Industrial Assessment Centers

IAC Student Meeting - Atlanta

COMPRESSED AIR ENERGY SAVINGS

Mark Krisa
Ingersoll Rand

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Agenda

- Who is Ingersoll Rand
- Compressor Industry Trends
- Energy Savings with Compressed Air
  - Leak Management
  - Pressure Reduction
  - Practical Examples

The Ingersoll Rand Company

- **A $14.1 billion diversified industrial company**
- **58,000 employees worldwide**
- **Operations in every major geographic region**
- **Strategic brands are #1 or #2 in their markets**

Our Corporate Structure

Ingersoll Rand

	Industrial Technologies	Climate Solutions Technologies	Security Technologies	Residential Solutions
Sectors				
Strategic Brands	Ingersoll Rand Club Car	TRANE THERMO KING	SCHLAGE	TRANE American Standard HEATING & AIR CONDITIONING SCHLAGE

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Our Corporate Structure

Industrial Technologies

President
Robert Zafari

$2.5B
annual revenue

Air, Tools, Fluids, Material Handling and Club Car

Products, services and solutions that enhance customers' energy efficiency, productivity and operations.

ARO
Ingersoll Rand
Club Car

Climate Solutions

President
Didier Teirlinck

$7.8B
annual revenue

HVACR systems and services

A broad portfolio of HVACR systems and services.

Trane
Thermo King

Security Technologies

President
John Conover

$1.7B
annual revenue

Electronic Security; Safety Solutions; Mechanical Security

Security/locks that make environments safe, secure and productive.

Bricard
Briton
CISA
Dor-O-Matic/Falcon
Falcon
Glynn-Johnson
Ingersoll Rand
Interflex
ITO Kilit
Ives
LCN
Legge
Martin Roberts
Monarch/Falcon
Normbau
Randi
Schlage
Steelcraft
Von Duprin

Residential Solutions

President
Gary Michel

$2.1B
annual revenue

Remote Home Management; HVAC Systems; Innovative Controls; Split Cooling/Heat Pumps; Appliance Modules; High-Efficiency Systems; Video Management; Clean Air

Security and climate control products that deliver safety, comfort and efficiency to homeowners.

Dexter
Kryptonite
Fusion
American Standard
Heating & Air Conditioning
Schlage
Schlage LiNK
Trane

Our Mission Statement

We are the world leader in creating and sustaining safe, comfortable and efficient environments.

Our portfolio of businesses is aligned around our mission

Our Enterprise Strategy

PATH TO PREMIER PERFORMANCE

Build a Progressive, Diverse and Inclusive Culture	Grow through Innovation, Emerging Markets and Services	Deploy Operational Excellence

Three Strategic Imperatives to Ensure Success

Our Corporate Structure

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Sectors

Strategic Brands

Industrial Technologies

Ingersoll Rand

Club Car

Climate Solutions Technologies

TRANE

THERMO KING

Security Technologies

SCHLAGE

Residential Solutions

TRANE

American Standard
HEATING & AIR CONDITIONING

SCHLAGE

Ingersoll Rand
Industrial Technologies

Industrial Technologies

Air Systems & Service

Centrifugal

Rotary

Reciprocating

Energy Efficiency and Sustainability Services

Tools
Fluid Handling
Material Handling

Tools

ARO

Fluid Handling

Material Handling

Compact Vehicles

Golf

Club Car

Transportation

Utility

Industry Trends

- Negligible efficiency increases in past 10 yrs
- VSD packaged with compressors
- Trend towards smaller compressors
  - 40 - 100hp rotary (+20% growth over past 5 yrs)
  - 750 - 1000hp centrifugal
- Energy savings - government, utility and corporate initiatives
- Air audits
- System controls
- Leak surveys
- System pressure reduction

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Fix Some Leaks

- Leak identification - easily executed
- Need more than inventory of locations
  - Estimate volume and cost
- Quantifying savings
  - Overestimated savings (20kW / 100cfm) $15k/y @ 8.5¢/kWh
  - Compressor operation not considered
    - Capacity controls - 3 - 7% reduction in kW / 10% reduction in flow
      - $15,000 savings becomes $4,500
      - Blow-off - zero return?
      - Draw down - power increase
- Leak management
  - Need accountability and validation / recurring program

