# MSR-Technology:
# Experience and acceptance of alternative insulating oils based on recycled naphthenic base oils

**STARKE & SOHN GmbH**
**MINERALÖLWERK**
**Aue • Hannover • Niebüll**

Transformer Life Management
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- Content
  - Introduction
  - **M**ultiple – **S**elektive – **R**efining: MSR-Technology
  - New insulating oils – Recycled insulating oils
  - Experience
    - Performance, aging characteristics, contaminants, Stray Gassing – chracked gasses, miscibility
  - Acceptance
    - Transformer manufacturer, switchgears manufacturers, transformer operators, service companies

- Introduction – Oils & Re-raffinates in the industry

  - Manufacturer & operators of transformers
    - use for decades mineral oil-based insulating oils
    - have accepted alternative products based on esters and are willing to use new product developments, such as GTL-based insulating oils
    - and name alternative insulating oils made on the basis of re-refined base oils commonly "recycled insulating oils“

  - Manufacturers & operators of machinery & equipment, cars, trucks
    - use since decades lubricants into their aggregates, which are made on the basis of re-refined base oils
    - have overcome initial resistances and concerns

  - Develops the "conservative transformer family" similar?

- Introduction – Refining

  - Refining - general
    - refining, purification, separation and / or concentration of a raw material (for example, oil, vegetable oils, sugar, metals, sea salt) through a defined, technical process for the purpose of recovery of output amounts to differentiated and specified quality level
    - Petroleum refining, Output: LPG, naphtha, gasoline, kerosene, diesel, heating oil (light / heavy), bitumen, lubricating oils, waxes, paraffins, coke ....

  - Refining of used oils (re-refining) - general
    - processing of the raw material "waste oil" (engine, transmission, engine oils etc.)
    - peneral oil re-refining, Output: base oils, flux oils, fuel oils, lubricants

  - Refining of used transformer oils - Starke & Sohn - especially
    - processing of the raw material "used transformer oil" “
    - Starke & Sohn, Output: base oils, lubricants

- Introduction - Recycling

  - Recycling according to German Wast Management & Recycling Act (KrWG)*
    - § 3-25: recycling within the meaning of this Act shall be any recovery operation by which waste is reprocessed into products, materials or substances, whether for the original or other purposes; it shall include the reprocessing of organic material but shall not include energy recovery and reprocessing into materials that are to be used as fuels or for backfilling operations.
  - Recycling according to ECHA guidance
    - extraction of a substance (or object) from waste in conjunction with a purpose and a demand for this substance (or object). The substance or object must satisfy the technical requirements for the specific purposes of satisfying existing legislation and standards applicable to products and do not become adverse environmental or human health impacts.

* KrWG, www.gesetze-im-internet.de
** when is a waste ceases to be waste, ECHA s:. Guidance on waste and recovered substances, Version 2, May 2010

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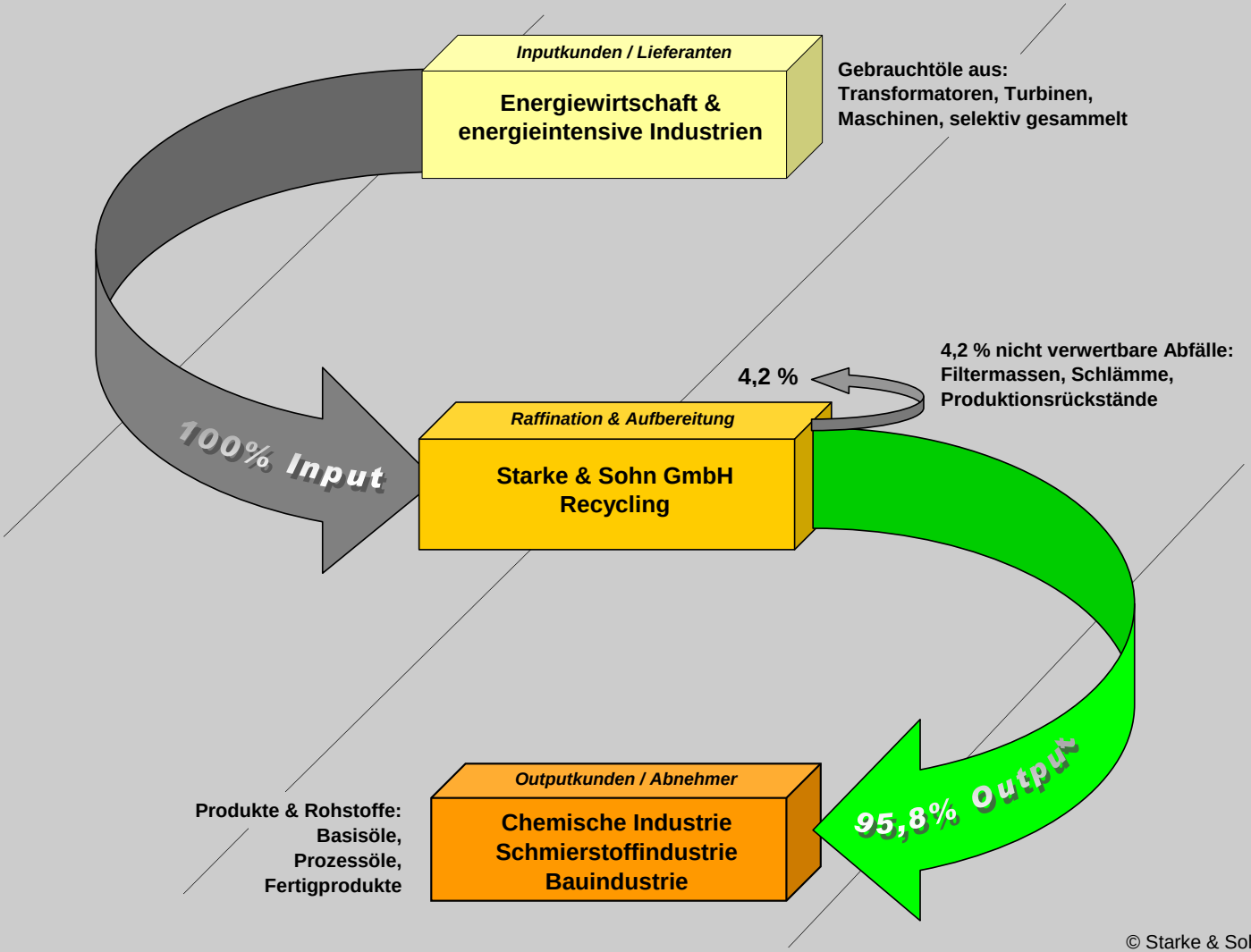
## Starke & Sohn GmbH: Recycling - kreislaufwirtschaftlicher Wertstoffstrom



- Recycling of used transformer oils by MSR-Technology :
  - **M**ultiple - **S**elective – **R**efining of used transformer oils by specialized processing
  - Based on defined and analytically determined metrics for each raw material input
  - Batch-oriented production according to specification (25 – 100 t batches)
  - Mechanical, thermal and physical-chemical process technologies, core competence: Adsorption

