Installation of Direct Drive Prototype Drive Units Dry Fork Station

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BASIN ELECTRIC POWER COOPERATIVE
A Touchstone Energy® Cooperative

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Direct Drive Motor Technology

- Introduced to the cooling tower market in 2008; 9 years experience
- In excess of 675 total units installed across all industries
- 100 utility size FL5800 frame Direct Drive cooling tower motors in shaft up configuration are in operation today.
- Introduced ACC design in 2013

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ACC Design Background

- Introduced Direct Drive design concept and solicited feedback at ACC Users Group in Gillette in 2012.
- Site visit to NV Energy and Dave Rettke at Higgins.
- At the 2014 Users Group meeting, reviewed the Dry Fork prototype installation, identified installation challenges and the motor final design. At the time of the meeting, the first unit had not been installed.
- At this meeting we will do a recap of the motor design and review the installation pictures.

ACC Industry Issues

"What we hear from Users"

- Need to improve reliability
  - 10 hrs to 2 - 3 days to months to change out failed units
- What separates each installation is the size of the ACC (elevation), geographic location (wind, ambient)
- Gearbox issues
  - Leaking gearboxes (seals), shock loading, high ambient conditions, pinion gear failures, windmilling, shaft driven pump, need to operate at required min speeds, backstops
- Maintenance issues
  - Motor lubrication, cleaning of bundles, desiccant change out, oil changes
- Environmental issues
  - Oil disposal
- Efficiency
  - ACC is highest parasitic load in plant; ability to reduce parasitic load will improve system efficiency and heat rate
- Frequency of inspections based on all of the above
- Noise concerns
- Less people to properly take care of equipment today

Design Considerations for ACC Direct Drive Motor Application

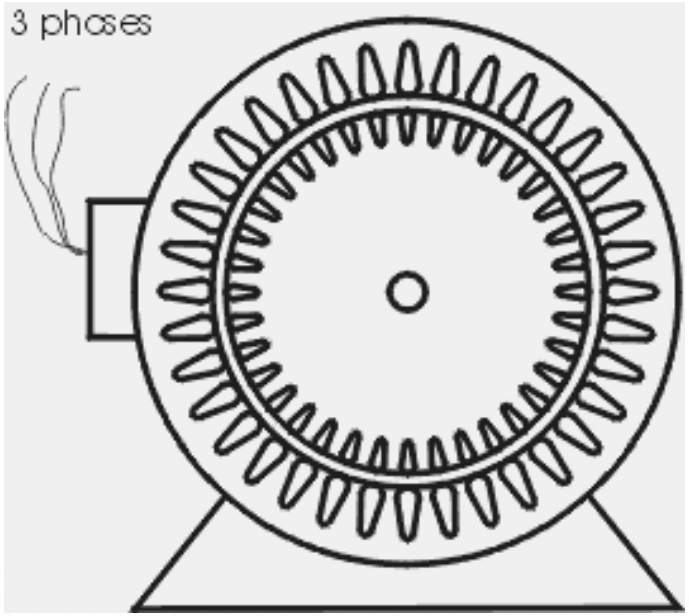
- More horsepower and slower speeds (more torque)
- Operating environment does not require totally enclosed motor
  - Known air flow for cooling
  - No “rain forest” effect
- Long drive shaft; varies by installation
- Ambient in structure is higher than at ground level
- Need to minimize weight; weight creates additional challenges
- Low noise preferred because of elevated structure and proximity to population centers
- Higher system efficiency will help reduce parasitic load and make the ACC a more attractive solution to the power market.
- Robust mechanical design to address wind issues

Plant Site Specifics

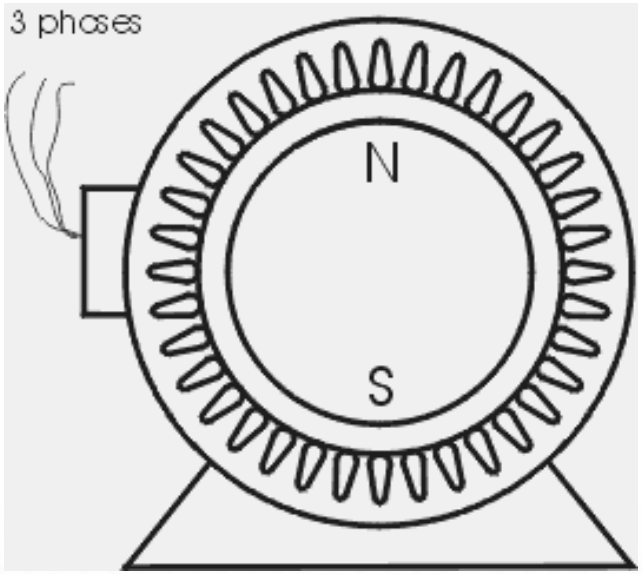
- Dry Fork Station is a coal fired plant that came on line in November, 2011. 45 cell ACC. 422 MW design capacity (385 MW net) coal fired.
- DF identified it's challenges in 2012: These include:
  - Requiring 15-20% more air than can be provided with existing motors during peak season. Currently pitched to max amps.
  - On occasion, do see wind gusts to 80 mph.
  - Large percentage of the gearboxes are leaking
- Rating is 250 HP at 104 rpm
  - Wanted a design that utilized a carrier bearing. Wyodak provided input that said they believed it helped. Xcel Comanche 3 provided similar feedback from other ACCUG meetings.

How do PM motors differ from Induction Motors?

Same:	stator, rotor diameter, 3 phase power
Different:	Induction has slip, PM is synchronous
	PM has no rotor losses, therefore – more efficient
	Induction is line start, PM requires drive or other means to start



Induction – squirrel cage motor

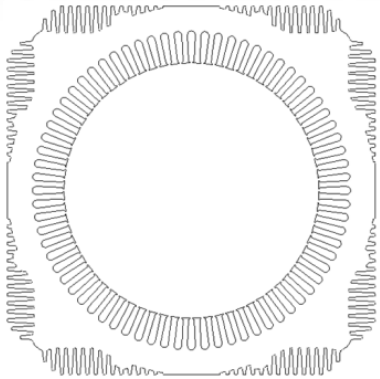


PM – salient pole

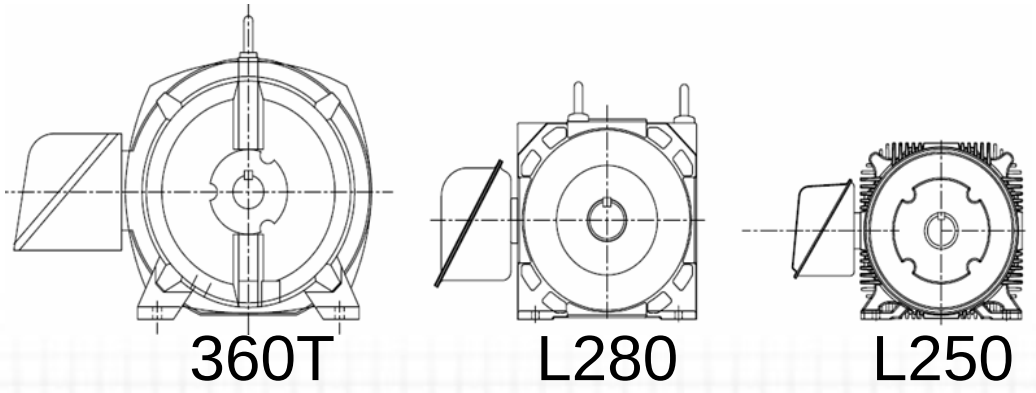
PM Motor Technology

- **Motor power density and increased efficiency**

Interior PM design



Saliency: the ability to control rotor position without a feedback device



75 HP, 1800 RPM

360T	9.00”
L280	7.00”
L250	6.25”

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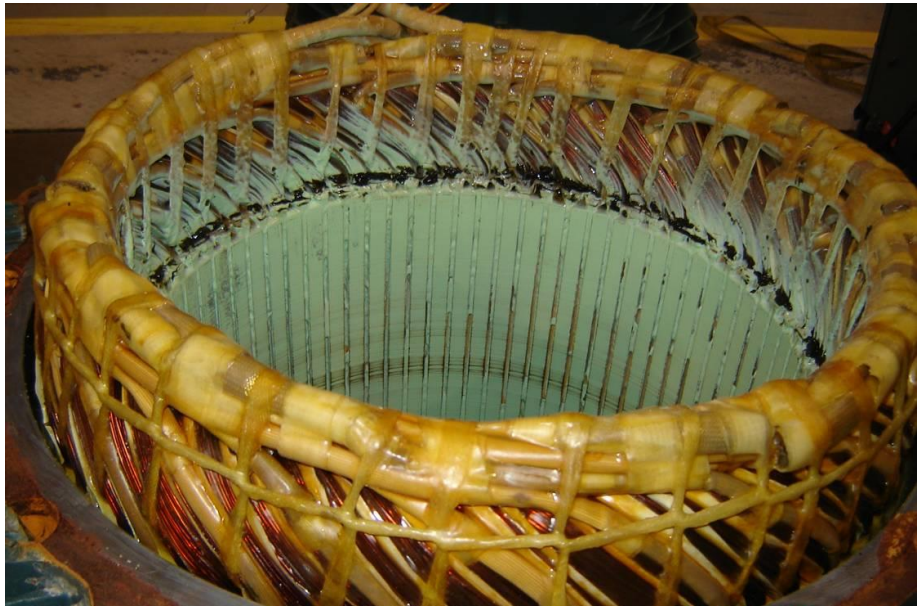
Class H VPI system



