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O&M Cost Reduction of a Coal-Fired US Merchant Plant Through an Optimized SCR Management Strategy Involving Catalyst Regeneration

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The Indiantown Generating Plant

Location: Indiantown, Florida

Owner: ICLP – Indiantown Cogeneration Limited Partnership

Operator: PG&E National Energy Group

Capacity: 360 MW electricity, 270 t process steam

Start-up: 1995

Boiler: Bituminous coal, PC-wall-fired

SCR: 3 layer reactor, initial fill 1 layer, plate-type catalyst, ~ 55% NOx removal efficiency

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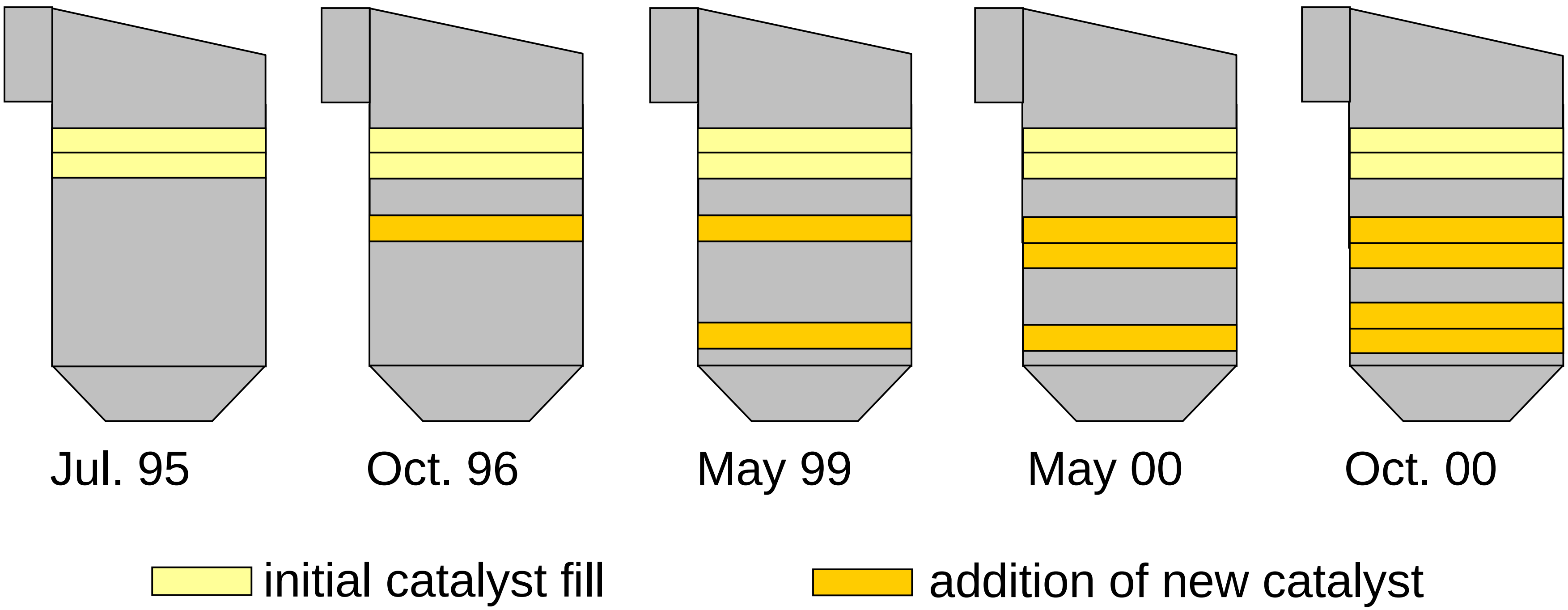
Catalyst Addition 1995 – 2000

After start-up on the initial catalyst fill of 2 half-layers in July 1995, additional half-layers of catalyst were installed as soon as the ammonia concentration in the flyash exceeded acceptable levels according to the following schedule:



Catalyst Deactivation Experience

Initial catalyst consumption: 6 half-layers in 7 years (1995 – 2002)

Catalyst suppliers forecast: 1 half-layer per year on the average

European SCR experience: ~15% of catalyst replacement annually

Indiantown Generating Plant's SCR versus European SCRs:

- Comparable coal
- Comparable boiler/burner configuration
- Comparable removal efficiencies
- Comparable unit size
- Indiantown operating experience of 1 half-layer per year on average equals ~16% of catalyst replacement annually

Conclusion: A long-term replacement frequency of 1 half-layer per year on average is expected for the Indiantown Generating Plant.

