PACIFIC
ENVIRONMENTAL
GROUP INC.

93 AUG 27 AM 11:36

August 25, 1993
Project 305-79.01

Mr. Robert Cave
Permit Services Division
Bay Area Air Quality Management District
939 Ellis Street
San Francisco, California 94109

Re: BAAQMD Authority to Construct Number 10111
Shell Service Station
285 Hegenberger Road at Leet Drive
Oakland, California
WIC No 204-7620-1502

Dear Mr. Cave:

On behalf of Shell Oil Company, Pacific Environmental Group, Inc. (PACIFIC) is performing environmental services at the referenced site. This letter serves as a written notification of our intent to initiate operation of a soil vapor extraction (SVE) system on Monday, August 30, 1993. The SVE system will utilize internal combustion (A-1) for Precurser Organic Compound abatement. PACIFIC will monitor and sample the influent and effluent vapors for each of the first 3 days of operation, thereafter every 2 weeks, per permit requirements. Results of the first 3 days operations analysis shall be submitted in a report to be received by the Bay Area Air Quality Management District by September 29, 1992.

If you have any question or require addition information, please do not hesitate to call.

Sincerely,

Pacific Environmental Group, Inc.

Mark W. Boyd

Mark W. Boyd
Staff Engineer

cc: Mr. Dan Kirk, Shell Oil Company
Mr. Barney Chan, Alameda County Health Care Services Agency

2025 Gateway Place, Suite 440, San Jose, California 95110 * (408) 441-7500 FAX (408) 441-7539
620 Contra Costa Blvd., Suite 209, Pleasant Hill, California 94523 (510) 825-0855 FAX (510) 825-0882

BAY AREA AIR QUALITY MANAGEMENT DISTRICT

February 22, 1993

FEB 26 1993
PACIFIC ENVIRONMENTAL GROUP, INC

Pacific Environmental Group, Inc.
2025 Gateway Place, Suite 440
San Jose, CA 95110

Attention: Justin Hawkins

Application Number: 10111
Equipment Location:
285 Hagenberger Road
Oakland, CA 94621

Gentlemen:

This is your Authority to Construct the following:

S-1 Soil Vapor Extraction System consisting of a 250 max cfm positive displacement vacuum blower, and ancillary equipment, abated by A-1, A-2, or A-3 and A-4 arranged in series:

A-1 VR Systems, Model V4, Internal Combustion Engine
A-2 Therm Tech, VAC 25, 250 scfm Catalytic Oxidation Unit
A-3 Westates, VSC 1200, 1,000 lb capacity Carbon Adsorption Vessel
A-4 Westates, VSC 1200, 1,000 lb capacity Carbon Adsorption Vessel

SEE ATTACHED CONDITIONS #9018

Notification

Please notify the District by letter at least **three days** before the initial operation of the equipment is to take place so that we may observe the equipment in operation and verify conformance with the Authority to Construct. Operation includes any **start-up** of the source for testing or other purposes. Operation of equipment without prior written notification to the District or beyond the start-up period without a Permit to Operate may result in enforcement action.

Start-Up Period

After receipt of the start-up letter required above, this Authority to Construct authorizes operation during the start-up period from the date of initial operation noted in your start-up letter until the Permit to Operate is issued, up to a maximum of 60 days. **All conditions (specific or implied) of the Authority to Construct are in effect during the start-up period.**

Fees

District Regulation 3 requires a fee for each new Permit to Operate. You will be invoiced upon receipt of your start-up letter. No permits will be issued until all outstanding fees are paid.

939 ELLIS STREET • SAN FRANCISCO, CALIFORNIA 94109 • (415) 771-6000 • FAX (415) 928-8560

Implied Conditions

In the absence of specific permit conditions to the contrary, the throughputs, fuel and material consumptions, capacities, and hours of operation described in your permit application will be considered maximum allowable limits. A new permit will be required before any increase in these parameters, or change in raw material handled, may be made.

Expiration

In accordance with Regulation 2-1-407, this Authority to Construct expires two years from the date of issuance unless substantial use of the authority has begun.

Correspondence

Please include your application number with any correspondence with the District regarding this matter. If you have any questions on this matter, please call **Robert E. Cave, Air Quality Engineer Assistant at (415) 749-5114.**

Very truly yours,

Milton Feldstein
Air Pollution Control Officer

by John A Swanson
Permit Services Division

JAS:REC:me
attachment

type '?' for SHOWPERM commands >> con t 9018

COND# 9018 --

1. Precursor Organic Compound (POC) emissions from Source S-1 shall be abated by either Abatement device A-1, I.C. Engine, or A-2, Catalytic Oxidizer, or A-3 & A-4, two 1,000 pound activated carbon vessels arranged in series, during all periods of operation.
2. The POC destruction efficiency of Abatement devices A-1, A-2, A-3, and A-4 shall be maintained at a minimum of 98.5% by weight for inlet concentrations greater than or equal to 3000 ppmv. For inlet concentrations below 3000 ppmv and greater than or equal to 1000 ppmv, a minimum destruction efficiency of 97% shall be maintained. For inlet concentrations below 1000 ppmv, a minimum destruction efficiency of 90% shall be maintained. The minimum destruction efficiency of 90% shall be waived if total emissions from the operation are less than 1 pound per day VOC and benzene emissions are less than 0.02 pounds per day.
3. A-1 shall be properly maintained and kept in good operating condition at all times. Influent flow shall not exceed 250 scfm. In no event shall benzene emissions to the atmosphere exceed 0.10 pounds per day.
4. To determine compliance with Conditions 2 and 3, the operator of this equipment shall:
   a. Analyze inlet gas stream to determine the flow rate and concentration of total VOC's present for each of the first three days of operation. Thereafter, the inlet gas shall be analyzed to determine the flow rate and concentration of total VOC's once every two weeks.
   b. Analyze exhaust gas to determine the concentration of benzene and total VOC's present for each of the first three days of operation. Thereafter, the exhaust gas shall be analyzed to determine the concentration of benzene once every two weeks.
   c. Calculate the benzene emission rate in pounds per day based on the exhaust gas analysis and the operating exhaust flow rate. The soil vapor flow rate shall be decreased, if necessary, to demonstrate compliance with Conditions 2 and 3.
   d. Submit to the District the test results and emission calculations for the first three days of operation within one month of start-up. All source test methods used shall be subject to the prior approval of the Source Test Section of the District Technical Division.
5. The operator of this source shall maintain the following information in a District-approved log for each month of operation of A-1:
   a. days of operation
   b. inlet and exhaust flow rate
   c. inlet and exhaust sampling date
   d. analysis results
   e. calculated emissions of benzene in pounds per day.

   Such records shall be retained and made available for inspection by the District for two years following the date the data is recorded.

I.C.E System

6. Once influent concentrations fall below 3000 ppmv, the abatement device may be changed from A-1, I.C. Engine to A-2, Catalytic Oxidizer. Such changeover shall take place only after written notification of same has been received by the District. Operation of the source shall then be subject to the conditions which follow.

7. A-2 shall be properly maintained and kept in good operating condition at all times. Influent flow shall not exceed 250 scfm. In no event shall benzene emissions to the atmosphere exceed 0.10 pounds per day. At no time shall the minimum operating temperature of A-2 be less than 600 degrees Fahrenheit. CAT-OX system

8. To determine compliance with Condition Number 7, A-2 shall be equipped with continuous measuring and temperature recording instrumentation consisting of at least 1 temperature probe in A-2 and at least one recording device, which will continuously record temperature.

9. The measuring and recording instrumentation to be installed and the specific placement within A-2 in condition number 8, is subject to the prior approval of the Source Test Section of the District Technical Division.

10. The temperature data collected from the temperature recorder shall be maintained in a file which shall be available for District inspection for a period of at least 2 years following the date on which such data are recorded.

11. Within ten days of abatement changeover from A-1 to A-2, the operator of this source, shall conduct an efficiency test to determine the weight percent reduction of Precursor Organic Compound (POC) emissions through A-2. As part of this test, the inlet and outlet exhaust to A-2 shall be analyzed to determine the Total Precursor Organic Compounds (POC's) and Benzene present and their respective concentrations. All test results shall be provided to the District within 30 days after testing has occurred. All source test methods used shall be subject to the prior approval of the Source Test Section of the District Technical Division.

12. The operator of this source shall maintain the following records for each day of operation of A-2:
   a. Hours and time of operation.
   b. Each emission test, analysis or monitoring results logged in for the day of operation they were taken.
   c. Analysis results for any catalyst plugs removed from the bed to determine remaining life of the catalyst.

   Such records shall be retained and made available for inspection by the District for two years following the date the data is recorded.

13. Once influent concentrations fall below 1000 ppmv, the abatement device may be changed from A-2, Catalytic Oxidizer to A-3 & A-4, carbon canisters arranged in series. Such changeover shall take place only after written notification of said abatement change has been received by the District. Operation of the source shall then be subject to the conditions which follow. CARBONS System

14. The second to last carbon bed, A-3, shall be changed out with unspent carbon upon the detection of 10% of the inlet stream concentration to the carbon bed as measured by a flame-ionization detector (OVA-FID) or other method approved in writing by the APCO.

CARBONS (CON'T)

15. The last carbon bed, A-4 shall be changed out with unspent carbon upon detection of breakthrough or 10 ppmv (measured as C1) as measured with a flame-ionization detector (OVA-FID) or other method approved in writing by the APCO.

16. The limits set forth in Conditions # 14 and # 15 shall apply to non-methane hydrocarbon emissions. To determine the presence of methane in the exhaust stream, a reading shall be taken with and without a carbon filter tip fitted on the OVA-FID probe. Concentrations measured with the carbon filter tip in place shall be considered methane for the purpose of these permit conditions.

17. The operator of this source shall monitor with an OVA-FID or other method approved in writing by the APCO at the following locations:
    a. At the exhaust of Source S-1; the inlet to carbon bed A-3.
    b. At the exhaust of A-3; the inlet to carbon bed A-4.
    c. At the outlet of carbon bed A-4; the carbon bed that is last in series prior to venting to the atmosphere.

18. These monitor readings shall be recorded in a monitoring log at the time they are taken. The monitoring results shall be used to estimate the frequency of carbon change out necessary to maintain compliance with conditions number 14 and 15.

19. To maintain compliance with conditions number 14 and 15, the monitoring shall be conducted on a daily basis. The operator of this source may propose for District review, based on actual measurements taken at the site during operation of the source, that the monitoring schedule be changed based on the decline in organic emissions and/or the demonstrated breakthrough rates of the carbon vessels. Written approval by the District must be received by the applicant prior to a change to the monitoring schedule.

20. The operator of this source shall maintain the following information in a District approved log for each month of operation of A-3, and A-4:
    a. The hours of operation.
    b. Each monitor reading or analysis result for the day of operation they are taken.
    c. The number of carbon beds removed from service.

    Any exceedance of conditions number 14 and/or 15 shall be reported to the Permits Division with the log as well as the corrective action taken. In addition, an exceedance of conditions number 14 and/or 15 shall be submitted to the District Enforcement Section at the time it occurs. The submittal shall detail the corrective action taken and shall include the data showing the exceedance as well at the time of occurrence.

21. The operator shall maintain a file containing all

measurements, records and other data that are required to be collected pursuant to the various provisions of this conditional Authority to Construct/Permit to Operate. All measurements, records and data required to be maintained by the applicant shall be retained for at least two years following the date the data is recorded.

22. Upon final completion of the remediation project, the operator of Source S-1 shall notify the district within two weeks of decommissioning the operation. CLOSURE

ATTACHMENT C

APPROVED BUILDING PLANS

3057901

FILE COPY

RECEIVED
APR 29 1993
PACIFIC ENVIRONMENTAL GROUP, INC.

Interim Remedial System Design Plans

Shell Service Station
285 Hegenberger Road at Leet Drive
Oakland, California
WIC No 204-5508-5504
Revision 1

APPROVED
CITY OF OAKLAND
Inspectional Services Dept
Building Inspection
(Elec. & Mech. Not Check.

PACIFIC
ENVIRONMENTAL
GROUP, INC.

2025 Gateway Place, Suite 440
San Jose, California 95110
(408) 441-7500
Fax (408) 441-7539

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Pleasant Hill, California 94523
(510) 825-0855
Fax (510) 825-0882

Interim Remedial System Design Plans

Shell Service Station
285 Hegenberger Road at Leet Drive
Oakland, California
WIC No 204-5508-5504
Revision 1

Prepared for

Shell Oil Company

Prepared by

Pacific Environmental Group, Inc.
2025 Gateway, Suite 440
San Jose, California 95110

B9301239

Project 305-79.01

PACIFIC ENVIRONMENTAL GROUP INC.

FIRE EXTINGUISHERS ~~AND EXIT SIGNS~~ AS REQUIRED BY FIRE MARSHAL.

FIGURES AND APPENDIX

FIGURES

APPENDIX

PACIFIC ENVIRONMENTAL GROUP, INC.

SHELL SERVICE STATION
285 Hegenberger Road at Leet Drive
Oakland, California

INTERIM REMEDIALSYSTEM DESIGN PLANS

PROJECT: 305-79.01 | DATE: 4-5-93

REGISTERED PROFESSIONAL ENGINEER
ROBERT K. WENZLAU
No. 37395
EXP. 6-30-96
CIVIL
STATE OF CALIFORNIA

REVISION	DESCRIPTION	DATE	APPROVED
0	ISSUED FOR PERMITS	3-30-93	
1	REVISION TO INCLUDE SEISMIC BRACING (FIGURES 11, 12 AND APPENDIX B)	4-5-93	

CONSTRUCTION NOTES

1.0 SCOPE

1.1 Current project is to install a soil remedial system at the referenced site (APN 42-4425-18-2). The remedial system will consist of the following elements: (1) five soil vapor extraction wells, (2) soil vapor extraction and treatment equipment, and (3) below grade conveyance piping to transport extracted soil vapor to the soil vapor extraction and treatment equipment compound.

1.2 Parties involved in this project: (1) Owner - Shell Oil Company, (2) Engineer - Pacific Environmental Group, Inc., and (3) Contractor.

2.0 GENERAL NOTES

2.1 All work shall be performed and completed in accordance with all Federal, State, and local building codes.

2.2 Engineer shall provide building, and air discharge permits. Contractor shall be responsible for obtaining all other permits.

2.3 Contractor shall be responsible for verifying all field dimensions with Engineer before beginning work. Any conflicts with details and notes shall be noted at this time.

2.4 Contractor shall arrange and schedule all inspections.

2.5 Contractor shall install equipment and appurtenances in accordance with respective manufacturers installation manuals.

2.6 Contractor shall submit a Site Safety Plan to Engineer 5 days prior to beginning work. Site Safety Plan shall be in accordance with U.S. Department of Labor, 29 CFR 1910.

2.7 New 120/240 volt, 100 amp, single phase, temporary electrical service shall be installed in accordance with Oakland and Pacific Gas and Electric (PG&E) standards and codes. New service shall be to an overhead service periscope attached to the equipment compound wall. Contractor shall install temporary service in accordance with PG&E's minimum requirements (green book).

2.8 Concrete shall have maximum water:cement ratio (gallons:sack) of 5:1 and shall have a minimum compressive strength of 2,500 psi.

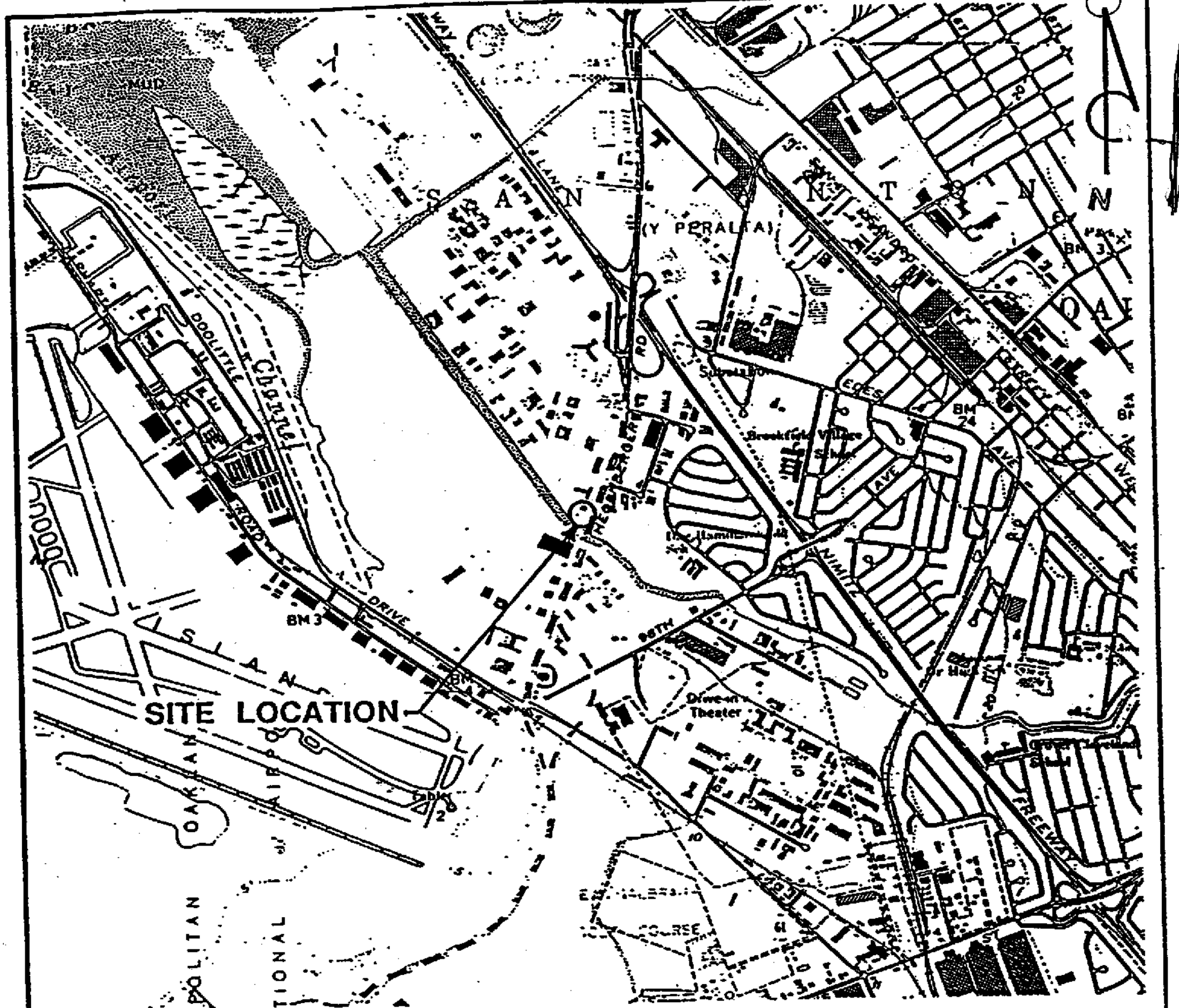
3.0 PIPING

3.1 All PVC pipe shall be solvent welded in accordance with Caltrans Section 20-2.15B(1) except where noted.

3.2 Above ground soil vapor conveyance pipe shall be attached to unistrut (or equivalent) at 6 foot spacing. Use unistrut P1119 pipe clamp (or equivalent). Conveyance pipe shall be strapped loosely to facilitate thermal expansion.

3.3 All utility pipe and conduit routed within treatment area shall be attached to unistrut (or equivalent) at 5 foot spacing.

3.4 Contractor shall paint all above ground utility pipe and conduit machine grey. Contractor shall clearly label pipe with flow direction.



