≤ 22800	≤ 500	< 1	0

Alternative Gas Review

Market overview

SF_6-free distribution switchgear 12 - 40.5 kV (examples):

	ABB	SIEMENS	Schneider Electric	nuventura	DRIESCHER · WEGBERG	efacec	EATON	G&W	S&C	MITSUBISHI ELECTRIC	TOSHIBA
Insulation	C5-FK mix	Dry air	Synth. Air	Dry air	C4-FN mix	Solid + air	Solid + air	Solid	C4-FN mix + solid	Dry air	Solid

SF_6-free transmission switchgear 72.5 - 170 kV (examples):

	LS IS	GE	HITACHI	HITACHI	HYUNDAI	ILJIN	SIEMENS energy	MITSUBISHI ELECTRIC	PINGGAO GROUP	MEIDEN	TOSHIBA
Design	GIS	GIS / LT	GIS	Live tank	GIS	GIS	GIS / LT	Dead tank	GIS	Dead tank	C-GIS
Insulation	C4-FN mix	C4-FN mix	C4-FN mix	Dry air	C4-FN mix O_2-free	Dry air	Techn. air	Techn. air	CO_2	Dry air	Solid
Switching	C4-FN mix	C4-FN mix	C4-FN mix	O_2 / CO_2	C4-FN mix O_2-free	Vacuum	Vacuum	Vacuum	Vacuum	Vacuum	Vacuum

Storage (C4, C5)

Gaseous storage

Advantages	Disadvantages
Certified gas	Relatively small quantities can be stored
Small gas compartments can be filled	Partial liquefaction possible when cooling down
No service cart necessary (only gas refilling device)	Mixing ratio cannot be changed on site

Partially liquefied storage

Advantages	Disadvantages
Large storage quantity	No direct withdrawal possible without service cart
Exact predefined gas mixture	Heating by service cart is time-consuming
Independent of outside temperature	Mixing ratio cannot be changed on site

Storage (C4, C5)

Comparison of storage capacity

Comparison of the maximum storage capacities of liquefied and gaseous mixtures of Alternatives Gases.

Comparison of storage capacity	6 % C4 and 94 % CO_2	6 % C5 and 94 % CO_2	Synthetic Air (20 % O_2 in 80 % N_2)
gaseous			
50 l cylinder, T = 20 °C	5.1 kg	1.6 kg	11.8 kg
600 l tank/cylinder bundle, T = 20 °C	61.3 kg	19.1 kg	141.6 kg
Filling pressure, T = 20 °C	46.9 bar	13.5 bar	200 bar
liquefied			
50 l cylinder, PH = 300 bar	28.3 kg	30.6 kg	Not applicable
600 l cylinder, PH = 70 bar	79.3 kg	85.6 kg	Not applicable

PH = Test pressure of the pressure tank. For synthetic air, a filling with 200 bar at 20 °C has been used as a calculation basis. Liquefaction of the mixture at this temperature cannot occur. For calculation of the liquefaction point, the ideal gas equation was used.

