

# **REINHOLD ENVIRONMENTAL Ltd.**



## **2011 APC Round Table & Expo Presentation**

July 11-12, 2011, in Cleveland, OH / Hosted by FirstEnergy

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**Howden**

# APC Round Table & Expo 2011

Upgrading Draft Fans to comply with U-MACT Regulations

John Magill

Date: July 11, 2011

# APC Round Table and Expo 2011

Upgrading Draft Fans to comply with U-MACT Regulations



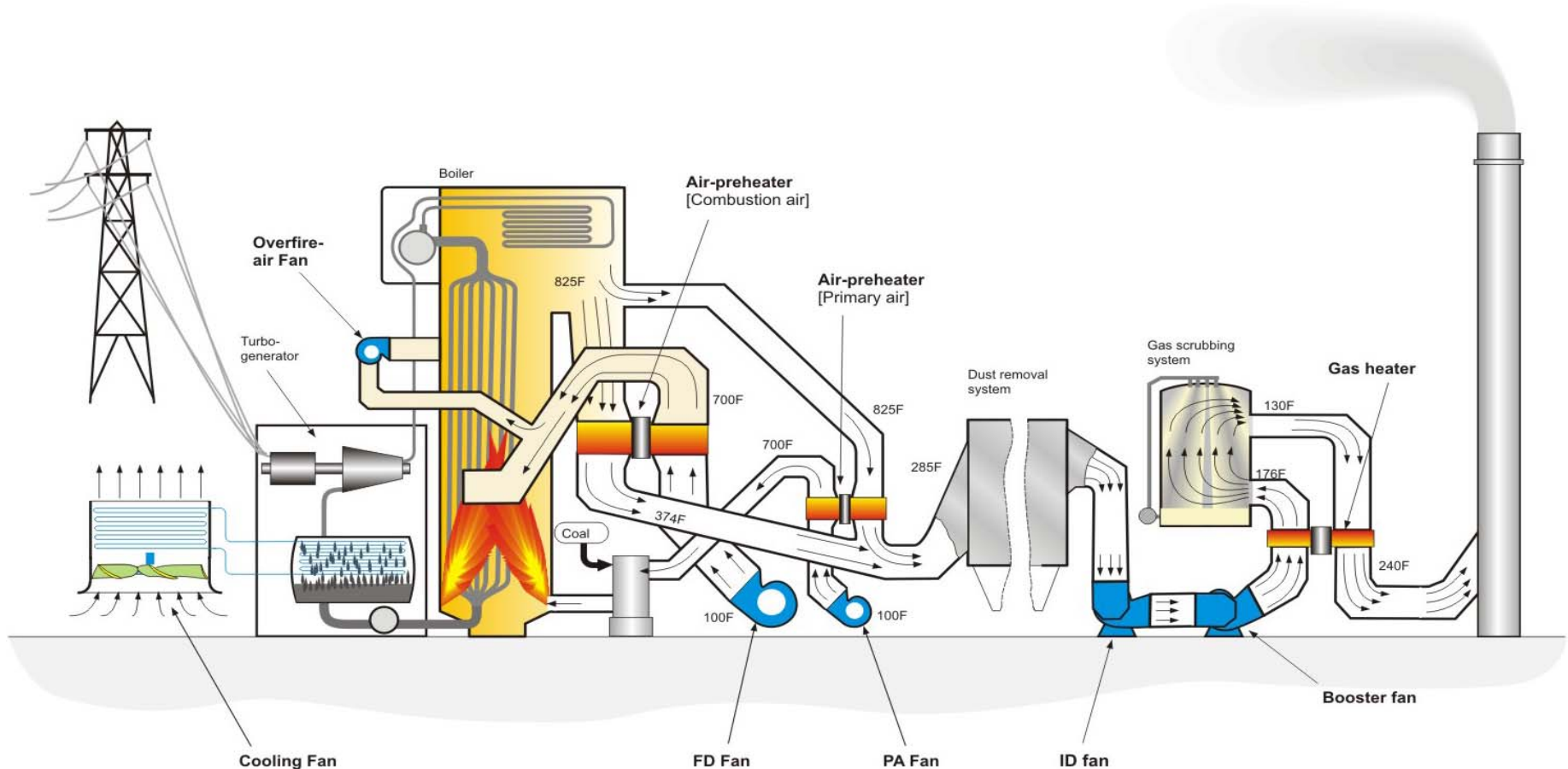
- 1 Current Practice
- 2 Fan Theory and Types Available
- 3 Assessment of fan requirements for upgraded performance
- 4 Options for upgrading fan performance
- 5 Costs/ benefits of the possible options



# Current Practice

The situation today

### Typical power plant layout with ESP and FGD scrubber



### Typical induced draft pressure requirements

- Traditional boiler with Electrostatic Precipitator - 25 to 30 inches wg
- Additional pressure requirement for SCR – 8 to 10 inches wg
- Additional pressure requirement for FGD (spray tower) – 6 to 8 inches wg
- Additional pressure requirement for FGD (submerged) – 20 to 25 inches wg
- Additional pressure requirement for baghouse – 8 to 10 inches wg
  - Total pressure requirement for all of the above – 47 to 75 inches wg.
  - Depending on what equipment you already have, and how much more you need to install, you may need to increase fan pressure requirements from 20% to over 100%!



# Fan Theory and Types

What are your choices?

### Fan Law Summary (from ANSI/AMCA 99)

Volume 
$$\left[ \frac{Q_c}{Q} \right] = \left[ \frac{D_c}{D} \right]^3 \left[ \frac{N_c}{N} \right] \left[ \frac{K_p}{K_{pc}} \right]$$

Total Pressure 
$$\left[ \frac{P_{tc}}{P_t} \right] = \left[ \frac{D_c}{D} \right]^2 \left[ \frac{N_c}{N} \right]^2 \left[ \frac{K_p}{K_{pc}} \right] \left[ \frac{\rho_c}{\rho} \right]$$

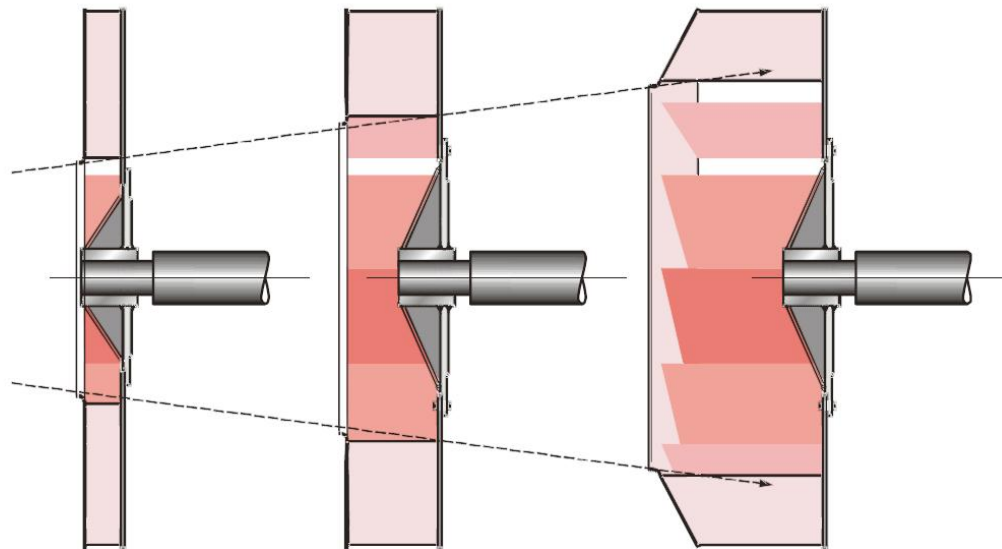
Velocity Pressure 
$$\left[ \frac{P_{vc}}{P_v} \right] = \left[ \frac{D_c}{D} \right]^2 \left[ \frac{N_c}{N} \right]^2 \left[ \frac{\rho_c}{\rho} \right]$$

