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INFORME TÉCNICO

Código de Documento: P019392-2-GE-INF-00003

Cliente: **Prime Energía Spa**

Proyecto: **Determinación de Mínimos Técnicos – Central Degañ II**

Asunto: **Informe de Mínimo Técnico – Central Degañ II**

Comentarios:

REV.	DD/MM/AAAA	ESTATUS	ESCRITO	VERIFICADO	APROBADO	VALIDADO
1	24/03/2022	Revisión Final	Alfredo Osses	Diego Larraín	Luis Garrido	Eduardo Andrzejewski
0	18/03/2022	Revisión Final	Alfredo Osses	Luis Garrido	Luis Garrido	Eduardo Andrzejewski
B	18/02/2022	Revisión Cliente	Alfredo Osses	Diego Larraín	Diego Larraín	Eduardo Andrzejewski
A	16/02/2022	Revisión Interna	Alfredo Osses	Diego Larraín	Diego Larraín	Eduardo Andrzejewski

TABLA DE CONTENIDO

RESUMEN EJECUTIVO

La central Degañ II está conformada por 10 grupos electrógenos Diésel idénticos, que totalizan una capacidad bruta instalada de 18,42 MW. Se ubica en la comuna de Ancud, Provincia de Chiloé, Región de los Lagos. El punto de conexión al SEN es la S/E Degañ.

Conforme a la resolución dispuesta por la CNE, las empresas generadoras deberán determinar e informar al Coordinador Eléctrico Nacional, el Mínimo Técnico de sus unidades generadoras en conformidad a las disposiciones del Anexo Técnico "Determinación de Mínimos Técnicos en Unidades Generadoras" de la Norma Técnica de Seguridad y Calidad de Servicio (NTSyCS) – Resolución exenta N°375.

En este contexto, se ha determinado para las 10 unidades generadoras diésel idénticas, el siguiente valor de Mínimo Técnico:

- **Mínimo Técnico de 457 kW_e por unidad generadora**, cuyo valor está fundamentado bajo las recomendaciones del fabricante de las unidades generadoras.

1. OBJETIVO

El presente informe tiene como objetivo determinar, informar y respaldar los valores de Mínimo Técnico de las unidades generadoras de la central Degañ II, conforme a las disposiciones establecidas en el Anexo Técnico “Determinación de Mínimos Técnicos en Unidades Generadoras” de la NTSyCS.

2. DEFINICIONES Y ABREVIACIONES

Definiciones

Mínimo Técnico	Se entenderá por Mínimo Técnico la potencia activa bruta mínima con la cual una unidad puede operar en forma permanente, segura y estable inyectando energía al SEN en forma continua.
Unidad	Unidad Generadora (Motor de combustión Interna acoplado a su respectivo generador eléctrico).

Tabla 1. Definiciones

Abreviaciones

CNE	Comisión Nacional de Energía
CEN	Consumo Especifico Neto
MT	Mínimo Técnico
PMAX	Potencia Máxima
FP	Factor de Potencia
NTSyCS	Norma Técnica de Seguridad y Calidad de Servicio
S/E	Subestación Eléctrica
SEN	Sistema Eléctrico Nacional
N-6	Nave 6
U_N	Unidad N

Tabla 2. Abreviaciones

3. DOCUMENTOS Y NORMAS APLICADAS

Los documentos aplicables para la determinación de Mínimos Técnicos en Unidades Generadoras son los siguientes:

1.	Anexo Técnico: Determinación de Mínimos Técnicos en Unidades Generadoras.
2.	Recomendaciones del Fabricante MTU: Grupo Electrógeno Diésel MTU 16V4000.
3.	ISO 8528-1: Reciprocating internal combustion engine driven alternating current generating sets -- part 1: application, ratings and performance.

Tabla 3. Documentos de Referencia

4. DESCRIPCIÓN DE LA CENTRAL

La central Degañ II, propiedad de Prime Energía Spa, se compone de 10 grupos electrógenos diésel idénticos en 1 nave. La central tiene como punto de conexión al sistema interconectado nacional la S/E Degañ.

En la Tabla 4 se indican los parámetros principales de cada unidad generadora.

Central Degañ II	Información	Referencia
Modelo Motor	MTU 16V4000	Hoja de datos Motor-Generador
Potencia Nominal Prime	1.842 kW	Hoja de datos Motor-Generador
Consumo Específico a 100% Carga	195 g/kWh	Hoja de datos Motor-Generador
Poder Calorífico superior	11.000 kcal/kg	Base equivalente
Velocidad Nominal	1.500 [rpm]	Hoja de datos Motor-Generador

Tabla 4. Información principal grupos electrógenos

Nave	Unidades	Marca – Modelo	Potencia Bruta Conjunta [MW]
N-6	U_1 - U_{10}	MTU 16V4000	18,42

Tabla 5. Distribución y Potencia Conjunta Grupos Electrógenos

Todos los motores de la central utilizan combustible Diésel y se encuentran configurados para operar en modo *Prime Power*[1] (ver Anexo A), cuya definición se presenta a continuación:

[1] Aplicable para suministros de energía de carga variable por una cantidad ilimitada de horas, acorde a la norma ISO 8528. Se permite una sobrecarga del 10% según normas ISO3046, AS2789, DIN6271 Y BS5514.

13.3.2 Prime Power (PRP)

Prime power is defined as being the maximum power which a generating set is capable of delivering continuously whilst supplying a variable electrical load when operated for an unlimited number of hours per year under the agreed operating conditions with the maintenance intervals and procedures being carried out as prescribed by the manufacturer (see Figure 2).

The permissible average power output (P_{pp}) over 24 h of operation shall not exceed 70 % of the PRP unless otherwise agreed by the RIC engine manufacturer.

Figura 1. Definición Potencia Prime, Norma ISO 8528

En la sección 7 (Anexos) se incluye documentación técnica de la central y sus unidades generadoras.

5. MÍNIMO TÉCNICO

Se requiere determinar y respaldar el Mínimo Técnico de las unidades generadoras de la central Degañ II. En los siguientes capítulos se indican y desarrollan las justificativas basadas de acuerdo con los siguientes criterios:

- Recomendaciones del fabricante de las unidades generadoras
- Registros operacionales de las unidades generadoras
- Referencias nacionales de unidades similares

5.1. Recomendaciones de Fabricantes

5.1.1. Fabricante de las Unidades Generadoras - MTU

El fabricante de los grupos electrógenos diésel recomienda operar la unidad a cargas mecánicas mayores o iguales 480 kW_m (recomendación adjunta en Anexo C) la cual corresponde a una potencia eléctrica de 457 kW_e (considerando la eficiencia de 95,2% del generador eléctrico).

La operación del motor a un valor menor al indicado anteriormente lleva a una disminución de la temperatura en el motor y por tanto a un modo de operación inadecuado para su operación en el largo plazo.

De manera adicional, se indica que el motor operando a bajas cargas puede mostrar el fenómeno denominado como ""Wet Stacking" (ducto de escape húmedo). A continuación de muestra un extracto de la carta enviada por el fabricante MTU:

Continuous Engine operation at loads between 115 kWm and 480 kWm should be avoided:
The Cylinder Cutout function is inactive at loads higher than approx. 115 kWm, the engine operates then in full engine mode. This leads to a temperature decrease in the engine and therefore to an inappropriate operation mode for long time operation. At loads higher than 480 kWm, the load is sufficient to ensure an acceptable level of engine temperature.