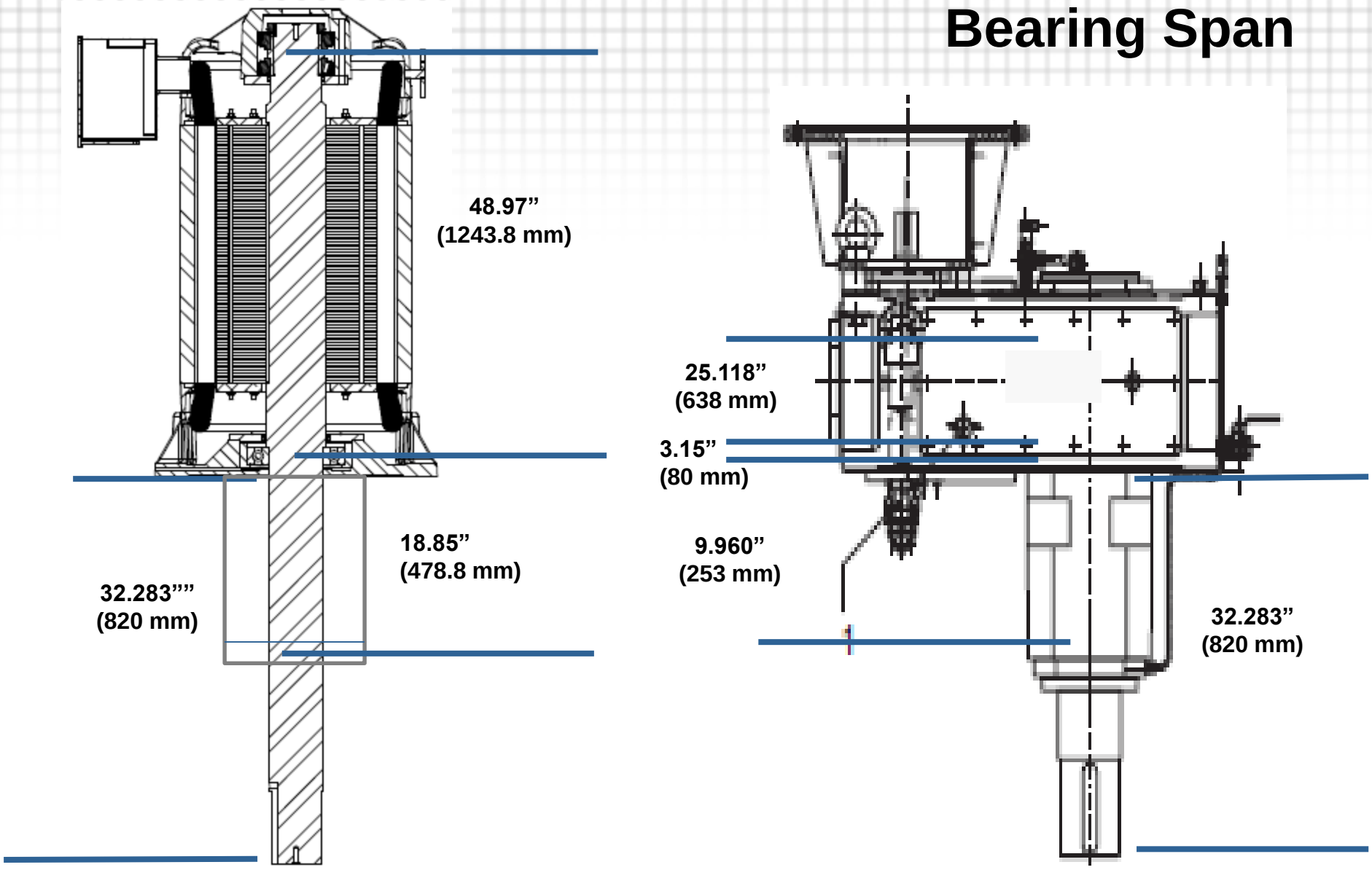
Green paint is epoxy coating for additional protection against moisture

Dry Fork ACC Direct Drive Motor

- **12,625 lb-ft of torque (250 HP @ 104 rpm)**
- **FL5832 frame**
- **Vertical shaft down**
- **Large output shaft (6.875” diameter and 42” long)**
- **Open blower design for cool operation**
  - DPG-FV (drip proof guarded force ventilated)
- **Low noise (84 dba sound pressure @ 1 meter)**
- **Carrier bearing for additional protection against side loading**
- **40 to 60 degree C ambient options**
- **Designed for use with the ABB ACS880 Cooling Tower drive**
- **Insulated bearing**
- **Class II shaft**
- **7800 lbs.**

The ACC Direct Drive Motor takes advantage of the environment to provide the most cost effective power dense solution available.

Bearing Span



Typical ACC design; not specific to Dry Fork

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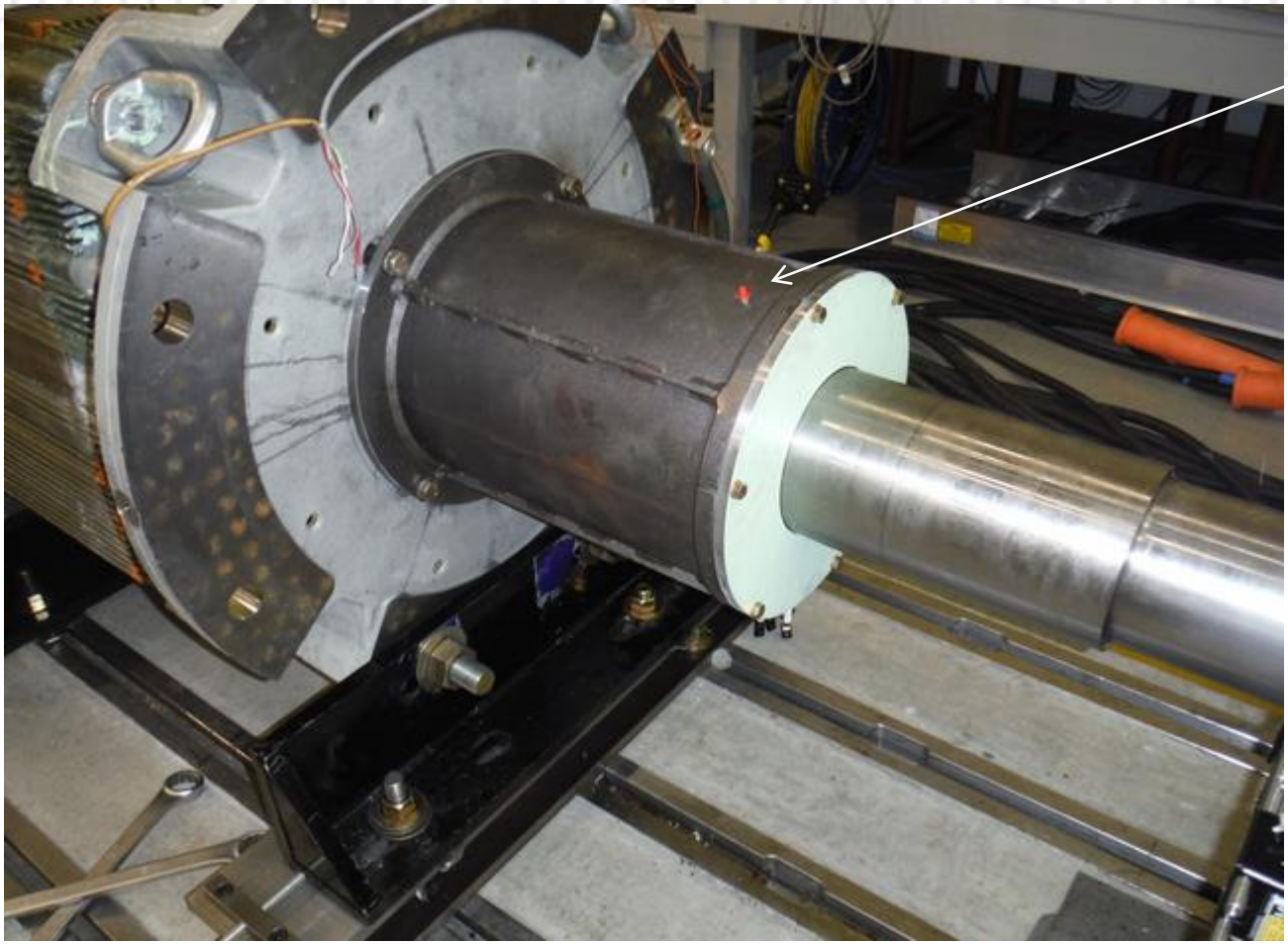
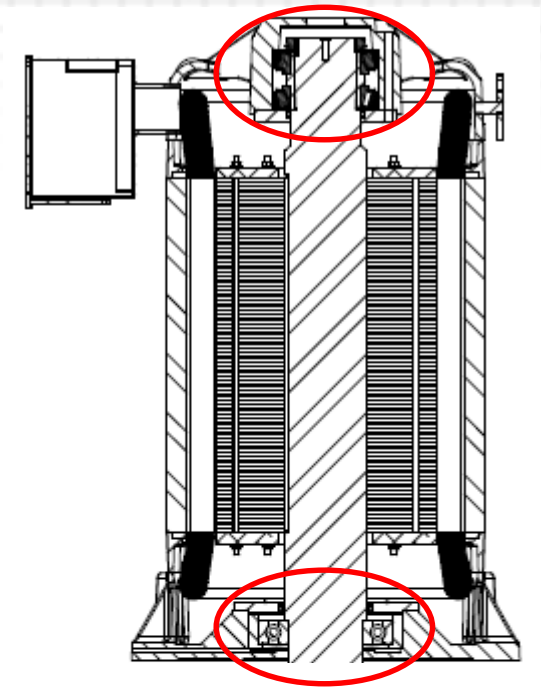
Carrier bearing



6200 series deep groove ball bearing

- Designed with greater clearance; only functions when motor sees wind gusts > 50 mph

Motor Bearing Design & Lubrication



- Tapered roller pair on opposite drive end and deep groove ball bearing on drive end.
  - Allows operation horizontally without axial loading
  - Allows shipping horizontally
- Designed for 100,000 hours L10 on both drive end and opposite drive end.
- Based on air flow, bearings are extremely cool running. Bearing temperature rise will be 80 deg C total temp or less based on 50 deg C ambient.
- Generous bearing cavities
- Use Mobil SHC460 synthetic lubricant. Based on these temps, we are looking at a 12 month relubrication schedule. Will vary by installation.

