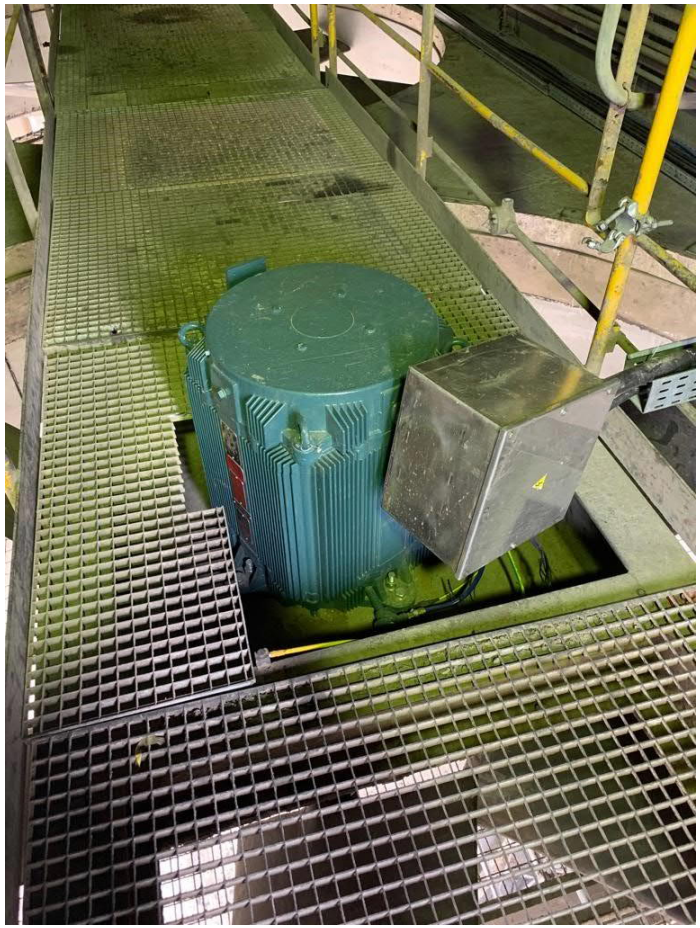
NOVEMBER 2019

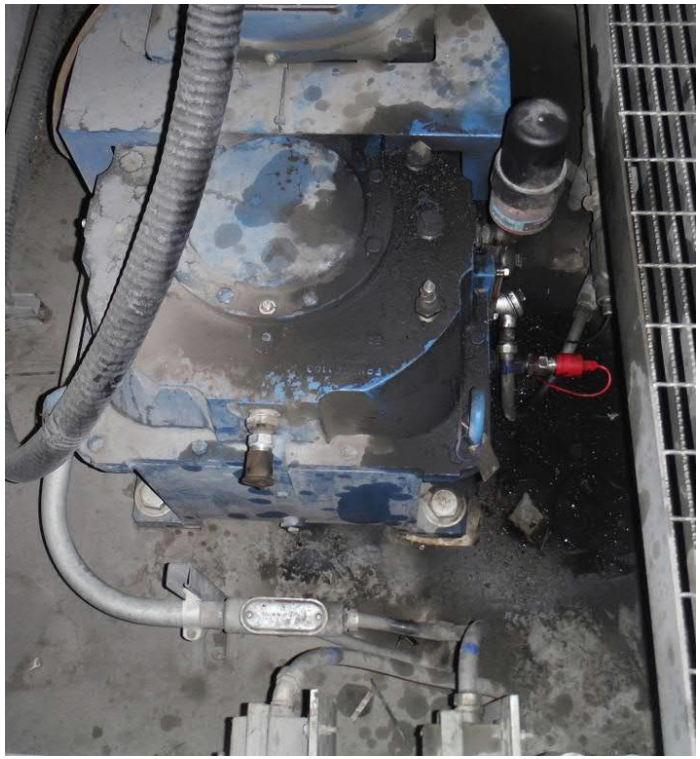
# Installation of PM Direct Drive Fan Motors

Updated 2019 by Marty Mates for ACCUG Queretaro

# Permanent magnet motor ready for installation, fan hub installed on shaft at motor factory



# Typical motor and reducer drive installation



# Direct drive motor technology

- Introduced to the cooling tower market in 2008;
  - 11 years experience
- In excess of 1200 total units installed across all industries
- 140 utility size FL5800 frame Direct Drive cooling tower motors in shaft up configuration are in operation today.
- Introduced ACC design in 2013 Installed in 2015
- 2019 new ACC retrofit installations in Texas and country of Jordan

# 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 to gather input and suggestions for ACC motor design.
- At the 2014 Users Group meeting, reviewed the Dry Fork prototype installation, identified installation challenges and the motor final design.
- This 2019 meeting we will recap the PM motor design and review installation pictures including Jordan.

# Industry issues

What we hear from users

- Need to improve reliability
  - 10 hrs to 2 - 3 days to months to change out failed units
- Each ACC installation has a unique design related to Size, (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

# Industry issues cont'd….

What we hear from users

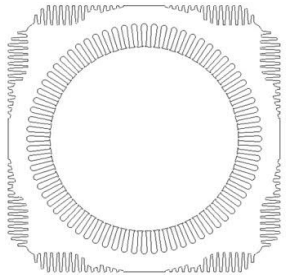
- Environmental issues
  - Oil disposal
- Efficiency
  - ACC is highest parasitic load in plant; ability to reduce parasitic load will improve system efficiency and heat rate
- Frequency of inspections based on all of the above
- Noise concerns
- Less people to properly take care of equipment today

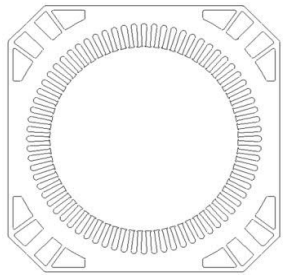
# Design considerations for application

- 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

# PM motor technology

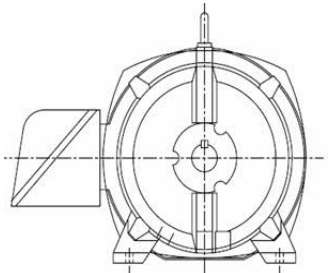
**Saliency: the ability to control rotor position without a feedback device**



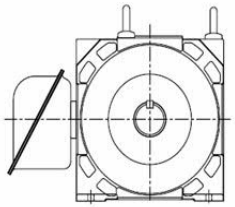


75 HP, 1800 RPM

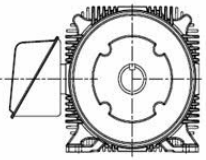
| | |
|---|---|
| 360T | 9.00” |
| L280 | 7.00” |
| L250 | 6.25” |