Please take in account that the engine will show "Wet Stacking". This means that at low load, oil traces may appear on the outside of the engine caused by oil accumulation in the exhaust pipe. These oil leakages will have no effect on reliability, load acceptance, maintenance schedule or any other technical data of the engine. For further information please refer to our White Paper "Information about Wet Stacking on Diesel Engines".

Figura 2. Extracto de carta de recomendación para operación a bajas cargas.

Mayor detalle del fenómeno mencionado anteriormente puede ser visto en la infografía del proveedor *Clifford Power* (ver ANEXO B).

5.1.2. Recomendaciones de otros Fabricantes

NFPA

La Asociación Nacional de Protección contra el Fuego (NFPA por sus siglas en inglés), advierte en su estándar número 110, de generadores de emergencia y standby, sobre el fenómeno "*Wet Stacking*". Esto se previene operando el motor con cargas sobre el 30% de la potencia nominal.

Aurora Generators

El fabricante de motores Aurora indica en su artículo "*What Happens To Engines Running Without Sufficient Loads*" (ver Anexo B) diversos problemas y riesgos asociados a la operación de motores diésel en bajas cargas.

Caterpillar

El fabricante de motores Caterpillar indica en su artículo "*The Impact Of Generator Set Underloading*" (ver Anexo B) los riesgos de operar motores diésel en cargas inferiores al 30% de su potencia nominal. Principalmente señala el riesgo acumulación de depósitos y humedecimiento del ducto de escape.

Cummins

El fabricante de motores Cummins también recomienda en sus manuales de operación una carga mínima del 30% para evitar la acumulación de depósitos de carbón producidos por la combustión incompleta del combustible; y reducir el riesgo de dilución de combustible en el aceite de lubricación del motor.

Precaución:	*Evitar funcionamientos sin carga que no sean por periodos cortos. Se recomienda una carga mínima del 30%. Esta carga ayudará a evitar la acumulación de depósitos de carbón en los inyectores, a causa del combustible sin quemar, y reduce el riesgo de dilución en combustible del aceite de lubricación del motor. El motor debe pararse lo antes posible después de que se hayan comprobado las funciones adecuadas.*

Figura 3. Carga mínima del 30% (Manual de operación Cummins)

Además, se advierte respecto a la temperatura del refrigerante, que al descender alrededor de los 60°C promueve estos efectos indeseados:

Precaución:	*Si la temperatura del refrigerante del motor baja demasiado, 60° C (140° F), el combustible crudo por la combustión incompleta lavará el aceite de lubricación de las paredes del cilindro y diluirá el aceite del cárter. En estas condiciones, no todas las piezas móviles del motor recibirán la cantidad correcta de lubricación.*

Figura 4. Precaución de operación con baja temperatura de refrigerante (60°C; Manual de operación Cummins)

5.2. Restricciones Ambientales u Operacionales

La central Degañ II no está sujeta a restricciones ambientales ni operacionales que pudiesen influir en la determinación del Mínimo Técnico de sus unidades.

5.3. Registros operacionales de unidades similares

En la Figura 5 se presentan registros operacionales de unidades similares, con el mismo modelo de bloque motor MTU 16V4000.

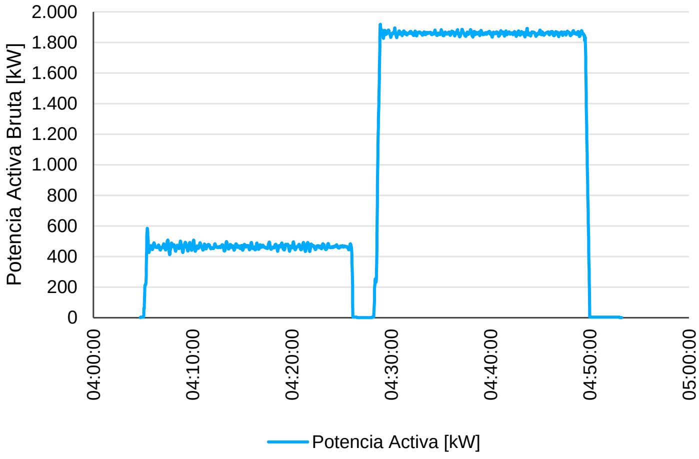

Figura 5. Registros operacionales tipo de unidad con bloque motor MTU 16V4000.

5.4. Antecedentes Nacionales

Como referencia, se han recogido valores de Mínimos Técnicos de unidades con características similares que operan a nivel nacional (ver Tabla 6).

Central	Potencia Nominal [kW]	Mínimo Técnico [kW]	Mínimo Técnico [%P_{nom}]	Fabricante
Degañ II	**1.842**	**457**	**25%**	**MTU**
Llanos Blancos	1.872	468	25%	MTU
San Javier I	1.872	468	25%	MTU
San Javier II	1.872	468	25%	MTU
Combarbalá	1.872	468	25%	MTU
Pajonales	1.872	468	25%	MTU
Los Cóndores	1.872	468	25%	MTU
Genpac– U_1 – U_{60}	1.600	480	30%	FG Wilson
Quellón II– U_1 - U_{10}	1.800	540	30%	Cummins
Quintay– U_1 y U_2	1.200	360	30%	Cummins
Placilla– U_1 y U_2	1.200	360	30%	Cummins
El Totoral– U_1 y U_2	1.200	360	30%	Cummins
Las Vegas– U_1 y U_2	1.050	360	30%	Cummins
La Portada– U_1-U_3-U_6	1.000	250	25%	Cummins
Chiloé– U_1 – U_9	1.200	600	50%	Caterpillar
Maule– U_3 – U_5	750	375	50%	Caterpillar

Tabla 6. Mínimos Técnicos de unidades similares características a nivel nacional

6. CONCLUSIONES

Expuestos los antecedentes del Capítulo 5 del presente informe, es posible determinar y respaldar el valor de Mínimo Técnico de las unidades generadoras de la central Degañ II.

Conforme a la sección 5.1.1, el fabricante de los grupos electrógenos MTU, recomienda operar las unidades a una potencia mecánica igual o mayor a 480 kW_m, la cual corresponde a una potencia eléctrica de 457 kW_e (considerando la eficiencia de 95,2% del generador eléctrico).

En vista de las justificativas anteriores, se ha determinado como Mínimo Técnico de las unidades generadoras, un valor de **457 kW_e**, el cual es aplicable a los 10 grupos electrógenos idénticos de la central.

7. ANEXOS

ANEXO A - INFORMACIÓN TÉCNICA DE LAS UNIDADES

ANEXO B - RECOMENDACIONES DE FABRICANTES

ANEXO C - DIAGRAMA UNILINEAL ELÉCTRICO

ANEXO D - LAYOUT CENTRAL GENERADORA

ANEXO A - INFORMACIÓN TÉCNICA DE LAS UNIDADES

MODEL
HMW-2200 T5
HEAVY RANGE
Container
Powered by MTU

Engine Specifications 1.500 r.p.m.

