Magnetic Bearing Centrifugal Compressor Technology

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2/15/11

About the author…

- Chris Mansour holds a BS in Construction Science, MS in Engineering and an MBA. 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. He has written standards, guidelines and specifications for commercial and institutional organizations. Chris has conducted hundreds of energy & forensic studies identifying energy saving opportunities and risks, diagnosing underperforming systems and prescribing cost effective solutions. He holds the following professional credentials:

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

FOCUS POINTS

- Primarily focusing on air-cooled chiller compressor topics (magnetic vs traditional):

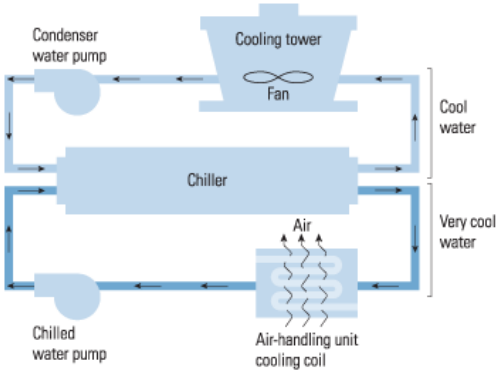
- SYSTEM INTEGRITY
- SYSTEM PERFORMANCE
- SYSTEM EQUIPMENT COSTS
- SYSTEM LIFECYCLE COST, ENERGY , AND MAINTENANCE
- MAGNETIC BEARING AIR-COOLED COMPRESSOR

Chiller Types:

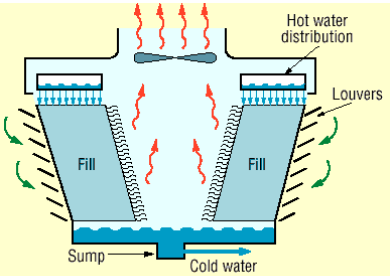
- Air-cooled, heat is rejected to the ambient air.
- Water-cooled, heat is rejected to some other water source like cooling towers

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



Induced draft, double-flow crossflow tower

Water-cooled:

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

Efficiency is the driving factor for selection:
Water-cooled: 0.33-0.6 KW/Ton
Air-cooled: 0.83-1.35 KW/Ton
Unitary: 1.3-2.8 KW/Ton

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

Traditional HVAC Compressor Technology – System Integrity

- Air-cooled chillers predominately fitted with scroll or screw compressors with the majority utilizing scrolls.
- Scrolls used on most packaged rooftop and split
- Similar efficiencies for air-cooled & split / rooftop DX systems
- Screw compressors have similar energy performance along with inherent noise and vibration characteristics
- Reciprocating compressors also have similar energy performance and are known to be loud
- Scroll and screw compressors are prone to mechanical failure due to lack of oil return.

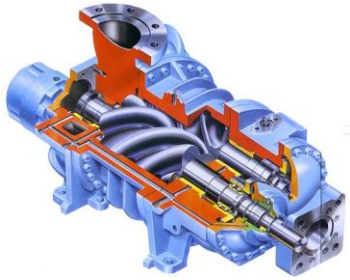
Compressor Types

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.

I have elected to exclude rotary & reciprocating due to the prevailing market of air-cooled chiller compressors; click the icon (left) for more information.

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.

ASHRAE Report

Air-cooled Equipment Chiller Costs

- Up front purchase costs for air-cooled scroll & screw chillers range from $450 to $550 per ton depending on the efficiency, size and miscellaneous features.

Magnetic Bearing Centrifugal Compressors – System Integrity

- The magnetic bearing centrifugal compressor was invented by Thermodyne in 1980 in France.
- This compressor was used in the petrochemical industry with great results– 30 years no failures
- The first compressor of this type was introduced into the HVAC industry in the early 1990's by Turbo-Core.
- Since this release Turbo-Core has reported zero compressor failures. Turbocor originally offered their compressor on water-cooled chillers.
- Turbocor now applies their compressor to to air-cooled chillers.

CENTRIFUGAL COMPRESSORS FITTED WITH ACTIVE MAGNETIC BEARINGS

G.-M. Punier, A. Gelen, and D. Bolusse

UDC 621.515:621.822

In 1980, the firm of Thermodyne began to take up new technologies for making centrifugal compressors that incorporated units that did not require lubrication. Users considered that 70% of the problems arising with centrifugal compressors are related to the oil systems used to lubricate the bearings and seals at the ends of the shafts. Also, the size and mass of these oil systems as made in accordance with API 614 standards were comparable with the parameters of the machines themselves.

Research was done on two technologies that allow one to avoid using oil in centrifugal compressors: dry gas seals and magnetic bearings, and from these the firm of Thermodyne devised machines that combine these technologies. When such machines were operated in various branches of industry, good results were obtained and valuable experience was accumulated.

During the design and manufacture of centrifugal compressors based on oil-free technology, the main developments occurred in machines equipped with dry gas seals. Four compressors of that type were equipped with active magnetic bearings AMB, and their total working time was more than 150,000 hours at the Lac deposit of Elf Acquitaine Production Company (France).

One cannot use AMB in these compressors without dry seals, but the combination allows one to avoid the use of high-pressure oil systems, which are the most liable to fail.

Over 80% of the production at Thermodyne consists of compressors fitted with dry gas seals. Almost all the machines supplied starting from 1993 have been equipped with them [1]. Over 120 machines of that type have been manufactured, and at present, the total working time of all machines in use has attained 1.5 million hours.

