ASME PTC-13 in Action: Practical Approach to Blower System Performance Testing

Hiran de Mel, P.E. and Julie Gass, P.E.
Keynote Speakers

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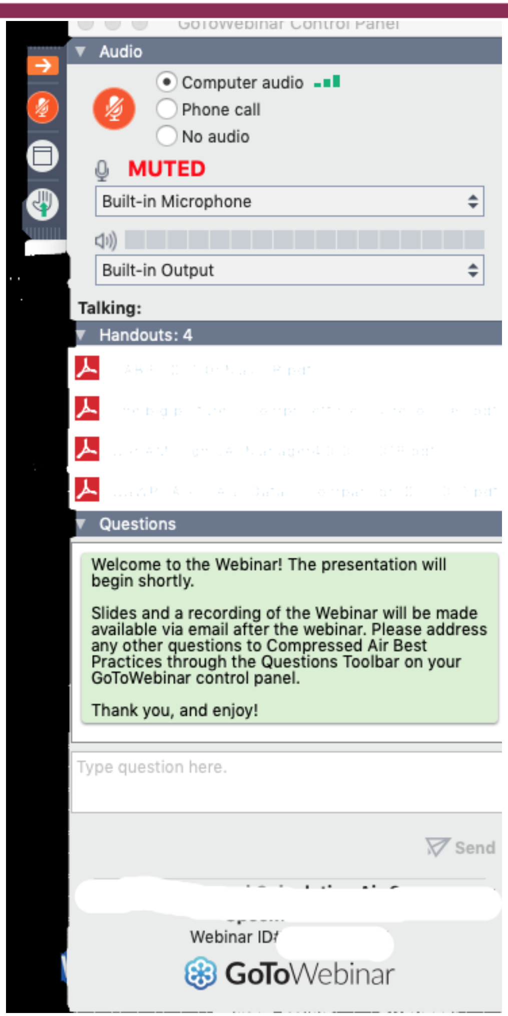

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ASME PTC-13 in Action: Practical Approach to Blower System Performance Testing

Introduction

Blower & Vacuum Best Practices Magazine

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The Speakers

Hiran de Mel, P.E.
Jacobs
Keynote Speaker

Julie Gass, P.E.
Black & Veatch
Keynote Speaker

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Today's Webinar

Hiran de Mel

- Brief Introduction to ASME PTC 13
- Specifying PTC 13
- Establishing Performance Points
- Developing a Test Plan
- Witness Test Roles and Responsibilities
- Inovair Blower Test 1
- Things Inovair did well and what can be improved

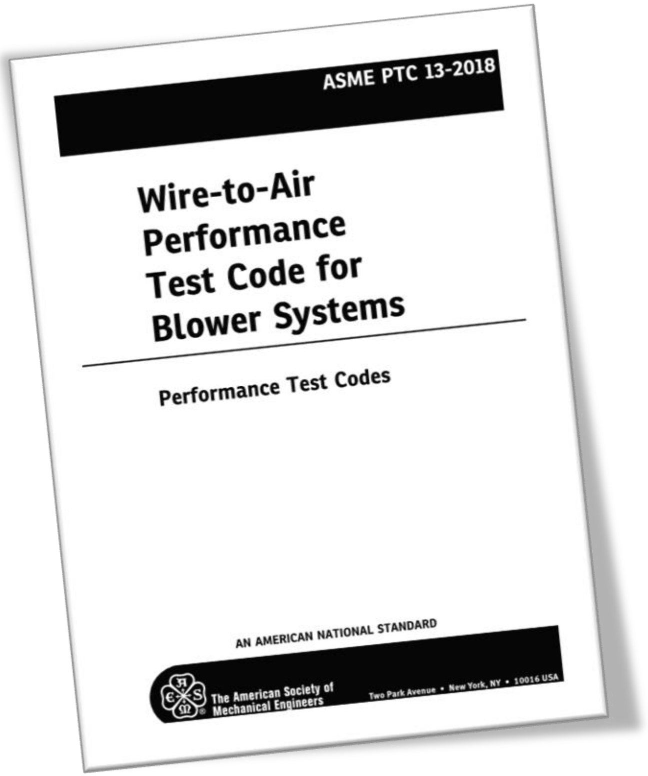
Julie Gass

- Inovair Blower Test 2
- Test Protocol submittal
- Witness Testing –How to Conduct & What to Look for
- Test Report and Presentation of Results
- Evaluating and Acceptance of Results
- Things Inovair did Well
- Areas for Improvement
- Summary

Overview of ASME PTC 13

"Wire-to-Air Performance Test Code for Blower Systems"

- Developed by: The American Society of Mechanical Engineers (ASME)
- Initiated by: Consortium for Energy Efficiency (CEE) in 2010
- Historical Context:
  - ASME PTC 9 (Displacement Compressors, Vacuum Pumps, Blowers) - First issued in 1915
  - ASME PTC 10 (Compressors and Exhausters) - First issued in 1934
- Purpose: Addresses advancements in blower and compressor technology



Technological and Industry Relevance

- Technological Developments:
  - New mechanisms, control techniques, and integrated systems
- Industry Impact:
  - Focused on wastewater treatment industry
  - Electrical energy usage
- Key Features:
  - Technology-neutral evaluation
  - Wire-to-air power consumption
  - Rigorous, industry-accepted test procedures

Limitations of ASME PTC 13

- Blower Packages with Intercoolers:
  - Not covered; refer to ASME PTC 10
- Blowers with Side Streams:
  - Excluded due to measurement deviations
- Blowers, Fans, and Compressors Applicable when:
  - Gas is air
  - Inlet pressure near atmospheric
  - Pressure ratio ≤ 3.0
  - Covers a range of blower types and applications
- Intent:
  - Standardize performance testing for centrifugal and PD blowers
- Testing without adjustment for uncertainty or including a tolerance, yield the best available indication of the actual performance of the tested equipment

ASME PTC 13 Testing Philosophy - Overview

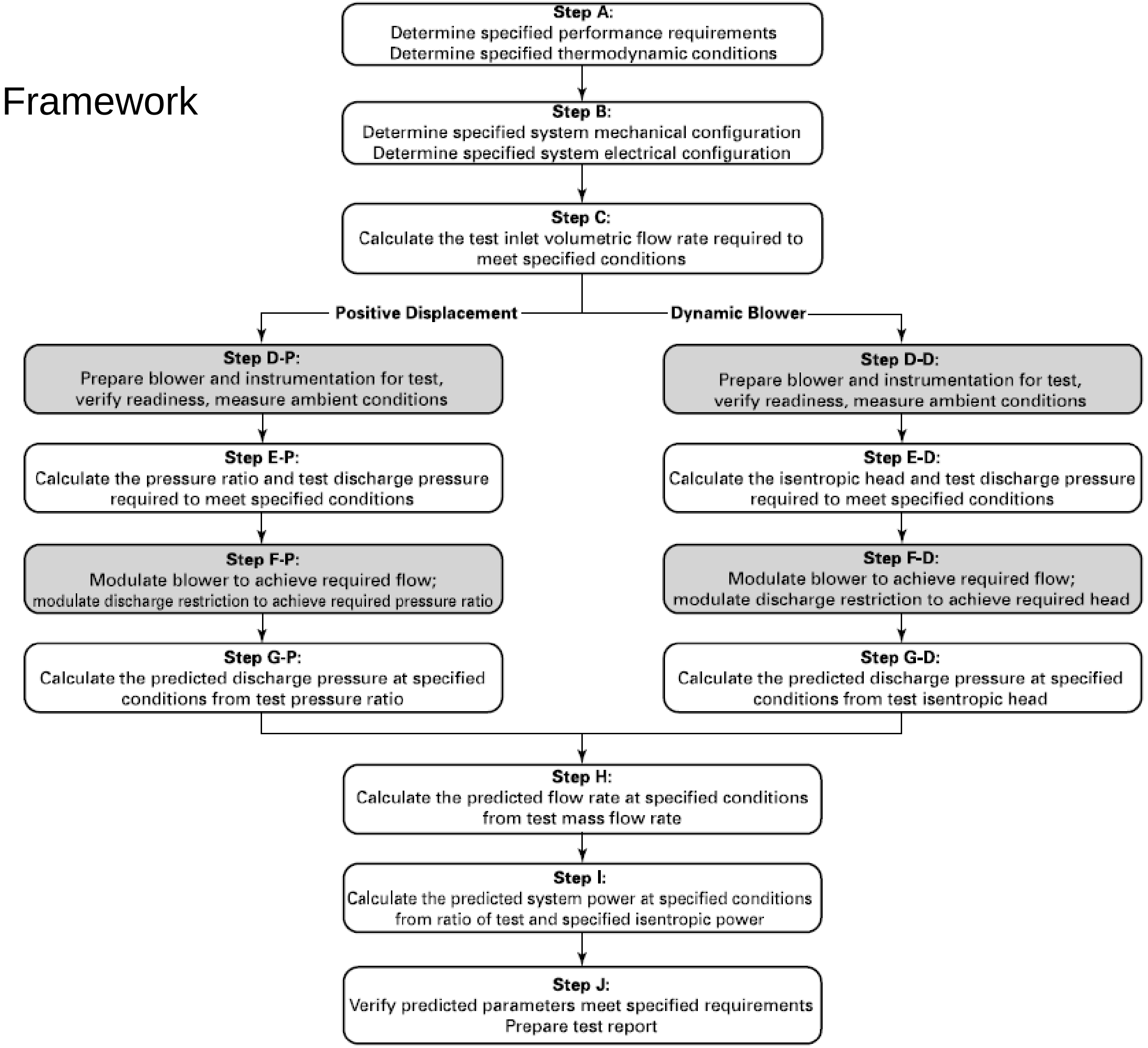
- Objective:
  - Measure "wire-to-air" performance, focusing on electric power consumption under specified conditions.
- Measurement Procedures:
  - Air Capacity: Inlet volumetric flow rate measured at the blower discharge.
  - Inlet Flow Calculation: Based on delivered mass flow and inlet density.
- Performance Verification:
  - Confirm compliance with specified conditions including flow rate, pressure, and environmental factors.

