UNIVERSIDAD NACIONAL DE INGENIERÍA

FACULTAD DE INGENIERIA MECÁNICA

"MANTENIMIENTO DEL GRUPO GENERADOR DE 57 MVA DE LA CENTRAL HIDRÁULICA CHARCANI V – EGASA"

INFORME DE SUFICIENCIA

Para optar el Título Profesional de:

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DEDICATORIA

A mis queridos padres Lola y Pedro, por darme el apoyo constante e incondicional durante la realización de mi carrera profesional; gracias por sus esfuerzos y enseñanzas, en los cuales me inculcaron con el ejemplo, los valores y virtudes que hoy en día son tan necesarios, en una sociedad donde cada vez más se requiere.

PROLOGO

El presente trabajo se refiere al desarrollo del mantenimiento de uno de los 3 grupos generadores de la Central Hidroeléctrica Charcani V con turbina peltón con una potencia de 57 MVA, perteneciente a la Empresa de Generación Eléctrica de Arequipa S.A. – EGASA; el cual tenía en promedio 14 años de servicio, para dicho estudio se ha considerado lo siguiente:

Inicialmente se ha preparado una breve reseña histórica de EGASA, con la finalidad de poder ubicar geográficamente dicha central y la infraestructura con la que cuenta la empresa, y en concordancia con nuestro Sistema de Gestión de la Calidad, dar a conocer el alcance, política y objetivos propios de la empresa, buscando con ello su mejoramiento continuo y el de la sociedad.
Se detalla a continuación el ámbito y dominio que abarca el desarrollo de los mantenimientos en todas las centrales hidráulicas, definiendo y desarrollando los tipos de planes de mantenimiento y la frecuencia con que se realiza estos, en forma anual.
Una vez y teniendo una mejor visión de la empresa en su conjunto y de la central en estudio, se detalla que criterios se tuvieron en consideración para la evaluación del estado en que se encontraba el grupo generador para determinar la forma y método de la intervención, para ello nos basamos en un estudio mas exhaustivo de los análisis predictivos, los cuales nos permiten determinar el grado de desgaste de los componente y partes del grupo; se realizo así un Análisis de Fallas, el cual involucra los Análisis de Aceite, Vibracional, de Termografía y de Aguas; a su vez también se realizo un Análisis Técnico e inspección en sitio del grupo en funcionamiento y fuera del mismo, conjuntamente con el Fabricante Alstom Francia; esto involucra el estator y rotor, partes soldadas, fijaciones, sistema de extractor de vapores, polos del rotor, residuos y deposiciones de aceite en el estator, etc..

Con ello se logro tener una idea mas clara del estado en que se encontraba la maquina, pudiendo así tomar la decisión de la realización de un Mantenimiento Total del Grupo Generador Nº 2, que consiste en el mantenimiento de todos los Equipos Electromecánicos e Hidráulicos en su conjunto, así como efectuar el Reapriete del Núcleo Estatorico y Mantenimiento del Generador.

A continuación se planifico, describió y programo la realización de dicho mantenimiento, diferenciando lo siguiente:
Trabajo en el Mantenimiento y Reapriete del Núcleo Estatorico, y
Mantenimiento General de Equipos Electromecánicos e Hidráulicos, esto involucra un mantenimiento eléctrico y mecánico.

Se realizo la descripción de los Cronogramas de Trabajo, y finalmente las pruebas a realizarse, evaluándose los costos que involucra dicho mantenimiento.

INDICE GENERAL

I. INTRODUCCIÓN

Hoy en día el mantenimiento, es una herramienta clave en todo proceso de producción, el cual con un adecuado y eficiente programa preventivo y predictivo, se puede asegurar una producción ininterrumpida del producto; como consecuencia de ello, la disminución de los costos de mantenimiento y los costos que conllevan esta parada.

Las labores de mantenimiento dentro de una planta son labores muy importantes, porque de ellas depende en gran parte la productividad para procesar un producto que garantice: la competencia en el mercado, el pago de los trabajadores, la utilidad a los propietarios y en general la supervivencia de la empresa.

Tanto el mantenimiento preventivo como predictivo, están basados en realizar tareas de mantenimiento a medida que se hagan necesarias, con el consiguiente mejora de la relación entre el costo de mantenimiento y el nivel de atención a los equipos, estos son herramientas que colaboran con la obtención de productos con los niveles de calidad exigidos en el mercado globalizado.

Es así que el Análisis de Vibraciones es una herramienta que permite detectar componentes mecánicos en malas condiciones, rodamientos poco confiables y bobinados eléctricos dañados, entre otras aplicaciones.

En Termografía las imágenes infrarrojas al detectar el calor irradiado por un objeto permite ubicar fallas incipientes en equipos eléctricos, desbalanceo térmico en motores de combustión interna, válvulas de compresores con pérdidas y mal funcionamiento de trampas de vapor, etc.

El análisis de Aceite (lubricantes, refrigerantes y aislantes) permiten detectar con tiempo desgastes mecánicos, deterioro de aislaciones o núcleos de transformadores, etc.

Para este estudio se ha tomado como referencia el Grupo Generador N° 2; que es uno de los 03 grupos de generación eléctrica de la Central Hidroeléctrica Charcani V de la Empresa de Generación Eléctrica de Arequipa EGASA, el cual será motivo del presente Informe Suficiencia de Ingeniería.

Finalmente es mi deseo y el de muchos jóvenes aportar experiencias y conocimientos a nuestro alma mater desde esta especialización como es el mantenimiento de equipos y maquinas de la industria en general, con el fin de superar los grandes retos que tenemos en la actualidad en nuestro país, ellos son las inmensas dificultades que viene arrastrando en materia económica, política, y social durante muchos decenios, para así poder encaminarse hacia un desarrollo sostenido basándose en la unión y esfuerzo de todos los peruanos.

ALCANCE

El presente trabajo enmarca todas las áreas operativas de uno de los 3 grupos generadores de la Central Charcani V, de la Empresa de Generación Eléctrica de Arequipa S.A., desarrollándose los sucesos desde la toma de decisión en la realización de este mantenimiento hasta su culminación.

OBJETIVOS

1. Evidenciar la importancia y necesidad de contar en este tipo de centrales con un sistema de monitoreo continuo con una alta confiabilidad, informe en tiempo real sobre la situación y estado de los equipos y sistemas que componen un grupo generador.

2. Exponer al lector en forma detallada, una herramienta de autoayuda para circunstancias en la que se encuentre involucrado en este tipo de mantenimiento, dándole una mejor visión de los procesos y etapas del mismo.

II. BREVE RESEÑA HISTORICA DE EGASA

1. UBICACIÓN E HISTORIA DE EGASA

EGASA, Empresa de Generación Eléctrica de Arequipa S.A., esta ubicada en el departamento de Arequipa, al sur del Perú; estando la Central Hidroeléctrica Charcani V a una altitud de 2963 m.s.n.m., el acceso a esta central es a través de dos vías una carretera afirmada que llega bordeando el río Chili y la otra carretera asfaltada construida durante la realización del proyecto. El clima durante el día llega a los 22°C y en las noches a los 4°C.

EGASA, Empresa de Generación Eléctrica de Arequipa S.A., se constituye el 15 de Marzo de 1994, y es parte integrante del Sistema Interconectado Nacional y tiene como objetivo la generación de Electricidad, la cual es producida a través de sus Centrales Hidráulicas y Térmicas, suministrando electricidad al Sistema Interconectado Nacional, así como a sus clientes libres.

Durante su primer año de operación, la administración realizó las gestiones necesarias para lograr el saneamiento y organización integral de la empresa. En dicho año las condiciones hidrológicas se presentaron muy favorables, situación que permitió cubrir íntegramente la demanda del Sistema Interconectado Sur Oeste con generación hidráulicas, quedando la Central Térmica de Chilina en estado de reserva fría.

En 1995, la empresa decidió ampliar su oferta térmica, para lo cual sé prevee la construcción de una nueva central térmica ubicada en la ciudad de Mollendo, procediéndose a la elaboración del expediente técnico para la convocatoria a Licitación Pública correspondiente, para la adquisición en una primera etapa de una central termoeléctrica de 30 MW. De otra parte, inicia la construcción del primer embalse de regulación horaria denominado Campanario sobre el río Chili, con capacidad para 90,000 m^3.

En 1996, se dio inicio a la construcción de la Central Térmica de Mollendo, así mismo entra en servicio el embalse de regulación horaria Campanario y se da inicio a las obras civiles del segundo embalse de regulación horaria – Puente Cincel. Las inversiones realizadas se destinaron principalmente al desarrollo de la capacidad de generación de la empresa. En el ejercicio 1997, EGASA impulsa un agresivo programa de inversiones, debiendo destacarse entre ellas la Central Térmica de Mollendo, el afianzamiento del sistema de comunicaciones, un programa de mantenimiento de todas las centrales de generación así como inversiones para la preservación del medio ambiente.

EGASA en 1998, se consolido una vez más como empresa líder en el Sistema Interconectado Sur. En el mes de abril ingresa en operación comercial la Central Térmica de Mollendo I Etapa, permitiendo incrementar la capacidad instalada de la empresa en 31,6 MW, a la vez que incorpora adelantos tecnológicos que posibilitan una operación más eficiente y segura del sistema con la consecuente disminución de los costos marginales.

En febrero de ese mismo año, como consecuencia de la inundación que sufriera la Central Hidroeléctrica de Machupicchu, EGASA asume la responsabilidad de cubrir la oferta de energía dejada de generar por EGEMSA. Para consolidar la oferta de energía en el Sistema Interconectado Sur, el gobierno aprobó la Ley 26976 –Ley de Emergencia en los Sistemas Eléctricos del Sur, por lo que EGASA decidió llevar a cabo la implementación de la Central Térmica de Mollendo II Etapa, la cual consta de 02 grupos de Turbina Generador con una potencia instalada del orden de 74,8 MW. En el ejercicio 1999, se culmina la obra de ampliación de la Central Térmica de Mollendo II- Etapa, ingresando en operación en el mes de julio. Cabe destacar que la potencia total de estas centrales I y II Etapa es de 106,5 MW, y que beneficia a más de dos y medio millones de pobladores de los departamentos de Arequipa, Moquegua, Cuzco, Puno, Tacna y Apurímac, así como al sector industrial y minero de la zona.

En el año 2000, EGASA inicia la construcción de la línea Charcani V – Chilina en 138 kV con 17.5 km de longitud, para garantizar la seguridad y confiabilidad del suministro a la zona Sur. También se inicia la implementación del moderno Centro de Control de Chilina, para el manejo automático de las Centrales de Generación.

2. ALCANCE DE EGASA

Actualmente EGASA establece, documenta, implementa, mantiene y mejora continuamente la efectividad de su Sistema de Gestión de la Calidad de acuerdo con los requisitos de la Norma ISO 9001:2000; el cual involucra al proceso de Generación de Electricidad de las Centrales Hidráulicas Charcani, las Centrales Térmicas de Chilina y Mollendo como proceso crítico; y a los procesos de Gestión de la Calidad, Mantenimiento, Comercialización, Compras, Recursos Humanos y de Medición y Análisis como procesos de soporte

Asimismo, se asegura la disponibilidad de recursos e información necesarios para apoyar la operación, medición, análisis e implantación de las acciones necesarias para alcanzar los resultados planeados y el mejoramiento continuo del proceso y actividades relacionadas.

3. POLÍTICA DE CALIDAD DE EGASA

Generamos electricidad, satisfaciendo a nuestros clientes y contribuyendo al desarrollo de la sociedad, mejorando continuamente nuestros procesos a través de la aplicación de un Sistema de Gestión de la Calidad de acuerdo con los requisitos de la Norma ISO 9001:2000

4. OBJETIVOS DE LA CALIDAD DE EGASA

- Consolidar a EGASA como uno de los principales actores en el Sistema Interconectado Nacional, en la operación de centrales eléctricas y comercialización de electricidad, optimizando la rentabilidad.
- Implantar y trabajar con un Sistema de Gestión de la Calidad

5. INFRAESTRUCTURA DE SUS UNIDADES HIDRÁULICAS Y TÉRMICAS

EGASA para cumplir con su política de calidad, se basa dentro de muchos aspectos en la infraestructura, capacidad y confiabilidad de sus plantas, contando para ello con centrales hidráulicas y térmicas.

La potencia instalada total de la empresa para el ejercicio 2000 ha sido de 342, 77 MW, siendo este superior en 2,75 % con relación a 1999; y una potencia efectiva de 324,18 MW, siendo este superior en el orden de 0,99% con relación a 1999.

La producción total de electricidad obtenida en el año 2000 fue de 1 041 542,40 MW, del cual el 89,12% ha correspondido a generación hidráulica y el 10,88% a generación térmica.

i. Unidades Hidráulicas

El parque generador hidráulico consta de 06 Centrales Hidráulicas (Charcani I, II, III, IV, V y VI), situadas al margen de la cuenca hidrológica del río Chili desde la cota de 3666 a 2650 msnm; con una potencia instalada de 184,63 MW.

En las centrales hidráulicas la secuencia de generación de electricidad desde la captación de agua hasta la generación misma es como sigue:

Represa de Pañe
Represa del Fraile
- Represa de Aguada Blanca
Central Hidroeléctrica Charcani V
Dique de Regulación Cincel
Central Hidroeléctrica Charcani IV
Central Hidroeléctrica Charcani VI
Dique de Regulación Campanario
Central Hidroeléctrica Charcani III
Central Hidroeléctrica Charcani I
Central Hidroeléctrica Charcani II

EGASA toma el recurso hídrico de la represa de Aguada Blanca y es dirigida hacia la Central Hidroeléctrica Charcani V.

A continuación se describirá la conformación de la Central Hidroeléctrica Charcani V, para ello se agrupara en 5 áreas, a saber:

1. Edificio de Servicios (E.S.)

Se tiene el Centro de control conformado por:

- Calculadores PCP, PCS y armario de repartición de Cables.
- Armario de Módem enlace con CM., AB, de AA, AI, y AM.
- Monitores y PCs, de archivo de eventos.
- Equipos de BLU AB, Tele Protección y Tele regulación.
- Sistemas electrónicos auxiliares como el sistema de reloj, contra incendio, onduladores y circuito cerrado de TV de casa de

maquinas.

- Auxiliares eléctricos: Tableros MT-LGA, BT-LKA; Fuentes de CC, Bancos de baterías, rectificadores, de 125V y 48V.
- Sistema de climatización del edificio de servicios: Grupo frigorífico, ventilación, regulación humificador, ductos y red de agua.
- Sistemas de Iluminación normal, emergencia del E.S.: Equipos del taller
- Grupo Diesel: Motor Cummins, Generador, Tableros de sistema de permutación de fuentes.
- PL: Acoplamiento de BB-138 kV, Equipos de AT. Estructuras, Red de tierra, Cerco
- PT: Celda de reparación, grúa, sistema agua contra Incendio, Iluminación, Red de tierra

2. **Grupo Generador 1, Ídem para el Grupo Generador 2 y 3:**

Equipo electrónico del circuito: RAPID77, Regulación de excitación, H-20, Módem de los sistemas de medición convertidores.

Tableros de medición y mando, Auxiliares propios, Sistemas de protección, Auxiliares del grupo, Bombas, Ventiladores.

Celdas de MT: Neutro, Excitación, Trafo.auxiliares propios, Disyuntor LKA, Trafo 2MVA, Celda LGA. Cable MT.

Trafo 57 MVA, Disyuntor Equipos de Alta Tensión.

Generador: Cojinete, Sistema de Freno, Refrigeración, Calefacción, contra incendio, aislamiento.

Sistema de Regulación de inyectores: Tanque de Aceite, acumulador, By-Pass.

Lubricación del grupo : Inyectores, Bombas, Válvula esférica, Cojinetes pívot, Generador, Turbina, Regulación.

Turbina, Inyectores, Válvula esférica, Anillos, Estanqueidad.

Auxiliares de Turbina: Rittmeyer, Seguridades, Sistema Hidroford, Desconexión automática.

3. Servicios Auxiliares de Casa de Maquinas (SA - CM)

Generador auxiliar hidroeléctrico RCS76, Regulador de excitación, Tableros de Control Protección, Permutación de fuentes.

Turbina Auxiliares Hidroeléctrico de Regulación de inyector, Caja de aceite, válvulas, cojinetes, lubricación, y refrigeración

Servicios auxiliares electrónicos, sistemas de reloj, Incendio, Intercomunicadores, Teléfono.

Tableros Auxiliares: LKA, LKB, LMA, fuentes de CC, Banco de baterías, rectificadores, 125V y 48V.

Sistemas de refrigeración Agua tratada, Cruda, drenaje, captación, estación reductora red de agua de servicios de CM.

Sistema de Climatización Casa de Maquinas, Ventilación, Grupos frigoríficos, Agua helada, Ductos, Regulación.

Sistemas de aire comprimido: compresores de regulación, Servicio y Talleres.

Iluminación Normal, Emergencia, Señalización, Tableros, red de tierra.

Grúas de 60 TN, Ascensor, Polipastos, equipos de taller.

4. Cámara de Válvulas y Teleférico (CV - TELEFRICO)

Auxiliares Electrónicos: H-20, Mediciones Hidráulicas, Transmisor de datos.

Suministro MT. Disyuntor Transformador, Tableros de distribución BT. Sistemas de protección

Fuente CC. 48 V, Banco de baterías, Distribución CC, Iluminación y Señalización

Parte Mecánica: Válvula mariposa, Central hidráulica de mando, By-pass, Drenaje, Seguridades.

Puente Grúa, winche para inspección del conducto forzado, junta dilatación del conducto forzado, chimenea de equilibrio.

Teleférico: Sistema electrónico de control y mando, sistema de protección.

Teleférico: Sistema motor, Sistema de Frenado, Seguridades, Grupo auxiliares rescate y electrógeno

Teleférico: Suministro Media Tensión, Transformador, Tableros distribución, Control, Iluminación, Puesta a tierra

Teleférico: Cabinas, Cables, Bailarinas (poleas guías), contrapesos y contrapesos.

5. **Bocatoma de Aguada Blanca (A.B.)**

Auxiliares electrónicos: H-20, Módem, BLU, Medidas de nivel de presa, sobre velocidad y sistemas de incendio

Suministro de M.T. disyuntor, Transformador, Tableros de distribución de BT., Protección, Control y señalización, y sistema de puesta a tierra

Fuente de CC: Banco de baterías, rectificadores, distribución en CC., Sistemas de iluminación

Sistema Compuertas: Central Hidroeléctrico de mando, control, y mecánica de las Compuertas, sistema Neumáticos de medición Hidroeléctrico, Compresores de mediciones y aireación de ductos.

Puente Grúa, ataguías y otros de uso de control de represa

Líneas de 13.8 kV: conductor, estructuras, sistema de pararrayos y ferreterías.

Otros Servicios: Iluminación y servicios de almacenes.

Líneas de 13.8 kV de servicios a Toma IV, Charcani V.

ii. Unidades Térmicas

El parque generador térmico consta de 02 centrales, una ubicada en la ciudad de Arequipa (Central térmica de Chilina con una potencia instalada de 50,85 MW y la otra central ubicada en la ciudad de Mollendo (Central Térmica de Mollendo) con una potencia instalada total de 107,29 MW.

La antigüedad y el tipo de equipo de cada una de las centrales hidráulicas, se muestra a continuación en los siguientes cuadros sobre Características Generales de Centrales Hidráulicas y Térmicas de EGASA, (Ver Anexo I).

III. MANTENIMIENTO DE LAS CENTRALES HIDRÁULICAS

El programa considera el mantenimiento de las 6 Centrales Hidráulicas, Servicios Auxiliares, Líneas de Transmisión y equipos relacionados tales como Teleférico, Diques de Regulación Horaria y otros.

Se considera el área de dominio de cada Central a todos los equipos que permitan el funcionamiento de los grupos generadores tales como: Toma de Agua, desarenadores, ductos de conducción, cámaras de carga o Tazas, Conducto forzado, Turbina, Generador ductos de descarga, sistemas eléctricos de potencia, auxiliares alternos y de corriente continua, iluminación y todos los equipos de maniobra y seguridades dentro de la central.

El programa de Mantenimiento Preventivo se ha diseñado para dos grandes grupos de acuerdo a la capacidad e importancia de los mismos:

- El programa de Mantenimiento de las Centrales Menores que agrupa a las

Centrales Hidráulicas: I, II, III, IV, VI y los dos diques de Regulación horaria Cincel y Campanario; este programa considera la ejecución de 04 planes de mantenimiento.

El programa de Mantenimiento de la Central Hidráulica Charcani V, este programa también considera la ejecución de 04 planes de mantenimiento.

1. SOBRE LOS ALCANCES DE LOS PLANES DE MANTENIMIENTO

i. PLAN 1

- Evaluar las condiciones de funcionamiento integral, controlando, temperatura, sonidos o vibraciones, presiones, mediciones, desgaste y observaciones que permitan evaluar las condiciones de trabajo y estado de conservación.
- Controlar el funcionamiento de cada uno de los elementos de control, protección y medición tales como, termostatos, termocuplas, presostatos, flujos tatos, relees, elementos de mando, medición, señalización, etc.
- Limpieza y protección que requiera para su conservación.
- Realizar engrase general, control de los niveles de lubricación y evaluar el estado de los cojinetes y rodamientos.
- En este plan se evalúa los posibles cambios y/o reparaciones a realizar en un plan mayor o próxima intervención.

ii. PLAN 2

- Además de realizar los trabajos previstos en el Plan 1, se realizan un muestreo de funcionamiento de censores, instrumentos de medición, se realizan reparaciones menores tales como reparaciones con soldadura de partes o elementos menores, medición de desgaste, y desmontajes que permitan evaluar estado de partes internas de maquinas o equipos.
- Se mide y evalúa aislamiento de generadores y equipo eléctrico, sistemas de puestas a tierra, entre otros.

iii. PLAN 3

- Además de los trabajos contemplados en el plan 2, se realizan cambios de partes a punto de falla o por límite de vida.
- Se realiza muestreo de funcionamiento de relees de protección, Señalización, protección de cojinetes, error de sistemas de medición, entre otros.
- Este plan es integral, aquí se revisa todo el conjunto del equipo, las partes mecánicas, eléctricas, electrónicas y equipos auxiliares.

iv. PLAN 4:

- Este es el llamado Over Holl, se realizan cambios importantes del conjunto, como son: cojinetes, turbina, válvulas, etc...
- En este plan se realizan las repotenciaciones y pruebas que permitan evaluar el estado de aislamientos, rendimientos y otros que indique el fabricante.

Las intervenciones se han considerado hacerlo cada 7 semanas en el caso de centrales menores y cada 06 semanas en el caso de la Central Charcani V; es decir cada 1200 y 1000 horas de servicio respectivamente para cada grupo de generación.

Durante el año se ha previsto realizar 08 intervenciones para las centrales menores, estas son:

06 intervenciones de tipo Plan 1, 03 en cada semestre;
01 intervención de tipo Plan 2, en el primer semestre y;
01 intervención de tipo Plan 3 en el segundo semestre.

Asimismo, se ha previsto realizar 09 intervenciones para la Central Charcani V, estas son:

07 intervenciones de tipo Plan 1, 04 en el primer semestre y 03 en el segundo semestre;

01 intervención de tipo Plan 2, en el primer semestre y;
01 intervención de tipo Plan 3 en el segundo semestre.

La intervención de un Over Holl se realiza de acuerdo a un estudio especial de análisis de las horas trabajadas, desgaste de los equipos, historial de las maquinas y de las instrucciones y recomendaciones dadas por el fabricante.

Dentro de los planes de mantenimiento se considera como base el recurso humano, es decir la participación de personal capacitado en el mantenimiento de dichos equipos que hace confiable el trabajo sobre éstos.

IV. EVALUACIÓN PARA LA DETERMINACIÓN DEL MANTENIMIENTO

Se tomo como referencia para el estudio al Grupo Generador N° 2

1. ANÁLISIS DE FALLAS – MANTENIMIENTO PREDICTIVO

i. Análisis de Aceite

Tipo de Máquina	Charcani V
Equipo	Cojinete de Empuje, Cojinete Alternador, Cojinete Turbina, Tanque de regulación.
Unidad	Grupo Generador Nº 2
Producto	Mobil DTE Heavy Medium – ISO 68 Aceite Hidráulico ISO 68.
Período de Servicio	: 23000 Horas

ANALISIS DE ACEITE (PPM) GRUPO II - (Horom: 72940)CHARCANI V

DESCRIPCION	Na	K	Li	V	Mg	Ca	Pb	Zn	Si	Cr	Ni	Cu	Al	Fe	Mn	Vis40°C cST
COJINETE EMPUJE	0.16	0.03	0.02	0.02	0.52	0.64	0	121	0.17	0.02	0	53.8	0.02	0.39	0.04	61.2
COJINETE ALTERNADOR	0.17	0.07	0.02	0.04	1.03	1.29	0.07	99.1	0.5	0	0	1.31	0.11	0.06	0.07	61.9
COJINETE TURBINA	0.09	0.01	0.05	0.1	0.31	0.21	0.21	125	0.26	0.07	0	89.2	0.08	2.08	0.14	60.8
TANQUE REGULACION	0.28	0.01	0.03	0.02	0.24	0.71	0.02	61.7	0.18	0.07	0.01	7.02	0.37	0.8	0.07	61.5

Análisis:

Se realizó un sistema de monitoreo de aceite hidráulico, el cual determina el contenido y características de los contaminantes del aceite; ya que en los componentes de los sistemas hidráulicas se tienen tolerancias internas muchos más pequeñas, explicadas por los niveles de presión más altos que se alcanzan, que al ser recorridas por un aceite con partículas por encima de su limite recomendado, ocasionaran un desgaste excesivo y por consiguiente menor vida útil. Por esto cada fabricante recomienda un nivel máximo de contaminación para cada componente definido básicamente por el principio de operación y la aplicación donde normalmente será utilizada.

En sistemas hidráulicos la contaminación del aceite explica el 90% de las fallas de los componentes; sin embargo normalmente no se le daba su real importancia debido principalmente a la dificultad de realizar las pruebas respectivas. Ahora es posible realizar el monitoreo permanente del aceite con equipos sofisticados y aun costo optimo, comparando con sus características de operación y las ventajas que otorga: aumento de la vida de los componentes, confiabilidad y por consiguiente disminución de costos de mantenimiento y producción.

En general, los sistemas hidráulicas como los instalados en nuestros equipos son diseñados, al igual que la mayoría de los sistemas de las centrales hidráulicas, para una gran confiabilidad, elevada eficiencia y el menor mantenimiento posible, en este caso, los sistemas hidráulicas se diseñan para trabajar con baja presión, tanques de fluido más grandes, volúmenes de aceite altos, componentes más robustos, diseño simple, etc. Todas estas razones conllevan a que sea permitido un nivel de contaminación más alto, comparado con otros sistemas.

Existen varias maneras de tomar muestras de aceite hidráulico, en esta oportunidad se muestreó siguiendo la recomendación del fabricante, que es hacerlo desde las líneas de presión y con aceite circulando en el ciclo normal, por medio de censores o componentes específicamente colocados, Sin embargo, lo más importante para realizar un buen monitoreo es la repetibilidad de las características de la toma de muestras, como presión, caudal, punto de la toma, aseguramiento de la limpieza de las botellas, etc., para de esta manera poder hacer una comparación real y confiable.

Así las muestras sacadas nos indica la presencia de una alta concentración de partículas (tamaño de 2 a 25 um), esto denota un elevado trabajo de los filtros (normalmente con mallas de 25 um) y por ende, un alto numero de horas de servicio, lo cual se refleja en el horometro (72940 horas de servicio); también se presenta un alto incremento de cobre causado probablemente por falta de presión de aceite, desgaste y/o fugas en el cojinete, y finalmente existe presencia de oxidación debido a un posible recalentamiento.

En sistemas con volúmenes de aceite pequeños la recomendación sería cambiar el aceite; sin embargo en nuestro sistema, como lo indica el fabricante, está permitido el centrifugado del aceite para la disminución de los contaminantes, así como del agua que pudiera haber ingresado al sistema. Como quiera que el aceite se degrada, no puede trabajar y centrifugarse indefinidamente por lo que también es importante la inspección visual de las muestras y del tanque para notar disociación o sedimentos, que indicarían un reemplazo inmediato.

Los resultados arrojados indican la necesidad de un cambio de aceite, debido tanto a los valores arrojados en la prueba, como por las recomendaciones del fabricante y del servicio técnico brindado por el que nos suministra el aceite.

A continuación en el Anexo II se presenta el cuadro de una parte de la información técnica de la Norma ISO 4406, que trata sobre la nomenclatura de la contaminación del aceite hidráulico, así como gráficos y tablas con algunos sistemas y sus niveles típicos de contaminación aceptables.

NIVELES DE CONTAMINACIÓN SUGERIDAS PARA VARIOS SISTEMAS HIDRÁULICO

CONTAMINACIÓN DE ACUERDO A ISO 4406		**MÁXIMO NIVEL DE PARTÍCULAS SUGERIDO**		**SENSIBILIDAD**	**TIPO DE SISTEMA**	**COMPONENTES TÍPICOS**
5μ m	15μ m	5μ m	15μ m			
13	9	4000	250	Súper crítica	Sistemas de control con muy alta confiabilidad: Laboratorios, aeroespacio.	Servo válvulas de alta eficiencia
15	11	16000	1000	Crítica	Sistemas servo de alta eficiencia, de alta presión y vida útil. Ejemplo: aviones, máquinas, herramientas, etc.	Servo válvulas industriales
16	13	32000	4000	Muy importante	Sistemas confiables de alta calidad. Requerimientos de maquinaria en general.	Bombas de pistones, válvulas proporcionales, controles de flujo compensados.
18	14	130000	8000	Importante	Maquinaria en general y equipos móviles. Mediana presión y capacidad media.	Bombas de paletas, válvulas de corredera.
19	15	250000	16000	Promedio	Sistemas industriales de baja presión y trabajo pesado, aplicaciones donde la larga vida no es crítica.	Bombas de engranajes, válvulas manuales y de asiento, cilindros
21	17	1000000	64000	Protección propia	Sistemas de baja presión con grandes tolerancias.	Bombas de carnero.

A continuación se presenta las Tablas de Interpretación y Contaminación de aceites según la Norma ISO 4406.

ii. Análisis Vibracional

Dentro de las partes a tener en cuenta para el diagnostico del problema, se puso especial énfasis en el Análisis Vibracional, aquí se presenta un reporte de las mediciones Globales y Análisis Espectrales de los Grupos Generadores de la Central Hidráulica Charcani V, la presentación es la siguiente:

1. Principios teóricos y metodología
2. Valores Globales de Velocidad de Vibración en mm/seg. (RMS); el Desplazamiento de la Vibración en μm P-P
3. Espectros de Frecuencia vs. Amplitud de Desplazamiento de vibración que muestran las fallas significativas
4. Interpretación y diagnóstico de los espectros
5. Gráficos de Tendencia por Cojinete
6. Recomendaciones Generales

1. PRINCIPIOS TEÓRICOS Y METODOLOGÍA

Con este reporte, se trata de dar una visión clara del estado general del Grupo Generador de la Central Charcani V, con solo revisar los gráficos de tendencia se puede tener una idea de en que punto del diagrama de la bañera se pueden encontrar, si se encuentran en perfecto estado, si tienen desgaste, soltura, si fueron intervenidos en mantenimiento apropiadamente o inapropiadamente, etc.

Asimismo se presentan como defectos o problemas aquellos puntos (cojinetes) que presenten altos niveles de vibración, estén cerca de sus niveles de alarma o tengan un patrón definido en el espectro, onda en el tiempo u órbita.

Los valores globales se toman en velocidad de vibración mm/seg. RMS y en desplazamiento de la vibración μm P-P para determinar el estado general del cojinete medido, tomando como término medio los siguientes límites de advertencia y alarma (Norma ISO 10816-5 – 2000):

GRUPO DE MAQUINAS DE EJE VERTICAL, COJINETES SOPORTADOS EN LA CIMENTACION, CASO DE LA CENTRAL CHARCANI V.

Velocidad de vibración en mm/seg.: En RMS

- Bueno (vibración de máquina nueva) < 1.6 mm/seg.
- Regular (Aceptable para operación irrestricta en periodos largos) > 1.6 y < de 2.5 mm/seg.
- En observación (NO ACEPTABLE para operación irrestricta en periodos largos) > 2.5 y < 4 mm/seg.
- Malo (Suficiente severidad para causar daño a la máquina) > 4 mm/seg. a más.

Desplazamiento de la vibración: En μm P-P

- Bueno (vibración de máquina nueva) < 30. μm
- Regular (Aceptable para operación irrestricta en periodos largos) > 30 y < 50. μm
- En observación (NO ACEPTABLE para operación irrestricta en periodos largos) > 50 y < 80 μm.
- Malo (Suficiente severidad para causar daño a la máquina) > 80 μm. a más.

El nivel máximo permisible que recomienda el fabricante de la Central Charcani V es de 60 μm P-P y se expone por ALSTOM en los protocolos de puesta en servicio donde se refieren a las normas NEMA MG5.1.

Los otros valores se han tomado de acuerdo a las normas ISO 10816-4 primera edición **INTERNATIONAL STANDARD ISO 10816-4. MECHANICAL VIBRATION – EVALUATION OF MACHINE VIBRATION BY MEASUREMENTS ON NON ROTATING PARTS – Part 5 MACHINE SETS IN HYDRAULIC POWER GENERATING**

AND PUMPING PLANT (NORMA INTERNACIONAL ISO 10816-4 VIBRACIONES MECANICAS – EVALUACION DE MAQUINAS CON MEDICIONES EN PARTES NO ROTATIVAS – Parte 5 MAQUINAS EN CENTRALES DE GENERACION HIDROELECTRICA Y PLANTAS DE BOMBEO).

También se pueden considerar las normas NEMA MG 1 Part 7. Machines up to 75 MW Table 7-1 Unfiltered Vibration Limits, turning speed 600 RPM 0.08 IN/SEC=2.0 mm/sec 0-P (aprox 1.4 mm/sec RMS).

En caso de disponer de niveles de vibración permisibles por maquina proporcionados por el fabricante se utilizaran estas como referencia de comparación y no las normas genéricas que se utilizan en el caso de no disponer recomendaciones del fabricante.

Respecto al análisis espectral se buscan los síntomas de falla en la concordancia de la frecuencia que se presenta en el espectro medido, en comparación de las frecuencias que debe dar el grupo, de acuerdo a sus RPM, armónicos (múltiplos de las RPM) o frecuencias de falla.

EQUIPOS UTILIZADOS

Analizador espectral VIBROSPECT FFT – SYSTEM 2 LITE marca Pruftechnik – Alemania.
Analizador y colector de datos 2117 marca CSI. Ambos de propiedad de EGASA.

METODOLOGIA:

Se expone las tendencias de las vibraciones en los gráficos, con la finalidad de hacer la comparación o análisis de como es el comportamiento de los grupos diagnosticados, se presentan los niveles medidos en Agosto 1999, Mayo 2002, Agosto 2002, Octubre 2002 y Enero 2003 fechas en que se realizaron mediciones con los mismos parámetros de medición así mismo son indicativos claros de desgaste, envejecimiento, anormalidades, etc. las mismas que son la esencia de la realización del presente reporte. En las próximas mediciones trimestrales se continuarán completando estas tendencias brindando una información importante que permitirá hacer un programa eficiente de acciones correctivas inmediatas.

Los valores que exceden los valores de observación o alarma están escritos en **color rojo**, y de los puntos que superen estos valores se han presentado los diagnósticos y recomendaciones.

En las tablas de valores medidos se presentan las últimas mediciones y las penúltimas con la finalidad de poder hacer una rápida evaluación de su comportamiento y estado.

2. VALORES GLOBALES EN DESPLAZAMIENTO (µm P-P) Y EN VELOCIDAD (mm/seg.) RMS

El desplazamiento es la medida dominante a bajas frecuencias (inferiores a 600 CPM) y esta relacionado a los esfuerzos de flexión de sus elementos. Relacionando esta sensibilidad a las RPM de las máquinas diagnosticadas (en su mayoría 600 RPM) las mediciones en desplazamiento RESALTARAN los problemas a bajas frecuencias presentes en el espectro de vibraciones, sub-armónicas y armónicas de baja frecuencia 1x, 2x, 3x. Estas vibraciones están relacionadas a los problemas que se presentan cercanos a estos rangos de frecuencia, por ejemplo, desalineamiento, desbalance, soltura, etc.
La velocidad es la rapidez del cambio del desplazamiento y esta relacionado a la fatiga del material, la velocidad se utiliza para evaluar la severidad de la vibraciones en las máquinas en el rango

de frecuencias desde 600 CPM hasta 60000 CPM. En este rango se observan los problemas que se presenten en mayores frecuencias como, problemas de turbina (13x, 20x, etc), solturas, turbulencia, resonancia, oil whirl etc.

De esto se puede concluir que en algunos casos no se presente concordancia entre el aumento de severidad en desplazamiento que deba aumentar necesariamente la severidad de velocidad en la misma proporción, el motivo de estas variaciones es el tipo de falla presente en la máquina, cada una de las cuales esta en un rango determinado de frecuencia lo que determina su influencia en el valor global medido y relacionado al tipo de medición (desplazamiento y velocidad).

En otras palabras y a manera de ejemplo: En caso de presentarse un problema de oil whirl en un cojinete, este se presentaría a una frecuencia de 0.42x-0.48x de las RPM (600), por lo tanto podría haber un aumento significativo en el valor global medido en desplazamiento mas no así no necesariamente se presentaría un aumento significativo en el medición global de velocidad. El mismo fenómeno podría presentarse en un caso de problema de turbina, el cual se presentaría a 20 x 20 veces 600 RPM = 12000 CPM, donde se podría observar un aumento significativo en el valor global medido en velocidad influenciado por la frecuencia a 12000 CPM que por el rango de frecuencia a la cual se presenta no influya directamente a las mediciones de baja frecuencia como el desplazamiento.

DATOS GENERALES

CENTRAL : CHARCANI 5

GRUPO : 2

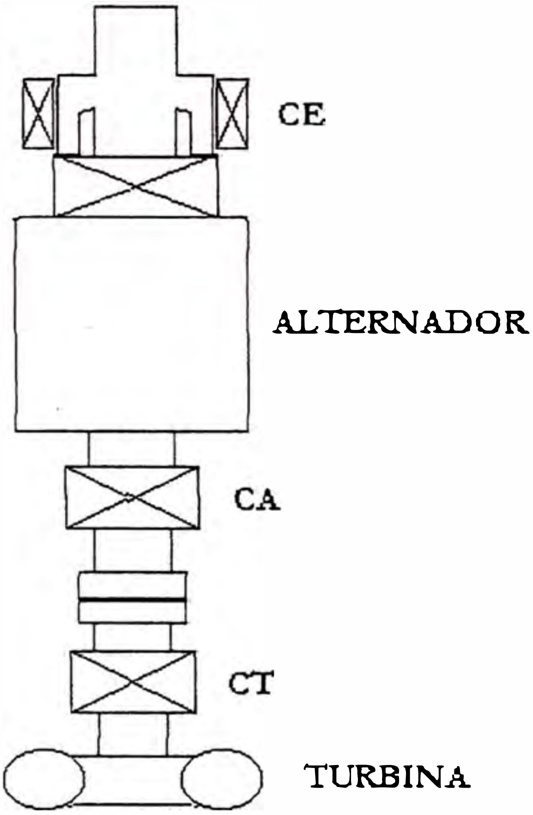
POTENCIA DE MEDICION : 43 Mw

HORAS MAQUINA : 88922.7

NUMERO DE ALABES DE TURBINA : 20

TURBINA y/o GENERADOR : Pelton, Alsthom

OTROS DATOS : RPM = 600



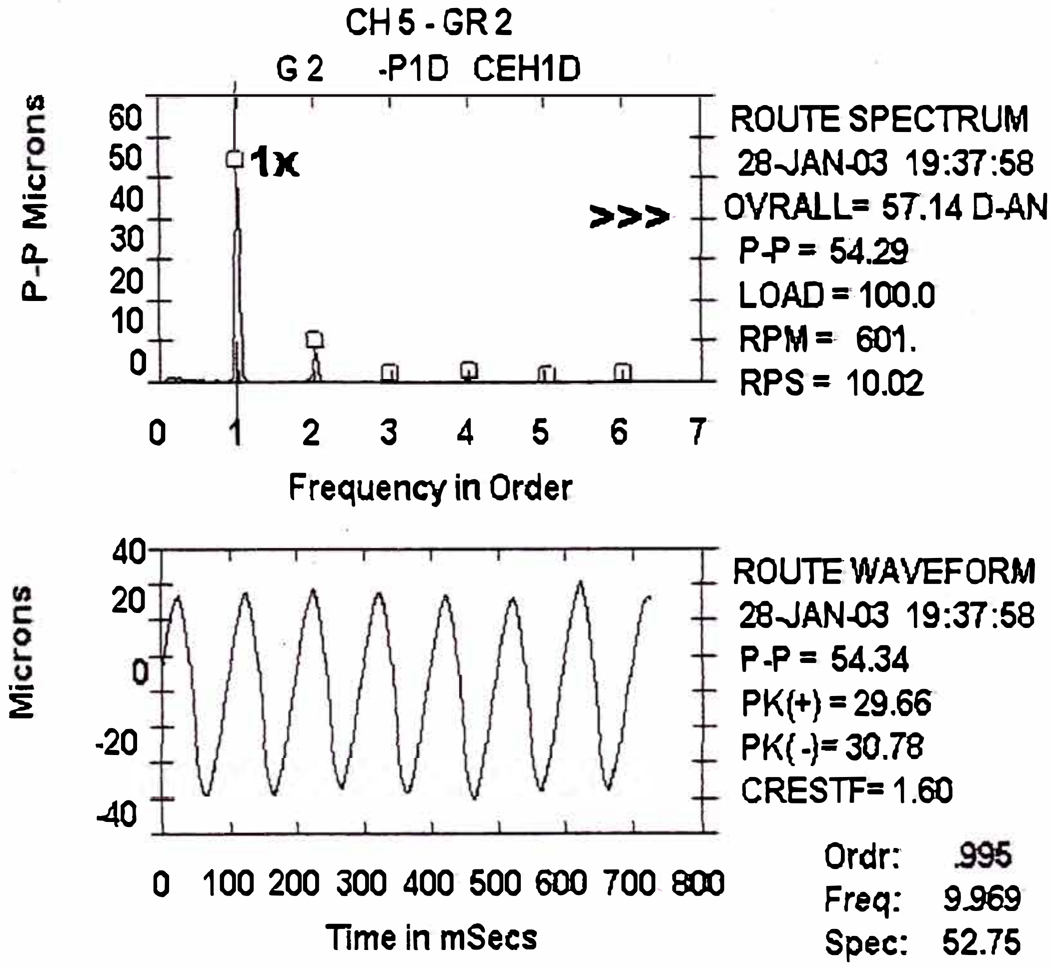
ESQUEMA DE DISTRIBUCION DE COJINETES Y DENOMINACION

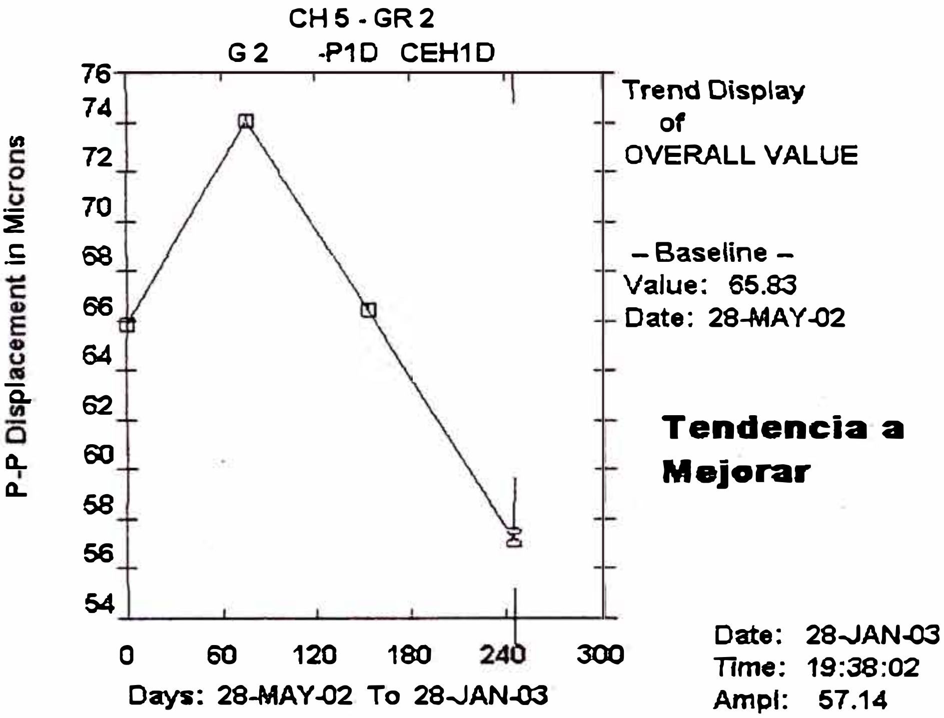
CE	mm/seg. 03/NOV/02	mm/seg. 28/ENE/03	µm P-P 03/NOV/02	µm P-P 28/ENE/03
HE1	1.4	1.9	**66.44**	**57.14**
HE2-a 90°	1.3	1.7	**68.67**	**50.99**
AE	0.8	1.1	8.57	8.17

CA	Mm/seg. 03/NOV/02	mm/seg. 28/ENE/03	µm P-P 03/NOV/02	µm P-P 28/ENE/03
HA	0.8	1.1	29.27	25.79
HA2-a 90°	0.8	1.1	31.43	25.00
AA	0.4	0.7	14.02	12.30

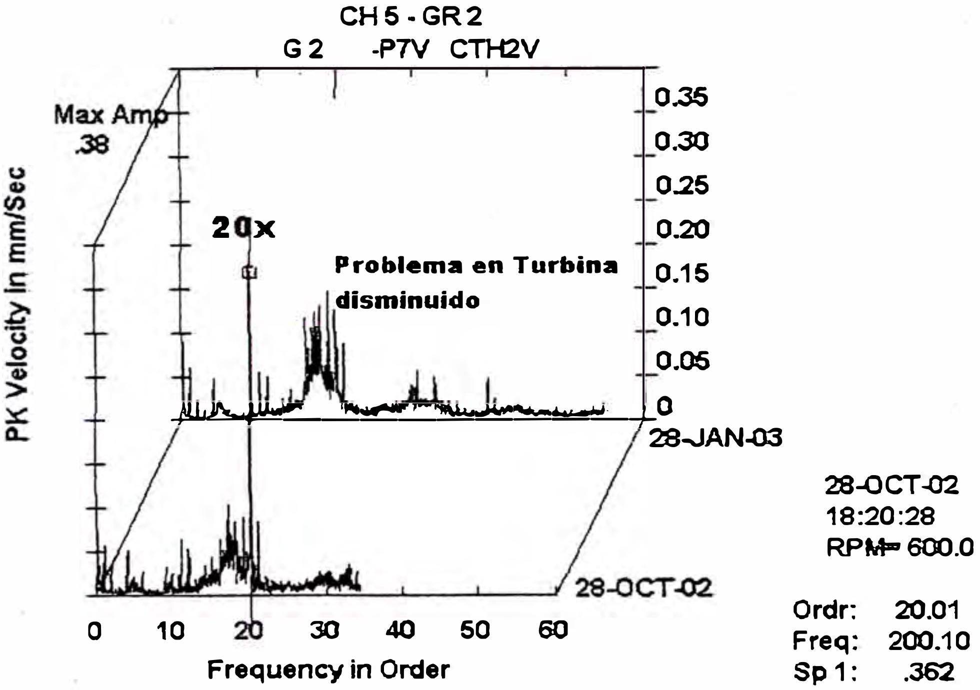
CT	Mm/seg. 03/NOV/02	mm/seg. 28/ENE/03	µm P-P 03/NOV/02	µm P-P 28/ENE/03
HT	1.0	2.2	4.10	3.32
HT2-a 90°	0.9	1.0	3.54	4.17
AT	0.6	1.0	2.4	4.12

3. ESPECTROS DE FRECUENCIA VS. AMPLITUD DE DESPLAZAMIENTO DE VIBRACION





Tendencia a Mejorar



20x

Problema en Turbina disminuido

4. INTERPRETACIÓN Y DIAGNOSTICO DE LOS ESPECTROS

- Debido a los resultados obtenidos, según la ultima evaluación realizada, se continúan detectando en el espectro y la onda en el tiempo del cojinete de empuje CE armónicos de la frecuencia de giro del alternador en el sentido radial con niveles globales de hasta **57.14 µm P-P** (nivel máximo permisible 60 µm P-P). Este defecto se debe a desalineamiento o inadecuado montaje de cojinetes, soltura o desgaste del cojinete de empuje.

- El nivel de vibraciones se encuentra sobre el nivel permisible máximo, anormal para ser un grupo recién reparado. De acuerdo a las normas ISO se encuentra en el rango En observación (NO ACEPTABLE para operación irrestricta en periodos largos) > 50 y < 80 *µm*.
- Debido a estos resultados se realizo un exhaustivo seguimiento, llegando a determinar que el cojinete turbina, presentaba holguras mayores a las determinadas según plano por lo que se esta programando su cambio respectivo.

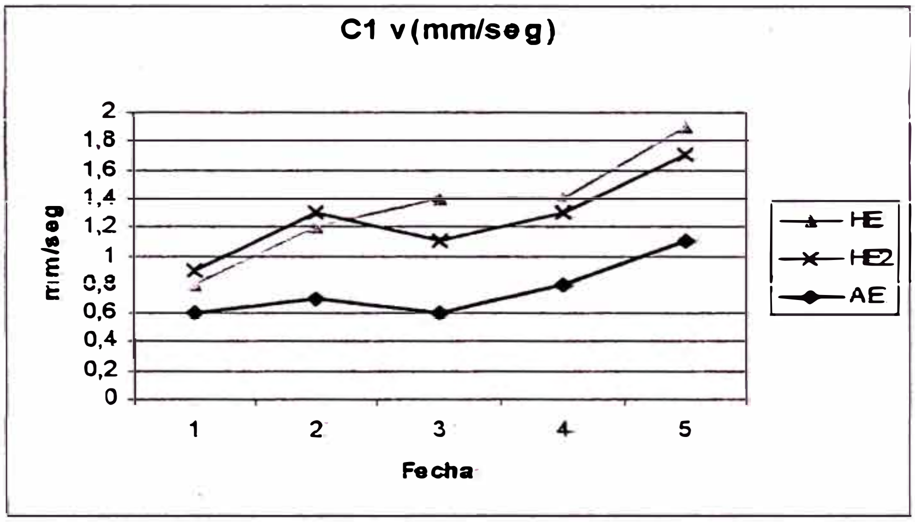
- Se observa una mejora en los niveles globales desde la última inspección de Noviembre del 2002, se puede observar la disminución de los picos relacionados a los problemas de flujo/turbulencia en la turbina provocados por defectos en los inyectores (agujas) y/o turbina.

5. GRÁFICOS DE TENDENCIA POR COJINETE

CHARCANI V GRUPO GENERADOR Nº 2

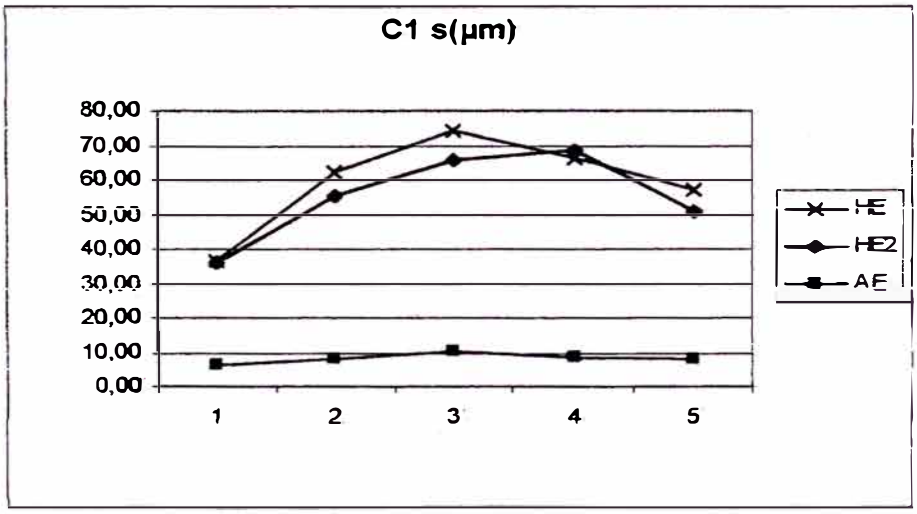
CE (En Velocidad de vibración mm/seg RMS)

CE	11-ago-01	21-may-02	12-ago-02	28-oct-02	28-ene-03
HE	0,8	1,2	1,4	1,4	1,9
HE2	0,9	1,3	1,1	1,3	1,7
AE	0,6	0,7	0,6	0,8	1,1



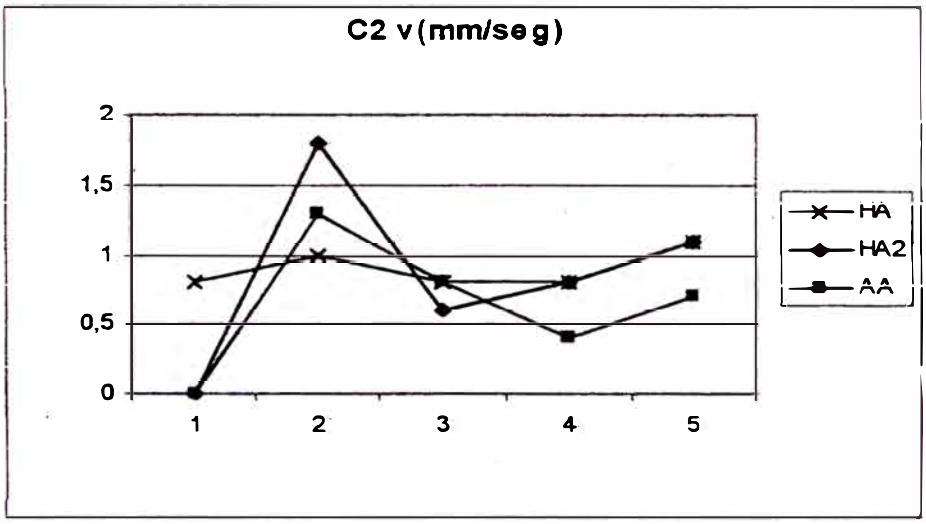
CE (En Desplazamiento µm P-P)

CE	11-ago-01	21-may-02	12-ago-02	28-oct-02	28-ene-03
HE	36,66	62,26	74,03	66,44	57,14
HE2	36,07	55,56	65,66	68,67	50,99
AE	6,22	8,09	10,01	8,57	8,17



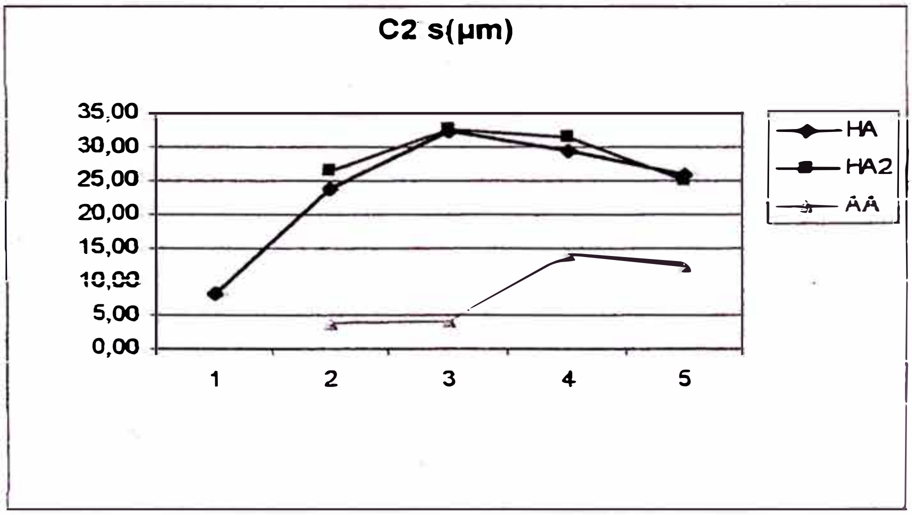
CA (En Velocidad de vibración mm/seg RMS)

CA	11-ago-01	21-may-02	12-ago-02	28-oct-02	28-ene-03
HA	0,8	1,0	0,8	0,8	1,1
HA2	0,0	1,8	0,6	0,8	1,1
AA	0,0	1,3	0,8	0,4	0,7



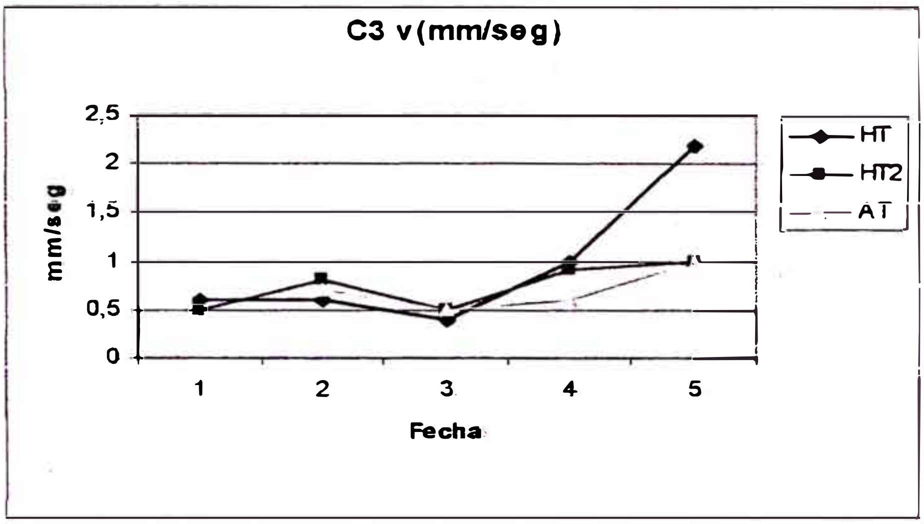
CA (En Desplazamiento µm P-P+A89)

CA	11-ago-01	21-may-02	12-ago-02	28-oct-02	28-ene-03
HA	8,29	23,71	32,45	29,27	25,79
HA2		26,45	32,76	31,43	25,00
AA		3,90	4,21	14,02	12,30



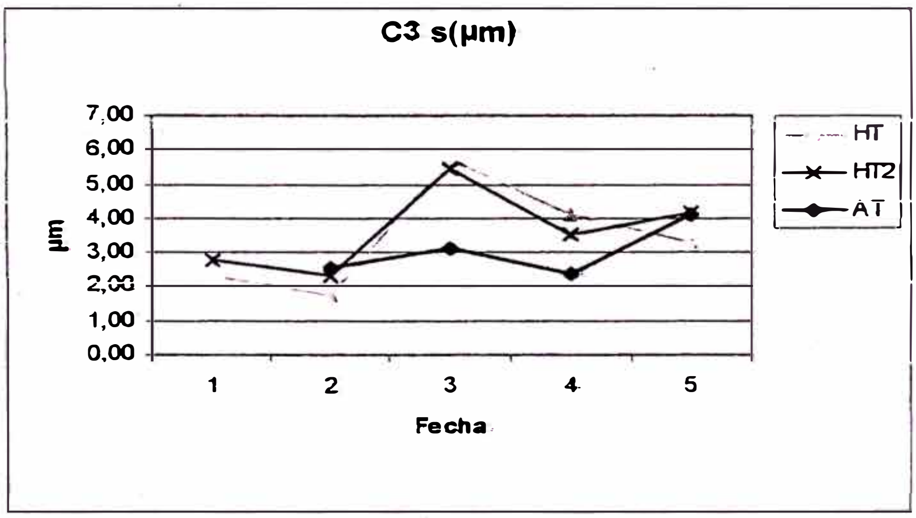
CT (En Velocidad de vibración mm/seg RMS)

CT	11-ago-01	21-may-02	12-ago-02	28-oct-02	28-ene-03
HT	0,6	0,6	0,4	1,0	2,2
HT2	0,5	0,8	0,5	0,9	1,0
AT		0,7	0,5	0,6	1,0



CT (En Desplazamiento µm P-P)

CT	11-ago-01	21-may-02	12-ago-02	28-oct-02	28-ene-03
HT	2,32	1,73	5,74	4,10	3,32
HT2	2,80	2,29	5,43	3,54	4,17
AT		2,57	3,11	2,40	4,12



6. RECOMENDACIÓN

- Inspeccionar el adecuado montaje de los cojinetes de empuje y alternador, así como el alineamiento del eje entre los cojinetes de empuje y generador.
- Reposicionar los cojinetes de ser necesario.
- Así mismo inspeccionar el estado de desgaste o deterioro de los cojinetes, reemplazar de ser necesario.
- Inspeccionar el adecuado montaje entre los ejes de alternador y turbina.

iii. Análisis de Termografía

EGASA, cuenta en sus instalaciones con Líneas de Transmisión, Unidades de Generación con excitación rotativa, Transformadores, Equipos de maniobra, tableros de control y fuerza. Estos equipos están expuestos a generar en sus conexiones, elementos rotativos o por operación incrementos de temperatura mas conocidos como puntos calientes.

Los puntos calientes se generan debido a problemas de conexión, fricción o incorrecta operación de los equipos. Estos puntos calientes al ser detectados es posible analizarlos y eliminarlos.

Mediante este procedimiento se reducen los tiempos de indisponibilidad de los equipos por falla o mantenimiento contribuyendo a reducir el índice de indisponibilidad de los equipos. La disminución de este índice es una de las metas trazadas por EGASA .

Por estas razones se ha decido contar con el servicio de análisis termográfico el cual forma parte del mantenimiento predictivo de EGASA.

- Durante las inspecciones de termografía, la detección de puntos calientes se realizo mediante el método de medición por comparación.

- La inspección en cada equipo o celda se realizo mediante un barrido sistemático (con la cámara infrarroja) a todo el equipo (Sus terminales de entrada y salida así como a los componentes del equipo).

- En los paneles y o celdas cubiertas mediante tapas, se destaparan las cubiertas solo cuando esto no represento un riesgo a la operación normal de la instalación, realizándose la inspección bajo la supervisión de EGASA.

- Con la finalidad de descartar falsos puntos calientes, todo punto caliente encontrado se analizo considerando el tipo de material, parámetros del medio ambiente y enfoques desde diferentes ángulos con el fin de eliminar factores distorcionantes (reflexiones de cuerpos calientes adyacentes, reflexión solar, variaciones de emisividad, etc.).
  De esta manera se realizo la inspección de termografía de las principales instalaciones y equipos de la Central Hidroeléctrica Charcani V, este es un aspecto fundamental de carácter evaluativo del programa de mantenimiento preventivo de EGASA.
  La evaluación termográfica permite mediante una cámara infrarroja determinar la temperatura de los cuerpos, registrada en una imagen termográfica donde los colores y sus variaciones cuantifican la temperatura del dispositivo al que corresponde la imagen.

Es importante señalar que, el grado de exactitud del valor leído para temperatura, depende también de la fidelidad de los parámetros considerados, que son: temperatura del ambiente, distancia al objeto y emisividad. En el caso de esta última es algo complejo determinar el valor preciso que corresponda a cada material. Como se puede observar en los reportes que se presentan luego, estos parámetros han sido considerados estándares (los más próximos a la realidad), para todos los equipos, con la finalidad de que quien corresponda pueda compararlos para sus trabajos de mantenimiento preventivo futuros con los resultados obtenidos en esta evaluación.

Está condición debe dejar claro, que este tipo de evaluaciones tiene como objetivo principal determinar si existen puntos dentro de un mismo material o dispositivo cuya temperatura esté por encima del promedio del conjunto, rompiendo la continuidad del color en la imagen.

En los reportes realizados se eligió un área crítica (la de mayor nivel de temperatura), es en esta área donde se ha hallado la temperatura del "componente principal" (que no necesariamente presenta averías), también se ha trazado un segmento sobre la zona cuyos niveles de temperatura son más importantes, y es de este segmento del que se desprende el diagrama "profile", que marca temperaturas para todos los puntos del mismo, y donde se puede contrastar a que nivel del promedio del equipo se hallan los puntos seleccionados. En algunos casos se han seleccionado un área o recuadro para determinar en él, porcentaje de cada escalón de temperatura; se entiende que si los resultados obtenidos en los "componentes principales" se hallan dentro o por debajo de los porcentajes mayores de niveles de temperatura, el dispositivo se halla en condiciones normales de operación.

Las condiciones de sobre temperatura para componentes eléctricos hasta 50% de su carga máxima son:

$\Delta T < 5°C$	Inspección normal.
$6°C < \Delta T < 15°C$	Mantener en observación
$16°C < \Delta T < 35°C$	Reparación.
$36°C < \Delta T$	Reparación inmediata.

Donde:

ΔT	Sobre temperatura (°C)
Tpc	Temperatura del punto caliente (°C)
Top	Temperatura de operación (°C)

La cuarta condición se refiere a que no existe garantía de que el componente con una sobre temperatura superior a 35°C, pueda resistir un día, un año, una transferencia, o una sobrecarga inesperada del sistema.

El calentamiento que experimenta el área defectuosa aumenta en proporción al cuadrado de la carga (Ley de Joule), es decir si la carga se duplica la temperatura del punto caliente se cuadriplica.

En el Anexo III se presenta el cuadro del resumen de los puntos calientes encontrados en la Central Hidroeléctrica Charcani V.

RESUMEN DE PUNTOS CALIENTES ENCONTRADOS

CENTRAL HIDRAULICA CHARCANI V

ITEM	Equipo / Lugar de medición	Observaciones
1	SISTEMA DE REFRIGERACION AGUA TRATADA BOMBA Nº 02	Sobretemperatura en bomba Nº2. Verificar resultados en mismos tiempos de funcionamiento
2	SISTEMA DE REFRIGERACION TABLERO DE MANDO (Parte posterior)	Sobretemperaturas considerables. Atender inmediatamente
3	GRUPO 3 - TABLERO RAPID 77	Verificar tarjetas 5 y 6
4	GRUPO 2 - CABLES DE ENERGIA (Inicio de la galeria)	Aparente sobretemperatura fase R
5	GRUPO 3 - CABLES DE ENERGIA (Inicio de la galeria)	Isoterma máxima en fase R
6	GRUPO 3 - TRANSFORMADOR DE POTENCIA (Caja de proteccion bornes lado primario)	Verificar conexionados en fases S y T
7	GRUPO 3 - SALIDA DE TRANSFORMADOR (Cadena se suspensión)	Normal, Observar fase R

En el Anexo III se presenta el Reporte de la Inspección Termográfica de la Central Hidráulica Charcani V.

iv. Análisis de Agua

A continuación se presenta el análisis realizada al agua utilizada en el Sistema de Refrigeración de los Grupos 1, 2 y 3 de la Central Hidráulica Charcani V:

ANALISIS DE AGUA (PPM) DE MUESTRAS TOMADAS EN CHARCANI V

MUESTRAS	DUREZA	ALCALINIDAD			TDS	ASPECTO	CONDUCT.	PH	Silice
		P	M	OH					
DUCTO FORZADO	45	0	44	0	138	CRISTALINO	260	6.97	1.5
MOTOR DIESEL	0				2040	ROSADO	3700	9.06	
AGUA TRATADA	40	0	72	0	109	CRISTALINO	206	6.65	1.5

Análisis:

Mas adelante se detallara el análisis en el ítem correspondiente a la Limpieza Química de los Equipos de Refrigeración del Grupo Generador N° 2.

2. ANÁLISIS TÉCNICO REALIZADO CON EL FABRICANTE ALSTOM FRANCIA EN SITIO.

El objetivo de esto, es realizar un análisis y evaluación del estado general del circuito magnético, observando el área de las uniones, a fin de detectar aflojamiento de las chapas magnéticas y un eventual inicio de desplazamiento o rotura, dicha evaluación lo realizaron conjuntamente el fabricante del generador ALSTOM FRANCIA y EGASA.

Se tomo en cuenta el número de horas de funcionamiento a la fecha de la inspección: 77010h.

Análisis:

En esta máquina se constata un desapriete, se presenta también una contaminación importante por aceite que necesita una limpieza completa y la instalación de un equipo de aspiración de los vapores de aceite así como la supresión de las fugas.

El estado general de la unidad 2, no presenta una degradación del paquete magnético; sin embargo, para evitar la aparición de estos daños irreversibles, aconsejamos una intervención rápida de mantenimiento para limpiar, reapretar el paquete magnético y suprimir las fugas de aceite, causa mayor de la contaminación de las unidades.

i. Condiciones adoptadas en el grupo generador 2 para este control

Para reducir al máximo el impacto de la parada sobre la capacidad de producción de la central, el control fue realizado máquina caliente: sin rotación en marcha mecánica durante 30 minutos para enfriamiento.

Partes y componentes desmontados para permitir el control:

a. Se desmontaron los dos enfriadores ubicados en el eje de cada unión (margen derecha e izquierda).
b. Desmontaje de dos tapas del guiado de aire inferior (piezas de poliéster) ubicadas también en los ejes de las uniones del circuito magnético.
c. Dos placas de cierre de la parte superior de la virola de la carcaza del estator.

ii. Observaciones en las áreas controladas

a) Diámetro Exterior del Circuito Magnético Unión Margen Derecha:

Se nota un deslocamiento axial de las dos partes del Circuito Magnético a la retirada del enfriador encontrándose una cantidad importante de aceite localizada a la vuelta de la placa de unión de carcasa, principalmente arriba de los discos inferiores.

Señales de vibraciones están visibles y materializadas por la huella negra en la región inferior de la unión.

b) **Diámetro Exterior del Circuito Magnético Unión Margen Izquierda:**

Mismas observaciones que el ítem anterior, por lo que se trata de la polución y el deslocamiento axial, aquí no hay señal visible de vibración.

c) **Diámetro Interior del Circuito Magnético Unión Margen Derecha:**

Señales de vibraciones por aflojamiento de las chapas magnéticas, y en función a la experiencia de otros grupos, se observa los mismos síntomas de aflojamiento: movimiento de láminas, almacenamiento de masa negra en las extremidades (chapas sin cola de milano); todo esto constata la necesidad del reapriete del circuito magnético.

El nomex de aislación de la unión quedó en la posición de origen.

d) **Diámetro Interior del Circuito Magnético Unión Margen Izquierda**

Mismas observaciones que para la otra unión, pero se sigue observando el grande nivel de polución perjudicial para el comportamiento del equipamiento.

e) **Diámetro Exterior Circuito Magnético parte superior virola carcasa: Margen Derecha e Izquierda**

No hay señal visible de desplazamiento de los componentes del sistema de apriete; se observo en particular las áreas de contacto de los pernos de nivelamiento y de contra apoyo (ϕ M30).

Se nota también el gran nivel de polución y una presencia de aceite condensado.

Se observa en el lado margen derecho y en las barras próximas de las salidas de fase, presencia de Efecto Corona, que es el polvo blanco siendo mezclado con polución y aceite, se aprecia el área visiblemente afectada.

iii. Medidas recomendadas a tomar en cuenta de modo inmediato

Realizar un seguimiento de la evolución de los índices de defectos detectados, aprovechando la oportunidad de las paradas por mantenimiento.

Los puntos a vigilar deberán estar concentrados al principio en la parte inferior del circuito magnético de cada unión, basta desmontar las tapas adecuadas del guiado de aire inferior, para efectuar la observación necesaria.

El tiempo requerido para este control no debería exceder de unas dos horas.

iv. Tipo de Intervención requerido a la brevedad

a. Limpieza del grupo:

Después del desmontaje 2 a 2 de los polos, deberá procederse a la limpieza del estator y del rotor utilizando un procedimiento de limpieza en seco industrial: Disolvente dieléctrico ecológico con aire presurizado. Este producto de limpieza es el ideal para solucionar el problema de la polución sin dañar el barniz y componentes aislantes, es necesario entonces la adquisición del equipo para poder utilizar este procedimiento, sin olvidar también un aspirador industrial potente.

b. Reapriete del Circuito Magnético

A continuación de la limpieza, proceder al reapriete del circuito magnético, utilizando un sistema hidráulico adecuado, equipado como mínimo de 2 gatos huecos, haciéndose necesario la adquisición de este equipo.

Nota:

El sistema de trabamiento de los pernos de apriete, pueden causar demora en el proceso de desmontaje, por los daños que se causaría si no se toman las precauciones necesarias. Es necesario por ello utilizar los equipos y herramientas adecuadas para retirar los puntos de soldadura y así evitar daños irreversibles de los mismos, reaprovechando así los pernos y tuercas.

Todos estos tiempos, así como la falta de precauciones a tener en cuenta en la protección del bobinado para evitar perforaciones durante el esmerilamiento, pueden alargar el tiempo total de la intervención, y deberán ser considerados en el cronograma de los trabajos, así como en el suministro de los materiales.

c. Aspiración de Vapores de Aceite - Fugas

Aprovechar la intervención para solucionar los problemas de fugas de aceite y realizar las modificaciones requeridas en los laberintos de los cojinetes y los equipos de recuperación de vapores de aceite.

Es posible realizar un estudio para verificar la posibilidad de implantación de nuevos sistemas, y realizar las modificaciones adecuadas en las piezas existentes.

3. CONCLUSIÓN FINAL

EGASA evaluando los informes de los mantenimientos predictivos respectivos, así como el análisis técnico realizado conjuntamente con el fabricante; y teniendo en cuenta que durante los 13 años de operación de las unidades generadoras, no se había realizado un Mantenimiento de Tipo Plan 4 Total (Over Holl), ni Reapriete del Circuito Magnético, acumulando este grupo a la fecha 77010 horas de trabajo, vio por conveniente priorizar y efectuar el Reapriete del Núcleo Estatórico y Mantenimiento del Generador, así como el Mantenimiento de todos los Equipos Electromecánicos e hidráulicos del Grupo Generador N° 02 de la Central Hidráulica Charcani V, a fin de evitar daños irreversibles posteriores.

De esta forma EGASA contrata a ALSTOM BRASIL para el Servicio de Reapriete del Núcleo Estatorico y Mantenimiento del Generador N° 2, así como el suministro de los repuestos necesarios para la operación del Grupo, esto comprende el servicio de montaje e instalación de los repuestos referidos, así como su puesta en operación, pruebas y óptimo funcionamiento del grupo, además los materiales a suministrar deben ser originales del fabricante, y cuando sean de terceros serán garantizados por el fabricante y serán entregados a EGASA en la Central Hidroeléctrica Charcani V, Arequipa, Perú.

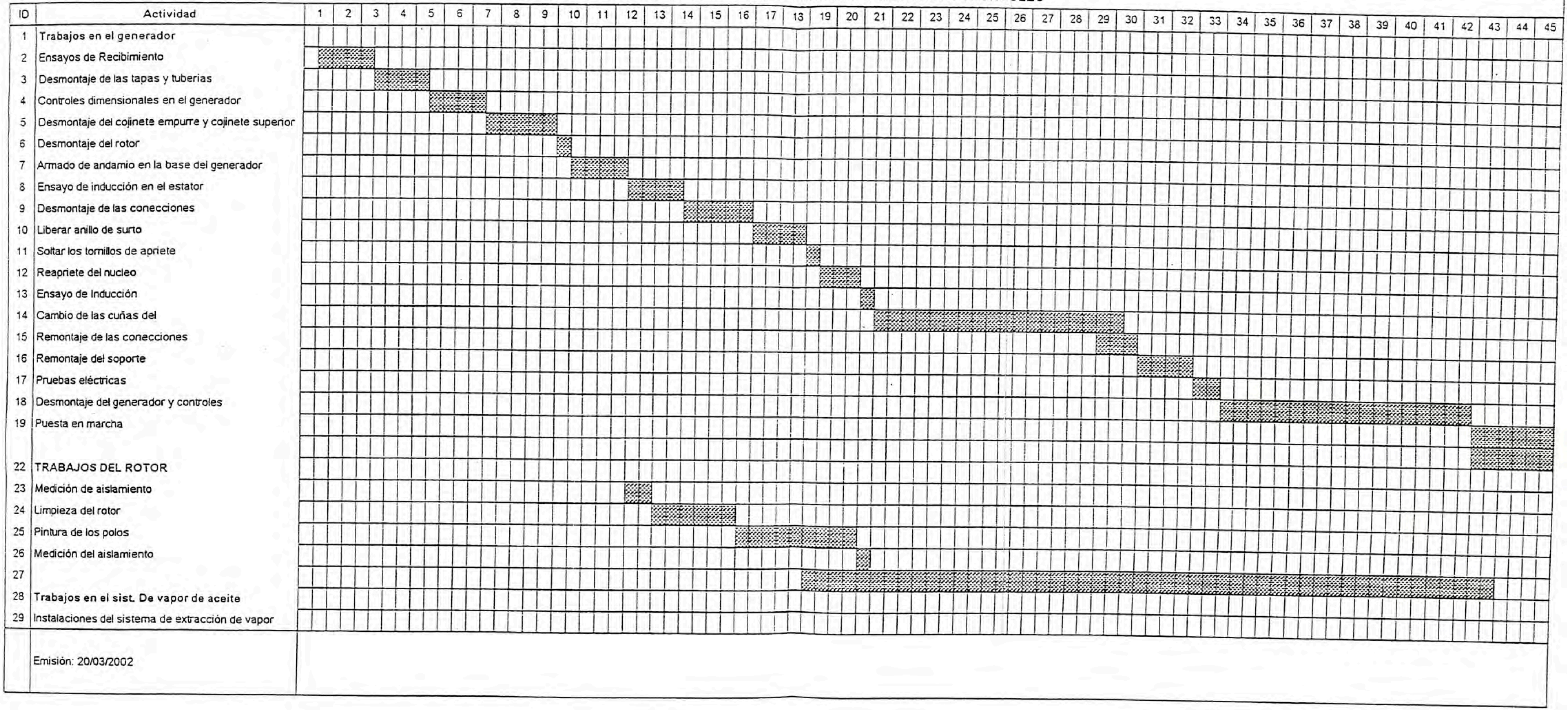
Dándose inicio con la evaluación de todos los equipos electromecánicos e hidráulicos, para la elaboración de la lista de repuestos y adquisición de los mismos.

V. DESCRIPCIÓN DEL MANTENIMIENTO DEL GRUPO GENERADOR N° 2 – CENTRAL HIDRÁULICA CHARCANI V

1. MANTENIMIENTO Y REAPRIETE DEL NÚCLEO ESTATOR HICO

i. Cronograma de Trabajo del Mantenimiento y Reapriete del Núcleo Estatórico.

CRONOGRAMA DE TRABAJO DE MANTENIMIENTO Y REAPRIETE DEL NUCLEO



ID	Actividad
1	**Trabajos en el generador**
2	Ensayos de Recibimiento
3	Desmontaje de las tapas y tuberías
4	Controles dimensionales en el generador
5	Desmontaje del cojinete empurre y cojinete superior
6	Desmontaje del rotor
7	Armado de andamio en la base del generador
8	Ensayo de inducción en el estator
9	Desmontaje de las conecciones
10	Liberar anillo de surto
11	Soltar los tornillos de apriete
12	Reapriete del nucleo
13	Ensayo de Inducción
14	Cambio de las cuñas del
15	Remontaje de las conecciones
16	Remontaje del soporte
17	Pruebas eléctricas
18	Desmontaje del generador y controles
19	Puesta en marcha
22	TRABAJOS DEL ROTOR
23	Medición de aislamiento
24	Limpieza del rotor
25	Pintura de los polos
26	Medición del aislamiento
27	
28	**Trabajos en el sist. De vapor de aceite**
29	Instalaciones del sistema de extracción de vapor

Emisión: 20/03/2002

ii. Descripción del Mantenimiento y Reapriete del Núcleo Estatórico.

El proceso de mantenimiento se inicio de la siguiente manera:

a. TRABAJOS EN EL GENERADOR

a.1 Ensayos de Recibimiento – Controles

Se inicia con la preparación de los Equipos de Ensayos para las Pruebas de Recibimiento de la Unidad Generadora N° 2, siendo estas las siguientes:

Operaciones del Grupo en Vacío

1. A 25% de Carga
2. A 50% de Carga
3. A 75% de Carga
4. A 100% de Carga

Monitoreo de Temperaturas

1. Cojinetes
2. Aceite
3. Agua en los Refrigeradores
4. Bobinado del Estator
5. Bobinado del Rotor
6. Núcleo del Estator
7. Aire Caliente
8. Aire Frío

Monitoreo de Vibraciones

1. Cojinete Guía Turbina
2. Cojinete Superior del Generador (Cojinete Pivot)
3. Cojinete Guía Inferior del Generador (Cojinete Alternador)

Monitoreo de Operación del Grupo

1. Potencia del Generador
2. Cos phi

3. Tensión del Generador
4. Corriente del Generador
5. Tensión del Excitación
6. Corriente de Excitación

Pruebas Eléctricas

1. Resistencia Ohmica del Bobinado del Estator.
2. Resistencia Ohmica del Bobinado del Rotor.
3. Resistencia de Aislamiento del Bobinado del Estator.
4. Resistencia de Aislamiento del Bobinado del Rotor
5. Controles de los RTD's.

a.2 Desmontaje de las tapas, tuberías, equipos e instrumentación Mecánicos.

El desmontaje se inicio con el retiro de la tapa circular del piso Nivel 63.

Desmontaje de la tapa del Sistema de Sobre velocidad – Nivel 63.

Desmontaje de las tapas de acceso a los Gatos de Frenado Nivel 58.

Desmontaje de las tuberías del sistema de refrigeración de agua del generador, alimentación de los 06 aerorefrigerantes.

Desmontaje de tapas guía de aire superior (fibra de vidrio) para verificar la distancia de entrehierro.

Desmontaje de las tapas laterales del estator.

Se adecuó 04 estufas para calentar el eje - anillo del colector hasta 65 °C y poder desmontarlo posteriormente.

Eléctricos

Desmontaje de la instrumentación, se realizo el retiro de los censores de temperatura como son los RTD´s, PT100 y termostatos del Cojinete Pivot: Empuje-Guía, Cojinete

Alternador y Cojinete Turbina.

Desmontaje de las líneas de fase y del neutro.

Se procede a desmontar el anillo de porta carbones (20 porta carbones), y la carcasa del anillo colector.

Desconexión de los cables eléctricos del anillo colector con el rotor

Desmontaje de las protecciones del anillo colector, casquete porta anillos, pista de carbón a tierra.

Se desmonta los cables eléctricos de las canaletas puestas sobre la cruceta.

Se realiza las pruebas respectivas de los parámetros de trabajo de los termostatos, estos son:

Termostatos Locales de la Turbina, grado 1: Cojinete Guía de la turbina.

Termostatos Locales de la Turbina, grado 2: Cojinete Guía de la turbina.

Termostatos Locales de la Turbina: Tele termómetro Sopac TLC, parte activa.

Se realiza las pruebas óhmicas de los PT100, como son:

1. PT 100 (3) : Cojinete Inferior Alternador – Parte Active - Aceite
2. RTD 100 (9) : Enrollamiento de Estator
3. PT 100 (2) : Entrada y salida de agua (Sonda Termométrica de resistencia)
4. PT 100 (2) : Parte metálica y Patín del Cojinete Pivot
5. Termómetro Local del Generador: Cojinete Alternador Inferior - Metal
6. Antifricción
7. PT 100 (6): Aire Frío, salida de aerorefrigerantes
8. PT 100 (6): Aire Caliente, entrada de aerorefrigerantes

9. Termómetro de Cojinete del Generador
10. Termómetro de Temperatura de aire caliente del generador

Dichas pruebas fueron realizadas utilizando:

- 01 Multímetro Marca: Kyoritsu, Modelo: 2002 PA

Se inspecciona los tubos aisladores de los termostatos (bulbos), los revestimientos de protección metálica, y las gomas de sellado para el montaje de los mismos (ver el Control de los Registros Mecánicos del Grupo).

a.3 Desmontaje del Cojinete Pivot, Cojinete Alternador y Cruceta Superior – Controles.

Se coordina sobre los Controles y Desmontaje de la Cruceta Superior y de los Cojinetes Pivot y Rotor Alternador correspondiente al Grupo Generador 2 de la Central Charcani V, y lo que se procederá conforme el siguiente procedimiento

a.3.1 Control de RUN – OUT

- Inyección operacional.
- Fabricación de los 04 soportes para el posicionamiento de los Relojes Comparadores en zona de acople, para eso se requerirá tener el punto de centrado en la parte superior de eje, con topografía.
- Después del RUN – OUT se colocara toda la maquina con marca R-R Posición Montante.

Procedimiento para la Prueba del Run – Out

El procedimiento a seguir se da con la ubicación de los 21 relojes comparadores para realizar las mediciones, estos serán ubicados sobre 05 zonas a saber:

- 04 relojes comparadores sobre la base de la superficie vertical del cojinete pivot
- 04 relojes comparadores sobre la base de la superficie vertical del cojinete alternador
- 04 relojes comparadores sobre la base de la superficie vertical de la brida de acople del eje del rotor
- 04 relojes comparadores sobre la base de la superficie vertical de la brida de acople del eje de la turbina
- 04 relojes comparadores sobre la base de la superficie vertical del cojinete turbina
- Para ello se colocara uno para la posición Amont , Aval, Derecha e Izquierda en forma horizontal
- Un reloj comparador sobre la base de la superficie horizontal del cojinete pivot para medir la altura de elevación del eje debido a la inyección de aceite por los patines del cojinete pivot

Se gira 720 grados al eje de la turbina, para verificar se inyecte aceite en los patines de inyección de aceite, generando una lamina de aceite de 0.007 mm, registrada en el comparador; el giro será antihorario según giro de rotación de la maquina en forma manual.

Luego de verificar el correcto giro del eje, se toma como referencia las siguientes posiciones:
Amont: Aguas Arriba como posición a 0 y 360 grados.
Lado Derecho respecto de Amont como posición a 90 y 450 grados
Aval: Aguas Abajo como posición a 180 grados.
Lado Izquierdo respecto de Amont como posición a 270 grados

Se gira el eje, tomando las medidas registradas en los relojes comparadores para cada posición.
Este proceso se repite 03 veces para mayor seguridad.

Se realizan las mediciones colocando todos los relojes a 5.00 mm.

Se entrega el protocolo de prueba del RUN – OUT.

De los resultados obtenidos se concluye que existe un ligero desalineamiento del eje, sin embargo, según la Norma NEMA DE STANDARDS PUBLICATION PUB. Nº MG 5.2-1972 referente a INSTALLATION OF VERTICAL HYDRAULIC – TURBINE – DRIVEN GENERATORS AND REVERSIBLE GENERATOR/MOTORS FOR PUMPED STORAGE INSTALLATIONS (INSTALACION DE TURBINAS HIDRÁULICA VERTICALES, GENERADORES Y REVERSIBLES GENERADOR/MOTOR PARA INSTALACIONES BOMBEADAS DE ALMACENAJE), se tiene lo siguiente:

1. En el numeral MG 5.2 – 8.11, Pág. 22 : SHAFT – PLUMB AND STRAIGHTNESS CHECK se hace **Referencia al Chequeo de la Linealidad y Verticalidad del eje,** aquí se estipula textualmente que este es un chequeo de la linealidad y verticalidad de los ejes combinados de generador y turbina. El uso de 4 líneas plomadas espaciadas 90 grados girando alrededor del eje es recomendada. Las lecturas deben ser tomadas de los mismos puntos de cada eje que fueron usados durante el chequeo inicial de fábrica.
   El eje ensamblado para ser considerado lineal no debe tener ningún punto desviado (referido a las variaciones

del diámetro) mas de 0.003 pulgadas (0.0762 mm) de una línea recta que une los puntos superiores con los inferiores. Para que el eje ensamblado sea considerado como vertical los puntos superiores e inferiores no deben desviarse de la plomada más de ¼ mil por pie (de la longitud del eje).

Información de planos de ingeniería:

1 mil = 0.0254 mm

¼ mil = 0.00635mm

0.00635*mm* *para* 0.3048 *m*

x mm para 1 m

x = 0.0208 mm / m

Para nuestro caso:

Longitud del eje = L eje generador + L eje turbina

L *total* = 6.725 + 2.700

L total = 9.425 m

Para esta longitud se tiene lo siguiente:

X = 0.19604 mm

El valor que dio como resultado fue inferior a este, estando dicho valor dentro de los márgenes tolerables.

2. Así también en el numeral MG 5.2 – 13.01, Pag. 30: VERTICAL HYDRAULIC – TURBINE GENERATOR SHAFT RUNOUT TOLERANCES – INSTALLATION CHECK (A. ROTATIONAL CHECK, METHOD 1) donde se hace Referencia a Tolerancias en la Prueba de RUNOUT de Turbina Generadores, se estipula una formula para hallar la tolerancia máxima, esta es:

T = 0.002 x L / D inches; donde:

L = The distance in inches from thrust surface to point of measurement (Distancia de Niveles entre el anillo móvil y el punto intermedio de contacto del cojinete turbina)

D = The thrust bearing outside diameter in inches (Diametro Extremo del anillo móvil)

Luego en milímetros tenemos:

T - 0.05 x L / D mm; donde:

L = 7325 mm

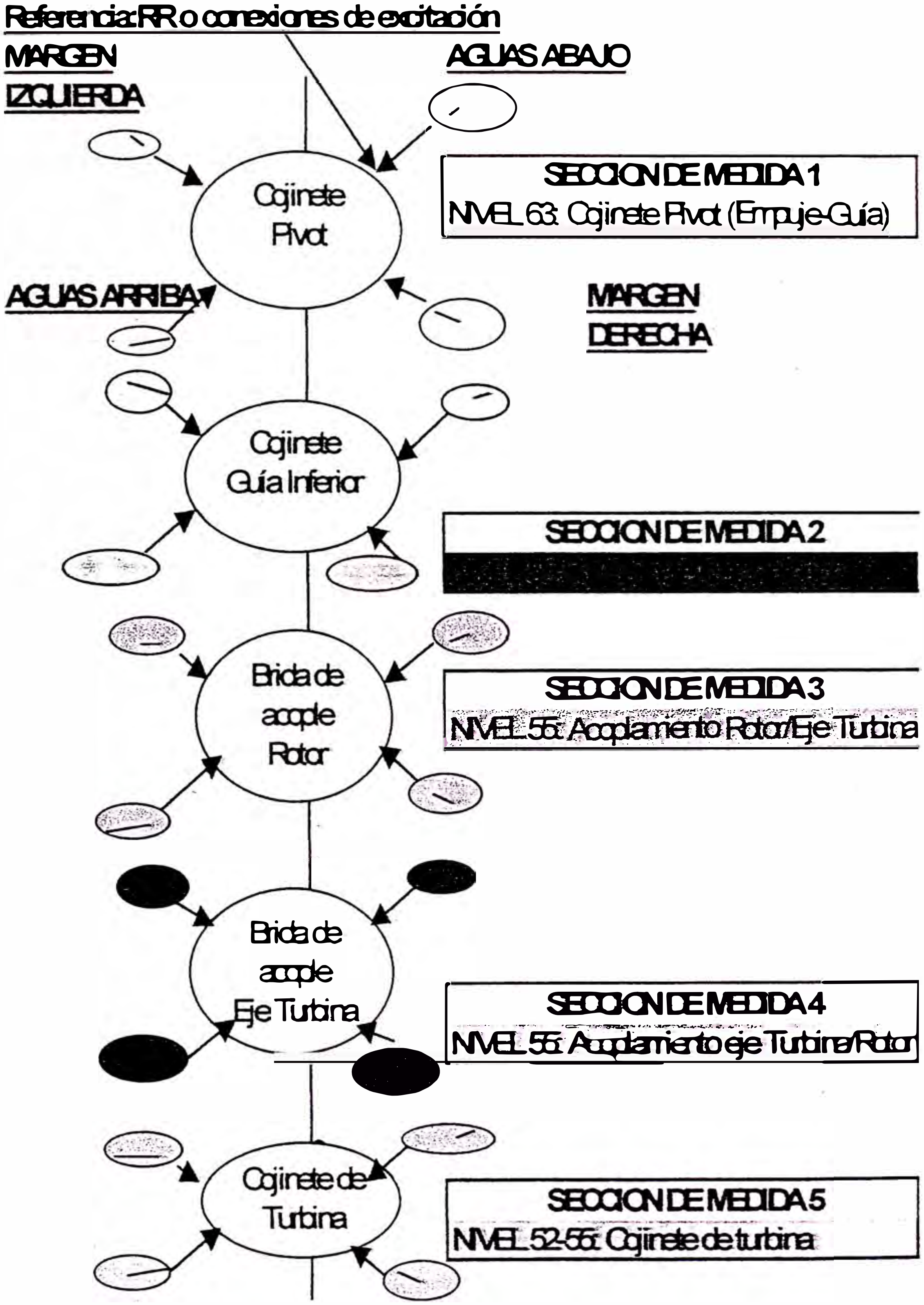
D = 1225 mm

T = 0.298979 mm

El valor que dio como resultado fue inferior a este, estando dicho valor dentro de los márgenes tolerables.

Se presenta el esquema de posición de los relojes comparadores.

POSICION DE LOS RELOJES COMPARADORES



a.3.2 Control de la Verticalidad y Centrado de la Maquina

- Preparar el dispositivo independiente de la maquina para la colocación y centrado del eje utilizando una plomada, en la parte superior.
- Retirar la tapa de seguridad ubicada en la rueda pelton para tener acceso al centrado del eje.
- Preparación del dispositivo de alojamiento de la plomada (depósito con aceite y un contrapeso con 04 aletas).
- Se realizo así la Prueba de Verticalidad del eje del generador.

a.3.3 Control de las luces de los 03 cojinetes, empujando con gata hidroeléctrica y con inyección en operación.