A new stage in the development of compressor engineering has been the development of centrifugal compressors containing AMB. The success of this technology has been assured by the manufacturers of AMB and by compressor-making firms, who have installed AMB in their machines.

The firm entitled Societé de Mecanique Magnetique (S2M) developed the ACTIDYNE AMB in the early 1980s. The working principle of these bearings is the use of stator electromagnets that attract a packet of magnetic plates mounted on the rotor. As this process is unstable, a regulation circuit is employed, which controls the attractive force in relation to the reading of the rotor position sensor on the bearing gap. In the same way, the end thrust AMB is regulated, as this controls the axial position of the rotor.

Also, to provide rotor deceleration when the compressor is shut down and the power supply is disconnected, there are auxiliary bearings (usually ball-bearing ones installed with small gaps).

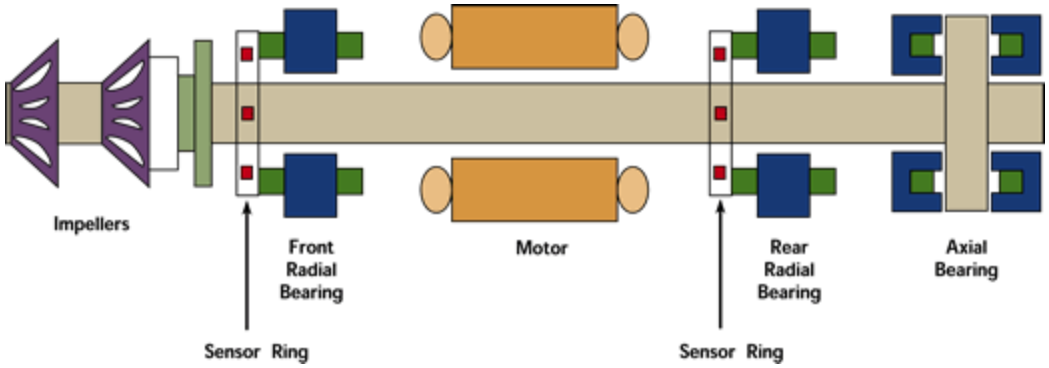
The AMB technology is constantly being upgraded. Originally, the power amplifiers for the control units were water-cooled, but they are now air-cooled. The control units are equipped with microprocessors, and the analog automatic control systems have been converted to digital ones.

Main AMB advantages:

– contactless operation (no wear);
– reduced mechanical losses (ventilation of the bearing and thrust end supports);
– power reduction in the auxiliary systems (oil pumps replaced by control electronics);

Thermodyne, Division of Framatome, France. Translated from Khimicheskoe i Neftegazovoe Mashinostroenie, No. 5, pp. 16–20, May, 1999.

Magnetic Bearing Centrifugal Compressor – System Integrity – Turbocor synonymous with "Copeland"



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

Magnetic Bearing Centrifugal air-cooled Chiller Equipment Costs

- New air-cooled chillers:$1000 to $1100 per ton
- Magnetic bearing compressor: $32,000
- Water-cooled retrofits: $240 to $370/ton
- Air-cooled retrofits: $50,000 to $65,000 per compressor

Energy Analysis:

- The analysis was run in Trace 700 8760 hourly analysis software
- This data represents costs for equipment, maintenance & energy for two 125 ton air-cooled chillers represented by York, Trane & Smardt Chillers.

MONTHLY UTILITY COSTS

By Chris Mansour, PE TFC

Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
					------- Monthly Utility Costs -------								
Alternative 1 York HE (scroll)													
Electric													
On-Pk Cons. ($)	16,002	13,690	11,004	7,724	9,096	10,897	12,245	12,160	8,619	9,242	10,660	14,551	135,889
On-Pk Demand ($)	7,688	7,650	7,279	4,308	4,645	5,117	5,646	5,248	4,493	5,525	7,204	7,677	72,480
Total ($):	23,690	21,340	18,282	12,032	13,741	16,014	17,892	17,408	13,111	14,768	17,864	22,228	208,369
Monthly Total ($):	23,690	21,340	18,282	12,032	13,741	16,014	17,892	17,408	13,111	14,768	17,864	22,228	208,369

Building Area = 98,685 ft²

Utility Cost Per Area = 2.11 $/ft²

Alternative 2 Turbocor													
Electric													
On-Pk Cons. ($)	15,268	13,037	10,022	6,560	7,351	8,378	9,303	9,268	6,851	8,112	9,725	13,830	117,705
On-Pk Demand ($)	7,351	7,315	6,881	3,807	3,745	4,209	4,695	4,305	3,554	5,102	6,784	7,328	65,075
Total ($):	22,619	20,352	16,904	10,367	11,095	12,587	13,997	13,574	10,405	13,214	16,510	21,157	182,780
Monthly Total ($):	22,619	20,352	16,904	10,367	11,095	12,587	13,997	13,574	10,405	13,214	16,510	21,157	182,780

