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KBR's Purifier™ or Purifierplus™ Technology for New or Revamp Ammonia Plants

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Topics

- Merger of M. W. Kellogg and Brown & Root
- Introduction to Purifier™ Process
- Introduction to Purifierplus™ Process
- Highlights/Status of KRES™ technology
- Highlights/Status of Purifier™ technology
- Use of KRES™ & Purifier™ to revamp ammonia plant
- Summary

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1998

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Processes for License
(From Combinations of Available Technologies)

- **Conventional Process**
 - SMR + conventional purification+ magnetite synthesis
- **KAAP Process**
 - SMR + conventional purification+ KAAP synthesis
- **Purifier Process**
 - SMR + Purifier + magnetite synthesis
- **PURIFIERplus Process**
 - KRES + Purifier + magnetite synthesis
- **KAAPplus Process**
 - KRES + Purifier + KAAP synthesis

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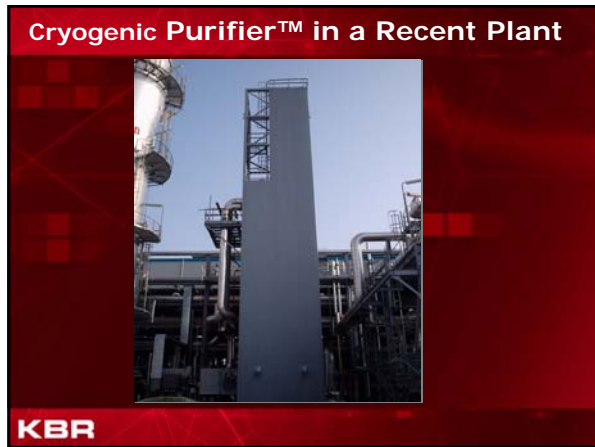
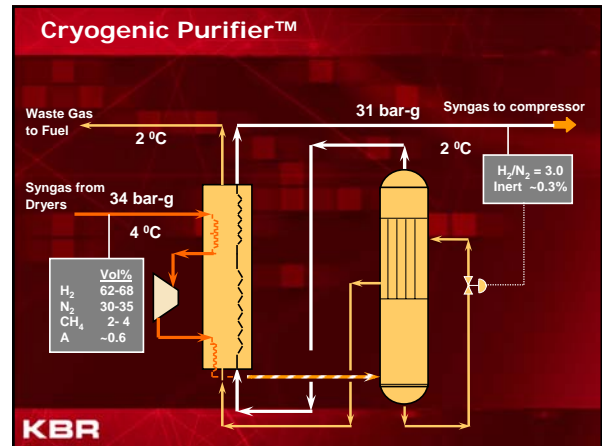
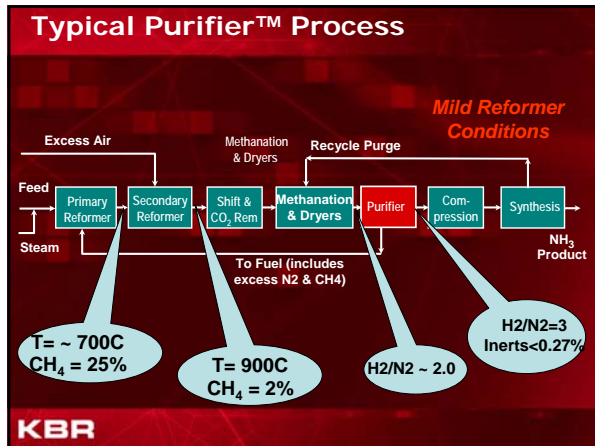
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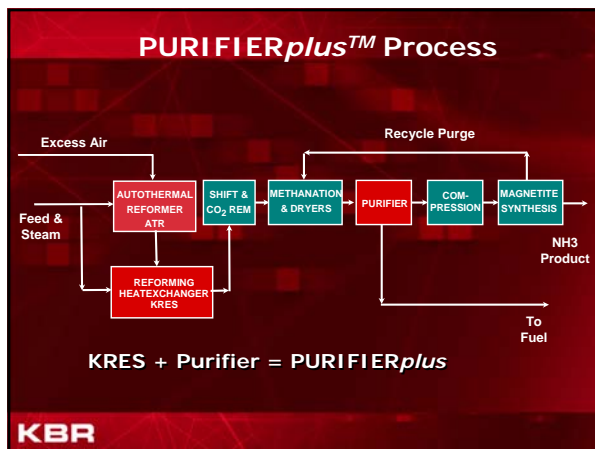
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Conventional Process