Se realiza el control de los juegos diametrales del Cojinete Pivot y Cojinete Turbina, arrojando en ambos el siguiente resultado:

Juego Diametral = 0.65 mm
Juego Radial = 0.325 mm

a.3.4 Preparación para el desmontaje de la Cruceta Superior

- Medidas del juego en las terminaciones (guías) de la junta cruceta
- Accionar los gatos de frenado para apoyar y levantar el rotor, colocando los calzos de baquelita.
- Colocar el anillo de fijación del eje de la turbina.
- Desmontaje del anillo de seguridad y accesorios de protección del Cojinete Pivot.
- Controlar la planicidad de la membrana de los gatos y la altitud con topografía, además se toma los niveles de los apoyos de la cruceta y de los 09 patines para tener como referencia posteriormente en el montaje.

- Se procede al desmontaje de la cruceta superior.
- Medición del entrehierro en la posición superior e inferior, arrojando valores entre 18.4 y 18.6 mm.
- Medición del centrado de la cruceta entre soporte y eje.
- Preparar base de suspensión del eje – turbina.
- Desacoplar el eje turbina.

Se inicia Desacoplando los espárragos de la brida de acople del generador - turbina, realizando el control respectivo de las elongaciones de los espárragos del acople, mientras tanto no se mueve el cojinete alternador.

- Desmontar del Cojinete Alternador:

  Se prepara el cojinete para el vaciado de aceite de la cuba interna.
  Se realizó el levantamiento del eje para medición de luces en el cojinete alternador intermedio.
  Juego Diametral = 0.6 mm
  Juego Radial = 0.3 mm

  Se realiza el desmontaje de las tapas, deflectores y la cuba, sí como sus partes.
  Desmontaje del intercambiador de calor aceite – agua.
  Se realizó el pre – montaje del cojinete alternador para realizar los controles respectivos diametrales del cojinete en 08 puntos en forma circular y 04 puntos en forma vertical (32 mediciones), para verificar la ovalidad del cojinete.

- Colocar el eje – turbina a su centro, esto abarca:
  - Centrado

Nivelado
Verticalidad
Planicidad

a.3.5 Desmontaje del Cojinete Pivot

1. **Desmontaje del Cojinete de Empuje**
   - Manguito
   - Vaina
   - Laberinto
   - Suncho
   - Sistema de Mangueras de Inyección de Aceite
   - Patines de Inyección de Aceite
   - Cambio de la goma de amortiguamiento del cojinete empuje de caucho sintético, controles y tolerancias

2. **Desmontaje del Cojinete Guía**

   Se realiza el desmontaje de las tapas, deflectores y la cuba.

   Nota:

   - Se realiza la limpieza e inspección de los componentes de los cojinetes, con sus respectivos controles.
   - Se realizó la limpieza e inspección de la cruceta.

   (Ver control de los Registros Mecánicos del Grupo)

a.4 Desmontaje del Rotor – Controles

Preparación de dispositivo para el desmontaje del rotor.

- Instalación del collarín en el eje del rotor.
- Se acopla las grúas y se prepara el puente para acoplarlo al eje del rotor

- Retiro del rotor

A continuación se realiza el desmontaje de los aero-refrigerantes del estator, así como el desmontaje de los gatos de frenado.
Se realiza un control de los gatos de frenado, cambiando los fines de carrera, así como las mangueras de presión de aire, y se realiza la prueba de presión de los gatos de frenado a una presión de 140 bar.

Se realiza la Limpieza Química de los 06 aero-refrigerantes del generador, así como los intercambiadores de calor Aceite – Agua de los Cojinetes Pivot, Alternador y Turbina. (Este informe se expone en el punto a.9).

a.5 Pruebas Eléctricas Controles.

Se inician los siguientes ensayos:

- Prueba de Resistencia Ohmica del Devanado del Estator
- Prueba de Resistencia Ohmica del Rotor
- Prueba de Aislamiento del Estator por fase
- Prueba de Aislamiento del Rotor
- Prueba de Tensión Aplicada con corriente continua (R, S, T), a una Tensión de 1.3 Un, midiendo la tensión y corriente de fuga.
- Prueba de Inducción Magnética (Magnetización) del Núcleo, esto para determinar los posibles puntos calientes.

a.6 Reapriete del Núcleo y Cambio de Cuñas - Controles

Se coordina los trabajos a realizarse en el Reapriete del Núcleo, la secuencia de trabajo es el siguiente:

- Realizar el Control Dimensional del Estator para verificar la Circularidad y Verticalidad del mismo, para ello sé harán los controles radiales en 16 puntos y en tres niveles, en cada punto se hará el control antes y después del Reapriete del Núcleo Estatórico

- Realizar el Control Dimensional de la Altura del Núcleo Estatorico antes y después del Reapriete del Núcleo Estatórico.
- Controlar el nivel de cada una de las chapas de apriete tanto en forma radial como tangencialmente, lo mismo que la luz entre cada chapa y el tope limitador de desplazamiento, o distanciamiento.
- Retiro de todo el sistema de cuñas y muelles de apriete de todas las ranuras, dejando 2 provisionales en cada barra para la limpieza; para ello se procede con el corte de los amarres de la cuñas en la parte superior e inferior del núcleo magnético; al termino de ello se da inicio al proceso de cambio de cuñas de apriete de las bobinas inferiores del núcleo magnético.
- Realizar la limpieza de todas las barras estatoricas y del núcleo, eliminando toda presencia de aceite y suciedad.
- Realizar un control de aflojamiento de laminas en toda la superficie del núcleo, pasar una capa de barniz conductor en la superficie de barra que apretara las cuñas, Se realizo una prueba de acuñamiento entre las barras 88 y 90, parte inferior, se empleo un barniz (resina epoxi) de compactación, se coloco fibra de vidrio de 0.2 mm de espesor (lamina de estratificado de vidrio) entre las chapas en 05 puntos, esto es para la aislamiento entre laminas del área reparada, dicha resina tiene un poder de capilaridad estimado a 5 mm hacia el interior de la superficie entre laminas.
- Realizar el Control Dimensional de la Altura de los Pernos Pivot instaladas en las placas de apriete de las chapas del Núcleo Magnético.
- Realizar el aflojamiento de cada uno de los pernos de apriete

del núcleo, y todos los trabajos previstos de reapriete, dejando cada uno con el ajuste correspondiente.

Se realiza así el corte de los seguros de los pernos de las placas de apriete de las chapas y el esmerilado de la soldadura del espárrago y la tuerca de las placas de apriete de las chapas del núcleo magnético, al final se realiza el corte de soldadura con fresas para darle el acabado adecuado y no dañar así los hilos del espárrago.

Se realiza el desmontaje de los soportes de aislamiento de los bobinados que no permitían el adecuado posicionamiento de los gatos hidráulicos para el proceso de reapriete de los espárragos en las placas de apriete de las chapas del núcleo magnético.

Se inicia el proceso de reapriete de los espárragos de las placas de apriete de las chapas del núcleo estatorico

Finalmente nuevamente se realizo el montaje de los seguros de los pernos de las placas de apriete del núcleo estatorico y los soportes de aislamiento del bobinado

Observación:

Se realizo cada día una limpieza del circuito magnético (chapas y bobinas) con aspiradora, para evitar la acumulación de virutas, realizando la limpieza de las chapas con aire comprimido y Dieléctrico: solvente no clorado SS-25.
Se protegió el bobinado con plástico en la realización de los trabajos y luego de cada limpieza, así mismo se protegió las ranuras entre tapas con cinta adhesiva de papel, y se coloco planchas de asbesto como protección en el momento del

esmerilado.

Se debe tener presente que las chispas del esmeril podrían ocasionar agujeros en el aislamiento de las bobinas, así también el alojamiento de virutas metálicas sobre las bobinas, estos originarían posteriormente una inducción, generando huecos localizados, presentando así cargas residuales parciales.

- Colocar todo el sistema de cuñas y muelles nuevos, realizando el control de ajuste en cada una de las barras.

  Se inicio así el proceso de selección de las cuñas de apriete de las barras estatóricas, a emplearse en el núcleo magnético.

  Como control de apriete, se considerara, que cuando no tenga apriete el alto máximo será 9.8 mm y el mínimo 7.9 mm,; asimismo durante el montaje deberá tenerse presente que las ranuras (ventanas) de las cuñas coincidan con los canales de ventilación del núcleo estatórico para facilitar el paso del aire de enfriamiento.

  Luego de terminado el proceso de acuñamiento de las barras inferiores, se realizo la limpieza del núcleo estatórico para realizar el control de presión de las cuñas de las barras inferiores del núcleo estatórico, a través del sistema de mola.

- Aplicar el barniz en los extremos de los paquetes del núcleo para evitar

  aflojamiento y vibraciones de las laminas en estas zonas, luego se realiza la limpieza de la zona inferior y superior del núcleo estatórico para el barnizado de compactación y amarre de las cuñas en la parte inferior y superior, utilizando barniz como la mezcla de una resina y el endurecedor, en la proporción de 2 a 1, posteriormente se realiza el reajuste de los amarres superior e inferior de las cuñas.

Terminado con todas las operaciones de reapriete y trabajos en el estator, se aplica la pintura de base y acabado a toda la superficie del núcleo, dando por concluida esta parte, para ello se realizo la limpieza general en el estator aplicando Dieléctrico: Solvente SS-25, procediéndose a realizar el pintado del mismo. (Ver el Control de los Registros Mecánicos del Grupo)

Procedimiento para el reapriete de los pernos de las placas de apriete de las chapas del núcleo estatórico

El sistema de apriete de las chapas del núcleo estatórico consta de 20 placas, cada una de estas consta de 2 espárragos con tuerca de ajuste M33 y de 2 pernos pívot, a excepción de 2 placas de apriete que consta de 3 espárragos, sumando así en total el sistema 42 espárragos de ajuste.

A continuación se dará el procedimiento a seguir para el ajuste de perno de solo una placa de apriete:

- Cada placa esta sujetada sobre los soportes del estator, por lo que se tiene que sacar los 2 pernos de sujeción M16.
- Se procede a realizar la marca de las posiciones iniciales de los espárragos de apriete y de los pernos pívot.
- Se realiza una primera medición radial y tangencial de la placa de apriete.
- Se limpia la base circular alrededor de la tuerca del espárrago y se coloca la arandela para luego posicionar el gato hueco hidráulico sobre esta; los datos técnicos son:

  F = 22000N

P = 2500 – 2800 PSI

- Se procede a colocar la base metálica sobre la cual ira posicionándose el reloj comparador, para las mediciones de elongación inicial y final, dicho palpador se posesionará sobre la parte superior del perno; inicialmente se colocara la aguja a 5.0 mm.
- Se procederá a acoplar la bomba hidroeléctrica.
- Se comenzara a dar presión sobre sistema hasta una presión que variara desde 2500 a 2800 PSI, dependiendo del ajuste y la elongación inicial del espárrago.
- A llegar a dicha presión se procede a aflojar la tuerca, avanzando en promedio 2 agujeros en sentido antihorario visto de planta, sumando así alrededor de 45 mm (espacio entre agujero y agujero aproximadamente es de 22 mm), se toma nota de la elongación del perno registrada en el reloj comparador, Medida1
- Se procede a quitar la presión al sistema , luego de ello están del sistema a cero PSI, se toma nuevamente la medida de elongación del espárrago registrado en el reloj comparador, Medida 2
- Para hallar la elongación inicial se restará las 2 medidas anteriores:

Elongación Inicial = Medida 1 – Medida 2

- Se procede a desmontar el gato hidráulico con el fin de verificar las marcas iniciales de posición del espárrago tuerca y base; cabe indicar que se espera que el perno respecto de la base no se halla desplazado, de ser así esto indicaría que el espárrago esta flojo y no esta sujeto a la carcaza
- Se coloca nuevamente el gato hidráulico sobre el espárrago, se posesiona la aguja del reloj comparador a 5mm, se conecta la bomba hidroeléctrica y se comienza a dar presión

sobre el sistema hasta obtener una presión que varia entre 2500 y 2900 PSI, y una elongación de 5.40 mm.

- Se registra la elongación del espárrago y se procede a ajustar la tuerca, avanzando en promedio 2 agujeros en sentido horario vista de planta.
- Se procede a quitar la presión del sistema, luego de ello; estando el sistema a 0 PSI, se toma nuevamente la medida de la elongación del espárrago registrada en el reloj comparador que es la Elongación Final del espárrago.
- El aumento de la elongación del espárrago o el desplazamiento vertical de la tuerca de ajuste se obtiene restando dichas elongaciones:

Variación de Elongación = Elongación Final - Elongación Inicial

- Se procede a desmontar la bomba y el gato hidráulico y se sigue los mismos pasos para el otro espárrago.
- Concluida esta parte se realiza una segunda medición radial y tangencial de la placa de apriete
- Se verifica el torque de los pernos pívot de la placa de apriete
- Se da por concluido el reapriete del espárrago de la placa de apriete de las chapas del núcleo estatórico.

a.7 Pruebas Eléctricas - Controles

Se inician los siguientes ensayos:

- Prueba de Resistencia Ohmica del Devanado del Estator
- Prueba de Resistencia Ohmica del Rotor
- Prueba de Aislamiento del Estator por fase
- Prueba de Aislamiento del Rotor
- Prueba de Tensión Aplicada con corriente continua (R, S, T), a

una Tensión de 1.3 Un, midiendo la tensión y corriente de fuga.

- Prueba de Inducción Magnética (Magnetización) del Núcleo, esto para verificar que no halla puntos calientes, lo cual se verifico con el apoyo de una cámara de análisis termográfico, el criterio de aceptación de los puntos calientes con aumento de temperatura mayor que 10°C requieren reparaciones y los puntos con aumento de temperatura entre 5°C y 10°C deberán ser estandarizados.

  Referencia:

  IEEE 56, Normal Working Flux Density 60'

  De acuerdo a las pruebas realizadas y según los protocolos entregados, el núcleo no tiene puntos calientes, y el punto caliente encontrado entre las ranuras 90-91 en la prueba anterior ha sido eliminado.

a.8 Montaje del Rotor – Controles

Se sigue los mismos lineamientos que en el desmontaje, pero en forma inversa.

a.9 Montaje de la Cruceta Superior, Cojinete Pivot y Cojinete Alternador - Controles.

Se sigue los mismos lineamientos que en el desmontaje, pero en forma inversa, además se realizan nuevamente todos los controles para verificarlos con los valores iniciales, y mantenerlos o modificarlos según el análisis realizado

Entre otros puntos tenemos:

Trabajos de limpieza y pulido de la brida del eje turbina.

Se realizó la modificación de la pieza U8 Vaina (componente del cojinete pivot), para realizar el rediseño y cambio de los deflectores de teflón cuya función es la de actuar como sello y aislante para no permitir el paso de los vapores de aceite; colocando en su defecto platinas de aluminio en forma inclinada para evitar de esta manera fuga de aceite por esta zona y ayudar a retener dichos vapores, este se instala sobre el cojinete de empuje.

Se realiza el montaje del sistema de refrigeración siguiente:

6 aerorefrigerantes aire – agua del sistema de refrigeración del generador con sus respectivas tuberías de alimentación al serpentín de refrigeración

1 intercambiador de Calor Aceite – Agua del Cojinete Pívot

1 intercambiador de Calor Aceite – Agua del Cojinete Alternador

1 intercambiador de Aceite – Agua del Cojinete Turbina

A continuación se hace referencia al siguiente reporte.

Informe de la Limpieza Química de los Equipos de Refrigeración del Generador Nº 2

DATOS TÉCNICOS DE LOS AEROREFRIGERANTES

Características de los equipos

	Aire	Agua
Potencia a disipar Kg/ hr	172000	
Temperatura de aire de entrada	75ºC	
Temperatura de salida de aire	40ºC	
Caudal de aire	5 m3 /s	
Pérdida de carga de aire m/m CE	15	
Temperatura de entrada		25ºC
Temperatura de salida		32ºC
Caudal		246 m3/h
Pérdida de carga		25 MCE
Presión de diseño del circuito		6 bar
Presión de prueba del circuito		10 bar

Los equipos cuyas características se señalan corresponden a los siguientes números de placa.

Aerorefrigerante Nº1	321/31754/83/01
Aerorefrigerante Nº2	321/31754/83/02
Aerorefrigerante Nº3	321/31754/83/03
Aerorefrigerante Nº4	321/31754/83/04
Aerorefrigerante Nº5	321/31754/83/05
Aerorefrigerante Nº6	321/31754/83/06
Aerorefrigerante Nº7	321/31754/83/07

TRABAJO REALIZADO EN AEROREFRIGERANTES

1. LIMPIEZA QUÍMICA DE LOS AEROREFRIGERANTES

En los 06 aerorefrigerantes se procedió de la siguiente manera:

1. Se inició con el traslado de los equipos de la sala de máquinas al patio de transformadores.
2. Se cargó con solución caliente de REYMATEK AW a los seis aerorefrigerantes y disponiéndolos en la tina de trabajo, ubicados en el patio de transformadores para su tratamiento posterior, luego de varios días.
3. Se inició en la apertura del primer aerorefrigerante y tomado como referencia para el inicio de los trabajos sucesivos.
4. Se realizó el arenado y limpieza del aerorefrigerante por el lado del agua. Desaceitado del lado del aire con solución caliente de descarbonizante y desengrasante hidrosoluble. Verificación de la limpieza total, enjuague de todos los tubos, y secado de las placas y tapas.
5. Secado de la pintura, colocación de empaquetaduras de teflón y ajuste de las tapas disposición del mismo en la pared para pruebas finales y pintura de acabado.
6. Se continúa con el alineamiento de las placas galvanizadas deformadas por choques u otros al desmontarse el rotor y otros equipos como las tuberías de refrigeración.

En general los espesores de los tubos variaron entre 1.2 a 1.3 mm.

La pintura epóxica ZincClad es aplicada a las tapas de todos los aerorefrigerantes.

En la operación de arenado húmedo se tuvo sumo cuidado que la arena no altere las láminas de conducción de transferencia de calor colocándose una lámina de madera y otra de plástico por las dos caras. En los acabados se ha secado los aerorefrigerantes con aire a presión y secado todas las pequeñas partículas de arena que pudiesen haber quedado.

Se procedió a llenar los equipos con agua desionizada y tratada con PREVENOX para ejecutar la prueba hidrostática a 12 BAR y ajuste de tapas para eliminar toda fuga y estanqueidad del sistema a presión constante por 1 ½ hora y en el caso de los seis aerorefrigerantes no han presentado fugas.

Se procedió al alineado de las lainas de conducción.

Se colocó los tapones de jebe, pintado con epóxica de igual tono que su estado original ya que el que tenía al inicio del trabajo era ligeramente más intenso por el carbón depositado.

Se han llevado los seis aerorefrigerantes y dispuesto en la sala de máquinas en el lugar de origen y sobre una manta de polietileno y cargados con agua tratada de baja dosificación y de naturaleza acorde con el medio ambiente, estos están con tapones de jebe.
No se han observado problemas de picaduras profundas en las tinas o tapas y se observa una mejora notable en la protección del sistema con el uso de esta pintura, sin embargo, consideramos es posible mejorar el tratamiento de agua del sistema.

2. SERPENTÍN DEL INTERCAMBIADOR DE ACEITE- AGUA DEL COJINETE SUPERIOR

Antes de la limpieza química se procedió a proteger el equipo con doble capa de polietileno evitando el deterioro por efectos ambientales tanto del polvo como del agua en el lado del aceite y del agua para evitar cualquier daño del equipo

Luego se procedió a la carga de cada mitad del serpentín con solución caliente de REYMATEK AW y recirculando hasta una temperatura de 70 °C y manteniendo la misma por 4 horas, se procedió a la descarga, neutralización con soda cáustica y enjuague hasta un pH de 6.5, luego se realizó el enjuague y la limpieza final a alta presión tubo por tubo.

El serpentín limpiado tiene en total nueve tubos en cada mitad.
Ejecutado la limpieza del equipo se procedió a llevarlo a sala de baterías con doble protección plástica y hermética.

Se cargó con conservante PREVENOX, que trabaja bien en estado estacionario o en operación.

El equipo quedó con tapones para evitar la evaporación del agua tratada con que se encuentran.

El espesor de los tubos de cobre es de 1.5 mm el equipo, este se encuentra en buen estado de conservación.

OBSERVACIONES

1. En el lado del aceite y en los puntos de conexión con el colector se observa óxido cúprico, éste es el causante de tener alto contenido de cobre en el aceite. Igualmente se ha observado acumulación de polvo y la eliminación del zinc en los extremos de los tubos que van hacia los colectores.

2. Se observa que en general el estado del equipo es bueno salvo lo indicado anteriormente que es una zona de 10 cm^2 de desgaste de la capa de zinc y en donde se observa la capa de óxido de cobre II.

3. Las dos mitades se dispusieron con tapones de jebe en la sala de baterías no habiendo la posibilidad de deterioro alguno o contaminación con agentes externos.
4. Las lainas de intercambiador se observa pequeña cantidad de polvo inusual en estos casos la misma que ha sido eliminada con aire.

3. LIMPIEZA QUÍMICA DE INTERCAMBIADOR DE ACEITE AGUA DEL COJINETE GUÍA

CARACTERÍSTICAS

AÑO	1983
INT. TUBES	LAU
PRESIÓN	3 BARS
N° DE FABRICACIÓN	4/82 1231 A01APAREIL OX 5 2400
EXTERIOR TUBES	HUILE
PRESIÓN DE SERVICIO	5 BARS
PRESIÓN DE PRUEBA	7.5 BARS

Se ha ejecutado una recirculación con agua previa a la limpieza química por cuanto existía gran acumulación de fangos de color celeste.

Luego se procedió a la descarga y carga con REYMATEK AW y recirculación en caliente a 60 °C por cuatro horas y se ha mantenido el equipo por 48 horas. Se ha observado abundante enfangamiento.

Se procedió a la descarga neutralización y enjuague para proceder a sacar las tapas.
La tapa anterior se la a protegido para evitar contaminación con polvo y agua o arena con doble forro plástico y jebes en tres puntos hermetizando el sistema por el lado del aceite.

Se procedió a la limpieza tubo a tubo limpieza de las placas y pintadlo de las mismas con pintura epóxica con protección anódica. Las placas son de acero inoxidable y no se observa problema de desgaste en los tubos y en las placas

Las tapas de fierro fundido se las ha arenado y pintado con pintura bituminosa se procedió al cambio de empaquetaduras cerrar y pintado de acabado según color del equipo con pintura esmalte rojo ocre.

El espesor mínimo de los tubos de cobre es de 1.2 mm El equipo se encuentra en buen estado de conservación.

Observaciones

1. El equipo se ha encontrado en el lado de agua con elevada concentración de fangos e incrustaciones además de sales de cobre soluble en forma de carbonates de cobre o carbonato básico de cobre.
2. Se procedió a ser una recarga de solución de soda cáustica y posterior inhibición y prevención con PREVENOX y descarga y secado para su conservación y disminuir la descarga en el ensamblaje del generador.

Se procedió a ingresar el equipo a sala de máquinas con plásticos de protección.

La pintura de los casquetes se ha dejado enfriar y previsto que no existan burbujas en la misma. Se ha determinado que no existan puntos sin pintar con tintas adecuadas en la evaluación de pinturas.
Se ha utilizado empaquetaduras de teflón indicadas para el caso y puesto las tapas.

4. LIMPIEZA QUÍMICA DEL INTERCAMBIADOR ACEITE AGUA DEL COJINETE DE TURBINA.

CARACTERÍSTICAS DEL EQUIPO

N° DE FABRICACIÓN	4/83 00898 / A03
APPAREIL	WX 4 2200
AÑO	1983
PRESIÓN DE SERVICIO	5 BARS
PRESIÓN DE PRUEBA	7.5 BARS

Se procedió a un enjuague con agua por presentar acumulación de fangos.

Se cargó y recirculado el equipo con REYMATEK AW en caliente por cuatro horas y dejado en reposo por 48 horas.

Se procedió a la descarga, enjuague y neutralización con soda cáustica, enjuague a pH 7.5.

Se procedió a destapar y enjuagar tubo por tubo.

El equipo a quedado totalmente limpio.

Se procedió a la pintura del lado anterior con pintura epóxica con inclusión de zinc y el lado opuesto se ha sellado el espacio intertubular con masilla epóxica con inclusión metálica y tapando los bordes de cobre, sellando de esta manera la posibilidad de continuar la corrosión galvánica y reconstituyendo la placa del intercambiador totalmente.

Se procedió a la carga con PREVENOX hecho la prueba hidrostática a 7.5 Bars, después de hora y media se procedió a la descarga , secado y tapado con protectores plásticos para su conservación en seco para facilitar las labores posteriores de montaje en el generador.

El espesor de los tubos de cobre es de 1.3 mm

Observaciones

1. Este es el equipo que se observa con mayor corrosión en la zona de unión placa - tubo y en las salida de agua.
2. Para eliminar incidencia de corrosión en la zona señalada se ha dispuesto resina epóxica para sellar toda la placa y los terminales de los tubos de cobre.
3. Al tener un sistema con condiciones de trabajo de bajas temperaturas no se ha tener problemas de corrosión sin embargo recomendamos en este caso sea inspeccionado en un año para determinar su estado de conservación.
4. La acumulación de fangos es negativa en sistemas en donde la corrosión galvánica es constante o más cuando se manifiesta por tener porosidad en las superficies comprometidas.
5. Se ha dejado el sistema en buenas condiciones.
6. Se prevee colocar válvulas tipo bola en el fondo con el objeto de purgas los intercambiadores de turbina y guía para evitar se conviertan en puntos de corrosión importante por enfangamiento ya que este incrementa la cantidad de oxigeno disuelto. Las purgas han de realizarse cuando menos una vez cada mes y en tiempo de lluvias se dispondrán a realizar cada semana.
7. Consideramos que el manejo del sistema puede conducir al tratamiento del agua con productos no contaminantes del medio ambiente y eliminar los problemas de incrustación y corrosión.
8. Se ejecuto las pruebas hidrostática en los intercambiadores a presión de 7.5 BAR.

5. LIMPIEZA DE LAS TUBERÍAS DE ALIMENTACIÓN DE AGUA AL SERPENTÍN DE INTERCAMBIO

1. Estas se han limpiado con DESCARLEX CP, se procedió a su enjuague Neutralización con soda cáustica y pasivación descarga y secado.
2. Conducción a la sala de máquinas.

OBSERVACIONES Y CONCLUSIONES FINALES

1. Las tuberías se han encontrado con depósitos de cobre elemental y compuestos oxidados de cobre. Este efecto es el mecanismo de oxidación en sistemas de cobre, hierro en donde se hace necesario pasivar el cobre e impedir que este oxide al hierro y así cíclicamente se incremente el proceso al aumentar la superficie de cobre comprometido en el efecto corrosivo de naturaleza galvánica y normal y óxido reducción del cobre soluble sobre el hierro.

   En el sistema se tiene "la ventaja" de tener una agua de naturaleza incrustante la que limita el depósito de cobre y limita el proceso rédox en las tuberías de conducción de agua pero disminuye la capacidad de intercambio de calor en los equipos por formación de incrustaciones calcáreas.

2. Los puntos del sistema que son vulnerables son el intercambiador de turbina y del alternador donde se tiene las placa de hierro y tubos de cobre con espacios intertubulares reducidos y con picaduras importantes .Una inadecuada protección hace que se incremente la diferencia de potencial cobre - hiero y se desencadene el proceso corrosivo que de por sí existe en el sistema de intercambio de calor en donde se incrementa por la diferencial de temperatura en el agua de entrada y de salida.

3. Los aero-refrigerantes no se ha observado incremento en la corrosión de la unión placa tubo mas sí en los bordes superiores de las tinas. Todos los aerorefrigerantes se han encontrado con inusual cantidad de carbón en el lado del alternador y restos de fibras de algodón productos de la limpieza.

4. En los intercambiadores aceite agua del sistema es donde se ha encontrado mayor acumulación de fangos y en algunos casos se ha encontrado tubos totalmente taponados de inertes (silicatos) con carbonato de calcio y derivados oxigenados de cobre los que han disminuido la capacidad de intercambio. Los intercambiadores de calor se ha observado un incremento en las picaduras en la unión de la placa con los tubos, de incidencia importante en el intercambiador aceite - agua de turbina, y en donde se ha ejecutado un sellado de la placa con masilla epóxica para eliminar el riesgo de paso de aceite al agua o recíprocamente y con el fin de lograr detener la corrosión del hierro. Estos equipos ya presentaron este problema desde el año 1 992 y se ha detenido mediante la aplicación de pintura epóxicas en superficies calentadas para un acabado adecuado de la pintura y prevención del sistema, que es la misma que se ha de aplicar en esta oportunidad y con las exigencias que requiere la conservación del equipo. Es necesario prever un sistema de purga de los equipos indicados con el objeto de eliminar el enfangamiento y corrosión del cobre por acumulación de oxígeno en el fango y oxidación diferencial la cual es la otra razón de haber encontrado mayores depósitos de compuestos de cobre soluble en los intercambiadores.

5. El agua del sistema debe de tratarse teniendo como primer objetivo eliminar o reducir drásticamente la corrosión cobre- hierro y segundo eliminar la formación de incrustaciones al lograr un valor de estabilidad en las características químicas del agua.

6. Los intercambiadores de aceite - agua de turbina y del alternador debe darse una protección total con masilla epóxica y ser exigentes en el revelado de no quedar porosidad por cuanto esta puede conducir a mantener el sistema con corrosión galvánica.

Preferentemente debe de tomarse ese cuidado con las dos placas.

7. Mantener las labores de mantenimiento de limpieza periódica en los aerorefrigerantes sacando el equipo y poniendo el de repuesto para ejecutar la limpieza por el lado del alternador y evitar se produzca acumulación de fibra de algodón así como se incremente el carbón depositado en las lainas el cual si bien es cierto es buen conductor del calor pero tiene el inconveniente de acumular aceite evaporado en el sistema y formar masas difíciles de remover y convertirse en aislantes.

8. Siempre purgar el fondo de los aerorefrigerantes ya que se ha encontrado cuatro de ellos taponados por magnetita y uno como consecuencia del fango deteriorado por corrosión por oxígeno disuelto.

9. En las labores de mantenimiento proteger el lado del aceite pues resulta totalmente extraño encontrar depósitos de insolubles (polvo)en este. Los abrasivos son los que destruyen el zinc y posteriormente el cobre de allí que en los análisis de aceites puedan tener valores incrementados de zinc y cobre.

10. Al instalar los equipos cuidar en purgar las líneas antes de su colocación para evitar desprendimientos que se producen por efecto de 1 corrosión incrementada por la estanqueidad del agua estos son causa de taponamientos en la puesta en operación del sistema.

a.10 Montaje de las tapas, tuberías, equipos e instrumentación

Se sigue los mismos lineamientos que en el desmontaje, pero en forma Inversa.

a.11 Ensayos de Entrega (Puesta en Marcha) - Controles

Se sigue los mismos lineamientos que en el desmontaje, pero en forma inversa. Se inicia con la preparación de los Equipos de Ensayos para las Pruebas de Entrega de la Unidad Generadora N° 2, siendo estas las siguientes:

Operaciones del Grupo en Vació:

1. A 25% de Carga
2. A 50% de Carga
3. A 75% de Carga
4. A 100% de Carga

Monitoreo de Temperaturas

1. Cojinetes
2. Aceite
3. Agua en los Aerorefrigeradores
4. Bobinado del Estator
5. Bobinado del Rotor
6. Núcleo del Estator
7. Aire Caliente
8. Aire Frío

Monitoreo de Vibraciones

1. Cojinete Guía Turbina
2. Cojinete Superior del Generador (Cojinete Pivot)
3. Cojinete Guía Inferior del Generador (Cojinete Alternador)

Monitoreo de Operación del Grupo

1. Potencia del Generador
2. Cos phi
3. Tensión del Generador
4. Corriente del Generador
5. Tensión del Excitación
6. Corriente de Excitación

Pruebas Eléctricas

1. Resistencia Ohmica del Bobinado del Estator.
2. Resistencia Ohmica del Bobinado del Rotor.
3. Resistencia de Aislamiento del Bobinado del Estator.
4. Resistencia de Aislamiento del Bobinado del Rotor
5. Controles de los RTD's.

Tener en cuenta lo siguiente:

1. **Giro mecánico**

    1.1 Giro mecánico sin excitación para:
    Comprobación de la temperatura de los cojinetes:
    Oscilación del eje y/o vibración de los cojinetes

    1.2 Balanceamiento dinámico y verificación de la Oscilación del eje o vibración de los cojinetes

    1.3 Sistema de freno
    Aplicación de los frenos en rotación;
    Tiempo de frenado
    Temperatura del anillo de frenado
    Descarga y ruidos anormales de las zapatas.
    Retorno de los frenos a la posición desactivada.

1.4 Prueba de Sobre velocidad e medición de la oscilación del eje y vibración y temperatura de los cojinetes.

2. Pruebas operacionales - Unidad sin carga

2.1 Comprobación de la secuencia de fase
Referencia: IEEE 115
2.2 Comprobación del equilibrio de la tensión
2.3 Comprobación de la operación de sincronismo
2.4 (manual y automático)
2.5 Medición de tensión del eje (comprobación del aislamiento de los cojinetes Referencia: IEEE115

b. Trabajos en el Rotor

b.1 Medición de Aislamiento – Controles antes y después del desmontaje

Se realizó las siguientes Pruebas Eléctricas de Aislamiento en 1 minuto y a 1000 V:
Prueba de Aislamiento del eje rotor a tierra resultando 800 Megaohms
Prueba de Aislamiento en el cojinete pivot (cruceta superior), entre el patín y la carcasa (tierra) resultando 800 Megaohms.
Se realizo las siguientes pruebas de aislamiento en 1 minuto y a 1000 V:
Prueba de Aislamiento en el anillo colector: Parte Inferior a tierra, resultando 8000 Megaohms
Prueba de Aislamiento en el anillo colector: Parte Superior a tierra, resultando 8000 Megaohms
Prueba de Aislamiento en el anillo colector: Parte Superior e Inferior, resultando infinito.
Prueba de Aislamiento en el porta carbones resultando infinito.

b.2 Limpieza del Rotor

Se realiza la limpieza del rotor con Dieléctrico: solvente no clorado SS-25.

b.3 Pintado de los polos

Se realizó el pintado del rotor, utilizando
1.1 Pintura (Componente A):
Catalizador (Componente B):Diluyente

c. Trabajos en el Sistema Extractor de Vapores de Aceite

Se inicia los trabajos de instalación del extractor de vapores de aceite con referencias técnicas de la Central Hidroeléctrica de San Gabán. Se ubica la posición del montaje de las tuberías de PVC para la extracción de vapores de aceite en la cuba de la cruceta superior.

iii. Control de los Registros Mecánicos y Eléctricos del Grupo Generador Nº 2 – Central Hidráulica Charcani V.

En el Anexo IV se muestran los registros correspondientes.

2. MANTENIMIENTO GENERAL DE EQUIPOS ELECTROMECÁNICOS E HIDRÁULICOS

i. Cronograma de Mantenimiento Eléctrico.

ii. Cronograma de Mantenimiento Mecánico.

PROGRAMA DE ACTIVIDADES DE MANTENIMIENTO ELECTRCIO
REPARACION GRUPO Nº 02 - C.H. CHARCANI V

ITEM	DESCRIPCION DE A ACTIVIDAD	RESPONSABLE	1	2	3	4	5	6	7	8	9	10	11	12	OBSERVACION
1	COLECTOR.														
	- Limpieza y control de desgastes de borneras de colector.	Caluchi											▨	▨	
	- Limpieza y control de portacarbones.	Caluchi												▨	
2	POLOS DEL ROTOR.														
	- Limpieza total de los polos con solvente dieléctrico y trapo industrial.	Caluchi												▨	02 personas de Apoyo
	- Mediciones de aislamiento de cada polo	Caluchi										▨	▨		
3	GENERADOR.														
	- Limpieza general de las borneras de junta de dilatación.	Caluchi													01 Apoyo
	- Mejoramiento de canaletas para el cableado de sondas.	Caluchi							▨	▨	▨	▨			01 Soldador
	- Diseño de puertas de acceso para la inspección de carbones	Caluchi									▨	▨	▨		
	- Prueba de sensores, termostatos y presostatos	Caluchi/Barreda		▨	▨	▨									
	- Inspección y limpieza de TPs, CTs, seccionador, pararrayos, transf. Auxiliar.	Caluchi							▨						
	- Prueba de los sensores de incendio incluido el percutor.	Caluchi								▨					
	- Inspección y limpieza general de los tableros de control, protección y auxiliares.	Caluchi								▨					
	- Pruebas de inyección secundaria y señalización de los reles del sistema de proteccion	La Torre/Caluchi			▨	▨	▨	▨							Apoyo del Operador
	- Control de los instrumentos de medición y señalización	Barreda					▨	▨							
4	SISTEMA DE EXCITACIÓN.														
	- Medición de aislamiento del transformador.	Caluchi	▨												
	- Limpieza de filtros de refrigeración de los tiristores	Caluchi	▨												
	- Pruebas de inyección secundaria y señalización de los reles del sistema de proteccion	La Torre/Caluchi							▨						Apoyo del Operador
5	TRANSFORMADOR DE AUXILIARES GENERALES														
	- Medición del aislamiento	Caluchi	▨												
	- Pruebas de inyección secundaria y señalización de los reles del sistema de proteccion	La Torre/Caluchi								▨					Apoyo del Operador
	- Inspección, limpieza y control de los disyuntores en 13,8 kV y 380 V.	Caluchi	▨												
6	TRANSFORMADOR DE POTENCIA 57 MVA														
	- Medición de aislamiento de cables y transformador	Sandoval													01 Apoyo
	- Revisión del sistema de incendio	Sandoval									▨				01 Apoyo
	- Limpieza general del tranformador	Sandoval									▨				01 Apoyo
	- Medición de la rigidez dieléctrica del aceite	Caluchi										▨			/
	- Pruebas de inyección secundaria y señalización de los reles del sistema de proteccion	La Torre/Caluchi								▨					Apoyo del Operador
7	REGULADOR DE TENSIÓN														
	- Control de las fuentes de alimentación.	Barreda	▨												
	- Inspección y limpieza de las cajas de tiristores, y seguridades del sistema.	Caluchi		▨											
	- Control del sistema de señalización y alarmas	Barreda			▨	▨									
	- Medición de los niveles de tensión en la cadena del regulador.	Barreda	▨												
	- Limpieza y ubicación de puntos calientes en las tarjetas.	Barreda	▨												
8	REGULADOR DE VELOCIDAD RAPID 77														
	- Evaluación de la bateria interna (poner en servicio por tres horas).	Barreda							▨						
	- Limpieza y ubicación de puntos calientes en las tarjetas.	Barreda							▨						
	- Evaluación del sistema de señalización, medición y mandos.	Barreda								▨	▨				Coordinar con mecanicos
9	MEDIDOR DE CAUDAL RITTMEYER														
	- Limpieza de los modulos de las tarjetas de alarma y señalización	Barreda										▨			
	- Verificación del cero del sensor *	Barreda										▨			
	- Verificación de los niveles de tension de la alimentación *	Barreda										▨			
	- Evaluación del sistema de medición local, distancia y telemedida	Barreda											▨		
10	AUTOMATA H20														
	- Limpieza general de de las tarjetas de los diferentes racks.	Barreda					▨								
	- Control y medición en las fuentes de alimentación de: AA, AI, AM y modems.	Barreda					▨								
	- Verificación de las medidas en los calculadores PCP y PCS	Barreda					▨								
	- Verificación de los enlaces AA-Ecram, AA-AI, AA-PCP, AA-PCS, AI-Ecram y AI-PCP	Barreda						▨							
	- Control de enlace entre Modems – PCP.	Barreda						▨							
	- Verificación de la emisión y recepción de datos del AM	Barreda						▨							
	- Revisión del estado de pararrayos y fusibles de los modems.	Barreda					▨								
11	PATIO DE LLAVES														
	- Limpieza general de los equipos de alta tensión.	Sandoval										▨			01 Apoyo
	- Verificación de estanqueidad de los equipos de alta tensión.	Sandoval										▨			01 Apoyo
	- Limpieza y Evaluación de los contactos de los seccionadores.	Sandoval										▨			01 Apoyo
	- Verificación del mando mecanico de los equipos de maniobra	Sandoval										▨			01 Apoyo
	- Prueba de simultaneidad de los interruptores	Caluchi													01 Apoyo

PROGRAMA DE ACTIVIDADES DE MANTENIMIENTO MECANICO MAYOR CORRESPONDIENTE AL GRUPO 2
CENTRAL HIDRAULICA CHARCANI V

DESCRIPCION DEL TRABAJO	RESPONS.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1,- COLECTOR																									
Realizar limpieza general con solvente SS-25 en los anillos colectores	SULLCA							▨	▨																
Asentar cuidadosamente el diámetro interno, eliminando las zonas de fuerte fricción.	SULLCA							▨	▨																
Verificar con un micrómetro de interiores la concentricidad del agujero.	SULLCA							▨	▨																
Limpieza de pernos y seguros	SULLCA							▨	▨																
2,- CRUCETA SUPERIOR																									
Limpieza general de asientos, cuñas y bases	SULLCA								▨	▨															
Asentado de todas las zonas de apoyo con soportes radiales y axiales.	SULLCA								▨	▨															
Tapa superior de la cruceta (sobrevelocidad), armado del mismo	SULLCA								▨	▨															
Revisión de los anillos de estanqueidad de Aluminio	SULLCA									▨	▨	▨													
Inspección de los soportes de la tuberia de CO2	SULLCA									▨	▨	▨													
Limpieza de pernos y seguros	SULLCA							▨	▨	▨	▨	▨													
Modificación de las tapas del porta escobilla, y pintado del mismo	FLORES																	▨		▨	▨	▨			
3,- COJINETE COMBINADO - PIVOT																									
3,1,- COJINETE EMPUJE																									
Limpieza general (eliminar todo tipo de residuo de aceite o polvo)	SULLCA											▨		▨											
Rectificado de puntos de fricción con esponja.	SULLCA											▨		▨											
Medición del diámetro interno a fin de determinar el grado de desgaste del material antifricción (babitt)	SULLCA											▨		▨											
Medición del grado de desgaste de los rasgadores y control de resortes.	SULLCA											▨		▨											
Verificación del desgaste y planicidad de los patines de apoyo.	SULLCA													▨	▨										
Verificación del aislante de los patines de apoyo	SULLCA													▨	▨										
Verificación del aislante en la corona de patines, base de jebe.	SULLCA													▨	▨										
Control de anillo movil (bulones)	SULLCA													▨	▨	▨									
Inspección de las mangueras flexibles (ver posible cambio de estas)	SULLCA													▨	▨	▨									
Limpieza de pernos y seguros	SULLCA											▨		▨	▨	▨									
Control de boyas de nivel de aceite	SULLCA														▨	▨									
3,2,- COJINETE GUIA																									
Limpieza general (eliminar todo tipo de residuo de aceite o polvo).	SULLCA															▨	▨								
Rectificado de puntos de fricción con esponja.	SULLCA															▨	▨								
Limpieza a los conductos de succión de aceite	SULLCA															▨	▨								
Ajuste del tranquilizador	SULLCA															▨	▨								
Revisión de los canales de orring (ver orring viton, para alta temperatura)	SULLCA																▨	▨							
Limpieza de los conductos de sondas	SULLCA																▨	▨							
Control y verificación de los aislantes de las sondas de temperatura	SULLCA																▨	▨							
Inspección de la vaina y del sello de estanqueidad	SULLCA																▨	▨							
Limpieza de pernos y seguros	SULLCA														▨	▨	▨	▨							
3,3,- TAPAS SUPERIOR E INFERIOR DE COJINETE COMBINADO - PIVOT																									
Verificar el diámetro interior de los sellos de las tapas para determinar su grado de desgaste.	SULLCA																			▨					
Control de alojamiento de orring	SULLCA																			▨					
Limpieza de pernos y seguros	SULLCA																	▨		▨					
Fabricación de manguitos para sonda, colocar las arandelas de cobre	TORNERO							▨	▨	▨	▨														
3,4,- ANILLO DE AGARRE Y ZUNCHO																									
Limpieza general y asentado de zonas dañadas por golpes (emplear piedra de asentar).	SULLCA																				▨	▨			
Verificar planicidad de zonas de apoyo;. medir con micrómetro de exteriores los espesores para controlar el paralelismo	SULLCA																				▨	▨			
Pasar macho a las partes roscadas y presentación de pernos, seguro de pernos.	SULLCA																				▨	▨	▨		
Limpieza de pernos y seguros	SULLCA																				▨	▨	▨		

DESCRIPCION DEL TRABAJO	RESPONS.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
3.5.- MANGUITO																									
Limpieza general	SULLCA																						▨	▨	
Asentado del diámetro interno (de manera especial las zonas que han sufrido oxidación y que presentan una fuerte friccion con el eje)	SULLCA																						▨	▨	
Verificar con micrómetro la concentridad del diámetro interno; también se ha de verificar la planicidad de la superficie de apoyo	SULLCA																						▨	▨	
Controlar el diámetro exterior con micrómetro de exteriores; rectificar los puntos que presenten rozamiento metal con metal	SULLCA																						▨	▨	
Limpieza de los alojamientos del obturador, pasar macho	SULLCA																						▨	▨	
3,6.- SISTEMA DE CIRCULACION DE ACEITE																									
Mantenimiento de las 02 bombas de circulación.	BARRIOS			▨	▨																				
Inspección de las conexiones y roscas de las sondas de temperatura	BARRIOS				▨	▨																			
Recalibración de manometros y presostatos	BARRIOS							▨	▨	▨															
Inspección de la valvula check - estanqueidad	BARRIOS				▨	▨																			
Inspección de los filtros de aceite	FIGUEROA				▨	▨																			
Inspección de los detectores de flujo	FIGUEROA							▨	▨																
4,- COJINETE ALTERNADOR																									
Inspección del Cojinete Alternador y acentado	CUBA							▨	▨																
Mantenimiento e inspección del extractor de vapores de aceite	CUBA							▨	▨	▨															
Inspección de roscas y acoplamientos de las sondas de temperatura	CUBA								▨	▨															
Inspección de los sellos de Aluminio	CUBA								▨	▨															
Presentación del armado de partes (tapas metalicas y de fibra de vidrio)	CUBA									▨	▨														
Control de bollas de nivel de aceite	CUBA									▨	▨														
Preparación de seguros	TORNERO											▨		▨	▨										
4,1,- GATOS DE FRENADO.																									
Medición del grado de desgaste y verificación de la planicidad de los ferrodos	CUBA										▨	▨													
Revisión de los fines de carrera	CUBA										▨	▨													
Revisión de la pista de frenado	CUBA											▨		▨											
Revisión del circuito neumatico	CUBA											▨		▨	▨										
Sondear las tuberias de los gatos de frenado	CUBA													▨	▨	▨									
Inspección del grado de desgaste de los sellos hidraulicos - Pruebas	CUBA													▨	▨	▨									
5. COJINETE TURBINA.																									
Limpieza general de cojinete (supeditado al desmontaje del cojinete T.)	ARISPE															▨	▨								
Mantenimiento de los detectores de flujo de aceite y agua	ARISPE															▨	▨								
Rectificar todos las áreas de fricción (esto esta supeditado al desmontaje del cojinete turbina)	SULLCA															▨	▨								
Medición del diámetro interno para determinar el grado de desgaste del cojinete (esto esta supeditado al desmontaje del cojinete turbina)	SULLCA															▨	▨	▨							
Verficación de los conductos de lubricación del cojinete (esto esta supeditado al desmontaje del cojinete turbina)	SULLCA																▨	▨							
Mantenimiento de las tuberias, niples, valvulas, diafragmas y revisión de las juntas de estanqueidad correspondientes al sistema de refrigeración del cojinete turbina	BARRIOS																			▨	▨	▨			
Inspección de sondas, respiradores y control de bollas	BARRIOS																			▨	▨				
5,1,- BRIDA DE ACOPLE DE EJE DE TURBINA.																									
Limpieza general , el cual incluye a los esparragos	SULLCA																							▨	
Asentado cuidadoso de superficies de contacto del acople.	SULLCA																							▨	
Control de los agujeros	SULLCA																							▨	
Fabricación de seguros inoxidables	TORNERO													▨	▨	▨									
6,- SISTEMA DE REGULACION DE MANDOS HIDRAUL.																									
Inspección y mantenimiento de las electrovalvulas de mando	BARRIOS																						▨	▨	
Mantenimiento de los motores de las bombas de regulación AE y AF	BARRIOS	▨	▨	▨																					
Mantenimiento del distribuidor del varimetro	BARRIOS																								
Inspección de las valvulas de bola de alta presión, ver fugas	BARRIOS							▨																	
Contraste y calibración de los manometros y/o cambio de estos	BARRIOS								▨																
Desmontaje del inyector Nº 5 (mas cercano a la valvula esferica)	BARRIOS					▨				▨															
Contraste y calibración de manometros de la valvula esferica	BARRIOS					▨																			
Control de los filtros de anillos de la valvula esferica	BARRIOS				▨																				
Control de los contactos de posición de la valvula esferica -Electrico	BARRIOS				▨																				
Cambio de aceite de la Caja de Regulación	BARRIOS																	▨							
Mantenimiento del distribuidor de mando de agujas, ver orrignes; desgaste de pistones	BARRIOS																▨	▨		▨	▨	▨			
																	▨	▨		▨	▨	▨			

DESCRIPCION DEL TRABAJO	RESPONS.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Mantenimiento de la Valvula de Intermitencia	BARRIOS									▨															
Mantenimiento de la Valvula detector de presión	BARRIOS										▨														
Mantenimiento de la Valvula distribuidor del obturador	BARRIOS											▨													
Mantenimiento del Servo mando deflectores	BARRIOS													▨	▨	▨									
Mantenimiento del Sistema Neumatico del Acumulador	BARRIOS																▨								
Mantenimiento de la Valvula By - Pass	BARRIOS																					▨	▨		
Mantenimiento de la Valvula Automatica de descompresión	BARRIOS																						▨	▨	
Inspección de la valvula de drenaje de la valvula esferica	BARRIOS																							▨	
Mantenimiento anillos aguas arriba y aguas abajo	BARRIOS																							▨	
Mantenimiento del Accionador	BARRIOS															▨									
Limpieza de las Valvula de las tomas de Ritmeyer, y tomas de presión de anillos	FIGUEROA										▨	▨													
Limpieza de la tuberia de Ritmeyer y sondeo de las tomas de agua	FIGUEROA											▨													
Inspección y mantenimiento de los filtros del extractor de aceite	FIGUEROA																								
Mantenimiento y reparación de la valvula de aislamiento, control de bolla y de la tapa del Acumulador, inspección de juntas y orrignes	BARRIOS													▨		▨	▨	▨							
Fabricación y montaje de las guias de aluminio del copiador de posición de agujas	TORNERO																▨	▨		▨	▨	▨	▨		
7.- MANTENIMIENTO DE LA TURBINA																									
Limpieza de las cucharas, soldar cuchara N° 20														▨	▨	▨									
Inspección y reparación de los deflectores	FLORES									▨	▨	▨													
Inspección y mantenimiento de las tuberias de engrase de los inyectores y cambio de las abrasaderas de estas tuberias	FLORES			▨	▨	▨		▨	▨																
Inspección y mantenimiento de la puerta de ingreso (sellado, ver el jebe especial)	FLORES																▨								
Inspección del paso de hombre, sellos y pernos.	FLORES																▨								
Inspección, y mantenimiento de agujas y toberas, revisión de cada inyector (bocina de bronce)	BARRIOS																				▨	▨			
Mantenimiento de los ejes de los deflectores, revisión de juntas	BARRIOS																				▨	▨	▨		
Evaluación de inyectores 1, 2, 3, 4 y 5, fugas y desgaste, Cambio de Inyector 1, Cambio de agujas 1, 2, 3, 4 y 5	BARRIOS																					▨	▨	▨	
Inspección del colector hasta la valvula esferica, valvula de drenaje	FIGUEROA															▨	▨								

OTROS TRABAJOS POR DEFINIR (TERCEROS)

1,- TURBINA
Inspección, mantenimiento y pintado de rejillas y bastidor.
Inspección y mantenimiento del pozo de descarga de agua turbinada
Limpieza general del cono y pintado del mismo
2,- SISTEMA DE REFRIGERACION
Limpieza quimica de los aerorefrigerantes
Limpieza quimica del intercambiador de aceite del Cojinete Pivot
Limpieza quimica del serpentin del Cojinete Alternador
Limpieza quimica del intercambiador de aceite del cojinete turbina.
Limpieza quimica a las tuberias del sistema de refrigeración de agua

3. OTROS TRABAJOS REALIZADOS

Dentro de los trabajos de mantenimiento, se aprovecho para realizar una serie de trabajos de importancia, teniendo como objetivo la renovación de equipos propios y complementarios de los grupos hidráulicos, en base a estudios por tiempo de vida y programados en el año 2001, asegurando de esta manera que los grupos presten las garantías de seguridad tanto para el personal que labora en las instalaciones, como para garantizar la confiabilidad de los mismos.

Dentro de estos trabajos cabe destacar los siguientes:

MANTENIMIENTO E INSPECCIÓN DEL TÚNEL DE ADUCCIÓN Y CAMBIO DE LA VÁLVULA MARIPOSA

La Central Hidráulica Charcani V, con 139 MW de potencia efectiva, se terminó de construir en Enero del año 1988, esta se abastece de agua desde la Represa de Aguada Blanca a través de un túnel de aducción a presión con una longitud total de 10 078 metros. El túnel posee un diámetro interno de 3.1 metros y fue revestido en su totalidad en concreto armado con 30 cm de espesor como mínimo, llegando en algunas zonas hasta 60 cm. Adicionalmente al concreto armado, se uso blindaje metálico en una longitud de 4 035 metros con acero de 12 mm de espesor. Al final de dicho túnel se encuentra una válvula mariposa de 2.2 m de diámetro que esta conectada a la tubería forzada de la central. La función de la válvula mariposa es cerrar el flujo de agua para dar mantenimiento a la tubería forzada y válvulas esféricas de los grupos de la central, o para casos de emergencia.

En las pruebas de llenado del túnel (Enero de 1988) se presentaron fisuras en las paredes internas que normalmente se producen por contracción del concreto, las cuales fueron correctamente tratadas con revestimiento epóxico, entrando el túnel en total operación en el mes de Noviembre de 1988, fecha en la que se iniciaron las pruebas de puesta en servicio de la Central Charcani V.

En el año 1997 el fabricante de la válvula mariposa, ASLTOM FRANCIA recomendó se cambie esta válvula, por presentar problemas de estanqueidad que podrían incrementarse en lo posterior.

A consecuencia de este informe y recomendación, EGASA procedió a la adquisición de una nueva válvula mariposa mediante concurso, y programó la inspección del túnel de aducción y cambio de la válvula para los primeros meses del año 2002. Cabe mencionar que para el cambio de la válvula se requiere necesariamente del vaciado del túnel; para ello EGASA contrató un seguro especial para cubrir posibles riesgos en el vaciado del túnel y cambio de la válvula mariposa.

VACIADO DEL TUNEL:

Para proceder al vaciado del túnel el consultor seleccionado por concurso S&Z preparó el Protocolo de Vaciado, Inspección y Llenado del Túnel de la C.H. Charcani V, el mismo que contempló vaciarlo en dos etapas.

El 23 de Enero del 2002, se inició el vaciado de la primera etapa, purgando la mayor parte de agua de la chimenea de equilibrio por las válvulas By-Pass de la ventana N° 1 del túnel a un régimen de 1.5 m por hora de altura y por un periodo de 16 horas.

La segunda etapa se inicio al día siguiente, comenzando a vaciar el túnel a través del turbinado del agua con un caudal regulado de un m3/seg con un descenso de 1.5 m /hora de altura, por un periodo de 28 horas. El volumen de agua evacuado del túnel fue del orden de 90 000 m3, lográndose vaciar por completo en 44 horas; luego se ventilo por 24 horas mas para proceder a su inspección.

INSPECCIÓN DEL TÚNEL

El día 26 y 27 de Enero se inspecciono la longitud total del túnel, desde la cámara de compuertas (Aguada Blanca) hasta la Cámara de Válvulas, en la cual participaron personal de EGASA, empresa SyZ, y el inspector de la compañía de seguros contratada. También participaron en la inspección del túnel la alta dirección de EGASA, compuesta por el Directorio y la Gerencia General.

También se realizo la inspección de parte del conducto forzado y de su junta de dilatación.

Durante el recorrido se pudo observa r que el tramo de concreto esta en buen estado de conservación, incluso se realizaron pruebas de resistencia del concreto con un esclerometro dando resultados de 360 y 320 kg/cm2 de resistencia a la compresión (resistencia de diseño f'c=245 kg/cm2). El tratamiento de las fisuras con la resina epoxica empleada, no ha sufrido deterioro alguno, conservándose hasta la actualidad en muy buenas condiciones. Cabe mencionar que no se encontraron huellas de retornos ni salidas de agua.

El tramo blindado se encontró en buen estado de conservación, no observándose deformaciones de blindaje ni menos desprendimientos de los tapones tratados con resina epoxica, la pintura en general esta en buen estado, acorde con los trece años de utilización continua del túnel.

También se inspeccionó la tubería forzada, la chimenea de equilibrio, y el tramo de distribución hacia las válvulas esféricas, encontrándose también estos en similar estado.

Durante los días 25 al 31 de Enero se procedió al reemplazó de la válvula mariposa, el cual se realizo dentro del cronograma previsto y sin mayores inconvenientes.

LLENADO DEL TUNEL:

El proceso de llenado se inicio el día 01 de Febrero del 2002, con un caudal promedio de 1,25 m3/s y una apertura de 25 mm de la compuerta de Aguada Blanca.

El llenado concluyo el día 2 de Febrero, procediéndose a realizar las pruebas de la válvula mariposa con carga estabilizada y pruebas de funcionamiento de los equipos en casa de maquinas.

El día 3 de Febrero se procedió al cierre de compuertas del túnel en Aguada Blanca para medir perdidas, después de haber tenido el túnel lleno y sin movimiento por 12 horas; la medición se realizo durante una hora cada 5 minutos. El resultado de la prueba de estanqueidad fueron satisfactorios al no registrarse perdidas.

Se procedió luego a poner en servicio la Central Hidráulica Charcani V, el mismo día 3 de Febrero , totalizando la parada de central solo doce días para llevar a cabo todo el proceso anterior.

Se concluyo luego de la inspección que el túnel se encuentra en excelente estado de conservación, acorde con los diseños definitivos y los procedimientos adecuados empleados en su proceso constructivo.

Con la experiencia adquirida durante esta inspección se establecerá un cronograma para futuras inspecciones, que permita que personal de EGASA realice el mismo trabajo.

Aprovechando la parada de la Central, también se realizo la inspección y reparación de las válvulas esféricas de los Grupos 2 y 3 de la Central Charcani V.

VI. COSTOS DE MANTENIMIENTO

El monto total del Reapriete del núcleo estatorico y mantenimiento del generador asciende a la suma de US. $ 714 869.96 (Setecientos Catorce Mil Ochocientos Sesenta y nueve y 96/100 Dólares Americanos).

En lo que respecta al Reapriete del Núcleo del Estator del Grupos N° 02, el monto a pagar por el presento contrato, a suma alzada, asciende al Us. $ 281 081.91 (Doscientos Ochenta y un Mil Ochenta y uno y 91/100 Dólares Americanos) incluido impuestos de la legislación tributaria peruana.

Respecto a los Suministros y a los servicios de Mantenimiento del Grupo N° 02 el monto a pagar, a suma alzada, asciende a la cantidad de US $. 65 407.40 (Sesenta y cinco Mil Cuatrocientos Siete y 40/100 Dólares Americanos) incluido impuestos de la legislación tributaria peruana.

Respecto al Mantenimiento y Calibración de 03 Reguladores de los Grupos, el monto a pagar asciende a la suma de US $ 14 811.36 (Catorce Mil Ochocientos once y 36 Dólares Americanos) incluido impuestos de la legislación tributaria peruana.

Respecto al Seguro de Desmontaje de los 02 Generadores (Grupos N° 02 y 03) el monto a pagar es de US $ 7 080.00 (Siete Mil Ochenta y 00/100 Dólares Americanos) incluido impuestos de la legislación tributaria peruana.

Se considera dentro de estos rubros los derechos de ad valorem, Impuesto General a las Ventas, gastos de agente de aduana y cualquier otro que se relacione directamente con la exportación temporal, internamiento y nacionalización de dichos bines en lo que respecta al valor agregado del Reapriete del Núcleo y mantenimiento.

Los materiales y repuestos a comprar para el mantenimiento se muestran en los anexos siguientes:

RELACION DE REPUESTOS PARA REPARACIONES Y MANTENIMIENTO DE GRUPOS GENERADORES DE FABRICACION FRANCESA DE CHARCANI V

1. RELACION DE LOS REPUESTOS DE LAS VALVULAS ESFERICAS CENTRAL HIDRÁULICA CHARCANI V FABRICANTE Y PROYECTISTA DE LOS EQUIPOS NEYRPIC (ALSTHOM) PLANOS DE REFERENCIA N°: GHF NT-CM / Q 428; ... Q 441

Item	Cant.	Unid.	Descripcion	Ref./Plano	N°: Plano: NT-CM/Q...	N°:Plano : NEYRPIC
1.1	1	Pieza	Anillo de Estanqueidad Fijo	U9	428	
1.2	1	Pieza	Anillo de Estanqueidad Movil	U10	428	
1.3	1	Jgos	Jgo. de Juntas para Anillos de Estanqueidad de V. Esferica según cada Jgo Contiene::			
1.3.1			- Juntas para anillo movil tipo "D"	F17	428	
1.3.2			- Juntas para anillo movil tipo "D"	F18	428	
1.3.3			- Juntas para anillo movil tipo "D"	F19	428	
1.3.4			- Junta toroidal (O-Ring)	F20	428	
4	20	Mtrs.	Cordon de Nitrilo de Ø 16 para Manguito de Desmontaje	F6	441	
5	1	Pza.	Valvula de cierre abertura anillo estanq. aguas arriba		428	

2. RELACION DE LOS REPUESTOS DEL SISTEMA DE REGULACION DE TURBINA CENTRAL HIDRÁULICA CHARCANI V

FABRICANTE Y PROYECTISTA DE LOS EQUIPOS NEYRPIC (ALSTHOM) PLANOS DE REFERENCIA N°:
GHF TN-CM / M-200

Item	Cant.	Unid.	Descripcion	Ref./Plano	N°: Plano: NT-CM/Q...	N°:Plano: NEYRPIC
2.1	5	Pieza	Distribuidor completo de aceite, mando de inyector	160	200	
2.3	1	Pieza	Electrovalvula 140V=, Mc. REXROTH; 4WE6D51/AG...	BG,BF,...	200	
2.4	1	Pieza	Electrovalvula 140V=, 0.2A; REXROTH; M-3SE10C20/...21 W.	BA, BE	200	
2.5	1	Pieza	Electrovalvula de 3 Vias, para aire; Mc: SOCOMECO-V; 140V=, 22 W; Tipo SNRI.	BJ	200	
2.7	2	Pieza	Tomas de presion 0-70Bar		200	
2.8	4	Pieza	Manometros 0-100 Bar, Esfera 90, conector 1/2"Ø	139;156;157	200	
2.11	1	Jgs.	**Repuestos para Bomba Regulacion S.IMO ALA 324L Conformado por: (Ref: pgs 4 y 5; Folleto N° ALA 003 NEYRPIC), Cada Jgo contiene:**		200	
2.11.1			-Un Sealing Washer (Rep: Item 139)			
2.11.2			- Un O-ring (Rep. Item: 140)			
2.11.3			- Un Sealining bush (Rep. Item: 509A)			
2.11.4			- Un O-ring (Rep. Item: 509B)			
2.11.5			- Dos Sping (Rep. Item: 509C)			
2.11.6			- Un Washer (Rep. Item: 509D)			
2.14	3	Pieza	Presostato Regulauto tipo: ZPN-207-SI EF; 0-100 Bar	CC, CG, LB	200	
2,15	1	Pieza	Valvula de aislamiente del acumulador	132	200	
2,18	1	Pieza	Valvula Rele mando de valvula esferica	116	200	
2.20	5	Jgs.	Orrienes para Distribuidor de Acente, mando de Inyectores, cada Jgo contiene:			
2.20.1			O-Ring de Øe 37 x 3.5 mm Esp.			
2.20.2			O-Ring de Øe 28 x 3.5 mm Esp.			
2.20.3			O-Ring de Øe 29 x 3.5 mm Esp.			
2.20.4			O-Ring de Øe 17 x 3.5 mm Esp.			
2.20.5			O-Ring de Øe 40 x 3.5 mm Esp.			
2.20.6			O-Ring de Øe 53 x 3.5 mm Esp.			
2.20.7			O-Ring de Øe 55 x 3.5 mm Esp.			
2.20.8			O-Ring de Øe 40 x 3.5 Esp.			

3. RELACION DE REPUESTOS DE COJINETE CONVINADO GUIA - EMPUJE Y TURBINA CENTRAL HIDRÁULICA CHARCANI V FABRICANTE Y PROYECTISTA DE LOS EQUIPOS NEYRPIC (ALSTHOM) PLANOS DE REFERENCIA N°: GHF TN-CM / Q 903

Item	Cant.	Unid.	Descripcion	Ref./Plano	N°: Plano: NT-CM/Q...	N°:Plano: NEYRPIC
3.2	2	Jgos.	Conjunto SELLO MECANICO, para Bomba de Circul. de aceite SCAM IMO Tipo:ACF-90-3N3F, Conformado por:			
3.2.1			- Rotating washer (Rep Item. 509A)			
3.2.2			- Rubber ring (Rep Item. 509C)			
3.2.3			- Disc (Rep Item. 509D)			
3.2.4			- Spring (Rep Item. 509E)			
3.2.5			- Gland (Rep Item. 511)			
3.2.6			- *O-ring for gland (Rep Item. 511A)*			
3.5	2	Pza	Sondas Termometricas Mc: Schulumberger, Platino 100 Ohm=0° (termostatos para Coj. Empuje)	CS,CT, CU, ...	903	
3.6	3	Pza	Controlador de nivel aceite del Coj. Empuje, Boya Acero Inox, con Guia, contacto acionado Magnetico.	CQ, LR, LS	903	
3.10	30	Pza	Arandela tipo estrella de seguridad (Lock-Washer), Cadmiada de Øi 12.0 x 1 mm de Esp.	F18, F19		511803
3.11	30	Pza	Arandela tipo estrella de seguridad (Lock-Washer), Cadmiada de Øi 10.5 x 1 mm de Esp.	F27		511818
3.12	20	Pza	Arandela plana (-Washer), de Øi 27 x 1.5 mm de Esp. De Cu, Sello para sondas			
3.13	50	Pza	Pernos M12 x 300 mm, paso 1.75; Acero Grado 6.6	F6		511803
3.14	30	Mtrs	Cordon de nitrilo de 2.7 mm Esp. para juntas de Manguito U1-EP10	F41		580839
3.15	100	Mtrs	Cordon de nitrilo de 6.4 mm Esp. para juntas Casqullo U7-EP10	F17, F20, F29		511802; y 511803
3.16	10	Pza	Manguera de Ø 6mm, alta presin con alma de acero para 300 Bar, con sus conectores y terminaciones en un extremo M30, paso 1.5mm: y el otro extrem Terminacion para ajuste y codo M16 Paso 1.5mm.	F11-EP13		580892
3.17	2	Pza	Segmento de PVC para Vaina U8 de Øi 869 y Øe 903 mm.	U9		511803
3.18	20	Pza	Juntas O-Ring de nitrilo de Øi 37.5 x 5.3 Esp.	F13	/Q909	580085
3.19	20	Pza	Juntas O-Ring de nitrilo de Øi 50 x 2.0 Esp.	EP2 U3	/Q909	580085
3.20	12	Pza	Juntas O-Ring de nitrilo de Øi 126 x 7.0 Esp.	EP10 U39 y F55		580870
3.21	30	Pza	Juntas O-Ring de nitrilo de Øi 75.6 x 5.3 Esp.	F21	/Q910	581095
3.22	20	Pza	Juntas O-Ring de nitrilo de Øi 19.8 x 3.6 Esp.	F5		580875
3.23	20	Pza	Juntas O-Ring de nitrilo de Øi 85 x 5.3 Esp.	F6		580875
3.24	20	Pza	Juntas O-Ring de nitrilo de Øi 35.6 x 3.6 Esp.	F7	/Q906	511798
3.25	20	Pza	Juntas O-Ring de nitrilo de Øi 74.7 x 5.3 Esp.			
3.26	20	Pza	Juntas O-Ring de nitrilo de Øi 68 x 4.0 Esp.			
3.27	20	Pza	Juntas O-Ring de nitrilo de Øi 84.0 x 3.2 Esp.			

Item	Cant.	Unid.	Descripcion	Ref./Plano	N°: Plano: NT-CM/Q...	N°:Plano: NEYRPIC
3.28	20	Mtrs	Condorn de nitrilo para O-Ring de Ø7 mm Esp.	F9	–	511798
3.29	12	Pza	Casquillo Aislante de Patin	U29	Q-903	
3.30	1	*Jgos*	Arandelas y Placas aislante conformado cada Jgo. por:		–	*580852*
3.30.1			- 15 Pzas de U28			
3.30.2			- 15 Pzas de U29			
3.30.3			- Una Pza de U30			
3.30.4			*- Una Pza de U31*			
3.30.5			- 8 Pzas de U32			
3.30.6			- 8 Pzas de U33			
3.30.7			- 24 Pzas. De U34			
3.30.8			- 24 Pzas. De U35			
3.31	20	Pza	Remache de Cobre, con Seguro para Rivet Ø6 x 20 mmLarg, Incluye Seguro de Ø 2 mm.			580832
3.32	40	Pza	Arandela plana (-Washer), de Øi 13 x 1.5 mm de Esp. De Cu, Sello para sondas		/Q903	
3.33	1	Pza	Conjunto de coneccion Equipotencia de patin Eje (Fourreau)	U36, 37, 38 F50, 51, 52, 53 y 54	/Q903	580865
3.34	1	Pza	Base de Goma apoyo de patines (COURONNE D' APPUI)	F22		511811

4. RELACION DE JUNTAS Y SELLOS USADOS EN DIVERSOS EQUIPOS DE LOS GRUPOS CENTRAL HIDRÁULICA CHARCANI V FABRICANTE Y PROYECTISTA DE LOS EQUIPOS NEYRPIC (ALSTHOM)

PLANOS DE REFERENCIA N°: GHF TN-CM / Q 903

NOTA: TODAS LAS JUNTAS CHEVRON Y SOLOSELE DEBEN SER DE FABRICACION JAMES WALKER (ENGLAND)

Item	Cant.	Unid.	Descripcion	Ref./Plano	N°: Plano: NT-CM/Q...	N°:Plano: NEYRPIC
4.1	2	Pza	Junta tórica (O-ring) de 3.6 x 26.2, Nitrilo	F8	431	
4.2	2	Pza	Junta tórica (O-ring) de 3.6 x 37.3, Nitrilo	F8	431	
4.3	3	Pza	Junta tórica (O-ring) de 5.3 x 40.6, Nitrilo	F26	475	
4.4	12	Pza	Junta tórica (O-ring) de 7 x 320, Nitrilo	F1	439	
4.5	6	Pza	Junta tórica (O-ring) de 10 x 252, Nitrilo	F	439	
4.6	6	Pza	Junta tórica (O-ring) de 10 x 230, Nitrilo	F25	439	
4.7	80	Mtrs.	Empaque redondo (Cordon de Nitrilo) de Ø 7 mm			
4.8	20	Mtrs.	Empaque redondo (Cordon de Nitrilo) de Ø 5.3 mm		472,	
4.9	5	Mtrs.	Empaque redondo (Cordon de Nitrilo) de Ø 2.7 mm		477	
4.10	100	Mtrs.	Empaque redondo (Cordon de Nitrilo) de Ø 8 mm			
4.11	50	Mtrs.	Empaque redondo (Cordon de Nitrilo) de Ø 6 mm			
4.12	50	Mtrs.	Empaque redondo (Cordon de Nitrilo) de Ø 10 mm		417, 441	
4.13	1	Pza	Junta Chevron 185 x 215 - 50.5, de Lona-Nitrilo	F9	431	
4.14	8	Pza	Junta Chevron 190 x 220 - 45, de Lona-Nitrilo	F5	439	
4.15	8	Pza	Junta Chevron 285 x 315 - 45, de Lona-Nitrilo	F8	439	
4.16	4	Pza	Junta Chevron 120 x 145 - 42, de Lona-Nitrilo	F6	439	
4.17	3	Pza	Junta Chevron 70 x 90 - 30, de Lona-Nitrilo	F19	442	
4.18	3	Pza	Junta Chevron 63 x 83 - 30, de Lona-Nitrilo	F11	442	
4.19	1	Pza	Sello SOLOSELE 100 x 120, de Lona-Nitrilo	F19	431	

5. **RELACION DE REPUESTOS PARA LOS GENERADORES CENTRAL HIDRÁULICA CHARCANI V FABRICANTE Y PROYECTISTA DE LOS EQUIPOS ALSTHOM ATLANTIQUE.**

PLANOS DE REFERENCIA N°: GHF AA-CM / ....

Item	Cant.	Unid.	Descripcion	Ref./Plano	N°: Plano: AA-CM/....
5.4	3	Pzs	Sonda termostato con 6 m de cable, dos unbrales ajustables Esfera 960mm, Escala 0-120°C, Para coj. Generador	28-10-081	C-004
5.5	1	Pza	Motor ventilador de cajas Thiritores, tipo: TZA-01- 335-41, 220/380 V, 7.5 KW, 60 HZ con termocontacto de bobinado Fab: Wichelh gebhardt	001ZV	S-004
5.6	2	Pza.	Caja de thiristores completo, Constituye de 3 Thiristores y su sistema de Proteccion	00...RD	S-004
5.7	60	Pzas	O-Roing de Nitrilo de Øi 333 mm x 7mm Esp; para Junta De garos de Freno ; Ref. Anillo R N° 60	N°: 9 y 10	H-004
5.8	20	Pzas	Junta de Nitrilo son Lona Para Øi 133, x Alto 20 mm; ,para Gato de Freno : Ref: Junta SE R N° 705	N° 11	H-004

COSTOS REFERENCIALES DE REPUESTOS

ITEM	CANT.	P.U.	P.TOTAL	DESCRIPCION
1				**Sistema de Regulación de Turbina (Plano NEYRPIC Nº 484703E)**
1.1	5	6934.87	34 674.34	Distribuidor completo de aceite, mando de inyector C Ref. 160
1.2	5	42.11	210.57	Tomas de presión 0 - 70 Bar
1.3	4	189.52	758.06	Manómetro 0-100 Bar Ref. 139, 156, 157
1.4	1	484.32	484.32	Boya sensor nivel de aceite JOLA tipo SSP 4WP4 Ref. LH
1.5	1	5608,26	5608.26	Bomba completa de regulación SCAM IMO typo ALA 32-4L N5ES con motor 12,6 kW/3500 rpm Ref. AE-AF
1.6	1	884,41	884,41	Juego de Juntas de sello del servomotor Ref. 159
1.7	1	7461,3	7461,3	Accionador TR 10 con 2 inyectores gira 160 bar Ref. FA
1.8	1	2274,19	2274,19	Variómetro tipo C20 (034.600.2086) Ref FB
1.9	1	6359,3	6359,3	Válvula de aislamiento de acumulador C Ref. 132
1.10	1	842,29	842,29	Elemento filtro 70 u del tanque de regulación C Ref 155
1.11				Juego de repuestos para bomba regulación SCAM IMO ALA 324L conformado por:
	3			Orring Rep. Item 520A
	3			Sealing Bush Rep. Item 509A
	3			Orring Rep. Item 509B
	3			Spring Rep. Item 509C
	3			Washer Rep. Item 509D
		954,6	954,6	
2				**Valvula Esferica (Plano NEYRPIC Nº 507963C - 507938A**
2.1	2	7812,25	15624,51	Anillo fijo Ref U9
2.2.	2	12641,39	25282,79	Anillo móvil Ref U10
3				**Cojinete Guia de Empuje (Plano NEYRPIC Nº 580988 - 584007**
3.1	1	15807,01	15807,01	Bomba completa de aceite de circulación SCAM IMO ACF090-N4-IRBO en sustitución de bomba ACF 90 3N2F que no se fabrica mas Ref. AI AJ
3.2	2	849,31	1698,62	Elementos de filtro doble de aceite de circulación del cojinete de empuje 40 um
3.3	2	1333,63	2667,26	Elementos de filtro doble de aceite de inyección del cojinete de empuje 70 um
3.4	3	1839	5517	Controlador de nivel de aceite del cojinete empuje con guía acero y rueda Ref. CQ LR LS

ITEM	CANT.	P.U.	P.TOTAL	DESCRIPCION
3.5	1	4344,82	4344,82	Juego repuestos para bomba SCAM IMO ACF90 3N27 Conformado por: Rotating washer Rep. Item 509A (Cant. 1) Rubber ring Rep. Item 509 C (Cant. 1) Disc Rep. Item 509D (Cant. 1) Sping Rep. Item 509E (Cant. 1) Gland Rep. Item 511 (Cant. 1) Oring for Gland Rep. Item 511A (Cant. 20)
3.6	1	954,6	954,6	Juego de repuestos para bomba de regulación SCAM IMO ALA 324L, conformado por: Oring Rep. Item 520A (Cant. 3) Sealing Bush Rep. Item 509A (Cant. 3) Oring Rep. Item 509B(Cant. 3) Sping Rep. Item 509C (Cant. 3) Washer Rep. Item 509D(Cant. 3)
4				**Alternador**
4.1	1	20832,68	20832,68	Juego de 6 zapatas de freno Ref. 7,8 (AA-CM/H-004)
4.2	3	4000,89	12002,66	Teletermometro con 6 m de cable dos brales ajustables, tem, metal coj Generador esfera 960,0-120C Ref. 28-10-081 Obs. AA/CM/C-004. Material equivalente al de origen y totalmente compatible con los equipos existentes.
4.3	1	23064,75	23064,75	Motor ventilador de caja de thiristores TZA 335-415 tp 10, 220/380 60Hz con termo contacto de bobinado. Material equivalente al de origen y totalmente compatible con los equipos existentes.
5				**Diversos**
5.1	2	884,41	1768,81	Termostato tipo ZT - 403 - SAM margen de ajuste 40- 120 °C, 2 micro inter, 6m cable sensor
		Total =	148341,6	

VII. CONCLUSIONES

Dentro de las conclusiones principales tenemos:

- Se evidenció la necesidad de implantar y definir un mantenimiento predictivo para garantizar el servicio del grupo generador de tal forma que se eviten las paradas imprevistas.
- Realizar las correcciones y renovaciones de los objetivos planteados en los mantenimientos preventivos de tal manera que eviten el deterioro y acortamiento de vida de servicio de los equipos que conforman el grupo generador.
- Capacitar al personal técnico en todos los niveles en forma continua.

VIII. ANEXOS

1. ANEXO I

Características Técnicas de las Centrales Hidráulicas y Térmicas de EGASA

CARACTERÍSTICAS TÉCNICAS
MINICENTRAL HIDRÁULICA CHARCANI I

CENTRAL	*unidad*		
Numero de unidades		2	
Potencia instalada	KW	1760	
Grupo		N ° 1	N ° 2
Diametro de tuberia forzada	mm	1490	
Puesta en servicio		3 de julio de 1998	18 de junio de 1998
Turbina			
Fabricante			
Tipo		Francis doble	Francis doble
Eje		horizontal	horizontal
Potencia	h p	1,350	1350
Caudal	m3/s	4.85	4.85
Salto	m	26	26
Velocidad	r.p.m.	450	450
Numero de Serie			
Generador			
Fabricante		Electro Mecánica Suiza S.A.	Electro Mecánica Suiza S.A.
Procendencia		Brasil	Brasil
Tipo		WH 1.100 H 16 PB 6	WH 1.100 H 16 PB 6
Numero de Serie		1,871	s/n
Potencia Aparente	kVA	1,100	1100
Potencia nominal	KW	880	880
Tension nominal	V	4160	4160
Amperios	A	153	153
Factor de potencia		0.8	0.8
Velocidad	r.p.m	450	450
Frecuencia	hz	60	60
Excitatriz			
Marca		Electro Mecánica Suiza S.A.	Electro Mecánica Suiza S.A.
Tipo			
N° de serie			
Potencia	kW	10	10
Tension	V	125	125
Amperios	A		
Regulador			
Modelo			
N° de serie			
Transformador			
Marca		Elecsur Industrial S.R. Ltda.	Elecsur Industrial S.R. Ltda.
N° de Serie		436	444
Potencia Nominal	KVA	1100	1100
Frecuencia	hz	60	60
Tension nominal		5200/4160	5200/4160
Grupo de conexion			

CARACTERÍSTICAS TÉCNICAS
CENTRAL HIDRÁULICA CHARCANI I

CENTRAL	unidad		
Numero de unidades		2	
Potencia instalada	KW	1472	
Grupo		N ° 1	N ° 2
Puesta en servicio		1929	1907
Turbina			
Fabricante		J.M. VOITH	J.M. VOITH
Tipo		FRANCIS	FRANCIS
Eje		horizontal	horizontal
Potencia	h p	1,500	700
Caudal	m3/s	5.02	2.57
Salto	m	27.2	27.2
Diametro de tuberia forzada	mm	1450	1200
Velocidad	r.p.m.	500	500
Numero de Serie		10202	2828
Generador			
Fabricante		Siemens Schuckert Werke	Siemens Schuckert Werke
Tipo		VFW 500 / 9-12	WJD 525
Numero de Serie		2005560D	195775 N
Potencia Aparente	kVA	1,250	590
Potencia nominal	KW	1,000	472
Tension nominal	V	5250 - Y	5700
Amperios	A	138	59.8
Factor de potencia		0.8	0.8
Velocidad	r.p.m	500	500
Frecuencia	hz	50	50
Excitatriz			
Marca		Siemens Schuckert Werke	Siemens Schuckert Werke
Tipo		GV - 240	V - 11
N° de serie		18913998	176447 - N
Potencia	kW	14.2	6.8
Tension	V	110	45
Amperios	A	129	155
Regulador			
Modelo		J.M. VOITH	J.M. VOITH
N° de serie		210556	157473 & 157869
Transformador			
Marca		B.B.C.	
N° de serie		L10642	
Potencia Nominal	KVA	11,500	
Frecuencia	hz	60	
Tension nominal		32820/10500-5250	
Grupo de conexion		Yd 11	
Tension de corto circuito		5,1/6,1%	
Regulacion		±2 x 2.5	
Posicion tap actual		3	

CARACTERÍSTICAS TÉCNICAS
CENTRAL HIDRÁULICA CHARCANI II

CENTRAL	unidad			
Numero de unidades		3		
Potencia instalada	KW	792		
Grupo		N° 1	N° 2	N° 3
Diametro tuberia forzada	mm	1000		
Puesta en servicio		1912	1912	1921
Turbina				
Fabricante		J.M.VOITH	J.M. VOITH	J.M. VOITH
Numero de Serie		4552	4553	7097
Tipo		FRANCIS	FRANCIS	FRANCIS
Eje		horizontal	horizontal	horizontal
Potencia	h p	390	390	390
Caudal	m3/s	2	2	2
Salto	m	18.7	18.7	18.7
Velocidad	r.p.m.	600	600	600
Regulador				
Modelo		J.M.VOITH	J.M. VOITH	J.M. VOITH
Numero de Serie		2182	2183	3657
Generador				
Fabricante		Siemens Schuckert Werke	Siemens Schuckert Werke	Siemens Schuckert Werke
Tipo		WJD 330/500	WJD 330/500	WJD 330/500
Numero de Serie		476365 - N	476366 - N	1182822 - N
Potencia aparente	kVA	330	330	330
Potencia nominal	KW	264	264	264
Tension nominal	V	5700/5000	5700/5000	5700/5000
Amperios	A	33,5/38,2	33,5/38,2	33,5/38,2
Factor de potencia		0.8	0.8	0.8
Velocidad	r.p.m	600	600	600
Frecuencia	hz	60	60	60
Excitatriz				
Marca		SSW	SSW	SSW
Tipo		GV - 190	GV - 190	GV - 190
N° de serie		395579 - N	395580 - N	1099527 - N
Potencia	kW	6.6	6.6	6.6
Tension	V	110	110	110
Amperios	A	60	60	60

CARACTERÍSTICAS TÉCNICAS
CENTRAL HIDRÁULICA CHARCANI III

CENTRAL	unidad		
Numero de unidades		2	
Potencia instalada	KW	4560	
Grupo		N° 1	N° 2
Puesta en servicio		1938	1942
Turbina			
Fabricante		J.M.VOITH	ESCHER WYSS
Numero de Serie		12697	9679
Tipo		FRANCIS DOBLE	FRANCIS DOBLE
Eje		horizontal	horizontal
Potencia	H p	3120	3260
Caudal	M3/s	5	5
Salto	m	57.5	57.5
Diámetro de tubería forzada	mm	1490	1490
Velocidad	r.p.m.	720	600
Regulador			
Modelo		J.M.VOITH	ESCHER WYSS
Numero de Serie		7446	740
Generador			
Fabricante		Siemens Schuckert Werke	ABB
Tipo		VFW500/22-10	PGCC 710 LD 12 B3
Numero de Serie		12697	349365
Año de fabricación		1938	1994
Potencia aparente	kVA	2800	2864
Potencia nominal	KW	2240	2320
Tension nominal	V	5250	5250
Amperios	A	308	315
Factor de potencia		0.8	0.81
Velocidad	r.p.m	720	600
Frecuencia	hz	60	60
Excitatriz			
Marca		Siemens Schuckert Werke	
Tipo		GV - 190	
N° de serie		395579 - N	
Potencia	kW	6.6	
Tension	V	110	
Amperios	A	60	

CARACTERÍSTICAS TÉCNICAS
CENTRAL HIDRÁULICA CHARCANI IV

CENTRAL	unidad			
Numero de unidades		3		
Potencia instalada	Kw	14400		
Grupo		N° 1	N° 2	N° 3
Puesta en servicio		1959	1963	1970
Turbina				
Fabricante		CHARMILLES	CHARMILLES	CHARMILLES
Numero de Serie		2193	2270	
Tipo		FRANCIS	FRANCIS	FRANCIS
Eje		horizontal	horizontal	horizontal
Potencia	h.p.	6910	6910	6910
Caudal	m3/s	5	5	5
Salto	m	117.35	117.35	117.35
Diametro tuberia forzada	mm	1200	1200	1200
Velocidad	r.p.m.	720	720	720
Generador				
Fabricante		BBC	BBC	BBC
Tipo		WAS 140/100/10	WAS 140/100/10	WAS 140/100/10
Numero de Serie				
Año de Fabricacion		1993	1993	1993
Potencia aparente	KVA	6000	6000	6000
Potencia nominal	KW	4800	4800	4800
Tension nominal	V	5250±5%	5250±5%	5250±5%
Amperios	A	660	660	660
Factor de potencia		0.8	0.8	0.8
Velocidad	r.p.m	720	720	720
Frecuencia	hz	60	60	60
Excitatriz				
Marca		BBC	BBC	BBC
Tipo		GF - 166 b	GF - 166 b	GF - 166 b
N° de serie		A.402116	A.603376	B.69734
Potencia	kW	30	30	30
Tension	V	78	78	78
Amperios	A	385	385	385
Transformador				
Marca		B.B.C.	B.B.C.	B.B.C.
N° de serie				L10463
Potencia Nominal	kVA	6000	6000	6000
Frecuencia	hz	50	50	50
Tension nominal		37000-36300-35600-34900-34200 / 5250	37000-36300-35600-34900-34200 / 5250	37000-36300-35600-34900-34200 / 5250
Grupo de conexion		Yd 11	Yd 11	Yd 11
Tension de corto circuito		6.30%	6.21%	6.30%
Regulacion		±2 x 2.0	±2 x 2.0	±2 x 2.0
Posicion tap actual		4	4	4

CARACTERÍSTICAS TÉCNICAS
CENTRAL HIDRÁULICA CHARCANI V

CENTRAL	Unidad			
Numero de unidades		3		
Potencia instalada	KW	135000		
Grupo		N ° 1	N ° 2	N ° 3
Puesta en servicio		1988	1989	1989
Turbina				
Fabricante		NEYRPIC	NEYRPIC	NEYRPIC
Tipo		PELTON	PELTON	PELTON
Puesta en servicio		11/11/88	12/07/88	19/12/88
Numero de modelo		67042	67042	67042
Eje		vertical	vertical	vertical
Potencia	kW	51290	51290	51290
Caudal	m3/s	8.3	8.3	8.3
Salto	m	706.4	706.4	706.4
Diametro tub c/grupo	mm	900	900	900
Diametro tuberia forzada	mm		3 tramos	sup/med/inferi
Velocidad	r.p.m.	600	600	600
Generador				
Fabricante		Alsthom Atlantic	Alsthom Atlantic	Alsthom Atlantic
Tipo		RYV 366.153	RYV 366.153	RYV 366.153
Numero de serie		411514	411515	411516
Potencia nominal	kVA	57000	57000	57000
Tension nominal	V	13800	13800	13800
Amperios	A	2385	2385	2385
Factor de potencia		0.85	0.85	0.85
Velocidad	r:p.m	600	600	600
Frecuencia	hz	60	60	60
Excitatriz				
Fabricante		Alsthom Atlantic	Alsthom Atlantic	Alsthom Atlantic
Tipo		Estatico c/tyristores	Estatico c/tyristores	Estatico c/tyristores
Tension	V	121	121	121
Amperios	A	1024	1024	1024
Transformador				
Marca		Alsthom Atlantic	Alsthom Atlantic	Alsthom Atlantic
N° de serie		224605-01	224605-02	224605-03
Potencia Nominal	kVA	57000	57000	57000
Frecuencia	hz	60	60	60
Tension nominal		149100 - 142000 - 134900 /	149100 - 145550 142000 - 138450 134900 / 13800	149100 - 142000 - 134900 /
Grupo de conexion		Y N d 11	Y N d 11	Y N d 11
Tension de corto circuito	%	13.20	13.38	13.22
Regulacion				
Posicion tap actual		2	2	2

EGASA
EMPRESA DE GENERACION ELECTRICA DE AREQUIPA S.A.