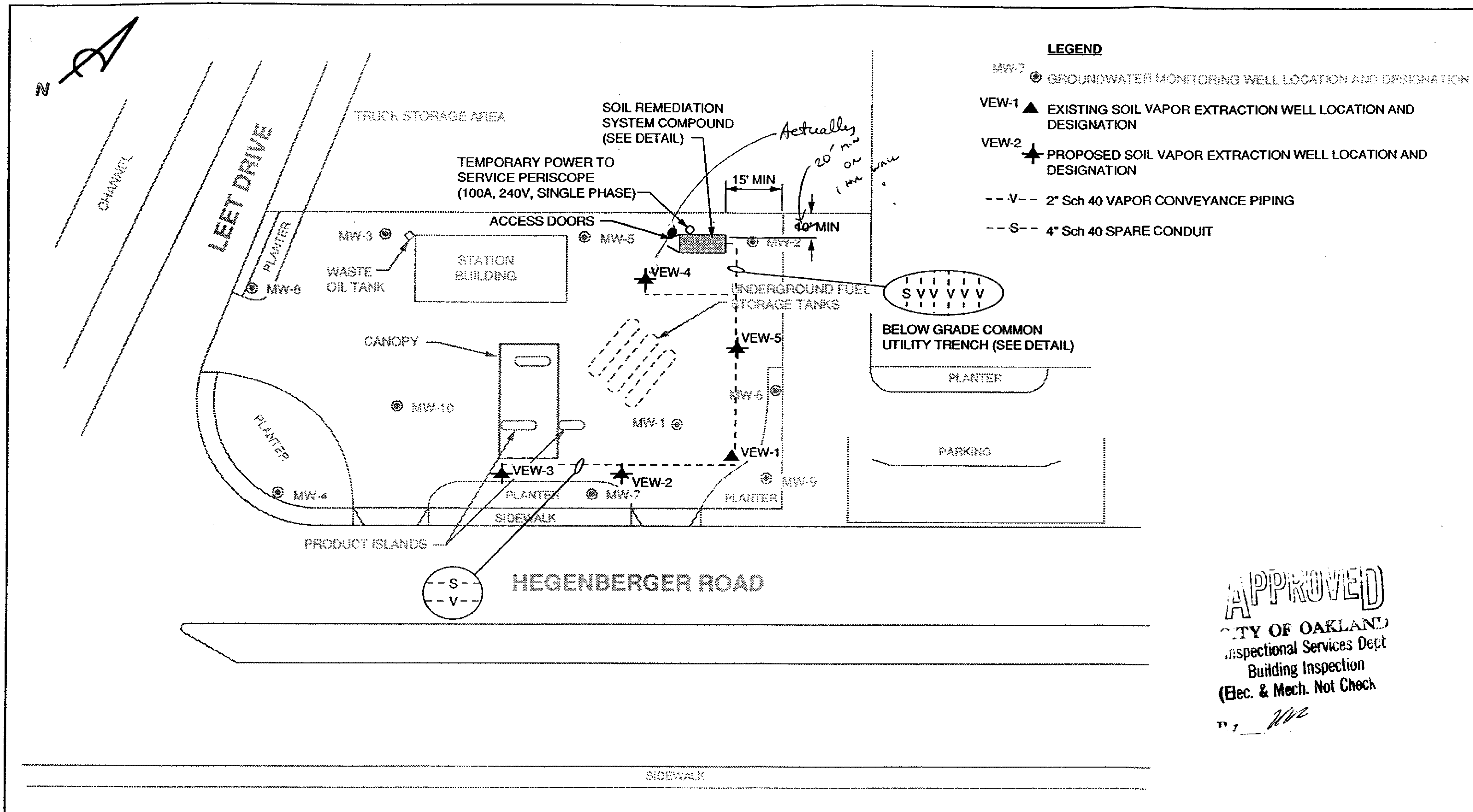
QUADRANGLE LOCATION

REFERENCES:
USGS 7.5 MIN. TOPOGRAPHIC MAP
TITLED: SAN LEANDRO, CALIFORNIA
DATED: 1959 REVISED: 1980
TITLED: OAKLAND EAST, CALIFORNIA
DATED: 1959 REVISED: 1980

SCALE

2000 0 2000 FEET

PACIFIC ENVIRONMENTAL GROUP INC.	SHELL SERVICE STATION 285 Hegenberger Road at Leet Drive Oakland, California SITE LOCATION MAP	FIGURE: 1 PROJECT: 305-79.01



PACIFIC ENVIRONMENTAL GROUP, INC.

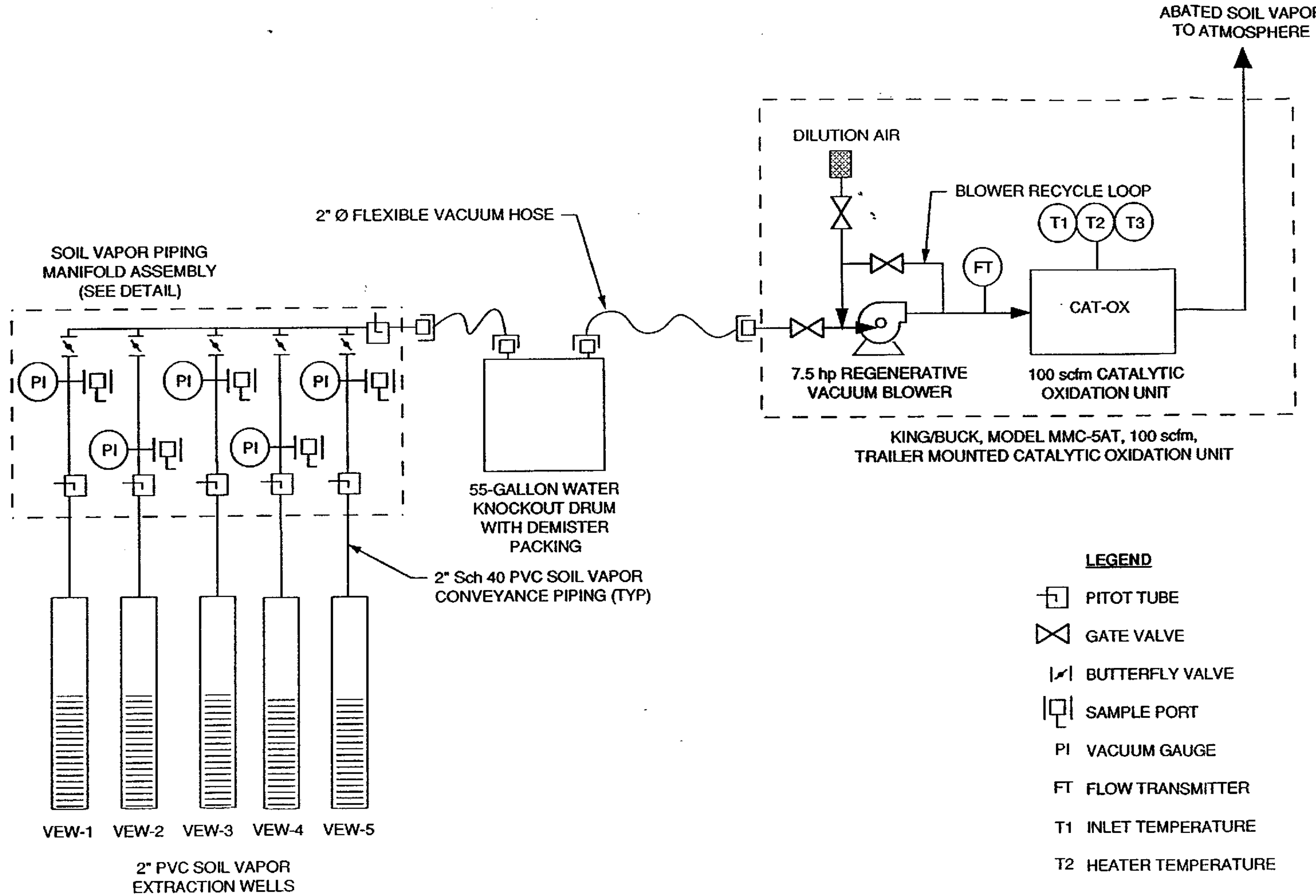
SCALE

0 40 80 FEET

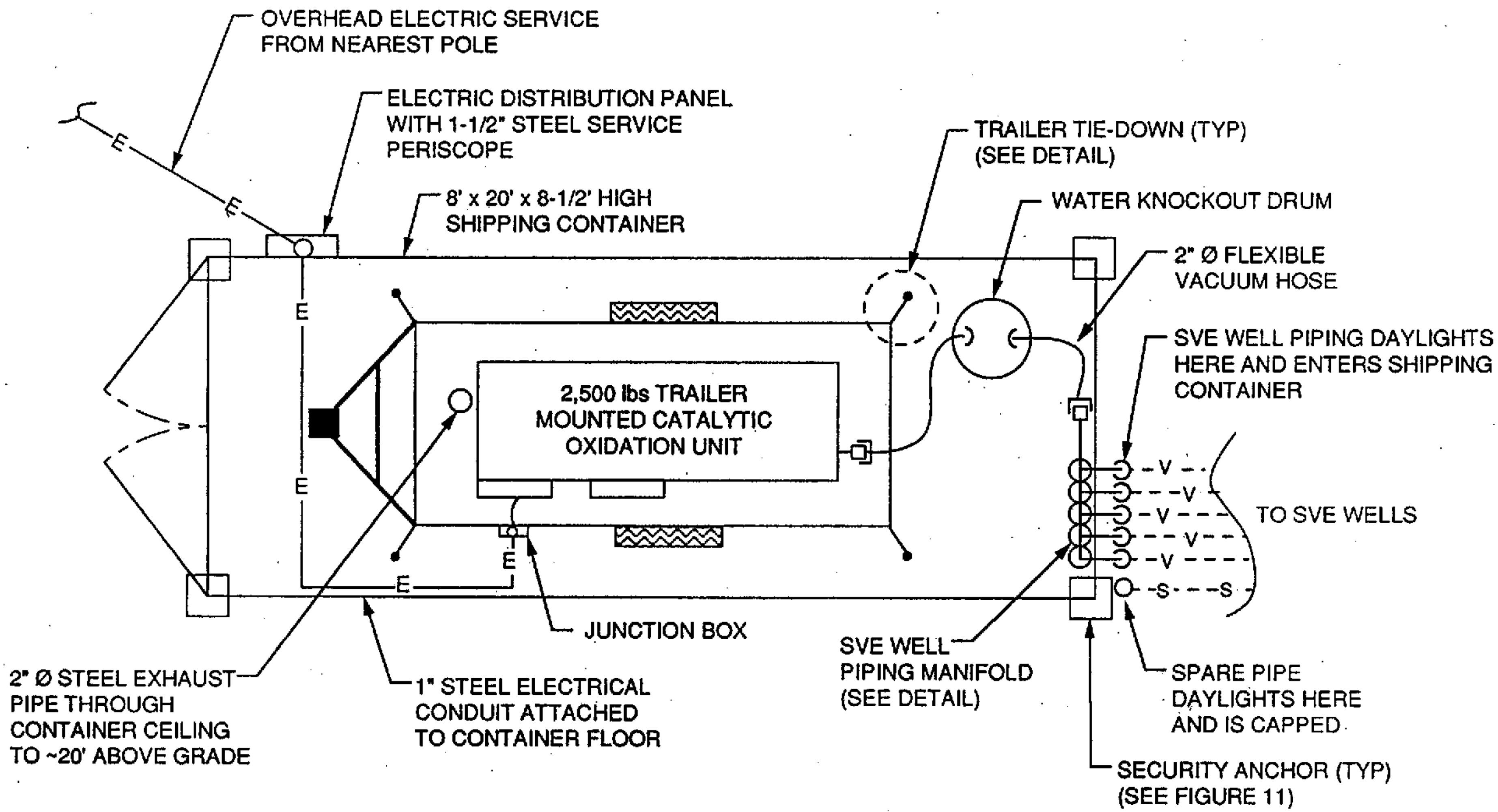
SHELL SERVICE STATION
285 Hegenberger Road at Leet Drive
Oakland, California

SITE PLAN

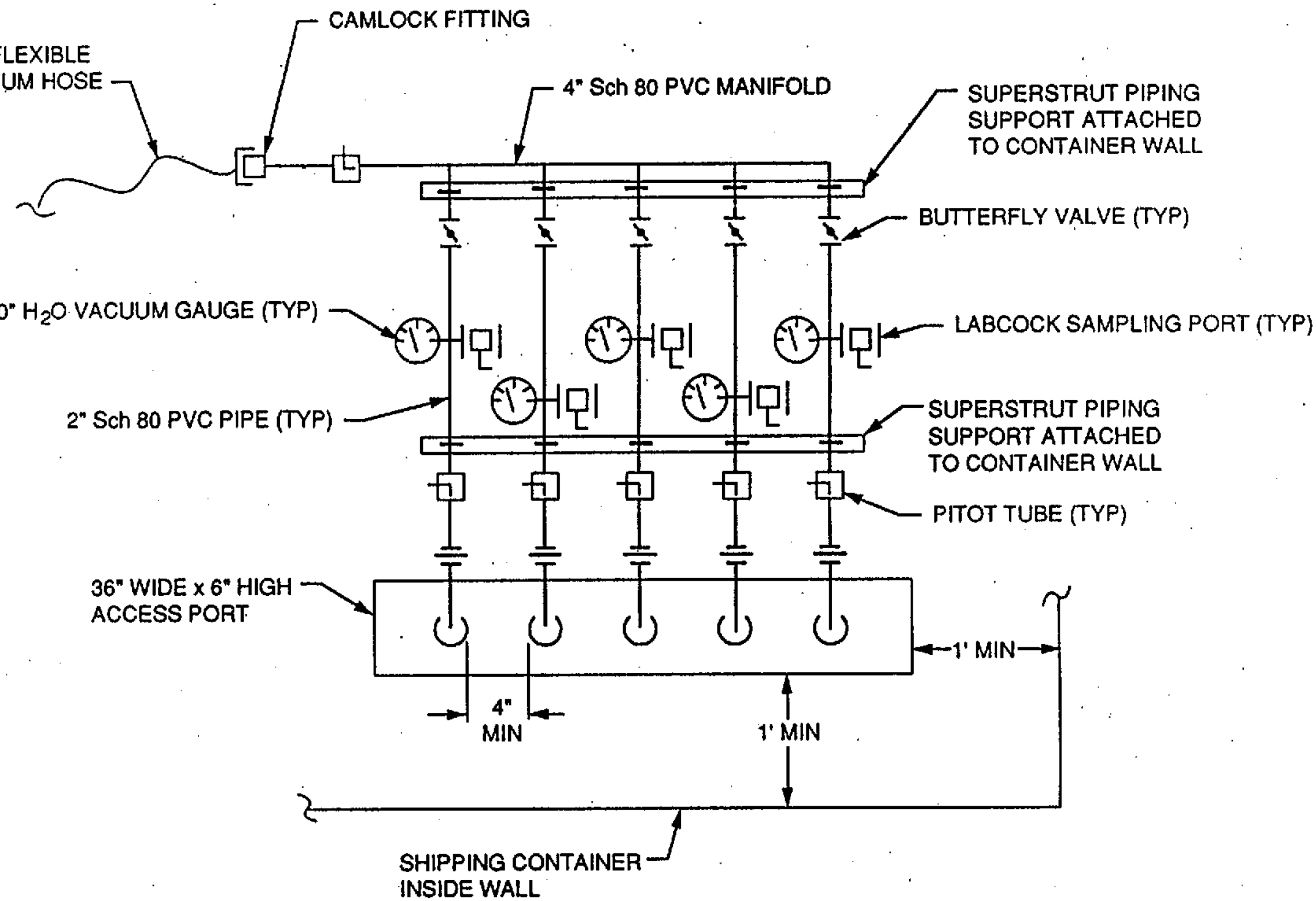
FIGURE: **2**
PROJECT: 305-79.01



PACIFIC ENVIRONMENTAL GROUP, INC.	NO SCALE	SHELL SERVICE STATION 285 Hegenberger Road at Leet Drive Oakland, California SVE PROCESS FLOW DIAGRAM	FIGURE: 3 PROJECT: 305-79.01



PACIFIC ENVIRONMENTAL GROUP, INC.	**SHELL SERVICE STATION** 285 Hegenberger Road at Leet Drive Oakland, California	FIGURE: 4
	SOIL REMEDIATION SYSTEM COMPOUND	PROJECT: 305-79.01



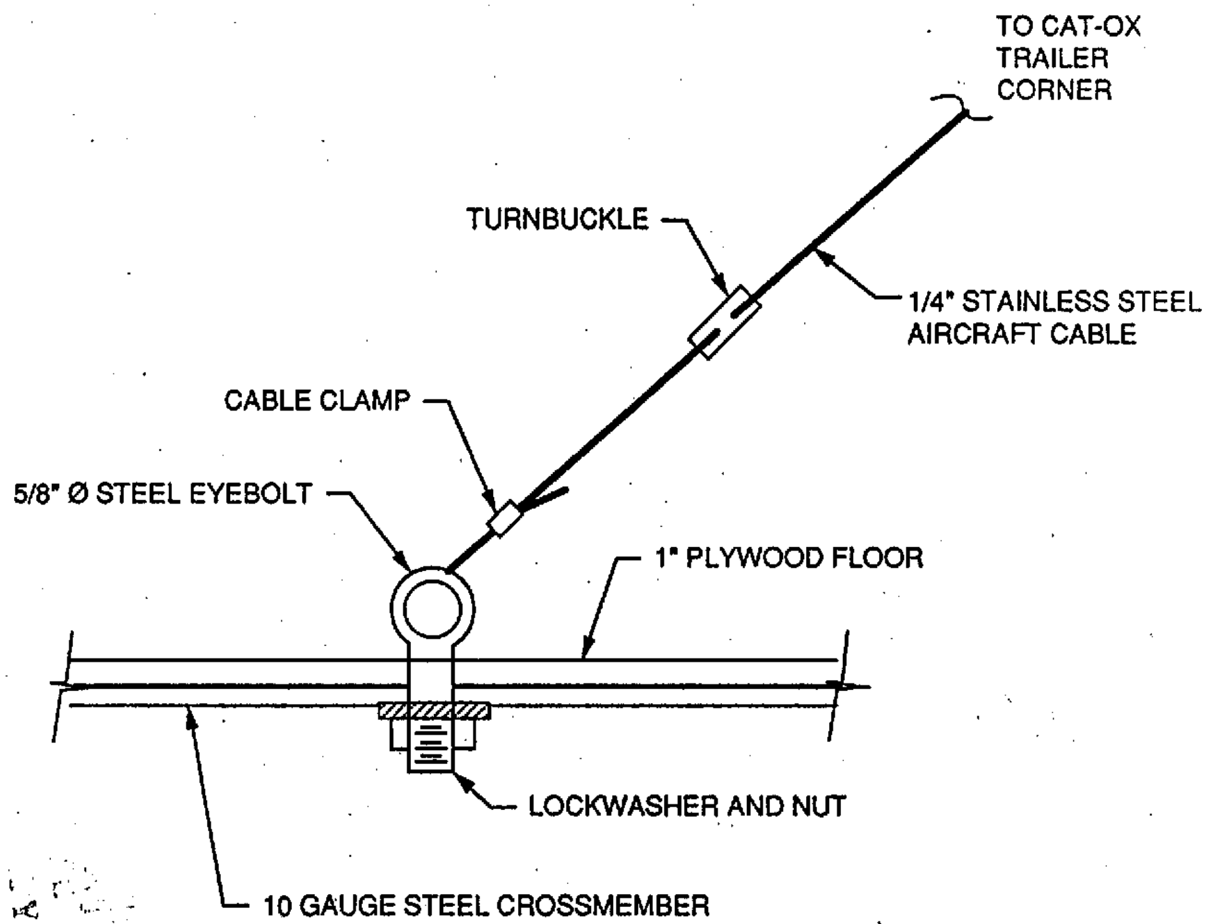
PACIFIC ENVIRONMENTAL GROUP, INC.

