

# Technical Description of the 1.6-100 Wind Turbine and Major Components

The wind turbine is a three bladed, upwind, horizontal-axis wind turbine with a rotor diameter of 100 m. The turbine rotor and nacelle are mounted on top of a tubular tower giving a rotor hub height of 80m. The machine employs active yaw control (designed to steer the machine with respect to the wind direction), active blade pitch control (designed to regulate turbine rotor speed), and a generator/power electronic converter system.

The wind turbine features a distributed drive train design wherein the major drive train components including main shaft bearings, gearbox, generator, yaw drives, and control panel are attached to a bedplate (see Figure 1).

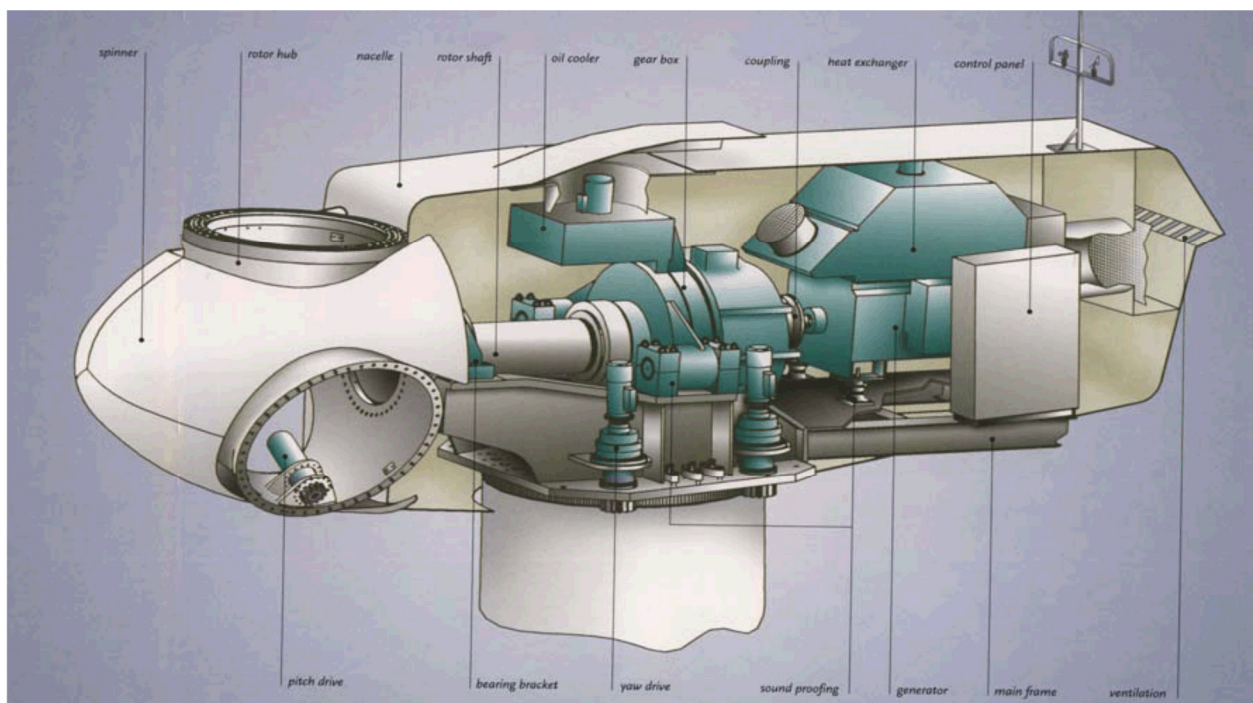


Figure 1: GE Energy 1.6-100 wind turbine nacelle layout

## Rotor

The rotor diameter is 100 m, resulting in a swept area of 7,854 m, and is designed to operate between 9.75 and 16.18 revolutions per minute (rpm). Rotor speed is regulated by a combination of blade pitch angle adjustment and generator/converter torque control. The rotor spins in a clock-wise direction under normal operating conditions when viewed from an upwind location.

Full blade pitch angle range is approximately 90°, with the 0°-position being with the airfoil chord line flat to the prevailing wind. The blades being pitched to a full feather pitch angle of approximately 90° accomplishes aerodynamic braking of the rotor; whereby the blades “spill” the wind thus limiting rotor speed.