Building Area = 98,685 ft²

Utility Cost Per Area = 1.85 $/ft²

Alternative 3 Trane HE (scroll)													
Electric													
On-Pk Cons. ($)	15,676	13,402	10,647	7,655	9,526	12,032	13,620	13,579	9,277	9,041	10,336	14,238	139,028
On-Pk Demand ($)	7,529	7,493	7,076	4,279	4,693	5,429	5,995	5,669	4,577	5,316	6,988	7,505	72,547
Total ($):	23,205	20,895	17,722	11,933	14,219	17,461	19,615	19,248	13,854	14,357	17,324	21,743	211,575
Monthly Total ($):	23,205	20,895	17,722	11,933	14,219	17,461	19,615	19,248	13,854	14,357	17,324	21,743	211,575

Building Area = 98,685 ft²

Utility Cost Per Area = 2.14 $/ft²

***NOTE these energy costs reflect whole building energy including receptacle power- the only difference between the alternatives are the chillers and associated equipment (15 hour/day op).**

SYSTEM LOAD PROFILES

By Chris Mansour, PE TFC

YLAA0141HE
System - 001

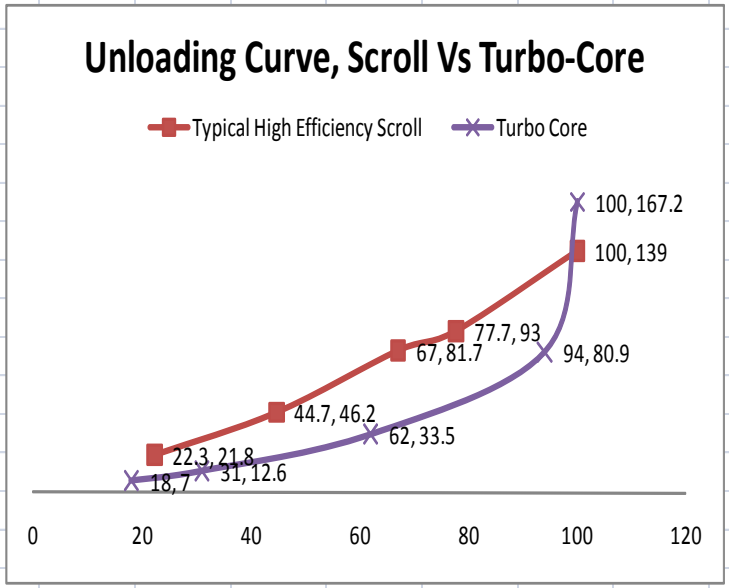
Percent Design Load	---- Cooling Load ---- Cap. (Tons)	Hours (%)	Hours	---- Heating Load ---- Cap. (Btuh)	Hours (%)	Hours	---- Cooling Airflow ---- Cap. (Cfm)	Hours (%)	Hours	---- Heating Airflow---- Cap. (Cfm)	Hours (%)	Hours
0 - 5	13.6	15	766	-106,358.5	20	537	5,530.8	18	981	2,049.2	8	223
5 - 10	27.2	12	607	-212,717.1	17	452	11,061.7	11	567	4,098.5	11	312
10 - 15	40.8	5	267	-319,075.6	16	434	16,592.5	5	293	6,147.7	9	246
15 - 20	54.4	6	320	-425,434.2	7	188	22,123.3	5	295	8,197.0	6	156
20 - 25	68.0	4	194	-531,792.7	9	237	27,654.2	4	227	10,246.2	7	178
25 - 30	81.5	15	782	-638,151.3	11	287	33,185.0	2	104	12,295.4	7	183
30 - 35	95.1	9	482	-744,509.8	7	190	38,715.8	2	97	14,344.7	7	203
35 - 40	108.7	6	311	-850,868.3	1	20	44,246.7	1	74	16,393.9	3	95
40 - 45	122.3	3	175	-957,226.9	1	40	49,777.5	2	127	18,443.1	3	86
45 - 50	135.9	4	204	-1,063,585.4	1	34	55,308.3	22	1,197	20,492.4	4	112
50 - 55	149.5	3	154	-1,169,943.9	1	24	60,839.2	5	294	22,541.6	5	148
55 - 60	163.1	5	243	-1,276,302.5	1	19	66,370.0	6	341	24,590.9	2	54
60 - 65	176.7	4	219	-1,382,661.0	1	28	71,900.9	6	343	26,640.1	6	163
65 - 70	190.3	3	151	-1,489,019.5	1	21	77,431.7	3	150	28,689.3	8	229
70 - 75	203.8	2	110	-1,595,378.1	0	0	82,962.5	2	133	30,738.6	0	0
75 - 80	217.4	2	88	-1,701,736.6	4	100	88,493.4	2	83	32,787.8	0	0
80 - 85	231.0	2	105	-1,808,095.1	2	64	94,024.2	0	20	34,837.0	1	21
85 - 90	244.6	1	28	-1,914,453.8	0	0	99,555.0	1	45	36,886.3	1	19
90 - 95	258.2	0	15	-2,020,812.3	0	0	105,085.9	0	20	38,935.5	0	0
95 - 100	271.8	0	0	-2,127,170.8	0	0	110,616.7	0	0	40,984.8	11	290
Hours Off	0.0	0	3,539	0.0	0	6,085	0.0	0	3,369	0.0	0	6,042

Load profile estimates the chiller plant would operate at 75% or better capacity

*Notice the percent of time the system operates as 75% load or better

air-cooled Scroll Vs Magnetic Centrifugal Efficiency – Performance

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 York KW/Ton/Yr/%Hr/%Loaded	83.352	KW
Avg TurboCore KW/Ton/Yr/%Hr/%Loaded	37.0662	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.

