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<thead>
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</thead>
<tbody>
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<td><strong>Docketed Date:</strong></td>
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</tbody>
</table>
REQUEST FOR STAFF APPROVED PROJECT MODIFICATION

ELK HILLS POWER PLANT

(99-AFC-1C)

By:
ELK HILLS POWER, LLC
CALIFORNIA RESOURCES CORPORATION

Submitted to:
CALIFORNIA ENERGY COMMISSION

November 18, 2015
REQUEST FOR STAFF APPROVED PROJECT MODIFICATION

ELK HILLS POWER PLANT

(99-AFC-1C)

1.0 INTRODUCTION

Elk Hills Power, LLC hereby requests staff approval of an insignificant project modification to the approved Elk Hills Power Project (EHPP). In accordance with Section 1769(a)(2) of the California Energy Commission (CEC) Siting Regulations, the proposed changes do not have the potential to have a significant effect on the environment and will not result in the change or deletion of a condition adopted by the CEC or cause EHPP to not comply with applicable laws, ordinances, regulations, and standards (LORS).

The project owner/operator submitting this application is Elk Hills Power, LLC. The permitted EHP facility is a natural gas-fired combined-cycle, cogeneration power generating plant. The plant is powered by two General Electric (GE) 7FA technology combustion turbine generators (CTGs). Exhaust gas from the CTGs is directed to two supplementary fired heat recovery steam generators (HRSGs) for the generation of high-pressure, intermediate pressure, and low-pressure steam that drives the steam turbine generator (STG). Supplementary firing (duct burner firing) capability is provided in each HRSG to generate additional steam for peak power production. The EHPP facility utilizes Selective Catalytic Reduction (SCR) systems for the control of NOx emissions and oxidation catalysts for the control of CO and VOC emissions. Fuel for the CTGs and duct burners is exclusively natural gas. A mechanical draft cooling tower provides heat rejection for the steam cycle. The cooling tower is comprised of six
cells and is equipped with high efficiency drift eliminators. One diesel-fired internal combustion engine is used to drive a fire water pump.

2.0 DESCRIPTION OF PROPOSED MODIFICATION (Sec. 1769(a)(2))

Elk Hills Power, LLC is requesting to install two 100% capacity vacuum pump skids to replace the present steam-jet based vacuum system. The system replacement would require a minor structural modification including a concrete slab and piping supports, and a building permit from the Kern County Building Department. A professional engineering stamped drawing are provided on Appendix A.

The new electric-motor-driven vacuum pump systems are an upgrade and are a more modern in-line system than current plant technology. This system is more effective at serving the intended function, and virtually trouble-free. The existing steam jet system has deteriorated and reduced operations reliability. The new vacuum pump system will improve operational reliability and reduce operational safety risk. The low maintenance on the new vacuum pump system should significantly reduce repairs and potential down time.

3.0 NECESSITY (Sec. 1769(a)(1)(B))

The proposed change is necessary because the existing vacuum pumps have deteriorated over time with use and due to corrosion/erosion, and have compromised EHPP’s power rating at times. The vacuum pumps will maintain constant vacuum pressure of the condenser, and are easier to troubleshoot, which will sustain reliable operation.

4.0 TIMING (Sec. 1769(a)(1)(C) and (D))

The facility has installed a vacuum system during the licensing proceeding. However, over the years the existing system degraded.
5.0 ANALYSIS OF THE EFFECT OF THE MODIFICATIONS ON THE ENVIRONMENT (Sec. 1769(a)(1)(E))

The changes will not cause any significant changes in the environment requiring mitigation. The changes do not undermine the assumptions, rationale, findings, or other bases of the final decision.

The area of installation is next to the steam turbine area where it was previously disturbed, see attached picture of the area where it will be installed. The concrete slab will be 2 feet deep, see attached drawing CRC-ELK-40-4031, which requires a minimal ground disturbance of the previously disturbed area.

The construction vehicles is approximately 5 vehicles and workers commute is during the normal business hour of 6AM – 4 PM. Approximately 12 workers working on this project for estimated length of three weeks.

The existing conditions on the certification that apply to this project is the VIS-1 to make the color of the equipment to match with the facility color.