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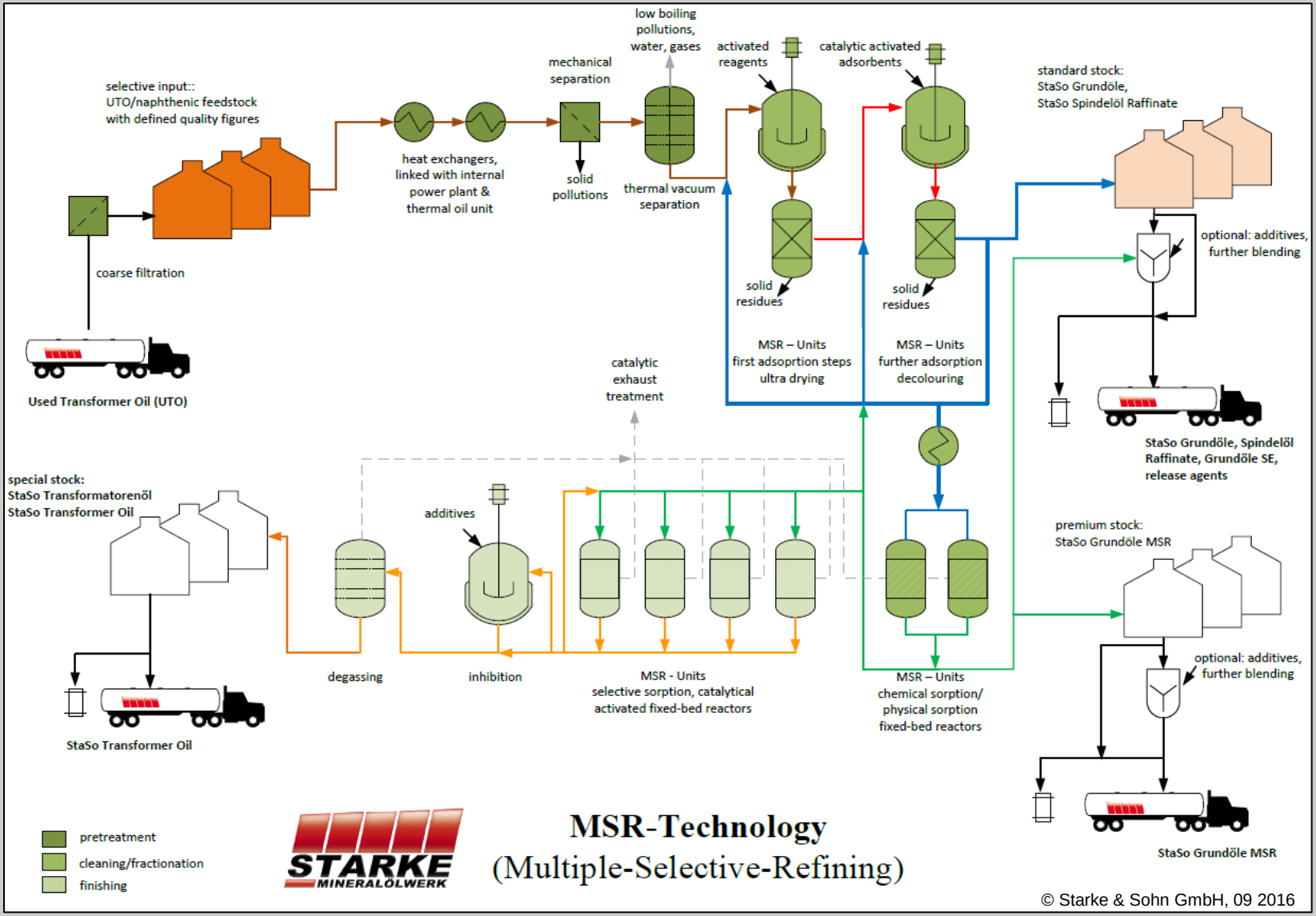
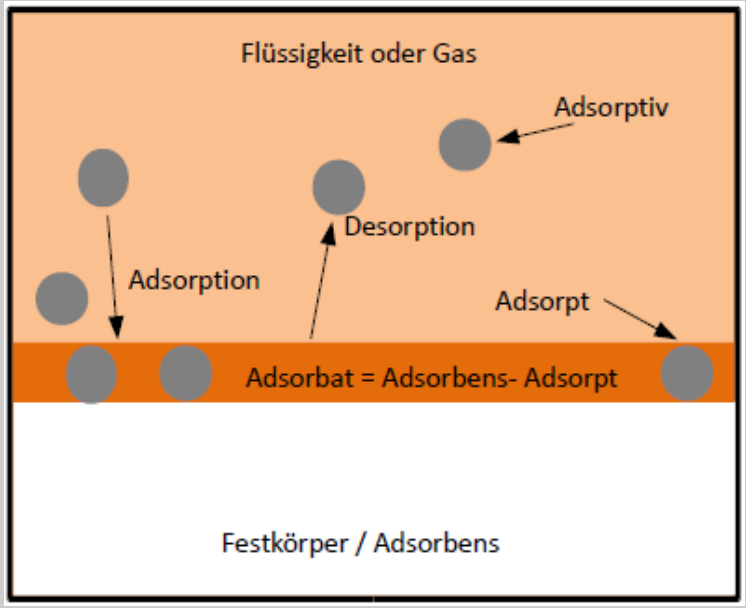
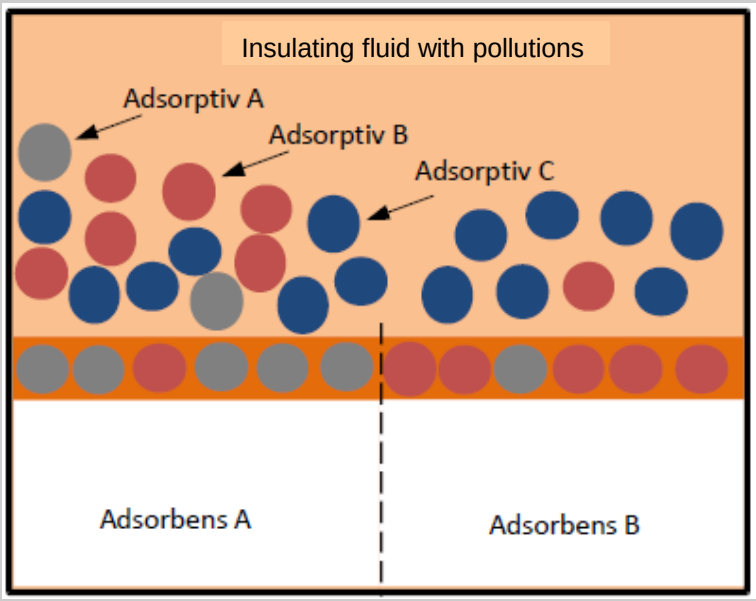


- Selective refining - core process: selective adsorption

Basic concept: Adsorption




specially: selective adsorption



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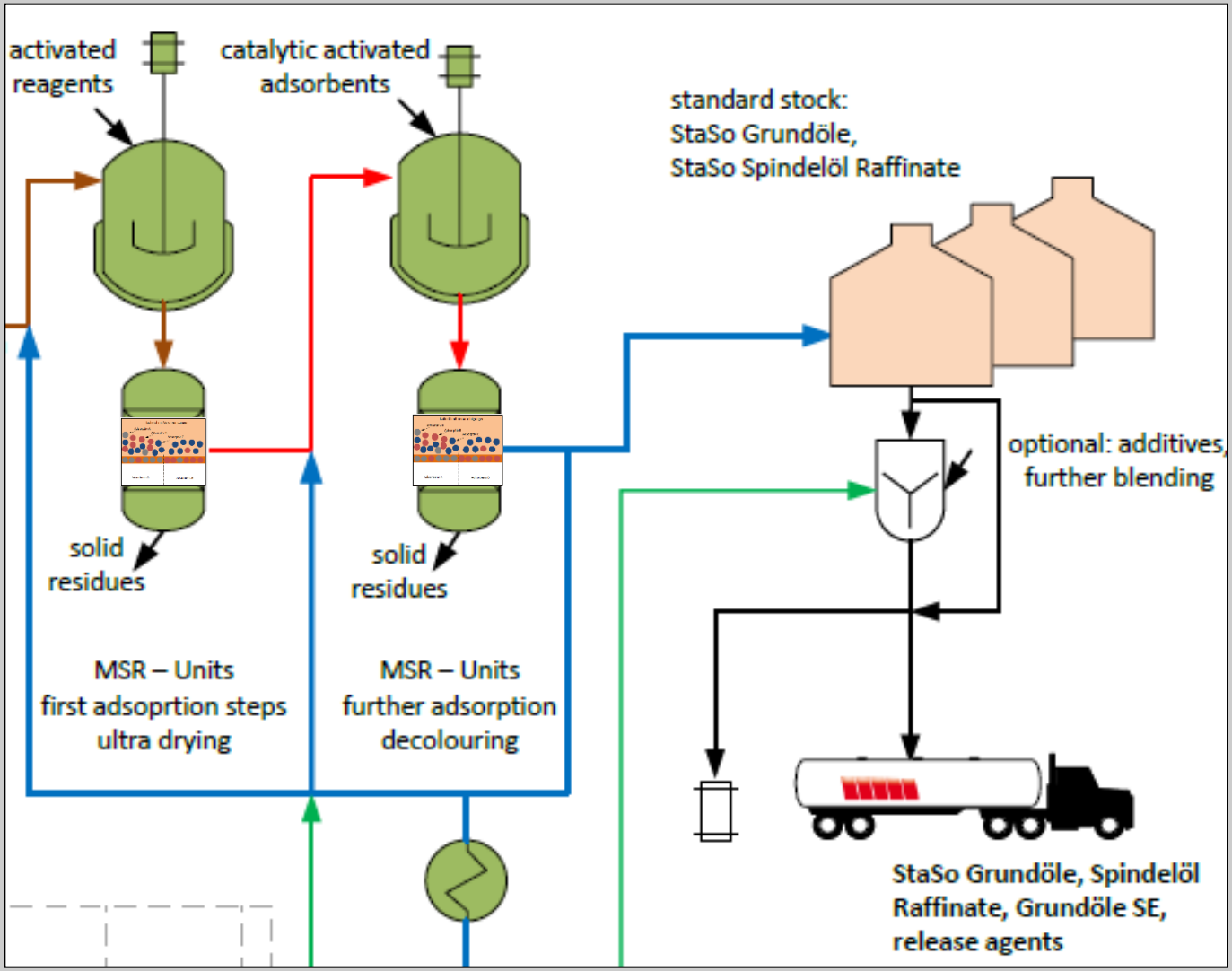