ENGINE		PRP	STANDBY
Rated Output	kW	1905	2102
Manufacturer		MTU	
Model		16V4000G63	
Engine Type		Diesel 4 strokes-cycle	
Injection Type		Direct	
Aspiration Type		Turbocharged and aftercooled	
Ciylinders Arrangement		16V	
Bore and Stroke	mm	170 x 210	
Displacement	L	76,3	
Cooling System		coolant	
Lube Oil Specifications		S10 W40	
Compression Ratio		16,5	
Fuel Consumption StandBy	l/h	492,73	
Fuel Consumption 100% PRP	l/h	436,41	
Fuel Consumption 75 % PRP	l/h	330,74	
Fuel Consumption 50 % PRP	l/h	231,9	
Fuel Consumption 25 % PRP	l/h	129,67	
Lube Oil Consumption Full Load		1 % of fuel consumption	
Total oil capacity including tubes, filters	L	300	
Total Coolant Capacity	L	665	
Governor	Type	Electrical	
Air Filter	Type	Dry	
Inner diameter exhaust pipe	mm	251	

Generator

Generator		
Poles	Num	4
Winding Conections (standard)		Star
Frame Mounting		S-0 21"
Insulation	Class	H class
Enclosure (according IEC-34-5)		IP23
Exciter System		self-excited, brushless
Voltage Regulator		A.V.R. (Electronic)
Bearing		Single bearing
Coupling		Flexible disc
Coating type		Standar (Vacuum impregnation)

Extracto especificaciones grupo motor generador

HIMOINSA GENERATORS

10 off Himoinsa HMW-2200-T5 Containerised Generators built with MTU 16V4000G63 exhaust emission optimised engine with special application.

Rated at 2307kVA for Prime Power and 2546kVA for Standby Power.

Set mounted radiator designed for high end temperatures 34°. Mecc Alte ECO 46-2L/4 alternator, oil primer and centrifuge fitted as confirmed by MTU, set mounted 4000A 4P motorised breakers.

	Generator Specification
Model:	Himoinsa 40' Containerised Genset – HMW-2200-T5 C40 2200KVA V400 AS20
Drawing:	Left hand breaker - built to drawing code: P-0501-15-DWG-MD-02
	Right hand breaker – built to drawing code: P-0501-15-DWG-MD-01
Container:	40' container to 80dBA at 1m at 110% load free field conditions at 32° Bunded container floor with optical alarm
RAL:	Container painted to RAL 2002
Container door key:	All generator containers at Redditch KEYA K211
Breaker Key No:	See Generator Summary List and Site Key Log
Energisation key no.	MS1
Power:	Standby Power 2541kVA / 2033kw (MTU 3D STOR APPLICATION)
	Prime Power 2303kVA / 1842kw
Voltage:	400V 3Ph 50Hz
Engine:	MTU 16V4000G63 Exhaust Emission Optimised Engine
Engine Speed:	1500rpm
Alternator:	Mecc Alte ECO46 2L/4A with MAUX excitation and anti-condensation heater Meccalte alternator AVR
Radiator:	Techno Group TG00094AA Contained within a separate compartment with multiple low noise variable speed cooling fans
Power Box:	CP6

3.2 Grupo electrógeno

3.2.1 Grupo electrógeno – Grupo de aplicación 3G

El grupo electrógeno está formado por un motor diesel montado con un generador en un mismo bastidor. El motor arranca y acciona el generador para producir energía eléctrica sobre demanda.

Grupos electrógenos para el suministro eléctrico continuo

Grupo de aplicación 3G – Servicio continuo, duración limitada, ICXN (Grid Stability Power)

Para compensar las puntas de carga se utiliza el grupo electrógeno paralelamente a una red eléctrica. En el servicio de corta duración con carga constante se utilizan los grupos electrógenos transitoriamente. Se utilizan en los campos de aplicación siguientes:
- Estabilización de la red pública (compensación de puntas de carga) cuando se alimentan energías (solar, eólica) renovables
- En programas de red tales como STOR y Emergency Capacity Program

Servicio continuo	Grupo de aplicación 3G
Modo de servicio	Servicio continuo, duración limitada
Base de cálculo	10 % sobrecargable (ICXN)
Factor de carga	< 100 %
Horas de servicio	1000 h, de ellas 500 h con el 100 % de carga sin interrupción

Ventajas

- Amplia gama de grupos electrógenos estandarizados para responder a las necesidades del cliente en cuanto a potencia, emisiones y otras prestaciones
- Posibilidad de selección entre diversos componentes (p. ej. filtro previo de combustible) y opciones (p. ej. refrigerador de combustible)
- La tecnología más moderna de motores diesel
- Los componentes principales más innovadores para un mayor rendimiento y una larga vida útil

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ANEXO B - RECOMENDACIONES DE FABRICANTES

To	To whom it may concern	Sender	MTU Friedrichshafen GmbH Maybachplatz 1 88045 Friedrichshafen Germany
Date	08.06.2018		

Subject: Quickstart 475 MW Project Chile

Dear Sirs,

For your Project Quickstart 475 MW Chile you asked about the Low Load operation capability for an

- Engine type 16V4000G24F
- Emission optimization NEA
- Application Group "Grid Stability" 3B

For this specific project only, we can provide the following approval:

Step	Period [h]	Load
1	≤12	70 kWm* – 115 kW m*
2	≥1	≥1370 kW m*

*all given loads refer to kW mechanical engine power output at 1500 rpm

Number of cycles: unlimited

Continuous Engine operation at loads between 115 kWm and 480 kWm should be avoided:
The Cylinder Cutout function is inactive at loads higher than approx. 115 kWm, the engine operates then in full engine mode. This leads to a temperature decrease in the engine and therefore to an inappropriate operation mode for long time operation. At loads higher than 480 kWm, the load is sufficient to ensure an acceptable level of engine temperature.

Please take in account that the engine will show "Wet Stacking". This means that at low load, oil traces may appear on the outside of the engine caused by oil accumulation in the exhaust pipe. These oil leakages will have no effect on reliability, load acceptance, maintenance schedule or any other technical data of the engine. For further information please refer to our White Paper "Information about Wet Stacking on Diesel Engines".

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MTU Friedrichshafen GmbH
i.A. Robert Welz

CLIFFORD POWER

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Information Sheet # 09

Your Reliable Guide for Power Solutions

Wet Stacking of Generator Sets and How to Avoid It

1.0 Introduction

Most standby generator systems up to five megawatts use the reciprocating internal combustion engine as the power source to drive the generator that produces the electrical power. The engines of choice are either diesel, natural gas or LPG fueled. A large percentage of standby power systems use the diesel engine. Diesel is a convenient independent fuel source and the compression ignition systems of diesel engines have a much higher thermal efficiency than the spark ignition system used by gas engines. However, one factor to be considered when selecting a diesel power source is the potential for "wet stacking."