SHELL SERVICE STATION
285 Hegenberger Road at Leet Drive
Oakland, California

SVE PIPING MANIFOLD ASSEMBLY

FIGURE: 5

PROJECT: 305-79.01



NOT TO SCALE

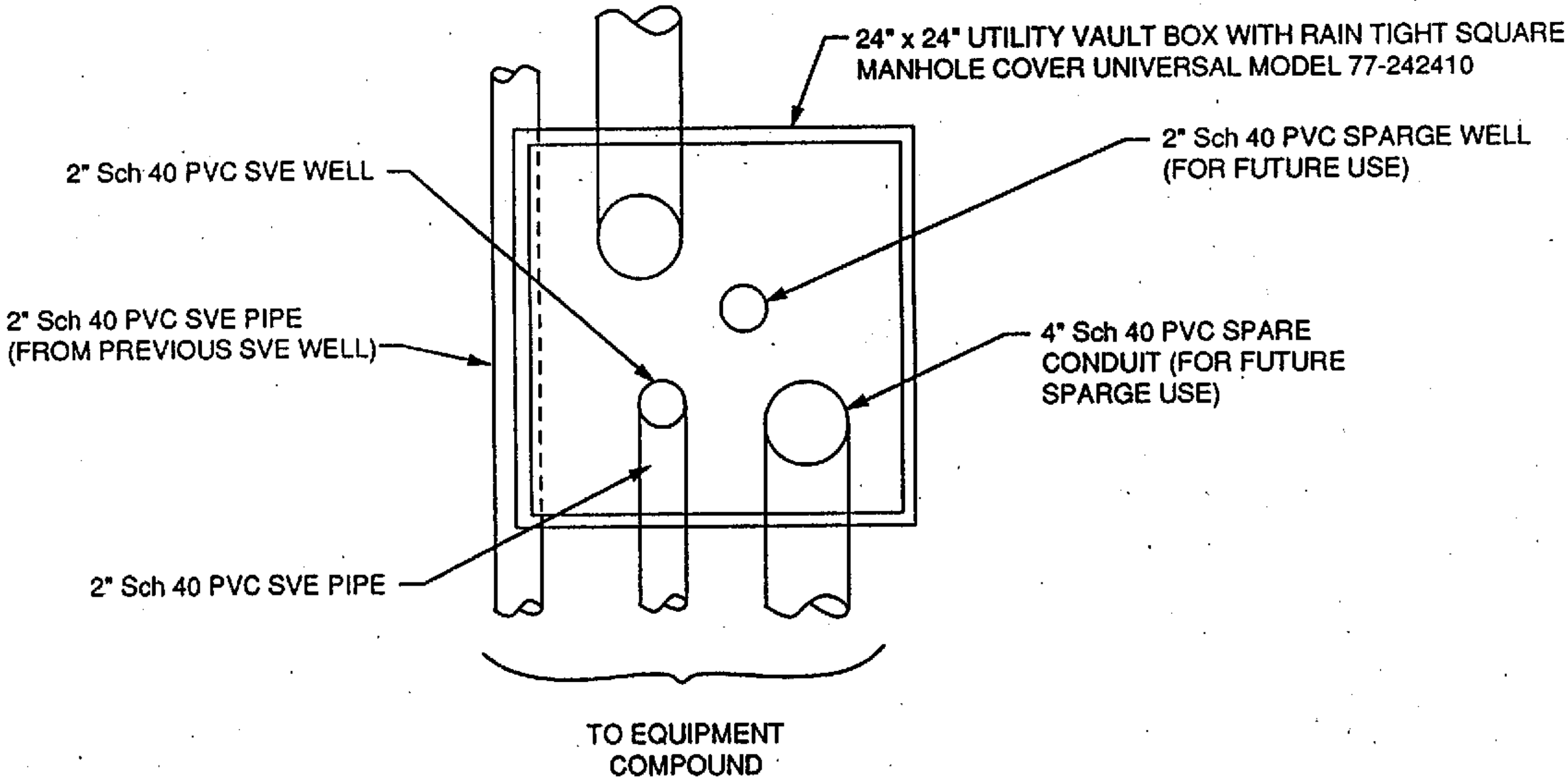
PACIFIC ENVIRONMENTAL GROUP, INC.

SHELL SERVICE STATION
285 Hegenberger Road at Leet Drive
Oakland, California

TRAILER SECURITY ANCHOR

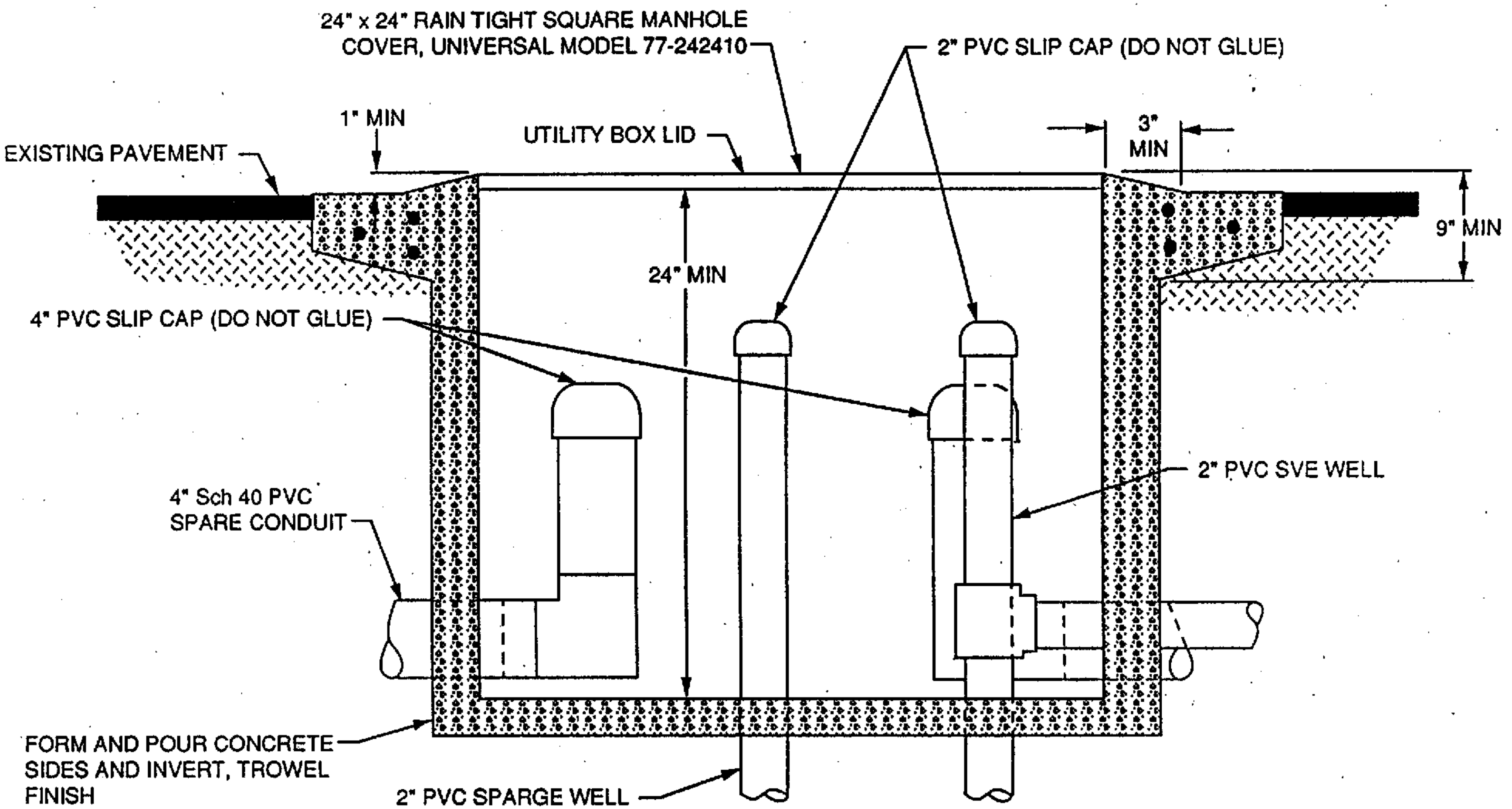
FIGURE: 6

PROJECT: 305-79.01



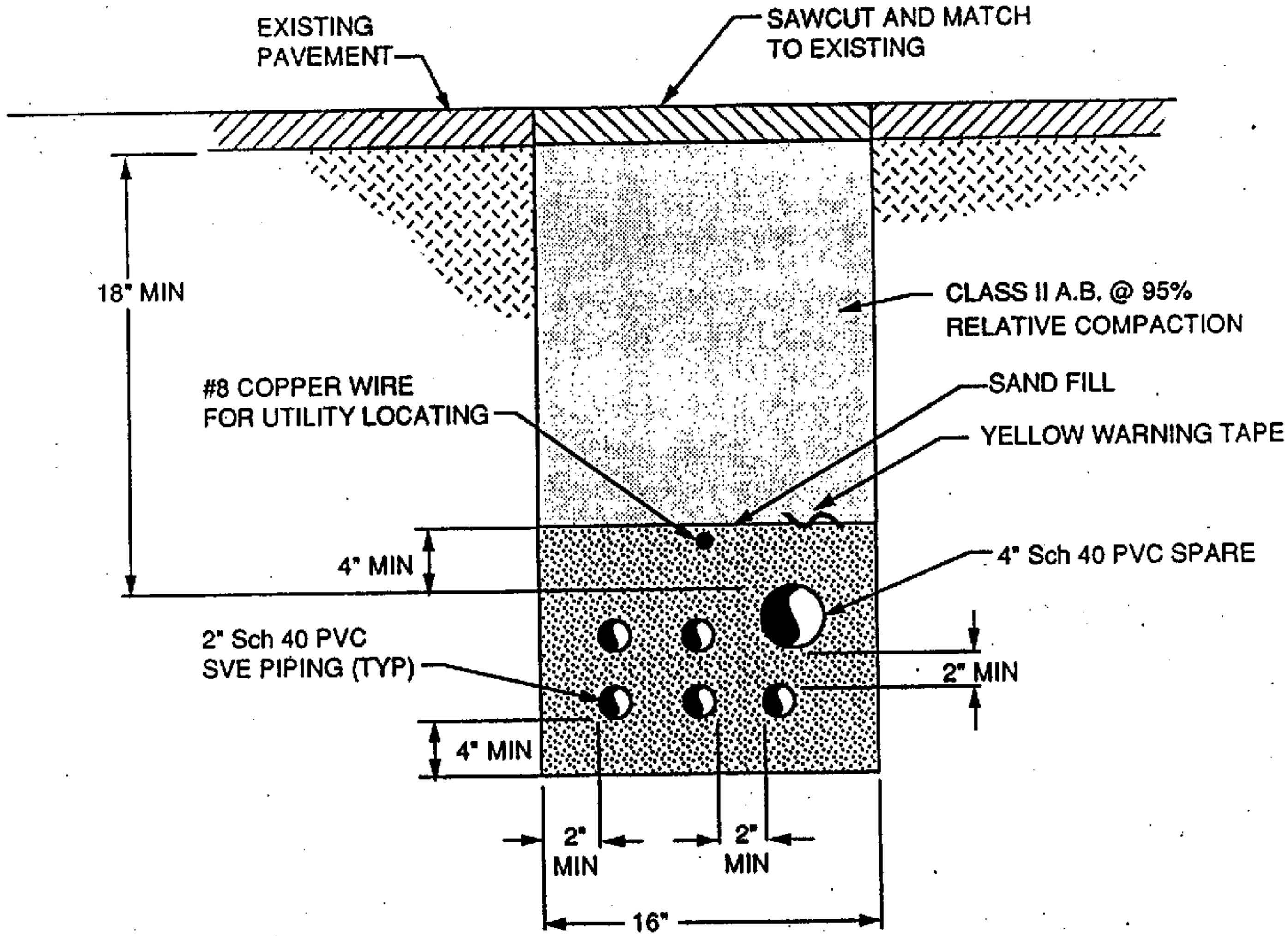
NOT TO SCALE

PACIFIC ENVIRONMENTAL GROUP, INC.	**SHELL SERVICE STATION** 285 Hegenberger Road at Leet Drive Oakland, California **SVE/SPARGE WELL HEAD PLAN VIEW**	FIGURE: 7 PROJECT: 305-79.01



NOT TO SCALE

PACIFIC ENVIRONMENTAL GROUP, INC.	SHELL SERVICE STATION 285 Hegenberger Road at Leet Drive Oakland, California	FIGURE: 8
	SVE/SPARGE WELL HEAD PROFILE VIEW	PROJECT: 305-79.01



NOT TO SCALE

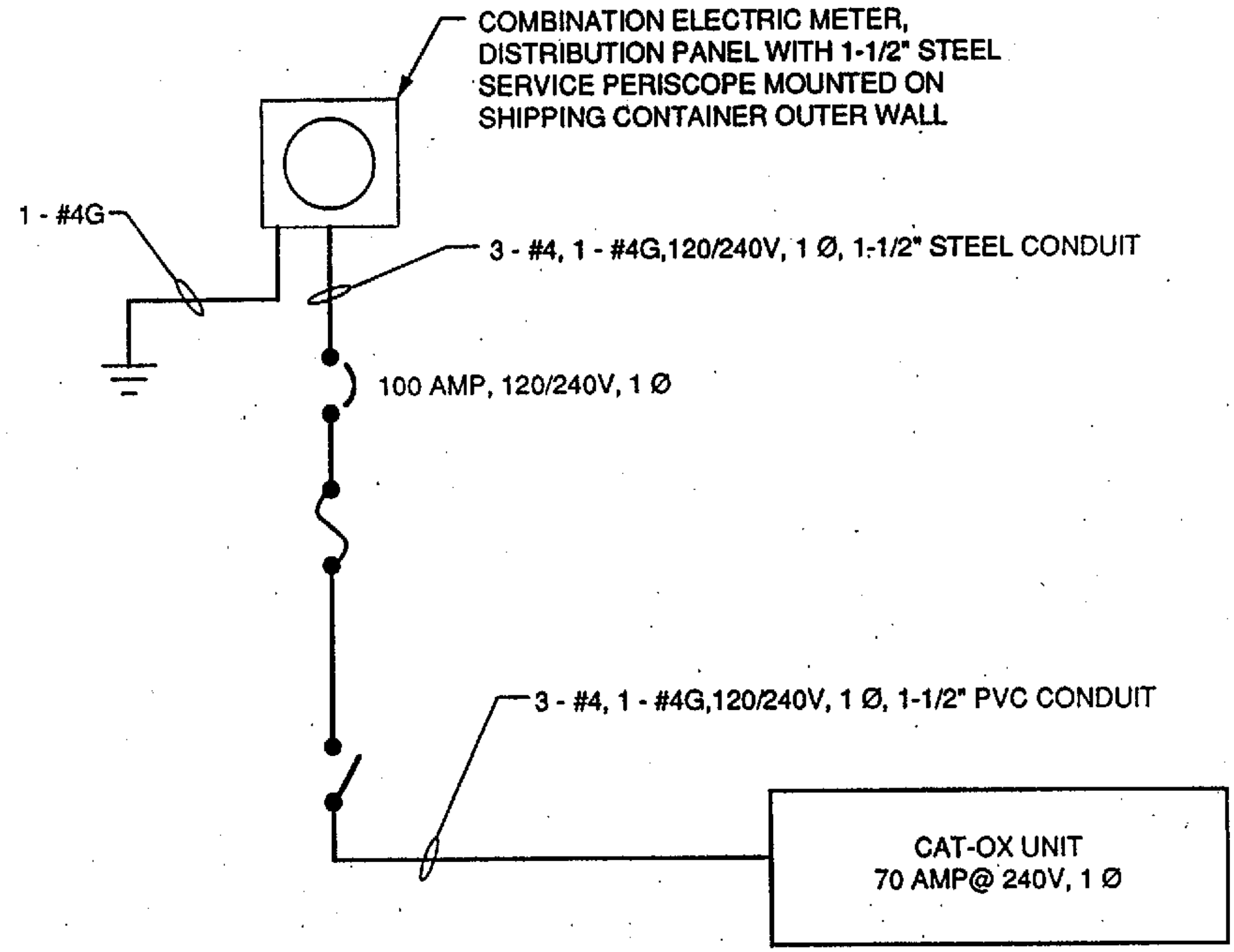
PACIFIC ENVIRONMENTAL GROUP, INC.

SHELL SERVICE STATION
285 Hegenberger Road at Leet Drive
Oakland, California

COMMON UTILITY TRENCH PROFILE

FIGURE: 9

PROJECT: 305-79.01



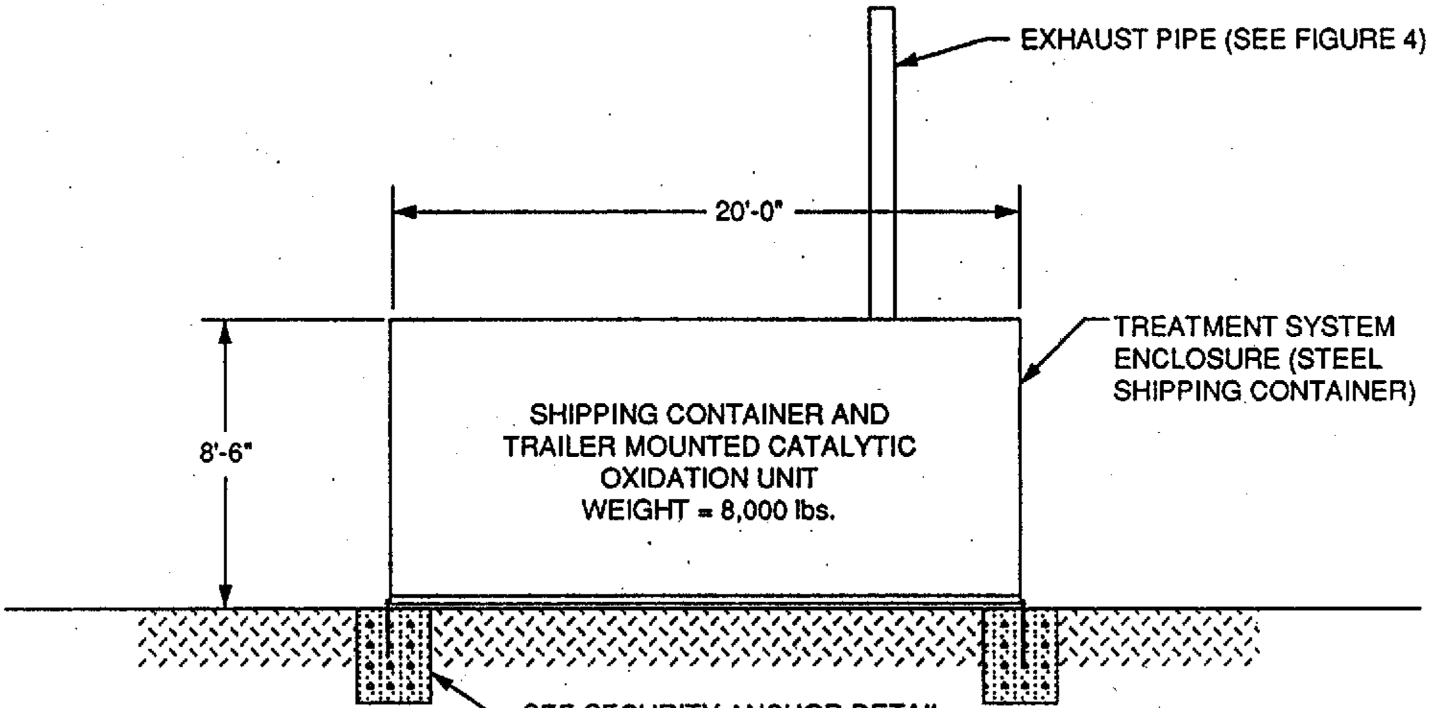
NOT TO SCALE

PACIFIC ENVIRONMENTAL GROUP, INC.