RPM-AC FINNED FRAME VARIABLE SPEED ALTERNATING CURRENT MOTOR
FL5832-DPFV, WITH DE BEARING CARRIER

619609-503

ENCLOSURE: OPEN DRIP PROOF

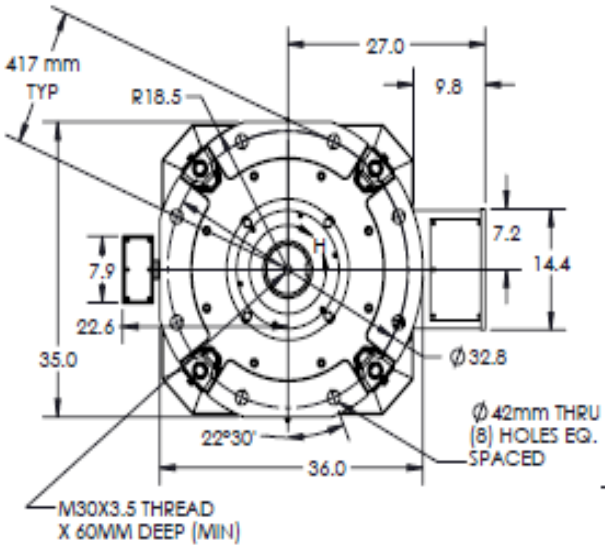
MOUNTING: FLANGE

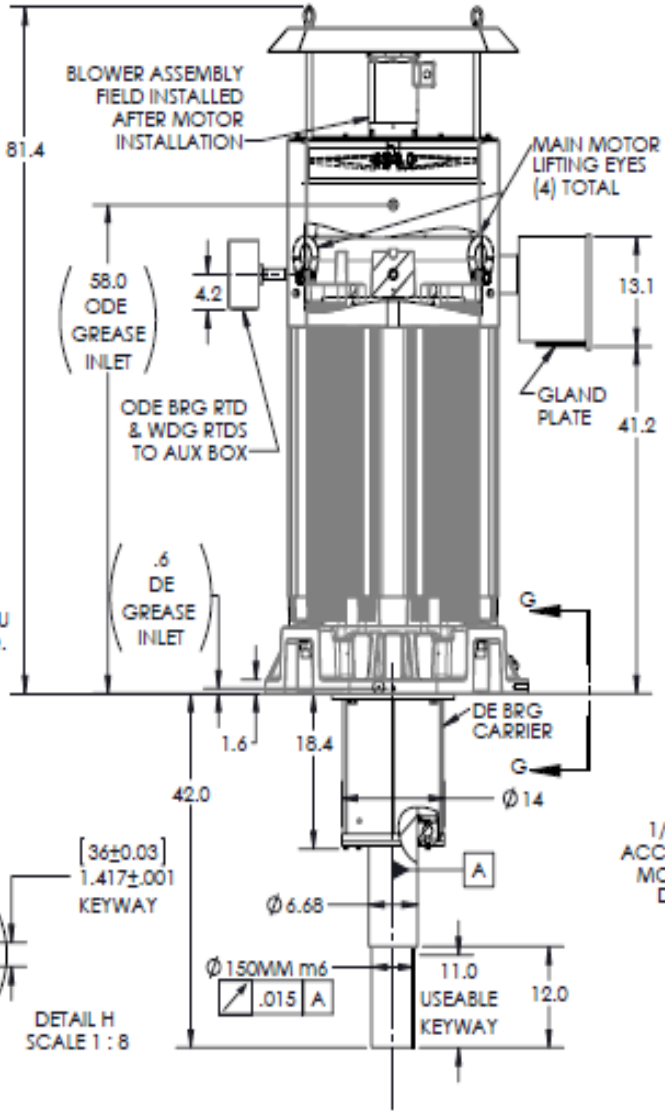
DRIVE METHOD: DIRECT

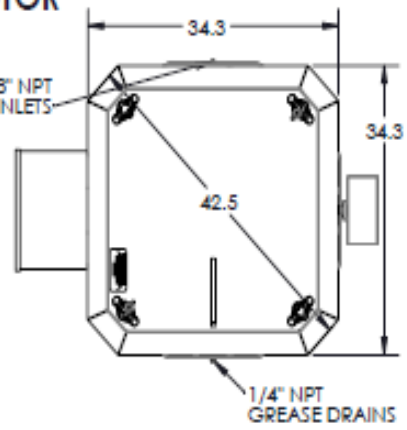
COOLING: BLOWER COOLED

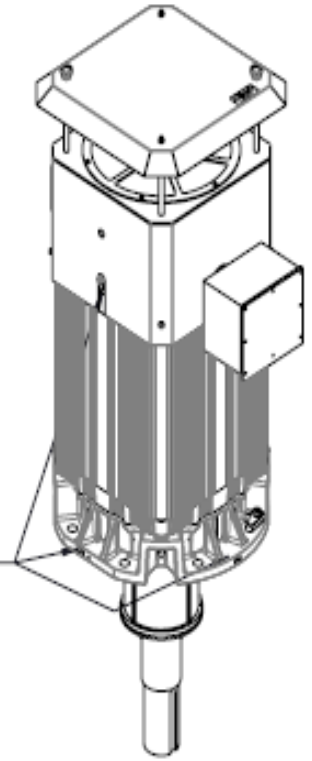
ROTOR TYPE: PERMANENT MAGNET

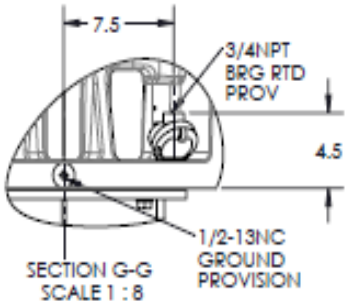
APPLICATION: AIR-COOLED CONDENSERS



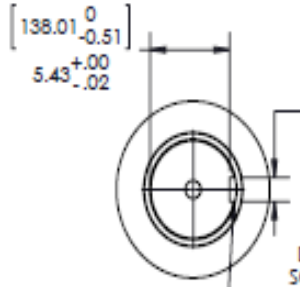








SECTION G-G
SCALE 1 : 8



DETAIL H
SCALE 1 : 8

36mm X 20mmX250mm KEY PROVIDED WITH MOTOR MAX HEIGHT FROM BOTTOM OF SHAFT TO TOP OF KEY IS158.01mm

FL5832	7679.6
FRAME SIZE	WT (LBS)

REV. DESC: INITIAL RELEASE			
REV: -	VERSION: 00	REVISED: 09:34:23 03/26/2014	TDR: 000000846259
MODEL NO. 619609-503			
BY: MGHJM22		B	

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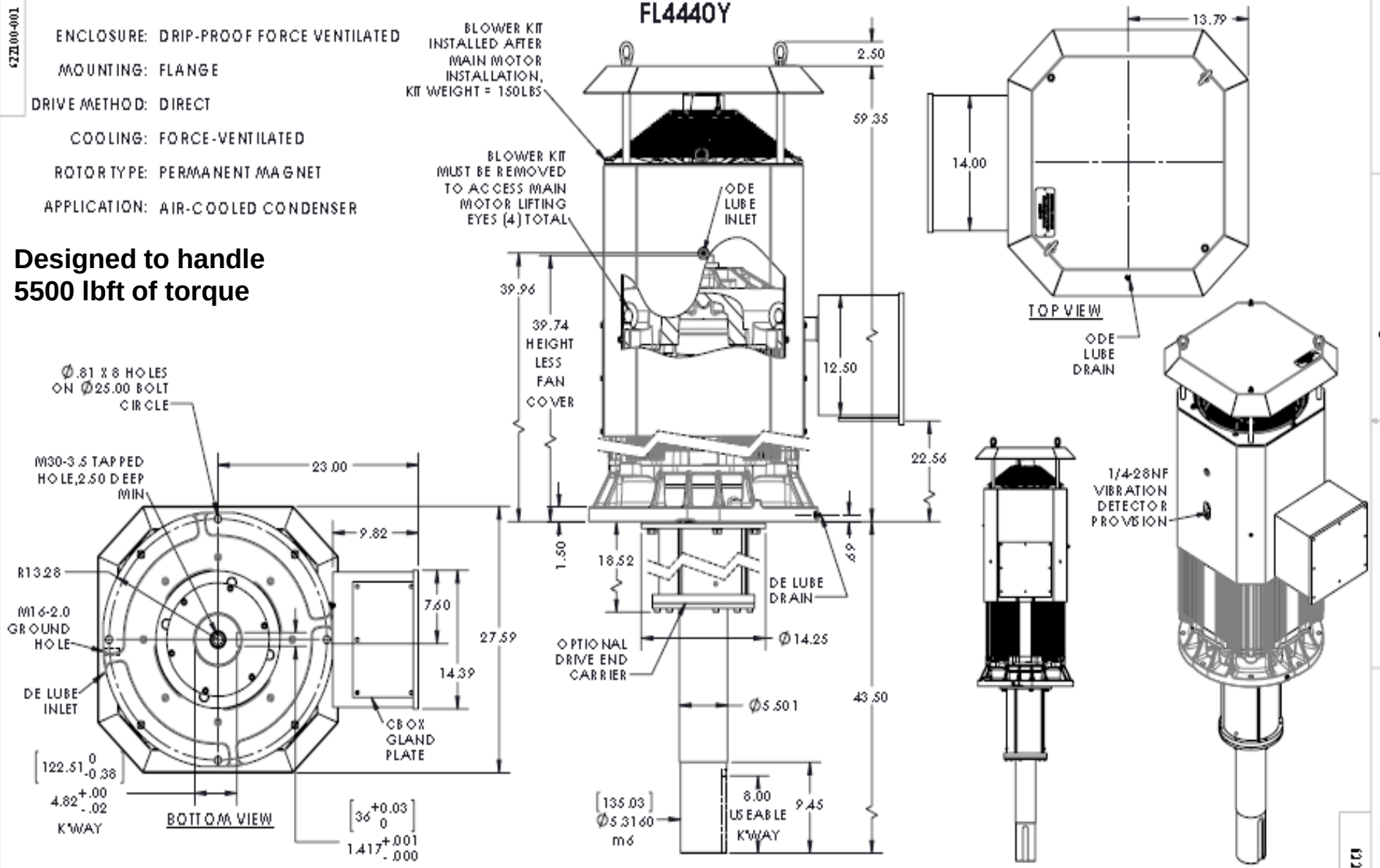
DIM SHT,FL5832-DPFV,ACC MOTOR,VERT S.D. METRIC W/ CARRIER