6.0 COMPLIANCE WITH LAWS, ORDINANCES, REGULATIONS AND STANDARDS (LORS) (Sec. 1769(a)(1)(F))

The proposed modification does not have a significant effect with currently applicable LORS.

7.0 POTENTIAL EFFECTS ON PUBLIC AND NEARBY PROPERTY OWNERS (Sec. 1769(a)(1)(G and I))
The proposed equipment change is not anticipated to affect nearby property owners or parties in the application proceedings or the public.

8.0 LIST OF PROPERTY OWNERS (Sec. 1769(a)(1)(H))

A list of property owners 1,000 feet of the plant site has previously been provided to the Commission CPM.

9.0 SUMMARY OF REQUEST

As demonstrated above, the requested changes to the Elk Hills Power’s Conditions of Certification is not anticipated to have an adverse effect on the public or the environment. The change will not affect compliance with applicable LORS. Accordingly, Elk Hills Power requests that the Energy Commission Staff expedite review of this petition, and request Commission approval of the proposed modified conditions in accordance with Title 20 CCR Section 1769.

Dated: November 18, 2015

Respectfully Submitted,

Sonnie Pineda
Sr. Environmental Advisor
Elk Hills Power
APPENDIX A

DESIGN PLAN, STRUCTURAL DRAWING AND P&ID
# CRC VACUUM PUMP INSTALLATION

## GAS PLANT SITE PLAN

### DRAWING LIST

<table>
<thead>
<tr>
<th>SHEET NO.</th>
<th>DRAWING NO.</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRC-EUKH-40-4000-01</td>
<td></td>
<td>Cover Sheet &amp; Drawing Index</td>
</tr>
<tr>
<td>CRC-EUKH-40-4000-02</td>
<td></td>
<td>General Notes</td>
</tr>
<tr>
<td>CRC-EUKH-40-4000-03</td>
<td></td>
<td>Foundation Location Plan</td>
</tr>
<tr>
<td>CRC-EUKH-40-4000-04</td>
<td></td>
<td>Pipe Support Details</td>
</tr>
</tbody>
</table>

## LOCATION MAP

**PROJECT SITE**

**CALIFORNIA RESOURCES CORPORATION**

**OXY ELK HILLS**

**CRC VACUUM PUMP INSTALLATION**

**COVER SHEET & DRAWING INDEX**

**DRAWING NO. SHEET NO. SCALE**

**CRC-EUKH-40-4000 01 1 PICTURE**

**DRAWING DATE:** 10-22-15

**UPLOADED:** 10-22-15

**FILE LOCATION:** C:\DRAFT\01-001510-20150306\01-001510-20150306.png
CONDENSER EXHAUST SYSTEM P&ID

california resources

SIHI Pumps Ltd.
225 Speedvale Ave. West
Guelph, ON, Canada, N1H6L8

Nozzle: Size: Type: Service:
N1 6" 150# RF Inlet
N2 6" 150# RF Discharge
N3 1" FNPT Make-up
N4 1" 150# RF Drain
N5 2" 150# RF Cooling Water Supply
N6 2" 150# RF Cooling Water Return
N7 3/4" FNPT Discharge to Atmosphere
(1) SYSTEM DESCRIPTION
Each vacuum system will include the following main components;
- Liquid ring vacuum pump
- Recirculation pump
- Separator
- Plate & frame heat exchanger

(2) INITIAL VACUUM PUMP START
Liquid-ring vacuum pumps require a prime of water such that the liquid level in the pump casing is at shaft center-line. This prime of liquid sets up the liquid-ring seal through centrifugal action in the machine, so that compression can occur. Upon start-up of a dry system, the vacuum pump casing must first be filled with water to the shaft centerline.

(3) SUCTION LINE
The suction line consists of a pneumatic actuated butterfly valve which will allow compressible gas to flow to the liquid ring vacuum pump. The valve will have a limit switch to indicate an open or closed position. There is a differential vacuum switch used to control when the valve is opened or closed. Two vacuum switches are also mounted on the suction line to control the liquid ring pump motor and a solenoid valve in the service liquid line.

The final component in the suction line is a pressure indicator. The pressure indicator will monitor the vacuum level of the vacuum pump.

(4) DISCHARGE SEPARATOR TANK
(a) General:
The separator tank is of a 2-phase design. The two phases consist of: 1.) Process Gas, 2.) Liquid Water. Separation is achieved through baffling, and centrifugal action.

