

Navigating Unpredictable Construction Challenges – Denver International Airport's Chiller Replacement Project

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Agenda

- ▶ **Background**
- ▶ **Existing System**
- ▶ **Capital Project Approach**
- ▶ **Design/Construction Approach**
- ▶ **Unforeseen Challenges**
- ▶ **What did we learn**



Image Courtesy of Denver International Airport

Background

- ▶ Opened February 1995
- ▶ 5th Busiest Airport
 - 70 million travelers in 2019
- ▶ Largest US Airport by Land Area
 - 53 square miles
- ▶ Current Square Footage:
 - 7,720,000 square feet
- ▶ Future Square Footage
 - 8,969,000



Image Courtesy of Denver International Airport

Background

- ▶ Central Utility Plant
 - Chilled & Heating Water
 - Serves Seven “Buildings”
 - 40 feet Below Grade
- ▶ Concourse Expansions
 - 39 additional gates
 - 1.25 million square feet
- ▶ Plans for more expansions...



Image Courtesy of Denver International Airport

Existing System

► History

- Natural Gas driven chillers
- 3 x 4,150 ton R-22 Chillers
- 2 x 2,500 ton R-123 Chillers (2015, VFD)
- 2 x 1,200 ton Free Cooling HX
- 1 x 4,150 ton Free Cooling HX
- 8 x 2,708 ton Cooling Towers (VFD)
- Pumping
 - Primary
 - Building Secondary
 - Tertiary Boosters (removed)

