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ADVANCED LOW TEMPERATURE GEOTHERMAL POWER CYCLES (THE ENTIV ORGANIC PROJECT)

GRANT NUMBER: DE-EE0004430

FINAL REPORT

NOVEMBER 18, 2015

AUTHORIZATION OF THE PROJECT STUDY

This project is authorized to evaluate the Kalex binary cycle and its application to low temperature geothermal sources.

Technip USA, Inc. in collaboration with MANNVIT HF and VATNASKIL CONSULTING ENGINEERS (a Mannvit subsidiary) has completed this Resource Viability Assessment of the Lower Klamath Lake Geothermal Area for Entiv Organic Energy, LLC. This assessment includes an overview of the electric power production potential of the geothermal wells located on the southeast margin of Lower Klamath Lake. Recurrent Engineering provided performance estimates for the Kalina Cycles.

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1 EXECUTIVE SUMMARY

The Entiv Organic Project focuses on utilizing an innovative, advanced ammonia-water mixed working fluid energy conversion cycle specifically designed for low temperature geothermal resource fluids. The ammonia-water mixed working fluid cycle, in its most basic form, has been proven for geothermal applications in the 1980's (Kalex Cycles SG 11 and 34).

In the early 2000's, Dr. Alex Kalina, the developer of the ammonia-water working fluid cycle for geothermal power applications, proposed and patented a new, improved ammonia water cycle referred to as the Kalex SG cycle that would self-compensate for changes in ambient, as well as production fluid, temperatures and production fluid flow variations, thereby significantly reducing the power generation penalty caused by off design conditions. Additionally, because the working fluid mixture can be tuned to a broad range of operating conditions, the cycle will offer significant performance advantages over current state of the art Organic Rankine Cycles for low temperature geothermal resources.

Recurrent bought the exclusive license to the early Kalina cycle technology and began to develop its own process upgrades, while Kalex went on to develop other ammonia-water cycles.

The project originally evaluated the Kalex SG-2a process due to its high efficiency with low temperature geosources. However, the associated annual financing cost of the capital cost exceeded the projected revenues for the project. The Kalex SG-16 was then evaluated in an effort to reduce capital costs. The SG-16 process did not meet the feasibility requirements for the project. Therefore, the Kalina KCS-34g was evaluated. The project was still not economical, although the KCS-34g appeared to be the most economical of the three process.

Due to site specific economic infeasibility, the Sponsor (Entiv) elected to not pursue the project further at this time.

2 PROJECT OBJECTIVES

2.1 PROJECT OBJECTIVES

The objectives of the Entiv Organic Project are to (i) validate the theoretical as well as actual performance advantages of an advanced ammonia-water mixed fluid cycle (Kalex) for both on and off design point operating conditions in low temperature geothermal resource applications, (ii) validate that Kalex offers significant economic benefits, (iii) prove that Kalex projects offer commercially competitive operational performance in terms of project capacity, availability, and operational overhead inclusive of safety, environmental considerations, ease of use, and efficiency.

2.2 PHASE 1

A detailed assessment of the Entiv Organic Project geothermal resource areas located in Siskiyou County, CA were completed using available data, which includes existing well data. Based on this data compilation, a comprehensive structural conceptual model was developed for the Lower Klamath Lake geothermal reservoir area.

Many of the promising low temperature geothermal wells in these areas were drilled in the early 2000's during an acute water supply crisis in the region, and were abandoned when the water was considered too warm or hot for agricultural or wetland purposes. These are generally high flow, low temperature resources ranging from 180 – 240°F. Deepening of existing wells and/or reservoir data acquisition is also foreseen as part of Phase 1.

Advanced low temperature cycles, can potentially achieve net electrical efficiencies in the range of 6 – 9.5% in the 180 – 240°F range. The predecessor Kalina Cycle has demonstrated efficiencies that are 15 – 20% lower (~4-8%). Due to exceedingly low efficiencies, traditional Organic Rankine Cycle (ORC) technology has not been able to achieve commercial success in this temperature range.

Once expected geothermal resource operating parameters have been determined, numerical models for the selected Kalex cycle will be developed to determine the theoretical performance for both on-design, as well as off-design operating conditions.

If, as expected, the numerical simulations and a paired economic feasibility study demonstrate that a Kalex based project offers commercially competitive performance, an engineering design program for a Kalex pilot project will be undertaken. The program will include all documentation required to permit and commence detailed engineering, procurement and construction of the project.

Permitting of the Kalex pilot project will also take place in conjunction with the engineering design activity. The permitting process will include geothermal power operating facility permits and drilling permits and will be wholly complete during Phase 2.

In addition to the proposed permitting activities, interconnection studies with the appropriate utility agency, will begin and be completed prior to finalization of Phase 2 activities.

Once the engineering design and economic feasibility studies for the Kalex system are completed, a final evaluation of all studies will be undertaken, and if the results are commercially favorable, Phase 2 of the project will be initiated.

2.3 PHASE 2

Additional characterization of the geothermal resource will take place to determine the optimal location for additional production or injection wells that may be required. Based on the results of the resource characterization process, up to two additional wells may be drilled to support continued long term operations of the pilot facility.

Permitting tasks associated with development of the well field gathering system will be completed.

Production and injection systems for transporting fluids to and from the pilot facility will be designed and installed once the appropriate permitting activities have taken place.

The pilot facility will be built by way of an Engineering, Procurement, and Construction (EPC) contract, utilizing the services of an EPC firm, specialist geothermal consulting engineers, as well as general constructors.

2.4 PHASE 3

To validate the long term viability of Kalex Cycle projects, the Kalex pilot project will be operated for a minimum of two years to report on the economic, performance, and operating characteristics of the facility. A review of the project will be undertaken to validate performance, and a final report will be created that includes a validation of technical and economic assumptions and documentation of lessons learned during the operational period. Note that design life of the plant will be 25 years.

In order to rapidly commercialize the technology, strategies will be developed for standardizing Kalex technology where possible, and will include plans for market penetration in the low temperature binary project arena.

The Purpose of this Resource Viability Assessment is to assess opportunities for electric power production from Entiv Organic Energy's geothermal resources in the Lower Klamath Lake Geothermal Area. The report's objective is to provide a decision basis for future development activities. The assessment reviews the characteristics of the geothermal resource and existing wells, outlines field development options, estimates the electric power production potential, and evaluates reservoir risk.

3 SCOPE OF WORK

The Entiv Organic Project focuses on utilizing an innovative, advanced ammonia-water mixed working fluid energy conversion cycle specifically designed for low temperature geothermal resource fluids.

The ammonia-water mixed working fluid cycle, in its most basic form, has been proven for geothermal applications in the 1980's (Kalina Cycles KCS 11 and 34).

In the early 2000's, Dr. Alex Kalina, the developer of the ammonia-water working fluid cycle for geothermal power applications, proposed and patented a new, improved ammonia water cycle referred to as the Kalex SG cycle that would self-compensate for changes in ambient, as well as production fluid, temperatures and production fluid flow variations, thereby significantly reducing the power generation penalty caused by off design conditions. Additionally, because the working fluid mixture can be tuned to a broad range of operating conditions, the cycle will offer significant performance advantages over current state of the art ORCs for low temperature geothermal resources.

3.1 PHASE 1 – FEASIBILITY STUDY AND ENGINEERING DESIGN AND PERMITTING

3.1.1 Subtask 1.1 Geologic Model of Target Geothermal Resource

All available geologic, geochemistry, and geophysical data for the Entiv Organic Project in the Lower Klamath Lake geothermal area, in Siskiyou County, CA will be compiled, and will include existing geological information, resource assessment reports, volumetric heat reserve estimated, and well production data. Deepening of existing wells and/or reservoir data acquisition is also foreseen. Based on this data compilation, a comprehensive structural conceptual model for the Lower Klamath Lake geothermal reservoir will be developed.

3.1.2 Subtask 1.2 Geothermal Production Estimate

Flow test data will be evaluated to determine geothermal fluid production rate and temperature. Most likely, best case and worst case scenarios will be developed based on this model to develop suitable design parameters for the Kalex cycle design points, providing critical information for optimized definition of the geothermal resource.

3.1.3 Subtask 1.3 Numerical Modeling of Kalex Cycle

Numerical models for the selected Kalex Cycles will be developed for the production scenarios developed in Subtask 1.2. In addition to variations in reservoir performance, various working fluid cooling scenarios (air cooled condensers, wet cooling towers, and hybrid cooling system), will be simulated to determine theoretical performance under various operating conditions.

3.1.4 Subtask 1.4 Pilot Project Engineering Design

Once final confirmation of high efficiencies of the Kalex cycles with low temperature geo-resources is confirmed by way of numerical modeling, the engineering design program for the project will commence. The engineering design program will include plant design, balance of plant facilities, and production and injection systems for transporting fluids to and from the pilot facility. The deliverables package will include all materials required to commence construction of the project, inclusive of civil and mechanical drawings, pilot plant layout drawings, heat mass balance diagrams, electrical one line diagrams, process and instrumentation diagrams, equipment and materials specifications, equipment and material lists, equipment/material/construction cost estimates.

3.1.5 Subtask 1.5 Pilot Project Economic Feasibility

Upon completion of the Project Engineering Design, an economic feasibility study will commence to determine the financial viability of the project based on the Kalex cycle. This study will include comprehensive analysis and financial models with capital costs, operating costs, installed cost per MWe, avoided cost of electricity, cost/benefit analysis, payback period, Levelized Cost of Energy (LCOE), Return On Investment (ROI), and quantification of any other beneficial attributes, such as climate change benefits, carbon offset, and all other environmental and renewable attributes associated with "low-to-no" emissions/carbon foot print geothermal power facilities. Sensitivity analysis of key parameters will also be performed.

3.1.6 Subtask 1.6 Environmental Permitting of Pilot Plant Construction

Permitting has been completed for the currently planned exploration drilling activities discussed in Subtask 1.1. Should the technical and financial conclusions support development of a Pilot Project, environmental permitting and interconnection studies required for the construction of the demonstration facility, as well as development of the well field gathering system, will also be completed.

The US Fish and Wildlife Service has determined that an Environmental Assessment under the National Environmental Policy Act is sufficient for review – this study will be completed in fall 2012. This approach should ensure that all permitting requirements have been completed prior to the completion of Phase 2 activities.

Preliminary discussions with an area Transmission Service Provider indicate that it is likely that adequate capacity exists in the area to support development of the Pilot Project. These studies are estimated to be complete well in advance of commercial operations of the Pilot Project.