Life Cycle Costs Analysis

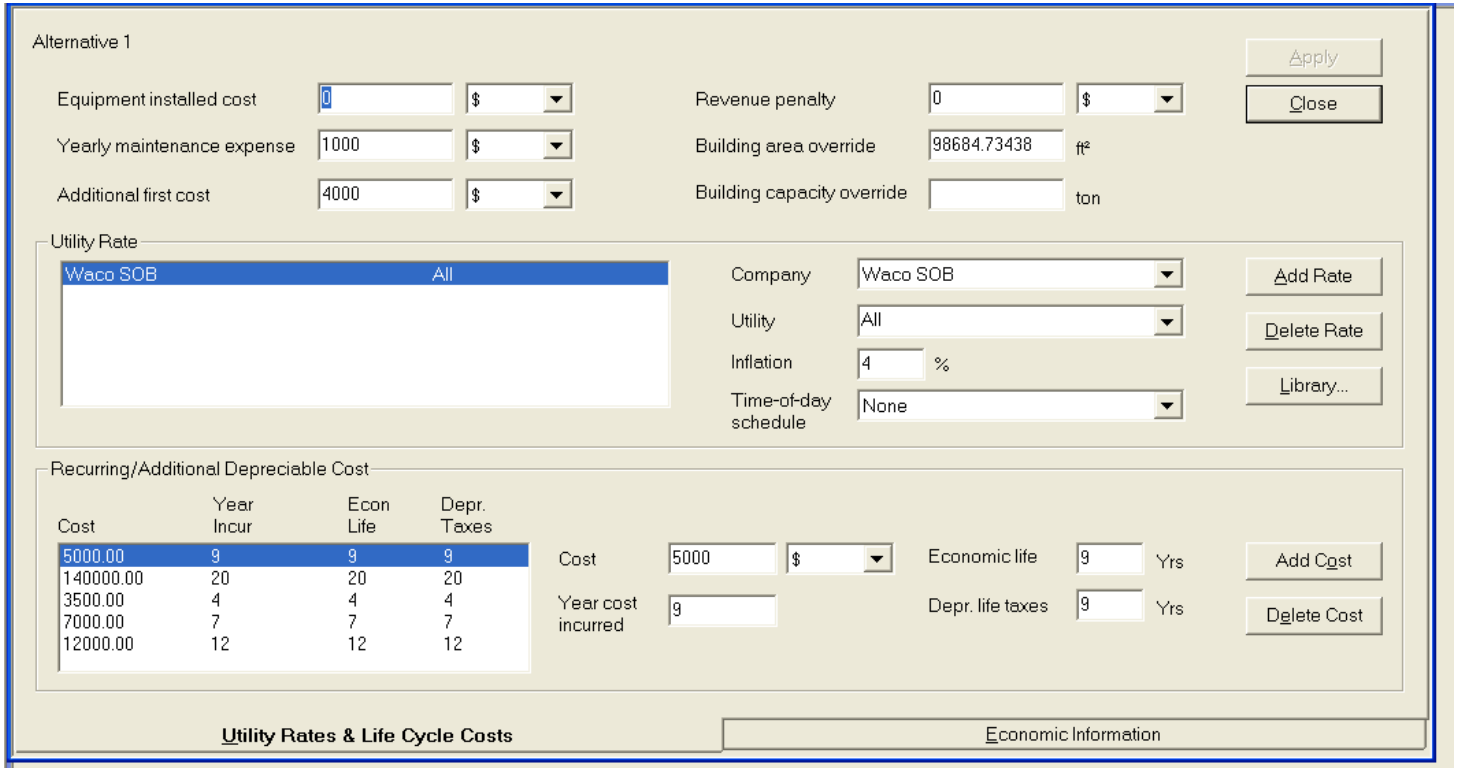
Analysis Parameters:

- The analysis was run in Trace 700 8760 hourly analysis software
- This data represents costs for equipment, maintenance & energy for two 125 ton air-cooled chillers represented by York, Trane & Smardt Chillers.
- An $125,000 premium is applied on the centrifugal magnetic compressors
- A $4000 premium on for York over the Trane chiller.
- Energy taken at $0.10 KWh & demand @ $10 per KW
- A three year payback is estimated.

*NOTE these energy costs reflect whole building energy including receptacle power for (5) 15 hour days – the only difference between the alternatives are the chillers and associated equipment.

Scroll Estimated Maintenance – System Maintenance

York HE



Scroll maintenance costs from maintenance records:

Year 4: replaced compressor + miscellaneous.