CARACTERÍSTICAS TÉCNICAS
CENTRAL HIDRÁULICA CHARCANI VI

CENTRAL	unidad		
Numero de unidades		1	
Potencia Instalada	KW		**8960**
Frecuencia de trabajo	Hz	50	**60**
Grupo			
Puesta en servicio		1 9 7 6	1 9 7 6
Turbina			
Fabricante		CHARMILLES	CHARMILLES
Tipo		HORIZONTAL	HORIZONTAL
Eje		FRANCIS HORIZONTAL	FRANCIS HORIZONTAL
Potencia	h.p.	12050	12450
Caudal	m3/s	15	15
Salto	m	69	69
Diametro tuberia	mm		1800
Velocidad	r.p.m.	428.6	514.3
Generador			
Fabricante		B B C	
Numero de Serie		HM - 20003	
Potencia aparente	kVA	10800	11200
Potencia nominal	KW		**8960**
Tension nominal	V	5250 Y	5250 Y
Amperios	A	1188	1233
Factor de potencia		0.8	0.8
Velocidad	r.p.m	428.6	514.03
Frecuencia	hz	50	60
Tipo		W A S 185 / 125 /14	
Excitatriz			
Marca		B B C	
Tipo		GF - 21670	piloto CFc 134 a
N° de serie		HM 270017	HM 270018
Potencia	kW	(90 / 60) / 146	piloto 3
Tension	V	(165 / 135) / 210	piloto 85
Amperios	A	(545 / 445) / 695	piloto 35
Transformador			
Marca		B.B.C.	
N° de serie		L11381	
Potencia Nominal	kVA	11200	
Frecuencia	hz	60	
Tension nominal	V	37000-36300- 35600-34900- 34200/5250	
Grupo de conexion		Yd 11	
Tension de corto circuito		6.20%	
Regulacion		±2 x 2.0	
Posicion tap actual		5	

CARACTERÍSTICAS TÉCNICAS
CENTRAL TÉRMICA DE CHILINA

CENTRAL	Unidad	Central Termica de Chilina		
GRUPOS DE VAPOR		N ° 1	N ° 2	N ° 3
Caldera				
Puesta en servicio	Año	1955	1968	1979
Fabricante		Franco Tosi	Franco Tosi	Standard Kessel
Tipo		Acuotubular	Acuotubular	Acuotubular
Produccion vapor	tn / h	20	42	54
Presion	kg / cm2	32	33	32
Temperatura	°C	410	410	410
Combustible		Industrial R500	Industrial R500	Industrial R500
Quemadores : tipo		mecanico	mec. c/fluido aux.	copa rotativa
numero		tres	dos	dos
N° de fabrica		6958	7678	
Turbina de condensacion				
Fabricante		BBC - BADEN	BBC - BADEN	BBC - M
Numero de fabrica		B. 22008	B. 44828	25 - 1036 -76
Tipo		D F g - 28	D F g - 34 BK	D K - 1180 - D
Potencia max. en bornes	kW	4000	7000	10000
Presion	atm	27	28	28
Caudal de vapor	tn / h	20	42	54
Temperatura de vapor	°C	400	400	410
Velocidad	r.p.m.	3000	3000	7600
Generador				
Fabricante		BBC - BADEN	BBC - BADEN	BBC - CEM
Tipo		WT 532 a	WT 321 g	MSBHD 900ML-4
N° de fabrica		B - 59991	B - 67857	FN-31223
Potencia nominal	kVA	5330	8750	12500
Tension nominal	V	5250	5250	10500
Amperios	A	586	550	687
Factor de potencia		0.75	0.8	0.8
Frecuencia	hz	50	50	60
Velocidad	r.p.m.	3000	3000	1800
Excitatriz				
Fabricante		BBC - BADEN	BBC - BADEN	ENCO
Tipo		G. F. T. 36 c	G. F. T. 36 c	A L 3 2 - 135 M2
N° de Fabrica		B - 60459	B - 68298	750591 - 1
Potencia	kW	23.5	42	86
Tension	V	90 - 102	150	264
Amperios	A	260 - 300	280	325
Frecuencia	hz	50	50	60
		Generador DC	Generador DC	Alternador
Transformador				
Marca				B.B.C.
N° de serie				L30174
Potencia Nominal	KVA			12500
Frecuencia	hz			60
Tension nominal	V			33480 / 10500
Grupo de conexion				Ynd 11
Tension de corto circuito				8.8
Regulacion				±2 x 2.5
Posicion tap actual				2

CARACTERÍSTICAS TÉCNICAS
CENTRAL TÉRMICA DE CHILINA

CENTRAL	unidad		
GRUPOS DIESEL		N ° 1	N ° 2
Motor			
Fabricante		CCM - SULZER	CCM - SULZER
Numero de serie		101161 - 101172	101178 - 104484
Tipo		12ZV - 40 - 48	12ZV - 40 - 48
Año de fabricacion		1985	1985
Año de puesta en servicio		1987	1987
Potencia nominal	kW	5230	5230
Velocidad	r.p.m	514	514
Tipo de combustible		Petroleo Res. Nº6/Dies. Nº2	Petroleo Res. Nº6/Dies. Nº2
Generador			
Fabricante		C. E. M.	C. E. M.
Tipo		MWPD 270-43 / 14	MWPD 270-43 / 14
Nº de fabrica			
Potencia nominal	kVA	6540	6540
Tension nominal	V	10500	10500
Amperios	A	363	363
Factor de potencia		0.8	0.8
Frecuencia	hz	60	60
Velocidad	r.p.m.	514	514
Excitatriz			
Fabricante		ENCO	ENCO
Tipo		A200 / 270 LM2A	A200 / 270 LM2A
Nº de Fabrica		840 300 / 1	840 300 / 2
Potencia	kW		
Tension	V	220	220
Amperios	A	8.6	8.6
Frecuencia	hz	60	60
Velocidad	r.p.m.	514.3	514.3
Factor de potencia		0.425	0.425
		Generador de iman permanente	Generador de iman permanente
Transformador			
Marca		DELCROSA	DELCROSA
N° de serie		124559T2	124559T1
Potencia Nominal	KVA	7700	7700
Frecuencia	hz	60	60
Tension nominal	V	34900 / 10400	34900 / 10400
Grupo de conexion		Y n d 11	Y n d 11
Tension de corto circuito		8.47%	8.47%
Regulacion		± 4 x 2.5	± 4 x 2.5
Posicion tap actual		7	7

CARACTERÍSTICAS TÉCNICAS
CENTRAL TÉRMICA DE CHILINA

CENTRAL	unidad	Central Termica de Chilina
CICLO COMBINADO		
Turbina a gas		
Fabricante		AEG
Numero de fabrica		G.E. 245247
Tipo		Ms - 5001 P
Año de fabricacion		1975
Año de puesta en servicio		1981
Potencia nominal base	kW	16350
Potencia nominal pico	kW	17650
Altitud	m.s.n.m.	2360
Velocidad de rotacion	r. p. m.	5100
N° de etapas turbina		dos
N° de etapas compresor		diecisiete
Generador		
Fabricante		AEG - Telefunken
Tipo		SU 1090 L4 / 2ED
N° de fabrica		277/267
Potencia nominal	kVA	32000
Tension nominal	V	13800
Amperios	A	1339
Factor de potencia		0.8
Frecuencia	hz	60
Velocidad	r.p.m.	3600
Excitatriz		
Fabricante		AEG
Tipo		SY 5638 / 8F +Six1 - 2s
N° de Serie		2771272
Potencia	kW	125
Tension	V	190
Tension excitacion	V	660
Velocidad	r.p.m.	3600
Tipo de aislamiento		F
Proteccion		R 44
Caldera de recuperacion		
Año de fabricacion		1981
Año de puesta en servicio		1982
Fabricante		Standard Kessel
Tipo		Acuotubular
Caudal nominal	tn / h	31.5
Caudal real	tn / h	30
Presion de vapor	kg / cm2	27.89
Temperatura de vapor	°C	410
Transformador		
Marca		VOLTA - WERKE
N° de serie		60628-001
Potencia Nominal	KVA	28000
Frecuencia	hz	60
Tension nominal	V	33000 / 13800
Grupo de conexion		*d Y n*
Tension de corto circuito		11.80%
Regulacion		± 2 x 2.5
Posicion tap actual		

CARACTERÍSTICAS TECNICAS CENTRAL TÉRMICA DE CHILINA

CENTRAL	unidad		
CONVERTIDOR DE FRECUENCIA		**Máquinas de 50 Hz**	**Máquina de 60 Hz**
Frecuencia de operacion	Hz	**50**	**60**
Caracteristicas como Motor			
Fabricante		Brown Boveri Cia.	Brown Boveri Cia.
Numero de serie		H M 250001	H M 250002
Tipo		W A 167 / 100 / 10	W A 167 / 100 / 12
Año de fabricacion		1978	1978
Año de puesta en servicio		1979	1979
Potencia	kW	8590	8590
Tension	V	5250	5250
Amperaje	A	1210	1210
Factor de potencia		0.8	0.8
Frecuencia	hz	50	60
Velocidad	r.p.m	600	600
Caracteristicas como Generador			
Potencia nominal	kVA	10480	10480
Tension nominal	V	5250	5250
Amperaje	A	1155	1155
Factor de potencia		0.8	0.8
Tension de excitacion	V	138	129
Corriente de excitacion	A	440	486
Frecuencia	hz	50	60
Velocidad	r.p.m.	600	600
Peso del Estator	ton	15	15
Peso del Rotor Completo	ton	16.2	17.2
Peso Total	ton	31.2	32.2
GD2	Kgm2	22500	21500
Rotor Excitatriz Auxiliar			
Tension	V	141	131
Amperaje	A	449	496
Motor de arranque			
Tipo		WSyn 2210 Wo SP HM 1001165	
Tension	V	5000	
Amperaje	A	74	
Rotor :			
- Potencia	kW	485	
- Tension	V	708	
- Corriente	A	484	
- Frecuencia	hz	50	
- Velocidad	r. p. m.	584	
Transformador			
Marca			B B C
N° de serie			L11387
Potencia Nominal	KVA		11500
Frecuencia	hz		50 / 60
Tension nominal	V		32820 / 10500 - 5250
Grupo de conexion			Y d 11
Tension de corto circuito	%		8.47
Regulacion			± 2 x 2.5
Posicion tap actual			2

EGASA

EMPRESA DE GENERACION ELECTRICA DE AREQUIPA S.A.

CARACTERÍSTICAS TÉRMICAS
CENTRAL TÉRMICA DE MOLLENDO

CENTRAL	unidad			
GRUPOS DIESEL		N° 1	N° 2	N° 3
Motor				
Fabricante		MIRLEES BLACKSTONE	MIRLEES BLACKSTONE	MIRLEES BLACKSTONE
Motor N°		7156-01	7156-02	7156-03
Serie		963801	964402	965002
Tipo		16MB 430	16MB 430	16MB 430
Año de fabricacion		1996	1996	1997
Año de puesta en servicio		*7 de abril de 1998*	*7 de abril de 1998*	*7 de abril de 1998*
Potencia nominal	kW	10961	10961	10961
Velocidad	r.p.m	514	514	514
Tipo de combustible		Industrial R500	Industrial R500	Industrial R500
Generador				
Fabricante		BRUSH	BRUSH	BRUSH
Tipo		BSM140,168/14	BSM140,168/14	BSM140,168/14
N° de serie		62355A-1P	62355A-2P	62355A-3P
Potencia nominal aparente	kVA	13208	13208	13208
Potencia nominal activa	Kw	10566	10566	10566
Tension nominal	V	13800	13800	13800
Amperios	A	553	553	553
Factor de potencia		0.8	0.8	0.8
Frecuencia	hz	60	60	60
Velocidad	r.p.m.	514	514	514
Excitatriz				
Fabricante		BRUSH	BRUSH	BRUSH
Tipo		XL92,28/24	XL92,28/24	XL92,28/24
N° de Fabrica		62355A-1E	62355A-2E	62355A-3E
Tension	V	282	282	282
Amperios	A	22	22	22
Frecuencia	hz	102.9	102.9	102.9
Velocidad	r.p.m.	514	514	514
Transformador				
Marca		ABB		
Tipo		TD 2AF		
N° de serie		L-30498		
Potencia Nominal	MVA	32/40		
Enfriamiento		ONAN/ONAF		
Frecuencia	hz	60		
Tension nominal	V	138000/13800		
Grupo de conexion		Y n d 5		
Tension de corto circuito		9,7/12.1%		
Regulacion		± 2 x 2.5%		

CARACTERÍSTICAS TÉCNICAS
CENTRAL TÉRMICA DE MOLLENDO

CENTRAL	unidad		
TURBINAS A GAS ALSTOM		TGM1	TGM2
Turbina a gas			
Fabricante		Alstom Turbines a Gaz	Alstom Turbines a Gaz
Numero de fabrica		140670	140680
Tipo		6 000 A	6 000 A
Año de fabricacion		1999	1999
Año de puesta en servicio		1999	1999
Potencia nominal base		37.4 MW	37.4 MW
Potencia nominal pico			
Altitud		100 m.s.n.m.	100 m.s.n.m.
Velocidad de rotacion		5 100 r.p.m.	5 100 r.p.m.
N° de etapas turbina		3	3
N° de etapas compresor		17	17
Generador			
Fabricante		Alstom	Alstom
Tipo		Cilíndrico T190-240	Cilíndrico T190-240
N° de fabrica		Estator 500383 Rotor 153751	Estator 500385 Rotor 153645
Potencia nominal		52 941 kVA 45 000 kW	52 941 kVA 45 000 kW
Tension nominal		13 800 V	13 800 V
Amperios		2 215 A	2 215 A
Factor de potencia		0.85	0.85
Frecuencia		60 Hz	60 Hz
Velocidad		3 600 r.p.m.	3 600 r.p.m.
Excitatriz			
Fabricante		Alstom	Alstom
Tipo		Diodo Giratorio TKJ 70-10	Diodo Giratorio TKJ 70-10
N° de Serie		500302	500370
Potencia		149 kW	149 kW
Tension		289 V	289 V
Tension excitacion		516 A	516 A
Velocidad		3 600 r.p.m.	3 600 r.p.m.
Tipo de aislamiento		F	F
Proteccion		59/81	59/81
Transformador			
Marca		Koncar Tipo 1 TBP 50 000 - 145	Koncar Tipo 1 TBP 50 000 -
N° de serie		308014	308013
Potencia Nominal		50 MVA (ONAN)	50 MVA (ONAN)
Frecuencia		60 Hz	60 Hz
Tension nominal		13 800/138 000 +/- 2x2.5 % V	13 800/138 000 +/- 2x2.5 % V
Grupo de conexion		Ynd5	Ynd5
Tension de corto circuito		11.78%	11.78%
Regulacion			
Posicion tap actual		1 (13 800/ 144 900 V)	1 (13 800/ 144 900 V)

2. ANEXO II

Cuadro parcial de la Información Técnica de la Norma ISO 4406 – Nomenclatura de la Contaminación de Aceite Hidráulico – Gráficos y tablas de sistemas y niveles típicos de contaminación aceptables

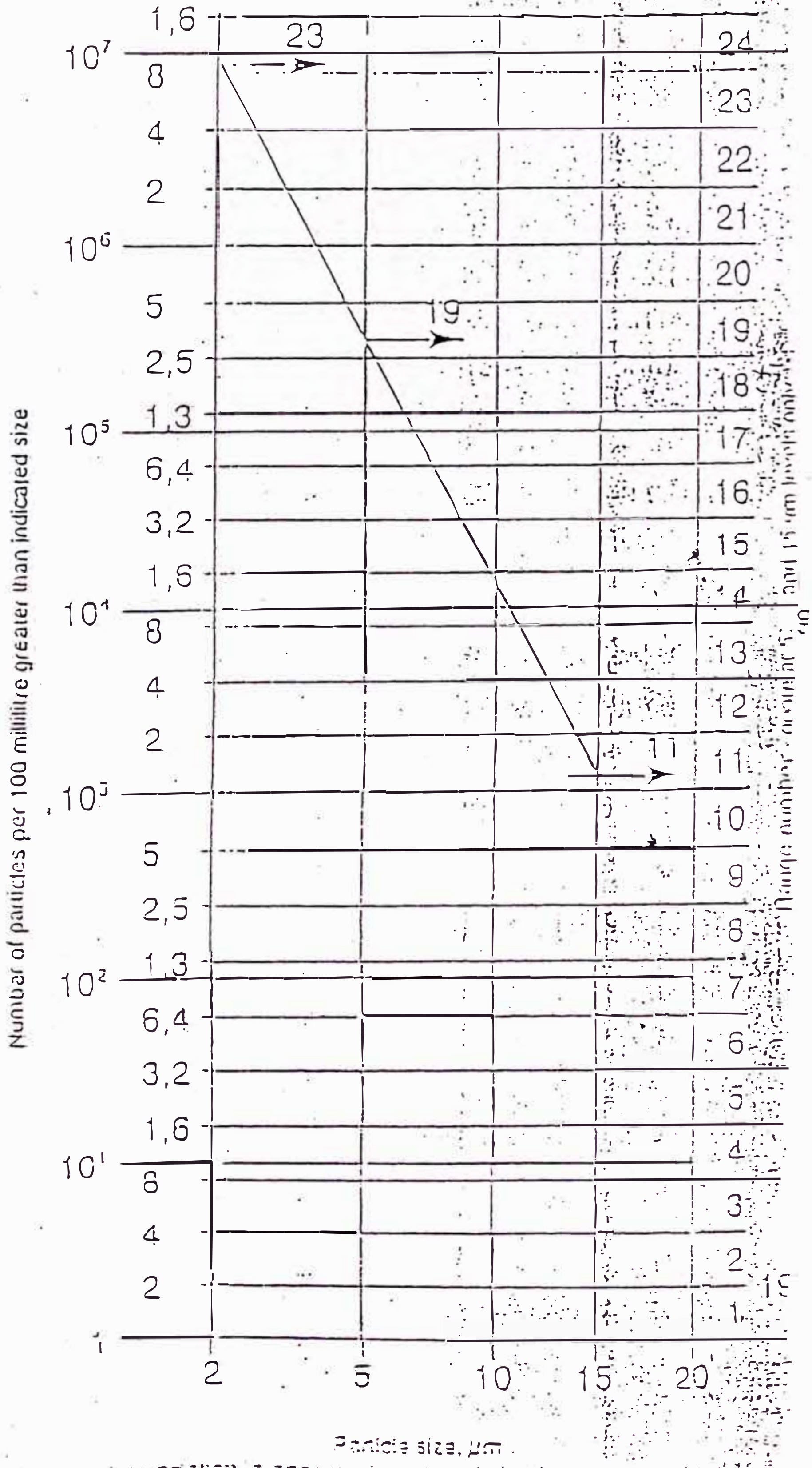
olid contaminants in fluid power systems vary in size, shape, form and quantity. The
ost-harmful contaminants are normally between 5 micron and 15 micron. The ISO
ode is the preferred method of reporting quantity of contaminants.

ne ISO code number
orresponds to
ontamination levels
ertaining to three sizes.

ne first scale number
presents the number
particles larger than
m per 100 millilitre of
uid, the second
umber for particles
rger than 5µm per
0 millilitre of fluid and
e third number for particles
rger than 15µm per
0 millilitre of fluid.

elow is a table of actual
sults obtained, of
ntamination within a
draulic Pump
durance test rig.

Particle Size	No. of Particles per 100ml of oil
2µ	7950100
5µ	280500
10µ	13500
15µ	1500
25µ	50
ISO code: 23/19/11	



Interpolation is acceptable; extrapolation is not permissible

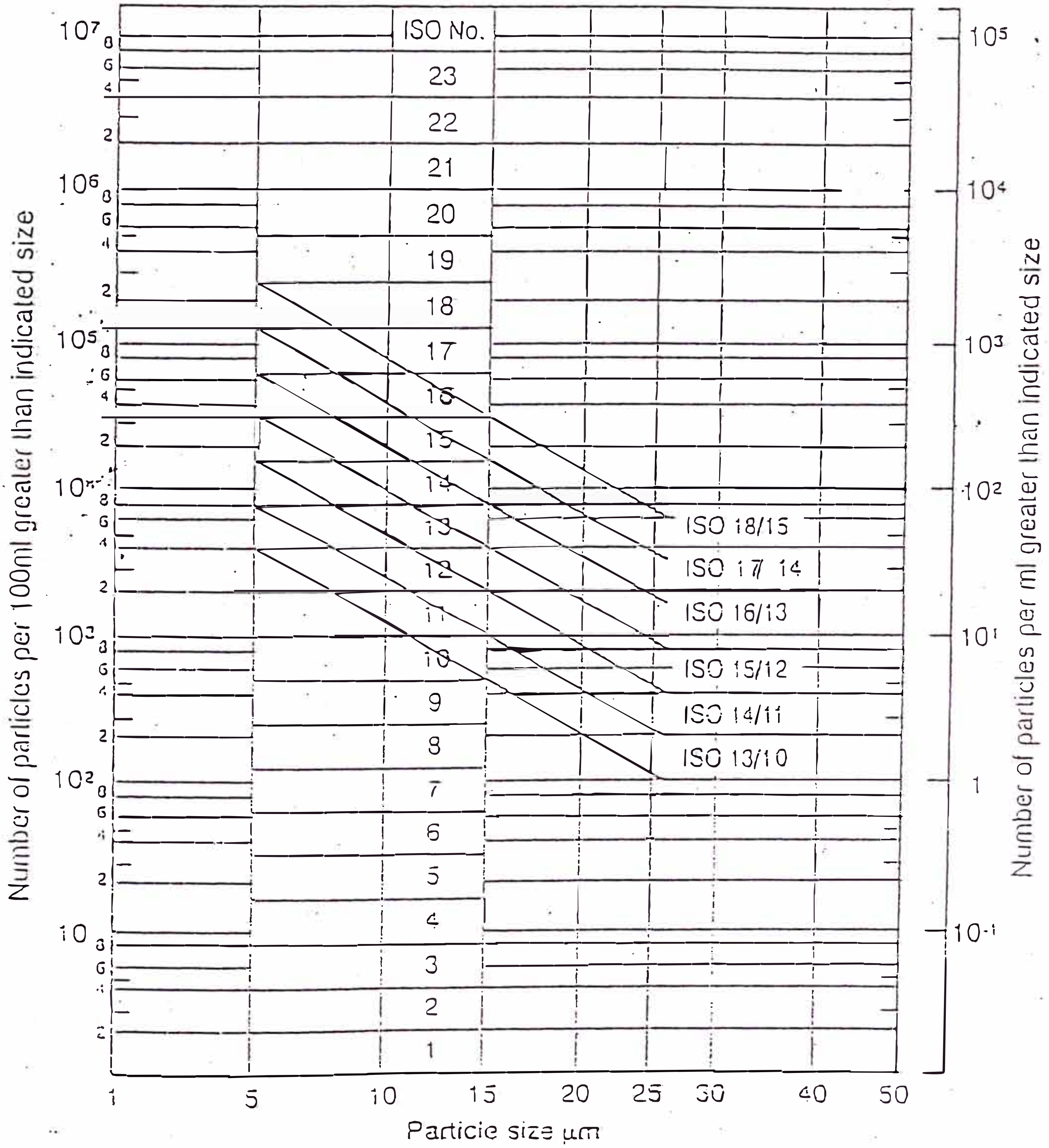
SO CONTAMINATION NUMBERS

Number of particles per 100 mL		Range number
More than	Up to and including	
8×10^6	16×10^6	24
4×10^6	8×10^6	23
2×10^6	4×10^6	22
1×10^6	2×10^6	21
500×10^3	1×10^6	20
250×10^3	500×10^3	19
130×10^3	250×10^3	18
64×10^3	130×10^3	17
32×10^3	64×10^3	16
16×10^3	32×10^3	15
8×10^3	16×10^3	14
4×10^3	8×10^3	13
2×10^3	4×10^3	12
1×10^3	2×10^3	11
500	1×10^3	10
250	500	9
130	250	8
64	130	7
32	64	6
16	32	5
8	16	4
4	8	3
2	4	2
1	2	1

For example code 20/18/13 indicates that there are between 500,000 and 1,000,000 particles larger than 2 microns and between 130,000 and 250,000 particles larger than 5 microns and between 4000 and 8000 particles larger than 15 microns.

ARTICLE DISTRIBUTION CHART TO ISO4406

ncluding various ISO level contamination grades



NAS 1638 Chart

NAS 1638

SIZE RANGE µm	Classes (based on maximum contamination limits, particles per 100 mL)													
	00	0	1	2	3	4	5	6	7	8	9	10	11	12
5-15	125	250	500	1000	2000	4000	8000	16,000	32,000	64,000	128,000	256,000	512,000	1,024,000
15-25	22	44	89	178	356	712	1425	2,850	5,700	11,400	22,800	45,600	91,000	182,400
25-50	4	8	16	32	63	126	253	506	1,012	2,025	4,050	8,100	16,200	32,400
50-100	1	2	3	6	11	22	45	90	180	360	720	1,440	2,880	5,760
over 100	0	0	1	1	2	4	8	16	32	64	128	256	512	1024

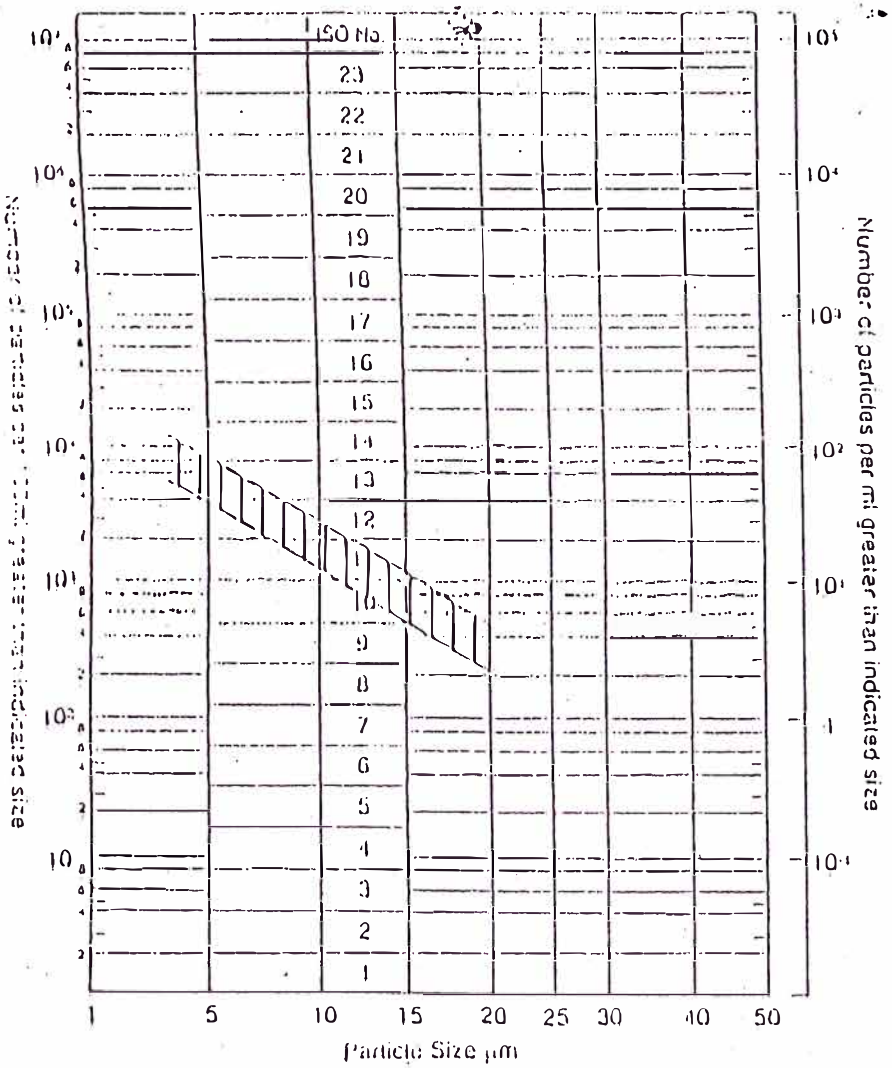
/NAS/SAE COMPARISON CHART

BS 5540/4 ISO/DIS 4406 CODE	Def. Std 05/42		NAS 1638 Class	SAE 749 Class
	Table A	Table B		
11/8	-	-	2	-
12/9	-	-	3	0
13/10	-	-	4	1
14/9	-	400F	-	-
14/11	-	-	5	2
15/9	400	-	-	-
15/10	-	800F	-	-
15/12	-	-	6	3
16/10	800	-	-	-
16/11	-	1 300F	-	-
16/13	-	-	7	4
17/11	1 300	2 000F	-	-
17/14	-	-	8	5
18/12	2 000	-	-	-
18/13	-	4 400F	-	-
18/15	-	-	9	6
19/13	4 400	6 300F	-	-
19/16	-	-	10	-
20/13	6 300	-	-	-
20/17	-	-	11	-
21/14	15 000	-	-	-
21/18	-	-	12	-
22/15	21 000	-	-	-
23/17	100 000	-	-	-

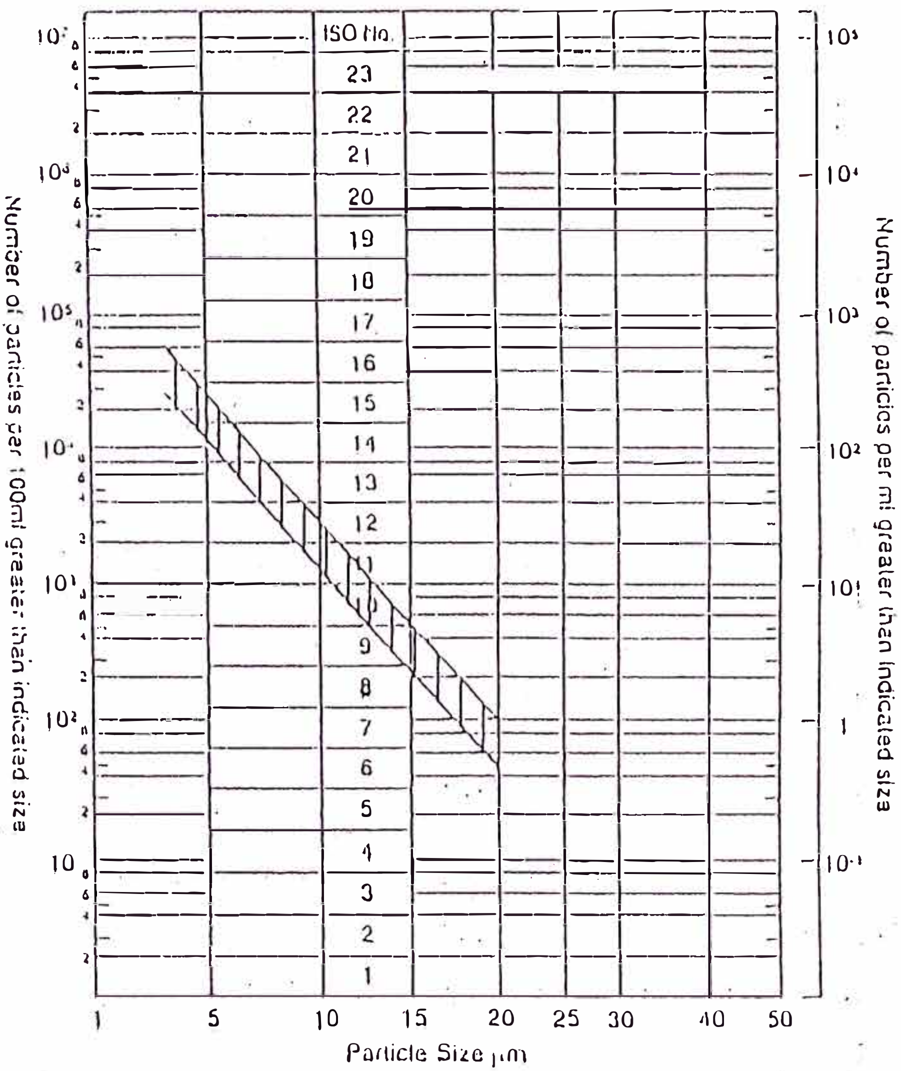
The above comparisons relate to particle count data only. To conform to any particular standard, reference should be made to the recommended experimental procedure.

Typical system applications and code numbers

These typical applications and ISO code numbers are taken from the UK Contamination Control Research Programme (1980-1984)
Ref. AHEM Guide to Contamination Control in Hydraulic Power Systems - 1985

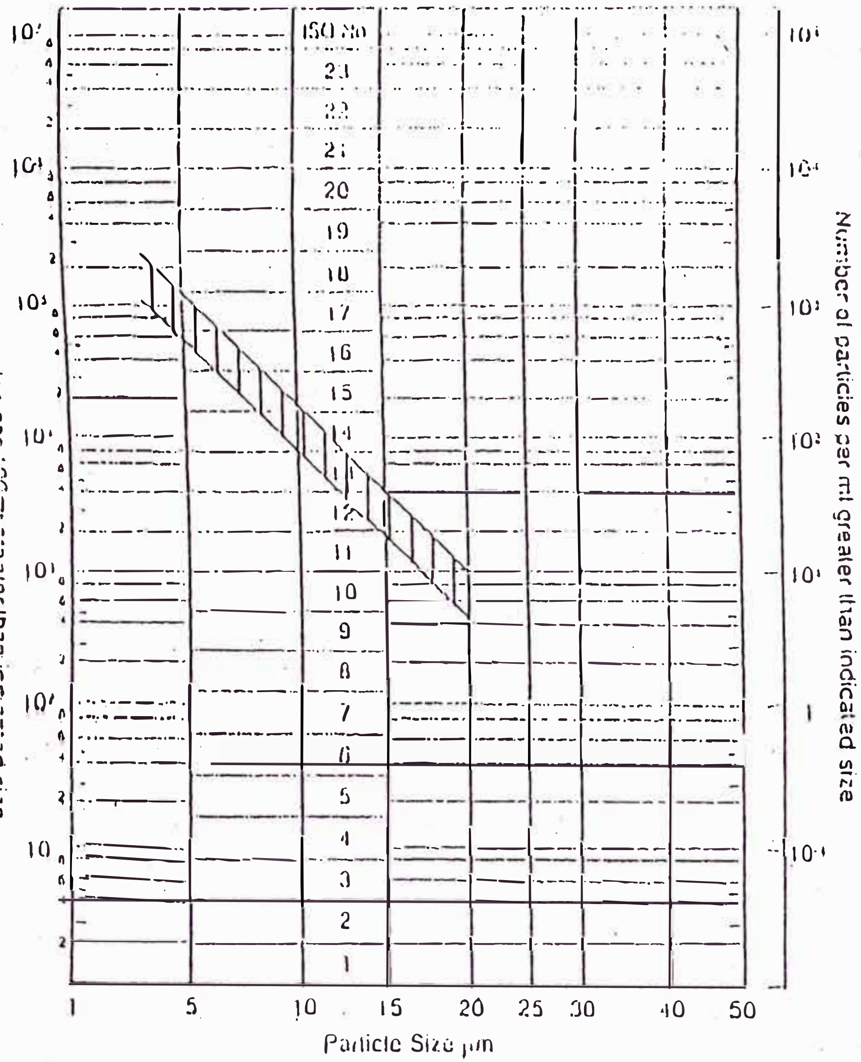


Solid Contaminant Code No 13/10
Application: Aircraft test stands

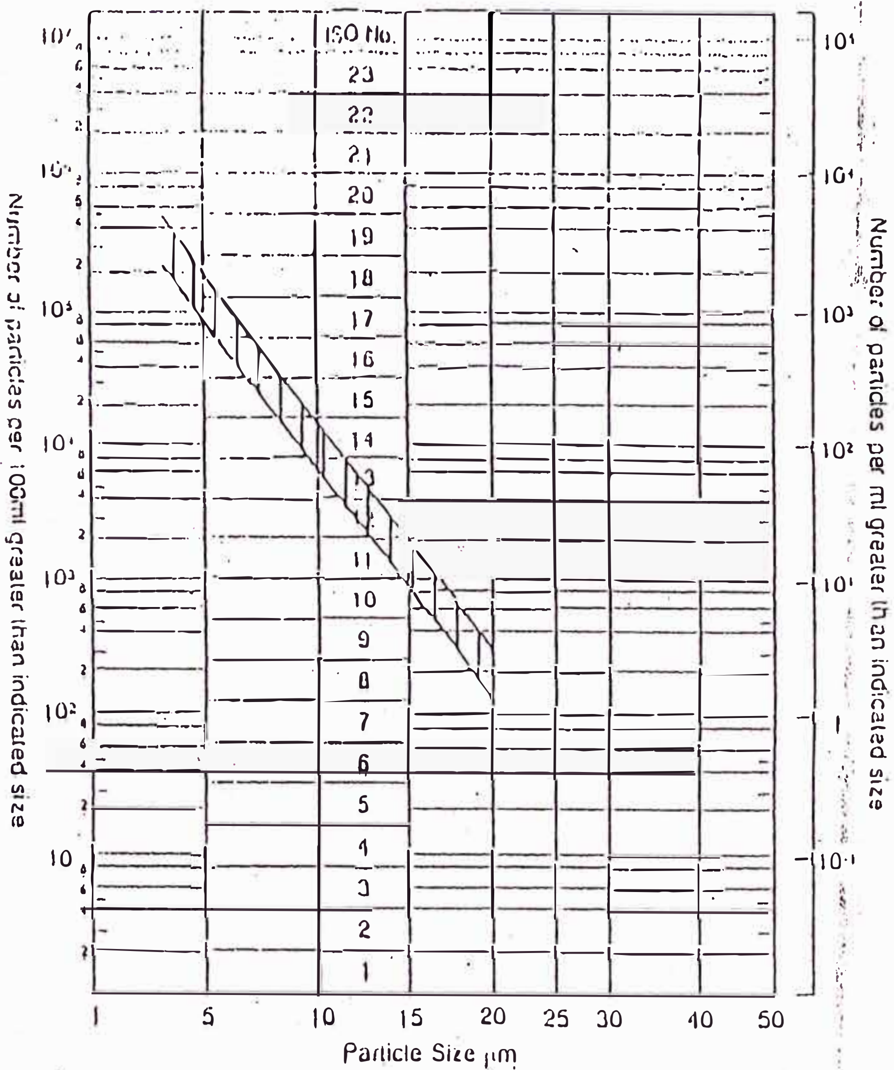


Solid Contaminant Code No 15/9
Application: Machine T

ISO CONTAMINATION CHARTS

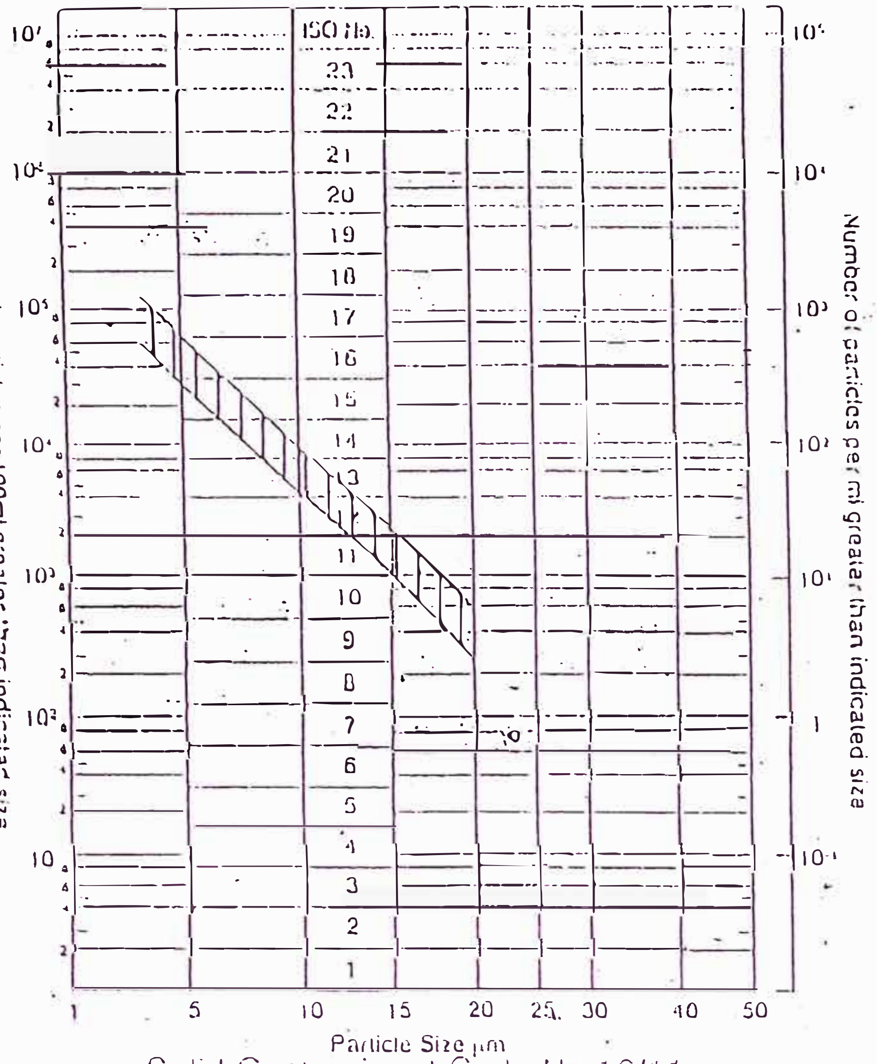


Solid Contaminant Code No 17/12
Application: Marine Installations



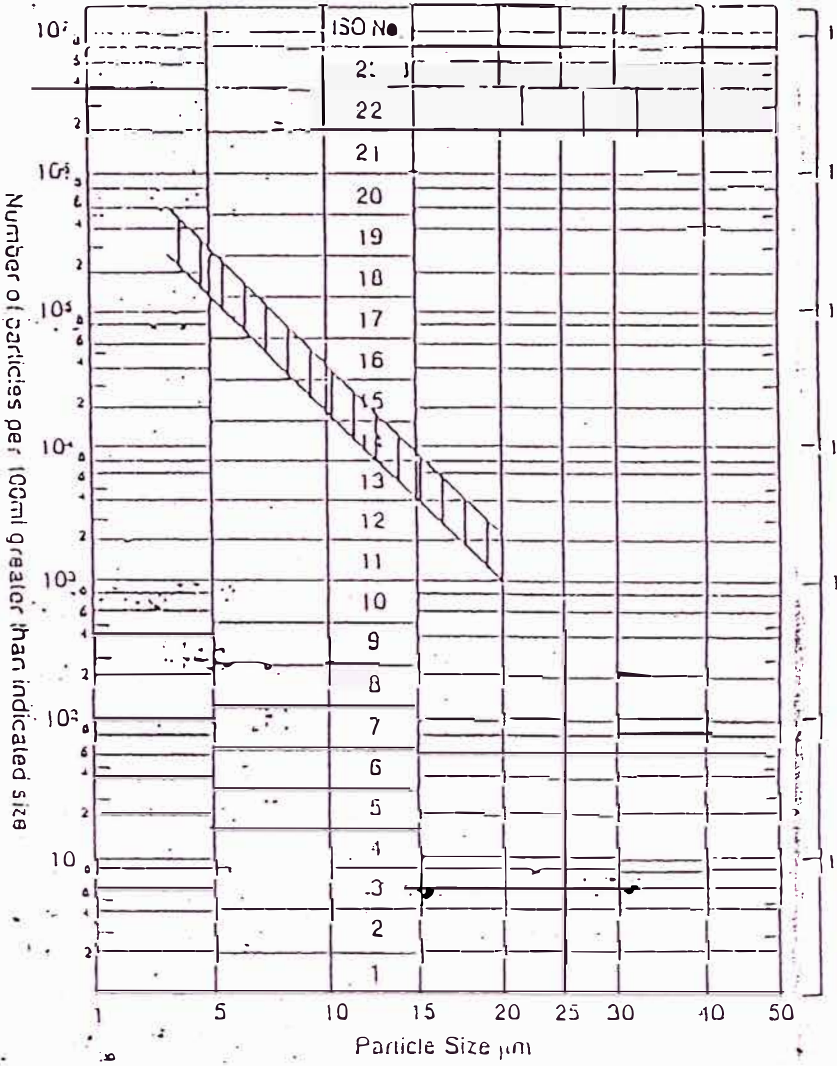
Solid Contaminant Code No 18/11
Application: Mobile Systems

ISO CONTAMINATION CHARTS



Solid Contaminant Code No 16/11

Application: Injection Moulding
Metalworking
Unused commercial [illegible] oil



Solid Contaminant Code No 18/13

Application: Mechanical Handling

CMED © UCC 1993

3. ANEXO III

Reporte de la Inspección Termográfica de la Central Hidráulica Charcani V

REPORTE TERMOGRAFICO CH. CHARCANI V

Equipo:	G2 - CELDA DE FASES (Fases S y T, [illegible] vista frontal)
Fecha:	06/09/2001
Hora:	02:42:34 p.m.
Temp. ambiente:	15.0 °C
Distancia al objeto:	3.0 m
Emisividad:	0.90
Transmisión:	0.97

Resultados:

Temperatura Punto 1 :	> 75.9 °C
Temperatura Punto 2 :	> 75.9 °C
Isoterma máxima:	76.0 °C

Observaciones:

Normal

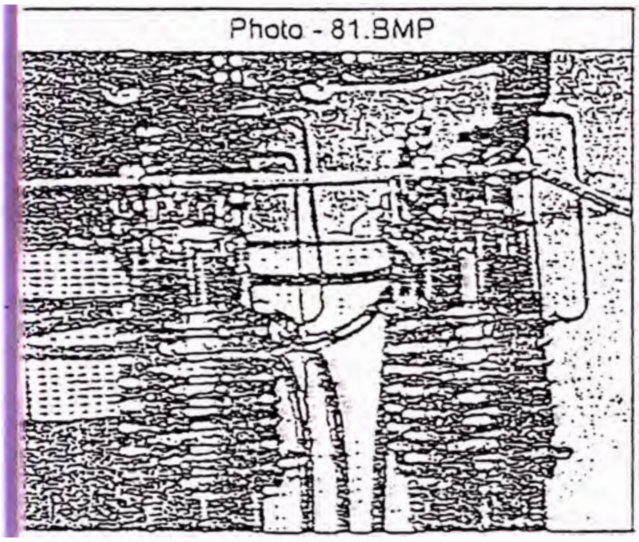
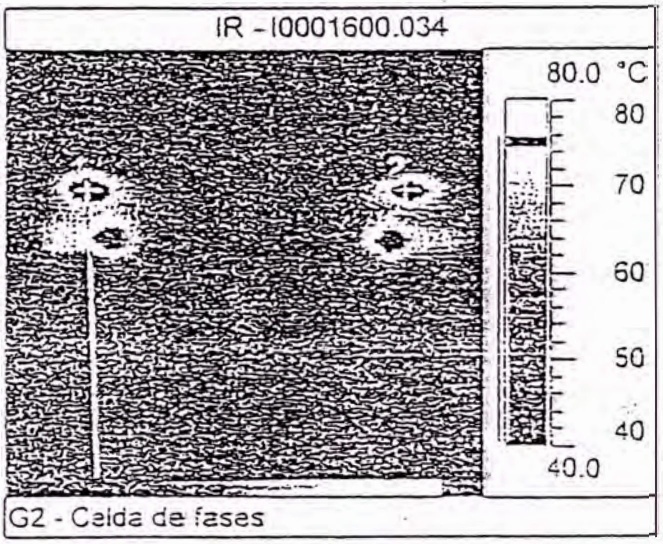
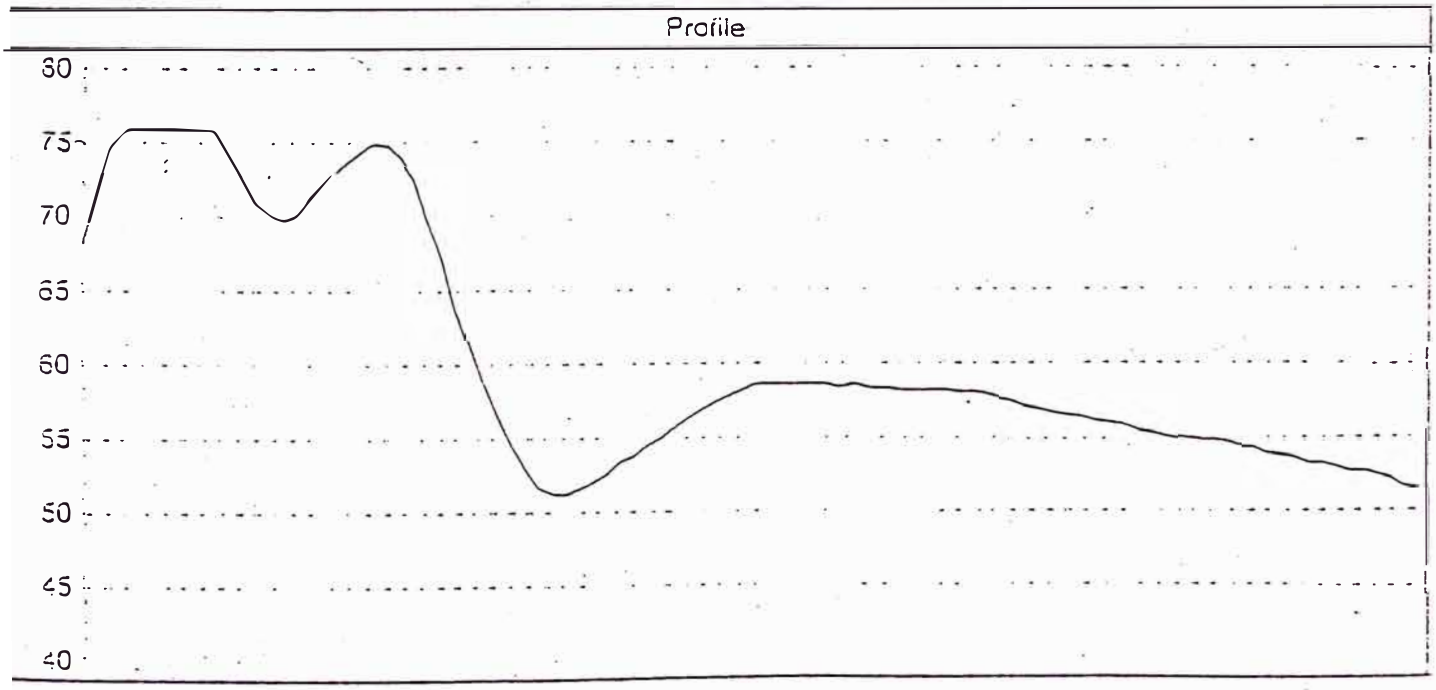


Photo - 81.8MP



IR - I0001600.034

G2 - Celda de fases



Profile

REPORTE TERMOGRAFICO CH. CHARCANI V

Equipo: G2 - CELDA DE FASES (vista lateral)

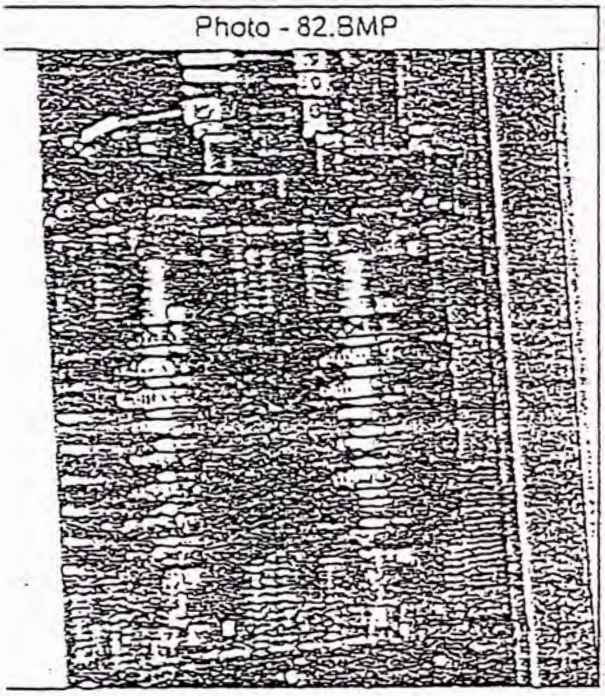
Fecha: .06/09/2001
Hora: 02:43:59 p.m.
Temp. ambiente: 15.0 °C
Distancia al objeto: 3.0 m
Emisividad: 0.90
Transmisión: 0.97

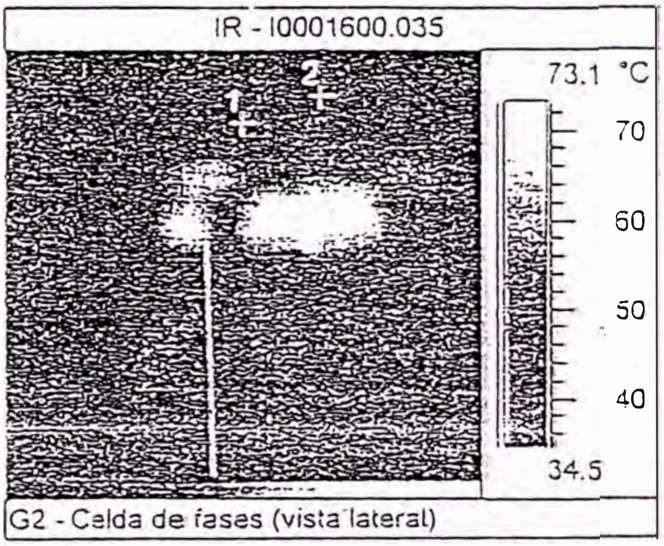
Resultados:

Temperatura Punto 1 : 39.2 °C
Temperatura Punto 2 : 38.1 °C

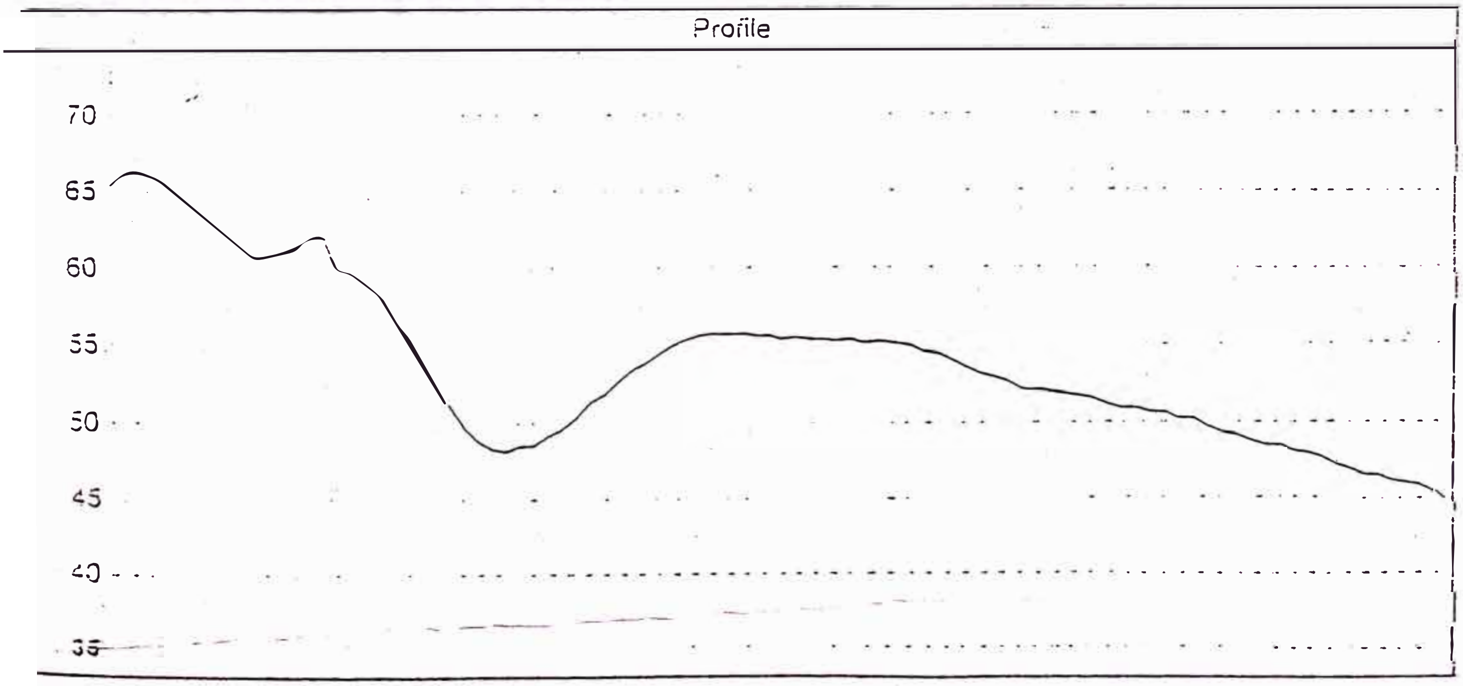
Observaciones:

Normal





G2 - Celda de fases (vista lateral)



REPORTE TERMOGRAFICO CH. CHARCANI V

quipo: G2 - CELDA NEUTRO

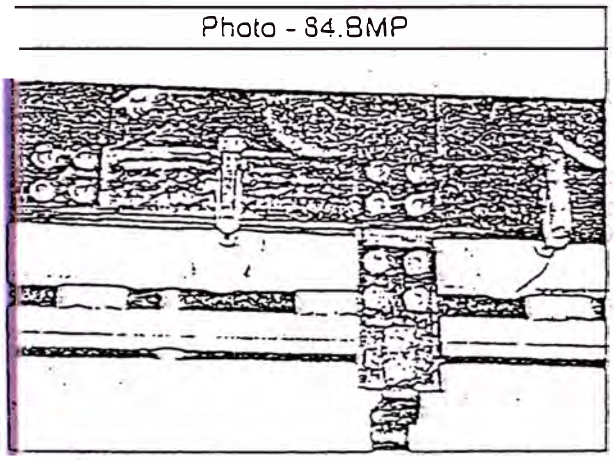
echa:	06/09/2001
ora:	02:48:43 p.m.
emp. ambiente:	15.0 °C
istancia al objeto:	3.0 m
misividad:	0.90
ransmisión:	0.97

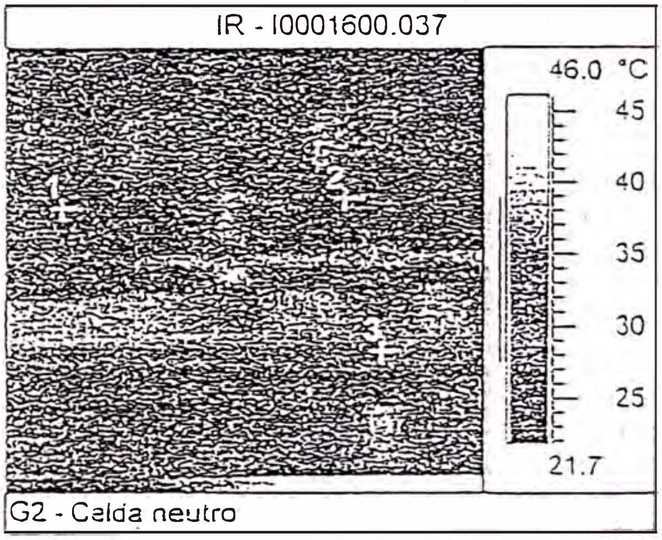
Resultados:

Temperatura Punto 1 :	33.8 °C
Temperatura Punto 2 :	34.9 °C
Temperatura Punto 3 :	31.8 °C

Observaciones:

Normal.





REPORTE TERMOGRAFICO CH. CHARCANI V

quipo: G2 - CELDA NEUTRO

echa: 06/09/2001
ora: 02:50:34 p.m.
emp. ambiente: 15.0 °C
istancia al objeto: 3.0 m
misividad: 0.90
ransmisión: 0.97

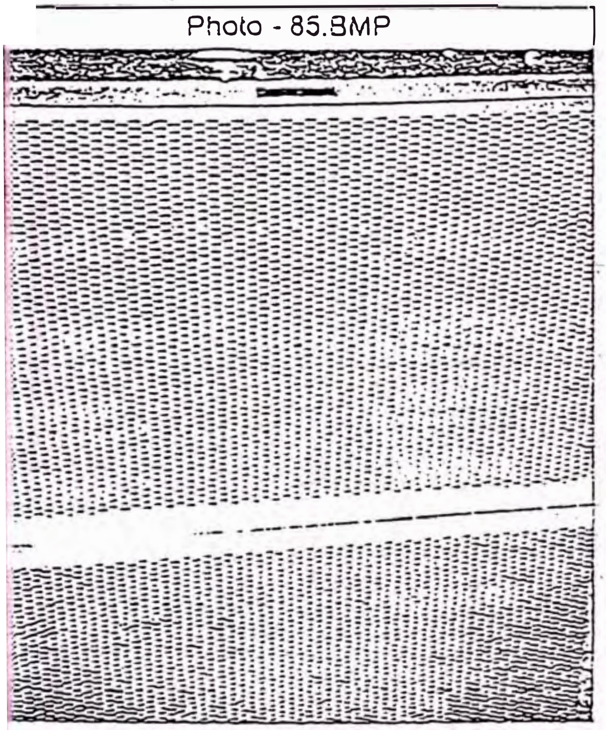
Resultados:

Temperatura Punto 1 : >44.7 °C
Temperatura Punto 2 : 42.3 °C
Temperatura Punto 3 : 40.9 °C

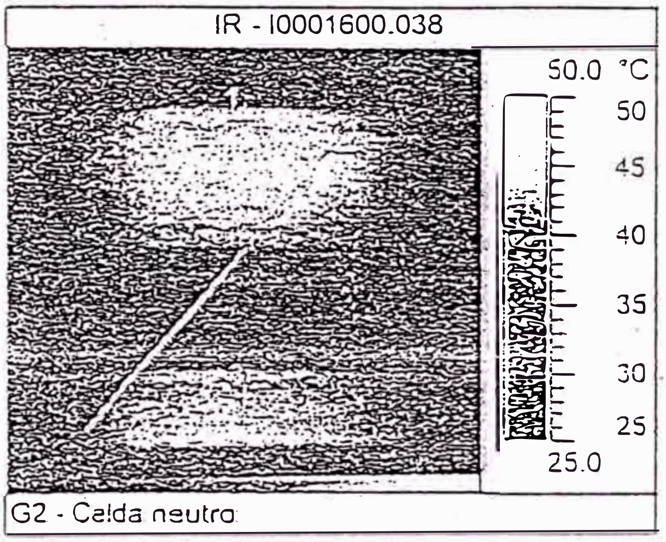
Observaciones:

Normal.

Photo - 85.BMP

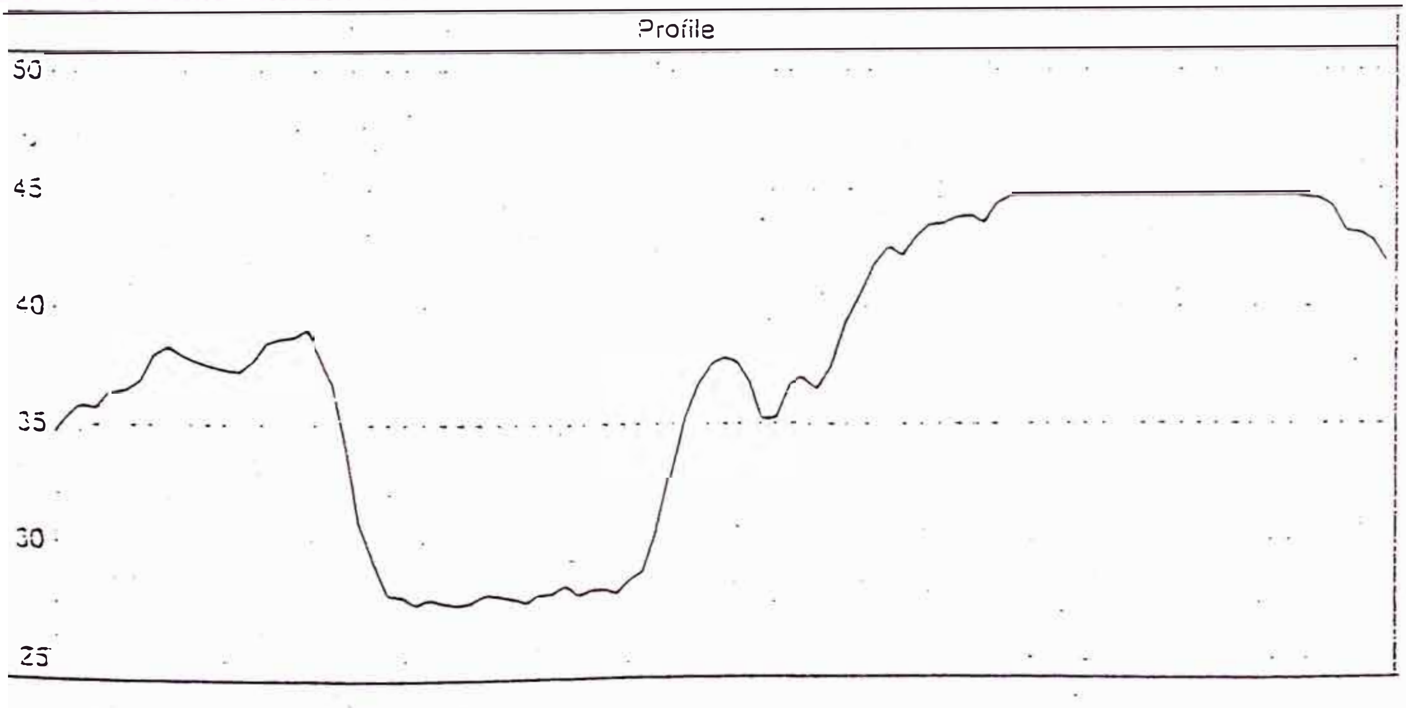


IR - I0001600.038



G2 - Calda neutro

Profile



REPORTE TERMOGRAFICO CH. CHARCANI V

ıipo: G2 - TRANSFORMADOR DE MEDIDA

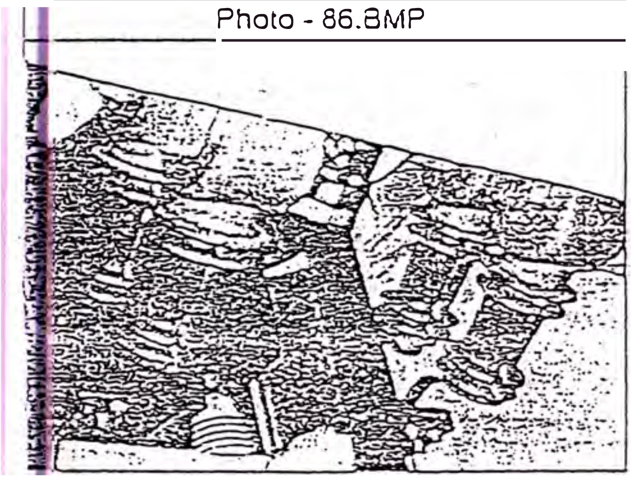
:ha:	06/09/2001
ra:	02:52:13 p.m.
np. ambiente:	15.0 °C
tancia al objeto:	3.0 m
isividad:	0.90
nsmisión:	0.97

Resultados:

Temperatura Punto 1	46.8 °C
Temperatura Punto 2 :	43.7 °C.
Temperatura Punto 3 :	48.0 °C
Temperatura Punto 4 :	45.8 °C

Observaciones:

Normal.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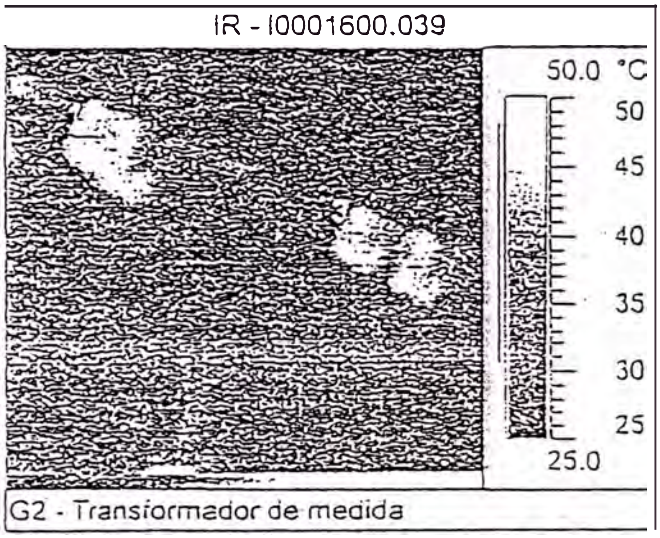

IR - I0001600.039

G2 - Transformador de medida

REPORTE TERMOGRAFICO CH. CHARCANI V

Equipo: G2 - TRANSFORMADOR 100 KVA

Fecha: 06/09/2001
Hora: 02:53:26 p.m.
Temp. ambiente: 15.0 °C
Distancia al objeto: 3.0 m
Emisividad: 0.90
Transmisión: 0.97

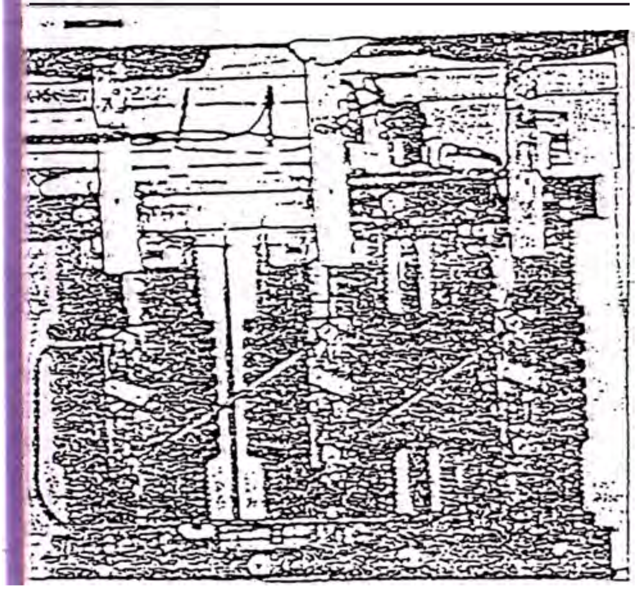
Resultados:

Temperatura Punto 1 :	37.5 °C
Temperatura Punto 2 :	36.8 °C
Temperatura Punto 3	37.9 °C
Temperatura Punto 4 :	28.1 °C
Temperatura Punto 5	28.3 °C
Temperatura Punto 6	28.6 °C

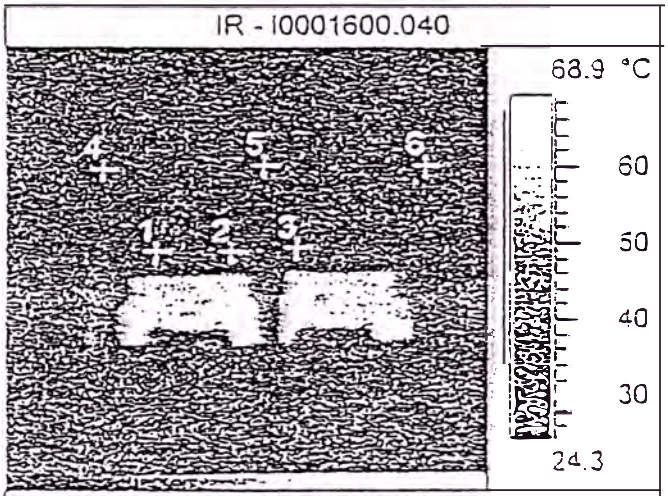
Observaciones:

Normal.

Photo - 87.BMP



IR - I0001600.040



G2 - TRANSFORMADOR 100 KVA

REPORTE TERMOGRAFICO CH. CHARCANI V

Equipo: G2 - INICIO GALERIA DE CABLES

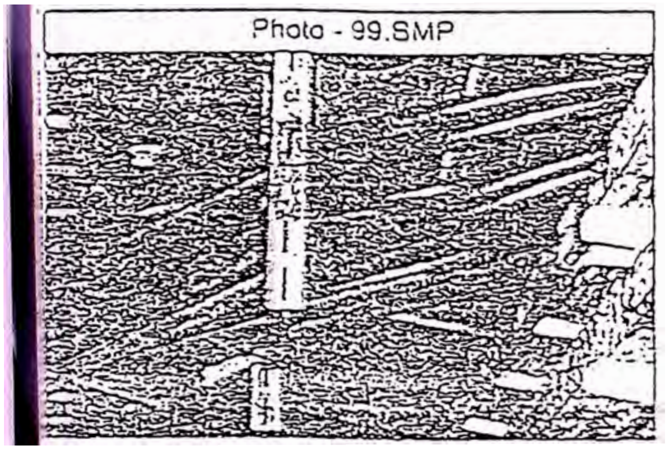
Fecha: 06/09/2001
Hora: 11:11:50 a.m.
Temp. ambiente: 15.0 °C
Distancia al objeto: 1.0 m
Emisividad: 0.98
Transmisión: 0.99

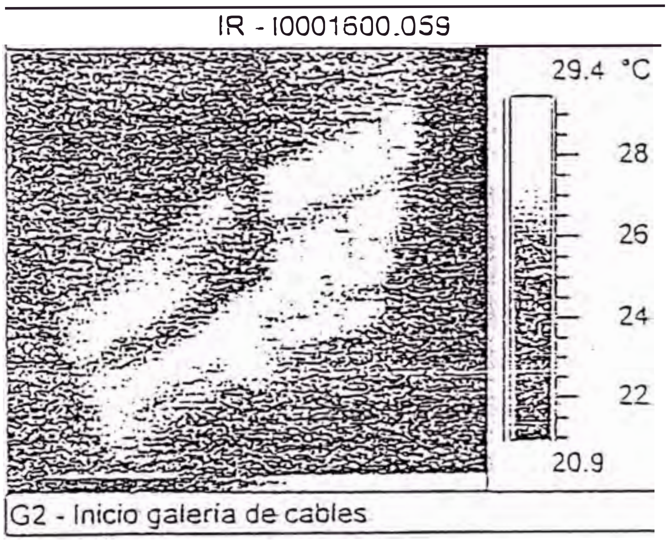
Resultados:

Temperatura Punto 1 (R) : 29.2 °C
Temperatura Punto 2 (S) 27.9 °C
Temperatura Punto 3 (T): 26.7 °C

Observaciones:

Normal. Aparente sobretemperatura fase R





REPORTE TERMOGRAFICO CH. CHARCANI V

Equipo: TRAMO INTERMEDIO GALERIA DE CABLES

Resultados:

Observaciones:
Normal

Fecha: 06/09/2001
Hora: 11:21:23 a.m.
Temp. ambiente: 15.0 °C
Distancia al objeto: 1.0 m
Emisividad: 0.98
Transmisión: 0.99

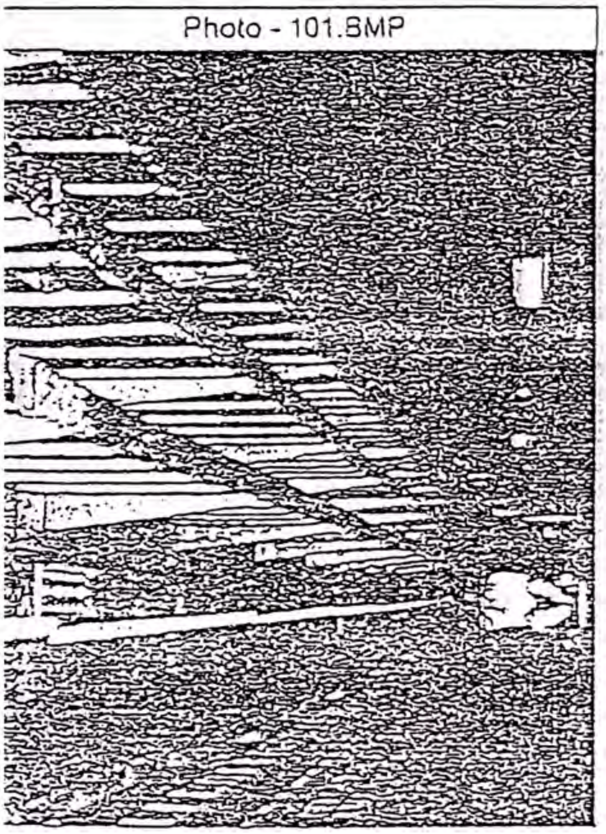
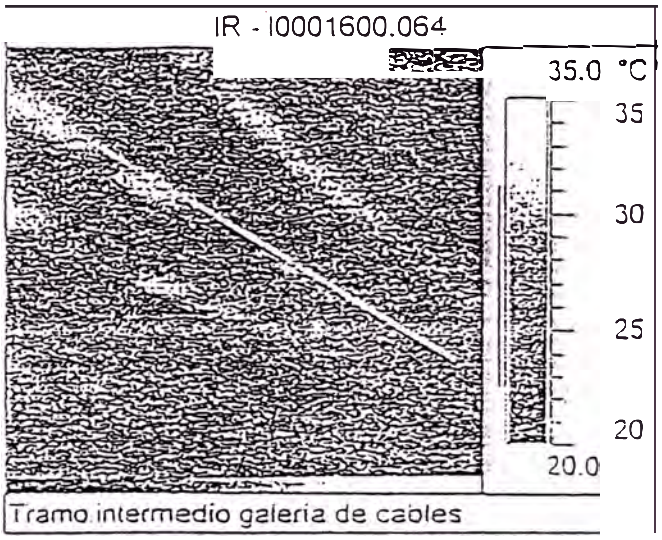


Photo - 101.BMP


IR - I0001600.064

Tramo intermedio galeria de cables

REPORTE TERMOGRAFICO CH. CHARCANI V

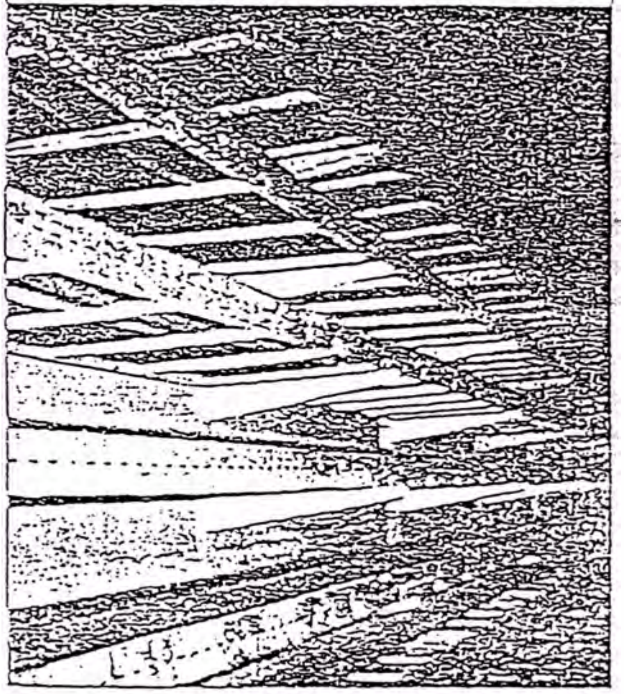
Equipo: ULTIMOS 50 m GALERIA DE CABLES

Resultados:

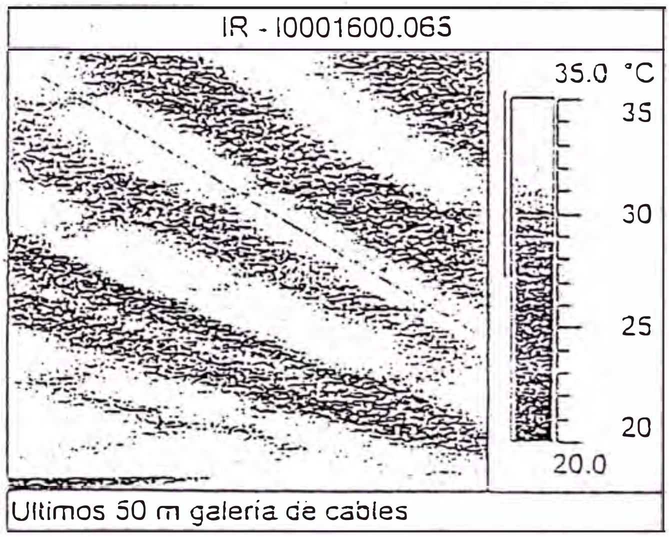
Observaciones:
Normal

Fecha: 06/09/2001
Hora: 11:26:16 a.m.
Temp. ambiente: 18.0 °C
Distancia al objeto: 1.0 m
Emisividad: 0.98
Transmisión: 0.99

Photo - 102.8MP

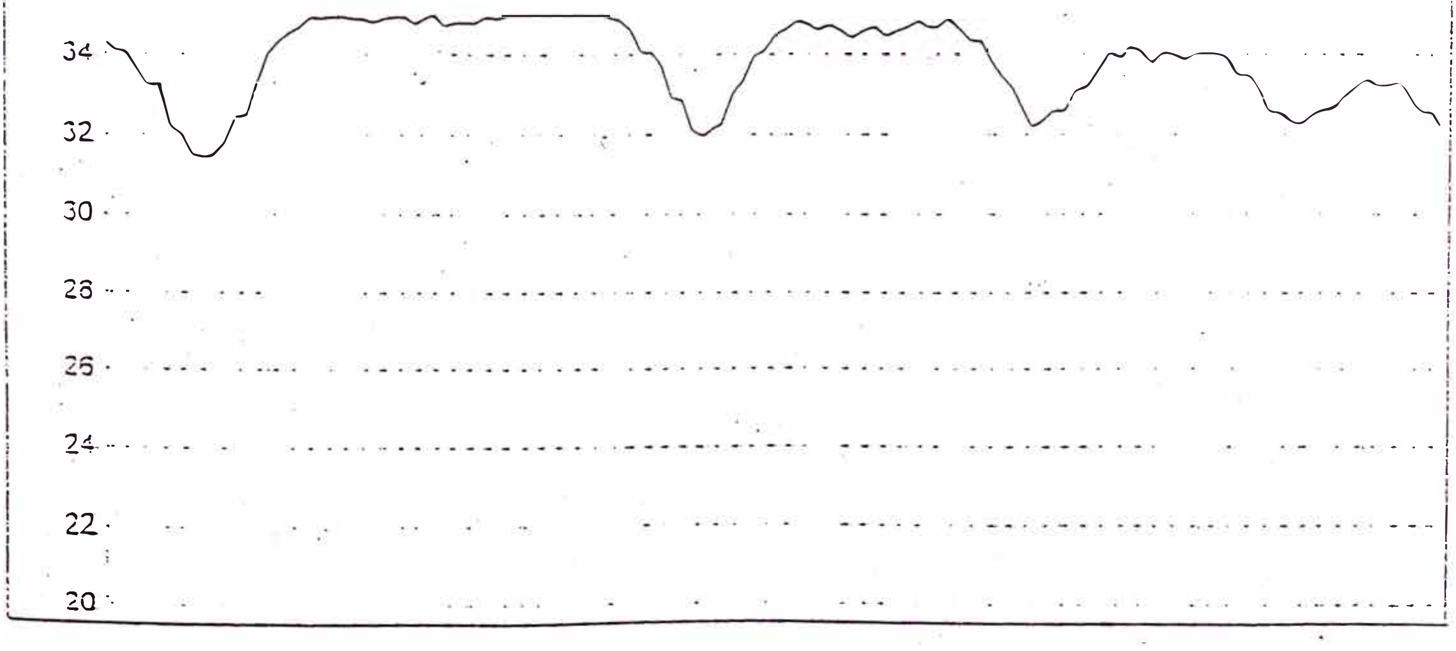


IR - I0001600.065



Ultimos 50 m galeria de cables

Profile



REPORTE TERMOGRAFICO CH. CHARCANI V

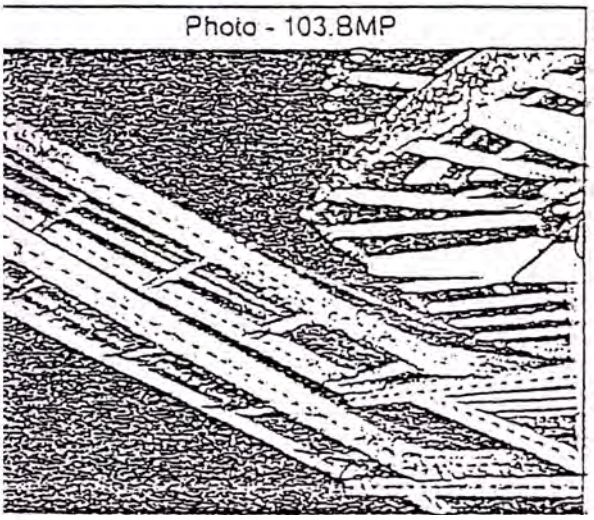
Equipo: TRAMO FINAL GALERIA DE CABLES

Resultados:

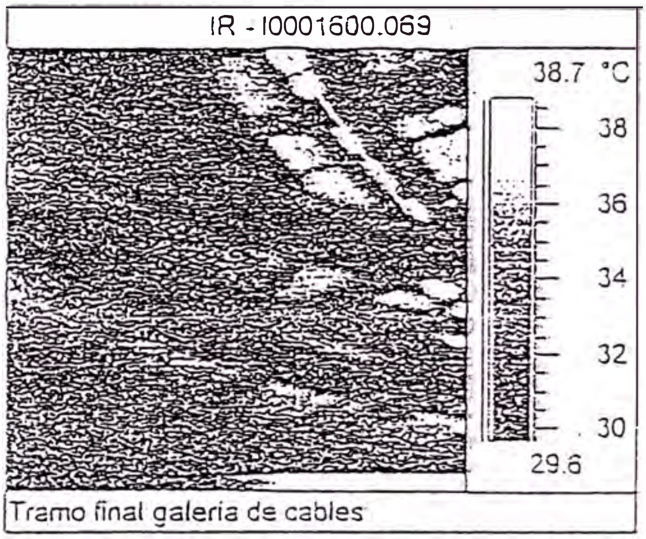
Observaciones:
Normal

Fecha:	06/09/2001
Hora:	11:35:37 a.m.
Temp. ambiente:	18.0 °C
Distancia al objeto:	1.0 m
Emisividad:	0.98
Transmisión:	0.99

Photo - 103.8MP

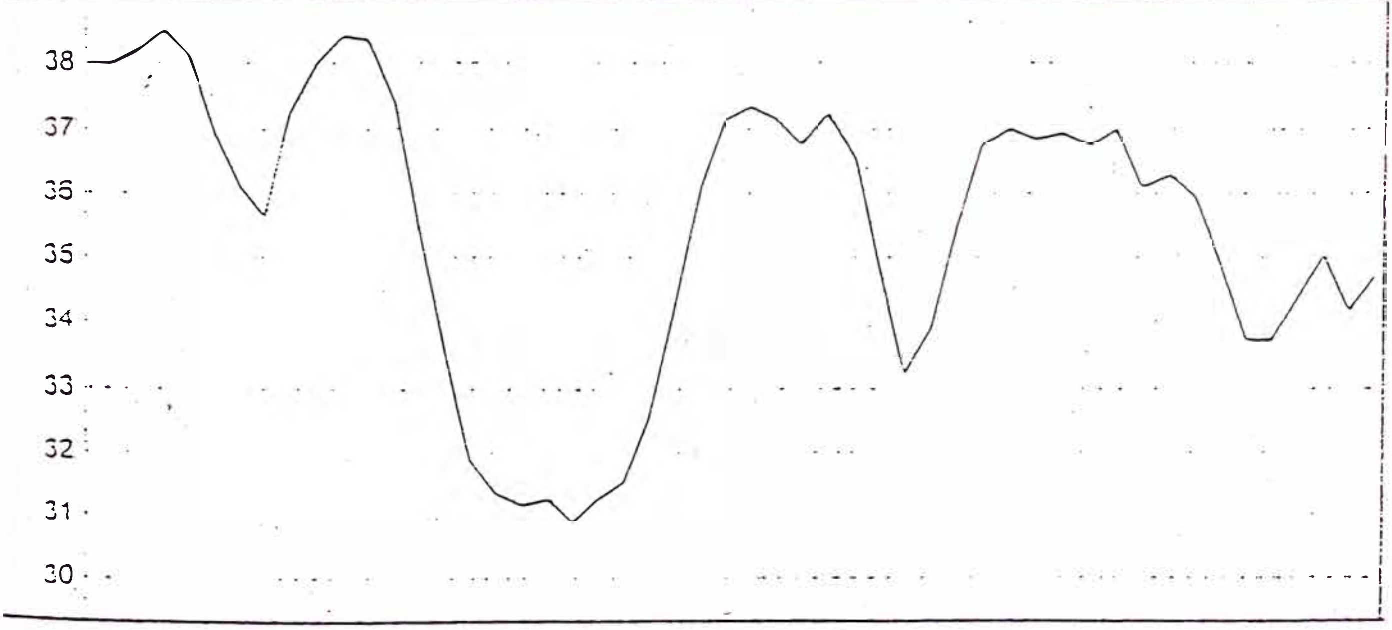


IR - I0001600.069



Tramo final galeria de cables

Profile



REPORTE TERMOGRAFICO CH. CHARCANI V

Equipo: SALIDA TRANSFORMADOR G2

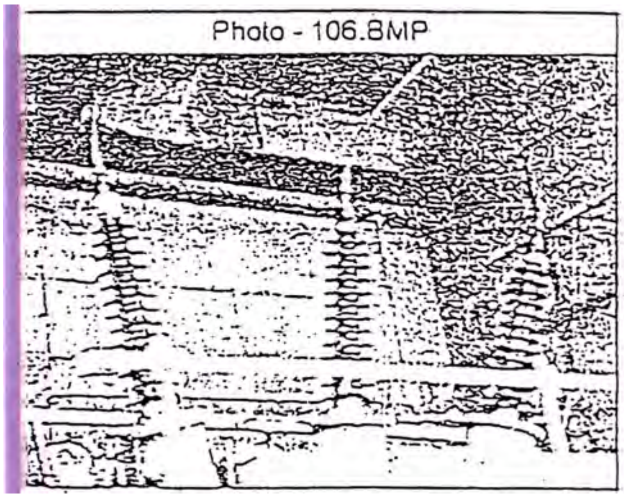
Fecha: 05/09/2001
Hora: 11:46:49 a.m.
Temp. ambiente: 18.0 °C
Distancia al objeto: 1.0 m
Emisividad: 0.98
Transmisión: 0.99

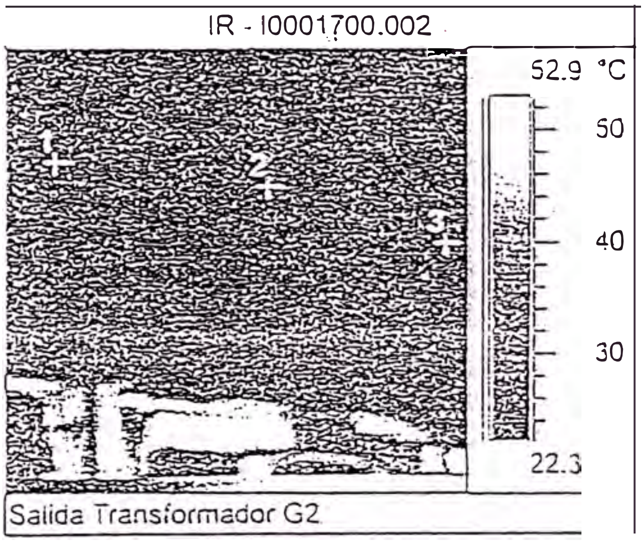
Resultados:

Temperatura Punto 1 (R) : 27.2 °C
Temperatura Punto 2 (S): 25.9 °C
Temperatura Punto 3 (T): 24.5 °C

Observaciones:

Normal





REPORTE TERMOGRAFICO CH. CHARCANI V

Equipo: G2 - CELDA PARARAYOS

Fecha:	06/09/2001
Hora:	02:46:37 p.m.
Temp. ambiente:	15.0 °C
Distancia al objeto:	3.0 m
Emisividad:	0.90
Transmisión:	0.97

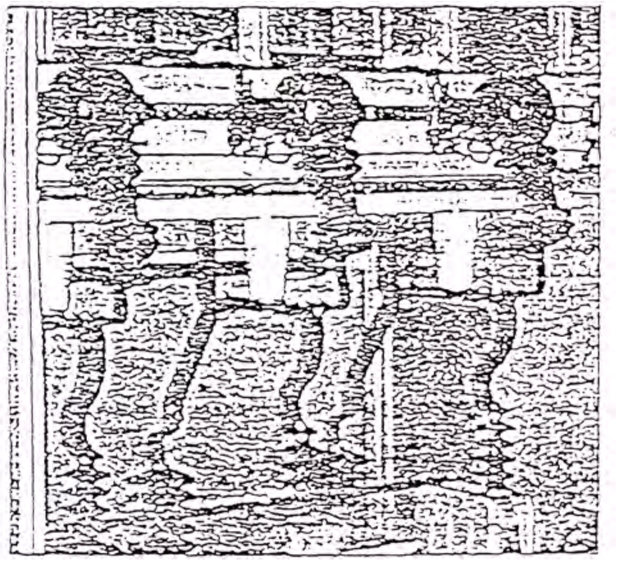
Resultados:

Temperatura Punto 1	42.9 °C
Temperatura Punto 2 :	43.6 °C
Temperatura Punto 3 :	45.4 °C

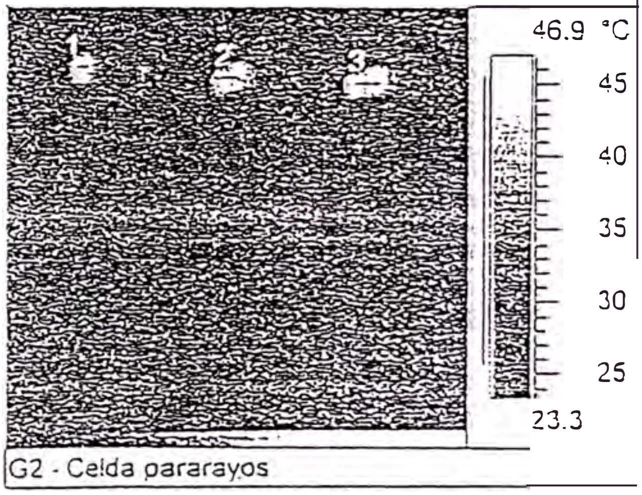
Observaciones:

Normal, medidas en transformador de medida. Nótese los conexionadas a menor temperatura, sin problemas.

Photo - 83.BMP



IR - I0001600.036



G2 - Celda pararayos

REPORTE TERMOGRAFICO CH. CHARCANI V

uipo: PARAYOS Y SALIDA G2

cha: 06/09/2001
ora: 11:53:24 a.m.
mp. ambiente: 20.0 °C
stancia al objeto: 9.0 m
nisividad: 0.98
ansmisión: 0.92

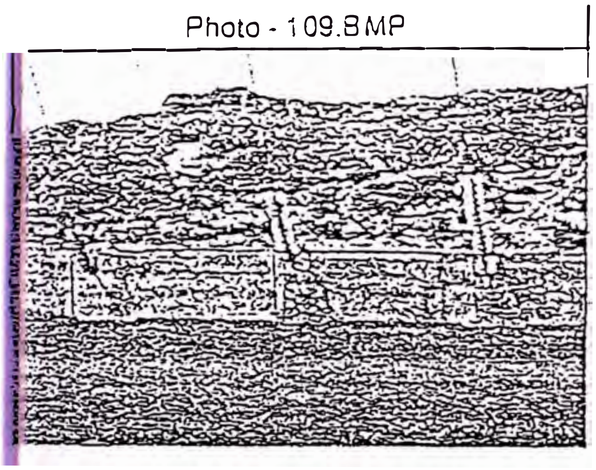
Resultados:

Temperatura Punto 1 (R): 21.1 °C
Temperatura Punto 2 (S): 21.4 °C
Temperatura Punto 3 (T): 19.6 °C

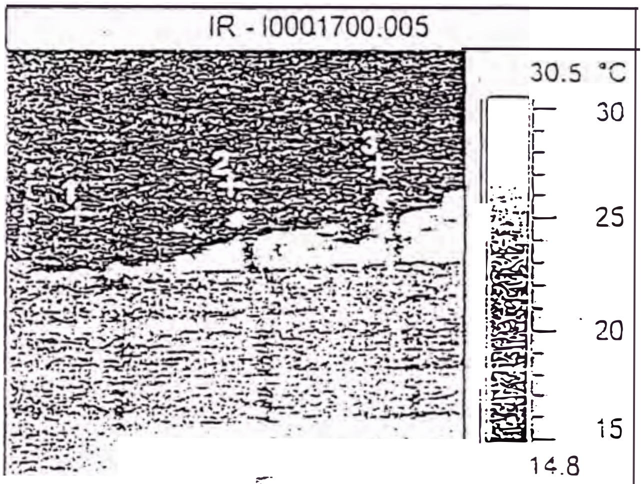
Observaciones:

Normal.

Photo - 109.8MP



IR - I0001700.005



Pararayos y salida G2.