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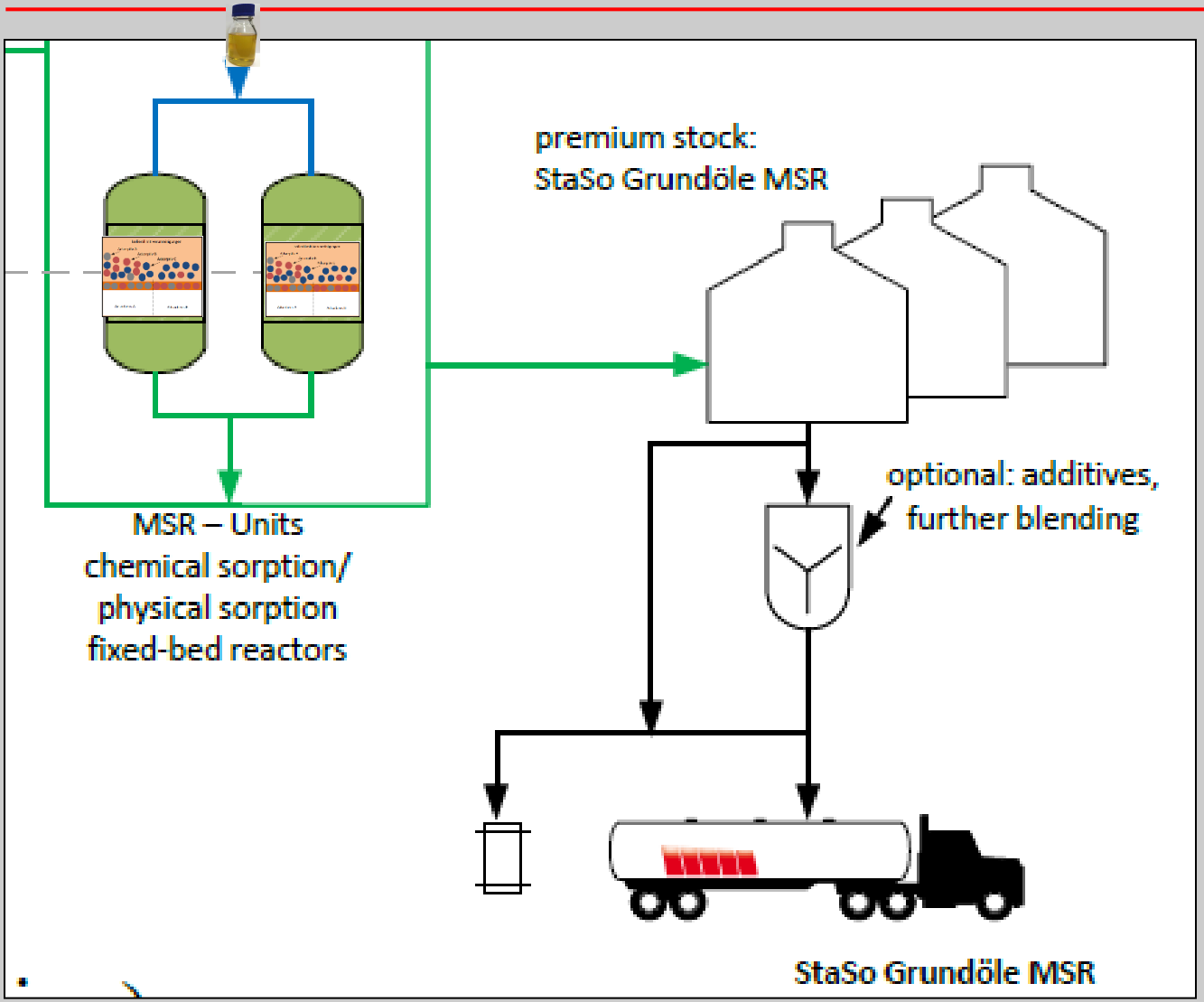
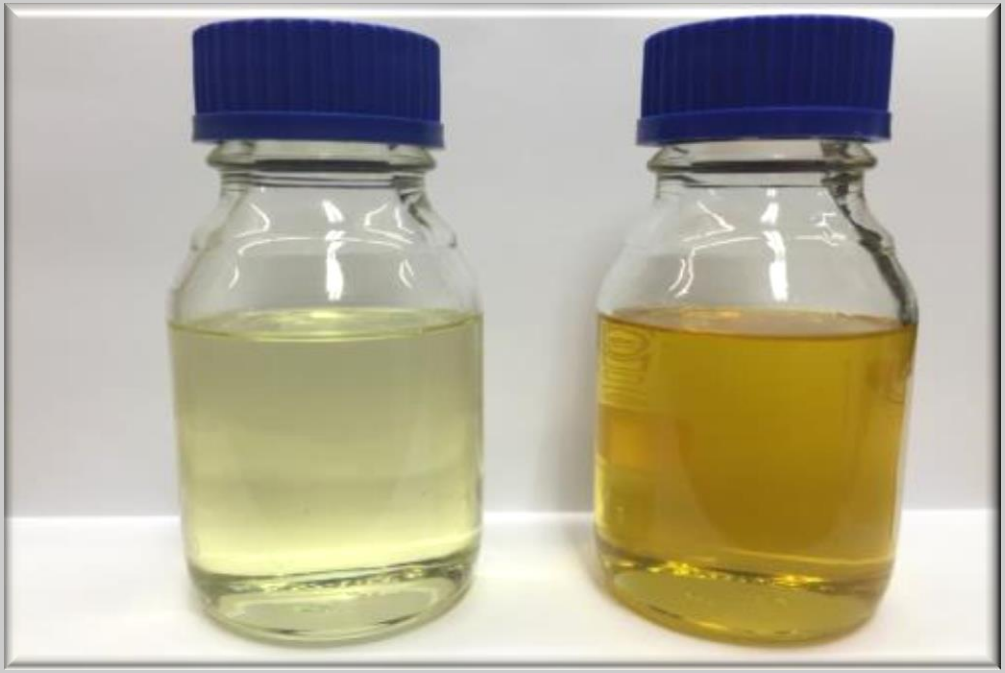