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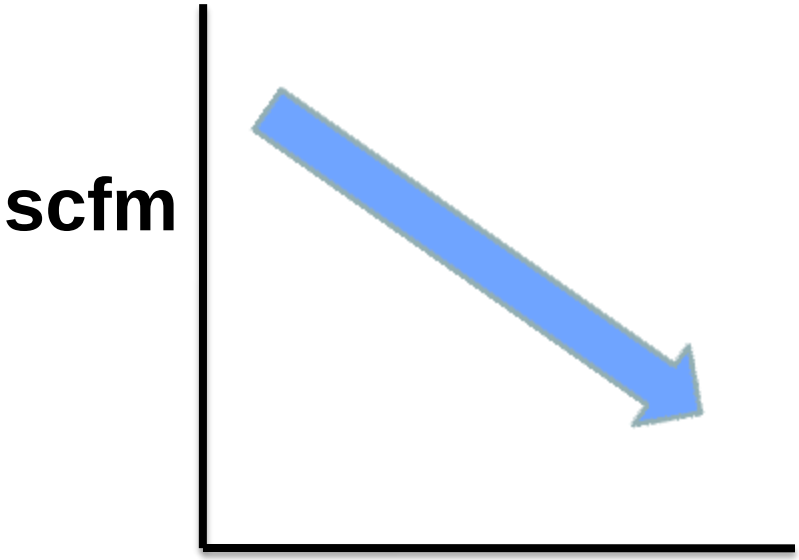
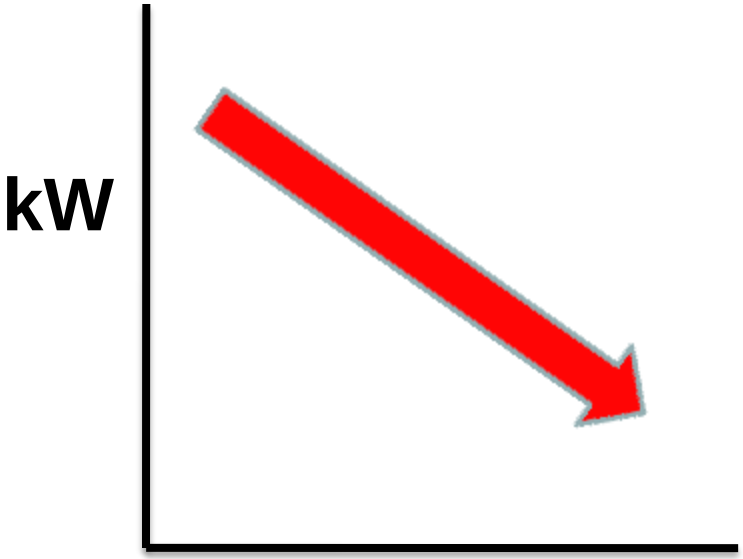
Lower Pressure