REPORTE TERMOGRAFICO CH. CHARCANI V

Equipo: PARAYOS Y TRANSF. DE TENSION
G-2

06/09/2001
Hora: 12:36:47 p.m.
Temp. ambiente: 15.0 °C
Distancia al objeto: 9.0 m
Emisividad: 0.98
Transmisión: 0.92

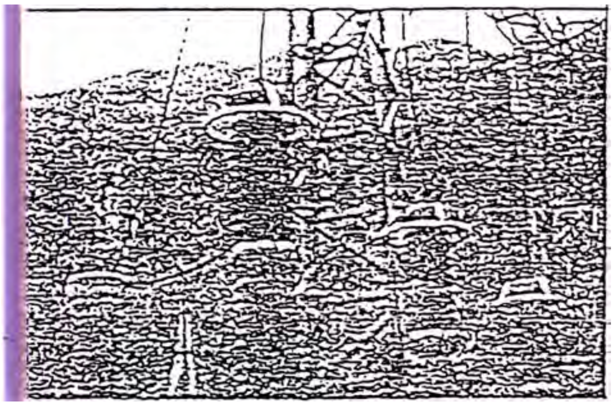
Resultados:

Temperatura Punto (R): 19.9 °C
Temperatura Punto 2 (S): 19.8 °C
Temperatura Punto 3 (T): 18.0 °C

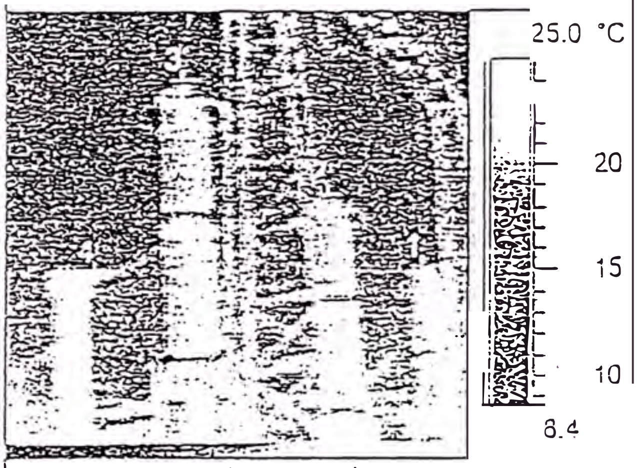
Observaciones:

Normal.

Photo - 110.BMP



IR - I0001700.008



Pararayos y transf. de tensión

REPORTE TERMOGRAFICO CH. CHARCANI V

Equipo: TRANSFORMADOR DE CORRIENTE G-2

Fecha:	06/09/2001
Hora:	12:39:01 p.m.
Temp. ambiente:	15.0 °C
Distancia al objeto:	9.0 m
Emisividad:	0.98
Transmisión:	0.92

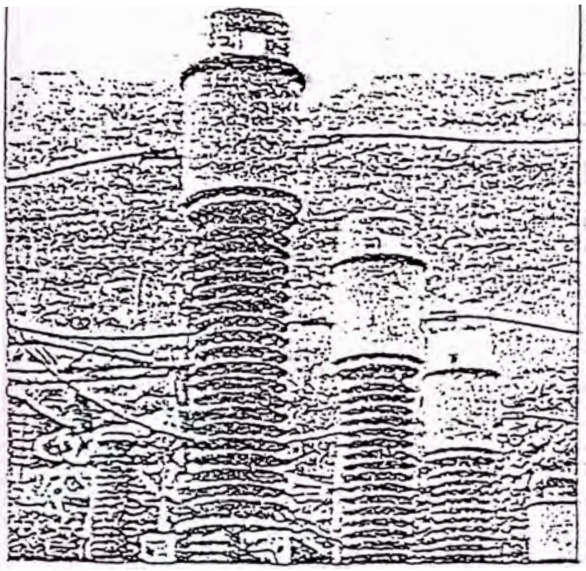
Resultados:

Temperatura Punto 1 (R)	19.0 °C
Temperatura Punto 2 (R):	20.2 °C
Temperatura Punto 3 (S):	18.2 °C
Temperatura Punto 4 (S):	19.6 °C
Temperatura Punto 5 (T):	17.9 °C
Temperatura Punto 6 (T):	19.7 °C

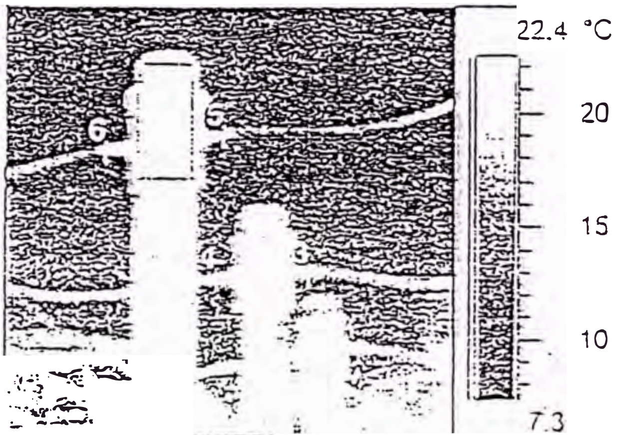
Observaciones:

Normal.

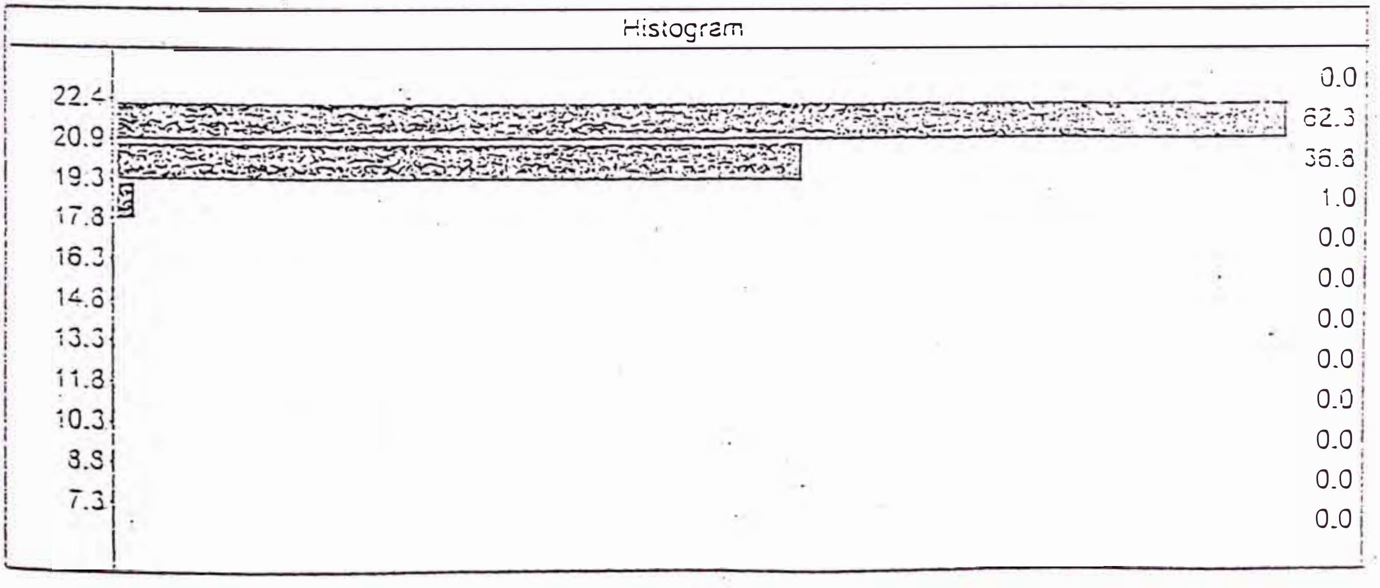
Photo - 112.8MP



IR - I0001700.010



Tranf. de Corriente G-2



REPORTE TERMOGRAFICO CH. CHARCANI V

Equipo: SECCIONADOR G-2

Fecha: 06/09/2001
Hora: 12:38:00 p.m.
Temp. ambiente: 15.0 °C
Distancia al objeto: 9.0 m
Emisividad: 0.98
Transmisión: 0.92

Resultados:

Temperatura Punto 1 (R) : 19.6 °C
Temperatura Punto 2 (R): 19.0 °C
Temperatura Punto 3 (S): 18.5 °C
Temperatura Punto 4 (S): 18.5 °C
Temperatura Punto 5 (T): 19.9 °C
Temperatura Punto 6 (T): 18.8 °C

Observaciones:

Normal.

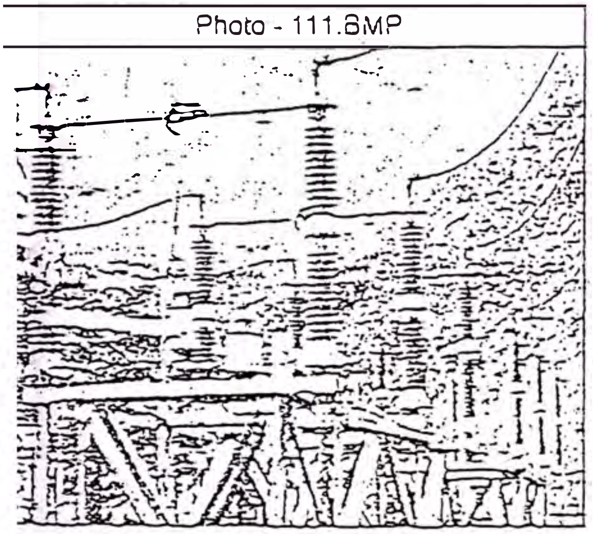
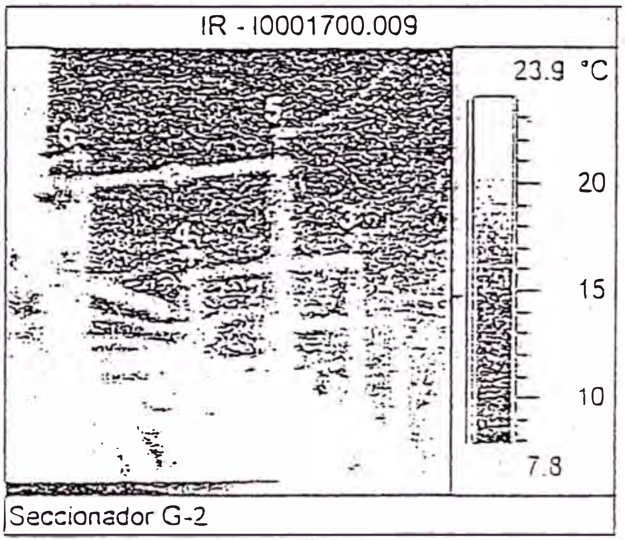
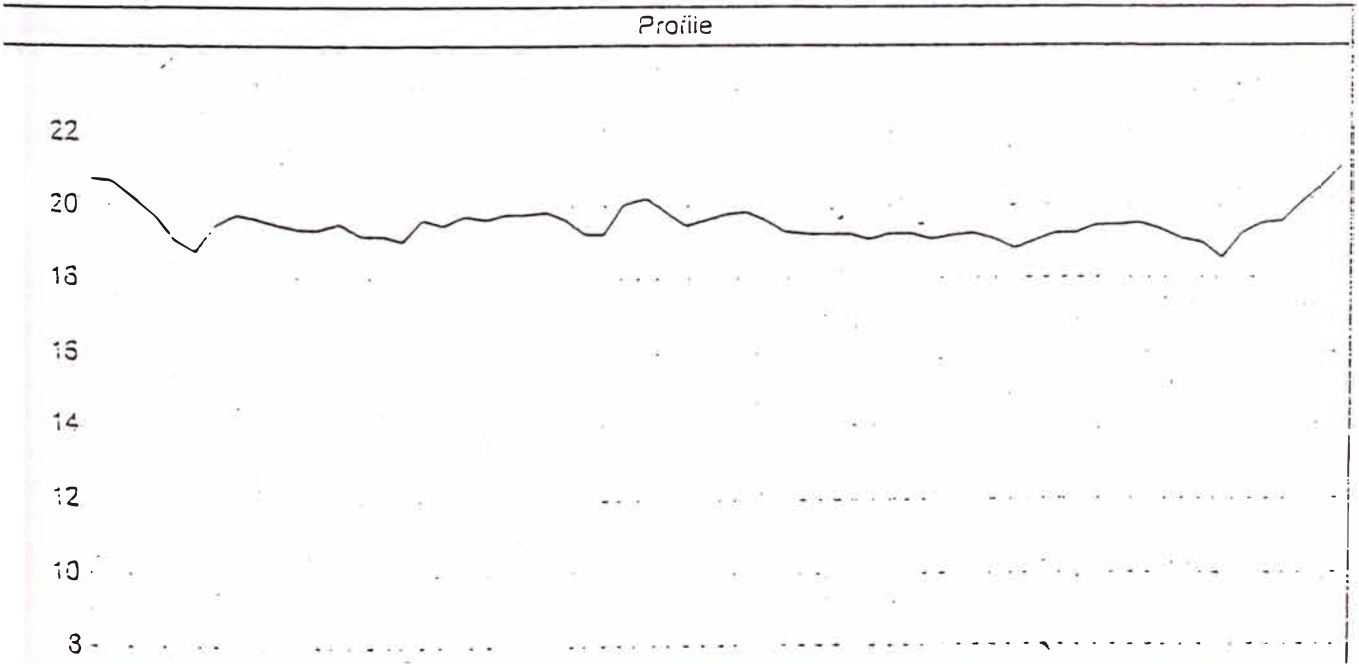


Photo - 111.BMP


IR - I0001700.009

Seccionador G-2


Profile

REPORTE TERMOGRAFICO CH. CHARCANI V

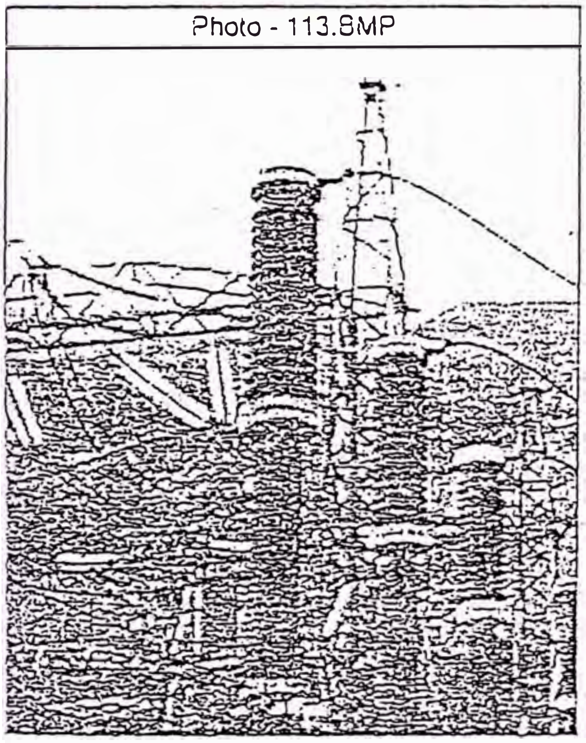
Equipo: INTERRUPTOR G-2

Fecha: 06/09/2001
Hora: 12:39:59 p.m.
Temp. ambiente: 15.0 °C
Distancia al objeto: 9.0 m
Emisividad: 0.98
Transmisión: 0.92

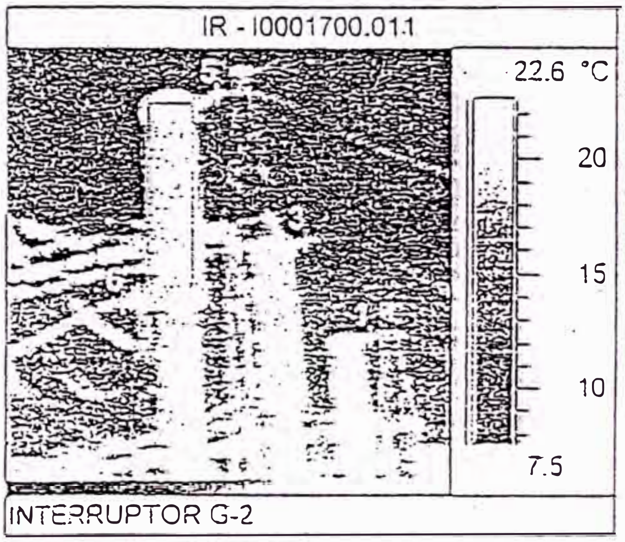
Resultados:
Temperatura.Punto (R) : 18.1 °C
Temperatura Punto 2 (R): 19.8 °C
Temperatura Punto 3 (S): 16.8 °C
Temperatura Punto 4 (S): 20.4 °C
Temperatura Punto 5 (T): 18.6 °C
Temperatura Punto 6 (T): 19.4 °C

Observaciones:
Normal.

Photo - 113.8MP

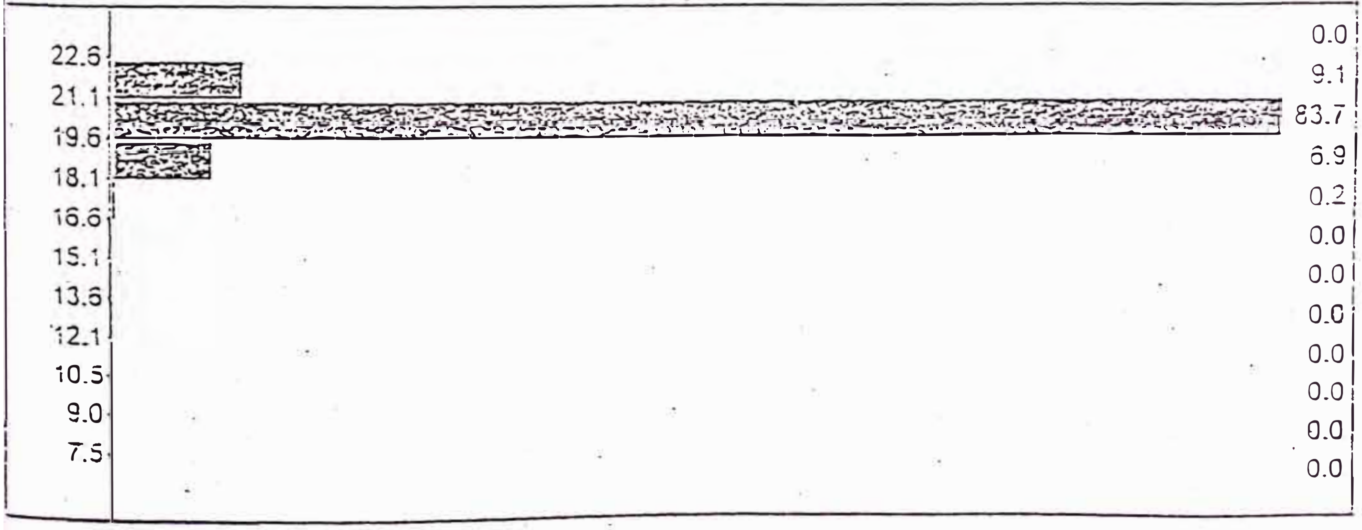


IR - I0001700.01.1



INTERRUPTOR G-2

Histogram



REPORTE TERMOGRAFICO CH. CHARCANI V

Equipo: SECCIONADOR DE BARRA G-2

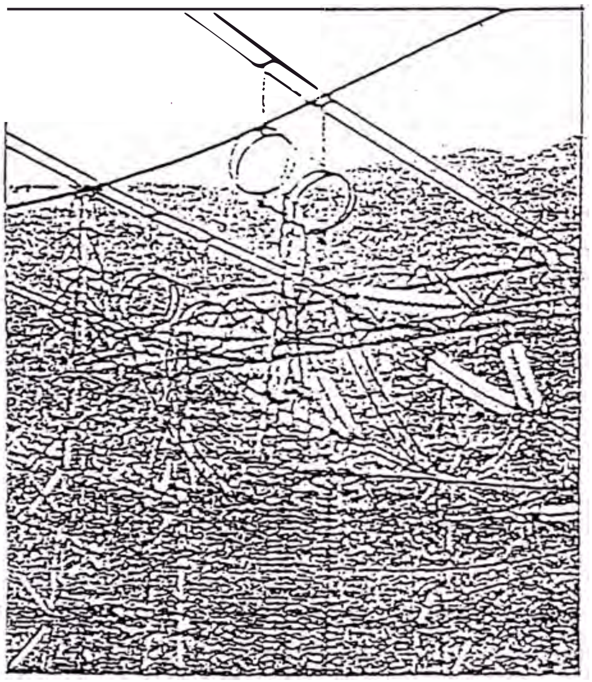
Fecha: 06/09/2001
Hora: 12:47:01 p.m.
Temp. ambiente: 15.0 °C
Distancia al objeto: 9.0 m
Emisividad: 0.98
Transmisión: 0.92

Resultados:

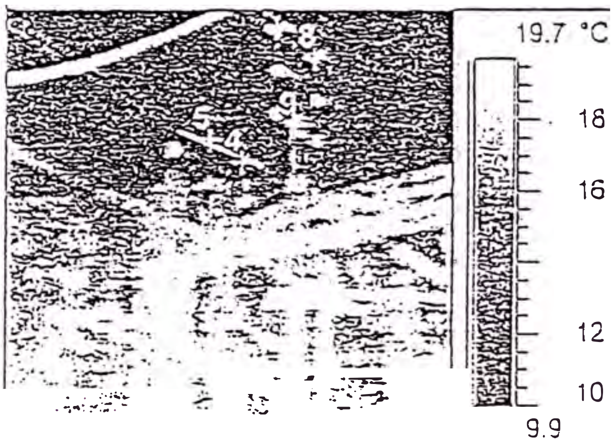
Temperatura Punto 4 (S): 15.4 °C
Temperatura Punto 5 (S): 16.3 °C
Temperatura Punto 6 (S): 17.7 °C
Temperatura Punto 7 (T): 17.6 °C
Temperatura Punto 8 (T): 17.2 °C
Temperatura Punto 9 (T): 17.5 °C

Observaciones:
Normal.

Photo - 114.8MP



IR - I0001700.014



Seccionador de barra G-2

REPORTE TERMOGRAFICO CH. CHARCANI V

Equipo: SECCIONADOR DE BARRA
ACOPLAMIENTO

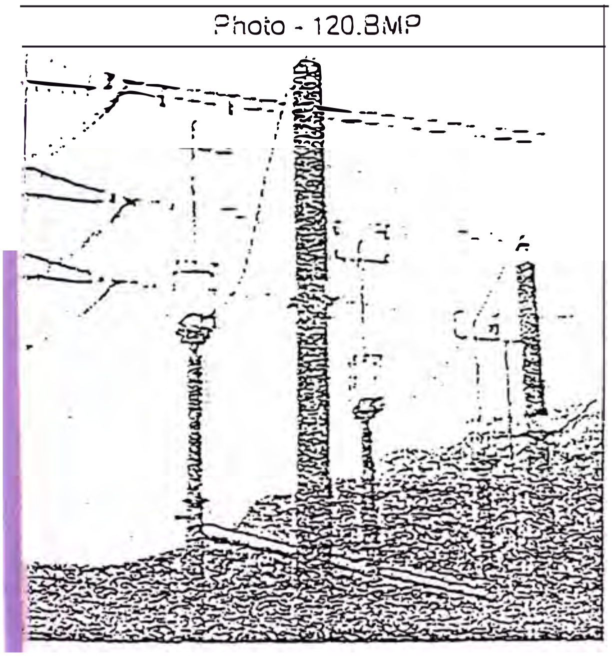
Fecha: 06/09/2001
Hora: 12:57:31 p.m.
Temp. ambiente: 15.0 °C
Distancia al objeto: 9.0 m
Emisividad: 0.98
Transmisión: 0.92

Resultados:

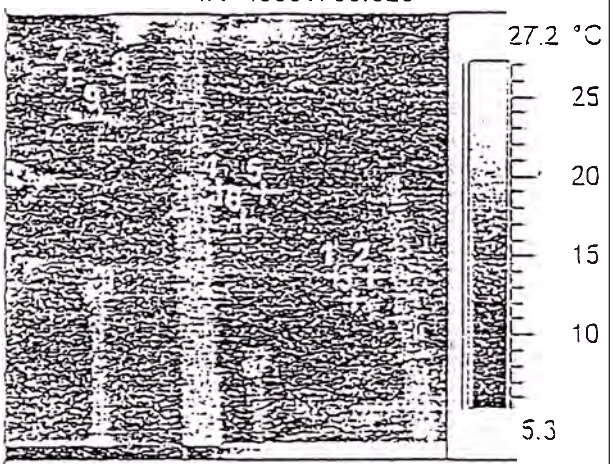
Temperatura Punto 1 (R): 17.7 °C
Temperatura Punto 2 (R): 17.0 °C
Temperatura Punto 3 (S): 16.9 °C
Temperatura Punto 4 (S): 17.2 °C
Temperatura Punto 3 (T): 16.9 °C
Temperatura Punto 4 (T): 17.2 °C

Observaciones:
Normal.

Photo - 120.BMP



IR - I0001700.020



Seccionador de barra acoplamiento

REPORTE TERMOGRAFICO CH. CHARCANI V

Equipo: G3 - CELDA DE FASES 13.8 KV
(Vista frontal)

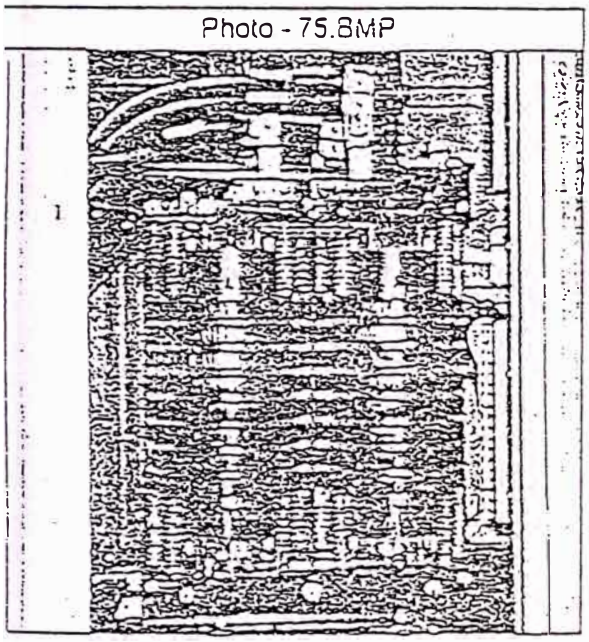
Fecha: 06/09/2001
Hora: 02:24:03 p.m.
Temp. ambiente: 15.0 °C
Distancia al objeto: 3.0 m
Emisividad: 0.90
Transmisión: 0.97

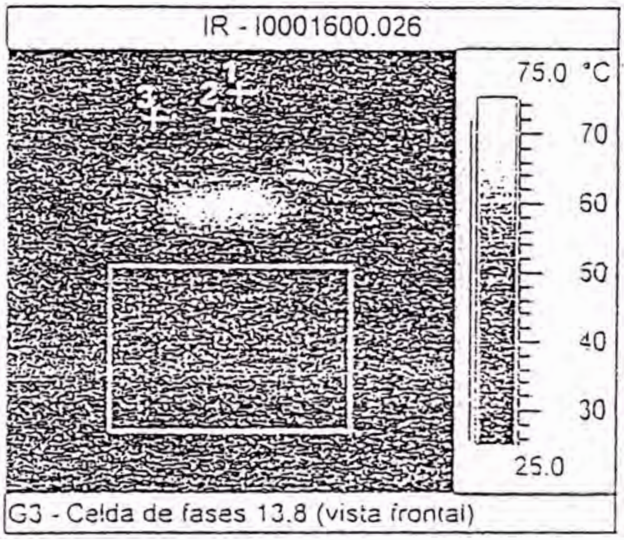
Resultados:

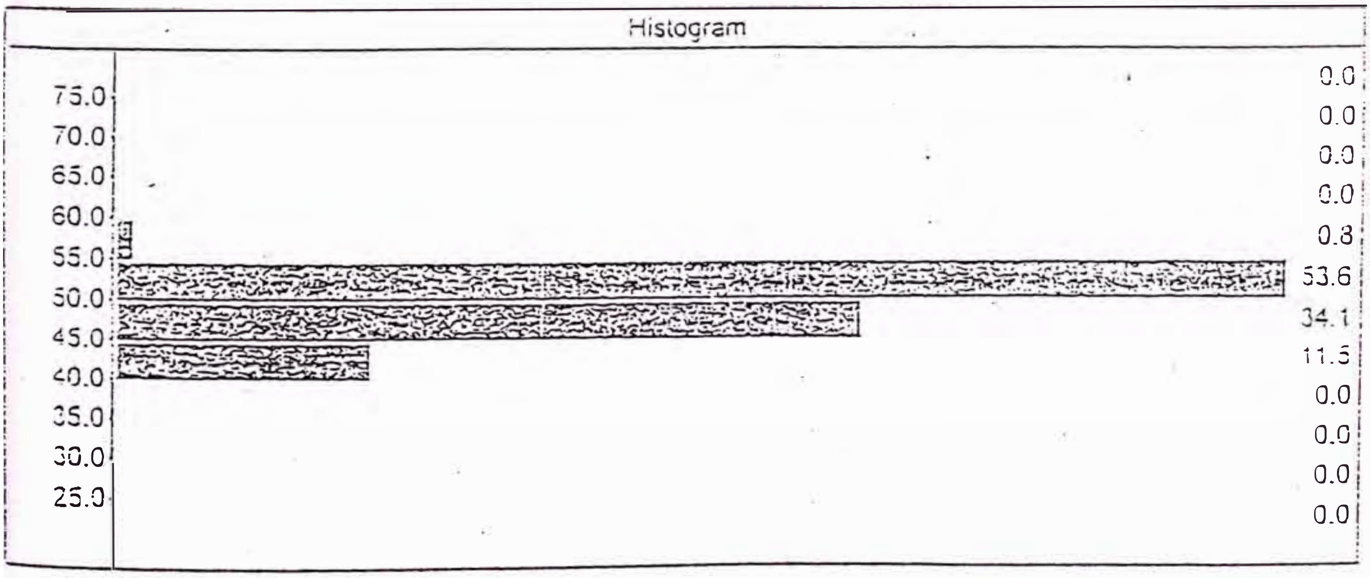
Temperatura Punto 1 38.2 °C
Temperatura Punto 2 : 39.1 °C
Temperatura Punto 3 39.5 °C

Observaciones:

Normal







REPORTE TERMOGRAFICO CH. CHARCANI V

Equipo: G3 - CELDA DE FASES 13.8 KV (Vista frontal)

Fecha: 06/09/2001
Hora: 02:27:33 p.m.
Temp. ambiente: 15.0 °C
Distancia al objeto: 3.0 m
Emisividad: 0.90
Transmisión: 0.97

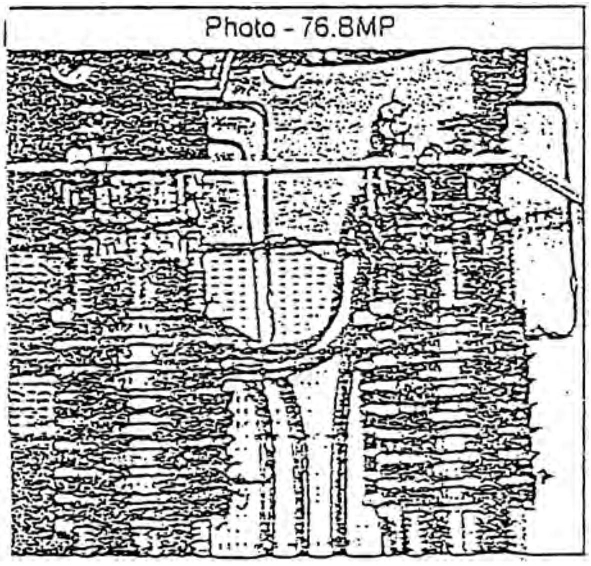
Resultados:

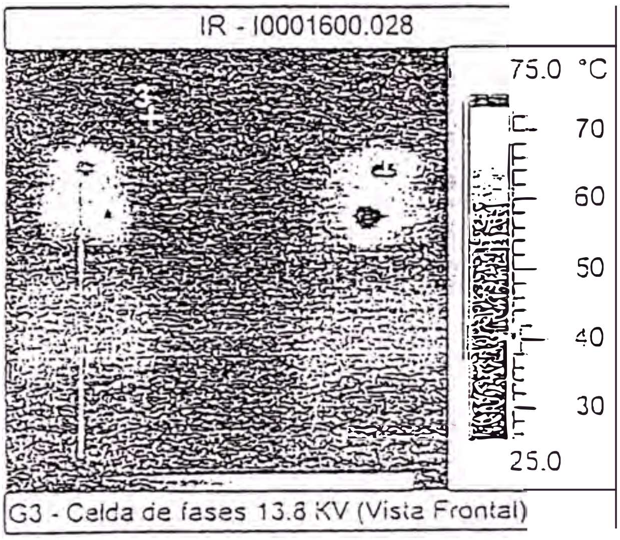
Temperatura Punto 1 : >74.3 °C
Temperatura Punto 2 : >74.3 °C

Isoterma máxima: 75.0 °C

Observaciones:

Normal





G3 - Celda de fases 13.8 KV (Vista Frontal)

REPORTE TERMOGRAFICO CH. CHARCANI V

Equipo: G3 - CELDA DE NEUTRO TRANSFORMADOR

Fecha:	06/09/2001
Hora:	02:36:57 p.m.
Temp. ambiente:	15.0 °C
Distancia al objeto:	3.0 m
Emisividad:	0.90
Transmisión:	0.97

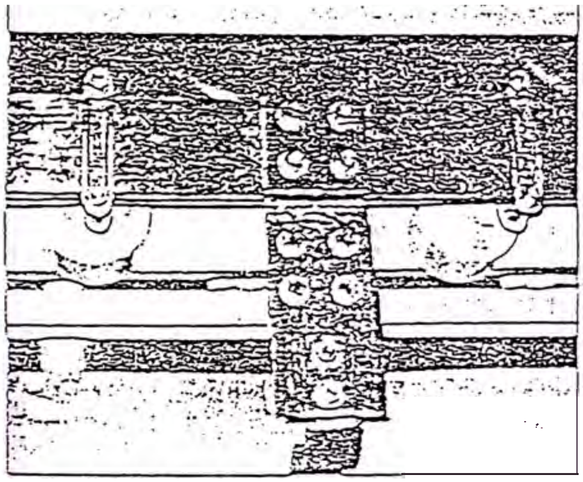
Resultados:

Temperatura Punto 1	35.4 °C
Temperatura Punto 2 :	34.1 °C
Temperatura Punto 3 :	34.3 °C

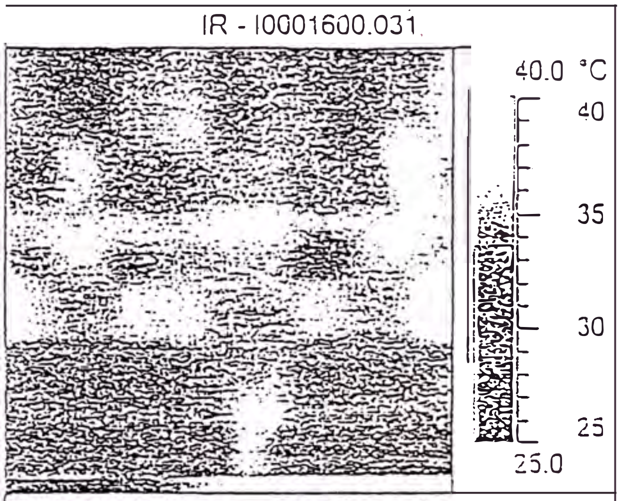
Observaciones:

Normal

Photo - 79.8MP



IR - I0001600.031



G3 Celda de Neutro - Transformador

REPORTE TERMOGRAFICO CH. CHARCANI V

Equipo: TRANSFORMADOR DE POTENCIA AUXILIAR 13.8/0.4 KV G3 (lado de baja izquierda)

Fecha: 06/09/2001
Hora: 10:37:19 a.m.
Temp. ambiente: 15.0 °C
Distancia al objeto: 2.0 m
Emisividad: 0.90
Transmisión: 0.98

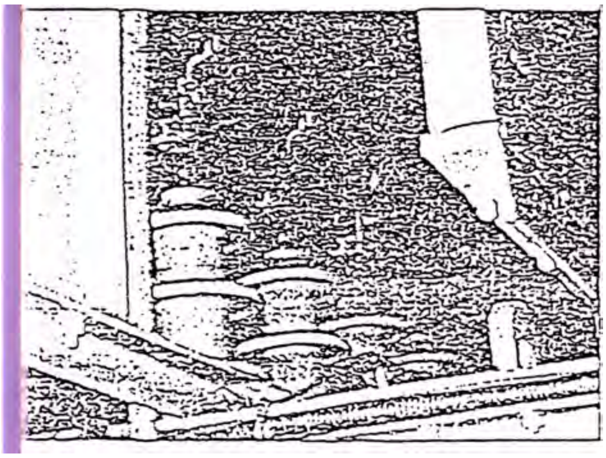
Resultados:

Temperatura Punto 1 31.1 °C
Temperatura Punto 2 29.2 °C
Temperatura Punto 3 : 27.7 °C

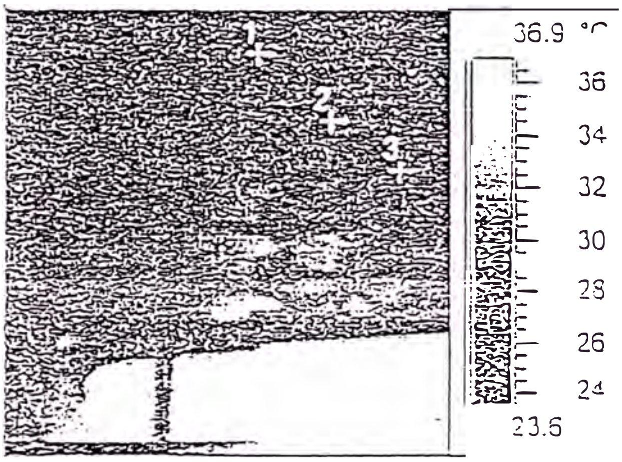
Observaciones:

Normal

Photo - 97.BMP



IR - I0001600.053



Transf. de pot. auxiliar 13.8/0.4 KV

REPORTE TERMOGRAFICO CH. CHARCANI V

Equipo: G3 - CELDA DE TRANSFORMADOR 100 KVA

Fecha: 06/09/2001
Hora: 02:38:14 p.m.
Temp. ambiente: 15.0 °C
Distancia al objeto: 3.0 m
Emisividad: 0.90
Transmisión: 0.97

Resultados:

Temperatura Punto 1	46.9 °C
Temperatura Punto 2	42.0 °C
Temperatura Punto 3	46.7 °C

Observaciones:

Normal

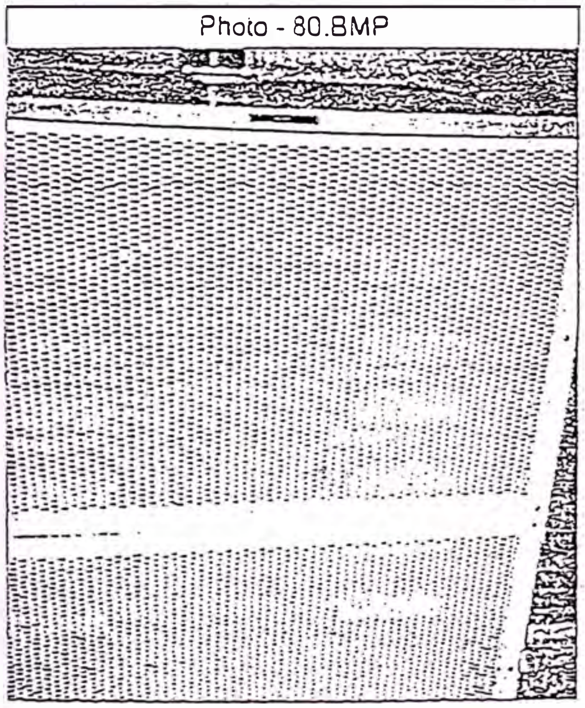
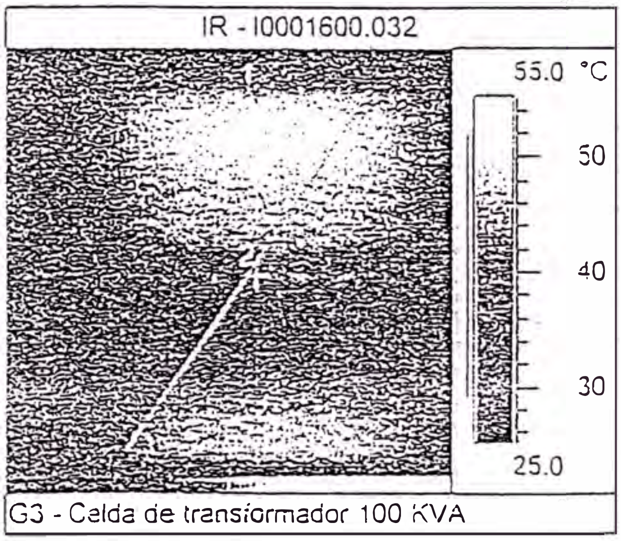
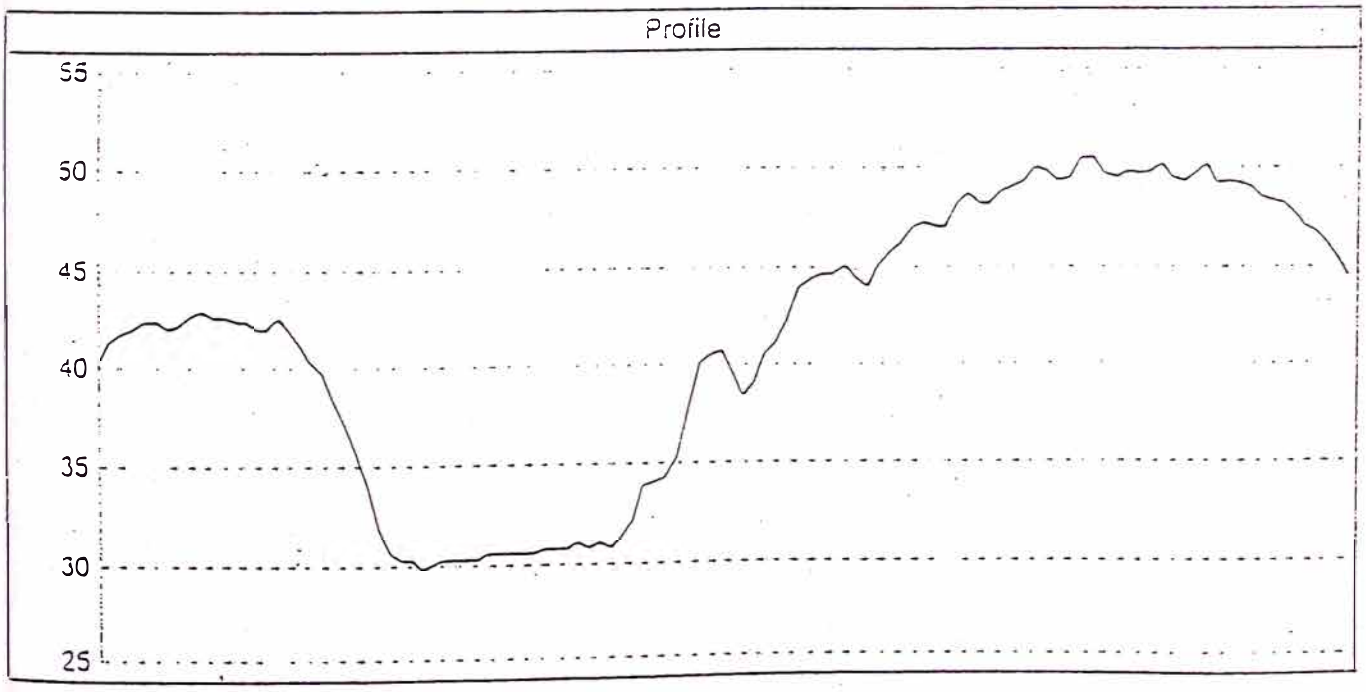


Photo - 80.BMP


IR - I0001600.032

G3 - Celda de transformador 100 KVA


Profile

REPORTE TERMOGRAFICO CH. CHARCANI V

Equipo: G3 - INICIO GALERIA DE CABLES

Fecha: 06/09/2001
Hora: 11:13:00 a.m.
Temp. ambiente: 15.0 °C
Distancia al objeto: 1.0 m
Emisividad: 0.98
Transmisión: 0.99

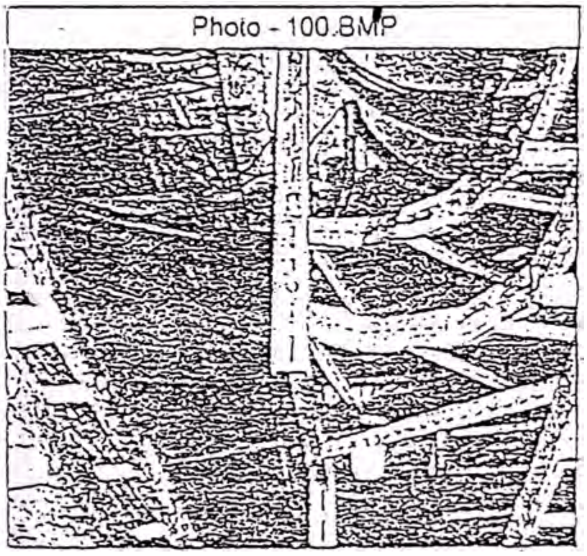
Resultados:

Temperatura Punto 1 (R) : > 31.4 °C
Temperatura Punto 2 (S) : 29.8 °C
Temperatura Punto 3 (T): 28.7 °C

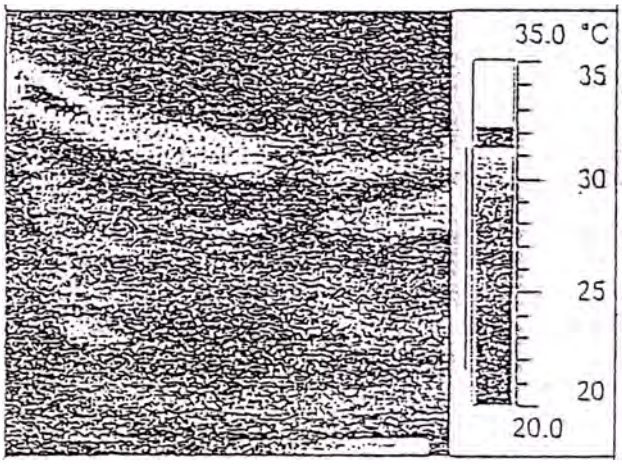
Isoterma máxima: 32.3 °C

Observaciones:
Isoterma máxima en fase R

Photo - 100.BMP



IR - I0001600.060



G3 - Inicio galeria de cables

REPORTE TERMOGRAFICO CH. CHARCANI V

Equipo: TRANSFORMADOR G3 (caja de conexión)

Fecha: 06/09/2001
Hora: 11:40:09 a.m.
Temp. ambiente: 18.0 °C
Distancia al objeto: 1.0 m
Emisividad: 0.98
Transmisión: 0.99

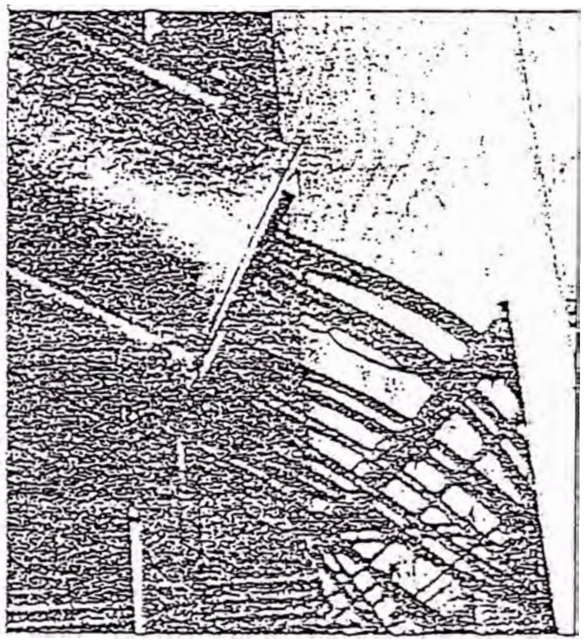
Resultados:

Temperatura Punto 1	>46.4 °C
Temperatura Punto 2	37.2 °C
Temperatura Punto 3 :	<25.7 °C

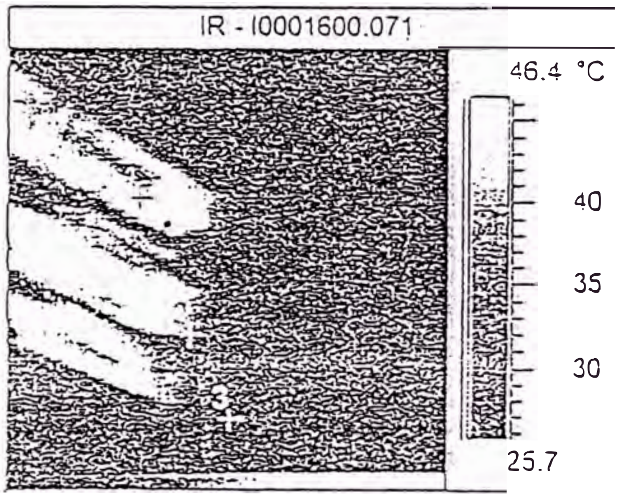
Observaciones:

Verificar conexionados en fases S y T

Photo - 105.BMP



IR - I0001600.071



Transformador G3 (caja de conexión)

REPORTE TERMOGRAFICO CH. CHARCANI V

Equipo: TRANSFORMADOR G3 (caja de conexión)

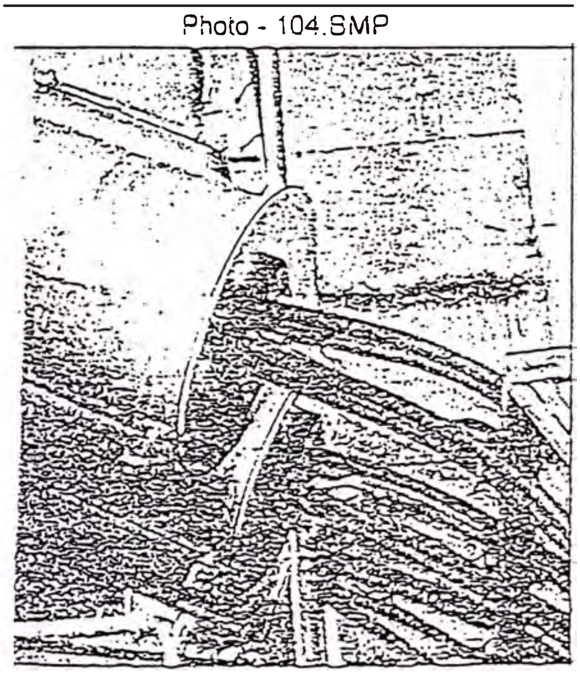
Fecha:	06/09/2001
Hora:	11:37:21 a.m.
Temp. ambiente:	18.0 °C
Distancia al objeto:	1.0 m
Emisividad:	0.98
Transmisión:	0.99

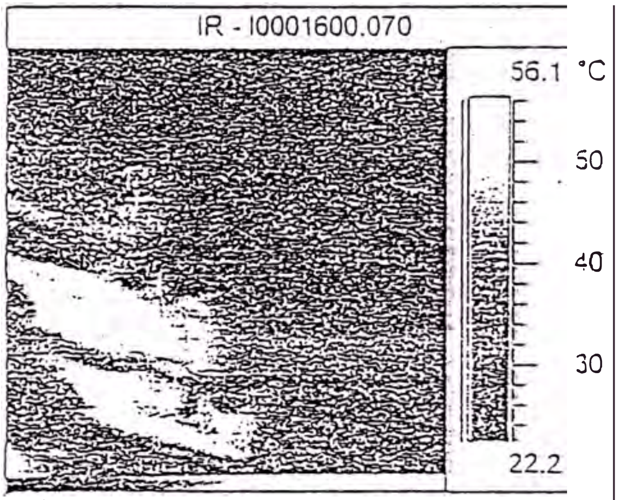
Resultados:

Temperatura Punto	40.9 °C
Temperatura Punto 2 :	53.4 °C
Temperatura Punto 3 :	52.3 °C

Observaciones:

Verificar conexionados en fases S y T





Caja de conexión llegada Transf. G3

REPORTE TERMOGRAFICO CH. CHARCANI V

Equipo: PARAYOS Y SALIDA G3

Fecha: 06/09/2001
Hora: 11:51:28 a.m.
Temp. ambiente: 20.0 °C
Distancia al objeto: 9.0 m
Emisividad: 0.98
Transmisión: 0.92

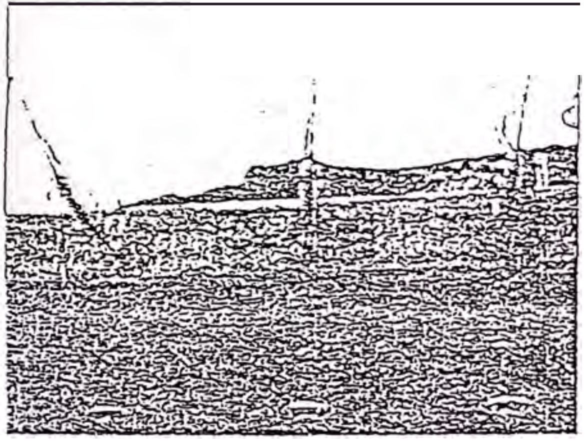
Resultados:

Temperatura Punto 1 (R) : 22.0 °C
Temperatura Punto 2 (S): 16.7 °C
Temperatura Punto 3 (T): 18.3 °C

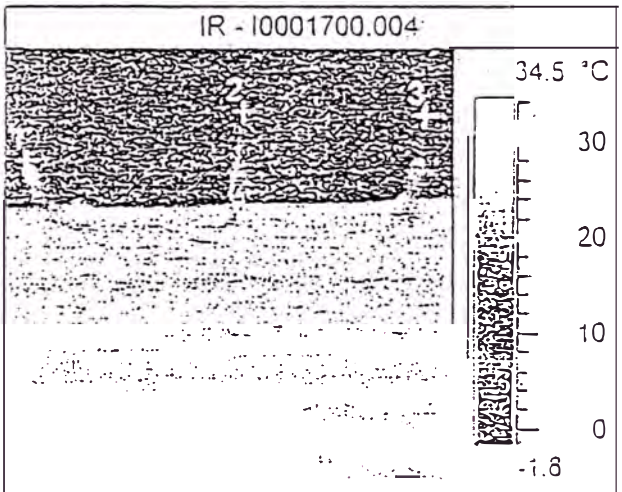
Observaciones:

Normal. Observar fase R

Photo - 108.8MP



IR - I0001700.004



Pararayos y salida G3

REPORTE TERMOGRAFICO CH. CHARCANI V

Equipo: G3 - CELDA PARARAYOS
TRANSF. DE MEDIDA

Fecha: 06/09/2001
Hora: 02:32:39 p.m.
Temp. ambiente: 15.0 °C
Distancia al objeto: 3.0 m
Emisividad: 0.90
Transmisión: 0.97

Resultados:

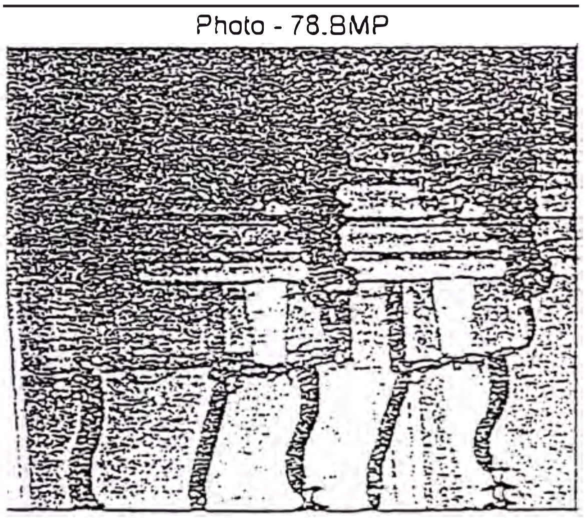
Temperatura Punto 1 : 35.5 °C
Temperatura Punto 2 > 37.4 °C

Isoterma máxima: 37.8 °C

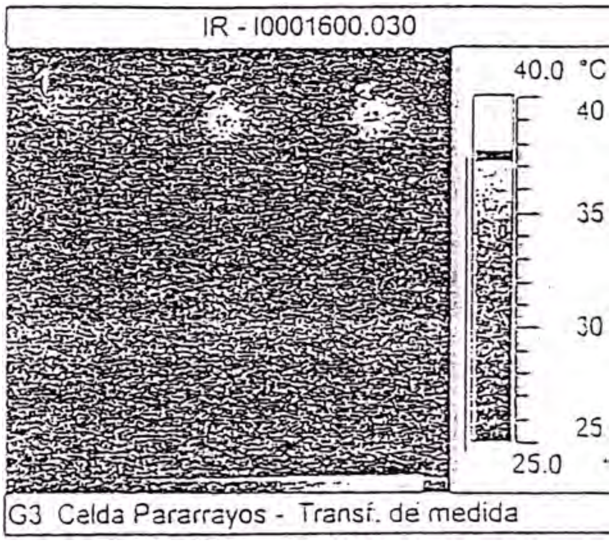
Observaciones:

Normal

Photo - 78.BMP



IR - I0001600.030



G3 Celda Pararrayos - Transf. de medida

REPORTE TERMOGRAFICO CH. CHARCANI V

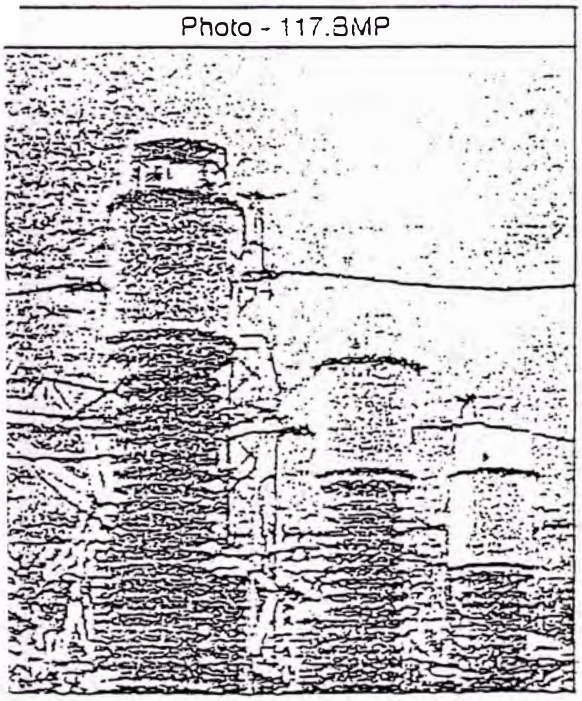
Equipo: TRANSFORMADOR DE CORRIENTE G-3

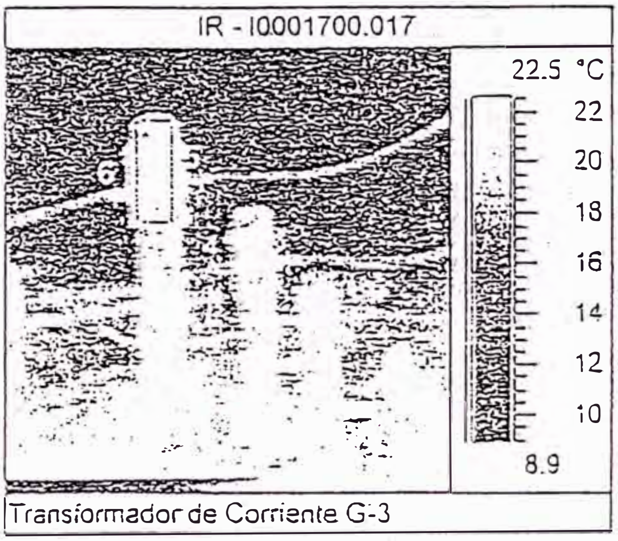
Fecha: 06/09/2001
Hora: 12:50:32 p.m.
Temp. ambiente: 15.0 °C
Distancia al objeto: 9.0 m
Emisividad: 0.98
Transmisión: 0.92

Resultados:

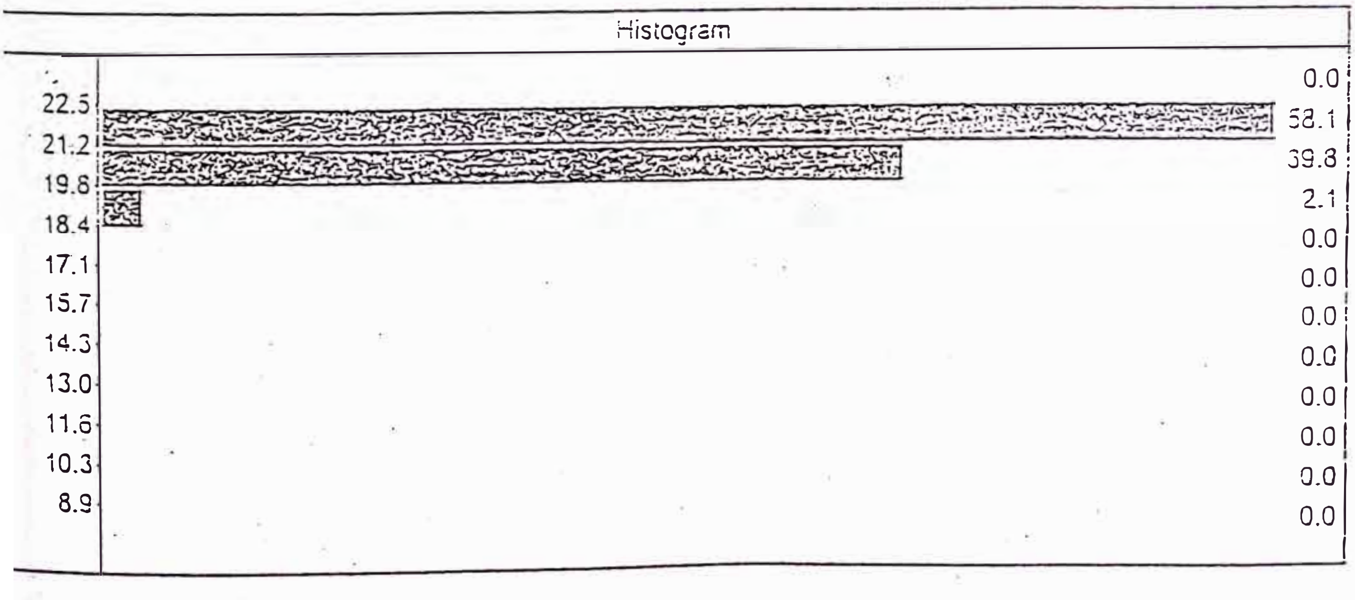
Temperatura Punto 1 (R): 19.8 °C
Temperatura Punto 2 (R): 19.2 °C
Temperatura Punto 3 (S): 18.9 °C
Temperatura Punto 4 (S): 19.8 °C
Temperatura Punto 3 (T): 18.9 °C
Temperatura Punto 4 (T): 19.8 °C

Observaciones:
Normal.





Transformador de Corriente G-3



REPORTE TERMOGRAFICO CH. CHARCANI V

Equipo: PARARYOS Y TRANSFORMADOR
TENSION G-3

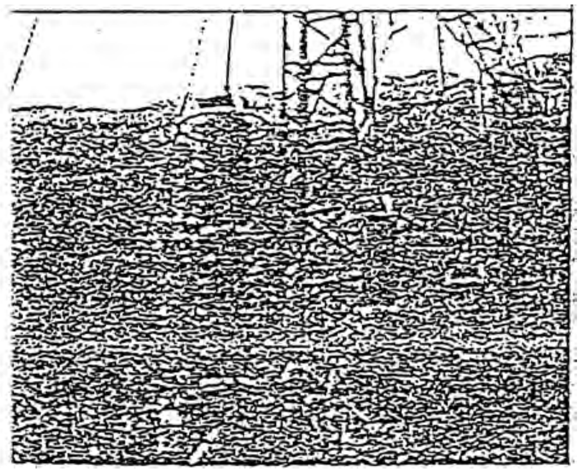
Fecha: 06/09/2001
Hora: 12:48:40 p.m.
Temp. ambiente: 15.0 °C
Distancia al objeto: 9.0 m
Emisividad: 0.98
Transmisión: 0.92

Resultados:

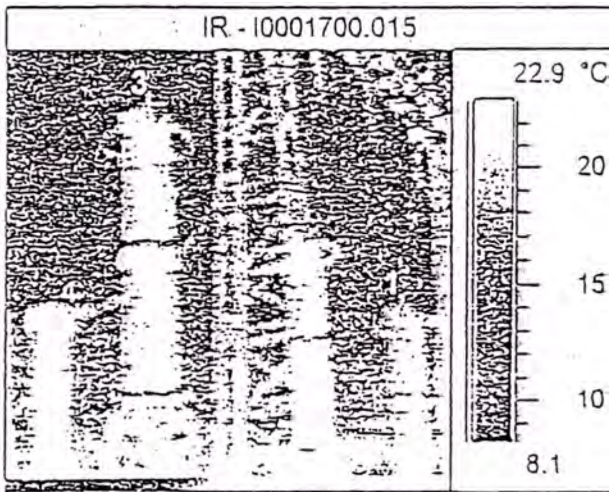
Temperatura Punto 1 (R): 19.2 °C
Temperatura Punto 2 (S): 19.6 °C
Temperatura Punto 3 (T): 17.1 °C
Temperatura Punto 4 (S): 19.4 °C

Observaciones:
Normal.

Photo - 115.BMP



IR - I0001700.015



Pararayos y Transf. de tensión G-3

REPORTE TERMOGRAFICO CH. CHARCANI V

Equipo: SECCIONADOR G-3

Fecha: 06/09/2001
Hora: 12:49:51 p.m.
Temp. ambiente: 15.0 °C
Distancia al objeto: 9.0 m
Emisividad: 0.98
Transmisión: 0.92

Resultados:

Temperatura Punto 1 (R): 19.3 °C
Temperatura Punto 2 (R): 19.2 °C
Temperatura Punto 3 (S): 18.8 °C
Temperatura Punto 4 (S): 18.8 °C
Temperatura Punto 3 (T): 18.8 °C
Temperatura Punto 4 (T): 18.8 °C

Observaciones:
Normal.

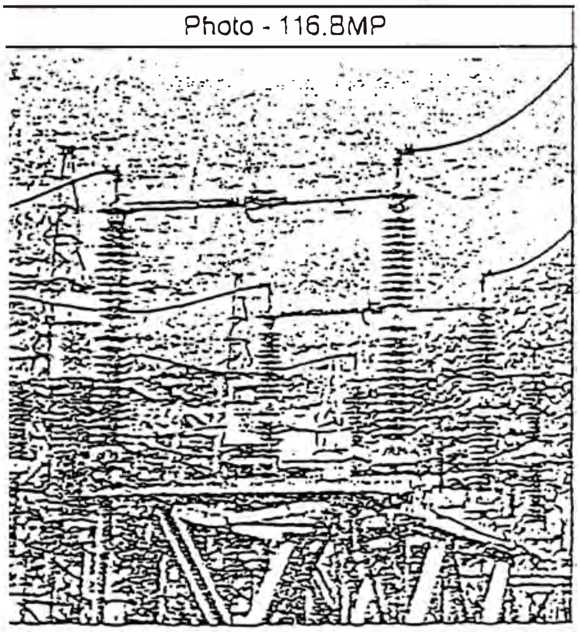
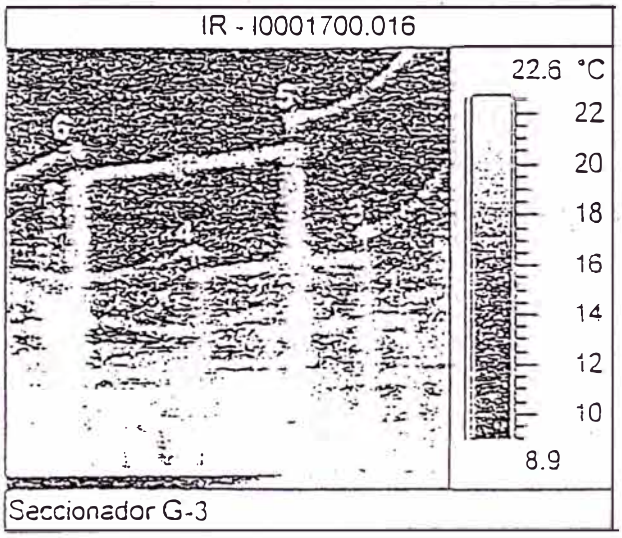
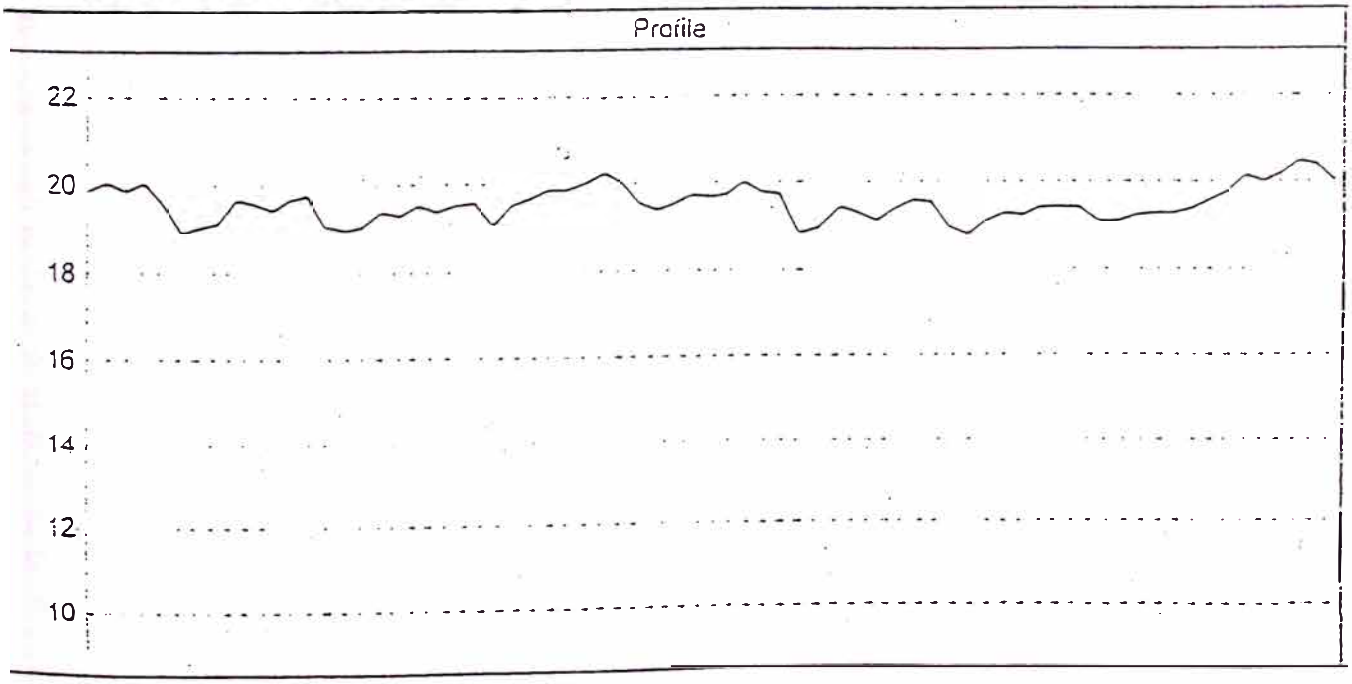


Photo - 116.8MP


IR - I0001700.016

Seccionador G-3

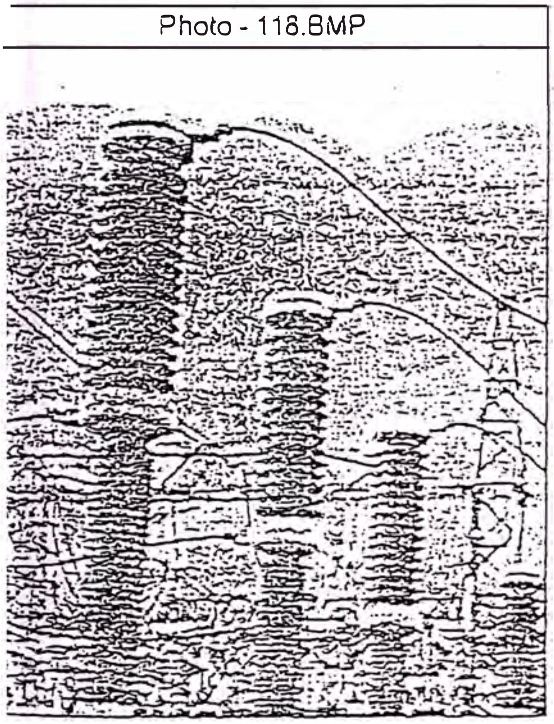

Profile

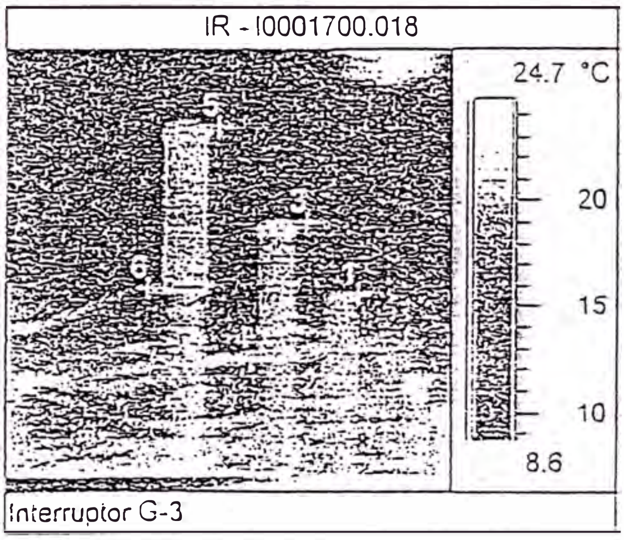
REPORTE TERMOGRAFICO CH. CHARCANI V

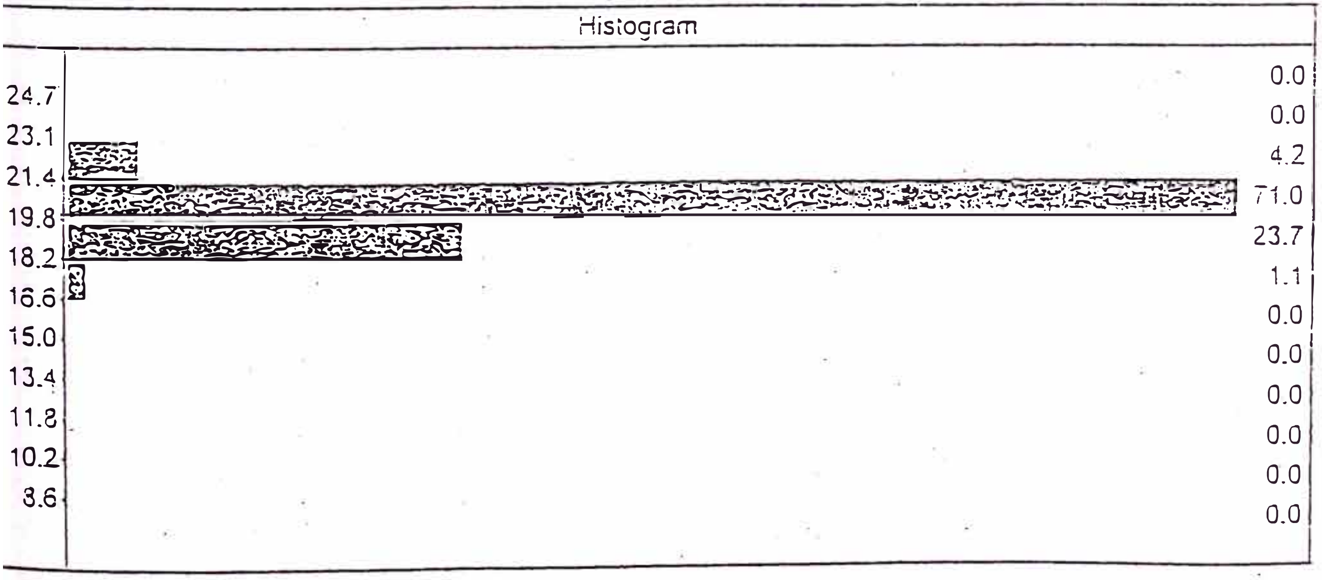
quipo: INTERRUPTOR G-3

cha: 06/09/2001
ora: 12:51:15 p.m.
emp. ambiente: 15.0 °C
stancia al objeto: 9.0 m
nisividad: 0.93
ansmisión: 0.92

Resultados:
Temperatura Punto 1 (R): 18.6 °C
Temperatura Punto 2 (R): 19.3 °C
Temperatura Punto 3 (S): 18.3 °C
Temperatura Punto 4 (S): 19.2 °C
Temperatura Punto 5 (T): 18.3 °C
Temperatura Punto 6 (T): 19.4 °C
Observaciones:
Normal.







REPORTE TERMOGRAFICO CH. CHARCANI V

Equipo: SECCIONADOR DE BARRA G-3

Fecha: 06/09/2001
Hora: 12:53:13 p.m.
Temp. ambiente: 15.0 °C
Distancia al objeto: 9.0 m
Emisividad: 0.98
Transmisión: 0.92

Resultados:
Temperatura Punto (R): 15.6 °C
Temperatura Punto 2 (R): 15.4 °C
Temperatura Punto 3 (S): 17.5 °C
Temperatura Punto 4 (S): 16.7 °C
Temperatura Punto 3 (T): 17.5 °C
Temperatura Punto 4 (T): 16.7 °C

Observaciones:
Normal.

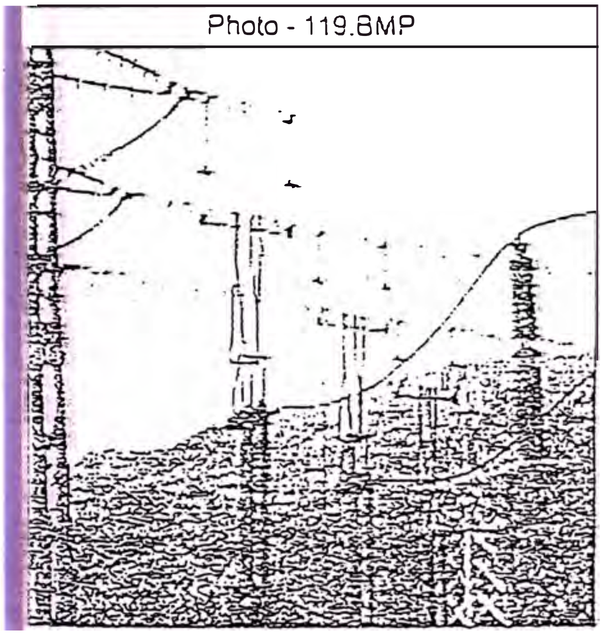
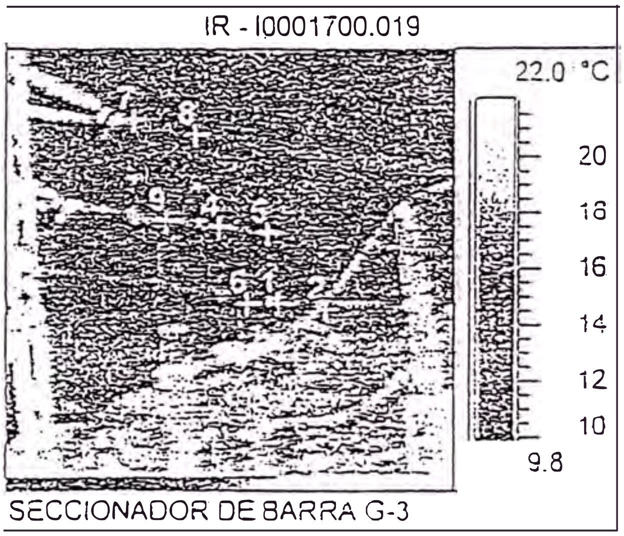


Photo - 119.BMP


IR - I0001700.019

SECCIONADOR DE BARRA G-3

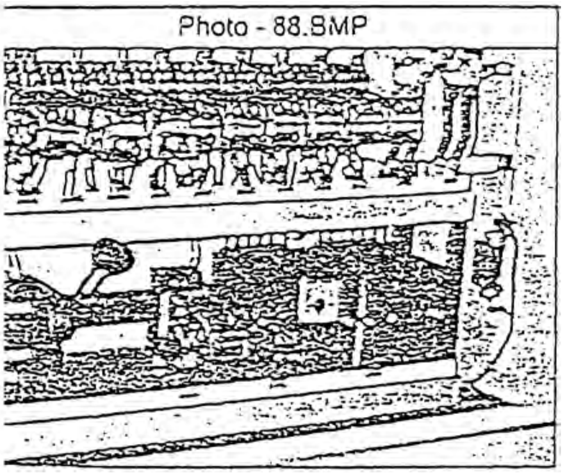
REPORTE TERMOGRAFICO CH. CHARCANI V

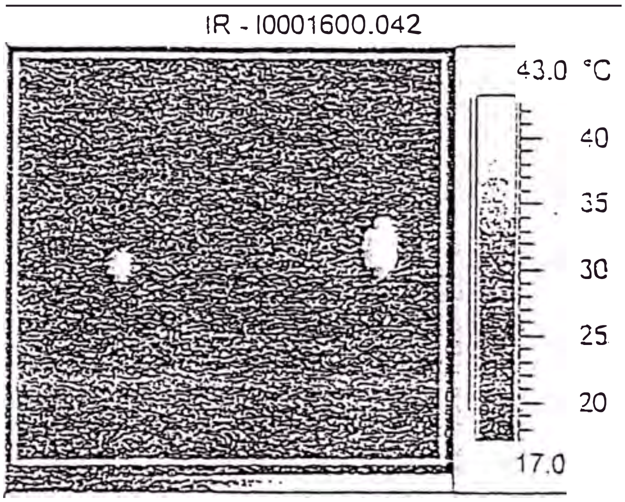
Equipo: BANCO DE CORRIENTE CONTINUA

Observaciones:

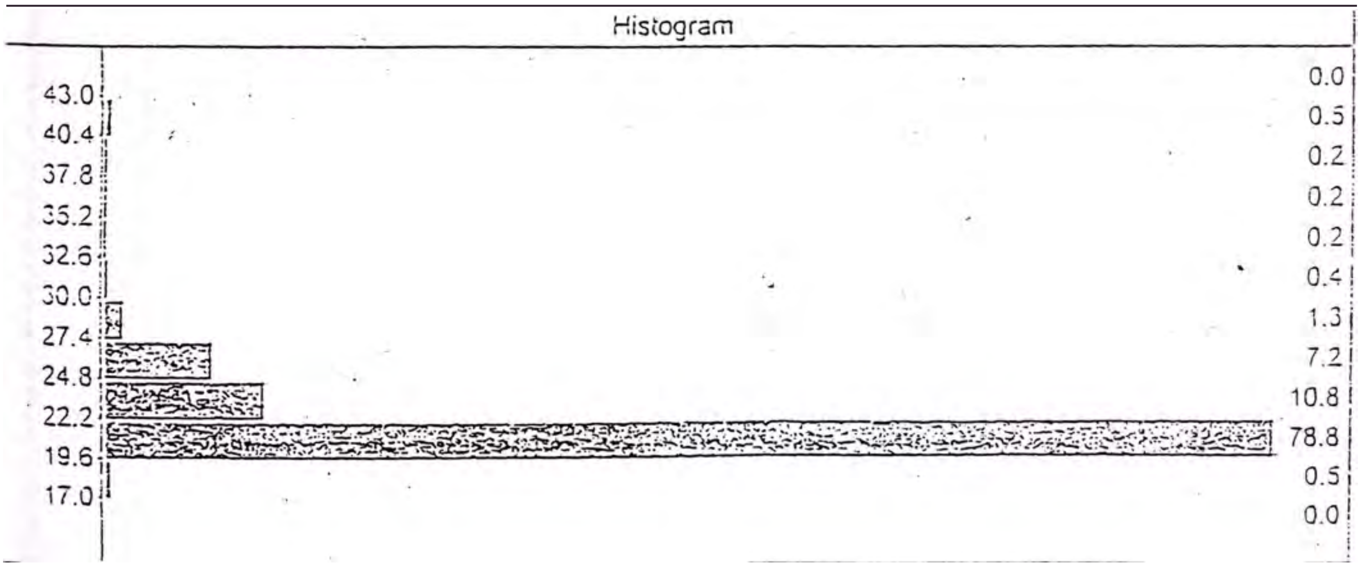
Normal.

Fecha: 06/09/2001
Hora: 03:04:00 p.m.
Temp. ambiente: 15.0 °C
Distancia al objeto: 1.0 m
Emisividad: 0.90
Transmisión: 0.99





Banco de corriente continua



REPORTE TERMOGRAFICO CH. CHARCANI V

Equipo: BANCO DE BATERIAS

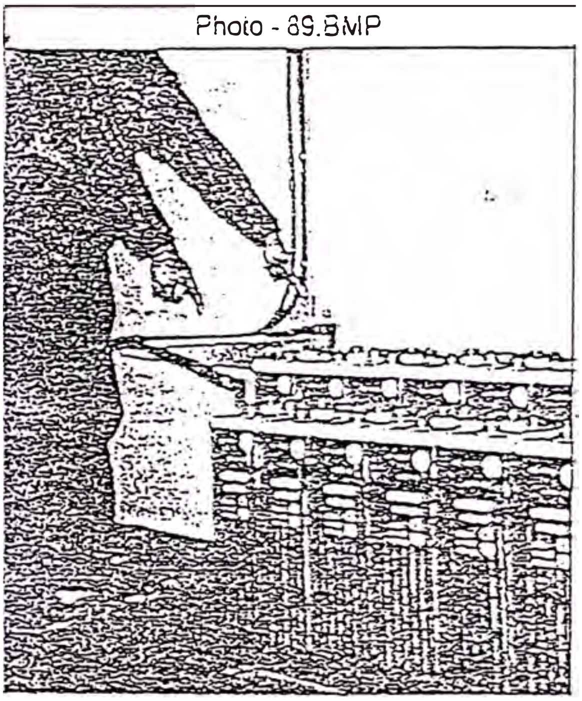
Fecha:	06/09/2001
Hora:	03:15:29 p.m.
Temp. ambiente:	15.0 °C
Distancia al objeto:	2.0 m
Emisividad:	0.90
Transmisión:	0.98

Observaciones:

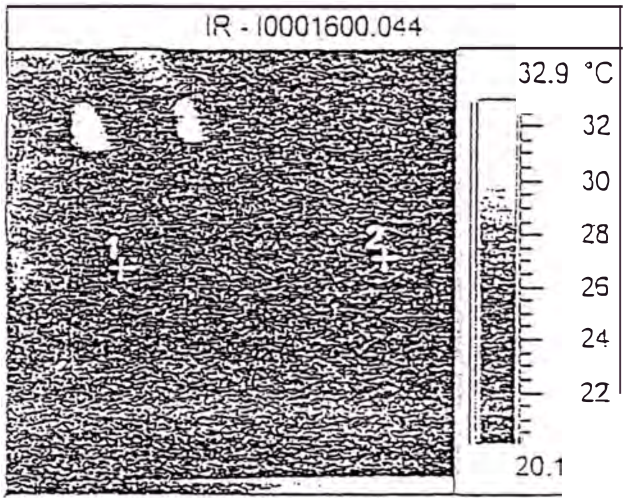
Normal.

Se ha requerido "manos" como punto de referencia, al dificultarse la visualización de los contactos.

Photo - 89.BMP



IR - I0001600.044



Banco de baterias

REPORTE TERMOGRAFICO CH. CHARCANI V

Equipo: BOMBAS DE AGUA TRATADA

Fecha: 06/09/2001
Hora: 03:22:54 p.m.
Temp. ambiente: 15.0 °C
Distancia al objeto: 2.0 m
Emisividad: 0.90
Transmisión: 0.98

Resultados:

Temperatura Punto 1 45.3 °C
Temperatura Punto 2 57.3 °C

Observaciones:

Sobretemperaturas en bomba N° 2.
Verificar resultados en mismos tiempos de funcionamiento.

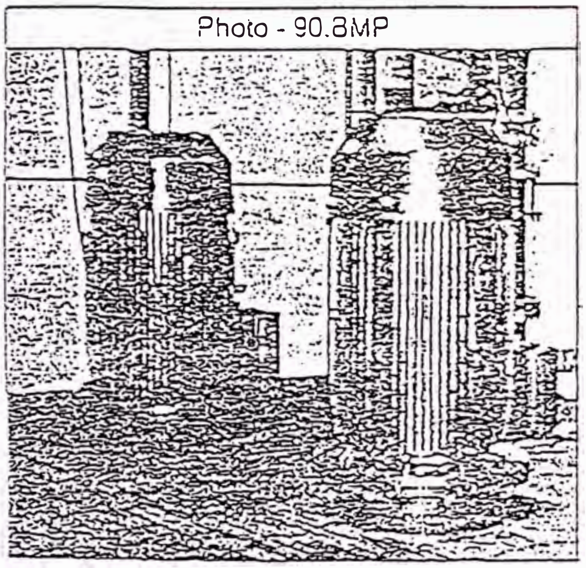
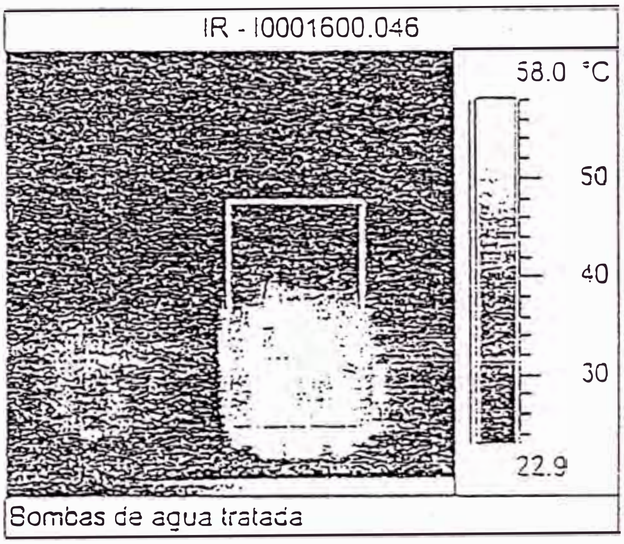
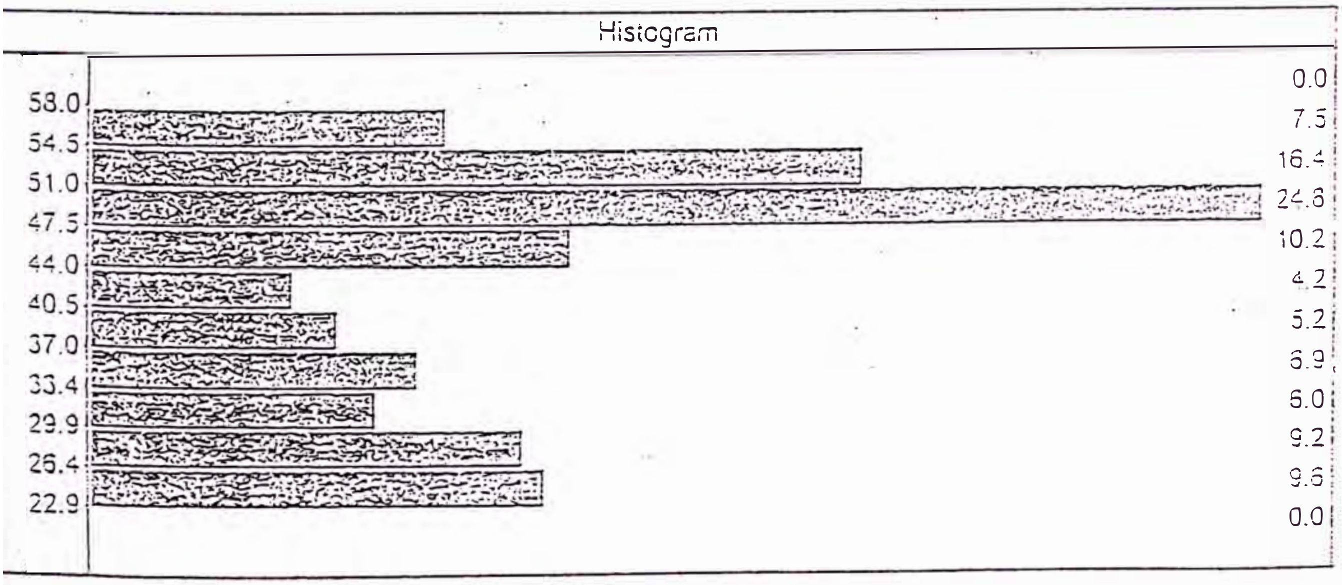


Photo - 90.8MP


IR - I0001600.046

Bombas de agua tratada


Histogram

REPORTE TERMOGRAFICO CH. CHARCANI V

Equipo: TABLERO LKA

Fecha:	06/09/2001
Hora:	11:01:01 a.m.
Temp. ambiente:	15.0 °C
Distancia al objeto:	1.0 m
Emisividad:	0.98
Transmisión:	0.99

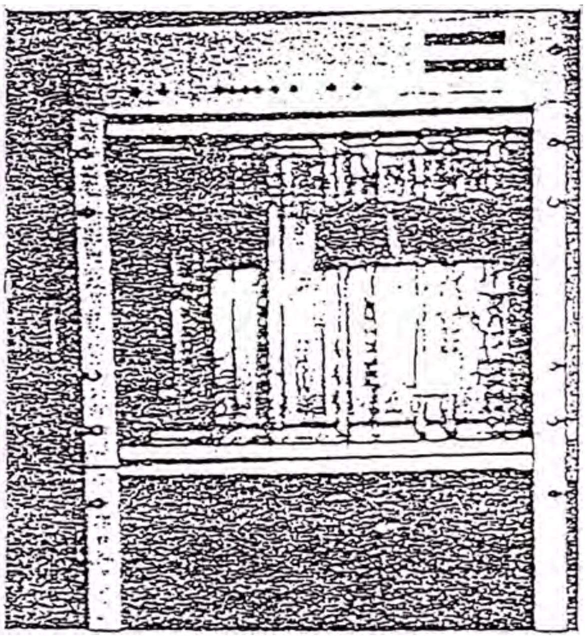
Resultados:

Temperatura Punto 1 :	36.0 °C
Temperatura Punto 2 :	37.5 °C
Temperatura Punto 3	37.9 °C.
Temperatura Punto 4 :	38.6 °C
Temperatura Punto 5	42.3 °C
Temperatura Punto 6	40.9 °C
Temperatura Punto 7 :	37.4 °C

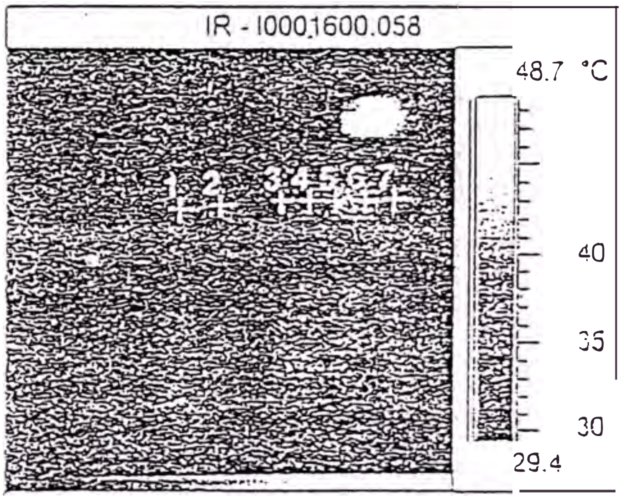
Observaciones:

Verificar tarjetas 5 y 6.