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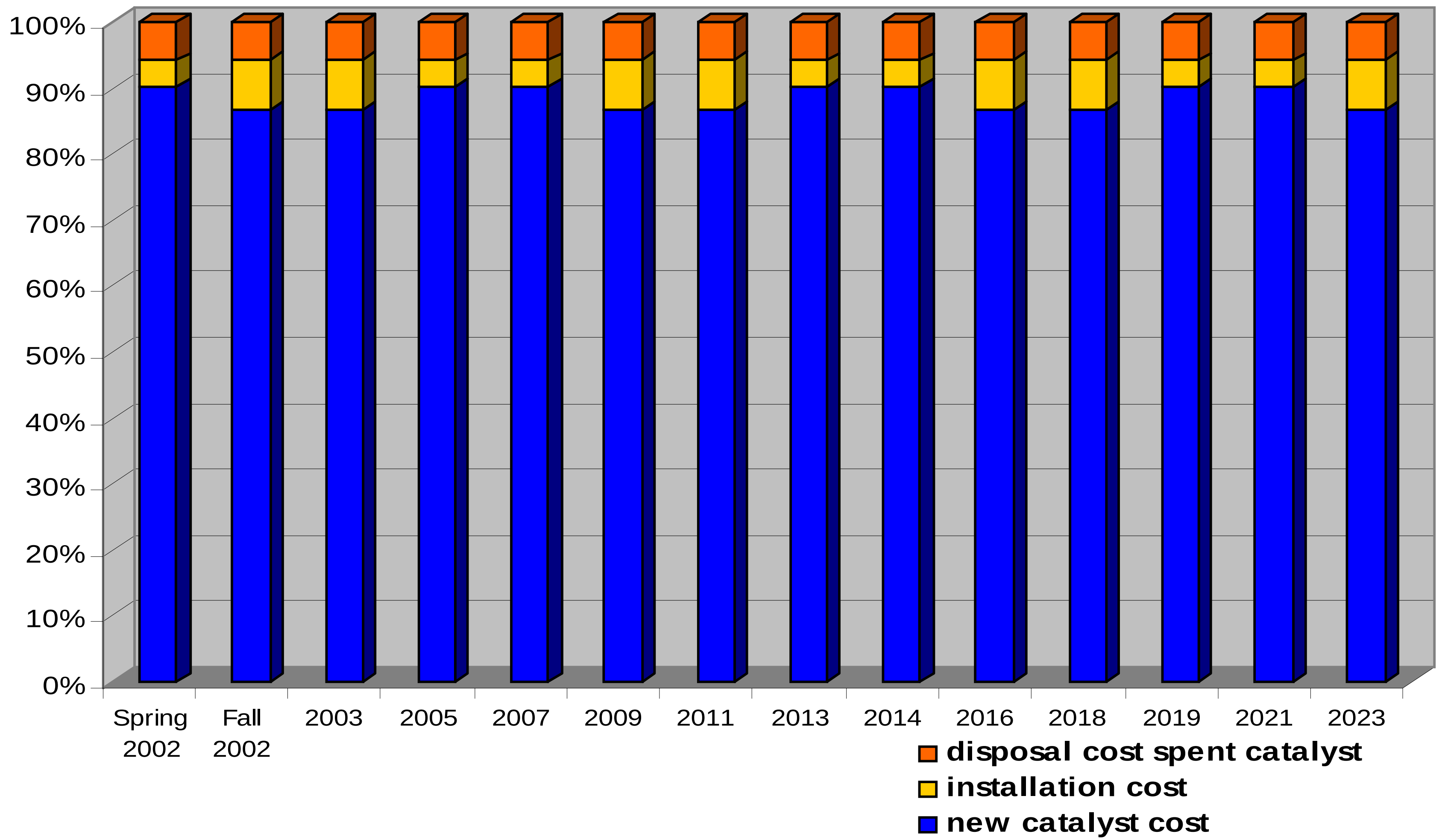
Catalyst Replacement Cost Estimate



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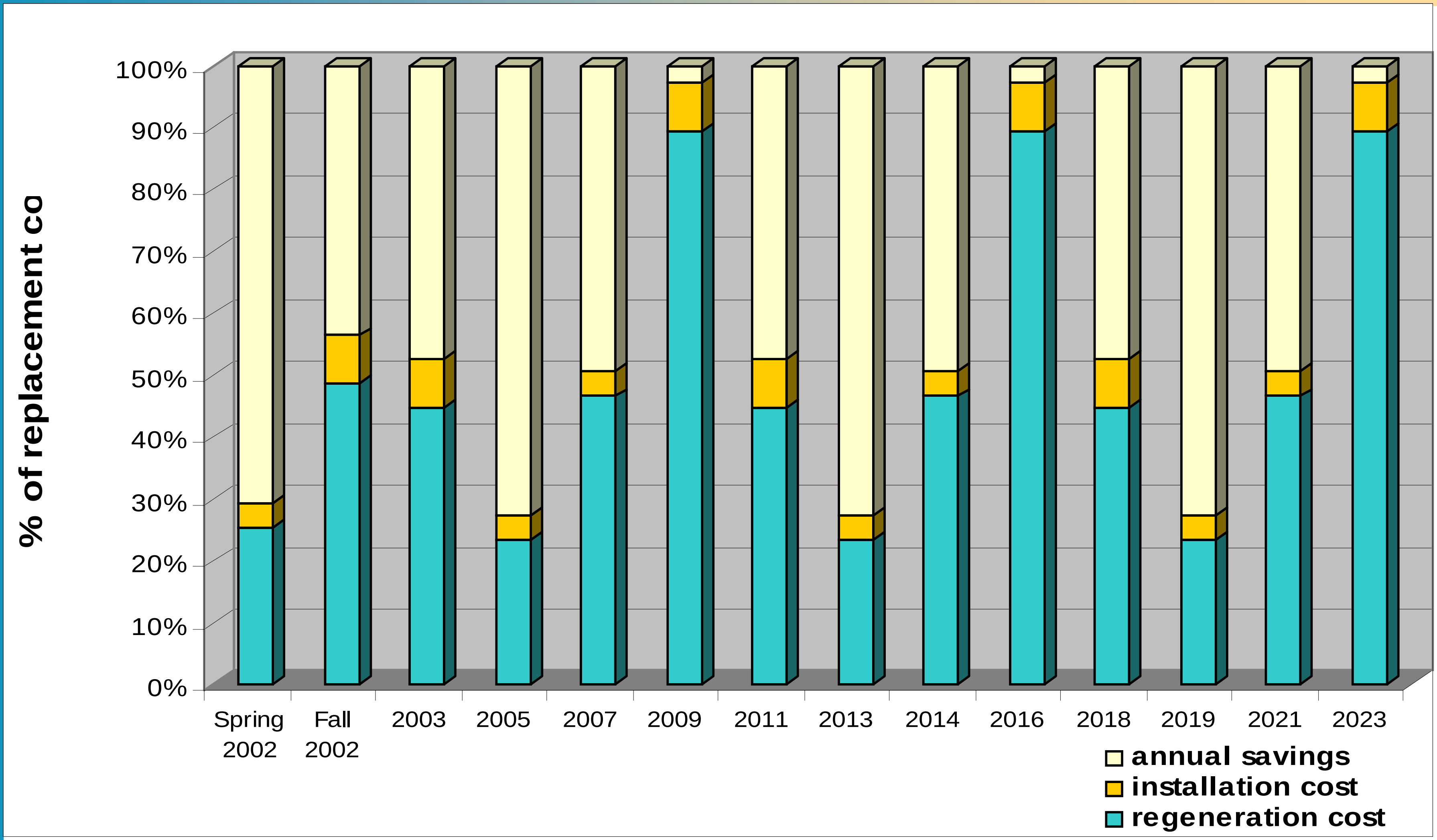
Catalyst Regeneration Cost Estimate