360T



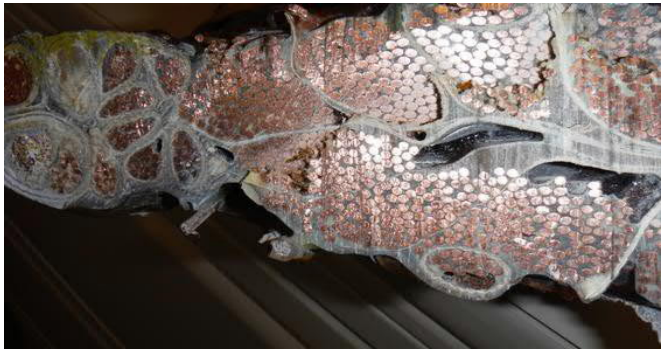
L280



L250

Motor power density and increased efficiency

# Class H VPI System



Green paint is epoxy coating for additional protection against moisture

# Dry Fork Station

## 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.

# Dry Fork Station

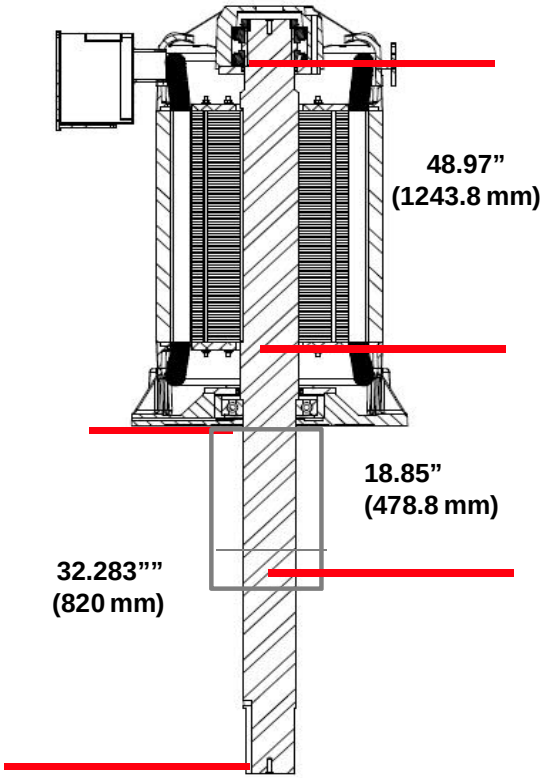
## Direct drive motor solution

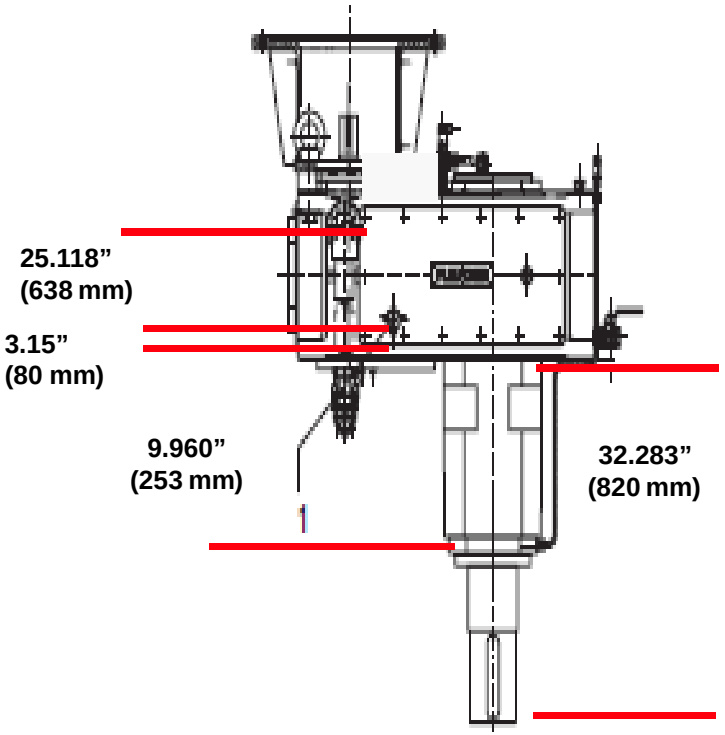
- 12,625 lb-ft of torque (250 HP @ 104 rpm)
- FL5832 frame
- Vertical shaft down
- Large output shaft (6.875” diameter and 42” long)
- Open blower design for cool operation
  - - DPG-FV (drip proof guarded force ventilated)
- Low noise (84 dba sound pressure @ 1 meter)
- Carrier bearing for additional 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.

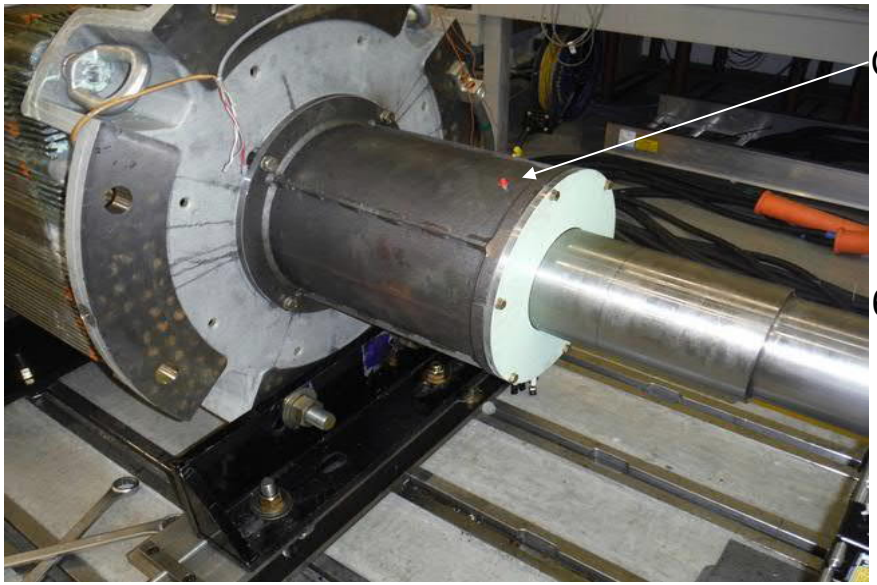
**Takes advantage of the environment to provide the most cost effective power dense solution available.**

# Dry Fork Station

## Direct drive motor solution – bearing span

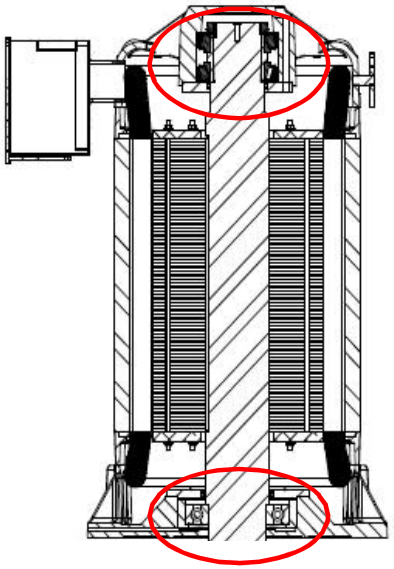





**Designed with greater clearance; only functions when motor sees wind gusts > 50 mph**

# Motor bearing design & lubrication



- Tapered roller pair on opposite drive end and deep groove ball bearing on drive end.
  - Allows 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, typically a 12 month relubrication schedule. Will vary by installation.