3.1.7 Subtask 1.7 Project Management

As required by the Funding Opportunity Announcement for this Financial Assistance award, the Recipient must provide data to the DOE Geothermal Data Repository (DOE-GDR). The Recipient must provide data to the DOE-GDR as it is generated, but no later than the end of each reporting quarter in which the data is generated. The data will be submitted to DOE-GDR at https://gdr.openei.org. The data will be made publicly available via the National Geothermal Data System (NGDS) once it has been submitted and accepted into the DOE-GDR system. If the data is protected or subject to a moratorium, it will not be made publicly available until the moratorium has expired, and it will be held in a secure section of the DOE-GDR. Protected Data will be treated according to the Intellectual Property Provisions. Please refer to the Provision entitled "DOE Geothermal Data Repository (DOE-GDR) Instructions for Recipients" in the award Special Terms and Conditions for specific data submission instructions.

Reports and other deliverables will be provided in accordance with the Federal Assistance Reporting Checklist following the instructions included therein. Additional deliverables deemed to be appropriate but not included as part of the checklist will also be provided on the basis of requests or discussions with DOE.

3.1.8 Go/No Go/Redirect Decision

A Go/No Go/Redirect decision will be made based upon a thorough analysis of all the results from Phase I Tasks and Objectives activities. Key decision criteria to proceed to Phase 2 will include geofluid temperatures and flows, long term sustainability of the geo-resource, expected Kalex pilot plant performance, and attractive rates of return to the local Independent Power Producer (IPP), for which the following minimum criteria will apply:

- Initial resource temperature = 185 deg. F
- Geofluid flow = 3,000 gpm
- Expected geothermal reservoir life = 15 years
- Kalex gross power output = 3 MW
- Levered pre-tax IRR = 8%

As defined and described herein, the Entiv Organic Project will cover all required steps in determining the feasibility of the proposed project during the Phase I activities.

The Recipient shall not continue into Phase II activities without written authorization from DOE. Should Phase II not be initiated, the Phase I Report and all review presentation materials shall serve as the final technical report for DOE purposes.

3.2 PHASE 2 – PROCUREMENT, INSTALLATION, AND COMMISSIONING OF EQUIPMENT

3.2.1 Subtask 2.1 Reservoir Model Development

An initial state reservoir model will be constructed utilizing the geologic model completed in Subtask 1.1, available reservoir parameters, well information for the target geothermal area, as well as the well flow data analyzed in Subtask 1.2. This model will be used as a tool to optimize the fluid management of the project geothermal field.

Surface location, downhole targets and well designs will be completed for any additional production and injection wells that may be required to develop the Lower Klamath Lake Geothermal Area, in Siskiyou County, CA. Flow and pressure response testing will be completed utilizing the existing production and monitoring wells in the area to define the engineering characteristics necessary to construct the reservoir management model, including location of the injection well(s).

The proposed pilot plant will utilize a purpose built production and injection well system. Well design will be according to design conditions developed in Subtasks 1.1 and 1.2, including diameters and casing depths. Large diameter casings will be employed to facilitate installation of a high-capacity submersible pump, with surface casing to a depth that minimizes the intrusion of shallow, cooler water. It is anticipated that the production well will provide sufficient low-temperature geothermal fluid to meet the design mass flow of the Kalex cycle facility. Based on the results of the resource characterization process and completed well productivity, it is expected that up to two additional wells will be drilled to support continued long term operations of the pilot facility.

3.2.2 Subtask 2.2 Pilot Project Engineering, Construction, and Procurement

Pilot project EPC work based on the engineering design under Subtask 1.4 will be performed. A local geothermal IPP will assure proper management of the entire project through all its technical and commercial phases.

Additionally, gathering and injection systems for transporting fluids to and from the pilot facility will be designed and installed once the appropriate permits are in place. This will include design, specification, and installation of production and injection piping, production pumps, and all additional required equipment.

3.2.3 Subtask 2.3 Technology Licensing

The ammonia water working fluid technology and these new patented systems are owned by Dr. Kalina via his company, Kalex, LLC. In May 2011, Technip (and Oski Energy) signed an exclusive license purchase agreement with Kalex to jointly license and market Kalex Geothermal Systems Technology worldwide. Technip will cost share a Kalex technology sublicense to the Entiv Organic Project.

3.2.4 Subtask 2.4 Project Management

As required by the Funding Opportunity Announcement for this Financial Assistance award, the Recipient must provide data to the DOE Geothermal Data Repository (DOE-GDR). The Recipient must provide data to the DOE-GDR as it is generated, but no later than the end of each reporting quarter in which the data is generated. The data will be submitted to DOE-GDR at https://gdr.openei.org. The data will be made publicly available via the National Geothermal Data System (NGDS) once it has been submitted and accepted into the DOE-GDR system. If the data is protected or subject to a moratorium, it will not be made publicly available until the moratorium has expired, and it will be held in a secure section of the DOE-GDR. Protected Data will be treated according to the Intellectual Property Provisions. Please refer to the Provision entitled "DOE GEOTHERMAL DATA REPOSITORY (DOE-GDR) INSTRUCTIONS FOR RECIPIENTS" in the award Special Terms and Conditions for specific data submission instructions.

Reports and other deliverables will be provided in accordance with the Federal Assistance Reporting Checklist following the instructions included therein. Additional deliverables deemed to be appropriate but not included as part of the checklist will also be provided on the basis of requests or discussions with DOE.

3.3 PHASE 3 – OPERATIONS AND MAINTENANCE

3.3.1 Subtask 3.1 Pilot Project Performance Monitoring and Analysis

The Entiv Organic ammonia water energy conversion project will be designed with the necessary instrumentation to allow a detailed monitoring of the Kalex Cycle process, providing a means of comparing the plant modeled performance and heat and mass balance to actual performance tests results conducted at different operating conditions. Operations and performance data will continue to be collected from the demonstration facility for a minimum of two years.

3.3.2 Subtask 3.2 Performance / Operations Validation

An independent firm will be selected to review the information and validate project performance.

3.3.3 Subtask 3.3 Final Report

A final report will be generated detailing the facility performance, operating characteristics, economics of construction and operations, attachment of Subtask 3.2 Independent Review, and documentation of "lessons learned" over the operational period.

4 GEOLOGIC MODEL OF TARGET GEOTHERMAL RESOURCE

All available geologic, geochemistry, and geophysical data for the Entiv Organic Project in the Lower Klamath Lake geothermal area, in Siskiyou County, CA will be compiled, and will include existing geological information, resource assessment reports, volumetric heat reserve estimated, and well production data. Deepening of existing wells and/or reservoir data acquisition is also foreseen. Based on this data compilation, a comprehensive structural conceptual model for the Lower Klamath Lake geothermal reservoir will be developed.

The Purpose of this Resource Viability Assessment is to assess opportunities for electric power production from Entiv Organic Energy's geothermal resources in the Lower Klamath Lake Geothermal Area. This report's objective is to provide a decision basis for future development activities by reviewing the characteristics of the geothermal resource and existing wells, outlining field development options, estimating the electric power production potential, and evaluating reservoir risk.

Information for this assessment was obtained from various reports supplied by Entiv Organic Energy, publicly available information sources, and site visits by Mannvit and Technip specialists in August 2011.

Since the Resource Viability Assessment in 2011 some additional work has been carried out in order to explore the resource further. This include flow testing of well 12-C, deepening of well 9-A and corresponding data gathering. Well 9-A was logged after the deepening but not flow tested. The Resource Viability Assessment has not been updated with the respect to this additional data and information.

Lower Klamath Lake Geothermal Area

The area targeted for geothermal development by Entiv Organic Energy is located at the southeast margin of the Lower Klamath Lake and is referred to as the Lower Klamath Lake Geothermal Area in this report. This area belongs to the upper Klamath Basin which encompasses the drainage basin of the Klamath River north of the Iron Gate Dam. The Klamath Basin contains a large ground-water flow system which is dominated by cold ground-water but is also known to host significant low- to intermediate geothermal systems, such as those at Klamath Falls, Olene Gap and Klamath Hills. The Klamath basin lies within a faulted plateau at an elevation ranging from 4,000 to 5,000 ft. The basin has a history of volcanic activity going back 35 million years and is characterized by a system of extensional faults trending in a north to northwest direction. Movements on the faults have created a series of structural sub-basins filled with sediments and separated by ranges. Displacements on the faults range from several hundred to several thousand feet.

An estimate of the electric power production capacity of the geothermal field was made using the volumetric method on the basis of the conceptual model and key resource data obtained from three wells, 9-A, 9-C and 12-C, drilled along the southeast margin of the Lower Klamath Lake in the early 2000's.

The geothermal field is probably fed by an upflow of geothermal fluid along a deep-seated fault underlying the Chalk Bluffs escarpment. This upflow spreads out laterally in a reservoir dominated by fractured basaltic rocks and covered by lake-fill sediments. Based on outflow temperatures in wells 12-C, 9-A and 9-C, reservoir temperatures range from 160 - 196°F, whereas, based on geo-thermometer calculations, temperatures of 210 - 250°F may be present deeper within the upflow zone.

The reservoir shape and volume are not well constrained. In map view, the thermal anomaly is interpreted to be elongated and aligned with the fault-controlled escarpment. The reservoir is estimated to extend approximately 4 miles along the escarpment and be approximately 1.5 miles wide. The thickness of reservoir rocks exposed in the wells is only a few hundred feet. It is likely, however, that the wells will be able to tap a significantly thicker reservoir section.

Estimates of recoverable heat and electric power generation capacity were made using the volumetric method and a conversion efficiency appropriate for the Kalex SG-2a power generation cycle.

The Kalex SG-2a cycle is structured as "cycle within a cycle." The system's working process is comprised of two interacting cycles, the main cycle and the internal, supporting cycle. The Kalex SG-2a was designed to improve efficiencies utilizing geo-sources below 300°F.

In order to cover the likely range of outcomes, three different estimates (Low, Middle and High) were made using three different sets assumptions. The Middle Case yields recoverable thermal output of 45 MWth and a gross electric power generation capacity of 3.2 MWe, both calculated over 15 years. Corresponding numbers for the other two cases are 117 MWth and 8.2 MWe (High Case), and 13.5 MWth and 0.94 MWe (Low Case).

Review of the well tests carried out in 2002 has uncovered some relatively minor inconsistencies and weaknesses, but the high fluid production capacities indicated by the tests are largely confirmed. Our analysis suggests slightly lower transmissivity values of about 2x104 to 5x104 ft2/day. Storativity values are found to range widely as before. An estimate was also obtained for the well loss coefficient for well 12-C. The results indicate that well production rates similar to those achieved during the constant rate discharge tests are realistic during initial stage of production from the reservoir. It is emphasized, however, that the long-term response of the reservoir to exploitation cannot be predicted with any confidence on the basis of these results. Longer-term testing, including interference testing and tracer testing, would be needed for that. In conclusion, it seems that the production capacity of the three existing wells is sufficient to deliver heat to a Kalex power plant scaled to the size of the underground heat reservoir.