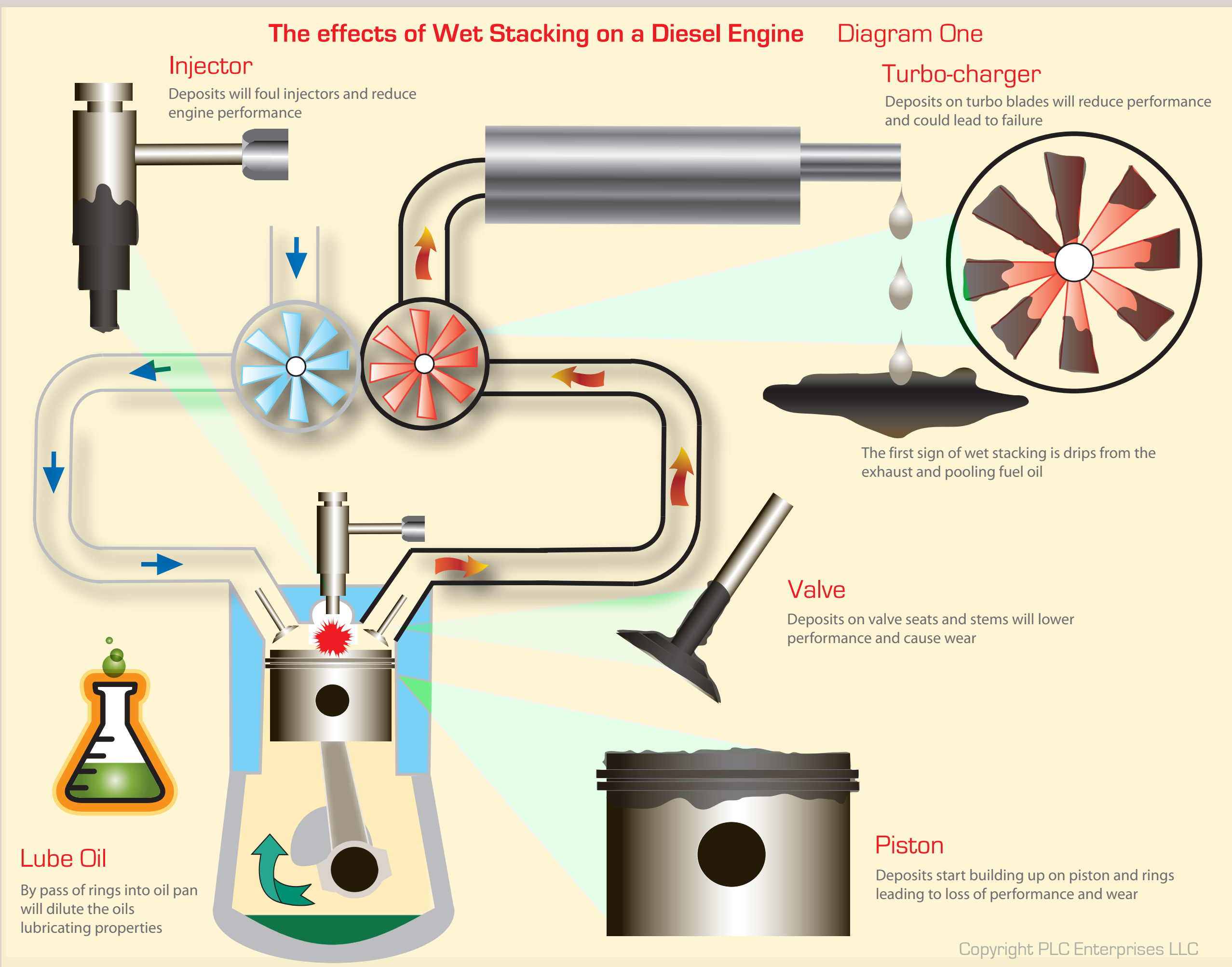
The National Fire Protection Agency (NFPA), in their NFPA 110 Code for Emergency and Standby Power Systems section 6 - 4.2 (1996 edition) refer to wet stacking as a field term indicating the presence of unburned fuel or carbon in the exhaust system. The later 1999 edition suggests a more quantitative method for determining the presence of wet stacking by measuring the exhaust gas temperature, explained later in this information sheet.

This information sheet discusses the causes of wet stacking, its effect on the engine, why it should be avoided and methods for eliminating the condition.

The designer of a generator system must take into account the potential for wet stacking when determining equipment for the system, load calculations and maintenance and service programs. The system designer should consider the following.

2.0 Causes of Wet Stacking:

Like all internal combustion engines, to operate at maximum efficiency a diesel engine has to have exactly the right air-to-fuel ratio and be able to sustain its designed operational temperature for a complete burn of fuel. When a diesel engine is operated on light loads, it will not attain its correct operating temperature. When the diesel engine runs below its designed operating temperature for extended periods, unburned fuel is exhausted and noticed as wetness in the exhaust system, hence the phrase wet stacking. (Continued over)



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San Antonio, TX 78249
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3.0 Engine Effect

When unburned fuel is exhausted out of the combustion chamber, it starts to build up in the exhaust side of the engine, resulting in fouled injectors and a buildup of carbon on the exhaust valves, turbo charger and exhaust.

Excessive deposits can result in a loss of engine performance as gases bypass valve seatings, exhaust buildup produces back pressure, and deposits on the turbo blades reduces turbo efficiency.

Permanent damage will not be incurred over short periods, but over longer periods, deposits will scar and erode key engine surfaces. (Diagram One) Also, when engines run below the designed operational temperature, the piston rings do not expand sufficiently to adequately seal the space between the pistons and the cylinder walls. This results in unburned fuel and gases escaping into the oil pan and diluting the lubricating properties of the oil, leading to premature engine wear.

3.0 Why To Avoid Wet Stacking

In addition to the adverse engine effect, the designer and user of a system have to consider:

- Expense - Excessive wet stacking will shorten engine life by many years and before planned replacement.
- Pollution - Many urban areas restrict the level of smoke emissions wet stacking produces.
- Power - Even before an engine is damaged, deposits will reduce maximum power. A prematurely worn engine will have a lower maximum power than it was designed to develop.
- Maintenance - An engine experiencing wet stacking will require considerable more maintenance than an engine that is adequately loaded.

4.0 NFPA Guidelines

Wet stacking is a recognized condition with organizations that write codes for standby generator set systems, such as the National Fire Protection Association (NFPA) which has issued several guide lines for controlling the effects.

The NFPA guidelines in Level 1 and 2 applications require exercising the unit at least monthly for 30 minutes under either of two methods:

1. Under operating temperature conditions and not less than 30 percent of the EPS name plate kW rating, or
2. Loading to maintain the minimum exhaust gas temperature as recommended by the manufacturer. (See NFPA 8.4.2.) Exhaust gas temperature specifications are available from the manufacturer of the unit.

5.0 Additional Conditions

The Joint Commission on Accreditation of Health Care Organizations (JCAHO), the organization that accredits health care institutions, has taken this testing to a level beyond the NFPA. They require testing of 12 times per year with testing intervals between 20-40 days. Testing generators for at least 30 minutes under a dynamic load of 30% or greater of the name plate rating.

Systems that do not meet the 30% load capacity have three options.

1. Increase the load to meet or exceed 30% of the name plate rating,
2. Maintain the minimum exhaust temperature as recommended by the engine manufacturer, or
3. Undertake load bank testing for a total of 2 hours continuous loading as follows: a) Load at 25% of name plate for 30 minutes b) 50% for 30 minutes c) 75% for 60 minutes.

JCAHO also recommends that all automatic transfer switches (ATS) are tested 12 times per year at 20 and 40 day intervals. The provider of the power system through planned maintenance programs can undertake load testing when testing the ATS.

6.0 Solutions to wet stacking:

The obvious solution is to always run the generator set with an electrical load that reaches the designed operational temperature of the diesel, or approximately 75% of full load. Built-up fuel deposits and carbon can be removed by running the diesel engine at the required operational temperature for several hours if wet stacking has not yet reached the level where carbon buildup can only be removed by a major engine overhaul. The following load bank solutions should prevent a reoccurrence of wet stacking.

Automatic auxiliary loading:

When the generator set is the only source of power and the connected load for periods is very light a auxiliary load bank. The auxiliary automatically switches on when it detects the facility load is too low to adequately load the generator. When the facility load increases the load bank will switch off.