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

ENCLOSURE: OPEN DRIP PROOF

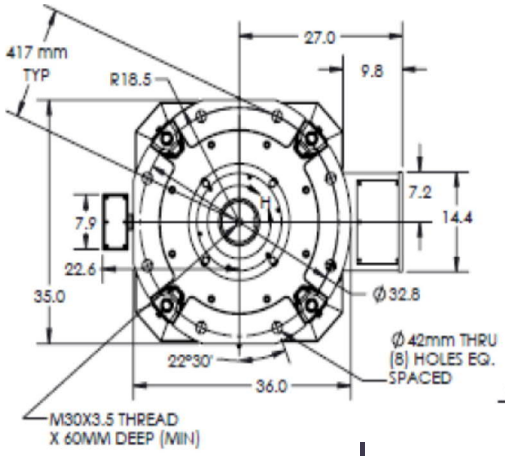
MOUNTING: FLANGE

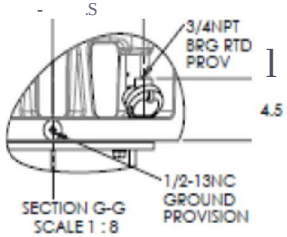
DRIVE METHOD: DIRECT

COOLING: BLOWER COOLED

ROTOR TYPE: PERMANENT MAGNET

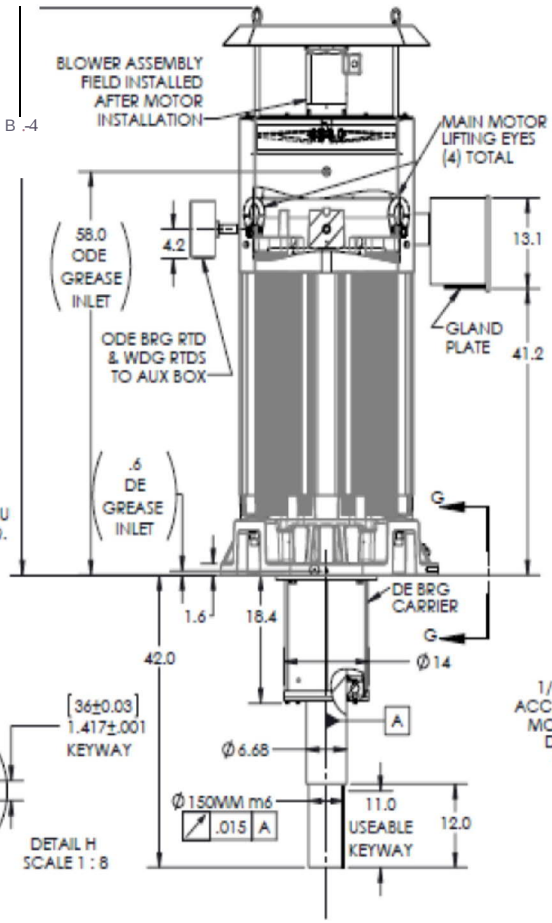
APPLICATION: AIR-COOLED CONDENSERS

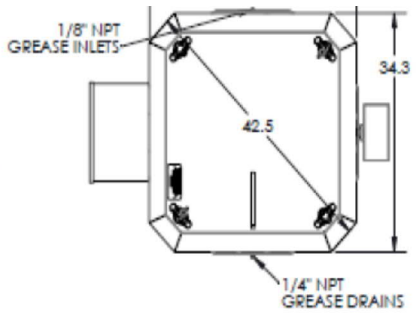


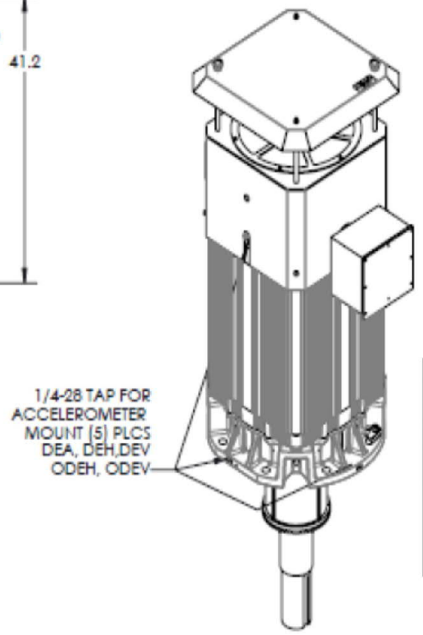





36mm X 20mmX250mm KEY PROVIDED WITH MOTOR MAX HEIGHT FROM BOTTOM OF SHAFT TO TOP OF KEY IS158.01mm



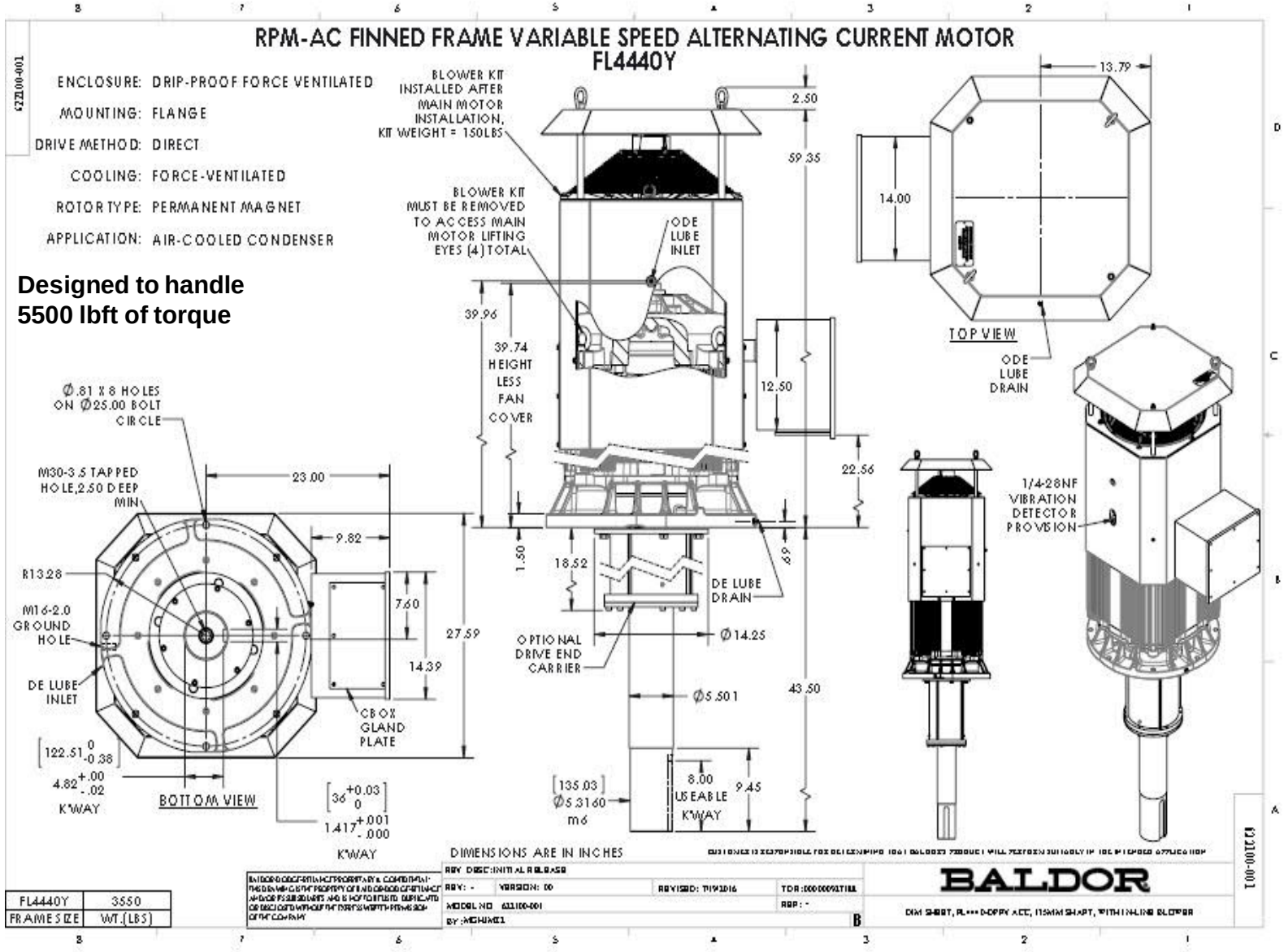

| FL5832 | 7679.6 |
|---|---|
| FRAME SIZE | WT (LBS) |

REV. DESC: INITIAL RELEASE
REV: - | VERSION: 00 | REVISED: 09:34:23 03/28/2014 | TDR: 000000846259
MODEL NO. 619609-503
BY: MOHUMZ2

BALDOR

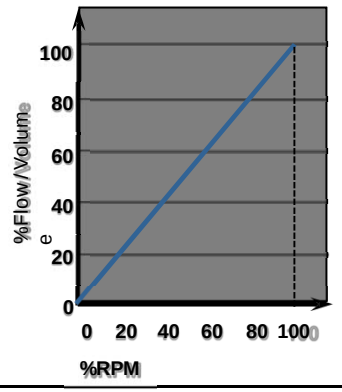
DIM SHT, FL5832-DPFV, ACC MOTOR, VERT S.D. METR

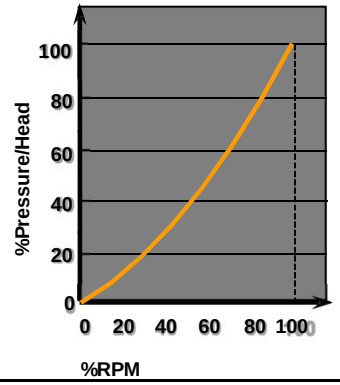
619609-503

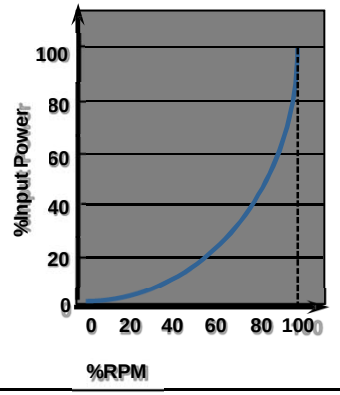

