Magnetic Bearing Centrifugal Compressor Technology

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About the author…

- Chris Mansour is a professional engineer with 25 years experience. He has served as a Design Engineer/PM on 15+ million square feet of MEP construction and energy projects with project sizes in excess of one million square feet and project costs as high as $8 billion. Chris served the State of Texas as the Manager for Facility & Energy Engineering for a 23M+ S.Ft. portfolio. He has written standards, guidelines and specifications for construction, operational, energy & maintenance aspects for commercial government & institutional organizations. Chris has conducted hundreds of energy & forensic studies identifying energy saving opportunities, identifying risks and opportunities, diagnosing underperforming systems and prescribing cost effective solutions. He holds the following credentials:

- Licensed Engineer (PE)
- MS Engineering, MBA
- Certified Energy Manager (CEM)
- LEED "Accredited Professional" (LEED-AP)
- Certified Building Commissioning Professional (CBCP)
- Certified Thermographer
- Certified Plumbing Designer (CPD) ASPE
- ASHRAE MEMBER
- Member of Association of Energy Engineers

Focus Points

Primarily focusing on air-cooled magnetic bearing centrifugal compressor (MBCC) chillers

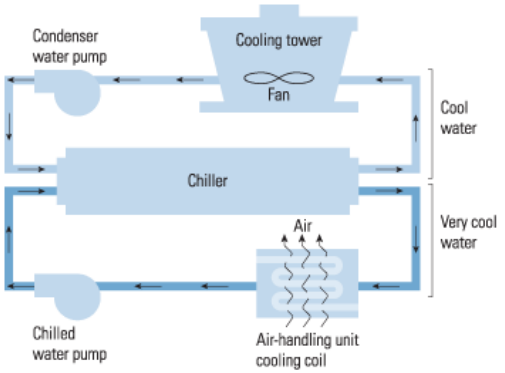
- A/C System Summary
- System Equipment Costs
- Commissioning
- Energy Performance
- Results @ LBJ

Chiller & A/C Types:

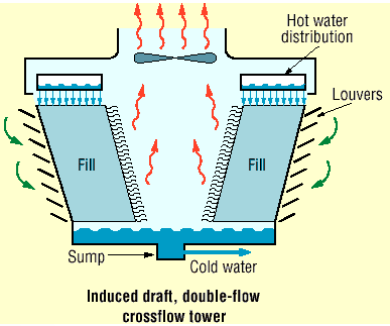
- Air-cooled, heat is rejected to the ambient air
- Water-cooled, heat is rejected to some other water source like cooling towers

Air-cooled :

- **No cooling tower or water treatment**
- **Less maintenance**
- **Usually runs between 0.83 and 1.35 KW/Ton for high efficiency systems**



Courtesy: E SOURCE; adapted from EPA



Water-cooled:

- **Efficiency 0.33-0.6 KW/Ton**
- **More maintenance**
- **More controls and components**

Efficiency is the driving factor for selection:
Water-cooled: 0.33-0.8 KW/Ton
Air-cooled: 0.83-1.35 KW/Ton
Unitary: 1.3-2.8 KW/Ton

Compressor Types

9.6 – 19.3 EER

Scroll

Scroll compressors are typically ganged due to limited capacities, i.e. a 125 ton air-cooled chiller may have up to 6 scroll compressors. This configuration allows for redundancy while increasing likelihood of mechanical failure.

9.6 – 13 EER

Screw

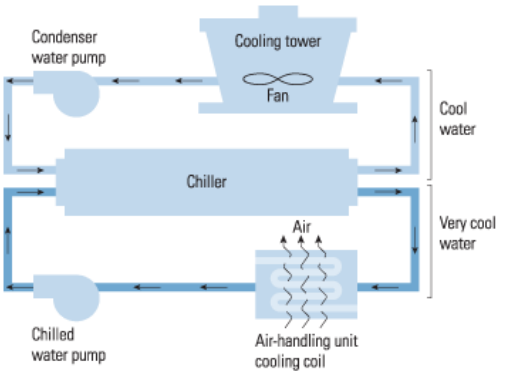
Screw compressors are known to be loud and prone to vibration. Failures can occur from excessive vibration and oil return. These compressors are expensive to maintain due to shaft alignment and bearing maintenance.

