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Small Scale Geothermal Power Generation

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ABSTRACT

This paper presents the technical aspects of "Geoportable™" which is a small scale geothermal power generation system and provides 1 to 20MW gross power output by dry steam and flash system.

At first, the article mentions the concept of Geoportable™ and the application examples. It seems to be very important to clearly describe why Geoportable™ is born in this time and expected by the developer of geothermal power plants.

Then, skid mounted modules are explained as a component of Geoportable™. Also, standardized with easy custom designed concept is applied to Geoportable™ to pursue customer's ultimate requirement. Namely, it is high performance, low cost and fast revenue. This is the essence of this paper.

In addition, an operation result of Geoportable™ is shown with high availability and reliability.

1. INTRODUCTION

After UN Sustainable Development Summit held in 2015, Sustainable Development Goals (SDGs) has been focused on every business sector. The reason is that every firm can contribute to the future on the earth or SDGs. Toshiba Energy Systems & Solutions Corporation (TOSHIBA) also admires this global movement and hopes to expand business with this idea, which is especially noted No.7 goal "Affordable and Clean Energy" and No.13 goal "Climate Action" in 17 SDGs.

Geothermal power is recognized as one of the renewable energy sources. It has big potential to produce electricity and heat for human's life activity as is well known. So, geothermal utilizing technology for power generation is thought to be one of the solutions to "Affordable and Clean Energy" and "Climate Action". TOSHIBA have over half a century of experience for geothermal power generation systems as the leader in the world. Since the first geothermal power plant "Matsukawa" in Japan in 1966, TOSHIBA has continued to produce many geothermal power generation systems worldwide, i.e. Geysers in USA, Cerro Prieto in Mexico, Philippines, Indonesia, Kenya, New Zealand, Iceland. Most of these are over 20MW gross output machines. Now TOSHIBA is trying to pursue another way to meet the recent social movement.

Geoportable™ is a small scale power generation system for 1 to 20MW gross output range. It has four types which are Geoportable 2, 5, 7 and X. Figure 1 shows the technical properties of each type.

Type	**Geoportable 2**		**Geoportable 5**	**Geoportable 7**	**Geoportable X**
Turbine type	Condensing	Back-pressure	Condensing	Condensing	Condensing
Output	1 to 3 MW	3 to 6 MW	3 to 6 MW	6 to 10 MW	7 to 20 MW
Main steam pressure	1.8 to 5bara	5 to 10 bara	3 to 9.5 bara	5 to 10 bara	3 to 10 bara
Main steam temperature	117 to 152 degC	152 to 180 degC	134 to 178 degC	152 to 180 degC	134 to 180 degC
Number of turbine stages	4		4	5	≦7
Exhaust type	Side		Upward	Upward	Axial
Control system	Low-pressure D-EHC High-pressure D-EHC		High-pressure D-EHC	High-pressure D-EHC	High-pressure D-EHC

Figure 1: Technical property for 4 types of Geoportable™

From here, Geoportable 5 will be used as representative for the explanation of Geoportable™. Geoportable 5 consists of 5 modules and 1 turbine generator control system (TGCS), which are turbine skid, generator skid, pump skid, valve skid, piping skid and 1 TGCS. Here, TGCS does not have only EHC/AVR function but also control and monitoring function for the whole small scale geothermal power plant and expandability for IoT. Figure 2 shows the 5 modules arrangement for Geoportable 5, which are turbine skid as No.1, generator skid as No.2, pump skid as No.3, valve skid as No.4 and piping skid as No.5, respectively. These are inside of an enclosure on a concrete foundation.