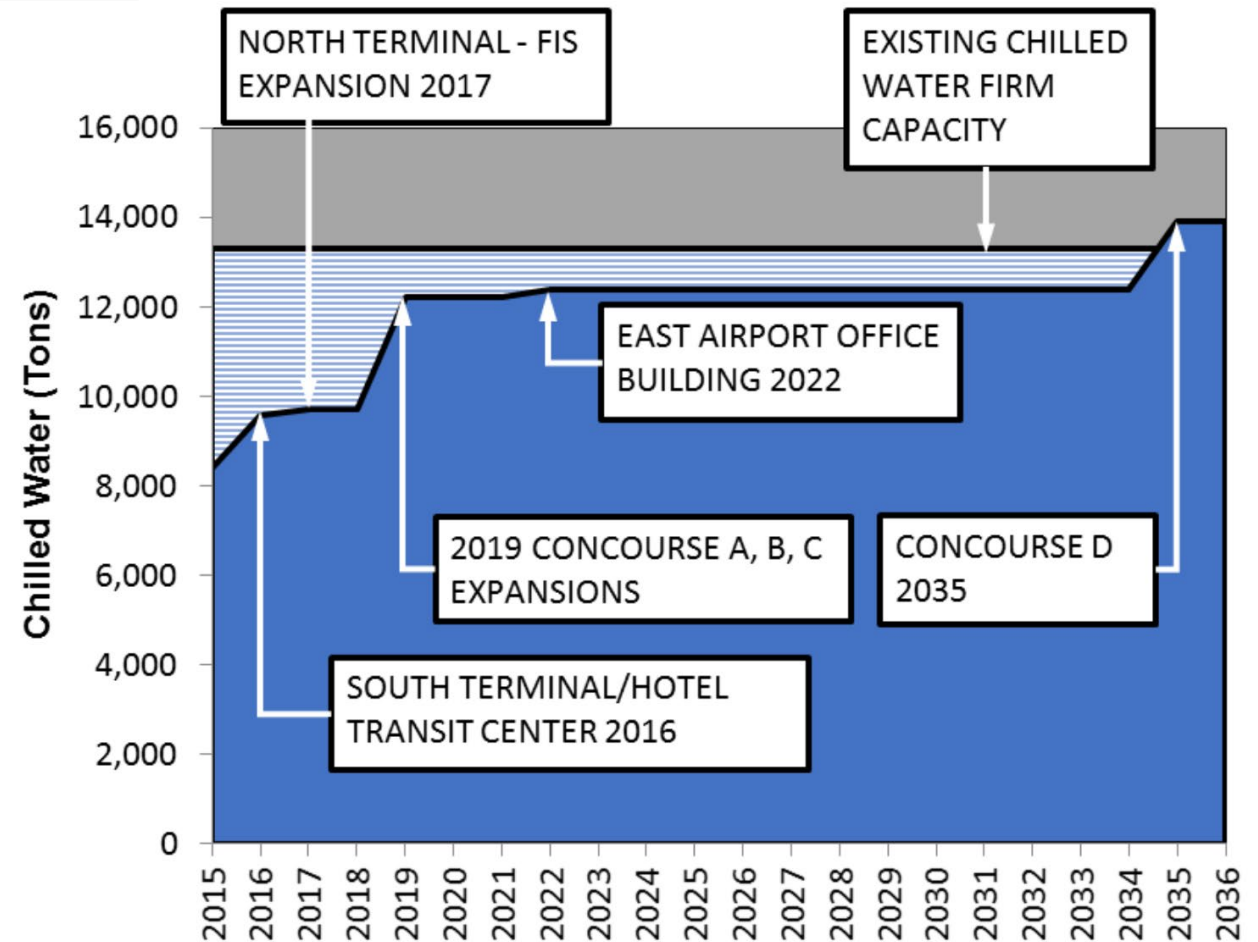


Image Courtesy of Denver International Airport

Capital Project Approach

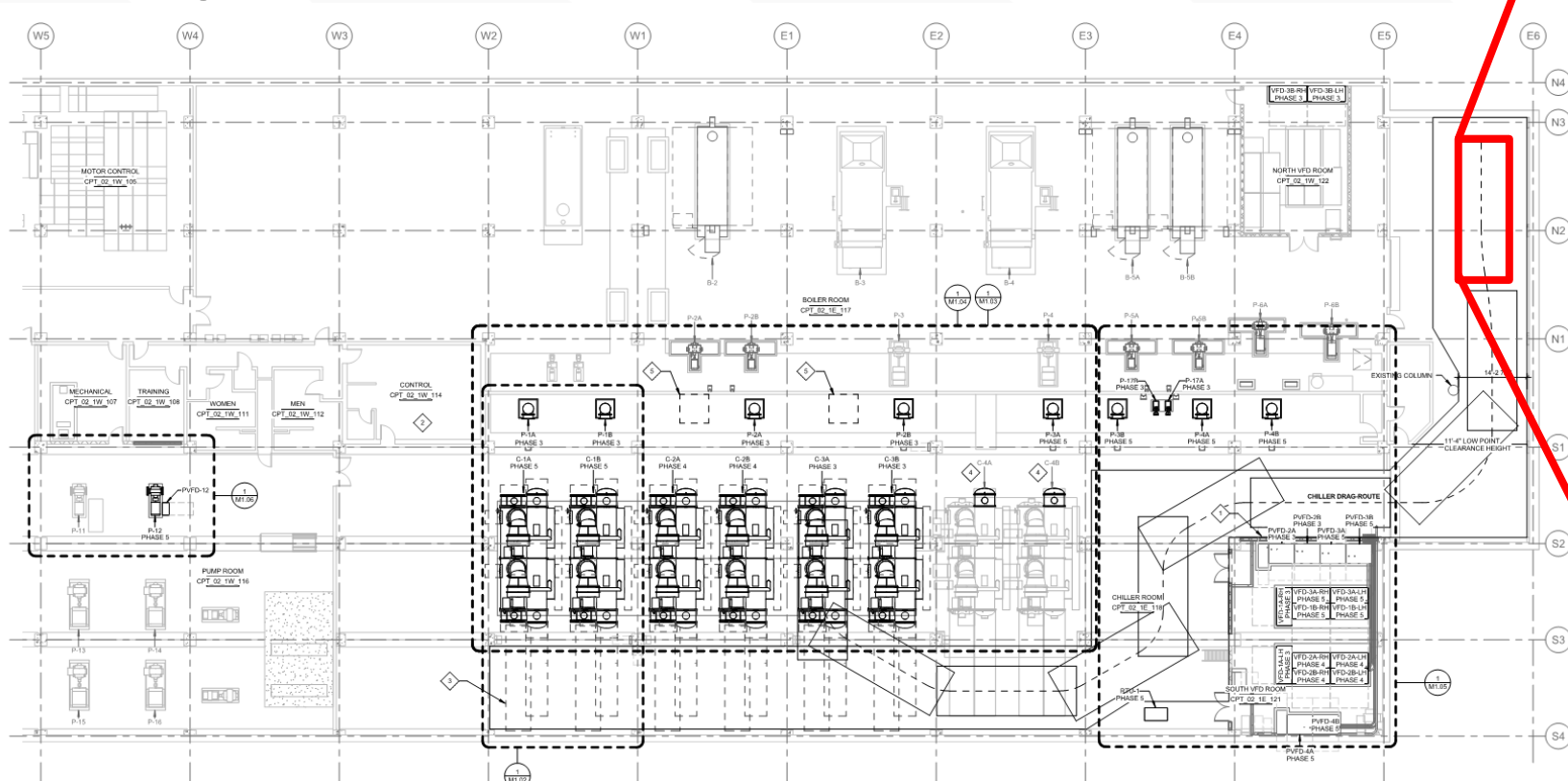
► Enabling Project

- R-22 Phase-out
- CW Pumping Issues
- CUP Capacity for Expansions
- Redundancy / Reliability for airport critical users