ASME PTC 13 Testing Philosophy - Methodology

- Adjustment of Test Conditions:
  - Match test conditions to specified parameters, emphasizing flow rate and isentropic head/pressure ratio.
- Testing Methodology:
  - Dynamic (Centrifugal) Blowers: Match operating speed with inlet flow rate and isentropic head, using additional flow control methods as needed.
  - Positive Displacement (PD) Blowers: Match operating speed with inlet flow rate and pressure ratio.
- Guidance on Deviations:
  - Detailed directives for acceptable variations in operating conditions and air properties.

Calculation Methodology Framework

Figure 5-1.1-1
Calculation Methodology Framework



Included in test

Determine by calculation

Specified Performance Test Points and Conditions

Table 2 Continuous Duty Operating Conditions					
100 Hp Blowers					
Operating Condition (1) (2)	**Inlet Temperature (deg. F)**	**Inlet Relative Humidity (%)**	**Discharge Airflow Rate (scfm)**	**Discharge Pressure (psig)**	**Total Wire Power (kW)**
Condition 1	95	80%	1,850	6.5	63.5
Condition 2	95	80%	665	6.5	34.1
Condition 3	85	80%	1,900	6.5	64.0
Condition 4	25	0%	685	6.5	36.2
Condition 5	65	80%	1,960	6.5	N/A
Condition 6	15	0%	725	6.5	N/A
Condition 7	95	80%	1,350	4.75	N/A
Condition 8	95	80%	325	4.75	N/A
Condition 9	15	80%	1,430	1.25	N/A
Condition 10	15	0%	355	1.25	N/A
60 Hp Blowers					
Operating Condition (1) (2)	**Inlet Temperature (deg. F)**	**Inlet Relative Humidity (%)**	**Discharge Airflow Rate (scfm)**	**Discharge Pressure (psig)**	**Total Wire Power (kW)**
Condition 1	95	80%	1,350	4.75	42.1
Condition 2	95	80%	325	4.75	17.2
Condition 3	85	80%	1,390	4.75	43.2
Condition 4	25	0%	335	4.75	19.0
Condition 5	65	80%	1,430	4.75	N/A
Condition 6	15	0%	355	4.75	N/A
Condition 7	15	80%	1,430	1.25	N/A
Condition 8	15	0%	355	1.25	N/A

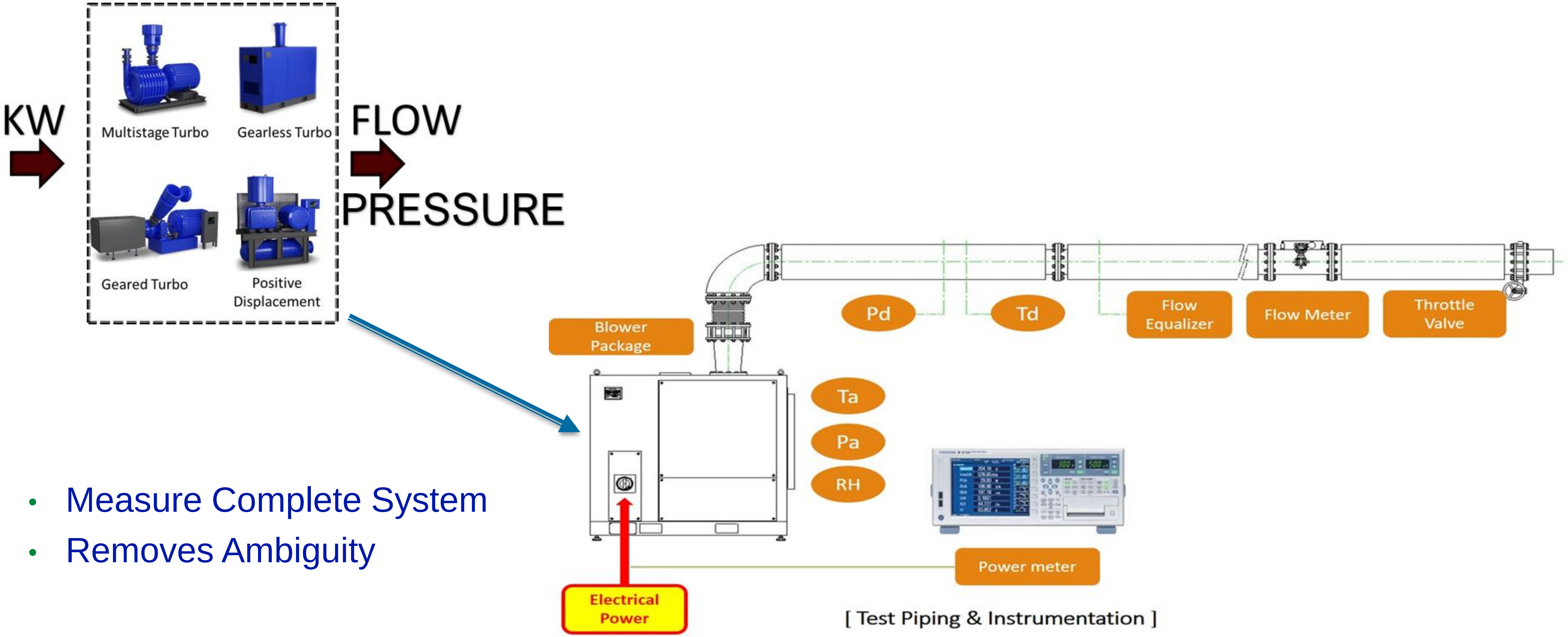
Notes:

(1) Each operating condition shall be considered with the discharge pressure and flow measured downstream of the check valve and shall include inlet losses as noted in Table 1.

(2) The blowers shall be capable of continuously operating between Operating Conditions listed. The Total Wire Power performance shall be guaranteed at Conditions 1, 2, 3, and 4 for each blower with no positive tolerance.

- During Testing
  - Establish performance envelope as specified
  - Measure blower performance at each point at test conditions
  - Calculate predicted blower performance at specified site conditions
  - Evaluate results