Traditional Air-Cooled Chiller Efficiencies – System Performance

- Scroll and screw compressors use oil to lubricate and protect mechanical components
- Results of ASHRAE Research Contract RP-751 suggest that a 15% oil buildup can reduce equipment efficiency by up to 50%
- A high efficiency 15 EER air-cooled scroll chiller could encounter diminished efficiencies of 12 EER with part load efficiencies of 14.8 EER
- This phenomenon has been known to occur within the first five years of operation

- What if you could reduce maintenance & maintain close to water-cooled chiller efficiencies?

Achieve higher efficiencies *** Avoid water treatment costs, additional pump energy and maintenance



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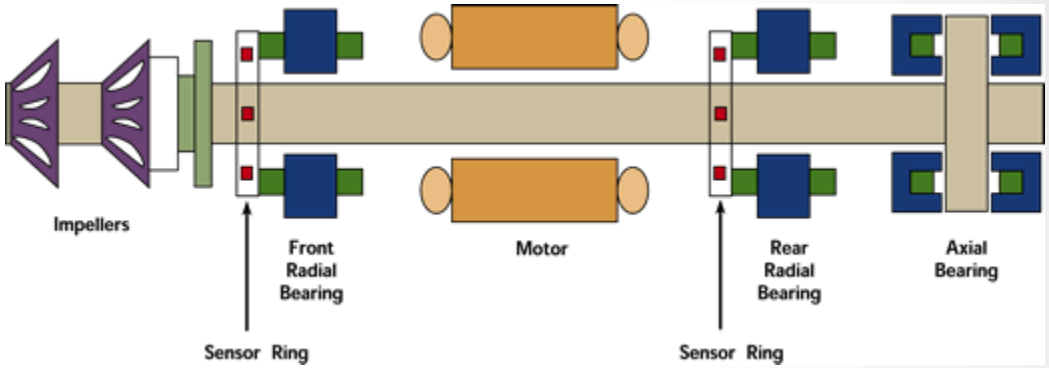
MBCC – Turbocor synonymous with "Copeland" (a number of manufacturers use Turbocor)



Magnetic bearing centrifugal compressors are oil free

Eliminates additional power for moving oil

Eliminates fouling the evaporator lines with oil residue

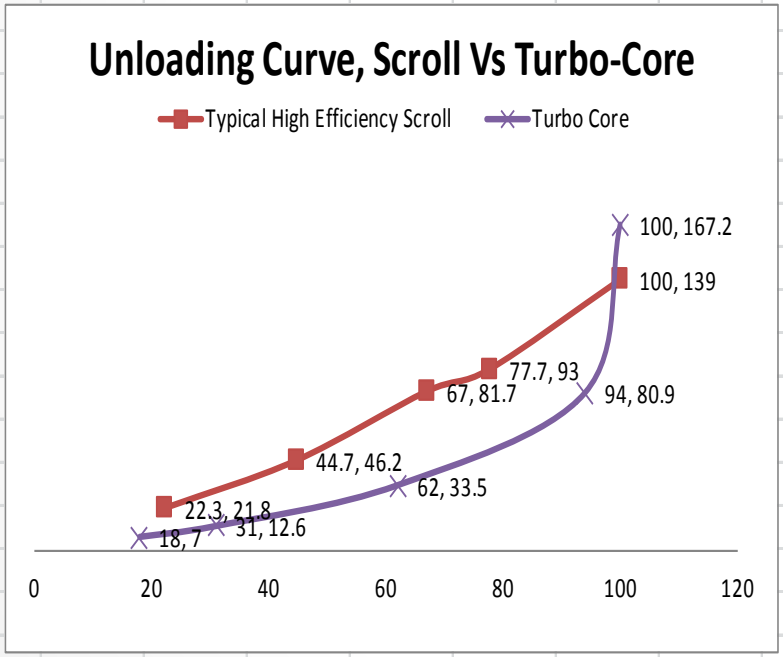
Eliminates failure due to oil return

Air-cooled Equipment Chiller Costs

- Up front purchase costs for air-cooled scroll & screw chillers average $500 per ton depending on the efficiency, size and miscellaneous features
- Up front purchase costs for magnetic bearing air cooled chillers is approximately $1000 per ton

Performance - Scroll Vs. MBCC Chillers

Air Cooled Chiller Performance			
York Unloading		TurboCore	
Percent	KW	Percent	KW
22.3	21.8	18	7
44.7	46.2	31	12.6
67	81.7	62	33.5
77.7	93	94	80.9
100	139	100	167.2