Design/Construction Approach

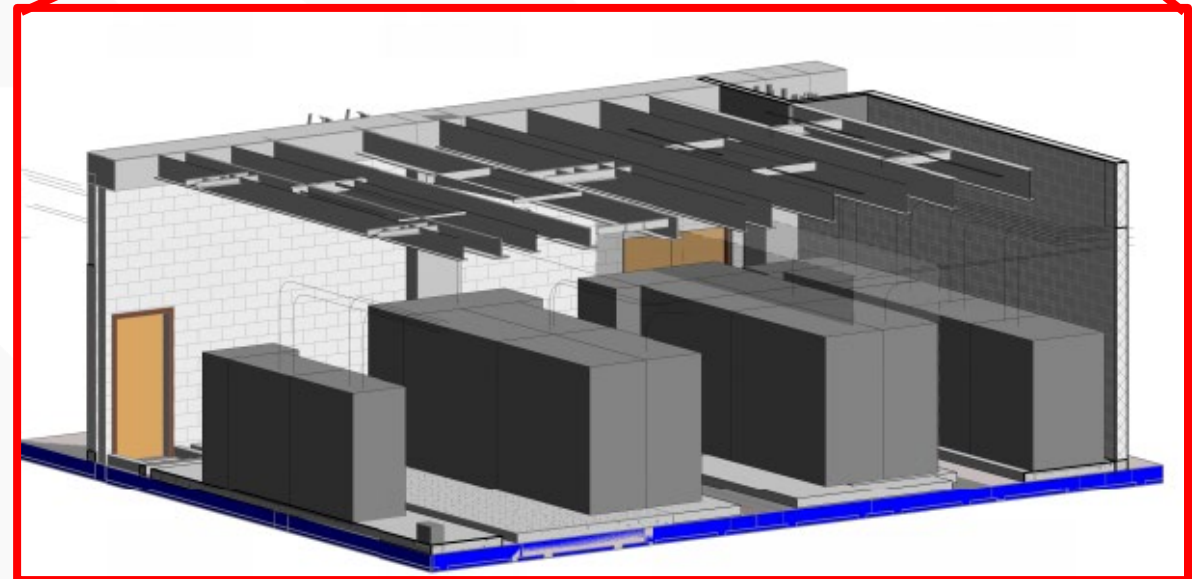
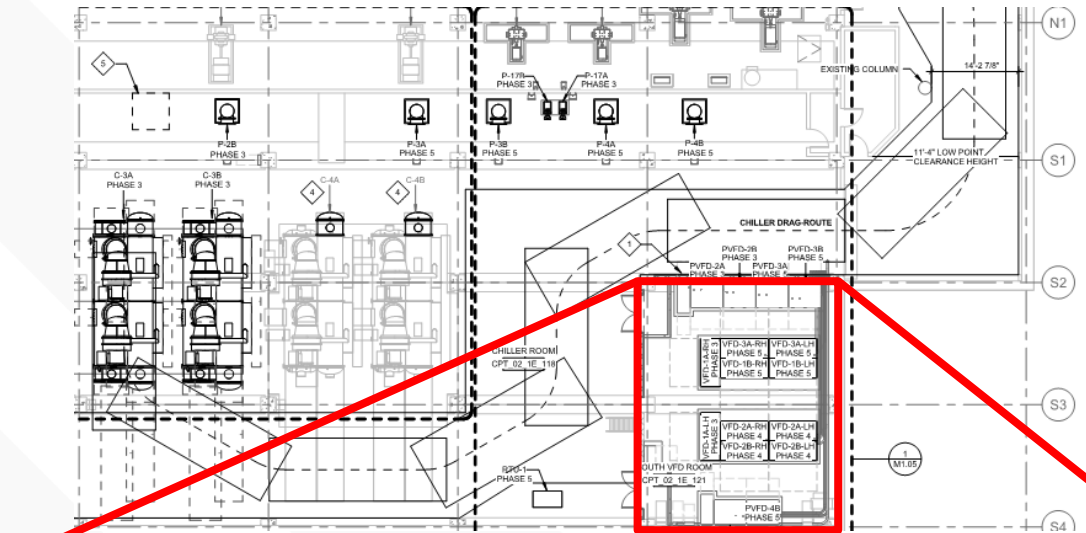
- ▶ 6 x 2,500 ton VFD Chillers - 20,000 tons Total
- ▶ Single set of CW pumps