RPM-AC FINNED FRAME VARIABLE SPEED ALTERNATING CURRENT MOTOR
FL4440Y
ENCLOSURE: DRIP-PROOF FORCE VENTILATED
MOUNTING: FLANGE
DRIVE METHOD: DIRECT
COOLING: FORCE-VENTILATED
ROTOR TYPE: PERMANENT MAGNET
APPLICATION: AIR-COOLED CONDENSER
Designed to handle
5500 lbft of torque
BLOWER KIT INSTALLED AFTER MAIN MOTOR INSTALLATION, KIT WEIGHT = 150LBS
BLOWER KIT MUST BE REMOVED TO ACCESS MAIN MOTOR LIFTING EYES (4) TOTAL
ODE LUBE INLET
ODE LUBE DRAIN
TOP VIEW
13.79
14.00
2.50
59.35
39.96
39.74 HEIGHT LESS FAN COVER
12.50
22.56
1.50
18.52
.69
DE LUBE DRAIN
Ø14.25
OPTIONAL DRIVE END CARRIER
Ø5.501
43.50
[135.03] Ø5.3160 m6
8.00 USEABLE K'WAY
9.45
1/4-28NF VIBRATION DETECTOR PROVISION
Ø.81 X 8 HOLES ON Ø25.00 BOLT CIRCLE
M30-3.5 TAPPED HOLE,2.50 DEEP MIN
23.00
9.82
R13.28
M16-2.0 GROUND HOLE
DE LUBE INLET
7.60
14.39
27.59
CBOX GLAND PLATE
[122.51 0 -0.38]
4.82 +.00 -.02
K'WAY
BOTTOM VIEW
[36 +0.03 0]
1.417 +.001 -.000
K'WAY
DIMENSIONS ARE IN INCHES
FL4440Y
FRAME SIZE
3550
WT.(LBS)
BALDOR