Photo - 98.BMP



IR - 10001600.058



Tablero LKA

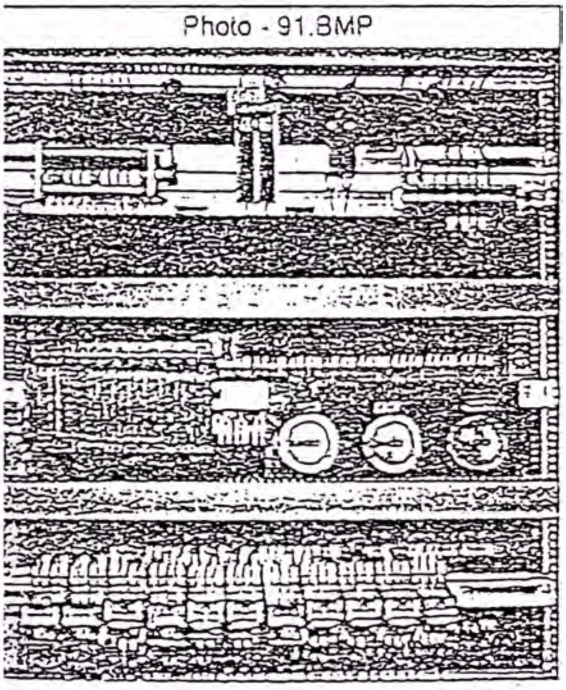
REPORTE TERMOGRAFICO CH. CHARCANI V

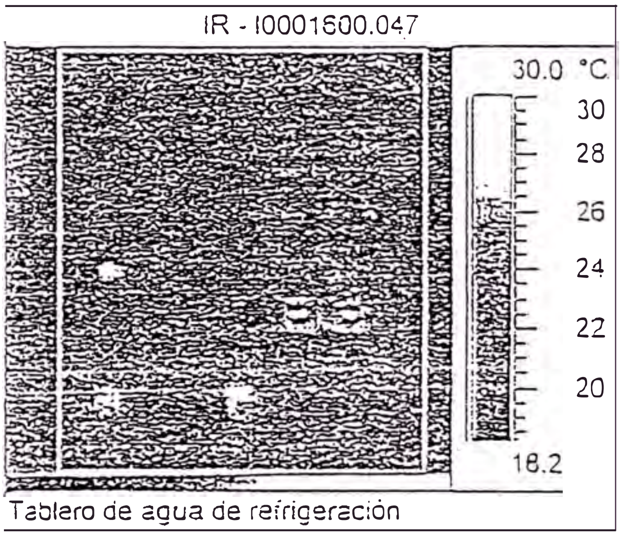
Equipo: TABLERO DE AGUA DE REFRIGERACION

Observaciones:

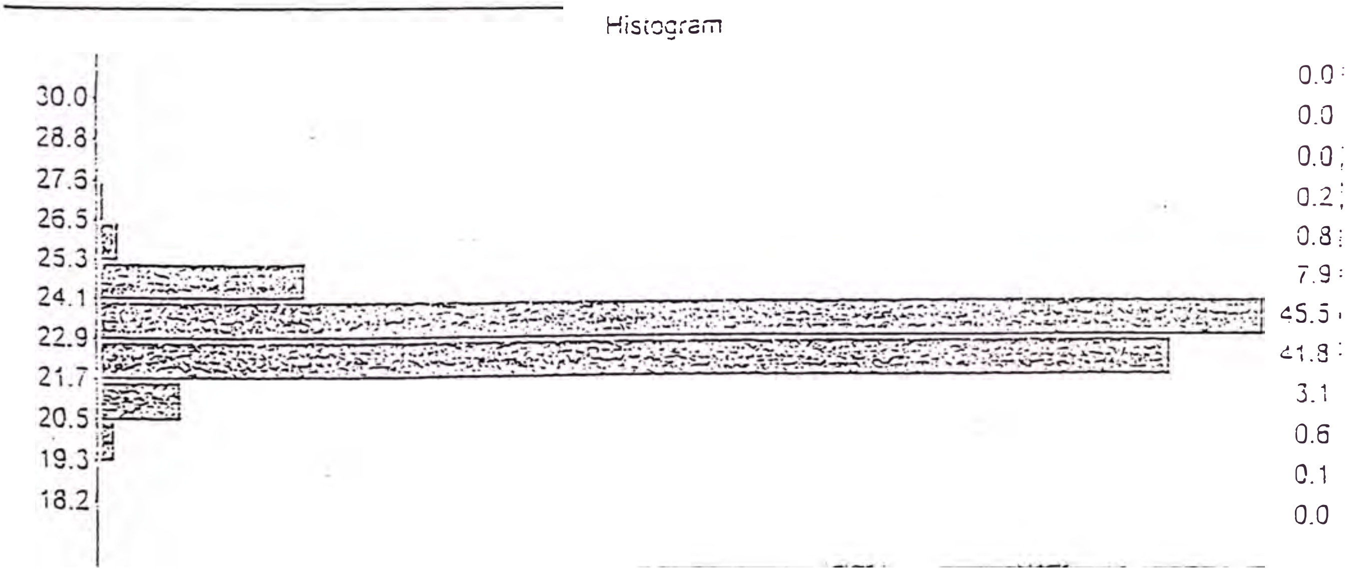
Normal

Fecha: 06/09/2001
Hora: 03:25:10 p.m.
Temp. ambiente: 15.0 °C
Distancia al objeto: 2.0 m
Emisividad: 0.90
Transmisión: 0.98





Tablero de agua de refrigeración



REPORTE TERMOGRAFICO CH. CHARCANI V

Equipo: TABLERO DE AGUA DE REFRIGERACION PARTE POSTERIOR

Fecha: 06/09/2001
Hora: 03:29:06 p.m.
Temp. ambiente: 15.0 °C
Distancia al objeto: 2.0 m
Emisividad: 0.90
Transmisión: 0.98

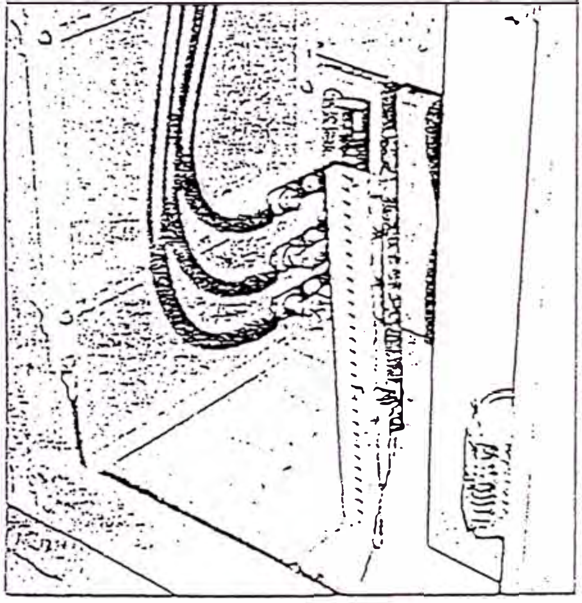
Resultados:

Temperatura Punto 1 >95.3 °C
Temperatura Punto 2 : 95.0 °C
Temperatura Punto 3 76.6 °C

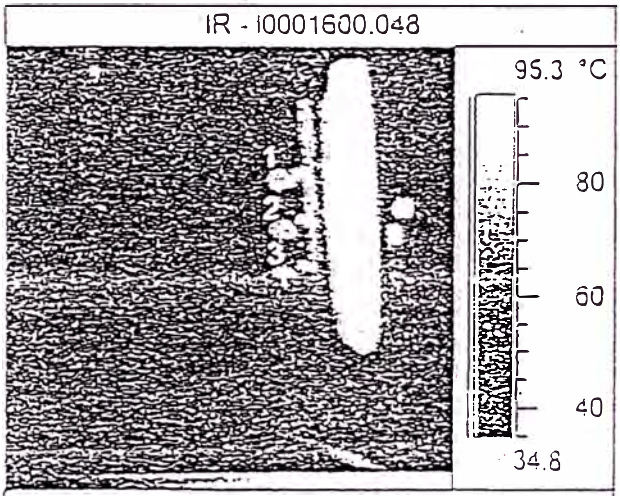
Observaciones:

Sobretemperaturas considerables. Atender inmediatamente.
Ver termograma siguiente (10001600.049)

Photo - 92.BMP



IR - 10001600.048



Tablero de agua de refrigeración (parte post.

REPORTE TERMOGRAFICO CH. CHARCANI V

Equipo: TABLERO DE AGUA DE REFRIGERACION PARTE POSTERIOR

Fecha: 06/09/2001
Hora: 03:30:39 p.m.
Temp. ambiente: 15.0 °C
Distancia al objeto: 2.0 m
Emisividad: 0.90
Transmisión: 0.98

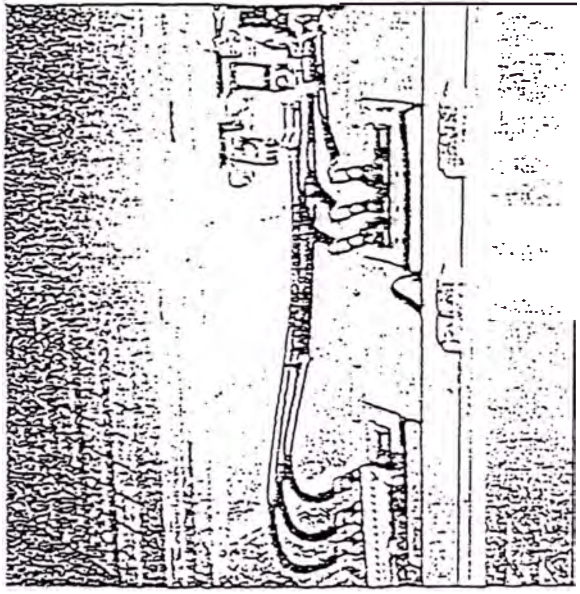
Resultados:

Temperatura Punto 1 : 47.3 °C
Temperatura Punto 2 : 50.3 °C
Temperatura Punto 3 : 52.0 °C
Temperatura Punto 4 : 81.4 °C

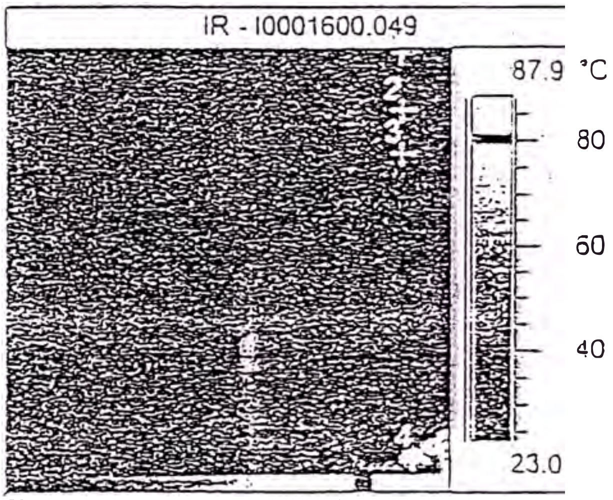
Observaciones:

Sobretemperaturas considerables. Atender inmediatamente.

Photo - 93.8MP



IR - I0001600.049



Tab. de agua de refrigeración parte post.

REPORTE TERMOGRAFICO CH. CHARCANI V

Equipo: TABLERO DE DRENAJE DE AGUA CRUDA

Fecha:	06/09/2001
Hora:	03:37:01 p.m.
Temp. ambiente:	15.0 °C
Distancia al objeto:	2.0 m
Emisividad:	0.90
Transmisión:	0.98

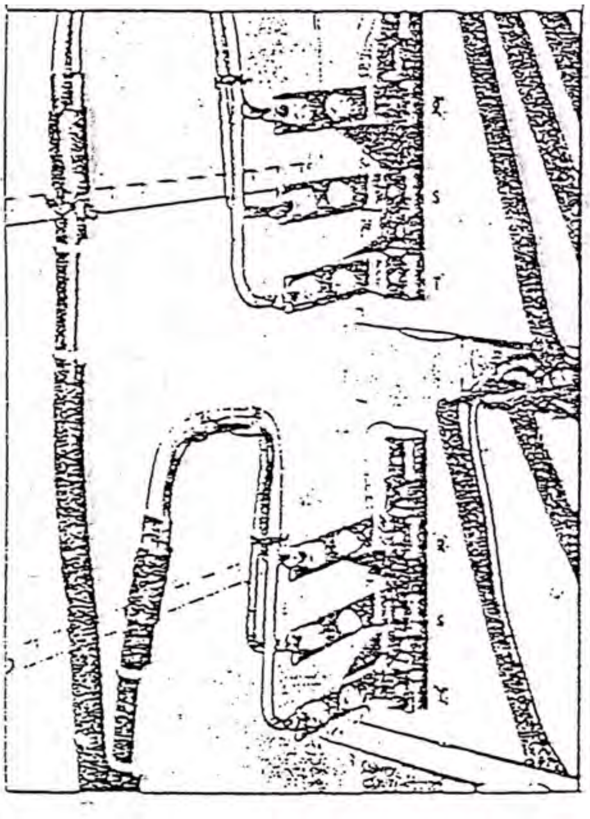
Resultados:

Temperatura Punto 1 :	28.4 °C
Temperatura Punto 2	28.3 °C
Temperatura Punto 3 :	28.4 °C
Temperatura Punto 4	29.5 °C
Temperatura Punto 5 :	29.2 °C
Temperatura Punto 6	30.1 °C

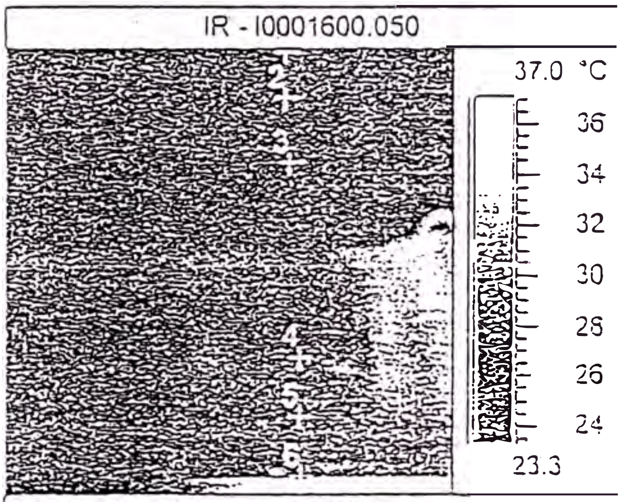
Observaciones:

Normal

Photo - 94.BMP



IR - I0001600.050



Tab. de drenaje de agua cruda

REPORTE TERMOGRAFICO CH. CHARCANI V

Equipo: TRANSFORMADOR DE POTENCIA
AUXILIAR 13.8/0.4 kv G3
(lado de alta)

Fecha: 06/09/2001
Hora: 10:31:46 a.m.
Temp. ambiente: 15.0 °C
Distancia al objeto: 2.0 m
Emisividad: 0.90
Transmisión: 0.98

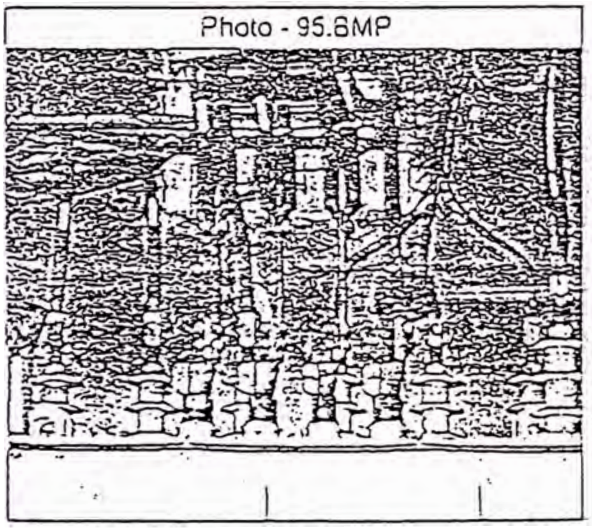
Resultados:

Temperatura Punto 1 : 30.0 °C
Temperatura Punto 2 : 30.3 °C
Temperatura Punto 3 : 29.3 °C
Temperatura Punto 4 : 29.6 °C
Temperatura Punto 5 : 29.9 °C
Temperatura Punto 6 30.8 °C

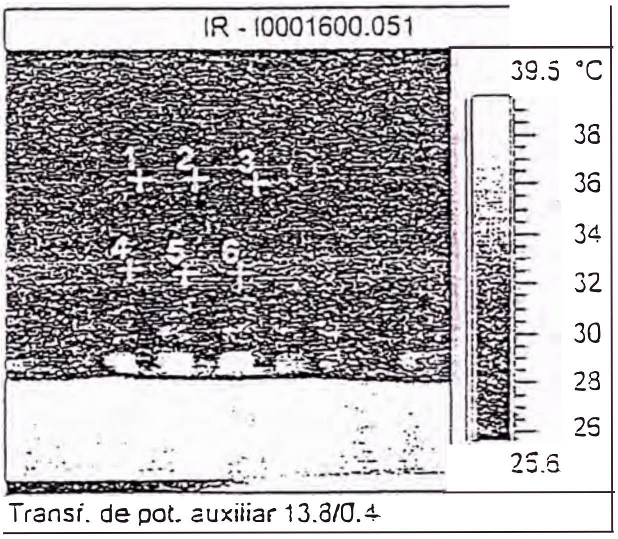
Observaciones:

Normal

Photo - 95.6MP



IR - 10001600.051



Transf. de pot. auxiliar 13.8/0.4

REPORTE TERMOGRAFICO CH. CHARCANI V

Equipo: TRANSFORMADOR DE POTENCIA AUXILIAR 13.8/0.4 KV G3 (lado de baja - derecha)

Fecha: 06/09/2001
Hora: 10:33:17 a.m.
Temp. ambiente: 15.0 °C
Distancia al objeto: 2.0 m
Emisividad: 0.90
Transmisión: 0.98

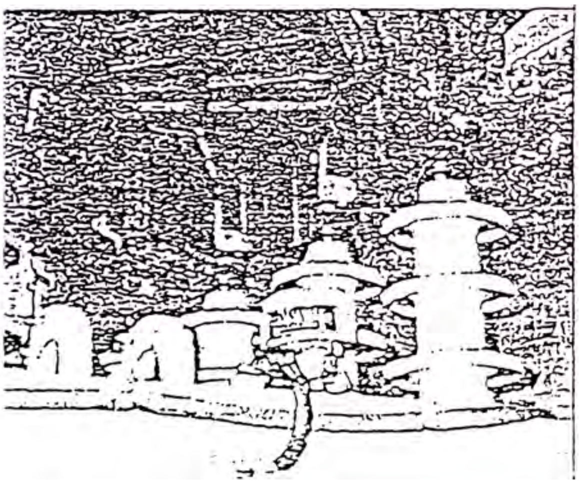
Resultados:

Temperatura Punto 1 : 28.5 °C
Temperatura Punto 2 : 28.9 °C
Temperatura Punto 3 : 29.4 °C

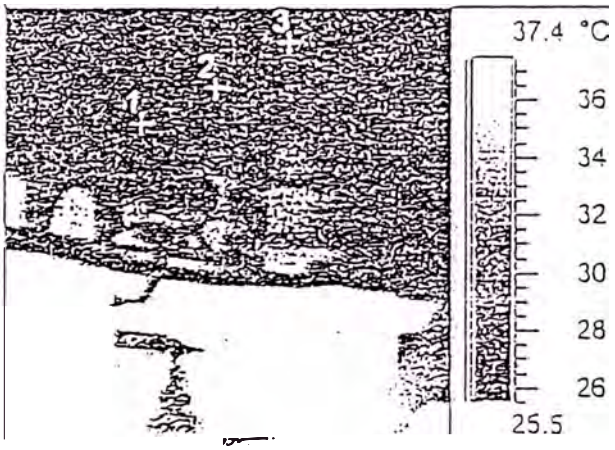
Observaciones:

Normal

Photo - 96.8MP



IR - 10001600.052

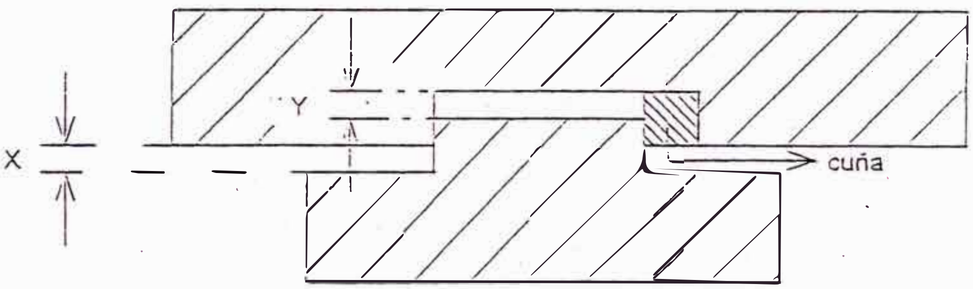


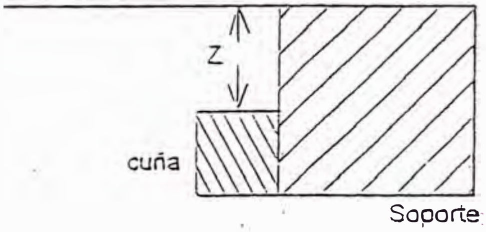
Transf. de pot. auxiliar

4. ANEXO IV

Cuadros de los Registros Mecánicos y Eléctricos del Mantenimiento y Control del Grupo Generador Nº 2 – Central Hidráulica Charcani V

GEC ALSTHOM NEYRPIC	CONTROL : GEOMETRICO	FICHA Nº :
Medición de las Luces de las Guías de la Cruceta Superior (extremos)		MEDIDAS REALIZADAS ANTES DEL DESMONTAJE DEL GRUPO
CLIENTE : EGASA	PROYECTO : CHARCANI V - GRUPO 2	

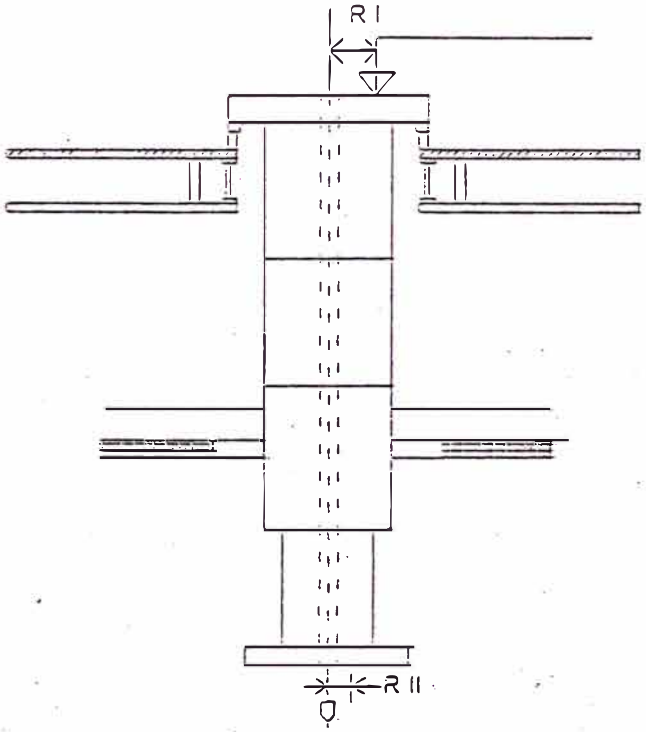


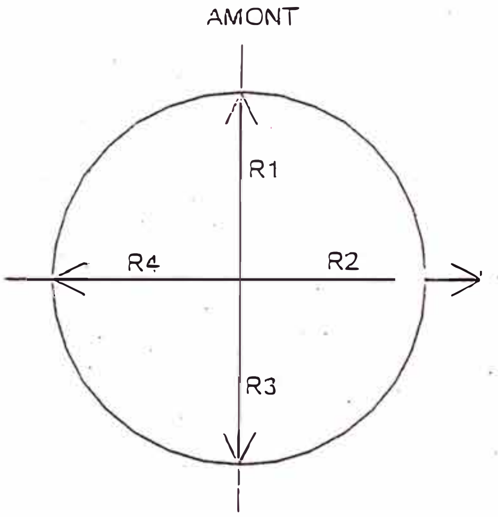


Brazo	X	Y	Z
1			
2			
3			
4			
5			
6			

BORADO POR:	APROVADO POR:	CLIENTE:	FECHA: PAGINA:

GEC ALSTHOM NEYRPIC	CONTROL : GEOMETRICO	FICHA Nº :
Verticalidad del Eje de la Turbina		MEDIDAS REALIZADAS ANTES DEL DESMONTAJE DEL GRUPO
NTE : EGASA	PROYECTO : CHARCANI V - GRUPO 2	





RI Teórico :		
0.02 mm/m		
PUNTOS	MEDIDA	DIFERENCIA
R1		
R2		
R3		
R4		

RII Teórico :		
0.02mm/m		
PUNTOS	MEDIDA	DIFERENCIA
R1		
R2		
R3		
R4		

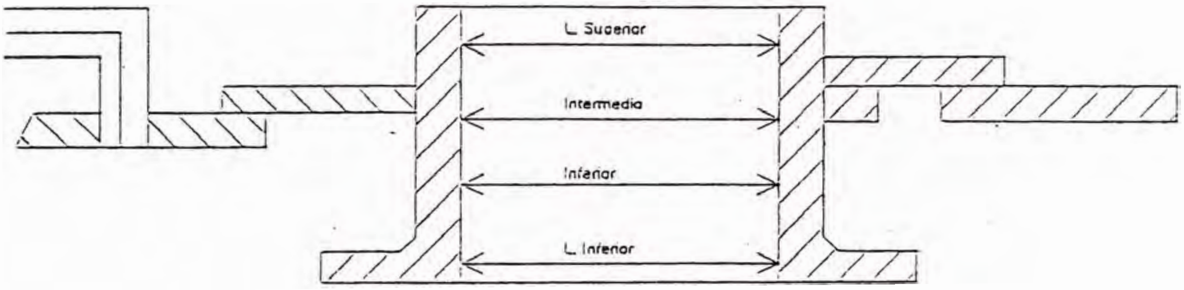
BORADO POR:	APROVADO POR:	CLIENTE:	FECHA: --/--/--
			PAGINA:

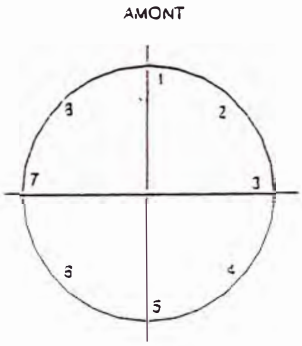
GEC ALSTHOM NEYRPIC	CONTROL : GEOMETRICO	FICHA Nº :

Medida Diametral del Cojinete Alternador

CLINTE :
EGASA

PROYECTO :
CHARCANI V - GRUPO 2





Punto	L. Superior	Intermedio	Inferior	L. Inferior
1				
2				
3				
4				
5				
6				
7				
8				

Distancia del micrómetro : 1 m.

ELABORADO POR:	APROBADO POR:	CLIENTE:	FECHA: PAGINA:

GEC ALSTHOM

NEYRPIC

CONTROL :

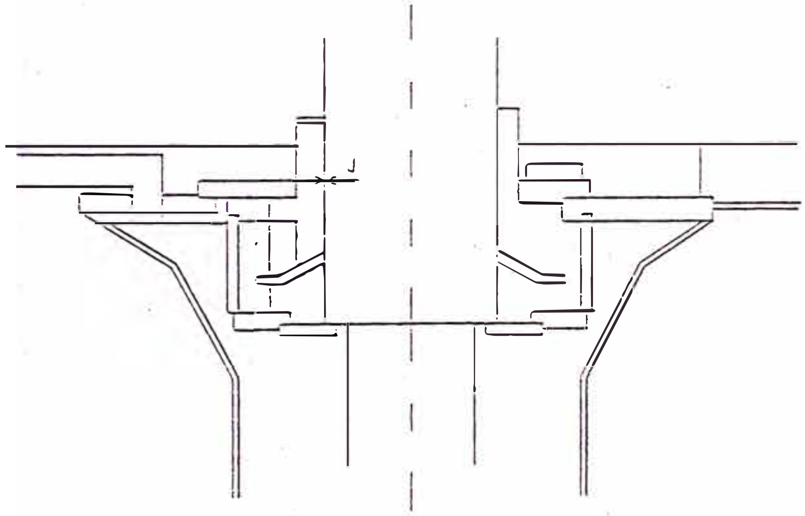
GEOMETRICO

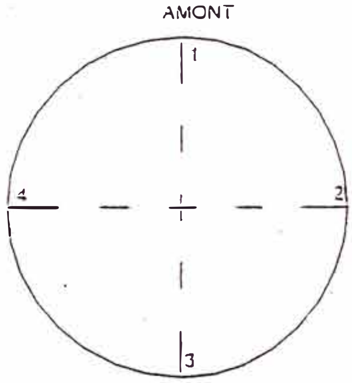
FICHA Nº :

Juego del Cojinete del Eje de la Turbina

ITE :
EGASA

PROYECTO :
CHARCANI V - GRUPO 2





J teórico :		
Tolerancia : □ 0.07		
	Medida	Diferencia
1		
2		
3		
4		

E BORADO POR:

APROBADO POR:

CLIENTE:

FECHA:

PAGINA:

GEC ALSTHOM

NEYRPIC

CONTROL :

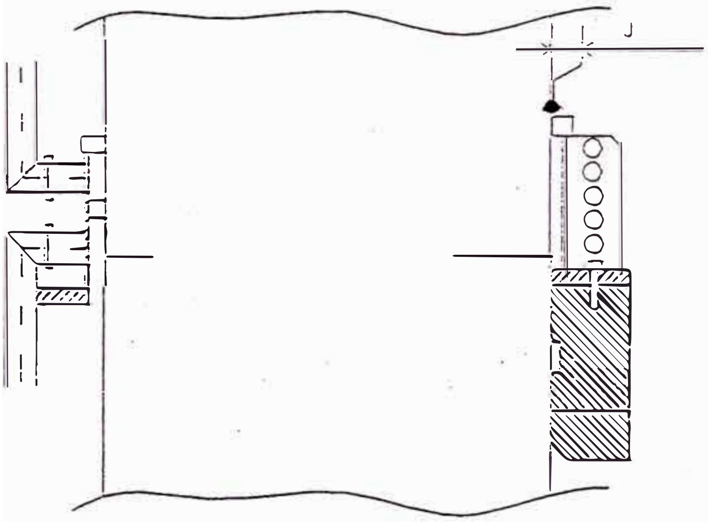
GEOMETRICO

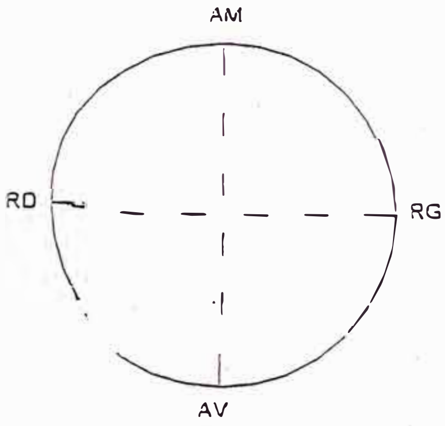
FICHA Nº :

Juego entre el Cojinete y el Laberinto - Turbina

CLIENTE :
EGASA

PROYECTO :
CHARCANI V - GRUPO 2





J Teórico :		
Tolerancia : ▯ 0.5		
Puntos	Medidas	Diferencia

BORADO POR:

APROBADO POR:

CLIENTE:

FECHA:

PAGINA:

GEC ALSTHOM
NEYRPIC

CONTROL :
GEOMETRICO

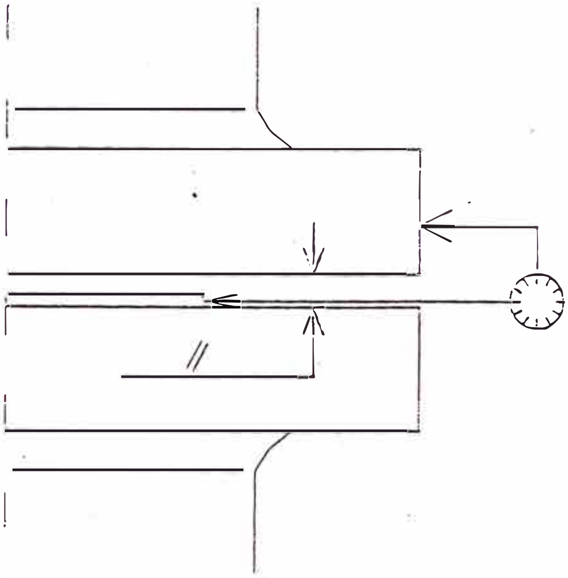
FICHA Nº :

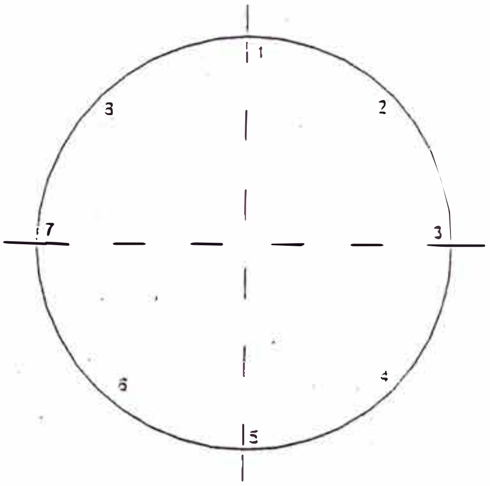
Acoplamiento Eje Turbina - Alternador

MEDIDAS REALIZADAS
ANTES DEL DESMONTAJE
DEL GRUPO

CLIENTE :
EGASA

PROYECTO :
CHARCANI V - GRUPO 2





Concentricidad		
Tolerancia : 0.02		
Puntos	Medida	Diferencia
1		
2		
3		
4		
5		
6		
7		
8		

Paralelismo		
Tolerancia : 0.02		
Puntos	Medidas	Diferencia
1		
2		
3		
4		
5		
6		
7		
8		

BORADO POR:

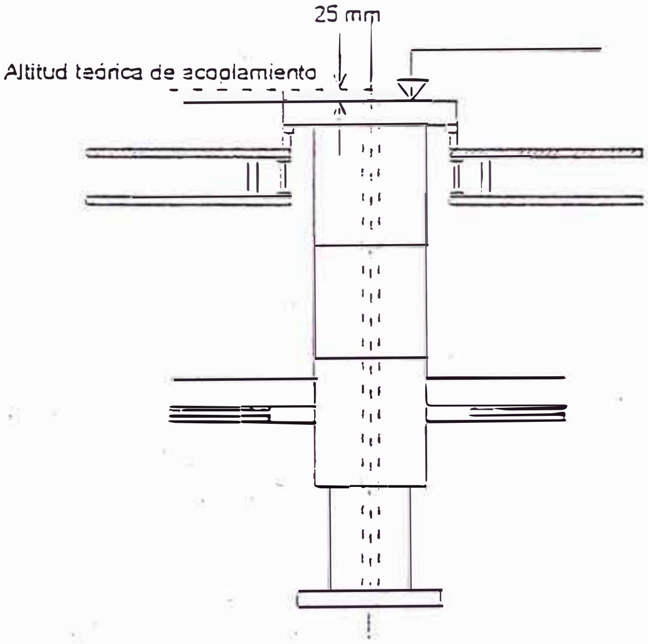
APROVADO POR:

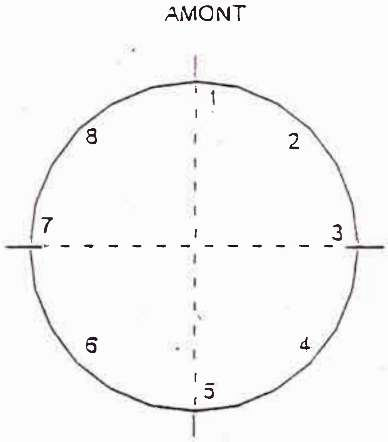
CLIENTE:

FECHA:

PAGINA:

GEC ALSTHOM NEYRPIC	CONTROL : GEOMETRICO	FICHA Nº :
ALTITUD DEL EJE TURBINA		MEDIDAS REALIZADAS DESPUES DEL MONTAJE DEL EJE DEL ROTOR DEL GRUPO
NTE : EGASA	PROYECTO : CHARCANI V - GRUPO 2	





Altitud Teórica :		
□1 mm		
PUNTOS	MEDIDA	DIFERENCIA
1		
2		
3		
4		
5		
6		
7		
8		

ORADO POR:	APROBADO POR:	CLIENTE:	FECHA:
			PAGINA:

GEC ALSTHOM

NEYRPIC

CONTROL :

GEOMETRICO

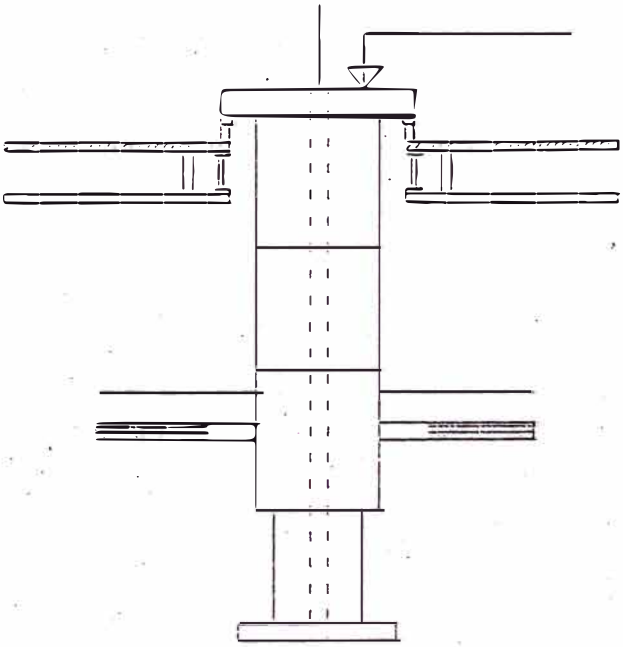
FICHA Nº :

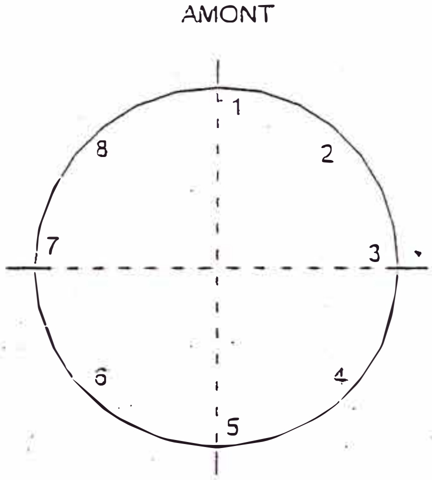
Nivelamiento del Eje de la Turbina

MEDIDAS REALIZADAS
DESPUES DEL DESMONTAJE
DEL GRUPO

NTE :
EGASA

PROYECTO :
CHARCANI V - GRUPO 2





0.02 mm/m		
PUNTOS	MEDIDA	DIFERENCIA
1		
2		
3		
4		
5		
6		
7		
8		

BORADO POR:

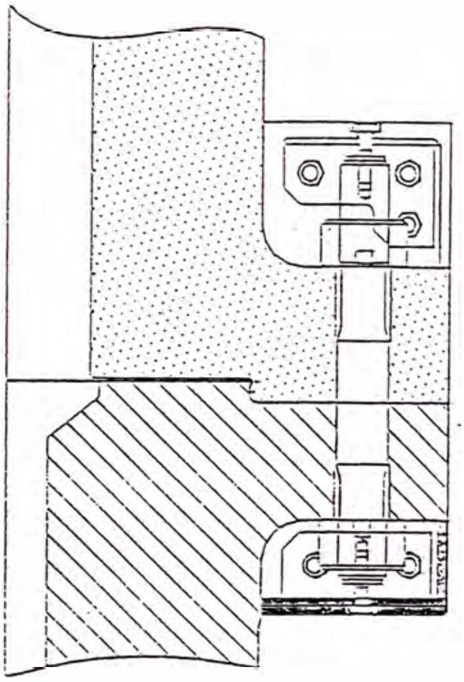
APROBADO POR:

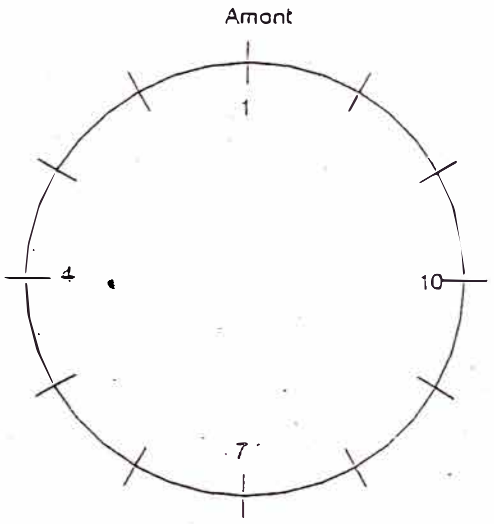
CLIENTE:

FECHA:

PAGINA:

GEC ALSTHOM NEYRPIC	CONTROL : GEOMETRICO	FICHA Nº :
Acoplamiento Eje Turbina - Generador Elongamiento de los Espárragos		MEDIDAS REALIZADAS ANTES DEL DESMONTAJE DEL GRUPO
C NTE : EGASA	PROYECTO : CHARCANI V - GRUPO 2	



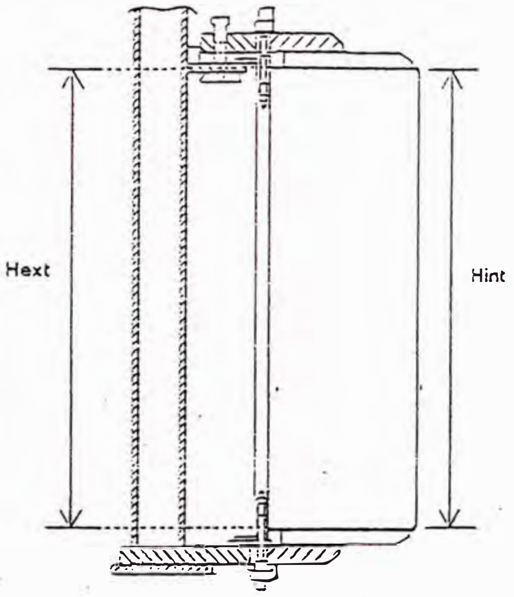


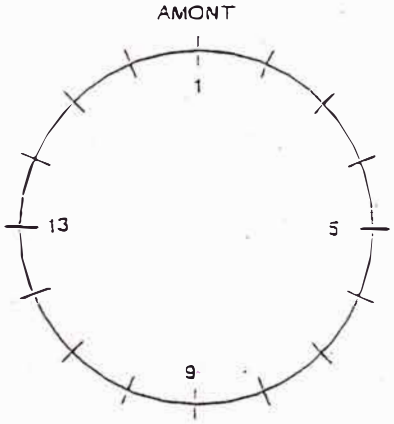
Elongamiento teórico 0.3,
Tolerancia : □ 0.1

Posición	Medida (ΔL)	Diferencia
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		

BORADO POR:	APROVADO POR:	CLIENTE:	FECHA: PAGINA:

GEC ALSTHOM NEYRPIC	CONTROL : GEOMETRICO	FICHA Nº :
Altura del Núcleo Estatórico		MEDIDAS REALIZADAS DESPUES DEL DESMONTAJE DEL GRUPO
CLIENTE : EGASA	PROYECTO : CHARCANI V - GRUPO 2	

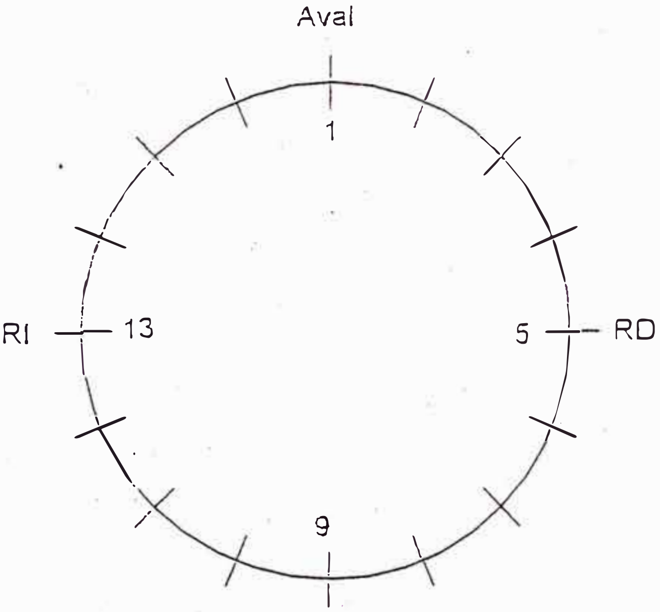


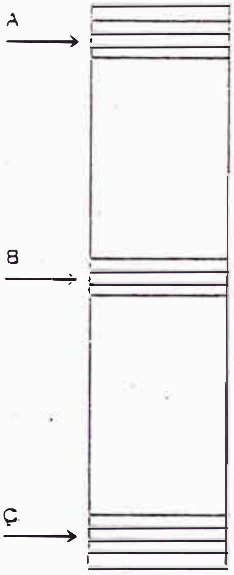


ALTURA TEORICA : 1530 mm				
	ALTURA INTERIOR (Hint)	DIFERENCIA	ALTURA EXTERIOR (Hext)	DIFERENCIA
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				

BORADO POR:	APROVADO POR:	CLIENTE:	FECHA: PAGINA:

GEC ALSTHOM NEYRPIC	CONTROL : GEOMETRICO	FICHA Nº :
Circularidad y Verticalidad del Núcleo Estatórico		
CLIENTE : EGASA	PROYECTO : CHARCANI V - GRUPO 2	





Punto	A	B	C	A'	B'	C'
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						

ELABORADO POR:	APROVADO POR:	CLIENTE:	FECHA:
			PAGINA:

REPORTE DE CONTROL	FECHA	
DENOMINADO CONTROL DE CUÑAS	DISEÑADO	
CLIENTE EGASA	PROYECTO: CHARCANI V-GRUPO 2	

- Nº de Ranuras : 126
- Nº de Cuñas/Ranura : 14
- Nº de lainas /Cuña : 6
- Tipo de Cunña : Mola

Ranura	Cuña 2		Cuña 4		Cuña 6		Cuña 9		Cuña 11		Cuña 13	
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												
32												

RADO	APROBADO	APROBADO P/CLIENTE

REPORTE DE CONTROL

FECHA

DEN MINADO CONTROL DE CUÑAS

DISEÑADO

CLIE TE EGASA

PROYECTO: CHARCANI V-GRUPO 2

- Nº de Ranuras : 126
- Nº de Cuñas/Ranura : 14
- Nº de lainas / Cuña : 6
- Tipo de Cuña : Mola

Ranura	Cuña 2		Cuña 4		Cuña 6		Cuña 9		Cuña 11		Cuña 13	
33												
34												
35												
36												
37												
38												
39												
40												
41												
42												
43												
44												
45												
46												
47												
48												
49												
50												
51												
52												
53												
54												
55												
56												
57												
58												
59												
60												
61												
62												
63												
64												

ORADO	APROBADO	APROBADO P/CLIENTE

REPORTE DE CONTROL		FECHA	
ENC INADO	CONTROL DE CUÑAS	DISEÑADO	
IENT:	EGASA	PROYECTO:	CHARCANI V-GRUPO 2

- Nº de Ranuras	126
- Nº de Cuñas/Ranura	14
- Nº de lainas / Cuña	6
- Tipo de Cuña	Mola

Ranura	Cuña 2		Cuña 4		Cuña 6		Cuña 9		Cuña 11		Cuña 13	
65												
66												
67												
68												
69												
70												
71												
72												
73												
74												
75												
76												
77												
78												
79												
80												
81												
82												
83												
84												
85												
86												
87												
88												
89												
90												
91												
92												
93												
94												
95												
96												

LAB RADO	APROBADO	APROBADO P/CLIENTE

REPORTE DE CONTROL

FECHA

DENOMINADO CONTROL DE CUÑAS

DISEÑADO

CLIENTE EGASA

PROYECTO: CHARCANI V-GRUPO 2

- Nº de Ranuras : 126
- Nº de Cuñas/Ranura : 14
- Nº de lainas / Cuña : 6
- Tipo de Cuña : Mola

Ranura	Cuña 2		Cuña 4		Cuña 6		Cuña 9		Cuña 11		Cuña 13	
97												
98												
99												
100												
101												
102												
103												
104												
105												
106												
107												
108												
109												
110												
111												
112												
113												
114												
115												
116												
117												
118												
119												
120												
121												
122												
123												
124												
125												
126												

ABORADO

APROBADO

APROBADO P/CLIENTE

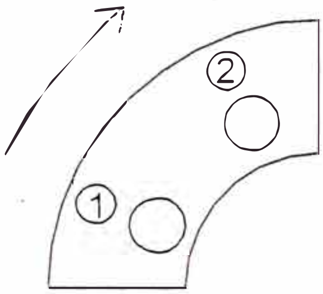
Control de la Placas de Presión del Estalor

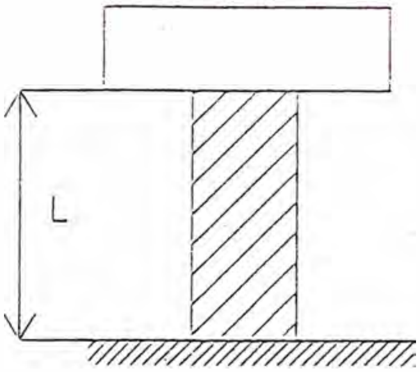
N° Placa*	Nivel Inicial		Nivel Final		Elongación			Torque (N.m)		
	Tangencial	Radial	Tangencial	Radial	A	B	C	A'	B'	C'
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										

La numeración es en sentido horario

Observaciones	Fecha :

GEC ALSTHOM NEYRPIC	CONTROL : GEOMETRICO	FICHA N° :
Control de las Holguras de las Trabas de Posicionamiento "X – Y – Z"		MEDIDAS REALIZADAS DESPUES DEL DESMONTAJE DEL GRUPO
CLIENTE : EGASA	PROYECTO : CHARCANI V - GRUPO 2	

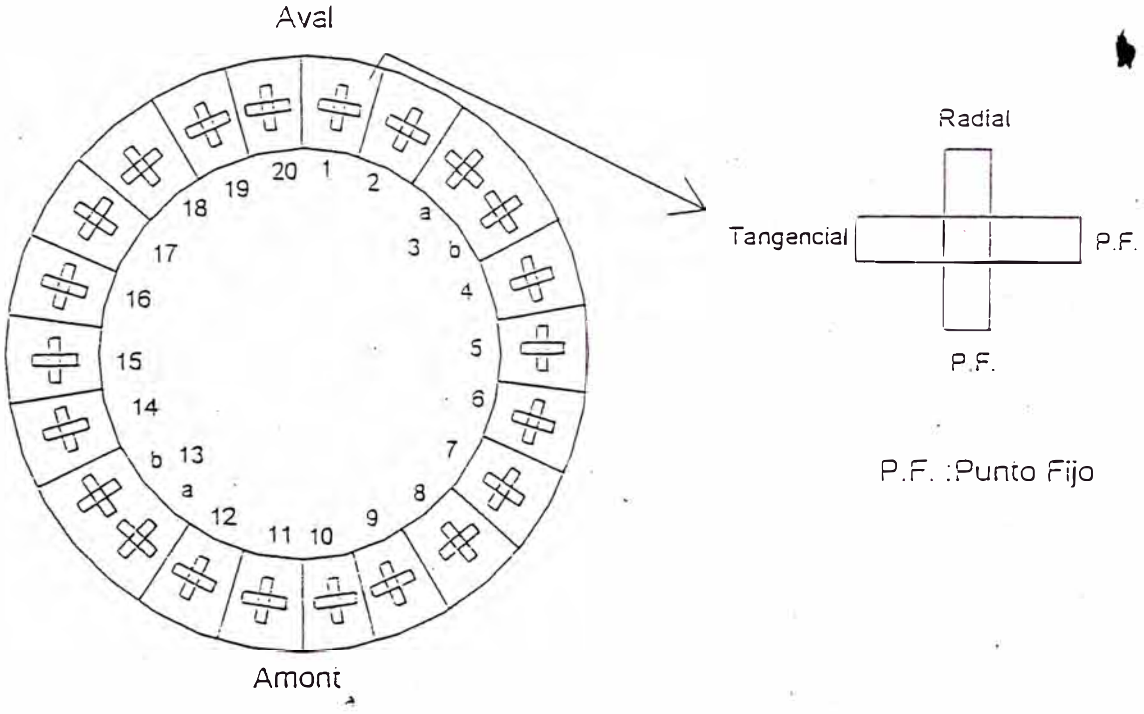




NUMERO DE PLANCHA	NUMERO DE PERNO		
	X (en mm)	Y (en mm)	Z (en mm)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			

ELABORADO POR:	APROBADO POR:	CLIENTE:	FECHA:
			PAGINA:

GEC ALSTHOM NEYRPIC	CONTROL : GEOMETRICO	FICHA Nº :
Nivel de las Placas del Estator		MEDIDAS REALIZADAS DESPUES DEL DESMONTAJE DEL GRUPO
CLIENTE : EGASA	PROYECTO : CHARCANI V - GRUPO 2	



P.F. :Punto Fijo

POSICION	RADIAL	TANGENCIAL	POSICION	RADIAL	TANGENCIAL
1					
2					
3 (a) 3 (b)					
4					
5					
6					
7					
8					
9					
10					

BORADO POR:	APROVADO POR:	CLIENTE:	FECHA:
			PAGINA:

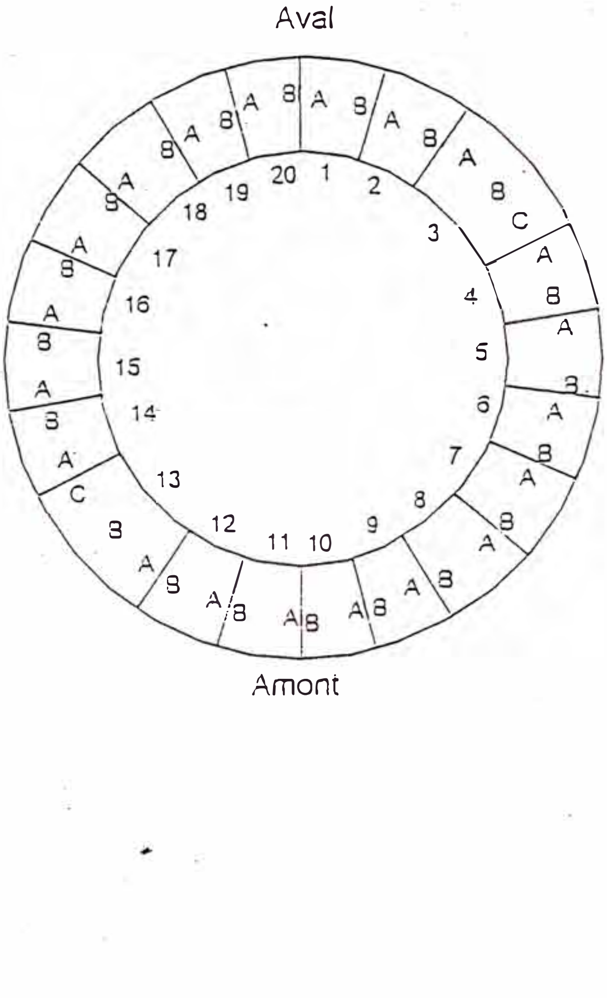
ontrol:

Mecánico

Prueba :

Posición de las placas del núcleo magnético

Placa No.	A	B	C	Placa No.	A	B	C
1				11			
2				12			
3				13			
4				14			
5				15			
6				16			
7				17			
8				18			
9				19			
10				20			



servaciones :

Fecha :

09/04/02

PRUEBA AL 25% DE CARGA

HORA INICIO : 15 : 00
HORA FINAL : 15 : 25

FECHA	HORA	13 : 00		13 : 30		14 : 00		14 : 30		15 : 00		15 : 30		16 : 00	
	Lectura Horómetro	83597.5		83598.3		83598.8		83599.2		33599.9		83600.1		83601.0	
		TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
COJINETES	COJINETE PATIN (EMPUJE)	74	68	76	68	75	68	78	68	76	68	76	68	77	69
	COJINETE GUIA (EMPUJE)	69	—	70	—	70	—	69	—	70	—	69	—	69	—
	COJINETE GENERADOR	74	75	75	75	74	75	72	76	74	76	70	70	68	70
	COJINETE TURBINA	—	59	—	59	—	59	—	59	—	59	—	59	—	59
		TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
ACEITE	ENT. ACEITE COJ. EMPUJE	53	—	51	—	51	—	50	—	52	—	47	—	49	—
	ENT. ACEITE COJ. GENERADOR	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	ENT. ACEITE COJ. TURBINA	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	SAL. ACEITE COJ. GUIA (EMP.)	60	—	60	—	60	—	57	—	55	—	55	—	55	—
	SAL. ACEITE EN EL COJ. GEN.	55	—	60	—	60	—	50	—	45	—	50	—	50	—
	SAL. ACEITE EN EL COJ. TURB.	50	—	50	—	50	—	50	—	50	—	50	—	50	—
		TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
AGUA DE LOS REFRIGERANTES	ENTRADA DE AGUA	24	25	24	25	24	25	24	25	23	25	25	25	24	25
	SAL. COJINETE EMPUJE	—	31	—	30	—	30	—	30	—	30	—	30	—	30
	SAL. GENERADOR	—	28	—	28	—	28	—	28	—	28	—	29	—	28
	SAL. COJINETE GENERADOR	—	29	—	29	—	29	—	28	—	28	—	28	—	28
	SALIDA COJINETE TURBINA	—	29	—	29	—	29	—	29	—	28	—	29	—	29
		TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
AIRE CALIENTE	AEROREFRIGERANTE 1	46	43	46	43	48	42	47	42	48	44	47	44	48	44
	AEROREFRIGERANTE 2	46	—	47	—	48	—	48	—	48	—	48	—	50	—
	AEROREFRIGERANTE 3	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	AEROREFRIGERANTE 4	46	—	48	—	47	—	48	—	47	—	47	—	60	—
	AEROREFRIGERANTE 5	46	—	47	—	48	—	48	—	48	—	48	—	50	—
	AEROREFRIGERANTE 6	48	—	47	—	49	—	50	—	—	—	51	—	—	—
AIRE FRIO	AEROREFRIGERANTE 1	28	28	26	28	28	28	32	29	29	32	25	34	28	34
	AEROREFRIGERANTE 2	29	—	29	—	31	—	32	—	28	—	30	—	30	—
	AEROREFRIGERANTE 3	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	AEROREFRIGERANTE 4	25	—	28	—	30	—	28	—	24	—	25	—	26	—
	AEROREFRIGERANTE 5	27	—	28	—	29	—	28	—	30	—	28	—	28	—
	AEROREFRIGERANTE 6	28	—	28	—	30	—	28	—	30	—	28	—	28	—
		TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
NUCLEO	ARROLLAMIENTO 1	45	—	46	—	46	—	46	—	46	—	50	—	52	—
	ARROLLAMIENTO 2	45	—	46	—	47	—	47	—	47	—	50	—	53	—
	ARROLLAMIENTO 3	45	—	46	—	46	—	46	—	46	—	50	—	53	—
	NUCLEO 1	—	46	—	46	—	46	—	46	—	46	—	47	—	47
	NUCLEO 2	—	46	—	46	—	46	—	47	—	47	—	47	—	47
	NUCLEO 3	—	46	—	46	—	46	—	46	—	46	—	46	—	46

MONITOREO DE OPERACION

		TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
PARAMETROS DE OPERACION	POT ACT. GEN. (MW)	12		12.5		12		13		12.5		25		23	
	POT REACT. GEN (MVAR)	+1		+1		+0.5		+1		+1		+2		+2	
	TENSION GEN (KV)	14		14		14		13.9		13.9		13.9		13.9	
	CORRIENTE GENERADOR (KA)	0.56		0.5		0.49		0.5		0.5		1		0.0	
	FACTOR DE POTENCIA	0.99		0.99		0.99		0.98		0.98		0.98		0.98	
	TENSION EXCITACION (V)	56		58		56		58		58		54		65	
	CORRIENTE EXCITACION (KA)	0.6		0.6		0.59		0.6		0.6		0.65		0.65	
	CAUDAL (m³/S)	2.2		2.2		2.2		2.3		2.2		4.3		4.1	
	POT. ACTIVA GRUPO 1 (MW)	44		44		43		45		45		42		42	
	POT. ACTIVA GRUPO 2 (MW)	45		46		44		47		48		44		44	
	POTENCIA TOTAL (MW)	101		102.5		99		105		105.5		111		109	
REGULACION PRESION	ENTRADA		0.72		0.72		0.72		0.72		0.72		0.72		0.72
	SALIDA		0.64		0.54		0.64		0.54		0.64		0.54		0.64

OBSERVACIONES

PRUEBA AL 50% DE CARGA

ORA INICIO : 15 : 25
ORA FINAL : 13 : 40

[illegible]	HORA	15 : 30		16 : 00		16 : 30		17 : 00		17 : 30		18 : 00		18 : 30	
	Lectura Horómetro	33600.1		33601.0		33601.4		32501.3		33602.3		33602.9			
		TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
COJINETES	COJINETE PATIN (EMPUJE)	76	68	77	69	75	68	77	67	76	63	78	77	78	68
	COJINETE GUIA (EMPUJE)	69	—	69	—	65	—	60	—	63	—	65	—	65	—
	COJINETE GENERADOR	70	70	68	70	75	77	72	77	69	77	70	76	70	76
	COJINETE TURBINA	—	59	—	59	—	59	—	59	—	59	—	59	—	59
		TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
ACEITE	ENT. ACEITE COJ. EMPUJE	47	—	49	—	50	—	35	—	45	—	49	—	49	—
	ENT. ACEITE COJ. GENERADOR	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	ENT. ACEITE COJ. TURBINA	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	SAL. ACEITE COJ. GUIA (EMP.)	55	—	55	—	60	—	60	—	60	—	62	—	62	—
	SAL. ACEITE EN EL COJ. GEN.	50	—	50	—	60	—	56	—	40	—	45	—	45	—
	SAL. ACEITE EN EL COJ. TURB.	50	—	50	—	50	—	50	—	52	—	50	—	50	—
		TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
[illegible]	ENTRADA DE AGUA	25	25	24	25	20	25	22	25	22	25	25	25	23	25
	SAL. COJINETE EMPUJE	—	30	—	30	—	30	—	30	—	30	—	30	—	30
	SAL. GENERADOR	—	28	—	28	—	28	—	28	—	28	—	28	—	28
	SAL. COJINETE GENERADOR	—	28	—	28	—	28	—	28	—	28	—	28	—	28
	SALIDA COJINETE TURBINA	—	29	—	29	—	29	—	29	—	29	—	29	—	29
		TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
AIRE CALIENTE	AEROREFRIGERANTE 1	47	44	48	44	49	53	50	43	50	43	50	43	50	43
	AEROREFRIGERANTE 2	48	—	50	—	50	—	50	—	50	—	51	—	51	—
	AEROREFRIGERANTE 3		—		—		—		—		—		—		—
	AEROREFRIGERANTE 4	47	—	60	—	52	—	60	—	54	—	58	—	58	—
	AEROREFRIGERANTE 5	48	—	50	—	50	—	52	—	52	—	50	—	50	—
	AEROREFRIGERANTE 6	51	—		—	52	—	47	—	49	—	56	—	56	—
AIRE FRIO	AEROREFRIGERANTE 1	25	34	28	34	27	34	30	34	28	34	29	32	29	32
	AEROREFRIGERANTE 2	30	—	30	—	—	—	—	—	40	—	30	—	28	—
	AEROREFRIGERANTE 3	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	AEROREFRIGERANTE 4	25	—	26	—	24	—	22	—	30	—	29	—	29	—
	AEROREFRIGERANTE 5	28	—	28	—	30	—	28	—	28	—	29	—	29	—
	AEROREFRIGERANTE 6	28	—	28	—	30	—	28	—	29	—	29	—	29	—
		TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
NUCLEO	ARROLLAMIENTO 1	50	—	52	—	59	—	60	—	60	—	60	—	60	—
	ARROLLAMIENTO 2	50	—	53	—	61	—	62	—	52	—	62	—	62	—
	ARROLLAMIENTO 3	50	—	53	—	60	—	60	—	60	—	61	—	61	—
	NUCLEO 1	—	47	—	47	—	47	—	47	—	48	—	48	—	48
	NUCLEO 2	—	47	—	47	—	48	—	48	—	48	—	48	—	48
	NUCLEO 3	—	46	—	46	—	48	—	48	—	48	—	48	—	48

MONITOREO DE OPERACION

		TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
PARAMETROS DE OPERACION	POT ACT. GEN. (MW)	25		23		24		22		24		24		24	
	POT REACT. GEN. (MVAR)	+2		+2		+2		+2		+6		+2		+2	
	TENSION GEN. (KV)	13.9		13.9		13.9		13.9		13.9		13.8		13.9	
	CORRIENTE GENERADOR (KA)	1		0.9		1		0.9		1		1		1.58	
	FACTOR DE POTENCIA	0.98		0.98		0.98		0.98		0.98		0.97		0.98	
	TENSION EXCITACION (V)	64		65		65		63		65		70		71	
	CORRIENTE EXCITACION (KA)	0.65		0.65		0.66		0.64		0.66		0.7		0.72	
	CAUDAL (m³/S)	4.3		4.1		4.2		4.1		4.3		4.2		7.2	
	POT. ACTIVA GRUPO I (MW)	42		42		44		42		44		45		42	
	POT. ACTIVA GRUPO II (MW)	44		44		46		44		45		47		44	
	POTENCIA TOTAL (MW)	111		109		114		108		113		116		110	
[illegible]	ENTRADA		0.72		0.72		0.72		0.72		0.72		0.72		0.72
	SALIDA		0.64		0.64		0.64		0.64		0.64		0.64		0.64

OBSERVACIONES: ____________________

PRUEBA AL 75% DE CARGA

HORA INICIO : 18 : 40
HORA FINAL : 21 : 10

		19:00		19:30		20:00		20:30		21:00	
[illegible]	HORA	19 : 00		19 : 30		20 : 00		20 : 30		21 : 00	
	Lectura Horómetro										
		TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
COJINETES	COJINETE PATIN (EMPUJE)	78	67	78	68	78	68	78	68	73	68
	COJINETE GUIA (EMPUJE)	65	—	65	—	67	—	68	—	65	—
	COJINETE GENERADOR	70	76	65	78	65	78	66	78	65	77
	COJINETE TURBINA	—	59	—	59	—	59	—	59	—	59
		TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
ACEITE	ENT. ACEITE COJ. EMPUJE	49	—	50	—	50	—	52	—	52	—
	ENT. ACEITE COJ. GENERADOR	—	—	—	—	—	—	—	—	—	—
	ENT. ACEITE COJ. TURBINA	—	—	—	—	—	—	—	—	—	—
	SAL. ACEITE COJ. GUIA (EMP.)	62	—	63	—	63	—	58	—	62	—
	SAL. ACEITE EN EL COJ. GEN.	60	—	60	—	60	—	60	—	60	—
	SAL. ACEITE EN EL COJ. TURB.	50	—	50	—	50	—	50	—	50	—
		TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
AGUA EN LOS [illegible]	ENTRADA DE AGUA	23	25	25	25	25	25	24	25	23	25
	SAL. COJINETE EMPUJE	—	30	—	30	—	30	—	30	—	30
	SAL. GENERADOR	—	28	—	29	—	29	—	29	—	28
	SAL. COJINETE GENERADOR	—	28	—	28	—	28	—	29	—	28
	SALIDA COJINETE TURBINA	—	29	—	30	—	30	—	30	—	29
		TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
AIRE CALIENTE	AEROREFRIGERANTE 1	50	43	52.5	43	54	43	54	43	50	43
	AEROREFRIGERANTE 2	51	—	53.5	—	55	—	54	—	51	—
	AEROREFRIGERANTE 3	—	—	—	—	—	—	—	—	—	—
	AEROREFRIGERANTE 4	58	—	55	—	55	—	55	—	58	—
	AEROREFRIGERANTE 5	50	—	53.5	—	54	—	54	—	50	—
	AEROREFRIGERANTE 6	56	—	54	—	54	—	54	—	56	—
AIRE FRIO	AEROREFRIGERANTE 1	29	32	30	35	30	35	30	35	29	32
	AEROREFRIGERANTE 2	28	—	—	—	—	—	—	—	28	—
	AEROREFRIGERANTE 3	—	—	—	—	—	—	—	—	—	—
	AEROREFRIGERANTE 4	29	—	24	—	28	—	28	—	29	—
	AEROREFRIGERANTE 5	29	—	28	—	29	—	29	—	29	—
	AEROREFRIGERANTE 6	29	—	29	—	29	—	29	—	29	—
		TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
NUCLEO	ARROLLAMIENTO 1	60	—	67	—	67	—	67	—	60	—
	ARROLLAMIENTO 2	62	—	68	—	68	—	69	—	62	—
	ARROLLAMIENTO 3	61	—	68	—	68	—	68	—	61	—
	NUCLEO 1	—	48	—	49	—	51	—	51	—	52
	NUCLEO 2	—	48	—	50	—	51	—	51	—	52
	NUCLEO 3	—	48	—	49	—	50	—	51	—	53

MONITOREO DE OPERACION

		TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
PARAMETROS DE OPERACION	POT ACT. GEN. (MW)	34	—	33	—	34	—	34	—	33	—
	POT REACT. GEN. (MVAR)	+2	—	+2	—	+2	—	+2.1	—	+2.1	—
	TENSION GEN. (KV)	13.9	—	13.8	—	13.8	—	13.8	—	13.8	—
	CORRIENTE GENERADOR (KA)	1.63	—	1.4	—	1.4	—	1.4	—	1.4	—
	FACTOR DE POTENCIA	0.98	—	1	—	1	—	0.99	—	0.99	—
	TENSION EXCITACION (V)	71	—	70	—	70	—	70	—	70	—
	CORRIENTE EXCITACION (KA)	0.72	—	0.7	—	0.7	—	0.7	—	0.7	—
	CAUDAL (m³/S)	6.1	—	6.2	—	6.2	—	6.2	—	6.2	—
	POT. ACTIVA GRUPO (MW)	44	—	41	—	44	—	43	—	43	—
	POT. ACTIVA GRUPO (MW)	44	—	43	—	45	—	45	—	45	—
	POTENCIA TOTAL (MW)	122	—	117	—	123	—	122	—	121	—
REGULACION PRESION	ENTRADA		0.72		0.72		0.72		0.72		0.72
	SALIDA		0.65		0.65		0.65		0.65		0.65

OBSERVACIONES : ____________________

PRUEBA AL 100% DE CARGA

HORA INICIO : 21 : 10
HORA FINAL : 11 : 30

[illegible]	HORA	21 : 00		22 : 00		22 : 30		23 : 00		23 : 30	
	Lectura Horómetro					83607.3		83607.5		83608.1	
		TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
COJINETES	COJINETE PATIN (EMPUJE)	78	68	74	68	75	68	76	68	76	68
	COJINETE GUIA (EMPUJE)	65	—	65	—	63	—	65	—	67	—
	COJINETE GENERADOR	65	77	70	78	70	78	71	78	75	78
	COJINETE TURBINA	—	59	—	59	—	59	—	59	—	59
		TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
ACEITE	ENT. ACEITE COJ. EMPUJE	52	—	46	—	40	—	45	—	46	—
	ENT. ACEITE COJ. GENERADOR	—	—	—	—	—	—	—	—	—	—
	ENT. ACEITE COJ. TURBINA	—	—	—	—	—	—	—	—	—	—
	SAL. ACEITE COJ. GUIA (EMP.)	62	—	60	—	60	—	59	—	60	—
	SAL. ACEITE EN EL COJ. GEN.	60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	50	[illegible]	50	[illegible]
	SAL. ACEITE EN EL COJ. TURB.	50	—	50	—	52	—	50	—	50	—
		TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
AGUA EN LOS REFRIGERANTES	ENTRADA DE AGUA	23	25	24	25	24	25	24	25	24	25
	SAL. COJINETE EMPUJE	—	30	—	31	—	31	—	31	—	31
	SAL. GENERADOR	—	28	—	30	—	30	—	30	—	30
	SAL. COJINETE GENERADOR	—	28	—	29	—	29	—	29	—	29
	SALIDA COJINETE TURBINA	—	29	—	30	—	30	—	30	—	30
		TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
AIRE CALIENTE	AEROREFRIGERANTE 1	50	43	57	43	59	44	59	43	59	44
	AEROREFRIGERANTE 2	51	—	58	—	60	—	54	—	51	—
	AEROREFRIGERANTE 3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	AEROREFRIGERANTE 4	58	—	60	—	60	—	55	—	58	—
	AEROREFRIGERANTE 5	50	—	58	—	60	—	54	—	50	—
	AEROREFRIGERANTE 6	56	—	58	—	60	—	54	—	56	—
AIRE FRIO	AEROREFRIGERANTE 1	29	32	31	36	31	37	31	36	31	34
	AEROREFRIGERANTE 2	28	—	34	—	34	—	35	—	36	—
	AEROREFRIGERANTE 3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	AEROREFRIGERANTE 4	29	—	31	—	31	—	30	—	30	—
	AEROREFRIGERANTE 5	29	—	30	—	30	—	30	—	30	—
	AEROREFRIGERANTE 6	29	—	30	—	30	—	30	—	30	—
		TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
NUCLEO	ARROLLAMIENTO 1	60	—	75	—	76	—	76	—	77	—
	ARROLLAMIENTO 2	62	—	78	—	78	—	79	—	80	—
	ARROLLAMIENTO 3	61	—	76	—	77	—	77	—	78	—
	NUCLEO 1	—	52	—	53	—	54	—	54	—	55
	NUCLEO 2	—	52	—	54	—	54	—	55	—	56
	NUCLEO 3	—	53	—	53	—	54	—	54	—	55

MONITOREO DE OPERACION

		TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
PARAMETROS DE OPERACION	POT ACT. GEN. (MW)	33	—	44.5	—	45	—	45	—	45	—
	POT REACT. GEN. (MVAR)	+2.1	—	0	—	+1	—	+2	—	+5	—
	TENSION GEN. (KV)	13.8	—	13.7	—	13.8	—	13.8	—	13.8	—
	CORRIENTE GENERADOR (KA)	1.4	—	1.85	—	1.85	—	1.88	—	1.88	—
	FACTOR DE POTENCIA	0.99	—	-0.99	—	-0.99	—	1	—	-0.99	—
	TENSION EXCITACION (V)	70	—	75	—	75	—	80	—	80	—
	CORRIENTE EXCITACION (KA)	0.7	—	0.74	—	0.75	—	0.77	—	0.77	—
	CAUDAL (m³/s)	6.2	—	8.5	—	8.5	—	8.6	—	8.5	—
	POT. ACTIVA GRUPO1 (MW)	43	—	44	—	40	—	40	—	45	—
	POT. ACTIVA GRUPO3 (MW)	45	—	46	—	44	—	45	—	46	—
	POTENCIA TOTAL (MW)	121	—	134.5	—	129	—	130	—	136	—

REGULACION PRESION	ENTRADA		0.72		0.72		0.72		0.72		0.72
	SALIDA		0.55		0.55		0.55		0.55		0.55

OBSERVACIONES : No se [illegible]

PRUEBA DE CALENTAMIENTO MARCHA EN VACIO SIN EXCITACION

INICIO : 9 : 25
FINAL : 9 : 50

HORA	9 : 30		10 : 00													
Lectura Horometro	83594.4		33594.9													
	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
COJINETE PATIN (EMPUJE)	74	67	30	68												
COJINETE GUIA (EMPUJE)	55	—	65	—												
COJINETE GENERADOR	65	74	74	76												
COJINETE TURBINA	—	58	—	58												
	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
ENT. ACEITE COJ. EMPUJE	—	—	45	—												
ENT. ACEITE COJ. GENERADOR	—	—	—	—												
ENT. ACEITE COJ. TURBINA	—	—	—	—												
SAL. ACEITE COJ. GUIA (EMP.)	60	—	55	—												
SAL. ACEITE EN EL COJ. GEN.	50	—	60	—												
SAL. ACEITE EN EL COJ. TURB.	61	—	50	—												
	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
ENTRADA DE AGUA	24	25	24	16												
SAL. COJINETE EMPUJE	—	30	—	30												
SAL. GENERADOR	25	26	—	26												
SAL. COJINETE GENERADOR	—	28	—	28												
SALIDA COJINETE TURBINA	—	28	—	28												
	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
AEROREFRIGERANTE 1	35	43	38	43												
AEROREFRIGERANTE 2	35.5	—	38	—												
AEROREFRIGERANTE 3	—	—	—	—												
AEROREFRIGERANTE 4	38	—	50	—												
AEROREFRIGERANTE 5	36	—	40	—												
AEROREFRIGERANTE 6	36	—	60	—												
AEROREFRIGERANTE 1	26	28	24	30												
AEROREFRIGERANTE 2	—	—	—	—												
AEROREFRIGERANTE 3	—	—	—	—												
AEROREFRIGERANTE 4	25	—	25	—												
AEROREFRIGERANTE 5	25	—	26	—												
AEROREFRIGERANTE 6	25	—	25	—												
	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
ARROLLAMIENTO 1	35	—	40	—												
ARROLLAMIENTO 2	36	—	40	—												
ARROLLAMIENTO 3	35	—	40	—												
NUCLEO 1	—	37	—	38												
NUCLEO 2	—	38	—	35												
NUCLEO 3	—	37	—	39												

MONITOREO DE OPERACION

	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
POT ACT. GEN. (MW)	—		—													
POT REACT. GEN (MVAR)	—		—													
TENSION GEN (KV)	—		—													
CORRIENTE GENERADOR (KA)	—		—													
FACTOR DE POTENCIA	—		—													
TENSION EXCITACION (V)	—		—													
CORRIENTE EXCITACION (KA)	—		—													
CAUDAL (m³/s)	—		—													
POT. ACTIVA GRUPO 1 (MW)	44		44													
POT. ACTIVA GRUPO 2 (MW)	46		45													
POTENCIA TOTAL (MW)	90		39													
ENTRADA		0.72		0.72												
SALIDA		0.64		0.64												

OBSERVACIONES

PRUEBA DE CALENTAMIENTO MARCHA EN VACIO CON EXCITACION

HORA INICIO : 11 : 30
HORA FINAL : 11 : 55

[illegible]	HORA	10 : 00		10 : 30		11 : 00		11 : 30		12 : 00		12 : 30	
	Lectura Horometro	33594.9		33595.1		33595.8		33596.3		33596.5		33597.1	
		TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
COJINETES	COJINETE PATIN (EMPUJE)	80	68	75	67	75	68	75	68	75	68	78	68
	COJINETE GUIA (EMPUJE)	55	—	60	—	68	—	68	—	60	—	70	—
	COJINETE GENERADOR	74	76	66	74	74	78	70	75	65	75	75	75
	COJINETE TURBINA	—	58	—	58	—	58	—	58	—	58	—	59
		TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
ACEITE	ENT. ACEITE COJ. EMPUJE	45	—			60	—	50	—	50	—	40	
	ENT. ACEITE COJ. GENERADOR	—	—	—	—	—	—	—	—	—	—	—	—
	ENT. ACEITE COJ. TURBINA	—	—	—	—	—	—	—	—	—	—	—	—
	SAL. ACEITE COJ. GUIA (EMP.)	55	—	60	—	45	—	45	—	30	—	50	—
	SAL. ACEITE EN EL COJ. GEN.	60	—	50	—	50	—	47	—	45	—	58	—
	SAL. ACEITE EN EL COJ. TURB.	50	—	50	—	50	—	50	—	50	—	50	—
		TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
AGUA EN LOS AEROREFRIGERANTES	ENTRADA DE AGUA	24	16	28	25	22	25	22	25	22	25	24	25
	SAL. COJINETE EMPUJE	—	30	—	30	—	31	—	30	—	30	—	30
	SAL. GENERADOR	—	26	—	27	—	28	—	30	—	29	—	29
	SAL. COJINETE GENERADOR	—	28	—	28	—	28	—	28	—	28	—	28
	SALIDA COJINETE TURBINA	—	28	—	28	—	29	—	28	—	29	—	29
		TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
AIRE CALIENTE	AEROREFRIGERANTE 1	38	43	44	42	43	42	43	42	44		44	42
	AEROREFRIGERANTE 2	38	—	44	—	44	—	44	—	44	—	46	—
	AEROREFRIGERANTE 3	—	—	—	—	—	—	—	—	—	—	—	—
	AEROREFRIGERANTE 4	50	—	60	—	50	—	50	—	45	—	46	—
	AEROREFRIGERANTE 5	40	—	42	—	44	—	44	—	44	—	46	—
	AEROREFRIGERANTE 5	60	—	48	—	50	—	50	—	50	—		—
AIRE FRIO	AEROREFRIGERANTE 1	24	30	25	30	24	28	24	29	24		26	30
	AEROREFRIGERANTE 2	—	—	—	—	—	—	—	—	—	—	—	—
	AEROREFRIGERANTE 3	—	—	—	—	—	—	—	—	—	—	—	—
	AEROREFRIGERANTE 4	25	—	28	—	26	—	26	—	24	—	24	—
	AEROREFRIGERANTE 5	26	—	28	—	28	—	28	—	28	—	28	—
	AEROREFRIGERANTE 5	25	—	28	—	28	—	28	—	28	—	28	—
		TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
NUCLEO	ARROLLAMIENTO 1	40	—	40	—	41	—	41	—	42	—	45	—
	ARROLLAMIENTO 2	40	—	42	—	45	—	42	—	44	—	45	—
	ARROLLAMIENTO 3	40	—	41	—	41	—	41	—	42	—	45	—
	NUCLEO 1	—	38	—	41	—	41	—	41	—	43	—	43
	NUCLEO 2	—	35	—	42	—	43	—	42	—	44	—	44
	NUCLEO 3	—	39	—	42	—	42	—	43	—	44	—	44

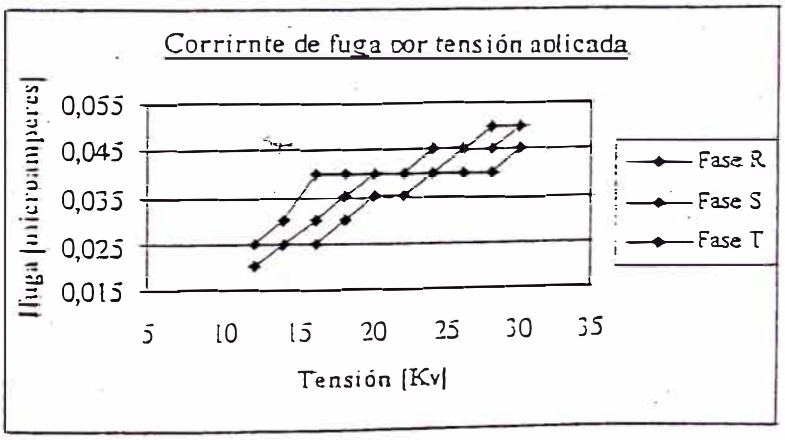
MONITOREO DE OPERACION

		TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL	TABLERO	LOCAL
PARAMETROS DE OPERACION	POT ACT. GEN. (MW)												
	POT REACT. GEN. (MVAR)												
	TENSION GEN. (KV)												
	CORRIENTE GENERADOR (KA)												
	FACTOR DE POTENCIA												
	TENSION EXCITACION (V)												
	CORRIENTE EXCITACION (KA)												
	CAUDAL (m³/S)												
	POT. ACTIVA GRUPO1 (MW)	44		44		45		44		44		44	
	POT. ACTIVA GRUPO2 (MW)	45		44		45		45		45		45	
	POTENCIA TOTAL (MW)	89		88		90		89		89		89	
REGULACION PRESION	ENTRADA		0.72		0.72		0.72		0.72		0.72		0.72
	SALIDA		0.64		0.64		0.64		0.64		0.64		0.64

OBSERVACIONES

Control: Eléctrico	Prueba : Tensión Aplicada

V [Kv]	t [min]	Fase R	Fase S	Fase T
10	0,5	0,04	0,04	0,04
	0,75	0,03	0,03	0,03
	1	0,025	0,025	0,02
	1,5	0,025	0,02	0,02
	2	0,02	0,02	0,02
	3	0,02	0,02	0,02
	4	0,02	0,02	0,02
	5	0,02	0,02	0,02
	6	0,02	0,02	0,02
	7	0,02	0,02	0,02
	8	0,02	0,02	0,02
	9	0,02	0,02	0,02
	10	0,02	0,02	0,02
12	13,14	0,025	0,02	0,02
14	15,56	0,03	0,025	0,025
16	18,17	0,04	0,03	0,025
18	20,24	0,04	0,035	0,03
20	22,19	0,04	0,04	0,035
22	24,04	0,04	0,04	0,035
24	25,42	0,045	0,04	0,04
26	27,12	0,045	0,045	0,04
28	28,37	0,05	0,045	0,04
30	29,57	0,05	0,05	0,045



bservaciones :	Fecha : 09/04/02

5. ANEXO V

Plan Estratégico de implementación de un Mantenimiento Predictivo a escala

Teniendo en consideración los puntos tratados anteriormente, EGASA vio por conveniente iniciar un Plan Estratégico de Implementación de un Mantenimiento Predictivo a Escala, a continuación se mencionan algunos de las implementaciones realizadas así como proyectos a realizar.

1. IMPLEMENTACIÓN DE UN SISTEMA DE MEDICIÓN DE DESCARGAS PARCIALES EN LOS TRES GRUPOS GENERADORES

EGASA tiene unidades generadoras en la C.H. Charcani V en 13800 voltios; nivel de tensión a la cual se pueden producir descargas parciales en estas maquinas, que puedan afectar la vida útil del aislamiento de los generadores, ocasionando posibles fallas irreversibles y cuya reposición demanden altas perdidas económicas a la empresa.

Las unidades de generación de la C.H. Charcani V tienen en promedio una antigüedad de catorce años en operación y en algunas inspecciones al generador se han registrado algunos síntomas del efecto corona en puntos cercanos a los bornes del generador. Por tanto se hace necesario medir y controlar el nivel de las descargas parciales que pudieran estar ocurriendo en los generadores.

Luego de realizados los estudios respectivos y enmarcado dentro de su política de mantenimiento de sus centrales de generación EGASA vio por conveniente trazarse el objetivo de la implementación gradual de un mantenimiento predictivo; el cual permitirá un monitoreo continuo y un diagnostico anticipado del estado de nuestras unidades, pudiéndose tomar de esta manera decisiones oportunas para la corrección de posibles fallas, antes que estas ocurran o se agraven; retribuyéndose así en un beneficio económico para la empresa debido a la protección de la vida útil de las maquinas así como la disminución del índice de indisponibilidad de nuestras unidades generadoras.

DATOS TÉCNICOS DE LAS UNIDADES DE GENERACIÓN

Esta central cuenta con tres unidades similares cuyas características técnicas son las siguientes:

DATOS GENERALES

Fabricante	ALSTHOM ATLANTIQUE (Francia)
Año Fabricación	1984
Potencia Nominal	57 MVA
Tensión Nominal	13,8 kV +- 10%
Factor de Potencia	0,85
Intensidad Nominal	2385 A
Velocidad síncrona	600 RPM
Frecuencia	60 Hz
Tensión de excitación	121 V
Corriente de excitación	1024 A

ESTATOR

(Grupo 2 y 3 fabricado en dos partes y ensamblado en obra, Grupo 1 recientemente ensamblado en planta)

Diámetro Interno estator	2850 mm
Diámetro Exterior estator :	3660 mm
Longitud	1530 mm
Numero de ranuras	126
Numero de salidas de ventilación	56 (ancho 4 mm)
Chapas magnéticas (Láminas)	0,5 mm de espesor, 1,1 W/kg para 1,5 Tesla, a 50Hz
Aislamiento de las chapas	Barnizadas en caliente a dos

	caras
Numero de paquetes	57

a. **DEVANADO**

Tipo	Imbricado con dos barras por ranura
Transposición	Roebel
Aislamiento	ISOTENAX N
Conformación de la barra :	2x24 conductores (5,6 x 2,24 mm desnudos 5,85 x 2,49 aislados)
Conexión	3 fases en estrella
Paso del devanado	1 a 9

b. **ROTOR**

Diámetro	2811 mm
Entrehierro	19,5 mm
Nº Bobinas	12
Nº Espiras por bobina	34,5

Por ello, en el mes de diciembre del año 2002 se adquirió e implemento un Sistema de Medición de Descargas Parciales instalados en los tres Grupos Generadores de Charcani V.

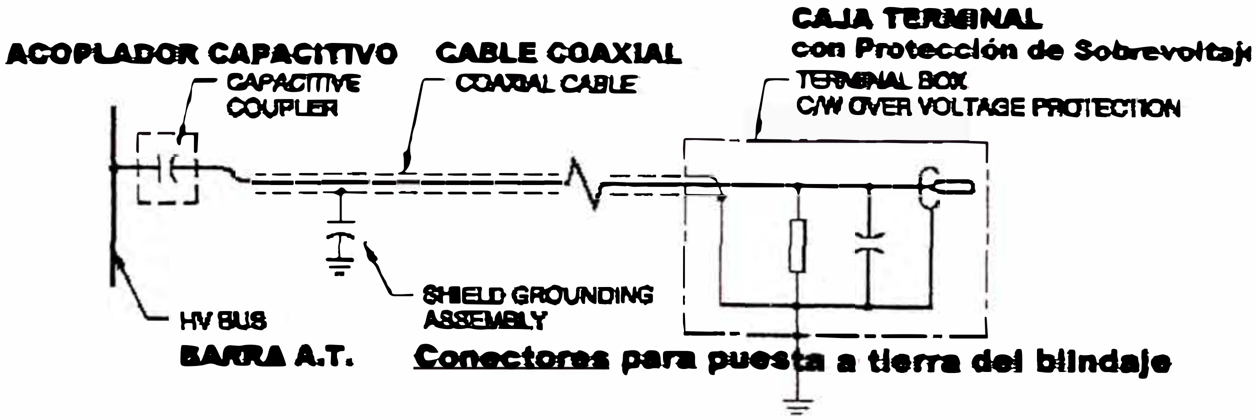
El fenómeno de descargas parciales en generadores se presenta debido a posibles fallas en el aislamiento del bobinado, el continuo proceso de descargas eléctricas y el aumento en magnitud deterioran el aislamiento debilitando sus propiedades dieléctricas. Como consecuencia, pueden ocurrir cortocircuitos en los devanados llegando incluso a colapsar el bobinado del estator.

El sistema de medición adquirido es un equipo canadiense marca ADWELL modelo PDA Premium capaz de detectar y medir la actividad de estas descargas parciales estando el generador en servicio. El seguimiento y control estadístico de este fenómeno nos permitirán diagnosticar el estado de nuestras unidades y tomar decisiones oportunas de intervenciones programadas si es necesario.

El equipo adquirido para cada unidad, consta de tres acopladores capacitivos de 80 pF que se encuentran instalados en los bornes de salida de cada fase del generador y permiten captar las señales emitidas por las descargas parciales, una caja terminal para la conexión del equipo de medición instalada en los tableros de mando (sala eléctrica Nivel 63) y el equipo portátil de medición PDA Premium. La visualización de los resultados se realizan a través de una computadora portátil (que no forma parte del suministro) instalado con el software de análisis proporcionado por ADWELL., el cual incluye lectura, gráficas y reporte con la interpretación respectiva de los resultados, siendo capaz de almacenar los valores de medición (base histórica por unidad de generación) y realizar reportes estadísticos que nos permitan realizar el análisis y evolución de los niveles de descargas parciales.