Design/Construction Approach

- ▶ Electrical Service Relocation
- ▶ Electrical equipment re-alignment

NAE Controller	Chiller	Condenser Water Pump	Chilled Water Pump	Cooling Tower
West	CH-1A	P-1A	P-11	CT-2
	CH-2A	P-2A	P-13	CT-4
	CH-2B	P-2B	P-14	CT-5
	CH-4A	P-4A		CT-8
East	CH-1B	1B	P-12	CT-3
	CH-3A	3A	P-15	CT-6
	CH-3B	3B	P-16	CT-7
	CH-4B	4B		CT-9
Service A	Service B	Service C		
CH-1A	CH-4A	CH-2A		
CH-1B	CH-4B	CH-2B		
P-1A	P-4A	CH-3A		
P-1B	P-4B	CH-3B		
CT-2	CT-4	P-2A		
CT-3	CT-6	P-2B		
CT-5	CT-8	P-3A		
CT-7	P-11	P-3B		
CT-9	P-14			
P-13	P-15			
P-16	P-12 (Note 3)			



Construction Phasing

► Known Challenges

- Equipment Rigging/Pathway
- Phased Seasonal Construction
- Working in an operating CUP
- Critical Users
- Electrical/Controls Alignment
- Operating Dissimilar Chillers
- Controls Alignment



Table 1: Chilled Water Capacity During Phasing

Chiller	Phase 1		Phase 2		Phase 2A		Phase 3		Phase 4		Phase 5	
	10/9/17 – 10/13/17		10/16/17 – 11/03/17		1/1/18 – 3/2/18		3/5/18 – 7/13/18		7/16/18 – 10/26/18		10/29/18-3/08/19	
	During	Completed	During	Completed	During	Completed	During	Completed	During	Completed	During	Completed
Chiller 1	4,150	4,150	4,150	4,150	-	4,150	4,150	4,150	4,150	4,150	-	-
Chiller 2	4,150	-	-	-	-	-	-	-	-	-	-	-
Chiller 3	-	-	-	-	-	-	-	-	-	-	-	-
Chiller 4A	2,500	2,500	2,500	2,500	-	2,500	2,500	2,500	2,500	2,500	-	2,500
Chiller 4B	2,500	2,500	2,500	2,500	-	2,500	2,500	2,500	2,500	2,500	-	2,500
Chiller 1A	-	-	-	-	-	-	-	-	-	-	-	2,500
Chiller 1B	-	-	-	-	-	-	-	-	-	-	-	2,500
Chiller 2A	-	-	-	-	-	-	-	-	-	2,500	2,500	2,500
Chiller 2B	-	-	-	-	-	-	-	-	-	2,500	2,500	2,500
Chiller 3A	-	-	-	-	-	-	-	2,500	2,500	2,500	2,500	2,500
Chiller 3B	-	-	-	-	-	-	-	2,500	2,500	2,500	2,500	2,500
Total Capacity	13,300	9,150	9,150	9,150	4,150*	9,150	9,150	14,150	14,150	19,150	10,000	20,000
Firm Capacity (N+1)	9,150	5,000	5,000	5,000	0*	5,000	5,000	10,000	10,000	15,000	7,500	17,500

* Note: This assumes that EX-1 and EX-2 are not operational.

Unforeseen Challenges

- ▶ *“Plans are nothing; Planning is Everything”* – Dwight Eisenhower
- ▶ Construction Start Date Delayed ~1 year
 - Funding
 - Not the same contractors that interviewed
 - Required new phasing plan