E03-619609-503

RPM-AC FINNED FRAME VARIABLE SPEED ALTERNATING CURRENT MOTOR
FL4440Y

ENCLOSURE: DRIP-PROOF FORCE VENTILATED
MOUNTING: FLANGE
DRIVE METHOD: DIRECT
COOLING: FORCE-VENTILATED
ROTOR TYPE: PERMANENT MAGNET
APPLICATION: AIR-COOLED CONDENSER

Designed to handle 5500 lbft of torque



DIMENSIONS ARE IN INCHES

FL4440Y	3550
FRAME SIZE	WT.(LBS)

REV DESC: INITIAL RELEASE			
REV: -	VERSION: 00	REVISED: 7/19/2016	TDR: 0000004718
MODEL NO: 633100-001			REP: -
BY: MSHUMEI		B	

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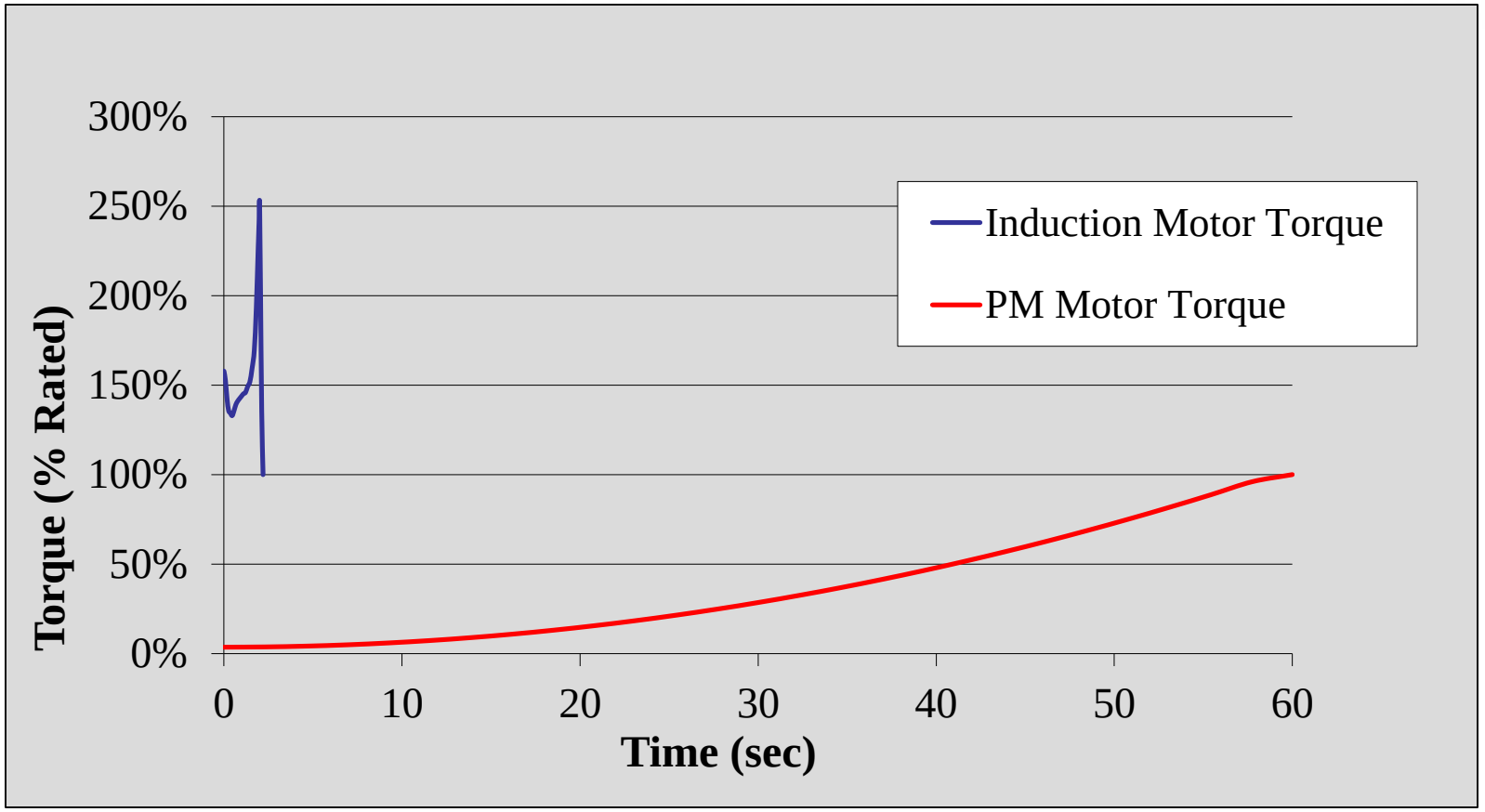
DIM SHEET, FL*** 4-DIGIT ACC, 115MM SHAFT, WITH INLINE BLOWER

633100-001

VFD Benefits

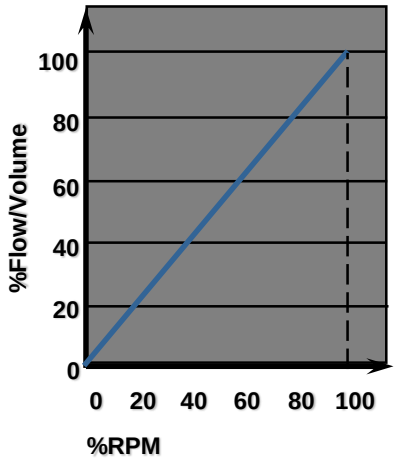
- Reduced transient torques in a “live” structure

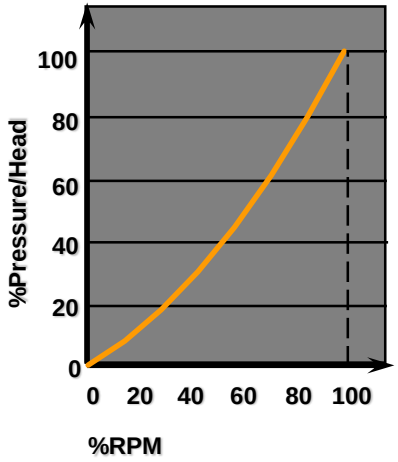


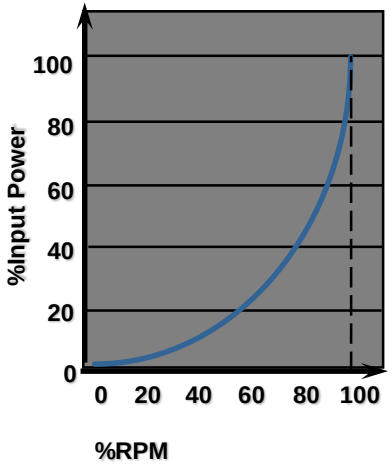
Efficiency Evaluation

- Affinity Fan Laws apply to Cooling Towers
  - **Air Volume is Directly Proportional to Speed**
  - **Pressure varies as Square of Speed**
  - **HP varies as Cube of Speed**

Speed	100%	90%	80%	70%	60%	50%	40%	30%
Volume	100%	90%	80%	70%	60%	50%	40%	30%
Pressure	100%	81%	64%	49%	36%	25%	16%	9%
HP Req'd	100%	73%	51%	34%	22%	13%	6%	3%







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ACC Drive Motor Control

- Matched Performance Drive & Motor
- Proven Technology Design focused on:
  - Ease of startup
  - Minimal maintenance
  - Efficiency of operation
- Utilizes unique control algorithms
  - Interior Permanent Magnet (IPM) Motor Control
  - Sensorless Vector algorithm
  - Smooth, low speed operation
- Provides small amount current to motor when not in use
  - ✓ Eliminates condensation in the motor – no space heaters required
  - ✓ Additional benefit of providing anti-wind milling torque (locks shaft); occurs after preset period of time.
  - Equivalent of 3% line reactor is included as standard
  - 300 meter lead length w/o filters

NO SPACE HEATERS REQUIRED

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ACC Single Drive Configuration

HP	Amps	WL	Size
150	180	2310	R7
200	240	3300	R8
250	302	4200	R9
300	361	4800	R9
350	414	6000	R9

	Total HT	HT less terms	Width	Depth
R7	34.77”	23.6”	11.22”	14.37”
R8	37.9”	26.8”	11.8”	15.2”
R9	37.6”	26.7”	15”	16.3”

- Zero stacking capability
- 40 deg C ambient; higher with derate

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ABB MACHsense-R Data Collection CBM

(6) Wdg RTDs
(1) DE Brg RTD
(2) ODE Brg RTD
(5) Accel Provisions DE-V, DE-H, DE-A, ODE-V, ODE-H

ABB MACHsense-R

- Development by ABB R&D
- Real time condition monitoring
- Monitor stator RTDs, bearing RTDs and accelerometers to be monitored. Dual outputs for use by both DF and Baldor.