Power 
$$\left[ \frac{H_c}{H} \right] = \left[ \frac{D_c}{D} \right]^5 \left[ \frac{N_c}{N} \right]^3 \left[ \frac{K_p}{K_{pc}} \right] \left[ \frac{\rho_c}{\rho} \right]$$

Static Pressure 
$$P_{sc} = P_{tc} - P_{vc}$$

Efficiency 
$$\eta_{sc} = \eta_{tc} \left[ \frac{P_{sc}}{P_{tc}} \right]$$

### Fan Specific Speed



Low Specific Speed  $\longrightarrow$  High Specific Speed

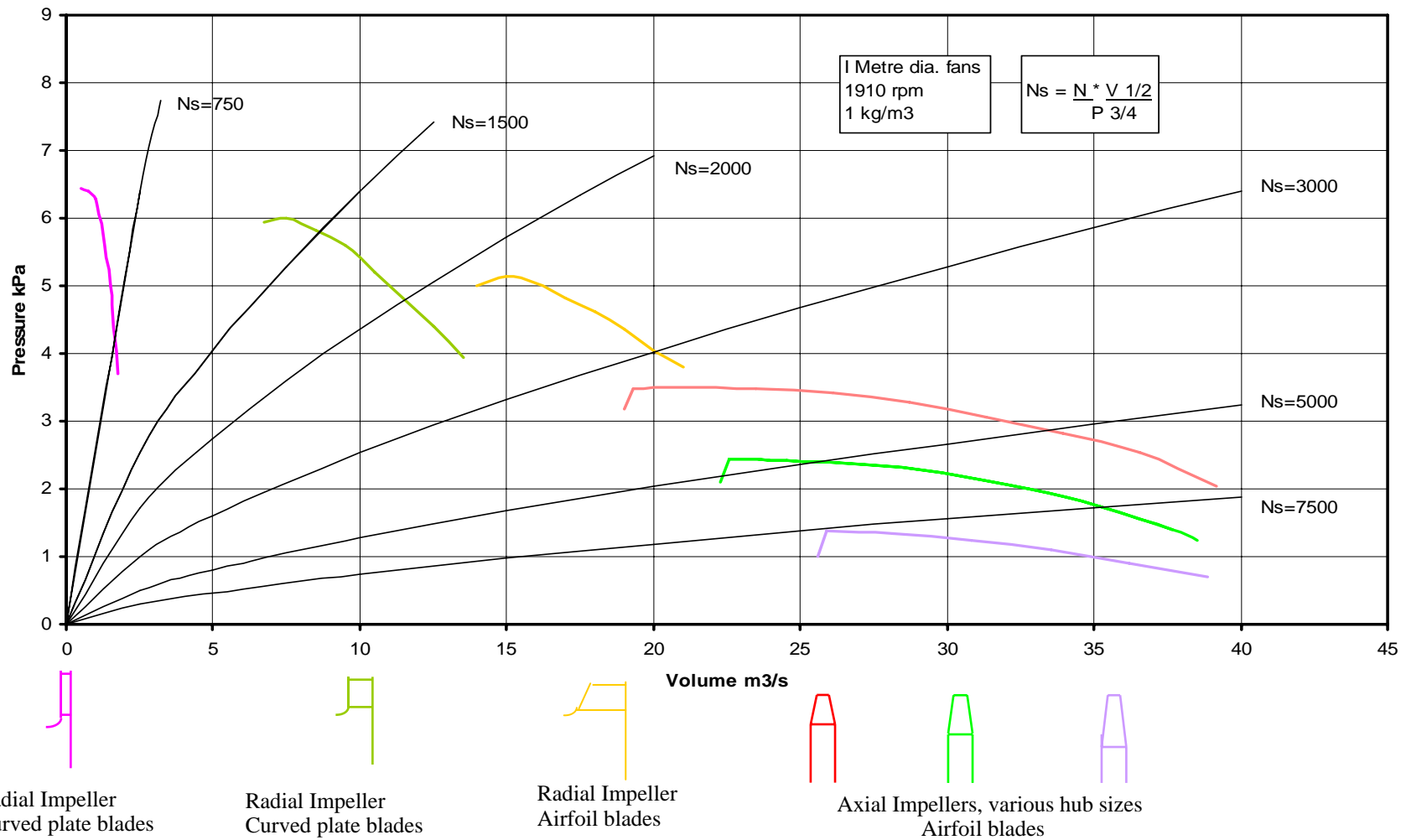
$$\text{Specific Speed} = \frac{\text{Rotational Speed} * \text{Volume}^{\frac{1}{2}}}{\text{Equivalent Pressure}^{\frac{3}{4}}}$$

- The ability of a fan to generate pressure and flow with impeller speed. It is the speed at which a fan of indeterminate diameter will run to produce unit flow at unit pressure.
- Low Specific Speed Fans produce high pressures at low flow.
- High Specific Speed Fans produce lower pressures at high flow.
- Specific Speed is proportional to impeller inlet diameter and impeller width for a given (fixed) wheel diameter.

### Impeller Ranges

#### Abridged Fan Range

(with lines of constant specific speed plotted)