Facility manual load bank:

Operated as described for the automatic load bank, but a manually operated system for use with light loads and when the larger load is also manually initiated. The load bank can also be used for load testing a system primarily used for standby power.

Portable load bank: The distributor for the diesel generator set is often the best qualified to undertake the maintenance of the system. Today it is very common for the owner of a standby generator system to outsource complete maintenance of the system and have a planned maintenance (PM) contract with a full service generator-set supplier.

During a regularly scheduled planned maintenance call, the distributor will bring in a portable load bank to run the generator at a load that maintains the designed operational temperature. Portable load banks range from a few 10kW thru 2MW units mounted on large trailers as pictured.

5.0 Note regarding - Joint Commission of Accreditation for Hospital Organizations (JCAHO)

We feel it of interest to note that many hospitals are now being accredited by the Joint Commission. This organization addresses emergency management of hospitals (such as occurs with loss of utility power, water, etc). They provide standards covering: provisioning of care, treatment and services, patients rights and responsibilities in hospitals, and this includes a reliable EPSS in most cases. There has to be a written emergency plan in place with clearly defined responsibilities and assignation of adequate staff, including multiple back-up personnel.

All such persons must be trained and their attendance should be taken into account by the EPSS supplier when arranging such courses. The EPSS maintenance requirements must conform to NFPA 110 for testing purposes, but in addition, calls for monthly testing of generator and automatic transfer switches.

More details can be found on JCAHO web site:

www.jointcommission.org

Typical Portable Load Bank

WHAT HAPPENS TO ENGINES RUNNING WITHOUT SUFFICIENT LOADS

Posted by **Aurora Generators** on **May 19, 2016**

Diesel engines can suffer damage as a result of misapplication or misuse - namely **internal glazing and carbon buildup**. This is a common problem in generator sets caused by failure to follow application and operating guidelines - ideally diesel engines should run at least around 60-75% of their maximum rated load. Short periods of low load running are permissible providing the set is brought up to full load, or close to full load on a regular basis. Internal glazing and carbon buildup is due to prolonged periods of running at low speeds and/or **low loads**. Such conditions may occur when an engine is left idling in a 'standby' generator unit, ready to run up when needed, (misuse); if the engine powering the set is over powered (misapplication) for the load applied to it, causing the diesel unit to be under loaded, or as is very often the case, when sets are started and run off load as a test (misuse). Running an engine under low loads causes lower cylinder pressures and consequent poor piston ring sealing since this relies on the gas pressure to force them against the oil film on the bores to form the seal. Low cylinder pressures cause poor combustion and resultant lower combustion pressures and temperatures.

This poor combustion leads to soot formation and unburned fuel residues which clogs and gums piston rings. This causes a further drop in sealing efficiency and exacerbates the initial low pressure. Glazing occurs when hot combustion gases blow past the now poorly sealing piston rings, causing the lubricating oil on the cylinder walls to 'flash burn', creating an enamel-like glaze, which smooth's the bore and removes the effect of the intricate pattern of honing marks machined into the bore surface. Which are there to hold oil and return it to the crankcase via the scraper ring.

Hard carbon also forms from poor combustion and this is highly abrasive and scrapes the honing marks on the bores leading to bore polishing, which then leads to increased oil consumption (blue smoking) and yet further loss of pressure, since the oil film trapped in the honing marks is intended to maintain the piston seal and pressures. Un-burnt fuel leaks past the piston rings and contaminates the lubricating oil. Poor combustion causes the injectors to become clogged with soot, causing further deterioration in combustion and black smoking.

The problem is increased further the formation of acids in the engine oil caused by condensed water and combustion by-products which would normally boil off at higher temperatures. This acidic buildup in the lubricating oil causes slow but ultimately damaging wear to bearing surfaces.

This cycle of degradation means that the engine soon becomes irreversibly damaged and may not start at all and will no longer be able to reach full power when required. Under loaded running inevitably causes not only white smoke from unburnt fuel but over time is joined by the blue smoke of burnt lubricating oil leaking past the damaged piston rings and the black smoke caused by the damaged injectors. This pollution is unacceptable to the authorities and any neighbors.

Once glazing or carbon buildup has occurred, it can only be cured by stripping down the engine and re-boring the cylinder bores, machining new honing marks and stripping, cleaning and de-coking combustion chambers, fuel injector nozzles and valves. If detected in the early stages, running an engine at maximum load to raise the internal pressures and temperatures, allows the piston rings to scrape glaze off the bores and allow carbon buildup to be burnt off. However, if glazing has progressed to the stage where the piston rings have seized into their grooves, this will not have any effect.

The situation can be prevented by carefully selecting the generator set in accordance with manufacturers printed guidelines.

For emergency only sets, which are islands, the emergency load is often only about 1/4 of the sets standby rating, this apparent oversize being necessitated to be able to meet starting loads and minimizing starting voltage drop. Hence, the available load is not usually enough for load testing and again engine damage will result if this is used as the weekly or monthly load test. This situation can be dealt with by hiring in a load bank for regular testing or, installing a permanent load bank. Both these options cost money in terms of engine wear and fuel use but are better than the alternative of under loading the engine.

THE IMPACT OF GENERATOR SET UNDERLOADING

Brian Jabeck
Market Development and Design Engineer Consultant
Electric Power Division

October 2014

CATERPILLAR®

INTRODUCTION

System health and reliability are critical to backup and prime power solutions for every facility, from mission critical data centers to neighborhood grocery stores. A generator set is a key piece of the power system, and proper operation and maintenance are essential to long-term system reliability that ensures availability and uptime.

While power systems vary in operation, application and load profile depending on the purpose and complexity, all power systems are designed with common goals: providing reliable power and maximizing system efficiency. To achieve these design goals, it is important to understand system operation, load profile and schemes, and required maintenance. This paper will focus on the operation of generator sets in low-load scenarios and what can result if they are used outside of these parameters.

GENERATOR SET RATED LOADS

First, it is important to understand that generator sets are designed to run and, to be specific, they are designed to run with load. This may seem trivial, but loading a generator set properly is essential to availability, healthy engine operation and long engine life.

The ideal operation targets of each generator set will depend on the application and rating. Generally speaking, standby- and prime-rated diesel generator sets are designed to operate between 50 and 85 percent of the full nameplate, while continuous-rated diesel generator sets are optimized between 70 and 100 percent load. Natural gas and biogas generator sets, independent of application and rating, are designed for operation between 70 and 100 percent of the nameplate rating.

Manufacturer service intervals and projected component life are based on operation in these ranges to deliver an ideal mix of product performance, power density and long-term operational life. This makes the design phase critical to ensure that the power generation system is sized to operate within the manufacturer's recommended load levels while meeting the facility requirements. Misapplying generator sets by underloading them for extended runs will impact product health, operation and uptime while increasing the opportunity for unplanned events and shutdowns.

DIESEL GENERATOR SETS

Operating a diesel generator set at load levels less than 30 percent of rated output for extended time periods impacts the unit negatively. The most prevalent consequence is engine exhaust slobber, which is also known as exhaust manifold slobber or wet stacking. Engine slobber is a black, oily liquid that can leak from exhaust manifold joints due to extended low- or no-load scenarios. Running at high idle with little or no load reduces the heat in the cylinder, allowing unburned fuel and oil deposits to leak through the exhaust slip joints.