# Efficiency Evaluation

## Affinity laws apply to cooling towers




| 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% |

# ACC Drive motor control

## Matched performance drive & motor

NO SPACE HEATERS REQUIRED

- 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

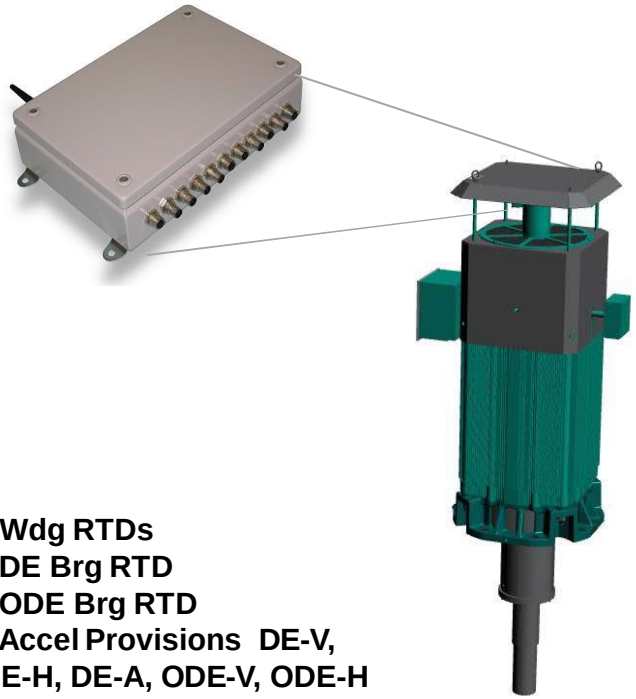
- Zero stacking capability
- 40 deg C ambient; higher with derate

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

| Drive | 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” |

# Condition monitoring

## ABB MACHsense-R



**(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 ABB.

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)

# Project specific data

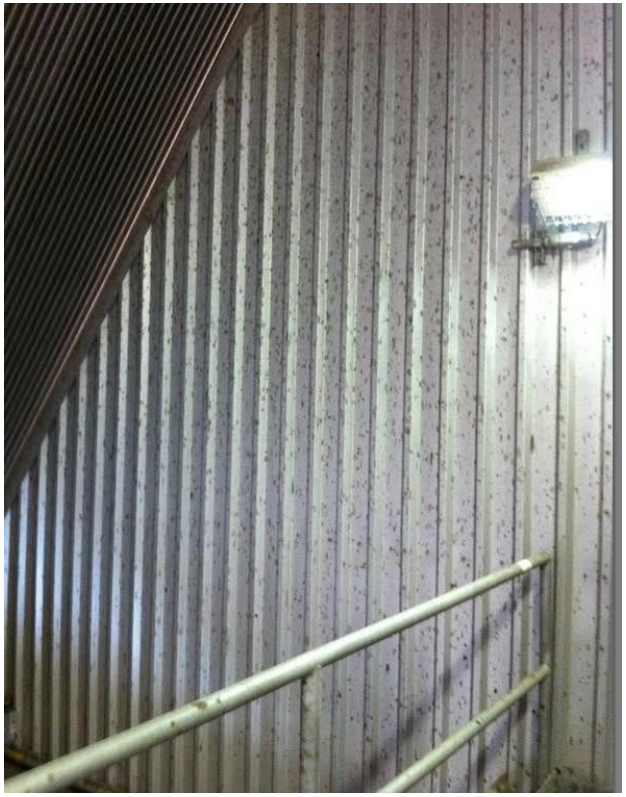
# Dry Fork Station

## Prototype installation

- (45) cell ACC
- Operational in 2011
- Installed (2) prototype units.
- Identified installation challenges.
- Motor #1 installed in April 2015.
- Motor #2 installed in April 2016.
- ABB provided hardware and DF performed the integration

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

# Implications of leaking gearboxes



Cleaning of fan blades requires collecting all run off contamination

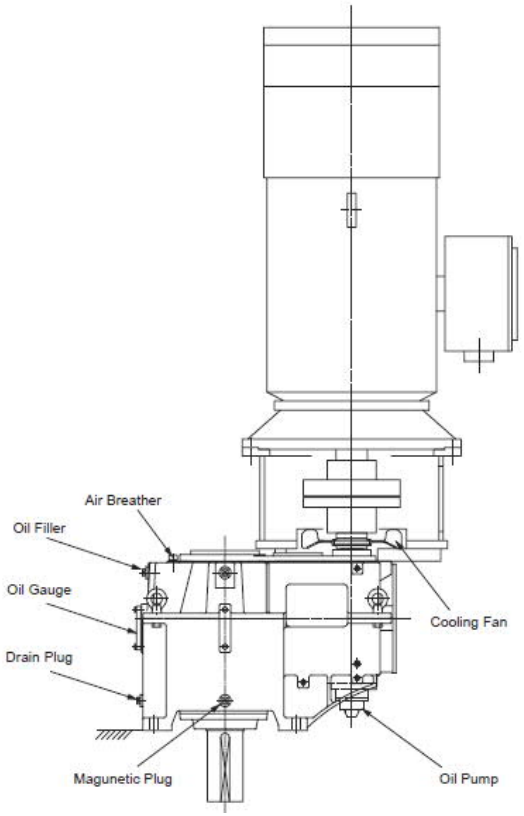
# Retrofit installation

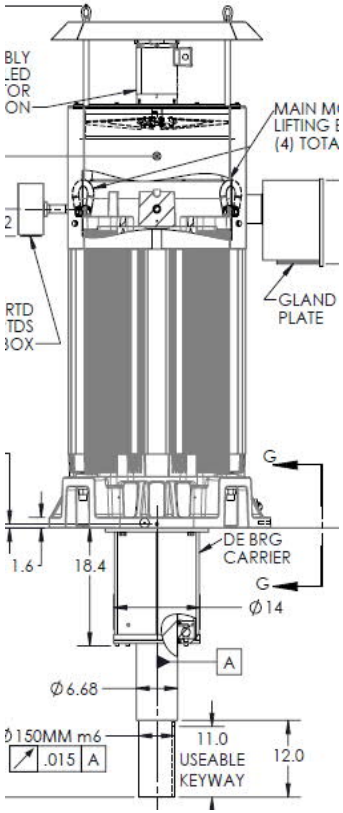

- Existing trolley system is rated for < 5000 lbs.
- How to install a drive motor that weighs more than the previous individual components?
- How to install a motor that is physically larger than the original components?