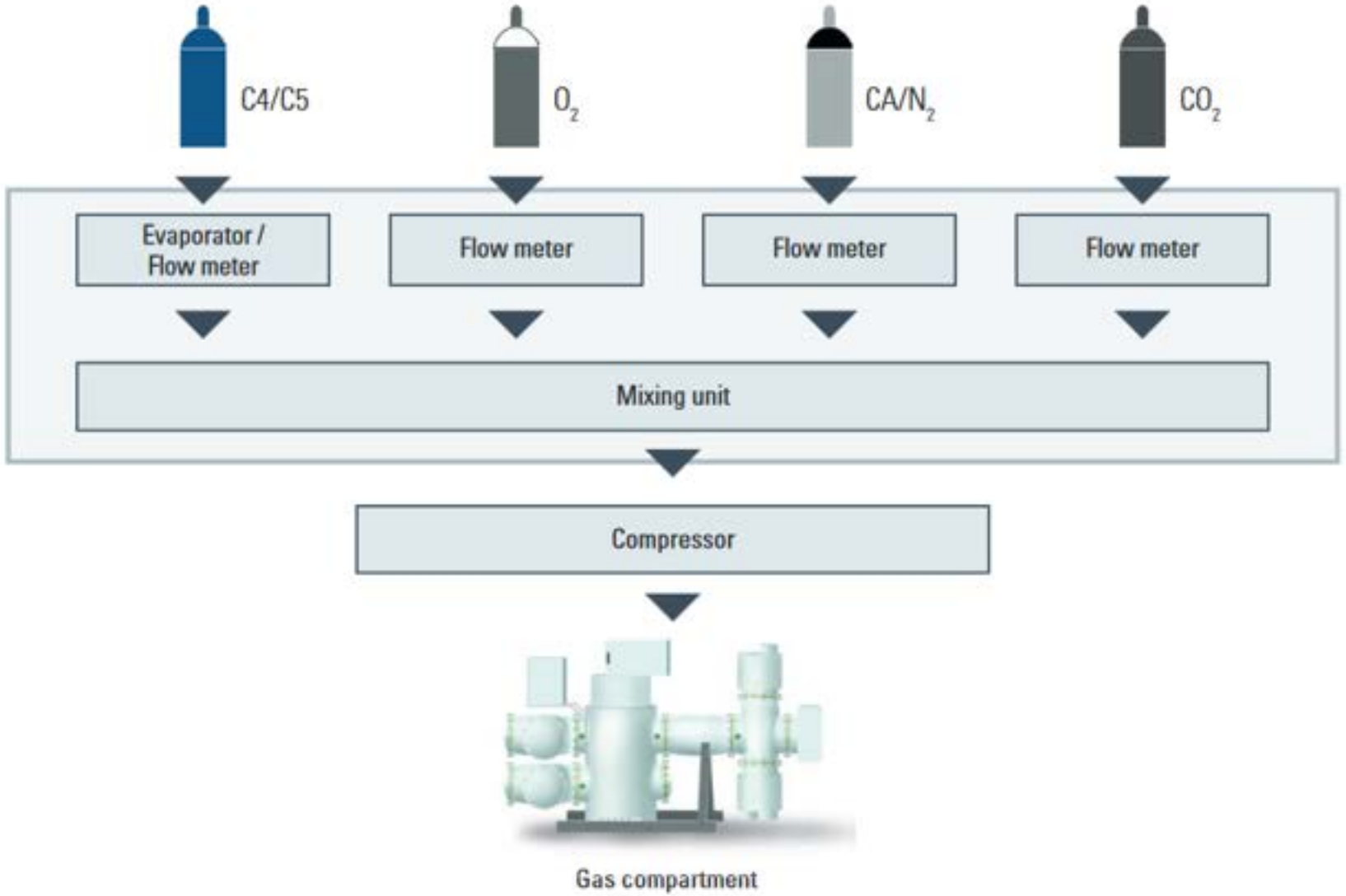
C4/C5 Off-Site Mixing

Gaseous

C4/C5 Off-Site Mixing

Liquid

C4/C5 Mixing On-Site

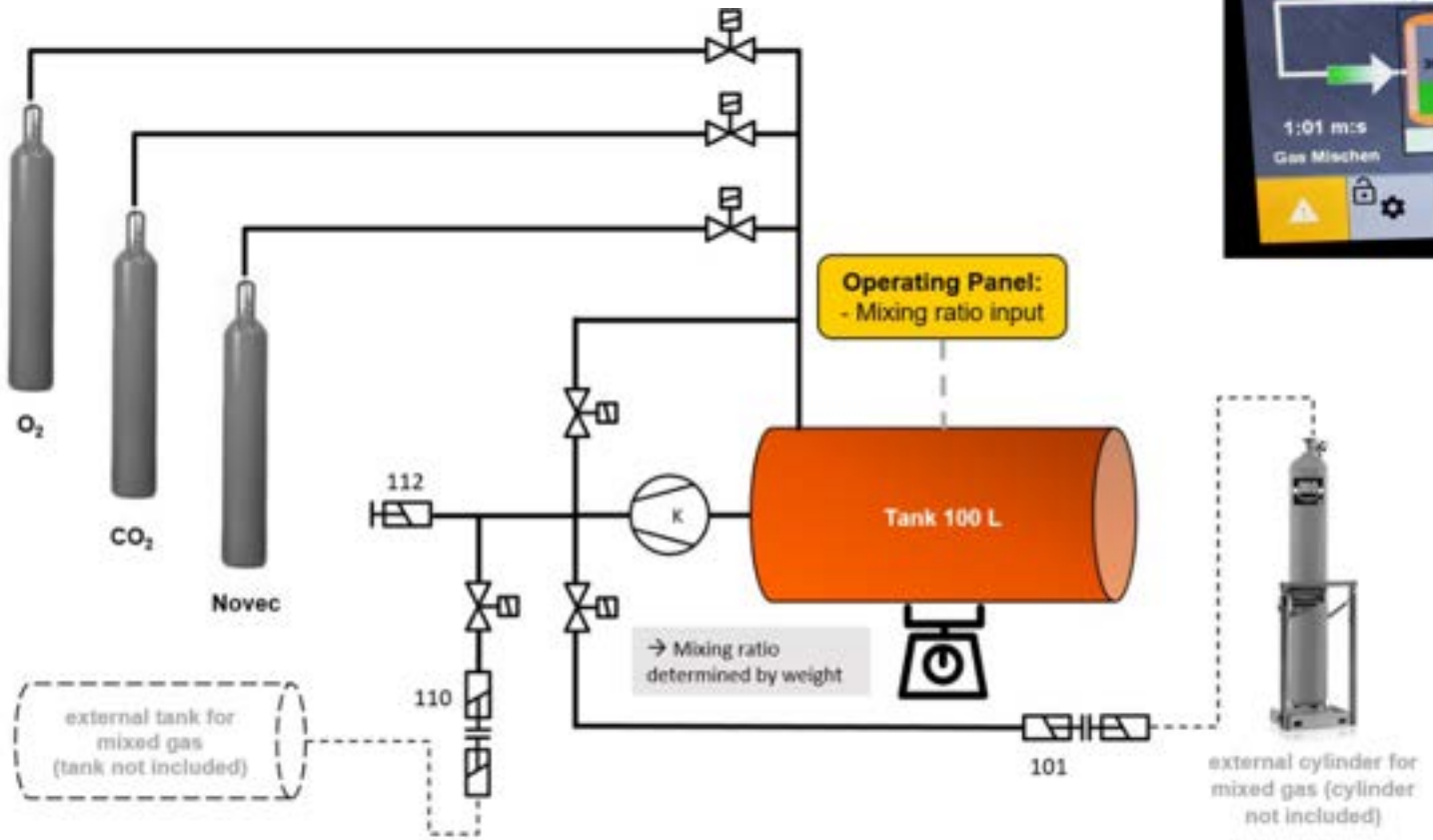


Preparation and Creating a Mixture

- Identify cylinder threads (examples C4/C5 vs SF6)
- Nitrogen Purging of cylinders prior to filling

Creating a Mixture

- Flow Diagram (in short form)
- Setting parameters on the mixing plant



Measuring a Mixture

- Using a Multi-Analyzer
- Lab Analysis
- Review of Sensors & Main Contaminants

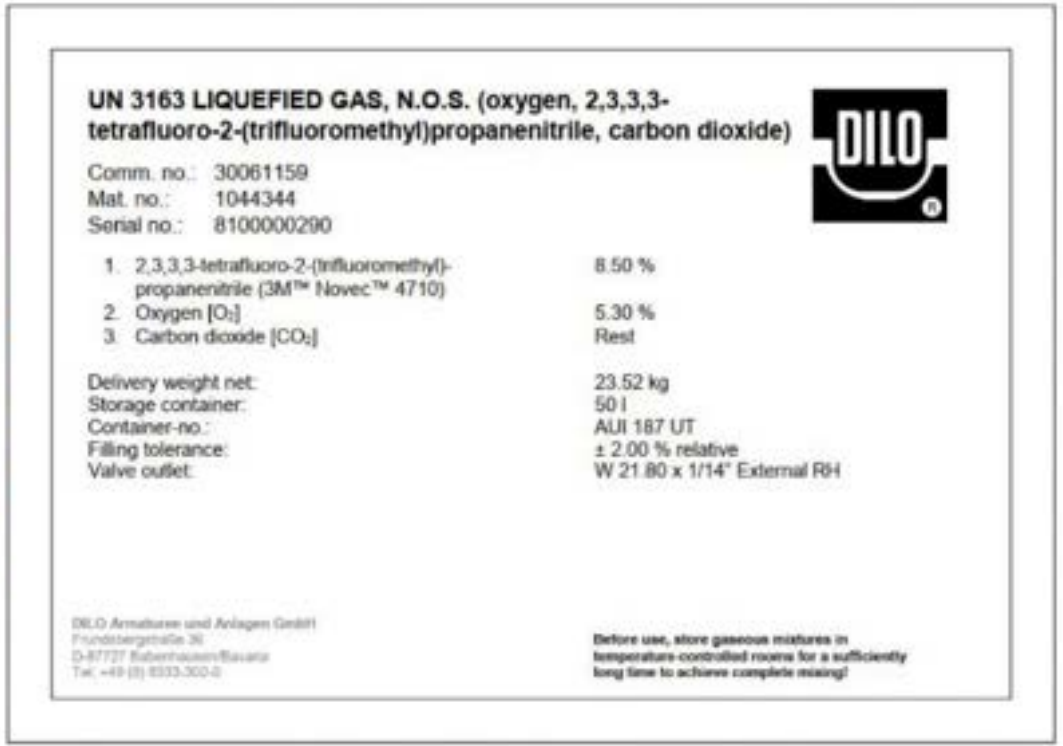
	Mol% 3M™ Novec™ 4710	Mol% 3M™ Novec™ 5110	Moisture	Mol% oxygen (O_2)	Mol% carbon dioxide (CO_2)	Concentration carbon monoxide (CO)
Measuring principle/sensor	Non-dispersive infrared sensor (NDIR)	Non-dispersive infrared sensor (NDIR)	Electronic dew point measurement (capacitive)	Electrochemical reaction	Non-dispersive infrared sensor (NDIR)	Electrochemical reaction
Measuring range	0 – 10 mol%	0 – 15 mol%	-60 °C to +20 °C	0 – 25 mol%	0 – 100 mol%	0 – 500 ppm
Measuring accuracy	≤ ±0.1 mol% (at < 7%) ≤ ±0.2 mol% (at ≥7%)	≤ ±0.1 mol% (at < 7%) ≤ ±0.2 mol% (at ≥ 7%)	≤ ±2°C (at > -40°C) ≤ ±3°C (at < -40°C)	≤ ±0.2% mol%	≤ ±2 mol%	±2% of measuring range