Measurements & Analysis of Data & Report

- Measurements and analysis are automatically performed by installed data collection system.
- Key Condition Parameters are transmitted wireless to server
- Monthly report is later delivered by Local Service Center(LSC)

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Project Specific Data

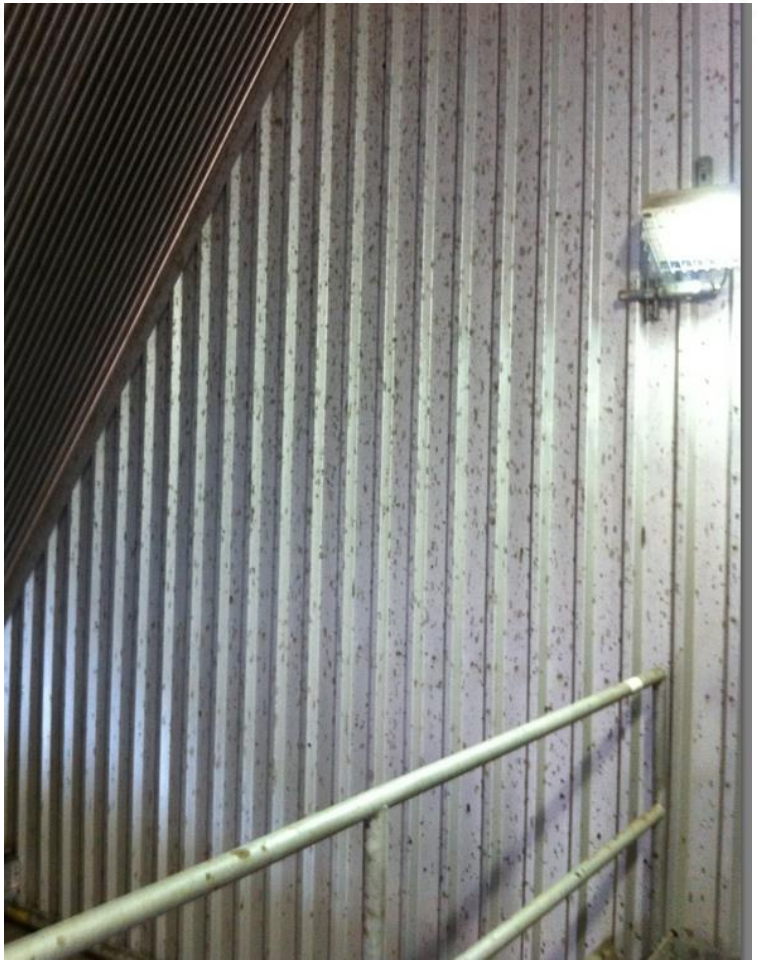
Dry Fork Station ACC Prototype Installation

- (45) cell ACC
- Operational in 2011
- Installing (2) prototype units for 18 month period.
- Identified installation challenges.
- Motor #1 installed in April 2015.
- Motor #2 installed in April 2016.

- Baldor to provide hardware and DF to provide the integration

Rating is 250 HP @ 104 rpm (12625 lb-ft)

Implications of leaking gearboxes



Unable to clean blades without collecting all run off

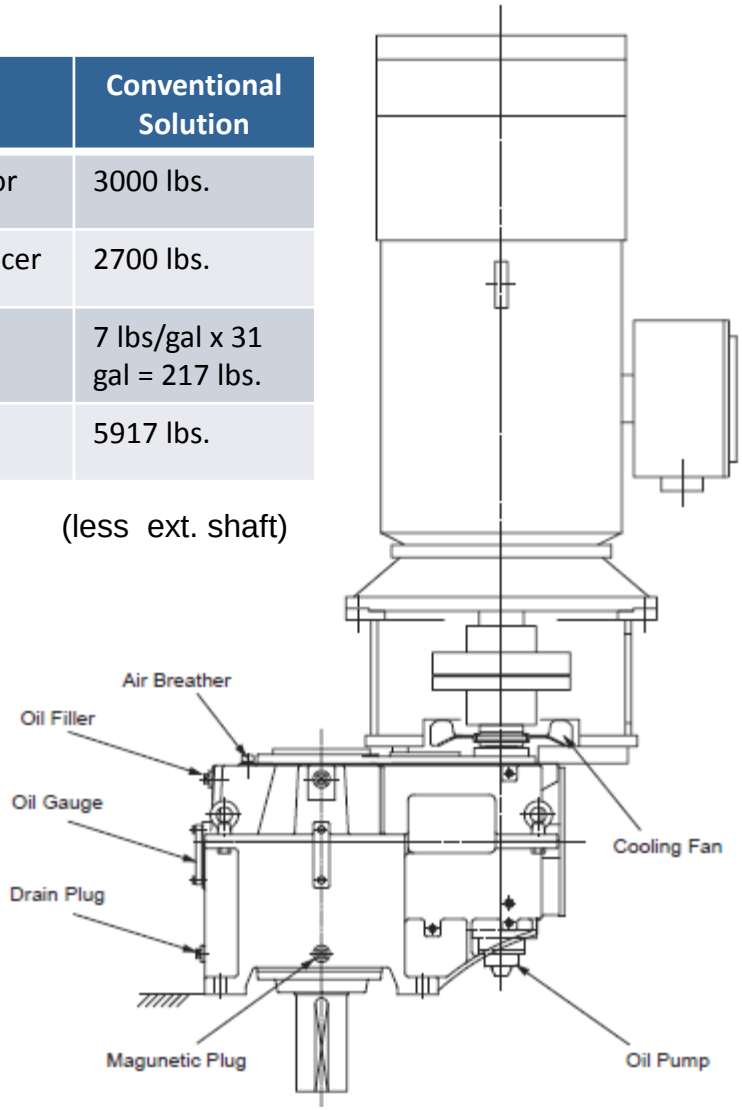
Retrofit Installation Challenges

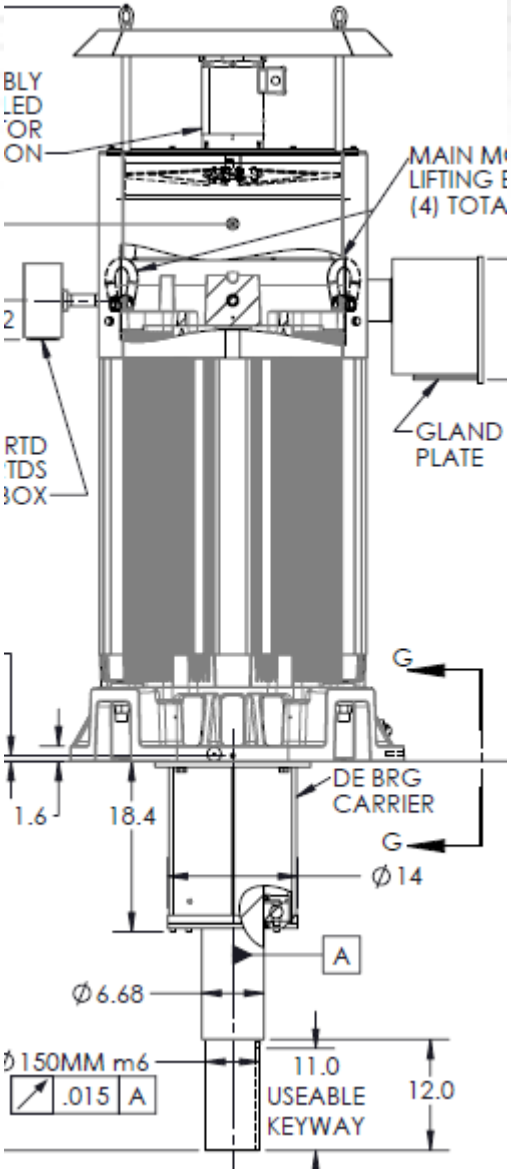
- Existing trolley system is rated for < 5000 lbs.
- How to install a drive motor that weighs more than the previous individual components?
- How to install a motor that is physically larger than the original components?

Dry Fork Weight Comparison

	Conventional Solution
Motor	3000 lbs.
Reducer	2700 lbs.
Oil	7 lbs/gal x 31 gal = 217 lbs.
Total	5917 lbs.

(less ext. shaft)





	DD
Motor	
Total	7679 lbs

Note: lifting weight is less blower assembly

(290 lbs)

Installed: 1762 lb. difference or 30% more
Lifting: 7389 lbs.