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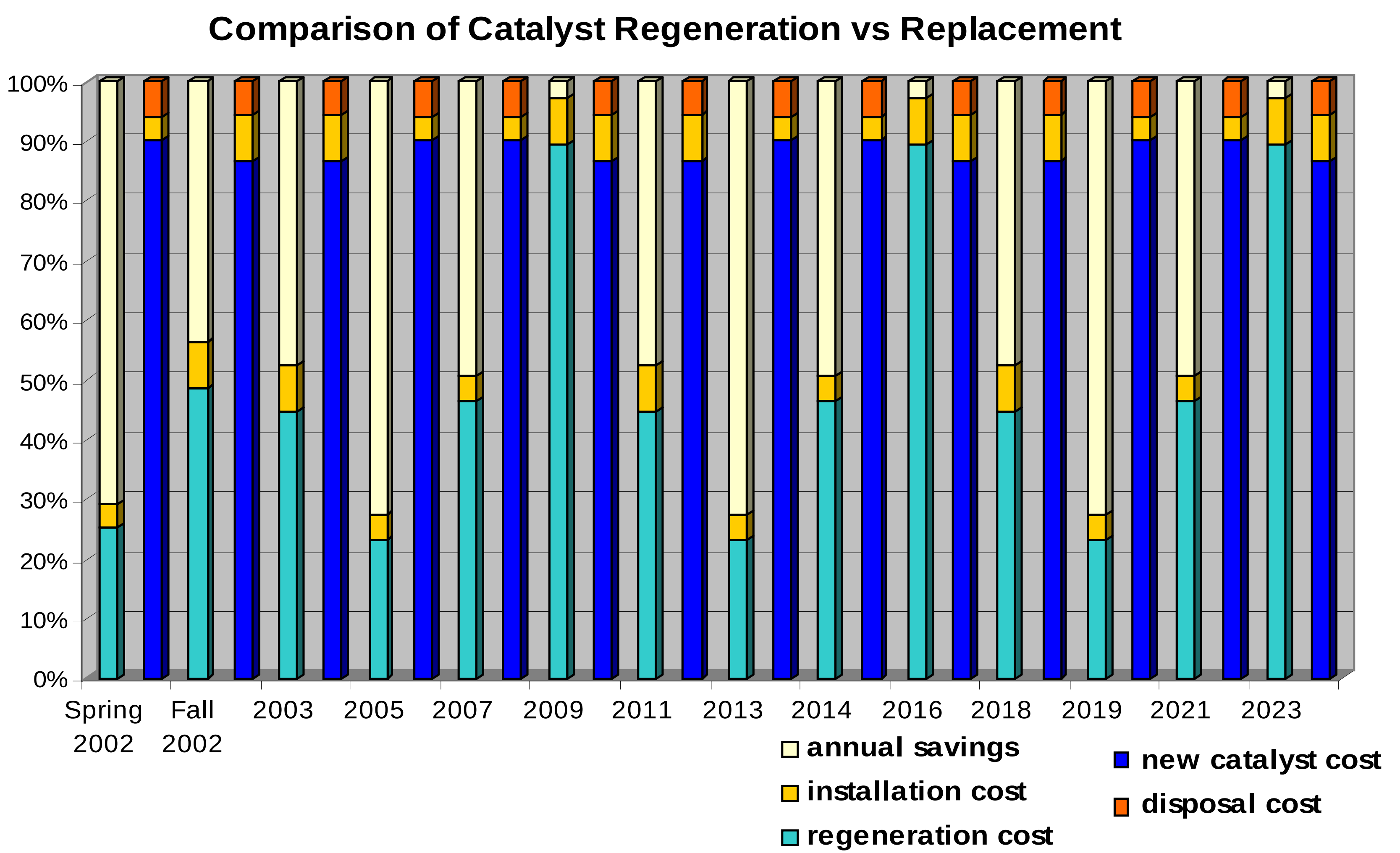
Economic Comparison
Regeneration Versus New Catalyst