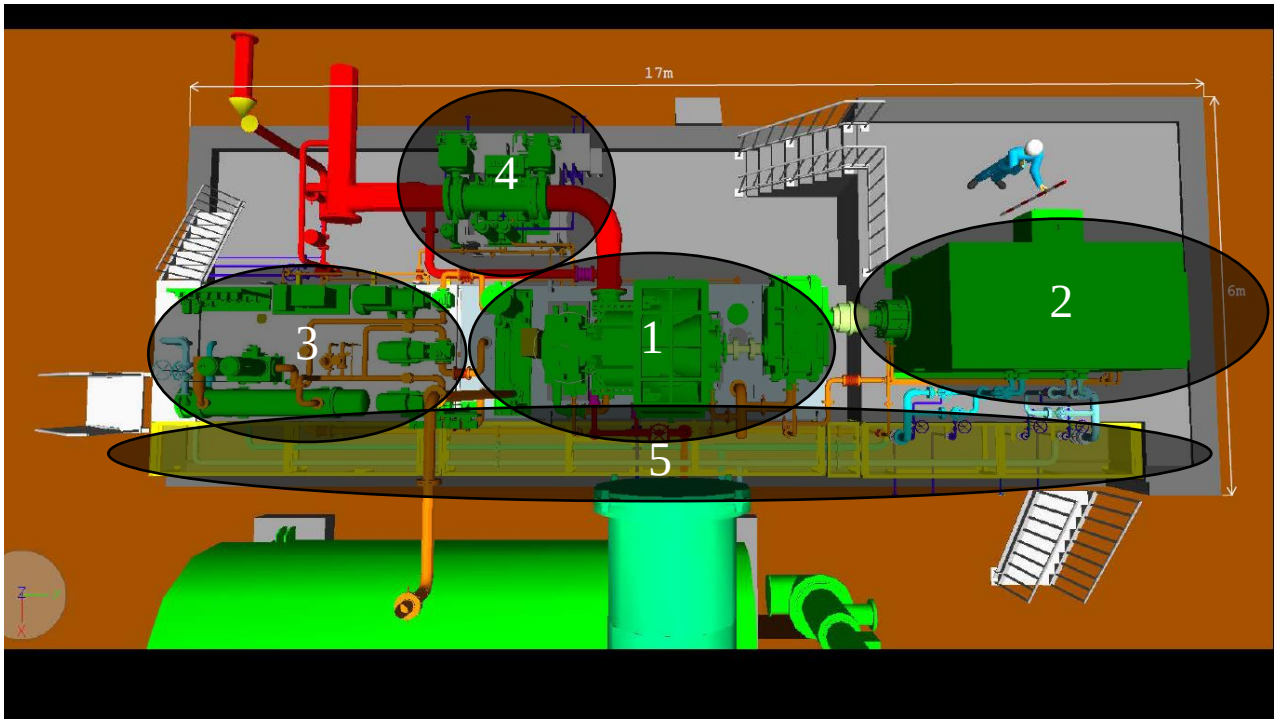

Figure 2: 5 modules arrangement for Geoportable 5 (top view)

Each module is assembled in the shop before shipping and transported by container from shop to site. Once these arrive at site, installation starts. The modules are set on the foundation which is prepared beforehand. Alignment is done for each module. After that, piping between modules is connected by bolting with flange connection. There is no weld fitting in this work. Finally, oil flashing is conducted promptly because of keeping cleanness inside of all equipment and piping for lubrication and control oil system. The oil equipment and piping are subject to cleaning or oil flashing before shipping. For the duration of transportation and storage at site, oil vaporizable anti-rusting sheet is covered over each module to prevent rust and contamination. This is a mechanical completion process at site. Now, the system is ready for steam flow initiation. This suggests a short installation time to early electricity produce and return on investment.

Regarding performance, cost and lead time, it is difficult to coexist in general. Especially in case of geothermal power generation, it is quite difficult due to steam condition being different site by site. Geoportable™ can offer the solution for this trade-off argument. As described in Figure 1, there are 4 types to cover 1 to 20MW. These are standardized with a flexibility of steam path and steam inlet design. This is a point. Standard design can make low price and short lead time, and furthermore changing design for critical parts according to the variety of steam condition can produce high performance. This is the Geoportable™ main concept.

Preparing Geoportable™ with this concept, TOSHIBA started to explore new markets and new applications, which means the approach to clean energy expanding and climate action. Following are the application examples. The purpose is to use unutilized geothermal energy effectively.