- Premium: **M**ultiple – **S**elective – **R**efined

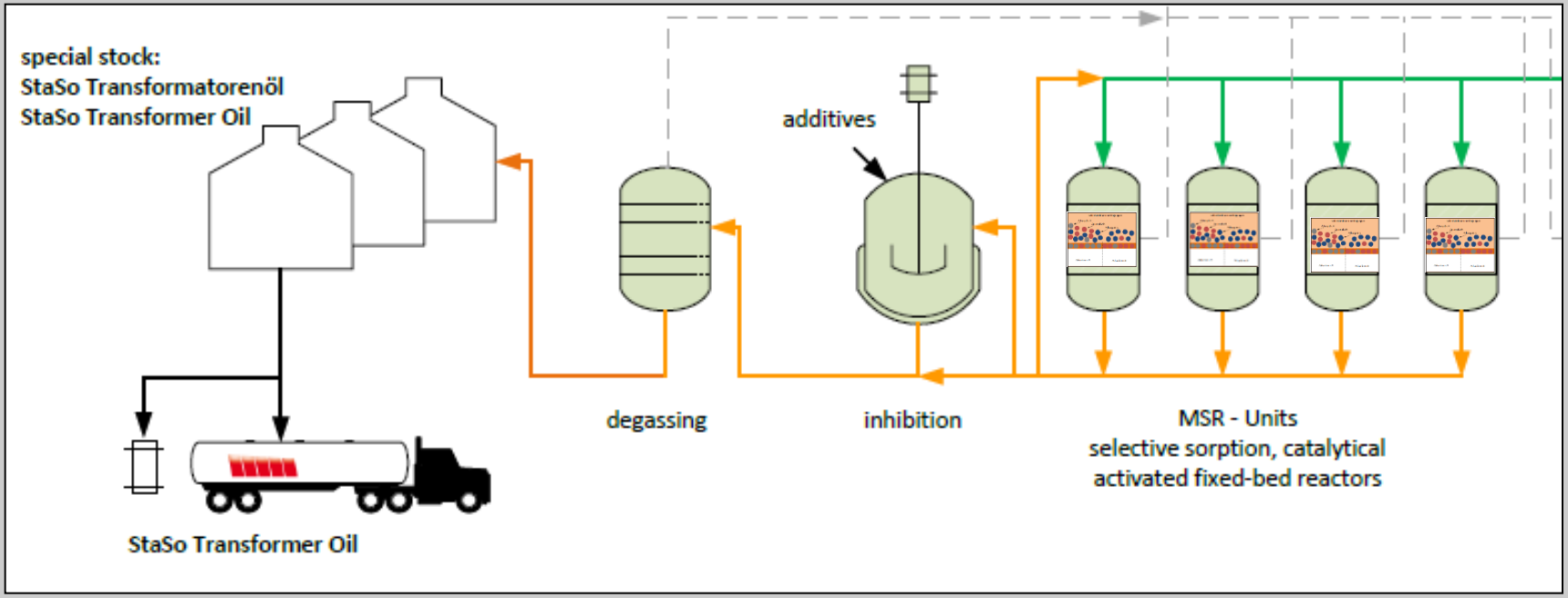


| Premium | Standard |
| --- | --- |
| StaSo Grundöl MSR 10/40 | StaSo Grundöl 10/40 |

High solubility for additives, low pour point, clear, almost colorless and odorless, API Group V base oil

- Premium: **M**ultiple – **S**elective – **R**efined

  – StaSo Grundöle MSR = basis for StaSo Transformer Oil




- <u>New insulating oils – recyceled insulating oils – Specs = Basis:</u>
  - Established standard IEC 60296:2012
    - for „Unused mineral insulating oils for transformers and switchgear“
  - Additional standard IEC 62701:2015
    - for „Recycled mineral insulating oils for transformers and switchgears“ – inhaltlich de facto identical, technical requirements (withdrawn from alleged grounds of discrimination)
  - Current in revision/maintenance: IEC 60296
    - IEC, TC10 Fluids for electrotechnical applications, MT 38 Maintenance of IEC 60296, a uniform standard for mineral insulating oils - regardless of the source of the oil molecules (crude oil, used oil, gas)

- ## New oil - Recycled insulating - StaSo Transformer Oil I

| | Unit | Test method | Guaranteed data IEC 60296, Tab 2 + (7.1) | | Typical data StaSo Transformer Oil I |
|---|---|---|---|---|---|
| | | IEC | Min | Max | |
| **1.Function** | | | | | |
| Viscosity, 40°C | $mm^2/s$ | ISO 3104 | | 12,0 | 9,8 |
| Viscosity, -30°C | $mm^2/s$ | ISO 3104 | | 1800 | 800 |
| Pour point | °C | ISO 3016 | | -40 | -50 |
| Water content (drum, IBC) | mg/kg | IEC 60814 | | 40 | 7 |
| Water content (bulk) | mg/kg | IEC 60814 | | 30 | 7 |
| Breakdown voltage | | | | | |
| -Before treatment | kV | IEC 60156 | 30 | | 40-70 |
| -After treatment | kV | | 70 | | >75 |
| Density, 20°C | $kg/m^3$ | ISO 12185 | | 895 | 870 |
| Dielectric dissipation factor (DDF) at 90°C | | IEC 60247 | | 0,005 | 0,001 |
| Particle counting | | IEC 60970 | | | 16 / 14 / 10 |

**- packed, e.g. in Drums & IBC:**

**- bulk:**

- New oil - Recycled insulating - StaSo Transformer Oil I

| | Unit | Test method | Guaranteed data IEC 60296, Tab 2 + (7.1) | | Typical data StaSo Transformer oil I |
|---|---|---|---|---|---|
| | | IEC | Min | Max | |
| **2. Refining / stability** | | | | | |
| Appearance | | IEC 60296 | Clear, free from sediment | | complies |
| Acidity | mg KOH/g | IEC 62021 | | 0,01 | <0,01 |
| Interfacial tension | mN/m | ISO 6295 | 40 | | 45 |
| Corrosive sulphur | | DIN 51353 | non corrosive | | non corrosive |
| Corrosive sulphur | | ASTM D 1275 B | non corrosive | | non corrosive |
| Corrosive sulphur | | IEC 62535 | non corrosive | | non corrosive |
| Total sulphur content | mg/kg | ISO 14596 | | (500) | 400 |
| DBDS | | IEC 62697-1 | | 5 | not detectable |
| Inhibitors | Wt % | IEC 60666 | 0,08 | 0,40 | 0,38 |
| Metal passivator additives | mg/kg | IEC 60666 | not detectable | | not detectable |
| - TTAA (metal passivator Irgamet 39®) | | IEC 60666 | | 5 | not detectable |
| - TAA (metal passivator Irgamet 30®) | | UPLC-MS/MS | | 5 | not detectable |
| - BTA (metal passivator) | | IEC 60666 | | 5 | not detectable |
| - TTA (metal passivator) | | IEC 60666 | | 5 | not detectable |
| Pour Point depressant | | IEC 60666 | not detectable | | not detectable |
| 2-Furfural content | mg/kg | IEC 61198 | | 0,05 | <0,05 |

- New oil - Recycled insulating - StaSo Transformer Oil I

| | Unit | Test method | Guaranteed data IEC 60296, Tab 2 + (7.1) | | Typical data StaSo Transformer oil I |
|---|---|---|---|---|---|
| | | IEC | Min | Max | |
| **3. Performance** | | | | | |
| Oxidation stability | | | | | |
| At 120°C, 500 h | | IEC 61125 C | | | |
| Total acidity | mg KOH/g | 1.9.4. of IEC 61125 | | 1,2 (0,30) | 0,04 |
| Sludge | Wt % | 1.9.1. of IEC 61125 | | 0,8 (0,05) | <0,02 |
| DDF/90°C | | 1.9.6. of IEC 61125 | | 0,500 (0,05) | 0,020 |
| **4. Health, safety and environment (HSE)** | | | | | |
| Flash point, PM | °C | ISO 2719 | 135 | | 145 |
| PCA content | Wt % | IP 346 | | 3 | <3 |
| PCB content | Wt % | IEC 61619 | | 2 | not detectable |
| **5. Other** | | | | | |
| Structural analysis | | IEC 60590/ | | | |
| - Aromativ hydrocarbons | | Brandes | | | 9 |
| - Paraffinic hydrocarbons | | | | | 52 |
| - Naphthenic hydrocarbons | | | | | 39 |

- Quality assurance: continuous fulfillment of defined Specs
  - Certified according to DIN EN ISO 9001:2008
  - Internal analytics & certificates of analysis per delivery
  - Batchwise production – batchwise approval (base oils & transformer oils)
  - StaSo Transformer Oil: 100 t / batch approval, including oxidation stability

- Experience: performance

  - External, independent analysis show performance according to IEC 60296:2012, (7.1)
    - for „ Unused mineral insulating oils for transformers and switchgear“

  - No long-term experience in power transformer area yet due to implementation of MSR-Technology in 2014
    - but

  - Analogue closures through experiences in the field of mobile oil regeneration
    - mobile oil regenerations lead to sustained reliable oil parameters & -conditions - stationary refining is more effective & efficient