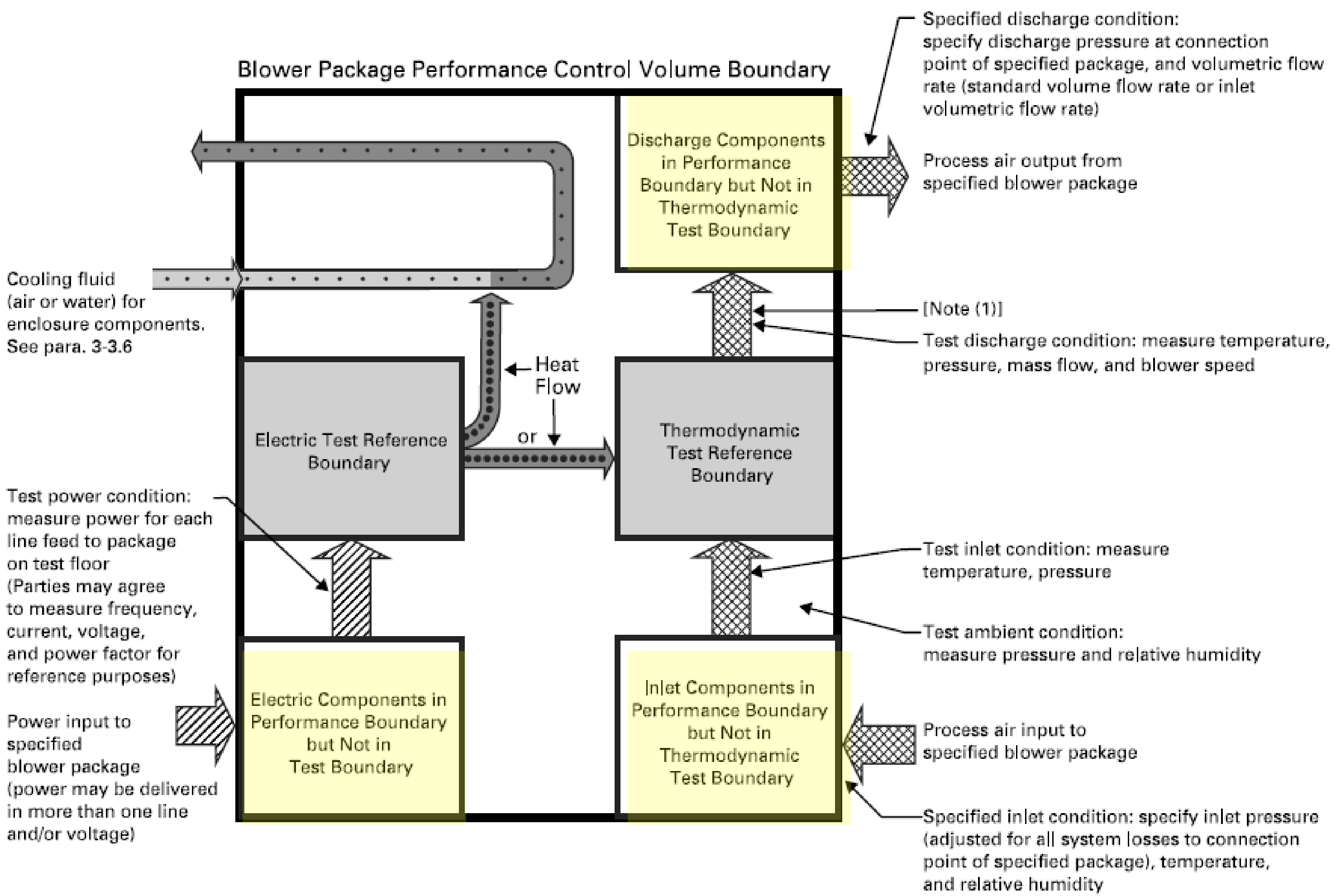
Typical PTC 13 Blower Test Stand Setup



- Measure Complete System
- Removes Ambiguity

Control Volume for Thermodynamic and Electrical Reference Boundary

Figure 3-5.2-1 Blower Package Performance Boundary and Internal Reference Boundaries



Included in test

Determine by calculation

NOTE:

(1) Test discharge operating condition: set blower condition to match inlet volumetric flow at specified condition for setting pressures.

(a) Determine, by calculation, specified inlet pressure to account for inlet components not in test boundary.

(b) Determine, by calculation, specified discharge pressure to account for discharge components not in test boundary.

(c) Set pressure to match specified isentropic head (centrifugal) or to match specified pressure ratio (displacement).

See Section 3-2.

Specify Thermodynamic Reference Boundary

Table 3-5.2-1 – Process and Fluid Components

		Included in Performance Boundary		
		Included in Test	Determine by Calculation	Not Applicable
a	Inlet filter	X		
b	Inlet silencer	X		
c	Discharge silencer			X
d	Inlet isolation valve			X
e	Throttling valve			X
f	After cooler			X
g	Misc. pipe and fittings	X		
h	Inlet air cooler			X
i	Discharge check valve			X
j	Discharge isolation valve			X
j	Enclosure doors or panel openings	X		
l	Estimated system inlet press drop		X	
k	Additional components not listed included as forming the blower Package			X

Specify Electrical Power Reference Boundary

Table 3-5.2-2 – Electrical Power Related Components

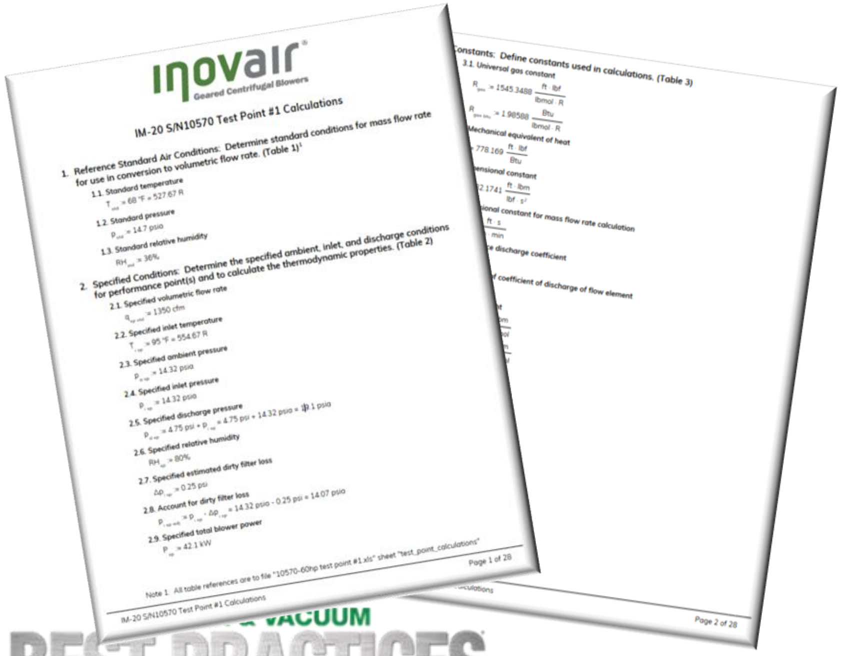
		Included in Performance Boundary		
		Included in Test	Determine by Calculation	Not Applicable
a	Drive motor	X		
b	Motor cooling fan(s)	X		
c	Magnetic Bearing and Controller			X
d	Bearing cooling fan(s)			X
e	Coolant Pumps			X
f	Lubrication Pumps and Accessories			X
g	Heat Exchanger Fans	X		
h	Package Cooling Fan	X		
i	VFD	X		
j	VFD Line Side Power conditioning Equipment			X
j	VFD Load Side Power conditioning Equipment	X		
l	Eddy Current or Variable Speed Clutch			X
k	Operation Control Panel(s)	X		
l	Power/isolation transformers and power supplies	X		
m	Power conditioner			X
n	Blower and motor cooling	X		
o	VFD cooling	X		
p	Additional components not listed included as forming the blower package			X

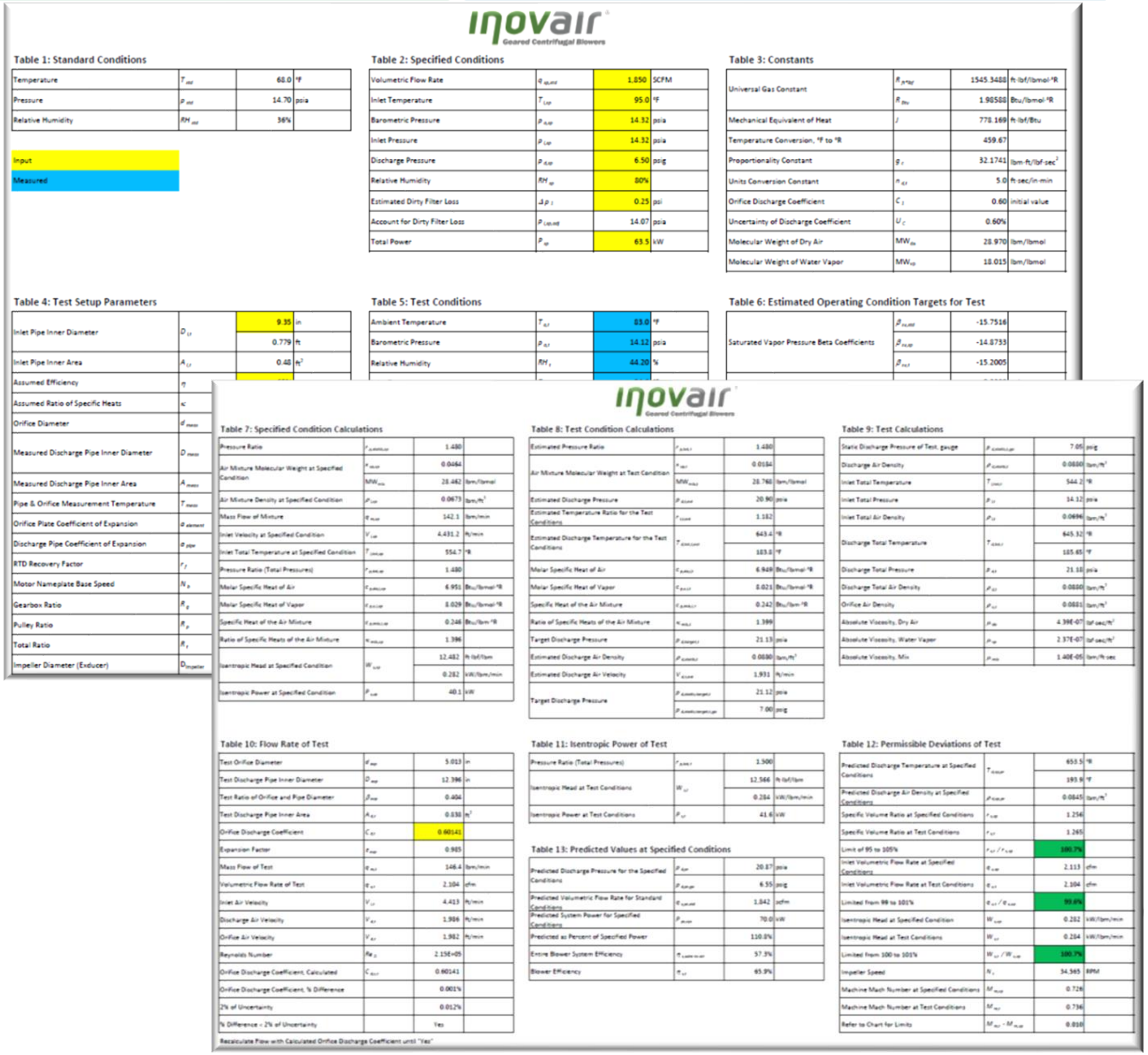
Establishing Performance Points, Calculations and Reporting

