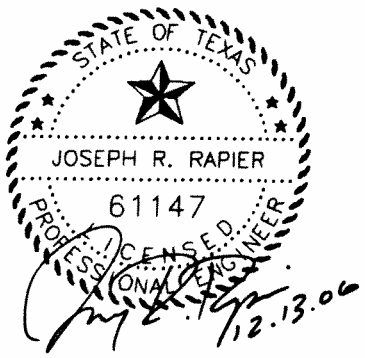
Design Report

NRCS – Natural Resources Conservation Service

Standard Drawings
Windmill Towers

December 2006

PSC Project # 01292604



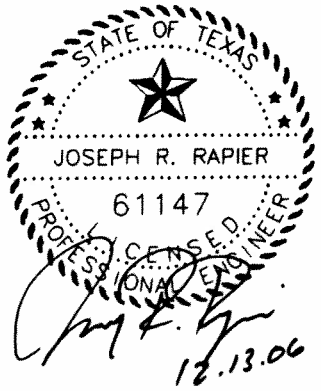
Certification: All components comply with the design requirements set forth in the Statement of Work, Texas NRCS Conservation Practice Standard 533, Windmill Tower and other referenced codes.

PSC **Parkhill, Smith & Cooper, Inc.**
Engineers ▪ Architects ▪ Planners

I certify to the best of my knowledge that Texas Standard drawings:

TX-EN-0497	**4 Post Steel Windmill Tower and Foundations For 8' Diameter Mill at 34' Height**
TX-EN-0498	**4 Post Steel Windmill Tower and Foundations For 12' Diameter Mill at 34' Height**
TX-EN-0499	**4 Post Steel Windmill Tower and Foundations For 16' Diameter Mill at 37' Height**

meet the design requirements in the Statement of Work for Standard Drawing for Windmill Tower, USDA-NRCS Task Order 53-7442-4-021, and Texas NRCS Conservation Practice Standard and Specifications, 533, Pumping Plant, and Texas Water Well Drillers and Pump Installers Administrative Rules and other referenced codes.



Parkhill, Smith & Cooper, Inc.
Engineers ▪ Architects ▪ Planners
4222 85th Street, Lubbock, Texas 79423
(806) 473-2200 FAX (806) 473-3500

TABLE OF CONTENTS

Page

PURPOSE 1

OVERVIEW OF WINDMILL TOWERS 1

APPLICABLE CODES 1

LOADS AND LOAD COMBINATIONS 2

DESIGN PROCEDURE 4

DESIGN ASSUMPTIONS 5

DESIGN LIMITATIONS 6

TOWER REQUIREMENTS 6

INSTALLATION 7

COST ESTIMATION TABLE 7

REFERENCES 8

APPENDICES

APPENDIX A – STATEMENT OF WORK

APPENDIX B – CALCULATIONS AND DATA FOR AN 8' WINDMILL ON A 34' STEEL TOWER

APPENDIX C – CALCULATIONS AND DATA FOR A 12' WINDMILL ON A 34' STEEL TOWER

APPENDIX D – CALCULATIONS AND DATA FOR A 16' WINDMILL ON A 37' STEEL TOWER

PURPOSE

The following structural design report and standard drawings for three (3) steel windmill towers includes construction and materials specifications, anchorage requirements, ladder, work platform, and all connector designs and details including bolts, welds, etc as described by the NRCS Statement of Work dated May 5, 2006 included in this report as Appendix A. The report and standard drawings have statewide application in Texas and have been prepared with the most economical new structural steel.

OVERVIEW OF WINDMILL TOWERS

The windmill towers are briefly described as follows:

1. Steel Windmill Tower with minimum tower height of 30 ft without the stub tower, prepared for the maximum anticipated condition for an 8 ft windmill motor pumping from a depth of 300 ft.
2. Steel Windmill Tower with minimum tower height of 30 ft without the stub tower, prepared for the maximum anticipated condition for a 12 ft windmill motor pumping from a depth of 660 ft.
3. Steel Windmill Tower with minimum tower height of 30 ft without the stub tower, prepared for the maximum anticipated condition for a 16 ft windmill motor pumping from a depth of 1600 ft.

APPLICABLE CODES

Texas NRCS Conservation Practice Standard and Specifications 533, Pumping Plant.

Texas Water Well Drillers and Pump Installers Administrative Rules.

Minimum Design Loads for Buildings and Other Structures ASCE 7-02.

American Institute of Steel Construction, Manual of Steel Construction, Allowable Stress Design. (AISC)

Building Code Requirements for Structural Concrete (ACI 318-02), American Concrete Institute.