Visible slobber does not necessarily indicate a problem with an engine, but it signals possible underloading concerns, low ambient temperatures or low jacket water temperature. In most circumstances, engine slobber alone, while unsightly, will not immediately harm an engine. However, slobber is a sign of underloading and could be an indication of other underloading effects. Long periods of light loading can lead to deposit build-up behind the piston rings, deposits developing inside the cylinders and, in extreme cases, cylinder liner polishing can occur. These conditions can lead to power losses, poor performance and accelerated wear of components, which can cause increased maintenance costs and unplanned downtime or failure.

GAS GENERATOR SETS

Gas generator sets above 1000 kW are typically used in prime power and non-emergency standby applications where the load profile is steady and at higher load levels. Optimal operating conditions for gas generator sets can range from 50 percent to 100 percent of the rated load. Caterpillar recommends not loading natural gas generator sets in any application below 50 percent of their rated load for any duration, and the ideal range for operation is at 70 percent load and above.

Gas engines do not typically slobber, but there are other effects of low-load operations. At low load, gas engines do not have enough cylinder pressure to maintain oil control in the cylinder. This allows the oil to work its way past the rings into the combustion chambers, leading to ash deposits. These deposits change the compression ratio, which can reduce the detonation margin. If the detonation margin is reduced sufficiently, detonation can occur. Detonation will decrease the life of the engine, damage components and lead to unplanned shutdowns or failures.

Similar to diesel generator sets, the extended operation of gas generator sets at low loads can lead to deposit build-up on the valves, spark plugs and behind the piston rings. In extreme cases deposits in the cylinder can develop, causing cylinder liner polishing.

Additionally, natural gas engines run rich at low loads to maintain combustion and ensure that the engine does not misfire. A rich air-to-fuel ratio causes the engine to deviate from the expected emissions levels, potentially leading to non-compliance with required emissions regulations. Also, a rich air-to-fuel ratio increases temperatures and can accelerate component wear.

As is the case with diesel generator sets, all of these conditions can result in power losses, poor performance and accelerated wear of components, resulting in increased maintenance costs and unplanned downtime or failure.

AFTERTREATMENT

Aftertreatment components such as diesel oxidation catalysts (DOC), selective catalytic reduction (SCR) components and diesel particulate filters (DPF) are commonplace in many locations and applications, and they are all impacted by low-load operation. Without proper design and planning, low-load operation will have an impact on all aftertreatment components, causing emissions targets to be missed and ultimately leading to engine shutdown.

A DOC or DPF that is operating below the minimum exhaust temperature can cause back pressure limits to reach critical levels in a short period of time and lead to generator set shutdown. This issue becomes more critical in distributed or modular systems where there is no paralleling capability to share load between multiple units and ensure that a generator set is not operating at low loads for extended periods of time.

Meeting the minimum temperature is also critical in applications with an SCR system. If the SCR system does not reach the minimum operating temperature, the system will not begin dosing diesel exhaust fluid (DEF) into the exhaust stream, causing higher than expected emissions levels and impacting federal or local site permits.

Some SRC systems may need to be equipped with an additional exhaust heater to help meet minimum exhaust temperature requirements. While this may help maintain temperature needs, it also requires additional load to operate, which increases system complexity, cost and maintenance, and it does not address the impact of underloading on the engine. A more effective approach is to ensure that each generator set meets its minimum load targets for improved long-term system reliability and durability.

LOW LOAD MANAGEMENT

If maintained properly, diesel and gas generator sets can operate at light loads for long periods of time with no harmful effects. After operation at low load levels, each impacted generator set should operate under increased load to raise the cylinder temperature and pressure, which cleans the deposits from the combustion chamber. In addition, if low load operation is expected to occur regularly, a more aggressive maintenance plan will help to ensure that there is no excessive component wear and the chances for unplanned downtime are minimized.

The first major consideration in managing low load is how to add load to a system if the building load is not enough, or if the customer does not want to use critical loads for generator set maintenance. This issue can be resolved by having access to installed system load banks or a quick connect system that will allow for load banks to be easily tied into the power system for testing or maintenance purposes. Accounting for these requirements during the design phase allows for seamless integration into the system, which can be more cost effective than having to retrofit a site after construction and installation are complete.

Caterpillar recommends a testing process for diesel and natural gas generator sets. For diesel generator sets, Caterpillar recommends loading the generator set to a minimum of 30 percent load for approximately 30 minutes for every four hours of light load operation. Exhaust temperature measurements should be taken at the exhaust manifold prior to the turbo or in the exhaust stack just after the turbo to confirm that the recommended exhaust temperatures are met during operation.

The requirements for natural gas generator sets are slightly different. First, Caterpillar recommends aggressively working to limit underloading natural gas generator sets. See Table 1 below for time limits on low load operation for natural gas engines. After the time limit for reduced load operation has expired, the engine should be operated for a minimum of two hours at a load factor of at least 70 percent. Following these guidelines will keep engine maintenance to a minimum and improve long-term product health and durability.

For more information on generator set maintenance and testing, please contact your local Cat dealer or reference the operation and maintenance manual.

Engine Load	Time Limit
0 to 30 percent	1/2 hour
31 to 50 percent	2 hours
51 to 100 percent	Continuous [1]
[1] For continuous operation, the manifold air pressure must be greater than the atmospheric pressure.	

Table 1: Time limits for low load operation of natural gas generator sets.

CONCLUSION

Underloading your power system impacts many individual components as well as overall system performance. While the simple solution is ensuring that your operational load is above 50 percent of the generator set nameplate, actual site conditions, site requirements and site expansion do not always line up with initial system design plans. This makes system underloading prevalent in the power generation market, specifically in the standby market. To help minimize the effects of underloading, it is critical to have operation and maintenance plans in place to maintain the health and reliability of the complete system and your generator set.

ABOUT

About Caterpillar

For nearly 90 years, Caterpillar Inc. has been making sustainable progress possible and driving positive change on every continent. Customers turn to Caterpillar to help them develop infrastructure, energy and natural resource assets. With 2013 sales and revenues of $55.656 billion, Caterpillar is the world's leading manufacturer of construction and mining equipment, diesel and natural gas engines, industrial gas turbines and diesel-electric locomotives. The company principally operates through its three product segments – Resource Industries, Construction Industries and Power Systems – and also provides financing and related services through its Financial Products segment. For more information, visit caterpillar.com. To connect with us on social media, visit caterpillar.com/social-media.