- Applying to used or lifeless production wells
- Applying to production wells waiting for large scale geothermal power plant
- Adding to existing large scale geothermal power plant to use wasted geothermal energy

2. COMPONENT

2.1 Process Flow Diagram

Figure 3 shows a typical process flow diagram for small scale geothermal power plant using Geoportable 5. Also it suggests the scope of Geoportable 5 by dashed line. EPC solution for small scale geothermal power plant can be offered with Geoportable™ core technology.

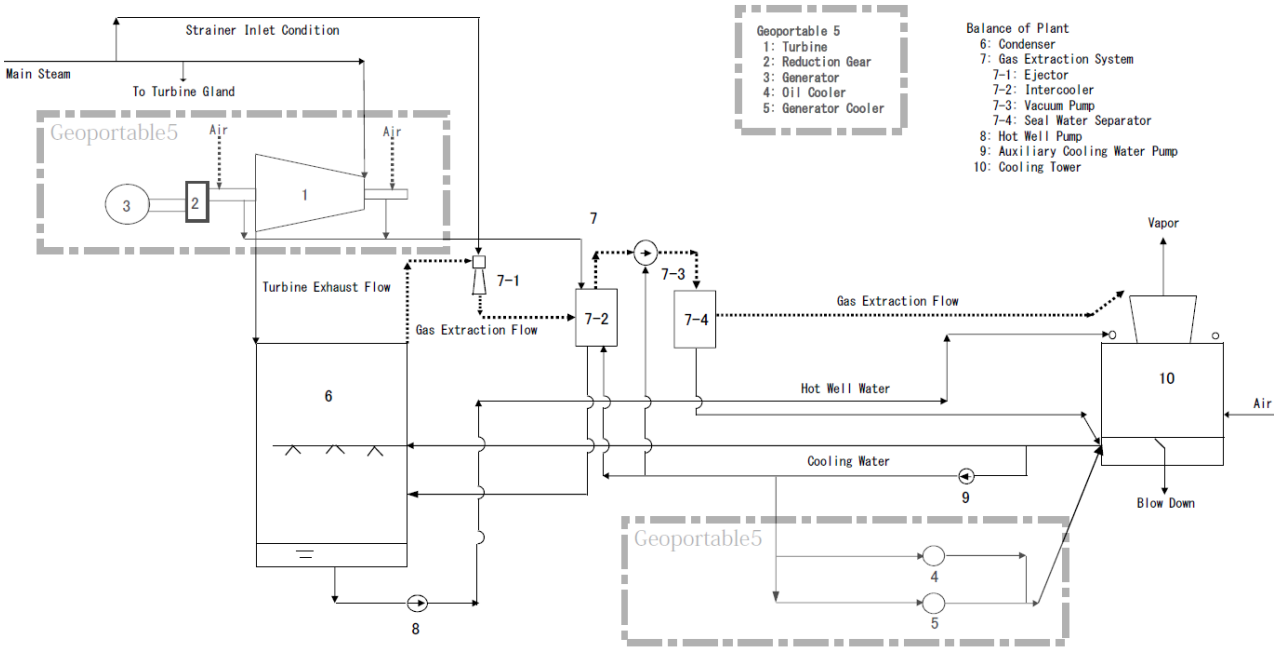

Figure 3: Typical Process Flow Diagram for Small Scale Geothermal Power Plant using Geoportable 5

2.2 Turbine Skid

Figure 4 shows Turbine Skid of Geoportable 5 in side view, which mainly consists of turbine, reduction gear, oil tank functioning as turbine base and gas extraction system for oil tank. The arrow on turbine indicates upward exhaust flow at exhaust duct.