SHELL SERVICE STATION
285 Hegenberger Road at Leet Drive
Oakland, California

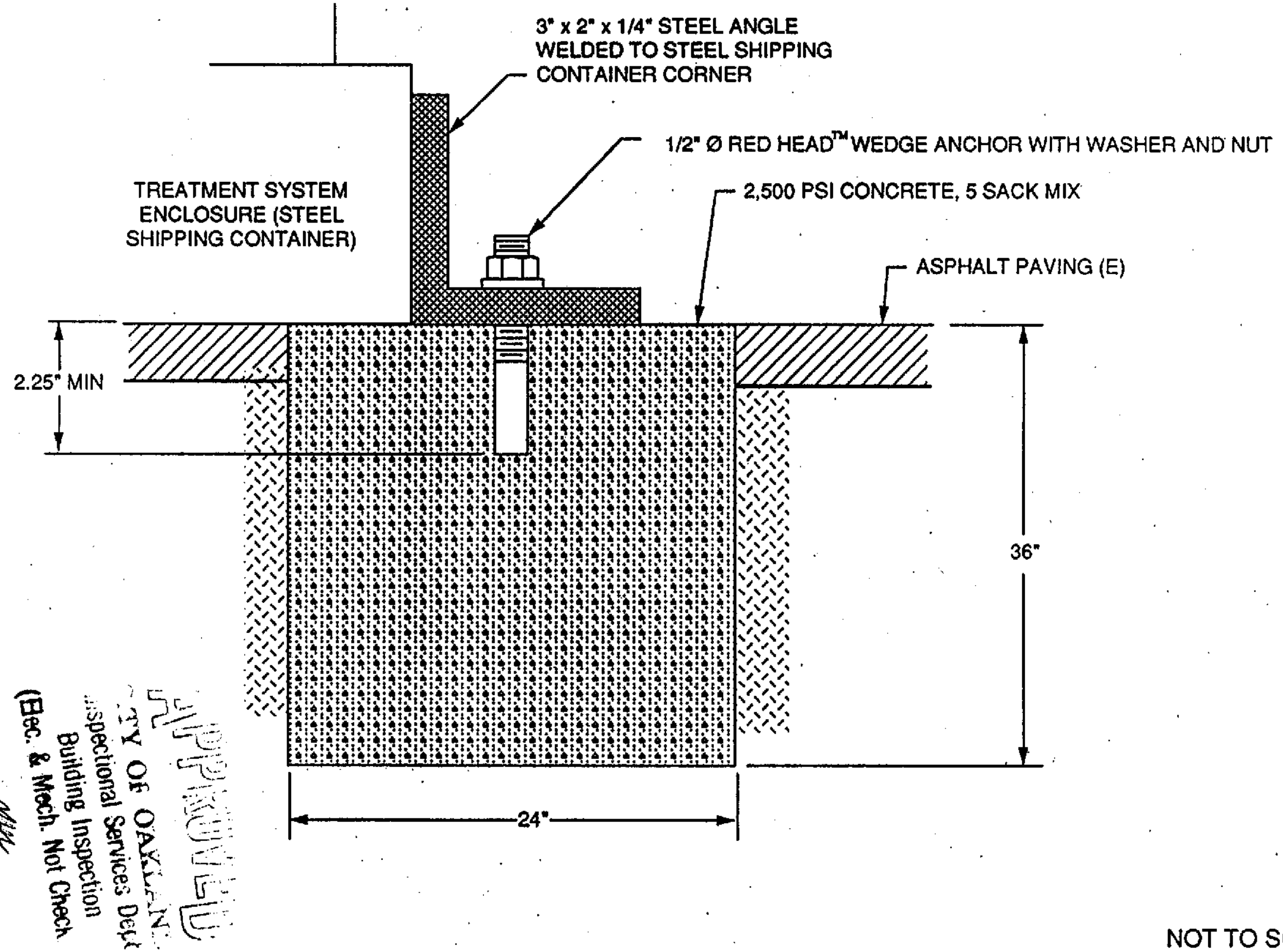
ELECTRICAL SINGLE LINE DIAGRAM

FIGURE: **10**
PROJECT: 305-79.01



NOT TO SCALE

PACIFIC ENVIRONMENTAL GROUP, INC.	**SHELL SERVICE STATION** 285 Hegenberger Road at Leet Drive Oakland, California	FIGURE: **11**
	TREATMENT SYSTEM ENCLOSURE PROFILE	PROJECT: 305-79.01



NOT TO SCALE

PACIFIC
ENVIRONMENTAL
GROUP, INC.

SHELL SERVICE STATION
285 Hegenberger Road at Leet Drive
Oakland, California

SYSTEM ENCLOSURE SECURITY ANCHOR DETAIL

FIGURE:
12
PROJECT:
305-79.01

APPENDIX A

MANUFACTURER SPECIFICATIONS

SPECIFICATIONS FOR K.B/H MMC-5A (100 scfm CatOx System)

CATALYTIC OXIDIZER WITH ELECTRIC PREHEATER

NOMINAL CAPACITY:	100 scfm
DAILY DESTRUCTION RATE of BTEX:	95 lbs
EQUIVALENT CONCENTRATION:	2500 ppm(v)
DIMENSIONS:	82" L x 24" W x 33" H
WEIGHT:	1,200 lbs
PREHEATER:	Electric; 9.0 kW, @ 240V
HEAT EXCHANGER EFFICIENCY:	45-50%
OPERATING TEMPERATURE:	800-950° F (typical)
MAXIMUM TEMPERATURE:	1,050° F
EFFLUENT TEMPERATURE:	450 -550° F (typical)
NMHC DESTRUCTION EFFICIENCY:	95-98%
BENZENE DESTRUCTION EFFICIENCY:	99% minimum
CATALYST VOLUME:	0.256 ft^3
GAS HOURLY SPACE VELOCITY:	23,400 HR^{-1}

FEATURES:

- VACUUM INDICATOR
- INLET FILTER
- BLOWER DISCHARGE TEMPERATURE INDICATOR
- BLOWER INLET MUFFLER
- PROCESS GAS FLOW SENSOR & INDICATOR
- DILUTION AIR VALVE (MANUAL) with FILTER/MUFFLER
- FLOW CONTROL FROM 100 DOWN TO 30 SCFM USING RECIRCULATION LOOP OF VCU
- PROCESS GAS LOW PRESSURE LIMIT SWITCH
- STAINLESS STEEL HEAT EXCHANGER
- TIC WITH AUTOTUNE FOR CATALYST REACTOR TEMPERATURE CONTROL
- TEMPERATURE INDICATION AT CATALYST ENTRY, INTERSTAGE, AND EXIT
- 3 STAGE CATALYST BED
- AUTOMATIC QUENCH AIR VALVE
- HIGH AND LOW TEMPERATURE SHUTDOWN
- EXHAUST STACK 2" DIAMETER x 84" HIGH

STANDARD VACUUM BLOWER (VCU): SELECTED TO MEET CUSTOMER'S SITE REQUIREMENTS.
A typical package would consist of the following:

TYPE:	Rotary Positive Displacement or Regenerative
BRAND (Typical):	M-D Pneumatics 3206
VACUUM @ CUST. P.O.C.:	5" Hg @ 100 SCFM
DRIVE MOTOR:	5 hp TEFC, 230V, 1 or 3 phase
DIMENSIONS:	48" L x 25" W x 25" H
INLET MUFFLER	Included
WEIGHT:	450 lbs

OPTIONS:

- TRAILER MOUNTED*, BED SIZE 5' W x 10' L
- EXTRA HIGH EFFICIENCY CATALYST (FOR SPECIAL CASES)
- VAPOR-LIQUID SEPARATOR w/ EXPLOSION PROOF FLOAT SWITCH
- VACUUM RELIEF VALVE
- SOUND ENCLOSURE
- MULTIPOINT RECORDER
- COMMUNICATION PACKAGE, PC or FAX
- AUTOMATIC EXOTHERM CONTROL USING DILUTION AIR VALVE
- EXHAUST EXTENSION, 2.5" DIAMETER PIPE

* The MMC-5A system consists of a catalytic oxidizer (CatOx) and vacuum/compressor unit (VCU). The two major components have their own base supports, suitable for forklift, and can be configured to customer's preferred layout. A trailerized option is also available.

KING, BUCK & ASSOCIATES, INC.

For The Joint Venture King,Buck/Hasstech

Specializing in the energy and chemical processing industries

SPECIFICATIONS FOR MMC-5A SERIAL #9020
PURCHASED BY PACIFIC ENVIRONMENTAL GROUP, SANTA CLARA, CA

CATALYTIC OXIDIZER

NOMINAL CAPACITY:	25% LEL @100 scfm
DIMENSIONS:	82"L x 24"W x 33"H
WEIGHT:	1,200#
PREHEATER:	Electric; 7.5kw, 30A @ 240v
OPERATING TEMPERATURE:	800-950° F
MAXIMUM TEMPERATURE:	1,050° F
EFFLUENT TEMPERATURE:	450° F
DISCHARGE STACK:	2" Diameter, 120" High
TYPICAL DESTRUCTION EFFICIENCY:	95-98%
CATALYST VOLUME:	.266 ft^3

BLOWER

TYPE:	Positive Displacement
BRAND:	M-D Pneumatics 3206
DRIVE MOTOR:	1 phase, 7.5hp TEFC (5.6kw, 40A)
DIMENSIONS:	48"L x 25"W x 25"H
WEIGHT:	450#

2384 San Diego Avenue, Suite 2 • San Diego, California 92110 • Telephone (619) 299-6431 • FAX (619) 299-8437

KING;BUCK/HASSTECH

MultiMode™ Combuster Component List

MMC-5A

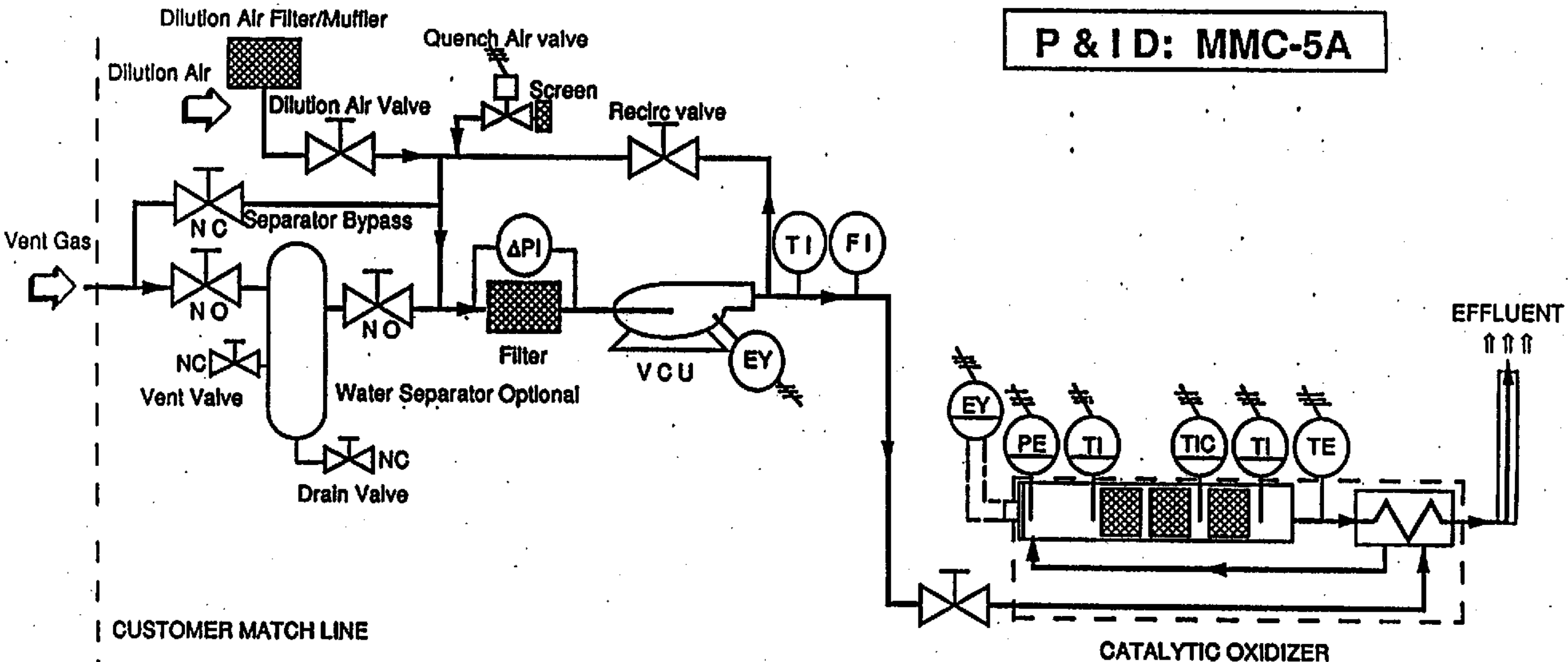
VCU (Vacuum Compressor Unit) and Manifold

Vacuum Compressor: Md Pneumatics, Model 3204 or equivalent
Electric drive motor, single- or 3-phase, hp depending on customer preference
Compressor inlet filter
Compressor discharge temperature indication
Dilution air valve
Dilution air Muffler/Filter
Automatic, programmable quench air valve
Recirculation valve (allows VCU discharge flow back to suction)
VCU discharge flow sensor
Flow indicator

CatOx-100

Catalytic Oxidizer, 100 scfm capacity
Electric preheater
3-stage catalyst
Process flow pressure switch
High temperature limit switch
Temperature indication at catalyst entry, inner stage, and exit
Microprocessor controlled temperature control

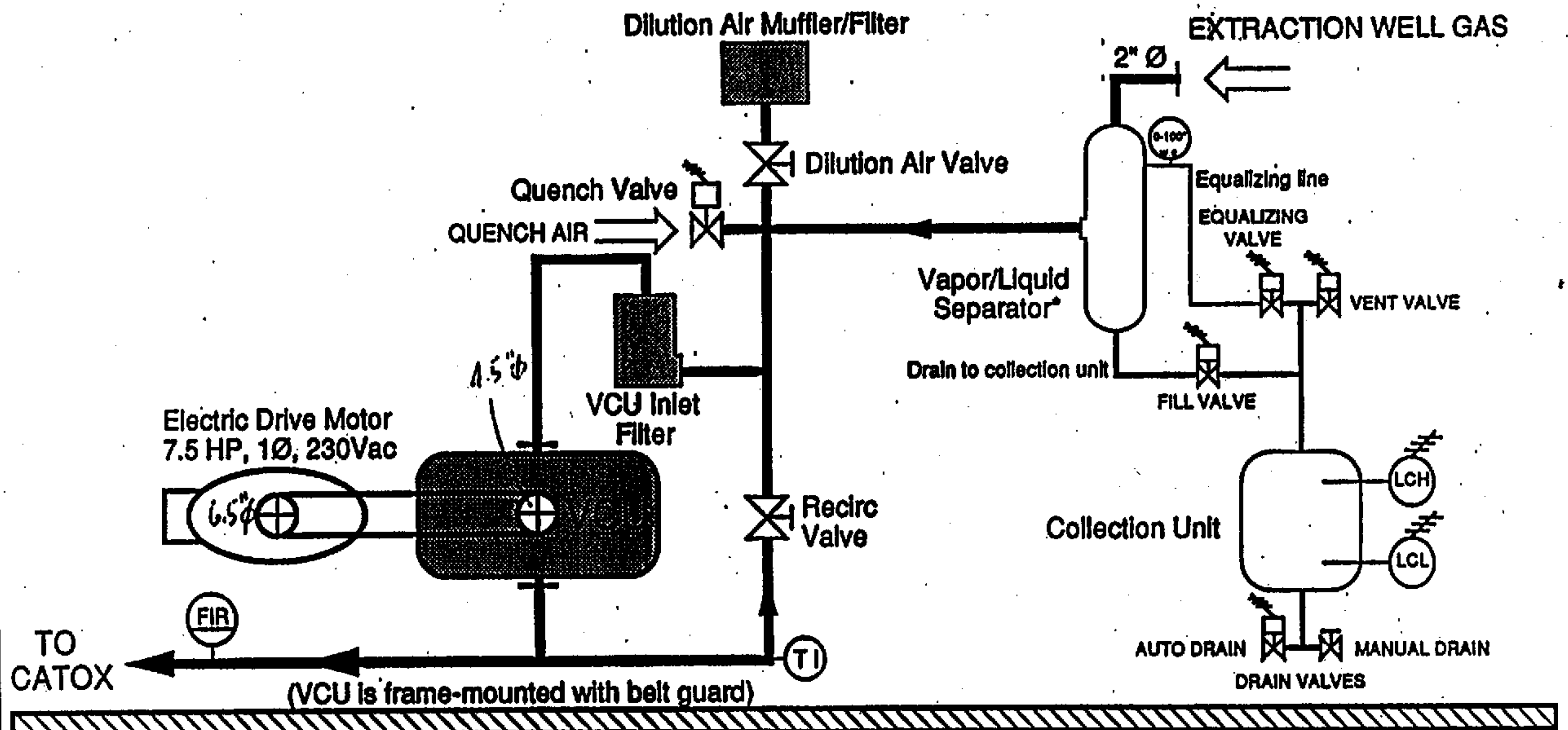
P & I D: MMC-5A



LEGEND

EY	Electrical/shut down signal
TI	Temperature indication
PI	Pressure indication
PR	Pressure regulator
SV	Solenoid valve
PE	Pressure shutdown signal
TE	Temperature shutdown signal
VCU	Vacuum Compressor Unit
TIC	Temperature indicating Controller