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	10/9/17 – 10/13/17		10/16/17 – 11/03/17		1/1/18 – 3/2/18		3/5/18 – 7/13/18		7/16/18 – 10/26/18		11/29/18-3/08/19	
	During	Completed	During	Completed	During	Completed	During	Completed	During	Completed	During	Completed
Chiller 1	4,150	4,150	4,150	4,150	-	4,150	4,150	4,150	4,150	4,150	-	-
Chiller 2	4,150	-	-	-	-	-	-	-	-	-	-	-
Chiller 3	-	-	-	-	-	-	-	-	-	-	-	-
Chiller 4A	2,500	2,500	2,500	2,500	-	2,500	2,500	2,500	2,500	2,500	-	2,500
Chiller 4B	2,500	2,500	2,500	2,500	-	2,500	2,500	2,500	2,500	2,500	-	2,500
Chiller 1A	-	-	-	-	-	-	-	-	-	-	-	2,500
Chiller 1B	-	-	-	-	-	-	-	-	-	-	-	2,500
Chiller 2A	-	-	-	-	-	-	-	-	-	2,500	2,500	2,500
Chiller 2B	-	-	-	-	-	-	-	-	-	2,500	2,500	2,500
Chiller 3A	-	-	-	-	-	-	-	2,500	2,500	2,500	2,500	2,500
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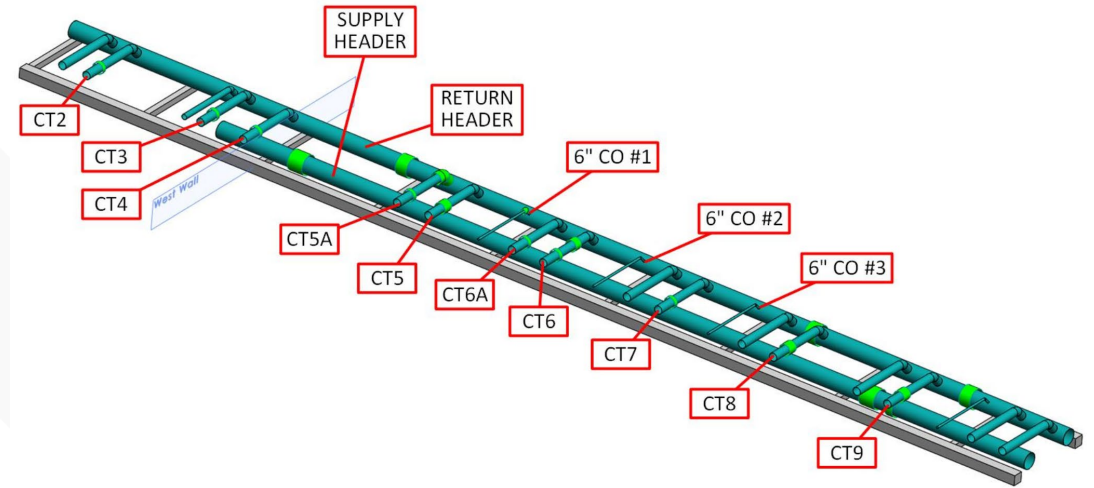
Unforeseen Challenges

► CW Pipe Degradation

- Started construction and encountered issues
 - Project delays
- Wall thickness testing done
- Prior knowledge but didn't get communicated
- Non-Destructive Testing Required
- Future project established

► Analysis for weld testing, hydro, and flushing

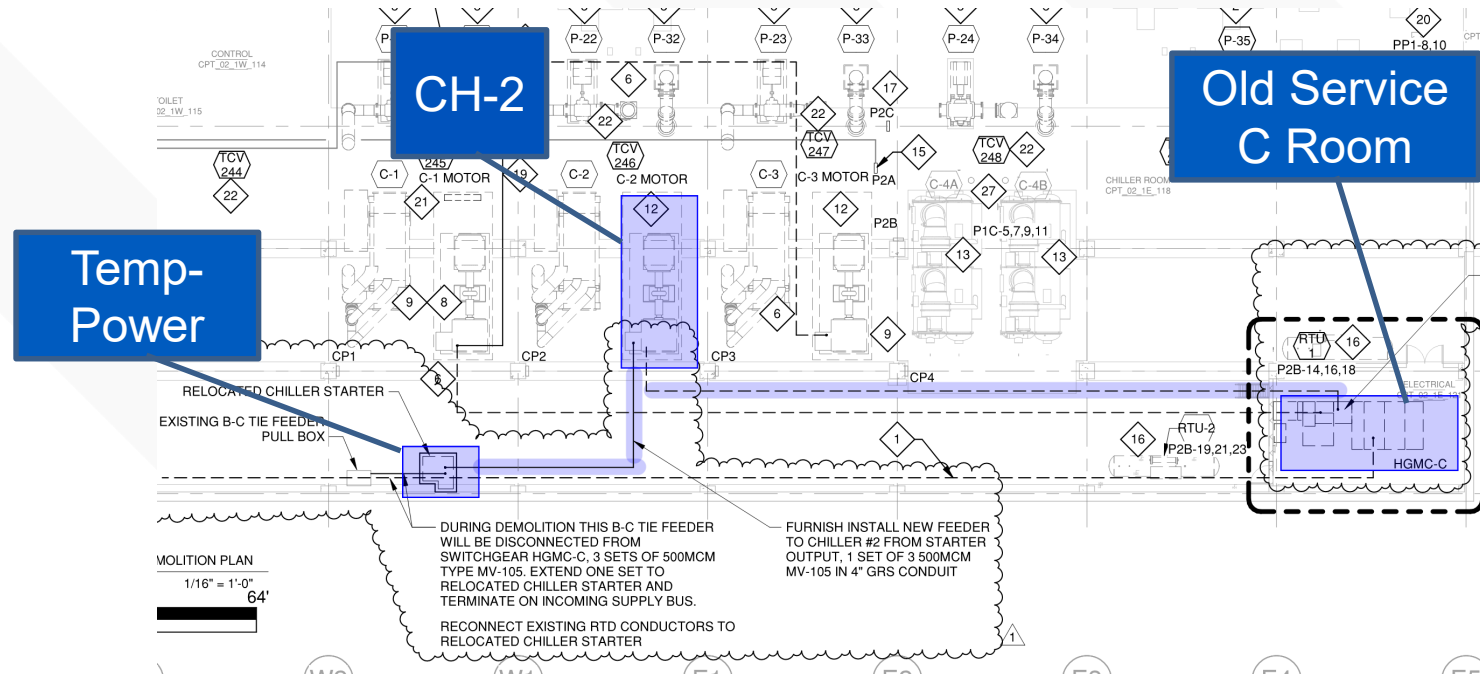
- Demo more pipe than anticipated
- Pressures
- Flows
- Operational Phasing