Typical Office Building Profile				
Percent Load	Cooling	KW York	KW Turbo	% Hours
Design	Tons	at tons	at tons	5221 Hr/year
5	13.6	43.6	14	15%
10	27.2	43.6	14	12%
20	54.4	43.6	14	15%
30	81.5	68	28	19%
40	108.7	88	39.2	15%
50	135.9	140	53.06	7%
60	163.1	152	62	8%
70	190.3	174	98	5%
80	217.4	188	132	3%
90	258.2	246	156	1%
100	271.8	278	334.4	1%
		133.1636	85.87818	

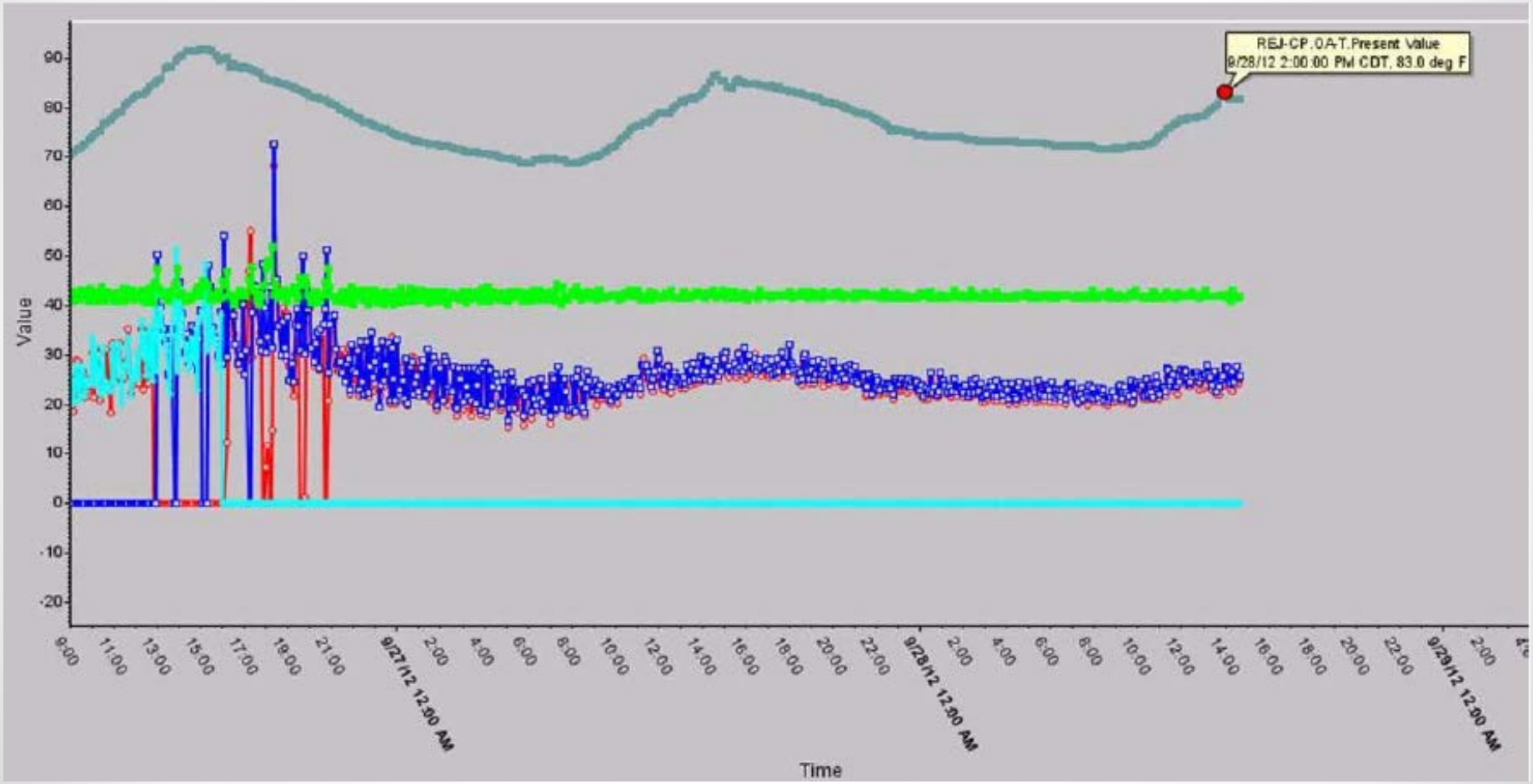
AVG KW/Ton (Scroll/Screw)	133.1636	KW
AVG KW/Ton (MBCC Chiller)	85.87818	KW

The Turbo-Core Vs Scroll air-cooled Chiller Analysis is based on Waco State Office Building: 98,000 Square feet, 250 tons of cooling, (2) 125 ton chillers, 16 hour, 5 day week operations, Variable primary distribution, Estimated $0.10/KWH, $10/KW demand (summer & winter); these rates are thought to be conservative; it should be acknowledged that the control system for the Turbocor is performing KW limiting to enhance energy savings through part load operations.