## Blades

There are three rotor blades used on each wind turbine. The airfoils transition along the blade span with the thicker airfoils being located in-board towards the blade root (hub) and gradually tapering to thinner cross sections out towards the blade tip.

## **Blade Pitch Control System**

The rotor utilizes three (one for each blade) independent electric pitch motors and controllers to provide adjustment of the blade pitch angle during operation. Blade pitch angle is adjusted by an electric drive that is mounted inside the rotor hub and is coupled to a ring gear mounted to the inner race of the blade pitch bearing (see Figure 1).

GE's active-pitch controller enables the wind turbine rotor to regulate speed, when above rated wind speed, by allowing the blade to "spill" excess aerodynamic lift. Energy from wind gusts below rated wind speed is captured by allowing the rotor to speed up, transforming this gust energy into kinetic which may then be extracted from the rotor.

Three independent back-up units are provided to power each individual blade pitch system to feather the blades and shut down the machine in the event of a grid line outage or other fault. By having all three blades outfitted with independent pitch systems, redundancy of individual blade aerodynamic braking capability is provided.

## **Hub**

The hub is used to connect the three rotor blades to the turbine main shaft. The hub also houses the three electric blade pitch systems and is mounted directly to the main shaft. Access to the inside of the hub is provided through a hatch.

## **Gearbox**

The gearbox in the wind turbine is designed to transmit power between the low-rpm turbine rotor and high-rpm electric generator. The gearbox is a multi-stage planetary/helical gear design. The gearbox is mounted to the machine bedplate. The gearing is designed to transfer torsional power from the wind turbine rotor to the electric generator. A parking brake is mounted on the high-speed shaft of the gearbox.

## **Bearings**

The blade pitch bearing is designed to allow the blade to pitch about a span-wise pitch axis. The inner race of the blade pitch bearing is outfitted with a blade drive gear that enables the blade to be driven in pitch by an electric gear-driven motor/controller.

The main shaft bearing is a roller bearing mounted in a pillow-block housing arrangement. The bearings used inside the gearbox are of the cylindrical, spherical and tapered roller type. These bearings are designed to provide bearing and alignment of the internal gearing shafts and accommodate radial and axial loads.

## **Brake System**

The electrically actuated individual blade pitch systems act as the main braking system for the wind turbine. Braking under normal operating conditions is accomplished by feathering the blades out of the wind. Any single feathered rotor blade is designed to slow the rotor, and each rotor blade has its own back-up to provide power to the electric drive in the event of a grid line loss.

The turbine is also equipped with a mechanical brake located at the output (high-speed) shaft of the gearbox. This brake is only applied as an auxiliary brake to the main aerodynamic brake and to prevent rotation of the machinery as required by certain service activities.

## **Generator**

The generator is a doubly-fed induction type. The generator meets protection class requirements of the International Standard IP 54 (totally enclosed). The generator is mounted to the bedplate and the mounting is designed so as to reduce vibration and noise transfer to the bedplate.

## **Flexible Coupling**

Designed to protect the drive train from excessive torque loads, a flexible coupling is provided between the generator and gearbox output shaft this is equipped with a torque-limiting device sized to keep the maximum allowable torque below the maximum design limit of the drive train.

## **Yaw System**

A roller bearing attached between the nacelle and tower facilitates yaw motion. Planetary yaw drives (with brakes that engage when the drive is disabled) mesh with the outside gear of the yaw bearing and steer the machine to track the wind in yaw. The automatic yaw brakes engage in order to prevent the yaw drives from seeing peak loads from any turbulent wind.

The controller activates the yaw drives to align the nacelle to the average wind direction based on the wind vane sensor mounted on top of the nacelle.

A cable twist sensor provides a record of nacelle yaw position and cable twisting. After the sensor detects excessive rotation in one direction, the controller automatically brings the rotor to a complete stop, untwists the cable by counter yawing of the nacelle, and restarts the wind turbine.

## **Tower**

The wind turbine is mounted on top of a tubular tower. The tubular tower is manufactured in sections from steel plate. Access to the turbine is through a lockable steel door at the base of the tower. Service platforms are provided. Access to the nacelle is provided by a ladder and a fall arresting safety system is included. Interior lights are installed at critical points from the base of the tower to the tower top.