Unforeseen Challenges

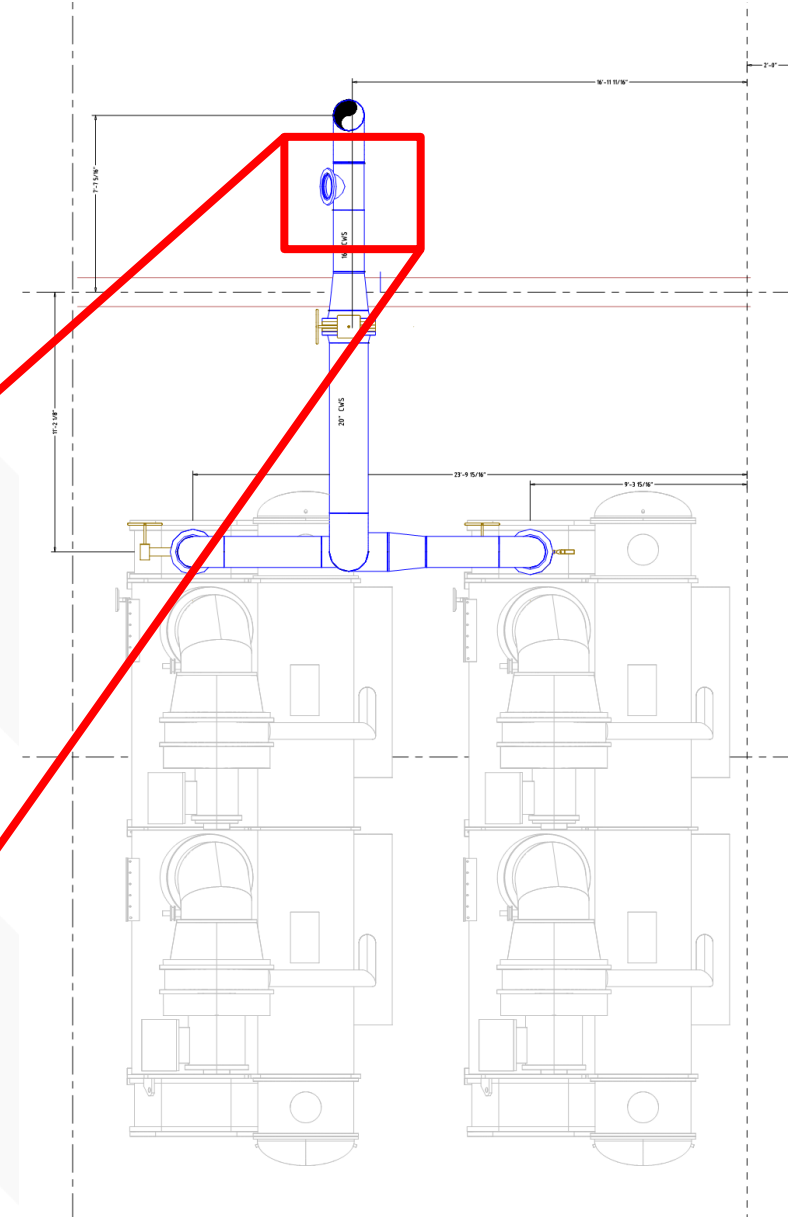
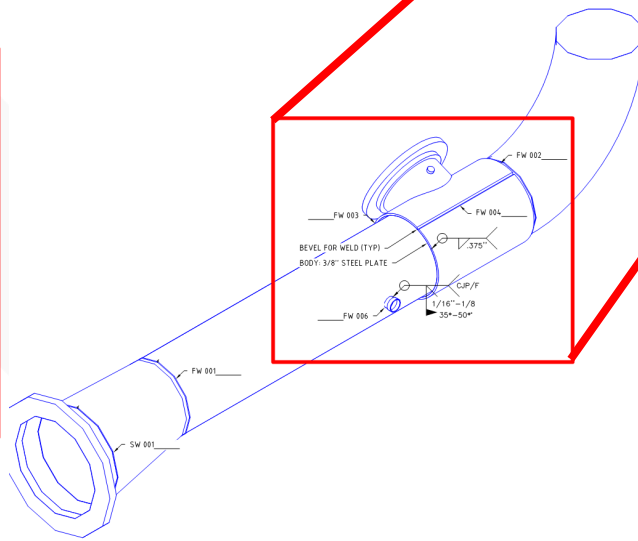
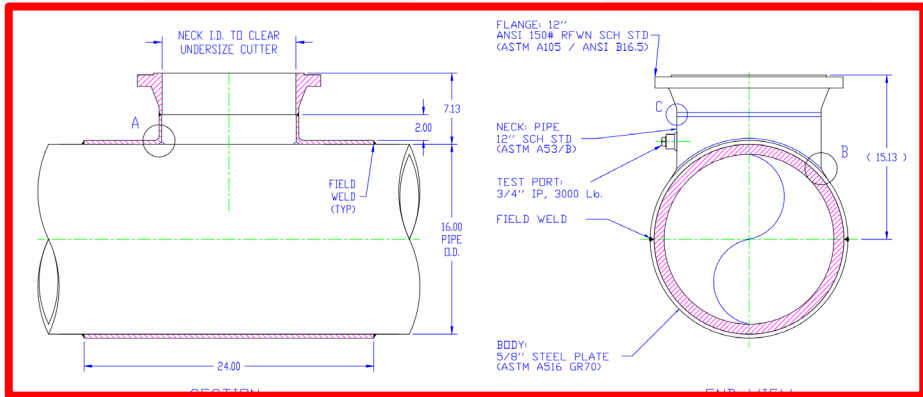
► Capacity Contingency