- Experiences: Sustainability of essential parameters of insulating oil

| 300 MVA Trafo, Bj. 1974, 62 t Isolieröl, Shell Diala D | vor Reg. in 10 2010 | nach Reg. in 10 2010 | nach Reg. in 03 2014 | Limits IEC 60422 |
|---|---|---|---|---|
| | | | | |
| Farbzahl | 3,5 | 0,5 | 1,5 | |
| NZ (mg/g) | 0,2 | <0,01 | 0,02 | <= 0,15 |
| Durchschlagsspannung (kV) | > 80 | 79,2 | > 80 | >= 50 |
| Verlustfaktor | 0,0323 | 0,0014 | 0,005 | < 0,2 |
| Wassergehalt (ppm) | 5 | 2 | 7 | <= 10 |
| Grenzflächenspannung (mN/m) | 15,4 | 41,7 | 29 | >= 22 |
| Inhibitorgehalt (%) | n.n. | 0,38 | 0,33 | > 0,15 |
| Korrosiv. Schwefel | nicht korrosiv | nicht korrosiv | nicht korrosiv | nicht korrosiv |

- Experiences: Sustainability of mobile regeneration, power couplers 95 t

| | | | | | |
|---|---|---|---|---|---|
| **Geräteart** | Transformator | **Leistung** | 600 MVA | **Ölmenge** | 95to |
| **Fabriknummer** | N303207 | **Übersetzung** | 380/220kV | **Entnahmestelle** | Ölprobehahn unten |
| **Baujahr** | 1979 | **Isolierflüssigkeit** | Texaco | **Regenerationsdauer** | 31 Tage |
| **Typ** | TFSN 8856 | **Fülldatum** | unbekannt | **Datum** | 04.10. - 03.11. |
| **Hersteller** | Trafo Union | | | | |

Assessment of sustainability by comparing the oxidation stability according to IEC 61125-C (500h)

**Results after mob.Reg:**

**total acid: 0,82 mg KOH/g**

**sludge: 0,19 %**

**DDF/90°C: 0,205**

| | | | |
|---|---|---|---|
| **Entnahmedatum** | 03.11.2011 | **Geräteart** | Transformator |
| **Eingangsdatum** | 04.11.2011 | **Fabriknummer** | N303207 |
| **Prüfdatum** | 24.01.2012 | **Baujahr** | 1979 |
| **Entnahmestelle** | unten | **Typ** | TFSN 8856 |
| **Entnahmetemperatur** | 52°C | **Hersteller** | Trafo Union |
| **Probenmenge** | > 1 Liter | **Leistung** | 600 MVA |
| **Probengefäß** | Aluminumflasche | **Übersetzung** | 380/220 kV |
| **Probennehmer** | Nissen | **Isolierflüssigkeit** | Texaco |
| | | **Fülldatum** | unbekannt |
| | | **Gesamt-/Ölgewicht** | -/95to |

**Prüfergebnisse**

| Analyseart | Norm | Analysenwert | Einheit |
|---|---|---|---|
| Oxidationsstabilität 500h; inhibierte Öle | IEC 61125 (Verfahren C) | | |
| Gesamtsäure | IEC 61125 (Verfahren C) | 0,82 | mg KOH/g |
| Schlammgehalt | | 0,19 | % |
| Dielektrischer Verlustfaktor 90°C | IEC 60247 | 0,2047 | |

**Bemerkung** Für regenerierte Transformatorenöle existieren keine genormten Vorgaben über die Nachhaltigkeit der Behandlung. Daher ist auch keine normgerechte Bewertung der Ergebnisse möglich.
Hinweise gibt Vergleich mit der "IEC 60296 - Neue Isolieröle für Transformatoren und Schaltgeräte.". In dieser sind folgende Grenzwerte angegeben:

- Gesamtsäure: max. 1,2 mg KOH/g
- Schlamm: max. 0,8 %
- Dielektrischer Verlustfaktor 90°C: max. 0,500

**New oil IEC 60296:**

**max. 1,2 mg KOH/g**

**max. 0,8 %**

**max. 0,5**

= > regenerated oil may have better values than is required for fresh oil!

- Experience: aging behavior / oxidation stability
  - Comparison oxidation stability according to IEC 61125 (120°C, 500h)