Dicho software de aplicación (medición y diagnósticos de los resultados), es capaz de filtrar los posibles ruidos que pudieran distorsionar la medición de los niveles de las señales de Descargas Parciales, así mismo es flexible para la integración a sistemas de comunicación SCADA.

A continuación se muestra el esquema de conexión del acoplador:



COUPLER SCHEMATIC DIAGRAM
DIAGRAMA ESQUEMATICO DEL ACOPLADOR

2. ADQUISICIÓN E IMPLEMENTACIÓN DE UN SISTEMA DE MONITOREO Y DIAGNOSTICO DEL ESTADO DE LOS GRUPOS GENERADORES POR ANÁLISIS DE LAS VIBRACIONES

Dentro de los planes de Adquisición de EGASA , se encuentra la implementación de un Sistema de Monitoreo y Diagnostico del Estado de los Grupos Generadores por Análisis de las Vibraciones.

La monitorización y el diagnóstico de daños de fallas de las máquinas hidráulicas mediante la medición y análisis de las vibraciones ha sido fundamental para la implementación de sistemas de mantenimiento predictivo, eso para optimizar la disponibilidad de las máquinas a un coste mínimo. Sin embargo, el análisis del comportamiento vibratorio de las máquinas hidráulicas puede ser una tarea muy compleja debido a los diferentes tipos de excitaciones que dan lugar en estos sistemas y en sus circuitos hidráulicos. Tales excitaciones son inducidas por daños de origen hidráulico, mecánico y eléctrico. Asimismo, las máquinas tienen diferentes comportamientos dependiendo de su tipo, instalación y condiciones de operación.

Los grupos hidráulicos durante su funcionamiento soportan esfuerzos dinámicos de origen hidráulico, mecánico y eléctrico que inducen vibraciones y establecen un estado de tensiones variables que provocan el envejecimiento y el desgaste de sus componentes. El nivel de deterioro de una máquina rotativa se refleja en las amplitudes de las vibraciones. Los niveles de vibraciones excesivos son peligrosos para el funcionamiento de las máquinas y están limitados por algunas normas vigentes. La monitorización del comportamiento vibratorio de los grupos hidráulicos tiene un creciente interés debido a diversos factores, algunos de los cuales son los siguientes:

- Actualmente se está procediendo a la gradual automatización de las centrales y esto implica el adoptar técnicas de control y monitorización suficientes para garantizar el buen funcionamiento y la seguridad estructural de los grupos.
- Se va requiriendo el incremento de la fiabilidad y seguridad en todos los sistemas de producción de energía.
- Se prevee la aparición de normativas más estrictas que las actuales para control de las máquinas.
- Los avances tecnológicos producidos en hidráulica en los últimos años, así como las mejoras en las técnicas de fabricación y materiales, han propiciado una mayor concentración de potencia en las máquinas de nuevos diseños y hace que sean más propensas a tener problemas de vibraciones.

El objetivo final es obtener la representación del espectro de las vibraciones de una máquina para su posterior análisis, para ello es necesario una serie de eslabones a saber:

- En la máquina, elegir un punto adecuado para la medida, así como la recopilación de los datos necesarios para el análisis de la máquina, como son el tipo de cojinetes, número de alabes, etc...
- Elección del tipo de sensor más adecuado, así como su sensibilidad y ancho de banda, y su fijación al punto de medida.

- Acondicionador: Sólo si el sensor lo requiere.
- Etapa de cálculo y medida: Un analizador que realice la transformada rápida de Fourier.
- Presentación de resultados y análisis: Un ordenador.

El método a seguir es el siguiente:

Mediante un transductor conseguimos transformar las vibraciones mecánicas en señal eléctrica, ya sea tensión, intensidad, frecuencia, etc.; esta señal eléctrica necesita de un acondicionador para hacerla utilizable para el sistema, así mediante un multiplexor logramos acoplar una salida para varias entradas, abaratando así la instalación.

Con el convertidor analógico-digital se transforma la señal para ser utilizada por un sistema informático. Toda esta información debe ser almacenada en algún dispositivo de memoria: Disco, cinta, etc..

Mediante una computadora se procesa la señal, permitiendo la realización de los análisis correspondientes y la posterior obtención de los resultados.

Existen dos niveles diferenciados:

Medidor de vibraciones: Da un valor global del desplazamiento o velocidad de la vibración. Cuando la vibración sobrepasa el valor preestablecido la máquina debe revisarse.

Analizador de vibraciones: La vibración se descompone según su frecuencia. Analizando el nivel de vibración en cada una de las frecuencias se puede determinar la causa de la anomalía.

3. PROYECTO REPRESA PILLONES

En lo referente al Proyecto de la Represa de Pillones de 800 millones de m^3 de capacidad, obra que asegurara un crecimiento en la potencia firme y capacidad de generación de EGASA, así como también proporcionara el agua necesaria para la ampliación prevista del desarrollo minero de Cerro Verde, dando a su vez un incremento del caudal de agua regulada en el río Chili, durante los meses de estiaje, beneficiando así a toda la ciudad y el sector agropecuario de la provincia de Arequipa.

6. ANEXO VI

Norma Internacional Standard ISO 18816-5. Mechanical Vibration - Evaluation of Machine Vibration by Measurements on Non-rotating Parts

INTERNATIONAL STANDARD

ISO 10816-4

First edition
1998-07-01

Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts —

Part 4: Gas turbine driven sets excluding aircraft derivatives

Vibrations mécaniques — Évaluation des vibrations des machines par mesurages sur les parties non tournantes —

Partie 4: Ensembles de turbines à gaz, à l'exception des turbines dérivées de celles utilisées en aéronautique

Reference number
ISO 10816-4:1998(E)

Contents

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X.400 c=ch; a=400net; p=iso; o=isocs; s=central

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 10816-4 was prepared by Technical Committee ISO/TC 108 *Mechanical vibration and shock*, Subcommittee SC 2 *Measurement and evaluation of mechanical vibration and shock as applied to machines, vehicles and structures*.

ISO 10816 consists of the following parts, under the general title *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts*:

Part 1: General guidelines

Part 2: Large land-based steam turbine generator sets in excess of 50 MW

Part 3: Industrial machines with nominal power above 15 kW and nominal speeds between 120 r/min and 15 000 r/min when measured in situ

Part 4: Gas turbine driven sets excluding aircraft derivatives

Part 5: Machine sets in hydraulic power generating and pumping plants

Part 6: Reciprocating machines with power ratings above 100 kW

Annex A forms an integral part of this part of ISO 10816. Annexes B and C are for information only.

Introduction

ISO 10816-1 is the basic document which describes the general requirements for evaluating the vibration of various machine types when the vibration measurements are made on non-rotating parts. This part of ISO 10816 provides specific guidance for assessing the severity of vibration measured on the bearing housings or pedestals of gas turbine driven sets. Measurements at these locations characterize reasonably well the state of vibration.

Two criteria are provided for assessing the machine vibration. One criterion considers the magnitude of the observed vibration; the second considers changes in the magnitude. It must be recognized, however, that these criteria do not form the only basis for judging the severity of vibration. For gas turbine sets, it is also common to judge the vibration based on measurements taken on the rotating shafts. Shaft vibration measurement requirements and criteria for gas turbine sets are addressed in separate documents, ISO 7919-1 and ISO 7919-4.

Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts —

Part 4:
Gas turbine driven sets excluding aircraft derivatives

1 Scope

This part of ISO 10816 gives specific guidance for assessing the severity of vibration measured on the bearing housings or pedestals of gas turbine driven sets.

The vibration criteria provided in this part of ISO 10816 apply to heavy-duty gas turbine sets. Aircraft derivative gas turbines (including gas turbines with dynamic properties similar to those of aircraft derivatives) are excluded from this part of ISO 10816. Large differences exist between these two turbine types in, for example, casing flexibility, bearing design, rotor to stator weight ratio and mounting structure. It is therefore necessary to establish separate criteria for these two turbine types.

This part of ISO 10816 is applicable only to heavy-duty gas turbines used in electrical and mechanical drive applications covering the power range above 3 MW and a speed range under load between 3 000 r/min and 20 000 r/min. This includes gas turbines directly coupled to other prime movers such as steam turbines, but the evaluation of the steam turbine vibration is not dealt with in this part of ISO 10816 (see the following exclusion list). It also includes any driven equipment not included in the exclusion list below.

The following are excluded from this part of ISO 10816:

- gas turbines with power outputs less than or equal 3 MW (see ISO 10816-3);
- gas turbine driven pumps (see ISO 10816-3);
- coupled steam turbines and generators with outputs less than or equal 50 MW (see ISO 10816-3);
- coupled steam turbines and generators with outputs greater than 50 MW (see ISO 10816-2);
- coupled compressors (see ISO 10816-3);
- gearbox vibration (see below).

The criteria of this part of ISO 10816 are applicable to the vibration measured on the bearing housings or pedestals of gas turbines and driven equipment using fluid-film bearings. They assume that the measurements are *in-situ* broad-band values taken under normal steady-state operating conditions. This part of ISO 10816 encompasses machines which may have gears or rolling element bearings but does not address the evaluation of the condition of those gears or bearings.

NOTE Gear vibration may be included in a future edition of this part of ISO 10816. Vibration of gears is presently addressed in ISO 8579-2.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 10816. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 10816 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 7919-4:1996, *Mechanical vibration of non-reciprocating machines — Measurements on rotating shafts and evaluation criteria — Part 4: Gas turbine sets*

ISO 10816-1:1995, *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 1: General guidelines*

3 Measurement procedures

The measurement procedures and instrumentation shall comply with the general requirements of ISO 10816-1 and are as follows.

For gas turbines, the measurement system used shall be capable of measuring broad-band vibration over a frequency range from 10 Hz to at least six times the highest shaft rotational frequency. If, however, the instrumentation is also to be used for diagnostic purposes, a wider frequency range and/or a spectral analysis may be necessary. If measurements from different machines are to be compared, care shall be taken to ensure that the same frequency range has been used.

The locations of vibration measurements shall be such that they provide adequate sensitivity to the dynamic forces of the machine but are not unduly influenced by external sources (such as combustion vibration, gear mesh vibration, etc.). Typically, this will require measuring in two orthogonal radial directions on each bearing cap or pedestal, as shown in figure 1. Although the transducers may be placed at any angular location on the bearing housings or pedestals, vertical and horizontal directions are usually preferred.

A single transducer may be used on a bearing cap or pedestal in place of the more typical pair of orthogonal transducers if it is known to provide adequate information on the magnitude of the machine vibration. In general, however, caution should be observed in evaluating vibration from a single transducer at a measurement plane since it may not be oriented to provide a reasonable approximation of the maximum value at that plane.

The characteristics of the measuring system should be known with regard to the effects of the environment including:

temperature variations

magnetic fields

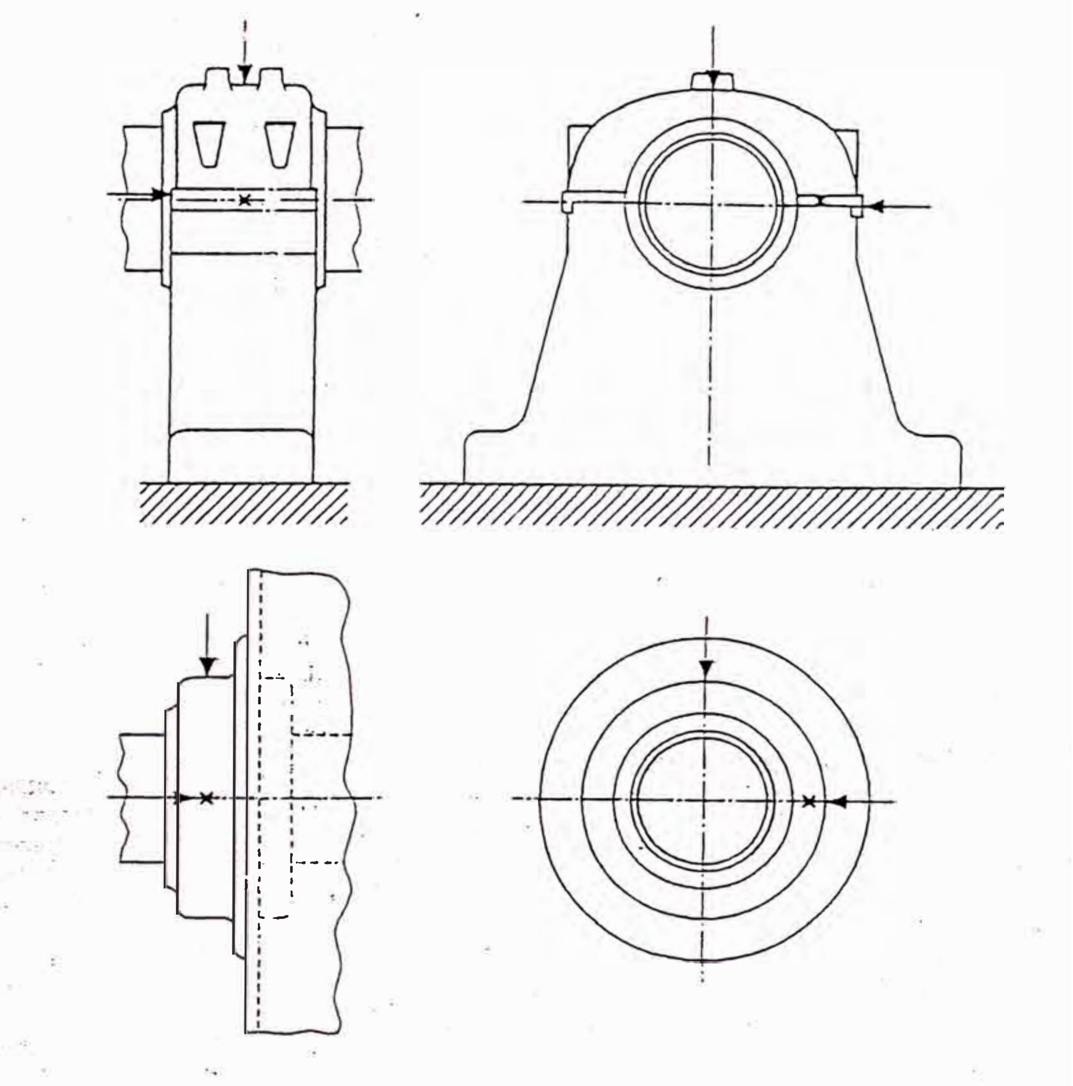
sound fields

power source variations

transducer cable length

transducer orientation.

Particular attention should be given to ensuring that the vibration-sensing transducers are correctly mounted and do not degrade the accuracy of the measurement.



NOTE The evaluation criteria in this part of ISO 10816 apply to radial vibration on all bearings and axial vibration on thrust bearings.

Figure 1 — Measurement points on main bearings

4 Evaluation

ISO 10816-1 provides a general description of the two evaluation criteria used to assess vibration severity on various classes of machines. One criterion considers the magnitude of observed broad-band vibration; the second considers changes in magnitude, irrespective of whether they are increases or decreases.

4.1 Criterion I: Vibration magnitude

This criterion is concerned with defining limits for absolute vibration magnitude consistent with acceptable dynamic loads on the bearings and acceptable vibration transmission into the environment through the support structure and foundation. The maximum vibration magnitude observed at each bearing or pedestal is assessed against four evaluation zones established from international experience. The maximum magnitude of vibration measured is defined as the vibration severity.

4.1.1 Evaluation zones

The following evaluation zones are defined to permit a qualitative assessment of the vibration of a given machine and to provide guidelines on possible actions.

Zone A: The vibration of newly commissioned machines would normally fall within this zone.

Zone B: Machines with vibration within this zone are normally considered acceptable for unrestricted long-term operation.

Zone C: Machines with vibration within this zone are normally considered unsatisfactory for long-term continuous operation. Generally, the machine may be operated for a limited period in this condition until a suitable opportunity arises for remedial action.

Zone D: Vibration values within this zone are normally considered to be of sufficient severity to cause damage to the machine.

Numerical values assigned to the zone boundaries are not intended to serve as acceptance specifications, which should be subject to agreement between the machine manufacturer and customer. However, these values provide guidelines for ensuring that gross deficiencies or unrealistic requirements are avoided. In certain cases, there may be specific features associated with a particular machine which would require different zone boundary values (higher or lower) to be used. In such cases, it is normally necessary for the manufacturer to explain the reasons for this and, in particular, to confirm that the machine will not be endangered by operating with higher vibration values.

4.1.2 Evaluation zone limits

Values for the zone boundaries are given in table A.1. The zone boundary vibration values were established from representative data provided by manufacturers and users. Since the data showed significant spread, the zone boundary values should be considered only as guidelines. The values in table A.1 apply to vibration measurements taken under steady-state operating conditions at rated speed or speeds. It should be noted, however, that the vibration of a gas turbine can be influenced by its mounting system and coupling arrangement to driven machines.

This part of ISO 10816 does not provide different evaluation zone values for gas turbine driven sets mounted on rigid and flexible foundations. This is consistent with ISO 7919-4 which deals with shaft vibration for the same class of machines. However, ISO 7919-4 as well as this part of ISO 10816 may be revised in the future to give different criteria for gas turbine driven sets mounted on massive concrete foundations and those mounted on lighter, tuned steel foundations, if additional analysis of survey data on such machines shows it to be warranted.

The common measurement parameter for assessing machine vibration severity is velocity. Table A.1 presents the evaluation zone boundaries based on r.m.s. (root-mean-square) velocity measurements. In many cases, however, it was customary to measure vibration with instruments scaled to read peak rather than r.m.s. vibration velocity values. If the vibration consists mainly of one frequency component, a simple relationship exists between the peak and r.m.s. values and the zone boundaries of table A.1 may be readily expressed in zero-to-peak values by multiplying by $\sqrt{2}$.

For gas turbine driven sets, it is common for the vibration to be predominantly at the running frequency of the machine. For such cases and when peak rather than r.m.s. values of vibration are being measured, a table equivalent to table A.1 can be constructed. The zone boundaries of table A.1 are multiplied by a factor of $\sqrt{2}$ to produce such an equivalent table for assessing peak vibration severity. Alternatively, the measured peak vibration values may be divided by $\sqrt{2}$ and judged against the r.m.s. criteria of table A.1.

4.1.3 Axial measurements

It is not common practice to measure axial vibration on the radial load carrying bearings of gas turbines during continuous operational monitoring. Such axial measurements are primarily used for periodic vibration surveys or for diagnostic purposes. When axial vibration is measured on an axial thrust bearing, the severity may be judged using the same criteria as for radial vibration.

4.2 Criterion II: Change in vibration magnitude

This criterion provides an assessment of a change in vibration magnitude from a previously established reference value. A significant increase or decrease in broad-band vibration magnitude may occur which requires some action even though zone C of Criterion I has not been reached. Such changes can be instantaneous or progressive with time and may indicate incipient damage or some other irregularity. Criterion II is specified on the basis of the change in broad-band vibration magnitude occurring under steady-state operating conditions. Such conditions allow for small changes in variables such as generator power output at the normal operating speed.

When Criterion II is applied, the vibration measurements being compared shall be taken at the same transducer location and orientation, and under approximately the same steady-state operating conditions of speed, load, and thermal condition. Significant changes from the normal vibration magnitudes should be investigated so that a dangerous situation may be avoided. When an increase or decrease in vibration magnitude exceeds 25 % of the upper value of zone B, such changes should be considered significant. Diagnostic investigations should then be initiated to ascertain the reason for the change and to determine what further actions are appropriate.

NOTE The 25 % value is provided as a guideline for a significant change in vibration magnitude, but other values may be used based on experience with a specific machine.

4.3 Operational limits

For long-term operation, it is common practice to established operational vibration limits. These limits take the form of ALARMS and TRIPS.

ALARMS: To provide a warning that a defined value of vibration has been reached or a significant change has occurred, at which remedial action may be necessary. In general, if an ALARM situation occurs, operation can continue for a period whilst investigations are carried out to identify the reason for the change in vibration and define any remedial action.

TRIPS: To specify the magnitude of vibration beyond which further operation of the machine may cause damage. If the TRIP value is exceeded, immediate action should be taken to reduce the vibration or the machine should be shut down.

In order to perform an investigation on the unit running at steady-state conditions but gradually proceeding to the vibration TRIP value, actions may be taken, such as reduction in load and speed, to stabilize the vibration to a constant or a lower value.

4.3.1 Setting of ALARMS

The ALARM values may vary considerably, up or down, for different machines. The values chosen will normally be set relative to a baseline value determined from experience for the measurement position or direction for that particular machine.

It is recommended that the ALARM value should be set higher than the baseline by an amount equal to 25 % of the upper limit of zone B. If the baseline is low, the ALARM may be below zone C.

Where there is no established baseline (for example with a new machine) the initial ALARM setting should be based either on experience with other similar machines or relative to agreed acceptance values. After a period of time, the steady-state baseline value will be established and the ALARM setting should be adjusted accordingly.

Where the baseline signal is non-steady and non-repetitive, some method of time averaging of the signal is required. This could be achieved with the aid of a computer.

It is recommended that the ALARM value should not normally exceed 1.25 times the upper limit of zone B.

If the steady-state baseline changes (for example after a machine overhaul), the ALARM setting should be revised accordingly. Different operational ALARM settings may then exist for different bearings on the machine, reflecting differences in dynamic loading and bearing support stiffnesses.

An example of establishing ALARM values is given in annex B.

4.3.2 Setting of TRIPS

The TRIP values will generally relate to the mechanical integrity of the machine. The values used will, therefore, generally be the same for all machines of similar design and would not normally be related to the steady-state baseline value used for setting ALARMS.

There may, however, be differences for machines of different design and it is not possible to give clear guidelines for absolute TRIP values. In general, the TRIP value will be within zone C or D, but it is recommended that the TRIP value should not exceed 1,25 times the upper limit of zone C. However, experience with a specific machine may prescribe a different value.

4.4 Supplementary procedures/criteria

The measurement and evaluation of vibration given in this part of ISO 10816 may be supplemented or replaced by shaft vibration measurements in accordance with ISO 7919-4. It is important to recognize that there is no simple way to relate bearing housing vibration to shaft vibration, or vice versa. The difference between the shaft absolute and shaft relative measurements is related to the bearing housing vibration but may not be numerically equal to it because of phase angle differences. Thus, when the criteria of this part of ISO 10816 and those of ISO 7919-4 are both applied in the assessment of machine vibration, independent shaft and bearing housing (or pedestal) vibration measurements should be made. If application of the different criteria leads to different assessments of vibration severity, the more restrictive zone classification generally applies unless there is significant experience to the contrary.

4.5 Evaluation based on vibration vector information

The evaluation considered in this part of ISO 10816 is limited to broad-band vibration without reference to frequency components or phase. This will, in most cases, be adequate for acceptance testing and for operational monitoring purposes. However, for long-term condition monitoring purposes and for diagnostics, the use of vibration vector information is particularly useful for detecting and defining changes in the dynamic state of the machine. In some cases, these changes would go undetected when using only broad-band vibration measurements (see, for example, ISO 10816-1).

Phase- and frequency-related vibration information is being used increasingly for monitoring and diagnostic purposes. The specification of criteria for this, however, is beyond the present scope of this part of ISO 10816.

Annex A
(normative)

Evaluation zone boundaries

Table A.1 — Evaluation zone boundaries based on bearing housing/pedestal vibration velocity, valid for shaft rotational speed 3 000 r/min to 20 000 r/min

Zone boundary	Vibration velocity mm/s (r.m.s.)
A/B	4,5
B/C	9,3
C/D	14,7
NOTE These values, which are the upper limits of zones A, B and C respectively, should apply to radial vibration measurements on all bearing housings or pedestals and to axial vibration measurements on housings containing an axial thrust bearing, under steady-state operating conditions at rated speed. Figure 1 shows typical measurement positions.	

Annex B
(informative)

Example of setting ALARM and TRIP values

Consider the case of a 3 000 r/min gas turbine. The operational ALARM settings for a new machine for which there is no prior knowledge of bearing vibration is normally set within zone C. The specific value is often set by mutual agreement between the customer and the machine manufacturer. For this example, assume it has been set initially at the lower limit of zone C for each bearing, which corresponds to 9,3 mm/s (r.m.s.).

After a period of machine operation, the customer may consider the option of changing the ALARM settings to reflect the typical steady baseline values of vibration at each bearing. Using the procedure described in 4.3.1 as the basis, the ALARM may be set for each bearing to equal the sum of the typical steady-state value obtained from experience with the specific machine, and 25 % of the upper limit of zone B.

The TRIP setting would remain at 14,7 mm/s (r.m.s.) in accordance with Criterion I. The basis for this is that the TRIP value is a fixed value corresponding to the maximum vibration to which the machine should be subjected.

Annex C
(informative)

Bibliography

[1] ISO 2954:1975, *Mechanical vibration of rotating and reciprocating machinery — Requirements for instruments for measuring vibration severity.*

[2] ISO 7919-1:1996, *Mechanical vibration of non-reciprocating machines — Measurements on rotating shafts and evaluation criteria — Part 1: General guidelines.*

[3] ISO 8579-2:1993, *Acceptance code for gears — Part 2: Determination of mechanical vibrations of gear units during acceptance testing.*

[4] ISO 10816-2:1996, *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 2: Large land-based steam turbine generator sets in excess of 50 MW.*

[5] ISO 10816-3:—[1], *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 3: Industrial machines with nominal power above 15 kW and nominal speeds between 120 r/min and 15 000 r/min when measured in situ.*

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[1] To be published.

ICS 17.160; 27.040

Descriptors: vibration, machinery, gas turbine engines, tests, mechanical tests, vibration tests, acceptance testing, estimation, vibration severity.

Price based on 9 pages

7. ANEXO VII

Norma Internacional Standard ISO 18816-5. Mechanical Vibration - Evaluation of Machine Vibration by Measurements on Non-rotating Parts

With the generator running at rated speed and with excitation applied, the magnitude, frequency, and phase angle of the generated voltage can be matched to that of the bus, and the generator breaker can be closed. Load should then be applied in small increments, and the temperature rise should be observed. When full load has been reached, it should be maintained for several hours and a careful check made of the temperature rise of windings and bearings, balance, collector ring and exciter brush operation, oil and water flow, ventilation, etc. Some adjustments may now be necessary to ensure continued successful operation.

14.3 Load Rejection Tests. Load rejection tests for governor and excitation system settings should be performed in the sequence of increasing loads up to full or maximum load. The unit speed and voltage rises should be carefully monitored with high response recording instruments. The maximum transient speed and voltage limits established by the generator manufacturer must be observed and maintained and the governor and excitation system adjusted.

14.4 Operation Check of Shaft Runout. An operation check of the shaft runout should be made after load rejection and while the generator is operating under full load (see 15.1).

15. Field Tests

15.1 Vertical Hydraulic-Turbine Generator Shaft Runout Tolerances, Installation Check. The runout of the combined turbine and generator shafts after installation should be checked by one of the following methods.

15.1.1 Rotational Check

15.1.1.1 Method 1. After aligning and plumbing the coupled generator and turbine shafts, the accuracy of the generator shaft thrust surface should be checked by the procedure outlined below. This method should be used for checking shafts equipped with adjustable-shoe-type thrust bearings. It may be used for checking shafts equipped with self-equalizing-type bearings if recommended by the generator manufacturer.

Mechanically rotate the unit, with the turbine guide bearing removed, and any generator bearings other than the one immediately adjacent to the thrust bearing backed off so as not to restrain the position of the shaft.

The remaining generator guide bearing prevents excessive side slip during rotation; however, unless this bearing is at approximately the same elevation as the thrust bearing, it also should be backed off or removed before the readings are taken.

Measure runout by plumb line or dial indicator readings at 90 degree intervals at both the thrust-bearing level and the turbine-guide-bearing level.

After making corrections for such side slip as has occurred in the thrust bearing, the shaft sideways deflection on the plumb lines or dial indicators should not be greater than 0.002 x *L/D* in, where

L = the distance in inches from thrust surface to point of measurement
D = the thrust bearing outside diameter in inches

15.1.1.2 Method 2. After initial operation of the combined unit, the accuracy of the generator shaft thrust surface should be checked by the procedure outlined below. This method should be used for checking shafts equipped with spring-type thrust bearings. It may also be used for checking shafts equipped with self-equalizing-type bearings if recommended by the generator manufacturer.

Dial indicators should be placed on two of the thrust-bearing segments in such a manner as to indicate the vertical movement of these segments. The unit should then be run and readings of the dial indicators recorded at approximately one-quarter of normal speed when the unit is decelerating. These readings will give an indication of the runout of the face of the thrust-bearing runner plate with respect to the shaft axis. This runout should be not greater than 0.002 in.

15.1.2 Operation Check. If the runout obtained by methods 1 and 2 (15.1.1) exceeds the allowable values, the runout at the guide bearings of the combined shaft should be checked with the unit running at normal speed and rated load with indicators mounted on the bearing supports. The runout of the unit

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10816-5

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Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts —

Part 5:
Machine sets in hydraulic power generating and pumping plants

Vibrations mécaniques — Évaluation des vibrations des machines par mesurages sur les parties non tournantes —

Partie 5: Groupes générateurs de puissance et installations de pompage hydrauliques

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Contents

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this part of ISO 10816 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 10816-5 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock*, Subcommittee SC 2, *Measurement and evaluation of mechanical vibration and shock as applied to machines, vehicles and structures*.

ISO 10816 consists of the following parts, under the general title *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts*:

- *Part 1: General guidelines*
- *Part 2: Large land-based steam turbine generator sets in excess of 50 MW*
- *Part 3: Industrial machines with nominal power above 15 kW and nominal speeds between 120 r/min and 15 000 r/min when measured in situ*
- *Part 4: Gas turbine driven sets excluding aircraft derivatives*
- *Part 5: Machine sets in hydraulic power generating and pumping plants*
- *Part 6: Reciprocating machines with power ratings above 100 kW*

Annex A forms a normative part of this part of ISO 10816. Annexes B and C are for information only.

Introduction

ISO 10816-1 is the basic document which describes the general requirements for evaluating vibration of various machine types when the vibration measurements are made on non-rotating parts. This part of ISO 10816 provides specific guidance for assessing the severity of vibration measured at the bearings, bearing pedestals or bearing housings of machine sets in hydraulic power generating and pumping plants when measurements are made *in situ*.

Two criteria are provided for assessing the machine vibration. One criterion considers the magnitude of observed vibration; the second considers changes in the magnitudes. It must be recognized, however, that these two criteria do not form the only basis for judging the severity of vibration. For most machine types it is also common to judge the vibration based on measurements taken on the rotating shaft. Shaft vibration measurement requirements and criteria are addressed in separate documents, ISO 7919-1 and ISO 7919-5.

Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts —

Part 5:
Machine sets in hydraulic power generating and pumping plants

1 Scope

This part of ISO 10816 gives guidelines for applying bearing housing vibration evaluation criteria measured under normal operating conditions at the bearings, bearing pedestals or bearing housings of the main machine sets in hydraulic power generating and pumping plants. These guidelines are presented in terms of both steady-state running vibration and any amplitude changes which may occur in these steady values. The numerical values specified are not intended to serve as the only basis for vibration evaluation, since, in general, the vibratory condition of a machine is assessed by consideration of both the bearing housing vibration and the associated shaft vibration (see introduction of ISO 10816-1 and ISO 7919-1).

This part of ISO 10816 is applicable to machine sets in hydraulic power generating and pumping plants where the hydraulic machines have speeds from 60 r/min to 1800 r/min, shell or shoe type sleeve bearings and a main engine power of 1 MW and more. The position of the shaft line may be vertical, horizontal or at an arbitrary angle between these two directions.

Machine sets covered by this part of ISO 10816 may be combined from

hydraulic turbines and generators,

pumps and electrical machines operating as motors, or

pump-turbines and motor-generators.

Auxiliary equipment (e.g. starting turbines or exciters lying in the shaft line) is included. Evaluation criteria are at present only given for the main bearings of the machine set.

This part of ISO 10816 is applicable also to single turbines or pumps connected to generators or electrical motors over gears or/and radially flexible couplings. However, electrical machines of this type should in principal be evaluated according to the criteria specified in ISO 10816-3.

This part of ISO 10816 is not applicable to the following:

pumps in thermal power plants or industrial installations (for these machines, see ISO 10816-3);

hydraulic machines or machine sets having rolling element bearings.

Consistent with clause 1 of ISO 10816-1:1995, bearing housing vibration of machine sets in hydraulic power generating and pumping plants may be determined with regard to following tasks:

task A: monitoring changes in vibrational behaviour;

task B: prevention of excessive kinetic load.

The criteria are applicable mainly for the vibration produced by the machine set itself. Special considerations should be made when necessary for vibration transmitted to the machine set from external sources.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 10816. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 10816 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 10816-1:1995, *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 1: General guidelines.*

IEC 60994, *Guide for field measurement of vibrations and pulsations in hydraulic machines (turbines, storage pumps and pump-turbines).*

3 Machine arrangements

Significant differences in design and arrangement of hydraulic machine sets require a separation into four principal groups with regard to the radial bearing stiffness, as follows.

Group 1: Horizontal machine sets with pedestal or end-shield bearings mounted on a rigid foundation, usually with operational speeds of above 300 r/min

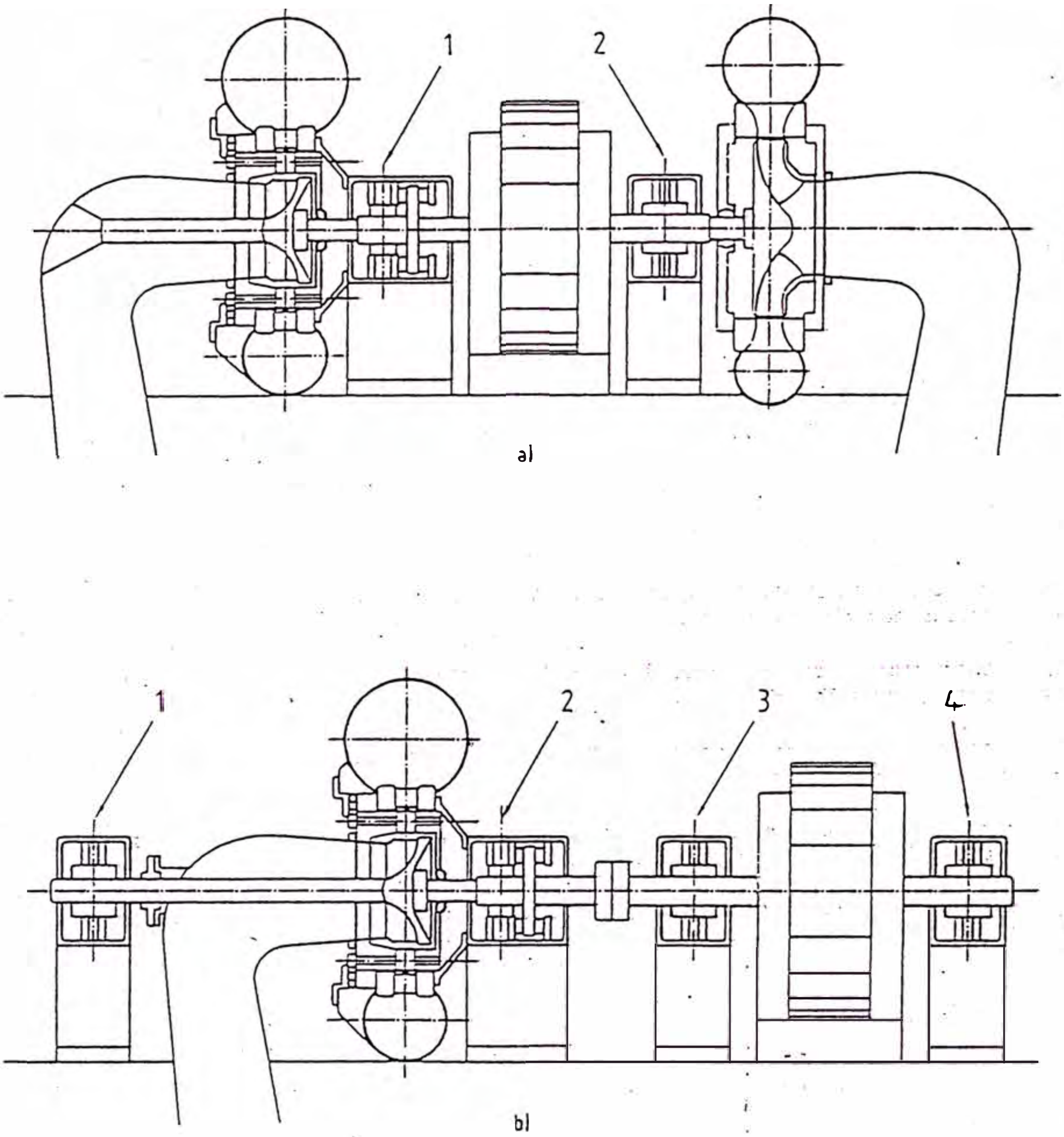
Group 2: Horizontal machine sets with bearing housings which are only braced against the casing of the hydraulic machine, usually with operational speeds of less than 300 r/min.

Group 3: Vertical machine sets with bearing housings which are all braced against the foundation, usually with operational speeds of between 60 r/min and 1 800 r/min.

Group 4: Vertical machine sets with lower bearing housings braced against the foundation and upper bearing housings braced against the generator stator only, usually with operational speeds of between 60 r/min and 1 000 r/min.

NOTE Umbrella-type machines belong to Group 4.

Figures 1 to 4 show examples for each group.

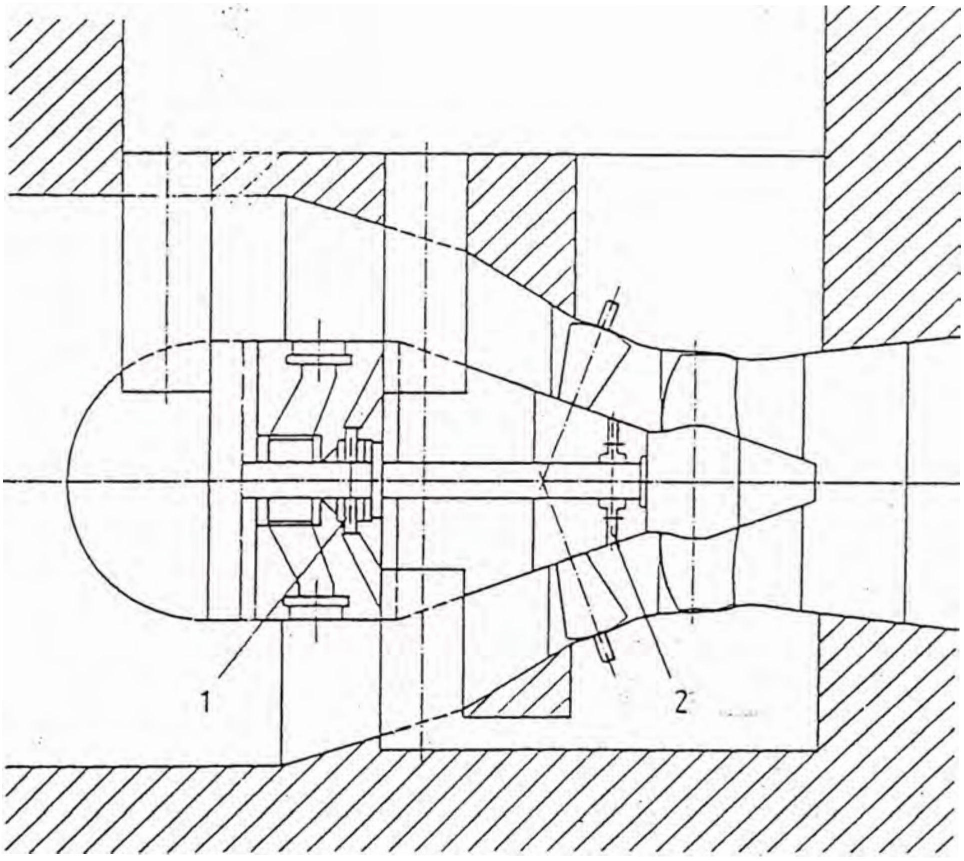


a)

b)

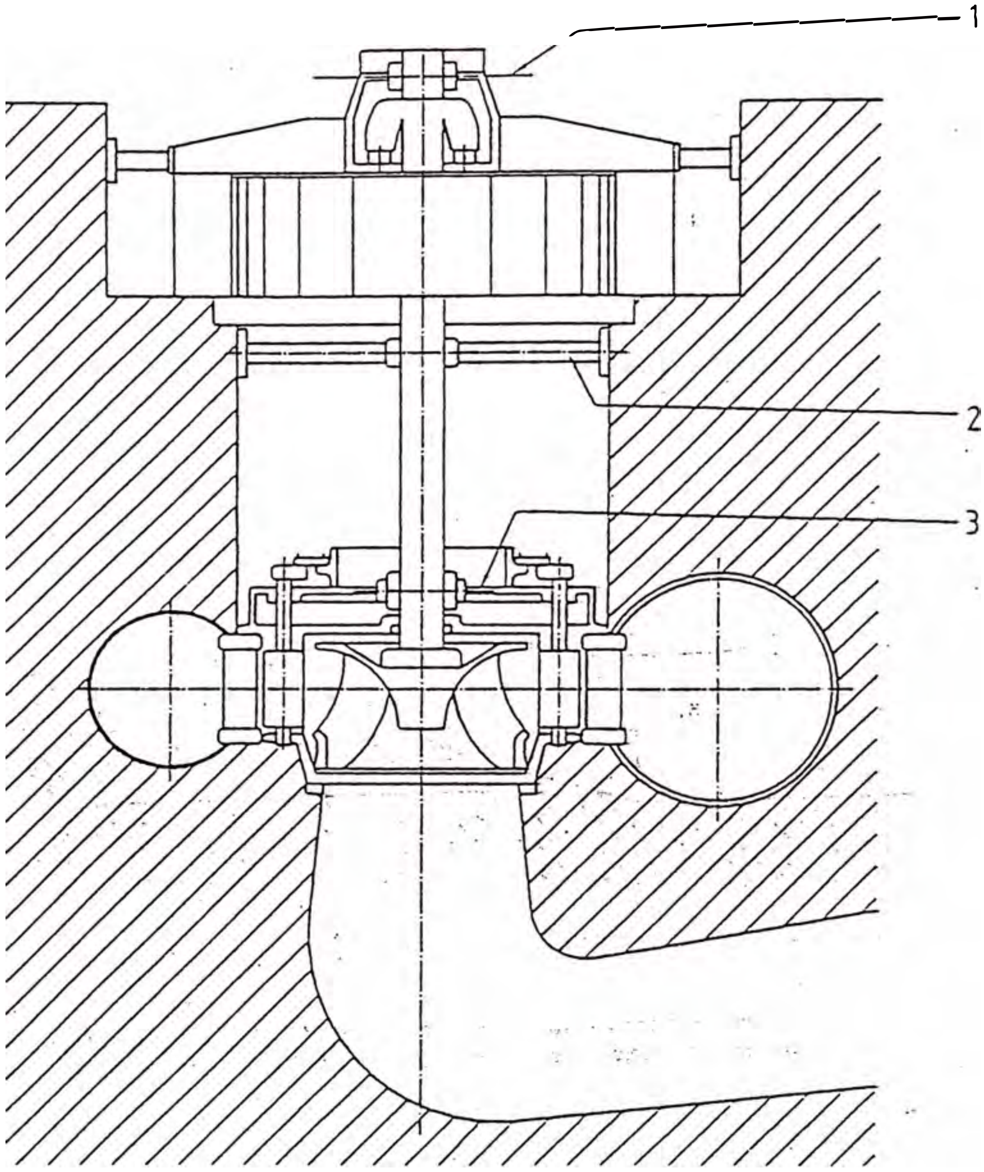
NOTE The numbers indicate measurement locations.

Figure 1 — Measurement locations for Group 1 machine sets with horizontal shaft and pedestal or end-shield bearings mounted on rigid foundation, usually with operational speeds of above 300 r/min



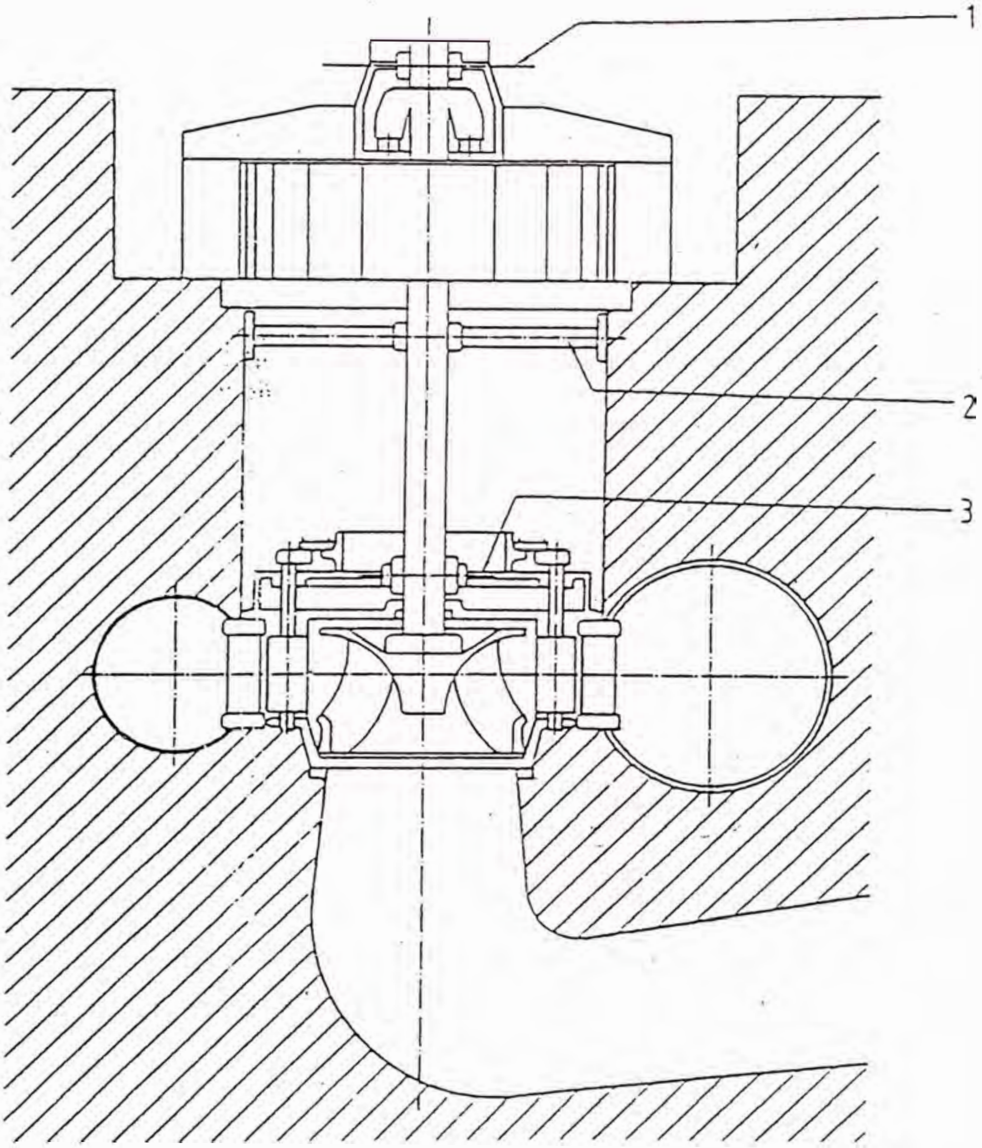
NOTE The numbers indicate measurement locations.

Figure 2 — Measurement locations for a Group 2 machine set with horizontal shaft and bearing housings which are only braced against the casing of the hydraulic machine, usually with operational speeds of less than 300 r/min



NOTE The numbers indicate measurement locations.

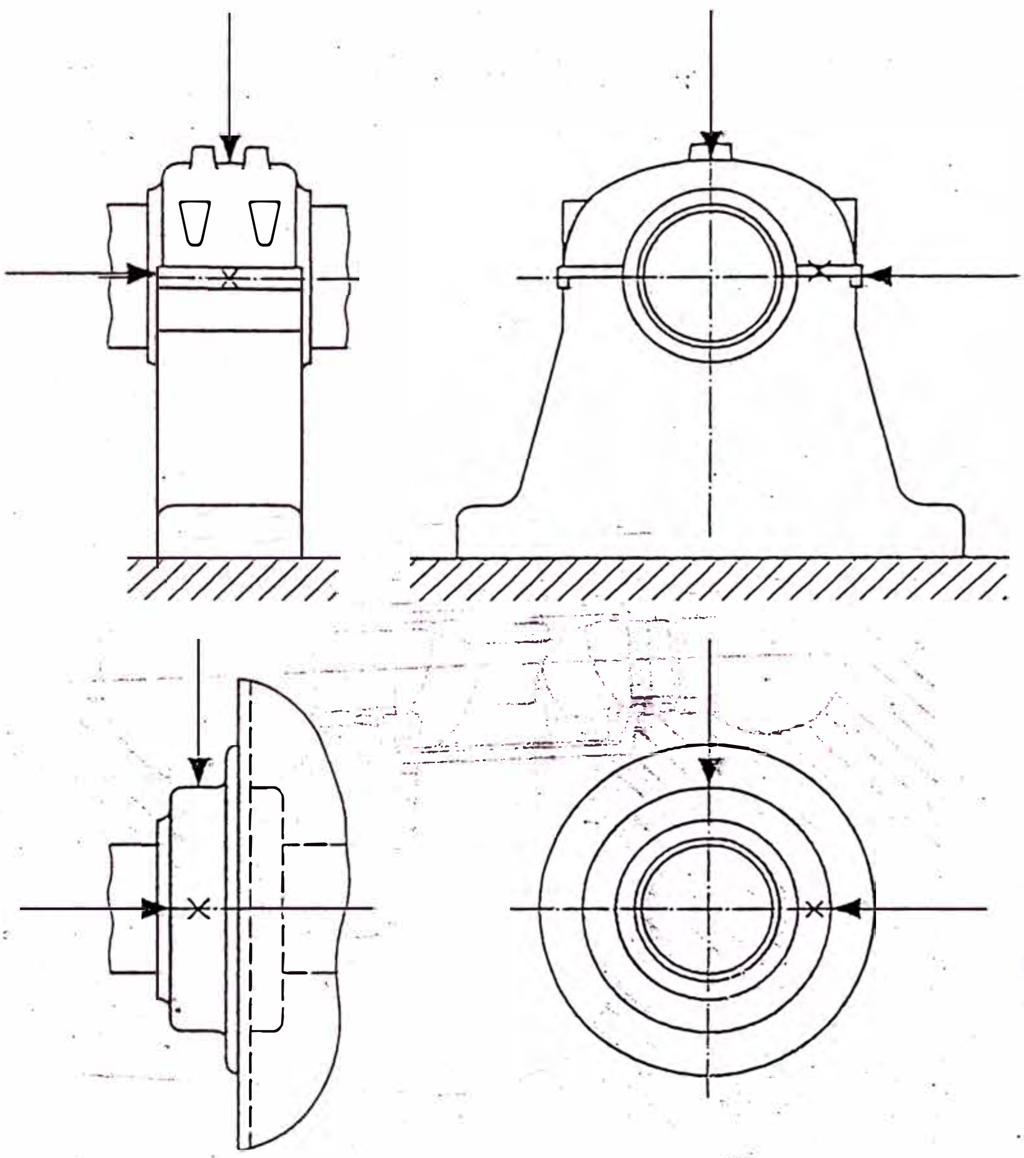
Figure 3 — Measurement locations for a Group 3 machine set with vertical shaft and bearing housings which are all braced against the foundation, usually with operational speeds of between 60 r/min and 1 800 r/min



NOTE 1 The numbers indicate measurement locations.

NOTE 2 Umbrella-type machines belong to this group.

Figure 4 — Measurement locations for a Group 4 machine set with vertical shaft, lower bearing housings braced against the foundation and upper bearing housing braced against the generator stator only, usually with operational speeds of between 60 r/min and 1 000 r/min



NOTE It is recommended that the location for horizontal measurements should be on the bearing pedestal and not on the bearing cap, whenever possible.

Figure 5 — Measurement locations and directions at pedestal or end-shield bearings

4 Measurement procedures and conditions

4.1 General

Follow the general procedures given in ISO 10816-1 and IEC 60994, subject to the recommendations given in 4.2 to 4.5.

4.2 Measurement type

Absolute bearing housing vibration measurements are commonly made on hydraulic machine sets using seismic transducers measuring the vibration velocity v_{rms} in millimetres per second or, after electronic integration, the vibration displacement s_{p-p} in micrometres. The vibration displacement s_{p-p} can also be measured directly as a relative quantity using displacement transducers in the case where a rigid non-vibrating support can be found.

Because of the special nature of the vibratory behaviour of hydraulic machines and their different speed ranges, these quantities have favoured ranges of application as follows:

a) For low-speed machines (below 300 r/min), the preferred measurement quantity is the vibration displacement s_{p-p}. If the spectrum is expected to contain high-frequency components, the evaluation should normally be based on broad-band measurements of both displacement and velocity.

b) For medium- and high-speed machines (300 r/min to 1 800 r/min), the preferred measurement quantity is the vibration velocity v_{rms}. If the spectrum is expected to contain low-frequency components, the evaluation should normally be based on broad-band measurements of both velocity and displacement.

4.3 Measurement locations and directions

Measurement tasks A and B (see clause 1) require measurements to be taken on exposed parts of the machine that are normally accessible and are representative locations for the so-called force flow in the supporting structure, for example on all main bearings of the machine set. Typical examples of measurement locations for hydraulic machines are shown in Figures 1 to 5.

Care shall be taken in this context to ensure that measurements reasonably represent the vibration of the bearing housings and do not include any local resonance or amplification. The locations and directions for vibration measurements shall be such that they provide adequate sensitivity to the dynamic forces of the machine under various operating conditions. Typically, this will often require two orthogonal radial measurement directions on each bearing cap, pedestal or housing. For low-speed machines with a horizontal shaft axis, such as bulb-turbines as shown in Figure 2, the measurement locations and directions shall be determined with great care.

CAUTION: The vibration measured at the lower guide bearings of vertical machines may sometimes be misinterpreted: the vibration level measured at such bearings and their surrounding supports which are rigidly embedded in the buildings is sometimes produced by hydraulic forces, directly transmitted from the hydraulic machine via the foundation. Such vibrations do not necessarily give a correct image of the vibration of the rotating shaft system.

For horizontal machines when using portable measuring instrumentation, take measurements in the vertical and horizontal directions 90° apart (perpendicular to the shaft axis) and, if possible, in the axial direction (parallel to the shaft axis) as shown in Figure 5.

A single transducer may be used on a bearing cap or pedestal in place of the more typical pair of orthogonal transducers if it is known to provide adequate information about the magnitude of the machine vibration. However, caution should be observed in evaluating vibration from a single transducer at a measurement location, because it may not be oriented to provide a reasonable approximation to the maximum value at that location.

In the case of vertical or inclined machine sets, the locations and directions that give maximum vibration readings shall be used, for example the stiff and the elastic axis (this is important for cases with spider arm support constructions), and the specific location and direction shall be recorded with the measurement. If possible, the setting of the transducers at different bearings should be in line. For vertical machines, the preferred measurement directions are upstream and 90° to that.

For monitoring purposes (task A) only, in some cases measurement locations may be reduced to the most important ones, mainly at machine sets with four or more bearings. The selection should be based on vibration performance analyses, simulating all types of faults or disturbing effects. Preferred measuring locations should be those where possible disturbing events produce significant bearing housing amplitudes (velocity or displacement).

4.2 Measurement type

Absolute bearing housing vibration measurements are commonly made on hydraulic machine sets using seismic transducers measuring the vibration velocity v_{rms} in millimetres per second or, after electronic integration, the vibration displacement s_{p-p} in micrometres. The vibration displacement s_{p-p} can also be measured directly as a relative quantity using displacement transducers in the case where a rigid non-vibrating support can be found.

Because of the special nature of the vibratory behaviour of hydraulic machines and their different speed ranges, these quantities have favoured ranges of application as follows:

a) For low-speed machines (below 300 r/min), the preferred measurement quantity is the vibration displacement s_{p-p}. If the spectrum is expected to contain high-frequency components, the evaluation should normally be based on broad-band measurements of both displacement and velocity.

b) For medium- and high-speed machines (300 r/min to 1 800 r/min), the preferred measurement quantity is the vibration velocity v_{rms}. If the spectrum is expected to contain low-frequency components, the evaluation should normally be based on broad-band measurements of both velocity and displacement.

4.3 Measurement locations and directions

Measurement tasks A and B (see clause 1) require measurements to be taken on exposed parts of the machine that are normally accessible and are representative locations for the so-called force flow in the supporting structure, for example on all main bearings of the machine set. Typical examples of measurement locations for hydraulic machines are shown in Figures 1 to 5.

Care shall be taken in this context to ensure that measurements reasonably represent the vibration of the bearing housings and do not include any local resonance or amplification. The locations and directions for vibration measurements shall be such that they provide adequate sensitivity to the dynamic forces of the machine under various operating conditions. Typically, this will often require two orthogonal radial measurement directions on each bearing cap, pedestal or housing. For low-speed machines with a horizontal shaft axis, such as bulb-turbines as shown in Figure 2, the measurement locations and directions shall be determined with great care.

CAUTION: The vibration measured at the lower guide bearings of vertical machines may sometimes be misinterpreted; the vibration level measured at such bearings and their surrounding supports which are rigidly embedded in the buildings is sometimes produced by hydraulic forces, directly transmitted from the hydraulic machine via the foundation. Such vibrations do not necessarily give a correct image of the vibration of the rotating shaft system.

For horizontal machines when using portable measuring instrumentation, take measurements in the vertical and horizontal directions 90° apart (perpendicular to the shaft axis) and, if possible, in the axial direction (parallel to the shaft axis) as shown in Figure 5.

A single transducer may be used on a bearing cap or pedestal in place of the more typical pair of orthogonal transducers if it is known to provide adequate information about the magnitude of the machine vibration. However, caution should be observed in evaluating vibration from a single transducer at a measurement location, because it may not be oriented to provide a reasonable approximation to the maximum value at that location.

In the case of vertical or inclined machine sets, the locations and directions that give maximum vibration readings shall be used, for example the stiff and the elastic axis (this is important for cases with spider arm support constructions), and the specific location and direction shall be recorded with the measurement. If possible, the setting of the transducers at different bearings should be in line. For vertical machines, the preferred measurement directions are upstream and 90° to that.

For monitoring purposes (task A) only, in some cases measurement locations may be reduced to the most important ones, mainly at machine sets with four or more bearings. The selection should be based on vibration performance analyses, simulating all types of faults or disturbing effects. Preferred measuring locations should be those where possible disturbing events produce significant bearing housing amplitudes (velocity or displacement).

The installation of one single transducer at the bearing pedestal or housing in horizontal or slightly inclined position is commonly considered adequate for continuous monitoring of Group 1 or 2 machine sets. For monitoring axial vibration of the machine, one transducer mounted on the thrust bearing is often sufficient.

4.4 Measurement equipment

The measurement equipment shall be capable of broad-band measurement of vibration with flat response within the following frequency ranges:

from at least a quarter of the nominal rotational frequency up to the product of three times the rotational frequency times the number of buckets or blades, if the measurement quantity is the vibration displacement s_{p-p};

from 2 Hz to 1 000 Hz if the measurement quantity is the vibration velocity v_{rms}.

NOTE If the measurement equipment is also to be used for diagnostic purposes, an upper frequency limit higher than that specified may be necessary (e.g. higher than 1 000 Hz in the case of vibration velocity measurements).

Vibration displacement can be measured as an absolute quantity with special seismic transducers or accelerometers. If standard equipment is applied, particular attention should be taken to ensure that the measuring instrumentation is fitted with specific electronic compensation to obtain a flat response over the specified frequency range.

For machines with nominal speeds lower than or equal to 300 r/min, vibration displacement is often measured as relative quantity (relative to the foundation) using contact or non-contact displacement transducers. These transducers shall be installed on rigid bars or frames fixed to rigid parts of the foundation. It is necessary to ensure that the natural frequencies of these elements are at least higher than ten times the nominal rotational frequency, and also they should not be a multiple of this frequency.

Vibration velocity shall be measured as an absolute quantity with seismic transducers or accelerometers. If seismic transducers are used, attention should be taken to ensure that the measuring instrumentation is fitted with specific electronic compensation to obtain a flat response over the total frequency range from 2 Hz to 1 000 Hz.

Transducers for absolute vibration measurements shall be mounted on rigid parts of the bearing housing or adjacent surrounding structures which can be classified to give a representative vibration response of the machine. Particular attention shall be given to ensure that transducer mounting complies with specifications from the transducer manufacturer. If additional elements for mounting such transducers are necessary, it shall be ensured that the natural frequencies of those elements are at least higher than ten times the nominal rotational frequency, and also they should not be a multiple of this frequency.

The characteristics of the measuring system shall be known with regard to the effects of the environment, including the following:

temperature variations;

magnetic fields;

sound fields;

power source variation;

transducer cable length;

transducer orientation.

Particular attention shall be given to ensuring that the vibration sensing transducers are correctly mounted and do not affect the vibration response characteristics of the machine.

4.5 Operational conditions

Measurements shall be carried out when the rotor and the main bearings have reached their normal steady-state operating temperatures and with the machine running under steady-state conditions.

5 Evaluation

5.1 General

ISO 10816-1 provides a general description of the two evaluation criteria used to assess vibration severity on various classes of machines. One criterion considers the magnitude of vibration observed by broad-band measurement; the second considers changes in magnitude, irrespective of whether they are increases or decreases.

5.2 Criterion I: Vibration magnitude

The reliable and safe running of a machine under normal operating conditions requires that the vibration magnitude should remain below certain limits consistent with, for example, acceptable kinetic loads and acceptable vibration transmission into the support structure and foundation. Generally, this criterion will be taken as the basis for the evaluation of machines in the absence of any other established knowledge of the satisfactory running characteristics for machines of that type (e.g. for new machine types).

The maximum vibration magnitude observed at each bearing pedestal or housing is assessed against the evaluation zones defined below:

Zone A: The vibration of newly commissioned machines would normally fall within this zone.

Zone B: Machines with vibration within this zone are normally considered acceptable for unrestricted long-term operation.

Zone C: Machines with vibration within this zone are normally considered unsatisfactory for long-term continuous operation. Generally, the machine may be operated for a limited period in this condition until a suitable opportunity arises for remedial action.

Zone D: Vibration values within this zone are normally considered to be of sufficient severity to cause damage to the machine.

Numerical values assigned to the zone boundaries are not intended to serve as acceptance specification, which shall be subject to agreement between the machine manufacturer and the customer. However, the zone boundaries provide guidelines for ensuring that gross deficiencies or unrealistic requirements are avoided. In certain cases, there may be specific features associated with a particular machine which would require different zone boundary values (higher or lower) to be used. In such cases, it is normally the responsibility of the machine manufacturer to explain the reason for this and, in particular, to confirm that the machine would not be endangered by operating with higher vibration values.

NOTE Vibration magnitudes for recommissioned units with increased output, usually characterized as "uprated", may be located in zone A or B. The choice of zone A or B depends, however, on the relation between the new excitation forces and the capacity of the new and re-used components to withstand long-term dynamic exposure.

5.3 Evaluation zone limits

5.3.1 Turbine operating conditions

Recommended values for the zone boundaries are given in Tables A.1 to A.4 for the four machine groups covered by this part of ISO 10816. Application of these criteria is valid for measurements in a radial direction on bearing pedestals or housings of machine sets with nominal speeds between 60 r/min and 1 800 r/min operating within the contractually permissible steady-state range, as well as at other load conditions if the machine has been made suitable for these particular conditions. Higher values of vibration may be permitted under the conditions specified in annex B.

Zone boundary values are specified for both measurement quantities. If both quantities, vibration velocity and displacement, are measured and compared to the corresponding values in Tables A.1, A.3 and A.4, the evaluation which is most restrictive shall apply.

The limiting values are applicable for all types of machine sets belonging to one group, independent of head and power, except for the restrictions given in clause 1. For hydrodynamically smoother running machines, normally lower bearing housing vibration may be expected.

In the case of pump-turbines, increased bearing housing vibration amplitudes may occur because of the runner design criteria, which are a compromise between the optimal design for a turbine and a pump runner.

The values in Tables A.1 to A.4 are based on statistical analyses of collected measurement data from more than 1 400 samples, collected worldwide from machine sets with different powers and speeds within all four groups. A brief description of the analysis procedure and the applied regression technique is given in annex C.

NOTE 1 In general, an overall judgement of the vibratory state of the machine is made on the basis of both the bearing housing vibration as defined above and the measurements performed on the shaft (see ISO 7919-5).

NOTE 2 As explained in annex C, the given limiting values are based on a statistical procedure and the defining of predictive limits; this was necessary due to the wide spread of the measured data. Therefore it should not be assumed that a correct correlation between zone boundaries and possible faults or troubles at the observed machine will exist in all cases.

5.3.2 Pump operating conditions

At present, sufficient data are not available to prepare criteria for machine sets in pump operating conditions. They will be incorporated in a future edition of this part of ISO 10816 when available.

5.3.3 Special operating conditions

Attention should be paid to the following operating conditions:

steady-state operating conditions at low partial load, at overload, and the frequent transient operating conditions during start-up and shut-down;

rare transient operating conditions such as emergency shut-down, no-discharge operation, and running through the brake quadrant with pumps and pump-turbines.

The evaluation of such processes is much more difficult than that of operation in the specified load range. At present there are insufficient data and experience available to establish limiting curves for these operating conditions. The less the operating condition corresponds to the nominal conditions, the more the flow within the hydraulic machine is disturbed; disturbances such as separation and swirl generate violent stochastic excitation. Due to the density of water, the forces caused by the stochastic excitation are much greater than in thermal turbo machines. Therefore during operation outside the specified load range, the bearing or structure vibrations caused by mass unbalance are, as a rule, totally masked by the stochastic components. Because of these large stochastic components under extra-ordinary operating conditions, less reliance should be given to the instantaneous value and more to the mean value over a representative measurement period.

5.3.4 Axial vibration

It is not common practice to measure axial vibration on main radial load-carrying bearings during continuous operational monitoring. Such measurements are primarily used during periodic vibration surveys or for diagnostic purposes. At thrust bearings, axial vibration in general correlates with axial pulsations which could cause damage to the axial load-carrying surfaces. Criteria for axial vibration of bearings cannot be given at present because of the lack of measured data.

5.4 Criterion II: Change in vibration magnitude

This criterion provides an assessment of a change in vibration magnitude from a previously established reference value when operating under steady-state conditions. A significant change in broad-band vibration magnitude may occur which requires some action even though the alarm zone C of Criterion I has not been reached. Such changes can be instantaneous or progressive with time and may indicate that damage has occurred or be a warning of an impending failure or some other irregularity. Criterion II is specified on the basis of change in broad-band vibration magnitude occurring under steady operating conditions. Steady operating conditions should be interpreted to include small changes in the machine power or operational conditions.

When Criterion II is applied, the vibration measurements being compared shall be taken at the same transducer location and orientation, and under approximately the same machine operating conditions. Obvious changes in the normal vibration magnitudes, regardless of their total amount, should be investigated, because a dangerous situation could then be avoided. When changes in vibration magnitude exceed 25 % of the upper boundary value of zone B (defined as B/C in Tables A.1 to A.4), such changes should be considered significant, particularly if they are sudden. Diagnostic investigations should be initiated to ascertain the reason for the change and to determine what further actions are appropriate.

NOTE The 25 % value is considered significant regardless of whether it is an increase or decrease in vibration. The 25 % value is provided as a guideline, but other values may be used based on experience with a specific machine.

5.5 Operational limits

5.5.1 General

For long-term operation, it is common practice to establish operational vibration limits. These limits take the form of ALARMS and TRIPS.

ALARMS: To provide a warning that a defined value of vibration has been reached or a significant change has occurred, at which remedial action may be necessary. In general, if an ALARM situation occurs, operation can continue for a period whilst investigations are carried out to identify the reason for the change in vibration and define any remedial action.

TRIPS: To specify the magnitude of vibration beyond which further operation of the machine may cause damage. If the TRIP value is exceeded, immediate action should be taken to reduce the vibration or the machine should be shut down.

Different operational limits, reflecting differences in dynamic loading and support stiffness, may be specified for different measurement positions and directions.

5.5.2 Setting of ALARMS

The ALARM values may vary considerably, up or down, for different machines. The values chosen will normally be set relative to a baseline value determined from experience for the measurement position or direction for that particular machine.

It is recommended that the ALARM value should be set higher than the baseline by an amount equal to 25 % of the upper limit of zone B. If the baseline is low, the ALARM may be below zone C.

Where there is no established baseline (for example with a new machine) the initial ALARM setting should be based either on experience with other similar machines or relative to agreed acceptance values. After a period of time, the steady-state baseline value will be established and the ALARM setting should be adjusted accordingly.

In either case it is recommended that the ALARM value should not normally exceed 1,25 times the upper limit of zone B (this limit is defined as B/C in Tables A.1 to A.4).

If the steady-state baseline changes (for example after a machine overhaul), the ALARM setting should be revised accordingly. Different ALARM settings, reflecting differences in dynamic loading and support stiffness, may exist for different measurement locations and directions.

5.5.3 Setting of TRIPS

The TRIP values will generally relate to the mechanical integrity of the machine and be dependent on any specific design features which have been introduced to enable the machine to withstand abnormal dynamic forces. The values used will, therefore, generally be the same for all machines of similar design and would not normally be related to the steady-state baseline value used for setting ALARMS.

There may, however, be differences for machines of different design and it is not possible to give clear guidelines for absolute TRIP values. In general, the TRIP value will be within zone C or D, but it is recommended that the TRIP value should not exceed 1,25 times the upper limit of zone C (this limit is defined as C/D in Tables A.1 to A.4).

5.5.4 Special operating conditions

When the machine is operating outside the normal load range and during all transient operating conditions, ALARM and possibly TRIP contacts shall be blocked for these conditions. If the machine should be monitored during these operating conditions too, a second set of ALARM and TRIP values shall be selected according to the maximum vibration values accepted during commissioning of the machine.

5.6 Supplementary procedures/criteria

The measurement and evaluation of machine vibration given in this part of ISO 10816 may be supplemented by shaft vibration measurements and the applicable criteria given in ISO 7919-5. It is important to recognize that there is no simple way to relate bearing housing vibration to shaft vibration, or vice versa. Thus, when the criteria of this part of ISO 10816 and those of ISO 7919-5 are both applied in vibration-severity assessment, independent shaft and bearing pedestal or housing vibration measurement shall be made. If application of the different criteria leads to different assessments of the machine vibration severity, the more restrictive zone classification is considered to apply.

5.7 Evaluation based on vibration vector information

The evaluation considered in this part of ISO 10816 is limited to broad-band vibration without reference to frequency components or phase. This will, in most cases, be adequate for acceptance testing and operational monitoring purposes. However, for long-term condition monitoring purposes and for diagnostics, the use of vibration vector information is particularly useful for detecting and defining changes in the dynamic state of the machine. In some cases, these changes would go undetected when using only broad-band vibration measurements (see, for example, ISO 10816-1). The specification of criteria for this, however, is beyond the scope of this part of ISO 10816.

Annex A
(normative)

Evaluation zone boundaries

Recommended values for the zone boundaries are give in Tables A.1 to A.4 for the four principal machine groups covered by this part of ISO 10816. They apply to the broad-band r.m.s. values of vibration velocity and the peak-to-peak values of vibration displacement when measured with equipment as specified in 4.4 on the bearing pedestals or housings in the radial direction. They are valid only for turbine operation within the contractually permissible steady-state range as well as at other load conditions, if the machine set has been made suitable for these particular conditions (for restrictions, see 5.3.1 to 5.3.3).

NOTE 1 Limiting values are defined by statistical evaluation of measured data (see annex C). They are not derived from an evaluation of the operational behaviour (e.g. occurrence of faults) of individual machines.

For some machine groups, recommended zone boundary values have to be subdivided corresponding to the differences in radial bearing stiffness. Separate values are given for the different measurement locations shown in Figures 1 to 4.

Zone boundary values are specified for both measurement quantities. If both quantities (vibration velocity and displacement) are measured and compared to the corresponding values in Tables A.1, A.3 and A.4, the evaluation which is most restrictive shall apply.

NOTE 2 Machines with Francis turbines might have higher vibration values at the bearing housings when there are draft tube excitations. Experience has shown that this excitation can occur even under standard operating conditions. In the case of heavy draft tube excitations at Francis turbines, the zone boundary values specified in Tables A.1, A.3 and A.4 have limited applicability. At present, insufficient measurement data are available to specify limits for machines with heavy draft tube excitations.

Table A.1 — Recommended evaluation zone boundaries for machines of Group 1: Horizontal machine sets with pedestal or end-shield bearings mounted on rigid foundation, usually with operational speeds of above 300 r/min

Zone boundary	At measurement location 1, 2, 3 and 4	
	Peak-to-peak displacement µm	R.m.s. velocity mm/s
A/B	30	1,6
B/C	50	2,5
C/D	80	4,0
NOTE Vibration levels of two-jet Pelton machines are strongly influenced by the orientation of the resulting steady-state force vector and the operating jet (lower or upper) under part-load conditions.		

Table A.2 — Recommended evaluation zone boundaries for machines of Group 2: Horizontal machine sets with bearing housings which are only braced against the casing of the hydraulic machine, usually with operational speeds of less than 300 r/min

Zone boundary	At measurement location 1 and 2 R.m.s. velocity mm/s
A/B	2.5
B/C	4.0
C/D	6.4
NOTE Displacement values cannot at present be given for this machine group since vibrations of the bulb with very low frequencies and high displacement amplitudes are frequently transmitted to the machine bearings. They may disguise at these parts all vibration displacement values originating from the machine itself. The recommended zone boundary values are not applicable to the evaluation of bulb vibration amplitudes.	

Table A.3 — Recommended evaluation zone boundaries for machines of Group 3: Vertical machine sets with bearing housings which are all braced against the foundation, usually with operational speeds of between 60 r/min and 1 800 r/min

Zone boundary	At all main bearings	
	Peak-to-peak displacement µm	R.m.s. velocity mm/s
A/B	30	1.6
B/C	50	2.5
C/D	80	4.0

Table A.4 — Recommended evaluation zone boundaries for machines of Group 4: Vertical machine sets with lower bearing housings braced against the foundation and upper bearing housings braced against the generator stator only, usually with operational speeds of between 60 r/min and 1 000 r/min

Zone boundary	At measurement location 1		At all other main bearings	
	Peak-to-peak displacement µm	R.m.s. velocity mm/s	Peak-to-peak displacement µm	R.m.s. velocity mm/s
A/B	65	2.5	30	1.6
B/C	100	4.0	50	2.5
C/D	160	6.4	80	4.0

NOTE 1 If a machine has a lower generator bearing without bracing against the foundation, the vibration should be evaluated according to measurement location 1.

NOTE 2 Umbrella-type machines belong to this group, evaluation zone boundaries are those for the main bearings.

Annex B
(informative)

Special features of bearing housing vibration of hydraulic machine sets

B.1 General

The principles of the mechanics of bearing housing vibration are explained in ISO 10816-1. They are based mainly on a broad spectrum of theoretical and experimental investigations on horizontal shaft machines. Until now, not as much attention has been paid to machines with vertical shafts which are more common for hydraulic machine sets.

For hydraulic machines, bearing housing vibration may occur over a wide range of frequencies. Possible causes of vibration are given in B.2 to B.4.

B.2 Mechanical causes

These are incorrect shaft alignment, bearing anisotropy, loose assemblies in rotating or stationary parts, and residual unbalance in the runner or impeller, the generator or the exciter rotor.

Frequencies to be expected are the frequency of rotation and its harmonics.

B.3 Electrical causes

These are inadequately equalized magnetic pull in the rotor of the coupled electrical machines.

Frequencies to be expected are the frequency of rotation and its harmonics.

B.4 Hydraulic causes

B.4.1 Flow through the waterways

Frequencies to be expected are the frequency of rotation, frequency of the blade or bucket passing, or various combinations of these.

B.4.2 Draft tube flow instabilities

These occur in Francis turbines even during steady-state operation outside the optimum efficiency range.

Frequencies to be expected are those below the frequency of rotation, often down to one-third to one-quarter of it. Resonance with hydraulic structures or with the grid might occur, aggravating the phenomenon.

B.4.3 Cavitation

This is due to incorrect flow conditions around the runner or impeller blade profiles, and occurs mostly within the higher load ranges. Another important reason for cavitation is a change in tail water level.

Frequencies to be expected are usually high ones, as for bursts.

B.4.4 Hydroelastic vibration

This can be due to incorrectly shaped discharge edges of hydraulic profiles (blades, buckets, stayvanes, etc.).

Frequencies to be expected are from below 100 Hz to several kilohertz (depending on profile dimensions and flow velocities). Often a pronounced beat character is observed.

B.4.5 Self-excited vibrations

These occur where the movement of mechanical parts (seals, clearances) influences the flow around or through them.

Frequencies to be expected are those slightly above the frequency of rotation, often coinciding with the bending natural frequencies of the rotating system.

In machines of type Group 3 and 4 at part-load or overload, higher vibration may occur due to hydraulic vortices. Provided that such machine conditions with restricted operational periods do not effect fatigue of main structural members (even with higher vibration levels but lying below the recommended limiting zones), the machine set may be made suitable also for these particular operating conditions.

B.5 Additional excitations

During regular transient operating conditions such as start-up and shut-down, additional excitation forces interact with the runner, inducing a wider spectrum and higher amplitudes. During load rejections, even Kaplan turbines can be subjected to draft tube instabilities (see B.4.2) with considerable subsynchronous bearing vibration amplitudes. Under similar conditions (especially for rotor arrangements with only two radial bearings) resonance phenomena can be observed at certain speeds while decelerating, with bearing vibration amplitudes containing one or more of the rotor's natural frequencies corresponding to the instantaneous speed.

At frequent transient operating conditions, such as start-up and shut-down, random excitations with broad-band spectra are dominant. In the case of extreme transients, occurring for example at a failure of a shut-off valve, the intensity of this broad-band excitation spectrum increases even more.

In contrast to thermal machines, hydraulic machines can normally be started-up and shut-down or power can be changed rapidly and frequently. Hydraulic machines are therefore often used for peak-load supply or for frequency and power control. Since such operations also involve frequent starts and stops, and often rapid changeover from one operational state to the other, these machines are exposed to enhanced vibration and stress. For peak-load or pump-storage equipment, transient operating conditions can become so frequent that the sum of the time intervals of increased vibration amounts to more than 1 ‰ of the overall operating time. These frequent transient operating conditions should then be evaluated separately with respect to the additional stress and fatigue on the bearings and other involved parts of the machine.

Annex C
(informative)

Analysis procedure and applied regression technique

Using data (measured quantities on bearing housings or pedestals) collected from 11 countries, two databases were established (data from different machine types with vertical or horizontal shaft orientation and different speeds). The databases were structured as follows:

measured bearing housing displacement s_{p-p} versus rotational speed of the machine;

measured bearing housing velocity v_{rms} versus rotational speed of the machine.

On some of the submitted rough data, modifications were necessary because of incompatibility. With the improved data sets the following steps in the described procedure (using a software package for statistical analysis) were performed (see reference [5]):

a) proof of data distribution within the specified speed range;

b) regression analysis using a "Multiplicative model" $Y = aX^b$ with transformed data in a log-log scaled database with the dependent variable *displacement* or *velocity* and the independent variable *rotational speed*;

c) computation and plot of

analysis of variance,

lack of fit and pure error test,

mean value regression curve with a defined 98 % probability limit and prediction limits (between 60 % and 95 % in steps of 5 %),

residuals,

normal plot of cumulative residuals,

F-test (for significance of regression model);

d) linearization of computed prediction curves (mainly near the boundaries, in the low- and high-speed range) in a double logarithmic scale;

e) definition of the prediction limit curve 85 % as zone boundary B/C, which implies that 92,5 % of all collected measurement data are below this evaluated prediction curve;

f) the ratios between the zone boundaries A/B, B/C and C/D were found through intensive discussions within the working group and with experts in other working groups about safety margins and trip or alarm settings.

Bibliography

[1] ISO 2954, *Mechanical vibration of rotating and reciprocating machinery — Requirements for instruments for measuring vibration severity.*

[2] ISO 7919-1, *Mechanical vibration of non-reciprocating machines — Measurements on rotating shafts and evaluation criteria — Part 1: General guidelines.*

[3] ISO 7919-5, *Mechanical vibration of non-reciprocating machines — Measurements on rotating shafts and evaluation criteria — Part 5: Machines sets in hydraulic power generating and pumping plants.*

[4] ISO 10816-3, *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 3: Industrial machines with nominal power above 15 kW and nominal speeds between 120 r/min and 15000 r/min when measured in situ.*

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8. ANEXO VIII

Norma Internacional Standard ISO 18816-6. Mechanical Vibration - Evaluation of Machine Vibration by Measurements on Non-rotating Parts

INTERNATIONAL
STANDARD

ISO
10816-6

First edition
1995-12-15

Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts —

Part 6:
Reciprocating machines with power ratings above 100 kW

Vibrations mécaniques — Évaluation des vibrations des machines par mesurages sur les parties non tournantes —

Partie 6: Machines alternatives de puissance nominale supérieure à 100 kW

Reference number
ISO 10816-6:1995(E)

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 10816-6 was prepared jointly by Technical Committees ISO/TC 108, *Mechanical vibration and shock*, Subcommittee SC 2, *Measurement and evaluation of mechanical vibration and shock as applied to machines, vehicles and structures,* and ISO/TC 70, *Internal combustion engines,* Subcommittee SC 2, *Performance and tests.*

ISO 10816 consists of the following parts, under the general title *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts:*

Part 1: General guidelines

Part 2: Large land-based steam turbine generator sets in excess of 50 MW

Part 3: Industrial machines with nominal power above 15 kW and nominal speeds between 120 r/min and 15 000 r/min when measured in situ

Part 4: Gas turbine driven sets excluding aircraft derivatives

Part 5: Machine sets in hydraulic power generating and pumping plants

Part 6: Reciprocating machines with power ratings above 100 kW

Annex A forms an integral part of this part of ISO 10816. Annexes B to D are for information only.

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Introduction

ISO 10816-1 gives general guidelines for the evaluation of machine vibration by measurements on non-rotating parts. This part of ISO 10816 is a new document which establishes procedures and guidelines for the measurement and classification of mechanical vibration of reciprocating machines. In general, this part of ISO 10816 refers to vibration of the main structure of the machine, and the guide values given for these vibrations are defined primarily to classify the vibration of the machine and to avoid problems with auxiliary equipment mounted on this structure. Recommendations for measurements and evaluation criteria are provided in this part of ISO 10816.

Typical features of reciprocating machines are the oscillating masses, the cyclically varying output (input) torques and the pulsating forces in the associated pipework. All these features cause considerable alternating forces on the main supports and vibration amplitudes of the main frame. The vibration amplitudes are generally higher than for rotating machinery but, since they are largely determined by the design features of the machine, they tend to remain more constant over the life of the machinery than for rotating machinery.

In the case of reciprocating machines, the vibration measured on the main structure of the machine and quantified according to this part of ISO 10816 may only give a rough idea of the stresses and vibratory states of the components within the machine itself. For example, torsional vibration of rotating parts cannot generally be determined by measurements on the structural parts of the machine. The damage, which can occur when exceeding the guide values based on experience with similar machines, is sustained predominantly by machine-mounted components (e.g. turbochargers, heat-exchangers, governors, filters, pumps), connecting elements of the machine with its peripheral parts (e.g. pipelines) or monitoring instruments (e.g. pressure gauges, thermometers). The question as from which vibration values damage is to be expected largely depends on the design of these components and their fastenings.

In some cases, special measurements on certain machine components will be required to ascertain that the vibration values are permissible. It also happens that even if measured values are within permissible guide values, problems may occur owing to the great variety of components which can be attached. Such problems can be, and have to be, rectified by specific "local measures" (e.g. by elimination of resonances). Experience has shown, however, that it is possible in the majority of cases to state measurable quantities characterizing the vibratory state and to give guide values for these. This shows that the measurable variables and the guide values permit a reliable evaluation in most cases. For the quantity described, which characterizes the vibration values of reciprocating piston machines in a simple manner, the term "vibration severity" will be used.

The vibration values of reciprocating piston machines are not only affected by the properties of the machine itself but also to a large degree by the foundation. Since a reciprocating machine can act as a vibration generator, vibration isolation between the machine and its foundation may be necessary. This, as well as the vibration response of the foundation, can have considerable effect on the vibration of the machine itself. These vibration conditions are also dependent on the transmissibility of the environment surrounding the machine and are therefore not entirely determined by the vibration values of the machine itself. This part of ISO 10816 can therefore only take an advisory role in relation to the effects of the machine on the environment.

Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts

Part 6:

Reciprocating machines with power ratings above 100 kW

1 Scope

This part of ISO 10816 specifies the general conditions and procedures for the measurement and evaluation of vibration, using measurements made on the non-rotating and non-reciprocating parts of complete machines. Shaft vibration, including torsional vibration, is beyond the scope of this part of ISO 10816.

It generally applies to reciprocating piston machines mounted either rigidly or resiliently with power ratings of above 100 kW. Typical examples of application are: marine propulsion engines, marine auxiliary engines, engines operating in diesel generator sets, gas compressors and engines for diesel locomotives.

The general evaluation criteria which are presented relate to both operational monitoring and acceptance testing. They are also used to ensure that the machine vibration does not adversely affect the equipment directly mounted on the machine.

Consideration should also be given to the machinery driven by or driving the reciprocating machine. These should be evaluated in accordance with relevant standards and classification for the intended duty.

It is recognized that the evaluation criteria may only have limited application when considering the effects of internal machine components; for example, problems associated with valves, loose pistons, piston rings, etc. are unlikely to be reflected in the measurements. Identification of such problems requires investigative techniques which are outside the scope of this part of ISO 10816. Noise is also outside the scope of this part of ISO 10816.

This part of ISO 10816 does not apply to machines installed in road vehicles (e.g. trucks, passenger cars, self-propelling construction machinery and tractors).

2 Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this part of ISO 10816. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this part of ISO 10816 are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 2041:1990, *Vibration and shock — Vocabulary*.

3 Definitions

For the purposes of this part of ISO 10816, the definitions given in ISO 2041 and the following definition apply.

3.1 vibration severity: A generic term that designates a value, or set of values, such as a maximum value, average or r.m.s. value, or other parameter that is descriptive of the vibration. It may refer to instantaneous values or average values.

NOTE 1 ISO 2041 includes two notes in the above definition. These notes are not applicable to this part of ISO 10816.

4 Measurements

4.1 Measuring instrument and measured quantities

Criteria for classifying vibration severity for reciprocating machines are specified in clause 5. The classifications are based on measurement of overall values of vibration displacement, velocity and acceleration over a frequency range of 2 Hz to 1 000 Hz.

It is recognized that the main excitation frequencies for reciprocating machines are generally found in the range 2 Hz to 300 Hz. However, when considering the complete machine including auxiliary equipment that is a functional part of the machine, a range of at least 2 Hz to 1 000 Hz is required to characterize the vibration. For special purposes, a different range may be agreed between the manufacturer and customer.

Since the overall vibration signal usually contains many frequency components, there is no simple mathematical relationship between the r.m.s. and peak, or peak-to-peak overall vibration measurements. Therefore the preferred measuring system should provide the overall r.m.s. values of displacement, velocity and acceleration with an accuracy of ± 10 % over the range 10 Hz to 1 000 Hz and an accuracy of $^{+10}_{-20}$ % over the range 2 Hz to 10 Hz. These values may be obtained from a single sensor whose signal is processed to derive the quantities not directly measured (e.g. an accelerometer whose output is integrated once for velocity and twice for displacement). Care should be taken to ensure that any processing does not adversely affect the required accuracy of the measuring system.

Both the frequency response and measured vibration amplitudes are affected by the method of attachment of the transducer(s). It is especially important to maintain a good attachment between the transducer and the machine when the vibration values are high. For example, ISO 5348 gives guidance on the mounting of accelerometers.

4.2 Points and direction of measurement

To ensure that the evaluation of the vibration measurements is as uniform as possible and, further, that the best possible comparison between different machines is achieved, preferred measurement positions are specified in figures 1 to 3. Generally, measurements should be taken at these points in the three machine-related main directions indicated.

The machines presented in figures 1 to 3 are examples only. For different versions (e.g. radial machines), similar measurement points apply.

Provided it is known from experience with similar machines at which points the maximum vibration severity is to be expected, it is not necessary to consider all the points specified in the figures. Accessible load-carrying bearing positions should be included. However, for acceptance testing, if fewer measurement points are used, this should be agreed between the manufacturer and customer.

If several measurement points are taken into account for more careful investigation or for comparative purposes, it is recommended that those of figures 1 to 3 be preferred.

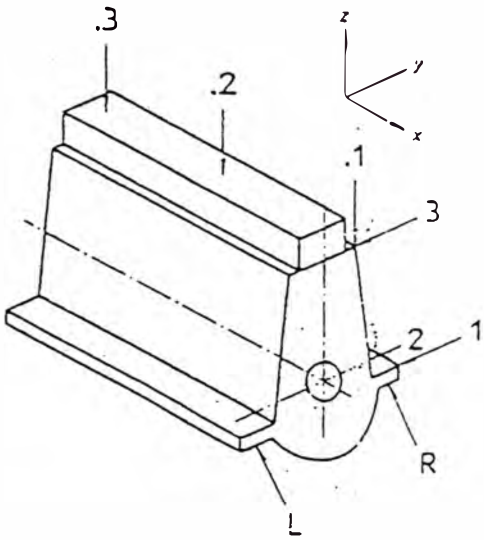
When selecting the exact measurement points, the configuration and installation restrictions of the particular machine involved should be allowed for. All measurement points are to be chosen in such a way that the vibration transducer is properly attached to the main structure of the machine.

Vibration measurements of machine-mounted components may give useful information regarding their failure, however the guide values referred to in this part of ISO 10816 apply to the positions given in figures 1 to 3 on the main structure of the machine.

EXAMPLE

The right-hand top edge of a frame, on the coupling end of a machine, in the y (horizontal) direction is designated as:

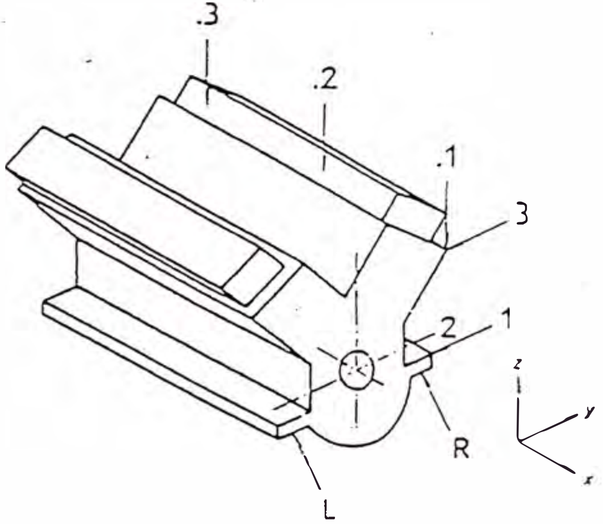
R3.1y



Key

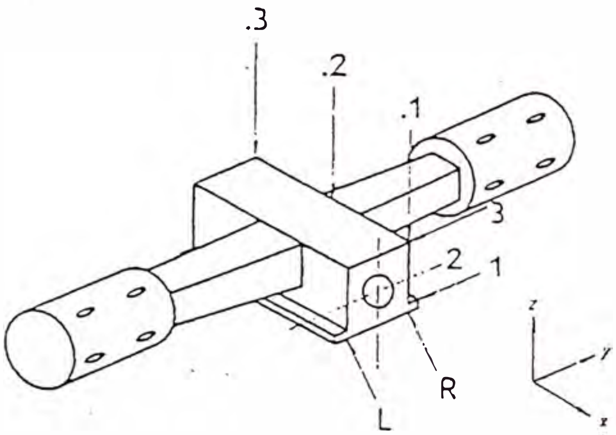
Sides of measurement	L	Left-hand when facing the coupling flange
	R	Right-hand when facing the coupling flange
Levels of measurement	1	Machine end of mounting
	2	Crankshaft level
	3	Top edge of frame
Measurement points related to machine length	.1	Coupling end
	.2	Mid-machine
	.3	Free end of machine

Figure 1 — Example of a vertical in-line machine



NOTE — See figure 1 for key.

Figure 2 — Example of a multicylinder Vee machine



NOTE — See figure 1 for key.

Figure 3 — Example of a horizontal opposed machine

4.3 Operating conditions during measurements

Measurements should be taken when the machine has reached its steady-state operating conditions (e.g. normal operating temperature). The determination of the machine vibration severity shall be based on the maximum vibration occurring over the entire power and speed range approved for normal operation.

4.4 Record of measured results

Records of measured results should include essential data of the machine and of the measuring system used. These data may be entered on forms 1 and 2, given in annex B, which can serve as a measurement record.

5 Vibration criteria

Vibration severity grades are presented numerically in table 1, and graphically in annex C. In order to quantify these it is necessary to measure the overall (broad-band) r.m.s. values (2 Hz to 1 000 Hz) of displacement, velocity and acceleration. Severity grades shall be obtained for each of the highest overall r.m.s. value of the displacement, velocity and acceleration measured on the main structure of the machine. The machine vibration severity grade is the highest of these three grades.

As an example, the vibration values given in table 2 were obtained at position R3.1 on the main structure of a machine. The corresponding vibration severity grades from table 1 are given in square brackets. As a conclusion, the machine vibration severity grade at this position is therefore 28. All other positions should be reviewed similarly to establish the maximum vibration severity grade over the machine.