P & I D: MMC-5A	
KING,BUCK/HASSTECH	
P10021	4-16-90

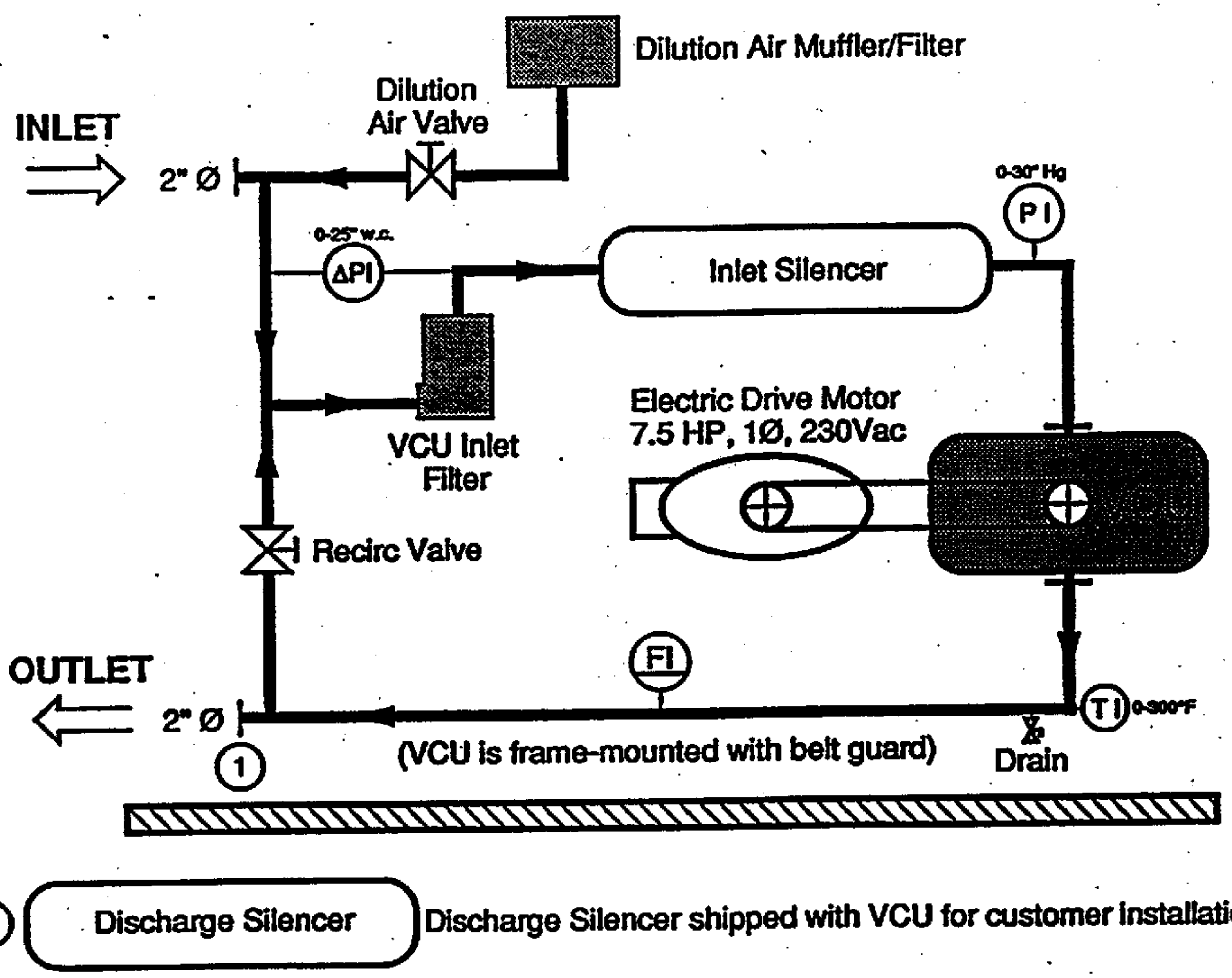


VCU:	MD Pneumatics, Model 3206 81L3, Serial No. 11007G90
Electric Drive Motor:	Balcor, Catalog No. L371OT
Dilution Air Filter/Muffler:	Solberg, 2"
VCU Inlet Filter:	Solberg, 2" L-type
Vapor/Liquid Separator:	Anderson, Model LCR-200
FIR:	Dwyer DS-200 Flow Sensor + Dwyer Series 600 dP X-mitter + Yokogawa Square Root Extractor and 6-point Strip Chart Recorder
TI:	Taylor dial-type thermometer
Quench Valve:	ASCO, 1", Catalog No. R8215B50
Equalizing Valve:	ASCO, 1/4", Catalog No. 8262C54
Vent Valve:	ASCO, 1/4", Catalog No. 8262C54
Fill Valve:	ASCO, 3/4", Catalog No. 8041C3
Drain Valve:	ASCO, 3/4", Catalog No. 804C3

*See M10011.3 for control schematic

VCU Piping Manifold	
PACIFIC ENVIRONMENTAL GROUP	
KING,BUCK/HASSTECH	
MMC-5A, Serial No. 9020	
M20021	8-7-90

VCU MANIFOLD



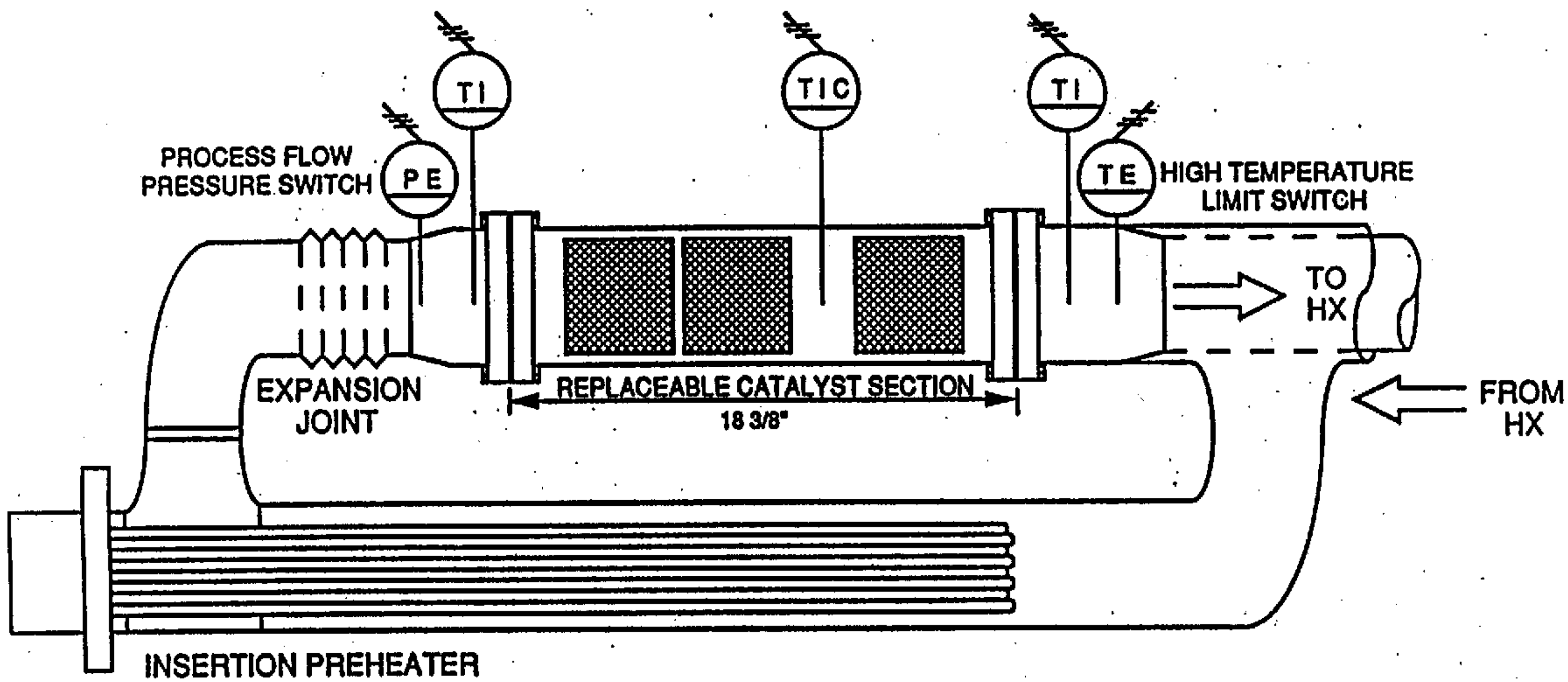
Discharge Silencer shipped with VCU for customer installation.

COMPONENTS

VCU: MD Pneumatics, Model 3206-81L3, Serial No. 11185L90 (2500 rpm)
Electric Drive Motor: Baldor Electric, Catalog No. L3710T, 7.5 hp/1Ø
Dilution Air Muffler/Filter: Solberg, 2"
VCU Inlet Filter: Solberg, 2" L-type
Inlet/Discharge Silencer: Burgess Manning, 2"
Flow Indication (FI): Dwyer DS-200 Flow Sensor + Dwyer Series 2000 Magnehelic dP gage
ΔPI: Dwyer Series 2000 Magnehelic dP gage
TI: Taylor, Dial-type Thermometer

VCU Piping Manifold	
PACIFIC ENVIRONMENTAL GROUP, INC.	
KING,BUCK/HASSTECH	
Serial No. 9033	
M20027	12-12-90

MMC-5A CATALYTIC OXIDIZER INTERNAL CONFIGURATION



CatOx Internal Configuration	
PACIFIC ENVIRONMENTAL GROUP	
KING,BUCK/HASSTECH	
MMC-5A, Serial No. 9020	
M40010	4-24-90

APPENDIX B

SEISMIC CALCULATIONS

SHELL SERVICE STATION
285 HEGENBERGER ROAD
OAKLAND, CA.

SUMMARY OF FINDINGS

I. FORCES ACTING ON RED HEAD™ DROP IN WEDGE ANCHORS

pg 2 DESIGN BASE SHEAR $V = 2,750$ lbs

pg 5 STRUCTURAL PERIOD $T = 0.00296$ sec

SINCE $T << 0.7$ sec

pg 5 CONCENTRATED LOAD AT TOP OF STRUCTURE $F_t = 0$

pg 5 DISTRIBUTED LOAD $F_1 = 2,750$ lbs

pg 6 SEISMIC PULLOUT FORCE PER SUPPORT $F_p = 293$ lbs

pg 6 WEDGE ANCHOR PULLOUT FORCE (PER MFG'R) $F_{WAP} = 4,038$ lbs

$\frac{F_{WA}}{F_p}$ = FACTOR OF SAFETY = 13.7

pg 7 SEISMIC SHEAR FORCE PER SUPPORT $F_s = 1,375$ lbs

pg 7 WEDGE ANCHOR SHEAR FORCE (PER MFG'R) $F_{WAS} = 5,175$ lbs

$\frac{F_{WAS}}{F_s}$ = SAFETY FACTOR = 3.7 ⇒ USE $\frac{1}{2}$" ø x $3\frac{3}{4}$" LONG RED HEAD™ DROP IN WEDGE ANCHORS

REGISTERED PROFESSIONAL ENGINEER ROBERT K. WENZLAU No. 37395 EXP. 6-30-96 CIVIL STATE OF CALIFORNIA

II. FORCES ACTING ON CABLE TIE DOWNS

pg 7 BREAKING STRENGTH (PER MFG'R) $F_{BS} = 2,363$ lbs

pg 7 RESULTANT FORCE, EACH CORNER $F_R = 1,406$ lbs

$\frac{F_{BS}}{F_R}$ = SAFETY FACTOR = 1.6 ⇒ USE ¼" ø STEEL 1x7 STRAND WIRE ROPE

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SCALE ______ SHEET 1 OF 11

SUMMARY OF FINDINGS (CONTINUED)

III. CONCRETE FOOTING SIZE REQUIREMENTS

pg 9	CONCRETE LOAD FOR 3'x2'x1' FOOTING	W_c = 900 lbs
pg 9	PASSIVE LOAD	P_p = 1,620 lbs
pg 9	FOOTING FRICTION	F_b = 405 lbs
pg 9	WALL FRICTION	F_s = 590 lbs
pg 10	OVERTURNING MOMENTS	M_1 = 293 lbs
pg 10	RESISTING MOMENTS	M_2 = 6,535 lbs

$\frac{M_2}{M_1}$ = SAFETY FACTOR = 22.3 ⇒ USE 3'x2'x1' FOOTING

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EARTHQUAKE DESIGN

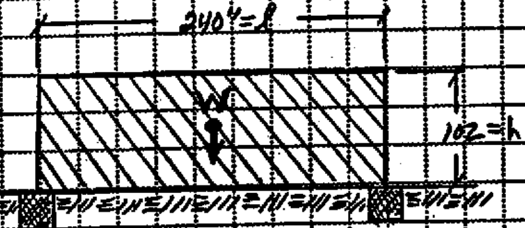
FIND: I. FORCES ACTING ON RED HEAD™ DROP IN WEDGE ANCHORS
II. FORCES ACTING ON CABLE TIE DOWNS
III. CONCRETE FOOTING SIZE REQUIREMENTS

GIVEN: TREATMENT SYSTEM ENCLOSURE → 5000 lbs
(STEEL SHIPPING CONTAINER 20'×8'×8.5')
KING-BUCK™ TRAILER MOUNTED CAT-OX UNIT → 2500 lbs
55 GALLON WATER KNOCKOUT DRUM → 460 lbs
7960 lbs
W = 8000 lbs

ASSUMPTIONS: NON-BUILDING STRUCTURE – SEC 2338
55 GALLON DRUM FULL (CONSERVATIVE, IT IS NEVER FULL)

I. FIND FORCES ACTING ON RED HEAD™ DROP IN WEDGE ANCHORS

STATIC FORCE PROCEDURE, EARTHQUAKE DESIGN (UBC-1991-CHAPTER 23)



SEC 2334.b
BASE SHEAR

$$V = \frac{ZICW}{R_w}$$

Z = SEISMIC ZONE, CA. IS IN ZONE 4
FIG NO 23-2 pg 194 UBC

Z = 0.4

I = IMPORTANCE FACTOR, HAZARDOUS FACILITY
TABLE NO 23-L, pg 186 UBC

I = 1.25

R_w = NUMERICAL COEFFICIENT, USE ITEM 11
TABLE NO 23-Q, pg 192 UBC

$R_w = 4$

C = NUMERICAL COEFFICIENT,
EQ 34-2, pg 162 UBC

$$C = \frac{1.25\ S}{T^{2/3}}$$

$C = 2.75$ UBC 2334.6.1 "C NEED NOT EXCEED 2.75 AND MAY BE USED FOR ANY STRUCTURE ....."

CHECK $\frac{C}{R_W} \geq .5$ (NONBUILDING STRUCTURE, AS OPPOSED TO $\frac{C}{R_W} \geq .075$)

$\frac{C}{R_W} = \frac{2.75}{4} = .688$ ∴ OKAY UBC 2334.6.1

S = SITE COEFFICIENT FOR SOIL CHARACTERISTICS:
TABLE NO 23-J, pg 184 UBC

$S = 1.5$ "SITE GEOLOGY AND SOIL CHARACTERISTICS UNKNOWN, THEREFORE USE S=1.5......"

DESIGN BASE SHEAR:

$$V = \frac{Z I C}{R_W} W = \frac{(0.4)(1.25)(2.75)}{4}(8000 \text{ lbs}) = 2,750 \text{ lbs}$$

$V = 2,750$ lbs

VERTICAL DISTRIBUTION OF LATERAL SEISMIC FORCE UBC 2334.6

$V = F_t + \Sigma F_i$ (ONE LEVEL ONLY)

$V = F_t + F_1$

WHERE IF $T \leq 0.7$ SEC, THEN $F_t = 0$

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NEED TO FIND T, USE METHOD B, NATURAL PERIOD METHOD

f = FREQUENCY = $\frac{1}{T}$
ω = CIRCULAR FREQUENCY

$\rightarrow \omega = \frac{2\pi}{T} \Rightarrow T = \frac{2\pi}{\omega}$

FOR A SIMPLE MASS ON A SPRING, NATURAL FREQUENCY IS:

$$\omega = \sqrt{\frac{K g_c}{m}}$$

COMBINE

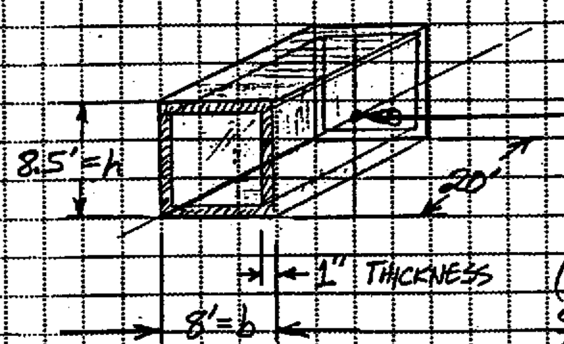
$$T = \frac{2\pi}{\sqrt{\frac{K g_c}{m}}} = 2\pi\sqrt{\frac{m}{K g_c}} \quad \text{WHERE } m = W$$

*
$$\boxed{T = 2\pi\sqrt{\frac{W}{K g_c}}}$$

* SEE SEISMIC DESIGN OF BUILDING STRUCTURES, 5TH ED, MICHAEL R. LINDEBURG, P.E.

NEED TO FIND K, STIFFNESS COEFFICIENT

ASSUME HOOKES LAW APPLIES, BODY EXPERIENCES PURE BENDING ∴ NEUTRAL AXIS PASSES THRU CENTROID (TIMOSHENKO, MECH OF MAT'LS, 2ND ED, pg 213)



(NOTE: FOR SHIPPING CONTAINER, BOX STRUCTURE OF 10 gauge STEEL, A 1" THICKNESS IS ASSUMED FOR MODELING/SIMPLIFICATION PURPOSES)

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K = STIFFNESS COEFF (CON'T.)

$$K = \frac{1}{\left(\frac{x}{\text{TOTAL LOAD}}\right)} = \left(\frac{x}{w\,l}\right)^{-1}$$

$$x = \frac{5\,w\,l^4}{384\,E_s I}$$ (SIMPLE BEAM WITH DISTRIBUTED LOAD)

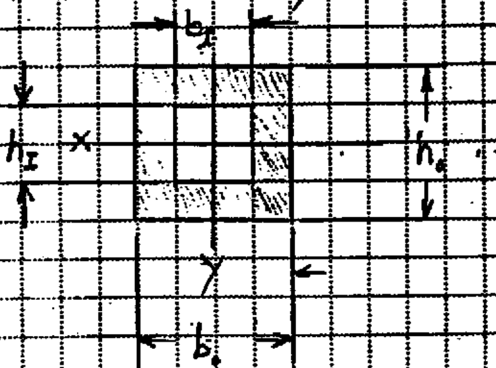
w = DISTRIBUTED LOAD

E_s = MODULUS OF ELASTICITY FOR STEEL
28×10^6 psi

$$K = \left(\frac{\frac{5\,w\,l^4}{384\,E_s I}}{w\,l}\right)^{-1} = \left(\frac{5\,l^3}{384\,E_s I}\right)^{-1} = \frac{384\,E_s I}{5\,l^3}$$

$$\boxed{K = \frac{384\,E_s I}{5\,l^3}}$$

NEED TO FIND I, AREA MOMENT OF INERTIA (ASSUMED 1" THICK WALLS)