**e.g. after mob.Reg:**

**total acid:** 0,82 mg KOH/g
**sludge:** 0,19 %
**DDF/90°C:** 0,205

**StaSo Transformer Oil I:**

**total acid:** 0,04 mg KOH/g
**sludge:** < 0,02 %
**DDF/90°C:** 0,02

**Standard New Oil IEC 60296:**

max. 1,2 mg KOH/g
max. 0,8 %
max. 0,5

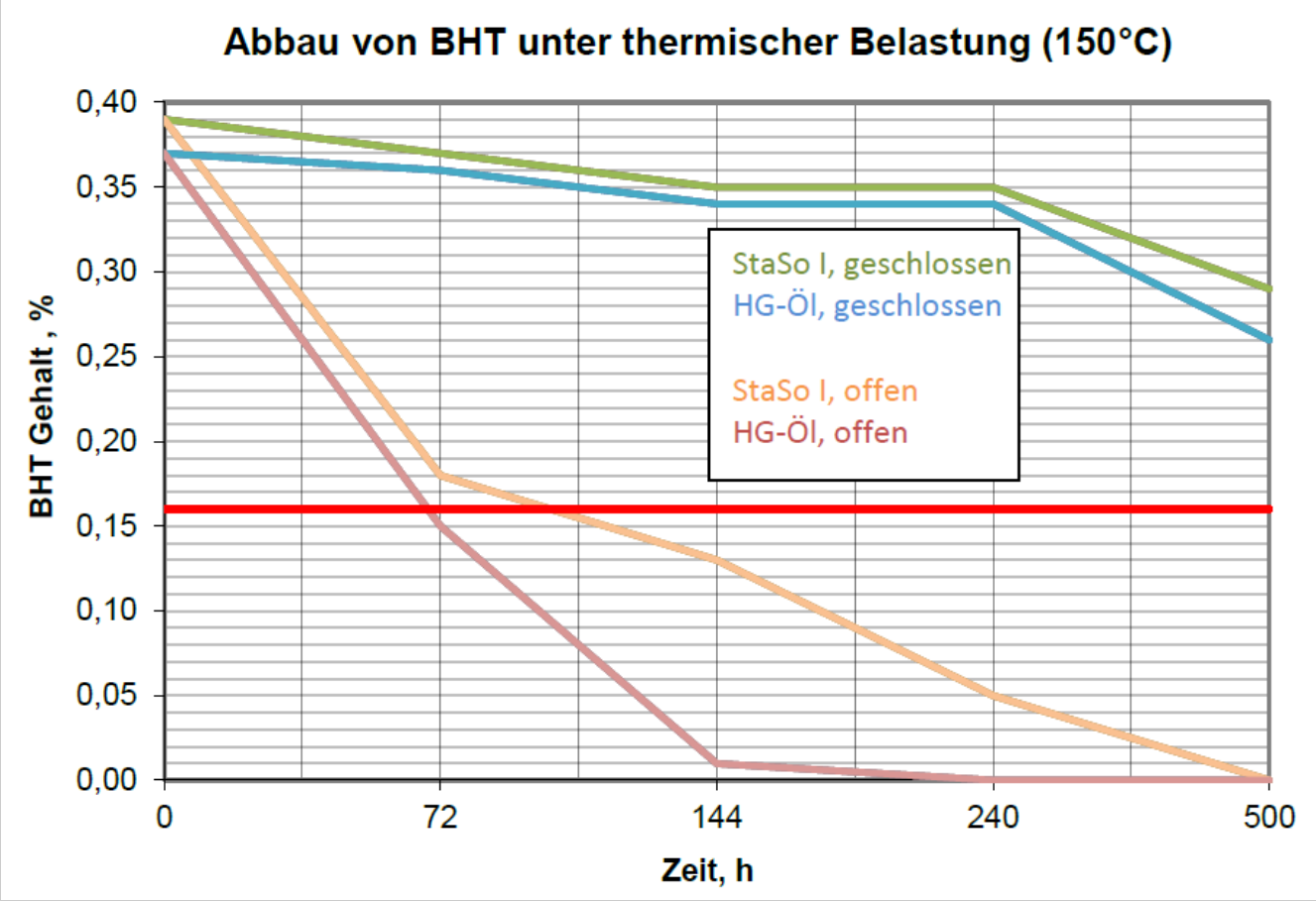
**HG-New Oil IEC 60296, 7.1:**

max. 0,3 mg KOH/g
max. 0,05 %
max. 0,05

**mobile regeneration => Standard-Insulating oil -Level**

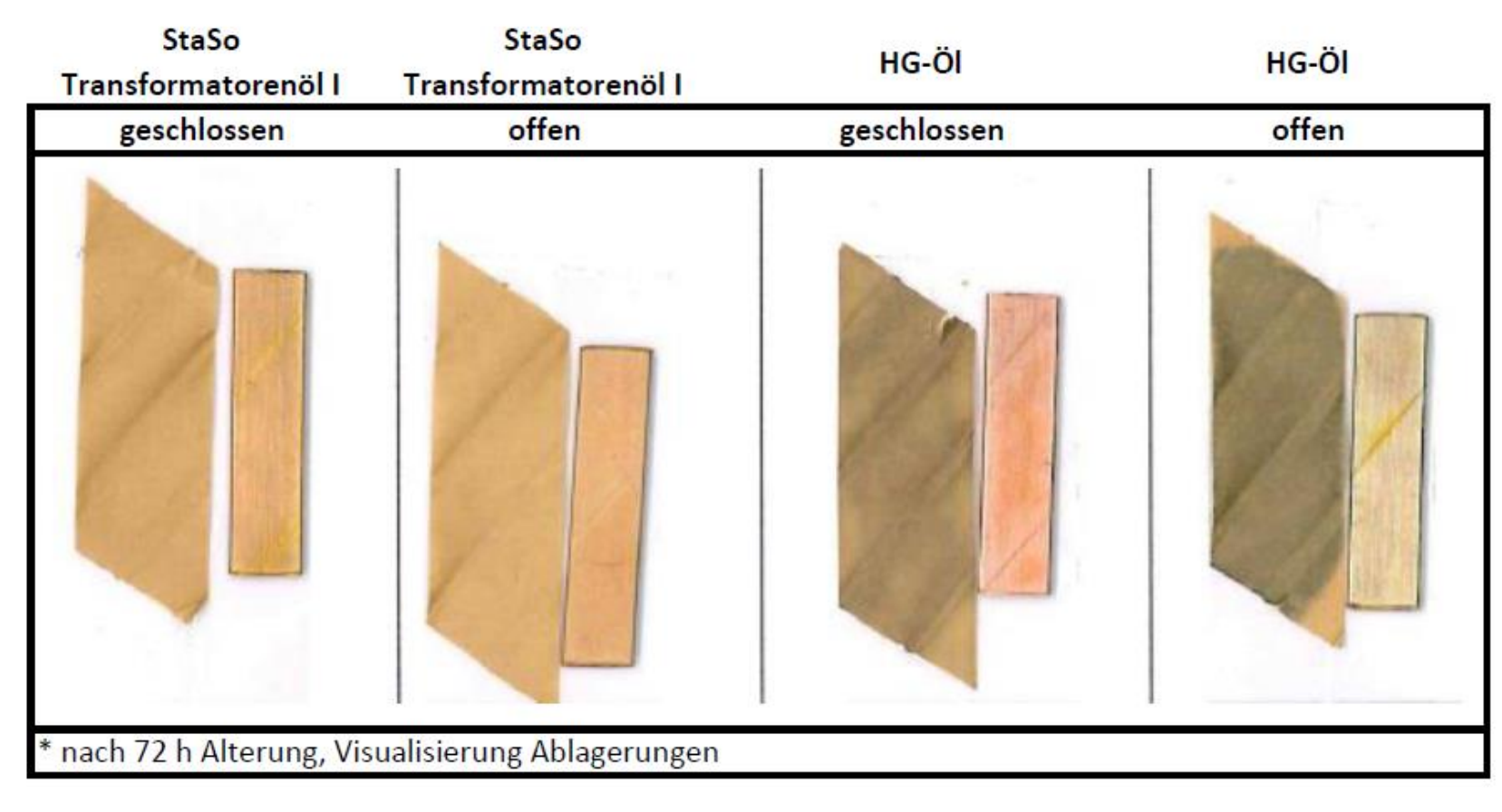
**stationary refining => High-Grade-Insulating oil-Level**

- Experience: aging behavior - no faster degradation of inhibitor




StaSo Transformatorenöl I und ein naphthenbasisches inhibiertes High-Grade-Isolieröl im Vergleich. Für den Test wurden 15ml in 20ml Vials jeweils offen und geschlossen bei 150°C gealtert und der Abbau des Inhibitors bestimmt.

- Experience: aging behavior - no increased sediment



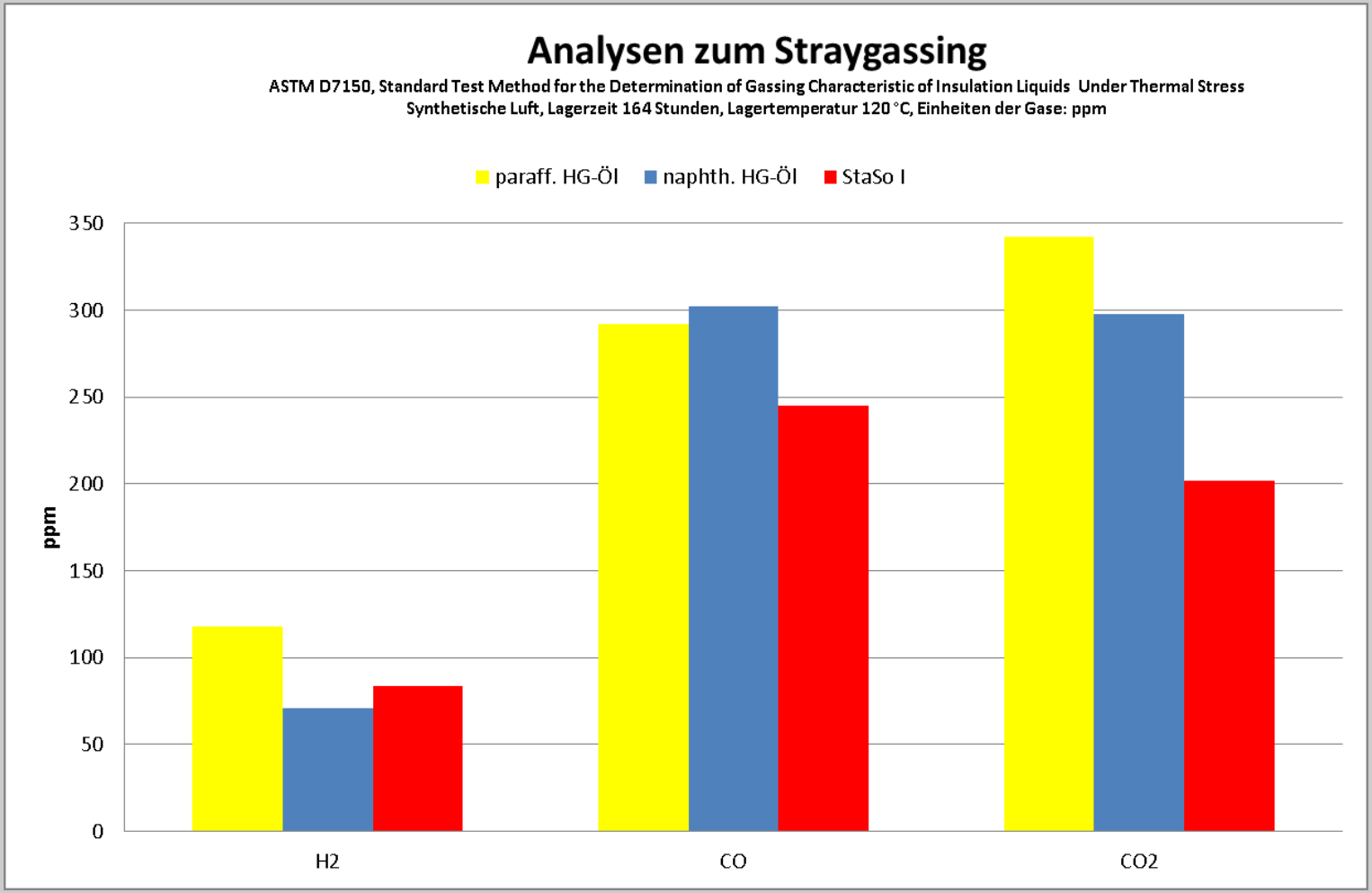
- Experience: impurities - no increased metal particles