- Demand CHW Peak Load higher than projected
- Moving Service C required 2x chillers to be offline
- N+1 Machine not reliable
- Contingency budget used to refeed CH-2 which was scheduled for demo



Unforeseen Challenges

- Existing CHW iso-valves smaller than documented
 - Valves are off main system supply header
 - Temporarily support critical users?
 - *To tap or not to tap...*



Unforeseen Challenges

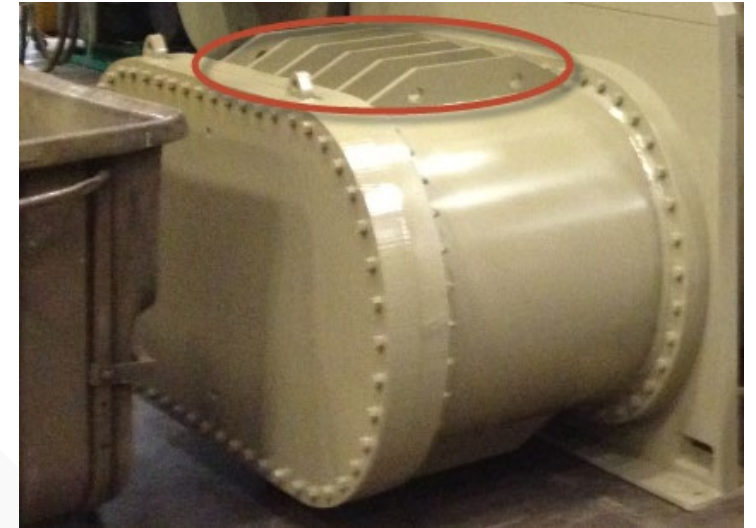
► Equipment Connections

- Custom Chiller Connections Required (Water Boxes)