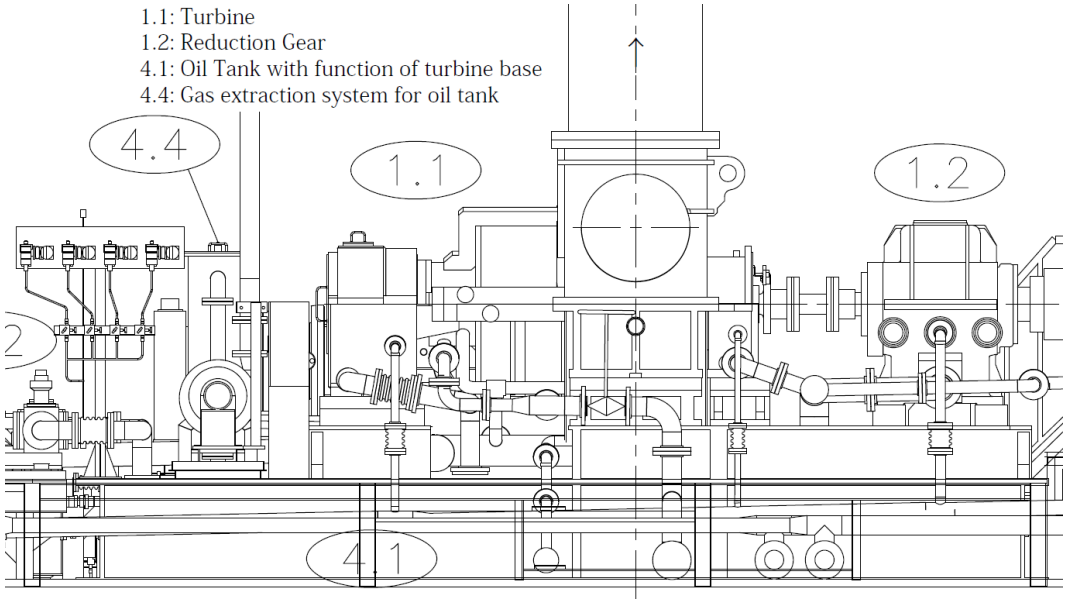

Figure 4: Turbine Skid of Geoportable 5 (side view)

The turbine is impulse type with 4 stages and single flow. Its revolution is around 6000 rpm. It has large cord nozzle partition to prevent clogging the steam path throat area and snubber blade for all stages to avoid stress corrosion cracking instead of tennon blade. Nozzle, blade and rotor material are stainless steel, 12Cr steel and CrMoV forged alloy, respectively. These properties are standardized in Geoportable 5. Meanwhile, steam path design has a flexibility to optimize the turbine performance under various steam conditions site by site.

The turbine connects to the generator by reduction gear, which has ratios for 50Hz and 60Hz. The revolution of low speed axis (generator side) is 1500 rpm for 50Hz and 1800 rpm for 60Hz because of 4 pole generator as explained later. 50Hz type reduction gear is shown in Figure 4.

Oil tank is set under the turbine and reduction gear to support the rotating machines tightly. Of course, it keeps oil to use lubrication and main steam valve control by EHC. There is also a gas extraction system on it to extract vapored gas from the oil tank.

2.3 Generator Skid

Figure 5 presents Generator Skid of Geoportable 5 in side view, which consist of generator and the cooler. Generator is 4-pole and TEWAC (Totally Enclosed Water to Air Cooling). The revolution is 1500 rpm or 1800 rpm for 50Hz and 60Hz, respectively. The largest capacity generator of 50Hz type is shown in Figure 5.