Field Development Options

This report focuses primarily on options for developing the geothermal field based on the existing wells 12-C, 9-A, 9-C. Production potential resulting from deepening of existing wells and drilling of new wells is only touched upon briefly. It is understood that a capacity to reinject all of the geothermal fluid extracted is a definite requirement for the field development. Given these constraints and the production characteristics of the three wells, the best strategy is to base the development on a single production well, 12-C, and one reinjection well. The reason for this is that due to its relatively high outflow temperature well 12-C is the most powerful heat producer despite having less favorable yield/draw-down characteristics than wells 9-A and 9-C. It seems that well 9-C is better suited as a reinjection well than 9-A because of its location at the northeastern margin of the thermal anomaly. In theory, injecting from the cold end of the elongated reservoir should make sweeping of the reservoir heat more effective than injecting into well 9-A which is located much closer to 12-C. The final selection may require more testing.

Reservoir fluid salinity is relatively low, pH is near-neutral, and gases are presumably not concentrated (this has however not been confirmed). Therefore, the corrosion and the scaling potential of the geothermal fluid is considered low. This must be studied in greater depths at later stages, when detailed analyses of the fluid are available.

By comparing the concentrations of various ions to the US Environmental Protection Agency (EPA) limits, it is evident that the concentration of some ions and components found in the produced water exceeds EPA limits, including Al, As, Fe, Mn and SO4, in addition to the pH.

Electric Power Production Potential

The power capacity estimates of the geothermal field have been taken a step beyond the stored-heat estimate given above by matching the Middle Case model to a specific Kalex SG-2a power plant cycle and to the production characteristics of well 12-C. Based on the testing of well 12-C in September 2011, a production rate of 3,650 gpm is selected for the calculations. In view of the draw-down curve determined for well 12-C, this corresponds to setting the down-hole pump at the maximum depth allowed by the casing. For the power cycle itself, the key assumptions/design requirements are a Start of Run (SOR) flow of 3,650 gpm and temperature of 196°F, an assumed End of Run (EOR) temperature of 178°F, and (a) water cooling tower(s) operating at 49°F.

Based on these assumptions an initial power plant capacity of 3.5 MWe (gross) or 3.2 MWe (net) is obtained (excluding the downhole pump and lesser parasitic loads associated with the plant). This output is calculated to decline to 3.1 MWe (gross) or 2.7 MWe (net) based on a postulated decline in inlet temperature of 1.2°F over the 15 year lifetime of the reservoir. Approximately 0.4 MWe of the power generated will be needed to run the downhole pump.

Four High Scenarios have been defined:

- The first “moderate risk” scenario envisions deepening of Well 9-A from its current 600 feet to around 2,000 feet intersecting an outflow zone at a peak temperature of 203°F. Under this scenario, a Kalex power plant’s SOR capacity would rise to 3.8 MW gross or 3.5 MW net.
- The second “moderate risk” scenario envisions drilling a new well a short distance west of Well 12-C and anticipates a 7°F hotter brine than currently produced from Well 12-C. Under this scenario, a Kalex power plant’s SOR capacity would rise to 3.8 MW gross or 3.5 MW net.
- The third “medium risk” scenario envisions deepening of Well 12-13 to reach the basaltic reservoir layer expected below the bottom of the well, and uncovering brine at 203°F, yielding a similar power plant performance to the first and second High scenarios.
- The final “higher risk” scenario speculates on a deeper “step-out” well. This scenario envisions drilling into the assumed reservoir upflow zone targeting a geofluid temperature of 239°F. Under this scenario, a Kalex power plant’s SOR capacity would rise significantly to 5.77 MW gross or 5.37 MW net. Significantly, the capital cost per MW of this Kalex power plant would be substantially reduced in this “higher risk” scenario.

Reservoir Risks

Several resource-related risks to the power plant project have been identified, including:

- The heat stored in the reservoir may be insufficient to support the power generation scenario outlined for the Middle Case. Several of the underlying parameters are not known well enough to exclude this possibility; they include the reservoir volume, reservoir temperature, abandonment temperature and recovery factor.
- Reservoir permeability and natural recharge may be insufficient to limit pressure drawdown to the maximum value assumed in this study. This would reduce the power output because of the limitations on pump depth imposed by the depth of the casing.
- The useful lifetime of the reservoir may be cut short by fast returns of cold water directly from the injection well to the production well. The risk is enhanced by the fractured nature of the reservoir and the location of production and reinjection wells along an assumed permeable fault.

All three risks, can be mitigated by longer-term testing of the production well-injection well doublet, including interference and tracer testing.

4.1 CHARACTERISTICS OF THE GEOTHERMAL RESOURCE

4.1.1 Regional Geology and Hydrogeology

The area targeted for geothermal development by Entiv Organic Energy is located at the southeast margin of the Lower Klamath Lake (Figure 1). From a physiographic and geologic viewpoint this area is located within a composite graben that forms the westernmost structural trough of the Basin and Range physiographic province (Sherrod and Pickthorn, 1992). From a hydrologic viewpoint the area belongs to the upper Klamath Basin (hereafter referred to as the Klamath Basin) which encompasses the drainage basin of the Klamath River north of the Iron Gate Dam. The Klamath Basin contains a large ground-water flow system which is dominated by cold ground-water but is also known to host significant low- to intermediate geothermal systems, such as those at Klamath Falls, Olene Gap and Klamath Hills (Gannett et al., 2010). An overview of the physiography of the Klamath Basin and the location of the known geothermal systems is shown in Figure 1.

The Klamath Basin spans the boundary between the Cascade Range and Basin and Range geologic provinces (Orr and others, 1992). The Cascade Range is a north-south trending volcanic zone extending from northern California to southern British Columbia characterized by volcanic centers, lava flows and other products of volcanic eruptions. The Basin and Range Province is a region of crustal extension characterized by subparallel fault-bounded basins separated by ranges. The Klamath Basin has been shaped by geological process operating in both provinces.

The Klamath basin lies within a faulted plateau at an elevation ranging from 4,000 to 5,000 ft. The basin has a history of volcanic activity going back 35 million years and is characterized by a system of extensional faults trending in a north to northwest direction. Movements on the faults have created a series of structural sub-basins filled with sediments and separated by ranges. Displacements on the faults range from several hundred to several thousand feet. A geological map of the Klamath basin is shown in Figure 2.

The geological units of the Klamath basin can be grouped into eight regional hydrogeological units (Gannett et al., 2010). A description of the units is presented in Table 1 and their spatial distribution is shown on the geological map in Figure 2.

4.1.1.2 Low-permeability sub-stratum

The regional ground-water system is bounded below by low-permeability lava and volcaniclastics of Miocene and older age (Unit 1). Weathering, hydrothermal alteration, and secondary mineralization have lowered the permeability of this unit.

4.1.1.3 Main aquifers

The main ground-water aquifers in the region are hosted by above lying series of late Miocene to Pliocene basaltic and andesitic lava flows and vent deposits (Unit 2). These deposits are widely distributed in the basin and are characterized by high permeability. They are known to be affected locally by hydrothermal alteration and secondary mineralization. The geothermal reservoirs at Klamath Falls, Olene Gap and Klamath Hills are mainly composed of rocks belonging to this unit. Rocks of this age are also developed as volcaniclastic and sedimentary deposits.

The Late Miocene to Pliocene volcaniclastic deposits (Unit 3) occur locally in the vicinity of eruptive centers but their hydrological properties are not well known.

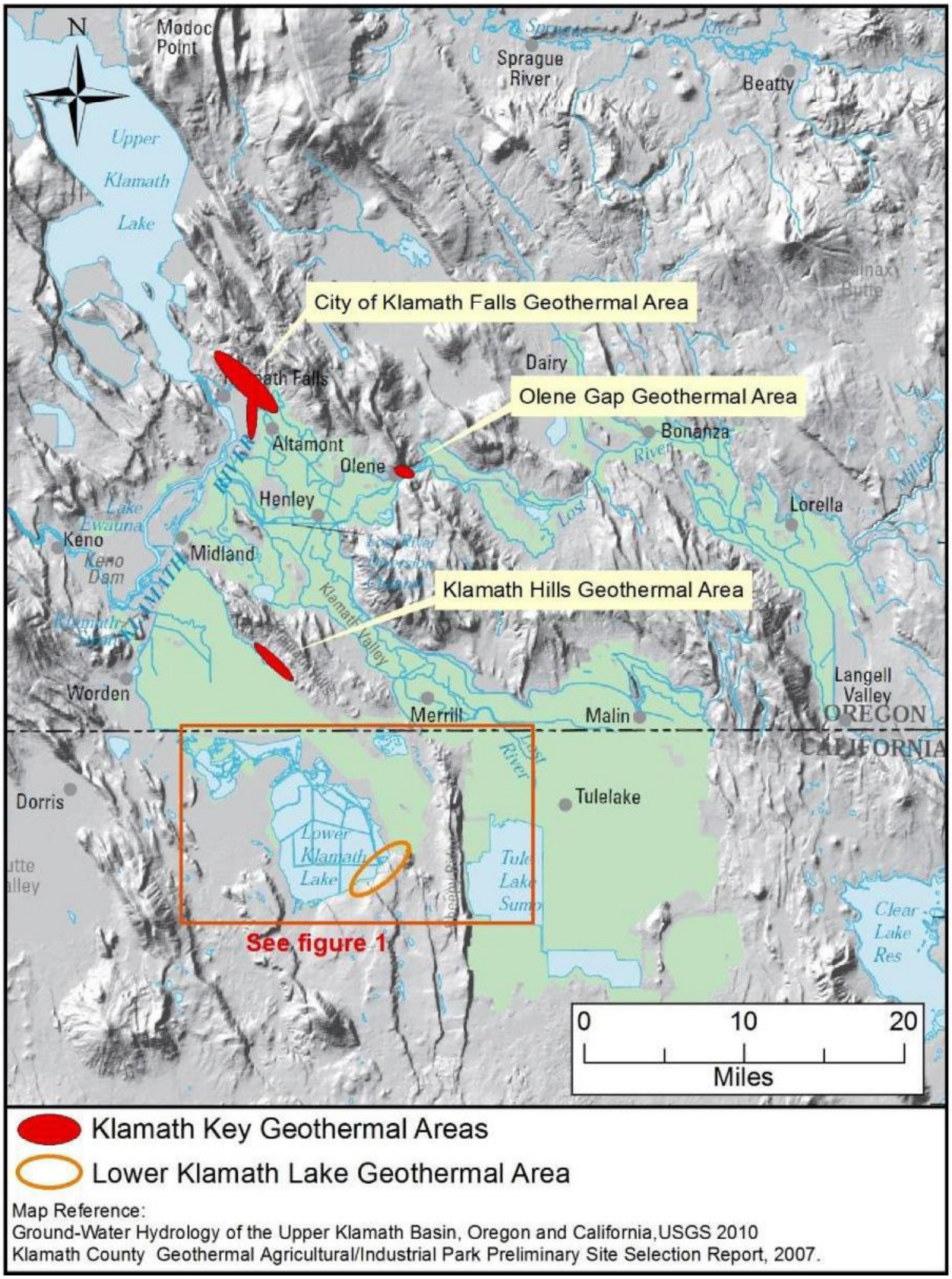


Figure 1. Overview of the Klamath Basin.