Year7: replaced three compressors

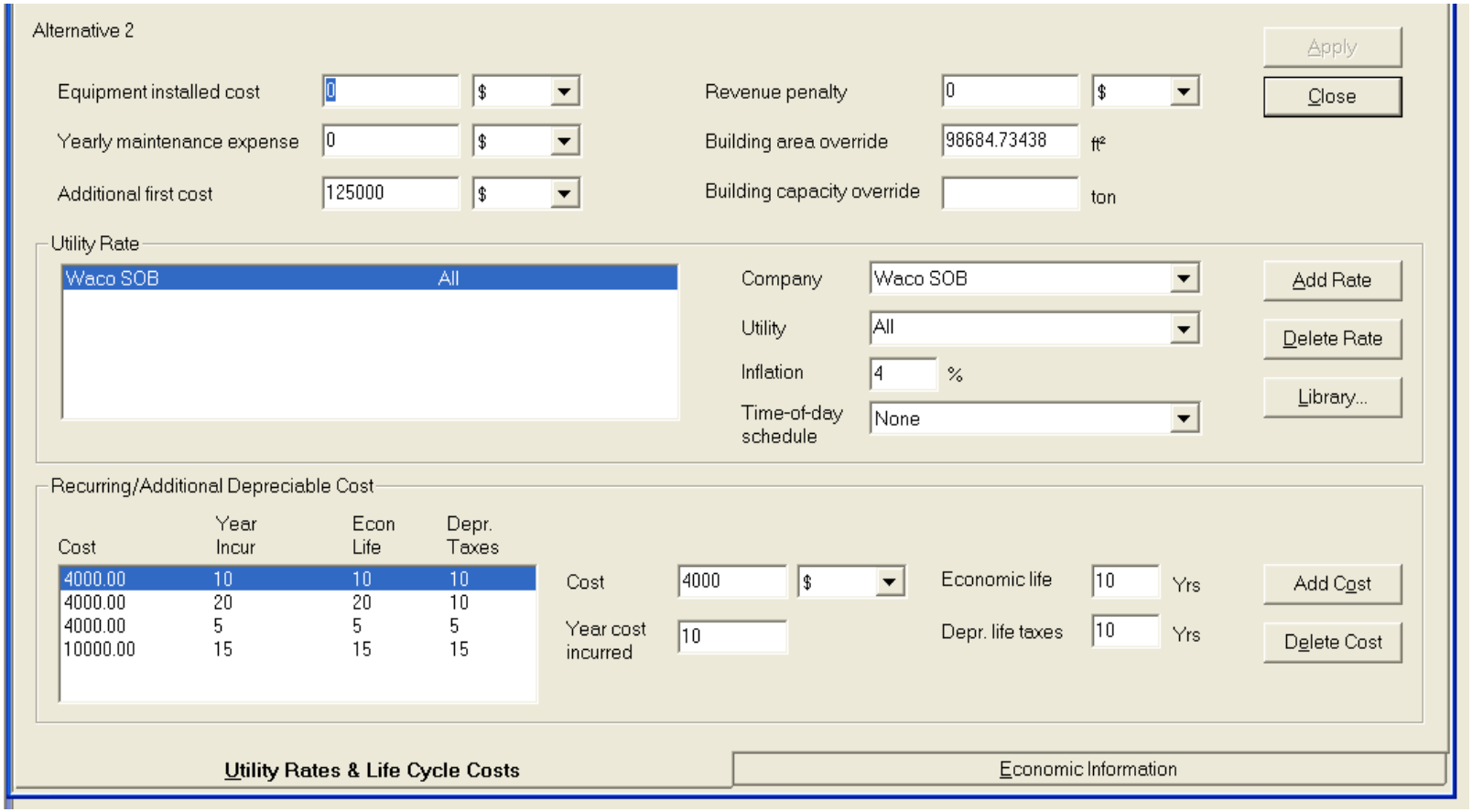
Year 9: Replaced 2 compressors

Year 12: Major refrigeration leak

Year 20: Replace Unit

These maintenance costs were obtained from maintenance records for two 125 ton, 12 year old air-cooled chillers. These chillers are scheduled to be replaced within three months.

Magnetic Centrifugal Estimated Maintenance



TurboCore assumed maintenance costs:

Additional First Costs (2) 125 ton chillers: $84,000

Year 5: Miscellaneous maintenance such as condenser fans & drives, minor leaks

Year10: Replace capacitors

Year 15: Miscellaneous maintenance such as condenser fans & drives, major leaks

Year 20: Replace capacitors

Upfront costs and typical maintenance costs were taken from historical accounts from owners

This data represents costs for equipment, maintenance & energy for two 125 ton air-cooled chillers for York, Trane & Turbo-Core (represented by Smardt Chillers).

Notice there is an $125,000 premium on the centrifugal magnetic compressors, a $4000 premium on for York over the Trane chiller. In this case, with energy taken at $0.10 KWh & demand @ $10 per KW, a three year payback is estimated.

***NOTE these energy costs reflect whole building energy including receptacle power- the only difference between the alternatives are the chillers and associated equipment.**

Economic Summary

Project Information

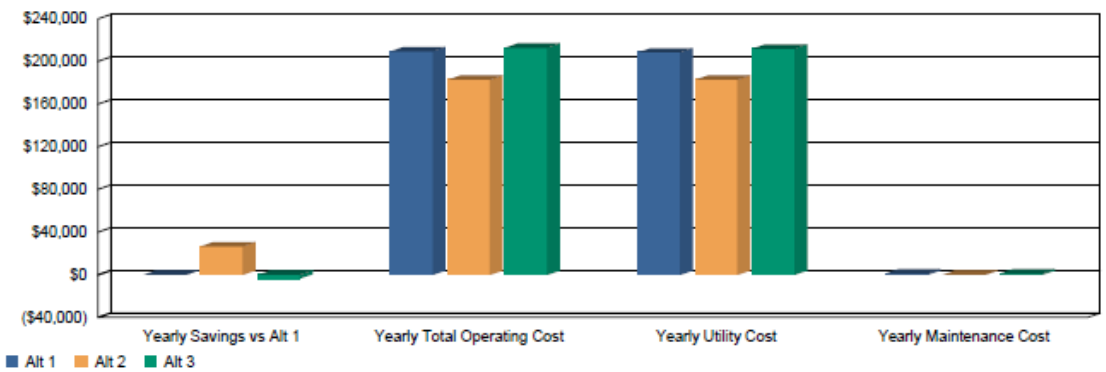
Location
Project Name
User
Company
Comments