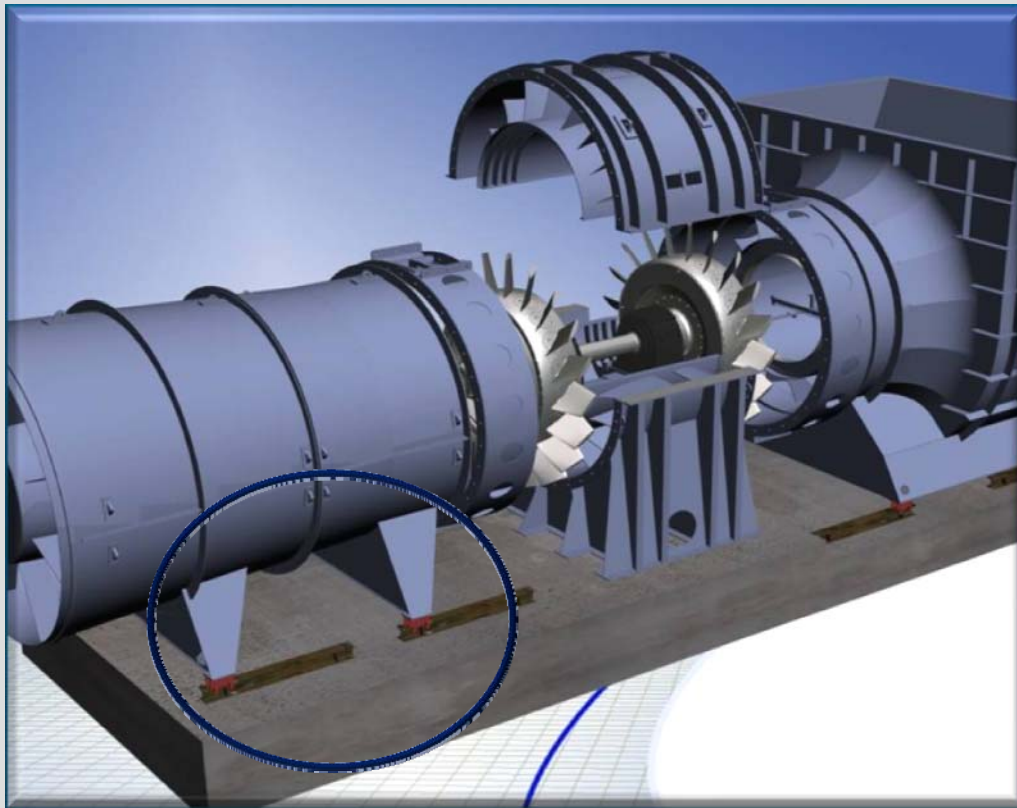




# Fan Theory and Types

## AXIAL FANS

### Typical axial ID fan



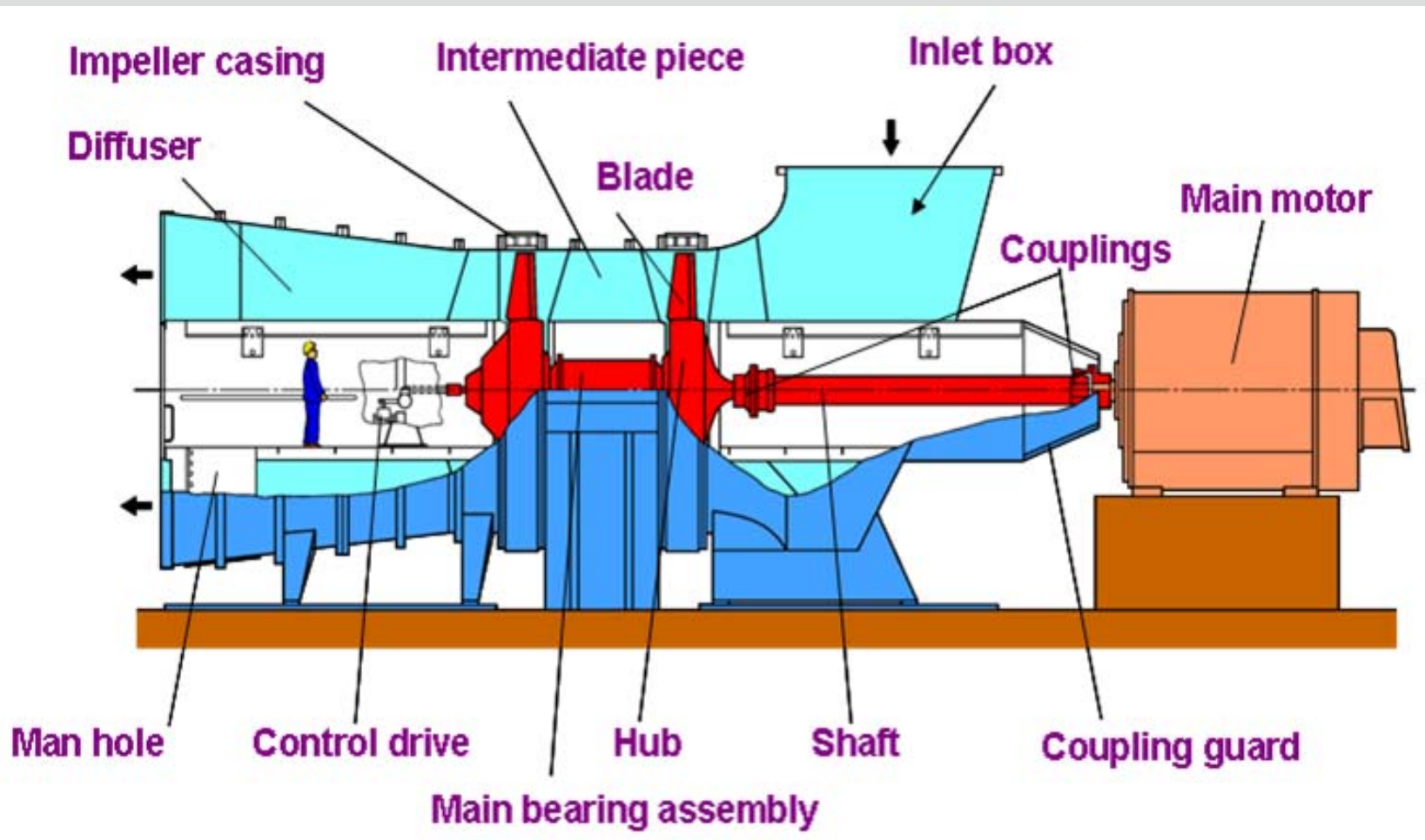
- Available in single and two-stage versions depending on pressure requirements
- Very High Specific Speed results in fewer fans being required for a given flow and pressure.
- Requires periodic re-builds of hub and main bearing assemblies.
- Maintains higher efficiency at lower loads

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Upgrading Draft Fans to comply with U-MACT Regulations