# Weight comparison

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

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



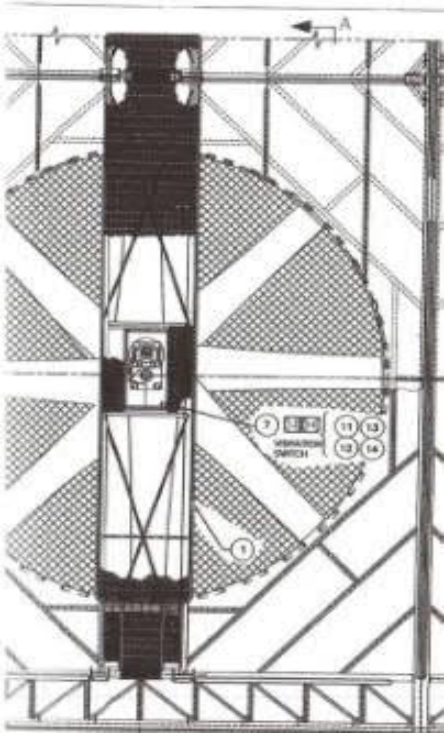




| Direct Drive | |
|---|---|
| Motor | |
| | |
| | |
| Total | 7679 lbs |

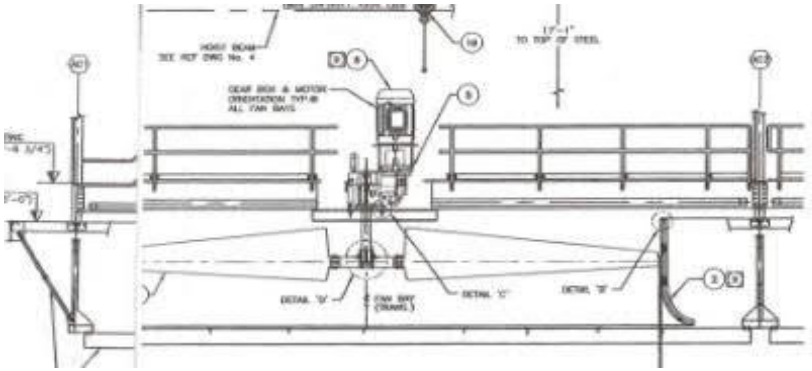
Note: lifting weight is less blower assembly (290 lbs)

# Installation challenges

## Motor #1

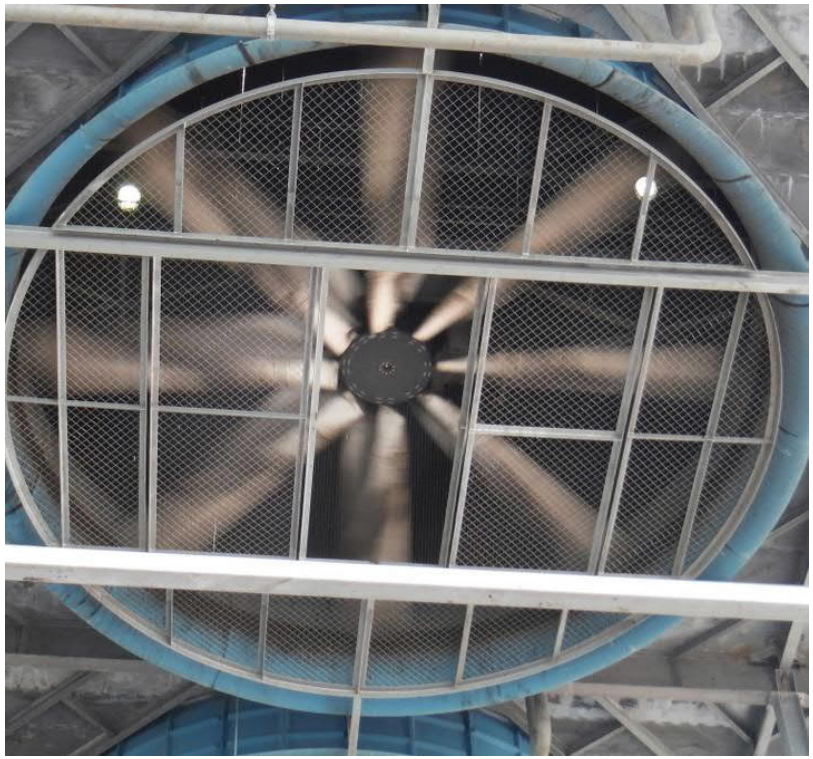


| | |
|---|---|
| Motor | 7800 lbs. |
| Mounting plate | 3300 lbs. |
| Hub | 300 lbs. |
| Fan | 3000 lbs. |
| Total | 14,300 lbs. |

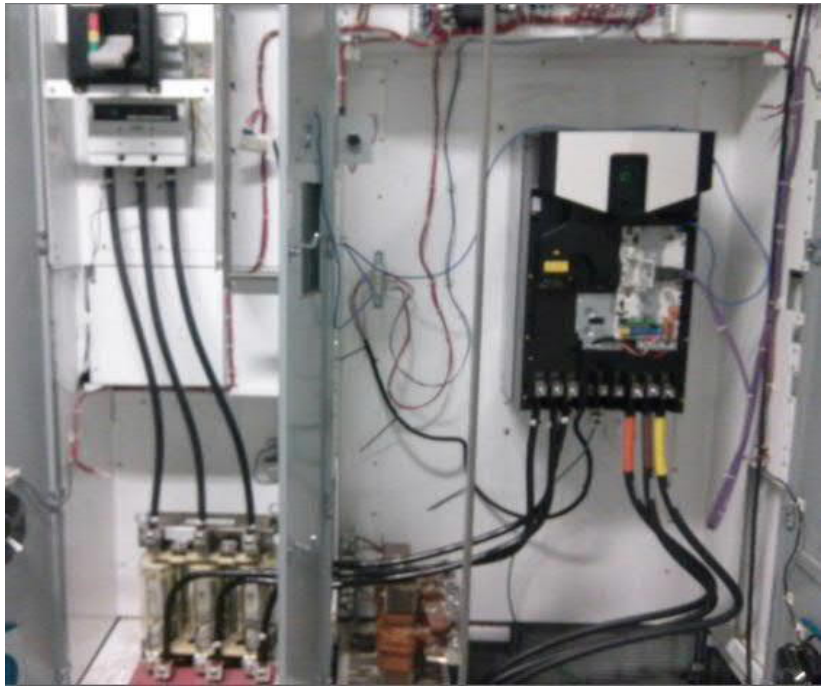


Lifting fan/motor/deck assembly as long as spreader bar is used to ensure the through rods are in pure tension

# Fan guard



# Drive installation



- 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.