(b) Water Level:
The reservoir of each tank is equipped with a liquid level sight glass.

(c) Level Switches:
High and low level switch will be used to monitor the liquid level in the separator. If the water level falls below the low level switch a signal will be sent to the DCS to open the make-up solenoid valve. If the water level rises above the high level switch, a signal will be sent to the DCS to close the make-up valve.

(d) Pressure:
The tank is designed to operate near atmospheric pressure.

(e) Discharge Check Valve:
a discharge check valve is located downstream of the silencer. The check valve is held in place by two flange connections (customer to supply a flange connection to mate with the flange on the separator). The check valve will have a manual lever arm which will allow an operator to manually close the valve off. By doing this, the discharged air flow will be redirected to the air flowmeter. It is important that a manual ball valve is opened before closing the manual check valve.

(f) Air Flowmeter:
an air flowmeter is used to check the amount of air leakage within the entire condenser exhauster system. Moisture can accumulate inside the air flowmeter. It is important to drain the liquid out by opening up a manual valve at the bottom of the flowmeter.

(5) SERVICE LIQUID LINE
The complete service liquid line runs from the bottom of each separator tank up to the service water supply connection on the vacuum pump. A recirculation pump will be used to move the liquid from the separator tank through the plate and
frame heat exchanger and eventually to the liquid ring vacuum pump. When the vacuum pump motor starts, there is a delay of 3 seconds before the recirculation pump starts. This will prevent any over filling of the liquid ring vacuum pump during startup. A pressure indicator with isolation valve will be located downstream of the recirculation pump to monitor the pressure level discharging from the pump. A manual ball valve will be used to control the amount of flow moving to the liquid ring vacuum pump.

Downstream of the heat exchanger will be a temperature indicator. The temperature indicator will monitor the temperature of the service liquid coming out of the heat exchanger.

Depending on the vacuum level of the liquid ring vacuum pump, the amount of service liquid flowrate must be controlled. To achieve this, orifice plates will be used to dictate the required amount of flow. Service liquid flow will be re-directed through orifice two by closing an actuated pneumatic solenoid valve. When vacuum levels fall below 5” Hg abs, vacuum switch mounted on the suction line will send a signal to the customer’s DCS to open the service liquid solenoid actuated pneumatic ball valve. An orifice plate will control the flowrate through this line. Service liquid flow will now be at its maximum flowrate (flowing through both orifice plates). When the vacuum level increases to 5.6” Hg abs, the vacuum switch will close the service liquid solenoid actuated pneumatic ball valve. This will reduce the service liquid flowrate to the original flow conditions.

(6) MAKE-UP LINE

The make-up line can be used to “prime” the pump during initial fill-up. Two manual ball valves are used to open or close this port pending on the usage. The make-up line can also be use to keep a steady level of service liquid in the separator tank. A y-strainer is added to this line to keep any large foreign particles out of the vacuum system which can cause damage to the system components.

(7) SPRAY LINE

Also part of the service liquid line is a spray line. The spray nozzle is located at the suction line upstream of the vacuum pump. A spray nozzle is used to condense and cool the vapor (inlet stream).

(8) START-UP

Hogging:

The initial startup of both vacuum pumps will be required to evacuate the condenser. There will be one primary pump and one secondary pump. The primary pump will be on all the time. The secondary pump will auto start once the primary pump trips.

When the vacuum pump starts, there is a slight delay (< 2 sec) before the pneumatic actuated butterfly valves will open allowing vacuum to be pulled in the condenser. The delay is caused by the differential vacuum switch which requires a delta P of <1” Hg to trip (causing the associated butterfly valve to open). The condenser pressure will go from atmospheric pressure (29.92” Hg abs) to deep vacuum. Once the vacuum pressure reaches the set pressure, the secondary pump vacuum switch will send a signal to the customer’s DCS to shutdown the motor for the secondary pump. The shutdown of the motor will close the associated pneumatic butterfly valve. The customer’s DCS must incorporate this interlock between the LRVP motor and the associated butterfly valve during the shutdown of the motor only (this shutdown should not occur during startup). Only the primary pump (Pump 1) will be on.