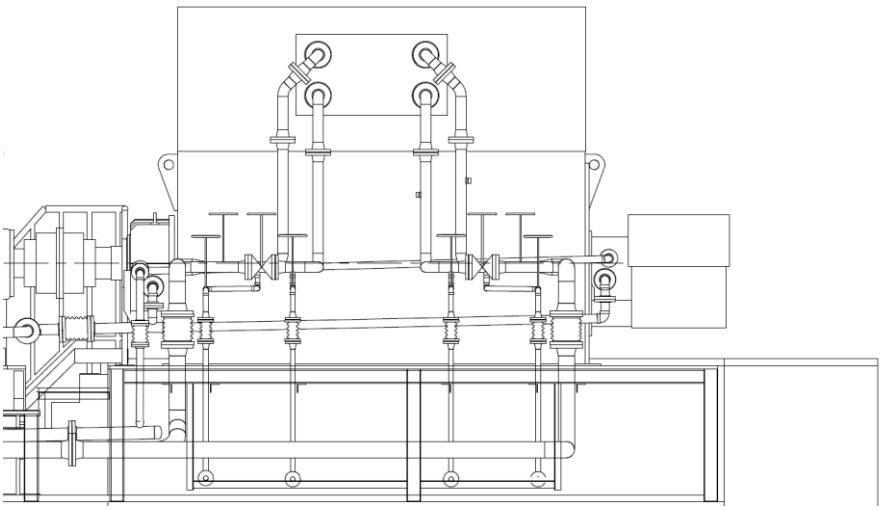

Figure 5: Generator Skid of Geoportable 5 (side view)

2.4 Pump Skid

Figure 6 presents the Pump Skid of Geoportable 5 in side view, which mainly consists of the oil pump, oil cooler and oil filter, and oil conditioning system shown in Figure 8 separately as an option. Pre-oil flashing or cleaning inside of oil path is carried out at the shop before shipping to reduce oil flashing work at site. The piping connection between oil pump and oil tank in the turbine skid is flange type with short flexible piping. This is also to shorten the installation work at site.

The oil pump normally consists of main oil pump x 2 and emergency oil pump x 1 as shown in Figure 8. These pumps are designed as standard ones for Geoportable 5. The oil cooler is also standardized as relatively large heat exchanging surface area to meet various cooling water temperature site by site.

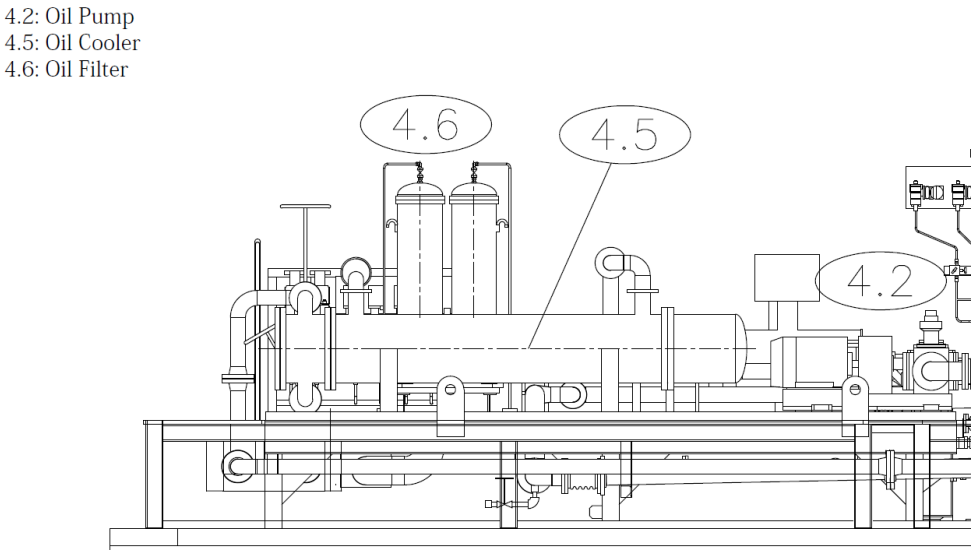

Figure 6: Pump Skid of Geoportable 5 (side view)

2.5 Valve Skid

Figure 7 shows the Valve Skid of Geoportable 5 in side view, which mainly consists of main steam stop valve, main steam control valve, main steam strainer, control oil accumulator, control oil filter and control oil pump. Main steam stop valve and main steam control valve are butterfly type valve with high pressure actuator. These are installed downstream from the main steam strainer. The arrow after main steam strainer indicates steam flow direction at the main steam inlet piping. Connection between valve skid and turbine skid at the main steam inlet piping is flange type, not welded.

High pressure for actuator driving force is achieved by the control oil pump, which is 50 MPaG. The actuator is double acting type to realize downsizing by the effect of spring eliminating.