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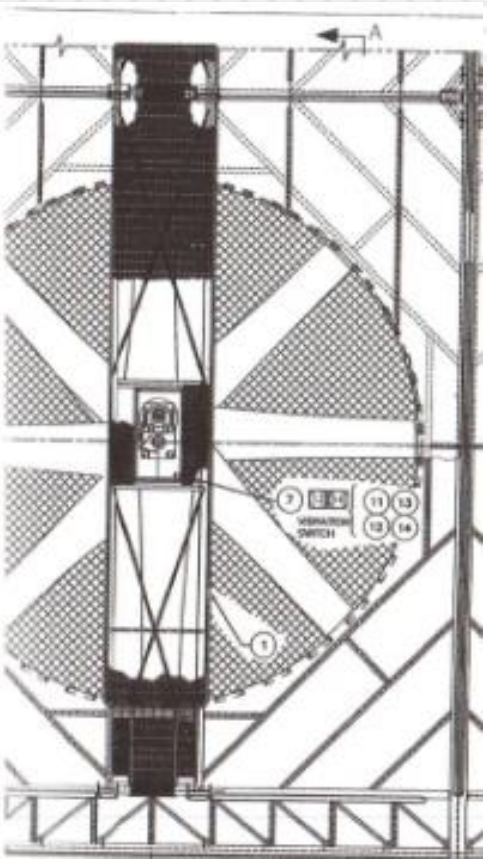
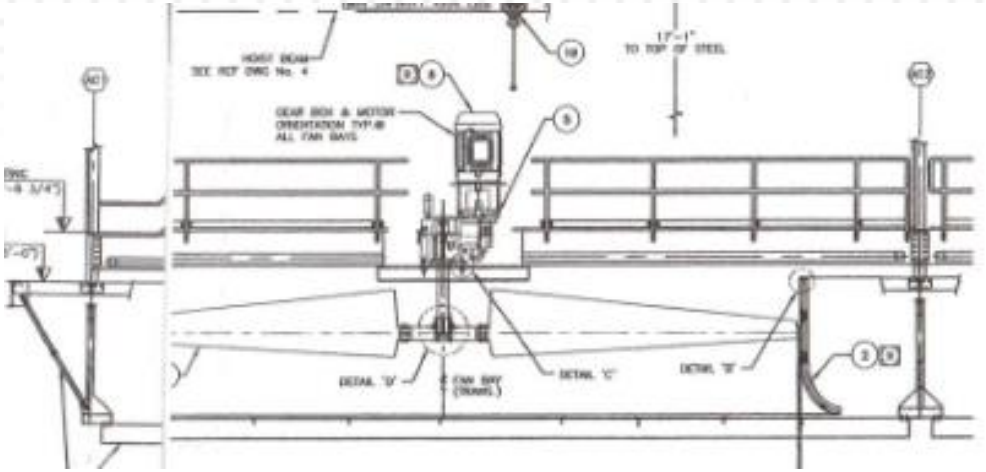
Installation Challenges





Motor: 7800 lbs
Mounting plate: 3300 lbs.
Hub: 300 lbs.
Fan: 3000 lbs
TOTAL 14,300 lbs

- Lifting fan/motor/deck assembly as long as spreader bar is used to ensure the through rods are in pure tension

Sound level data

Dry Fork Station Sound Pressure Levels

Data taken at 6 ft

28-Jun-16

Ambient was 63 deg; approx 8:30 am

% speed	RPM	Value dba
35	36	83
40	42	83
45	47	83
50	52	83
55	57	83
60	62	82.8
65	68	83
70	73	83.5
75	78	83.5
80	83	83.5
85	88	83.5
90	94	84.5
95	99	85
100	104	85.5

- Additional measured data:
  - Measured at door, closed, out of airstream. 83.5 dba
  - Siemens at same location is 84 dba.

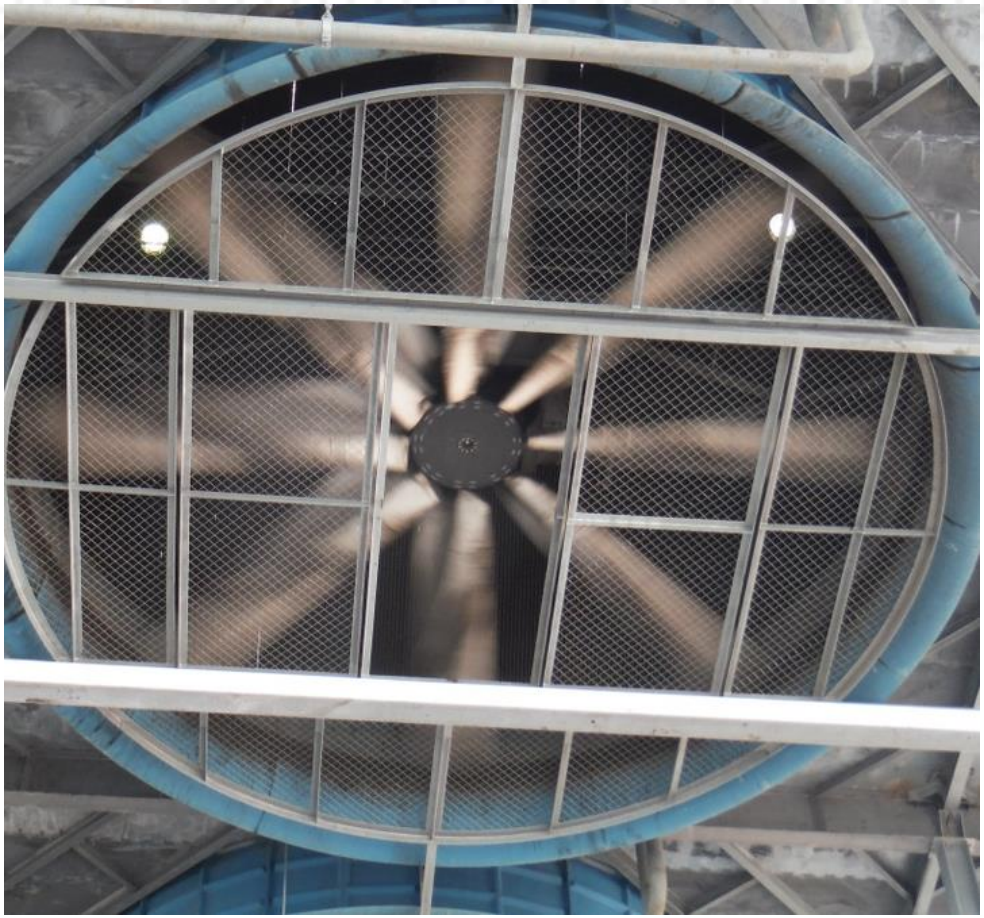
Outside of ACC in walkway

- Siemens was 82 – 82.5 dba
- Baldor was 81.5 dba

Location

- Siemens @ 6 ft – 87 dba (1.3)
- Siemens @ 6 ft – 88 dba (1.2)
- Siemens @ 3 ft – 90 dba (1.1)

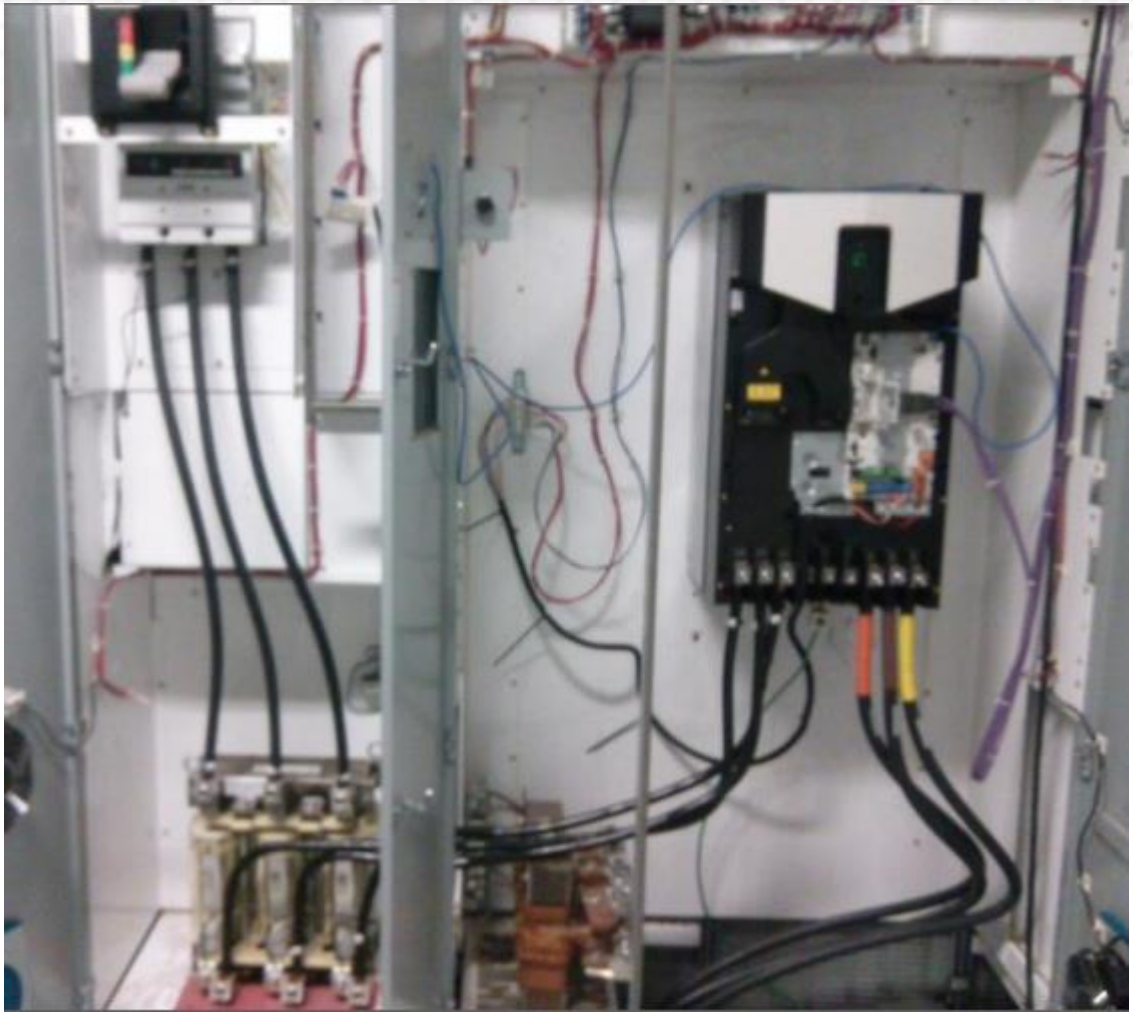
Fan Guard



Dry Fork installation specifics

- 6 voltage buses; (3) with (8) motors and (3) with (7) motors
- Each voltage bus has (2) active harmonic filters installed in each MCC lineup
  - During operation of motor 1.4, it was determined that none of the harmonic filters were working. Measured THD in excess of 17%. Units still out of operation as of this date.
- Long term plan is to replace crane with chain hoist
- Most recent changeout took (2) days both mechanical and electrical. Believe can get that down to 1.5 days. Crew of 5 including crane operator.
- Space heaters included for motor #2. The last 3 rows are shut down in the winter so power will be removed from the drive.
- Shorting/Isolation contactor included for motor #2.
- Replace standard fan guard with steel cable. This is a weight reduction savings.
- During the warmest weather conditions, it is difficult to operate all the fans at 100% speed because of low voltage bus conditions. All fans are set to operate based on current limit. Speed will decrease as voltage sags. Is this common to other installations?