Reduced artificial demand



Reduced power



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Lower Pressure

Artificial Demand

Volume of air associated with operating at higher than required pressure

Relative value → must know both pressures

$V_2 = \{V_1 \times [(P_2 + 14.5) / (P_1 + 14.5)]\}$

$V_{art} = (V_1 - V_2) \times (\%_{unregulated\ load})$

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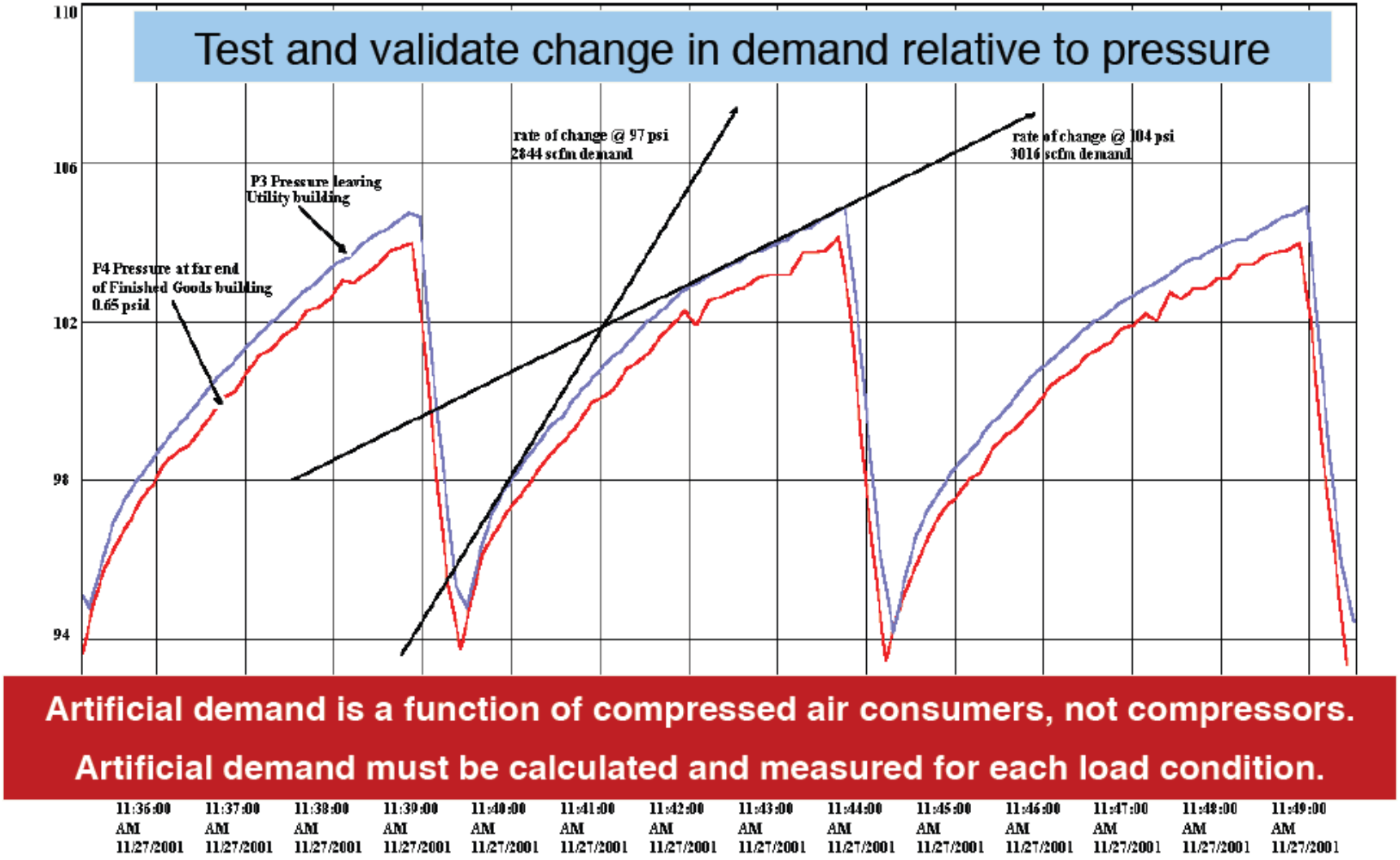
Artificial Demand



Artificial demand is a function of compressed air consumers, not compressors.

Artificial demand must be calculated and measured for each load condition.

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Lower Pressure

Reduced power

- Positive displacement - approximately 1% kW for every 2 psi
  - Applies within 5-10 psi of design pressure at element discharge, not package discharge pressure.
  - Would a 300 psi compressor consume 0 kW at 100 psi?

- Dynamic (centrifugal) – Compressor dependant
  - compressor design & installed components (impellors / diffusers)
  - mechanical condition
  - Ambient conditions
  - Load condition