Cover strata

Interbedded with and partly overlying the late Miocene to Pliocene volcanic aquifers are fine-grained continental sedimentary deposits of from the same time period (Unit 4). These deposits typically have low permeability. They are found both within the present basins and ranges and are probably remnants of older sedimentary basins.

The late Miocene to Pliocene rocks are overlain by various types of rocks of Quaternary age. For the purpose of the present study, the important rock types are late Pliocene to Recent sedimentary rocks, especially alluvial deposits in stream-valleys and lake deposits in the major lake basins (Unit 8). These rocks are also characterized by low permeability. The other Quaternary rock types are not thought to be of importance in the central part of the basin. This includes moderately permeable sedimentary deposits (Unit 5), basaltic and andesitic lavas and vent deposits (Unit 6) and volcaniclastic deposits (Unit 7) both of which can be highly permeable.

Table 1. Generalized Hydrogeologic units in the Klamath Basin, Oregon and California.

Unit No.	Hydrogeologic unit	Map symbol	Lithologic and hydrologic characteristics
8	Quaternary sedimentary deposits	Qs	Lithology: Fine- to coarse-grained sediments deposited in stream valleys and major lake basins. Permeability: The lake basin deposits, predominantly fine grained and have low permeability. Permeable coarse-grained deposits occur in stream valleys and locally in the lake basins.
7	Quaternary volcaniclastic deposits	Qvp	Lithology: Pyroclastic flows and air fall material (pumice, ash, and lapilli) deposited during the climactic eruption of Mt. Mazama that formed Crater Lake, and debris avalanche deposits of the Shasta River Valley. Permeability: Air fall deposits are highly permeable. Pyroclastic flows and debris deposits may have low permeability.
6	Quaternary volcanic rocks	Ov	Lithology: Basaltic and andesitic lavas and vent deposits occurring in the Cascade Range and around Medicine Lake Volcano. Permeability: These materials are generally highly permeable, but may not be saturated at high elevations.
5	Quaternary to late Tertiary sedimentary rocks	QTs	This unit has very limited distribution. Lithology: Fine- to coarse-grained unconsolidated to moderately indurated sedimentary deposits. Permeability: Not well known, but may be moderately permeable at some locations.
4	Late Tertiary sedimentary rocks	Ts	Lithology: Fine-grained continental sedimentary deposits incl. bedded diatomite, mudstone, siltstone, and sandstone. Permeability: Generally low permeability, but contains permeable strata at some locations.
3	Late Tertiary volcaniclastic rocks	Tvpt	Lithology: Palagonitized basaltic ash and lapilli deposits associated with eruptive centers. Permeability: Hydrologic characteristics not well known, but springs known to emerge from basal contact with unit Ts.
2	Late Tertiary volcanic rocks	Tv	By far the most widely developed aquifer unit in the study area. Lithology: Basaltic and andesitic lava flows and vent deposits. Lesser amounts of silicic domes and flows. Permeability: Moderate to high permeability, locally reduced by hydrothermal alteration and secondary mineralization.
1	Older Tertiary volcanic and sedimentary rocks	Tovs	Unit forms substratum and boundary to the regional ground-water system Lithology: Miocene and older volcanic and volcaniclastic deposits. Permeability: Generally low due to weathering, hydrothermal alteration, and secondary mineralization.

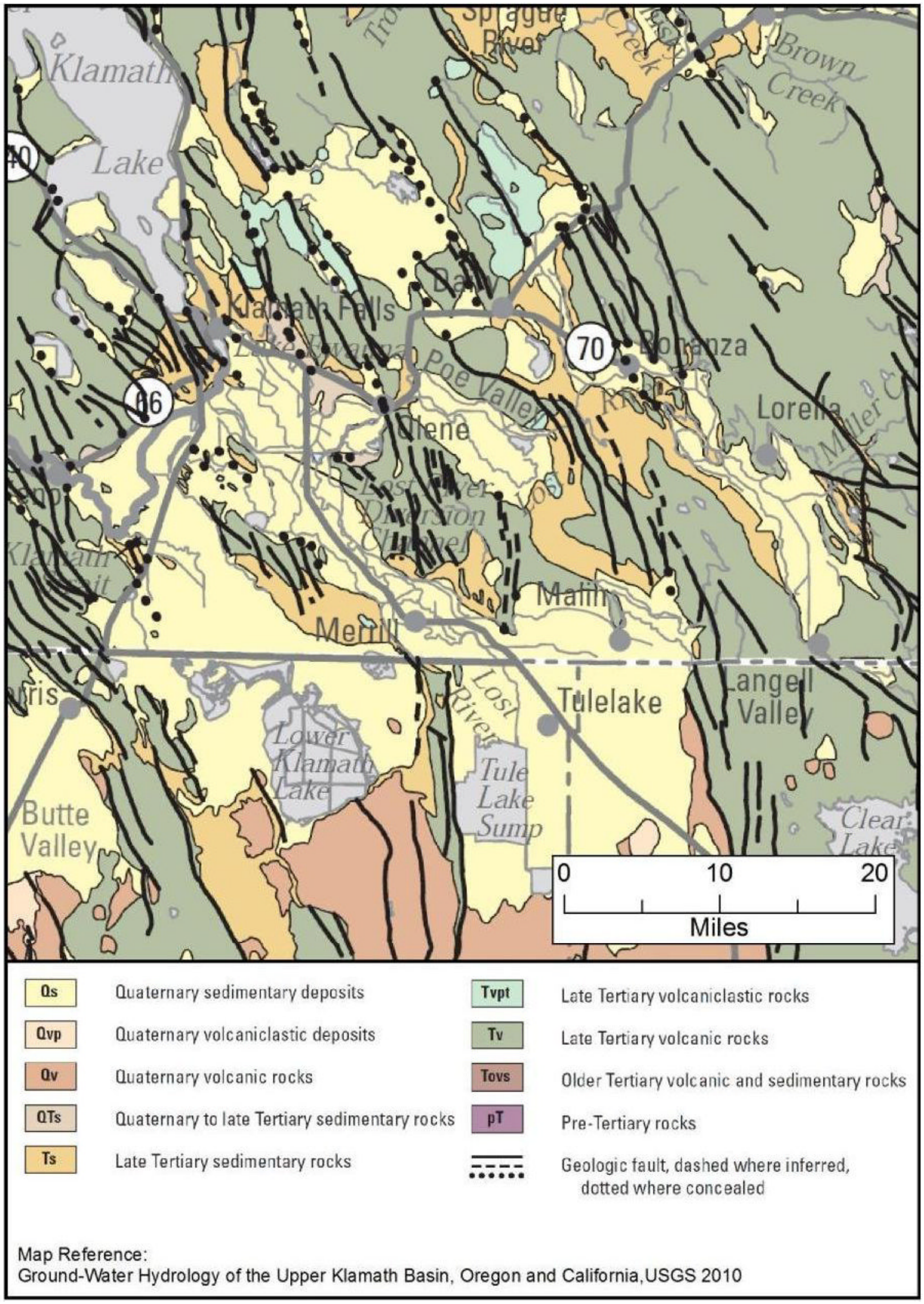


Figure 2. Geological map of the Klamath Basin.

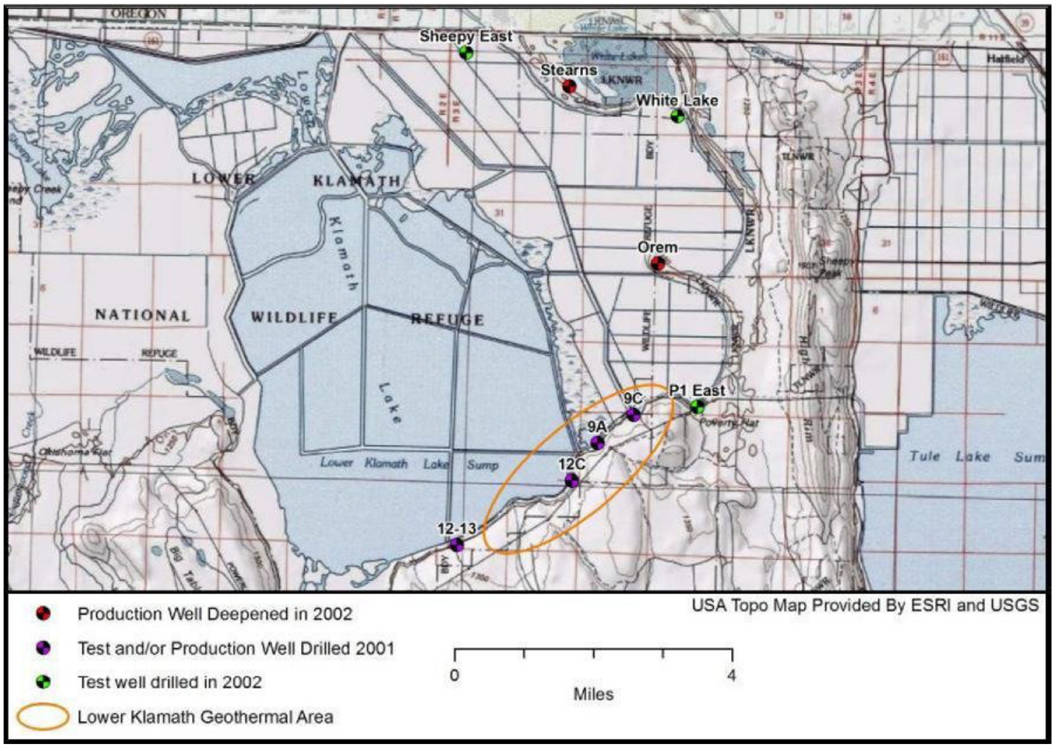


Figure 3. Lower Klamath Lake Geothermal Area. The area targeted for development is located at the southeastern margin of the lake. The location of wells drilled for groundwater development are shown.