I_I, b_I, h_I = INSIDE

I_o, b_o, h_o = OUTSIDE

$b_I = 7.8333$ ft
$h_I = 8.3333$ ft
$b_o = 8$ ft
$h_o = 8.5$ ft

$$I_I = \frac{h_I b_I^3}{12} = \frac{(8.3333)(7.8333)^3}{12} = 334 \text{ ft}^4$$

$$I_o = \frac{h_o b_o^3}{12} = \frac{(8.5)(8)^3}{12} = 363 \text{ ft}^4$$

$$I = I_o - I_I = 363 - 334 = \boxed{29 \text{ ft}^4 = I}$$

$$K = \frac{384 E_s I}{5 l^3} = \frac{384 \left(28 \times 10^6 \frac{lb}{in^2}\right)\left(29 \, ft^4\right)\left[\frac{144 \, in^2}{1 \, ft^2}\right]}{5 \, (20 \, ft)^3}$$

$$\boxed{K = 1.12 \times 10^9 \, \frac{lb}{ft}}$$

SOLVE FOR STRUCTURAL PERIOD:

$$T = 2\pi \sqrt{\frac{W}{K g_c}} = 2\pi \sqrt{\frac{8000 \, lb}{\left(1.12 \times 10^9 \frac{lb}{ft}\right)\left(32.2 \frac{ft}{sec^2}\right)}}$$

$$\boxed{T = 0.00296 \text{ sec}}$$

$T = 0.00296 \text{ sec} << 0.7 \text{ sec}$ ∴ $F_t = 0$

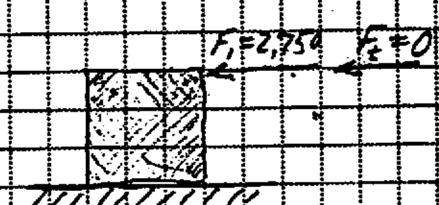
$\boxed{F_t = 0}$ CONCENTRATED LOAD AT TOP OF STRUCTURE

DISTRIBUTED LOAD F_x OVER HEIGHT: $F_x = F_1$ (ONE STORY STRUCTURE)

$$F_1 = \frac{(V - F_t) \, w_1 h_1}{w_1 h_1} = V - F_t = V - 0$$

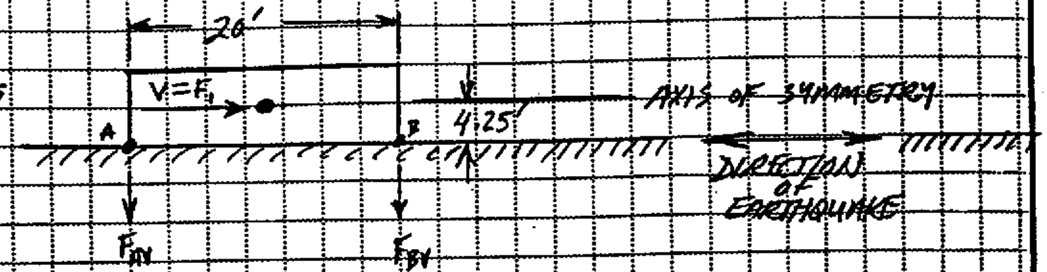
$$F_1 = V = 2,750 \text{ lbs.}$$

$$\boxed{F_1 = 2,750 \text{ lbs}}$$



FIND REACTIONS AT BASE DUE TO SEISMIC LOAD:

$F_1 = 2,750$ lbs



$\curvearrowleft^{+} \Sigma M_B = F_1 (4.25') - F_{AV} (20') = 0$

$F_{AV} = \dfrac{F_1 (4.25)}{20} = \dfrac{2750 (4.25)}{20} = 584.4 = 585$ lbs

$+\downarrow F_V = 0 \quad F_{AV} = F_{BV} = F_{SUPPORT} = 585$ lbs

∴ TOTAL PULL OUT FORCE DUE TO TWO SUPPORTS ON EACH END (4 TOTAL) USING AXIS OF SYMMETRY

$F_{PULLOUT} = F_{SUPPORT} / 2 = 585 / 2 =$ **293 lbs SEISMIC PULLOUT FORCE PER SUPPORT**

COMPARE PULLOUT FORCE DUE TO SEISMIC LOAD TO MANUFACTURER'S SPECIFICATIONS:

1/2" ϕ x 3/4 LONG RED HEAD™ DROP IN WEDGE ANCHOR:

ULTIMATE PULLOUT LOAD = 5384 lbs

SAFETY FACTOR (REDUCE BY 25%)

$\text{ULTIMATE PULLOUT LOAD}_{\text{SAFETY}} = 4038$ lbs

4038 lbs >> 293 lbs ∴ OKAY

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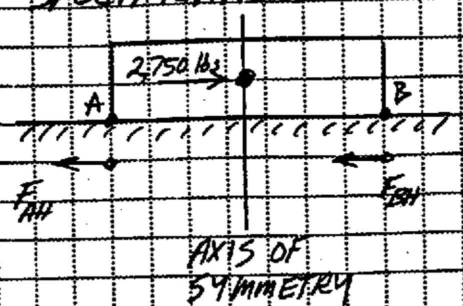
COMPARE SHEAR FORCE DUE TO SEISMIC LOAD TO MANUFACTURER'S SPECIFICATIONS:



$\overset{+}{\leftarrow} \Sigma F_H = F_{AH} + F_{BH} = 2750$ lbs

SYMMETRY $\Rightarrow F_{AH} = F_{BH}$

$\therefore F_{AH} = F_{BH} = \frac{2750}{2} =$ **1375 lbs SEISMIC SHEAR FORCE PER SUPPORT**

$\frac{1}{2}$" ∅ x 3¾" LONG RED HEAD™ DROP IN WEDGE ANCHOR:

ULTIMATE SHEAR FORCE = 6,900

SAFETY FACTOR (REDUCE BY 25%)

ULTIMATE SHEAR FORCE = 5,175 lbs

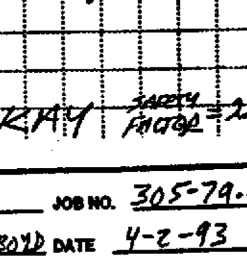
5175 lbs >> 1375 lbs ∴ OKAY

~~II. FIND FORCES ACTING ON CABLE TIE DOWNS~~

COMPARE TENSILE FORCES IN ANCHORING CABLE TO MANUFACTURER'S SPECIFICATIONS (2500 lb CATOX UNIT INSIDE STEEL SHIPPING CONTAINER)

(4) ¼" ∅ STEEL 1x7 STRAND WIRE ROPES

BREAKING STRENGTH = 3,150 lbs/each



SAFETY FACTOR (REDUCE BY 25%)

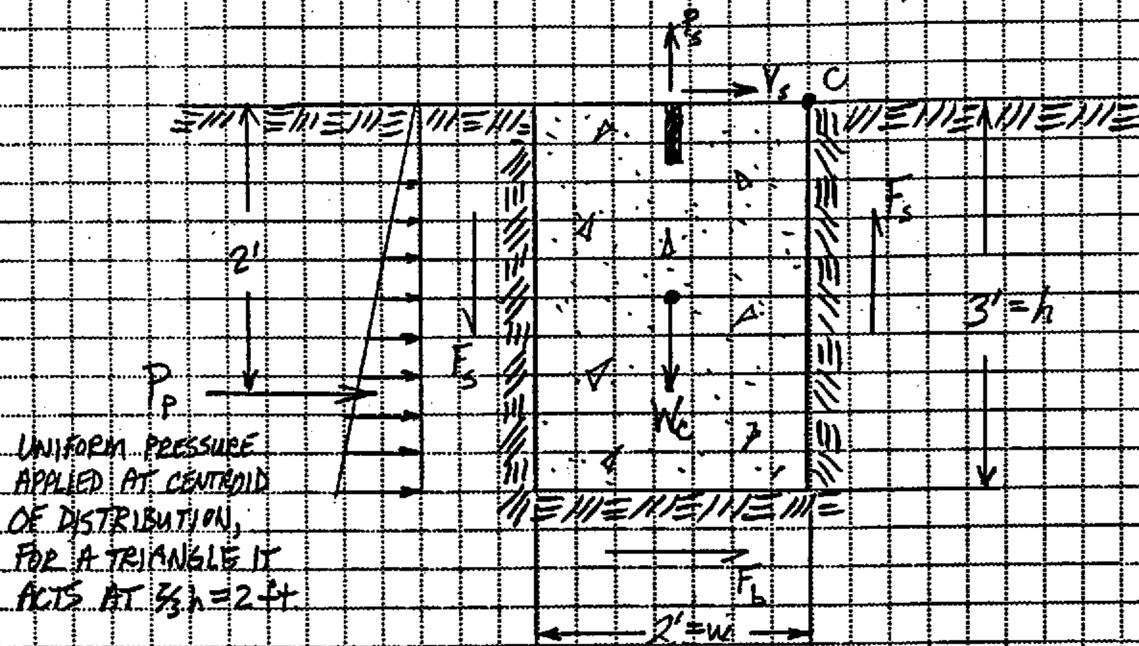
BREAKING STRENGTH = 2363 lbs/each

$F = \sqrt{(1375)^2 + (293)^2} = 1406$ lbs/each

∴ SINCE **1406 lbs << 3150 lbs** ∴ OKAY SAFETY FACTOR = 2.24

III. CONCRETE FOOTING SIZE REQUIREMENTS

ASSUME FOOTING SIZE = 3' height x 2' width x 1' depth



P_s = SEISMIC PULLOUT FORCE = 293 lbs (FROM PAGE 6)

V_s = SEISMIC SHEAR FORCE = 1375 lbs (FROM PAGE 7)

P_p = PASSIVE LOAD

F_s = WALL FRICTION

F_b = FOOTING FRICTION

W_c = CONCRETE LOAD

ASSUME:

$\gamma_s = 120$ lbs/ft³ DENSITY OF SOIL

$\phi = 30°$ ANGLE OF FRICTION

$i = 0°$ ANGLE BETWEEN BACKFILL SURFACE AND HORIZONTAL

$\gamma_c = 150$ lbs/ft³ DENSITY OF CONCRETE

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W_c = CONCRETE LOAD:

$W_c = \gamma_c h w d = (150 \frac{lb}{ft^3})(3 ft)(2 ft)(1 ft) = 900$ lbs

$W_c = 900$ lbs

P_p = PASSIVE LOAD:

$P_p = \frac{1}{2} \gamma_s h^2 K_p \cos i = \frac{1}{2} \gamma_s h^2 K_p$

$K_p = \frac{1 + \sin\phi}{1 - \sin\phi} = \frac{1 + \sin 30}{1 - \sin 30} = \frac{1.5}{.5} = 3$

$P_p = \frac{1}{2}(120 \frac{lbs}{ft^3})(3 ft)^2(3) = 1{,}620 \frac{lbs}{ft}$

$P_p = (1620 \frac{lb}{ft})(1 ft\ depth) = 1{,}620$ lbs

$P_p = 1{,}620$ lbs

F_b = FOOTING FRICTION:

$F_b = \mu R$ where $R = W_c$ and $\mu = 0.45$ (FRICTION BETWEEN SOIL AND CONCRETE)

$F_b = (0.45)(900 lbs) = 405$ lbs

$F_b = 405$ lbs

F_s = WALL FRICTION:

$F_s = P_p \tan \delta$ where $\delta = \frac{2}{3}\phi = 20°$

$F_s = (1{,}620 lbs)(\tan 20°) = 590$ lbs

$F_s = 590$ lbs

MOMENTS ABOUT POINT "C" ∴ (SEE SKETCH, PAGE 8)

LET M_1 = OVERTURNING MOMENTS (+)

LET M_2 = RESISTING MOMENTS (+)

(+) $M_1 = \Sigma fd = P_S (1 ft) = (293 lbs)(1 ft) = 293$ ft lbs

$$M_1 = 293 \text{ ft lbs}$$

(+) $M_2 = \Sigma fd = W_c (1 ft) + F_b (3 ft) + F_s (2 ft) + P_p (2 ft)$

$M_2 = 900(1) + 405(3) + 590(2) + 1620(2)$

$$M_2 = 6535 \text{ ft lbs}$$

$M_1 << M_2$ ∴ OKAY

SAFETY FACTOR = $\frac{M_2}{M_1} = \frac{6535}{293} = 22$ OKAY

USE 3'X2'X1' CONCRETE FOOTING

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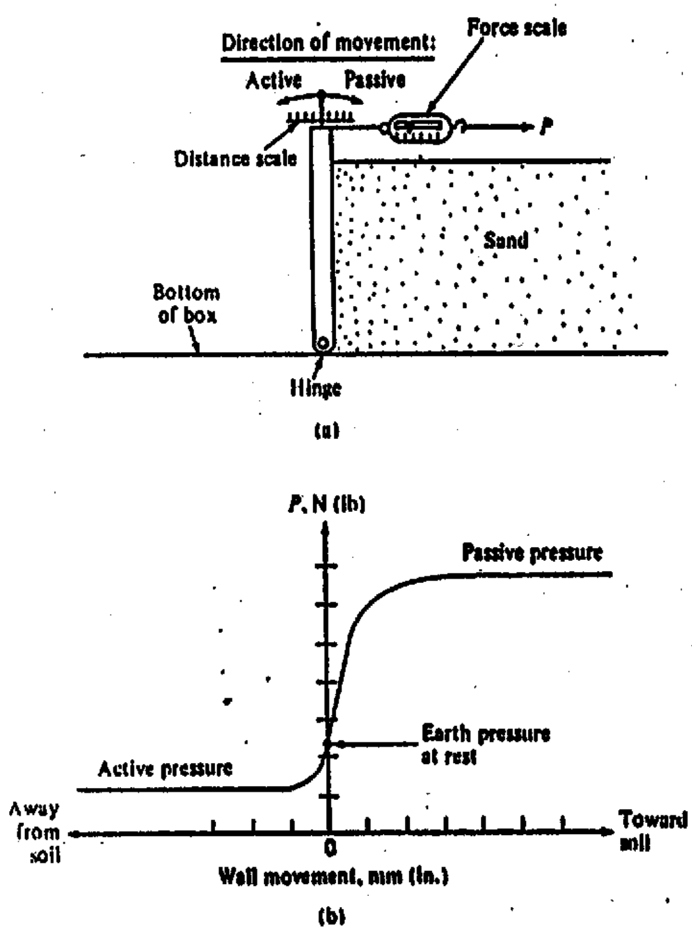
4th Ed.
Soil Engineering
Merlin G. Spangler
Richard L. Handy

21.2. MOBILIZATION OF ACTIVE AND PASSIVE EARTH PRESSURES

The relationship between active and passive earth pressures can be demonstrated by a simple experiment with a model retaining wall in a box. The wall is hinged at the bottom and held by a spring scale at the top, so that by pulling on the scale the force on the wall may be varied and measured, Fig. 21.1. Dry sand is carefully poured into the space on one side of the wall, and the scale reading noted. The pulling force in the scale is then relaxed, and the force reduced until it finally reaches and holds a minimum value as the wall moves outward. The soil now is in the *active state*, and the force on the spring is indicative of the *active pressure* of soil on the wall. Then the spring is pulled until the force on the wall increases to a maximum value as the soil shears and the wall pushes it forward and upward. The wall movement now has

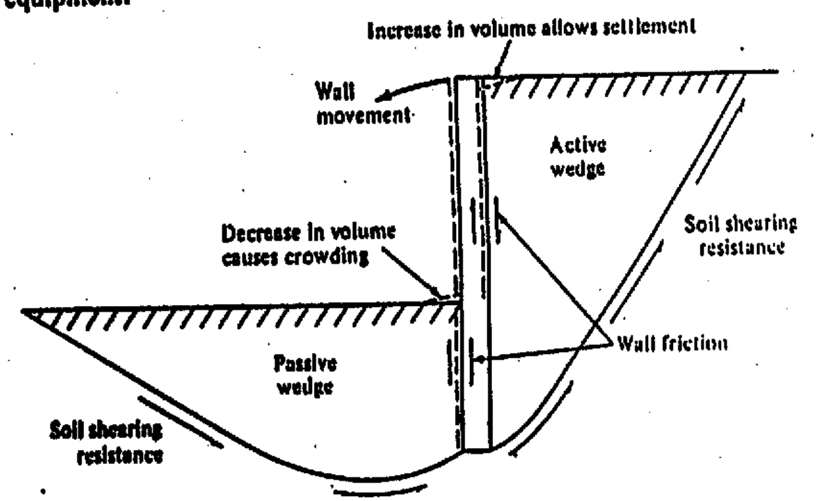


created a *passive resistance state* in the soil, and the maximum force on th spring is indicative of the *passive pressure* on the soil. This experiment ar the results are shown in Fig. 21.1. Note that for either the active or passi states to develop, the wall must move. If the wall does not move, an inte mediate stress state exists called *earth pressure at rest*. This pressure cond tion which develops with zero lateral strain was discussed in connection wi consolidation of clays in Section 17.35.

For greatest economy, retaining walls are designed only sufficien strong to resist active pressure. They therefore must be allowed to mov and should not be rigidly keyed in to adjacent buildings, and so forth, unle they are designed to resist the higher at-rest pressure. Vertical walls often a built with a slight initial tilt or batter toward the soil so that subsequ movement under soil pressure will bring it to a vertical position. Otherw the wall will develop a top-outward tilt which, while not necessarily dang ous, may give that impression to anybody standing in the shadow of the w

21.3. EXAMPLES OF PASSIVE EARTH PRESSURE

It may at first seem unlikely that a wall ever would be built to push into soil and mobilize passive earth pressures. A common example is illustra in Fig. 21.2. Here the wall has been extended below grade sufficiently active earth pressures developed on the high side of the wall are opposec the much higher passive earth pressures on the low side, and the wa stable. Pressures from passive wedges also play an important role in fou tion bearing capacity (Fig. 22.11). Passive earth pressures thus are impor and are useful. Passive pressures also are developed during earth movin bulldozers or plows, and retaining wall theory is used in design of equipment.



conjugate ratio becomes

$$K = \frac{1 - \sin\phi}{1 + \sin\phi} = \tan^2\left(45° - \frac{\phi}{2}\right) \qquad (21.3)$$

in which ϕ is the angle of internal friction of soil.

In this form, K is often called Rankine's ratio of lateral pressure to vertical pressure. Also, it is sometimes called the hydrostatic pressure ratio. Equation 21.3 is derived from Mohr theory later in this chapter.

21.7. WALL FRICTION

According to the Rankine theory, the line of action of the resultant pressure on a retaining wall is parallel to the slope of the backfill surface. This means that the resultant is horizontal when the backfill is level; but it has a vertical component, and is therefore inclined with the horizontal, when the backfill is on a slope. Experimental evidence indicates that a vertical component is present even when the backfill surface is level, because of the tilt of the wall. That is, as shown in Fig. 21.2, tilting away from the active zone increases the available volume on that side so the soil tends to sag downward. This causes a downward shearing force on the wall. On the passive side the soil volume decreases and squeezes the soil upward, causing an upward shearing force. The limiting value of these shearing forces relates to the coefficient of friction between the soil and the wall:

$$V = F \tan\delta \qquad (21.4)$$

in which

- V = vertical component of resultant pressure
- F = component of resultant pressure normal to back face of wall
- δ = angle of friction between soil and retaining wall

The angle δ can never be greater than the angle ϕ of internal friction of the soil. In practice δ is frequently assumed to be about two-thirds of ϕ.

It is to be noted that the vertical components of the resultant pressures usually decrease the calculated overturning moment on a retaining wall, as illustrated in Fig. 21.4. The upward rotation of the resultant force R results in a slight reduction of K. More important is the effect on moments, the overturning moment being reduced because F is less than P, and the resisting moment being added to by wall friction.

Example 21.1

In Fig. 21.4, the height of the wall is ...

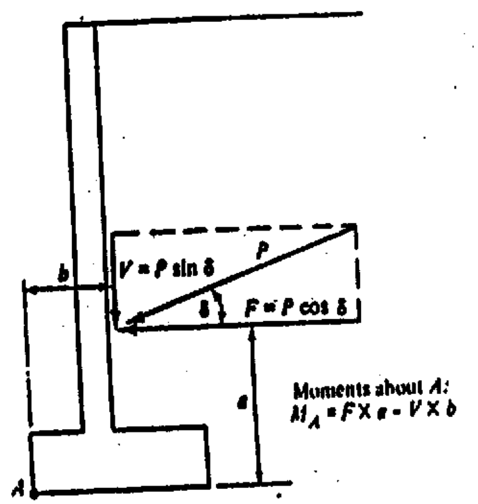


Figure 21.4 Reduction of overturning moment by wall friction on a retaining wall.

