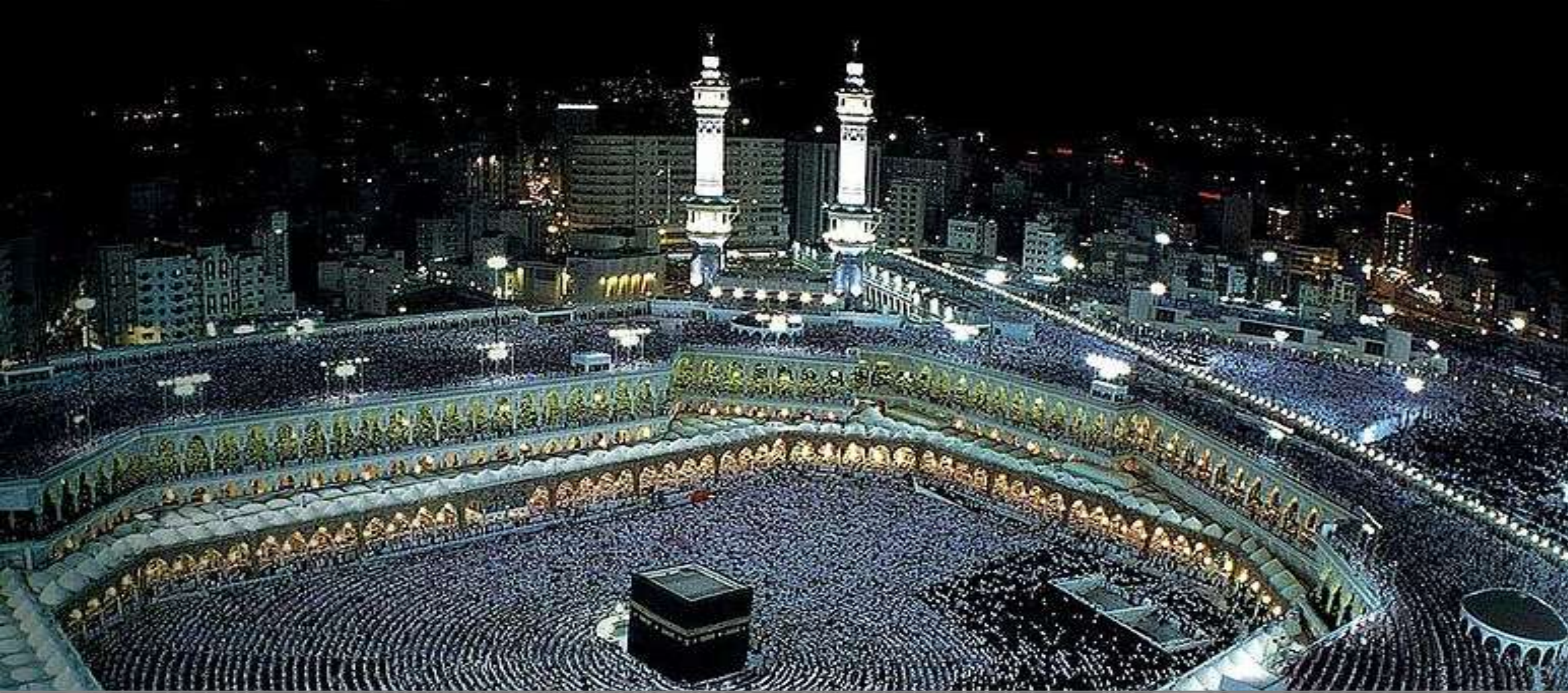
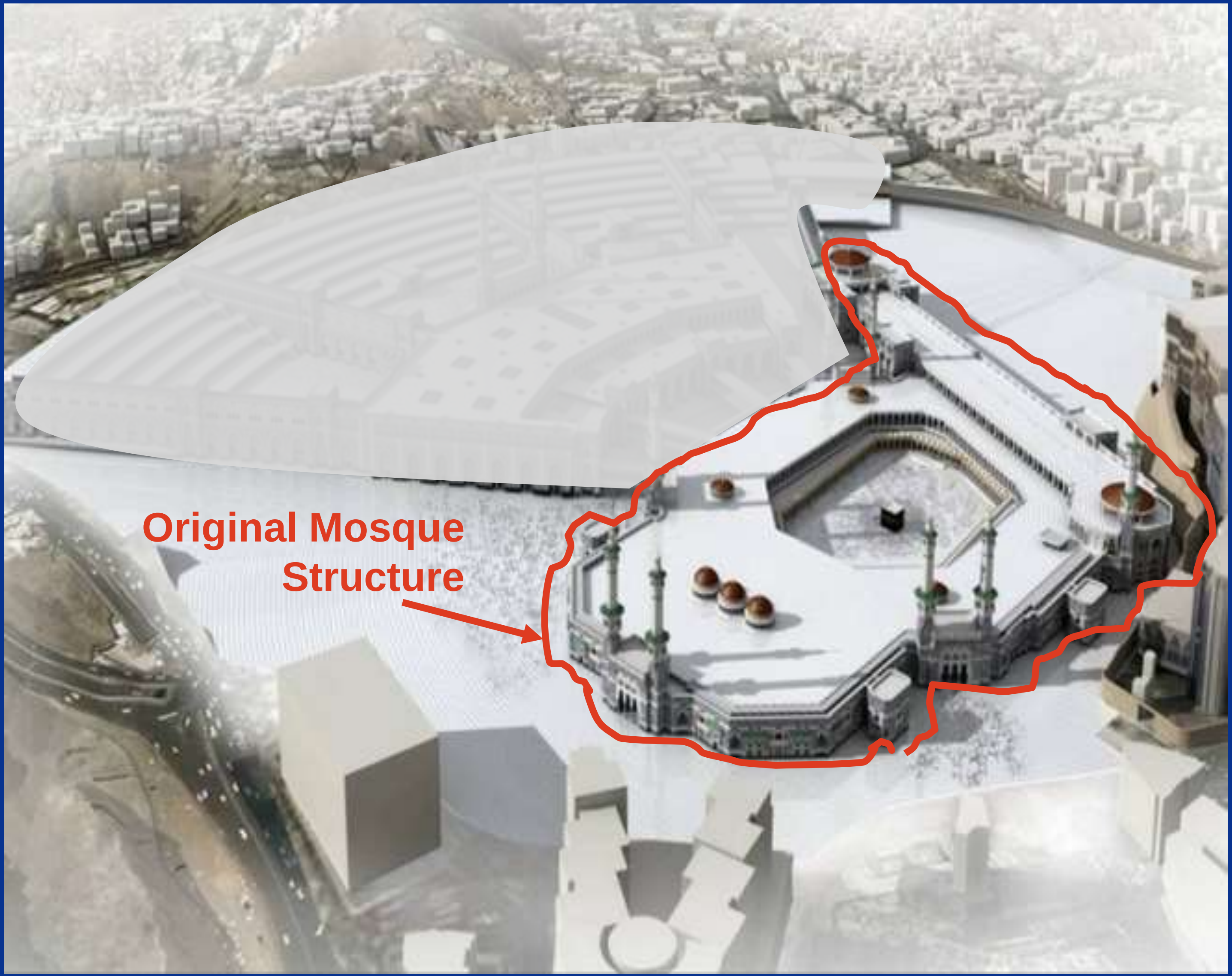