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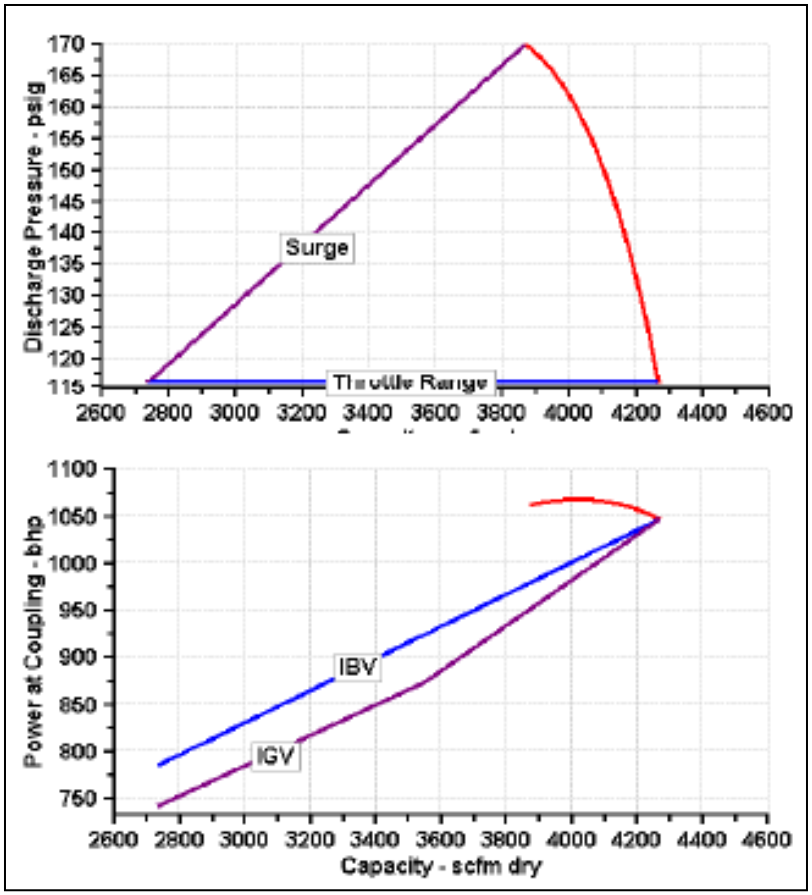
Lower Pressure

- Reduced power
  - Dynamic (centrifugal) - depends on the curve

DESIGN POINT PERFORMANCE (Standard Industrial Tolerances Applied)
Reference flows were computed based on dry mass flow

INLET CONDITIONS			CAPACITY Discharge scfm dry	DISCHARGE PRESSURE psig	COUPLING POWER bhp	SPECIFIC bhp/100 scfm dry	ISO EFF %
Pb	=	14.400 psia	3869.29	169.982	1061.53	27.435	66.46
P1	=	14.100 psia	3909.40	168.156	1064.53	27.230	66.71
T1	=	95.0 deg F	3949.51	165.779	1066.61	27.006	66.91
RH	=	60 %	3989.63	162.783	1067.76	26.763	67.08
TW	=	80.0 deg F	4029.74	159.089	1067.94	26.501	67.18
BG	=	3575.0 rpm	4069.85	154.603	1067.13	26.220	67.19
Mhp	=	122.0 bhp	4109.97	149.212	1065.29	25.920	67.08
REFERENCE CONDITIONS			4150.08	142.784	1062.37	25.599	66.81
Ps	=	14.700 psia	4190.19	135.155	1058.30	25.257	66.32
Ts	=	60.0 deg F	4230.31	126.133	1052.98	24.891	65.52
RHs	=	0 %	----------Specified Discharge Pressure----------				
GUARANTEE TOLERANCES			4268.78	115.821	1046.77	24.521	64.30
Capacity	=	+/- 4%	----------				
Specific Power	=	+/- 5%	4270.42	115.487	1046.25	24.500	64.28