SOLUTION. (a) Without wall friction:

$$P = \tfrac{1}{2}\gamma H^2 K = \tfrac{1}{2}(15)(6)^2(\tfrac{1}{3}) = 90 \text{ N/m } (6.17 \text{ lb/ft})$$
$$M_A = P \times a = 90 \times \tfrac{6}{3} = 180 \text{ N}\cdot\text{m/m } (40.5 \text{ ft-lb/ft})$$

(b) With wall friction, let $\delta = 20°$, and estimate K from Equation 21.

$$P = \tfrac{1}{2}\gamma H^2 K = 90 \text{ N/m } (6.17 \text{ lb/ft})$$
$$\begin{aligned} M_A &= F \times a - V \times b \\ &= P\cos\delta \times a - P\sin\delta \times b \\ &= 90\cos 20 \times 2 - 90\sin 20 \times 1 \\ &= 169 - 31 = 138 \text{ N}\cdot\text{m/m } (31.1 \text{ ft-lb/ft}) \end{aligned}$$

In practice, wall friction is frequently neglected in design as an added fac of safety, or for high walls, the analysis of Coulomb is used.

21.8. PLANE OF FAILURE ACCORDING TO COULOMB THEORY

The Coulomb theory, which was proposed in 1773, is based upon the c cept of a plane of failure extending diagonally upward and backward thro the earth backfill, as shown in Fig. 21.5. The triangular mass of soil betw this plane of failure and the back face of the retaining wall is someti referred to as the sliding wedge. It is reasoned that, if the retaining wall v suddenly removed, the soil within the sliding wedge would slump downw Therefore, an analysis of the forces acting on the sliding wedge at incip

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Richard L. Handy

TABLE 21.5 Design Values of Unit Weight and Friction Angle for Soil Backfill

Backfill Material	Unit Weight γ kN/m³ (lb/ft³)	Internal Friction Angle ϕ (deg)
Soft plastic clay	16–19 (105–120)	0–10
Wet, fine silty sand	17–19 (110–120)	15–30
Dry sand	14–17 (90–110)	25–40
Gravel	19–21 (120–135)	30–40
Loose loam	12–14 (75–90)	30–45
Compact loam	14–16 (90–100)	30–45
Compact clay	14–17 (90–110)	25–45
Cinders	6 (40)	25–45
Compact sand-clay	18–20 (115–125)	40–50
Water	9.81 (62.4)	0

21.21. SUBMERGED BACKFILL VERSUS DRAINAGE

The lateral pressure produced by a saturated submerged soil is equal to the full hydrostatic pressure of the water in the soil pores plus the pressure exerted by the soil solids. The most convenient way to determine the lateral pressure due to a submerged backfill is to compute these two components separately and to add the results together. The hydrostatic pressure can be computed by applying Equation 21.9 and taking γ as 9.81 kN/m (62.4 lb/ft³) and K as 1.0 ($\phi = 0°$). The pressure due to the soil solids also can be computed by applying Equation 21.9 and using the buoyant unit weight of the solid particles and a value of K corresponding to the friction angle ϕ of the soil in the saturated state. *Note that this is not the same* as using the saturated unit weight of the soil and applying the same K to the soil and water collectively, which is incorrect and on the unsafe side. Also, since water can sustain no shearing resistance, water pressure always acts normal to the wall surface, regardless of wall friction and the direction of the resultant soil pressure.

Most retaining walls are not designed to withstand full hydrostatic pressure plus the pressure from submerged soil, and therefore should be provided with adequate drainage facilities to ensure that the backfill soil will not become saturated. Weep holes 100 to 150 mm (4 to 6 in.) in diameter should be placed in the wall at intervals along its length and at the lowest elevation at which free outlet drainage can be maintained. If a vertical layer of crushed rock or coarse gravel about 200 to 300 mm (8 to 12 in.) thick is placed directly behind the wall, the effectiveness of the weep holes will be greatly enhanced. In case the backfill soil is fine-grained material, a graded filter should be placed between the soil and the rock in order to prevent clogging of the drainage system by migration of the soil fines into the coarse

the life of the structure, a longitudinal drain may be placed beh an elevation a little above that of the footing. A drain near the serves no useful purpose. Water collected by the footing drai ried to outlets at the ends of the wall; or, in the case of a ve may be discharged through headers extending through the wall 50 to 100 m (150 to 300 ft). Seepage stresses act downward tow and are usually small compared to precision of the analytical

21.22. EXPANSIVE CLAY

Often the fill behind retaining walls is not selected, and theref times involve expansive clay soils. If an expansive soil is pla wall dry and later becomes wet and expands, the wall usually times sufficiently to cause structural damage to the wall and co tures. Since the soil shear strength is no longer acting to hol from the wall, but instead is pushing against the wall, the p condition applies. It therefore is usually impractical to desi strain an expanding clay. If expansive clay must be used, a b is to ensure that it is fully expanded when it is being backfille for saturated conditions and wetting during backfilling. Anoth to stabilize the clay with hydrated lime. Loose backfilling of will not solve the problem, since the entire soil skeleton mad ual clay clods will expand and exert pressure on the wall.

21.23. METHODS FOR DEVELOPING RESISTING MOM

The several methods for developing resisting moments to o ing of retaining walls are illustrated in Fig. 21.15. In the cas wall, Fig. 21.15(a), resisting moments are developed by th wall W times the horizontal distance x between its centroid overturning A, plus a soil weight W_s times its correspond Cantilever walls, Fig. 21.15(b), conserve concrete but req reinforcement, the main resisting moment coming from th Crib or gabion walls are gravity structures which use soil tively, for mass, Figs. 21.15(c) and (d).

Floor-braced walls, Fig. 21.15(e), are common for base sionally give problems, particularly if backfilling is done bef place. Steel reinforcement is needed in the wall to preven simple beam.

Although braced excavations, Figs. 21.15(f) and (g), temporary support during construction, a much "cleaner" sults from the use of tiebacks which may be left in place to the permanent structure, Figs. 21.15(h) and (i). The tiebacks downward at about 45° to avoid encountering buried utilitie

Reinforced Concrete Design
Chu-Kia Wang
Charles G. Salmon.

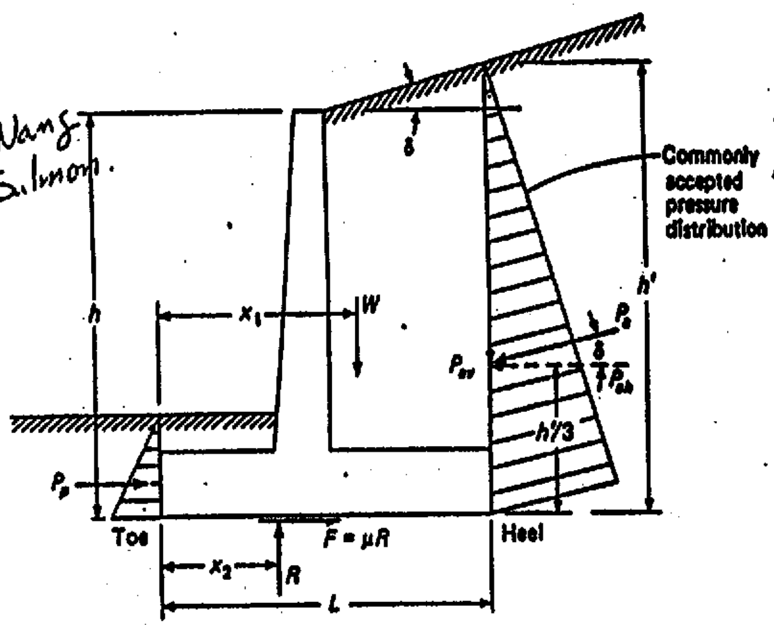


Figure 12.3.1 Forces on retaining wall.

where μ is the coefficient of friction between the soil and the footing. Table 12.3.1 gives the coefficients of friction as recommended by the 1958 AR[EA] specification [4] and these may serve as a guide to typical values in lie[u of] more accurate ones.

Table 12.3.1 VALUES OF COEFFICIENT OF FRICTION BETWEEN SOIL AND CONCRETE, 1958 AREA SPECIFICATIONS

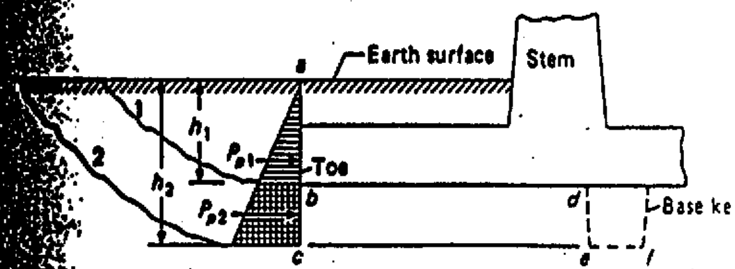
SOIL	μ
Coarse-grained soils (without silt)	0.55
Coarse-grained soils (with silt)	0.45
Silt	0.35
Sound rock (with rough surface)	0.60

The inclusion of some passive resistance P_p on the toe of the foo[ting] may or may not be justified. Certainly, to actually develop passive pres[sure] in the soil in front of the wall, the concrete must have been placed wit[hout] using forms for the toe and without disturbing the soil against which [the] concrete is placed.

Referring to Fig. 12.3.2, the ordinary passive resistance against the [toe] is

$$P_{p1} = \tfrac{1}{2}C_p w h_1^2 \qquad (12.3...)$$

[el]evation. If when all reliable resistances have been included, th[e] [safe]ty remains inadequate, a base key (Fig. 12.3.2) may be used. E[...] [the] base key, when placed in an unformed excavation against un[...] [ma]terial, may be expected to develop an additional passive forc[e] [...] the possible failure plane from line 1 to line 2.



[Fig]ure 12.3.2 Passive resistance and effect of base key.

The base key develops the additional resistance

$$P_{p2} = \tfrac{1}{2}C_p w(h_2^2 - h_1^2)$$

[...] also, an inert region, *bced* of Fig. 12.3.2, is created which [...] [fri]ction plane from *bd* to *ce*. Thus the frictional force developed [...] [bas]ed on the angle α, the angle of internal friction of the soil, ra[ther than] the friction angle between soil and concrete. Normally, tan [...] [gra]nular material, so that, by making the base key sufficiently dee[p] [...] inert block, additional frictional resistance is developed.

Finally, the magnitude and distribution of the soil pressur[e] [...] [inv]estigation. Usual practice is to require the resultant vertical [...] [...] inside the middle third of the footing for sand and gravel sub[base] [...] the middle half for rock subbase. In addition, the maximum [...] [m]ay not exceed the allowable value. Comments regarding allowab[le] [...] [cap]acity as well as some typical safe bearing values are to be [...] [Cha]p. 20.

Referring to Fig. 12.3.3(a), when the entire footing is under [...] the basic equation for combined bending and axial compres[sion] [...] 1-ft strip along the wall is

$$p = \frac{R}{L} \pm \frac{Re(L/2)}{L^3/12} = \frac{R}{L}\left(1 \pm \frac{6e}{L}\right)$$

[For] the limiting condition of zero stress at the heel, $e = L/6$; [Eq. (12.3.)]6 is valid for all positions of R within the middle third.

When the resultant R is outside the middle third [Fig. 12.3.[...] [...] force equilibrium requires

$$R = \tfrac{1}{2}p_t(3x_2)$$

2R

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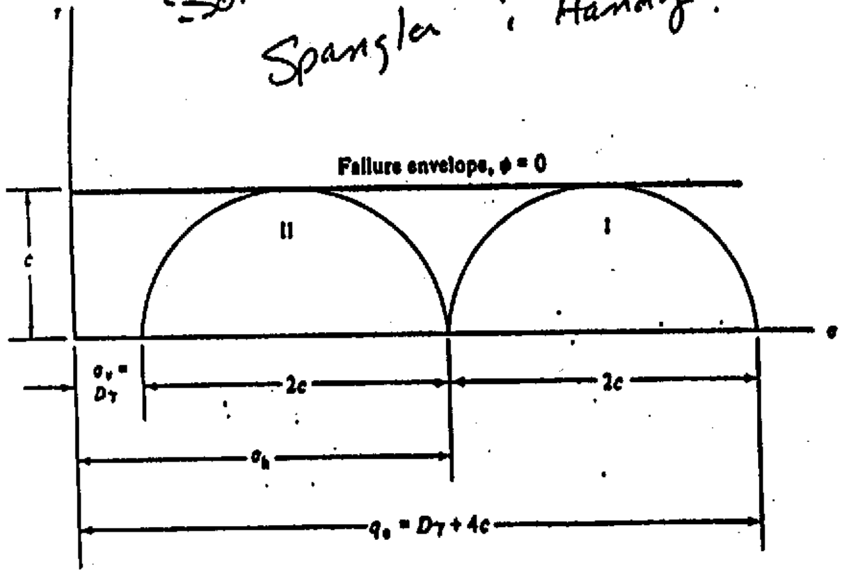


Figure 22.10 Mohr circles showing stress conditions in a $\phi = 0$ soil at failure—I: under a foundation; II: adjacent soil at the same level (see Fig. 22.9)

the minor principal stress for the square I in Fig. 22.9, and the major princi-pal stress at failure becomes $q_0 = D\gamma + 4c$. Subtracting surcharge, the n bearing capacity is therefore

$$q_0 = 4c = 2q_u \qquad (22.1$$

where q_0 is the bearing capacity and q_u is the unconfined compressi strength. This equation also is conservative for the same reasons as Equ tion 22.9, but supports the common use of unconfined compressive streng for bearing capacity of small structures on clay, the nominal factor of safe being 2.

A similar approach, subject to the same criticisms, may be used for so with both cohesion and internal friction. These and other analytic metho are reviewed in a historic context by Jumikis (*5*).

22.10. TWO-DIMENSIONAL ANALYTICAL METHODS BASED ON OBSERVED SHEAR PLANES

Although the assumed geometry of shear in Fig. 22.9 somewhat resemb the observed failure in Fig. 22.2(b), there are some major discrepancies, a the Rankine or principal stress solutions therefore would not be realistic ev if boundary friction were included. Where a potential bearing capacity fa ure involves shearing, the problem may be analyzed by using trial surfa and one of the methods suggested for analysis of slope stability, such as t method of slices. However, this is laborious and not precise because assumptions made in that analysis, although the method of slices is preferred over other methods for nonhomogeneous soil conditions.

One of the major contributions of Terzaghi was to adapt a theoretical solution by Prandtl to bearing capacity problems in soils. Prandtl was concerned with resistance of metal to a punch. He assumed zero friction between the metal and the punch, and that the metal is weightless. Terzaghi assumed essentially the same failure geometry, but added the effects of bearing friction and surcharge soil weight. An essential element of the Prandtl system is a central wedge of soil under the foundation, which moves vertically as the foundation settles and thus pushes the adjacent soil aside. Such wedges have been observed in model studies (see Fig. 22.2c), and are known to form during driving of pile, explaining why flat-ended pile drive about as easily as cone-ended ones.

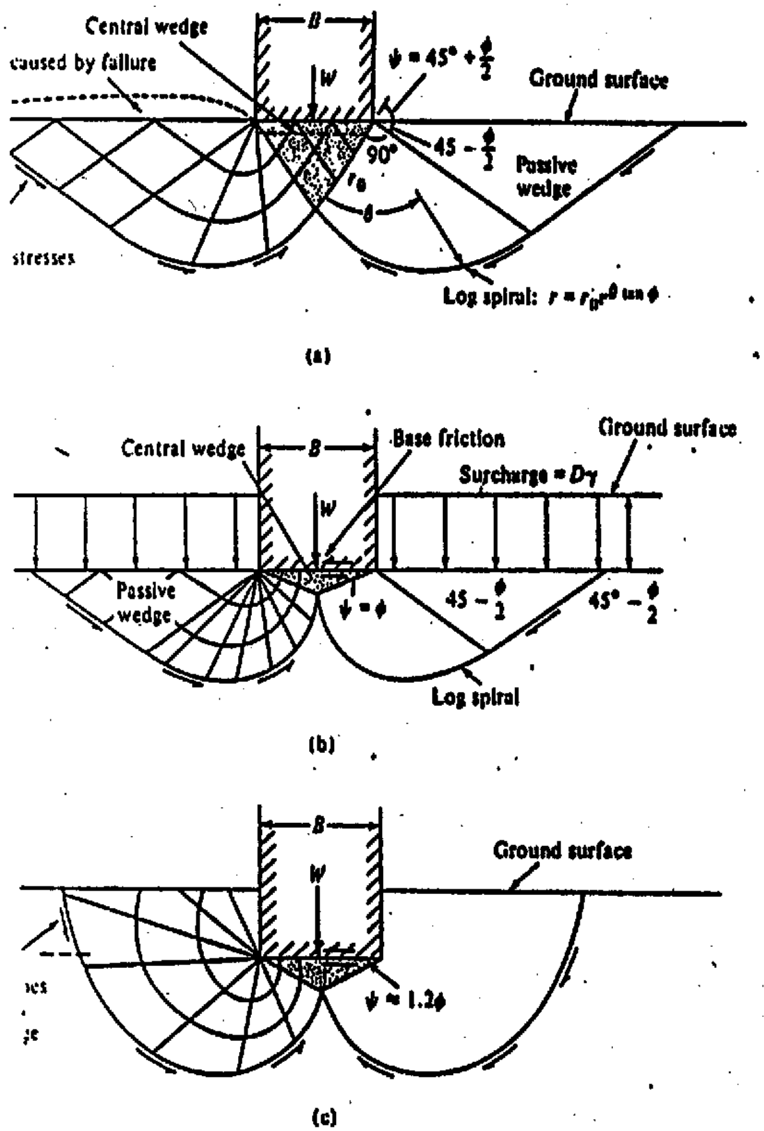
The shape of the basal soil wedge has a considerable influence in the analysis, and is a subject for conjecture. Prandtl's wedge, Fig. 22.11(a), was drawn with a downward base angle $\psi = 45 + \phi/2$. This is consistent with a frictionless base, since the major principal stress then must be vertical, and the angle of shear lines with the major principal stress direction is $45 + \phi/2$. Terzaghi (*15*) proposed that since soil under load tends to bulge laterally due to Poisson's ratio, an inwardly directed horizontal friction should develop at the foundation base, Fig. 22.11(b). As a limiting case the wedge base angle ψ should equal ϕ. Meyerhof let the base angle vary, and found that the most critical condition should be reached when ψ is about 1.2ϕ (*9*), assuming that the base friction is mobilized. Other workers have questioned whether such flat wedges do occur, the steeper Prandtl geometry being apparent in scale models.

22.10.1. Bearing Capacity Equation. The format for bearing capacity equations is in terms of dimensionless bearing capacity factors designated N_γ, N_c, and N_q.

$$q_0 = \underset{\text{width}}{\frac{\gamma B}{2} N_\gamma} + \underset{\text{cohesion}}{cN_c} + \underset{\text{surcharge}}{\gamma D N_q} \qquad (22.11)$$

where q_0 is the bearing capacity in force per unit area, γ is the soil unit weight, B the width of the foundation, c the soil cohesion, and D the depth of the foundation. All three "N" bearing capacity factors are functions of the internal friction angle ϕ and the assumed shape of the failure zone. A useful advantage of this equation is that it allows one to see separately the effects of foundation width, soil cohesion, and surcharge.