Third Expansion of Holy Haram Makkah Chiller Plants in Shamiya and Ajiad

Amar Farjo – Lead Staff Engineer – Johnson Controls

Tuesday, 11 December, 2018

THIRD EXPANSION OF HOLY HARAM MAKKAH

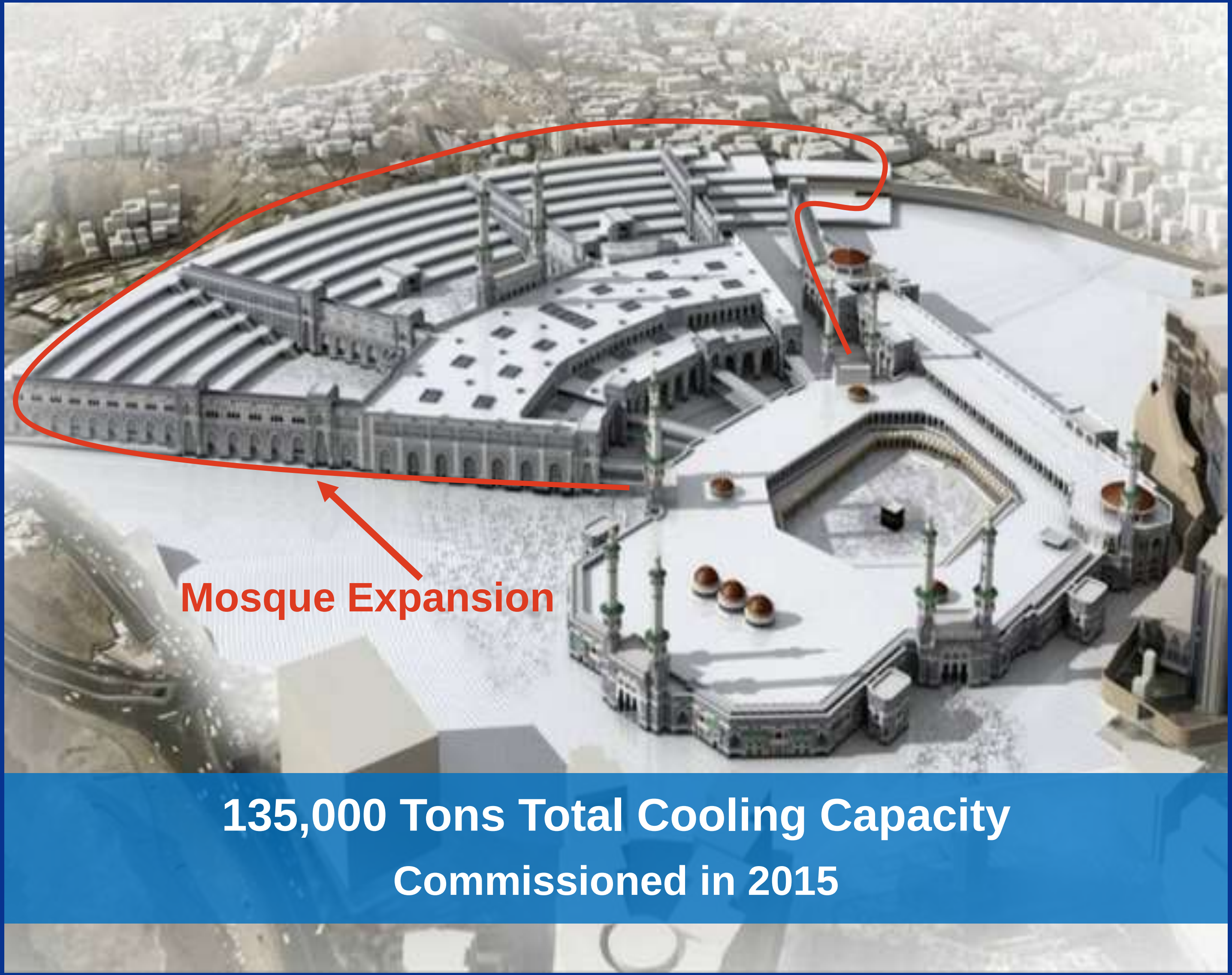


Original Ajiad Plant

13,600 tons cooling capacity

- 34 air-cooled packaged reciprocating chillers
- 400 tons capacity each
- Installed 1993

THIRD EXPANSION OF HOLY HARAM MAKKAH



135,000 Tons Total Cooling Capacity

Commissioned in 2015

Shamiya Plant

120,000 tons water-cooled

- 24 YORK Titan OM Chillers
- 5,000 tons net cooling capacity each

First Phase: 80,000 tons

- 8 YORK OM – fixed speed
- 8 YORK OM – variable speed

Second Phase: 40,000 tons

- 8 YORK OM – fixed speed

Ajiad Plant Expansion

15,000 tons air-cooled

- 3 YORK OM – variable speed
- 5,000 tons net cooling capacity each

Ajiad District Cooling Plant

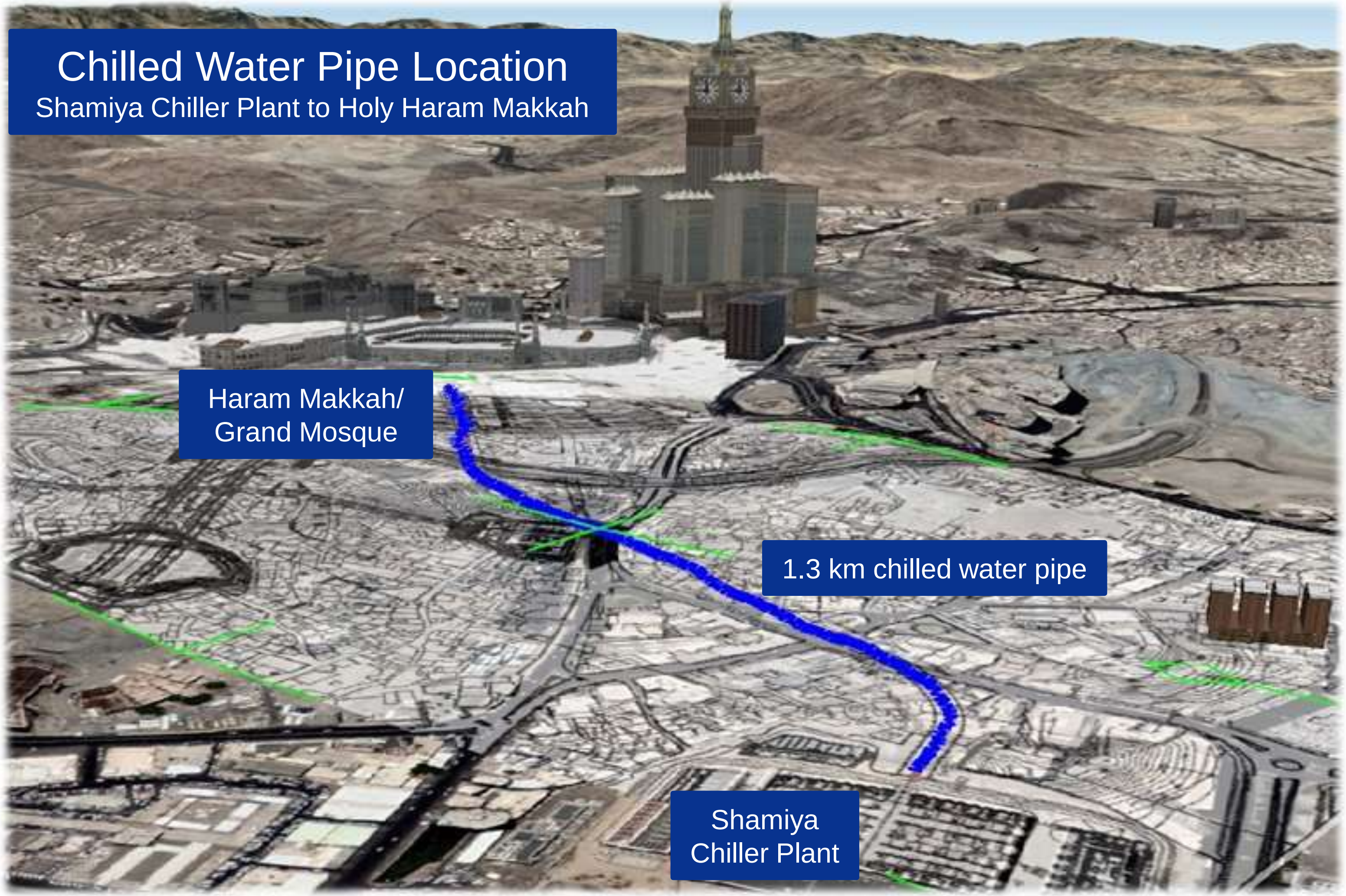
- Located across from the Holy Haram Makkah
- 34 – 400 ton air-cooled YORK reciprocating chillers
- Installed 1993

Shamiya District Cooling Plant

- Located less than 2 km from the Holy Haram Makkah
- Designed for 32 X 5000 Ton water-cooled chillers.
  - 24 chillers are installed.
  - 16 chillers are commissioned and in operation
  - 8 chillers not yet commissioned.
  - 8 more chillers to be ordered in future.
- Commissioning was between 2013- 2015

Chilled Water Piping from Shamiya Plant – 3D Layout

- Approximately +/- 1.3 km of chilled water piping from Shamiya Chiller Plant to Holy Haram Makkah



Chilled Water Piping from Shamiya Plant – Utility Tunnel

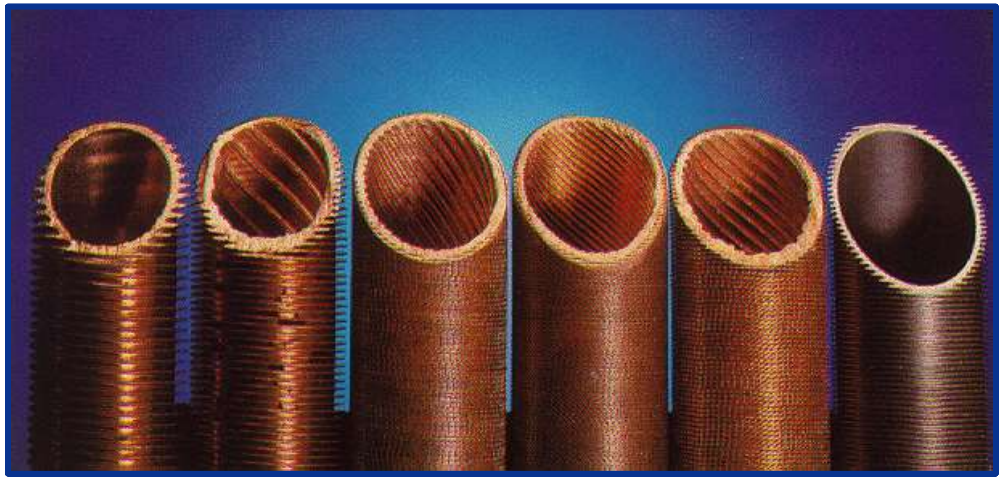
- Approximately +/- 1.3 km of chilled water piping from Shamiya Chiller Plant to Holy Haram Makkah
- Two chilled water loops
- 1200 mm (47.24”) diameter pipes