Table 1 — Vibration severity grades
(2 Hz to 1 000 Hz)

Vibration severity grade	Limiting values of overall vibration measured on the machine structure		
	Displacement µm (r.m.s.)	Velocity mm/s (r.m.s.)	Acceleration m/s^2 (r.m.s.)
1,1	≤ 17,8	≤ 1,12	≤ 1,76
1,8	≤ 28,3	≤ 1,78	≤ 2,79
2,8	≤ 44,8	≤ 2,82	≤ 4,42
4,5	≤ 71,0	≤ 4,46	≤ 7,01
7,1	≤ 113	≤ 7,07	≤ 11,1
11	≤ 178	≤ 11,2	≤ 17,6
18	≤ 283	≤ 17,8	≤ 27,9
28	≤ 448	≤ 28,2	≤ 44,2
45	≤ 710	≤ 44,6	≤ 70,1
71	≤ 1125	≤ 70,7	≤ 111
112	≤ 1784	≤ 112	≤ 176
180	> 1784	> 112	> 176

NOTE — The values were derived from constant displacement in the range 2 Hz to 10 Hz, constant velocity from 10 Hz to 250 Hz and constant acceleration from 250 Hz to 1 000 Hz.

The vibration severity value associated with a particular type of machine depends on its size and mass, the characteristics of the mounting system and the operating conditions, etc. It is therefore necessary to take account of the various purposes and circumstances concerned when applying the vibration severity grades. The maximum value measured across the overall length of the machine will then be used for determining the vibration severity. Reciprocating machine classification numbers and guide values are presented in annex A.

Flexible mountings are used extensively to reduce the effect of a machine on its environment. The design and application of these are outside the scope of this part of ISO 10816.

NOTES

2 Guidelines for vibration isolators are given in ISO 2017.

3 Guidelines for vibration effects on buildings are given in ISO 4866.

Table 2 — Example of vibration values

Position	Measured vibration values		
	Displacement µm (r.m.s.)	Velocity mm/s (r.m.s.)	Acceleration m/s^2 (r.m.s.)
R3.1x	100 [grade 7,1]	15 [grade 18]	9 [grade 7,1]
R3.1y	150 [grade 11]	16 [grade 18]	8 [grade 7,1]
R3.1z	250 [grade 18]	22 [grade 28]	10 [grade 7,1]

Annex A
(normative)

Machine vibration classification

Vibration classification numbers and guide values for reciprocating machines are given in table A.1. The guidance values assist in evaluating the vibration severity to which the machine frame and attached ancillaries and equipment may be subjected.

A reciprocating machine could well be classified by more than one class depending upon its type, application, size, configuration, flexible or rigid mounting and speed. For example, many industrial and marine diesel engines may be classified in either classification number 5, 6 or 7.

As and when circumstances permit, recommendations for acceptable guide values of vibration severity for particular types of machine will be prepared. Until such time, classifications may be agreed between the manufacturer and customers, using experience or results of operation.[1]

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[1] Information on vibration values of reciprocating machines collected in accordance with this part of ISO 10816 are welcomed and should be communicated to the national standards body in the country of origin for transmission to the secretariat of ISO/TC 108/SC 2.

Table A.1 — Vibration classification numbers and guide values for reciprocating machines

Vibration severity grade	Maximum values of overall vibration measured on the machine structure			Machine vibration classification number						
	Displacement µm (r.m.s.)	Velocity mm/s (r.m.s.)	Acceleration m/s² (r.m.s.)	1	2	3	4	5	6	7
				Evaluation zones						
1,1				A/B	A/B	A/B	A/B	A/B	A/B	A/B
	17.8	1.12	1.76							
1.8										
	28.3	1.78	2.79							
2.8										
	44.8	2.82	4.42							
4.5										
	71.0	4.46	7.01							
7,1				C						
	113	7.07	11.1							
11				D	C					
	178	11.2	17.6							
18					D	C				
	283	17.8	27.3							
28						D	C			
	448	28.2	44.2							
45							D	C		
	710	44.6	70.1							
71								D	C	
	1125	70.7	111							
112									D	C
	1784	112	176							
180										D

Key to zones

A: The vibration of newly commissioned machines would normally fall within this zone.

B: Machines with vibration within this zone are normally considered acceptable for long-term operation.

C: Machines with vibration within this zone are normally considered unsatisfactory for long-term continuous operation. Generally, the machine may be operated for a limited period in this condition until a suitable opportunity arises for remedial action.

D: Vibration values within this zone are normally considered to be of sufficient severity to cause damage to the machine.

NOTE — Vibration values for reciprocating machines may tend to be more constant over the life of the machine than for rotating machines. Therefore zones A and B are combined in this table. In future, when more experience is accumulated, guide values to differentiate between zones A and B may be provided.

Annex B
(informative)

Forms for vibration measurements on reciprocating machines

Vibration measurements on reciprocating machines
Measurement record
Form 1

B.1 General

Record No.: ____________________ Installation site: ____________________
Date: ____________________ Measured by: ____________________

B.2 Details of reciprocating machine

Kind: Diesel engine/compressor 1)
Function: driver/driven 1)
Manufacturer: ____________________
Type/Serial No.: ____________________
Machine ID No.: ____________________
Configuration: in-line horizontal/vertical; Vee; opposed 1)
Number of cylinders: __________
Working cycle: two/four stroke 1); single/double effect 1)
Related speed: __________ r/min
Speed during measurement: __________ r/min
Related power: __________ kW
Power during measurement: __________ kW
Mounting: rigid/resilient 1); directly/on baseplate 1)
Connection: rigid/flexible 1)

Notes: ____

B.3 Details of measuring system

Instrument type: ____________________ Make: ____________________
Transducer type: ____________________ Attachment: ____________________

Does the measuring system comply with the requirements of 4.1 of ISO 10816-6:1995; i.e. overall r.m.s. values 10 Hz to 1 000 Hz with accuracy ± 10%; 2 Hz to 10 Hz with accuracy $^{+10}_{-20}$ %? Yes/No 1)

Notes: ____

B.4 Results

Sketch machine below. Designate measurement points in accordance with figures 1 to 3 of ISO 10816-6:1995.

Measurement values: Enter in form 2.

Measurement records, spectra, diagrams, etc. should be attached, giving points and directions of measurement, and the power and speed at the time of measurement, if applicable.

<table>
<tr><td> </td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td colspan="8">Directions of measurements: related to crankshaft axis (see figures 1 to 3 of ISO 10816-6:1995)
x = axial; y = horizontal-transverse; z = vertical</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

1) Delete/supplement as appropriate.

Vibration measurements on reciprocating machines
Measurement results

Form 2

Measurement point No. as sketch	Speed tr/min	Power kW	Measurement quantity: r.m.s. overall values (2 Hz à 1 000 Hz)									Notes
			Horizontal-transverse			Vertical			Axial			
			d µm M1) C1)	v mm/s M1) C1)	a m/s^2 M1) C1)	d µm M1) C1)	v mm/s M1) C1)	a m/s^2 M1) C1)	d µm M1) C1)	v mm/s M1) C1)	a m/s^2 M1) C1)	

1) Mark as appropriate: M = measured directly
C = calculated from frequency spectrum

Annex C
(informative)

Vibration severity grade nomograph

The vibration nomograph given as figure C.1 shows a range of vibration severity grades. A multifrequency vibration system cannot easily be classified on a discrete frequency scale, therefore the limiting values for each grade are primarily presented in table 1. Machines with a multifrequency vibration should therefore be classified by comparing the measured overall values of displacement, velocity and acceleration with the values given in table 1.

Severity grades are obtained for each of the highest overall r.m.s. value of the displacement, velocity and acceleration measured on the main structure of the machine. The vibration severity grade of the machine is the highest of these three grades.

NOTE 4 If a machine is known from frequency analysis to have only one vibration frequency component present at a particular frequency, this may be classified directly using the nomograph, using only one of the parameters displacement velocity or acceleration.

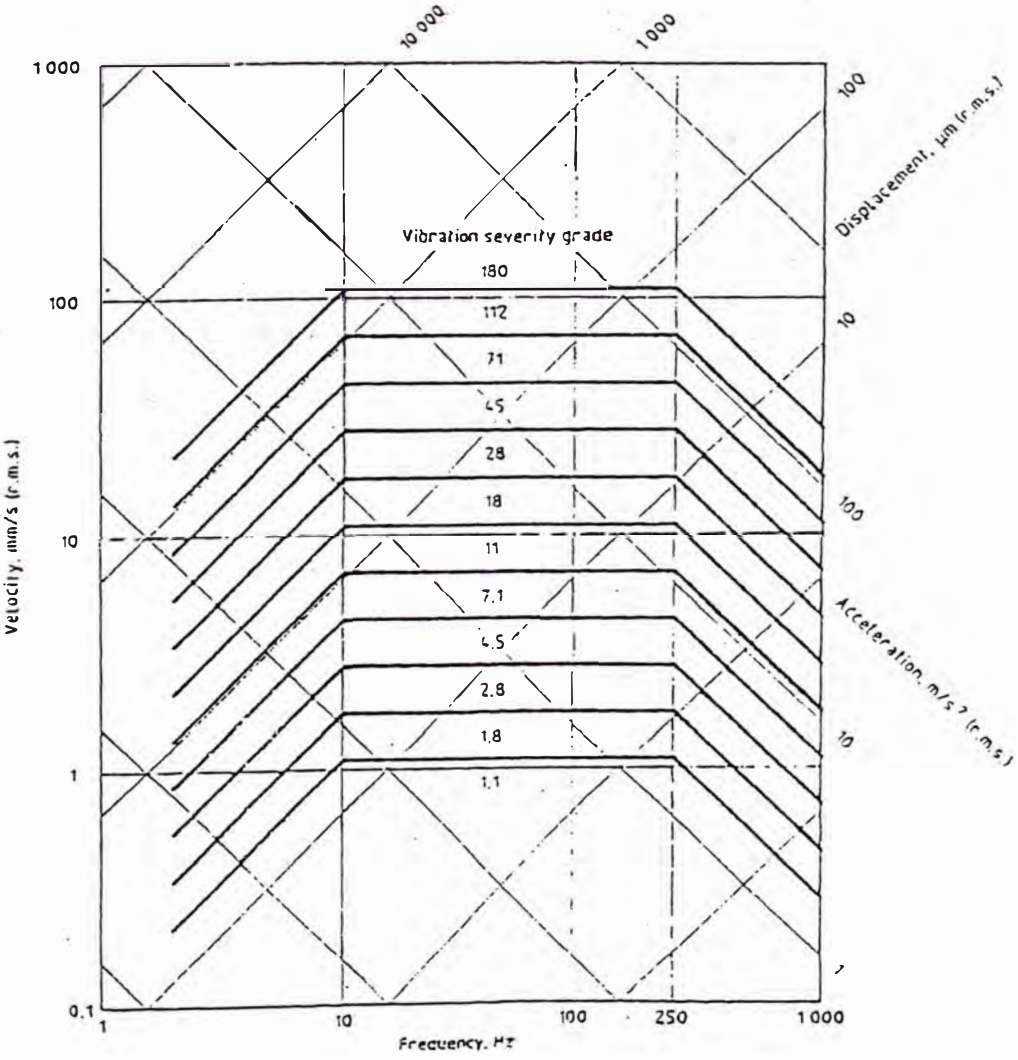

Figure C.1 — Vibration severity grade nomograph

Annex D
(informative)

Bibliography

[1] ISO 2017:1982, *Vibration and shock — Isolators — Procedure for specifying characteristics.*

[2] ISO 2954:1975, *Mechanical vibration of rotating and reciprocating machinery — Requirements for instruments for measuring vibration severity.*

[3] ISO 4866:1990, *Mechanical vibration and shock — Vibration of buildings — Guidelines for the measurement of vibrations and evaluation of their effects on buildings.*

[4] ISO 5348:1987, *Mechanical vibration and shock — Mechanical mounting of accelerometers.*

[5] ISO 8528-9:1995, *Reciprocating internal combustion engine driven alternating current generating sets — Part 9: Measurement and evaluation of mechanical vibrations.*

[6] ISO 10816-1:1995, *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 1: General guidelines.*

ICS 17.160

Descriptors: vibration, machinery, piston machines, reciprocating engines, tests, vibration tests, acceptance testing, estimation, vibration severity.

Price based on 10 pages

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9. ANEXO IX

Norma Standards Publication NEMA. Sobre Instalation of Vertical Hydraulic – Turbine – Driven Generators and Reversible Generator/Motors for Pumped Storage Installations

PUB. NO. MG 5.2-1972

NEMA

STANDARDS PUBLICATION

INSTALLATION OF
RTICAL HYDRAULIC-TURBINE-DRIVEN GENERATORS AND REVERSIBLE GENERATOR/MOTORS FOR PUMPED STORAGE INSTALLATIONS

NAL ELECTRICAL MANUFACTURERS ASSOCIATION 155 EAST 44th STREET, NEW YORK, N. Y. 10017

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(By-Law—Art. V. Sec. 1)

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(By-Law—Art. V, Sec. 2, Subsection B)

Authorized Engineering Information

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(By-Law—Art. V, Sec. 6, 1st Sentence)

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At the end of each standard in this publication appear the words "NEMA Standard" or "Suggested Standard for Future Design," which indicate the status of the standard. These words are followed by a date which indicates when that standard was adopted in its present form by the Association.

The classification "Authorized Engineering Information" is designated similarly.

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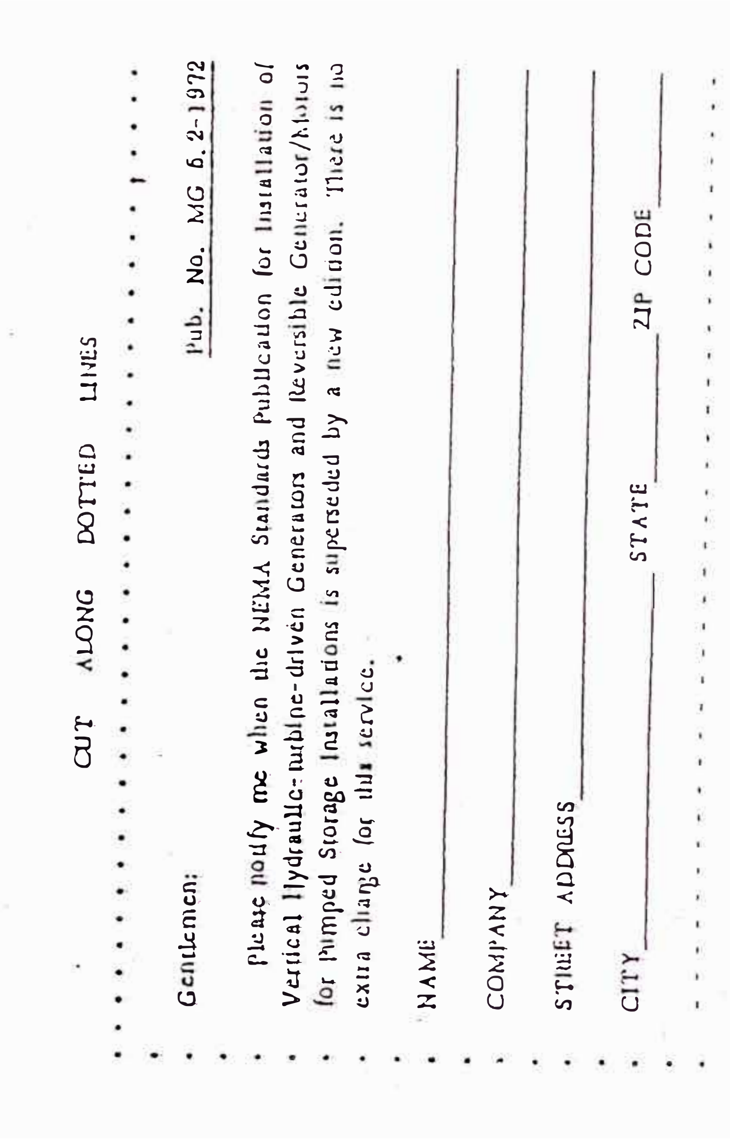

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FOREWORD

Hydraulic-turbine-driven generators, because of their physical size, are usually shipped in several parts l are completely assembled for the first time when they are installed in the power house. The installation, n, becomes a continuation of the manufacturing process, and many of the operations involved are those ich are normally performed in the factory on smaller generators. Close tolerances must be maintained in : fit and alignment of the various parts. The use of proper installation procedures is essential to achieve isfactory operation of the unit.

The suggested procedures for the installation of vertical-shaft hydraulic-turbine-driven generators, as esented in this publication, were developed by the Large Generator Group of the Motor and Generator Section d were approved for publication by the National Electrical Manufacturers Association. These procedures are sed upon the combined experience of all member companies in the Group—experience gained during the anufacture and erection of such generators which are now producing millions of kilovoltamperes.

This publication is periodically reviewed by the Large Generator Group of the Motor and Generator Section f NEMA for any revisions necessary to keep it up to date with advancing technology. Proposed or recommended revisions should be submitted to:

Technical Director
Manager, Engineering and Safety Regulations Department
National Electrical Manufacturers Association
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New York, New York 10017

TABLE CONTENTS

INSTALLATION OF VERTICAL HYDRAULIC—TURBINE—DRIVEN GENERATORS AND REVERSIBLE GENERATOR/MOTORS FOR PUMPED STORAGE INSTALLATIONS

Part 1
TOOLS AND FACILITIES

MG 5.2-1.01 TOOLS AND FACILITIES

Adequate working and storage areas are essential for efficient installation of the generators. Crane facilities, compressed air, a water supply and electric power should be available at all times.

An office with a desk or table for spreading out drawings; a small machine shop; a storeroom for the storage of tools, small parts and supplies; and space for mechanics' tool boxes should be provided.

A suitable set of special tools should be provided for craft labor other than those tools personally provided by the crafts (usually consisting only of hand tools). Typically, the tool set may include the following:

1. Set of large wrenches.
2. Pipe bending and threading equipment.
3. Welding and burning equipment.
4. Soldering and brazing equipment.
5. Power tools.
6. Sledge hammer.
7. Jacks.
8. Manual hoist.
9. Light rigging equipment.
10. Precision measuring tools.
11. Electrical test equipment, including a high-potential test set, an ohmmeter, and voltmeters and ammeters for a wide range of electrical measurements.

The following tools, each designed for use with a particular design of generator, are often necessary or highly desirable for erecting the machine:

1. Shaft lifting device.
2. Rotor lifting device.
3. Slings of proper length and size for the major lifting operations.
4. Rotor erection pedestal.
5. A plate for supporting the shaft in a vertical position. The plate is anchored in the concrete floor of the assembly area or in a pit of the proper depth to bring the rotor to a convenient distance above the floor. For the rotor of a generator which has its thrust bearing above the rotor, this plate must be capable of supporting the weight of the assembled parts with the shaft.

Authorized Engineering Information 6-1-1959, revised 12-16-1971.

Part 2
PERSONNEL

MG 5.2-2.01 PERSONNEL.

A crew of skilled workmen with sufficient helpers and a supervisor experienced in the installation of vertical hydraulic-turbine-driven generators are essential. In addition to electricians and mechanics, men skilled in pipe fitting, welding, rigging and coil winding are usually needed.

In many cases the generator manufacturer is given the job of installing the equipment which he furnishes. In such cases, he will provide a supervisor and all other personnel needed. Otherwise, it is recommended that one of the generator manufacturer's field representatives be employed to provide technical direction of the installation. His familiarity with the construction of the generator and experience in the installation of similar machines are valuable assets.

Close cooperation between the purchaser, the generator manufacturer, the turbine manufacturer, the governor manufacturer and any installation contractors involved is necessary to assure proper installation in the most efficient manner. Agreement on the general procedures to be followed should be reached before actual erection begins.

Authorized Engineering Information 6-1-1959, revised 12-16-1971.

Part 3
GENERATOR CONSTRUCTION

The following paragraphs give a brief description of the construction features of vertical hydraulic-turbine-ven generators that have an important bearing on their installation.

5.2-3.01 GENERAL ARRANGEMENT

The basic elements of the generator are the stator ame, magnetic core and windings), rotor (shaft, rust block, spider and poles with windings), thrust aring, one or two guide bearings, upper and lower ackets (for the support of bearings and other parts), d soleplates (also referred to as foundation caps) ich are bolted to the foundation and form supports r the stationary parts of the machine. Other comonents may include a direct-connected exciter, a lot exciter, rotor brakes or combined brakes and cks, foundation bolts, platform, stairway and ndrails, and an air-discharge housing or a totally-closed ventilating system with surface air coolers.

The thrust bearing may be located above the otor or, alternatively, below the rotor. The guide earings are located one above and one below the otor. However, if the thrust bearing is above the otor, occasionally only one guide bearing, located bove the rotor, is provided. Similarly, if the thrust earing is below the rotor, sometimes only one uide bearing, located below the rotor, is used.

The upper bracket is supported from the stator rame. On small generators with their thrust bearing above the rotor, the lower bracket may be integral with or bolted to the stator frame. Otherwise, it is upported on its own set of soleplates.

Authorized Engineering Information 6-1-1959.

MG 5.2-3.02 ROTOR CONSTRUCTION

The rotor spider of a small low-speed generator is usually of cast or fabricated construction and has a solid rim to which the poles are attached by bolts or studs (bolted-pole construction). The spider is shrunk on and keyed to the shaft.

The larger low-speed machines generally employ a fabricated steel hub and spider arms with a rim built up of segmental steel laminations which are bolted together and driven by keys at the ends of the spider arms. The poles are held by dovetails to the laminated rim. The spider is either shrunk on and keyed to the shaft or is bolted to a flange or flanges forged integral with the shaft.

High-speed generators require a rotor spider which is built up of circular steel laminations or plates. The poles are attached to the outer periphery of the spider by dovetails. The spider is shrunk on and keyed to the shaft.

There are still other rotor constructions which may be used in special cases.

Authorized Engineering Information 6-1-1959, revised 12-16-1971.

MG 5.2-3.03 SHAFT AND COUPLING

The generator coupling is usually forged integral with the shaft. The thrust block or collar which transmits all vertical forces from the shaft to the thrust bearing is usually forged integrally with the shaft if the thrust bearing is below the rotor; but, if the thrust bearing is above the rotor, a separate collar is shrunk on and is suitably keyed to the shaft.

If the turbine is of the adjustable-blade propeller (Kaplan) type, a hollow generator shaft is required so that oil pipes can be carried through the shaft from the oil head at the top of the generator to the turbine servomotor. Occasionally, on small machines it is required that the generator coupling form the cover of the servomotor housing. In such cases, an especially designed oversize coupling is used. Otherwise, the cover is a separate piece which is part of the turbine shaft assembly, and a conventional generator coupling is used.

Authorized Engineering Information 6-1-1959, revised 12-16-1971.

MG 5.2-3.04 THRUST BEARING

The thrust bearing must carry the combined weight of the rotating parts of the generator and the turbine plus the hydraulic thrust imposed on the turbine runner.

Small machines have an antifriction-type combined thrust and guide bearing, such as the angular contact ball bearing or the spherical-roller thrust bearing, if speed and thrust limitations permit. Larger machines with greater thrust loads have a plate or runner and shoe-type bearing.

In the usual construction of plate or runner and shoe-type bearings, the rotating element consists of a flat circular plate or runner which bears on a stationary member consisting of a number of babbitt-faced segments or bearing shoes. These shoes are supported in a manner which is designed to equalize the loading between shoes and to allow each shoe to assume the proper position with respect to the runner. Three different arrangements in common use are:

1. In the "adjustable-shoe-type" bearing, the shoes are restrained so that they do not rotate, but each is free to rock on the spherical end of a jack screw which supports it. The jack screws provide a means of adjusting the height of each shoe individually to obtain equal loading of all shoes. They are also used to adjust the elevation of the rotor and to plumb the shaft. In some cases, measuring devices are permanently located in each jack-screw assembly for direct measurement of the load on the shoe.

2. The "self-equalizing-type" bearings are also designed so that each shoe can pivot on its support. To equalize the load among the shoes, two different arrangements are used. With three-shoe bearings, the shoes are supported by a single spherical seated member. With a greater number of shoes, the equalizing support consists of a system of interlocking levers which allows small vertical movements of the shoes while maintaining uniformity of shoe loading.

3. The "spring-type" bearing has relatively thin and flexible babbitted segments, each supported on a bed of closely spaced precompressed springs. This allows each segment to adjust itself to the proper position with respect to the runner while a uniform pressure is maintained on all segments.

Plate or runner and shoe-type bearings operate while immersed in a reservoir of lubricating oil. In the smaller sizes, the heat which is generated may be removed by the flow of ventilating air over the bearing housing. In the larger sizes, it is usual to circulate water through cooling coils located in the bearing housings. Occasionally, the oil is circulated through an external heat exchanger.

A thrust bearing located above the rotor is usually insulated from its supporting structure to prevent the flow of shaft currents. The latter result from permeance variations in the stator core and tend to flow lengthwise along the shaft, out through a bearing on one end of the rotor, and return through the frame and the bearing at the other end of the rotor. Such current flow can be prevented by opening the circuit at any point. It is most convenient to open the circuit above the rotor which requires insulation of the bearings and all other metallic parts which make contact with the shaft above the rotor. Either a single layer of insulation or a double layer with a metallic component between the two layers may be used. The latter may be tested by applying a voltage between the inner metallic component and the outer metallic parts.

Authorized Engineering Information 6-1-1959, revised 12-15-1971.

MG 5.2-3.05 GUIDE BEARINGS

If the thrust bearing is located above the rotor, the upper guide bearing may be combined with the thrust bearing, with the outer cylindrical surface of the thrust block or runner acting as the guide bearing journal. Both bearings operate in the same oil reservoir. In some large machines, however, the guide bearing may be located below the thrust bearing in a separate oil reservoir. If the thrust bearing is located below the rotor, the lower guide bearing is usually combined with the thrust bearing.

Most guide bearings are self-oiled and are designed to pump oil to the upper portion when the lower portion is immersed in oil. The bearings may be of the sleeve type, either solid or split, or of the segmental type. The latter are made up of a number of segments which are independently adjustable in a radial direction to permit convenient adjustment of the bearing clearance.

A guide bearing which is located above the rotor is usually insulated in the manner described in MG 5.2-3.04 for the thrust bearings.

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MG 5.2-3.06 BRAKES AND JACKS

The function of the brakes is to bring the rotor to rest from coasting speed after the turbine gates have been closed and to hold it at rest against a small amount of gate leakage. The brakes should never be applied at runaway speed, or even at normal speed. In the interest of prolonged life and low maintenance of brake parts, the application of brakes on hydraulic-turbine-driven generators should be delayed until the speed of the unit has dropped to at least 20 to 30 percent of normal speed. Brakes are usually operated by compressed air at a pressure of about 100 pounds per square inch.

Brakes may also be used as jacks. When jacking, they are usually operated by oil at a pressure of 1000 to 3500 pounds per square inch by means of an oil pump used solely for this purpose. In this case, the header is so arranged that air may be admitted to and released from one end and oil admitted to and released from the other end. A blocking device is generally used so that the rotor can be held in the raised position without depending upon the maintenance of oil pressure.

If the turbine is of the adjustable-blade propeller type and flange couplings are used to connect the oil supply pipes to the servomotor, it may be necessary to raise the generator rotor an extra amount by special jacks or other means during assembly to connect the pipe couplings.

The brakes and jacks are usually supported on the lower bracket but, in some cases, the relation between the turbine pit diameter and generator rotor diameter is such that the brakes and jacks can be supported on their own soleplates. If the rotor has a rim of solid metal, this rim may form the braking surface; otherwise, a separate brake plate is used.

Authorized Engineering Information 6-1-1959, revised 12-16-1971.

MG 5.2-3.07 FIELD ASSEMBLY REQUIREMENTS

Many hydraulic-turbine-driven generators must be shipped disassembled to keep within the size and weight limitations of transportation and handling facilities. Even when these limitations can be met by an assembled generator, the generator may be shipped disassembled to reduce the possibility of damage during shipment and to facilitate final inspection and cleaning of the unit before operation.

Machines of moderate size may be shipped with the stator, rotor and bearing brackets separate but with each of these parts completely assembled. With larger machines, however, some or all of these components must be shipped in two or more parts to meet the limitations of transportation facilities. The stator may be shipped in two or more sections. The sections are bolted or welded together and the windings completed across the joints during installation. The rotor may be shipped complete except for the shaft. In this case, the rotor is shrunk on or otherwise attached to the shaft in the field. The rotors of low-speed machines having cast or rolled steel rims may be split into two parts which are joined by shrink links during installation. Large machines with laminated rims will have the rim stacked on the spider and the field poles attached at the destination. On large high-speed machines, the spider itself, if built up of laminations or steel plates, may be assembled in the field. If the spider is of fabricated steel construction, it may be shipped in several parts which must be bolted or welded together during installation. The bearing brackets, too, may be of such a size that they must be shipped in several pieces which are bolted or welded together at the destination. In all cases where the machines are not shipped completely assembled, such components as exciter armatures, exciter stators, bearing parts, air coolers, etc., are packed separately.

Because it is impractical to duplicate in the factory all of the conditions which will exist at the installation site, it is usually necessary to perform certain machining operations in the field in order to assure proper fit and positioning of all parts. This will also correct any minor distortions which occur during shipment. Typical of the operations that may be required are:

1. Reaming or finish boring of holes for bolts holding a rotor spider to the shaft flanges.
2. Machining of chocks to fit between soleplates and the parts they support.
3. Drilling and reaming of dowel holes.
4. Reaming or finish boring of coupling bolt holes.
5. Drilling and tapping of holes for mounting of accessories, conduit, piping, etc.
6. Fitting of various sheet-metal parts, such as air housings and deck plates.
7. Bending and fitting of conduit, water and oil piping, etc.

Authorized Engineering Information 6-1-1959, revised 12-16-1971.

Part 4

ALIGNMENT OF COMBINED GENERATOR AND TURBINE SHAFTS IN FACTORY

MG 5.2-4.01 FACTORY PREASSEMBLY AND ALIGNMENT

Factory preassembly and alignment at the plant of either the turbine or generator manufacturer is recommended for the combined generator and turbine shafts of large hydraulic-turbine generator units. This procedure requires checking the runout and fitting the coupling bolts. The use of factory facilities to handle the heavy and cumbersome parts has obvious advantages. Furthermore, should it prove necessary to remachine any of the parts or to take other corrective measures to reduce the runout, this can be done quickly and conveniently. The resultant saving in installation time, which may be substantial, justifies this procedure on large field-assembled units.

The method of making the runout check and the recommended runout tolerances are given in Appendix A.

When the best relative position of the two couplings has been determined, each is match-marked so that the same relative position can be obtained in field assembly.

Where the generator manufacturer or the turbine manufacturer makes this factory alignment check, it is preferable for the same manufacturer to provide the coupling bolts and for his representative to supervise the closing of the coupling in the field to

Part 5
INSTALLATION PRECAUTIONS

MG 5.2-5.01 POSITION REFERENCES

When the unit is properly installed, the turbine runner should be supported in the center of the head cover and bottom ring and at the proper elevation with respect to the water surfaces of these stationary parts. Since the positions of the turbine head cover and bottom ring are fixed before installation of the generator can begin, the resultant position of the turbine coupling must be used as the reference for the location of the generator irrespective of any previously established centerline or elevation.

Prior to erection of the generator, the turbine runner and shaft must be centered properly and supported in a position at a specified elevation (usually 1/4 to 3/4 inch) below the correct operating position. The turbine coupling can then be used to locate the soleplates and other parts of the generator.

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MG 5.2-5.02 HANDLING OF GENERATOR PARTS

Generator components must be handled carefully to prevent damage to windings and other parts.

When lifting stator frames, the slings should be so arranged that the weight is supported by the lifting bars and not by the reinforcing members of the frame.

Shafts should never be supported on the journal surfaces. With the shaft vertical, rotors may be handled by slings through the spider. Tapped holes in the end of the shaft must not be used to lift a complete rotor, but they are sometimes used to attach a device for handling the shaft only. A lifting trunnion may be used for handling the complete rotor. For machines furnished with a separate thrust collar, the trunnion may fit on the shaft in place of the collar.

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MG 5.2-5.03 MATCHING OF PARTS

When assembling machines in the field, attention must be paid to all matchmarks. Where more than one unit is being furnished, each machine should be assembled from parts having the same serial number or otherwise identified by the manufacturer as being parts of the same machine.

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MG 5.2-5.04 USE OF PLUMB LINES

A plumb line should consist of a steel piano wire attached to a heavy bob. A 0.016-inch-diameter wire and a plumb bob weighing not less than 35 pounds are satisfactory.

Providing fins on the plumb bob and allowing it to hang in a pail of heavy oil will damp its swings and expedite the work. In use, the plumb line should be protected from all strong air currents.

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MG 5.2-5.05 PRECAUTIONS IN WELDING

A serious hazard to bearings is electric welding on any part of the generator or turbine. A bearing can be damaged very quickly if welding current passes through it.

As far as possible, all electric welding, especially on the rotating elements, should be done before the bearings are assembled. If welding must be done after assembly of the bearings, the following precautions should be observed:

1. Connect the ground cable from the welder directly to the part being welded and to no other part of the machine.

2. In the case of uninsulated bearings, separate the stationary and rotating parts. For solid guide bearings, the bearings must be removed. For segmental guide bearings, the segments must be backed off and paper inserted between the journal and the babbitt. For thrust bearings, the rotor should be jacked up. In some designs, if necessary to insure complete separation, the driving dowels between runner and thrust block can be removed. A solid ground to the generator shaft should be maintained during assembly.

3. If there is any possibility that a bearing, particularly a thrust bearing, has been subjected to any flow of welding current, it should be inspected before being restored to service.

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MG 5.2-5.06 CLEANLINESS

At all times, bearing parts, generator coils, ventilating ducts, exciter commutators and collector rings should be shielded from dirt and other extraneous material. Special effort should be made to exclude metal chips, filings, weld spatter or other conducting material from the windings.

If construction work is being done, all parts of the generator should be covered when necessary to exclude dust and dirt. In all cases, the generator assembly area must be protected from the weather. In no case should construction work be carried on above the generator while it is being erected.

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MG 5.2-5.07 KEEPING RECORDS

Permanent records should be kept of all settings, clearances and tolerances established during erection of the generator. Such records are particularly useful if, at a later date, it appears that a change in alignment has occurred. Without adequate records it is difficult to determine the cause of the damage or the most suitable remedy.

To retain accurate alignment records, permanent reference plugs should be inserted in the concrete foundation.

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Part 6
RECEIVING, STORAGE AND UNPACKING

MG 5.2-6.01 RECEIVING

Immediately upon receipt of shipment, all materials should be checked against the manufacturer's shipping list for loss and inspected for damage during transit. Any loss or damage discovered should be reported at once to the carrier, and his agent should be given an opportunity to make an appropriate investigation. In all cases copies of reports of damage or loss made to the carrier should be sent to the manufacturer. If concealed damage is found after the parts are unpacked, this should be reported in a similar manner.

Machined surfaces are coated with a rust-preventive material before shipment. If there are signs of damage to such surfaces, the protective compound should be removed, the rust and moisture eliminated and the coating reapplied. Where runners, bearing journals and other highly polished surfaces are involved, the manufacturer should be consulted before any action is taken.

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MG 5.2-6.02 STORAGE

All material should be placed under adequate cover immediately upon its receipt. Packing cases are not suitable for unprotected storage. Instead, the equipment should be stored in a clean, dry place and protected against rodents and termites. Exposure to very low temperatures and extreme temperature variations should be prevented.

During storage all insulated windings should be protected against sweating and freezing by a safe and reliable heating system which will keep the temperature of the windings above the dewpoint of the surrounding air. An electric fan-type heater with a thermostatic control is excellent. For disassembled wound stator sections, assembled rotors or poles, about 15 watts per 1000 pounds is usually sufficient if the heat is applied inside the crates. The temperature of the sections should be maintained at approximately 10°C above the outside ambient temperature.

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Machines in storage should be inspected and the insulation resistance measured at periodic intervals. Records should be kept and any significant drop in resistance should be investigated. It may prove necessary to increase the heat input to limit the moisture absorption. Such precautions during storage will avoid costly deterioration of parts and an abnormally long dry-out time after installation.

Parts on which final alignment and running clearances depend, such as shafts, couplings and bearings, are machined to close tolerances. Consequently, adequate blocking must be provided when storing such parts to prevent distortion of their machined surfaces. Supports must not be placed under journal surfaces nor should wood supports be in direct contact with the shaft. Large parts, such as rotor spiders and stator sections, must be supported to distribute their weight uniformly and thus avoid any permanent deformation.

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MG 5.2-6.03 UNPACKING

Upon unpacking, the contents of all boxes should be checked against the manufacturer's packing list. If windings or parts with machined surfaces have been exposed to a low temperature, their coverings should not be removed until they have been warmed to approximately the temperature of the room where they will be unpacked.

Rust-preventive coatings on machined surfaces should not be removed until the parts are to be installed. The solvent used should be one specified by the generator manufacturer. In no case should any abrasive material, such as sandpaper or metallic scrapers, be used to remove the rust-preventive coatings.

After the finished surfaces have been thoroughly cleaned, any burrs or bumps received in shipping or handling should be removed with a fine file, scraper or stone, except where highly polished runners, bearing journals, etc., are involved. In the latter case, the manufacturer should be consulted for specific instructions.

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Part 7
ERECTION PROCEDURES

MG 5.2-7.01 GENERAL

The erection procedures described in Part 7 are those which will generally prove most satisfactory. Special circumstances, however, may arise in any installation which make it desirable to depart somewhat from these procedures.

The erection procedure for generators which are shipped completely assembled necessarily differs from that for the machines which are assembled in the field. Furthermore, field-assembled generators require a somewhat different erection procedure if the thrust bearing is located above the rotor than they do if it is located below the rotor. Finally, the procedure for field-assembled machines having a spring-type or self-equalizing-type thrust bearing differs from that for machines having an adjustable-shoe-type thrust bearing. Hence, the five cases to be covered are:

1. Generator shipped completely assembled (see MG 5.2-7.02).
2. Generator assembled in the field, thrust bearing above the rotor—spring-type or self-equalizing-type thrust bearings (see MG 5.2-7.03).
3. Generator assembled in the field, thrust bearing above the rotor—adjustable-shoe-type thrust bearing (see MG 5.2-7.04).
4. Generator assembled in the field, thrust bearing below the rotor—spring-type or self-equalizing-type thrust bearings (see MG 5.2-7.05).
5. Generator assembled in the field, thrust bearing below the rotor—adjustable-shoe-type thrust bearing (see MG 5.2-7.06).

The step-by-step erection procedures are outlined in MG 5.2-7.02 through MG 5.2-7.06 for these five cases. More detailed information on certain steps in the erection procedures are given in Part 8.

Some generator components must be assembled in the erection bay before they are incorporated into the final assembly over the turbine pit. Such subassembly work should be scheduled properly so that it will fit into the final erection procedure which is outlined in MG 5.2-7.02 through MG 5.2-7.06. Ample time should be allowed for major operations, such as the field assembly of a generator rotor.

In all cases, the foundation bolts are placed in position while the forms for the concrete foundations are being built (see MG 5.2-8.01).

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MG 5.2-7.02 GENERATOR SHIPPED COMPLETELY ASSEMBLED

1. Lift the generator into place on the foundation with the soleplates bolted to the bottom of the machine.
2. Center the shaft in guide bearings and stator bore; check air gap; and temporarily lock in place.
3. Adjust elevation and horizontal position of soleplates (see MG 5.2-8.02) until the generator coupling is in alignment with the turbine coupling and at the correct elevation. Tighten foundation bolts.
4. Close the generator-turbine coupling (see MG 5.2-8.10), and check the elevation of the turbine runner.
5. Make shaft-plumb and straightness check (see MG 5.2-8.11) where the design of the machine permits, and recheck centering of shaft in guide bearings.
6. Grout the soleplates (see MG 5.2-8.02).
7. Dowel generator to soleplates (unless predoweled).

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IG 5.2-7.03 GENERATOR ASSEMBLED IN THE FIELD, THRUST BEARING ABOVE THE ROTOR—SPRING-TYPE OR SELF-EQUALIZING-TYPE THRUST BEARINGS

1. Place the soleplates for the stator frame (and those for the lower bracket*) in position over the foundation bolts, and adjust them to a level position at approximately the correct elevation. Temporarily tighten foundation bolts. (For grouting, see MG 5.2-8.02).

2. Place the assembled lower bracket into position on its soleplates and install holding-down bolts.

3. Place the stator on its soleplates and install holding-down bolts; if the stator is sectionalized, close the joints in the frame and complete the stator winding across the joints (see MG 5.2-8.03).

4. Adjust the elevation of soleplates (see MG 5.2-8.02) until the top surface of the stator frame is level and at the correct elevation. Also, check to see that the stator forms a true circle and make any necessary adjustments. Assembly of air coolers and any internal wiring and piping (see MG 5.2-8.07) can usually start at this time.

5. Place the assembled upper bracket on the stator frame and shim under ends of arms until the thrust bearing supporting surface is at the correct elevation.

6. Suspend a plumb line from the upper bracket to the turbine shaft, centering the line with respect to the upper guide bearing fit. Shift the bracket on the stator to center the plumb line in the stator core, and temporarily dowel the bracket to the frame to facilitate reassembly.

7. Center the assembly of the stator and upper bracket to the turbine shaft.

8. Adjust the elevation and position of soleplates supporting the lower bracket (see MG 5.2-8.02) until the guide bearing support is at the proper elevation and is centered with respect to the turbine shaft; then tighten the lower bracket foundation bolts*.

9. Remove the upper bracket and lower the assembled rotor (see MG 5.2-8.04) into the stator, resting the rotor on the jacks or, where they are provided, on special blocks.

10. Replace the upper bracket and assemble the thrust bearing (see MG 5.2-8.05) and thrust block.

11. Lower the rotor so that the weight of the rotor is transferred to the thrust bearing and check thrust bearing insulation (see MG 5.2-8.09).

12. Check to see that the rotor is approximately centered axially with respect to the stator core.

13. Check the elevation and alignment of the generator coupling with the turbine coupling and make adjustments, if necessary.

14. Close the generator-turbine coupling (see MG 5.2-8.10), and check the elevation of the turbine runner.

15. Perform shaft-plumb and straightness check (see MG 5.2-8.11) and make necessary adjustments.

16. Center the turbine runner and establish trammel points at all guide bearings (including the turbine guide bearing) in cooperation with the turbine erector.

17. Check the shaft runout by rotation check method 1 (par. A of MG 5.2-13.01) if this method is selected and is applicable (see MG 5.2-8.13). In this case, the upper guide bearing should first be installed or other provision made to prevent excessive side slip during rotation of the shaft.

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* When the lower bracket is integral with or bolted to the stator frame, this step is omitted from the erection procedure.

18. Check the axial position and centering of the lower guide bearing support and make necessary adjustments in the position and elevation of the lower bracket*.

19. Install any thermal devices in the thrust bearing and oil reservoir. The thrust bearing oil coolers may be installed at this time following final inspection (see MG 5.2-9.02) depending on the generator manufacturer's recommendations.

20. Install the upper guide bearing (unless already installed) and then the lower guide bearing (see MG 5.2-8.06). (The turbine guide bearing should now be installed.) If the bearings are of the sleeve type, check the clearances all around the journal and, if necessary, recenter the bearing support and/or bracket. If segmental-type bearings are used, adjust each segment to the correct clearance. Check the trammel points at the turbine guide bearing after installing each bearing to make sure that the shaft has not shifted. Also, check the insulation of the upper guide bearing (see MG 5.2-8.09).

21. Install exciters, collector rings and brush rigging (see MG 5.2-8.14) and complete the internal wiring to these devices.

22. Check air gap for uniformity (see MG 5.2-8.08).

23. Dowel the upper bracket to the stator frame and dowel the stator frame (and lower bracket*) to the soleplates.

24. If not done previously, grout the soleplates (see MG 5.2-8.02).

25. Install enclosing covers, stairs, handrails, etc., if provided.

26. After complete assembly of all parts (including turbine and governor parts) that are located above the generator rotor, check the insulation of all possible paths for shaft current (see MG 5.2-8.09).

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MG 5.2-7.04 GENERATOR ASSEMBLED IN THE FIELD, THRUST BEARING ABOVE THE ROTOR—ADJUSTABLE-SHOE-TYPE THRUST BEARING

1. Place the assembled lower bracket in position on the foundation with its soleplates bolted to the bracket arms. Bring the bracket to the correct elevation and center the bracket to the turbine shaft with a plumb line. For grouting of the lower bracket soleplates, see MG 5.2-8.02. Final centering of the bracket will be done later by removing the pipe spacers from around the bracket hold-down bolts and moving the bracket on its soleplates*.

2. Place the stator soleplates in position and set them to the correct elevation angle and radius. For grouting, see MG 5.2-8.02. The lower bracket is a working platform for this operation.

3. Place the stator on its soleplates and install holding-down bolts; if the stator is sectionalized, close the joints in the frame and complete the stator winding across the joints (see MG 5.2-8.09).

4. Adjust the elevation of soleplates (see MG 5.2-8.02) until the top surface of the stator frame is level and at the correct elevation. Also, check to see that the stator forms a true circle and make any necessary adjustments. Assembly of air coolers and any internal wiring and piping (see MG 5.2-8.09) can usually start at this time.

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* When the lower bracket is integral with or bolted to the stator frame, this step is omitted from the erection procedure.

5. Place the upper bracket on the stator. Center the stator and upper guide bearing fit to the turbine shaft. Install temporary dowels in the upper bracket arms.

6. Remove the upper bracket and lower the assembled rotor (see MG 5.2-8.04) into the stator, resting the rotor on the jacks or, where they are provided, on special blocks.

7. Replace the upper bracket and assemble the thrust bearing (see MG 5.2-8.05) and thrust block.

8. Lower the rotor so that the weight of the rotor is transferred to the thrust bearing and check thrust bearing insulation (see MG 5.2-8.09).

9. Check to see that the rotor is approximately centered axially with respect to the stator core.

10. Adjust the thrust bearing jack screws until the generator coupling face is at the correct elevation and parallel with the turbine coupling face. Shift the generator rotor horizontally until two couplings are in alignment.

11. Close the generator-turbine coupling (see MG 5.2-8.10), and check the elevation of turbine runner.

12. Perform shaft-plumb and straightness check (see MG 5.2-8.11) and make necessary adjustments.

13. Center the turbine runner and establish trammel points at all guide bearings (including the turbine guide bearing) in cooperation with the turbine erector.

14. Check the thrust bearing shoes for uniformity of loading and make necessary adjustments (see MG 5.2-8.12).

15. Check the shaft runout by rotation check method 1 (par. A of MG 5.2-13.01) if this method is selected and is applicable (see MG 5.2-8.13). In this case the upper guide bearing should first be installed or other provision made to prevent excessive side slip during rotation of the shaft.

16. Check the axial position and centering of the lower guide bearing support and make necessary adjustments in the position and elevation of the lower bracket*.

17. Install any thermal devices in the thrust bearing and oil reservoir. The thrust bearing oil coolers may be installed at this time following final inspection (see MG 5.2-9.02) depending on the generator manufacturer's recommendations.

18. Install the upper guide bearing (unless already installed) and then the lower guide bearing (see MG 5.2-8.06). (The turbine guide bearing should now be installed.) If the bearings are of the sleeve type, check the clearances all around the journal and, if necessary, recenter the bearing support and/or bracket. If segmental-type bearings are used, adjust each segment to the correct clearance. Check the trammel points at the turbine guide bearing after installing each bearing to make sure that the shaft has not shifted. Also, check the insulation of the upper guide bearing (see MG 5.2-8.09).

19. Install exciters, collector rings and brush rigging (see MG 5.2-8.14) and complete the internal wiring to these devices.

20. Check air gap for uniformity (see MG 5.2-8.08).

21. Dowel the upper bracket to the stator frame and dowel the stator frame (and lower bracket*) to the soleplates.

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* When the lower bracket is integral with or bolted to the stator frame, this step is omitted from the erection procedure.

If not done previously, grout the soleplates (see MG 5.2-8.02).

Install enclosing covers, stairs, handrails, etc., if provided.

24. After complete assembly of all parts (including turbine and governor parts) that are located above the generator rotor, check the insulation of all possible paths for shaft current (see MG 5.2-8.09).

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MG 5.2-7.05 GENERATOR ASSEMBLED IN THE FIELD, THRUST BEARING BELOW THE ROTOR—SPRING-TYPE OR SELF-EQUALIZING-TYPE THRUST BEARINGS

1. Place the soleplates for the stator frame in position over the foundation bolts, and adjust them to a level position at approximately the correct elevation. Temporarily tighten foundation bolts (for grouting, see MG 5.2-8.02).

Place the soleplates for the lower bracket in position over the foundation bolts, and adjust them to a level position at approximately the correct elevation. Tighten foundation bolts (for grouting, see MG 5.2-8.02). (This step in the erection procedure, of course, does not apply if the soleplates are embedded in the foundation.)

3. In the erection area, assemble together the lower bracket, shaft, thrust bearing and lower guide bearing (see MG 5.2-8.05 and MG 5.2-8.06). If the guide bearing is of the segmental type, tighten four segments against the journal to keep the shaft in position. Perform the necessary fitting of any thermal devices in the bearings and oil reservoir (see MG 5.2-8.15).

4. Place the lower bracket assembly in its approximately correct location on the soleplates. If the soleplates were not grouted (step 2) or embedded in the foundation, install the lower bracket holding-down bolts.

5. Place the stator on its soleplates and install holding-down bolts; if the stator is sectionalized, close the joints in the frame and complete the stator winding across the joints (see MG 5.2-8.03).

6. Adjust the elevation of the lower bracket and shift its position until the generator coupling is at the correct elevation and is in alignment with the turbine coupling.

7. Close the generator-turbine coupling (see MG 5.2-8.10) and check the elevation of the turbine runner.

8. Perform shaft-plumb and straightness check (see MG 5.2-8.11) and make necessary adjustments.

9. Center the turbine runner and establish trammel points at the generator lower guide bearing and at the turbine guide bearing (in cooperation with the turbine erector).

10. If the lower bracket soleplates were grouted (step 2) or were embedded in the foundation, fit and install chocks between the bracket arms and soleplates when they are required, and install holding-down bolts. Otherwise, tighten the foundation bolts and grout the lower bracket soleplates (see MG 5.2-8.02).

11. Recheck the shaft plumbness and centering of the turbine runner and make any necessary adjustments.

12. Adjust the elevation of the stator soleplates (see MG 5.2-8.02) until the top surface of the frame is level and at the correct elevation. Also, check to see that the stator forms a true circle and make any necessary adjustments. Center the stator around the shaft and tighten stator foundation bolts. Assembly of air coolers and any internal wiring and piping (see MG 5.2-8.07) can start at this time.

13. Install the assembly of rotor spider, rim and poles on the shaft (see MG 5.2-8.04).

14. Replumb the shaft with the rotor weight supported by the thrust bearing.

15. Check the shaft runout by rotation check method 1 (par. A of MG 5.2-13.01) if this method is selected and is applicable (see MG 5.2-8.13).

16. Check to see that the rotor is approximately centered axially with respect to the stator core and, if not done previously, grout the stator soleplates (see MG 5.2-8.02).

17. Install the assembled upper bracket and center it to the shaft.

18. If an upper guide bearing is provided, align and axially locate its support. Also, establish trammel points at the upper guide bearing.

19. Adjust the clearance of the lower guide bearing, then install any thermal devices in the thrust bearing and oil reservoir. The thrust bearing oil coolers may be installed at this time or following final inspection (see MG 5.2-9.02) depending on the generator manufacturer's instructions.

20. Install and adjust clearance of the upper guide bearing, if provided. (The turbine guide bearing should also be installed at this time and its clearance adjusted.) Recheck the trammel points to be sure the shaft has not shifted.

21. Check the insulation of the upper guide bearing, if provided (see MG 5.2-8.09).

22. Install exciters, collector rings and brush rigging (see MG 5.2-8.14), and complete the internal wiring to these devices.

23. Check air gap for uniformity (see MG 5.2-8.08).

24. Dowel the upper bracket to the stator frame, the stator frame to the soleplates, and the lower bracket to the soleplates.

25. Install enclosing covers, stairs, handrails, etc., if provided.

26. After complete assembly of all parts (including turbine and governor parts) that are located above the generator rotor, check the insulation of all possible paths for shaft current (see MG 5.2-8.09).

Authorized Engineering Information 6-1-1959, revised 12-16-1971.

MG 5.2-7.06 GENERATOR ASSEMBLED IN THE FIELD, THRUST BEARING BELOW THE ROTOR—ADJUSTABLE-SHOE-TYPE THRUST BEARING

1. Some of the generators of this type are designed so that the shaft and thrust bearing assembly can be placed through the top of the lower bracket after the bracket has been set on the foundation. For machines of this type, the procedure for setting the lower bracket and stator can be identical to the method used on adjustable shoe bearings with the thrust bearing above the rotor.

2. Place the assembled lower bracket in position on the foundation with its soleplates bolted to the bracket arms. Bring the bracket to the correct elevation and center the bracket to the turbine shaft with a plumb line. For grouting of the lower bracket soleplates, see MG 5.2-8.02. Final centering of the bracket will be done later by removing the pipe spacers from around the bracket hold-down bolts and moving the bracket on its soleplates.

3. Place the stator soleplates in position and set them to the correct elevation, angle and radius. For grouting, see MG 5.2-8.02. The lower bracket is a working platform for this operation.

4. Place the stator on its soleplates and install holding-down bolts; if the stator is sectionalized, close the joints in the frame and complete the stator winding across the joints (see MG 5.2-8.03).

5. Thrust bearing parts can be preassembled around the shaft and this assembly can be placed in the lower bracket.

6. On machines where the shaft and thrust bearing cannot be assembled through the top of the lower bracket, it will be necessary to preassemble the shaft and bearing in the bracket and place this as a unit on its foundation; otherwise, the procedure is as outlined in steps 2 to 5, inclusive.

7. Adjust the elevation of the lower bracket and shift its position until the generator coupling is at the correct elevation and is in alignment with the turbine coupling.

8. Close the generator-turbine coupling (see MG 5.2-8.10) and check the elevation of the turbine runner.

9. Perform shaft-plumb and straightness check (see MG 5.2-8.11) and make necessary adjustments.

10. Center the turbine runner and establish trammel points at all guide bearings (including the turbine guide bearings) in cooperation with the turbine erector. If not done previously, grout the lower bracket soleplates (see MG 5.2-8.02).

11. Adjust the elevation of the stator until the top surface of the frame is level and at the correct elevation. Also, check to see that the stator forms a true circle and make any necessary adjustments. Center the stator around the shaft and tighten the stator foundation bolts. Assembly of air coolers and any internal wiring and piping (see MG 5.2-8.07) can usually start at this time.

12. Install the assembly of rotor spider, rim and poles on the shaft (see MG 5.2-8.04).

13. Replumb the shaft with the rotor weight supported by the thrust bearing.

14. Check the thrust shoes for uniformity of loading and make necessary adjustments (see MG 5.2-8.12).

15. Check the shaft runout by rotation check method 1 (par. A of MG 5.2-13.01) if this method is selected and is applicable (see MG 5.2-8.13).

16. Check to see that the rotor is approximately centered axially with respect to the stator core and, if not done previously, grout the soleplates (see MG 5.2-8.02).

17. Install the assembled upper bracket and center it to the shaft.

18. If an upper guide bearing is provided, align and axially locate its support. Also, establish trammel points at the upper guide bearing.

19. Adjust the clearance of the lower guide bearing; then install any thermal devices in the thrust bearing and oil reservoir. The thrust bearing oil coolers may be installed at this time or following final inspection (see MG 5.2-9.02) depending on the generator manufacturer's recommendations.

20. Install and adjust clearance of the upper guide bearing, if provided. (The turbine guide bearing should also be installed at this time and its clearance adjusted.) Recheck the trammel points to be sure the shaft has not shifted.

21. Check the insulation of the upper guide bearing, if provided (see MG 5.2-8.09).

22. Install exciters, collector rings and brush rigging (see MG 5.2-8.14), and complete the internal wiring to these devices.

23. Check air gap for uniformity (see MG 5.2-8.08).

24. Dowel the upper bracket to the stator frame, the stator frame to the soleplates, and the lower bracket to the soleplates.

25. Install enclosing covers, stairs, handrails, etc., if provided.

26. After complete assembly of all parts (including turbine and governor parts) that are located above the generator rotor, check the insulation of all possible paths for shaft current (see MG 5.2-8.09).

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Part 8
DETAILS OF ERECTION PROCEDURES

MG 5.2-8.01 PLACING OF FOUNDATION BOLTS

The proper size and the location of the foundation bolts are shown on the generator outline drawing. Metal templates should be used to assure accurate positioning of the bolts while the foundation is being poured. Alternatively, the bolts with plates or large washers on the lower end may be set in pipes 1 to 2 inches larger than the bolts or in tapered rectangular pockets in the foundation which are larger at the lower end. The nuts at the lower end of the bolts should be welded to the plates or washers and to the bolts. The pipes or pockets are filled with concrete when the soleplates are grouted.

The foundation bolts and the pipes, if used, should be left unpainted to provide a better bond with the concrete.

Authorized Engineering Information 6-1-1959, revised 12-16-1971.

MG 5.2-8.02 POSITIONING AND GROUTING OF SOLEPLATES

Soleplates are often positioned by bolting them to the part which they support (stator frame or lower bracket) before grouting so that proper positioning of the part brings the soleplates to the correct location. The holes for the holding-down bolts are usually drilled oversize to allow some adjustment of the position of the supported part after the soleplates have been grouted. Initially, the bolts should be centered in the holes. This is conveniently accomplished by placing sleeves of proper dimensions in the bolt holes. Sometimes, it is advantageous to locate accurately and grout the soleplates before the supported part is brought into position.

During the erection procedure, grouting of the soleplates should be done at the time specified by the manufacturer.

The elevation of the soleplates may be adjusted by means of jack screws, sliding parallels or double parallel wedges. In the case of the stators of large machines, convenient adjustment of the elevation is possible if provision is made in the foundation so that a jack can be placed alongside each soleplate to raise and lower the stator with the soleplates attached. After a soleplate has been brought to the correct elevation, it can be supported in this position by flat plates or shims. In all cases, the soleplates must rest on a support which is substantial enough to carry the total vertical loading until the soleplates are grouted.

After final positioning, chocks, if required, are machined to fit accurately into the space between each soleplate and supported part.

When grouting soleplates, the base mass of concrete should be thoroughly cleaned. The surface should be roughed up by chipping and then wetted and slurried. A stiff, fine grout should then be forced into the space around and under the soleplate, making sure that every crevice is filled. The use of vibrators for distributing the grout is not recommended, since their use may disturb the alignment of the soleplates.

Sufficient space must be allowed for installing any radial dowels as shown on the generator outline drawing or in accordance with the manufacturer's instructions.

Authorized Engineering Information 6-1-1959, revised 12-16-1971.

MG 5.2-8.03 ASSEMBLY OF STATOR

If the stator is shipped in two or more sections, each section of the stator is placed in position on the soleplates and is bolted to the adjacent section. The sections are then carefully aligned so that the cores match at each split. The manufacturer should specify the procedure to use and the tolerances required in making up the splits.

The installation and connection of the stator coils at the joints can start as soon as the joints are aligned and can continue while other work is being done until the rotor is placed in the machine. In some cases, the lower bracket may be placed temporarily in position and used as a base for the winding platform. The procedures recommended by the generator manufacturer should be followed. The work should be done, under the technical direction of the manufacturer's representative, by winders who have had experience in winding large generators.

After the coils are in the slots but before connections are made, the newly installed coils and those which have been disturbed should be given a high-potential test in accordance with the recommendations of the generator manufacturer.

Coil connections should be made in accordance with the connection diagram furnished by the generator manufacturer. The materials and methods used to complete the insulation of the machine should also be in accordance with instructions provided by the generator manufacturer.

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MG 5.2-8.04 ASSEMBLY OF ROTOR

The procedure to be followed in the assembly of a generator rotor will vary considerably for the different designs and must be specified by the generator manufacturer. However, the suggestions which follow are generally applicable:

A. Shrinking of Rotor Spider on Shaft*

The spider bore and the shaft diameter should be compared at the same temperature to make sure that the proper interference fit will be provided. The key dimensions should be checked and all burrs and sharp corners removed. Both keyways should be checked for straightness and parallelism. Finally, it is desirable to lubricate the keys and keyway with a mixture of graphite and machine oil before assembly.

The shaft should be in a vertical position when the spider is shrunk onto it to minimize the shaft distortion due to uneven cooling. The spider should be heated in an oven or temporary enclosure by suitable heaters. The heating should be done slowly and evenly to prevent distortion. The oven temperature should not exceed 250°C for a rotor without poles. The shrinking operation should be performed before the poles are attached; otherwise, the temperature should not exceed 100°C. With an interference fit of 1/2 mil per inch of diameter, a temperature difference between the spider and shaft of approximately 75°C to 150°C is required.

To determine that the correct clearance has been obtained, the hot rotor bore should be checked with a micrometer or pin gage which is at the same temperature as the shaft. After the rotor spider has been properly positioned on the shaft, air should be blown against the side of the spider which is next to the shaft shoulder so that the spider will cool and seize on this side first and not pull away from the shoulder as it cools.

If the spider consists of more than one axial section, the sections may be shrunk on one at a time. Alternatively, the sections may be lined up when cold and the heat applied while they are supported in a position around the shaft above the fit. After the oven has been removed, and without disturbing the spider, the shaft is pulled up through the spider bore by the crane to the correct position. The shaft-lifting device provided must be suitable for lifting the total weight of the shaft and spider. With either method of assembly, it is essential that the dovetail slots for the poles on the periphery of the spider be kept in alignment. This can be accomplished by the use of several aligning bars in these slots.

There is always some danger of the rotor seizing on the shaft before it reaches the proper location. Therefore, arrangements should be made beforehand for quick disassembly if it should prove necessary. A trial lift with the spider cold is also desirable to mark the final crane position for quicker action with the hot spider.

B. Assembly of Rim Having Sections Held Together By Shrink Links

A pin gage should be made that is longer (by 2 or 3 mils per inch of length) than the distance between the shoulders of the key (shrink link) when cold. When not actually in use, this gage should be kept lying on the rim so that it will remain at the same temperature as the rim.

Before heating the keys, the two sections of the rims should be brought into contact with temporary bolts or clamps and lined up properly. The keys should be heated slowly and uniformly until the gage will move freely between the shoulders. The keys must not be heated to a temperature above 350°C. They will expand approximately 1 mil per inch for each 88°C rise.

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*In heat shrinking a rotor spider to a shaft, the possibility exists that the shaft may be distorted. It is recommended that, whenever possible, this assembly procedure be done at the factory so that heat straightening and machining of the thrust collar and bearing journal surfaces may be performed as required.

Since the lower surface of the rim is often used as a braking surface, it is preferable that the keys be flush with the bottom of the rim. When heated, the keys should project about 0.014 inch below the rim so that after cooling, they will be flush at the bottom of the rim. To accomplish this, the rim can be supported by a flat bar at the joint with a 0.014-inch shim between the rim and the bar on each side of the keyway. If the key projects after cooling, it should be ground off flush and smooth.

C. Assembly of Laminated Rim

If the thrust bearing is above the rotor, the rotor and shaft are usually assembled together in the erection area and handled as a unit. Hence, provision must be made to support the shaft from the coupling in a vertical position for assembly of the spider and laminated rim. On the other hand, if the thrust bearing is below the rotor, the rotor and shaft are usually handled separately, the rotor being assembled independently of the shaft. This means that steel blocking (or an erection pedestal) should be provided in the erection area for the support of the rotor at its center. In any case, the central support should be capable of carrying the weight of the completed assembly. The height should be such that the bottom of the spider is about 2 feet from the floor. The floor at the ends of the arms must be able to support the full weight of the rim and poles.

The rotor spider, generally of fabricated construction, is installed on the shaft or attached to the central support. If it was shipped in several parts, the parts should be assembled in accordance with the manufacturer's instructions.

The rotor spider with the brake plates attached should be leveled, and blocking should be installed for supporting the ends of the spider arms and the rim at the correct elevation. A check should be made after each pressing of the punchings to make sure that the rim is being assembled in a horizontal plane and at right angles to the axis of the shaft.

To prevent serious rotor unbalance, the rim laminations for each ring around the rotor should be taken from the same package.

Accurate positioning and alignment of the rim laminations must be maintained as they are stacked. This may involve the use of temporary keys, assembly pins or shims as recommended by the generator manufacturer. Each layer of laminations should be seated by tapping with a heavy mallet, and the stack should be pressed at intervals of 12 to 20 inches as the rim is assembled.

After the stacking is complete, the rim studs should be tightened to the tension specified by the generator manufacturer. After final tightening, the stud nuts are locked by welding.

The method of installing the rim drive keys varies with the design and should be specified by the generator manufacturer.

D. Field Pole Assembly

All poles should be located so that their centers are in the same plane at right angles to the shaft and coinciding, as nearly as possible, with a plane through the center of the stator core. Proper axial location of the poles can be checked by measurements taken from a machined surface on the shaft, such as a shoulder or flange. Either a tram mounted on the shaft or a wye level may be used.

It is important that iron-to-iron contact be obtained between the pole core and the spider rim for the full length of the pole; otherwise, the pole may loosen after a short period of operation and cause fatigue failure of the pole fastening. Hence, before the poles are installed, the spider surface and the base of the pole should be cleaned and deburred. If the poles are attached by means of dovetails, the bearing surface of the dovetails, the spider slots and the keys should also be cleaned and deburred. The corners of the keys should be inspected and filed, if necessary, to make sure that they will fit within the radius of corners of the dovetails and rim slots. Finally, each pole should be checked to make sure that the field winding collar does not extend below the base of the poles. If there is any question, the pole can be installed without the bottom collar and a measurement taken to the top of the pole from the shaft or rim surface. The pole is then removed and reinstalled with the collar in place and the same measurement taken. The dimension should be the same. Another method for checking the correct seating of a pole is to fully tighten the pole and then heat the coil by passing current through it. If the pole was loose, it can be tightened further after it has cooled. A loose pole must be removed, and the filler removed or the bottom collar trimmed until the pole seats firmly.

For the mounting of dovetail poles, the manufacturer's instructions for installing the keys should be followed with respect to the use of proper lubricant, designation of drive-in and drive-out keys, necessity for redriving keys, ultimate tightness of pole, removal of excess key length, and installation of locking plates over the dovetail slots.

For poles which are held in place by radial bolts or studs (bolted poles), the bolts should be tightened in accordance with the manufacturer's instructions.

After the poles are installed, the field winding should be checked for correct polarity, uniformity of field-coil impedance or alternating-current voltage drop, grounds, open circuits, resistance and high-resistance joints.

E. Bolting of Rotor Spider to Shaft

Rotor spiders which are bolted to the end of the generator shaft or to shaft flanges are generally held by circles of close-fitting bolts or dowels. The bolt holes in the spider and shaft may be drilled undersize in the factory. During assembly, after the rotor is lowered onto the shaft, the bolt holes are reamed or finish-bored to the proper size. The details of the procedure to be followed in this assembly operation should be specified by the generator manufacturer.

Authorized Engineering Information 6-1-1959, revised 12-16-1971.

MG 5.2-8.05 ASSEMBLY OF THRUST BEARINGS

Each of the different designs of thrust bearings requires a somewhat different assembly procedure, and this should be specified by the generator manufacturer. In all cases, however, cleanliness and careful workmanship are extremely important.

A bearing can easily be ruined by even a little lint or dirt. Consequently, precautions should be taken during assembly of the bearing to avoid the presence of dust and dirt by eliminating other construction work above and in the vicinity of the generator.

Finally, before assembly, all parts of the bearing, bearing housing and oil reservoir should be inspected to insure absolute freedom from dirt, lint or other foreign matter. Any rags used around a bearing should be free of lint (never use cotton waste). Lint-free paper towels are available which are excellent. When specified by the generator manufacturer, the bearing oil coolers should be given a hydrostatic test.

After assembly, the thrust bearing should be kept covered to exclude dust and dirt. The oil reservoir should be filled with clean filtered lubricating oil, or the bearing otherwise protected in accordance with the generator manufacturer's recommendations to prevent corrosion.

Authorized Engineering Information 6-1-1959, revised 12-16-1971.

MG 5.2-8.06 ASSEMBLY OF GUIDE BEARINGS

The precautions outlined in MG 5.2-8.05 to keep dirt, lint and other foreign matter out of the thrust bearing should also be observed in connection with the guide bearings.

Sleeve-type bearings, either solid or split, are not adjustable. Therefore, if the bearing clearances differ appreciably from those shown on the manufacturer's assembly drawing or instruction book, the manufacturer should be consulted. If it is necessary to scrape a bearing in the field, it should be done only by someone with considerable experience in the installation of bearings.

Segmental bearings made up of independently adjustable segments should be set to the clearance shown on the assembly drawing or in accordance with the manufacturer's instructions.

The elevation of a self-oiled bearing must be such that the oil groove, if any, is completely covered by the opposite member. The elevation must also be such that, when the rotor is raised to its maximum upward position by the jacks, the bottom of the journal will be below the center of the guide bearing.

After the bearing has been assembled, the remaining parts of the oil reservoir are added. Clearances between these parts and the shaft must be adequate to prevent rubbing.

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MG 5.2-8.07 INSTALLATION OF LUBRICATION SYSTEM

Every section of pipe forming a part of the lubrication system should be freed of scale, reamed at both ends and blown out with compressed air or steam before being connected. Rapping the pipe with a rawhide or wooden mallet while blowing out will help to dislodge any foreign matter which may have entered during construction. Pipe compound or a suitable oil-resistant varnished should be used on all threaded joints.

To clean the pipes, oil should be circulated through them for several hours. The oil leaving the pipes should by-pass the reservoir and should be filtered to remove dirt. The reservoir itself should be filled with oil and drained, several times if necessary, to remove all traces of dirt. Finally, it should be filled with clean filtered oil.

It is recommended that the lubricating oil used be in accordance with the generator manufacturer's specifications. Oils from different producers should not be mixed without the approval of the producers.

A sample of the lubricating oil should be checked periodically to determine its acidity, water content, degree of sludge formation, and presence of any foreign material. This will indicate when treatment or replacement of the oil is desirable.

For further information on the design, flushing and cleaning, and purification of the lubrication systems see the following ASME Standards. Copies are available from the American Society of Mechanical Engineers, 345 East 47th Street, New York, N.Y. 10017.

1. ASME Standard No. LOS-5D1, "Recommended Practices for the Design of Oil Systems for Lubrication and Control of Hydroelectric Equipment" *
2. ASME Standard No. LOS-5C1, "Recommended Practices for the Flushing and Cleaning of Oil Systems for Lubrication and Control of Hydroelectric Equipment"
3. ASME Standard No. LOS-5P1, "Recommended Practices for the Purification of Oil Systems for Lubrication and Control of Hydroelectric Equipment"

* Still under development, not yet available.

Authorized Engineering Information 6-1-1959, revised 12-16-1971.

MG 5.2-8.08 CHECKING AIR GAP

The variations in the air gaps should be in accordance with the tolerances specified by the manufacturer. If the average air gap varies appreciably from that shown on the assembly drawing, the manufacturer should be consulted. In measuring the air gap, care should be taken to measure from iron to iron at the tangential center of the pole face. A tapered air-gap gage or a long feeler gage may be used. If the end ring of the amortisseur winding projects above the top of the pole, a small block attached to a wire can be held over the top of the pole and an air-gap gage placed on the top of the block.

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MG 5.2-8.09 CHECK OF INSULATION AGAINST SHAFT CURRENTS

Bearings and other parts, such as instrument elements, Kaplan features, conduit, piping, etc., which make contact, directly or indirectly, with the shaft above the rotor are usually insulated from the supporting structure to eliminate the possibility of shaft currents. This insulation should be checked with a 500-volt insulation resistance meter and, if the resistance is less than 20,000 ohms, the insulation should be inspected and the necessary corrections made. In the case of a thrust bearing, the insulation should be checked with the weight of the rotor on the bearing.

If double insulation is provided (two layers of insulation with a metallic compound between the layers), its resistance can be checked with the machine completely assembled. However, each parallel path must be checked individually. Often the insulation is shunted by some temporary connection such as a tool, scrap material or dirt. A complete visual inspection should be made to eliminate this possibility.

Where single insulation is used, all connections between the rotor and the frame at the lower end of the machine must be removed to test the bearing insulation, or each individual joint must be isolated and tested individually.

Authorized Engineering Information 6-1-1959.

MG 5.2-8.10 CLOSING OF GENERATOR-TURBINE COUPLING

The closing of the coupling between the generator and the turbine shafts is preferably done under the supervision of the representative of the manufacturer who furnished the coupling bolts. If the two shafts were assembled for a shop check of the runout in the plant of the turbine manufacturer or the generator manufacturer, the same manufacturer usually provides the coupling bolts.

If the two shafts were assembled in a factory, they should be assembled at the installation in the same relative angular position as indicated by the factory-placed matchmarks. If the two shafts were not assembled in a factory but the high points on the faces of the two couplings have been determined (usually marked with the letter "H" on the outer cylindrical surface of the flange), the coupling should be assembled so that these points will be 180 degrees apart.

If the hydraulic turbine is of the adjustable-blade propeller (Kaplan) type, the arrangement may be such that, before the coupling is closed, the generator rotor (or the shaft and the attached thrust bearing runner) is raised sufficiently to make connections to the oil pipes which supply oil to the blade servomotor. The generator rotating assembly is then lowered so that the weight is transferred back on to the thrust bearing.

Before drawing the couplings together, their mating surfaces must be in alignment, parallel, clean and free from burrs. The couplings must be drawn up evenly to prevent distortion.

After the couplings have been drawn together, the bolt holes must be reamed or finish-bored (unless this has already been done in a factory assembly) to fit the permanent bolts. The fit of the bolts should be in accordance with the latest revision of the "American National Standard for Integrally Forged Flanged Type Shaft Couplings for Hydroelectric Units," B49.1-1967*. The bolts must be tightened evenly to a tension which is sufficiently in excess of that required to carry the vertical load so that the friction between the coupling faces will, alone, carry the maximum torque to be transmitted. The bolt tension can best be determined by an accurate measurement of the elongation. The required elongation should be obtained from the supplier of the bolts.

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* Copies are available from the American National Standards Institute, Inc., 1430 Broadway, New York, N.Y. 10018.

Authorized Engineering Information 6-1-1959, revised 12-16-1971.

MG 5.2-8.11 SHAFT-PLUMB AND STRAIGHTNESS CHECK

This is a plumb-wire check of the straightness and plumbness of the combined generator and turbine shafts. The use of four plumb lines spaced 90 degrees apart around the shaft is recommended. The readings should be taken from the same points on each shaft that were used during the factory runout check. The shaft assembly shall be considered to be straight when no runout check point (correlated for diameter variations) deviates more than 0.003 inch from a straight line joining the top and bottom points. The shaft assembly shall be considered to be plumb when the top and bottom points do not deviate from plumb by more than 1/4 mil per foot of shaft length.

0,02 mm/METRO

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MG 5.2-8.12 EQUALIZING THE LOAD ON ADJUSTABLE-SHOE-TYPE BEARINGS

Adjustable-shoe-type bearings must be properly adjusted in order that the thrust load will be equally divided among all of the bearing shoes. There are various types of bearing designs which afford a means of reading the shoe loading directly. In some bearing designs, a strain gage is permanently located in each jack screw and, by connecting the strain gages to a suitable instrument, a direct reading can be obtained of the thrust load carried by each shoe. From such readings, adjustments are readily made to equalize the loading on all shoes. In other bearing designs, the deflection of a built-in member is measured at each shoe to determine loading.

For bearing designs without built-in measuring devices, the "slugged arc" method may be used to equalize the load. There are several variations of this method, each giving equally good results.

The manufacturer's instruction book should describe the bearing design and the method to be used.

Authorized Engineering Information 6-1-1959.

MG 5.2-8.13 CHECK OF SHAFT RUNOUT

An installation check of the runout of the combined generator and turbine shafts is desirable. Three different methods of making this check are described in MG 5.2-13.01. As indicated therein, the methods applicable depend upon the type of thrust bearing furnished with the generator.

If the rotation check by method 1 is used, it must be performed during the erection of the generator to avoid subsequent disassembly of the machine.

Authorized Engineering Information 6-1-1959.

MG 5.2-8.14 ASSEMBLY OF EXCITERS, COLLECTOR RINGS AND BRUSH RIGGING

The main exciter armature is often designed with a flanged shaft having a rabbeted fit which bolts to the end of the generator shaft. The pilot exciter shaft, in turn, may be attached to the main exciter shaft through one or more bolted joints. This means that great care must be taken in the assembly of these armatures. Any foreign material between the flange faces or uneven tightening of the coupling bolts will cause excessive commutator runout.

Generator guide bearings may necessarily have a diametral clearance as great as 20 mils and, under some conditions, the shaft may float in the bearings. Therefore, a small amount of commutator runout at operating speed can be expected. Any check of commutator runout should be made with a dial indicator rather than by visual observations.

The collector rings for the direct-current field current should be carefully assembled in accordance with the manufacturer's instructions. For the reasons mentioned, a small amount of collector ring runout at operating speed can be expected. Collector ring eccentricity should be checked with a dial indicator.

Collector ring surfaces can often be kept in good condition by periodically reversing the polarity of the brushes. When collector rings and exciter leads are brought out to a circuit breaker, cables should be long enough to permit such reversal.

The brushes should be staggered across the collector rings to minimize grooving but, to prevent formation of brush slivers, should not extend beyond the edges of the rings. The brushholder springs should be adjusted in accordance with the generator manufacturer's instructions.

Authorized Engineering Information 6-1-1959.

MG 5.2-8.15 INSTALLATION OF INSTRUMENTS AND RELAYS

Various instruments and relays, or their sensing elements, are often mounted on the generator and must be installed during its erection. This applies to such devices as oil level indicators, bearing temperature relays, indicating and recording thermometers for bearing and air temperatures, water-flow indicators, differential control temperature relay and overspeed device. This equipment and its associated wiring and piping must be carefully installed, making sure that it does not short-circuit the bearing insulation, that is, provide a conducting path from any point on the shaft above the rotor to the stator frame. Suitable insulation must be provided at the proper points.

Authorized Engineering Information 6-1-1959.

Part 9

INITIAL NO-LOAD OPERATION

MG 5.2-9.01 GENERAL

Do not apply voltage to any winding until the condition of the insulation has been checked as described in Part 11. All field circuit breakers should be open, field rheostats in the "all-in" position, and the voltage regulator turned to the "off" position.

Authorized Engineering Information 6-1-1959.

MG 5.2-9.02 PREPARATION FOR INITIAL START

Preparation of the generator for the initial start should include the following:

1. During the last few days before the initial start and after all welding has been completed, make a final inspection of the thrust and guide bearings and prepare them for the initial start in accordance with the manufacturer's instructions.
2. Examine the interior of the stator, the air gap, exciters, collector rings, top of the rotor and the space between poles for loose objects such as bolts, nuts, tools, etc.
3. Make sure that all moving parts have sufficient clearance from the nearest stationary parts.
4. Check the electrical clearance around all parts which are to be energized.
5. Check the tightness of all foundation bolts and holding-down bolts.
6. Clean the commutators and collector rings and check the seating of brushes.
7. See that all protective devices are operating properly.
8. Turn on the bearing and air cooling water (just before starting up).

Authorized Engineering Information 6-1-1959.

MG 6.2-9.03 INITIAL START

It is customary for a representative of the purchaser to coordinate the initial start with direct supervision by the governor manufacturer's representative. The time of the start and the general procedure to be followed should be determined by the purchaser in consultation with the representatives of the turbine, governor and generator manufacturers. The purchaser's personnel should operate the unit with such guidance as is necessary from the equipment manufacturers' field representatives.

The turbine should be shut down as often as is required at the request of any of the manufacturers' field representatives and opportunity should be afforded for making such inspections and adjustments as the manufacturer's representative deems necessary.

The following starting procedure is suggested:

1. Start the turbine and accelerate rapidly to a speed of one-third to one-half of rated speed but not less than 50 rpm so that the bearing oil film will be established quickly.
2. Hold this speed constant and note the bearing temperatures at 1-minute intervals until they become constant. Any rapid or continued rise of the bearing temperature should be investigated.
3. After the bearing temperature becomes constant and the unit is operating smoothly, the speed should gradually be increased to rated speed.
4. If vibration becomes excessive at any time while the unit is being brought up to rated speed, the unit should be shut down and balanced as described in Part 10.

During no-load operation, various checks and adjustments of the turbine and governor are normally made.

Authorized Engineering Information 6-1-1959.

MG 5.2-9.04 CHECK OF SHAFT RUNOUT

When applicable, checking the runout of the face of the thrust bearing runner with respect to the shaft, as described in method 2 (par. A of MG 5.2-13.01) may be done at this time. However, it may be necessary to balance the rotating parts of the machine before this check can be made. See Part 10.

Authorized Engineering Information 6-1-1959, revised 12-16-1971.

Part 10
BALANCING

G 5.2-10.01 BALANCING

The rotating parts of the generator should be in namic balance. This may require the addition of lance weights to the rotor. Their size and location e, in some cases, determined entirely by trial id error; however, it is usually desirable to take easurements which will define the horizontal otion of the shaft under various conditions and, om this data, calculate the size and location of e balance weights required.

The minimum data required to make the calulations is the motion of the shaft (magnitude of e horizontal movement and the location of the igh spot") at one axial location with (1) the rotor its original condition and (2) a trial balance eight added to the rotor. However, if dynamic ibalance is present, requiring the addition of lance weights in two planes, it may be necessary determine the motion of the shaft at two or more ial locations with (1) the rotor in its original contion, (2) a trial weight added in one balance plane id (3) a trial weight added in the second balance ane.

The horizontal movement of the shaft can be easured with a dial indicator and the approximate ocation of the "high spot" established by applying thin coat of whitewash to the surface and then radually bringing in the point of a pencil or scribe ntil it just makes contact with the white-washed rea once each revolution of the shaft. In some ases, the use of special balancing equipment, degned to establish the motion of the shaft more recisely, results in a more accurate determination f the size and location of the required balance eights. This is particularly true for higher speed nits.

Various methods have been published for calulating, from the data taken as described in the oregoing paragraphs, the size and location of the alance weights required.

Balance weights should be attached to the rotor in the manner prescribed by the generator manufacturer.

If, at a later time, it becomes necessary to remove a balance weight, it should be replaced in exactly the same position. Before disassembling a pole on a high-speed machine, its axial position should be accurately marked so it can be replaced in the same position. Should it become necessary to replace a field coil or a complete pole, the balance must be rechecked.

The turbine runner shall also be in dynamic balance to insure that the turbine-generator unit balance and shaft runout are acceptable. Occasionally the overall balance and shaft runout of the unit will not respond to balancing only the generator rotor. In this situation balancing should be done on the turbine runner. The results may be checked by driving the unit with the generator as a synchronous motor and the turbine unwatered with a minimum seal water flowing.

Since the nature of hydraulic turbines is such that shaft runout or vibration may result from hydraulic forces within the turbine, unwatered operation will also serve to separate mechanical unbalance from hydraulic disturbances.

If mechanical construction permits, further separation of the turbine and generator unbalance can be achieved by running the generator as a motor with the turbine uncoupled.

Should undue vibration develop during operation of the generator, before adding or shifting balance weights, check the possibility of the vibration being caused by misalignment, settling of the foundation, uneven air gap, rubbing of rotating parts, loose parts, bent shaft, short-circuited field coil or unbalanced stator currents. Then, if necessary, add or shift the balance weights.

Authorized Engineering Information 6-1-1959, revised 12-16-1971.

Part 11
INSULATION TESTING AND DRYING OUT

MG 5.2-11.01 MEASUREMENT OF WINDING INSULATION RESISTANCE

The insulation resistance of the armature and field windings of the generator and exciter(s) serves as an indication of whether or not the machine is in condition for operation and dielectric testing. Insulation resistance measurements of the windings shall be made in accordance with the latest revision of the IEEE "Recommended Practice for Testing Insulation Resistance of Rotating Machinery," Publication No. 43*.

All insulation resistance test results should be referred to the manufacturer for analysis and approval. From these data, the manufacturer can determine whether "drying out" of the windings is required before dielectric testing and operation.

Authorized Engineering Information 6-1-1959, revised 12-16-1971.

MG 5.2-11.02 DRYING OUT OF WINDINGS

If drying out of the windings is recommended by the manufacturer, the following procedures are suggested:

1. The temperature of the winding should generally not be allowed to exceed 90°C when measured by a resistance or temperature detector or 75°C when measured by a thermometer. In cases where moisture penetration of the insulation is usually severe, it will be necessary to convert the moisture to a gas. This result can usually be achieved by working within these temperature limitations. However, they may be exceeded by a few degrees if it becomes apparent that the insulation resistance is not changing as expected. The rate of heating should be such that this temperature is attained in not less than 6 hours and, preferably, in not less than 12 hours. The winding should be brought up to temperature slowly by steps to avoid gassing of entrapped moisture and possible rupture of insulation.

The armature winding should preferably be dried out by the short-circuit method. When this method is used, the machine is operated at rated speed with all phases of the armature winding short-circuited. Enough field current is applied to give an armature current (usually between 60 and 100 percent of rated armature current) which will produce the rate of temperature rise specified in item 1. This heating should be continued until the insulation resistance readings, corrected for any temperature differences, approach constancy. A slight amount of ventilation must be provided to exhaust the moisture-laden air.

3. The armature winding can also be dried out by passing direct current through it with the machine stationary. A high-current low-voltage source of direct-current power, such as a welding generator, is required. Where possible, the phases of the winding should all be connected in series or in parallel, so that all phases will carry the same current. Where the phase currents are unbalanced, the maximum current in any phase should be limited to that which will give the heating rate specified in item 1. Since the machine is stationary, this current is usually between 25 and 50 percent of rated current. A slight amount of ventilation must be provided to exhaust the moisture-laden air.

4. Even though the short-circuit method is used to dry out the armature winding, the resulting current in the field winding is not generally sufficient for adequate drying out of the field. One method for drying out the field is to operate the machine under load for several days. Alternatively, the field can be dried out by applying direct current to the field with the rotor stationary, but with the current limited so that the temperature given in item 1 will not be exceeded. This current should not be passed through the

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brushes; instead, the leads should be connected to copper bands clamped around the connector rings.

5. An alternative method of drying out armature windings is by means of electric space heaters. They should be located in air spaces under the machine or at the back of the stator core and be distributed around the periphery of the machine to allow for an even distribution of heat.

   If the rotor is not in place, the ends of the machine may be closed with end bells or with large tarpaulins to reduce the heat loss. A slight amount of ventilation must be provided to exhaust the moisture-laden air.

   Precautions should be taken to prevent fire when this type of heat is applied.

6. Further details of drying out windings are given in the IEEE "Recommended Practice for Testing Insulation Resistance of Rotating Machinery," Publication No. 43*.

Authorized Engineering Information 6-1-1959, revised 12-16-1971.

MG 5.2-11.03 HIGH-POTENTIAL TESTS

A. General Considerations

The procedure to be followed in making the high-potential test should be in accordance with the latest revision of the IEEE "Test Procedure for Synchronous Machines," Publication No. 115*.

The frequency of the test voltage should be 25 to 60 hertz. The wave shape shall have a deviation factor not exceeding 0.1.

B. Units Not Completely Wound in the Factory

Where the assembly of a winding is completed at the destination, precluding the possibility of final high-potential tests at the factory, it is recommended that high-potential tests be made, using the following test voltages, immediately after final assembly and before the machine is put into service.† The winding should be in good condition and the tests not applied when the insulation resistance is low because of dirt or moisture. (For additional details, see MG 5.2-11.01.)

† In some cases, it may be desirable to give the stator a final high-potential test before installing the rotor.

1. Armature Windings—The test voltage should be an alternating voltage whose effective value (taken as the crest value divided by $\sqrt{2}$) is 1000 volts plus twice the rated voltage of the machine (see Note III).

2. Field Windings, Generators—The test voltage should be an alternating voltage whose effective value (taken as the crest value divided by $\sqrt{2}$) is ten times the rated excitation voltage but in no case less than 1500 volts.

3. Field Windings, Reversible Motor/Generators—The test voltage should be an alternating voltage whose effective value (taken as the crest value divided by $\sqrt{2}$) is as follows:

   a. Machine to be started with its field short-circuited or closed through an exciting armature—ten times rated excitation voltage but in no case less than 2500 volts nor more than 5000 volts.

   b. Machine to be started with a resistor in series with the field winding—twice the rms value of the IR drop across the resistor but in no case less than 2500 volts, the IR drop being taken as the product of the resistance and the current which would circulate in the field winding if short-circuited on itself at the specified starting voltage.

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c. Machine to be started with its field open-circuited and sectionalized—1 1/2 times the maximum rms voltage which can occur between terminals of any section under the specified starting conditions but in no case with less than 2500 volts or ten times the rated excitation voltage per section, whichever is the larger.

d. Machine to be started with its field open-circuited and connected in series—1 1/2 times the maximum rms voltage which can occur between the field terminals under the specified starting conditions but in no case with less than 2500 volts or ten times the rated excitation voltage, whichever is the larger.

4. Rotating Exciter(s)—The test voltage should be in accordance with the latest revision of the "American National Standard Rotating Exciters for Synchronous Machines," C50.5-1955[‡], and the test procedure should be in accordance with the latest revision of the IEEE "Test Code for Direct-Current Machines," Publication No. 113[*].

C. Additional Test Made After Installation

When a test is made after installation on a new machine which has previously passed its high-potential test at the factory and whose windings have not since been disturbed, the test voltage should be 85 percent of the values specified in par. B for machines having voltage ratings above 5000 volts and kVA ratings of 6250 and above, and 75 percent of the values specified in par. B for other machines.

NOTE I—Due to the high voltages used, dielectric tests should be conducted only by experienced personnel, and adequate safety precautions should be taken to avoid injury to personnel and damage to property.

NOTE II—Following an alternating-voltage high-potential test, the tested winding should be discharged to ground before it is touched by personnel.

NOTE III—A direct instead of an alternating voltage is sometimes used for high-potential tests on primary windings of machines rated 6000 volts or higher. In such cases, a test voltage equal to 1.7 times the alternating-current test voltage (effective value) as given in par. B is recommended.

Direct-voltage high-potential tests shall be made in accordance with latest revision of the IEEE "Insulation Testing of Large A-C Rotating Machinery with High Direct Voltage," Publication No. 95[*].

Following a direct-voltage high-potential test, the tested winding must be thoroughly grounded. The insulation rating of the winding and the test level of voltage applied determine the period of time required to dissipate the charge and, in many cases, the ground must be maintained for several hours to dissipate the charge to avoid personnel hazard.

Authorized Engineering Information 6-1-1959, revised 12-16-1971.

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[*] Copies are available from the Institute of Electrical and Electronics Engineers, 345 East 47th Street, New York, N.Y. 10017.

[‡] Copies are available from the American National Standards Institute, Inc., 1430 Broadway, New York, N.Y. 10018.

Part 12
INITIAL OPERATION UNDER LOAD

MG 5.2-12.01 CONNECTION TO POWER SYSTEM

Before connecting the generator to the power system, the phase sequence of the generator and the connections to the synchroscope should be checked and, if correct, the generator leads can be connected permanently.

With the generator running at rated speed and with excitation applied, the magnitude, frequency and phase angle of the generated voltage can be matched to that of the bus, and the generator breaker can be closed. Load should then be applied in small increments, and the temperature rises should be observed. When full load has been reached, it should be maintained for several hours and a careful check made of the temperature rise of windings and bearings, balance, collector ring and exciter brush operation, oil and water flow, ventilation, etc. Some adjustments may now be necessary to insure continued successful operation.

Authorized Engineering Information 6-1-1959, revised 12-16-1971.

MG 5.2-12.02 OPERATION CHECK OF SHAFT RUNOUT

If an operation check of the shaft runout is required, it should be made in accordance with par. 3 of MG 5.2-13.01 after the generator is operating under full load.

Authorized Engineering Information 6-1-1959.

Part 13
FIELD TESTS

MG 5.2-13.01 VERTICAL HYDRAULIC-TURBINE GENERATOR SHAFT RUNOUT TOLERANCES—INSTALLATION CHECK

The runout of the combined turbine and generator shafts after installation shall be checked by one of the following methods:

A. Rotational Check

Method 1—This method shall be used for checking shafts equipped with adjustable-shoe-type thrust bearings. It may be used for checking shafts equipped with self-equalizing-type bearings if recommended by the generator manufacturer.

After aligning and plumbing the coupled generator and turbine shafts, the accuracy of the generator thrust bearing shall be checked by the following procedure:

The unit shall be mechanically rotated, with the turbine guide bearing removed, and any generator bearings other than the one immediately adjacent to the thrust bearing backed off so as not to restrain the position of the shaft.

The generator guide bearing remaining effective prevents excessive side slip during rotation: However, unless this bearing is at approximately the same elevation as the thrust bearing, it also should be backed off or removed before the readings are taken.

Runout shall be measured by plumb line or dial indicator readings at 90 degree intervals at both the thrust bearing level and the turbine guide bearing level.

After making corrections for such side slip as has occurred in the thrust bearing, the shaft shall show a sideways deflection on the plumb lines or dial indicators not greater than 0.002 x L/D inches, where:

[illegible] ≤ 1/2 AMPLITUDE

L = the distance in inches from thrust surface to point of measurement.

D = the thrust bearing outside diameter in inches.

Method 2—This method shall be used for checking shafts equipped with spring-type thrust bearings. It may also be used for checking shafts equipped with self-equalizing-type bearings if recommended by the generator manufacturer.

After initial operation of the combined unit, the accuracy of the generator thrust bearing shall be checked by the following procedure:

Dial indicators shall be placed on two of the thrust bearing segments in such a manner as to indicate the vertical movement of these segments. The unit shall then be run and readings of the dial indicators recorded at approximately one-quarter of normal speed when the unit is decelerating. These readings will give an indication of the runout of the face of the thrust bearing runner plate with respect to the shaft axis. This runout shall be not greater than 0.002 inch.

