SCR Performance: Impacts of Power Plant Dispatch and Fuels

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DUKE ENERGY®

Background – Power Generation and NOx Control

- Selective Catalytic Reduction (SCR) on Electric Generating Units (EGU's):
  - Wide-spread application is recent: Mostly in past 10 to 15 years
  - Retrofit applications dominate
  - Regulatory Driver: Allowance-based NOx programs (NOx SIP Call, CAIR, CSAPR)
  - Initially installed for ozone season control. Later, CAIR and CSAPR brought in annual allowance requirements
  - Strategy: Install SCR on large, base-load units to minimize cost of managing allowances fleet wide.
- Duke Energy:
  - Installed 21 retrofit SCRs from 2002 to 2015
  - Generally no applicable NOx emissions limits – permitted for ozone season allowance management (also supports annual CSAPR)
  - Cayuga SCRs installed primarily for mercury oxidations (MATS)

SCR Design, Performance & Guarantees

- SCR design performance guarantees are based on:
  - Assumed inlet NOx concentration, flow rate, and temperature
  - Burning design basis fuel
  - Specific catalyst amount and its activity
  - Maximum ammonia slip of less than 2 ppm
  - Full load, steady state conditions
- SCR performance exceeding guarantee is inhibited by:
  - SCR reactor size and shape
  - Capacity of the ammonia injection system
- Duke Energy has only one SCR designed to achieve 0.075 lb/mmBtu across all operating conditions
  - Cliffside Unit 6 (operational in 2011) subject to 0.07 lb/MMBtu limit

Duke Energy Retirements Since 2010

Coal Units	Capacity (MW)	Year:
Buck 3-6	370	2011-2013
Cape Fear 5,6	316	2012
Cliffside 1-4	210	2011
Dan River 1-3	290	2012
Edwardsport 6-8	160	2011
Gallagher 1,3	280	2012
H.F. Lee 1-3	382	2012
Miami Fort 6	163	2015
Riverbend 4-7	466	2013
Robinson 1	177	2012
Sutton 1-3	553	2013
Weatherspoon 1-3	170	2011
W.C. Beckjord 1-6	862	2012-2014
W.S. Lee 1,2	200	2014
Total	4,599	MW

Combustion Turbines	Capacity (MW)	Year:
Cape Fear ST1,2; CT1,2	82	2012-2013
Buck CT7, 8, 9	104	2012
Buzzard Roost CT 6-15	198	2012
Dan River CT4,5,6	98	2010-2012
H.F. Lee CT1,2,3,4	75	2012
Miami Wabash CT4	16	2011
Riverbend CT8,9,10,11	135	2010-2012
Robinson CT1	11	2013
Beckjord CTs 1-4	160	2014
Total	879	MW

New Combined Cycle Projects 2011-2020

Unit name:	Capacity (MW)	First Year of Operation
Buck CC	668	2011
Dan River CC	651	2012
H.F. Lee CC	910	2012
Sutton CC	622	2013
Richmond County CC	606	2011
Total	3,457	
W.S Lee (South Carolina)	670	2018 (projected)
Asheville	495	2020 (projected)
Citrus County	1,640	2019 (projected)