SHAMIYA PLANT YORK TITAN OM CHILLERS
24 CHILLERS – 5,000 TON EACH – WATER-COOLED

- 13800V / 3ph / 60Hz, 6000 HP motor
- 16 chillers: 13800V / 3ph / 60Hz Solid State Starters
- 8 chillers: High voltage Variable Speed Drives
- Compressor castings with high design working pressure
- Condenser design working pressure >300 PSIG for potential future refrigerant change
- Allen Bradley PLC control panel
- Automatic Tube Brushing system
- Vibration monitoring system for entire driveline
- Seismic spring isolators

Shamiya Plant YORK OM Chillers – Heat Exchangers

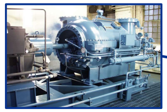
- YORK engineered and manufactured heat exchangers
- Customized to meet the unique project applications and requirements
  - ASME code shells
  - Bolt-on marine water boxes
  - Integral sub-cooler in condenser
- TSE (treated sewage effluent) water is used in the condenser loop
- Condenser corrosion/erosion protection:
  - 90/10 CuNi tube materials, 0.035” tube wall
  - CuNi clad tube sheets
  - High performance polymer composite coating and zinc anodes for waterbox protection

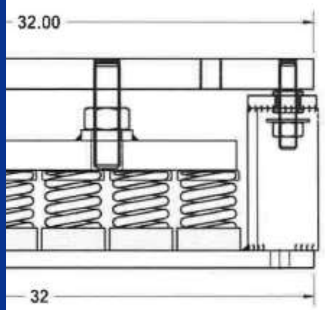


Heat Exchanger Tubes

Condenser Waterbox End with Zinc Anodes prior to coating

Shamiya Plant YORK OM Chillers





mensions

= 32 inch (81.3 cm)

16 inch (40.6 cm)

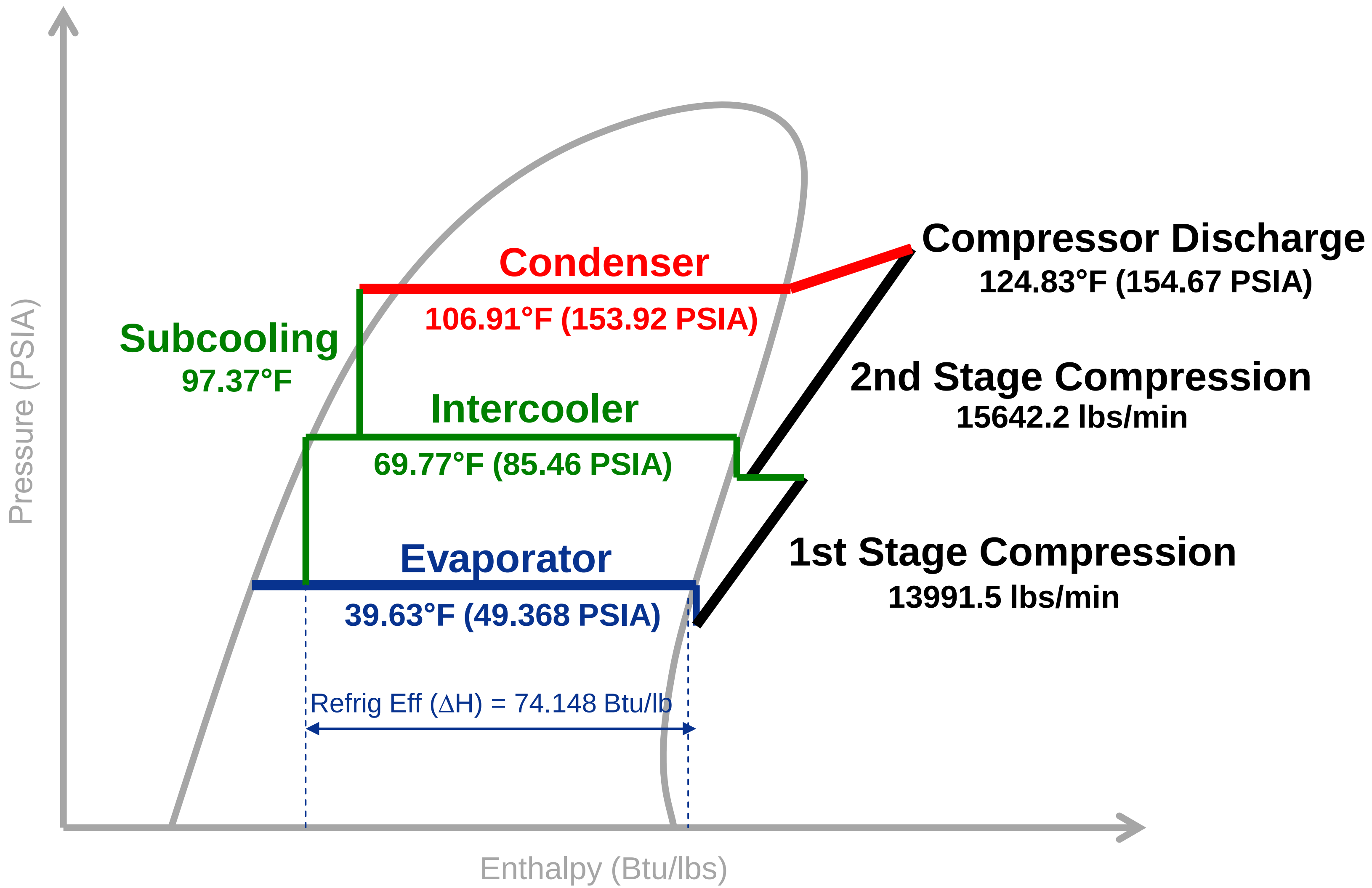
g height range =
~ 12-1/2 inch
~ 31.75 cm)

nate weight =
s (499 kg)

(currently using R-134a)

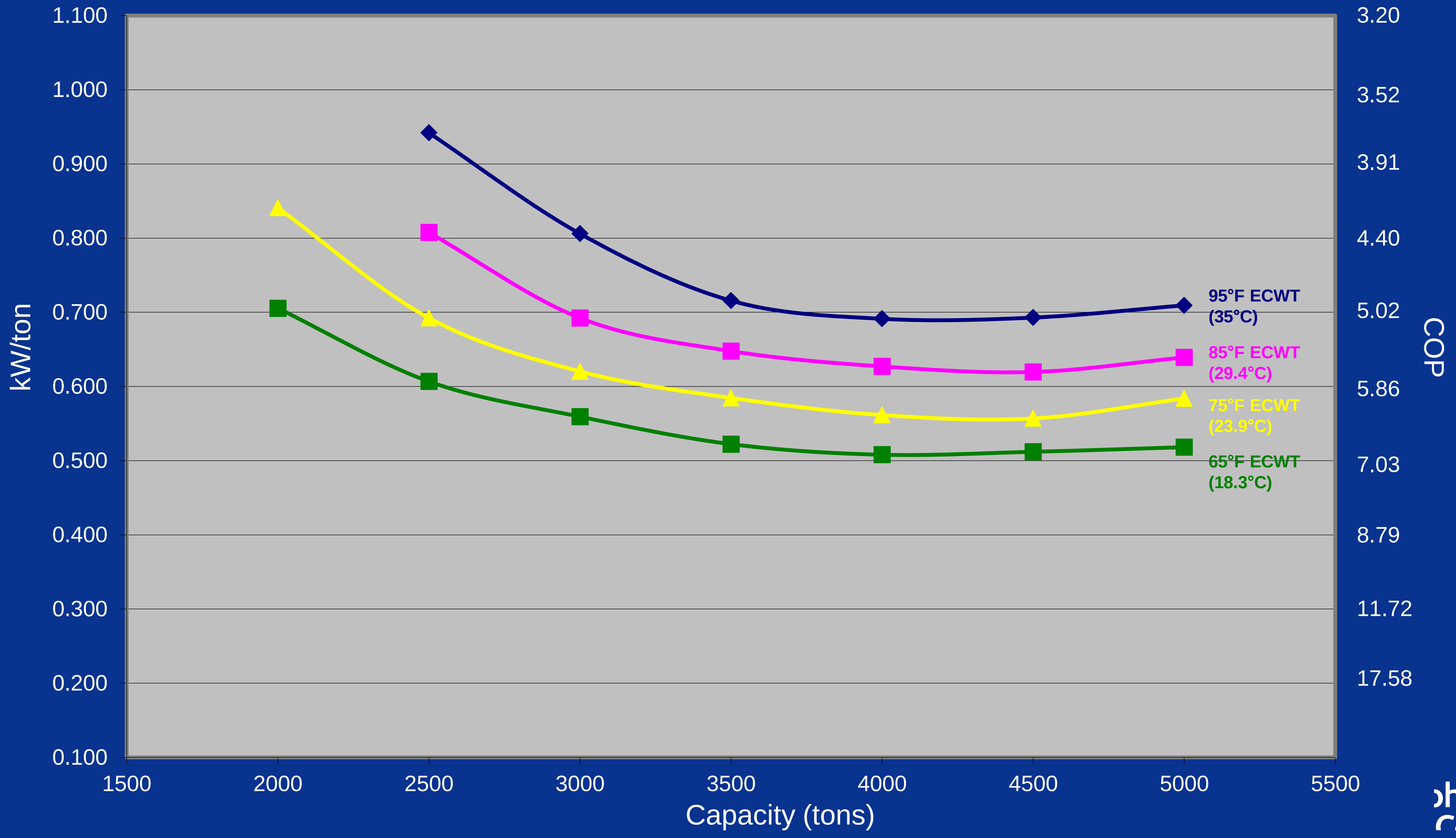
Shamiya Plant YORK OM Chillers – Pressure/Enthalpy Diagram