## Axial Fan



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## Axial Fan

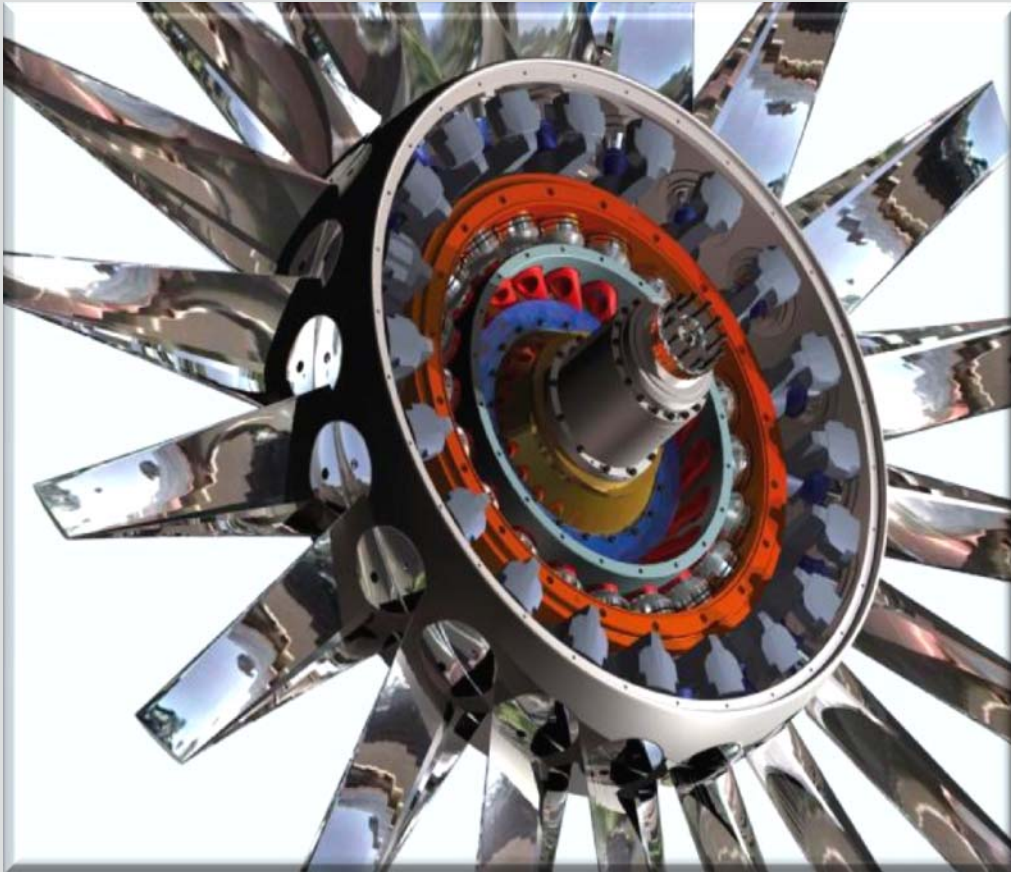


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## Upgrading Draft Fans to comply with U-MACT Regulations



### Typical impeller details



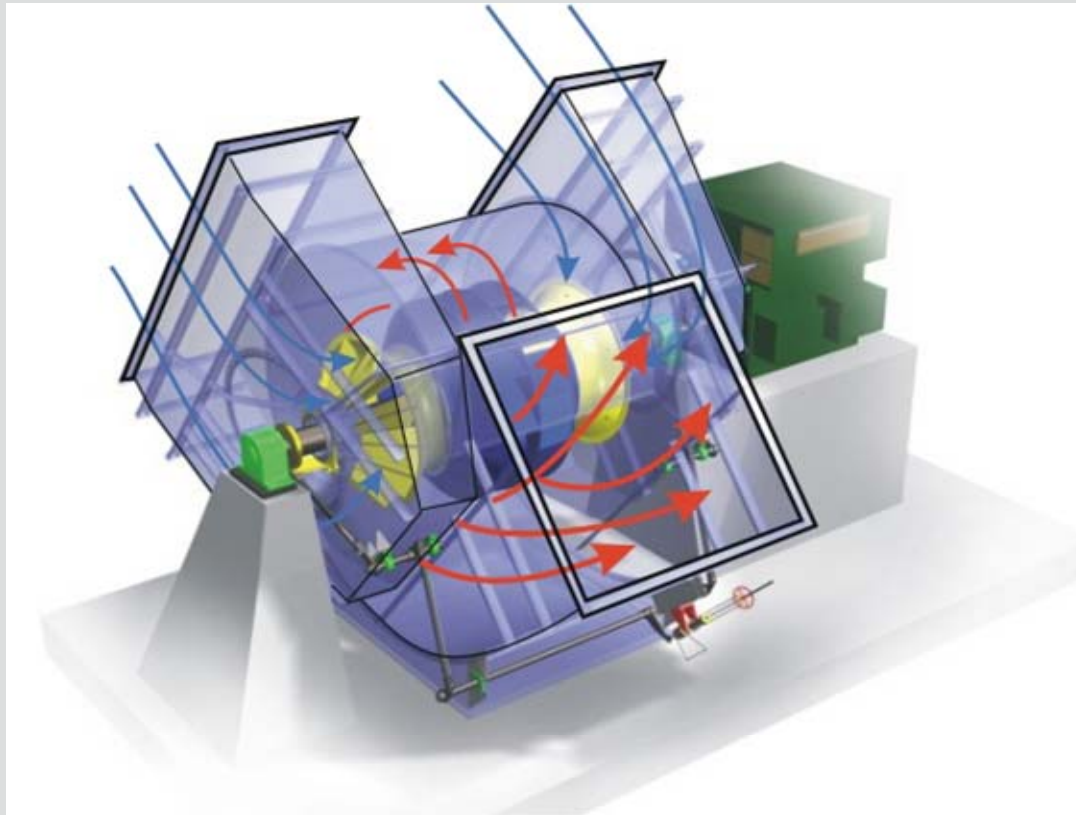
- Ability to alter pitch angle in operation maintains high efficiency over a wide range of flows and pressures
- Modern high-pressure blade profiles have significantly reduced the size of the fan needed to perform a given function



# Fan Theory and Types

## **CENTRIFUGAL FANS**

### Typical centrifugal ID fan



- Only a single stage is required to provide sufficient pressure for any power plant ID application
- Limitation in Specific Speed may require a greater number of fans to provide sufficient flow
- Low maintenance requirements
- Can maintain very high efficiency at lower loads by use of variable speed control.
- Variable inlet vanes and inlet louver damper controls are alternate options.

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## Typical centrifugal ID fan



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## Assessment of fan requirements for upgraded performance

### Steps to follow to identify new fan requirements:

- **First, find out what the current fans and system are doing**
  - Perform a field performance test to establish the performance of the existing fans and the current system resistance as both may have changed over the years
  - If a retrofit is being considered, evaluate the existing fans and their foundations for stiffness and resonant frequencies