Diesel Solutions Center: ***http://www.catelectricpowerinfo.com/wp***

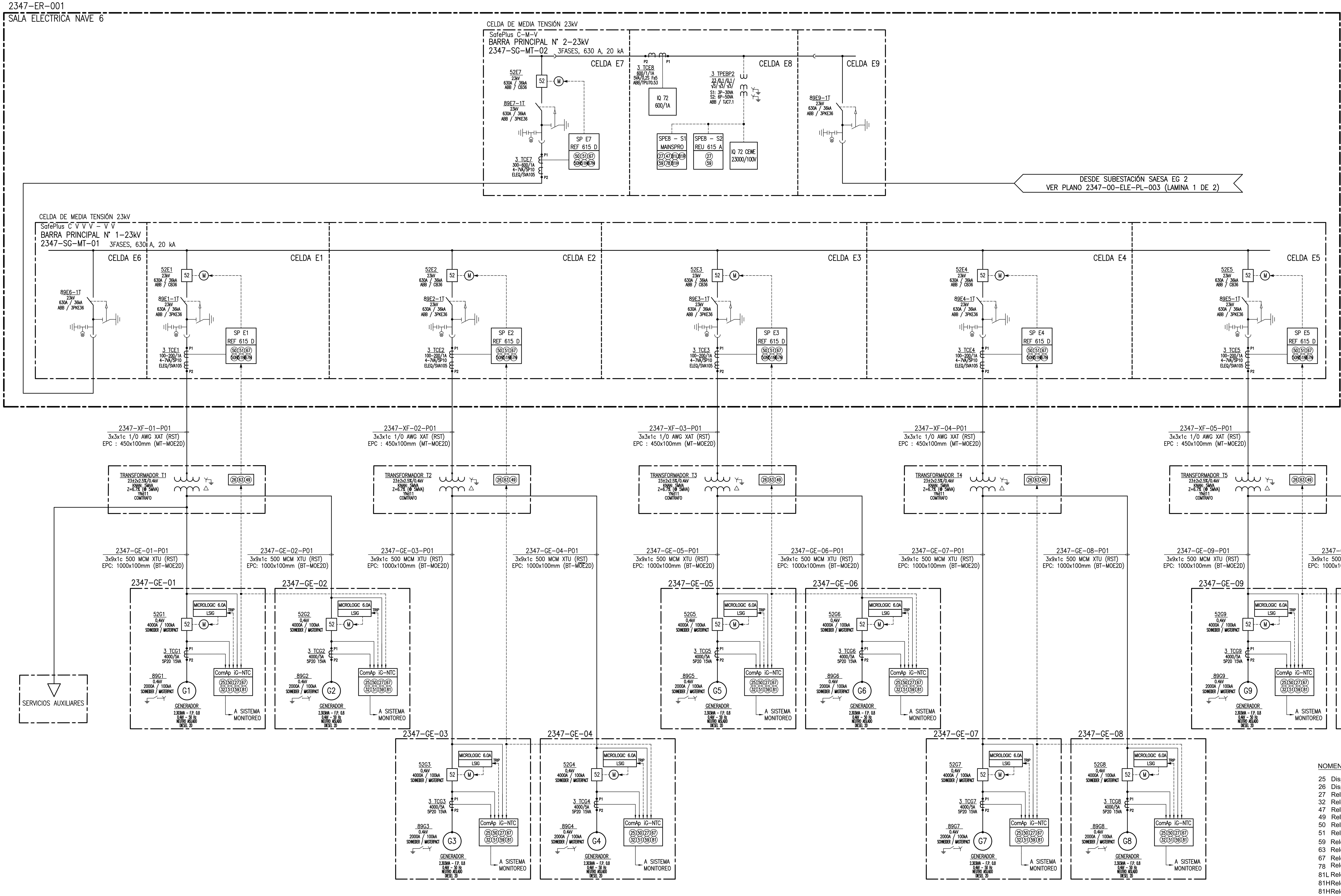
Online Community: ***https://caterpillar.lithium.com/t5/Electric-Power-Generation/ct-p/EPG***

Facebook: ***http://www.facebook.com/Caterpillar.Electric.Power***

YouTube: ***http://www.youtube.com/CatPowerGeneration***

LEXE0832-00 October 2014

ANEXO C - DIAGRAMA UNILINEAL ELÉCTRICO



SIMBOLOGIA

INTERRUPTOR DE PODER MEDIA TENSIÓN	52
DESCONECTADOR	
DESCONECTADOR DE OPERACIÓN MOTORIZADA	
DESCONECTADOR C/ PAT, CON UN SOLO MECANISMO CONMUTADOR DE LINEA A TIERRA Y OPERACIÓN MOTORIZADA	
TIERRA	
MUFA	
TRANSFORMADOR DE POTENCIA DE 2 DEVANADOS	
TRANSFORMADOR DE CORRIENTE	
TRANSFORMADOR DE POTENCIAL	
TRANSFORMADOR DE POTENCIAL CON 2 SECUNDARIOS	
CONEXIÓN ESTRELLA	
CONEXIÓN ESTRELLA CON PUNTO NEUTRO SOLIDAMENTE ATERRIZADO A TIERRA	
CONEXIÓN DELTA	

NOMENCLATURA DE FUNCIONES

25 Dispositivo de sincronización o puesta en paralelo
26 Dispositivo térmico
27 Relé de mínima tensión
32 Relé direccional de potencia
47 Relé de asimetría
49 Relé térmico para máquina, aparato o transformador
50 Relé instantáneo de sobre intensidad o de
51 Relé de sobreintensidad temporizado
59 Relé de sobretensión
63 Relé de presión de gas, líquido o vacío
67 Relé direccional de sobreintensidad de c.a.
78 Relé ángulo de desfase
81L Relé de baja frecuencia
81H Relé de sobre frecuencia
81H Relé de tasa de cambio de frecuencia + filtro

DIAGRAMA UNILINEAL FUNCIONAL

NAVE N° 6

N° PLANO	DESCRIPCION
7710-01-CP-PL-024	DIAGRAMA UNILINEAL FUNCIONAL GENERAL

REFERENCIAS

N°	DIBUJO	REVISO	FECHA	DESCRIPCION
A	V.B.G.	R.T.R.	19-10-2021	EMITIDO PARA REVISION INTERNA
B	V.B.G.	R.T.R.	12-11-2021	EMITIDO APROBACION CLIENTE
C	V.B.G.	R.T.R.	20-12-2021	EMITIDO APROBACION CLIENTE
0	V.B.G.	R.T.R.	23-12-2021	EMITIDO PARA CONSTRUCCIÓN
1	V.B.G.	R.T.R.	10-01-2022	EMITIDO PARA CONSTRUCCIÓN
	V.B.G.	R.T.R.	25-01-2022	EMITIDO PARA CONSTRUCCIÓN

EMISIONES

NOTAS

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DISEÑADOR	V. BECERRA G.
INGENIERO	R. TAPIA R.
REVISOR	M. SAN MARTIN A.
FECHA	OCTUBRE 2021
PROYECCION	

DEGAÑ NAVE N° 6
CENTRAL DE RESPALDO DEGAÑ
DIAGRAMA UNILINEAL FUNCIONAL GENERAL

ESCALA	PLANO N°	REV.
INDICADA	2347-01-ELE-PL-001	2

ANEXO D - LAYOUT CENTRAL GENERADORA

DESCRIPCION EQUIPOS		
NAVE 1		
ITEM	DESCRIPCION	POTENCIA
1	GENERADOR G01	1,28 MW
2	GENERADOR G02	1,28 MW
3	GENERADOR G03	1,28 MW
4	GENERADOR G04	1,28 MW
5	GENERADOR G05	1,28 MW
6	GENERADOR G06	1,28 MW
7	GENERADOR G07	1,28 MW
8	FUERA DE SERVICIO	N/A
9	GENERADOR G09	1,28 MW
10	GENERADOR G10	1,28 MW
11	GENERADOR G11	1,28 MW
12	TRANSFORMADOR T01	2MVA–23/0.415kV
13	TRANSFORMADOR T02	2MVA–23/0.415kV
14	TRANSFORMADOR T03	2MVA–23/0.415kV
15	TRANSFORMADOR T04	2MVA–23/0.415kV
16	TRANSFORMADOR T05	2MVA–23/0.415kV
17	TRANSFORMADOR T06	2MVA–23/0.415kV
18	TRANSFORMADOR T07	2MVA–23/0.415kV
19	N/A	N/A
20	TRANSFORMADOR T09	2MVA–23/0.415kV
21	TRANSFORMADOR T10	2MVA–23/0.415kV
22	TRANSFORMADOR T11	2MVA–23/0.415kV