- Two-stage R-134a refrigerant diagram – one stage of Intercooling with subcooling

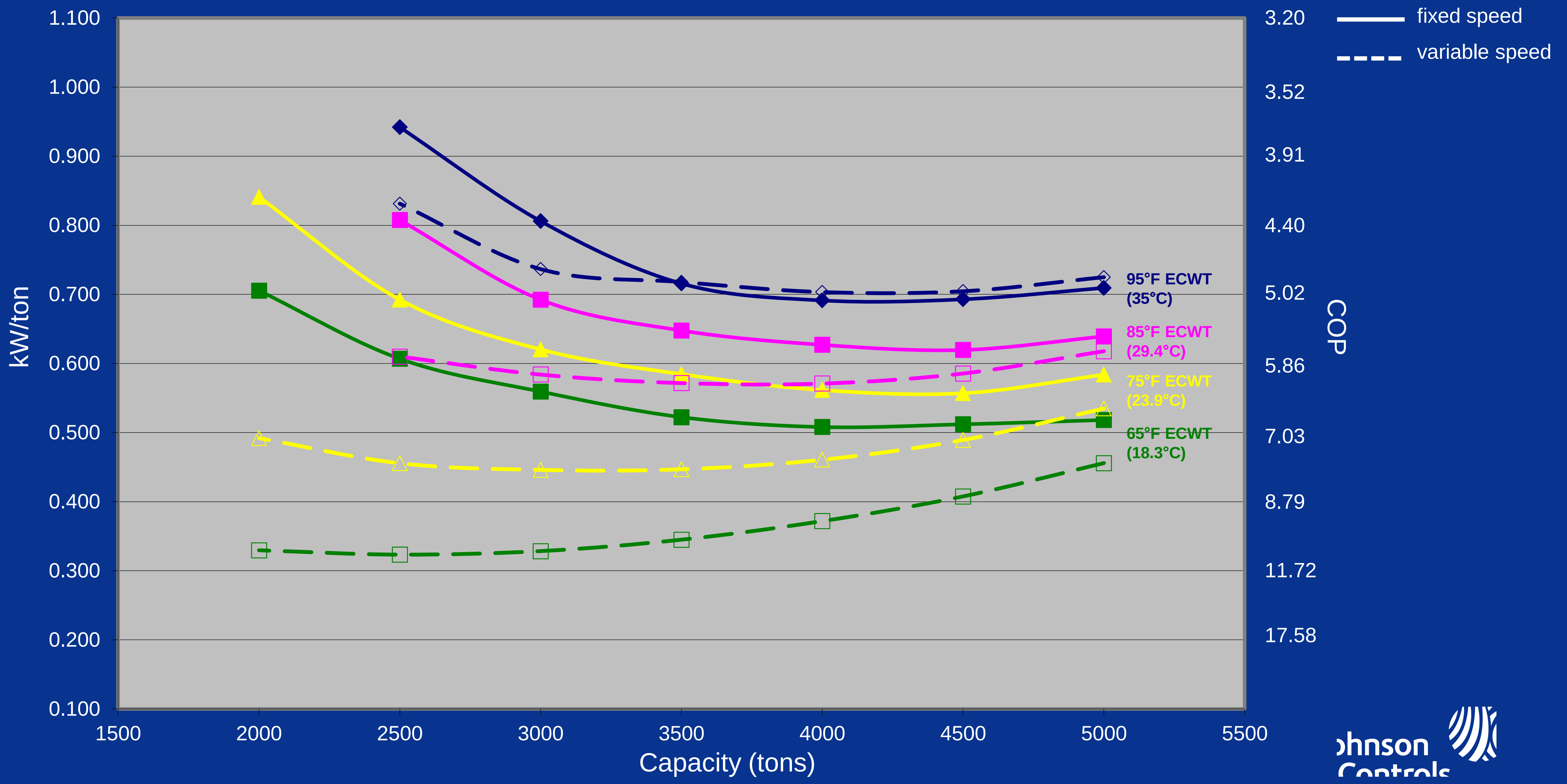


SHAMIYA PLANT YORK TITAN OM CHILLER PERFORMANCE FIXED SPEED

VARYING ECWT (ENTERING CONDENSER WATER TEMPERATURES)



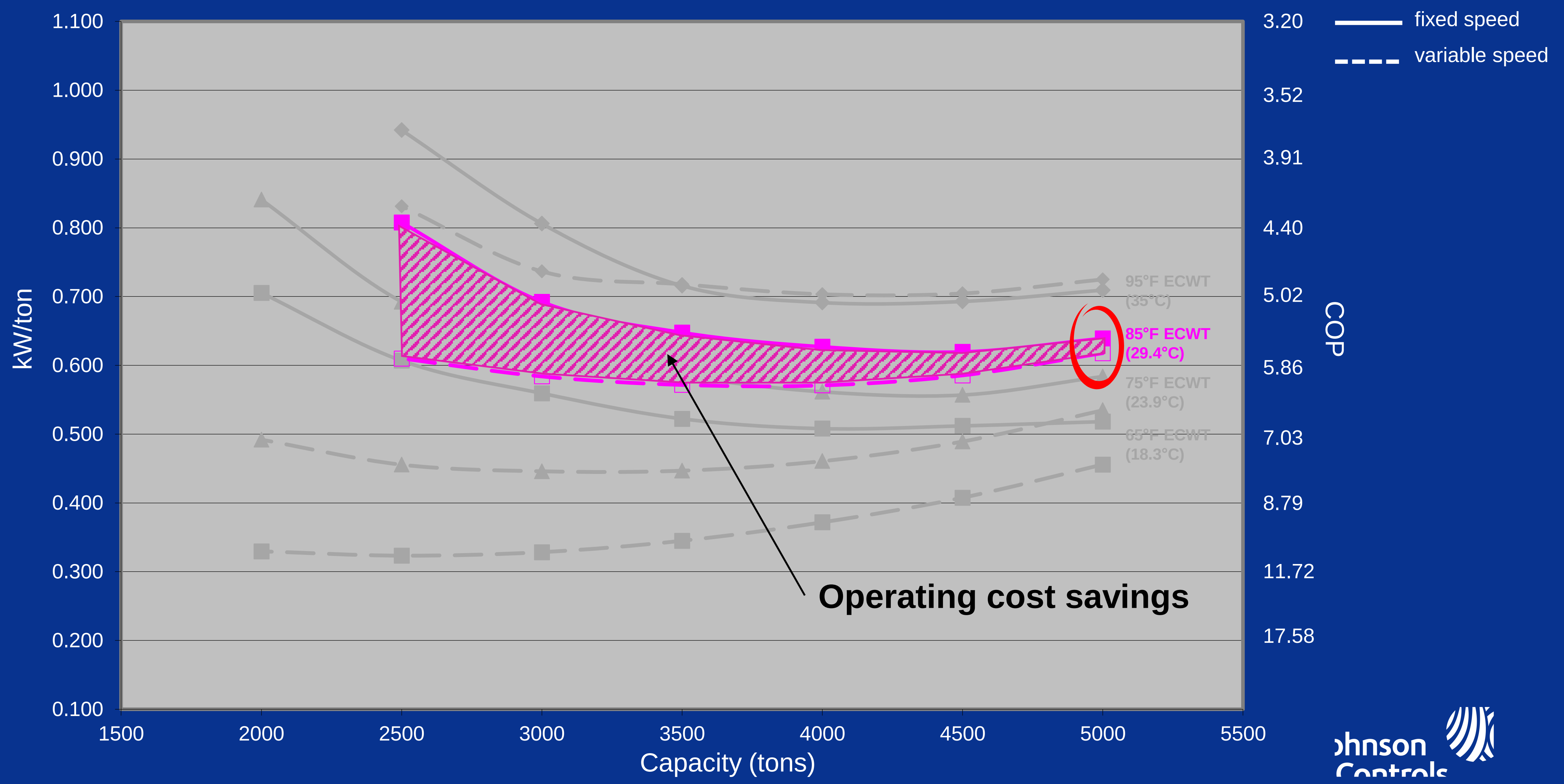
SHAMIYA PLANT YORK TITAN OM CHILLER PERFORMANCE
FIXED SPEED VS VARIABLE SPEED
VARYING ECWT (ENTERING CONDENSER WATER TEMPERATURES)