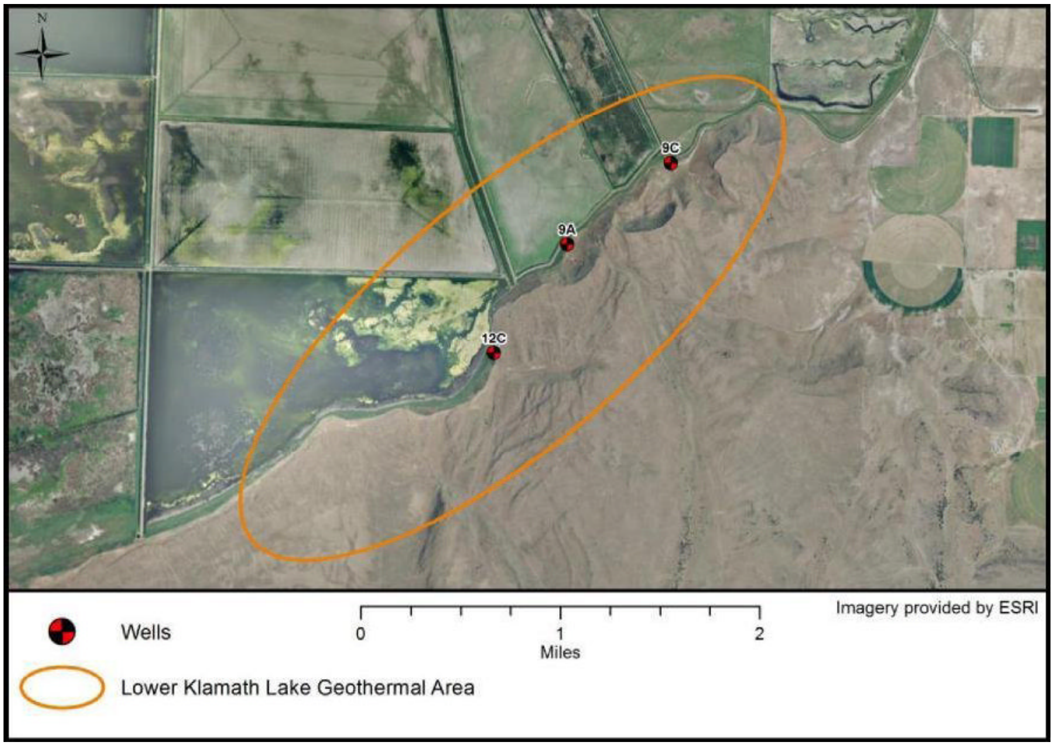


Figure 4. Development area and groundwater wells with geothermal potential. Wells 12C, 9A and 9C have potential for geothermal development.

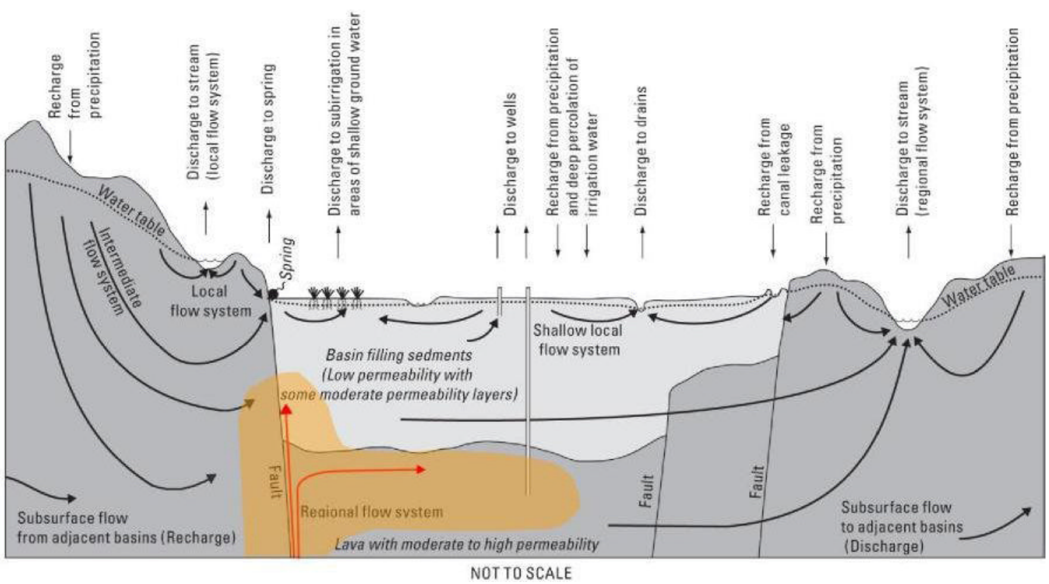


Figure 5. Schematic illustration of the geological and hydrological setting of geothermal systems in the Klamath Basin. Modified from Gannett et al. (2010).

4.1.2 Lower Klamath Lake Geothermal Area

4.1.2.1 Key Resource Data

The Lower Klamath Kale Geothermal Area was discovered as result of drilling for cold groundwater by the U.S. Fish and Wildlife Service in 2000-2002. In this period nine test wells and six production wells were drilled at ten different sites in the Lower Klamath National Wildlife Refuge adjacent to Lower Klamath Lake (see Figure 3). The wells ranged in depth from 446 ft to 1458 ft with an average of 1100 ft. The drilling target was in all cases the permeable Late Tertiary volcanics (cf. Table 1, Unit 2) that host the main groundwater aquifer in the region. The top of the basalts was only reached at six of the sites at depths ranging from 42 ft to 1452 ft. High to moderate yields were obtained at five of the sites (12-C, 9-A, 9-C, Stearns and Otey Island), but low yields at other sites.

The data gathered during the drilling campaign is the most important data available for the evaluation of the Lower Klamath Lake Geothermal area. It consists of:

- Lithological descriptions
- Information on mud losses and elevated outflow temperatures during drilling
- Descriptions of well response to stimulation using airlifting and surging
- Data and interpretation results from short step-rate discharge tests and longer constant-rate discharge tests
- Estimates of long term production capacity.
- Laboratory analyses of water quality samples collected from well discharge

The data and results from the drilling campaign are described in WESCORP and Golder Associates, Inc. (2001, 2002 and 2003).

Elevated temperatures, associated with geothermal conditions, were encountered in five of the wells, i.e. 12-C, 9-A, 9-C, P1 East and White Lake. The two latter wells gave low yields and were not flow-tested whereas the others gave more promising results. The key characteristics of wells 12-C, 9-A and 9-C established by hydraulic testing and measurements of outflow temperatures are summarized in Table 2.

Table 2. Main characteristics of wells 12-C, 9-A, and 9-C.

Well	Depth (feet)	Outflow temperature (°F)	Approximate long-term flow capacity (gpm)	Specific capacity (gpm/ft)
9-A	600	167	7,300	266
9-C	802	157	6,200	265
12-C	1254	192	3,650	15.7

4.1.2.2 Conceptual Model

The basic elements of the conceptual model for the Lower Klamath Lake Geothermal Area are illustrated in Figure 5.

The geothermal system is interpreted to be driven by an upwelling of hot water along a fault zone running along the Chalk Bluffs escarpment which defines the southern edge of the Lower Klamath Lake (cf. Figure 1 to Figure 4). The deep source of the hot water is not known. It can be heating either by the prevailing geothermal gradient or by deep-seated intrusives. The hot water is interpreted to enter from below into the regional groundwater aquifer hosted by the late Tertiary basalts where it spreads out and mixes with the cold water. Steady-state flow of this fluid has heated an elongated body of reservoir rocks extending a long the escarpment. The volume or shape of the reservoir is not well constrained. In map view its outline is approximated by an ellipse with its center located close to well 12-C and extending in the northeast direction a short distance beyond well 9-C. This limit corresponds to a temperature of approximately 158 °F. The reservoir is postulated to extend in a southwest direction towards well 12-13.

4.1.2.3 Volumetric Capacity Estimate

An estimate of the electric power production capacity of the geothermal field was made using the volumetric method on the basis of the conceptual model and key resource data presented above.

The volumetric method

The method is based on estimating the energy content of the geothermal system by assessing the reservoir volume and the predominant reservoir temperature above given cutoff temperature, or rejection temperature which is based on the energy conversion technology assumed. The recoverable thermal energy is then estimated from the thermal energy available in the reservoir by using thermal recovery factor for the producible fraction of the reservoir's thermal energy.

The volumetric method assumes the reservoir rocks to be porous and permeable and the water mass extracted from the reservoir mines the heat from the overall volume of the reservoir. No recharge of reservoir fluids or flux of thermal energy to the reservoir volume is assumed.

The foundation for the volumetric method is simply to use the first law of thermodynamics to predict how much thermal energy can be recovered from a geothermal reservoir volume. The energy content (*Q*) stored in the geothermal reservoir includes both the energy in the reservoir rocks and the fluid and can be estimated as:

$$Q = Ah(T_i - T_f)\{(1-\phi)c_r\rho_r + \phi c_l \rho_l\}$$

Where:

Q	Stored heat in the reservoir volume (J)
A	Surface area of the reservoir (m^2)
h	Reservoir thickness (m)
T_i	Initial reservoir temperature (°C)
T_f	Final (or abandonment) temperature of reservoir (°C)
C_r	Specific heat capacity of the rock matrix (J/kg K)
C_l	Specific heat capacity of the reservoir fluid (J/kg K)
ρ_r	Density of the rock matrix (kg/m^3)
ρ_l	Density of the reservoir fluid (kg/m^3)
ϕ	Porosity of the rock matrix

It is further assumed that the heat capacity per unit reservoir volume of the entire system is isotropic. The following equation is then used to estimate the recoverable thermal energy that can be converted to electricity, i.e. the electrical power potential of the geothermal resource:

$$E = \frac{QR_f C_e L_f}{t}$$

Where:

E	Electrical Power Potential
R_f	Power plant conversion efficiency
C_e	(W_e) Thermal recovery factor
L_f	Power plant load factor
t	Power plant lifetime

The thermal recovery factor (*R1*) determines the fraction of the energy that can be extracted from the reservoir rocks to the stored energy in the reservoir. Historically, a constant recovery factor of 0.25 has been used for uniformly porous and permeable geothermal reservoirs. More recent analysis of data from fractured reservoirs indicates that the recovery factor is closer to 0.1, with a range of approximately 0.05 to 0.2. In general this apparent discrepancy in the recovery factor reflects the contrast in thermal energy recovery from complex, fracture-dominated reservoirs compared to the uniform, high-porosity reservoirs (Williams et al., 2008).

The power plant conversion efficiency (C_e) describes how efficiently the recovered heat from the geothermal resources is converted to electricity. The efficiency is often taken to be 10%, but varies between power plant conversion cycles and the temperature of the resource.