MBCC Operation

- The magnetic bearing chillers usually have at least two compressors
- The compressors are controlled by a micro-processing control panel that operates the compressors at optimum ranges based on real-time data feedback
- This optimization capitalized on affinity laws which follow squared and cubed root energy and power savings
- Optimizing against affinity laws achieves a dramatic part-load savings

MBCC Commissioning Results:



MBCC Pitfalls

- Never select MBCC systems to match the load, always oversize, (J-hook efficiency curve)
- LBJ chillers ran in 108F ambient at .85 KW/ton despite lift issues
- Select qualified design & install company with at least 5 chiller installs within the last 2 years
- Always allow more time for start-up. Request a factory test before equipment leaves the factory. All air cooled systems should be witnesses on a 4-point test, 25%,50%,75% & 100% (Same ambient is acceptable)- goal is to witness compressor staging
- Trend log compressor activity, kw loading should be somewhat steady, no yoyos
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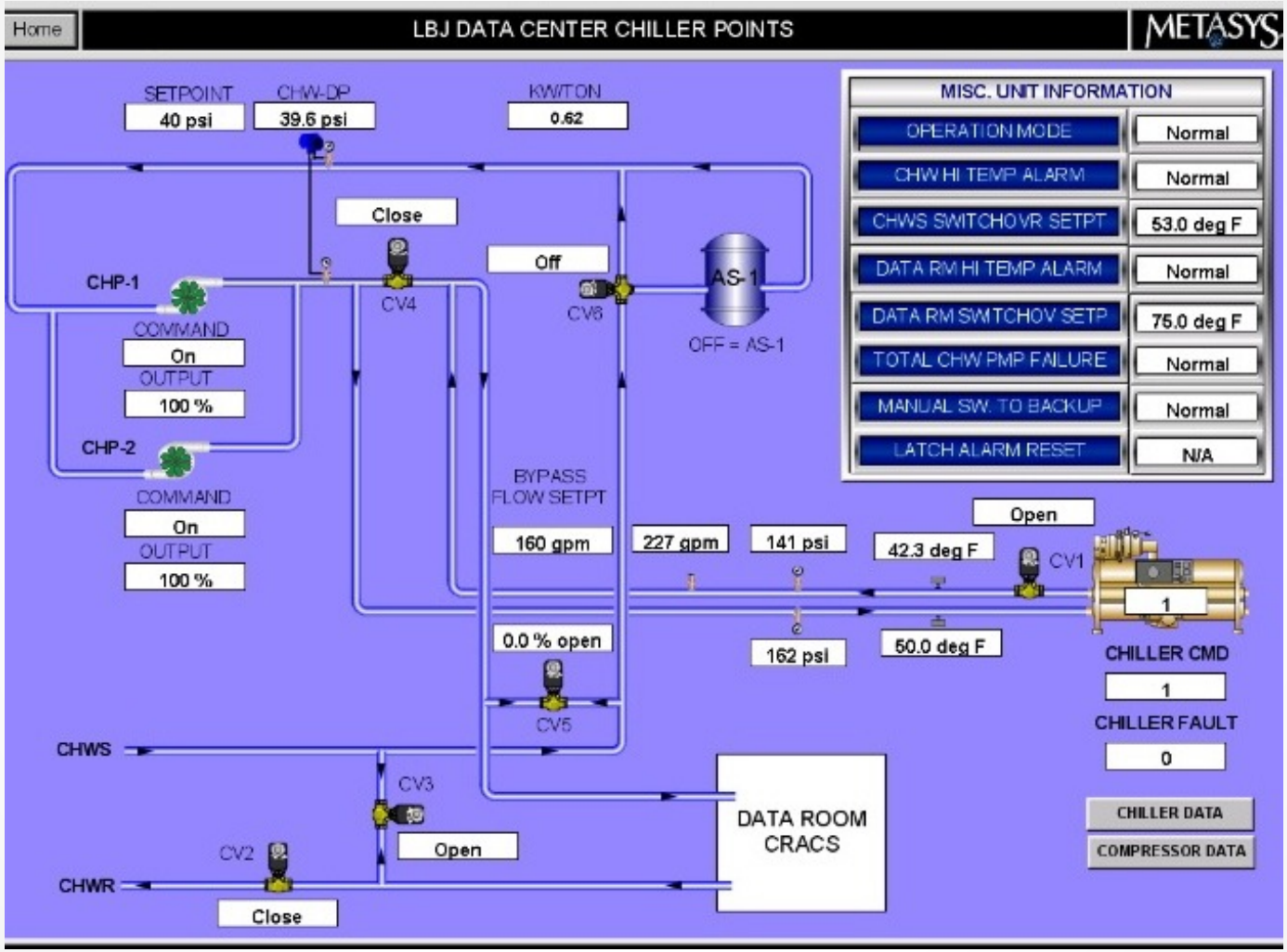
LBJ MBCC Chiller Challenges