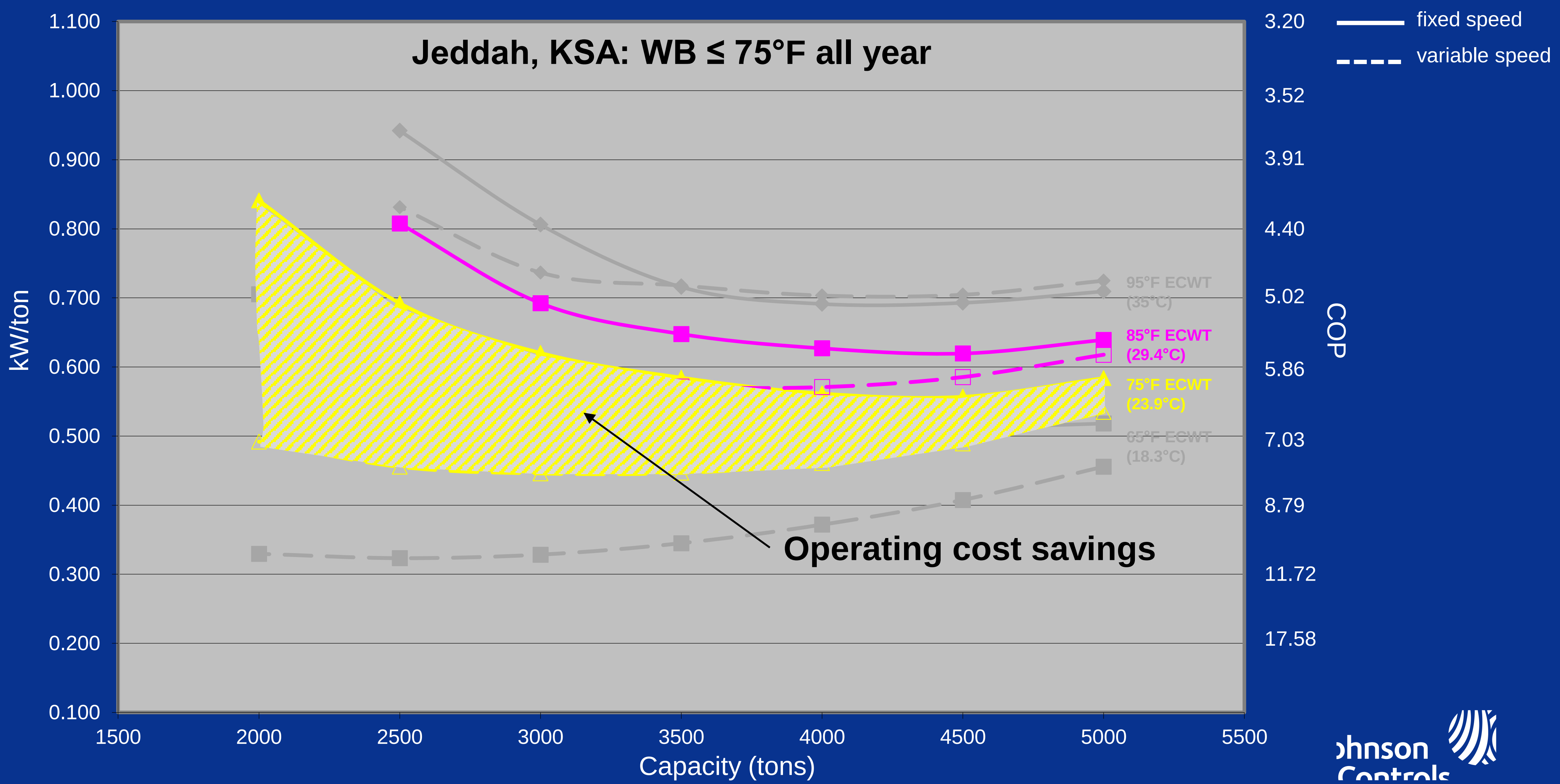
SHAMIYA PLANT YORK TITAN OM CHILLER PERFORMANCE

FIXED SPEED VS VARIABLE SPEED

VARYING ECWT (ENTERING CONDENSER WATER TEMPERATURES)



SHAMIYA PLANT YORK TITAN OM CHILLER PERFORMANCE
FIXED SPEED VS VARIABLE SPEED
VARYING ECWT (ENTERING CONDENSER WATER TEMPERATURES)



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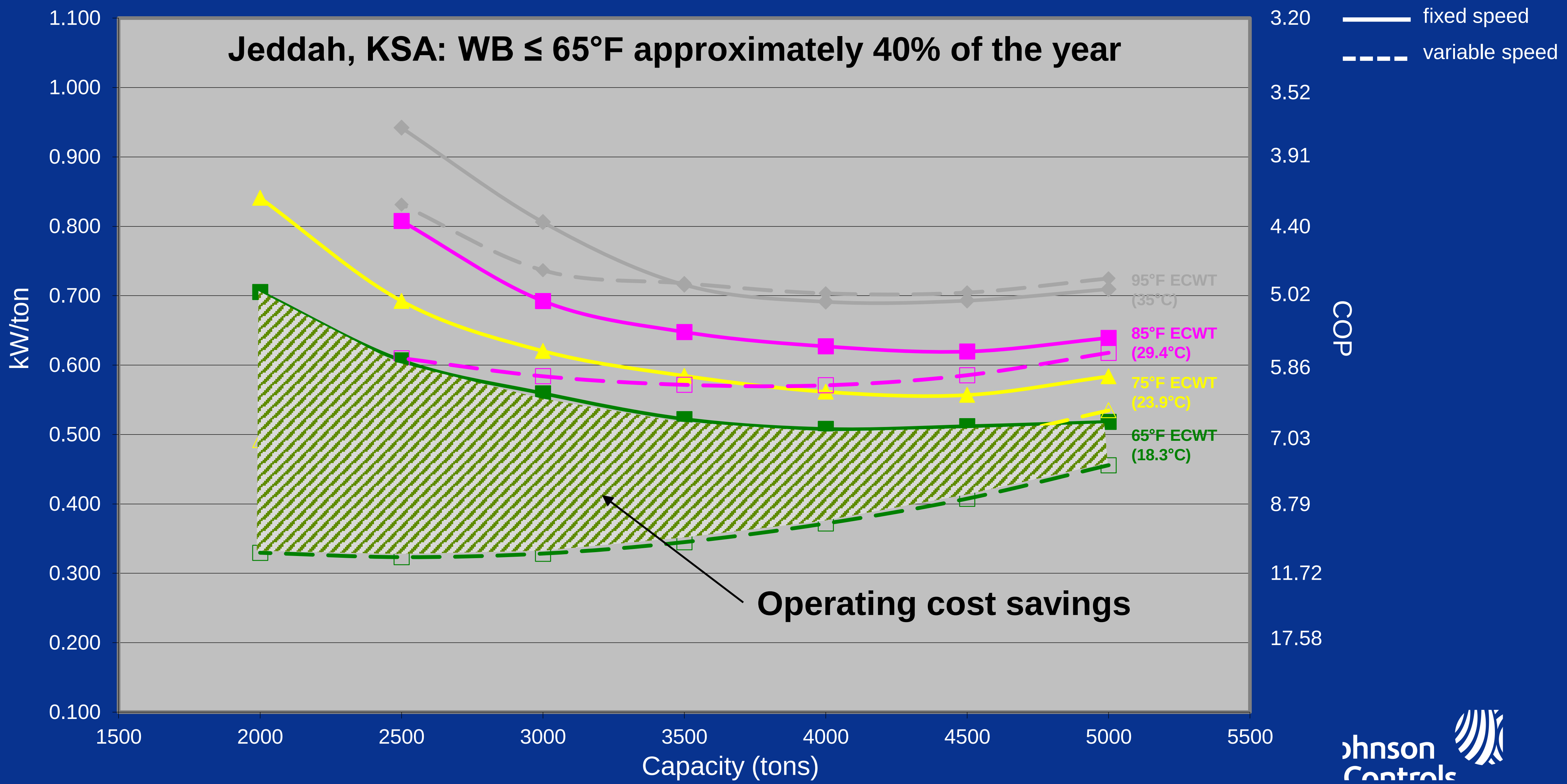
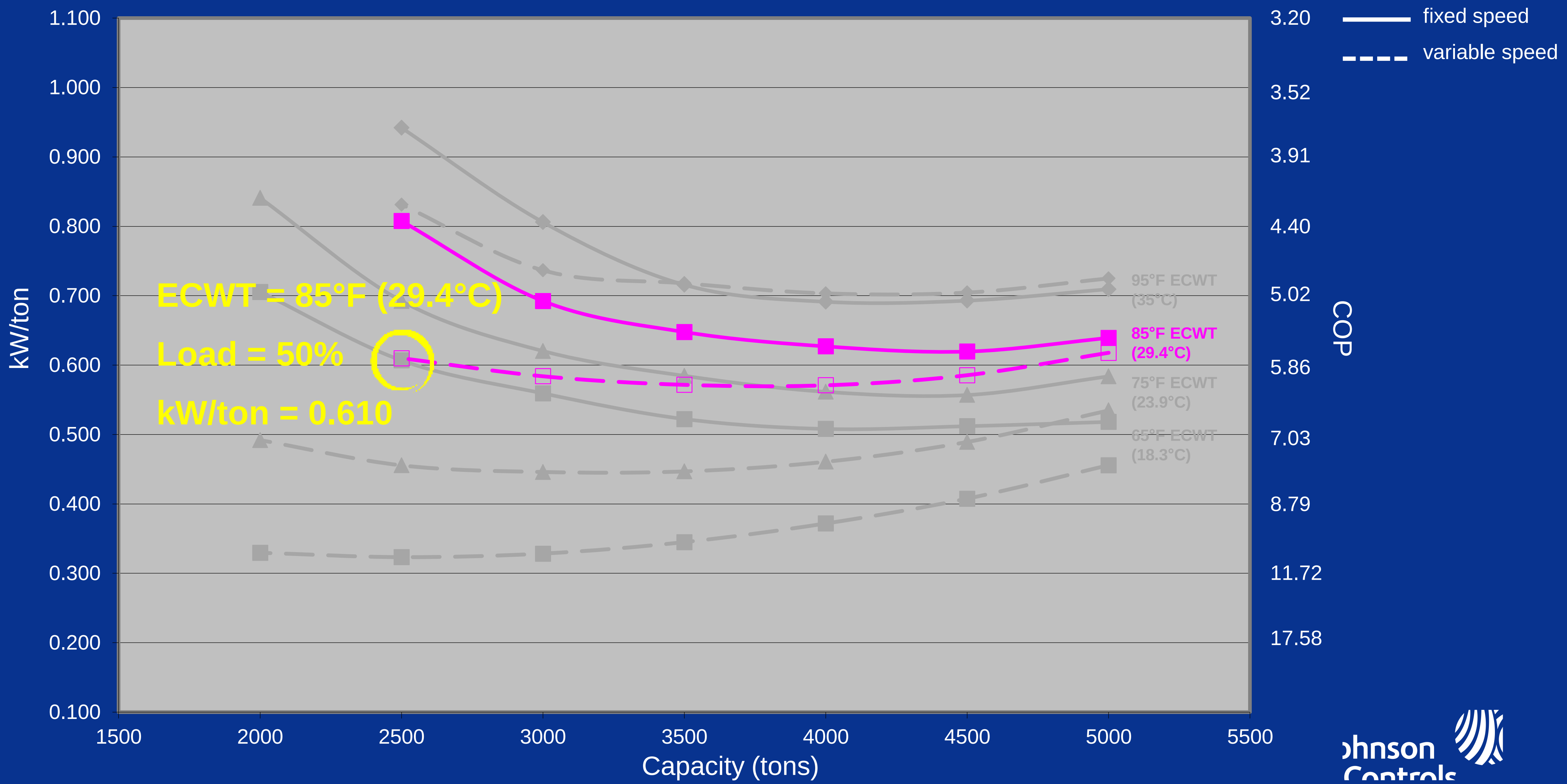
SHAMIYA PLANT YORK TITAN OM CHILLER PERFORMANCE
FIXED SPEED VS VARIABLE SPEED
VARYING ECWT (ENTERING CONDENSER WATER TEMPERATURES)