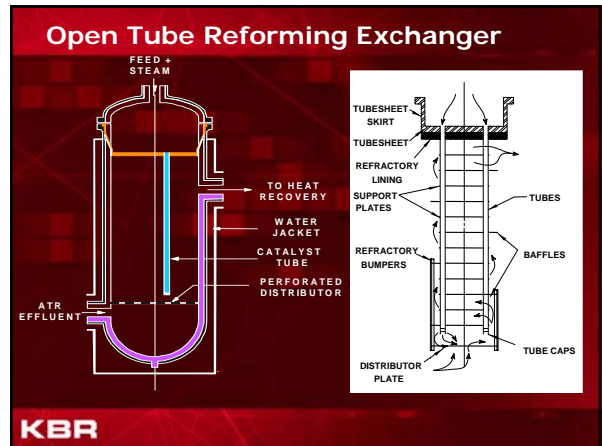
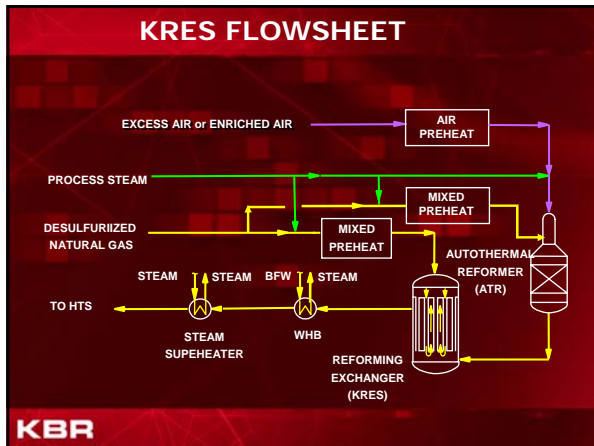
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- ### UNIQUE DESIGN FEATURES OF KRES
- Simple open tube arrangement
 - Single Tube sheet is located on the cold end
 - Bundle is completely removable for easy inspection
 - No-tube-in-the window segmented baffle design results in true cross flow on the shell side
 - Shell lined with dual layer internal refractory
 - Shell externally water jacketed
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Process Benefits of KRES

- Eliminate excess steam production
- Use cheaper fuel in package boiler
- Reduce plant pressure drop
 - Reforming exchanger & ATR in parallel
- Flexible design & operation
 - Vary split of feed between ATR & exchanger
 - Vary amount of excess air used in ATR
- Reduces CO₂ & NOx emissions
- Improve plant reliability

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Other Benefits of KRES

- Saves 3-5% of ammonia plant capital cost
- Scalable to large capacities
- Reduces reforming start up time by one-half
- Takes less plot area
- Requires less maintenance
- Ideal fit with Purifier Process

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KRES Experience

<u>Client</u>	<u>Country</u>	<u>MT/Day</u>	<u>Year</u>
Ballance	New Zealand	90	2009
Chambal	India	430	2008
Liaohe	China	1100	2003
Methanex	Canada	350	1994

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KRES Experience (Cont'd)

- Methanex 350 t/d unit started up in 1994 in Canada and has been trouble-free
- KBR optimized the design of KRES unit resulting in 40~60% lower cost
- Second KRES unit at 1100 MTPD for Liaohe in China started up in 2003

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Liaohe KRES Revamp Project

- Ammonia Plant
 - KBR "conventional" ammonia design from 1970s
 - Nameplate capacity = 1000 mt/day
 - Operating at ~1070 mt/day
- KBR scope
 - Feasibility study
 - Licensing & Extended BED

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Reforming Exchanger Tube Bundle