## **Nacelle**

The nacelle houses the main components of the wind turbine generator. Access from the tower into the nacelle is through the bottom of the nacelle. The nacelle is ventilated. It is illuminated with electric light. A hatch at the front end of the nacelle provides access to the blades and hub. The rotor can be secured in place with a rotor lock.

## **Anemometer, Wind Vane and Lightning Rod**

An anemometer, wind vane and lightning rod are mounted on top of the nacelle housing. Access to these sensors is accomplished through a hatch in the nacelle roof.

## **Lightning Protection**

The rotor blades are equipped with a lightning receptors mounted in the blade. The turbine is grounded and shielded to protect against lightning, however, lightning is an unpredictable force of nature, and it is possible that a lightning strike could damage various components notwithstanding the lightning protection deployed in the machine.

## Wind Turbine Control System

The wind turbine machine can be controlled automatically or manually from either an interface located inside the nacelle or from a control box at the bottom of the tower. Control signals can also be sent from a remote computer via a Supervisory Control and Data Acquisition System (SCADA), with local lockout capability provided at the turbine controller.

Service switches at the tower top prevent service personnel at the bottom of the tower from operating certain systems of the turbine while service personnel are in the nacelle. To override any machine operation, Emergency-stop buttons located in the tower base and in the nacelle can be activated to stop the turbine in the event of an emergency.

## Power Converter

The wind turbine uses a power converter system that consists of a converter on the rotor side, a DC intermediate circuit, and a power inverter on the grid side.

The converter system consists of a power module and the associated electrical equipment. Variable output frequency of the converter allows operation of the generator.

## Technical Data for the 1.6-100

### Rotor

Diameter	100 m
Number of blades	3
Swept area	7,854 m <sup>2</sup>
Rotor speed range	9.75 to 16.18 rpm
Rotational direction	Clockwise looking downwind
Maximum tip speed	84.7 m/s
Orientation	Upwind
Speed regulation	Pitch control
Aerodynamic brakes	Full feathering

### Pitch System

Principle	Independent blade pitch control
Actuation	Individual electric drive

### Yaw System

Yaw rate	0.5 degree/s
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## 1.6-100 Calculated Third Octave Band Apparent Sound Power Level LWA,k

Table 1 provides reference values per IEC 61400-11, based on the total apparent sound power level (A-weighted) defined in the general product acoustic specification for this turbine type. The uncertainties for octave sound power levels are generally higher than for total sound power levels. Guidance is given in IEC 61400-11, Annex D. The third octave-band spectra are for information only.

1.6-100 with 80 m HH - Normal Operation 3rd Octave Band Spectra									
Standard WS at 10m [m/s]	5	5.5	6	6.5	7	8	9	10-Cutout	
Hub Height WS at 80 m [m/s]	7	7.7	8.4	9.1	9.7	11.1	12.5	14-Cutout	
Frequency [Hz]	25	60.2	62.2	64.2	65.9	67.6	69.1	69.2	69
	32	63.2	65.1	67.1	68.8	70.5	72	72.1	71.9
	40	66.2	68.2	70.1	71.9	73.5	75.1	75.1	74.9
	50	69	71	73	74.7	76.4	77.9	78	77.8
	63	72	73.9	75.9	77.6	79.3	80.9	80.9	80.7
	80	75	77	78.9	80.7	82.4	83.9	83.9	83.7
	100	77.5	79.5	81.5	83.2	84.9	86.4	86.5	86.3
	125	80	82.2	84.2	86	87.9	89.8	90.1	90.2
	160	81.4	83.8	85.7	87.1	89.1	91.4	92.1	92.5
	200	82.2	84.7	86.1	86.7	88.7	91.3	92.2	92.9
	250	83.7	86.2	87.2	87.1	88.6	90.7	91.6	92.2
	315	84.7	87.3	88.3	87.9	88.7	90	90.6	91
	400	85	87.5	88.8	88.7	89.1	89.6	89.8	89.9
	500	85.2	87.9	89.6	90.1	90.6	90.7	90.5	90.3
	630	84.8	87.5	90	91.7	92.4	92.6	92.2	91.8
	800	83.9	86.6	89.7	92.4	93.7	94.3	93.9	93.5
	1000	82.5	85.4	89.1	92.6	94.5	95.6	95.3	95
	1250	81.4	84.1	88.1	92.5	94.9	96.7	96.5	96.3
	1600	80.7	82.5	86.1	90.7	93.5	96	95.9	95.8
	2000	80.9	82.3	84.9	88.3	91.4	94.5	94.7	94.7
2500	80.5	81.9	83.8	86.1	88.9	91.9	92.3	92.3	
3150	78.8	80.2	81.8	83.7	85.9	88.4	88.7	89.1	
4000	75.6	76.9	78.4	80.2	82.1	83.8	84	83.9	
5000	71.4	72.5	73.9	75.5	77.2	78.7	78.7	78.4	
6300	65.2	65.9	67	68.6	70.3	71.7	71.8	71.2	
8000	55.3	55.5	56.2	57.9	59.7	61.5	62.9	60.8	
10000	42.9	42.3	42.7	44.4	46.5	48.6	49	48.1	
12500	26.9	25.2	25.1	27.3	29.7	33.6	32.1	32.2	
16000	3.7	0.4	-0.4	2.2	5.2	8.9	9	9.3	
20000	-21.9	-27.3	-29	-25.9	-22.3	-18.3	-17.4	-16.8	
Total apparent sound power	94.8	97.3	99.5	101.5	103.3	104.9	105	105	