Study Life: 25 years
Cost of Capital: 5 %
Alternative 1: YLAA0141HE
Alternative 2: Smardt TurboCore
Alternative 3: Trane RTAC 140 High

Economic Comparison of Alternatives

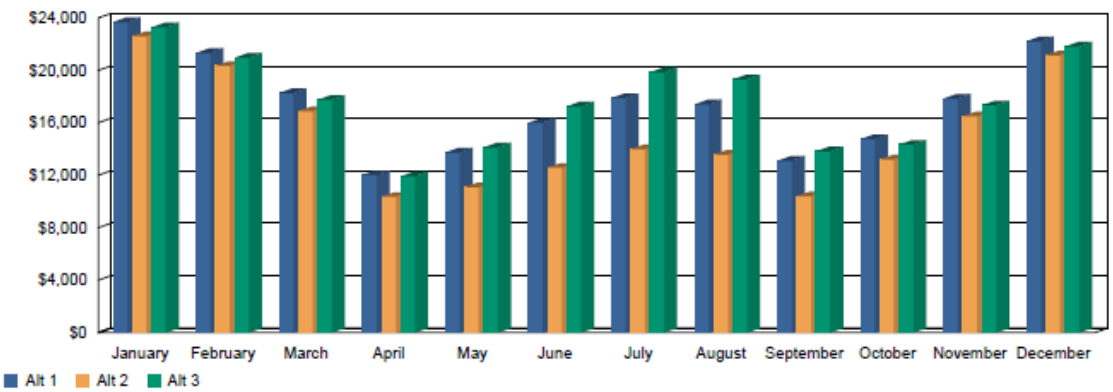
	Yearly Savings ($)	First Cost Difference ($)	Cumulative Cash Flow Difference ($)	Simple Payback (yrs.)	Net Present Value ($)	Life Cycle Payback (yrs.)	Internal Rate of Return (%)
Alt 2 vs Alt 1	26,590	121,000	1,308,243	4.6	617,996	No Payback	1,000.0
Alt 3 vs Alt 1	-3,492	-4,000	-119,222	1.1	-63,464	No Payback	Does Not Payback
Alt 2 vs Alt 3	26,590	125,000	1,427,465	4.2	681,460	No Payback	1,000.0

Annual Operating Costs



	Yearly Savings vs Alt 1	Yearly Total Operating Cost ($)	Yearly Utility Cost ($)	Yearly Maintenance Cost ($)
Alt 1	0	209,369	208,369	1,000
Alt 2	26,590	182,780	182,780	0
Alt 3	-3,492	212,861	211,861	1,000

Monthly Utility Costs



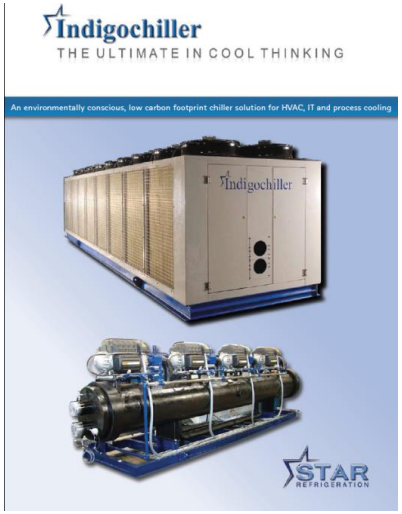
Magnetic Bearing Air-Cooled Chiller High Points

Manufacturers & Service

- Representation is equally important as performance: As of 1/31/2010 **York, McQuay, Multistack & Smardt** offer magnetic centrifugal compressors on their chillers (water-cooled). YPS & Texas Chiller Systems, both local companies, are certified on Turbocor compressors.
- Smardt & Multistack are currently the only manufacturers offering an air-cooled version in the Texas region. However there are a dozen other manufacturers that also offer an air-cooled version and more are expected to follow:

Magnetic Centrifugal air-cooled Chiller Manufacturers

For about the first 10 years the technology was only utilized by a couple of chiller manufacturers. Since 2002 eight other manufacturers have followed suit including the 3 of the "Big 4", York, McQuay, Trane.



Retrofit History:

- The Turbo-Core, magnetic centrifugal compressor has been applied in many retrofit applications with success on both air & water-cooled systems:

NEVADA SURE BET PROGRAM
Offered By: NV Energy
Administered By: KEMA Services, Inc

Turbocor Variable-Speed, Magnetic Bearing Chiller

Clark County School District operates more than 300 schools in and around Las Vegas, Nevada. The District pays almost 40 million dollars per year in electric bills. As a result, management of energy costs receives a great deal of attention from the School District facilities – both in new school design as well as existing school operations and maintenance. In 2005, an old, noisy and inefficient air-cooled chiller at Fitzgerald Elementary School needed replacement. Through an initiative by the Energy Innovations Group, in San Diego California, a proposal from the Las Vegas McQuay dealer to install a Turbocor chiller was developed. The Turbocor is a relatively newly available high-efficiency variable-speed, oil-free centrifugal compressor. The oil-free magnetic bearings reduce friction and the losses inherent with handling and cooling lubricating oil. The compressor has exceeded efficiently estimates and operated trouble-free for more than two years. As a result, the District has proceeded with several additional installations.