- Follow PTC-13 calculation procedures:
  - Section 5 - Computation of Results
  - Section 6 - Report of Results
  - *Section 7 - Test Uncertainty*
  - Mandatory Appendix I - Airflow Conversions
  - Nonmandatory Appendices
    - A - Sample Uncertainty Calculations
    - B - Sample Calculation: Dynamic Blowers
    - C - Sample Calculation: PD Blowers
    - D - Sample Calculation: Machine Reynolds Number Correction
    - E - Sample Calculation: Orifice Flowmeter

Developing a Test Plan

- Develop test plan with test report template
- Develop Test point calculation Sheets
- Develop sample calculations
- Conduct pretest





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Witness Test Roles and Responsibilities

Role and Responsibilities of the Test Witness

- Specify testing requirements
- Review and approve test plan
- “Bear witness” the test was conducted in conformance with purchase contract requirements
- Ascertain that the proposed test plan meets contract requirements and the requirements of ASME PTC 13
- Make observations to document that the test facilities and conduct of the test are in accordance with contract and ASME PTC 13
- Review the final report from the testing entity to evaluate the reported results represent the experience of the test
- Exercise an opinion as to whether the test results indicate that the blower equipment has met contractual requirements

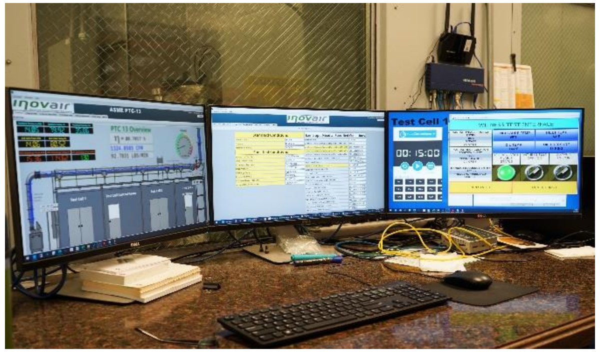
Role and Responsibilities of the Test Entity

- Prepare a detailed test plan that describes facilities and equipment, methods of testing, predictive calculations and calculation aids, proposed allowable tolerances in test results, and final reporting examples.
- Provide all the equipment, personnel, resources, and logistics to conduct the tests described in the test plan.
- Operate all the equipment involved in the test.
- Collect and record all data.
- Provide a comprehensive report of the test and the site performance results predicted through application of ASME PTC 13.

Inovair Blower Test Stand

- Insulated blower discharge and flow measurement station
- Separate test room with multiple computer screens

- Blower with inlet measurement station
- VFD with control panel



Things Inovair did well and what can be improved

- Inovair prepared a detailed test plan, test report template and sample calculation sheets
- Sample calculation were submitted with the test protocol in advance
- Multiple resubmittals were required with the test protocol. Not as many with the test report
- Blowers were mechanically pretested and ran in a stable manner during test
- Inovair blower components are manufactured onsite. Other components are sourced locally
- Inovair was able to manufacturer blower components and retest in a week
- Pretest must include performance testing and verification of the test points
- Inovair needs update blower performance information based on ASME PTC 13 testing

Inovair Blowers

2 Stacked Units

Single Unit with VFD

Test Protocol/Procedure Submittal

- Review test protocol submittal at least 30 days in advance
- Schedule meeting with vendor to expedite review if needed
- Submittal should include:
  - Calibration certificates of all instruments to be used dated within previous 12 months
  - Points to be tested – guarantee points and 5-point curve if required
  - Test arrangement including flow meter straight runs
  - Flow meter information
  - Data collection sheet
  - Rotor balance reports
- Several resubmittals were required. Will go more smoothly next time.
- Inovair submitted sample PTC13 calculation which expedited the report submittal. (Recommend requiring sample calculation of one test point for thermodynamic condition correction)

Witness Testing – Performance Guarantees

Vendor shall guarantee the following power numbers for the operating points listed below.

Performance Table

	A	B	C	D	E	F	G	H	I (G x H)
	Temp (°F)	RH (%)	Total Inlet Flow per Blower (ICFM)[1]	Total Inlet Flow per Blower (SCFM)	Blower Discharge Pressure (psig)	Blower Inlet Pressure Losses (psi)	Guaranteed Power per Blower[2] (kW)	Weight Factor (%)	Factored Power per Blower (kW)
1	100	95	1,754	1,533	9.4	0.3	64.2	15	9.6
2	68	80	1,582	1,533	9.4	0.3	62.0	50	31.0
3	100	95	1,315	1,150	9.4	0.3	47.5	10	4.8
4	68	80	1,186	1,150	9.4	0.3	46.5	25	11.6
								TOTAL	57.0

Notes:

1. Flow shall be measured on the discharge side during testing and corrected to ICFM.
2. Guaranteed power consumption indicated shall be the total wire-to-air power consumption of each blower and shall account for any and all losses including, but not limited to, harmonic filters, motor inefficiencies, AFD inefficiencies, cooling fans or cooling pumps, bearing power requirements, and blower controls.
3. Performance testing shall test for each specific blower operating point to demonstrate conformance.

2-3. ACCEPTABLE MANUFACTURERS. Blower shall be manufactured by Inovair, without exception:

Witness Testing

Blower on Test Stand

VFD on Test Stand

Witness Testing – How to Conduct

- Witness any required onsite instrument calibration or calibration verification
- Verify calibration certificates are available for all instruments & that they match protocol submittal
- Check test stand arrangement to verify it matches protocol submittal
- Review points to be taken and number of readings at each point
- Record test instrument information and verify adequacy including instrument mfr, model, serial, range, division
- Record blower and VFD serial numbers
- Verify location of power measurement & which items are included
- Check route for local direct instrument readings if required

Witness Testing – How to Conduct, cont'd

- Verify thermal stability before starting each reading: No more than 1 deg F change in differential temperature within 5 min
- Start test and timer for readings
- Witness local direct readings and data acquisition readings
- Compare local with DAQ readings
- For centrifugal machines, verify rise to surge requirements are being met
- Take screen shots of DAQ screen
- Request copies of DAQ readings
- If the vendor requires a signature, it should be to verify the readings recorded were the readings witnessed
- Do not sign indicating the unit has passed until there is time to review test report independently in office

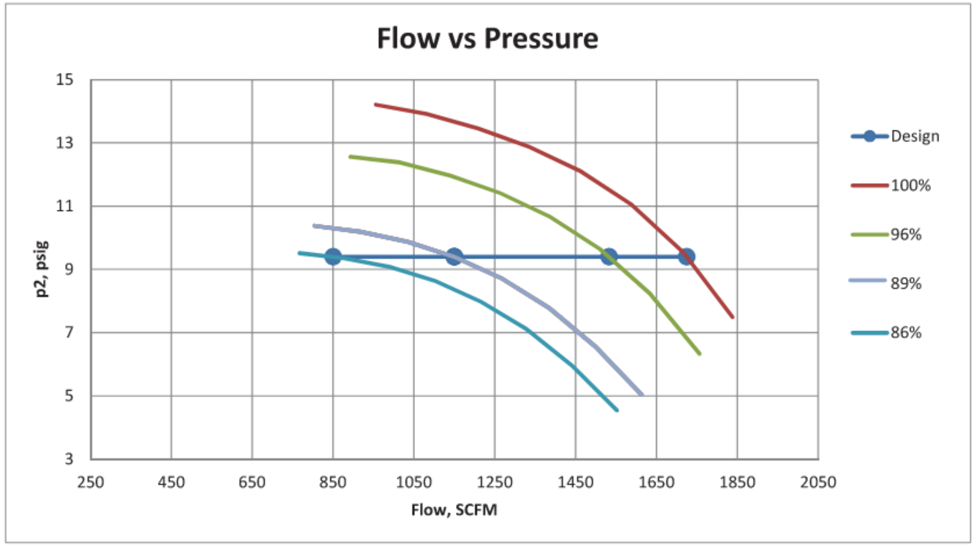
Witnessing & Discussion of Readings in Test Lab

