

# EFFECTS OF HYDROGEN SULFIDE IN GEOTHERMAL POWER PLANTS OF CALENERGY INTERNATIONAL LTD. LEYTE OPERATIONS

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## ABSTRACT

*CalEnergy International Ltd. is currently operating three geothermal plants in the province of Leyte. These are the 733.5 Gross MW CE-Cebu Geothermal Power Company in Upper Mahiao, the 232.5 Gross MW Visayas Geothermal Power Company in Malitbog and the 780 Gross MW CE-Luzon Geothermal Power Company in Mahanagdong.*

*In any geothermal plant, emissions of hydrogen sulfide (H<sub>2</sub>S) gas are inevitable. This gas is harmful not only to human beings at a certain level of concentration but also to process equipment and instruments with materials of construction made of iron, copper and silver. After two years of commercial operations, the three geothermal power plants have experienced several shutdowns due to malfunctioning of the DCS/PLC, false alarm instrument signals and loose electrical contacts. To address this problem, the most probable cause must be determined for immediate solutions. Corrosion attack by hydrogen sulfide was first taken into consideration.*

*This paper presents the adverse effects of hydrogen sulfide in operations and maintenance as experienced by the three geothermal plants of CalEnergy International Ltd. Leyte Operations and the solutions taken to correct the problem.*

## 1.0 INTRODUCTION

In the Visayan island group of central Philippines where the province of Leyte belong, CalEnergy International Limited is currently operating three geothermal plants with a combined capacity of electrical energy gross output of 546 MW. During the first two years of commercial operation, the three geothermal plants were operating normally. It was on the

third year of operation that these plants encountered several problems due to malfunctioning of DCS and PLC components. Further investigation showed that most of the electrical wirings in the field mounted electrical junction boxes were adversely affected by hydrogen sulfide corrosion attack. The most severe problems encountered by our geothermal plants were the failure of the turbine generator rotor coils in one of the plants and the failure of the generator exciter coil in another plant due to hydrogen sulfide corrosion attack. Corrective measures were immediately implemented and most importantly the preventive measures were strengthened to prevent re-occurrence.

## 2.0 GEOTHERMAL PLANT HISTORY

### 2.1 CE-Cebu Geothermal Power Company

The gross output of CE- Cebu is 133.5 MW consisting of four GCCU (Geothermal Combined Cycle Unit) with a total gross capacity of 128 MW and a brine plant with a gross capacity of 5.5 MW. Its commercial operation started on June 25, 1996.

In the early year of 1999, the plant had experienced several shutdowns due to tripping of equipment motors caused by the malfunctioning of electrical control breakers. Other shutdown problems encountered were malfunctioning of PLC systems. Field mounted electrical junction boxes were also the source of false instrumentation signals. The worst problem encountered was the failure of turbine generator rotor coils due to the short circuiting of the windings when the silver phosphorous bracing failed due to hydrogen sulfide corrosion attack. (Figures 1a to 1d). A thorough technical evaluation was conducted by installing a corrosion coupon inside the control rooms and OEC power shelters to determine their

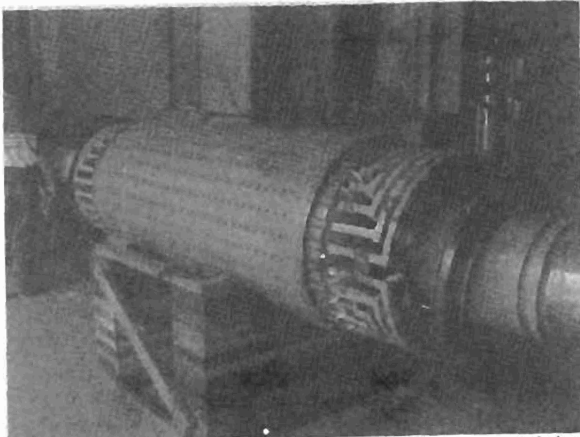


Figure 1a. STG #40 Generator Rotor retaining removed. Exciter and coupling side view, as opened.