Table 1: Calculated Apparent Third Octave Band Sound Power Level (A-weighted), 1.6-100 with 80 m hub height as function of Wind Speed  $v_{10m}$

## Tonal Audibility

At the reference measuring point  $R_0$ , a ground distance from the turbine base equal to hub height plus half the rotor diameter, the 1.6-100 turbine has an expected value for tonal audibility of  $\Delta L_{a,k} < 2$  dB, irrespective of wind speed, hub height, and grid frequency.<sup>2</sup>

## Uncertainty Levels

The apparent sound power levels given above are calculated mean levels. If a wind turbine noise performance test is carried out, it needs to be done in accordance with the regulations of the international standard IEC 61400-11, ed. 2.1: 2006. Uncertainty levels associated with measurements are described in IEC/TS 61400-14.

Per IEC/TS 61400-14,  $L_{WA,d}$  is the maximum apparent sound power level resulting from  $n$  measurements performed according to IEC 61400-11 standard for 95 % confidence level:  $L_{WA,d} = \overline{L_{WA}} + K$ , where  $\overline{L_{WA}}$  is the mean apparent sound power level from  $n$  IEC 61400-11 testing reports and  $K = 1,645 \cdot \sigma_T$ .

The testing standard deviation values  $\sigma_T$ ,  $\sigma_R$  and  $\sigma_P$  for measured apparent sound power level are described by IEC/TS 61400-14 where  $\sigma_T$  is the total standard deviation,  $\sigma_P$  is the standard deviation for product variation and  $\sigma_R$  is the standard deviation for test reproducibility.

Assuming  $\sigma_R < 0.8$  dB and  $\sigma_P < 0.8$  dB typical values, leads to calculated  $K < 2$  dB for 95 % confidence level.

## IEC 61400-11 and IEC/TS 61400-14 Terminology

- $L_{WA,k}$  is wind turbine apparent sound power level (referenced to  $1^{-12}$  W) measured with A-weighting as function of reference wind speed  $v_{10m}$ . Derived from multiple measurement reports per IEC 61400-11, it is considered as a mean value.
- $\sigma_P$  is the product variation i.e. the 1.56-100 unit-to-unit product variation; typically  $< 0.8$  dB
- $\sigma_R$  is the overall measurement testing reproducibility as defined per IEC 61400-11; typically  $< 0.8$  dB with adequate measurement conditions and sufficient amount of data samples
- $\sigma_T$  is the total standard deviation combining both  $\sigma_P$  and  $\sigma_R$
- $K = 1,645 \cdot \sigma_T$  is defined by IEC/TS 61400-14 for 95 % confidence level
- $R_o$  is the ground measuring distance from the wind turbine tower axis per IEC 61400-11
- $\Delta L_{a,k}$  is the tonal audibility according to IEC 61400-11, described as potentially audible narrow band sound