The thermal recovery factor, plant efficiency and abandonment temperature (Tf) are explicit limitations set by the operational procedures, as defined by the power plant and the technique used for harnessing the heat resource.

The power plant load factor (*L1*) describes the plant availability, allowing for maintenance breaks and unforeseen problems related to shutdowns. For most geothermal power plants supplying base load power this factor is usually between 90 and 95%.

Power plant lifetime factor, or project lifetime (*t*), is divided to the converted electrical energy to calculate the average power plant output in MW_e. Generally the power plant lifetime factor is assumed 20 to 30 years.

INPUT AND OUTPUT PARAMETERS		Symbol	Unit	Values		
				Middle case	High case	Low case
Input						
AREA	Area of the reservoir	A	km2	12,2	15	9,3
THICKNESS	Thickness of the reservoir	h	m	400	600	250
ROCK DENSITY	Density of reservoir rocks	ρr	kg/m3	2850	2850	2850
POROSITY	Porosity of reservoir rocks	φ	-	0,10	0,10	0,10
RECOVERY FACTOR	Fraction of stored heat in reservoir that can be extracted to the surface	Rf	-	0,14	0,14	0,14
ROCK SPECIFIC HEAT	Specific heat of reservoir rock at reservoir conditions	Cr	kJ/kg°C	0,9	0,9	0,9
TEMPERATURE	Initial temperature of reservoir	Ti	°C	81	83	79
FLUID DENSITY	Density of the reservoir fluid	ρl	kg/m3	972	972	972
CONVERSION EFFICIENCY	Fraction of recoverable thermal energy that can be converted to electricity	Ce	-	0,070	0,070	0,070
FLUID SPECIFIC HEAT	Fluid specific heat	Cl	kJ/kg°C	4,195	4,195	4,195
PLANT LIFE	Useful lifetime of power plant	t	years	15	15	15
LOAD FACTOR	Ratio of generation capacity used for production to installed capacity calculated on an annual basis	Lf	-	0,95	0,93	0,97
REJECTION TEMPERATURE	Final (or abandonment) temperature of reservoir	Tf	°C	70	68	72
Output						
THERMAL CAPACITY			MWth	45,42	116,69	13,49
GROSS POWER CAPACITY			MWe	3,18	8,17	0,94
PARASITIC LOAD	Downhole production pump only		MWe	0,40	0,40	0,40
NET POWER CAPACITY	Net of production pump load		MWe	2,78	7,77	0,54

Table 3. Power output estimates for three cases (Low, Middle and High) obtained using the volumetric method.

Results

The model parameters and the resulting capacity estimates for the Lower Klamath Lake Geothermal Area are presented in Table 3 and Table 4.

Geothermal resources need to have sufficient volume, temperature and permeability, in order to be capable of supplying a geothermal power plant. The volumetric method provides a means to estimate the heat content of a geothermal reservoir, but not to estimate the reservoir permeability or the pressure response due to the production, which is the governing factor determining power production potential of geothermal reservoirs. The resource estimate presented here does not imply a guarantee that the generation capacity can be achieved.

INPUT AND OUTPUT PARAMETERS		Symbol	Unit	Middle Case		
				Value	Upper limit	Lower limit
Input						
AREA	Area of the reservoir	A	km^2	12,2	15	9,3
THICKNESS	Thickness of the reservoir	h	m	400	600	250
ROCK DENSITY	Density of reservoir rocks	ρ_r	kg/m^3	2850	2850	2850
POROSITY	Porosity of reservoir rocks	φ	-	0,10	0,10	0,10
RECOVERY FACTOR	Fraction of stored heat in reservoir that can be extracted to the surface	Rf	-	0,14	0,14	0,14
ROCK SPECIFIC HEAT	Specific heat of reservoir rock at reservoir conditions	C_r	kJ/kg°C	0,9	0,9	0,9
TEMPERATURE	Initial temperature of reservoir	Ti	°C	81	83	79
FLUID DENSITY	Density of the reservoir fluid	ρl	kg/m^3	972	972	972
CONVERSION EFFICIENCY	Fraction of recoverable thermal energy that can be converted to electricity	C_e	-	0,070	0,070	0,070
FLUID SPECIFIC HEAT	Fluid specific heat	Cl	kJ/kg°C	4,195	4,195	4,195
PLANT LIFE	Useful lifetime of power plant	t	years	15	15	15
LOAD FACTOR	Ratio of generation capacity used for production to installed capacity calculated on an annual basis	Lf	-	0,95	0,93	0,97
REJECTION TEMPERATURE	Final (or abandonment) temperature of reservoir	Tf	°C	70	68	72
Output						
THERMAL CAPACITY			MWth	45,42	116,69	13,49
GROSS POWER CAPACITY			MW_e	3,18	8,17	0,94
PARASITIC LOAD	Downhole production pump only		MW_e	0,40	0,40	0,40
NET POWER CAPACITY	Net of production pump load		MW_e	2,78	7,77	0,54

Table 4. Upper and lower limits used in sensitivity analysis of the Middle Case.

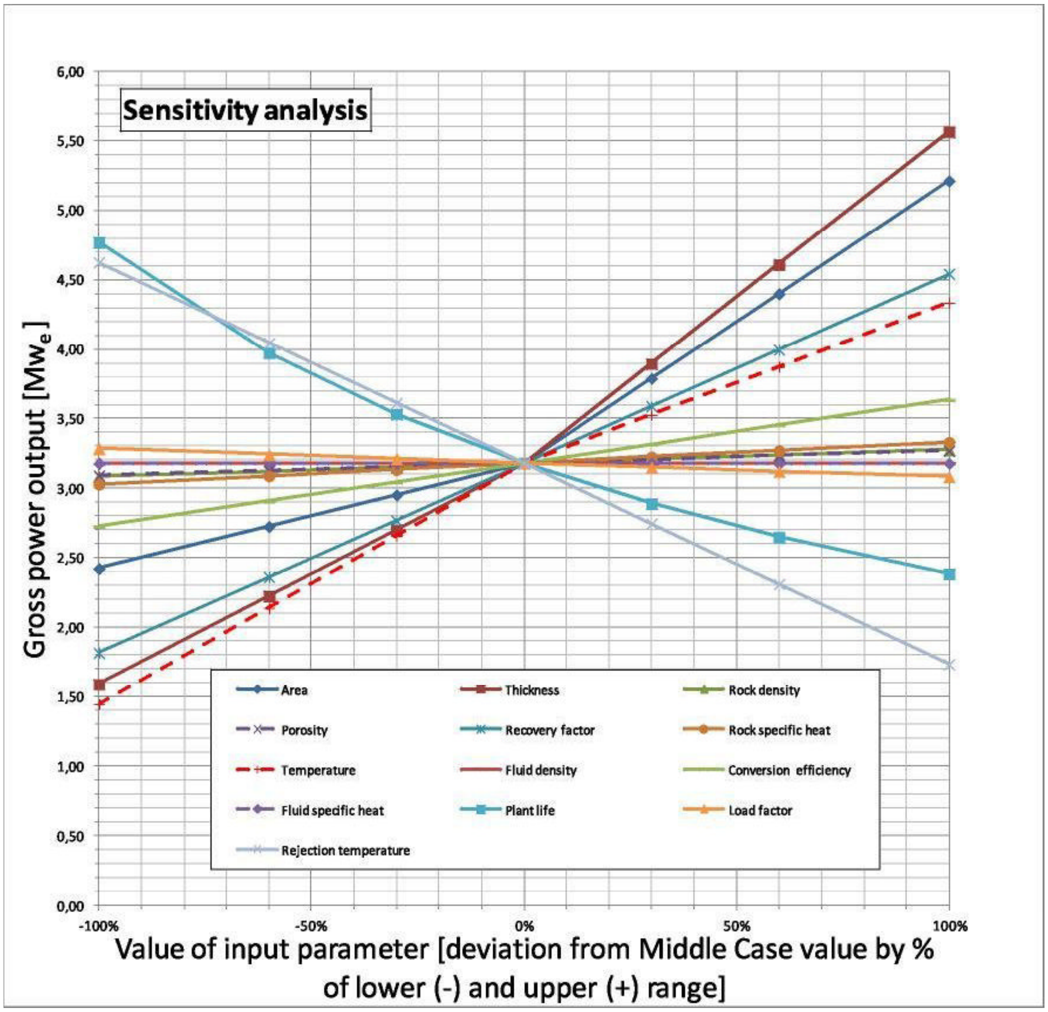


Figure 6. Sensitivity analysis of the power output in the Middle Case.

Each curve shows the change in power output in response to deviation in the corresponding input parameter from its reference value. The deviation in the input parameter is expressed as a percentage of the low (-) and high (+) high range defined in Table 4.

4.2 WELL TEST REVIEW

Vatnaskil has performed review of specified well tests performed and analyzed by Golder Associates in 2002 in the Lower Klamath region of Oregon, USA. Furthermore, estimates of fluid and heat production capacities for the wells have been obtained (see Section 3.3). The primary findings of the study are outlined below.

Tests of wells 9-A, 9-C and 12-C were to be reviewed with respect to appropriateness of methodology, analysis performed and conclusions made, in the report prepared by Golder Associates in 2002 for Water and Energy Services, Mercer Island, Washington.

For each of these wells, a step rate test and a constant discharge test were performed in September 2001, with observations of water level drawdown in the production well as well as in two test (observation) wells. Water levels in the pumping wells were recorded using a handheld electronic water level meter, whereas in the observation wells, water level was monitored with pressure transducers connected to data loggers and with an electric water level tape. Flow rates were measured using an instantaneous and totalizing propeller flowmeter. The pumping test data were analyzed by Golder using the well hydraulics software AQTESOLV, implementing the Cooper-Jacob, Theis and Theis recovery methods to assess the aquifer hydraulic properties. The analyses were only applied to the constant discharge tests, utilizing the step rate tests more as precursors to the constant discharge tests

In the following, the primary focus is on reviewing the analysis of the constant discharge tests performed by Golder and compare their findings to reevaluated aquifer characteristics from reestablished analysis of the test data. Supporting analysis on the step rate tests, furthermore aid in assessing the appropriateness of the methodology and appraising confidence and uncertainties associated with the overall analysis.

4.2.1 Testing of Well 12-C

A total of four steps were executed during the step rate test, at 1,298 gpm, 1,856 gpm, 2,543 gpm and 3,100 gpm. Figure 7 shows a digitized version of the step rate test as reported by Golder *(Well 12-C is labeled as 12A)*. The run time of each step was not long enough for the drawdown to stabilize. Important information can though be drawn from the test, beyond conclusions made in the Golder report as outlined in Section 3.2.4 below.