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Conclusions of Economic Comparison

Assumptions:

- Regeneration recovers activity of $k_{reg}/k_0 > 0.9$
- Regenerated catalyst deactivates at the same rate as new catalyst in the same reactor
- A 20 year catalyst exchange program forecast is used
- Cost of regeneration is ~ 52% of new catalyst

Conclusions:

- Accumulated savings over 20 years > 50% of the cost of new catalyst
- Accumulated savings over a period of 20 years > $ 5 million in catalyst alone
- Avoidance of any potential liability exposure associated with the disposal of spent catalyst as hazardous waste

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Catalyst Regeneration Test Program

Catalyst Regeneration Test Program demanded by PG&E NEG:

- Bench-scale testing of deactivated catalyst sample
- Chemical composition analysis of deactivated catalyst sample
- Catalyst regeneration of that sample witnessed by PG&E NEG
- Bench-scale testing of that regenerated catalyst sample
- Chemical composition analysis of regenerated catalyst sample
- Personal contact of PG&E NEG personnel with three power plant operators who have long-term operating experience with regenerated catalyst to verify SCR-Tech's claims first hand

The personal contact, power plant site visits and the Catalyst Regeneration Test Program were completed with the assistance of SCR-Tech in Germany in March 2002.

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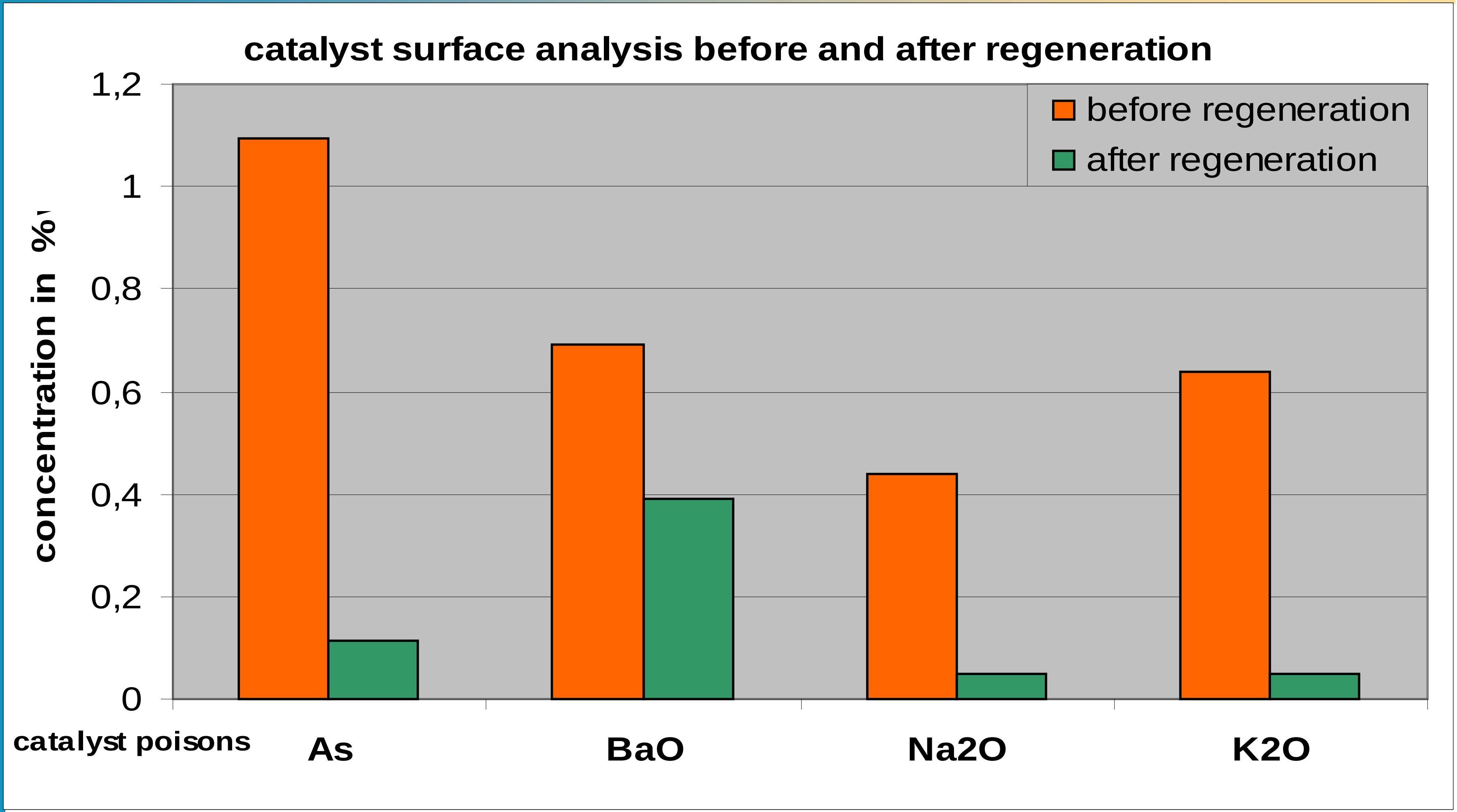
Catalyst Regeneration Test Program – Chemical Analysis Results