B. Operation Check

If the runout obtained by Methods 1 and 2 (see par. A) exceeds the allowable values, the runout at the guide bearings of the combined shaft shall be checked with the unit running at normal speed and rated load with indicators mounted on the bearing supports. The unit shall be considered as meeting the requirements of this standard if the runout (exclusive of skate*) does not exceed 70 to 80 percent of the diametrical clearance in the guide bearings and if the temperature of the guide bearing does not exceed 75°C.

*Skate is the lateral random movement of a shaft superimposed on the periodic runout. This movement may be up to the full clearance of the bearing and is generally not considered significant in an analysis of shaft motion.

NEMA Standard 3-15-1956, revised 12-16-1971.

In addition to machining inaccuracies of the bearing collar and runner being the cause of shaft runout, other causes may occur such as electrical or mechanical unbalance of the generator rotor, improper connection at the generator coupling, or hydraulic or dynamic unbalance of the turbine runner. (See Part 10.)

Authorized Engineering Information 3-15-1956, revised 12-16-1971.

MG 5.2-13.02 ELECTRICAL TESTS

The larger generators (above 6250 kVA) usually receive only winding resistance measurements and dielectric tests at the factory, and any additional testing must be done after installation at the site. Certain additional tests are desirable to provide information which will allow a more accurate prediction to be made of generator performance under various operating conditions.

As a minimum, these tests should include:

1. Winding resistance measurements.
2. Open-circuit saturation curve.
3. Short-circuit saturation curve.
4. Field current at rated kVA, power factor and voltage.

Only calibrated instruments should be used, and the test procedure should be in accordance with the latest revision of the IEEE "Test Procedure for Synchronous Machines," Publication No. 115*.

It is recommended that a representative of the generator manufacturer be present when the foregoing tests are made.

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Authorized Engineering Information 12-16-1971.

APPENDIX A

(This Appendix is quoted from the NEMA Standards Publication for Large Hydraulic-turbine-driven Synchronous Generators, MG 5.1-1969.)

MG 5-1.63 VERTICAL HYDRAULIC-TURBINE-GENERATOR SHAFT RUNOUT TOLERANCES—SHOP CHECK

A. Combined Turbine and Generator Shafts, Turbine and Intermediate Shafts, and Generator and Intermediate Shafts

When the alignment of the combined turbine and generator shafts, generator and intermediate shafts, and turbine and intermediate shafts is checked at the factory, it shall be done by rotating the shafts in a lathe or on a vertical alignment table. The couplings should be match marked before disassembly. The amount of runout, determined by the reading of an indicator held stationary with respect to the lathe or table, shall not exceed the following tolerances:

Point Indicated	Tolerances, Inches
1. Combined Turbine and Generator Shafts (No Intermediate Shaft Used)	
a. Cylindrical surface of all guide bearing journals	0.003
b. (1) Face of thrust block (if forged integral with shaft) before attachment of thrust bearing runner	0.00075
(2) Face of thrust block (if not forged integral with the shaft) calculated from runout of face of retaining ring groove, or shoulder on the shaft bearing against the thrust block*	0.0015
c. Turbine water-seal surface	0.003
d. Male or female portion of coupling at runner end of turbine shaft	0.0015
e. Face of coupling at runner end of turbine shaft	0.0015
2. Combined Generator and Intermediate Shafts	
a. Cylindrical surface of all guide bearing journals	0.003
b. (1) Face of thrust block (if forged integral with shaft) before attachment of thrust bearing runner	0.00075
(2) Face of thrust block (if not forged integral with the shaft) calculated from runout of face of retaining ring groove, or shoulder on the shaft bearing against the thrust block*	0.0015
c. Male or female portion of coupling at turbine end of intermediate shaft	0.001
d. Face of coupling (inside and outside the bolt circle) at turbine end of intermediate shaft	0.001
3. Combined Turbine and Intermediate Shafts	
a. Cylindrical surface of all guide bearing journals	0.003
b. Turbine water-seal surface	0.003
c. Male portion of coupling at generator end of intermediate shaft	0.001
d. Face of coupling (inside and outside the bolt circle) at generator end of intermediate shaft	0.001
e. Male or female portion of coupling at runner end of turbine shaft	0.0015
f. Face of coupling at runner end of turbine shaft	0.0015

*If the thrust block is not forged integral with the shaft, it is not necessary to reassemble the block on the shaft for the shop check of the combined generator and intermediate or turbine shaft.

B. Individual Generator Shaft

When the shafts are to be aligned at a location other than the generator manufacturer's factory, the tolerances on the runout of the individual generator shaft shall not exceed the following:

Point Indicated	Tolerances, Inches
1. Generator Shaft	
a. Cylindrical surface of all guide bearing journals	0.002
b. Face of integral runner or thrust block before attachment of thrust bearing runner	0.00075
c. If the thrust bearing runner is separate, the thickness variation at constant radius, measured at inner and outer diameter	0.0005
d. Male or female portion of coupling	0.001
e. Face of coupling (inside and outside the bolt circle) †	0.00075
f. Outside cylindrical surface of coupling	0.002
g. Balance of shaft exclusive of indicated points	0.015

† Mark cylindrical surface of shaft flange with "H" to show high point of face of coupling. The mark shall not interfere with future shaft indications or the fit of the coupling guard.

NEMA Standard 7-16-1969.

C. Individual Turbine and Intermediate Shaft

Experience indicates that the prescribed tolerances on the combined shafts will usually be met if the runout, when the shafts are checked individually in the same manner as that described in par. A, does not exceed the following tolerances:

Point Indicated	Tolerances, Inches
1. Turbine Shaft	
a. Cylindrical surface of all guide bearing journals	0.002
b. Water seal surfaces	0.002
c. Male or female portion of couplings	0.001
d. Face of coupling (inside and outside the bolt circle) at generator end of turbine shaft ‡	0.00075
e. Face of coupling at runner end of turbine shaft	0.001
f. Outside cylindrical surface of couplings	0.002
g. Balance of shaft exclusive of indicated points	0.015
2. Intermediate Shaft	
a. Male or female portion of couplings	0.001
b. Face of couplings (inside and outside the bolt circle) ‡	0.00075
c. Outside cylindrical surface of couplings	0.002
d. Balance of shaft exclusive of indicated points	0.015

‡ Mark cylindrical surface of shaft flange with "H" to show high point of face of coupling. The mark shall not interfere with future shaft indications or the fit of the coupling guard.

It is recommended that a shaft alignment drawing be prepared showing the location of shaft check points for the information of the field erector.

Authorized Engineering Information 7-16-1969.

IEEE
Std 1095-1989

IEEE Guide for Installation of Vertical Generators and Generator/Motors for Hydroelectric Applications

Sponsor

Energy Development and
Power Generation Committee
of the
IEEE Power Engineering Society

Approved December 6, 1989
IEEE Standards Board

IEEE Std 1095-1989, *IEEE Guide for Installation of Vertical Generators and Generator/Motors for Hydroelectric Applications*, describes installation procedures for synchronous generators and generator/motors rated 5000 kVA and above to be coupled to hydraulic turbines having vertical shafts.

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Foreword

(This Foreword is not part of IEEE Std 1095, IEEE Guide for Installation of Vertical Generators and Generator/Motors for Hydroelectric Applications.)

Large hydraulic turbine-driven generators are shipped as components and completely assembled and installed at the site. The installation, therefore, becomes a continuation of the manufacturing process, and many of the operations involved are those that are normally performed in the factory on smaller generators. Close tolerances must be maintained in the fit and alignment of the various parts. The use of proper installation procedures is essential to achieve satisfactory operation of the unit.

This Guide incorporates much of the information previously found in the National Electrical Manufacturers Association (NEMA) publication MG 5.2, Installation of Vertical Hydraulic-Turbine-Driven Generators and Reversible Generator/Motors for Pumped Storage Installations. MG 5.2 was originally issued in 1972 and revised in 1976 and 1977. NEMA sponsorship was withdrawn and MG 5.2 was rescinded in September, 1982.

In 1985 the Energy Development and Power Generation Committee of the IEEE Power Engineering Society agreed to sponsor the Guide, and the Hydroelectric Power Subcommittee undertook the task of reviewing, revising, and reissuing it.

The IEEE Std 1095, IEEE Guide for Installation of Vertical Generators and Generator/Motors for Hydroelectric Applications Working Group wishes to acknowledge the contributions made to the guide by R. D. Handel and J. M. Quigley.

At the time this Guide was approved, the members of the Working Group were as follows:

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SECTION PAGE

Contents

SECTION PAGE

IEEE Guide for Installation of Vertical Generators and Generator/Motors for Hydroelectric Applications

1. Introduction and Scope

The procedures for installation, described in this Guide, apply to all types of synchronous generators and generator/motors rated 5000 kVA and above to be coupled to hydraulic turbines or hydraulic pump/turbines having vertical shafts. All references made in this Guide to "generators" apply equally to "generator/motors."

2. References

Definitions, characteristics, and test methods not specifically covered in this Guide should comply with the following documents insofar as they are applicable:

[1] ANSI C50.5-1966, Rotating Exciters for Synchronous Machines.

[2] ANSI C50.10-1977, American National Standard General Requirements for Synchronous Machines.[1]

[3] ANSI C50.12-1982, American National Standard Requirements for Salient-Pole Synchronous Generators and Generator/Motors for Hydraulic Turbine Applications.

[4] ANSI/IEEE Std 113-1985, Guide on Test Procedures for DC Machines.

[5] ANSI/IEEE Std 115-1983, IEEE Guide: Test Procedures for Synchronous Machines.[2]

[6] ANSI/IEEE Std 810-1987, Standard for Hydraulic Turbine and Generator Integrally Forged Shaft Couplings and Shaft Runout Tolerances.

[7] IEEE Std 43-1974, IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery.

3. Tools and Facilities

3.1 General. In general, the erector should have the complement of necessary tools and materials ready for use prior to the start of installation. Considerable time and money can be lost if these items are not ready when needed. The responsibility for the supply of erection tools and materials falls into the following main categories:

(1) Those supplied by the erector
(2) Those supplied by the manufacturer
(3) Those supplied by the customer

The following subsections will briefly describe these categories and will act as a guide for a typical installation. It is not intended that the lists be all-inclusive.

3.2 Erection Contractor-Supplied Tools. The tools and erection materials required for erection of a hydro unit are varied and numerous. The list below is indicative of the required items to be supplied by the erector:

(1) Portable power tools
(2) Stationary power tools
(3) Sets of large wrenches, ratchets, slugging, and impact wrenches
(4) Jacks and hydraulic rams
(5) Sledgehammers and air hammers
(6) Pipe bending and threading equipment
(7) Welding and burning equipment
(8) Soldering and brazing equipment
(9) Manual and small power hoists
(10) Jib crane for building the rotor rim and positioning the field pole assemblies
(11) Light rigging equipment
(12) Miscellaneous consumable items

[1] ANSI publications are available from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018.

[2] ANSI/IEEE publications can be obtained from ANSI or the Institute of Electrical and Electronics Engineers, Service Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331.

FIGURES

magnetic core, and windings), rotor (shaft, thrust block, spider, rim, and poles with windings), thrust bearing, one or two guide bearings, upper and lower brackets (for the support of bearings and other parts), and soleplates, which are bolted to the foundation and form supports for the stationary parts of the machines. Other components may include a direct-connected exciter or starting motor, rotor brakes or combined brakes and jacks, foundation bolts, platform, stairway and handrails, and an air-discharge housing or a totally enclosed ventilating system with surface air coolers.

The thrust bearing can be located above or below the rotor. When only one guide bearing is utilized, it is normally located near the thrust bearing. When two guide bearings are used, one is located above and one below the rotor. A generator with the thrust bearing located above the rotor is referred to as a suspended generator (see Fig 1). A generator with the thrust bearing and a single guide bearing below the rotor is referred to as an umbrella generator (see Fig 2). An umbrella generator with a second guide bearing is referred to as a modified umbrella generator (see Fig 3).

The upper bracket is supported from the stator frame and occasionally requires radial restraint by the generator enclosure. On small generators with their thrust bearing above the rotor, the lower bracket may be integral with or bolted to the stator frame. Otherwise, the lower bracket is supported on its own set of soleplates.

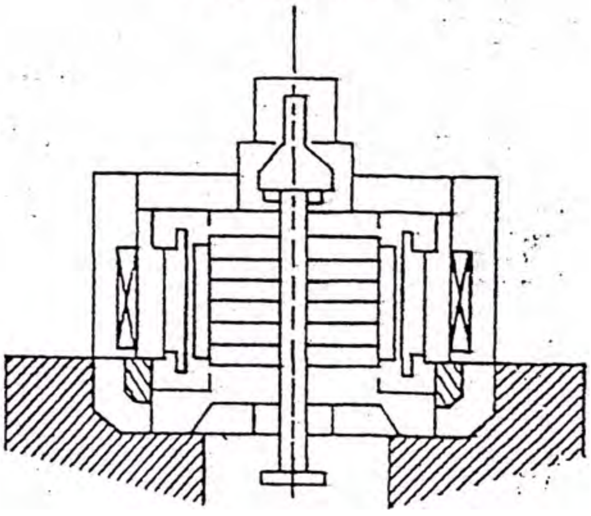
5.2 Stator Construction. The stator frame is usually fabricated from steel plate. Small-diameter stators can be shipped in one piece with the core stacked and the winding installed at the factory. Larger-diameter stators are sectionalized for shipping purposes, the number of sections depending upon shipping limitations, and the sections bolted or welded together at the site.

The sections may be stacked and wound at the factory or at the site, depending on preference or site requirements. If wound at the factory, the coils or bars adjacent to the splits may be shipped separately and the winding completed at the site.

Soleplates, which may have provision for levelling and centering, are grouted into the foundation. On larger diameters, provision is made to permit radial movement between the frame and the soleplates to accommodate thermal effects.

The stator core is composed of electrical grade steel laminations treated with

Fig 1
Suspended Generator



(13) Stator winding tools
(14) Precision measuring tools
(15) Electrical test equipment, including high-potential test sets, kelvin bridge, ohmmeter, megger (500, 1000, 2500 V ranges), voltmeters and ammeters

Craft labor groups are to have personal hand tools available.

3.3 Manufacturer-Supplied Tools. Certain tools will be called for in the customer specification and will be supplied as part of the contract. To be sure of the supply of these tools, the erector should contact the manufacturer and the customer. In most cases, these tools become the property of the customer and are left in good condition after the installation is complete:

(1) Shaft, rotor, and stator lifting devices
(2) Slings of proper length and size for the major lifting operations
(3) Rotor erection pedestal
(4) A plate for supporting the shaft in a vertical position. The plate is anchored in the assembly area concrete floor or in a pit of the proper depth to bring the rotor to a convenient distance above the floor.
(5) Pole and coil lifting device
(6) Thrust-bearing removal equipment
(7) A set of special wrenches and tools

The manufacturer will, in some instances, supply the erector with special erection tools. These tools are to be agreed upon with the customer prior to the start of erection, preferably during contract negotiations, and are not usually considered as part of the normal erection equipment.

3.4 Customer-Supplied Materials, Services, and Facilities. The customer often supplies various erection materials, services, and facilities for the erector. The customer specification will often spell out definite items that will be furnished. The specific responsibilities of each party should be checked for every job. Some typical items are as follows:

(1) Use of powerhouse cranes and crane-lifting beams
(2) Supply of a crane operator
(3) Compressed air
(4) Water
(5) Electric power
(6) Office space and administrative areas
(7) First-aid equipment
(8) Living accommodations for certain people
(9) Oil and oil filtering equipment for bearings
(10) Storage space for erection tools and equipment
(11) Grout
(12) Certain instrumentation
(13) Erection pedestal soleplates
(14) Assembly areas
(15) Security clearance for power plant access

4. Personnel

It is essential to have a crew of skilled workers with sufficient helpers and a supervisor experienced in the installation of vertical hydraulic turbine-driven generators. In addition to electricians and mechanics, workers skilled in pipe fitting, welding, rigging, and coil winding are usually needed.

In cases where the generator manufacturer is given the job of installing the equipment that he furnishes, he will provide a supervisor and all other personnel needed. Otherwise, it is recommended that one of the generator manufacturer's field representatives be employed to provide technical direction of the installation. The representative's familiarity with the construction of the generator and experience in the installation of similar machines are valuable assets.

Close cooperation between the purchaser, the generator manufacturer, exciter manufacturer, turbine manufacturer, governor manufacturer, and any installation contractors involved is necessary to assure proper installation in the most efficient manner. Agreement of the general procedures to be followed should be reached before actual erection begins.

5. Generator Construction

The following paragraphs give a brief description of the construction features of vertical hydraulic turbine-driven generators that have an important bearing on their installation.

5.1 General Arrangement. The basic elements of the generator are the stator (frame,

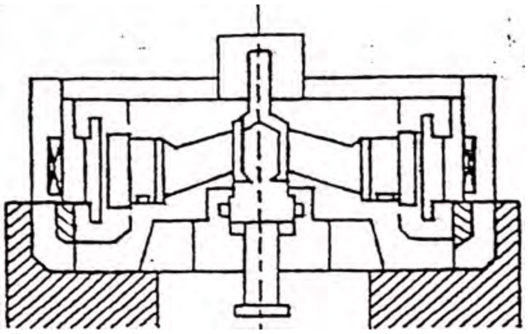


Fig 2
Umbrella Generator

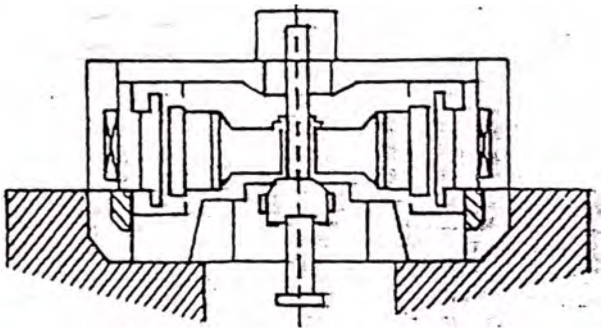


Fig 3
Modified Umbrella Generator

(3) The smooth surface may be on the underside of a circular flat plate or runner which has been precisely machined to have uniform thickness. This runner, which may be one or two pieces, is attached to the underside of the thrust collar or ring and transfers the load to the shoes.

6.5.2 Thrust-Shoe Support. The babbitt-faced thrust shoes are supported in a manner that is designed to equalize the loading between shoes and to allow each shoe to assume the proper position (slight tilt) with respect to the rotating thrust surface to establish and maintain a thin wedge-shaped oil film. The following four different forms of thrust-segment support systems are in general use:

(1) The rigid support, or adjustable-shoe type, in which the shoes are restrained so they do not rotate, but each is free to pivot on the spherical end of a jackscrew that supports it. The jackscrews provide a means of adjusting the height of each shoe individually to obtain equal loading of all shoes. They are also used to adjust the elevation of the rotor and to plumb the shaft. In some cases, measuring devices are permanently located in each jackscrew assembly for direct measurement of the load on the shoe.

(2) The semi-rigid support, or self-equalizing type. These bearings are also designed so that each shoe can pivot on its

insulating enamel and stacked on keybars or core studs attached to the frame. The laminations are clamped in place by means of finger and flange assemblies, with the required clamping pressure applied and maintained with core studs.

The stator winding may consist of single- or multi-turn coils or half-turn bars. Double-layer windings, having two coil sides per slot, are most commonly used. The coils or bars are secured in the stator slots by wedges driven in grooves located at the top of the slots and by side-packing provided separately or integrally with the coil or bar. End windings are braced to restrain movement due to short circuits and to prevent possible downward movement of the stator coils or bars. Temperature detectors are generally installed between coils in a selected number of slots to indicate the temperature of the winding during operation.

5.3 Rotor Construction. The rotor of a small low- or medium-speed generator has a spider, which is generally shrunk on and keyed to the shaft. This spider is usually fabricated such that the hub, web, and rim are a single piece. The rim is a solid steel ring to which the poles are attached by bolts, studs, or dovetails.

Large low- and medium-speed machines have a fabricated spider with a separate rim, which is built up of segmental steel laminations bolted together to form one or several homogeneous rings. This rim is free to expand without constraint from the spider, but it is keyed to the spider periphery for torque transmission and centering. Often the rim is shrunk onto the spider to minimize the differential radial movement between the two structures at some level above rated speed. The field poles are held by dovetails to the laminated rim.

The spider design will vary considerably depending upon the configuration of the shaft and bearing system, the type of ventilation, the machine speed, and the ratio of rotor diameter to axial length.

Large low-speed machines with the thrust bearing above the rotor usually have a continuous shaft through the rotor. In this case, the spider is either shrunk on and keyed to the shaft, or bolted to one or two flanges forged integral with the shaft. Some medium-speed machines may also have this construction.

Large low-speed machines with the thrust bearing below the rotor usually have the main shaft terminating at the underside of the spider hub. The spider hub must be designed for this attachment, which will utilize one or more of the following: fitted bolts, bolts and torque pins, radial keys, or radial dowels.

Large medium-speed machines with large axial length compared to rotor diameter often are built with the spider hub serving as a section of the total shaft system. This construction is most common where the thrust bearing and a guide bearing are below the rotor, and there is need for a second guide bearing above the rotor. The main shaft terminates at the underside of the spider hub. An upper shaft is bolted to the top of the spider hub, thus completing the shaft system between guide bearings.

High-speed generators generally require a rotor spider, which is built up of circular steel laminations, plates, or forgings. The poles are attached to the outer periphery of the spider by dovetails. The spider is shrunk on and keyed to the shaft.

5.4 Shaft and Coupling. The generator coupling is often forged integrally with the shaft. The thrust block or collar, which transmits all vertical forces from the shaft to the thrust bearing, is often forged integrally with the shaft if the thrust bearing is below the rotor. If the thrust bearing is above the rotor, a separate collar is shrunk on and keyed to the shaft.

If the turbine is of the adjustable-blade propeller (Kaplan) type, a hollow generator shaft is required so that oil pipes can be carried through the shaft from the oil head at the top of the generator to the turbine servomotor.

5.5 Thrust Bearing. The thrust bearing carries the combined weight of the rotating parts of the generator and the turbine plus the hydraulic thrust imposed on the turbine runner. Thrust bearings used are the flat-type having segmental, stationary, babbitt-lined shoes.

5.5.1 Thrust Surface. The rotating thrust surface, which transfers load to the shoes, may be any of the following:

(1) A smooth surface on the underside of the integral thrust collar of the main shaft
(2) A smooth surface on the underside of a one-piece thrust collar or ring which is separate from the shaft

5.6 Guide Bearings. If the thrust bearing is located above the rotor, the upper guide bearing may be combined with the thrust bearing, with the outer cylindrical surface of the thrust block or runner acting as the guide-bearing journal. Both bearings operate in the same oil reservoir. In some large machines, however, the guide bearing may be located below the thrust bearing in a separate oil reservoir. If the thrust bearing is located below the rotor, the lower guide bearing is usually combined with the thrust bearing and shares a common reservoir.

Most guide bearings are self-oiled and are designed to pump oil to the upper portion when the lower portion is immersed in oil. The bearings may be of the sleeve type, either solid or split, or of the segmental type. The latter are made up of a number of segments that are independently adjustable in a radial direction to permit convenient adjustment of the bearing clearance.

A guide bearing that is located above the rotor is usually insulated in the manner described in 5.5 for the thrust bearings.

5.7 Brakes and Jacks. The function of the brakes is to bring the rotor to rest after the turbine gates have been closed and to hold it at rest against a small amount of gate leakage. Subject to agreement of the manufacturers, brakes should normally be applied in the range of 15% to 60% of rated speed. Brakes are usually operated by compressed air at a pressure of about 100 lb/in^2.

Brakes may also be used as jacks. When jacking, they are usually operated by oil at a pressure of 1000 to 3500 lb/in^2 by means of a motor-driven or hand-operated oil pump used solely for this purpose. In this case, the header is so arranged that air may be admitted to and released from one end, and oil admitted to and released from the other end. As a safety measure, a blocking device is generally used so that the rotor can be held in the raised position without depending upon the maintenance of oil pressure.

If the turbine is a Kaplan type and flange couplings are used to connect the oil supply pipes to the servomotor, it may be necessary to raise the generator rotor an extra amount by special jacks or other means during assembly to connect the pipe couplings.

The brakes and jacks are usually supported on the lower bracket but, in some cases, the relation between the turbine pit diameter and generator rotor diameter is such that the brakes and jacks can be supported on their own soleplates. If the rotor has a rim of solid metal, this rim may form the braking surface; otherwise, separate segmental brake plates are used.

5.8 Field Assembly Requirements. Most hydraulic turbine-driven generators must be shipped disassembled to keep within the size and weight limitations of transportation and handling facilities. Even when these limitations can be met by an assembled generator, the generator may be shipped disassembled to reduce the possibility of damage during shipment and to facilitate final inspection and cleaning of the unit before operation.

Machines of moderate size may be shipped with the stator, rotor, and bearing brackets separate but with each of these parts completely assembled. With larger machines, however, some or all of these components should be shipped in two or more parts to meet the limitations of transportation facilities. The stator may be shipped in two or more sections.

The sections are bolted or welded together and the windings completed across the joints during installation. For very large machines, stator frames may be assembled at site along with core stacking and winding installation. The rotor may be shipped complete except for the shaft. In this case, the rotor is shrunk on or otherwise attached to the shaft in the field.

The rotors of low-speed machines having cast or rolled steel rims may be split into two parts, which are joined by shrink links during installation. Large machines with laminated rims will have the rim stacked on the spider and the field poles attached at the destination. On large high-speed machines, the spider itself, if built up of laminations or steel plates, may be assembled in the field. If the spider is of fabricated steel construction, it may be shipped in several parts, which must be bolted or welded together during installation.

The bearing brackets, too, may be of such a size that they must be shipped in several pieces, which are bolted or welded together at the destination. In all cases where the machines are not shipped completely assembled, such components as exciters, bearing parts, air support. In most self-equalizing types, these supports consist of systems of interlocking levers that allow small vertical movements of the shoes in order to maintain uniformity of shoe loading.

(3) The semi-flexible support, or spring type. These bearings have relatively thin and flexible babbitted segments, each supported on a bed of closely spaced precompressed springs, or pieces of specially formed metal. This allows each segment to adjust itself to the proper position with respect to the runner while a uniform pressure is maintained on all segments.

(4) Flexible-support type, in which the segments are positioned or restrained by a suitable structure and are mounted for load support on interconnected hydraulic bellows or cylinder devices. The hydraulic interconnection maintains uniformity of shoe load sharing. It should be noted, however, that this type of flexible bearing support has insufficient angular rigidity to maintain a horizontal thrust surface plane. This fact requires that bearings with flexible support mechanisms and, in some cases, even semi-flexible supports, need to have special consideration given to shaft support during erection and when alignment checks are made.

6.5.3 Bearing Lubrication. Thrust bearings operate immersed in a reservoir of lubricating oil. Oil circulates across the bearing by the pumping action of the rotating thrust surface and provides a continually changing oil film between the shoes and the thrust surface. The heat generated in the oil film may be removed by one of the following methods:

(1) For small bearings, the heat may be removed by the flow of machine-ventilating air over the walls of the bearing housing.

(2) In the larger sizes, it is usual to circulate water through cooling coils submerged in the oil in the bearing housing.

(3) The oil may be circulated by a motor-driven pump or by pumping action of the bearing from the bearing housing to an external heat exchanger.

Thrust bearings with high loss density in the oil film, the result of necessary high load pressure or high peripheral speed, may need more cooling than can be obtained by the above methods. Supplementary cooling may be obtained by either of the following methods:

(4) Circulating water through passages located in each shoe. This system requires careful assembly to ensure that there are no leaks in the piping and hoses inside the bearing housing.

(5) Circulating the lubricating oil through passages in the shoes. Either external pump or the self-pumping action of the bearing can be used to force the oil through the passages.

6.5.4 High-Pressure Oil-Lift System. Most large thrust bearings are equipped with a high-pressure oil-lift system. This usually is a packaged unit consisting of one or more motor-driven pumps, motor controls, pressure switches and gauges, strainers, filters, and check valves. Oil is pumped from the bearing reservoir and supplied at high pressure to a special port in each shoe, which is connected to a shaped groove in the central part of the babbitt surface. Before starting the machine, the high-pressure oil is forced between the babbitt and the rotating thrust surface, thereby establishing an oil film. This protects the bearing from possible damage upon initial start and ensures an oil film until the speed is sufficient to maintain the film. Similarly, during unit shutdown the high-pressure oil system is used to prevent damage due to low rotational speeds.

6.5.5 Bearing Insulation. A thrust bearing located above the rotor is usually insulated from its supporting structure to prevent the flow of shaft currents. The latter result from permeance variations in the stator core and tend to flow lengthwise along the shaft, flow out through a bearing on one end of the rotor, and return through the frame and the bearing at the other end of the rotor. Such current flow can be prevented by opening the circuit at any point. It is most convenient to open the circuit above the rotor, which requires insulation of the bearings and all other metallic parts that make contact with the shaft above the rotor. Either a single layer of insulation or a double layer with a metallic component between the two layers may be used. The latter is used to test the dielectric strength of the insulation by applying a voltage between the inner metallic component and the outer metallic parts.

7.3 Matching of Parts. When assembling machines in the field, attention should be paid to all matchmarks. Where more than one unit is being furnished, each machine should be assembled from parts having the same serial number or otherwise identified by the manufacturer as being parts of the same machine.

7.4 Use of Plumb Lines. A plumb line should consist of a steel piano wire attached to a heavy plumb bob. A 0.016 in diameter wire and a plumb bob weighing not less than 35 lb are satisfactory.

Providing fins on the plumb bob and allowing it to hang in a pail of heavy oil will dampen its swings and expedite the work. In use, the plumb line should be protected from all strong air currents.

7.5 Precautions in Welding. A serious hazard to bearings is electric welding on any part of the generator or turbine. A bearing can be damaged very quickly if welding current passes through it.

Whenever possible, all electric welding, especially on the rotating elements or bearing support brackets, should be done before the bearings are assembled. If welding must be done after assembly of the bearings, the following precautions should be observed:

(1) Ensure that the part being welded is connected to station ground grid.

(2) Connect the ground cable from the welder directly to the part being welded and to no other part of the machine.

(3) In the case of uninsulated bearings, separate the stationary and rotating parts. For solid guide bearings, the bearings must be removed. For segmental guide bearings, the segments must be backed off and paper inserted between the journal and the babbitt. For thrust bearings, the rotor should be jacked up. In some designs, if necessary to ensure complete separation, the driving dowels between runner and thrust block can be removed. A solid ground to the generator shaft should be maintained during assembly.

(4) If there is any possibility that a bearing, particularly a thrust bearing, has been subjected to any flow of welding current, it should be inspected before being restored to service.

7.6 Cleanliness. At all times, bearing parts, generator coils, ventilating ducts, exciter commutators, and collector rings should be shielded from dirt and other extraneous material. A special effort should be made to exclude metal chips, filings, weld spatter, or other conducting material from the windings and the rotor.

If construction work is being done, all parts of the generator should be covered where necessary to exclude dust and dirt. In all cases, the generator assembly area must be protected from the weather. In no case should construction work be carried on above the generator without adequate protection to the equipment and workers.

Experience has shown that dirt, small pieces of metal, and other extraneous materials will be left in any area of a hydro machine that is accessible to man. Therefore, the following procedures are recommended:

(1) Machine components should be inspected thoroughly before they are moved into the generator erection area.

(2) Workers should wear coveralls.

(3) Tools and assembly materials should be checked in and out at the appropriate time to ensure nothing has been left in the machine.

(4) Workers in generator erection areas should carry as few personal items as possible in their pockets and, when necessary, should declare personal items upon entry and exit.

(5) Generator erection areas should be cleaned daily.

7.7 Keeping Records. Permanent records should be kept of all settings, clearances, and tolerances established during erection of the generator. Such records are particularly useful if, at a later date, it appears that a change in alignment has occurred. Without adequate records it is difficult to determine the magnitude and cause of the change in alignment and the most suitable remedy.

To retain accurate alignment records, permanent reference plugs should be inserted in the concrete foundation.

8. Receiving, Storing, and Unpacking

8.1 Receiving. Upon receipt of shipment, all materials should be checked against the coolers, air baffles, air housings, etc., are packed separately.

Because it is impractical to duplicate in the factory all of the conditions that will exist at the installation site, it is usually necessary to perform certain machining and fabrication operations in the field in order to assure proper fit and positioning of all parts. This will also correct any minor distortions that occur during shipment or fabrication. Typical of the operations that may be required at site are the following:

(1) Reaming or finish boring of holes for bolts holding a rotor spider to the shaft flanges
(2) Machining of chocks to fit between soleplates and the parts they support
(3) Drilling and reaming of dowel holes
(4) Reaming or finish boring of shaft-coupling bolt holes
(5) Drilling and tapping of holes and welding for mounting of accessories, conduit, piping, etc.

6. Preparation of Generator and Turbine Shafts in Factory

6.1 Factory Preassembly and Alignment. Preassembly and alignment of the combined turbine or generator shafts may be carried out at the factory of either the turbine or generator manufacturer. This procedure requires fitting the coupling bolts and checking the runout. It provides a convenient opportunity to remachine any of the parts or to take other corrective measures to reduce the runout, should this prove necessary.

The method of making the runout check and the recommended runout tolerances are given in 4.1 of ANSI/IEEE Std 810-1987 [6][4].

When the best relative position of the two couplings has been determined, each is matchmarked so that the same relative position can be obtained in field assembly.

It is preferred that the manufacturer making the factory alignment check also provide the coupling bolts, and the manufacturer's representative supervise the closing of the coupling in the field to assure correct assembly.

6.2 Field Alignment. When factory alignment of the combined shafts is not performed, runout checks are made on the individual shafts at the plants of the respective manufacturers. The method of making the runout check and the recommended runout tolerances are given in 4.2 and 4.3 of ANSI/IEEE Std 810-1987 [6]. The coupling bolt holes are drilled undersize for final reaming and fitting of the coupling bolts in the field.

7. Installation Precautions

7.1 Position References. When the unit is properly installed, the turbine runner should be supported in the center of the head cover and bottom ring, and at the proper elevation with respect to the water seal surfaces of these stationary parts. Since the positions of the turbine head cover and bottom ring are fixed before installation of the generator can begin, the resultant position of the turbine coupling must be used as the reference for the location of the generator, irrespective of any previously established center line or elevation.

Prior to erection of the generator, the turbine runner and shaft must be centered properly and supported in a position at a specified elevation (usually 1/4 in to 3/4 in) below the correct operating position. The turbine coupling can then be used to locate the soleplates and other parts of the generator.

7.2 Handling of Generator Parts. Generator components shall be handled carefully to prevent damage to windings and other parts.

When lifting stator frames, the slings should be arranged so that the weight is supported by the lifting bars and not by the reinforcing members of the frame.

Shafts should never be supported on the journal surfaces. With the shaft vertical, rotors may be handled by slings through the spider. Tapped holes in the end of the shaft should not be used to lift a complete rotor, but they are sometimes used to attach a device for handling the shaft only. A lifting trunnion may be used for handling the complete rotor. For machines furnished with a separate thrust collar, the trunnion may fit on the shaft in place of the collar.

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[4] The numbers in brackets correspond to those of the references listed in Section 2.

Table 1
Recommended Storage Location and Maintenance Schedule

Type of Equipment	Storage	
	Outdoor	Indoor
Spider, spider arms, thrust bracket, thrust-bracket arms, upper bracket top plate, upper bracket oil pot, upper bracket arms, air-housing deck, spider baffles, air-housing walls		
Recoat machined surfaces (if necessary)	3*	6
Inspect (general)	1	2
Thrust-bearing shoes, lower guide-bearing shoes, upper guide-bearing shoes, endbell assemblies, thrust-bearing base ring, rim punchings—rotor, misc. hardware, misc. instruments, special tools		
Recoat machined surfaces (if necessary)	N/R†	6
Inspect (general)	N/R	1
Stator frame sections		
Recoat machined surfaces (if necessary)	N/R	6
Megger winding	N/R	2
Inspect (rodent activity—general)	N/R	Weekly
Generator shaft		
Recoat machined surfaces (if necessary)	2	3
Inspect (general)	1	1
Field poles and coils		
Inspect coils (general)	N/R	1
Inspect (rodent activity-general)	N/R	1
Thrust-bearing runner		
Inspect (general)	N/R	2
Transformers, inverter, converter, cyclo-converter, switchgear assemblies, excitation system; reactor assembly, starting [illegible]		
Inspect (general)	N/R	1

* Numbers represent intervals in months between activities.
† N/R indicates location not recommended.

Ventilation is important to proper drying, and heat alone is useful in preventing condensation. A useful guide is to provide 40 W of heat per 1000 lb of material to be kept warm. No heated part should exceed a total temperature of 150 °F.

Machined surfaces are coated with a rust-preventive material before shipment. If there are signs of damage to such surfaces, the protective compound should be removed, the rust and moisture eliminated, and the coating reapplied. Where thrust-bearing runners, bearing, and other highly polished surfaces are involved, the manufacturer should be consulted before any action is taken. As with parts stored outdoors, adequate blocking must be provided when storing parts having close tolerances to prevent distortion of their machined surfaces. All machine surfaces should be given an additional coat of slushing compound for added protection while in storage.

All electric equipment and instrumentation is susceptible to deterioration if allowed to become damp or if exposed to corrosive atmosphere. The equipment should be kept sealed in a packing box with an active desiccant, surrounded by a plastic bag, until it is ready for installation.

The field coils mounted on poles may be stacked two or three high in their packing crates, provided proper precautions are taken to prevent mechanical damage. Space should be available between stacks for air circulation.

It is recommended that the wound stator sections be stored in a manner to protect against moisture and dust. The stator sections should be properly supported off the floor and completely enclosed. All insulated windings should be protected against sweating and freezing by a safe and reliable heating system, which will keep the temperature of the windings above the dewpoint of the surroundpacking lists and assembly drawings for loss or shortage and inspected for damage during transit. Any loss or damage discovered should be reported at once to the carrier, and the carrier's agent should be given an opportunity to make an appropriate investigation. In all cases, copies of reports of damage or loss made to the carrier should be sent to the generator manufacturer. If concealed damage is found after the parts are unpacked, this should be reported in a similar manner.

A thorough inspection for damage to component's packing and protective coatings should be performed. All damaged protective coatings and covers should be repaired. All damaged crates should be opened, inspected, and resealed. All remaining crates should be inspected in sufficient time to obtain replacement parts in the event of shortage or damage. All piping and coverings must be intact.

All material should be placed under adequate cover immediately upon its receipt. Packing cases are not suitable for unprotected storage.

Machines in storage should be inspected and the insulation resistance of windings measured at periodic intervals. Records should be kept and any significant drop in resistance should be investigated. It may prove necessary to increase the heat input to limit the moisture absorption. Such precautions during storage will avoid costly deterioration of parts and an abnormally long dry-out time after installation.

It is important that all parts be stored properly or much time and expense will be incurred due to cleaning and refinishing parts during erection.

8.2 Storing. The following information should enable field personnel to protect the equipment from the time of arrival until the time the machine is assembled. Such protection will increase the chance of a long, reliable service life based on the best possible initial condition when the unit is first placed in service.

In storing generator components, considerations should be given to the following factors:

(1) Protecting from the elements
(2) Preventing moisture condensation
(3) Protecting from dust and dirt
(4) Safeguarding against mechanical damage
(5) Protecting from rodents, insects, and other species that may be able to penetrate the packing

The recommended conditions of storage of parts and the frequency of inspection and extent of testing are given in Table 1. The list of parts is not all-inclusive.

8.2.1 Outdoor Storage. In general, the following practices should be followed for the parts recommended to be stored outdoors:

(1) Storage site selected should be in a well drained area that is not subject to flooding.
(2) Components should rest on timbers at least 6 in above the ground.
(3) No machined surfaces should rest on the blocking. That is, all machined surfaces should be exposed. If this requirement cannot be met, machined surfaces must rest on oil-impregnated paper at the points of contact.
(4) Metal housings should be stored with concave surfaces facing down so that water cannot collect.
(5) All items should be covered with waterproof material (plastic, canvas, etc.) that allows space for air circulation and room for inspection.

Before storing in these conditions, a thorough inspection for damage to components' packing and protective coatings should be performed. All damaged protective coatings and covers must be repaired. Any marks on the finish due to handling and shipping must be repainted. All machined surfaces must be given an additional coat of slushing compound for added protection while in storage.

Parts on which final alignment and running clearances depend are machined to close tolerances. Consequently, adequate blocking must be provided when storing such parts to prevent distortion of their machined surfaces. Large parts such as rotor spiders must be supported to distribute their weight uniformly and thus avoid any permanent deformation.

8.2.2 Indoor Storage. If a well ventilated warehouse is used, the temperature should be maintained at about 15 °F above exterior temperature to prevent moisture condensation. Space heaters used inside the shelter should be kept at least 3 in away from metal and at least 6 in from combustible materials.

9.2 Generator Shipped Completely Assembled

(1) Lift the generator into place on the foundation with the soleplates bolted to the bottom of the machine.

(2) Center the shaft in guide bearings and stator bore; check air gap; and temporarily lock in place.

(3) Adjust elevation and horizontal position of soleplates (see 10.2) until the generator coupling is in alignment with the turbine coupling and at the correct elevation. Tighten foundation bolts.

(4) Close the generator-turbine coupling (see 10.10) and check the elevation of the turbine runner.

(5) Make shaft-plumb and straightness check (see 10.11) where the design of the machine permits, and recheck centering of shaft in guide bearings.

(6) Grout the soleplates (see 10.2).

(7) Dowel generator to soleplates (unless predoweled).

9.3 Generator Assembled in the Field, Thrust Bearing Above the Rotor, Spring-Type or Self-Equalizing-Type Thrust Bearing

(1) Place the soleplates for the stator frame and for the lower bracket (if it is not integral with or bolted to the stator frame) in position over the foundation bolts, and adjust them to a level position (perpendicular to the stator plumb) at approximately the correct elevation. Temporarily tighten foundation bolts. (For grouting, see 10.2.)

(2) Place the assembled lower bracket into position on its soleplates and install hold-down bolts.

(3) Place the stator on its soleplates and install hold-down bolts; if the stator is sectionalized, close the joints in the frame and complete the stator winding across the joints (see 10.3).

(4) Adjust the elevation of soleplates (see 10.2) until the top surface of the stator frame is level and at the correct elevation. Also, check to see that the stator forms a true circle and make any necessary adjustments. Assembly of air coolers and any internal wiring and piping (see 10.7) can usually start at this time.

(5) Place the assembled upper bracket on the stator frame and shim under ends of arms until the thrust-bearing supporting surface is level and at the correct elevation.

(6) Suspend a plumb line from the upper bracket to the turbine shaft, centering the line with respect to the upper guide bearing fits. Shift the bracket on the stator to center the plumb line in the stator core, and temporarily dowel the bracket to the frame to facilitate reassembly.

(7) Center the assembly of the stator and upper bracket to the turbine shaft and recheck roundness.

(8) Adjust the elevation and position of soleplates supporting the lower bracket (see 10.2) until the guide-bearing support is at the proper elevation and is centered with respect to the turbine shaft; then tighten the lower bracket foundation bolts (omit this step when lower bracket is integral with or bolted to the stator frame).

(9) Remove the upper bracket and lower the assembled rotor (see 10.4) into the stator, resting the rotor on the jacks or, where they are provided, on special blocks.

(10) Replace the upper bracket and assemble the thrust bearing (see 10.5) and thrust block.

(11) Lower the rotor so that the weight of the rotor is transferred to the thrust bearing and check thrust-bearing insulation (see 10.9).

(12) Check to see that the rotor is approximately centered axially with respect to the stator core. Allowance should be made for deflection in the bearing bracket, which will result from the weight of turbine rotating parts and hydraulic thrust.

(13) Check the elevation and alignment of the generator coupling with the turbine coupling and make adjustments, if necessary. Allow for deflection of the bearing bracket.

(14) Close the generator-turbine coupling (see 10.10) and check the elevation of the turbine runner.

(15) Perform shaft-plumb and straightness check (see 10.11) and make necessary adjustments.

ing air. About 40 W/1000 lb may be sufficient if the heat is applied inside the enclosure. If the storage area ambient temperature has a variance of more than 5 °F in one day, additional heating may be needed.

The electrical condition of the stator sections should be monitored using a 2500 Vdc megger. The insulation resistance should be measured for a period of 10 min. Records should be kept and any significant drop in resistance should be investigated. The polarization index of the stator insulation should not be allowed to fall below two (2).

The generator shaft should be inspected to determine that the bearing journal and thrust face are free from moisture. Following the inspection of this area, the rust-preventive compound should be reapplied if necessary. It is also recommended that the shaft be lifted after three months of storage, the support area inspected, and rust preventive reapplied if necessary.

Since the shaft is machined to very close tolerances, adequate blocking shall be provided to prevent distortion. Supports should not be placed under journal surfaces, nor should wood supports be in direct contact with the shaft. Protection should be provided with oil-impregnated paper at the points of contact.

8.3 Unpacking. Upon unpacking, the contents of all boxes should be checked against the manufacturer's packing list. If windings or parts with machined surfaces have been exposed to low temperature, their coverings should not be removed until they have been warmed to approximately the temperature of the room where they will be unpacked.

Rust-preventive coatings on machined surfaces should not be removed until the parts are to be installed. The solvent used should be one specified by the generator manufacturer. In no case should any abrasive material, such as sandpaper or metallic scrapers, be used to remove the rust-preventive coatings.

After the finished surfaces have been thoroughly cleaned, any burrs or bumps received in shipping or handling should be removed with a fine file, scraper or stone, except where highly polished runners, bearing journals, etc., are involved. In the latter case, the manufacturer should be consulted for specific instructions.

9. Erection Procedures

9.1 General. The erection procedures described herein are those that will generally prove most satisfactory. Special circumstances, however, may arise in any installation that make it desirable to depart somewhat from these procedures.

The erection procedure for generators which are shipped completely assembled differ from that for machines which are assembled in the field. Furthermore, field-assembled generators require a somewhat different erection procedure if the thrust bearing is located above the rotor than they do if it is located below the rotor. Finally, the procedure for field-assembled machines having a spring-type or self-equalizing-type thrust bearing differs from that for machines having an adjustable-shoe-type thrust bearing. Hence, the five cases for which this section is applicable are as follows:

(1) Generator shipped completely assembled (see 9.2)
(2) Generator assembled in the field, thrust bearing above the rotor, spring-type or self-equalizing-type thrust bearing (see 9.3)
(3) Generator assembled in the field, thrust bearing above the rotor, adjustable-shoe-type thrust bearing (see 9.4)
(4) Generator assembled in the field, thrust bearing below the rotor, spring-type or self-equalizing-type thrust bearing (see 9.5)
(5) Generator assembled in the field, thrust bearing below the rotor, adjustable-shoe-type thrust bearing (see 9.6)

The step-by-step erection procedures for these five cases are outlined in 9.2 through 9.6. More detailed information on certain steps in the erection procedures is given in Section 10. Some generator components must be assembled in the erection bay before they are incorporated into the final assembly in the generator pit. Such subassembly work should be scheduled properly so that it will fit into the final erection procedure, which is outlined in 9.2 through 9.6. Ample time should be allowed for major operations, such as the field assembly of a generator rotor and stator stacking and winding.

In all cases, the foundation bolts are placed in position while the forms for the concrete foundations are being built (see 10.1).

(7) Replace the upper bracket and assemble the thrust bearing (see 10.5) and thrust block.

(8) Lower the rotor so that the weight of the rotor is transferred to the thrust bearing and check thrust-bearing insulation (see 10.9).

(9) Check to see that the rotor is approximately centered axially with respect to the stator core.

(10) Adjust the thrust-bearing jackscrews until the generator coupling face is at the correct elevation and parallel with the turbine-coupling face. Shift the generator rotor horizontally until the two couplings are in alignment.

(11) Close the generator-turbine coupling (see 10.10) and check the elevation of the turbine runner.

(12) Perform shaft-plumb and straightness check (see 10.11), and make necessary adjustments.

(13) Center the turbine runner and establish trammel points at all guide bearings (including the turbine guide bearing) in cooperation with the turbine erector.

(14) Check the thrust-bearing shoes for uniformity of loading and make necessary adjustments (see 10.12).

(15) Check the shaft runout by rotation check method 1 (10.1.1.1) if this method is selected and is applicable (see 10.13). In this case, the upper guide bearing should first be installed or other provision made to prevent excessive side slip during rotation of the shaft.

(16) Check the axial position and centering of the lower guide-bearing support and make necessary adjustments in the position and elevation of the lower bracket. (Omit this step when lower bracket is integral with or bolted to the stator frame.)

(17) The thrust-bearing oil coolers may be installed at this time following final inspection (see 11.2) depending on the generator manufacturer's recommendations.

(18) Install the upper guide bearing (unless already installed) and then the lower guide bearing (see 10.6). (The turbine guide bearing should be installed.) If the bearings are of the sleeve type, check the clearances all around the journal and, if necessary, re-center the bearing support or bracket or both. If segmental-type bearings are used, adjust each segment to the correct clearance. Check the trammel points at the turbine guide bearing after installing each bearing to make sure that the shaft has not shifted. Also, check the insulation of the upper guide bearing (see 10.9).

(19) Install rotating exciters (if provided), collector rings, and brush rigging (see 10.14), and complete the internal wiring to these devices.

(20) Check air gap for uniformity (see 10.8).

(21) Dowel the upper bracket to the stator frame and dowel the stator frame (and lower bracket when it is not integral with or bolted to the stator frame) to the soleplates. This doweling must not prevent thermal differential expansion of components.

(22) If not done previously, grout the soleplates (see 10.2).

(23) Install enclosing air shrouds, covers, stairs, handrails, etc., if provided.

(24) After complete assembly of all parts (including turbine and governor parts) that are located above the generator rotor, check the insulation of all possible paths for shaft current (see 10.9).

9.5 Generator Assembled in the Field; Thrust Bearing Below the Rotor, Spring-Type or Self-Equalizing-Type Thrust Bearing

(1) Place the soleplates for the stator frame in position over the foundation bolts, and adjust them to a level position at approximately the correct elevation. Temporarily tighten foundation bolts. (For grouting, see 10.2.)

(2) Place the soleplates for the lower bracket in position over the foundation bolts, and adjust them to a level position at approximately the correct elevation. Tighten foundation bolts. (For grouting, see 10.2.) (This step in the erection procedure does not apply, of course, if the soleplates are embedded in the foundation.)

(3) In the erection area, assemble together the lower bracket, shaft, thrust bearing, and lower guide bearing (see 10.5 and 10.6). If the guide bearing is of the

(16) Center the turbine runner and establish trammel points at all guide bearings (including the turbine guide bearing) in cooperation with the turbine erector.

(17) Check the shaft runout by rotation check method 1 (15.1) if this method is selected and is applicable (see 10.13). In this case, the upper guide bearing should first be installed or other provision made to prevent excessive side slip during rotation of the shaft.

(18) Check the axial position and centering of the lower guide bearing support and make necessary adjustments in the position and elevation of the lower bracket. (Omit this step when the lower bracket is integral with or bolted to the stator frame.)

(19) The thrust-bearing oil coolers may be installed at this time following final inspection (see 11.2) depending on the generator manufacturer's recommendations.

(20) Install the upper guide bearing (unless already installed) and then the lower guide bearing (see 10.6). (The turbine guide bearing should now be installed.) If the bearings are of the sleeve type, check the clearances all around the journal and, if necessary, re-center the bearing support or bracket or both. If segmental-type bearings are used, adjust each segment to the correct clearance. Check the trammel points at the turbine guide bearing after installing each bearing to make sure that the shaft has not shifted. Also, check the insulation of the upper guide bearing (see 10.9).

(21) Install rotating exciters (if provided), collector rings, and brush rigging (see 10.14), and complete the internal wiring to these devices.

(22) Check air gap for uniformity (see 10.8).

(23) Dowel the upper bracket to the stator frame and dowel the stator frame (and lower bracket, when not integral with or bolted to the stator frame) to the soleplates. This doweling must not prevent thermal differential expansion of components.

(24) If not done previously, grout the soleplates (see 10.3).

(25) Install enclosing air shrouds, covers, stairs, handrails, etc., if provided.

(26) After complete assembly of all parts (including turbine and governor parts) that are located above the generator rotor, check the insulation of all possible paths for shaft current (see 10.9).

9.4 Generator Assembled in the Field, Thrust Bearing Above the Rotor, Adjustable-Shoe-Type Thrust Bearing

(1) Place the assembled lower bracket in position on the foundation with the bracket arms bolted to the soleplates. Bring the bracket to the correct elevation and center the bracket to the turbine shaft with a plumb line. For grouting of the lower bracket soleplates, see 10.2. Final centering of the bracket will be done later by removing the pipe spacers from around the bracket hold-down bolts and moving the bracket on its soleplates. (Omit this step when lower bracket is integral with or bolted to the stator frame.)

(2) Place the stator soleplates in position and set them to the correct elevation, angle, and radius. (For grouting, see 10.2.) The lower bracket is a working platform for this operation.

(3) Place the stator on its soleplates and install hold-down bolts; if the stator is sectionalized, close the joints in the frame and complete the stator winding across the joints (see 10.3).

(4) Adjust the elevation of soleplates (see 10.2) until the top surface of the stator frame is level and at the correct elevation. Also, check to see that the stator forms a true circle and make any necessary adjustments. Assembly of air coolers and any internal wiring and piping (see 10.7) can usually start at this time.

(5) Place the upper bracket on the stator. Center the stator and upper guide bearing fit to the turbine shaft. Install temporary dowels in the upper bracket arms.

(6) Remove the upper bracket and lower the assembled rotor (see 10.4) into the stator, resting the rotor on the jacks or, where they are provided, on special blocks.

9.6 Generator Assembled in the Field, Thrust Bearing Below the Rotor, Adjustable-Shoe-Type Thrust Bearing

(1) Some of the generators of this type are designed so that the shaft and thrust-bearing assembly can be placed through the top of the lower bracket after the bracket has been set on the foundation. For machines of this type, the procedure for setting the lower bracket and stator can be identical to the method used on adjustable shoe bearings with the thrust bearing above the rotor.

(2) Place the assembled lower bracket in position on the foundation with its soleplates bolted to the bracket arms. Bring the bracket to the correct elevation and center the bracket to the turbine shaft with a plumb line. (For grouting of the lower bracket soleplates, see 10.2.) Final centering of the bracket will be done later by removing the pipe spacers from around the bracket hold-down bolts and moving the bracket on its soleplates.

(3) Place the stator soleplates in position and set them to the correct elevation, angle, and radius. (For grouting, see 10.2.) The lower bracket is a working platform for this operation.

(4) Place the stator on its soleplates and install hold-down bolts; if the stator is sectionalized, close the joints in the frame and complete the stator winding across the joints (see 10.3).

(5) Thrust-bearing parts can be preassembled around the shaft and this assembly can be placed in the lower bracket.

(6) On machines where the shaft and thrust bearing cannot be assembled through the top of the lower bracket, it will be necessary to preassemble the shaft and bearing in the bracket and place this as a unit on its foundation; otherwise, the procedure is as outlined in steps 2 to 5, inclusive.

(7) Adjust the elevation of the lower bracket and shift its position until the generator coupling is at the correct elevation and is in alignment with the turbine coupling. Fine elevation adjustment may be accomplished by use of the thrust-bearing jackscrews.

(8) Close the generator-turbine coupling (see 10.10) and check the elevation of the turbine runner.

(9) Perform shaft-plumb and straightness check (see 10.11) and make necessary adjustments.

(10) Center the turbine runner and establish trammel points at all guide bearings (including the turbine guide bearings) in cooperation with the turbine erector. If not done previously, grout the lower bracket soleplates (see 10.2).

(11) Adjust the elevation of the stator until the top surface of the frame is level and at the correct elevation. Also, check to see that the stator forms a true circle and make any necessary adjustments. Center the stator around the shaft and tighten the stator foundation bolts. Assembly of air coolers and any internal wiring and piping (see 10.7) can usually start at this time.

(12) Install the assembly of rotor spider, rim, and poles on the shaft (see 10.4).

(13) Replumb the shaft with the rotor weight supported by the thrust bearing.

(14) Check the thrust shoes for uniformity of loading and make necessary adjustments (see 10.12).

(15) Check the shaft runout by rotation check method 1 (15.1.1.1) if this method is applicable (see 10.13).

(16) Check to see that the rotor is approximately centered axially with respect to the stator core and, if not done previously, grout the stator soleplates (see 10.2).

(17) Install the assembled upper bracket and center it to the shaft.

(18) If an upper guide bearing is provided, align and axially locate its support. Also, establish trammel points at the upper guide bearing.

(19) Adjust the clearance of the lower guide bearing. The thrust-bearing oil coolers may be installed at this time or following final inspection (see 11.2) depending on the generator manufacturer's recommendations.

(20) Install and adjust clearance of the upper guide bearing, if an upper guide bearing is provided. (The turbine guide bearing should also be installed at this time and its clearance adjusted.)

segmental type, tighten four segments against the journal to keep the shaft in position. Perform the necessary fitting of any thermal devices in the bearings and oil reservoir (see 10.15).

(4) Place the lower bracket assembly in its approximately correct location on the soleplates. If the soleplates were not grouted (step 2) or embedded in the foundation, install the lower bracket hold-down bolts.

(5) Place the stator on its soleplates and install hold-down bolts; if the stator is sectionalized, close the joints in the frame and complete the stator winding across the joints (see 10.3).

(6) Adjust the elevation of the lower bracket and shift its position until the generator coupling is at the correct elevation and is in alignment with the turbine coupling.

(7) Close the generator-turbine coupling (see 10.10) and check the elevation of the turbine runner.

(8) Perform shaft-plumb and straightness check (see 10.11) and make necessary adjustments.

(9) Center the turbine runner and establish trammel points at the generator lower guide bearing and at the turbine guide bearing (in cooperation with the turbine erector).

(10) If the lower bracket soleplates were grouted (step 2) or embedded in the foundation, fit and install chocks between the bracket arms and soleplates when they are required, and install hold-down bolts. Otherwise, tighten the foundation bolts and grout the lower bracket soleplates (see 10.2).

(11) Recheck the shaft plumbness and centering of the turbine runner and make any necessary adjustments.

(12) Adjust the elevation of the stator soleplates (see 10.2) until the top surface of the frame is level and at the correct elevation. Also, check to see that the stator forms a true circle and make any necessary adjustments. Center the stator around the shaft and tighten stator foundation bolts. Assembly of air coolers and any internal wiring and piping (see 10.7) can usually start at this time.

(13) Install the assembly of rotor spider, rim, and poles on the shaft (see 10.4).

(14) Replumb the shaft with the rotor weight supported by the thrust bearing.

(15) Check the shaft runout by rotation check method 1 (13.1.1.1), if this method is selected and is applicable (see 10.13).

(16) Check to see that the rotor is approximately centered axially with respect to the stator core and, if not done previously, grout the stator soleplates (see 10.2).

(17) Install the assembled upper bracket and center it to the shaft.

(18) If an upper guide bearing is provided, align and axially locate its support. Also, establish trammel points at the upper guide bearing.

(19) Adjust the clearance of the lower guide bearing, then install any thermal devices in the thrust bearing and oil reservoir. The thrust-bearing oil coolers may be installed at this time or following final inspection (see 11.2), depending on the generator manufacturer's instructions.

(20) Install and adjust clearance of the upper guide bearing, if an upper guide bearing is provided. (The turbine guide bearing should also be installed at this time and its clearance adjusted.) Recheck the trammel points to be sure the shaft has not shifted.

(21) Check the insulation of the upper guide bearing, if provided (see 10.9).

(22) Install rotating exciters (if provided), collector rings, and brush rigging (see 10.14), and complete the internal wiring to these devices.

(23) Check air gap for uniformity (see 10.8).

(24) Dowel the upper bracket to the stator frame, the stator frame to the soleplates, and the lower bracket to the soleplates. This doweling must not prevent thermal differential expansion of components.

(25) Install enclosing air shrouds, covers, stairs, handrails, etc., if provided.

(25) After complete assembly of all parts (including turbine and governor parts) that are located above the generator rotor, check the insulation of all possible paths for shaft current (see 10.9).

the stator is placed in position on the soleplates and bolted to the adjacent section. The sections are then carefully aligned so that the cores match at each split. The manufacturer should specify the procedure to use and the tolerances required in making up the splits.

Stators that are to be stacked and wound at the site generally have had the core studs and the keybars on which the core laminations are stacked installed at the factory.

Each stator frame section is placed in position on the soleplates and bolted to the adjacent section. On stators equipped with radial keying systems, care should be taken to ensure that the frames are not welded to the soleplates as this will defeat the purpose of the keying system, which is to permit radial freedom of the stator. On stators equipped with radial support rods, care should be taken that the frame is free to expand and contract along the clearance provided by the connecting structures and the rods are positioned to allow equal in and out movement after the stator and rotor centers have been adjusted. The frame is then centered by measurements taken from a center wire, referenced to the center line of the turbine, to the keybars. Centering screws are usually provided to facilitate the line-up.

The frame should be checked to ensure that it is level, at the correct elevation, and round within tolerances specified by the generator manufacturer. Keybars should be checked for verticality, and those adjacent to the joints should have their chordal dimensions checked against the chords of the remaining keybars.

When the stator frame has been thus set up and assembled, it is made ready for the stacking of the core and the assembly of the winding. Both operations are intricate in nature and should be carried out under close supervision by the generator manufacturer's erection supervisor. Close attention must be paid to cleanliness and every effort made to provide and maintain the proper working conditions.

If stacking and winding are performed in the erection bay instead of in the generator pit, the finished stator should be positioned in the pit with level, elevation, verticality and concentricity referenced to the stator core by several measurements around the periphery.

The installation and connection of the stator coils at the joints can start as soon as the joints are aligned and can continue while other work is being done, until the rotor is placed in the machine. In some cases, the lower bracket may be placed temporarily in position and used as a base for the winding platform. The procedures recommended by the generator manufacturer should be followed. The work should be done, under the technical direction of the manufacturer's representative, by winders who have had experience in winding large generators.

After the coils are in the slots but before connections are made, the newly installed coils and those that have been disturbed should be given a high-potential test in accordance with the recommendation of the generator manufacturer, or as agreed upon with the customer.

Coil connections should be made in accordance with the connection diagram furnished by the generator manufacturer. The materials and methods used to complete the insulation of the machine should also be in accordance with instructions provided by the generator manufacturer.

10.4 Assembly of Rotor.

The procedure to be followed in the assembly of a generator rotor will vary considerably for the different designs and should be specified by the generator manufacturer. However, the following suggestions are generally applicable:

10.4.1 Shrinking of Rotor Spider on Shaft[4]

The spider bore and the shaft diameter should be compared at the same temperature to make sure that the proper interference fit will be provided. The key dimensions should be checked and all burrs and sharp corners removed. Both keyways should be checked for straightness and parallelism. Finally, it is desirable to lubricate the keys and keyway with a mixture of graphite and machine oil before assembly.

The shaft should be in a vertical position when the spider is shrunk onto it to minimize the shaft distortion due to uneven cooling. The spider should be heated in an oven or temporary enclosure by suitable heaters. The heating should be done slowly and evenly to

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[4] In heat shrinking a rotor spider to a shaft, the possibility exists that the shaft may be distorted. It is recommended that, whenever possible, this assembly procedure be done at the factory so that heat straightening and machining of the thrust collar and bearing journal surfaces may be performed as required.

Recheck the trammel points to be sure the shaft has not shifted.

(21) Check the insulation of the upper guide bearing, if provided (see 10.9).

(22) Install rotating exciters (if provided), collector rings, and brush rigging (see 10.14), and complete the internal wiring to these devices.

(23) Check air gap for uniformity (see 10.6).

(24) Dowel the upper bracket to the stator frame, the stator frame to the soleplates, and the lower bracket to the soleplates. This doweling must not prevent thermal differential expansion of components.

(25) Install enclosing air shrouds, covers, stairs, handrails, etc., if provided.

(26) After complete assembly of all parts (including turbine and governor parts) that are located above the generator rotor, check the insulation of all possible paths for shaft current (see 10.9).

10. Details of Erection Procedures

10.1 Placing of Foundation Bolts. The proper size and the location of the foundation bolts are shown on the generator outline drawing. Most foundation bolts are coaxial assembly of a long rod threaded at both ends and a pipe sleeve 1 or 2 in larger in diameter than the rod. A nut at the lower end supports a square plate, which in turn supports the pipe sleeve. The sleeve is welded to the plate, and the nut is welded to both the plate and the rod (bolt).

A metal template or jig should be used to assure accurate positioning of the bolt assemblies while the foundation is being poured. Until the soleplates are grouted, concrete and other foreign matter should not be allowed in the space between the sleeve and the bolt because this would prevent the small lateral movement of the bolt often necessary when the soleplates and machine parts are finally positioned.

Alternatively, tapered rectangular pockets, which are larger at the lower end, may be formed in the foundation at the foundation bolt locations. Later the foundation bolts can be grouted into these pockets, after the soleplates are positioned. The foundation bolt assemblies should be left unpainted to provide a better bond with the concrete.

10.2 Positioning and Grouting of Soleplates. Soleplates are often positioned by being bolted to the part that they support (stator frame or lower bracket) before being grouted so that proper positioning of the part brings the soleplates to the correct location. The holes for the hold-down bolts are usually drilled oversize to allow some adjustment of the position of the supported part after the soleplates have been grouted. Initially, the bolts should be centered in the holes. This is conveniently accomplished by placing sleeves of proper dimensions in the bolt holes. Sometimes, it is advantageous to locate accurately and grout the soleplates before the supported part is brought into position.

The elevation of the soleplates may be adjusted by means of jackscrews, sliding parallels, or double parallel wedges. In the case of the stators of large machines, convenient adjustment of the elevation is possible if provision is made in the foundation so that a jack can be placed alongside each soleplate to raise and lower the stator with the soleplates attached. After a soleplate has been brought to the correct elevation, it can be supported in this position by flat plates or shims. In all cases, the soleplates must rest on a support that is substantial enough to carry the total vertical loading until the soleplates are grouted.

After final positioning, chocks, if required, are machined to fit accurately into the space between each soleplate and supported part.

During the erection procedure, grouting of the soleplates should be done at the time specified by the generator manufacturer. Before grouting soleplates, the base mass of concrete should be thoroughly cleaned. The surface should be roughed up by chipping, then wetted and slurried. A stiff, fine grout should then be forced into the space around and under the soleplate, making sure that every crevice is filled. The use of vibrators for distributing the grout is not recommended, since their use may disturb the alignment of the soleplates.

Sufficient space must be allowed for installing any radial dowels as shown on the generator outline drawing or in accordance with the generator manufacturer's instructions.

10.3 Assembly of Stator. If the stator that has been stacked and wound at the factory is shipped in two or more sections, each section of flange. Either a tram mounted to the shaft or a wye level may be used.

It is important that iron-to-iron contact be obtained between the pole core and the spider rim for the full length of the pole; otherwise, the pole may loosen after a short period of operation and cause fatigue failure of the pole fastening. Hence, before the poles are installed, the spider surface and the base of the pole should be cleaned and deburred. If the poles are attached by means of dovetails, the bearing surface of the dovetails, the spider slots, and the keys should also be cleaned and deburred. The corners of the keys should be inspected and filed, if necessary, to make sure they will fit within the radius of corners of the dovetails and rim slots. Finally, each pole should be checked for correct seating on the rim of the generator rotor. The field pole bottom (base) collar should not interfere with the seating of the pole on the rim. If there is any question, the pole can be installed without the bottom collar and a measurement taken to the top of the pole from the shaft or rim surface. The pole is then removed and reinstalled with the collar in place and the same measurement taken. The dimension should be the same. Another method for checking the correct seating of a pole is to fully tighten the pole and then heat the coil by passing current through it. If the pole was loose, it can be tightened further after it has cooled. A loose pole must be removed or the bottom collar trimmed until the pole seats firmly.

For the mounting of dovetail poles, the generator manufacturer's instructions for installing the keys should be followed with respect to the use of proper lubricant, designation of drive-in and drive-out keys, necessity for redriving keys, ultimate tightness of pole, removal of excess key length, and installation of locking plates over the dovetail slots.

For poles that are held in place by radial bolts or studs (bolted poles), the bolts should be tightened in accordance with the generator manufacturer's instructions.

After the poles are installed, the field winding should be checked for correct polarity, uniformity of field-coil impedance or ac voltage drop, grounds, open circuits, resistance, and high-resistance joints.

10.4.4 Bolting of Rotor Spider to Shaft. Rotor spiders, which are bolted to the end of the generator shaft or to shaft flanges, are generally held by circles of close-fitting bolts or dowels. The bolt holes in the spider and shaft may be drilled undersize in the factory. During assembly, after the rotor is lowered onto the shaft, the bolt holes are reamed or finish-bored to the proper size. The details of the procedure to be followed in this assembly operation should be specified by the generator manufacturer.

10.5 Assembly of Thrust Bearings. Each of the different designs of thrust bearings requires a somewhat different assembly procedure, which should be specified by the generator manufacturer. In all cases, however, cleanliness and careful workmanship are extremely important.

A bearing can easily be ruined by even a little lint or dirt. Consequently, precautions should be taken during assembly of the bearing to avoid the presence of dust and dirt by eliminating other construction work above and in the vicinity of the generator.

Finally, before assembly, all parts of the bearing, bearing housing, and oil reservoir should be inspected to ensure absolute freedom from dirt, lint, or other foreign matter. Any rags used around a bearing should be free of lint (never use cotton waste). Lint-free paper towels are an excellent choice. The bearing oil coolers should be given a hydrostatic test.

After assembly, the thrust bearing should be kept covered to exclude dust and dirt. The oil reservoir should be filled with clean filtered lubricating oil, or the bearing otherwise protected in accordance with the generator manufacturer's recommendations to prevent corrosion.

10.6 Assembly of Guide Bearings. The precautions outlined in 10.5 to keep dirt, lint, and other foreign matter out of the thrust bearing should also be observed in connection with the guide bearings.

Sleeve-type bearings, either solid or split, are not adjustable. Therefore, if the bearing clearances differ appreciably from those shown on the generator manufacturer's assembly drawing or instruction book, the manufacturer should be consulted. If it is necessary to scrape a bearing in the field, it should be done only by someone with considerable experience in the installation of bearings.

prevent distortion. The oven temperature should not exceed 250 °C for a rotor without poles. The shrinking operation should be performed before the poles are attached; otherwise, the temperature should not exceed 100 °C. With an interference fit of 1/2 mil/in of diameter, a temperature difference between the spider and shaft of approximately 75° to 100 °C is required.

To determine that the correct clearance has been obtained, the hot rotor bore should be checked with a micrometer or pin gauge that is at the same temperature as the shaft. After the rotor spider has been properly positioned on the shaft, air should be blown against the side of the spider that is next to the shaft shoulder so that the spider will cool and cairn on this side first and not pull away from the shoulder as it cools.

If the spider consists of more than one axial section, the sections may be shrunk on one at a time. Alternatively, the sections may be lined up when cold and the heat applied while they are supported in a position around the shaft above the fit.

After the oven has been removed and without disturbing the spider, the shaft is pulled up through the spider bore by the crane to the correct position. The shaft-lifting device provided must be suitable for lifting the total weight of the shaft and spider. With either method of assembly, it is essential that the dovetail slots to the poles on the periphery of the spider be kept in alignment. This can be accomplished by the use of several aligning bars in these slots.

There is always some danger of the rotor seizing on the shaft before it reaches the proper location. Therefore, arrangements should be made beforehand for quick disassembly if it should prove necessary. A trial lift with the spider cold is also desirable to mark the final crane position for quicker action with the hot spider.

10.4.2 Assembly of Laminated Rim. If the thrust bearing is above the rotor, the rotor and shaft are usually assembled together in the erection area and handled as a unit. Hence, provision must be made to support the shaft from the coupling in a vertical position for assembly of the spider and laminated rim. On the other hand, if the thrust bearing is below the rotor, the rotor and shaft are usually handled separately, the rotor being assembled independently of the shaft. This means that steel blocking (or an erection pedestal) should be provided in the erection area for the support of the rotor at its center.

In any case, the central support should be capable of carrying the weight of the completed assembly. The height should be such that the bottom of the spider assembly is about 2 ft from the floor. The floor at the ends of the arms must be able to support the full weight of the rim and poles.

The rotor spider, generally of fabricated construction, is installed on the shaft or attached to the central support. If it was shipped in several parts, the parts should be assembled in accordance with the generator manufacturer's instructions.

The rotor spider with the brake plates attached should be leveled, and blocking should be installed for supporting the ends of the spider arms and the rim at the correct elevation. A check should be made after each pressing of the punchings to make sure that the rim is being assembled in a horizontal plane and at right angles to the axis of the shaft.

Accurate positioning and alignment of the rim laminations must be maintained as they are stacked. This may involve the use of temporary keys, assembly pins, or shims as recommended by the generator manufacturer. Each layer of laminations should be seated by tapping with a heavy mallet, and the stack may be pressed at intervals of 12 to 20 in as the rim is assembled.

After the stacking is complete, the rim studs should be tightened in the pattern and to the tension specified by the generator manufacturer. After final tightening, the stud nuts are locked by welding.

The method of installing the rim drive keys varies with the design and should be specified by the generator manufacturer.

In designs requiring the rim to be shrunk onto the spider, the procedure should be in accordance with the generator manufacturer's instructions.

10.4.3 Field Pole Assembly. All poles should be located so that their centers are in the same plane at right angles to the shaft and coinciding, as nearly as possible, with a plane through the center of the stator core. Proper axial location of the poles can be checked by measurements taken from a machined surface on the shaft, such as a shoulder or should be assembled so that these points will be 180 degrees apart.

If the hydraulic turbine is of the adjustable-blade propeller (Kaplan) type, the arrangement may be such that, before the coupling is closed, the generator rotor (or the shaft and the attached thrust-bearing runner) is raised sufficiently to make connections to the oil pipes that supply oil to the blade servomotor. The generator rotating assembly is then lowered so that the weight is transferred back on to the thrust bearing.

Before drawing the couplings together, their mating surfaces must be in alignment, parallel, clean, and free from burrs. The coupling must be drawn up evenly to prevent distortion.

After the couplings have been drawn together, the bolt holes must be reamed or finish-bored (unless this has already been done in a factory assembly) to fit the permanent bolts. The fit of the bolts should be in accordance with ANSI/IEEE Std 810-1987 [6], unless otherwise specified by the generator manufacturer. The bolts must be tightened evenly in accordance with the manufacturer's instructions.

10.11 Shaft-Plumb and Straightness Check. This is a plumb-wire check of the straightness and plumbness of the combined generator and turbine shafts. The use of four plumb lines spaced 90 degrees apart around the shaft is recommended. The readings should be taken from the same points on each shaft that were used during the factory runout check. The shaft assembly shall be considered to be straight when no runout check point (correlated for diameter variations) deviates more than 0.003 in from a straight line joining the top and bottom points. The shaft assembly shall be considered to be plumb when the top and bottom points do not deviate from plumb by more than 1/4 mil/ft of shaft length.

10.12 Equalizing the Load on Adjustable-Shoe-Type Bearings. Adjustable-shoe-type bearings must be properly adjusted in order that the thrust load will be equally divided among all of the bearing shoes. There are various types of bearing designs which afford a means of reading the shoe loading directly. In some bearing designs, a strain gauge is permanently located in each jackscrew and, by connecting the strain gauges to a suitable instrument, a direct reading can be obtained of the thrust load carried by each shoe. From such readings, adjustments are readily made to equalize the loading on all shoes. In other bearing designs, the deflection of a built-in member is measured at each shoe to determine loading.

For bearing designs without built-in measuring devices, the "slugged arc" method may be used to equalize the load. There are several variations of this method, each giving equally good results.

The generator manufacturer's instruction book should describe the bearing design and the method to be used.

10.13 Check of Shaft Runout. An installation check of the runout of the combined generator and turbine shafts should be required, especially where combined alignment has not been performed at the factory. Three different methods of making this check are described in 16.1.1 and 16.1.2. As indicated therein, the methods applicable depend upon the type of thrust bearing furnished with the generator.

If the rotation check by method 1 is used, it shall be performed during the erection of the generator to avoid subsequent disassembly of the machine.

10.14 Assembly of Rotating Exciters (If Provided), Collector Rings, and Brush Rigging. The main exciter armature, if used, is often designed with a flanged shaft having a rabbeted fit which bolts to the end of the generator shaft. The pilot exciter shaft, if used, may be attached to the main exciter shaft through one or more bolted joints. This means that great care must be taken in the assembly of these armatures. Any foreign material between the flange faces or uneven tightening of the coupling bolts will cause excessive commutator runout.

Generator guide bearings may have substantial diametrical clearance and, under some conditions, the shaft may float in the bearings. Therefore, commutator runout at operating speed can be expected. Commutator runout checks should be made with a dial indicator rather than by visual observations, and should be within the generator manufacturer's tolerances.

Segmental bearings made up of independently adjustable segments should be set to the clearance shown on the assembly drawing or in accordance with the generator manufacturer's instructions.

The elevation of a self-oiled bearing must be such that the oil groove, if any, is completely covered by the opposite member. The elevation must also be such that, when the rotor is raised to its maximum upward position by the jacks, the bottom of the journal will be below the center of the guide bearing.

After the bearing has been assembled, the remaining parts of the oil reservoir are added. Clearances between these parts and the shaft must be adequate to prevent rubbing.

10.7 Installation of Lubrication System. Every section of pipe forming a part of the lubrication system should be freed of scale, reamed at both ends, and blown out with compressed air or steam before being connected. Rapping the pipe with a rawhide or wooden mallet while blowing out will help to dislodge any foreign matter which may have entered during construction. Pipe compound or a suitable oil-resistant varnish should be used on all threaded joints.

To clean the pipes, oil should be circulated through them for several hours. The oil leaving the pipes should bypass the reservoir and should be filtered to remove dirt. The reservoir itself should be filled with oil and drained, several times if necessary, to remove all traces of dirt. Finally, it should be filled with clean filtered oil.

It is recommended that the lubricating oil used be in accordance with the generator manufacturer's specifications. Oils from different producers should not be mixed without the approval of the producers.

10.8 Checking Air Gap. The variations in the air gaps should be in accordance with the tolerances specified by the generator manufacturer. If the average air gap varies appreciably from that shown on the assembly drawing, the manufacturer should be consulted. In measuring the air gap, care should be taken to measure from iron to iron at the tangential center of the pole face. A tapered air-gap gauge or a long feeler gauge may be used. If the end ring of the amortisseur winding projects above the top of the pole, a small block attached to a rod can be held against the top of the pole and an air-gap gauge placed between the block and the stator bore.

10.9 Check of Insulation Against Shaft Currents. Bearings or thrust collars, and other parts, such as instrument elements, Kaplan features, conduit, piping, etc., that make contact, directly or indirectly, with the shaft above the rotor are usually insulated from the supporting structure to eliminate the possibility of shaft currents. This insulation should be checked with a 500 V insulation resistance meter and, if the resistance is less than 200 000 Ω, the insulation should be inspected and the necessary corrections made. In the case of a thrust bearing, the insulation should be checked with the weight of the rotor on the bearing.

If double insulation is provided (two layers of insulation with a metallic compound between the layers), its resistance can be checked with the machine completely assembled. However, each parallel path must be checked individually. Often the insulation is shunted by some temporary connection such as a tool, scrap material, or dirt. A complete visual inspection should be made to eliminate this possibility.

Where single insulation is used, all connections between the rotor and the frame at the lower end of the machine must be removed to test the bearing insulation, or each joint must be isolated and tested individually.

10.10 Closing of Generator-Turbine Coupling. The closing of the coupling between the generator and the turbine shafts should be done under the supervision of the representative of the manufacturer who furnished the coupling bolts. If the two shafts were assembled for a shop check of the runout in the plant of the turbine manufacturer or the generator manufacturer, the same manufacturer usually provides the coupling bolts.

If the two shafts were assembled in a factory, they should be assembled at the installation in the same relative angular position as indicated by the factory-placed matchmarks. If the two shafts were not assembled in a factory but the high points on the faces of the two couplings have been determined (usually marked with the letter "H" on the outer cylindrical surface of the flange), the coupling

(10) Turn on the bearing and air cooling water (just before starting up).

11.3 Initial Start. It is customary for a representative of the purchaser to coordinate the initial start with direct supervision by the governor manufacturer's representative. The time of the start and the general procedure to be followed should be detailed by the purchaser in consultation with the representatives of the turbine, governor, excitation system, and generator manufacturers. The purchaser's personnel should operate the unit with such guidance as is necessary from the equipment manufacturers' field representatives.

The turbine should be shut down as often as is required at the request of any of the manufacturers' field representatives and opportunity should be afforded for making such inspections and adjustments as the manufacturers' representatives deem necessary.

The initial starting procedure should be agreed upon with the turbine and generator manufacturer. The following is a typical procedure:

(1) With the high-pressure lift pump running, release the generator brakes and crack the wicket gates sufficiently to allow the unit to creep. Check for any rubbing or abnormal noises.

(2) Accelerate the unit to a speed of one-third to one-half of rated speed but not less than 50 rpm so that the bearing oil film will be established quickly.

(3) Hold this speed constant and note the bearing temperatures at intervals of 1 min until they become constant. Any rapid or continued rise of the bearing temperature should be investigated.

(4) After the bearing temperature becomes constant and the unit is operating smoothly, the speed should gradually be increased to rated speed.

(5) If vibration becomes excessive at any time while the unit is being brought up to rated speed, the unit should be shut down and balanced as described in Section 12.

During no-load operation, various checks and adjustments of the turbine and governor are normally made.

11.4 Check of Shaft Runout. When applicable, checking the runout of the face of the thrust-bearing runner with respect to the shaft, as described in method 2 (16.1.1.2) may be done at this time. However, it may be necessary to balance the rotating parts of the machine before this check can be made. See Section 12.

12. Balancing

The rotating parts of the generator should be in dynamic balance. This may require the addition of balance weights to the rotor. Their size and location are, in some cases, determined entirely by trial and error; however, it is usually desirable to take measurements that will define the horizontal motion of the shaft under various conditions and, from this data, calculate the size and location of the balance weights required.

The minimum data required to make the calculations is the motion of the shaft (magnitude of the horizontal movement and the location of the "high spot") at one axial location with (1) the rotor in its original condition and (2) a trial balance weight added to the rotor. However, if dynamic unbalance is present, requiring the addition of balance weights in two planes, it may be necessary to determine the motion of the shaft at two or more axial locations with (1) the rotor in its original condition, (2) a trial weight added in one balance plane, and (3) a trial weight added in the second balance plane.

The use of special balancing equipment, designed to establish the precise motion of the shaft, results in an accurate determination of the size and location of the required balance weights. This is particularly true for higher speed units. Alternatively, the horizontal movement of the shaft can be measured with a dial indicator and the approximate location of the "high spot," which is established by applying a thin coat of whitewash to the surface and then gradually bringing in the point of a pencil or scribe until it just makes contact with the white-washed area once each revolution of the shaft.

Various methods have been published for calculating, from the data taken as described in the foregoing paragraphs, the size and location of the balance weights required.

Balance weights should be attached to the rotor in the manner prescribed by the generator manufacturer.

The collector rings for the dc field current should be carefully assembled in accordance with the generator manufacturer's instructions. For the reasons mentioned, collector ring runout at operating speed can be expected. Collector ring eccentricity should be checked with a dial indicator.

Collector ring surfaces can often be kept in good condition by periodically reversing the polarity of the brushes. When collector rings and exciter loads are brought out to a circuit breaker, cables should be long enough to permit such reversal.

To ensure that satisfactory contact between the brushes and collector rings is obtained, bedding of brushes is recommended. Bedding should be performed when installing new brushes or following the switching of brushes to different brush holders.

Use medium-fine sandpaper (not coarser than 660 grains/in^2). Secure the abrasive paper to the collector ring by means of adhesive tape. With all brushes in the holders, set brushes against the abrasive paper with normal operating brush pressure. Turn the rotor by hand in the normal direction of rotation of the machine (do not press on the brush holders by hand). Should it not be possible to turn the rotor, pull the abrasive paper back and forth underneath the brushes, taking care to avoid rounding of the brush edges. When the brushes have been bedded in, carefully remove any remainder of adhesive tape from the collector rings and clean the entire brushgear by thorough vacuuming with a suitable brush attachment.

The brushes should be staggered across the collector rings to minimize grooving but should not extend beyond the edges of the rings to prevent formation of brush slivers. The brushholder springs should be adjusted in accordance with the generator manufacturer's instructions.

10.15 Installation of Instruments and Relays. Various instruments and relays, or their sensing elements, are often mounted on the generator and must be installed during its erection. This applies to such devices as oil level indicators, bearing temperature relays, indicating and recording thermometers for bearing and air temperatures, waterflow indicators, differential control temperature relay, and overspeed device. This equipment should be checked before installation. Its associated wiring and piping should be carefully installed, making sure that it does not short-circuit the bearing insulation, that is, a conducting path from any point on the shaft above the rotor to the stator frame. Suitable insulation should be provided at the proper points.

11. Mechanical Run

11.1 General. Do not apply voltage to any winding until the condition of the insulation has been checked as described in Section 13. The purchaser's written initial operation procedure should include instructions concerning all auxiliary devices and systems.

11.2 Preparation for Initial Start. Preparation of the generator for the initial start should include the following checks:

(1) During the last few days before the initial start and after all welding has been completed, make a final inspection of the thrust and guide bearings and prepare them for the initial start in accordance with the generator manufacturer's instructions.

(2) Make sure that all lubricating oil systems have an adequate supply of oil and all pumps and their control systems have been tested.

(3) Make sure that cooling water valves have been checked for the proper open or close position. Similarly, any pumps and automatic controls should be tested.

(4) Examine the interior of the stator, the air gap, exciters, collector rings, top of the rotor, and the space between poles for loose objects such as bolts, nuts, tools, etc.

(5) Make sure that all moving parts have sufficient clearance from the nearest stationary parts.

(6) Check the electrical clearance around all parts that are to be energized.

(7) Check the tightness of all foundation bolts and hold-down bolts.

(8) Clean the commutators and collector rings and check the seating of brushes.

(9) See that all protective devices are operating properly.

this current is usually between 25% and 50% of rated current. A slight amount of ventilation must be provided to exhaust the moisture-laden air.

(4) Even though the short-circuit method is used to dry out the armature winding, the resulting current in the field winding is not generally sufficient for adequate drying out of the field. One method for drying out the field is to operate the machine under load for several days. Alternatively, the field can be dried out by applying direct current to the field with the rotor stationary, but with the current limited so that the temperature given in item 1 will not be exceeded. This current should not be passed through the brushes; instead, the current should be applied to the machine field at the connection to the collector rings.

(5) An alternative method of drying out armature windings is by means of electric space heaters. They should be located in air spaces under the machine or at the back of the stator core and be distributed around the periphery of the machine to allow for an even distribution of heat. If the rotor is not in place, the ends of the machine may be closed with end bells or with large tarpaulins to reduce the heat loss. A slight amount of ventilation must be provided to exhaust the moisture-laden air. Precautions should be taken to prevent fire when this type of heat is applied.

(6) Further details of drying out windings are given in the IEEE Std 43-1974 [7].

13.3 High-Potential Tests. The procedure to be followed in making the high-potential test should be in accordance with IEEE Std 115-1983 [5]. The test voltages, frequency, and wave shapes should be in accordance with ANSI C50.10-1977 [2].

Where the assembly of a winding is completed at the destination, precluding the possibility of final high-potential tests at the factory, it is recommended that high-potential tests be made on the armature and field winding immediately after final assembly and before the machine is put into service. In some cases, it may be desirable to give the stator a final high-potential test before installing the rotor. The winding should be in good condition and the tests not applied when the insulation resistance is low because of dirt or moisture. (For additional details, see 13.1.)

When a test is made after installation on a new machine which has previously passed its high-potential test at the factory and whose windings have not since been disturbed, the test voltage should be reduced in accordance with ANSI C50.10-1977 [2].

The test voltage for rotating exciters should be in accordance with ANSI C50.5-1955 [1], and the test procedure should be in accordance with ANSI/IEEE Std 113-1985 [4].

Due to the high voltages used, dielectric tests should be conducted only by experienced personnel, and adequate safety precautions should be taken to avoid injury to personnel and damage to property. Following an alternating-voltage, high-potential test, the tested winding must be discharged to ground before it is touched by personnel. Following a direct-voltage, high-potential test, the tested winding must be grounded and thoroughly discharged. The insulation rating of the winding and the test level of voltage applied determine the period of time required to dissipate the charge and, in many cases, the ground must be maintained for several hours to dissipate the charge to avoid personnel hazard.

14. Initial Operation

14.1 No-Load Operation with Excitation. After the unit has been balanced and has had a dry-out run, it should be operated at rated speed and its voltage built up slowly by applying excitation. The terminal voltage and field current should be recorded and compared with the generator manufacturer's calculated no-load saturation curve. At rated voltage, the voltage balance should be checked and an operational check of shaft runout should be performed (see 15.1).

14.2 Connection to Power System. Before connecting the generator to the power system, the phase sequence of the generator and the connections to the synchroscope should be checked and, if they are correct, the generator leads can be connected permanently.

If, at a later time, it becomes necessary to remove a balance weight, it should be replaced in exactly the same position. Before disassembling a pole on a high-speed machine, its axial position should be accurately marked so it can be replaced in the same position. Should it become necessary to replace a field coil or a complete pole, the balance must be rechecked.

The turbine runner should also be in dynamic balance to ensure that the turbine-generator unit balance and shaft runout are acceptable. Occasionally the overall balance and shaft runout of the unit will not respond to balancing only the generator rotor. In this situation balancing should be done on the turbine runner. The results may be checked by driving the unit with the generator as a synchronous motor and the turbine unwatered with a minimum seal water flowing.

Since the nature of hydraulic turbines is such that shaft runout or vibration may result from hydraulic forces within the turbine, unwatered operation will also serve to separate mechanical unbalance from hydraulic disturbances.

If mechanical construction permits, further separation of the turbine and generator unbalance can be achieved by running the generator as a motor with the turbine uncoupled. Some machines run in this mode may be unstable. The manufacturer should be consulted before operating in this condition.

Should undue vibration develop during operation of the generator, before adding or shifting balance weights, check the possibility of the vibration being caused by misalignment, settling of the foundation, uneven air gap, rubbing of rotating parts, loose parts, bent shaft, short-circuited field coil, or unbalanced stator currents. Then, if necessary, add or shift the balance weights.

13. Insulation Testing and Drying Out

13.1 Measurement of Winding Insulation Resistance. The insulation resistance of the armature and field windings of the generator and exciter(s) serves as an indication of whether or not the machine is in condition for operation and dielectric testing.

Insulation resistance measurements of the windings should be made in accordance with IEEE Std 43-1974 [7].

All insulation resistance test results should be referred to the generator manufacturer for analysis and approval. From these data, the manufacturer can determine whether "drying out" of the windings is required before dielectric testing and operation.

13.2 Drying Out of Windings. If drying out of the windings is recommended by the generator manufacturer, the following procedures are suggested:

(1) The temperature of the winding should generally not be allowed to exceed 90 °C when measured by a resistance temperature detector or 75 °C when measured by a thermometer. The rate of heating should be such that this temperature is attained in not less than 6 h and preferably, in not less than 12 h. The winding should be brought up to temperature slowly by steps to avoid gassing of entrapped moisture and possible rupture of insulation.

(2) The armature winding should preferably be dried out by the short-circuit method. When this method is used, the machine is operated at rated speed with all phases of the armature winding short-circuited. Enough field current is applied to give an armature current (usually between 60% and 100% of rated armature current), which will produce the rate of temperature rise specified in item 1. This heating should be continued until the insulation resistance readings, corrected for any temperature differences, approach constancy. A slight amount of ventilation must be provided to exhaust the moisture-laden air.

(3) The armature winding can also be dried out by passing direct current through it with the machine stationary. A high-current, low-voltage source of dc power, such as a welding generator, is required. Where possible, the phases of the winding should all be connected in series or in parallel, so that all phases will carry the same current. Where the phase currents are unbalanced, the maximum current in any phase should be limited to that which will give the heating rate specified in item 1. Since the machine is stationary,

(exclusive of skate[6]) should not exceed 80% of the diametrical clearance in the guide bearings and the temperature of the guide bearing should not exceed 85 °C.

In addition to machining inaccuracies of the thrust collar and thrust-bearing runner, there may be other causes of shaft runout, such as electrical or mechanical unbalance of the generator rotor, improper connection at the generator coupling, or hydraulic or dynamic unbalance of the turbine runner.

15.2 Electrical Tests. The larger generators (above 5000 kVA) usually receive only winding resistance measurements and dielectric tests at the factory, and any additional testing shall be done after installation at the site. Certain additional tests are desirable to provide information that will allow a more accurate prediction to be made of generator performance under various operating conditions.

As a minimum, these tests should include:

(1) Winding resistance measurements
(2) Short-circuit saturation curve
(3) Open-circuit saturation curve
(4) Field current at rated kVA, power factor, and voltage

Test procedure should be in accordance with ANSI/IEEE Std 115-1983 [5].

It is recommended that a representative of the generator manufacturer be present when the foregoing tests are made.

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[6] Skate is the lateral random movement of a shaft superimposed on the periodic runout. This movement may be up to the full clearance of the bearing and is generally not considered significant in an analysis of shaft motion.

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10. ANEXO X

Información Fotográfica presentada en medio magnético (CD-Room) referente al mantenimiento realizado en el Grupo Generador Nº 2 – Central Hidráulica Charcani V

11. ANEXO XI

Planos de detalle y de montaje presentado en medio magnético (CD-Room) del Grupo Generador Nº 2 – Central Hidráulica Charcani V

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