Johnson Controls

SHAMIYA PLANT YORK TITAN OM CHILLER PERFORMANCE
FIXED SPEED VS VARIABLE SPEED
VARYING ECWT (ENTERING CONDENSER WATER TEMPERATURES)



SHAMIYA PLANT YORK TITAN OM CHILLER PERFORMANCE VARIABLE SPEED REAL WORLD OPERATION

ECWT = 81°F (27.4°C)

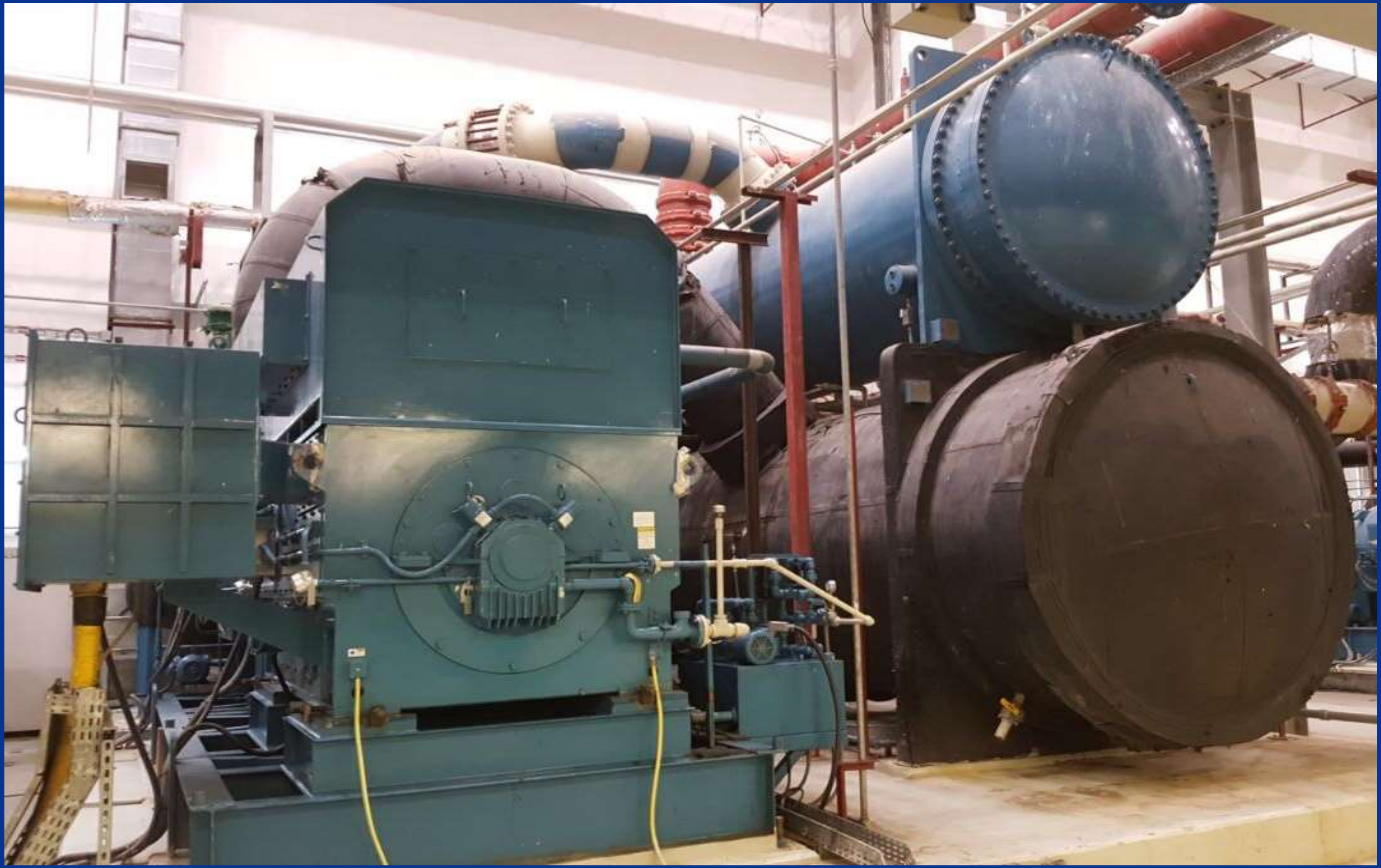
0.571 kW/ton

2472.3 tons

48.6% load

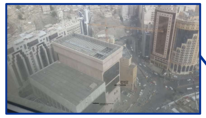
Johnson Controls

AJIAD PLANT EXPANSION YORK TITAN OM CHILLERS
3 CHILLERS – 5,000 TON EACH – WATER-COOLED (RADIATORS)



- 4160V / 3ph / 60Hz, 9000 HP motor.
- 13.8 KV Variable Speed Drives.
- Compressor castings with high design working pressure.
- Condenser design working pressure >300 PSIG for potential future refrigerant change
- Allen Bradley PLC control panel.
- Vibration monitoring system for entire driveline