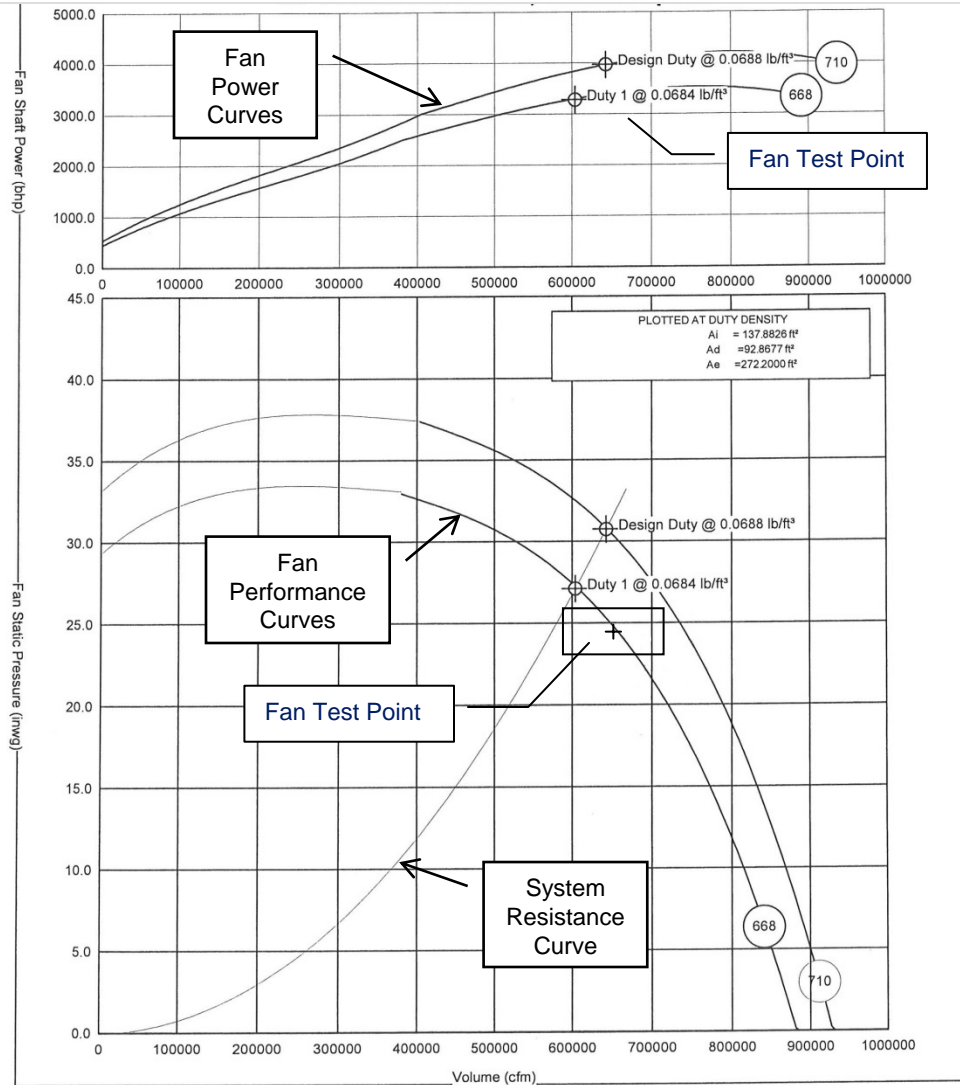


## **Assessment of fan requirements for upgraded performance**

**Field Performance Testing**

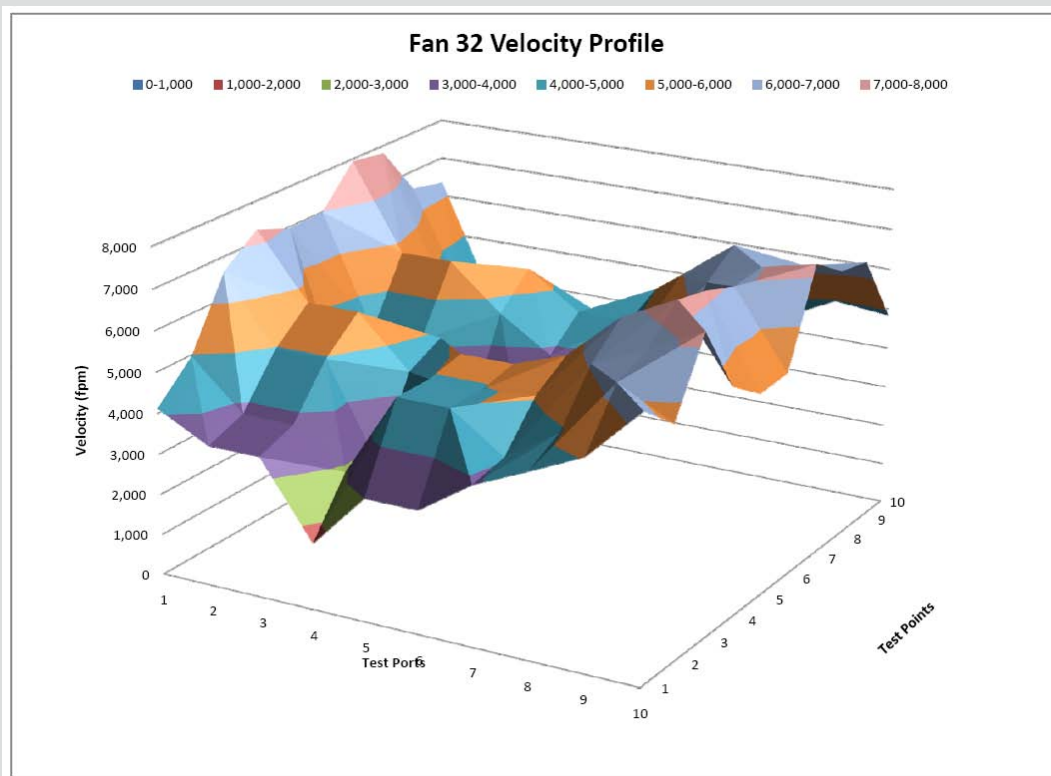
## Comparison of Field Performance Testing Standards

- **AMCA 203**
  - Most common fan field test – can test any fan or installation
  - Test uncertainties typically higher, varying from 5-10%
- **AMCA 803**
  - Specifically written for Industrial Process and Power Generation Fans
  - Approximately 3-4% uncertainty
  - Mandates good flow profiles at fan inlet.
- **ASME PTC-11**
  - More complicated equipment and procedures
  - Can provide uncertainties as low as 2-3%



## Sample Fan Performance Curve Plot

- Flow vs. Fan Shaft Power
- Flow vs. Static Pressure
- Rectangular Boxes Around Test Points Indicate Measurement Uncertainty Windows for 95% Confidence Limits



*3-D Velocity Profile*

## Test Data Presentation

- 3-D Velocity Profiles Can Be Mapped For Test Points to Identify Flow Patterns and Obstructions

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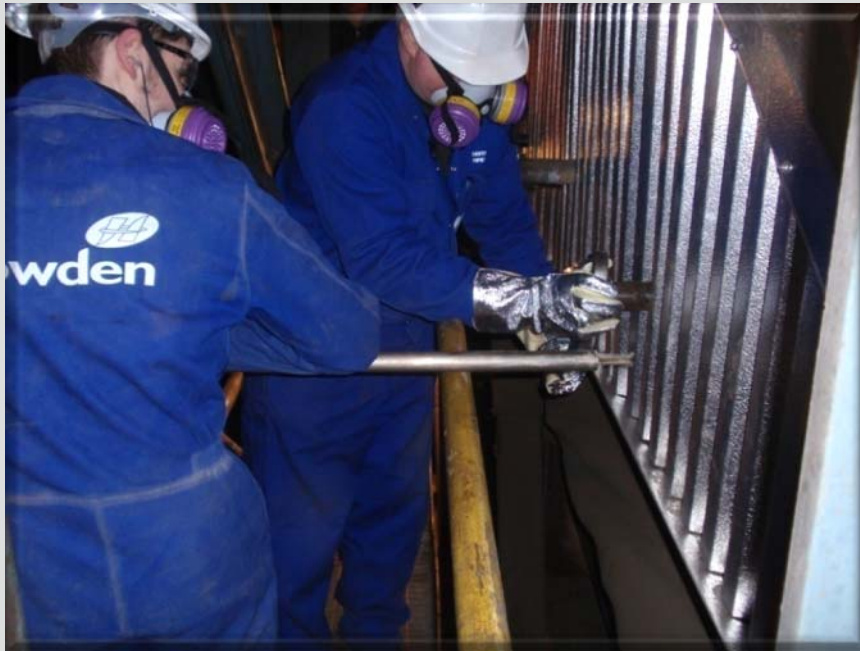
Upgrading Draft Fans to comply with U-MACT Regulations



## Test Ports

- Customer Installed Test Ports- Located Upstream of Inlet Vanes

### Performance Testing



*Breathing apparatus may be required for ID or booster fan testing*



*Probes can be long and unwieldy, especially in tight spaces*



## Test Equipment

- Computerized Data Acquisition System for 5 Hole Probe Air Flow Testing
- Provides Yaw and Pitch Angles as Required by PTC-11
- Provides Faster Data Collection, Allowing for More Test Points – Eliminates Human Averaging
- 6', 8', and 12' Length Probes Available