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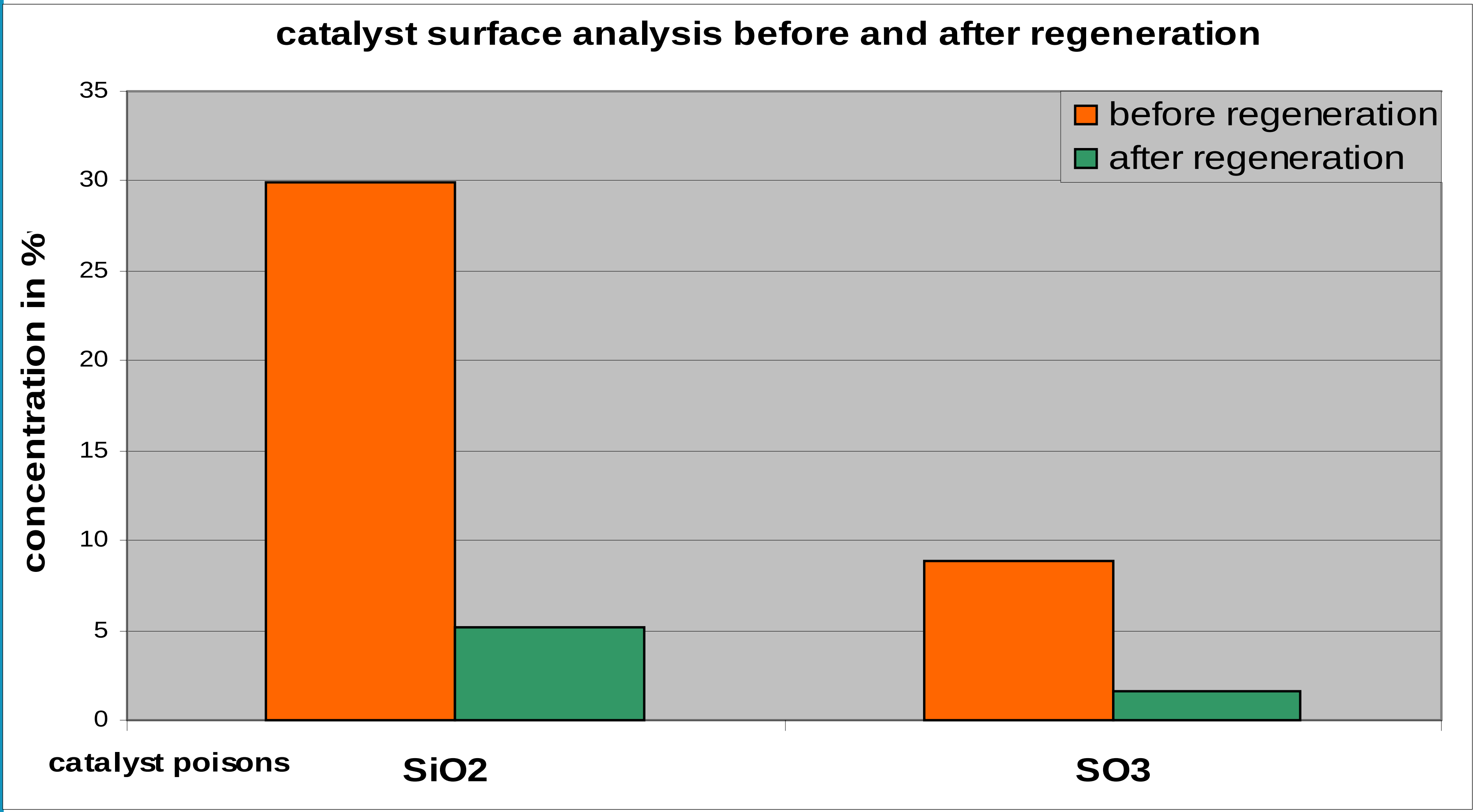
Catalyst Regeneration Test Program – Chemical Analysis Results