Witness Testing

What to Look for

- While moving up curve, pressure should increase and flow decrease
- Lack of stability between readings at same point
- Objectionable vibration
- Objectionable temperature
- Objectionable noise
- Overhead door opening
- Cooling fan starting or stopping

Example Blower Curve



Test Report & Presentation of Results

- Check sample calculation vs specified site ambient conditions, recorded test lab conditions and PTC13 for methodology
- Compare DAQ readings submitted with screen shots or copies provided at time of test
- Spot check of witnessed local direct instrument values vs values in test report
- Compare local direct readings with DAQ readings (this process should be started during the test)
- Verify required curves have been submitted and that serial numbers are indicated
- Recheck rise to surge requirements are met

Evaluation & Acceptance of Results

- Check flow, pressure, and power vs requirements
- Verify whether power guarantees are met by including weighting factors, present worth factor, etc.

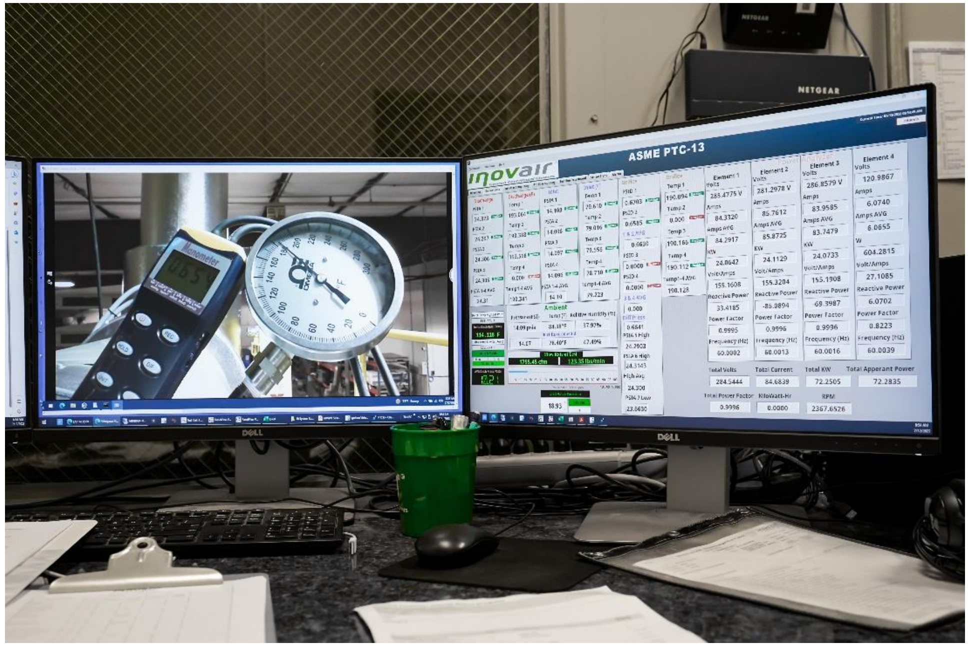
Things Inovair Did Well

- Blowers ran in a stable manner
- A camera was added to view the instruments on the catwalk from the floor (saved time and enhanced safety)
- Inovair has the capability to modify impellers onsite in case a machine does not perform as required
- Sample calculation was submitted with test protocol in advance of test report
- Initially there were not enough blanks on the data sheet to allow recording of 3 readings at each point but this was quickly corrected

Catwalk Flow Instruments & View in Test Lab

Catwalk with orifice plate instruments

Camera image of catwalk instruments & DAQ screen



Data Collection Sheet

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Test Point Data Collection & Notes						
Blower Package	**Test Point**			**Date**		**Time**
Parameter	**Symbol**	**Reading #1**	**Reading #2**	**Reading #3**	**Average Reading**	**Notes**
Ambient						
Barometric Pressure	p_a					
Ambient Temperature	T_a					
Relative Humidity	RH					
Inlet						
Inlet Pressure	p_i					
Inlet Temperature	T_i					
Discharge						
Discharge Pressure	p_d					
Discharge Temperature	T_d					
Orifice & Flow						
Orifice Upstream Pressure	p_o					
Orifice Downstream Temperature	T_o					
Orifice Differential Pressure	Δp_o					
Volumetric Flow Rate	q_v					
Power						
Motor Speed	N_m					
System Power	P_{sys}					
Auxiliary Power	P_{aux}					
Total Power	P_{tot}					
Additional Notes						

Areas for Improvement

- Multiple resubmittals were required for both the test protocol and test report
- Some of the engineering units did not appear in the test report
- Local, direct reading instruments had to be calibrated onsite on the first day of testing. Temperature instruments were time-consuming requiring 8 hrs for everything
- No local relative humidity gauge or pressure upstream of orifice
- Opening/closing of overhead door or running other blowers in test area can affect thermal equilibrium. Inovair was aware of it.
- Most of these issues will be corrected prior to the next test

Test Instrument Cart

Summary

- Before arriving at the manufacturer’s shop: Preplanning, reviewing test protocol, pretesting, agreeing on test arrangement, reviewing calibration certificates as well as advance sample calculations (not required but recommended).
- First day at the shop: Performing any needed calibrations, verifying installed instruments and test arrangement.
- All of the above saves time in the long run and results in a better test
- Learning curve for manufacturer and witness: Expect additional time required when a vendor first implements PTC 13 including test protocol submittal, onsite testing, and test report submittal.
- Inovair quickly adjusted to the requirements of PTC13 and a smoother test is anticipated in the future

The Speakers

David Sperber P.E.,
VP Sales and Marketing

Glen Roderique
Sales Engineer for Geared Centrifugal Blowers

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PTC13 Testing as a Quality Control Tool

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IN THE USA

Blowers Built on a History of Performance

Accessible Technologies Inc. (ATI): the market leader in single stage centrifugal compression for 30 Years

1994

ProCharger Superchargers

30 Years of High Performance - Up to 75 psi and 6,000 scfm

1998

Airport De-icing

Operating in Extreme Environments

2010

Continuous Duty Industrial

Performance in 24x7 Dirty, Dusty, Environment

2011

Military Ground Support

99.9% Up-Time for Critical Operations

2012

Wastewater

Highest Efficiency with Leading Reliability

Over 55,000 Geared Centrifugal Units Sold

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Geared Centrifugal Blowers

Vertically Integrated Manufacturer

Inovair is "Buy America" Compliant

- Vertically integrated manufacturer with secure U.S. supply chain
- Factory support from **Kansas** four building campus headquarters and **California** regional office with 100 Employees
- Buy America, Build America (BABA) - Manufactured in the U.S. with greater than 55 percent of the total cost of all components from the United States

Inovair is the only high efficiency blower designed, manufactured, and supported in the U.S.A.

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Inovair PTC 13 Test Cell Implementation

Challenges of Implementation

- Constructing a near lab-level test cell within our existing facility
- Balancing the size of the system for current and future needs
- Sourcing equipment and instrumentation to meet the standard

Rewards/Payback of Implementation

- Improving and supplementing our in-house testing capabilities
- Increasing our awareness, focus on entire blower package/system performance
- Providing the capability for us to meet customer project specifications with less uncertainty

Inovair's fully functional PTC 13 test facility

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Blower Testing to Validate Efficiency