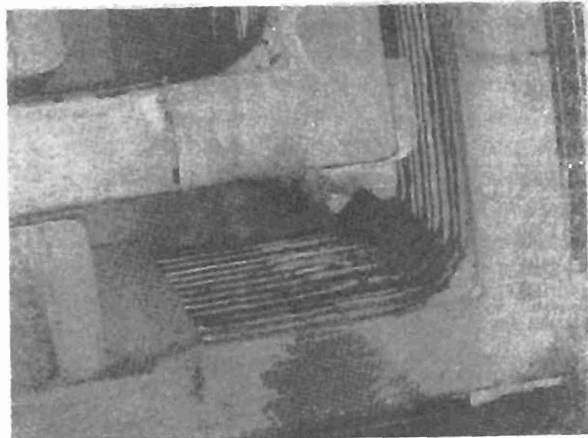


Figure 1b. STG #40 Generator Rotor winding close up of black deposits on the soldered connection, as opened.

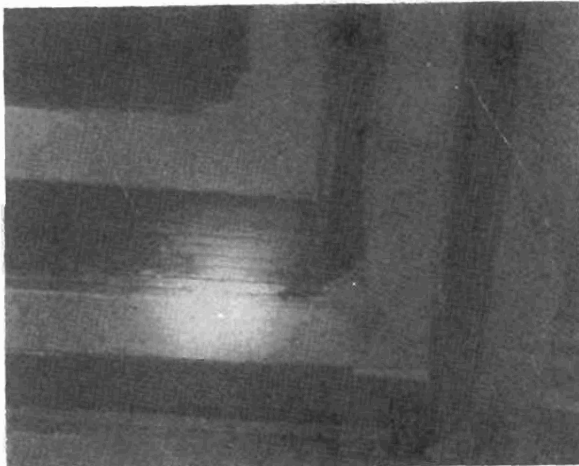


Figure 1c. STG #20 Generator Rotor winding, coupling side, positive of black deposits, as opened.

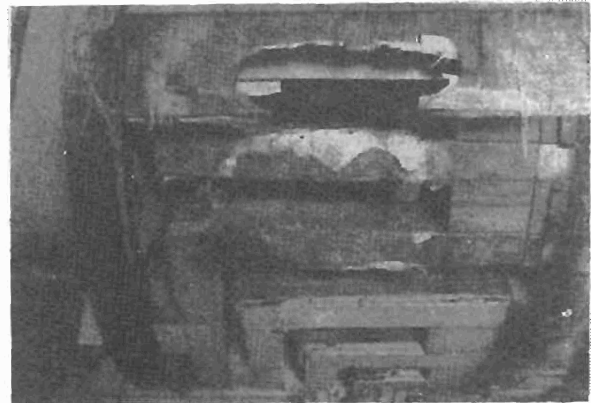


Figure 1d. STG #20 Generator Rotor winding exciter side shorted pole to pole between no.5 and 6. as opened.

environmental conditions. Based on the Instrument Society of America, Standard ISA 71.04, results showed that environmental conditions of all the control rooms and power shelters are severe and fall under ISA Class GX where electronic/electrical equipment are not expected to survive due to corrosive attack. Hence, the common attributing factor of all the problems above is the adverse effect of hydrogen sulfide coming from the geothermal steam. Individual problem assessments were conducted to determine the specific action to be initiated to correct the problems. Corrective measures are as follows:

### 2.1.1 Malfunctioning of PLC System

Cleaning followed by coating of the Printed Circuit Board (PCB) to Industry Standards were initiated.

In the cleaning process, a mixture of solvents and Vapor Phase Corrosion Inhibitors which are specifically formulated to clean and protect printed circuit boards were used. Selected solvents provide excellent cleaning qualities to remove rust, grease and other contaminants and flux residues after soldering and prior to coating. The residual Vapor Phase Corrosion Inhibitors does not affect the electronic performance in any way and will provide protection against corrosive vapors until a conformal coating is applied.

In the coating process, a solution of vinyl copolymers and organic corrosion inhibitors in an isopropanol base is applied by spraying. The coating material is a rapid drying product, treated components can be used within 15 minutes of coating. The film formed is hard, non-tacky, non-conductive and transparent. It does

not encourage dust collection and it allows ready inspection of coated components. The film, if required, can be removed at a later date by wiping off with methylated spirits.

The deans and coated printed circuit boards are protected further by installing material pads consisting of a nylon foam impregnated with a Vapor Phase Corrosion Inhibitor (V.P.C.I.) paste inside the system cabinets. This material works by emitting gas molecules, that condense onto metal surfaces of the edge connectors, plugs and sockets providing protection against the widest range of corrosive contaminants. This process does not affect electronic characteristics.