**Die Untersuchung des obigen Musters ergab folgendes Resultat:**

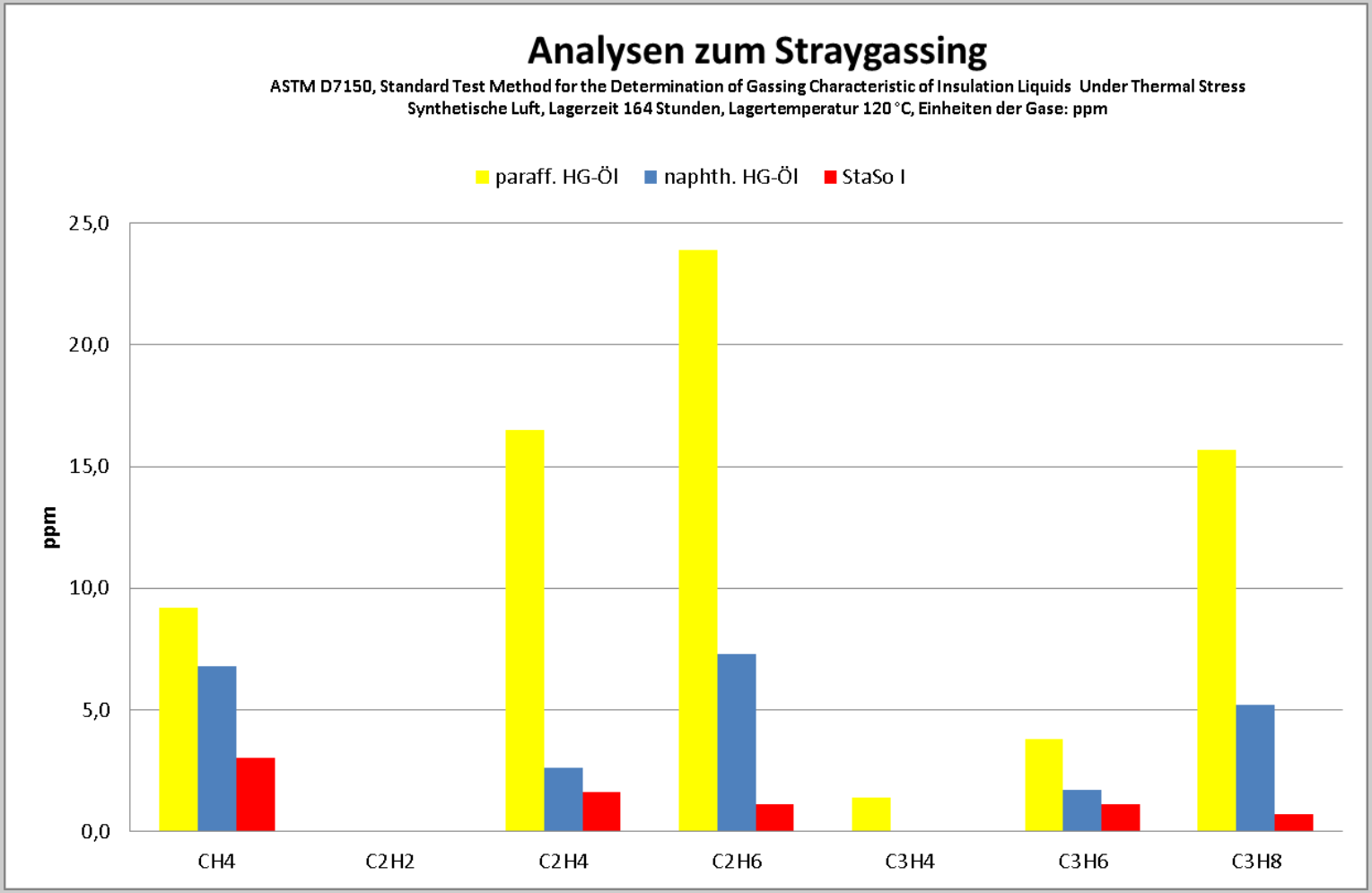
| | | | |
|---|---|---|---|
| Silber, Ag | ICP-Scan | <1 | mg/kg |
| Aluminium, Al | ICP-Scan | 2 | mg/kg |
| Bor, B | ICP-Scan | <1 | mg/kg |
| Barium, Ba | ICP-Scan | <1 | mg/kg |
| Calcium, Ca | ICP-Scan | <1 | mg/kg |
| Cadmium, Cd | ICP-Scan | <1 | mg/kg |
| Chrom, Cr | ICP-Scan | <1 | mg/kg |
| Kupfer, Cu | ICP-Scan | <1 | mg/kg |
| Eisen, Fe | ICP-Scan | <1 | mg/kg |
| Kalium, K | ICP-Scan | <1 | mg/kg |
| Magnesium, Mg | ICP-Scan | <1 | mg/kg |
| Mangan, Mn | ICP-Scan | <1 | mg/kg |
| Molybdäen, Mo | ICP-Scan | <1 | mg/kg |
| Natrium, Na | ICP-Scan | <1 | mg/kg |
| Nickel, Ni | ICP-Scan | <1 | mg/kg |
| Phosphor, P | ICP-Scan | <1 | mg/kg |
| Blei, Pb | ICP-Scan | <1 | mg/kg |
| Silicium, Si | ICP-Scan | <1 | mg/kg |
| Zinn, Sn | ICP-Scan | <1 | mg/kg |
| Titan, Ti | ICP-Scan | <1 | mg/kg |
| Vanadium, V | ICP-Scan | <1 | mg/kg |
| Zink, Zn | ICP-Scan | <1 | mg/kg |

* Source: external ICP-Analysis, Intertek, P160708, 08 2015

- Experience: straygassing - tend to have lower gas formation



- Experience: straygassing - tend to have lower gas formation



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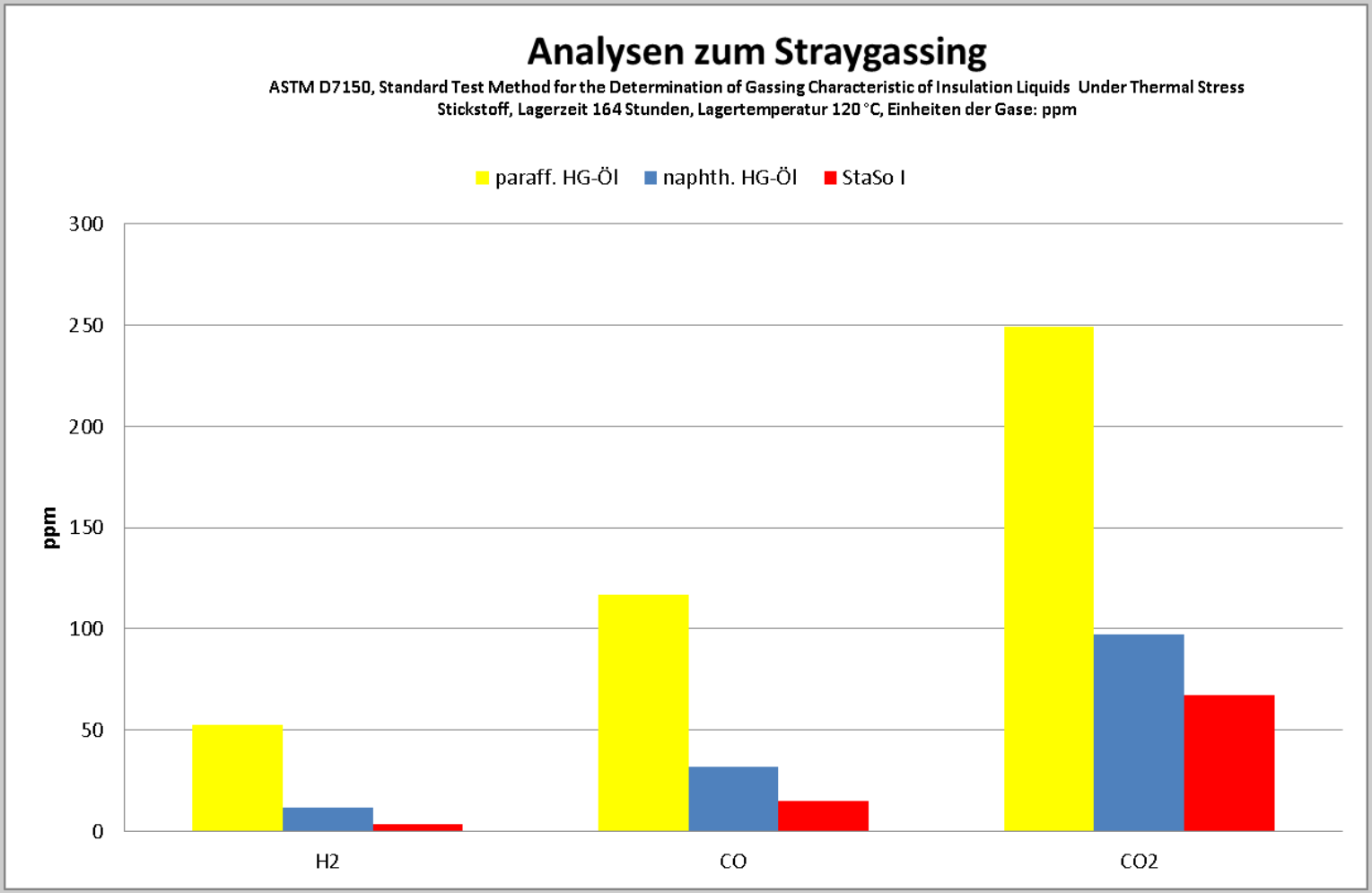