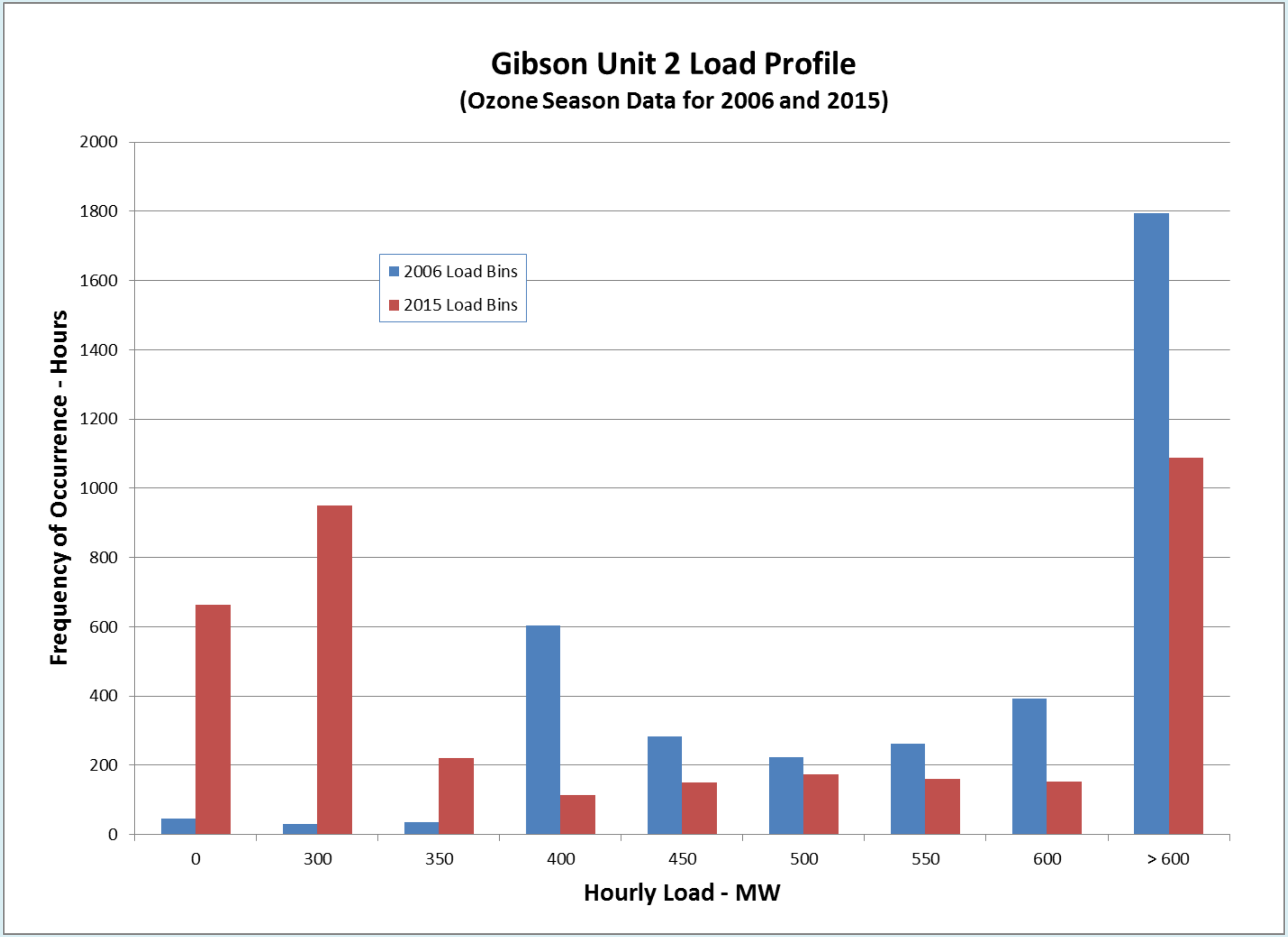
The New Reality – The Coal EGU World Has Changed

- SCR controlled units no longer operate at their design steady state, base loaded, conditions
  - Units with SCRs must now cycle more frequently and operate at lower minimum loads due to the addition of renewables and combined cycle units
  - NOx emission rates will increase as a unit changes load

    (non-steady state conditions)
  - Lower loads reduce gas temperatures which require ammonia injection be curtailed or even halted, which increases NOx
- Low NOx burner experience with aggressive operation:
  - Accelerated boiler tube wear – need to accept higher boiler NOx to avoid reliability concerns