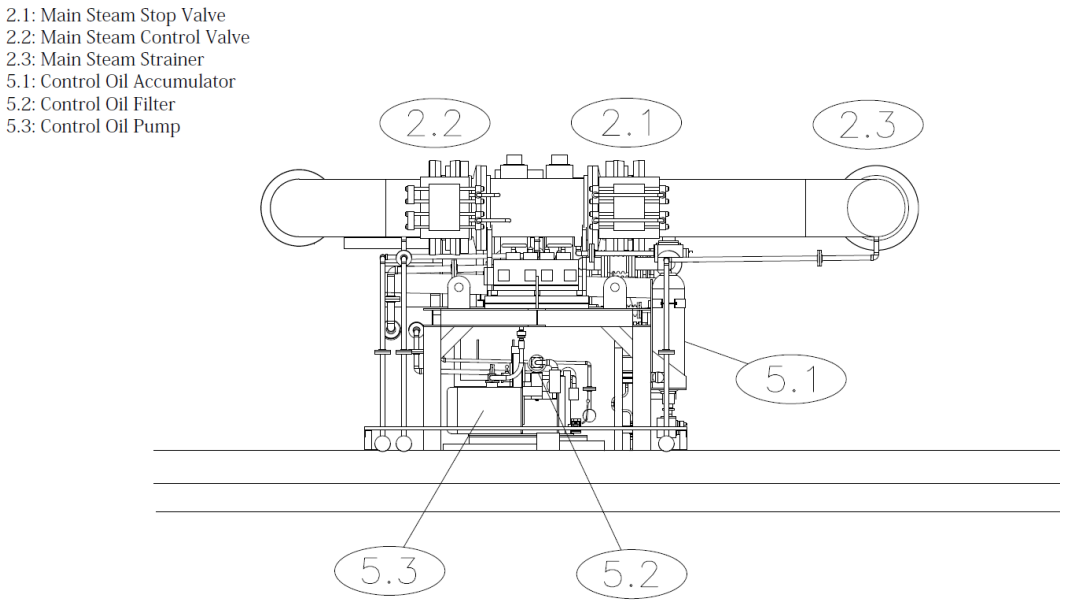

Figure 7: Valve Skid of Geoportable 5 (side view)

2.6 Piping Skid

Figure 8 presents the Piping Skid of Geoportable 5 as yellow highlighted in top view, which consist of stainless steel piping for lubrication oil, cooling water and various drains under the grating or platform. The grating or platform has an important role which can be walked on for daily operation and maintenance after commercial operation starts. Lubrication oil supplies to the turbine and reduction gear on the turbine skid and generator from the pump skid via piping in the piping skid. Cooling water for the oil cooler and generator cooler is also supplied through the piping in the piping skid. Each piping between the piping skid and the other skid connects by bolting with flange and short flexible piping to reduce site work. There is no welding work at site.

The piping skid is separated into 2 or 3 parts longitudinally for transportation from shop to site. Once these separated piping skid parts arrive at site, they are set and assembled, and then piping connection work starts.