Holding:

To maintain the vacuum level only one pump is required. If there is a leak within the condenser and the vacuum level starts to increase (moving towards atmospheric), the vacuum switch will send a signal to the customer’s DCS to start the secondary vacuum pump. With the secondary pump motor in operation, the associated pneumatic actuated butterfly valve will not automatically open. A differential vacuum switch will monitor the vacuum level upstream and downstream of the butterfly valve. To open the butterfly valve, a differential upstream and downstream of the valve must be less than 1” Hg abs. Once that is achieved, the differential vacuum switch will send a signal to the customer’s DCS to open the pneumatic actuated butterfly valve. The vacuum level will now move deeper in vacuum. Once the set point of the vacuum switch is reached, the vacuum switch will trip sending a signal back to the customer’s DCS to shutdown the secondary pump motor.

It is important to know that the secondary pump was on during the holding operation. SIHI recommends an alarm signal in the customer’s DCS to inform that an issue has occurred which caused the vacuum level to change. Further investigation by a technician on where the leak is coming from must be performed.
(9) LRVP – TRB SYSTEM

SIHI’s TRB (Total Recirculation System) is designed to conserve the use of liquid used for utilities. Fluid that is discharged from the LRVP will collect in the separator and recycled back to the LRVP service liquid port. A plate and frame heat exchanger will be required to maintain an appropriate service liquid temperature. Adequate cooling liquid flow and temperature will prevent any issues with the system process and with the pump (refer to proposal for temperatures and flow).

(10) SHUTDOWN

To shutdown the vacuum system during operation, the vacuum pressure must return back to atmospheric pressure (when operating in deep vacuum). The vacuum pump must be power down to allow the pressure of the system to return back to atmospheric pressure. Make sure the manual ball a valve in the make-up line is closed along with the pneumatic actuated ball valve. Open the manual ball valve in the drain line to dispose of any service liquid in the system (if required).
CALIFORNIA RESOURCES COMPANY

VACUUM PUMPS INSTALLATION

ELK HILLS, CALIFORNIA

STRUCTURAL CALCULATIONS

FOR

PIPE SUPPORT FOUNDATIONS
(NON-ANCHOR SUPPORT)
## Table of Contents

<table>
<thead>
<tr>
<th></th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Governing Codes and Criteria</td>
<td>3</td>
</tr>
<tr>
<td>Seismic Coefficients</td>
<td>3</td>
</tr>
<tr>
<td>Foundation and Soils Information</td>
<td>4</td>
</tr>
<tr>
<td>Loading</td>
<td>5</td>
</tr>
<tr>
<td>Steel Adequacy Check</td>
<td>6</td>
</tr>
<tr>
<td>Drilled Pier Adequacy Check</td>
<td>7</td>
</tr>
</tbody>
</table>
GOVERNING CODES & DESIGN CRITERIA

California Building Code (CBC), 2013 edition
International Building Code (IBC), 2012 edition
ASCE / SEI 7-10

SEISMIC COEFFICIENTS

Non-Building Structure: Pipe Support

MCE Spectral Response Accelerations, SRA

Risk Category: II (All Other Facilities)

Site Soil Classification: D

Site Coefficients:

Adjusted SRA Parameters:

Design SRA Parameters:

Seismic Design Category: D

Structure Type: Inverted Pendulum Type Structure

Table 15.4-2, ASCE 7-05

Period of the Structure:

Design Response Spectrum:

Seismic Response Coefficient:

Strength Level Base Shear:

Vertical Component

WIND LOAD: Pipe Supports

Risk Category:

Basic Wind Speed:

Exposure Category:

Height of Structure from Grade, z:

Velocity Pressure Exposure Coefficient:

Topographic Factor:

Directionality Factor:
WIND LOAD: Pipe Supports (Continued)

Gust Effect Factor:  
Velocity Pressure:  
Force Coefficients:  
Strength Level Wind Pressure:

By Inspection, Seismic Load Governs

FOUNDATION & SOIL INFORMATION

Concrete Strength fc': 4000 psi  
Reinforcement Strength fy: 60000 psi  
Unit weight of concrete, \( \gamma_c = \) 150 pcf  
Unit weight of Soil, \( \gamma_s = \) 110 pcf

Foundation Type:

Footing
Allowable Soil Pressure 1500 psf DL + LL
Min Pipe Load, \( P_p = \) 40 psf Gravity Pipe Load

\[ q_v = 0.00256 \cdot K_v \cdot K_f \cdot V^2 \]

\[ f = q_v \cdot G \cdot C_f \]

G = 0.85  
\( q_v = \) 25.0 psf  
\( C_f = \) 1.20  
f = 26 psf
T-TYPE SUPPORT TYPE II

LOADING CRITERIA

Thermal load is applied as 0.3 times the pipe gravity load on support.