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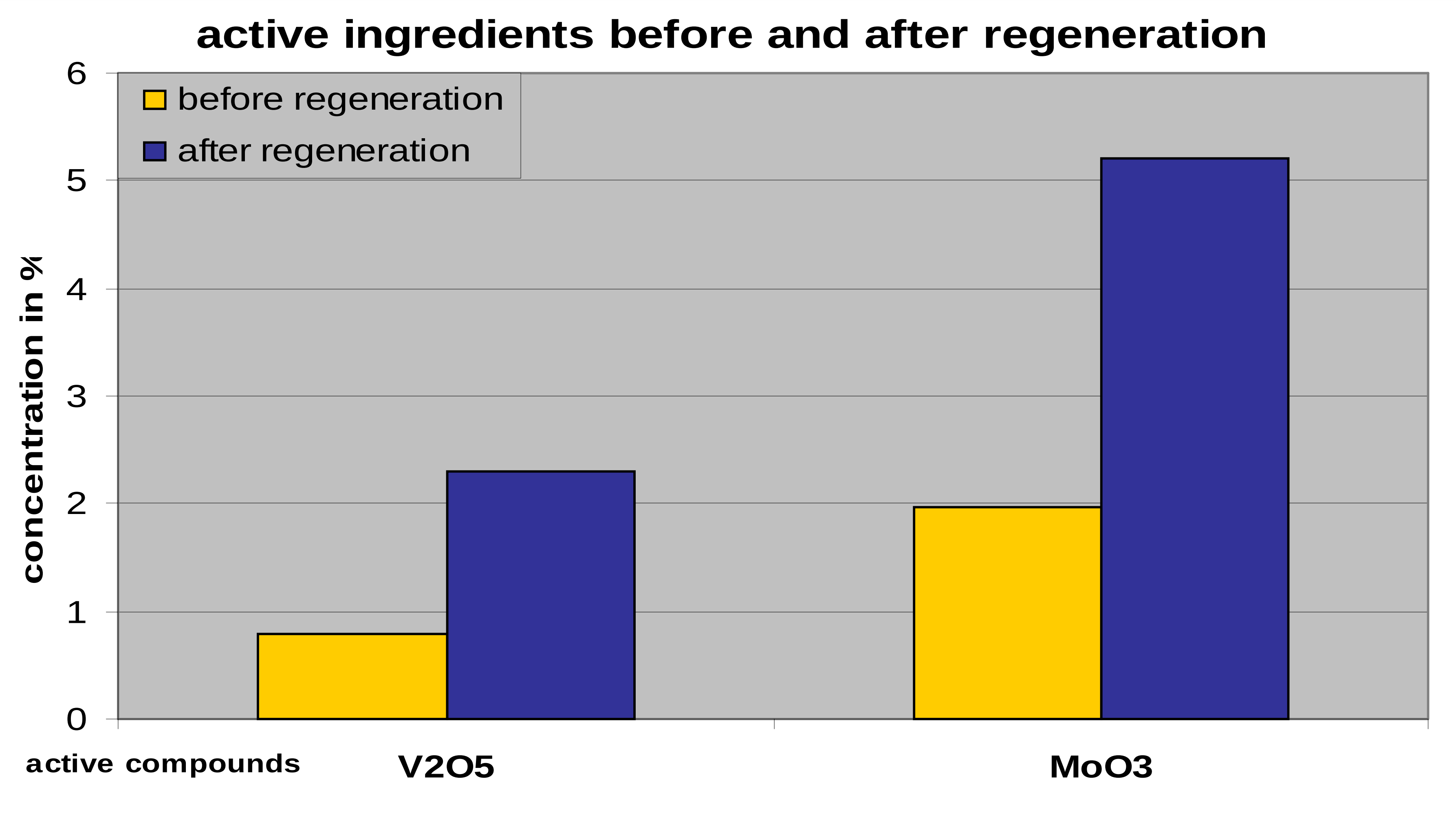
Catalyst Regeneration Test Program – Chemical Analysis Results



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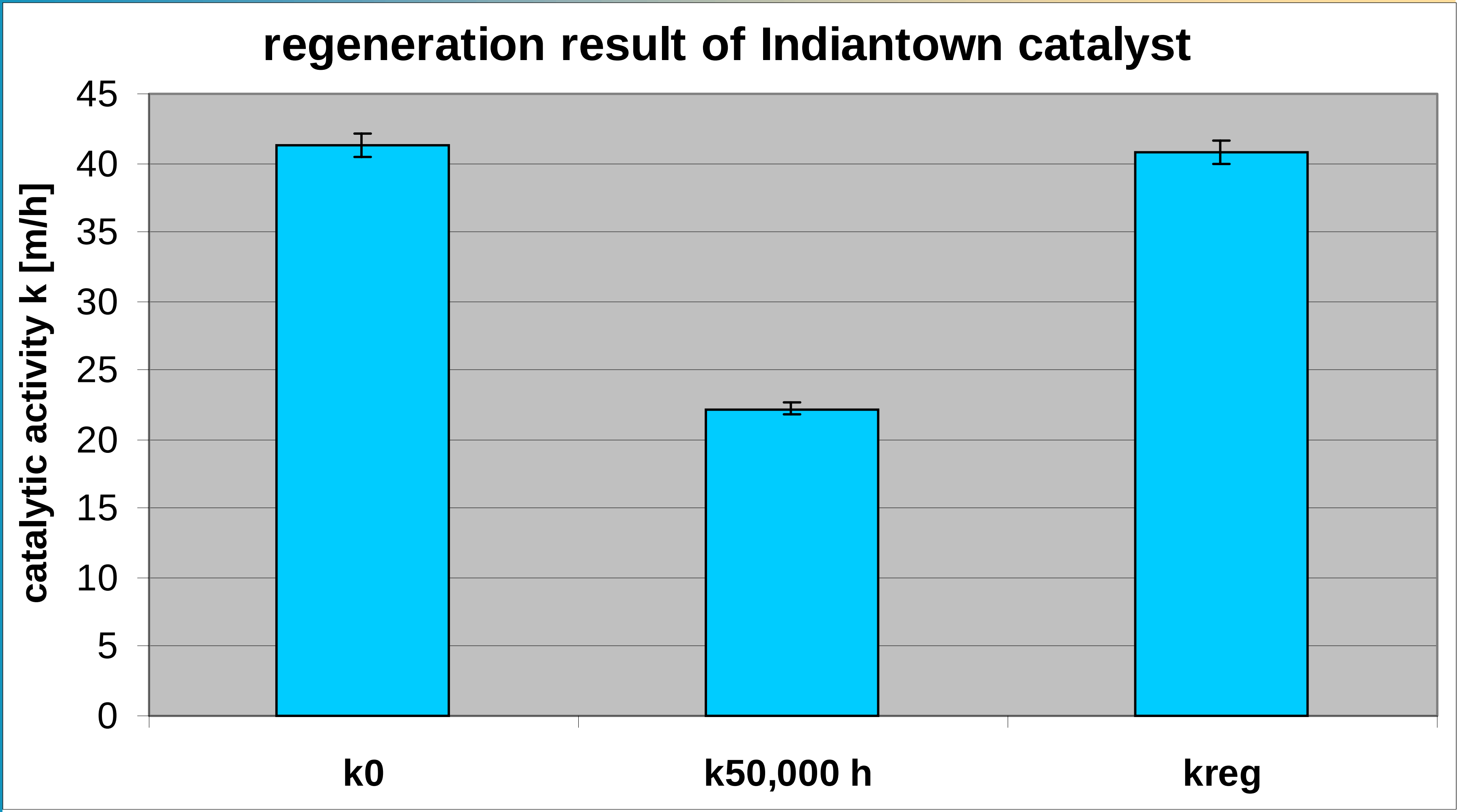
Catalyst Regeneration Test Program – Activity Test Results