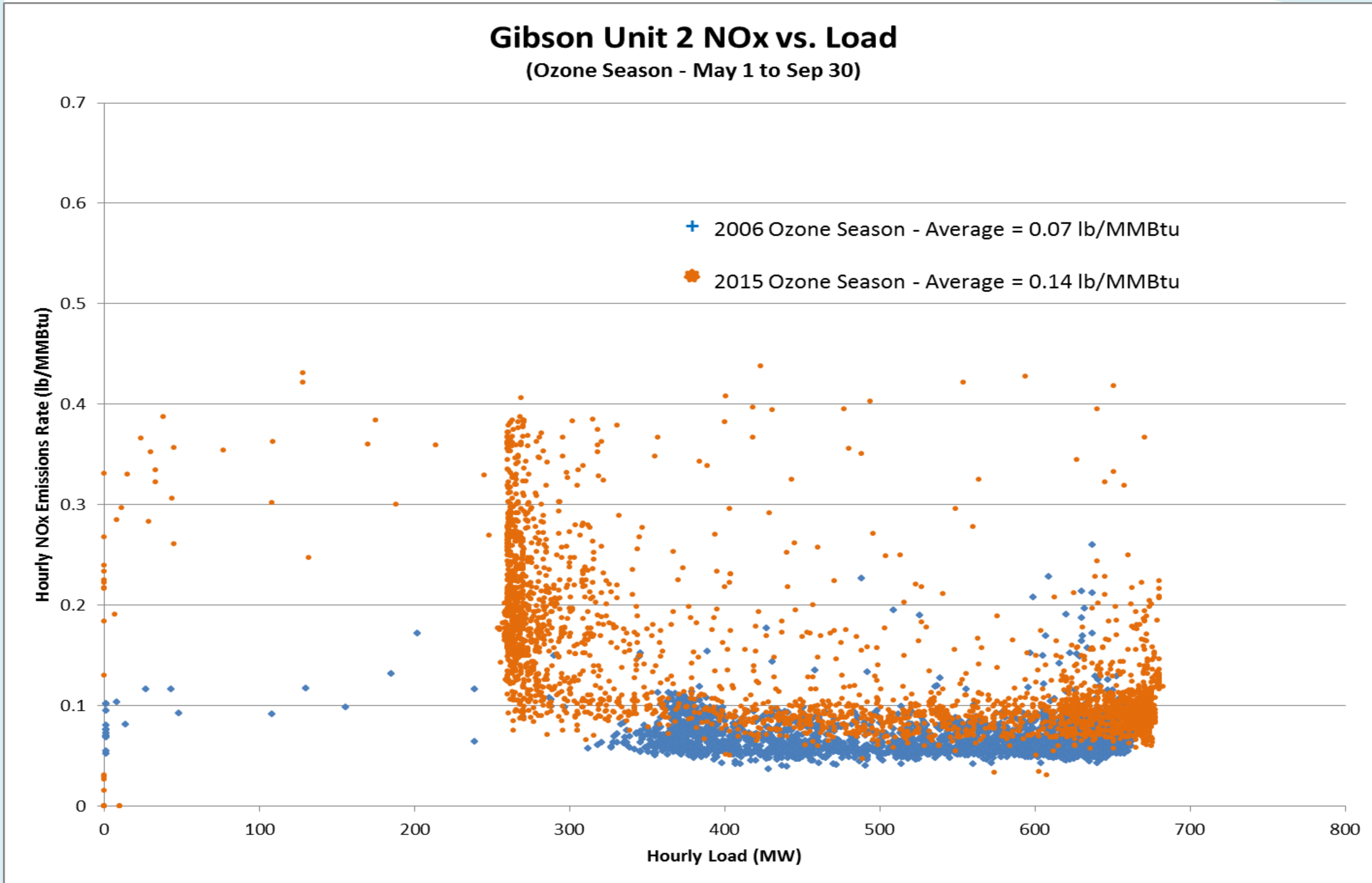
The New Reality – The Coal EGU World Has Changed

- Coal quality has shifted because low sulfur CAPP coal (original design) is less available
  - Available coal has a higher sulfur content
  - Sulfur oxides react with ammonia and cause ABS deposits that plug air heaters, particularly at lower loads and temperatures
  - Limiting ammonia feed can reduce pluggage but increases NOx
  - Higher arsenic levels accelerate catalyst degradation
- MATS adds more constraints
  - SCRs oxidize mercury and increase its capture but reduces the catalyst available for NOx control
  - Boiler tuning that optimizes CO and reduces organic HAP emissions can increase SCR inlet NOx



Gibson Unit 2 Load Profile
(Ozone Season Data for 2006 and 2015)
2006 Load Bins
2015 Load Bins
Frequency of Occurrence - Hours
0
200
400
600
800
1000
1200
1400
1600
1800
2000
0
300
350
400
450
500
550
600
> 600
Hourly Load - MW