ISO 9001 CERTIFIED

Form 3.2.1-D Rev. 0

**TECHNICAL PROPOSAL INFORMATION**

Customer: NextEra Energy Resources Date: 01/16/12

Proposal No: - Spec No: FPLE GENERAL SPEC REV 4 11/04/08 Item No: 2211374/A

RATING						
Type	Transformer	Class	H Winding	X Winding	Y Winding	
Phase	3		525 Wye kV	121 Wye kV	34.5 Delta kV	
Hertz	60	ONAN	189,000 KVA	189,000 KVA	63,000 KVA	
Temp Rise	65 °C	ONAF	252,000 KVA	252,000 KVA	84,000 KVA	
Insul Liquid	NON PCB OIL TYPE II	ONAF	315,000 KVA	315,000 KVA	105,000 KVA	
		-	- KVA	- KVA	- KVA	

ADDITIONAL TAP VOLTAGES		
H Winding (Kv)	± 16 of 0.625 %	LTC - FCBN
X Winding (Kv)	-	-
Y Winding (Kv)	Buried	

CONNECTIONS FOR OPERATION						
Transformers in Bank	To Transformer From	Phase	Connected	To Transformer To	Phase	Connected
-	-	-	-	-	-	-

PERFORMANCE BASED ON A LOADING OF				DIELECTRIC TESTS				INSULATION LEVELS		
								ITEMS	Basic Lightning Impulse (kV)	
								Winding	Bushings	
H Winding	525.0 kV	189.0 MVA		Applied Voltage	H Winding	50 kV	H Line	1425	1425	
X Winding	121.0 kV	189.0 MVA		(To other winding and ground)	X Winding	50 kV	H neutral	150	150	
Y Winding	- kV	- MVA			Y Winding	- kV	X line	550	650	
-	-	-	-	Induced Voltage	One Hour	475 kV	X neutral	150	150	
-	-	-	-		Enhancement	550 kV	Y line	-	-	

PERFORMANCE DATA, Based on <b>85</b> °C Reference Temperature, <b>189</b> MVA Altitude: <b>1000</b> Mts.					
Losses and Exciting Current				Regulation	
Excitation	% Ex	No Load Kw (20°C)	Total Loss Kw	Power Factor	% Regulation
100%	0.491	186	482	0.80	5.123
110%	0.897	256 *	552 *	1.0	0.476
-	-	* Not Guaranteed		-	-

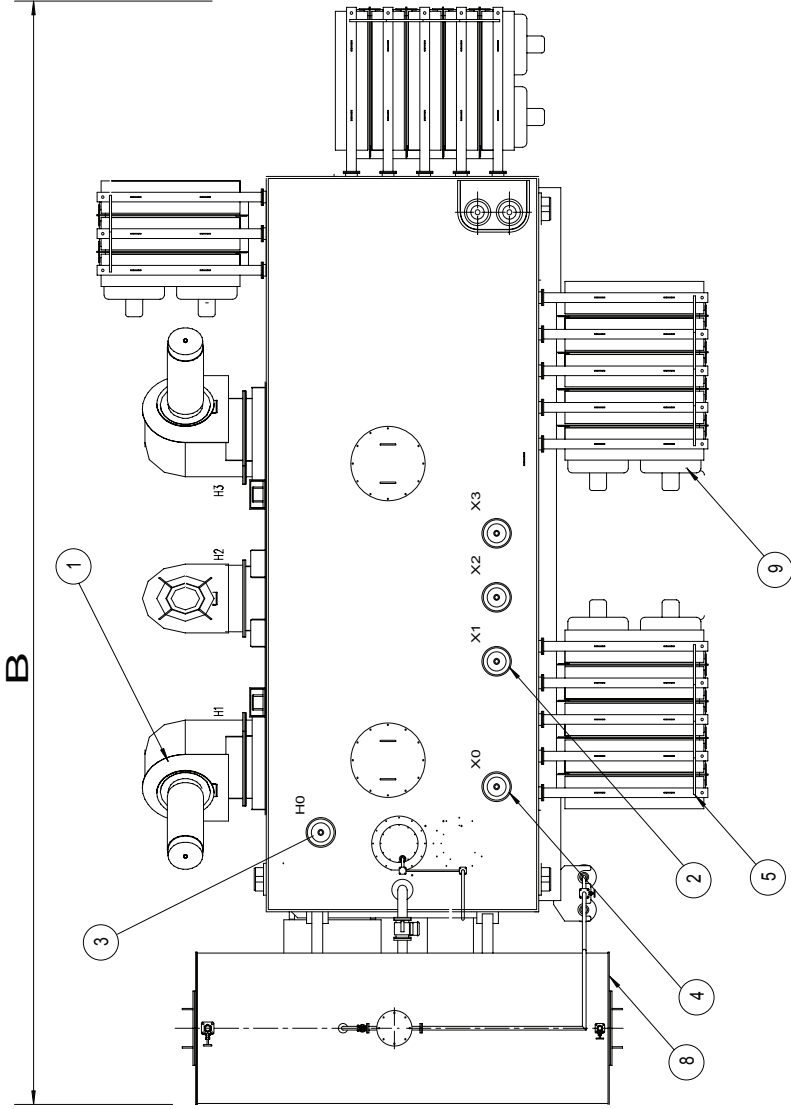
AUXILIARY (COOLING) LOSSES			
Transformer KVA	Class	KWatts Loss	
189,000	ONAN	0	
252,000	ONAF	6	
315,000	ONAF	12	
-	-	-	
-	-	-	
Average Sound Level		88/90/91 dB	ONAN/ONAF/ONAF