Activity of new catalyst is based on vendor information and deactivated catalyst. Regenerated catalyst activities were determined by bench-scale reactor testing.

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Catalyst Regeneration Test Program – Conclusions

Catalyst Regeneration Test Program demanded by PG&E NEG revealed the following results:

- Catalyst was deactivated as expected ($k/k_0 \sim 0.5$)
- Catalyst poisons can be successfully removed
- Catalyst activity after regeneration was $k_{reg}/k_0 = 0.99$
- No increase of the SO_2/SO_3 conversion rate above the original conversion rate guarantee for new catalyst

Conclusion: Catalyst regeneration appears technically feasible and economically viable!

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Bremen City Utilities (swb-synor) Hastedt Cogeneration Station Unit 15

- 170 MW PC-fired, dry bottom boiler, start-up in 1989
- Burns mostly world market import coal plus secondary fuel (e.g. pet coke, sewage sludge, bone meal etc.)
- 4-layer SCR reactor, 3 layers in operation, 144 m^3 of catalyst
- NOx removal efficiency ~ 75%, NH_3 slip < 1ppm
- Catalyst regeneration used since 1999, k_{reg}/k_0 > 0,94 on average
- Total amount of catalyst regenerated for all units ~ 700 m^3

Conclusions:

- Catalyst is exchanged randomly between the various SCRs with no differentiation between new and regenerated catalyst.
- No difference in deactivation between new and regenerated catalyst; deactivation rate depends on fuel type only.

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Power Cooperative Weser (GKW) Veltheim Power Station Unit 3

- 330 MW cyclone fired, wet bottom boiler with 100% flyash re-injection (very high gaseous As-concentration), start-up in 1970
- Burns mostly world market import coal plus secondary fuel (e.g. sewage sludge, bone meal etc.)
- 5-layer SCR reactor, 4 layers in operation, 640 m^3 of catalyst
- NOx removal efficiency > 85%, NH_3 slip < 3 ppm
- Regenerated catalyst used since 2000, average deactivation rate ~ 10% after > 10,000 operating hours, identical with other catalyst

Conclusions:

- No difference in deactivation between new and regenerated catalyst; deactivation rate only dependent on arsenic content.
- Limestone injection effectively curbs catalyst deactivation.

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Hamburg City Utilities (HEW) Tiefstack Cogeneration Station Units 1 & 2

- 180 MW PC-fired, dry bottom boilers, start-up in 1991/92
- Burns mostly world market import coal, no secondary fuel
- 4-layer SCR reactor, 3 layers in operation, 300 m^3 of catalyst
- NOx removal efficiency ~ 90%, NH_3 slip < 2 ppm
- Regenerated catalyst used since 1998, total amount of catalyst regenerated for all units ~ 500 m^3, $k_0/k_{reg} > 1$ on average
- Some catalyst has been regenerated twice already

Conclusions:

- Catalyst is exchanged randomly between the various SCRs with no differentiation between new and regenerated catalyst.
- No difference in deactivation between new, regenerated and re-regenerated catalyst; deactivation rate for all catalyst is 6 – 8% annually at base load.

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Site Visits and Experience Verification – Conclusions

The personal visits with three power plant operators with long term operating experience with regenerated catalyst revealed:

- No different deactivation of regenerated versus new catalyst observed during operation

2. No need for differentiation between new and/or regenerated catalyst by the operator

- Several regenerations seem possible without degradation in regeneration or catalyst performance

Conclusion: Operating experience with regenerated catalyst was confirmed to be positive throughout!

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Future Catalyst Management Strategy

Original catalyst management strategy was based on a 3 full-layer operation with a perpetual exchange of 1 full-layer as needed and disposal of spent catalyst.

New catalyst management strategy is based on 4 half-layers installed with a perpetual exchange of 1 half-layer as needed by a regenerated half-layer kept in stand-by by SCR-Tech.