AIR-COOLED TURBOCOR

RETROFIT OF AN AIR-COOLED CHILLER WITH AN OIL-LESS CENTRIFUGAL COMPRESSOR

EAST COUNTY FAMILY RESOURCE CENTER
COUNTY OF SAN DIEGO

December 2005

Navy Techval

Turbocor

- 80 Ton Chiller Compressor
- Oil Free Magnetic Bearings
- Integral VFD and Micro Processor

Navy Techval has found simple pay backs between 4 and 8 years.
40% to 65% energy savings.

Navy Techval recommends installing oil free magnetic bearing chiller compressors at other Navy sites where:

Other Evaluations on Payback:

Navy Techval

The Table below presents a synopsis of the data collected for these two proje

Project Site	Project Type	Site Characteristics	$/KWH	Tons	Annual Kwh savings	Annual Energy $ Savings	% Savings	Cost	$/Ton	Payba (years
San Diego April/May 2005	Compressor Retrofit	Year round cooling, old compressors screw	$0.121	160	199,000	$24,000	41%	$138,718	$867	5.8
San Diego January 2006	Add 3rd compressor and Condensing water reset	Year round cooling, old compressors screw	$0.121	240	193,596	$23,232	47%	$178,687	$744	7.7
San Diego April 2006	Add 3rd compressor and Condensing water reset	Year round cooling, old compressors screw	$0.121	240	210,240	$25,229	47%	$178,687	$744	7.1
Newport Sep/Nov 2005	New Chiller	Year round cooling, old chiller recip	$0.115	80	227,760	$26,192	65%	$100,783	$1260	3.8

NEVADA SURE BET PROGRAM
Offered By: NV Energy
Administered By: KEMA Services, Inc

Turbocor Variable-Speed, Magnetic Bearing Chiller

Project Results

	Total
Demand Reduction	16 kW
Annual Energy Savings	51,000 kWh
Annual Energy Cost Savings	$5,230
Project Cost (Approximate)	$17,000
Sure Bet Incentive	$3,130
Simple Payback Period	2.7 Years

This information is posed on DOE's website and listed as an effective emerging technology for energy savings.

AIR-COOLED TURBOCOR

RETROFIT OF AN AIR-COOLED CHILLER WITH AN OIL-LESS CENTRIFUGAL COMPRESSOR

EAST COUNTY FAMILY RESOURCE CENTER
COUNTY OF SAN DIEGO

December 2005

Implementation Costs	
Compressor Retrofit	$ 50,000
Reciprocating Compressor Cost	$ (12,800)
Incentive	$ (14,715)
Total Installed Cost	$ 22,485
Est. Annual Energy Savings	$ 8,000
Simple Payback (yrs)	2.8

Problems Encountered: Data gained through Paul Kistler, PE CEM, Engineer for the US Navy

Navy Techval

Turbocor Problems

Newport

•Thermister failed. Thermister was replaced and problem has not recurred.

•Automatic Expansion Valve not tuned properly. Valve was adjusted and problem has not recurred.

San Diego

•Insulated Gate Bipolar Transistor (IGBT) failed. Decision was made to replace compressor since it was relatively easy to do. Replacement took two hours. Problem has not recurred.

•Power surge damaged one of three Turbocors. Compressor was replaced. Waiting final report on incident. Turbocor has stated that electronics have been improved since this compressor was installed.

Techval

Negative Feedback:

- Blog postings between 2004 & 2006 indicate a number of electronic failures
- Blog postings between 2007 & 2009 indicate vast improvements with failures significantly reduced
- Vendor source indicates that the magnetic bearing compressor does not have enough lift to maintain 44 LWT at 95 F ambient, however over a dozen air-cooled manufactures sell air-cooled versions, and Leander ISD, a local school district, has operated an air-cooled magnetic bearing chiller as high as 108 F successfully.
- A number of retrofits have been applied to existing chillers, early installations reported a number of electronic problems which were resolved by applying a more robust component enclosure to keep moisture and dust away from the electronics.

Progression

Two common complaints:

1. A number of electronic failures due to component enclosure. Today that enclosure has been improved to keep moisture and dust out and electronic failures have been drastically minimized.
2. A learning curve for HVAC technicians- many blogs were started concerning the magnetic bearing chiller. Early postings nearly questioned and protested the application. In the past couple of years the posts have evolved toward question and answer blogging, sharing experiences and solving problems.

Progression

- Although this technology has been improved recommendations have been made to purchase a 5 year warranty and mandate training for the compressor.
- It is likely there will be continued challenges, as with ALL chiller systems. With this said there is a consensus that the energy savings, nearly twice as efficient as traditional air cooled chiller compressors, far outweigh the above stated problems.

Positive Feedback

After interviewing Amandeep Singh, Energy Engineer for Center for Sustainable Energy, California:

- Since 2004 San Diego County implemented 100's of magnetic bearing centrifugal compressors on surrounding city, county and state buildings.
- Although the program had some rough startups due to either initial calibration or electronic failure it has continued and is considered to be a big success.
- There have been no compressor failures and since the start of the program there have been minimal electronic failures.
- They have also not experienced a lift problem on air-cooled chiller applications.
- The program has been successful enough that it is expanding and the prescription for the magnetic bearing compressor comes nearly automatic for both air and water-cooled chillers provided that the chillers do not operate at peak loads.