PERCENT IMPEDANCE VOLTS					
% IZ	Between Windings	At kVA	% IZ Zero	Between Windings	At kVA
8	H-X	189,000	8*	H-X	189,000
-	-	-	-	-	-
-	-	-	-	-	-

\* APPROXIMATE ONLY, NOT GUARANTEED

EFFICIENCIES ( p.f = 1 ) AT 189 MVA				
Load	Full Load	3/4 Load	1/2 Load	1/4 Load
%	99.746	99.752	99.726	99.569

MECHANICAL DATA	
Not for Construction Purposes	
Outline Dwg No:	DW 221137A4
<b>Dimensions</b> (Approximate)	Ft. (Mts.)
Height (A)	32.8 (10.00)
Width (B)	52.2 (15.90)
Depth (C)	23.8 (7.25)
Height over Cover (D)	16.4 (5.00)
Untanking (Plus slings) (E)	30.7 (9.37)
<b>Shipping</b> Dimensions: Ft WxDxH	36.4 x 12.6 x 16.3
<b>Masses</b> (Approximate)	pounds (Kg)
Core and Coils	446,970(202,750)
Tank and Fittings	146,240 (66,340)
Liquid 32,720 Gal	245,820(111,500)
<b>Total Mass</b>	839,030(380,590)
<b>Shipping</b> without OIL	538,510(244,270)
<b>Shipping</b> with OIL H=	-----



- 1.- H. V. BUSHINGS "H"
- 2.- L. V. BUSHINGS "X"
- 3.- NEUTRAL BUSHING "H0"
- 4.- NEUTRAL BUSHING "X0"
- 5.- RADIATORS
- 6.- LOAD TAP CHANGER
- 7.- CONTROL CABINET
- 8.- CONSERVATOR TANK
- 9.- FANS
- 10.- H.V. SURGE ARRESTER (IF SUPPLY, NOT SHOWN)
- 11.- L.V. SURGE ARRESTER (IF SUPPLY, NOT SHOWN)

NOTE: THIS DRAWING IS A PRELIMINARY PROPOSAL AND DOES NOT INDICATE THE EXACT DETAILS OF CONSTRUCTION, ARRANGEMENT OF ACCESSORIES OR THE FINAL DIMENSIONS OF THE TRANSFORMER. THIS INFORMATION SHOULD NOT BE USED FOR FINAL CONSTRUCTION ARRANGEMENTS OR FOR THE FOUNDATION UNLESS SPECIFICALLY APPROVED BY THE FACTORY. ALL DIMENSIONS AND WEIGHTS ARE APPROXIMATE