Drive installation Motor 1.4



Notice size of available space. Total length available is 56” including space for input breaker and input line reactor.

Output reactor not required with ACS880 drive.

Elimination of output line reactor will improve voltage level to the motor.

Motor 1.3 Shorting Disconnect

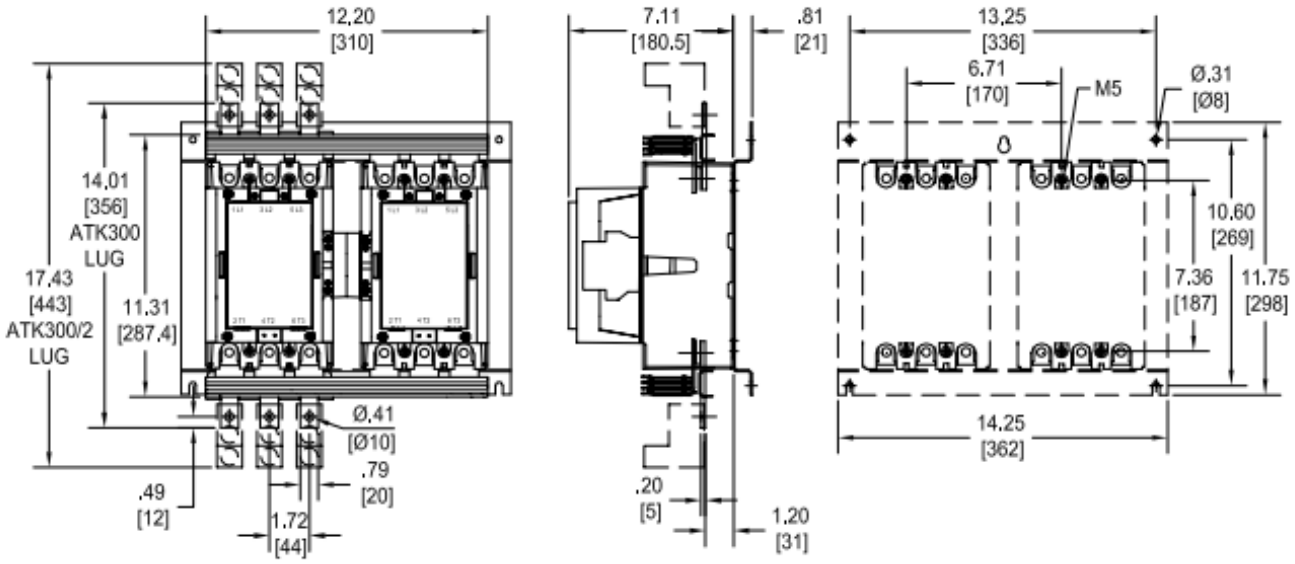
- Provides a “disconnect” for maintenance purposes.
- Not only disconnects the motor from the drive but also shorts the leads thereby preventing windmilling
- Utilizing the disconnect does not allow for trickle current functionality to be operational (space heaters)
- Able to stop unit from 75 rpm in reverse in approx. 5 seconds.

Drive Installation Motor 4.1

(2) Definite purpose contactors installed

Allows start/stop operation of fan during high windmilling conditions (up to 75 rpm in reverse direction)

Shorting/Isolation Contactor



- Is available as an option to “hold” the fan (shorted) when the fan is in the stopped condition. Prevents the fan from windmilling. Upon a drive start command, the contactors change state and allow the drive to now control the motor.

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Dry Fork Future Plans

Based on their analysis of the operation of the prototype units, Dry Fork has stated that it is their intention to replace the balance of the fan units with Direct Drive technology.

Timing and approach are yet to be determined.

Two options being considered.

1. Replace select number of units per year and install in fall or spring. Also replace as they fail.

2. Take a scheduled outage and replace all units. Where as this may have been a more preferred approach in the past, with the challenges today of being a coal plant, this may be harder to do.

Justification Points Identified by Dry Fork

- Drain and flush gearboxes; 20-25% have already (5 years) been done due to silica. Unable to filter out due to fineness. Estimating will need to do this to all units on a 6-10 year cycle.
- Would have to rebuild/replace all gearboxes within 10 years. Would include carrier bearing in redesign.
- Significant number of gearbox units leaking oil. As noted in the pictures, significant cleaning is required.
- For environmental reasons alone, the ability alone to eliminate oil, maintenance and storage is significant.
- During winter months, to maintain proper oil flow to the gearbox, minimum fan speed is 15% of full speed.
- Estimating will be able to reduce maintenance manpower by 75% going to Direct Drive technology (man hours/unit).

Presenters

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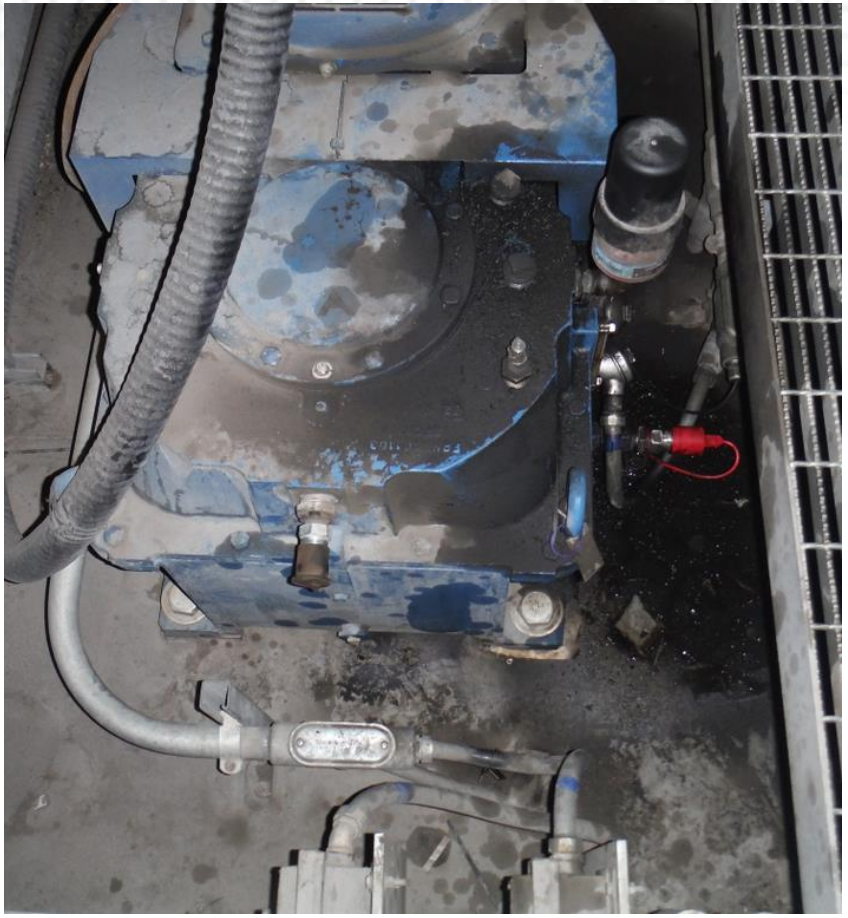
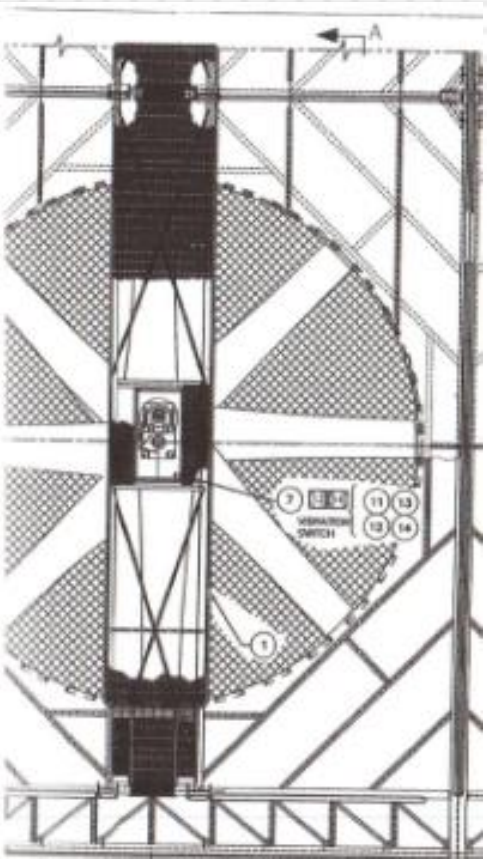
Installation photos