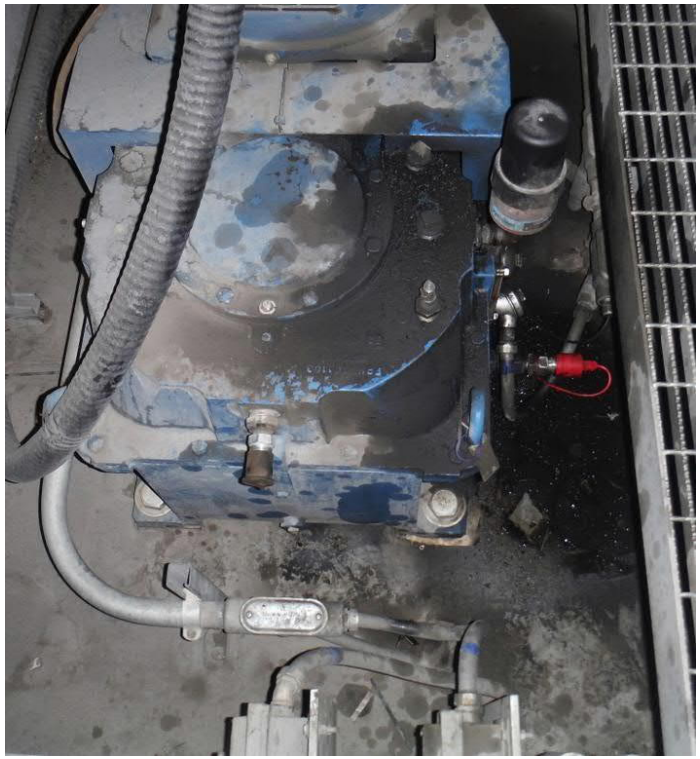
- Provides a “disconnect” for maintenance purposes.
- Not only disconnects the motor from the drive but also shorts the leads thereby preventing windmilling
- Utilizing the disconnect does not allow for trickle current functionality to be operational (space heaters)
- Able to stop unit from 75 rpm in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

# Advantages 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).

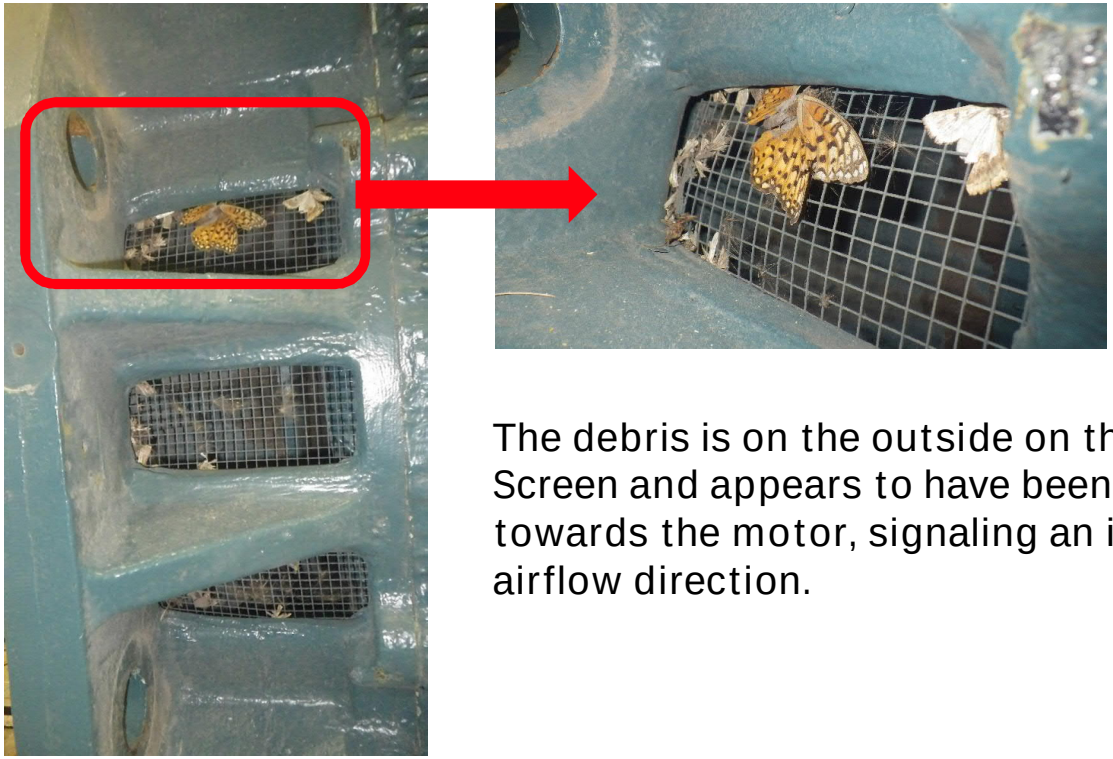
# Installation photos

# Typical motor and reducer drive installation



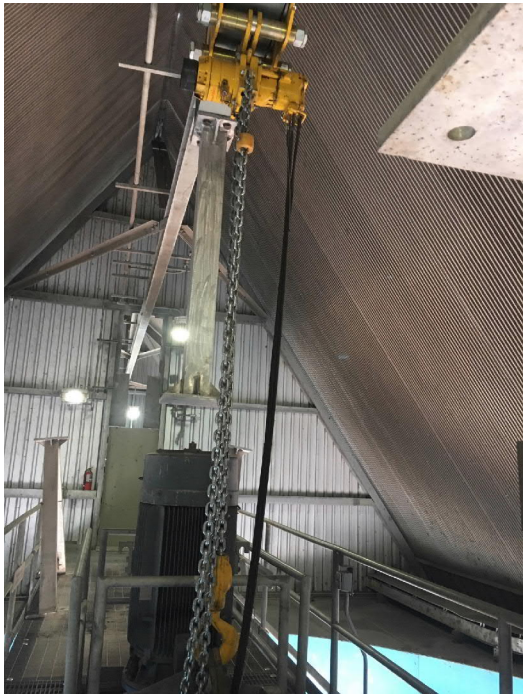
# Permanent magnet motor ready for installation, fan hub installed on shaft at motor factory

# Observations



The debris is on the outside on the Exhaust Screen and appears to have been sucked in towards the motor, signaling an incorrect airflow direction.