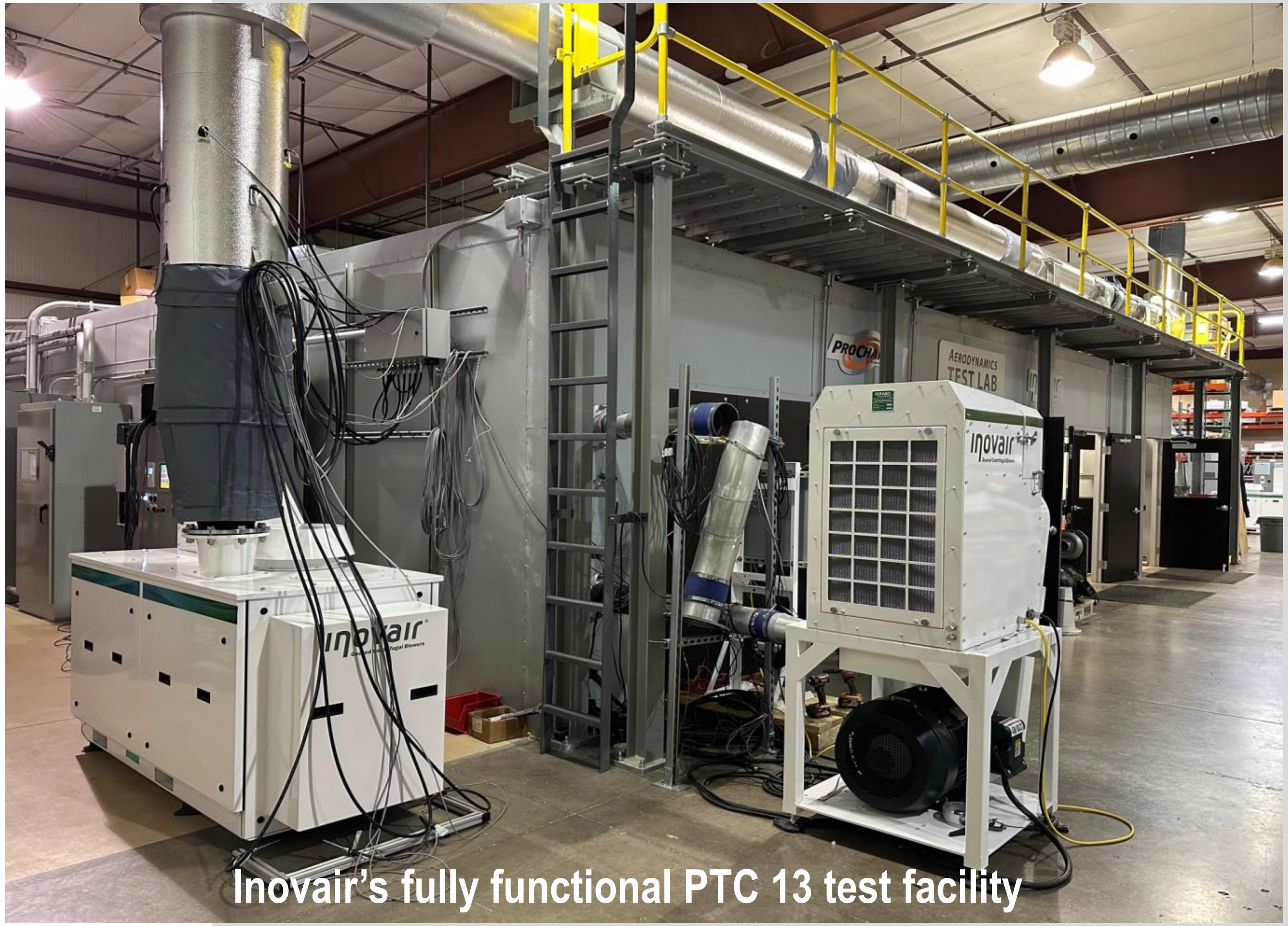
ASME PTC-13

- Method to validate “wire to air” performance for all power components to substantiate total electrical operating power of the blower package

- Testing used to confirm component selection to optimize efficiency
  - Gearbox Selection based on Speed
  - Impeller Selection from 50+ options
  - VFD manufacturer variations

- Blower Component Quality Control

- Inovair staff member has joined the PTC13 committee.



Inovair’s fully functional PTC 13 test facility

Inovair®
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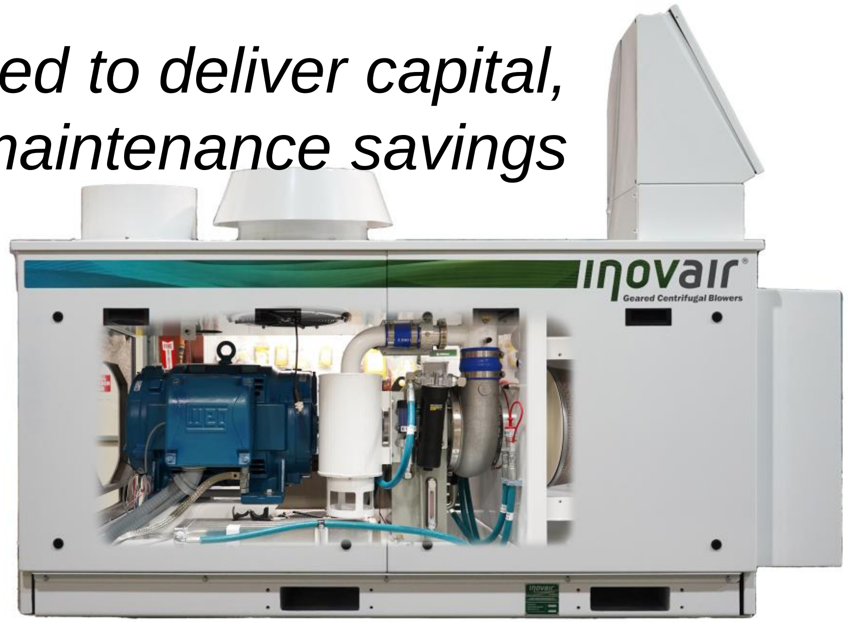
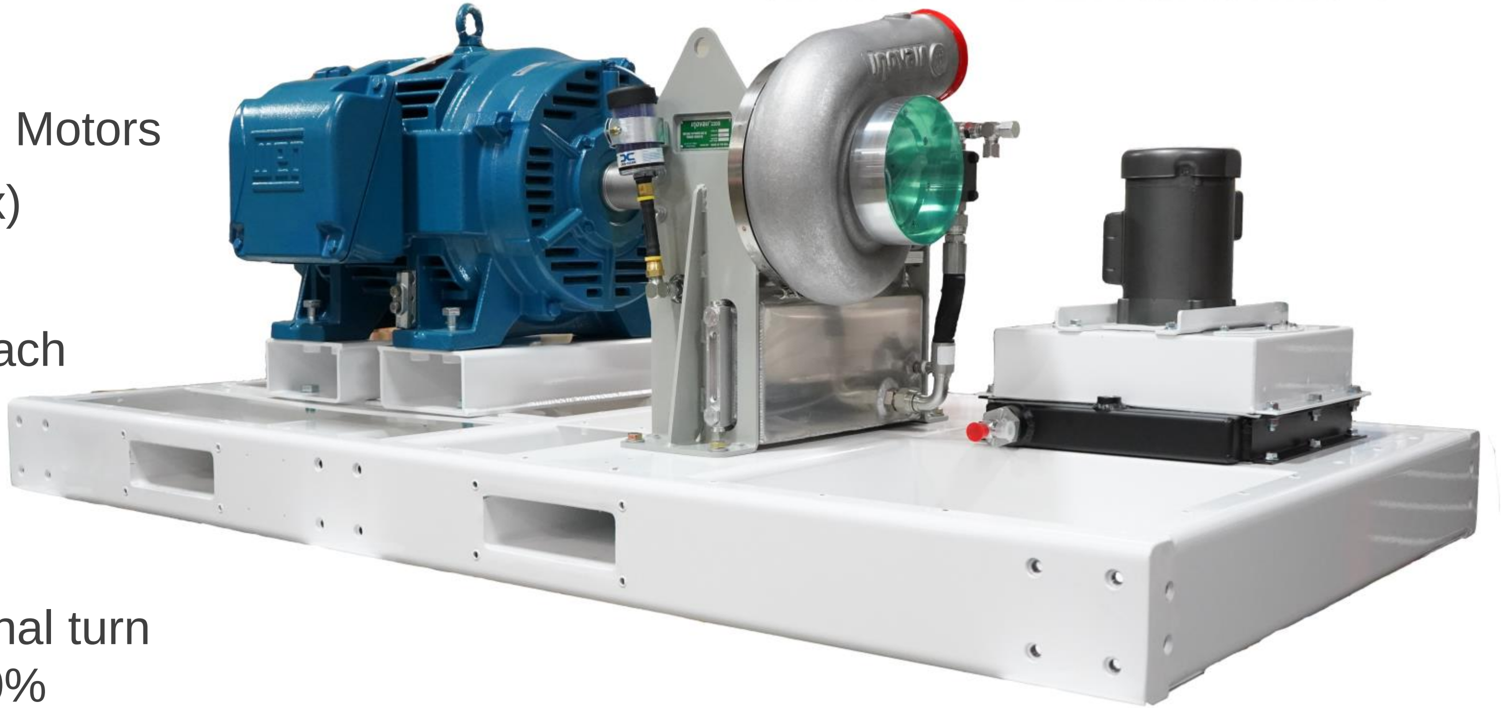
Design Philosophy Focused on Simplicity