Reduce pressure 20 psig

135 - 115 psig → -11.5hp + 78 scfm

-78 scfm → -19.1hp

Total = -30.6hp /1058.3 hp = **-2.9%**

29% of the assumed 10% reduction

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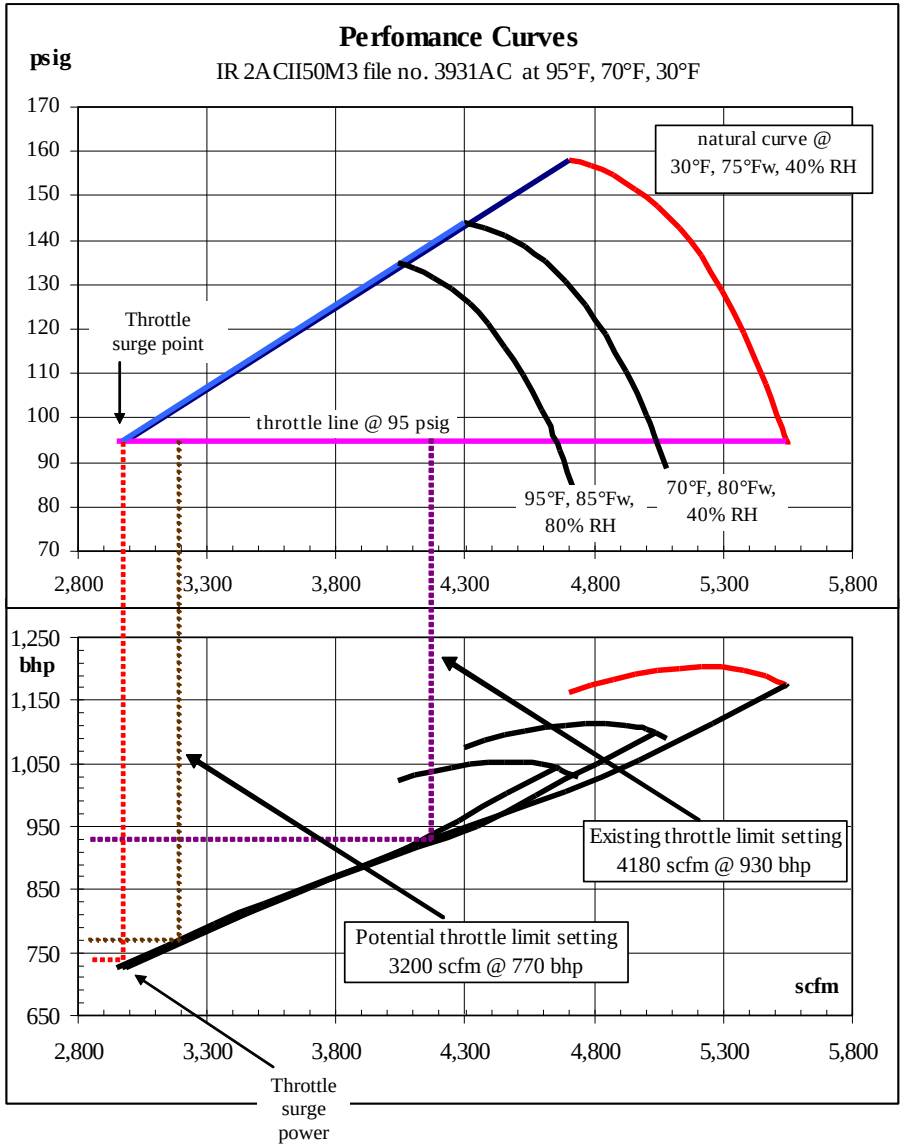
Lower Pressure



Performance will change based on:

- Ambient conditions
- Cooling water
- Cooler fouling
- Dirt loading
- Mechanical degradation

To do it correctly:

- Estimate based on engineering data
- Performance test to validate

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Identifying Pressure Issues Perceived or Actual

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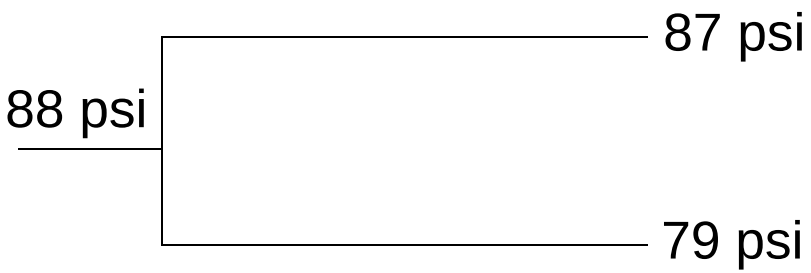
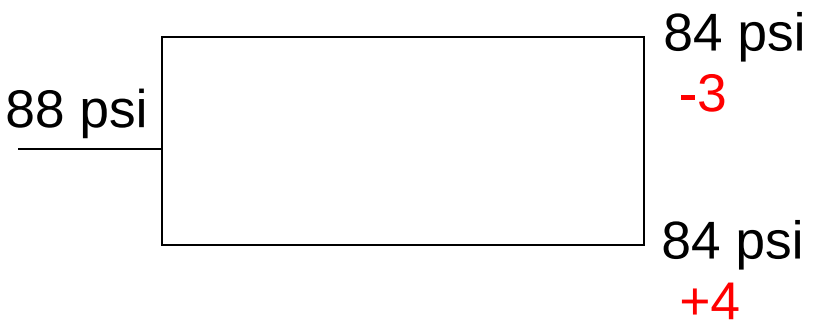
Piping Configuration – Loop or No Loop

- A piping loop allows for flexibility and growth
- Piping does not need to be looped to minimize pressure loss – just sized correctly
- Connecting 2 parallel lines can reduce pressure loss in 1 and increase in the other





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Issues With Existing Pipe Networks

"Velocity of compressed air in the supply header should not exceed 20 ft/sec".