### Test Equipment

#### “S”-Type Pitot Tubes and 5-Hole Probes

- For Conducting Duct Velocity Traverses to AMCA and ASME Test Standards
- Data may be Measured with Hand Held Pressure Meters or Automatic Data Acquisition Systems

#### “S”-Type Pitot Tubes

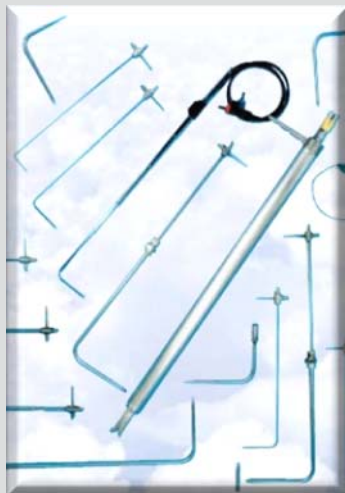
- For Measurements on High Dust Load Applications

#### 5 – Hole Probe

- For Measuring Spiraling Flow



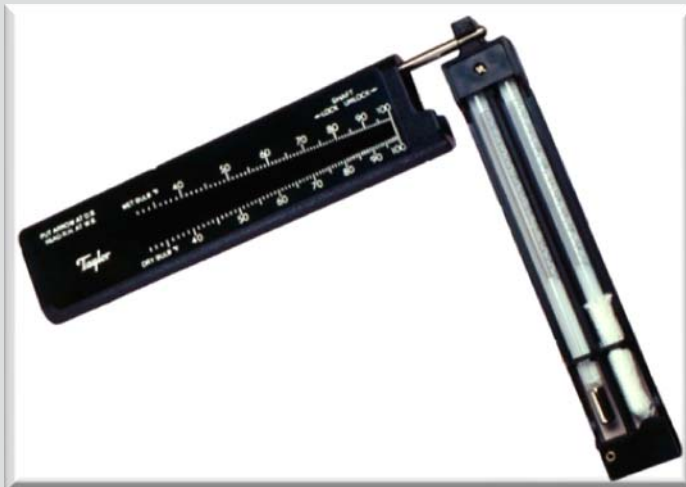
### Additional Test Equipment



- Gas Composition Analysis Systems for O<sub>2</sub>, CO<sub>2</sub>, CO, NO<sub>x</sub>, and Temperature
- Digital Manometers in Pressure Ranges Zero to 4, 20, 40, and 200 Inches of H<sub>2</sub>O
- Laser and/or Stroboscope Systems for Shaft Speed Measurements
- Pitot Tubes – Length May be Adjusted On Site to Accommodate a Variety of Duct Sizes

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## Additional Test Equipment

- Slack Tubes Ranging Up to 100 Inches
- Temperature Meters
- Manual and Digital Psychrometers
- All Equipment Calibrated to Require Accuracy Under AMCA and ISO Testing Standards



# Assessment of fan requirements for upgraded performance

**IMPACT TESTING**

### Static Impact Testing



### Foundation Impact Testing





## Options for upgrading fan performance

### Options for upgrading fan performance:

- ❖ **Centrifugal fans only**
  - Add blade tips
  - Rotor retrofit at same speed
  - Rotor retrofit at higher speed
  
- ❖ **All fans**
  - Add booster fans
  - Replace existing fans with new fans

### **ID fan upgrade issues to be considered:**

- **Is wheel tipping possible? (Lowest cost solution)**
- **Is a rotor retrofit possible?**
- **If simply adding a booster fan, is there sufficient real estate for the new fan, and its associated ductwork and controls?**
- **If installing completely new fans, are axials or centrifugals the best solution for my case?**
- **If centrifugal fans are chosen, what is the best means of controlling them?**
- **If installing new fans, will they fit on existing foundations?**
- **What is the necessary outage time for the conversion?**
- **What other costs will be involved, such as control systems, civil engineering work, ductwork additions or modifications, demolition of existing equipment, etc.**



### Centrifugal fan blade tips

Limited to pressure increases up to about 10 to 15% maximum. This prevents its use in many upgrade situations.

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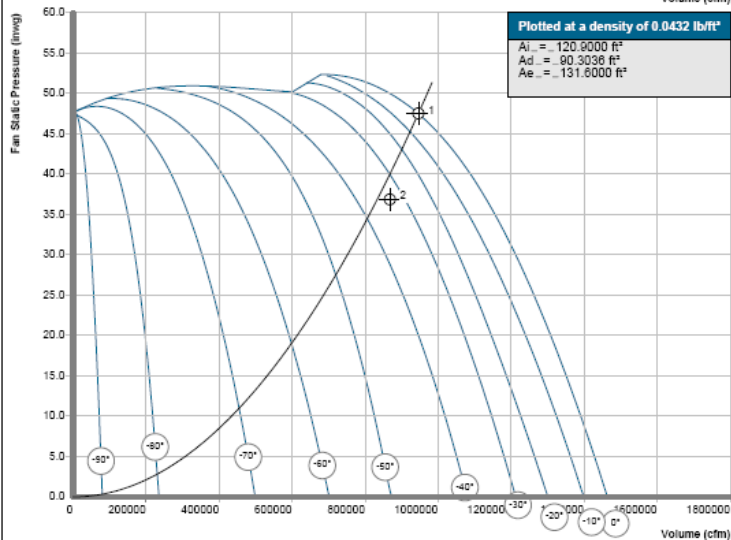
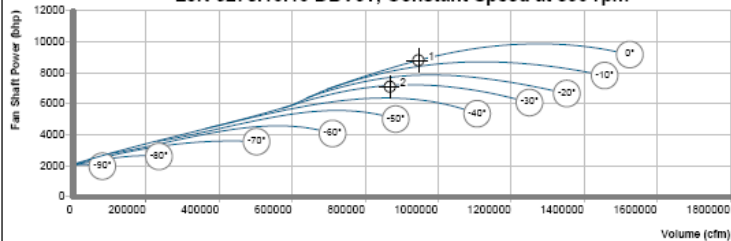


Howden North America Inc.  
HOWDEN FAN PROGRAM - VERSION 1.0.0.1  
PERFORMANCE CURVE



Client or Buyer :  
Clients Ref :  
Our Ref :  
File :  
Date : Friday, July 08, 2011  
Application : Induced Draft  
Destination :