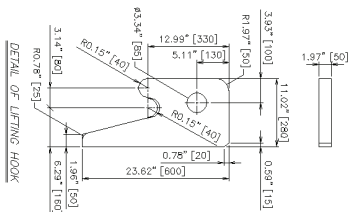
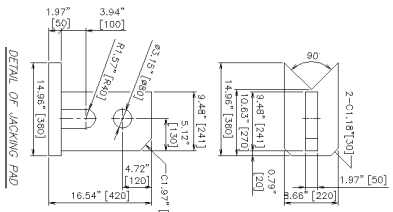
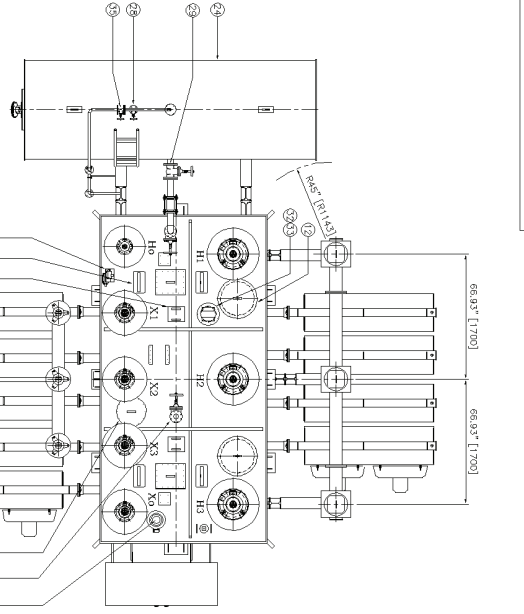
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Drawing:

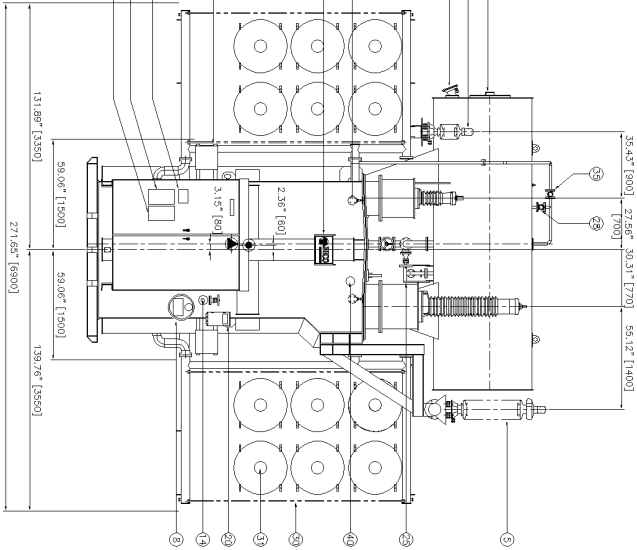
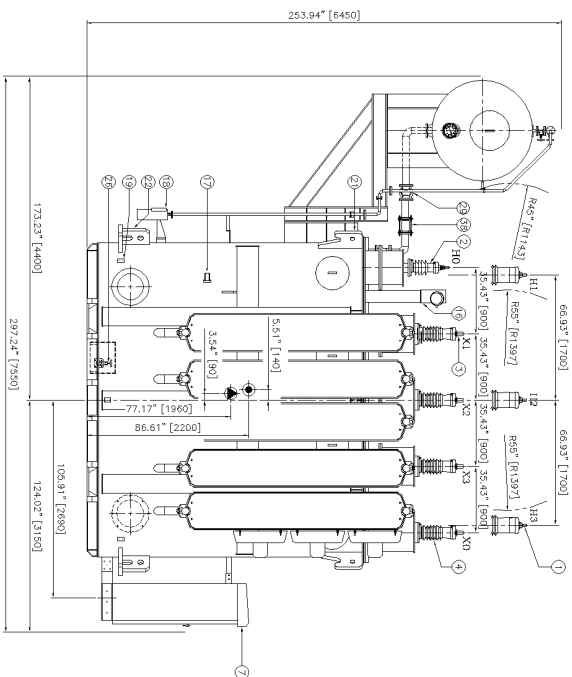
No. 221137A4



PART LIST



**# WEIGHT #**  
**CORE AND COIL :** 140.432 lbs ( 63,700 kg )  
**TANK AND FITTING :** 66.607 lbs ( 29,800 kg )  
**INSULATING OIL :** 51,146 lbs ( 23,200 kg )  
**(WITHOUT OIL)** : 171,076 lbs ( 77,600 kg )  
**TOTAL :** 257,276 lbs ( 116,700 kg )