The bearing capacity factors depend only on the soil friction angle ϕ, and on the assumed geometry. The equations for N_c and N_q, Table 22.3, are analytical and exact and may be programmed, while the equations for N_γ are derived by curve-fitting to values determined by trial. Generally the Terzaghi factors are the most conservative, but have been shown to be accurate for cohesive soils (*1*). Factors based on both the Terzaghi and Prandtl geometries are presented in Table 22.3. Analogous factors were developed by



11 Idealized bearing capacity failure geometries drawn for $\phi = 20°$. . with base angle $\psi = 45 + \phi/2$; (b) Terzaghi with rough base, $\psi = \phi$; ɪof with rough base, ψ varied for minimum bearing value.

on the basis of the geometry of Fig. 22.11(c), with shearing resis- ı the surcharge. While logical, the Meyerhof factors tend to be on side for larger embedment depths, probably because the shearing of the surcharge may not be mobilized. That is, any compression close to the foundation will tend to allow progressive failure, the

TABLE 22.3 Bearing Capacity Factors for Long Foundations[a]

	Terzaghi Rough Base			Prandtl-Reisner Smooth Base			$N_{\gamma,q}$[g] (Eq. 22.12)
ϕ	N_γ[b]	N_c[c]	N_q[d]	N_γ[e]	N_c[c]	N_q[f]	
0	0.0	5.7	1.0	0.0	5.1	1.0	—
5	0.5	7.3	1.6	0.5	6.5	1.6	—
10	1.2	9.6	2.7	1.2	8.3	2.5	1.9 ± 0.8
15	2.5	13	4.4	2.6	11	3.9	3.4 ± 0.9
20	5.0	18	7.4	5.4	15	6.4	6.0 ± 1.1
25	9.7	25	13	11	21	11	11 ± 1
30	20	37	22	22	30	18	20 ± 2
35	42	58	41	48	46	33	41 ± 6
40	100	96	81	110	75	64	89 ± 20
45	300	170	170	270	130	130	—
LOCAL SHEAR							
0	0.0	5.7	1.0	0.0	5.1	1.0	—
5	0.3	6.7	1.4	0.3	6.0	1.3	—
10	0.7	8.0	1.9	0.7	7.0	1.8	1.3 ± 0.7
15	1.2	9.6	2.7	1.2	8.3	2.5	1.9 ± 0.8
20	2.0	12	3.8	2.1	10	3.4	2.8 ± 0.9
25	3.2	14	5.3	3.4	12	4.6	4.1 ± 1.0
30	5.0	18	7.4	5.4	15	6.4	6.0 ± 1.1

[a] $q_0 = \frac{\gamma B}{2} N_\gamma + cN_c + \gamma D N_q$.
[b] After Bowles (1). Approximate equation fit by the authors: $N_\gamma = 1.1(N_q - 1) \tan 1.3\phi$.
[c] $N_c = (N_q - 1) \cot \phi$ (exactly).
[d] $N_q = \frac{e^{(1.5\pi - \phi)\tan\phi}}{2\cos^2(45 + \phi/2)}$ (exactly).
[e] Equation fit by Vesić (17): $N_\gamma = 2(N_q + 1) \tan \phi$.
[f] $N_q = e^{\pi \tan \phi} \tan^2 (45 + \phi/2)$ (exactly).
[g] $N_{\gamma,q} = \frac{1}{2}(N_\gamma + N_q) \pm$ standard deviation.

surpassed before the rest of the shear is mobilized. This has been verified by experiments by Vesić.

Example 22.3

A clay soil has $\phi = 10°$, $c = 19.2$ kPa (400 lb/ft²), and $\gamma = 15.7$ kN/m³ (100 lb/ft³). Evaluate the relative influences of footing width and depth on total supporting capacity of a footing 1.22 m (4 ft) wide and 1.52 m (5 ft) deep.

SOLUTION. From Table 22.3 for a rough footing $N_\gamma = 1.2$, $N_c = 9.6$, and $N_q = 2.7$. Therefore according to Equation 22.11,

$$q_0 = \frac{15.7(1.22)}{2}(1.2) + (19.2)(9.6) + 15.7(1.52)(2.7)$$
$$= 11.5 + 184 + 64.4 \text{ kPa} = 260 \text{ kPa } (5430 \text{ lb/ft}^2)$$

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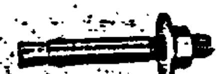
WEDGE ANCHORS



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¼"/20	1¾"	⅜"	¾"	1⅛"	1550	1828	WS-1416	3A442	$33.11	$31.66	100	2.2
	2¼	¾	¾		2200	1910	WS-1422	3A443	40.60	38.81	100	4.2
	3¼	1¾	¾		3061	1991	WS-1432	3A444	46.12	46.99	100	5.0
⅜/16	2¼	⅛	1½	1½	3219	4029	WS-3822†‡	3A445	24.25	21.78	50	4.5
	2¾	½	1½		5678	4906	WS-3826†‡	3A446	25.85	23.29	50	5.2
	3	1⅛	1½		5935	4581	WS-3830†‡	3A447	26.10	23.48	50	5.1
	3¾	1⅞	1½				WS-3836†‡	3A448	34.65	30.97	50	6.6
	5	3¼	1½				WS-3850†‡	3A449	40.20	36.94	50	7.6
½/13	2¾	½	1⁵⁄₁₆	3¼	5384	6900	WS-1228†‡	3A450	22.63	20.51	25	5.0
	3¾	1⅛	1⁵⁄₁₆		7553	7449	WS-1236†‡	3A451	23.32	21.50	25	5.5
	4¼	1½	1⁵⁄₁₆		9003	7096	WS-1242†‡	3A452	24.43	22.93	25	6.4
	5½	2¾	1⁵⁄₁₆				WS-1254†‡	3A453	28.21	26.55	25	7.7
	7	4¼	2⅛				WS-1270†‡	3A454	34.95	32.83	25	9.3
⅝/11	3½	½	1¾	2¾	8000	12478	WS-5834†‡	3A455	17.95	16.27	10	4.8
	4½	1½	1¾		10178	13285	WS-5842†‡	3A456	18.49	16.82	10	4.3
	5	1½	1¾		12453	14002	WS-5850†‡	3A457	19.31	17.76	10	8.2
	6	2½	1¾				WS-5860†‡	3A458	20.30	19.05	10	8.3
	7	3½	1¾				WS-5870†‡	3A459	22.76	22.26	10	8.1
	8½	5½	1¾				WS-5884†‡	3A460	25.43	24.22	10	8.8
¾/10	4¼	2¼	1¾	3¼	9621	18129	WS-3442†‡	3A461	21.32	20.31	10	6.7
	4¾	¾	1¾		16489	18585	WS-3446†‡	3A462	22.85	21.84	10	7.4
	5½	1½	1¾		19053	19042	WS-3454†‡	3A463	29.61	27.19	10	7.8
	6¼	2¼	1¾				WS-3462†‡	3A464	31.26	29.47	10	8.7
	7	3	1¾				WS-3470†‡	3A465	33.60	31.74	10	8.6
	8½	4½	1¾				WS-3484†‡	3A466	39.35	37.37	10	12.8
	10	6	1¾				WS-34100‡	3A467	48.34	45.71	10	14.9

(*) Ultimate load capacity in 4000 PSI stone aggregate concrete. For load capacities in structural lightweight aggregate concrete refer to ICBO Report No. 1372. Safe working loads for single installations under static loading should not exceed 25% of the ultimate load capacity. (†) Indicates UL Listing. (‡) Indicates FM listing. Do not use for continuous low temperature applications below 0°F/–17.8°C.

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¼"/20	⅜"	⅜"	1"	2,204	1,986	RM-14	3A492	$38.17	$35.55	100	26
⅜/16	½	½	1⅝	6,350	3,968	RM-38†‡	3A493	28.27	25.21	50	22
½/13	⅝	¾	2	8,544	6,502	RM-12†‡	3A494	47.01	44.89	50	52
⅝/11	⅞	1	2½	15,218	10,350	RM-58†‡	3A495	41.83	41.04	25	80
¾/10	1	1¼	3³⁄₁₆	17,255	13,962	RM-34†‡	3A496	69.97	65.52	25	128

(*) Ultimate load capacity in 4310 PSI ¾ inch crushed limestone aggregate concrete. For load capacities in structural lightweight aggregate concrete refer to ICBO Report No. 1372. Safe working loads for single installations under static loading should not exceed 25% of the ultimate load conditions. (†) Indicates UL Listing. (‡) Indicates FM listing.

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3A493	RT-138	3A498	3.06	2.98	0.3
3A494	RT-112	3A499	3.56	3.51	0.6
3A495	RT-158	3A501	$5.64	$5.52	0.8
3A496	RT-134	3A502	8.31	8.12	1.1

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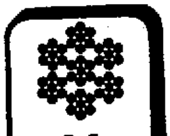
7×7 Strand Core


7×19 Strand Core

All wire ropes listed here have excellent strength. Corrosion resistance is very good. Breaking strength conforms to latest revision of Federal Specification Mil-RR-410D except where indicated. 7×19 construction is available in two classes: 3450T series meets only the breaking strength requirements of Federal Specification Mil-RR-410D. The 3332T series is a full compliance category that meets all the requirements of Federal Specification Mil-W-83420. To meet all requirements, this rope must pass thorough exceptional quality control testing plus offer a reduced stretch factor and increased fatigue resistance. All Mil-W-83420 Federal Specification galvanized rope is lubricated prior to shipment.

Nonflex 1×19—Single Strand* / Flexible 7×7—Strand Core*

Dia.	1×19 Break. Strgth. Lbs.	1×19 Cut Lengths No.	NET/FOOT	1×19 100-Ft. Lengths No.	NET/LGTH.	1×19 300-Ft. Lengths No.	NET/LGTH.	7×7 Break. Strgth. Lbs.	7×7 Cut Lengths No.	NET/FOOT	7×7 100-Ft. Lengths No.	NET/LGTH.	7×7 300-Ft. Lengths No.	NET/LGTH.
1/32"	185	3450T51♦•	$0.05	3450T571♦•	$4.00	3450T572♦•	$8.00	—	—	—	—	—	—	—
3/64"	375	3450T52♦•	.05	3450T581♦•	4.80	3450T582♦•	9.00	—	—	—	—	—	—	—
1/16"	500	3450T13•	.08	3450T132•	7.00	3450T133•	18.00	480	3450T24	$0.16	3450T243	$16.00	3450T246	$38.00
3/32"	1,200	3450T14•	.12	3450T142•	10.00	3450T143•	24.00	920	3450T28	.22	3450T282	19.00	3450T283	51.00
1/8"	2,100	3450T15•	.15	3450T153•	11.00	3450T154•	30.00	1,700	3450T29•	.29	3450T329•	24.00	3450T225•	54.00
5/32"	3,300	3450T16•	.18	3450T163•	15.00	3450T164•	38.00	2,800	3450T29•	.35	3450T292•	24.00	3450T293•	63.00
3/16"	4,700	3450T17•	.29	3450T172•	23.00	3450T173•	57.00	3,700	3450T31•	.46	3450T313•	40.00	3450T315•	105.91
1/4"	6,200	3450T19•	.38	3450T192•	31.00	3450T193•	81.00	6,100	3450T32•	.47	3450T322•	41.00	3450T325•	108.00

Extra Flex 7×19—Strand Core* / Extra Flex 7×19—Strand Core—Full Compliance

Dia.	Break. Strgth. Lbs.	Cut Lengths No.	NET/FOOT	100-Ft. Lengths No.	NET/LGTH.	300-Ft. Lengths No.	NET/LGTH.	Full Compl. Break. Strgth. Lbs.	Cut Lengths No.	NET/FOOT	100-Ft. Lengths No.	NET/LGTH.	300-Ft. Lengths No.	NET/LGTH.
3/32"	1,000	3450T37	$0.33	3450T511	$29.00	3450T715	$75.00	1,000	3332T51	$0.36	3332T512	$29.00	3332T513	$73.00
1/8"	2,000	3450T38	.34	3450T383	31.00	3450T784	81.00	2,000	3332T52	.42	3332T522	34.00	3332T523	98.00
5/32"	2,800	3450T39	.40	3450T392	36.00	3450T394	98.00	2,800	3332T53	.46	3332T532	38.00	3332T533	98.00
3/16"	4,200	3450T41	.47	3450T413	41.00	3450T743	109.00	4,200	3332T54	.58	3332T542	48.00	3332T543	128.91
7/32"	5,600	3450T42	.48	3450T423	41.00	3450T424	108.00	5,600	3332T55	.68	3332T552	57.00	3332T553	158.00
1/4"	7,000	3450T43	.71	3450T433	62.00	3450T438	155.00	7,000	3332T56	.78	3332T562	68.00	3332T563	176.00
9/32"	8,000	3450T44	.89	3450T443	82.00	3450T445	135.00	—	—	—	—	—	—	—
5/16"	9,800	3450T45	.84	3450T453	74.00	3450T455	192.00	9,800	3332T58	.94	3332T582	78.99	3332T583	199.72
3/8"	14,400	3450T46	.96	3450T463	84.00	3450T464	215.00	14,400	3332T59	1.18	3332T592	98.00	3332T593	252.02

*Not lubricated. ♦Supplied in 1×7 construction. •Not covered by Federal Spec. Mil-RR-410D.

Galvanized Steel 7-Wire Guy Strand


1×7 Single Strand

• Abrasion Resistance—Good
• Flexibility—Low

1×7—SINGLE STRAND—Also known as messenger strand. This moderate strength strand is recommended for guying, control and support purposes. It is also excellent for supporting telephone and electrical cables.

Dia.	Breaking Strength Lbs.	No.	NET/FOOT 1-99	100-299	300-Up
1/4"	3,150	3466T54	$0.18	$0.16	$0.14
5/16"	5,350	3466T55	.26	.22	.20
3/8"	6,950	3466T56	.31	.27	.24
1/2"	12,100	3466T58	.56	.46	.42

Galvanized Iron Sash Cord


6×7 Fiber Core

• Abrasion Resistance—Moderate
• Flexibility—Very Good

6×7—FIBER CORE—Use for connecting sash to window weights and connecting sliding doors to counterweights. Galvanized sash cord is also ideal for operating freight elevator gates, shades, curtains, bells, whistles, and for any other application where an inexpensive metallic cord of relatively low strength is required. This cord is not prelubricated.

Dia.	Breaking Strength Lbs.	No.	NET/FOOT 1-99	100-299	300-Up
1/16"	140	3449T14	$0.31	$0.27	$0.24
3/32"	315	3449T15	.32	.28	.25
1/8"	500	3449T16	.50	.44	.39
5/32"	840	3449T17	.51	.45	.40
3/16"	1,150	3449T18	.47	.42	.38
7/32"	1,840	3449T19	.58	.52	.47

Galvanized Improved Plow Steel Wire Rope


6×19 Fiber Core — 6×19 IWRC

Fiber Core • Abrasion Resistance—Moderate
IWRC • Abrasion Resistance—Good

6×19—FIBER CORE OR IWRC—Use for rigging, guying and tow ropes in applications where rope is not continually bending over sheaves and around drums. Strength is about 10% less than a nongalvanized rope of the same grade and classification. Flexibility is very good. Breaking strength conforms to latest revision of applicable Federal Specification RR-W-410.

Dia.	Breaking Strength Lbs.	No.	NET/FOOT 1-99	100-299	300-Up
FIBER CORE					
3/8"	10,980	3454T13	$1.38	$1.11	$0.95
1/2"	19,260	3454T14	1.82	1.63	1.38
5/8"	30,000	3454T15	2.67	2.36	1.89
IWRC					
1/2"	20,600	3454T21	2.29	1.94	1.80

Galva-Flex Wire Rope


6×37 Fiber Core — 6×37 IWRC

Fiber Core • Abrasion Resistance—Low
IWRC • Abrasion Resistance—Moderate

6×37—FIBER CORE OR IWRC—The large number of small wires per strand provides excellent flexibility and high fatigue resistance. This improved plow steel wire rope is ideal for use on small drums and sheaves.

To help avoid crushing, use well-designed sheaves and grooved drums. IWRC is less susceptible to crushing than fiber core. This wire rope

Dia.	Breaking Strength Lbs.	No.	NET/FOOT 1-99	100-299	300-Up
FIBER CORE					
1/4"	4,940	3323T71	$1.86	$1.60	$1.38
3/8"	10,980	3323T72	2.49	2.14	1.85
1/2"	19,260	3323T73	3.14	2.70	2.33
IWRC					
1/4"	5,300	3323T21	2.11	1.81	1.58
3/8"	11,800	3323T22	2.83	2.43	2.16
1/2"	20,600	3323T23	3.86	3.10	2.67

All descriptions of wi... ments are provided to help you choose the proper wire rope for your individual needs. To ... engineering practices.

Galvanized and Type 304 stainle... ...red with vinyl or nylon coating ... conforms to applicable Federal ... Choose cut lengths. 50-foot coils ...

ADVANTAGES OF WIRE RO...

(1) Increases cable life by protectin...
(2) Protects pulleys and drums fro...
(3) Seals in lubricant and seals ... moisture.
(4) Protects hands, clothing, and a... ...ay come into contact with cable...
(5) Helps maintain full original ca...
(6) Provides good handling surfac...

7×7 STRAND

...re Cable Dia.	Finish Cable Dia.	Break. Strength Lbs.	Cut Leng... No.	NET/F...
GALVANIZED STEEL				
...	1/16"	270	3696T4	...
...	3/32"	480	3696T27	...
...	1/8"	480	3696T1	...
...	1/8"	920	3696T6	...
...	5/32"	920	3696T7	...
...	3/16"	920	3696T2	...
...	1/8"	480	3420T121	...
...	3/16"	920	3420T122	...
...	1/8"	480	3420T125	...
...	3/16"	920	3420T126	...
STAINLESS STEEL				
...	1/16"	270	3696T8	...
...	3/32"	480	3696T9	...
...	1/8"	480	3696T11	...
...	1/8"	920	3696T12	...
...	5/32"	920	3696T13	...
...	3/16"	920	3696T5	...
...	1/8"	480	3420T381	...
...	3/16"	920	3420T382	...
...	1/8"	480	3420T383	...
...	3/16"	920	3420T384	...

7×19 STRAND

...re Cable Dia.	Finish Cable Dia.	Break. Strength Lbs.	Cut Le... No.	NET/...
GALVANIZED STEEL				
...	3/16"	2,000	3696T3	...
...	7/32"	2,000	3696T21	...
...	1/4"	4,200	3696T22	...
...	5/16"	4,200	3696T23	...
...	5/16"	7,000	3696T24	...
...	11/32"	9,800	3696T25	...
...	15/32"	14,400	3696T26	...
...	3/16"	2,000	3420T161	...
...	5/16"	4,200	3420T162	...
...	3/16"	2,000	3420T169	...
...	5/16"	4,200	3420T171	...
STAINLESS STEEL				
...	3/16"	1,760	3697T21	...
...	7/32"	1,760	3697T22	...
...	1/4"	3,700	3697T23	...
...	5/16"	3,700	3697T24	...
...	5/16"	6,400	3697T25	...
...	11/32"	9,000	3697T26	...
...	15/32"	12,000	3697T27	...
...	3/16"	1,760	3420T410	...
...	5/16"	3,700	3420T413	...
...	3/16"	1,760	3420T423	...
...	5/16"	3,700	3420T426	...

...ll descriptions of wire rope a... ...dividual needs. To select wi...