This statement is generalized.

Piping must be sized such that the cost of the resistance does not exceed the offsetting power over the required return period

- Never make assumptions regarding pipe size
  - Simultaneously record pressure across piping (validated test)
  - Measure across potential restrictions to segment total losses
  - Measure beyond the pipe – POU components, dryers, filters, etc
  - Point of use losses – filters, regulators, poly-tube

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Problem Solving

- Root Cause Analysis
- 5 Whys
- Always more than one solution

What do we typically do

- Root Blame Analysis
- “Solution is outside of my control”

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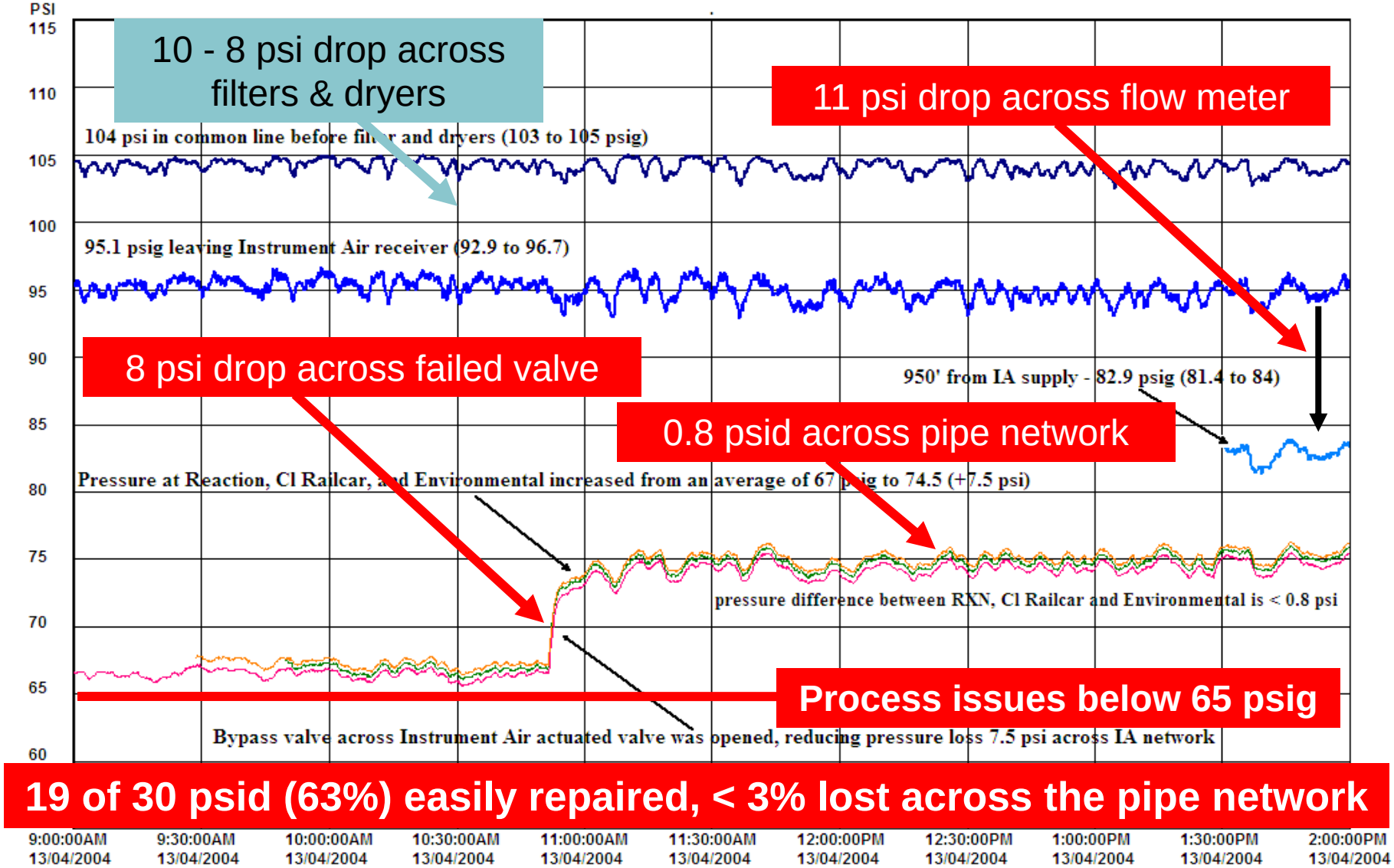
40 psid Loss Across 3,000' Pipe Network