Ajiad Plant YORK Titan OM Chillers



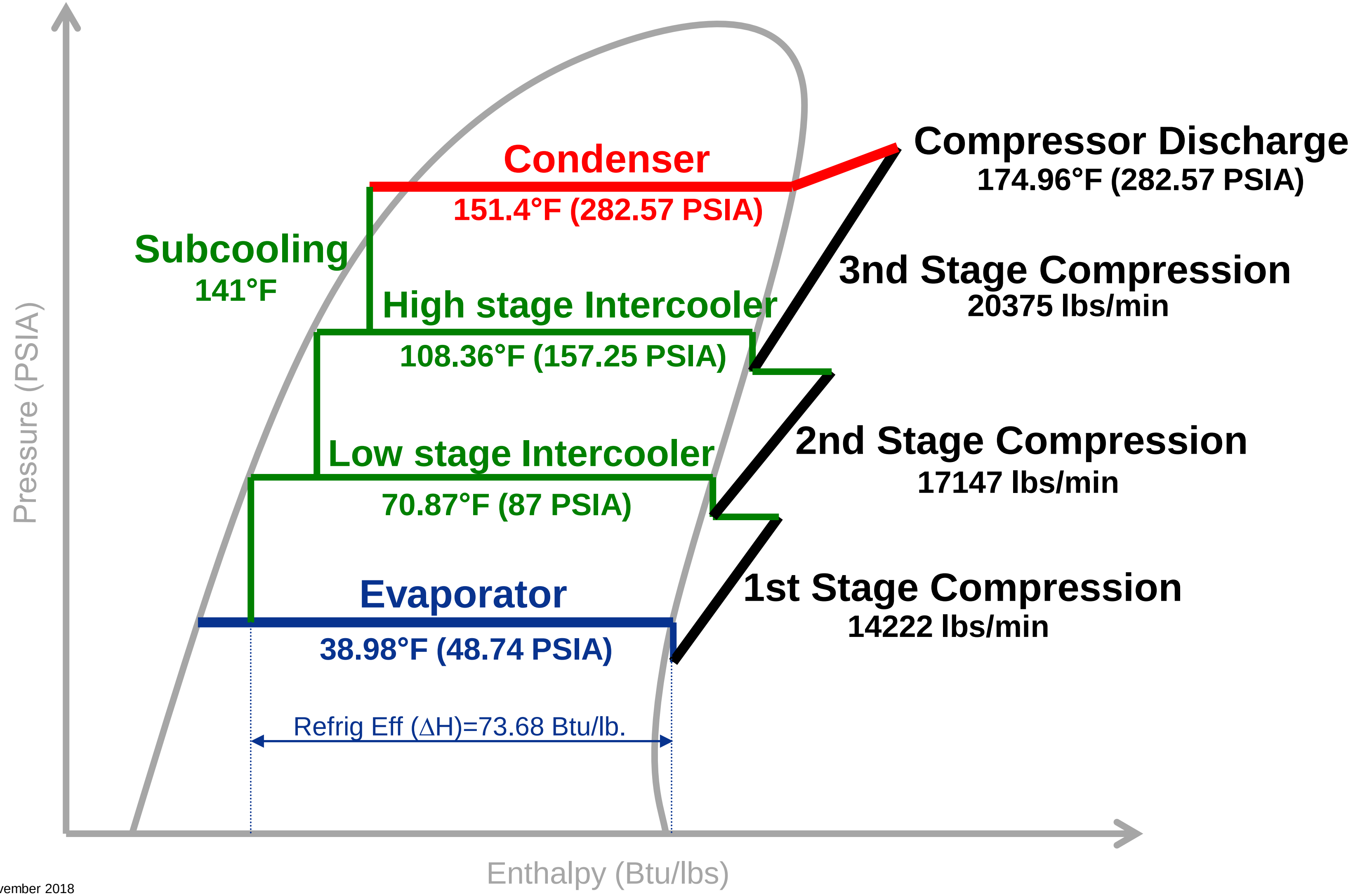
YORK OM multi-stage compressor driveline skid