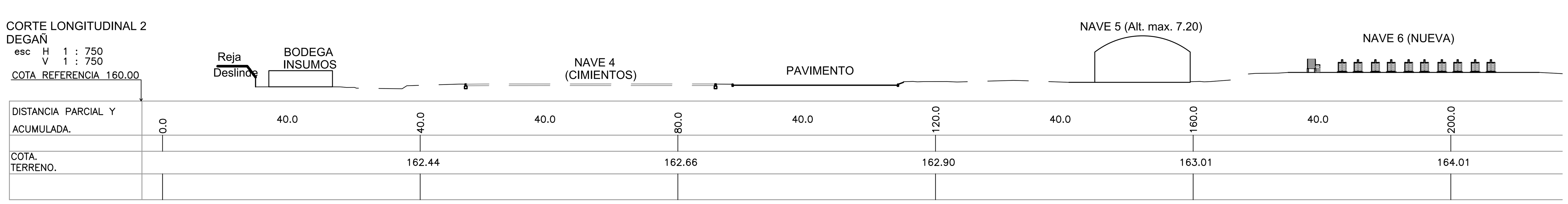
DESCRIPCION EQUIPOS		
NAVE 2		
ITEM	DESCRIPCION	POTENCIA
23	FUERA DE SERVICIO	N/A
24	GENERADOR G13	1,28 MW
25	GENERADOR G14	1,28 MW
26	GENERADOR G15	1,640 MW (REEMPLAZO)
27	GENERADOR G16	1,28 MW
28	GENERADOR G17	1,640 MW (REEMPLAZO)
29	GENERADOR G18	1,640 MW (REEMPLAZO)
30	GENERADOR G19	1,28 MW
31	GENERADOR G20	1,28 MW
32	GENERADOR G21	1,28 MW
33	GENERADOR G22	1,28 MW
34	N/A	N/A
35	TRANSFORMADOR T02	2MVA–23/0.415kV
36	TRANSFORMADOR T03	2MVA–23/0.415kV
37	TRANSFORMADOR T04	2MVA–23/0.415kV
38	TRANSFORMADOR T05	2MVA–23/0.415kV
39	TRANSFORMADOR T06	2MVA–23/0.415kV
40	TRANSFORMADOR T07	2MVA–23/0.415kV
41	TRANSFORMADOR T08	2MVA–23/0.415kV
42	TRANSFORMADOR T09	2MVA–23/0.415kV
43	TRANSFORMADOR T10	2MVA–23/0.415kV
44	TRANSFORMADOR T11	2MVA–23/0.415kV

DESCRIPCION EQUIPOS		
NAVE 5 (TRASLADO)		
ITEM	DESCRIPCION	POTENCIA
45	GENERADOR G34	0.878 MW
46	GENERADOR G35	0.878 MW
47	GENERADOR G36	0.878 MW
48	GENERADOR G37	0.878 MW
49	GENERADOR G38	0.878 MW
50	GENERADOR G39	0.878 MW
51	TRANSFORMADOR T01	2MVA–23/0.415kV
52	TRANSFORMADOR T02	2MVA–23/0.415kV
53	TRANSFORMADOR T03	2MVA–23/0.415kV

DESCRIPCION EQUIPOS		
NAVE 6 (NUEVA)		
ITEM	DESCRIPCION	POTENCIA
54	GENERADOR REDDITCH G1	1,842 MW
55	GENERADOR REDDITCH G2	1,842 MW
56	GENERADOR REDDITCH G3	1,842 MW
57	GENERADOR REDDITCH G4	1,842 MW
58	GENERADOR REDDITCH G5	1,842 MW
59	GENERADOR REDDITCH G6	1,842 MW
60	GENERADOR REDDITCH G7	1,842 MW
61	GENERADOR REDDITCH G8	1,842 MW
62	GENERADOR REDDITCH G9	1,842 MW
63	GENERADOR REDDITCH G10	1,842 MW
64	TRANSFORMADOR T1	5MVA–23/0.40kV
65	TRANSFORMADOR T2	5MVA–23/0.40kV
66	TRANSFORMADOR T3	5MVA–23/0.40kV
67	TRANSFORMADOR T4	5MVA–23/0.40kV
68	TRANSFORMADOR T4	5MVA–23/0.40kV

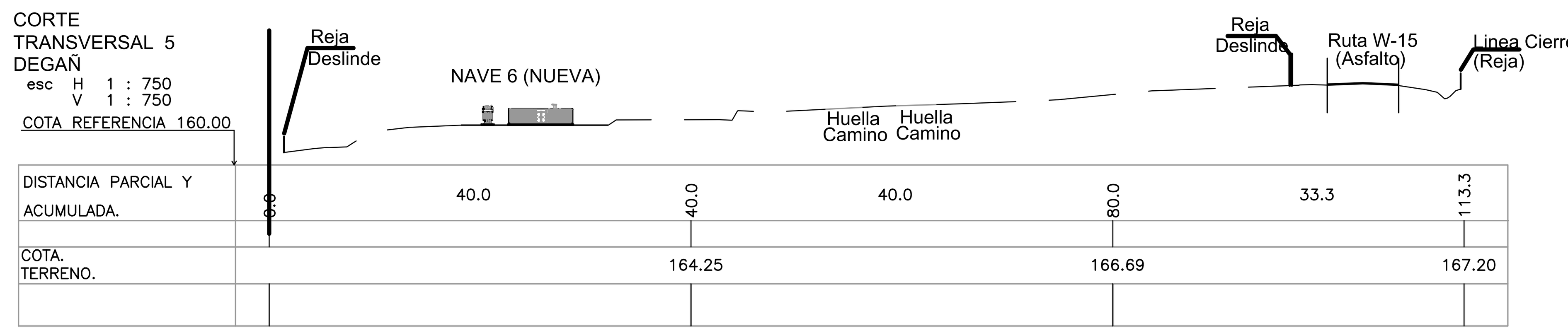
DISPOSICION DE EQUIPOS PRINCIPALES – PLANTA GENERAL

Esc. 1:350



CORTE (A)

Esc. 1:750



CORTE (B)

Esc. 1:750

REFERENCIAS N° PLANO	DESCRIPCION

EMISIONES N°	DIBUJO	REVISO	FECHA	DESCRIPCION
A	V.B.G.	M.S.M.	21-12-2021	EMITIDO REVISION INTERNA
B	V.B.G.	M.S.M.	24-12-2021	EMITIDO APROBACION CLIENTE

NOTAS:

1. ELEVACIONES Y DIMENSIONES INDICADAS EN MILÍMETRO (S.I.C).
2. LAS COTAS PREVALECEN POR SOBRE EL DIBUJO.
3. VIENTO PREDOMINANTE NOROESTE (NO).

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DISEÑADOR V. BECERRA G.
INGENIERO M. SAN MARTIN A.
REVISOR R. TAPIA R.
FECHA DICIEMBRE 2021
PROYECCION

TER. DEGAÑ (139) Y TER. DEGAÑ II (510)

DISPOSICION DE EQUIPOS – PLANTA GENERAL

ESCALA INDICADA
PLANO N° 2347-02-ELE-PL-001
REV. B

G:\Unidades compartidas\2347 Ingeniería PG Degan\4_Departamentos\33_Ingeniería\CEN\2021-12-24\2347-02-ELE-PL-001-B (2).dwg