### **2.1.2 Electrical Junction Boxes Problems.**

False alarm signals from instruments have been attributed to loose electrical connections, caused by hydrogen sulfide corrosion attack. Critical failures have resulted in a plant shutdown. To address the problem, our maintenance group initiated a "Thinning Process" wherein the tip of freshly stripped insulated wires are dipped into a molten lead, cooled down and inserted into the relay terminals. To further safeguard the junction boxes from corrosive gas attack, material pads of nylon foam impregnated with Vapor Phase Corrosion Inhibitor (V.P.C.I.) paste are placed inside the electrical junction boxes. This material works by emitting gas molecules which condense into metal surfaces providing protection against the widest range of corrosive contaminants. Boxes are then sealed thoroughly using silicon sealants to prevent intrusion of corrosive gas.

### **2.1.3 Failure of Turbine Generator Rotor Coils**

Following a plant trip caused by activation of the generator ground fault relay, a turbine generator was found grounded due to the formation of copper sulfide corrosion products in the copper coils of the rotor. All rotor coils were replaced with new material. To prevent recurrence of the same problem, the following preventive measures were initiated:

1. Modification of the generator cooling air purification system.

Cooling air for generator coils was pressurized by installing a blower or a force draft fan upstream of the air purifying and filtering media. The filter replacement periodicity was changed from yearly to quarterly.

2. Monitoring and testing of filters.
3. Investigation on bulk media replacement
4. installation of copper corrosion coupon downstream of the filter media.

This serves as a double check on the quality of filtered air going into the generator coils.

5. Use of a highly sensitive H<sub>2</sub>S gas analyzer to monitor the H<sub>2</sub>S concentration level of purified air downstream of the new bulk filter media.
6. Leak testing of generator. Reducing air flow generator reduces exposure to bad air. Plug leaks.

### **2.f.4 Air Purification of Control Rooms and Power Shelters.**

Control rooms and power shelters are areas where sensitive electrical and electronic parts are located. The air handling unit that maintain the desired room temperature are introducing atmospheric air containing corrosive H<sub>2</sub>S gas into the rooms through their makeup plenum. To protect these sensitive electrical and electronic parts, air that re-circulates inside these rooms must be purified to an acceptable level that conforms ISA Standards. Air purification units installed are the following:

1. Three Positive Pressurization Units (PPU).

Two units are installed at GCCU 1 and 2 control room and GCCU 3 and 4 control room (Figure 2). One unit installed at Central Station Control (CSC) room (Figure 3). Make up air is filtered and purified. While air inside the room is re-circulated, thus re-filtered and re-purified.

2. Twelve Industrial Side Access Units (ISA)

These are installed at Power Shelters. Make up air is also filtered and purified. Air inside

*the room* is recirculated to the unit for refiltration and repurification (Figure 4).

The above air purification units are using bulk filter media composed of activated alumina and activated carbon impregnated with potassium hydroxide (KOH) and sodium bicarbonate (NaHCO<sub>3</sub>). Activated carbon serves as a catalytic site for adsorption of molecules. The primary active ingredient, potassium hydroxide, then chemically reacts with the gases and permanently remove them from the air stream. Sodium bicarbonate enhances the chemical reaction process while also serving as an odor neutralizer.

## 2.2 Visayas Geothermal Power Company.

The gross capacity of VGPC is 232.5 MW in one powerhouse composed of three 77.5 MW Fuji turbine units. The first unit started its commercial operation on July 25, 1996 while unit 2 and 3 started commercial operation on July 25, 1997.

In the first two years of operation, the plant operated normally. In its third year of operation, the plant experienced operational problems. Some field mounted electrical junction were the source of false alarm signals to process control. It was found out that the electrical connections on relay terminals were severely affected by hydrogen sulfide attack.

VGPC has experienced fewer problems in the DCS system as compared to the other two plants since the motor control center (MCC) and the central station control (CSC) rooms are pressurized with a dean and chemically purified cooled air from our air handling unit (AHU).