In Golder's report, it is stated that the specific capacity (the pumping rate divided by the drawdown) of the well, also often referred to as productivity index, ranged from 18.9 gpm/ft during the first step to 14.9 gpm/ft during the last step of the step-rate pumping test. However, reading from the drawdown time series for the step test, the drawdown is 32 feet at the end of the first step. Since that step was performed at about 1300 gpm, the specific capacity should be about 40 gpm/ft rather than about 18 gpm/ft as indicated in the report. For the last step, good agreement is obtained with Golder's report, i.e. about 15 gpm/ft.

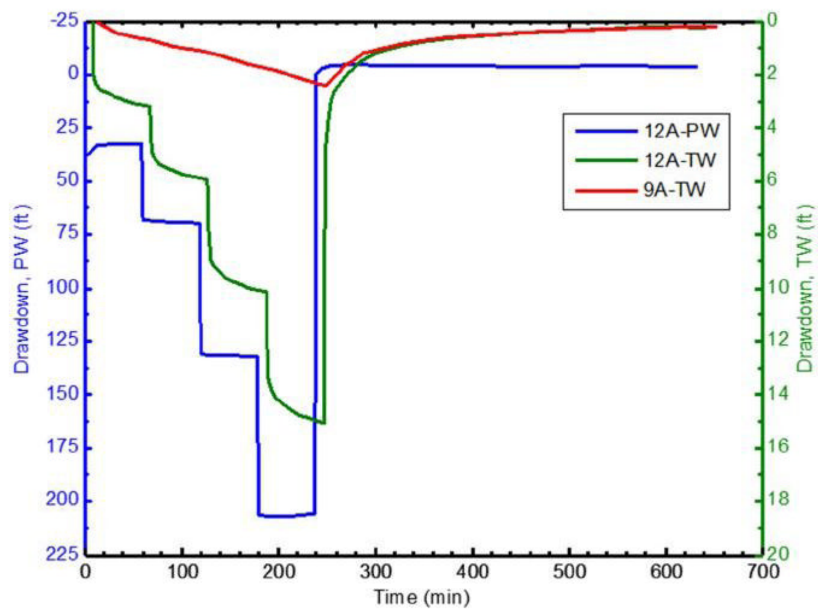


Figure 7. 12-C well step rate test measurements, digitized from Golder's report.

A constant rate test was performed at a discharge rate of 3,000 gpm. Figure 8 shows a digitized 16 version of the measured drawdown in the observation wells as reported by Golder *(Well 12-C is labeled as 12A)*. Table 5 provides a summary of the test and analysis, synthesized from Golder's report.

Table 5. Summary of the 12-C well test, synthesized from Golder's report

12-C well test (1)								
Well name	Depth drilled (ft)	Casing depth (ft)	Water level (ft bgs)	Dist. P-well (ft)	T (ft2/day)	S	Analysis method	Comments/ Discrepancies
12-C PW	1254	400	28.1	0	7.68E+05	N/A	C-J	T = 134000 ft²/day in Table 3
12-C TW	1198	438	30.4	59	3.03E+05	1.21E-04	C-J	
					3.48E+05	4.93E-05	Theis	S=0.0001 in Table 3
					2.01E+05	N/A	Theis rec	Data sheet missing in Appendix A
9-A TW	448		23.1	3400	4.98E+04	7.51E-05	C-J	water level from 9A P-well
					4.69E+04	8.81E-05	Theis	
					4.79E+04	N/A	Theis rec	

Pump intake at 260 ft bgs; Water temperature 88.8 °C

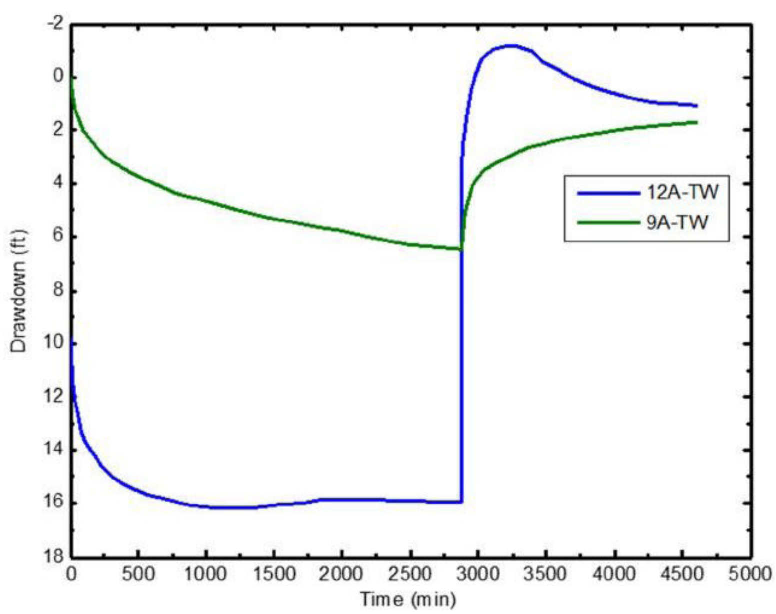


Figure 8. Measured drawdown in observation wells 12C-TW and 9A-TW boreholes during the constant discharge test in the 12-C Production Well, digitized from Golder's report.

Theis method assumes an infinite, homogeneous aquifer and can be outlined as follows:

$$P = P_0 - \frac{Q \cdot \rho_w \cdot g}{4 \cdot \pi \cdot T} \cdot W(u)$$

$$u = \frac{r_w^2 \cdot S}{4 \cdot T \cdot t}$$

Where:

P = pressure [Pa]
P_0 = initial pressure [Pa]
Q = pumping rate [m^3/s]
r_w = density of water [kg/m^3]
g = acceleration of gravity [m/s^2]
T = transmissivity [m^2/s]
W(u) = well function
r_w = well radius [m]
S = storage coefficient
t = time [s]

The well function is the exponential integral:

$$W(u) = \int_u^\infty \frac{e^{-\mu}}{\mu} d\mu$$

On the left half of Figure 3, the theoretical function W(u) is plotted against u. Furthermore, the drawdown, ***s***, defined as ***s = (P-P0)/(r$_w$ g)***, is plotted against r2/t, where r is the distance from the pumping well to the point where drawdown ***s*** occurs. Theis superposition method aims to translate these data to align them on a common plot resulting in estimates on ***T*** and ***S*** from the corresponding displacement values. The right half of Figure shows the superimposed values, both as inferred from the 2002 analysis by Golder, as well as the present analysis (2011). The alignment is good in both cases. However, there are different combinations of ***T*** and ***S*** values obtained in the present analysis than in the 2002 analysis. Such a combination is not uniquely obtained, although there should be a combination that minimizes the difference between measured and computed drawdown values.

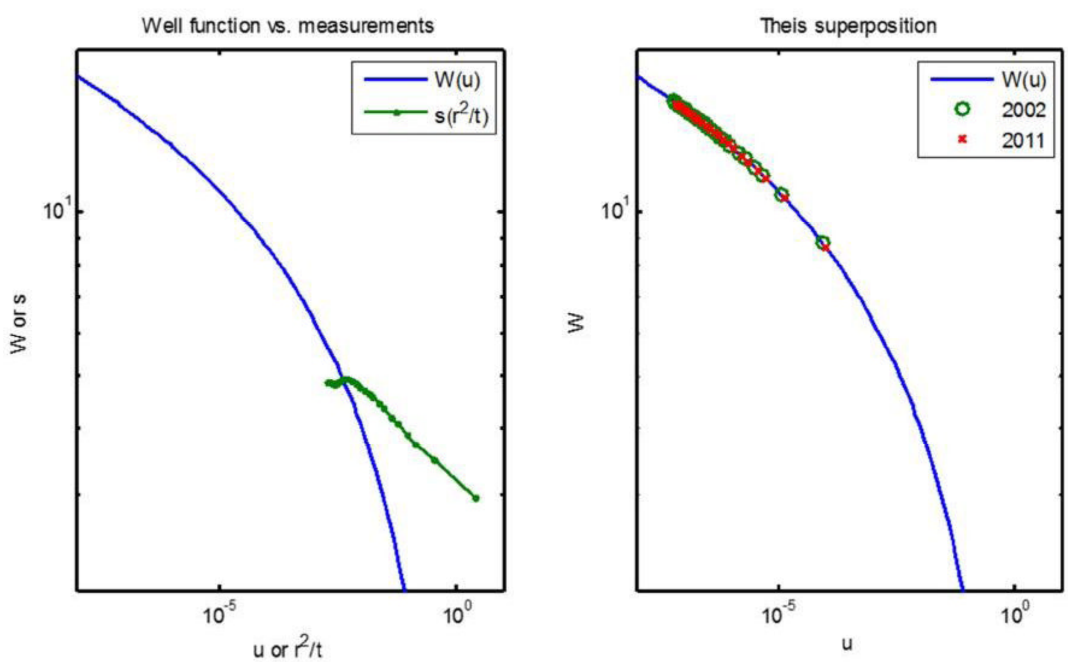


Figure 9. Overlaying Theis well function and measurements in observation wells 12A-TW boreholes during the constant discharge test in the 12-A Production Well, prior to (left) and after (right) Theis superposition.

As shown in Figure , the T and S combination obtained in the 2002 Theis analysis results in computed drawdown far from the measured profile in observation well 12-A TW during 12-A PW constant rate test. The T and S combination in the 2011 Theis analysis on the other hand result in computed drawdown fairly close to the measured values.

The Cooper-Jacob approximation assumes that the well function can be significantly simplified by neglecting second and higher-order terms in the infinite series. This method provides a simple graphical approach to finding T and S values from slopes and intersects of tangential lines to the measured timeseries of drawdown on a semi-logarithmic plot. Selecting a suitable location on the graph for the tangential estimates is though not necessarily simple, particularly for drawdown series that have not stabilized in time. This will results in non-uniquely determined combinations of T and S. Furthermore, the approximation is only considered applicable where u is less than 0.02, which can limit the usability of the method.

Figure shows how computed drawdown results from the T and S combination obtained in 2002, which is far from the measured profile in observation well 12-A TW during 12-A PW constant rate test. A much closer agreement is obtained in the 2011 analysis.