Designed to deliver capital, energy, and maintenance savings

- **Integrally geared**
  - Robust, reliable and cost effective
  - 16.65:1 step-up ratio
- **Speed based control**
  - VFD:1800/3600 RPM TEFC 60 Hz Motor
- **Designed using off the shelf components**
  - 60 Hertz VFD
  - Standard NEMA Frame 1750 RPM Motors
  - PLC (Allen Bradley Compact-Logix)
- **Efficiency**
  - 50+ impeller stages matched for each application
- **Additional Features**
  - Quite Operation
  - Internal bypass to allow for additional turn down beyond 50%, turndown to 30%





Integrally-Geared Centrifugal Compressor

- 2-stage gearbox integrated into compressor unit to obtain the designed impeller speed
- Typical operating speeds: 35,000-45,000 rpm
- Designed for up to 22 psi and 60,000 rpm
- Gearboxes rated for up to 600 HP
- High precision gears manufactured to AGMA II standards
- Assemblies balanced to G2.5/G6.3

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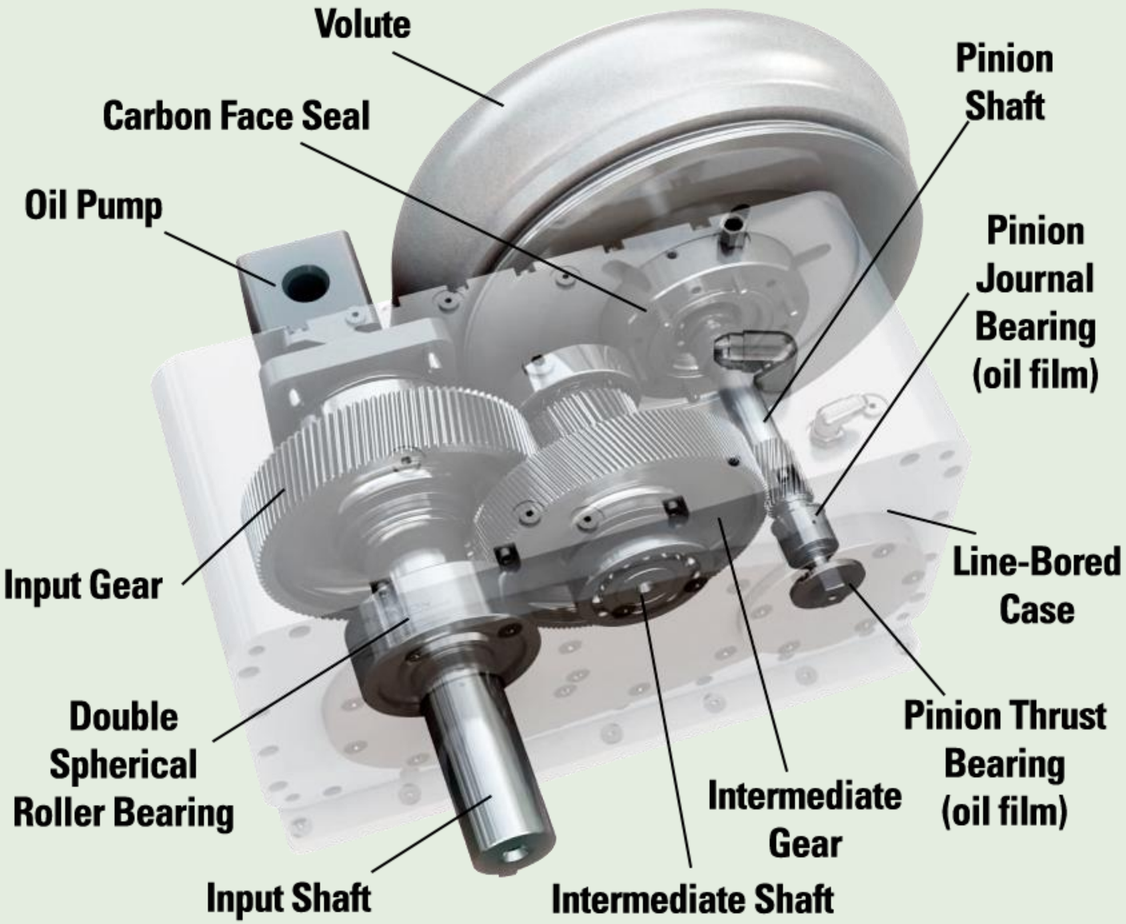
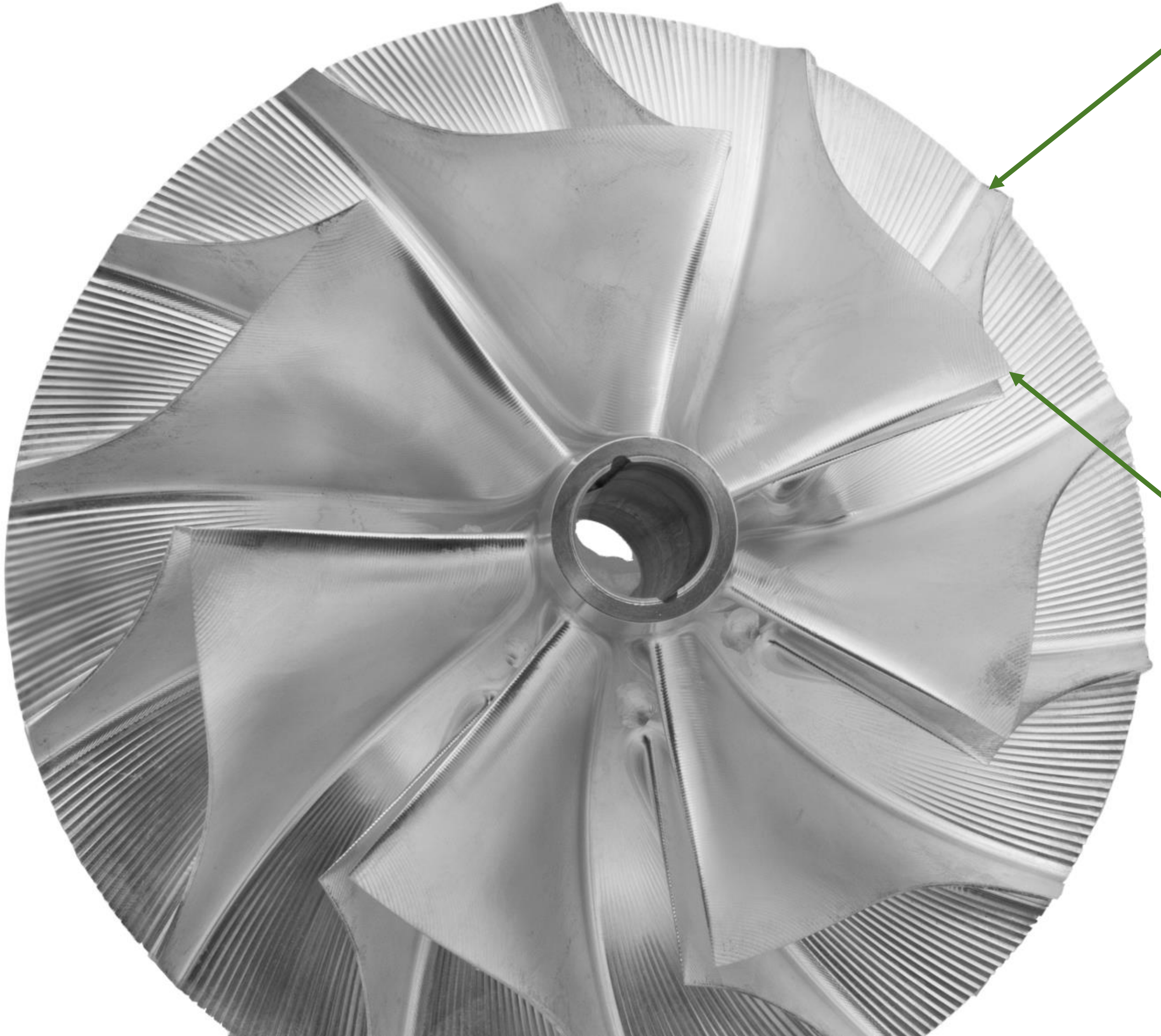
Geared Centrifugal Blowers



Designed & manufactured in Lenexa, KS

High Efficiency Impellers

Proper relationships between exducer diameter and blade height and inducer diameter must be maintained, along with blade geometry, to ensure highest efficiency.



Exducer (outside) diameter and rotational speed (RPM) determine tip speed and thus pressure capability. Pressure increases by a square of the speed.

Inducer diameter and rotational speed effects flow. Flow increases 1:1 with speed.