ITEM	DESCRIPTION	TYPE	QTY	MAKER
1	H.V BUSHING	1.8x7.12184K	3	ABB T&O (USA)
2	H.X NEUTRAL BUSHING	1.35N, 150V BIL, 1200A, INBOARD END	1	ABB T&O (USA)
3	X.Y BUSHING	G25N0412AT	1	ABB T&O (USA)
4	X.Y NEUTRAL BUSHING	25N, 150V BIL, 1200A, INBOARD END	3	ABB T&O (USA)
5	H.V ARRESTER	34K, 2000V BIL, 3000A, INBOARD END	1	ABB T&O (USA)
6	X.Y ARRESTER	34K, 2000V BIL, 3000A, INBOARD END	3	SIDENS
7	LOCAL CONTROL PANEL	304, 600-2011-48G (96W DIA 92H)	3	SIMENS
8	DE-ENERGIZED TYPE OPERATOR HANDLE WITH WARNING MARK & NAME PLATE	302, 003-2R3C1-48G(500 Dia 92H)	1	HCO(KOREA)
9	HI/O MARK	A	1	SUNGJIN(KOREA)
10	NAMETPLATE		1	HCO(KOREA)
11	VALVE NAMETPLATE		1	HCO(KOREA)
12	MANHOLE / HANDHOLE		14	HCO(KOREA)
13	PRESSURE RELIEF DEVICE WITH CABLE CONNECTOR	Q7203-60F	1	QUALTRON(USA)
14	RAPID PRESSURE RISE RELAY WITH SHUT-OFF VALVE	900-003-02	1	QUALTRON(USA)
15	OIL LEVEL INDICATOR FOR CONDENSATOR	Q42 SERIES	1	QUALTRON(USA)
16	GAS ACCUMULATION INDICATOR	Q38-002-01	1	QUALTRON(USA)
17	ACCUMULATION INDICATOR	Q38-002-01	1	QUALTRON(USA)
18	SAMPLING VALVE FOR GAS	MTD7973	1	TAIJUN(KOREA)
19	DEHYDRATING BREATHER		4	HCO(KOREA)
20	GROUNDING PAD & COVER	A, P, T(USA)	1	HCO(KOREA)
21	TEMPERATURE GAUGE	THC-1000-51303 WITH TEMPERATURE PROBE 11	4	HCO(KOREA)
22	LIFTING HOOK FOR MAIN TANK		4	HCO(KOREA)
23	JACKING PAD WITH HAULING HOLE		4	HCO(KOREA)
24	LIFTING STUD FOR CORE & COIL ASSY"		4	HCO(KOREA)
25	CONDENSATOR WITH RUBBER BAG	SFP-0000-1200	1	PRONAL(FRANCE)
26	CONDENSATOR DEAN VALVE WITH SLIMP SAMPLING DEVICE & SLIMP		1	HCO(KOREA)
27	LOWER FILTER/DRAIN VALVE WITH SAMPLING DEVICE	127T58 2"	1	UNITED BRASS(USA)
28	VACUUM VALVE FOR MAIN TANK		1	HCO(KOREA)
29	VACUUM VALVE FOR CONDENSATOR FOR MAIN TANK		1	HCO(KOREA)
30	CONDENSATOR CONNECTING VALVE		2	HCO(KOREA)
31	BLOWER WITH VALVE		9	HCO(KOREA)
32	EQUALIZING BUSHING FOR END FRAME ASSY"	F280-497121PH (1/2HP 1140RPM)	12	KEBEL TERT(USA)
33	GROUNDING BUSHING FOR CORE	Z0098	1	FORCELAM(USA)
34	PAUL PROTECTION WASI PLATE		2	HCO(KOREA)
35	EQUALIZING VALVE FOR CONDENSATOR		1	HCO(KOREA)
36	GATE VALVE	1"	2	HCO(KOREA)
37	OIL TEMPERATURE-LEVEL CURVE PLATE		1	HCO(KOREA)
38	STAINLESS STEEL BELLOWS		1	HCO(KOREA)
39	JUNCTION BOX FOR FAN (LOADED ON TANK WALL)		2	HCO(KOREA)
40	BI-METALLIC OTI	167-323-01 with well-Assembly	1	QUALTRON(USA)

**# NOTE #**  
 1. DIMENSION TOLERANCE : ± 2%  
 2. ALL DIMENSIONS ARE IN INCHES [MILLIMETERS].  
 3. DIMENSION AND WEIGHT WILL BE CHANGED SLIGHTLY AFTER DETAIL DESIGN.  
 4. MARK : COMPLETE CENTER OF GRAVITY (WITH OIL)  
 5. MARK : COMPLETE CENTER OF GRAVITY (WITHOUT OIL)