Transverse seismic load is applied considering a guide spacing of 60 feet maximum.

Non-Anchor pipe support, operating or seismic

\[ H_{\text{trans}} = 0.30 \times W_{\text{pipe}} \]

Seismic transverse load ASD Level load

\[ = 0.68 \text{ kips} \]

Consider a 6" load eccentricity with respect to centerline of column.

Hydrotest Load  Operating Load  Dead + Seismic Transverse (Guide)
Design Load: **GRAVITY LOAD + THERMAL (OPERATING)**

**Steel Pipe Support**

- **H**<sub>max</sub> = 10.40 ft
- Support Width, **W** = 2.00 ft
- Distance between supports, **S** = 20.00 ft

- Posts Diam., **Ø** = 6.00 in
- Thickness, **t** = 0.28 in Std.
- **Ø**<sub>Ø</sub> = 6.63 in
- **Ø**<sub>t</sub> = 0.67 in
- **S**<sub>x</sub> = **S**<sub>y</sub> = 8.50 in³
- Weight = 19.0 lb/ft
- Steel Area, **A** = 5.58 in²
- **F**<sub>y</sub> = 35.00 ksi
- Steel/Steel Friction Factor, µ = 0.30

**Min. Supported Pipes Loads**

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<tr>
<th>Ø or Width (in)</th>
<th>#</th>
<th>Weight (lb/ft or psf)</th>
<th>Pipe/Tray Content</th>
<th>Total (k)</th>
<th>V (k)</th>
<th>Ve (k)</th>
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**Code Check**

- Column and Beam
- ASD Design

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<tr>
<th>X</th>
<th>Member</th>
<th>Shape</th>
<th>Code Check</th>
<th>Lo...</th>
<th>L</th>
<th>L.</th>
<th>L.</th>
<th>D</th>
<th>L.</th>
<th>Pnc/e</th>
<th>Ptctom</th>
<th>Mnylo</th>
<th>Mnzlo</th>
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<tr>
<td>1</td>
<td>M1</td>
<td>PIPE 6.0</td>
<td>.182</td>
<td>0</td>
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<th>Joint Label</th>
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<th>Y[in]</th>
<th>Z[in]</th>
<th>X Rotat...</th>
<th>Y Rotat...</th>
<th>Z Rotat...</th>
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<tr>
<td>1</td>
<td>1</td>
<td>N4</td>
<td>-0.77</td>
<td>-0.14</td>
<td>-3.17</td>
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<td>N4</td>
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<td>0.091</td>
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<td>7.66e-3</td>
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</table>
Foundation

See previous pages
Axial Load, P = 1230 lbs
Lateral Load, V = 560 lbs
Moment, M = 6093 lbs-ft

Pedestal Width, b = 0.00 ft
Pedestal Height, h = 0.00 ft
Weight of Ped, Wp = 0 lbs

Try Fdn Length, L = 22.50 ft
Try Fdn Width, D = 18.50 ft
Fdn Thickness, t = 2.00 ft
Weight of Fdn, Wf = 124875 lbs

P = P + Wp + Wf = 126105 lbs

Overturning Force @ Bottom of Footing
Mo = M + V (h + t)
Mo = 7213 lbs-ft

\[ e = \frac{Mo}{P} = 0.06 \text{ ft} \]
\[ a = \frac{D}{2} - e = 0.00 \text{ ft} \]
\[ A = L \times D = 416.25 \text{ sf} \]
\[ S = \frac{L \times D^2}{6} = 1283.44 \text{ ft}^3 \]

Soil Bearing Pressure, SBP
SBP = \( \frac{P}{A} + \frac{Mo}{S} \)
SBP = 308.58 psf

SBP_{allow} = 2000 psf DL + LL + Seismic (Soils Report)

D/C = \( \frac{SBP}{SBP_{allow}} \) < or = 1.0
D/C = \[ 0.15 < 1.0, \text{ OK} \]