Inovair's impellers are machined at the Kansas City campus using one of three 5-axis CNC mills.

inovair®
Geared Centrifugal Blowers

Versatile Control Systems - constant or varying head applications

- In house UL 508A panel shop
- Standard and custom master control panels
- AB CompactLogix PLC’s (custom options available)
- Multiple sensor inputs
- Easily integrates into SCADA or OEM controls
- Accessibility to system programming logic

Control Panels are engineered and built in-house

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Process Considerations

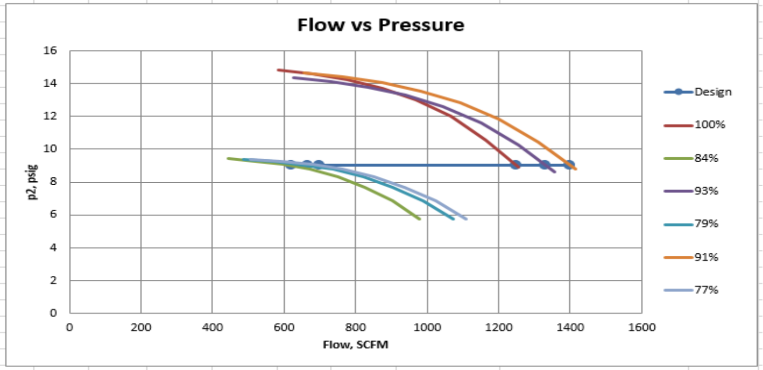
- **Airflow Turndown**
  - Aeration Basins
    - Airflow Based on Demand
    - D.O. Control
  - Lagoons, MBR's, IFAS Systems

inovair® Efficient • Quiet • Compact

Project: Morris, IL
Aero Stage: IF2-23-090
Altitude (ft): 515

Point	Speed	Flow	Pressure	Temp	RH	Motor HP	System Power	Design Condition	Isen. Eff.
(#)	(%)	(scfm)	(psig)	(F)	(%)	(hp)	(KW)		(%)
1	100%	1250	9.00	100	90%	70.2	56.8	Max. Flow @ Max. Temp.	72%
2	84%	620	9.00	100	90%	32.1	26.3	Min. Flow @ Max. Temp.	78%
3	93%	1330	9.00	50	36%	63.7	51.5	Max. Flow @ Avg. Temp.	72%
4	79%	665	9.00	50	36%	29.9	24.5	Min. Flow @ Avg. Temp.	77%
5	91%	1400	9.00	20	20%	63.3	51.2	Max. Flow @ Min. Temp.	72%
6	77%	700	9.00	20	20%	29.4	24.1	Min. Flow @ Min. Temp.	78%

HP based on +/- 5% tolerance
SCFM based on 68F, 36% RH, 14.7 psia



VS

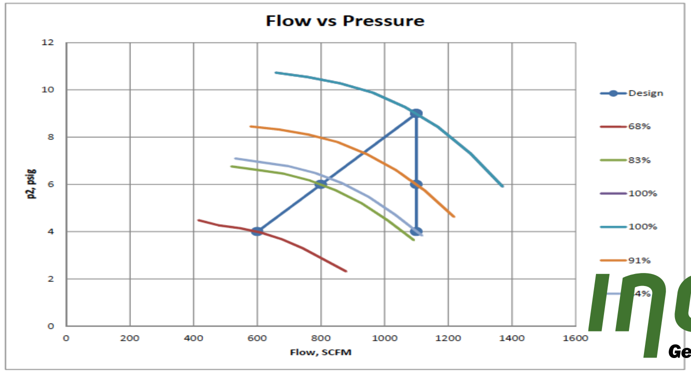
- **Varying Water Depths**
  - Equalization Tanks
  - Sludge Holding Tanks
  - Aerobic Digesters
  - SBR's

inovair® Geared Centrifugal Blowers

Project: Varying Head
Aero Stage: IF2-13-100
Altitude (ft): 0

Point	Speed	Flow	Pressure	Temp	RH	Motor HP	System Power	Design Condition
(#)	(%)	(SCFM)	(PSIG)	(F)	(%)	(HP)	(KW)	
1	68%	600	4.00	100	36%	14.3	12.0	Min. Flow EQ/Digester
2	83%	800	6.00	100	36%	27.4	22.4	Mid Flow EQ/Digester
3	100%	1100	9.00	100	36%	53.4	43.3	Max. Flow EQ/Digester
4	100%	1100	9.00	100	36%	53.4	43.3	Max. Flow SBR
5	91%	1100	6.00	100	36%	40.0	32.6	Mid Flow SBR
6	84%	1100	4.00	100	36%	31.5	25.8	Min. Flow SBR

HP bases on +/- 5% tolerance
SCFM based on 68F, 36% RH, 14.7 psia



inovair® Geared Centrifugal Blowers

Inovair Product Line

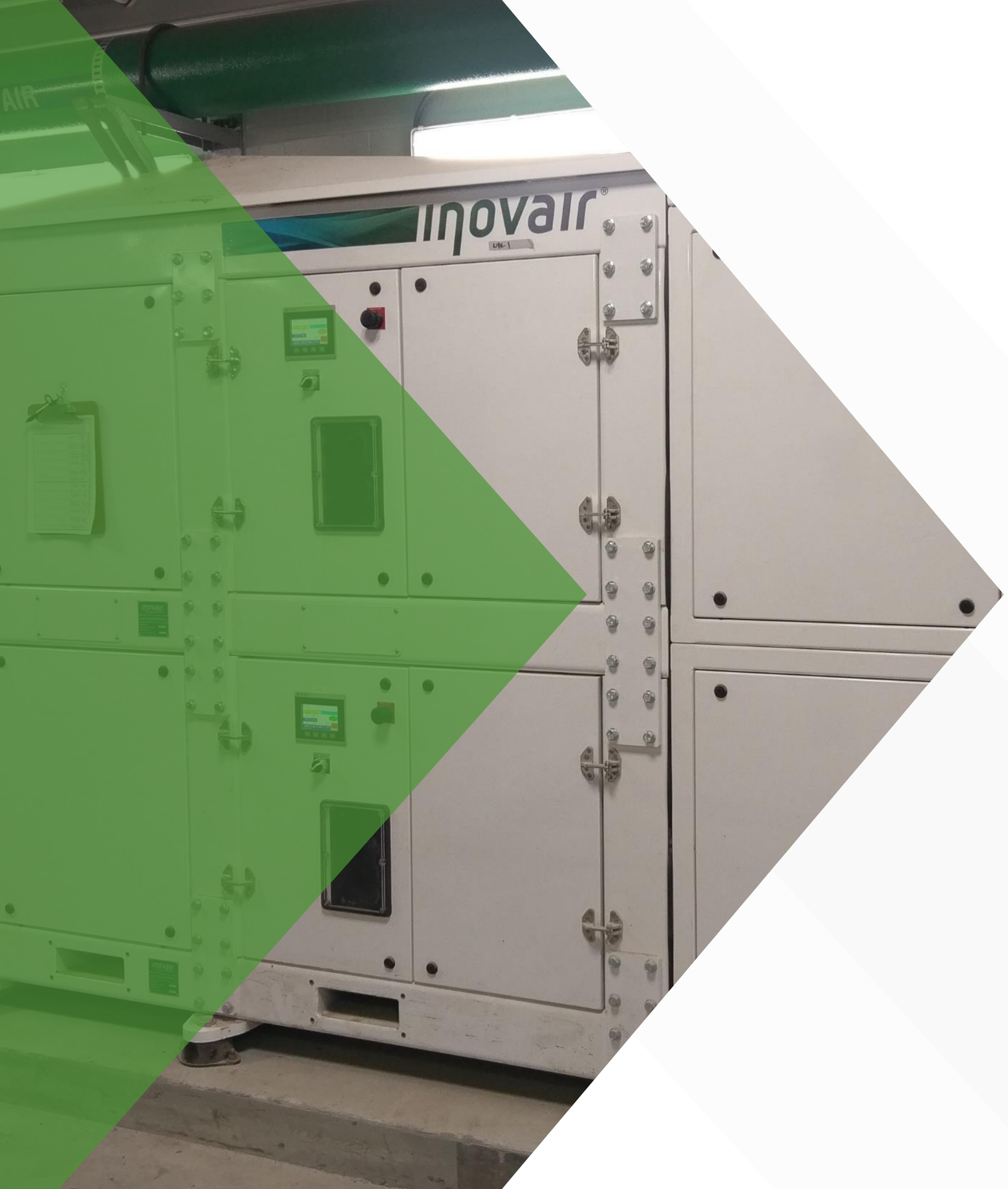
Design Ranges

- Airflow up to 12,000 SCFM
- Power from 15 hp to 600 hp
- Pressure up to 22 PSI

Inovair's geared centrifugal blower are designed to deliver capital, energy, and maintenance savings

IO/IM SERIES MACHINE LINEUP

inovair® Geared Centrifugal Blowers



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Geared Centrifugal Blowers

THANK YOU!

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PROCHARGER

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Q&A

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Thank you for attending!

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PDH Certificates will be e-mailed to Attendees by within 2 days

February 2024 Webinar

Centrifugal vs Rotary Screw Air Compressor Performance: Full Load and Part Load Efficiency

Mike Lenti
Compressed Air Consultants
Keynote Speaker

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