LOADS AND LOAD COMBINATIONS

LOADS

Dead Load

The dead load is the estimated total weight of the steel structure and the windmill. An additional load of 250 pounds has been added to the top of each tower representing one (1) man atop the tower. The unit weight of each windmill (tower not included) is provided by the manufacturer as given below:

8' windmill	355 pounds
12' windmill	1090 pounds
16' windmill	2450 pounds

Wind Load

The design wind load is the load acting on the windmill from wind pressure as per ASCE 7-02, Section 6. The wind pressure acting on the windmill is calculated as maximum 90 miles per hour wind (WL). The design wind loads for the steel towers have been generated using Wind Loads for Structures 2002, Version 1.9, a wind load analysis software package created by Standards Design Group, Inc. The software determines the external forces applied to each component within the towers due to a 90 miles per hour wind. The average width of each tower and mean height of the corresponding mill was used to generate the wind loads. The wind loads were then applied to the towers in a 3D computer model. Wind load factors in the design include:

Basic Wind Speed (V)	90 mph
Terrain Exposure	D
Gust Effect Factor	0.85
Structure Category	I
Force Coefficient on Tower (C_f)	3.21
Force Coefficient on Mill (C_f)	1.60
Importance Factor (I)	0.80

Snow/Ice Load

The design snow loads (SL) as per ASCE 7-02 do not provide for snow drifts on towers. Therefore, calculations for ice loads due to freezing rain and snow have been included in the design per ASCE 7-02, Section 10. Ice load factors used in the design include:

Topographic Factor (K_{zt})	1.18
Surface Roughness	D
Ice Thickness (t)	¾"

Maximum Axial Load

The maximum axial load (ALM) as per the NRCS Statement of work, includes loads from sucker rods, pipe column and water column. Worst case scenario of steel pipe and sucker rods has been considered in the analysis.

Maximum Pumping Load

The maximum axial load under maximum pumping rates (ALP), as per the NRCS Statement of Work, includes loads from sucker rods, pipe and water columns. Worst case scenario of steel pipe and sucker rods has been considered in the analysis.

Maximum Static Load

The maximum axial load under static conditions (ALS), as per the NRCS Statement of Work, includes loads from sucker rods and pipe column. Worst case scenario of steel pipe and sucker rods was considered in the analysis.

Load Combinations

The analysis includes the following load combinations as per the NRCS Statement of Work dated May 5, 2006.

1. Dead Load + Wind Load (DL+WL)
2. Dead Load + Wind Load + Static Load (DL+WL+ALS)
3. Dead Load + Axial Load (DL+ALM)
4. Dead Load + 20% Wind Load + Pumping Load (DL+20%WL+ALP)
5. Dead Load + Snow/Ice Load + Pumping Load (DL+SL+ALP)
6. Dead Load + Wind Load + 20% Snow/Ice Load (DL+WL+20%SL)

Critical Load Cases

The critical load cases for each component of an 8' windmill on a 34' steel tower are as follows:

Foundations	Load Combination 2
Corner Posts	Load Combination 2
Horizontal Girts	Load Combination 6
Wind Braces	Load Combination 6

The critical load cases for each component of a 12' windmill on a 34' steel tower are as follows:

Foundations	Load Combination 2
Corner Posts	Load Combination 2
Horizontal Girts	Load Combination 6
Wind Braces	Load Combination 6

The critical load cases for each component of a 16' windmill on a 37' steel tower are as follows:

Foundations	Load Combination 2
Corner Posts	Load Combination 2
Horizontal Girts	Load Combination 6
Wind Braces	Load Combination 6

DESIGN PROCEDURE

STEEL WINDMILL TOWERS

The loads and load combinations listed above were used to analyze each steel windmill tower. The structural analysis and design for each of the steel components of the towers has been performed in accordance with the allowable stress design method of the Ninth Edition of the Steel Construction Manual published by the American Institute of Steel Construction.

The 8' mill on a 34' tower, 12' mill on a 34' tower, and the 16' mill on a 37' tower have all been modeled in RISA-3D, Version 5.0, a finite element and matrix analysis software package. The model determines the internal forces within each component due to combinations of external gravity loads on the system. The model analyzes the data and determines the combined stresses caused by the axial forces, shear forces and bending moments. The resulting stresses and maximum forces from the computer analyses are compared to the allowable stresses dictated by code for steel. The resulting deflection and support reactions are tabulated as well. The results of the computer analysis and the input and output from RISA-3D can be found in the Appendices of this report.

FOUNDATIONS

The loads and load combinations listed above were used to analyze the tower foundations. Each tower is supported by either a drilled pier or a square footing at each corner post (4 total). The results from the computer model were used to calculate required foundation sizes. Each foundation has been designed based on bearing pressure and overturning. A design bearing pressure of 2,000 pounds per square foot has been used for the soils below the foundations. The weight of the concrete pier or footing and side bearing soil has been calculated to resist the towers from overturning. The volume of soil calculated to resist overturning is equal to a 45 degree wedge from vertical with the same width as the pier or footing. Additional 10 degree wedges from horizontal on either side of the pier or footing are also included.

The resulting foundation sizes and corresponding towers are as follows:

8' mill on a 34' tower	2'-0" diameter x 4'- 0" deep pier or 2'- 6" square x 3'- 0" deep footing
12' mill on a 34' tower	3'-0" diameter x 4'-0" deep pier or 3'- 6" square x 3'- 0" deep footing
16' mill on a 37' tower	3'-0" diameter x 5'-0" deep pier or 4'- 6" square x 3'- 0" deep footing.