A major problem encountered by the plant was the failure of the exciter of turbine generator unit no. 3 due to short circuiting of the coil end connection at permanent magnet generator (PMG) side of slot no, 33 top coil and no. 34 top coil (Figure 5). Laboratory analysis of the dust collected in the area of failure showed a presence of copper sulfide (CuS). It is suspected that dust accumulated between the coils, and then the coil surface treatment peeled off due to overheating caused by ventilation interference. It is possible that CuS produced by H<sub>2</sub>S gas contributed to the failure. Inspection of unit 1 and 2 exciter coils showed also the presence of copper sulfide black deposits (Figures 6a and

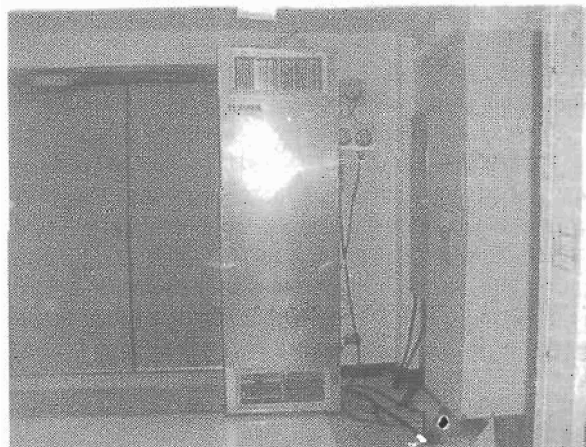


Figure 2. Two units of this 500 cfm capacity Positive Pressurization Unit (PPU) installed at GCCU 1 and 2 Control Room and GCCU 3 and 4 Control Room.

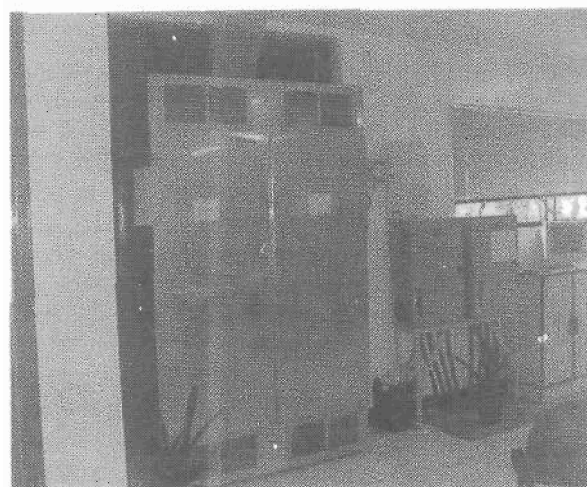


Figure 3. A 2,000 cfm capacity Positive Pressurization Unit installed at Central Station Control (CSC) Room,

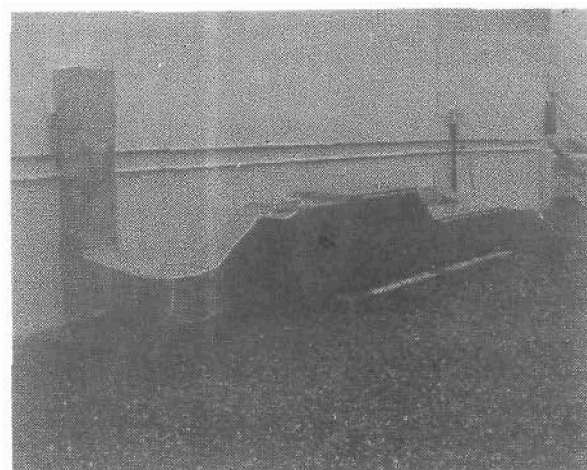


Figure 4. Twelve units of this 500 cfm capacity Industrial Side Access (ISA) Units installed in twelve Power Shelters.

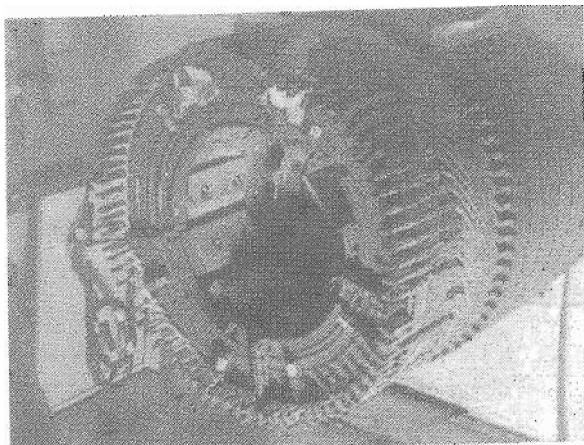


Figure 5. Exciter of turbine generator unit 3.