# Crane used for installatiopn



Changeout process took 24 hours once crane was on site

# Walkway

# replaced gearbox

# Direct drive motor

# Existing mounting plat was used for motor #1

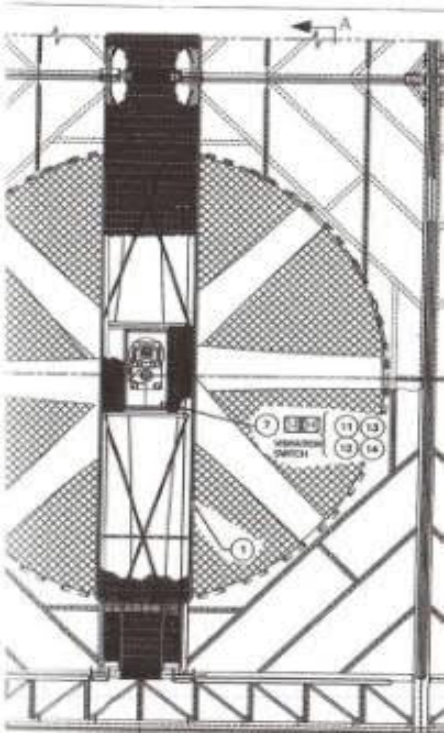
# Motor and fan being reattached

# Site team designed & fabricated lifting mechanism

# New mounting place fabricated for motor #2

# Motor #2 at location 4.1

# Installation challenges



| | |
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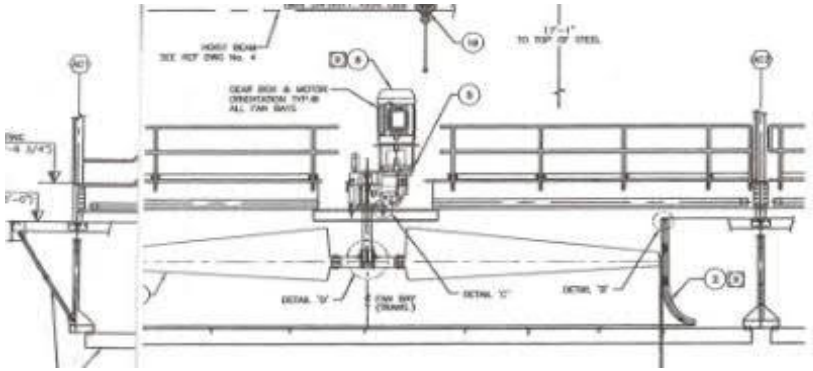
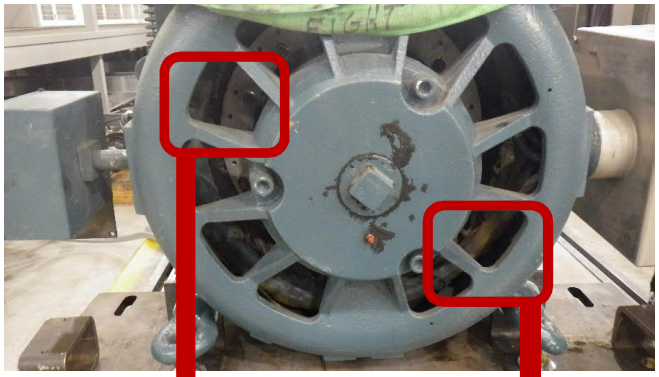
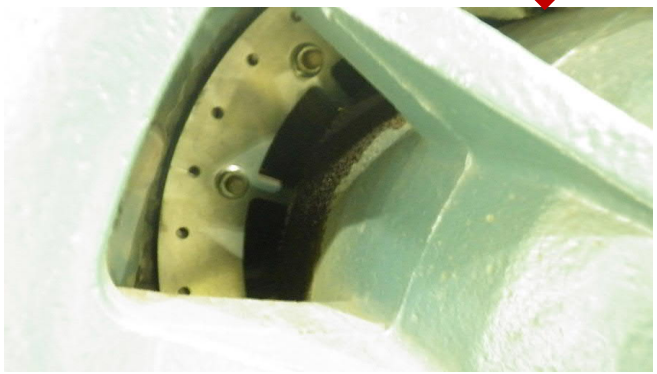
| Fan | 3000 lbs. |
| Total | 14,300 lbs. |

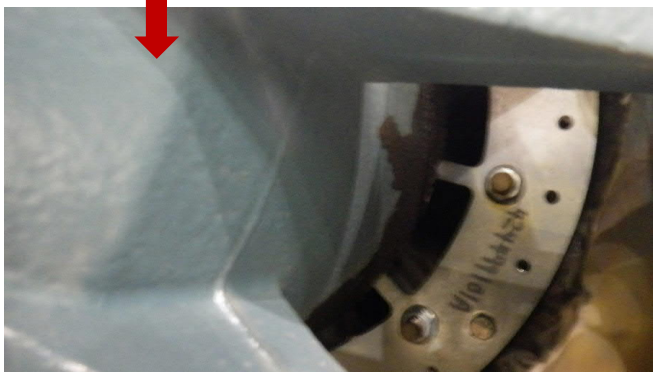


Lifting fan/motor/deck assembly as long as spreader bar is used to ensure the through rods are in pure tension

# Cleaner opposite drive end



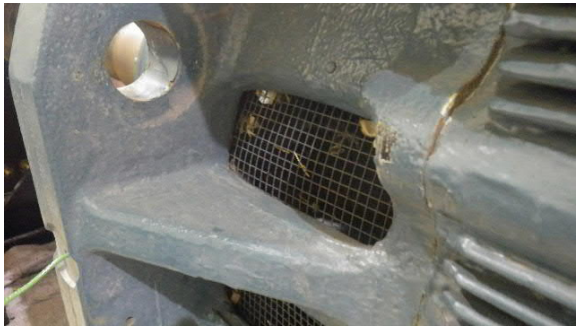




# Cleaner opposite drive end

## Before

## After

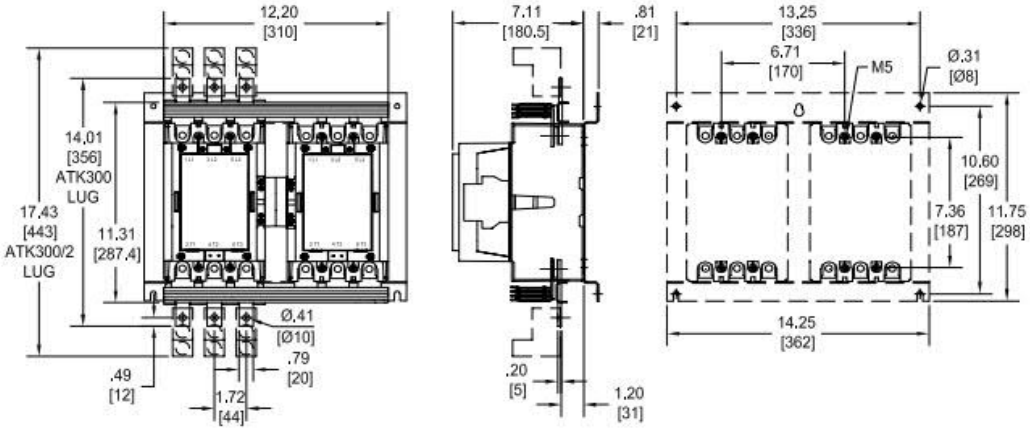


# Sound level data

| % 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 - 84 dba.
- Outside of ACC in walkway
  - Siemens was 82 – 82.5 dba
  - ABB was 81.5 dba
  - Siemens @ 6 ft – 87 dba (1.3)
  - Siemens @ 6 ft – 88 dba (1.2)
  - Siemens @ 3 ft – 90 dba (1.1)

# 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.

# 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.
- Crane used to install prototype units has been updated with chain hoist
- Retrofit changeout took (2) days both mechanical and electrical. Future installations will take 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 installed in 2017.
- Replaced standard steel fan guard with Kevlar net system. Significant 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.