Safety Factor Against Overturning, SF
SF = \( \frac{Mr}{Mo} \) > or = 1.5
Mr = 0.9P D / 2 = 1049824 lbs-ft resisting moment

SF = 145.55 > 1.0, OK

Use 22.5 ft x 18.50 ft x 2.00 ft Footing
By inspection, provide #5 @ 12" max., o.c. rebar, top and bottom, both directions
Base Plate

Design Load
See Support Reactions from RISA Analysis & Design in Appendix

\[ P_u = 1.11 \text{ k} \quad \text{Compression} \]
\[ V_u = 1.56 \text{ k} \]
\[ M_u = 15.55 \text{ k}\cdot\text{ft} \]

Try Base Plate Dimension

Width, \( B = 14.00 \text{ in} \)
Length, \( N = 14.00 \text{ in} \)
Edge Dist., \( E = 1.50 \text{ in} \)
Thicknes, \( t_p = 1.00 \text{ in} \)

Depth or Diameter of Column, \( D = 6 \text{ in} \)
Concrete Strength, \( f_c' = 4.00 \text{ ksi} \)
Plate Yield Strength, \( F_y = 36 \text{ ksi} \)

Area of base plate, \( A_1 = B \cdot N = 196 \text{ in}^2 \)
Area of conc. support, \( A_2 = 342 \text{ in}^2 \)
\[ A_2 / A_1 = 1.74 \quad \text{OK} \]

Eccentricity, \( e = M_u / P_u = 168.60 \text{ in} \)

Design bearing stress
\[ F_p = 0.85 \phi_c f_c' (A_2 / A_1)^{0.5} < \text{or} = 1.7 \phi_c f_c' \]
\[ F_p = 2.69 \text{ ksi} \quad \text{OK} \]
\[ A' = (N/2) - E = 5.50 \text{ in} \]
Let \( f_p = F_p = 2.69 \text{ ksi} \)
\[ f' = f_p B N' / 2 = 235.79 \text{ k} \]
\[ A = \{ f' + \text{or} - k_1 \} / (f_p B / 3) \]
\[ f_1 = 0.00 \text{ ksi} \]

Tension per Anchor Bolt, \( N_{ua} \)
\[ T_u = (f_p A B / 2) - P_u \]
\[ T_u = 14.66 \text{ k} \]
\[ N_{ua} = T_u / \text{Number of anchors per side} \]
\[ N_{ua} = 7.33 \text{ k} \]
**Base Plate (cont)**

Shear per anchor bolt, \( V_{ua} = \frac{V_u}{\text{Number of Anchor Bolts Resisting Shear}} \)

\[ V_{ua} = 0.39 \text{ k} \]

**Bending of Base Plate**

**Compression side**

\[ N - \delta D = 9.20 \text{ in} \]

\[ M_{pl} = 68.15 \text{ k - in} \]

Assume effective width, \( b = 14 \text{ in} \)

Thickness of Base Plate

\[ t_p = \left( \frac{4 M_{pl}}{b 0.9F_y} \right)^{0.5} = 0.78 \text{ in} < t_p \text{ provided, OK} \]

**Tension side**

Distance of anchor to edge of column, \( d = 2.65 \text{ in} \)

Assume effective width, \( b = 5 \text{ in} \) conservative

\[ M_{pl} = N_{ua} x d \]

\[ M_{pl} = 19.43 \text{ k - in} \]

Thickness of Base Plate

\[ t_p = \left( \frac{4 M_{pl}}{b 0.9F_y} \right)^{0.5} = 0.69 \text{ in} < t_p \text{ provided, OK} \]

**Use**

14.00 in x 14.00 in x 1.00 in thick base plate

**Weld column to base plate using full penetration groove weld**
Anchor Bolt

Material Properties and Dimensions

- Anchor Bolt Yield Strength, \( f_{ya} = 36 \text{ ksi} \)
- Anchor Bolt Tensile Strength, \( f_{ut} = 60 \text{ ksi} \)
- Spacing of Anchor Bolts, \( s = 11.50 \text{ in} \)
- Edge Distance of Anchor Bolts, \( c_a = 24.00 \text{ in} \)
- Concrete Strength, \( f_{c'} = 4.00 \text{ ksi} \)
- Length of anchor bolt, \( L = 18.00 \text{ in} \)
- Anchor Bolt Projection, \( p = 5.00 \text{ in} \)
- Number of Anchor in group action?
  - no
- Embedment of anchor bolt, \( h_e = L - p - t_n - 0.5 = 11.75 \text{ in} \)