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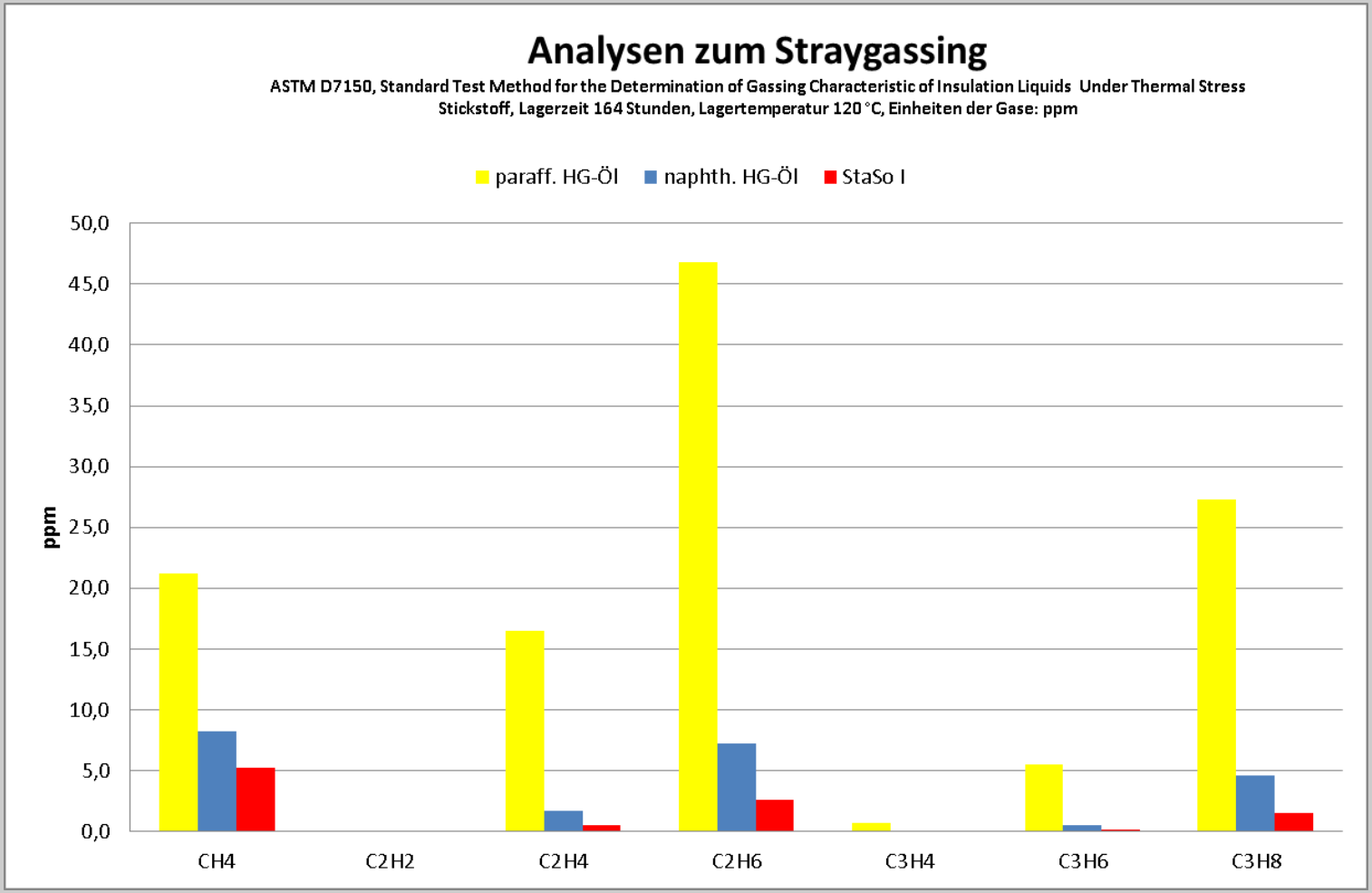

- Experiences: miscibility - no problems expected

  - StaSo Transformer Oils are miscible and compatible
    - with all the insulating oils of the same class, the same group, same value LCSET (Lowest Cold Start Energizing Temperature - starting temperature under charge: standard -30 ° C)

  - In doubt:
    - miscibility analysis
    - Foaming, oxidation stability, corrosive sulfur / potential corrosiveness

- Acceptance StaSo I: transformer manufacturer (OEM)

  - manufacturer of distribution transformers
    - number of current approvals : 7 in europe
    - usually product approval on the basis of in-house tests
    - thousands of transformers filled trouble-free and in use

  - manufacturer of power transformers
    - number of current approvals : 4 in europe
    - usually product approvals on the basis of in-house tests
    - announced first first fill project
    - sporadically in the positioning phase : waiting for the IEC Standard

  - expectations: over average price advantage
    - why?
    - must "recycled" products be cheaper?

- Acceptance StaSo I: manufacturer of tap changer

  - statement world leader
    - specified for use in manufactured tap-changers:
      - : „Oils according to IEC 60296 or equivalent standards“
    - recycled insulating oil, which meets the same limits, are considered as equivalent standard
    - there are no concerns about using appropriate, recycled mineral oils in tap changers

- Acceptance StaSo I: transformer operators

  - Transmission grid and distribution grid operators :
    - increasing acceptance and use in the service fill area
    - i.e. in case of tap changer revisions: the confirmation of the manufacturer is given (MR)
    - direct approvals from the ranks of energy suppliers (eg. E.ON, RWE, EnBW, Steag, Vattenfall) are helpful and are already partly given
    - readiness rises to request explicitly StaSo I in cases of transformer procurements at the OEM and therefore also in the first fill.
    - in cases of inspections / repairs increasingly been recommended and used by the service companies

- Acceptance StaSo I: transformer operators

  - Power generators / power plant operators
    - already explicit approvals given
    - readiness to request StaSo I explicitly in the cases of transformer procurements rise
    - communication & definition of responsibilities between transformer manufacturers & operators is crucial here
    - increasing number of approvals by OEM is supportive

- Acceptance StaSo I: Service companies

  - Service in the low- to medium-voltage range
    - mainly lower demand quantities of packaged goods
    - quality level IEC 60296 is decisive here, the "brand" not as crucial

  - Service in the high voltage range
    - at repairs / retrofits customer demand for certain insulating oils (only one type in network)
    - but: service companies recommend increasingly StaSo I as similar, technical alternative with reasoning : quality, approvals, references

- Summary: experience and acceptance

  - Quality and performance of StaSo transformer oils are competitive
  - The explained refining technology ensures a consistant quality level
  - Such insulating oils will be explicitly integrated into future relevant specifications and standards
  - A tendencial advantageous oxidation and “stray gassing" behavior is to be verified through further analysis and practical experience
  - An increasing acceptance by transformer manufacturers, grid operators, power plant operators and service companies is given
  - Environmental, economic and technical aspects contribute to this as well

- Outlook:
  - Long-term relationships within the energy industries are helpful
    - reliability, partnership & credibility is given
    - versatile reputations from other areas around the theme of transformer oil
      - recycling
      - mobile regeneration
      - transformer oil analysis
  - Recycled insulating oils will establish themselves on the market
    - as a useful addition to the well-known qualities
    - the "conservative transformer family" will develop and open up similar to other branches of industry with regard to the use of recycled products

Thank you very much

for your attention