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Rev Waco @ 105 Ambient

CLIENT Texas Equipment Solutions

Model	Q_o Tons	Shell and tube evaporator: T.IN t_{WE} F	T.OUT t_{WL} F	Pass No	Conn'n NB"	P.Drop ΔP, psi (ft H_2O)	Flow v GPM(US)	Air Cooled Condenser: T.Air Ambient F	No of Fans	Sound Pwr Lw dB	Fan Pwr Pe kW	A.Flow v CFM (000s	Compressors, each: Q'ty	Cooling Capacity Q_o, Tons	Abs'd Power P_e, kW	Running Current Amp	Full L. Current FLC,A	Total Sound Pwr Lw dB	Total absorbed power incl. fans and COP (EER) at various loads (460V 3PH 60 Hz): P_e, kW	MCA, A	Run, A	100%	75%	50%	25%	NPLV	Size: Length in	Width in	Height in	Operating Weight lbs
Specified AA054.2BG7.34V	127.1	57.0	44.1	3	5	5.36	236	105.1	8	94.6	18.1	108.8	2.0	63.5	74.6	98.6	135	94.9	167.2	331.6	225	1.32	0.85	0.53	0.40	0.60	242	93	100	11640
High Static Fans - Free Discharge						12.4																9.1	14.1	22.7	30.3	19.9				
Alternative AA054.2BG7.34E	126.5	57.0	44.1	3	5	5.32	234.6	105.1	8	84.1	14.3	98.8	2.0	63.3	74.2	98.1	135	86.9	162.7	329.5	222	1.29	0.83	0.56	0.43	0.63	242	93	100	11640
EC Fan Option						12.3																9.33	14.50	21.40	28.00	19.18				

Table 2.
System performance under various cooling loads, Specified option.

Item	Calculated Power Consumption: As per ARI 550/590-2003				Total
Cooling demand, %	100	75	50	25	
Cooling load, Tons	127	95	64	32	
Absorbed Power, kW	167.2	80.9	33.5	12.6	
kW/Ton	1.32	0.85	0.53	0.40	
Time at this load, %	1%	42%	45%	12%	100%
Annual cons., MWh	14.6	297.4	132.0	13.2	457
Annual cost, k$					45.7

Table 3.
System performance under various cooling loads, Alternative option.

Item	Calculated Power Consumption: As per ARI 550/590-2003				Total
Cooling demand, %	100	75	50	25	
Cooling load, Tons	127	95	63	32	
Absorbed Power, kW	162.7	78.5	35.5	13.5	
kW/Ton	1.29	0.83	0.56	0.43	
Time at this load, %	1%	42%	45%	12%	100%
Annual cons., MWh	14.2	288.5	139.7	14.2	457
Annual cost, k$					45.7

Table 4.
Estimated Installed Sound Pressure Level dB A weighted

Specified **78.8** at **3.4** feet from source
Unit is installed on an unenclosed roof or similar flat surface

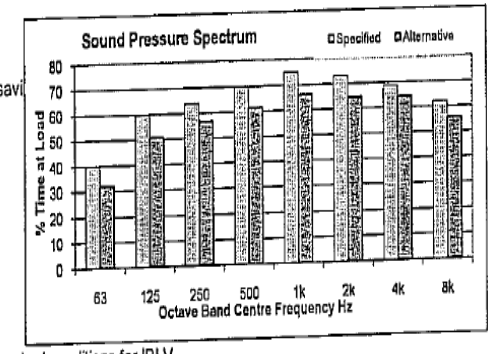
Alternative **70.7** at **3.4** feet from source
Unit is installed on an unenclosed roof or similar flat surface

A weighted Sound spectrum - Sound Pressure Level dBA at installation conditions and distance from source as defined above.

	63	125	250	500	1k	2k	4k	8k
Specified	40	60	64	70	75	73	69	62
Alternative	32	51	57	61	66	65	64	56

Linear sound spectrum - Total Unweighted dB Sound Power Level L_W

	63	125	250	500	1k	2k	4k	8k
Specified	82	92	88	89	91	88	84	79
Alternative	74	83	81	81	82	79	80	73



Notes:
1. Terms of delivery: as per attached Quotation No. Q08-0000
2. Rated in accorandance with ARI Standard 550/590.
3. Variable chilled water flow rates are acceptable within indicated limits for pump power savi
4. Assumed data for the purpose of this calculations:
   Annual running time, hours 8750
   Mean annual energy cost, $/kWh 0.1
   Portion of time at each load
5. Performance figures are within tolerance of simulation software.
6. Peformance based on standard evaporator fouling (0.0001 h.ft².°F/Btu)
7. Chiller operates on refrigerant R134a.
8. COP for 100% is constant as it is calculated for ARI-designated temperatures.
9. Performance is based on 3 feet elevation above sea level.
10. COP and NPLV figures are based on selection conditions - these are NOT the ARI standard conditions for IPLV

Conclusion:

With all things considered this technology has matured to a point where advantages outweigh disadvantages. Limited implementation should be risked to prove these discovered advantages, learn the maintenance pitfalls, other costs of operation and capitalize on efficiencies. This implementation should be thought of as a multipronged program with extended maintenance agreements, maintenance training, operations training and energy monitoring for energy savings.