Concrete cover at the top = 2.00 in

Steel Strength in Tension, \( N_{sa} \)

Try 0.75 in diameter ASTM F1554 GR 36 Threaded Rod

\[ A_{ste,N} = 0.334 \text{ si} \quad \text{AISC Table 7-17} \]

\[ N_{sa} = A_{ste,N} f_{ut} = 20.04 \text{ k} \]

\[ \phi N_{sa} = 15.03 \text{ k} \]

\[ n \phi N_{sa} = 15.03 \text{ k} \]

Concrete Breakout Strength in Tension, \( N_{cb} \)

\[ N_c = 16 \lambda_{c} f_{c'}^{0.5} h_e^{5/3} \quad \text{for 11 in} < h_e < 25 \text{ in} \]

\[ N_c = k_c \lambda_{c} f_{c'}^{0.5} h_e^{1.5} \quad \text{for all other values of} \ h_e \]

\[ N_c = 61.45 \text{ k} \]

\[ A_{NCo} = 9 h_e^2 = 1243 \text{ si} \]

\[ n A_{NCo} = 1243 \text{ si} \]

\[ A_{Nc} = (3 h_e)(3 h_e) = 1243 \text{ si} \quad < n \text{ Anco, OK} \]

Reference: ACI 318-11 Appendix D
Anchor Bolt (cont)

Concrete Breakout Strength in Tension, $N_{cb}$ (cont)

$N_{cb} = A_{Nc} \psi_{C,N} \psi_{CP,N} N_b / A_{Nco}$  
for single anchor or group of anchors where $s > or = 3 h_{ef}$

$N_{cbg} = A_{Nc} \psi_{C,N} \psi_{CP,N} N_b / A_{Nco}$  
for group of anchors where $s < 3 h_{ef}$

$N_{cb} = 61.45 \, k$  
$\phi N_{cb} = 43.02 \, k$  
$\phi = 0.70$ Condition B  
for cracked concrete

Pullout Strength in Tension, $N_{pn}$

Try Heavy HEX Nut for 0.75 in Threaded Rod or Bolt

Area of Heavy HEX Nut, $A_n = \frac{3^{0.5}}{2} W^2 = 1.353 \, si$  
$W = 1.250 \, in$  
Area of Rod or Bolt, $A_b = \pi d_o^2 / 4 = 0.442 \, si$  
$d_o = 0.75 \, in$

$A_{brg} = A_n - A_b = 0.911 \, si$

$N_p = 8 A_{brg} f_{c'} = 29.16 \, k$  
$N_{pn} = \psi_{CP} N_p = 29.16 \, k$  
$\psi_{CP} = 1.0$ cracked concrete

$\phi N_{pn} = 20.41 \, k$  
$\phi = 0.70$ Condition B

Concrete Side-Face Blowout Strength in Tension, $N_{sb}$

By inspection, concrete side-face blowout strength will not govern the design since the anchors are not in close proximity to the edge of the concrete ($c_a > 0.4 \, h_{ef}$) and / or due also to the presence of confining reinforcements.

Governing Concrete Tensile Strength, $0.75 \phi N_{nc}$

$0.75 \phi N_{nc} = 15.31 \, k > N_{ua}$, OK

Governing Steel Tensile Strength, $\phi N_{sa}$

$\phi N_{sa} = 15.03 \, k > N_{ua}$, OK

Steel Strength in Shear, $V_{sa}$

Base Plate Over Grout Pad? yes  
$V_{sa} = 0.8 \times 0.60 A_{se,v} f_{uta} = 9.62 \, k$

$\phi V_{sa} = 6.25 \, k$  
$\phi = 0.65$ for ductile steel element

Concrete Breakout Strength in Shear, $V_{cb}$

Note: The following strength calculations are for anchors loaded towards the edge of the concrete member. For anchors that are not loaded towards the edge of the concrete or for anchors that are very far from the edge of the concrete or where anchor reinforcements are provided, the concrete breakout strength in shear will not govern or not applicable.