General Labeling

- Material # Identification →
  - Ratio of mixed gases
  - Weight of gas mixture
  - Container Size
  - Valve type Contaminants

DCGasC5*-5,90/5,60/CO2g 600l +5C mF

DCGas = DILO Certified Gas
C5-5,90/5,60/CO2 = Mixture C5 consisting of: 5.9 % Novec 5110, 5.6 % O2 und 88.5 % CO2
g = State of aggregation of the gas: here gaseous
600 l = The container: Here 600 l tank
+5°C = Ambient temperature
mF = with pressure vessel



UN 3163 LIQUEFIED GAS, N.O.S. (oxygen, 2,3,3,3-tetrafluoro-2-(trifluoromethyl)propanenitrile, carbon dioxide)

DILO

Comm. no.: 30061159
Mat. no.: 1044344
Serial no.: 8100000290

1. 2,3,3,3-tetrafluoro-2-(trifluoromethyl)-propanenitrile (3M™ Novec™ 4710)	8.50 %
2. Oxygen [O_2]	5.30 %
3. Carbon dioxide [CO_2]	Rest
Delivery weight net:	23.52 kg
Storage container:	50 l
Container-no.:	AUI 187 UT
Filling tolerance:	± 2.00 % relative
Valve outlet:	W 21.80 x 1/14" External RH

DILO Armaturen und Anlagen GmbH
Frundsbergstraße 30
D-87727 Babenhausen/Bavaria
Tel. +49 (0) 8333-302-0

Before use, store gaseous mixtures in temperature-controlled rooms for a sufficiently long time to achieve complete mixing!

QR Labeling

- Benefits for operators
  - Reduces risk of cross contamination
  - Simplifies inventory management

Gas Mixture End of Life or New beginning?

- Reconditioning is possible with C4 & C5
- Separation Plant in development
- Cons to incineration:
  - Permanent loss of product
  - Increased cost of GIE ownership
  - Extended lead times due to vendor reliance

Frequently Asked Questions

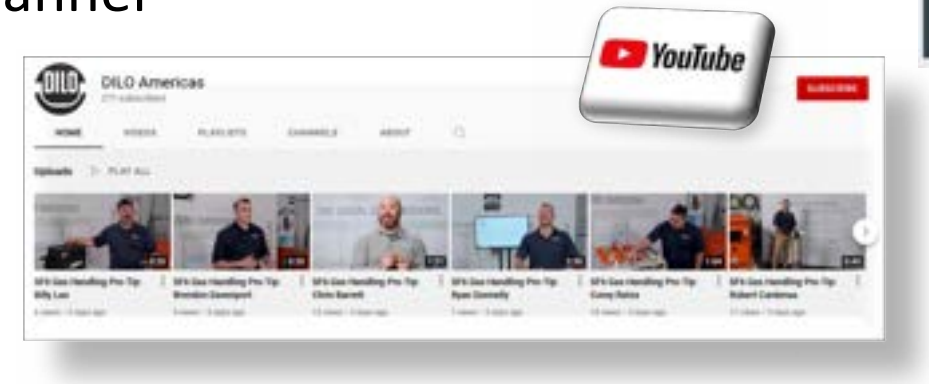
- Do I have to purchase Novec directly for a vendor to create a mixture?
- Are alternative gases able to be reconditioned?
- Can storage be liquid *AND* gaseous?
- What are ways I can simplify my documentation processes?

Closing Remarks & Resources

- DILO. WhitePapers

- DILO. Training & Certification

- DILO Media
  - Check out our Blog!
  - Pro-tip videos
  - DILO Americas – YouTube Channel



Thank you!

Questions??