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Comparison of Energy Use

GCal/Metric Ton - LHV

	Before Revamp	After Revamp
Feed Natural Gas	5.4	6.2
Fuel Natural Gas	3.8	0.3
Total Natural Gas	9.2	6.5
Coal-Fired boiler & other credits	0.0	2.1
Total (excl. ASU)	9.2	8.6

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History of KBR Purifier™ Process

Invention	1964
First Commercial Plant	1966
First Patented	1969
Subsequent Patents (19)	1969 - Present
Most Recent Plant	2006

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Benefits of Purifier Technology

- Reliability
 - Several plants have run 3-4 years without shutdown
 - Low reforming temperatures mean lower stress
 - Less sensitive to problems in shift & CO₂ units
- Flexibility
 - Simple & precise H₂/N₂ ratio control
 - Purifier stabilizes entire plant operation

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Benefits of Purifier Technology (Cont'd)

- Low Energy Consumption
 - Lower S/C
 - Lower reforming temperature – less fuel
 - Higher loop conversion with low inerts
 - Proven lowest consumption of 6.5 Gcal/MT
- Reduced Capital Cost
 - Smaller reforming section
 - No purge gas recovery unit
 - Smaller synloop equipment

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Purifier™ Plant Experience

Plant	Location	Year	MTPD
Unocal	USA	1966	680
Kemira	Netherlands	1968	1360
First Miss	USA	1968	900
Asahi	Japan	1971	900
Yara # C	Netherlands	1971	900
PCS N2	USA	1978	1360
BASF	Germany	1982	1360
Yara # D	Netherlands	1984	1500
Yara # E	Netherlands	1984	1750

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Purifier™ Plant Experience (Continued)

Plant	Location	Year	MTPD
Yara TR2	Trinidad	1988	1360
Jinxi	China	1993	1000
Jianfeng	China	1993	1000
Sichuan	China	1995	1000
Sinopec/UGPW	China	1997	1000
Safco	Saudi Arabia	1999	1500
CNOOC	China	2003	1500
BFPL	Australia	2006	2200
Jianfeng	China	2010	1500

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Proven Reliability – KBR Ammonia Plants

Source: G P Williams Survey for 2000-'01

- Top 3 longest runs are for **KBR** plants
- 4 of the top 5; 6 out of top 10 longest runs are **KBR** plants
- KBR Purifier plants have 3.6% service factor advantage over non-KBR plants

	Service factor	Longest run
Non-KBR Plants	90.6%	385 days
KBR Conventional	92.7%	432 days
KBR Purifier	94.2%	624 days
All Plants	91.5%	424 days

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Proven Reliability of Purifier Designs

- BFPL has had two shutdowns in 2007 – both caused by feed gas outages
- PCS in USA ran for **1395 days**
- Yara Unit D
 - has averaged 95.5% stream factor
 - Runs of **934 & 1375** consecutive days
- Yara Unit E
 - has averaged 97.3% stream factor
 - ran for **960** consecutive days

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Purifier Experience at CNOOC Chemical



Project Background



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Hainan Island



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CNOOC Project

- Grassroots fertilizer plant at Dongfang
- Ammonia plant – 1500 mt/d
 - Purifier™ front end
 - Gas turbine to drive air compressor
 - aMDEA for CO₂ removal
 - Horizontal, 3-bed magnetite converter
- Urea plant – 2700 t/d
 - Stamicarbon synthesis process using pool condenser
 - HFT granulation process
- KBR scope – E, P, Ca
- Construction by CNOOC

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CNOOC Performance Test Data

	<u>Gcal/Metric (LHV) Ton of NH₃</u>	
Natural Gas	<u>Measured</u>	<u>Expected</u>
Feed	6.25	6.32
Fuel	<u>1.93</u>	<u>1.91</u>
Subtotal	8.18	8.23
Export Steam	<u>-1.72</u>	<u>-1.75</u>
Net	6.46	6.48
Electricity	<u>0.03</u>	<u>0.03</u>
Total Energy	6.49	6.51