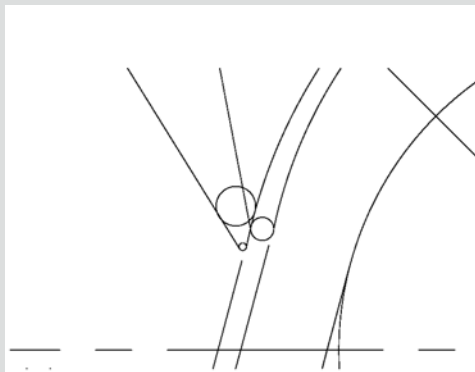
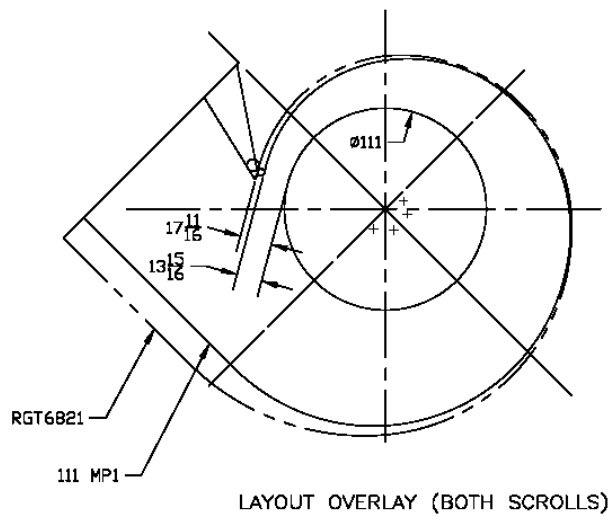
L5N 3278.10.10 DBV6T, Constant Speed at 890 rpm



1 Design Duty @ 0.0432 lb/ft³      2 Normal @ 0.0449 lb/ft³

## Rotor retrofit selection method:

1. Select the ideal fan, assuming all-new equipment.



## Rotor retrofit selection method:

2. Compare the selected ideal fan casing and boxes with existing equipment and consider modifications to existing casing/boxes to minimize losses.

Pay particular attention to the position and geometry of the cut-off.

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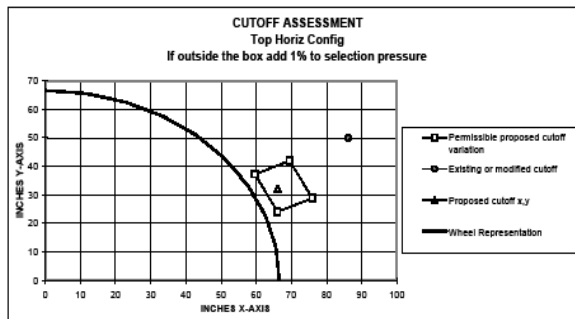
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### HOUSING DERATE CALC

	EXISTING	PROPOSED
VEL CO	11440	8159
HSG LOSS		1.13
CO LOSS	2.21	
CO LOSS DELTA	1.09	
VEL 360	15996	13567
HSG LOSS		1.13
360 LOSS	1.56	
360 LOSS DELTA	0.44	
HSG DERATE->		
DELTA AVERAGE	0.76	
INLET BOX DERATE->		
INLET BOX VEL	4418	3976
INLET BOX LOSS	0.74	0.59
BOX DERATE (DELTA) AT DENSITY	0.06	

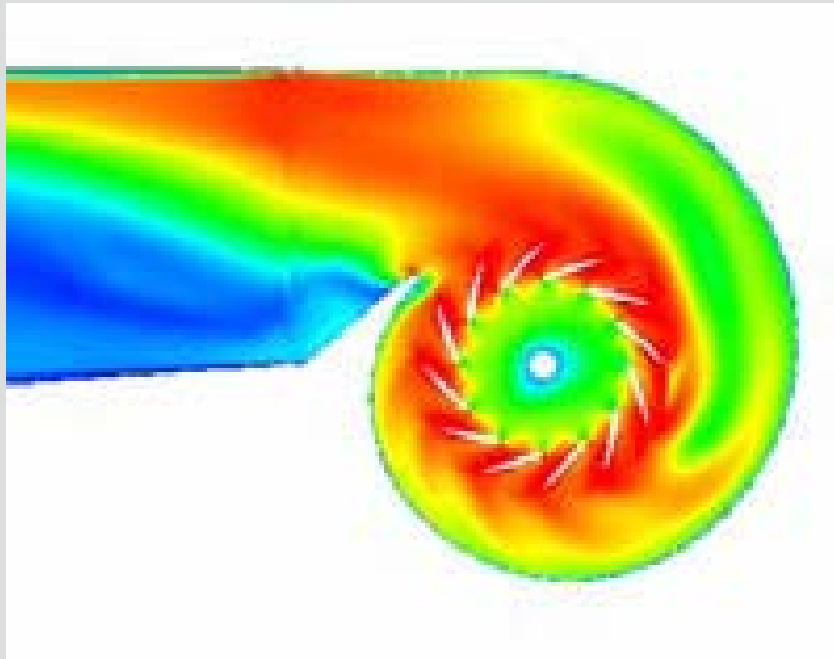
HOUSING + INLET BOX DERATE \_\_\_\_\_



TOTAL DERATE: \_\_\_\_\_

## Rotor retrofit selection method:

3. Estimate “retrofit de-rate” using proprietary software.



### Rotor retrofit selection method:

4. Alternatively, use CFD to estimate the “retrofit de-rate”, particularly for fan housings that are not well-matched to the new wheel.

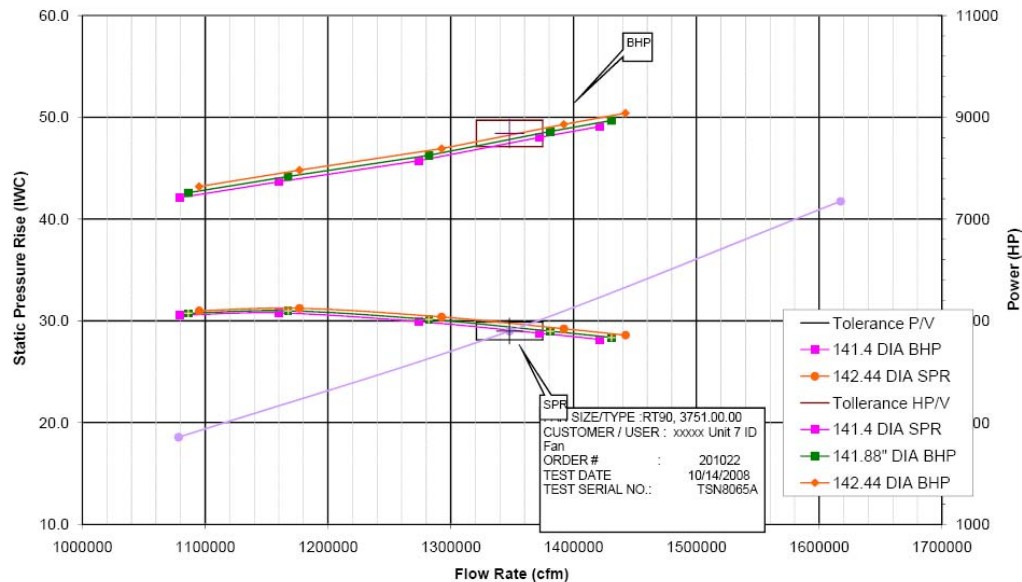
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## Upgrading Draft Fans to comply with U-MACT Regulations



XXXXXXX Unit 7 ID Fan Model Test Results - Test Block

Customer's Existing Housing / Std Width Impeller



## Rotor retrofit selection method

5. Verify estimate using model test. (AMCA 210 & AMCA 802)

A model test is an excellent method of verifying performance estimates prior to manufacturing the fan. Any issues can be resolved in the laboratory rather than at site.