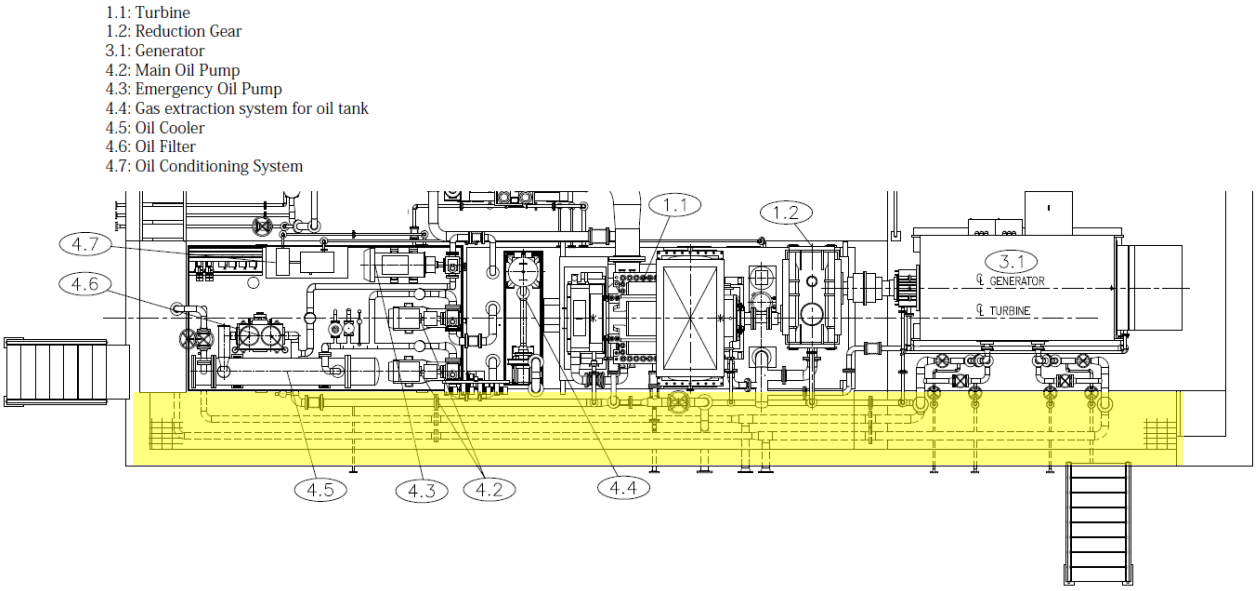

Figure 8: Piping Skid of Geoportable 5 (yellow highlighted, top view)

3. OPERATIONAL RESULT

Regarding operation result of Geoportable™, Geoportable 2 will be used as representative because the detailed operation and maintenance data during 4 years could be obtained from a customer. The valuable data is thanks to Waita-Kai LLC and Chuo Electric Power FURUSATO Geothermal and New Energy Co., Ltd., which operate and maintain Waita geothermal power plant (WGPP) in Japan using Geoportable 2.

Figure 9 presents the 4 years' operation result from commissioning starting date Dec.26, 2014 to Jun.17, 2019 for WGPP. There are many shut down days which is identified by zero Effective Power, which is defined by average gross output per day. It causes mainly less than 4 months' cyclic well cleaning work for the sole production well due to clogging by $CaCO_3$ (calcium carbonate). The other reason of shut down is grid maintenance work by Kyushu Electric Power Co., Inc. (KEPCO), due to black out in the electrical grid caused by natural disasters (heavy rain, fire, earthquake), 2 times of periodic inspection with overhaul for WGPP and 2 times of maintenance work for Geoportable 2. One of the maintenance work was electrical board replacement due to erosion. Another one was mechanical maintenance work, which is lubrication oil filling for the coupling gear.

2 times of periodic inspection and 2 times of maintenance work should be considered to calculate Availability of Geoportable 2, which is shown as the yellow highlights in Figure 9. Then, Availability of Geoportable 2 is 96.4% over 4 years' operation. It is very high availability, which means high reliability of Geoportable™ overall. The calculation formula of Availability is given by (1).

$$Availability = 1 - \left(\frac{Ts}{Tt}\right) \quad (1)$$

where *Ts and Tt* are shut down or zero Effective Power days and total calendar days from commercial operation date Jun.16, 2015 to Jun.17, 2019, respectively. However, well cleaning work, grid maintenance work by KEPCO and black out in the electrical grid caused by natural disasters are not included in *Ts* and *Tt* because these causes for shut down are not related to Geoportable 2. Again, 2 times of periodic inspection and 2 times of maintenance work should be considered solely to calculate Availability. However, mechanical maintenance work is removed because the day is not zero Effective Power day, whose Effective Power is 1.3MW.

Regarding the production well clogging phenomena for WGPP, more detailed explanation will be conducted. It is easy to understand the behavior by the trend of wellhead pressure in Figure 9, which shows pressure decrease and restoration over less than 4 months' cycle. Once the wellhead pressure is decreased by around half, it is restored by well cleaning work. This was an unfortunate property for the WGPP in the past. However, chemical dosing was successful to prevent the clogging from the end of 2018 as shown in Figure 9.