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CNOOC Fertilizer Project



BFPL Ammonia Plant Australia

- Capacity 2200 MTPD
- Commissioned April 2006 – Largest Purifier plant in operation
- Flow sheet similar to CNOOC except no gas turbine and all cold ammonia product for export
- Expected energy consumption ~ 6.8 Gcal/MT
- Performance Test completed in June 2006. Met all capacity & performance guarantees
- Highest Capacity achieved **2340 MTPD**

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Location



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BFPL Ammonia Plant Australia



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Plant View



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BFPL Performance Test Data

Natural Gas	<u>Gcal(LHV)/Metric Ton of NH3</u>	
	<u>Measured</u>	<u>Expected</u>
Feed	5.76	6.05
Fuel	1.59	1.43
Subtotal	7.35	7.48
Export Steam	-0.61	-0.66
Net	6.74	6.82
Electricity	0.04	0.04
Total Energy	6.78	6.86

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BFPL Ammonia Plant Australia



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Syngas Production Comparison

<u>Primary Reformer</u>	<u>Purifier</u>	<u>Conventional</u>
No. of tubes	65%	100%
Tube Diameter, mm OD	125	110
Heat Flux, kcal/hr-m ²	55,000	76,000
Radiant Duty	66%	100%
Tube Life, years	12-25	~10
Catalyst Volume	85%	100%
Catalyst Life, years	10	<5
Outlet Temperature, C	700	800-840

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Primary Reformer – Smaller Size & Milder Conditions for 2200 mtpd Ammonia Plant



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BFPL Ammonia Plant Australia



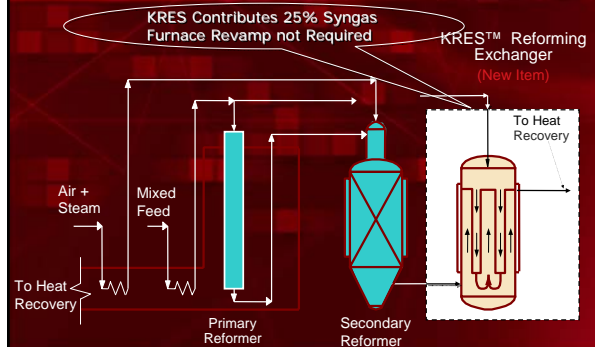
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KRES Revamp Application



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KRES Revamp Advantages

- Potential to increase reforming capacity by 25%
- Primary Reformer tube life is increased by lowering tube exit temperature
- Parallel operation lowers pressure drop through reforming section
- Flexible Operation – split of reforming duty can be varied between Primary Reformer and KRES
- Efficiency of primary reformer furnace improves since convection duty is increased relative to radiant duty.
- KRES can be fabricated in India, China, US etc.,

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KRES Revamp for Capacity Increase with major Energy Saving – Case Study

Benefits/performance changes:

- Capacity increased 1600 to 2000 t/d (25%) with RLNG feed stock
- CO₂ production – to convert all ammonia to urea
- Shortfall in steam production balanced by recovering low grade waste heat
- CO₂ removal revamped- high efficiency e.g. a MDEA;
- Revamped syn-loop to high efficiency KBR design
- Optimize drivers power vs. steam turbine
- Overall energy saving about 0.60 Gcal/MT of ammonia or total energy ~ 7.35 Gca/MT (feed, fuel, power and steam/BFW credit) after revamp

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Purifier™ Revamp Application

- Purifier unloads primary reformer and synthesis loop.
- Can be used to significantly increase plant capacity – say up to 50%
- Milder operating condition of Primary Reformer extends tube life
- Reliability of RG Boiler improves due to lower gas inlet temperature – lower risk of tube failure
- Higher CO₂ production compared to conventional revamp
- Pure and dry synthesis make up gas to synthesis loop – improves capacity of synthesis loop and life of synthesis catalyst

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Summary

- KBR Purifier™ technology is one of the best ammonia technology
- KRES complements Purifier™ – resulting in Purifier*plus*™ technology
- Proven **lowest** energy consumption
- Highest **proven** reliability
- Design features like Purifier, KRES, and optimized synthesis loop also **lower capital cost**

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THANK YOU

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