19 of 30 psid (63%) easily repaired, < 3% lost across the pipe network

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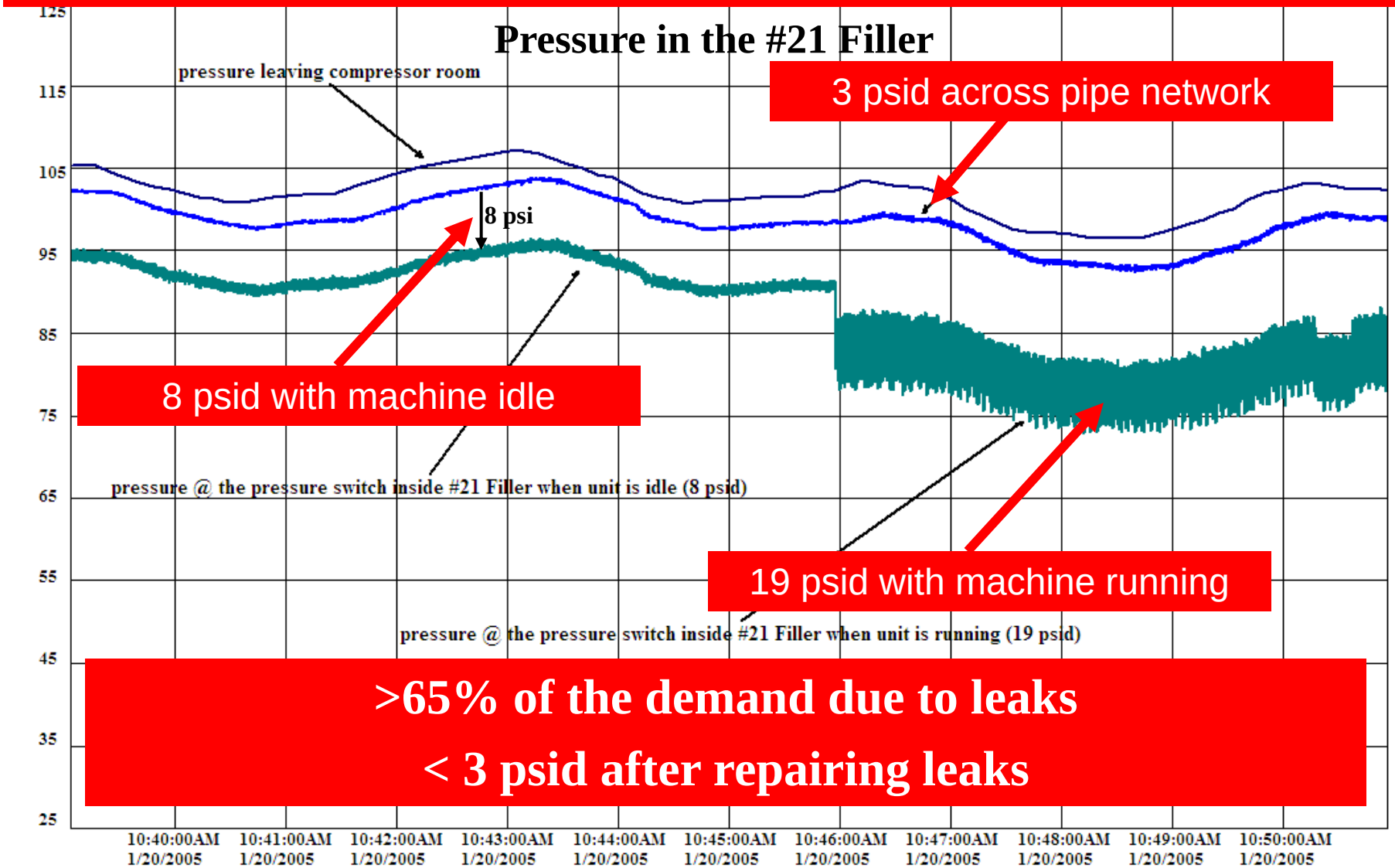
Filler Machine Shutting Down on Low-Pressure Alarm



>65% of the demand due to leaks

< 3 psid after repairing leaks

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Thank You

Questions or Comments

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