13,800V Variable Speed Drive – 8,000 Hp

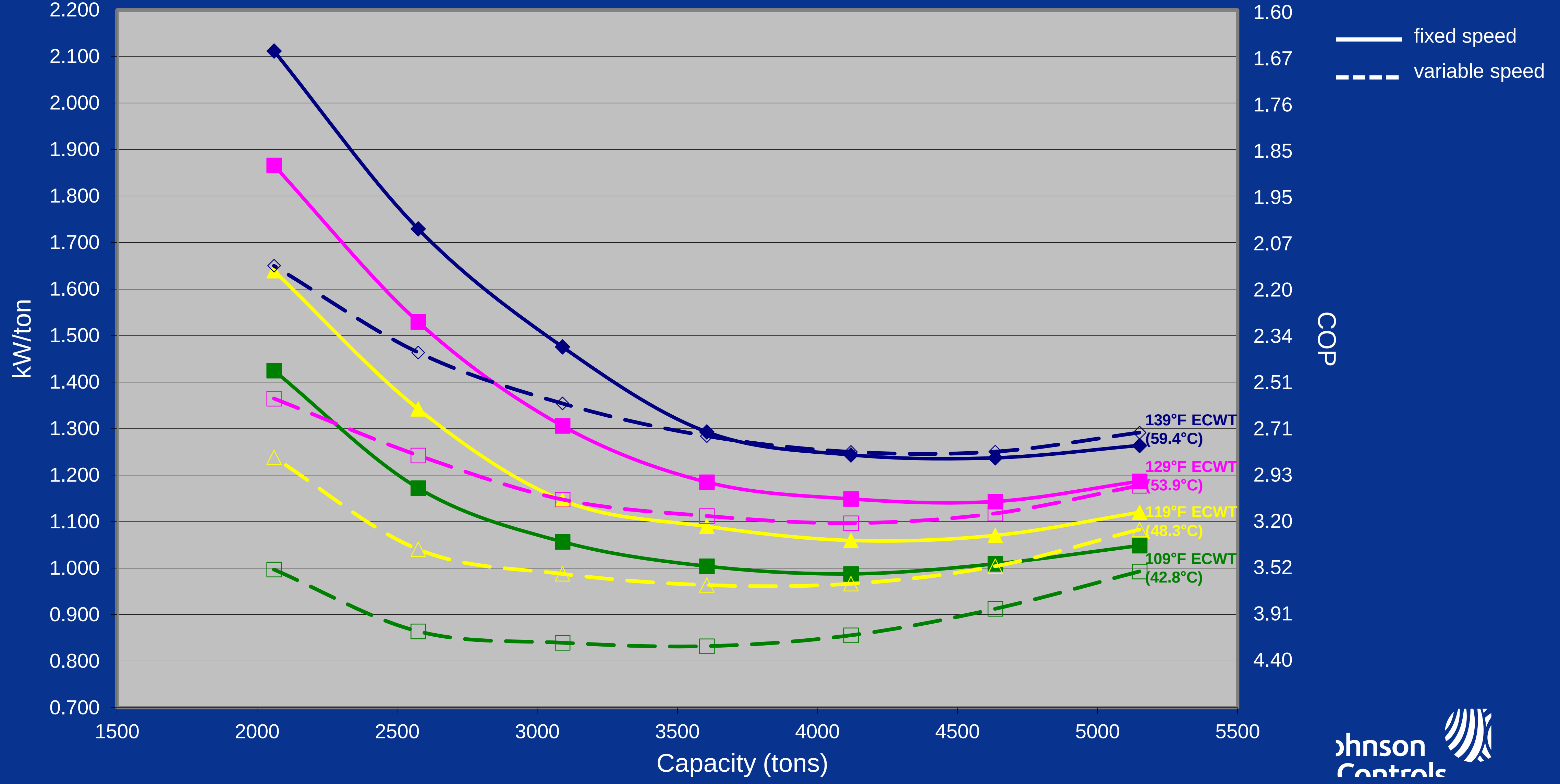
Air-Cooled Radiators

Ajiad Plant YORK Titan OM Chillers – Pressure/Enthalpy Diagram

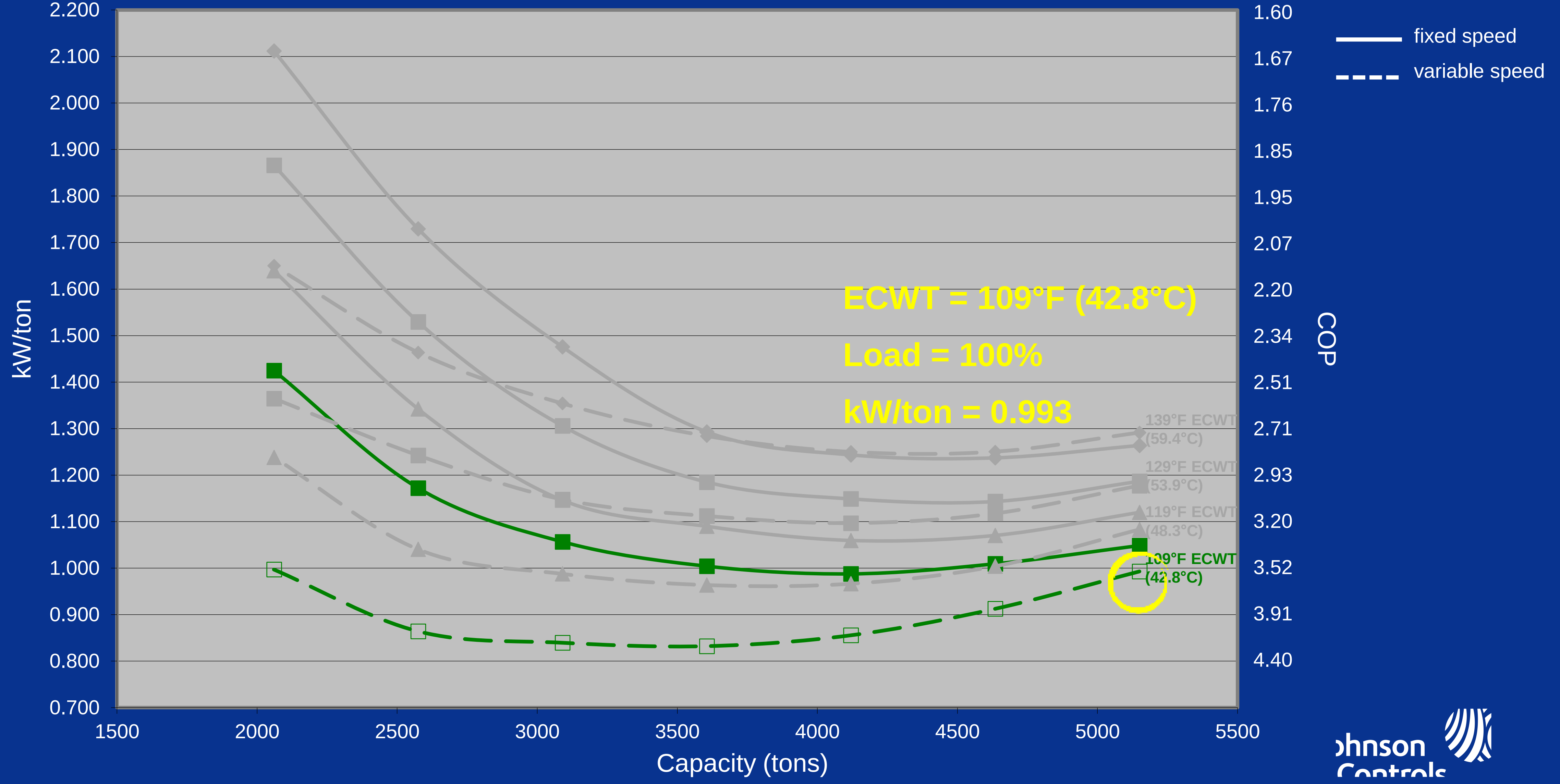
- Three-stage R-134a refrigerant diagram – two stages of Intercooling with subcooling



AJIAD PLANT YORK TITAN OM CHILLER PERFORMANCE
FIXED SPEED VS VARIABLE SPEED
VARYING ECWT (ENTERING CONDENSER WATER TEMPERATURES)



AJIAD PLANT YORK TITAN OM CHILLER PERFORMANCE
FIXED SPEED VS VARIABLE SPEED
VARYING ECWT (ENTERING CONDENSER WATER TEMPERATURES)

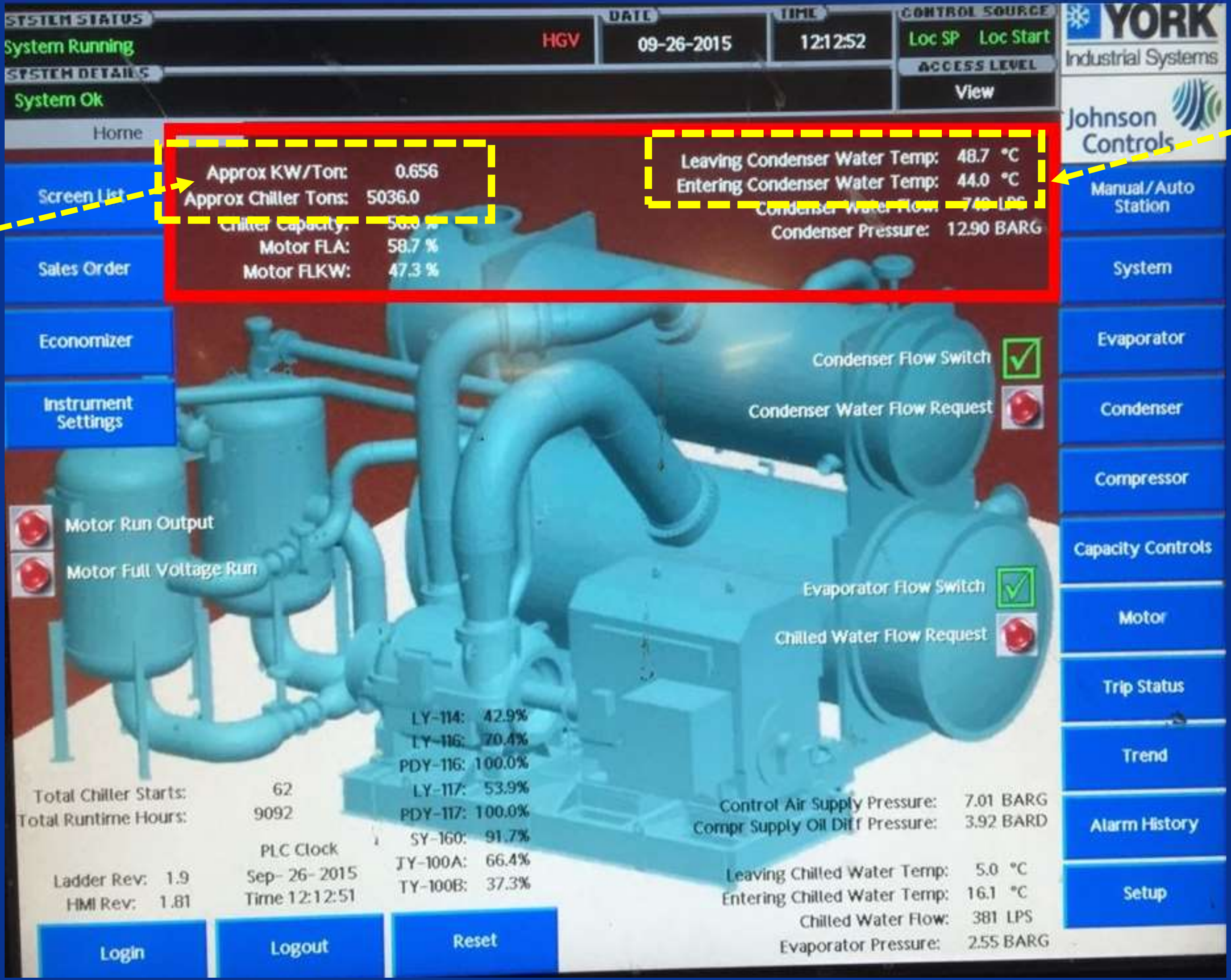


AJIAD PLANT YORK TITAN OM CHILLER PERFORMANCE
VARIABLE SPEED REAL WORLD OPERATION

0.656 kW/ton

5036 tons

97.8% load



ECWT = 111°F
(44.0°C)

QUESTIONS?

Amar Farjo
Lead Staff Engineer
Johnson Controls

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(717) 771-6224

APPENDIX

Weather Data – Dhahran, Saudi Arabia (coastal – similar to Jeddah)

YORK

Master Weather Data

Options Edit

Country: Saudi Arabia State/Province: n/a City: Dhahran

Temp						Temperature Bin-Hours			Chiller Plant Operation View				Avg.	Total
Bin(°F)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	WB(°F)	Hours
115.0=>119.9	0	0	0	0	0	1	2	2	0	0	0	0	74.0	5
110.0=>114.9	0	0	0	0	3	17	29	28	3	0	0	0	73.0	80
105.0=>109.9	0	0	0	1	16	72	100	91	33	2	0	0	73.0	315
100.0=>104.9	0	0	0	5	46	114	126	123	81	13	0	0	74.0	508
95.0=>99.9	0	0	1	20	94	115	126	109	112	54	0	0	73.0	631
90.0=>94.9	0	0	5	44	117	147	177	165	110	97	11	0	73.0	873
85.0=>89.9	0	1	19	88	152	148	151	174	165	116	52	1	72.0	1067
80.0=>84.9	1	5	44	126	180	87	31	51	160	160	99	6	70.0	950
75.0=>79.9	12	28	96	164	103	18	1	2	51	179	149	48	67.0	851
70.0=>74.9	59	74	160	163	28	2	0	0	4	97	177	122	63.0	886
65.0=>69.9	138	147	194	81	3	0	0	0	0	23	138	169	60.0	893
60.0=>64.9	197	184	149	24	0	0	0	0	0	3	72	193	57.0	822
55.0=>59.9	185	142	59	5	0	0	0	0	0	0	16	140	53.0	547
50.0=>54.9	105	66	15	1	0	0	0	0	0	0	3	51	48.0	241
45.0=>49.9	36	23	2	0	0	0	0	0	0	0	0	10	42.0	71
40.0=>44.9	7	3	0	0	0	0	0	0	0	0	0	2	37.0	12
35.0=>39.9	1	1	0	0	0	0	0	0	0	0	0	0	32.0	2
30.0=>34.9	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
25.0=>29.9	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
20.0=>24.9	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
Total	741	674	744	722	742	721	743	745	719	744	717	742		8754

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