- Chiller initially set to bring all three compressors on at low load conditions, based on outside ambient temperatures. This caused unstable operation
- Chiller PID loop adjusted too slow too much
- Drives were added to the pumps, however the pump impellers were selected at 70% of maximum size which negated the need for turn-down
- New BMS sensors not properly calibrated, even analog sensors had calibration problems
- 3rd party BACNET cards went out twice (once DOA)

MBCC Chiller – Training

Onsite training and formal class or factory training is recommended.

LBJ Chiller Performance



Performance at 97F Ambient, 76 Tons, 0.62 KW/Ton (not including pumps)

MBCC Chiller ROI

Economic Summary

Project Information

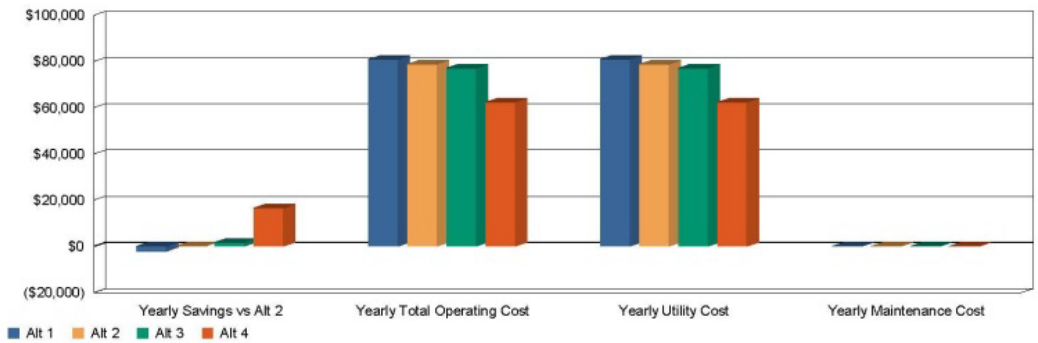
Location
Project Name
User
Company
Comments

Study Life: 20 years
Cost of Capital: 3 %
Alternative 1: load shifts osa from conf rms to ahu1
Alternative 2: VFDs at all Pumps
Alternative 3: VFDs at all pumps and AHUs
Alternative 4: VFDs pumps AHUs Mag Chiller

Economic Comparison of Alternatives

	Yearly Savings ($)	First Cost Difference ($)	Cumulative Cash Flow Difference ($)	Simple Payback (yrs.)	Net Present Value ($)	Life Cycle Payback (yrs.)	Internal Rate of Return (%)	Life Cycle Cost
Alt 2 vs Alt 1	2,069	4,000	37,387	1.9	26,787	2.0	51.7	26,786.70
Alt 3 vs Alt 1	3,782	14,000	61,632	3.7	42,260	4.0	26.8	42,260.42
Alt 4 vs Alt 1	18,628	114,000	258,568	6.1	163,143	6.9	15.4	163,143.20
Alt 3 vs Alt 2	1,712	10,000	24,245	5.8	15,474	6.5	16.3	15,473.72
Alt 4 vs Alt 2	16,559	110,000	221,181	6.6	136,357	7.5	13.9	136,356.50
Alt 4 vs Alt 3	14,847	100,000	196,936	6.7	120,883	7.6	13.7	120,882.80

Annual Operating Costs



	Yearly Savings vs Alt 2	Yearly Total Operating Cost ($)	Yearly Utility Cost ($)	Yearly Maintenance Cost ($)	Plant kWh/ton-hr
Alt 1	-2,069	80,898	80,898	0	1.032
Alt 2	0	78,829	78,829	0	0.990
Alt 3	1,712	77,116	77,116	0	1.037
Alt 4	16,559	62,270	62,270	0	0.681

Consumption $0.06 KWH
Demand Winter $12.93 KW
Demand Summer $13.91 KW

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Questions

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