Advantages:

- **Savings of over $ 5 million in cumulative SCR maintenance cost over the next 20 years of operation**
- **Savings of > $ 60,000 in additional annual revenue through reduced parasitic load**
- **Reduced SO_3 load in the system**

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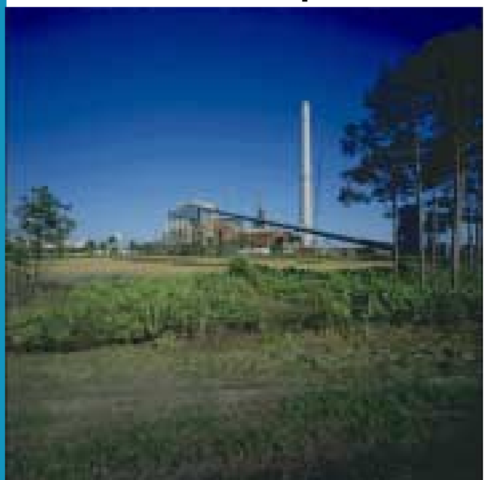
4 Half-Layer SCR Operation After 2002

Transition period: May 02 – Replacement of the 2 initial half-layers by 1 new half-layer; regeneration of 1 half-layer of the removed catalyst.



Oct 02 – Removal of all but the new half-layers, regeneration of 2 half-layers; reinstallation of 3 regenerated half-layers.

Future SCR operation: – Operation of only 4 half-layers at any given time.

– Replacement of 1 half-layer of exhausted catalyst by 1 half-layer of regenerated catalyst, regeneration of the removed half-layer and placement in stand-by.

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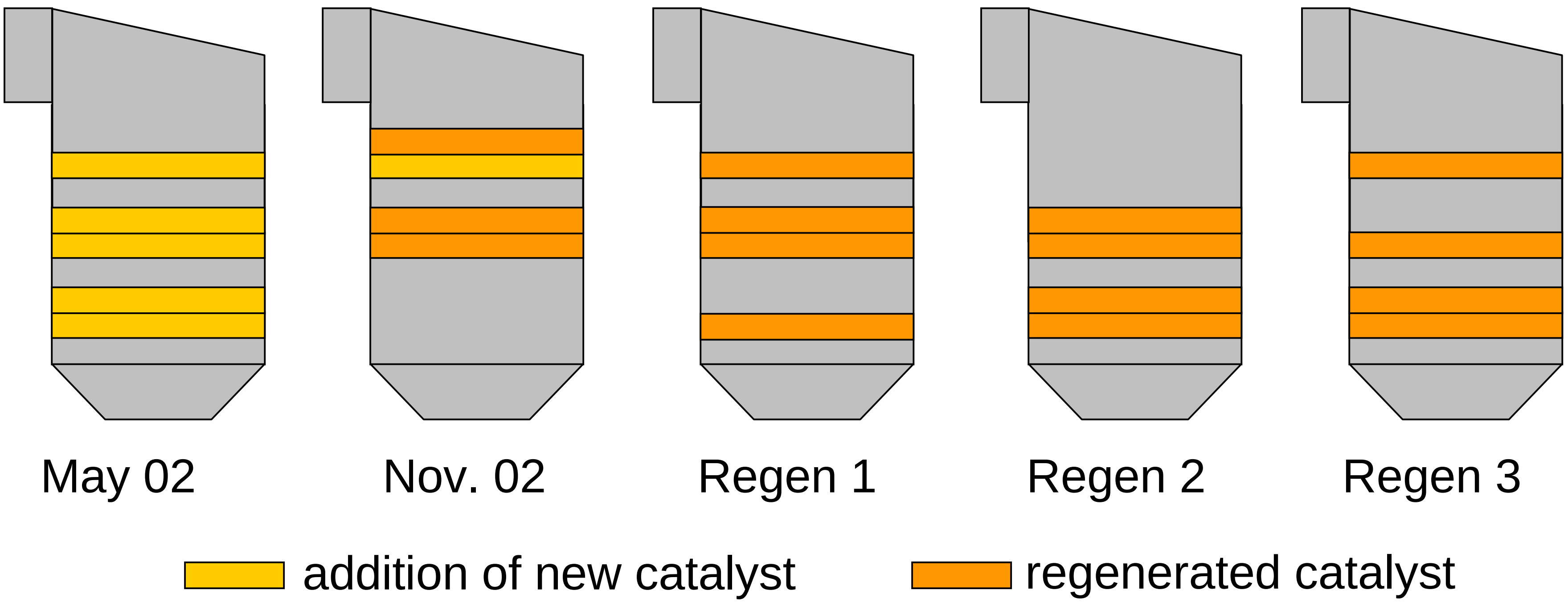
Catalyst Exchange Plan After 2002

Transition from the former 3 full-layer SCR operating scheme to the new 4 half-layer SCR operating scheme including future catalyst exchange and regeneration cycles:



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Conclusions

- Catalyst regeneration was found to be a technically feasible technology and is economically very attractive.
- Long term operating experience was found to be positive, meaning deactivation of regenerated catalyst is identical to new catalyst in the same SCR reactor.
- Maintenance cost savings for ICLP of ~ 50% on average over catalyst replacement (> $ 5 million over 20 years).
- 4 half-layer operation saves PG&E NEG > $ 60,000 per year in operating cost over a 3 full-layer operation.
- Cost & potential hazardous waste liabilities associated with catalyst disposal can be largely avoided.

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?? Questions ??

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