The results of the computer analysis and the calculations for the foundations can be found in the Appendices of this report.

DESIGN ASSUMPTIONS

WEIGHT OF MATERIALS

PSC assumed the following weight of the corresponding materials:

Steel	490 lb/ft^3
Concrete	150 lb/ft^3
Water	62.4 lb/ft^3
Ice	6 lb/ft^3
Soil	105 lb/ft^3

CONCRETE

Steel windmill tower foundation design is based on using concrete with 28-day compressive strength of 3,000 psi.

STEEL

PSC assumed the steel angles and flat bar have a modulus elasticity of 29 x 10^6 pounds per square inch with a yield strength greater than or equal to 36,000 pounds per square inch. All steel angles and flat bar shall be painted or galvanized to prevent rust and corrosion. All bolts, nuts and washers shall be grade 5 steel or better.

FOUNDATIONS

PSC assumed an allowable soil bearing capacity of 2,000 pounds per square foot at the base of each foundation. No skin friction on the piers or footings is permitted in the analysis.

LOADS

Wind Load

PSC assumed an allowable wind design velocity of 90 miles per hour.

Live Load

PSC assumed an additional load of 250 pounds atop each tower to account for one (1) man on the tower. Although this load application is a live load, the load was applied in the dead load case.

Snow/Ice Load

PSC assumed the intent of the design to be ice loads rather than snow loads as stated in the statement of work. Ice loads provide for a safer, more conservative analysis with real applications in the field.

Maximum Pumping Load

PSC assumed ALP to be equal to ALM in the absence of water friction within the pipe column. According to the mill manufacturers' publications, the water flow from an 8', 12' and 16' mill is not high enough to generate water friction in a pipe.

DESIGN LIMITATIONS

LOCATION

The steel windmill tower design shall be limited to windmills used in the state of Texas only. For windmills used near the Gulf coastline, where design wind speeds are higher, additional analysis and requirements may be required.

TOWER REQUIREMENTS

The use of other windmill towers and/or tower configurations is acceptable provided that the tower has been designed to meet the requirements set forth in the statement of work in the appendices of this report. Alternate towers may also be designed for maximum loads and load combinations within a specified geographical area of Texas. The design must be signed and sealed by a licensed professional engineer, licensed to practice in Texas.

INSTALLATION

Extreme caution must be taken during the assembly and installation of a windmill tower. Wear and use appropriate safety equipment including, but not limited to, an ANSI approved hard hat, steel-toed boots and a safety harness. Care must be taken to tighten all bolts and nuts at each level of the tower prior to constructing or climbing on the next level of the tower. Always avoid erecting a windmill tower below or near overhead power lines.

It is important that the foundations be excavated and erected as shown on the drawings. The anchor posts with anchor feet may be set in place prior to erecting the tower. Allow 72 hours for the concrete to cure before beginning tower erection.

The windmill tower may be assembled on the ground and then hoisted into place using a crane. Caution must be taken not to damage any of the members during hoisting. The tower may also be erected in place from the ground up. When erecting the tower one section at a time from the ground up, scaffolding planks may be used at each level.

Care must be taken to bolt together each connection as shown in the details. The corner posts must be overlapped as shown in order for the girts and braces to properly fit. Refer to the details provided on the drawings for proper erection and assembly. Upon completion of the tower, check all bolted connections and tighten any loose bolts. Refer to the manufacturers assembly instructions for proper installation of the stub tower, platforms and mill.

COST ESTIMATION TABLE

	Materials				Protective Coating			Foundation		
Tower	Angle + Bolts		Pipe	Ladder	Paint	Angle Galvanize	Pipe Galvanize	Piers	Footings	Most Economical
8' Mill	$312.00	$152.50	$854.00	$58.00	$65.00	$284.50	$559.50	$658.00	$562.00	$1,149.50
12' Mill	$458.00	$152.50	$854.00	$58.00	$65.00	$396.50	$559.50	$881.00	$816.00	$1,549.50
16' Mill	$625.00	$155.00	$994.00	$58.00	$65.00	$525.00	$642.00	$1,101.50	$1,155.50	$2,004.50

Notes:

Price of steel members is based on current pricing data as of June 2006

Price of foundation includes current pricing data for excavation as of June 2006

REFERENCES

1. ASCE Committee 7-02, *Minimum Design Loads for Buildings and Other Structures*, American Society of civil Engineers, Reston, Virginia, 2003.

2. AISC Committee, *Manual of Steel Construction, Allowable Stress Design*, Ninth Edition American Institute of Steel Construction, Inc., Chicago, IL, 1989.

3. Texas NRCS Conservation Practice Standard and Specifications 533, Pumping Plant.

4. Texas Water Well Drillers and Pump Installer Administrative Rules.

5. Donald P. Coduto, Foundation Design: Principles and Practices, Prentice Hall, Englewood Cliffs, New Jersey, 1994.

6. ACI Committee 318, *Building Code Requirements for Structural Concrete (ACI 318-02)*, American Concrete Institute, Farmington Hills, MI, 2002.