► AHJ

- Code changes - City of DEN Code Amendments
- Refrigerant leak detection to be integrated with Fire Alarm

2. The replacement of the chillers (R-123) requires the refrigerant leak detection to be modified. This is a significant upgrade that will require a new refrigerant leak detection system that complies with section 606.8 in the 2016 DFC Amendments. The COMMCON and BOILERAC permits both state that a deferred submittal is required for the refrigerant leak detection system. **Section 1105.3 in the 2015 IMC states that refrigerant detectors shall be provided as required by section 606.8 in the IFC. Section 606.8 in the 2015 IFC has been amended per the 2016 DFC amendments. A refrigeration detection system is an emergency alarm system per section 908.6 and shall be designed and installed per section 908.8 in the 2016 DFC amendments. Provide complete shop drawings for the proposed refrigerant leak detection system including the following information in SECTION N103.11 IN THE 2016 DFC AMENDMENTS TO THE 2015 IFC.**



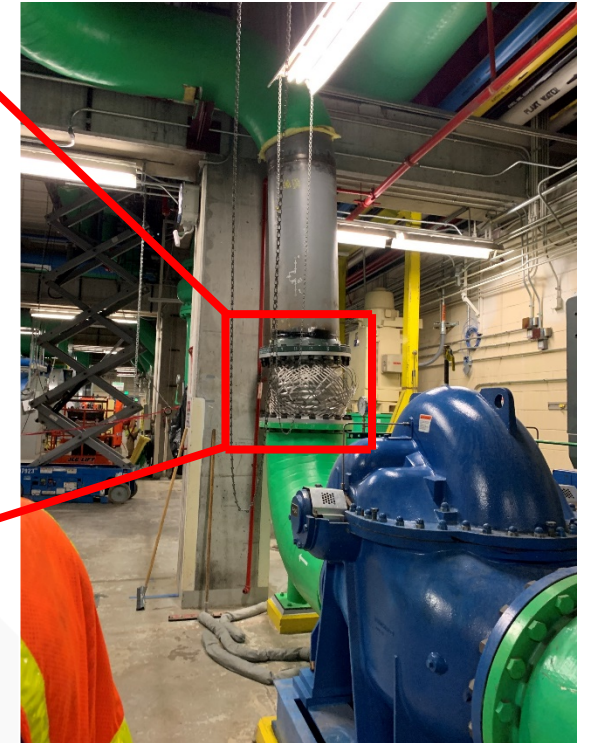
Unforeseen Challenges

- ▶ *Lots of cooks in the kitchen...*
- ▶ Pressure Event(s)
 - Event #1
 - New Construction Phasing
 - Series Pumping
 - Event #2
 - Controls snafu, CW pump left in hand
 - 72-hour test procedure re-written

Event #1



Event #2



Images Courtesy of Denver International Airport

LESSONS LEARNED

- ▶ Approach
 - Flexible and ready to react
 - Contingencies
 - Proactively engage AHJ
- ▶ Maintenance
 - Investing in O&M saves money long term
 - Required for sustainable and reliable system
- ▶ Teaming
 - Quality / Selection process is critical
 - Partnering / Peak Performance
- ▶ Vision and Communication
 - Engineering
 - Operations
 - Maintenance
 - A/E Partners



New Chillers 3A and 3B Install Completed Oct 2019
Image Courtesy of Denver International Airport

Questions?

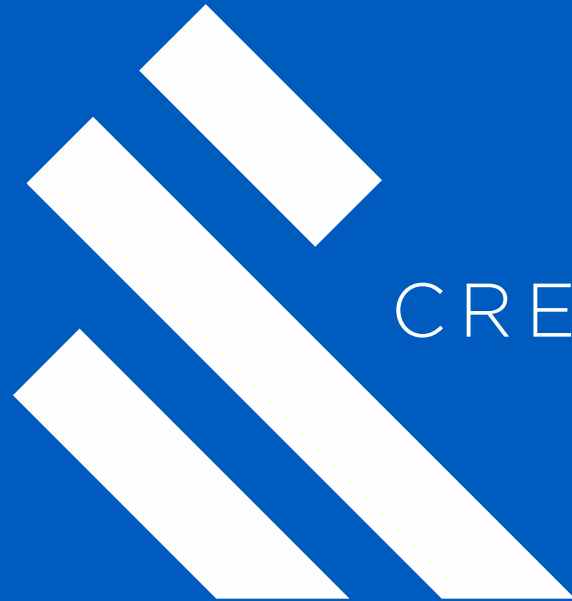
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