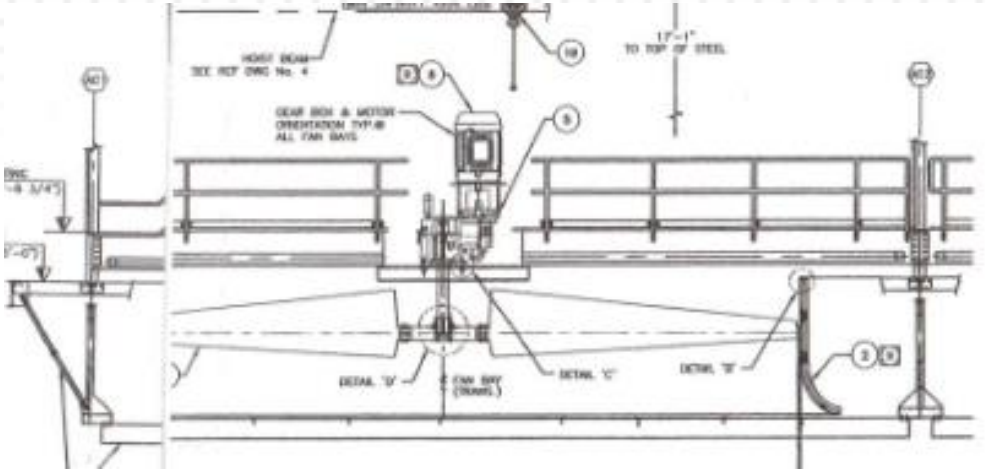
Existing Dry Fork Installation



Unit is ready for installation, fan hub is installed

Installation Challenges





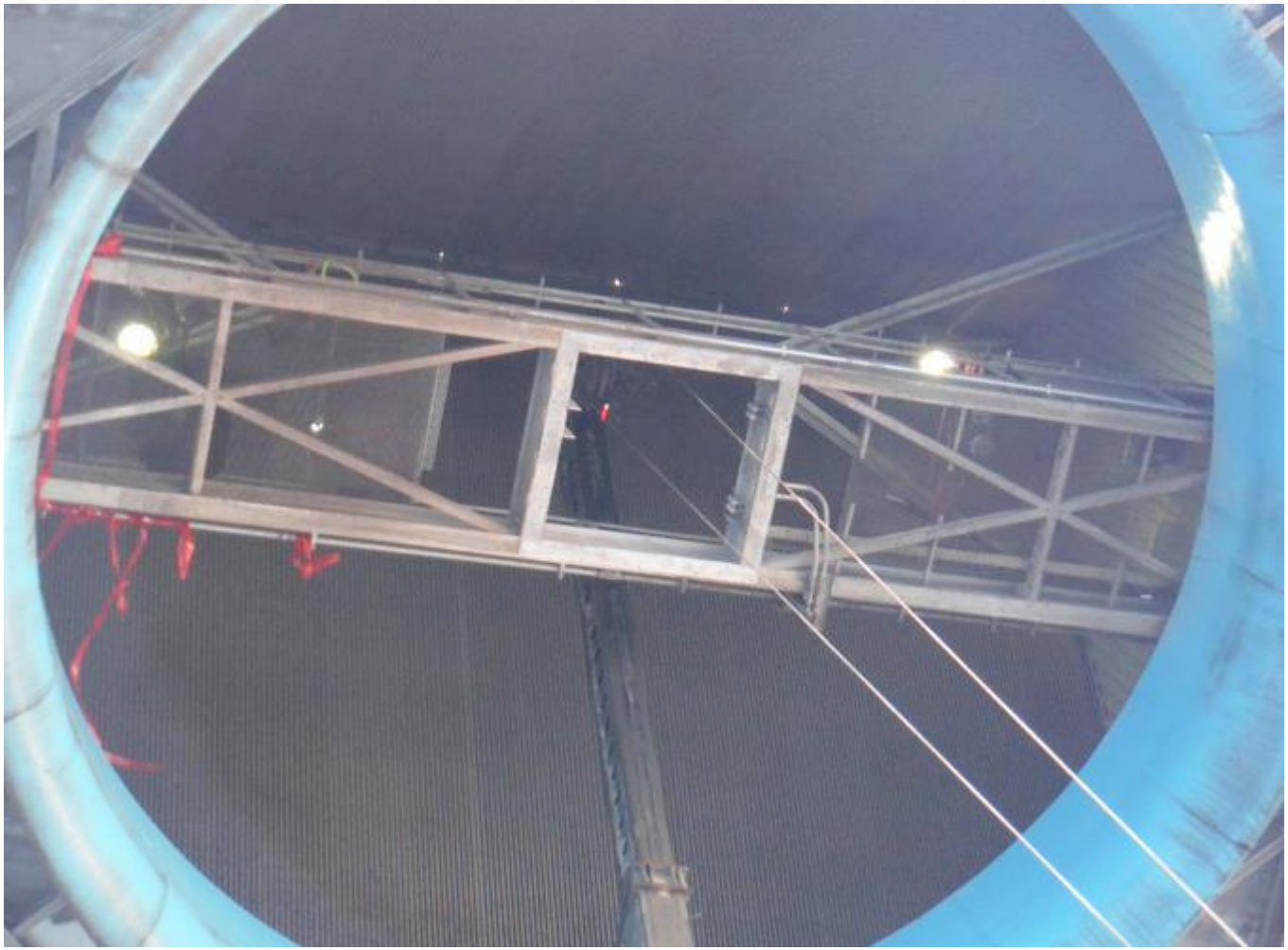
Motor: 7800 lbs
Mounting plate: 3300 lbs.
Hub: 300 lbs.
Fan: 3000 lbs
TOTAL 14,300 lbs

- Lifting fan/motor/deck assembly as long as spreader bar is used to ensure the through rods are in pure tension

Crane used for installation

- Changeout process took 24 hours once crane was on site.

Crane Used for Installation



Existing Mounting Plate Was Used for Motor #1

Motor/Fan being re-attached

Basin designed lifting mechanism

New Mounting Plate Fabricated for Motor #2

Installed unit; with and without hood

unit shown without blower installed

Lifting the unit for installation

Motor/Fan being re-attached

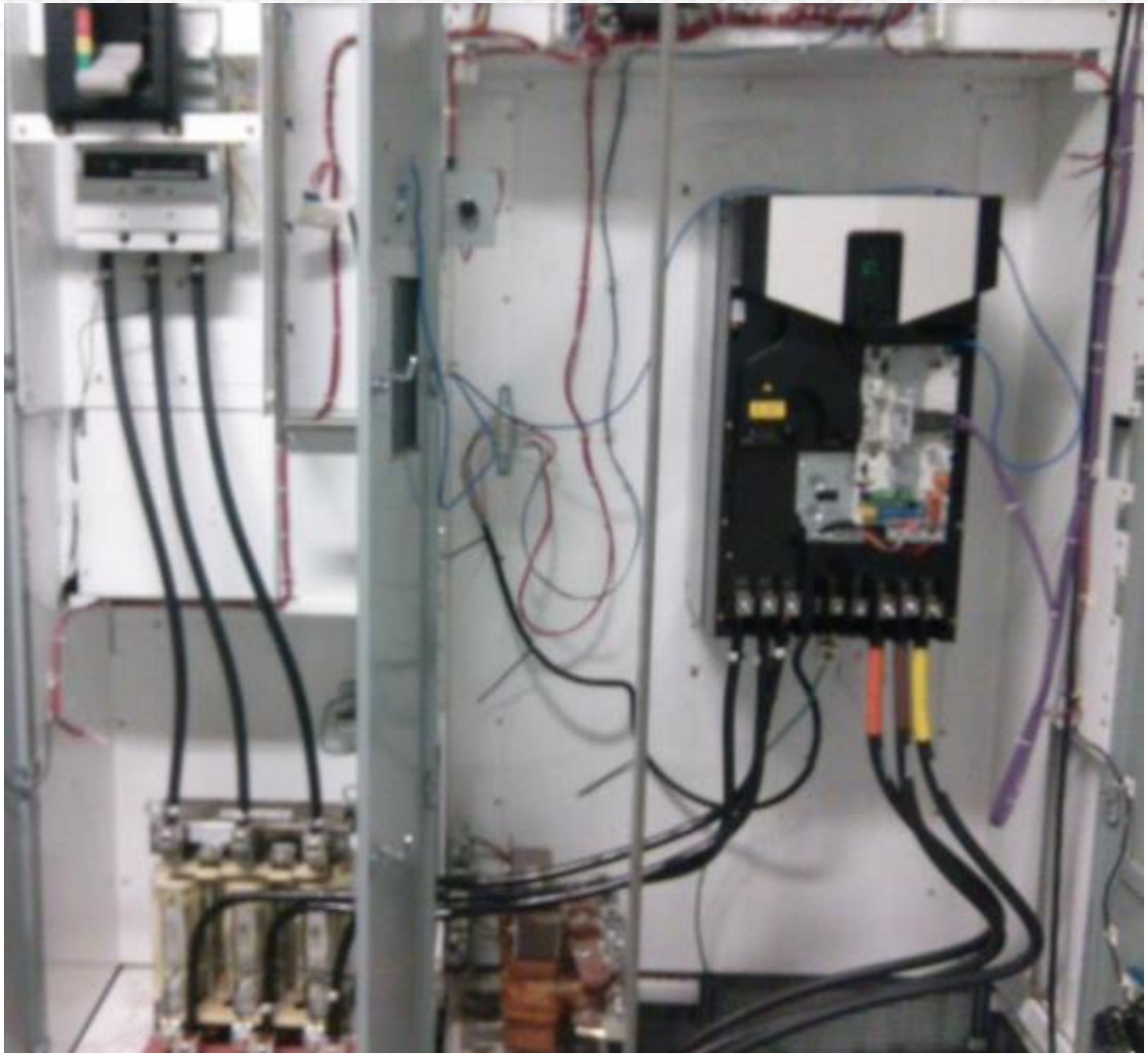
Installation Photos

Low noise hood is installed
Measured sound pressure at door: 83.5 dba

New Mounting Plate Fabricated for Motor #2

Motor #2 at Location 4.1

Drive Installation

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