Impact of Unit Load on SCR Operation

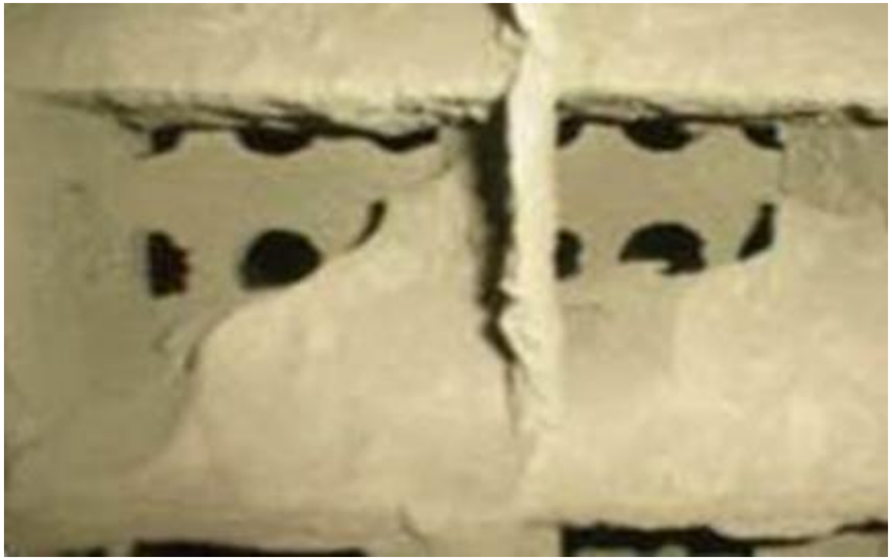


Consequences of "Aggressive" SCR Operation

Rotary Air Preheater

Rotary Air Preheater Basket Fouling

Tubular Primary Air Heater



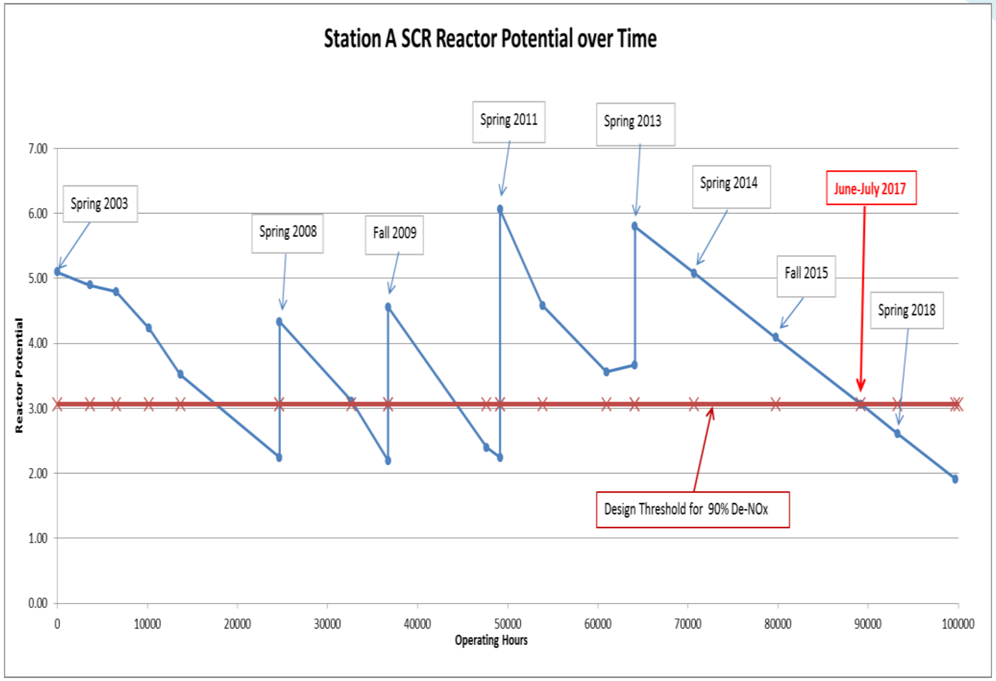
Precipitator Perforated Plate

Duke Energy CSAPR Update Comments on SCR Performance

- Average SCR performance at 0.075 lb/mmBtu is not feasible without reconstructing the SCR reactor and support systems
  - The incremental NOx removal cost will far exceed $1,300/ton
- Average performance at 0.10 lb/mmBtu is generally feasible provided sufficient time is given to prepare.
  - Simply adding more ammonia will not work
  - Catalyst management plans must be revised and implemented
  - Need to understand how MATS compliance will be affected
- <u>Recommendation:</u> EPA should use 0.10 lb/mmBtu to calculate the allowance budgets

SCR Catalyst Management

- Over time SCR Catalyst loses its effectiveness
- Catalyst management plans anticipate this deterioration and schedule routine catalyst changes
- New catalyst has a one year lead time and is formulated for specific applications
- Exchanges can only occur during scheduled maintenance outages



- Because Duke Energy operates 22 SCRs, outage coordination and scheduling is critical
- Catalyst management plans must consider systemwide needs as well as maintaining optimum performance on individual units.

Summary – Impacts of Changes in Coal EGU Operation on SCR Performance

- SCR design limits the ability to respond to changes
- Market changes have had significant impact on coal-fired EGU operation
  - Natural gas prices, renewable generation and coal quality
- SCR operation must be managed to meet competing concerns:
  - NOx emissions, reliability (ABS formation and catalyst replacement schedules), minimum load dispatch, and MATS compliance, for example
- Expectations for average performance must consider the range of operation