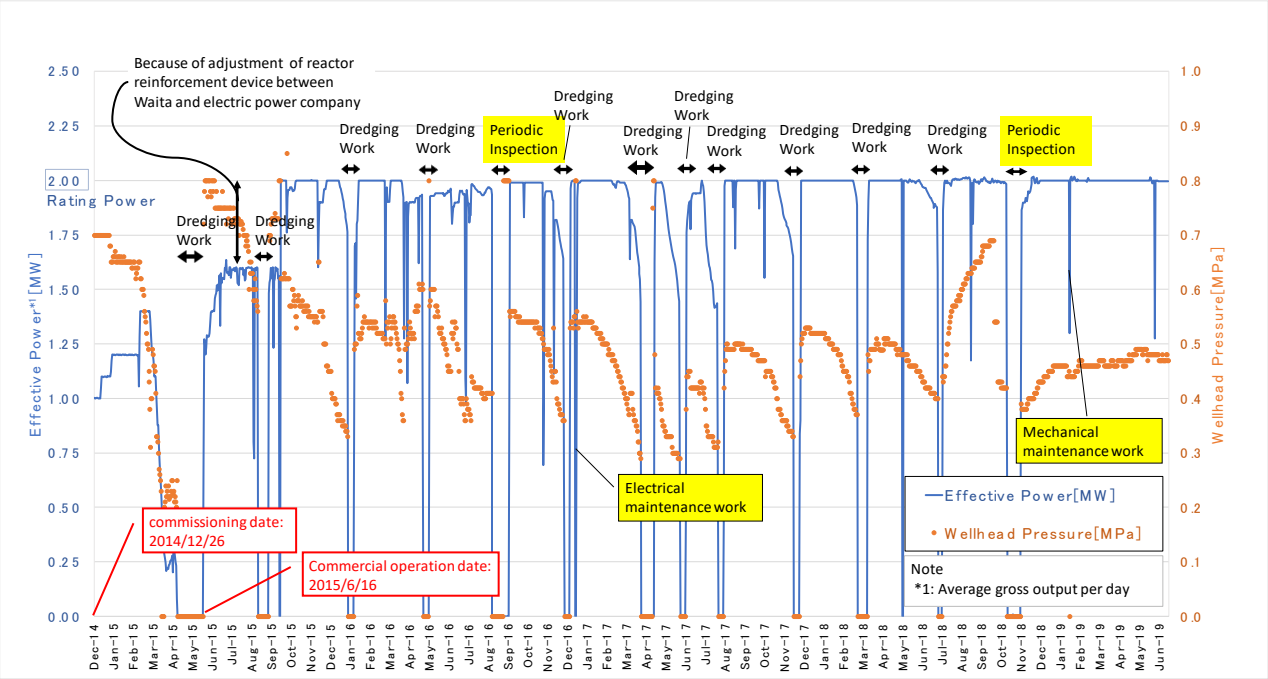

Figure 9: Operation Result of Geoportable 2 applied Waita Geothermal Power Plant in Japan (by courtesy of Waita-Kai LLC and Chuo Electric Power FURUSATO Geothermal and New Energy Co., Ltd.)

4. CONCLUSION

Geoportable™ can contribute social assignment or SDGs as one of the solutions with the following properties. It is very meaningful to provide this concept system in the global market for human's future.

- Standardized machine with easy custom designed concept for high performance, low cost and fast revenue
- 4 types (Geoportable 2, 5, 7 and X) for 1 to 20 MW gross power output applied to dry steam and flash system
- Skid mounted modular structure

High availability and reliability are confirmed by 4 years' operation result of Geoportable 2, which is WGPP.

REFERENCES

Kazuhiro Wada, Junichiro Maedomari and Kenichiro Furuya: Small Geothermal Power Generation System for Well Head, *GRC Transactions*, Vol. 41, 2017