### **Rotor retrofit issues to be considered:**

#### **❖ In all cases:**

- Will the new wheel perform adequately in the old housing?
- Do we need to perform a model test to verify estimated performance
- Will housing modifications (inlets, VIV, cut-off) be excessive?
- Is the existing housing in good condition?
- Must the shaft or bearings and/or pedestals be replaced?
- Is connecting ductwork adequate for the higher pressure?

#### **❖ For speed increases:**

- Are the foundations suitable for the higher speed?
- Will the higher vibration frequency excite other equipment in the vicinity?
- Can the shaft be designed with adequate critical speed without choking the fan inlets?
- Will there be erosion issues due to the higher fan speed?

## Axial or Centrifugal – your choice:

### Axials

- Typically, two axials can do the performance of four centrifugals, at approximately the same total power consumption
- Axials maintain high efficiency over a wide range of performance by varying blade pitch in operation
- Axials are significantly more expensive per fan due to complexity of blade pitch mechanism and hydraulics
- Axials **MUST** have routine periodic rebuilds of hubs and main bearing units, typically every six to eight years
- Heavy dust burdens can erode blade leading edges, leading to efficiency loss
- Axials may require less real estate and smaller foundations

## Axial or Centrifugal – your choice:

### Centrifugals

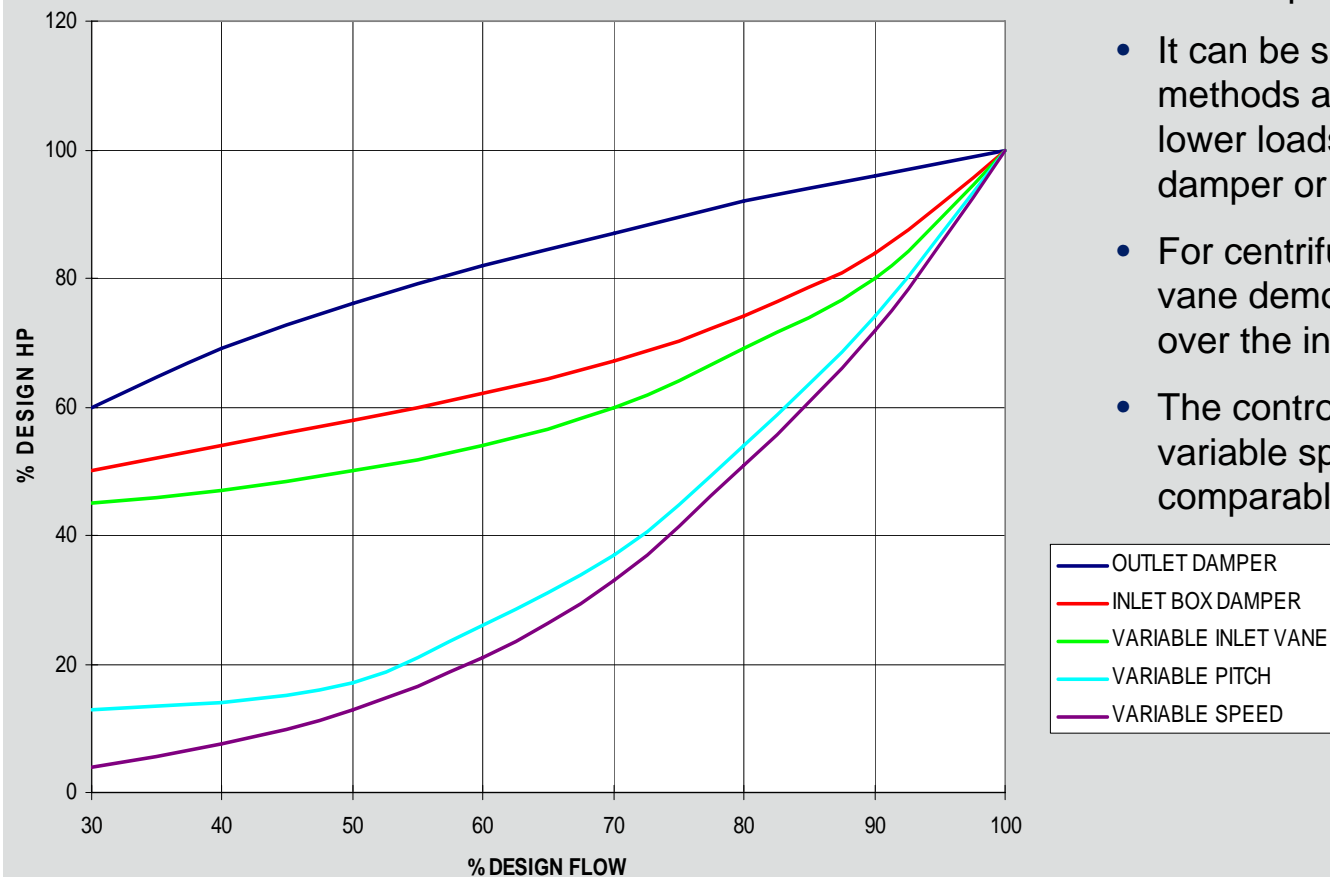
- Rugged well proven designs
- If controlled by variable inlet vanes, or inlet louver dampers, efficiency reduces quickly with lower loads.
- If controlled by variable speed, efficiency is maintained at high level at all loads
- Centrifugals are significantly less expensive per fan due to simple design
- Minimal maintenance required compared to axial
- Performance is relatively insensitive to erosion of blade leading edges
- May require more real estate and heavier foundations

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## Upgrading Draft Fans to comply with U-MACT Regulations



### Comparison of control methods for axial and centrifugal fans



- Graph shows relative power consumption versus flow.
- It can be seen that all control methods are significantly better at lower loads than a simple system damper or fan discharge damper
- For centrifugal fans, the variable inlet vane demonstrates an advantage over the inlet louver damper
- The controllable pitch axial and the variable speed centrifugal are comparable in efficiency at all loads.



## **Costs / Benefits of the possible options**

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### Indicative Costs for Upgrading fans for an Additional 12” of Pressure on an 800MW Boiler

Type of Upgrade	Equipment Included	Exclusions	Cost/fan in \$M	Cost/boiler in \$M
Centrifugal Rotor Retrofit	Wheel/shaft, housing mods, bearings, inlet, VIV, lube skids, bearings, coupling, model test.	Motor, installation	.9	3.6
Add New Centrifugal Booster Fan	Complete centrifugal fan	Motor, foundations, ductwork, installation	1.3	5.2
Add New Axial Booster Fan	Complete axial fan	Motor, foundations, ductwork, installation	2.6	5.2
Replace with New Centrifugal Fans	Complete centrifugal fan	Motor, foundations, ductwork, installation	1.75	7
Replace with New Axial Fans	Complete axial fan	Motor, foundations, ductwork, installation	3.5	7

Note: If a VFD is chosen for the centrifugal fan, the fan cost will reduce slightly (no VIV) but the VFD cost must be considered.

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**Our experience at your service**  
Thank you for your time



## **John Magill**

Vice-President, Engineering

### **Howden North America Inc.**

7909 Parklane Rd

Columbia

South Carolina SC 29201

Office: 803 741 2764

Mobile: 803 361 5045

Email: [jmagill@howdenbuffalo.com](mailto:jmagill@howdenbuffalo.com)

[www.howden.com](http://www.howden.com)