$V_{cb} = A_{Vc} \psi_{ed,V} \psi_{C,V} \psi_{h,V} V_b / A_{Vco}$  
for single anchor

$V_{cbg} = A_{Vc} \psi_{ed,V} \psi_{C,V} \psi_{h,V} V_b / A_{Vco}$  
for group of anchors
Anchor Bolt (cont)

\[ A_{vc0} = 4.5 c_{a1}^2 = 2592 \text{ si} \]

\[ n_v A_{vc0} = 2592 \text{ si} \]

\[ h_a = 24.00 \text{ in } \text{thickness of concrete member} \]

\[ Avc = 2 (1.5 c_{a1}) (\text{ha}) \]

\[ A_{vc} = 1728 \text{ si} \]

\[ < n Avco, \text{OK} \]

\[ s_1 = s = 11.50 \text{ in} \]

\[ V_b \text{ shall be the smaller of} \]

\[ V_b = \left[ 7 \left( \frac{l_e}{d_b} \right)^2 \left( d_b \right)^{0.5} \right] \lambda_a \left( f_{c'} \right)^{0.5} c_{a1}^{1.5} \]

\[ V_b = 9 \lambda_a \left( f_{c'} \right)^{0.5} c_{a1}^{1.5} \]

\[ V_b = 66.93 \text{ k} \]

\[ V = 66.93 \text{ k} \]

\[ \phi V_{cb} = 38.25 \text{ k} \]

\[ \phi = 0.70 \text{ Condition B} \]

Concrete Pryout Strength in Shear, \( V_{cp} \)

\[ V_{cp} = k_{cp} N_{cp} \text{ for single anchor} \]

\[ V_{cp} = k_{cp} N_{cp} \text{ for group of anchors} \]

\[ V_{cp} = 122.91 \text{ k} \]

\[ \phi V_{cp} = 86.03 \text{ k} \]

\[ \phi = 0.70 \text{ Condition B} \]

Governing Concrete Shear Strength, \( 0.75 \phi V_{nc} \)

\[ 0.75 \phi V_{nc} = 28.69 \text{ k} \]

\[ > Vua, \text{OK} \]

Governing Steel Shear Strength, \( \phi V_{sa} \)

\[ \phi V_{sa} = 6.25 \text{ k} \]

\[ > Vua, \text{OK} \]

Check Interaction Equation (anchor is loaded in tension and shear)

Steel Strength Interaction

\[ 0.2 \times \phi V_{sa} = 1.25 \text{ k} \]

\[ > Vua, \text{SDC C and Higher} \]

\[ \phi N_{sa} = 15.03 \text{ k} \]

\[ > Nua, \text{OK} \]

\[ 0.2 \times \phi N_{sa} = 3.01 \text{ k} \]

\[ < Nua, \text{See Below Interaction} \]

\[ \phi V_{sa} = 6.25 \text{ k} \]

\[ * \]

\[ (N_{ua} / \phi N_{sa}) + (V_{ua} / \phi V_{sa}) \leq 1.20 \]

\[ (N_{ua} / \phi N_{sa}) + (V_{ua} / \phi V_{sa}) = 0.55 < 1.2, \text{OK} \]
Anchor Bolt (cont)

Concrete Strength Interaction

\[
\begin{align*}
0.2 \times 0.75 \phi V_{nc} &= 5.74 \text{ k} > V_{ua} \\
0.75 \phi N_{nc} &= 15.31 \text{ k} > N_{ua}, \text{ OK} \\
0.2 \times 0.75 \phi N_{nc} &= 3.06 \text{ k} < N_{ua}, \text{ See Below Interaction} \\
0.75 \phi V_{nc} &= 28.69 \text{ k} *
\end{align*}
\]

\[
\begin{align*}
(N_{ua} / 0.75 \phi N_{nc}) + (V_{ua} / 0.75 \phi V_{nc}) &\leq 1.20 \\
(N_{ua} / 0.75 \phi N_{nc}) + (V_{ua} / 0.75 \phi V_{nc}) &\leq 0.49 < 1.2, \text{ OK}
\end{align*}
\]

Use 0.75 in diameter ASTM F1554 GR 36 Threaded Rod x 18 in long with 12 in Embedment (4 total per base plate)