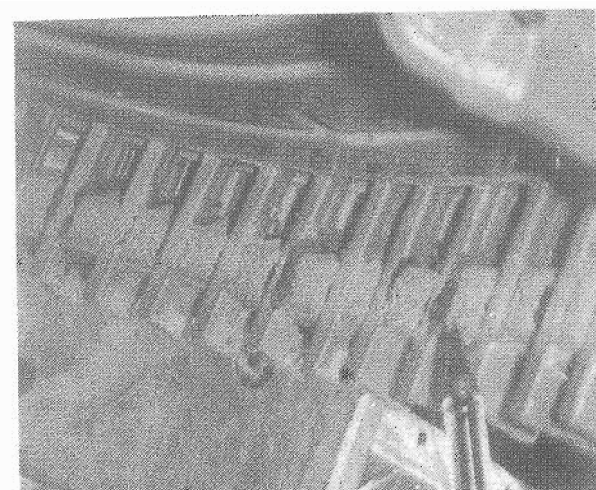


Figure 6a Unit 1 exciter mil-end showing the presence of copper sulfide (CuS) black deposits.



Figure 6b. Unit 1 exciter coil-end showing the presence of copper sulfide (CuS) black deposits.

6b) Corrective and preventive measures initiated are as follows:

### 2.2.1 Electrical Junction Boxes Problems

Thinning process as fully described in item 2.1.2 was employed.

### 2.2.3 Failure of the exciter of turbine generator unit no. 3

Intensive repair of the damaged exciter coil was done in place to save operational downtime. The entire exciter unit was replaced with a new spare during the year 2000 scheduled plant turnaround.

As a preventive measure, the following are recommended to be done at the next periodic inspection in order to prevent the possibility of coil short circuit.

- Visual inspection
- Testing, such as megger test, etc.
- Continuous monitoring of operational data.
- Blowing fresh and a Glean dry air to rotor coil-end portions for cleaning.
- Re-treatment of anti-tracking epoxy varnish "Neo Gose #200" on the rotor coil-end surface to enhance prevention tracking ability.

## 2.3 CE-Luzon Geothermal Power Company

The gross capacity of CE-Luzon is 180 MW. One powerhouse composed of two units of 60 MW Toshiba turbines and the other powerhouse composed of one unit of 60 MW Toshiba turbines. The plant started its commercial operation on July 25, 1997.

The plant also operated normally in its first two years of operation and started experiencing operational problems in its third year of commercial operation. Operational troubles in common to the three plants includes the false alarm signal of instruments due to corrosion of electrical wiring terminals in electrical junction boxes. The plant also experienced problems in the DCS as caused by hydrogen sulfide corrosion attack to the printed circuit boards. Corrective and preventive measures initiated are as follows:

### 2.3.1 Electrical Junction Boxes Problem.

Thinning Process was also employed as outlined in section 2.1.2.

### 2.3.2 Malfunctioning of DCS System.

Cleaning followed by coating of the printed circuit boards (PCB) to Industry Standards were initiated. Full description of the process is outlined in the previous section 2.1.1.

Preventive measures were further strengthened by installing an additional air purification and pressurization units in the following area:

- a.) Site B Electrical Equipment Room. Two Corrosive Air (CA) units at 4,000 cfm capacity for air re-circulation only and one Positive Pressurization Unit (PPU) at 2,000 cfm capacity for room pressurization and re-circulation.
- b.) Site B Control Room. Installed one Positive Pressurization Unit (PPU) at 2,000 cfm capacity for room pressurization and air re-circulation.

## 3.0 CONCLUSION

Hydrogen sulfide (H<sub>2</sub>S) gas being one of the major component of the non condensable gas (NCG) in geothermal steam is a significant enemy of operations and maintenance in any geothermal power plant. It attacks materials made of iron, silver and copper. Since these metals are present in the plant motor control centers, process instrumentation electrical junction boxes, printed circuit boards of programmable logic control (PLC) system and distributed control system (DCS), several protective measures must be initiated to avoid plant shutdown and prevent company revenue loss.

Turbine generator being the heart of the major equipment of a geothermal power plant, special care should be taken into consideration to prevent H<sub>2</sub>S corrosive gas attack to the generator coils. CalEnergy International Ltd. Leyte Operations has learned through experience the adverse effect of hydrogen sulfide (H<sub>2</sub>S) in the three geothermal power plant. Hence, corrective measures were initiated

and moreover the preventive maintenance systems were strengthened.

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