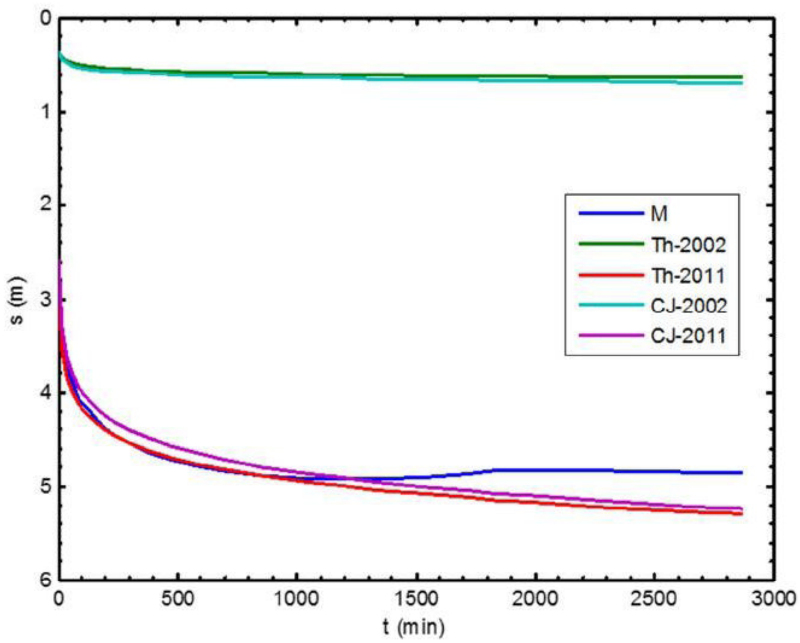


Figure 10. Verification of computed drawdown versus measurements (M) in observation well 12-A TW boreholes during 12-A PW constant rate test, using values of T and S estimated from Theis (Th) and Cooper-Jacobs (CJ) methods in Golder's report (2002) and from the present analysis (2011).

Comparable analysis was performed to verify computed drawdown versus measurements in observation well 9-A TW during the 12-A PW constant rate test (Figure 11). The analysis of 2002 provide better combinations of T and S than for the 12-A TW observation well, although the combination in the 2011 Theis analysis compares better. Here, the Cooper-Jacob method is marginally applicable due to the relatively large values of u, hence a better comparison to measurements for the Theis method in the 2011 analysis.

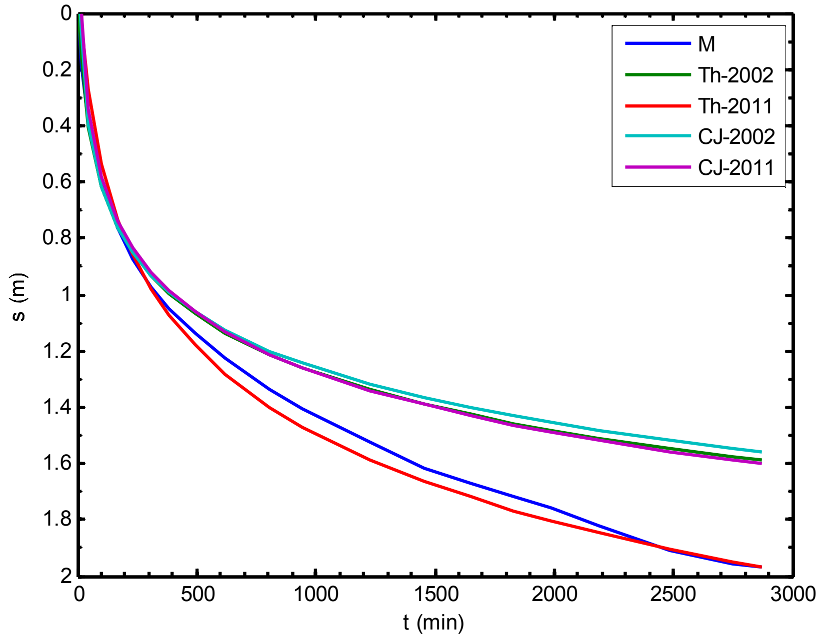


Figure 11. Verification of computed drawdown versus measurements (M) in observation well 9-A TW during 12-C PW constant rate test, using values of T and S estimated from Theis (Th) and Cooper-Jacobs (CJ) methods in Golder's report (2002) and from the present analysis (2011).

4.2.2 Testing of Well 9-A

A total of four steps were executed during the step rate test, at 2,510 gpm, 4,017 gpm, 5,055 gpm and 6,338 gpm. Figure 1 shows a digitized version of the step rate test as reported by Golder. The run time of each step was not long enough for the drawdown to stabilize. The drawdown in the 9-A Test Well is greater than in the 9-A Production Well for the majority of the test period. However, during the constant rate test the drawdown in the two wells is quite comparable, greater though in the production well (Figure). The constant discharge test of well 9-A PW consisted of 8 hour run at a rate of 6,200 gpm, followed by monitored recovery for 48 hours after pumping was ceased. Table 6 provides a summary of the test and analysis from Golder's report.

Similar analysis to those described above for testing of well 12-A were performed. The results are shown in Figure 14 and Figure 15 for observation wells 9-A TW and 9-C TW, respectively. Better agreement to measured drawdown is obtained in both cases for the 2011 analysis.

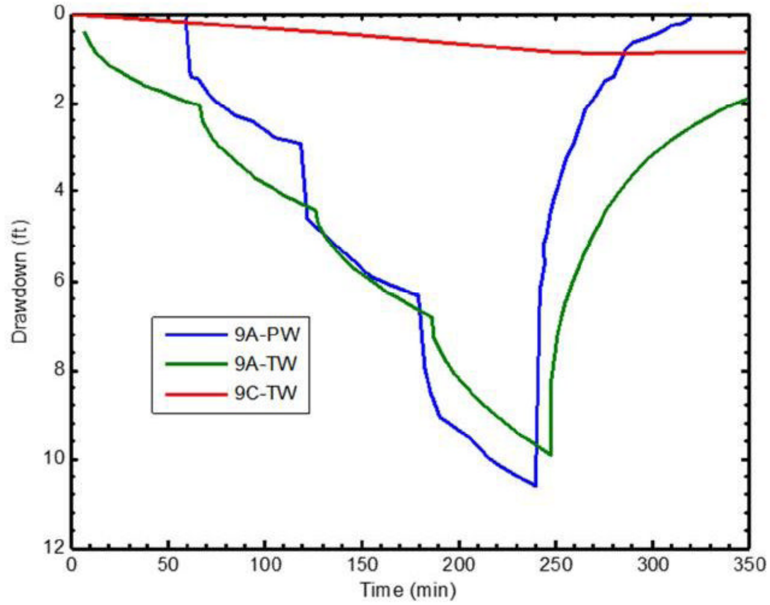


Figure 12. 9-A Well step rate test measurements, digitized from Golder's report.

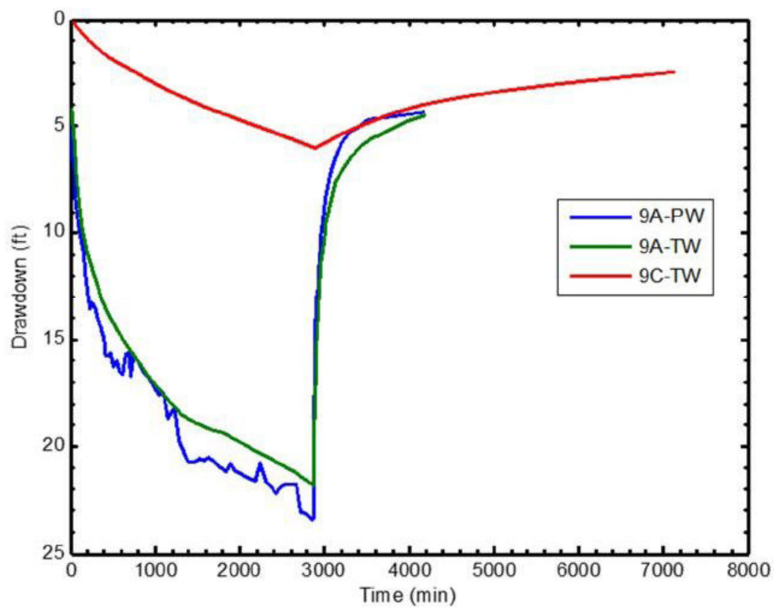


Figure 13. Measured drawdown in 9-A Production Well and observation wells 9A-TW and 9C-TW during the constant discharge test in the 9-A Production Well, digitized from Golder's report.

Table 6. Summary of the 9-A well test, synthesized from Golder's report.

9-A well test (1)								
Well name	Depth drilled	Casing depth	Water level	Dist. P-well	T	S	Analysis method	Comments/ Discrepancies
	(ft)	(ft)	(ft bgs)	(ft)	(ft2/day)			
9-A PW	600	410	23.1	0	2.42E+04	N/A	C-J	
9-A TW	448		23.1	60	8.86E+04	0.02092	C-J	water level from 9A PW; S=0.2 in Table 3
					5.94E+04	0.03556	Theis	
					4.44E+04	N/A	Theis rec	
9-C TW	787	711	30.4	3500	3.14E+05	0.000936	C-J	
					2.13E+05	0.00125	Theis	
							Theis rec	Analysis not performed

(1) **Pump intake at 200 ft bgs; Water temperature 75 °C**

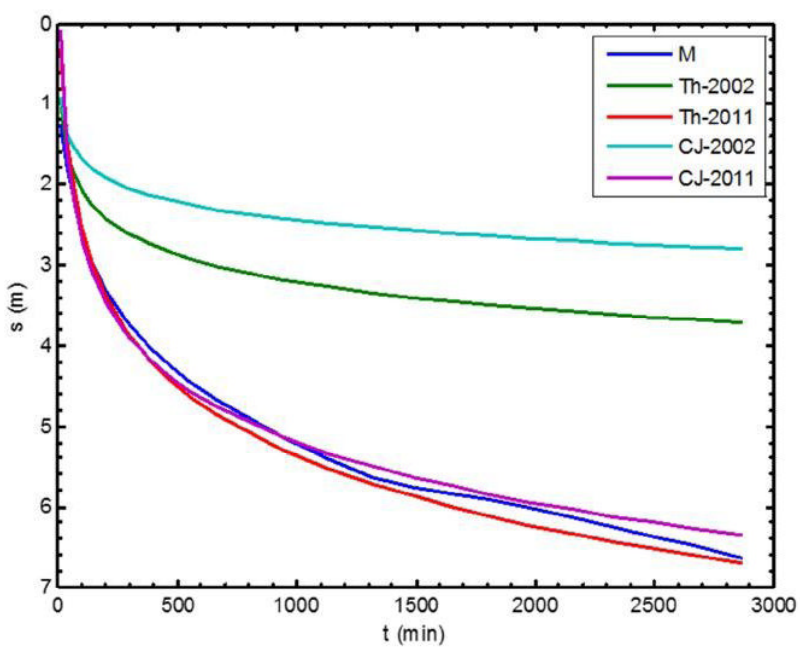


Figure 14. Verification of computed drawdown versus measurements (M) in observation well 9-A TW during 9-A PW constant rate test, using values of T and S estimated from Theis (Th) and Cooper-Jacobs (CJ) methods in Golder's report (2002) and from the present analysis (2011).

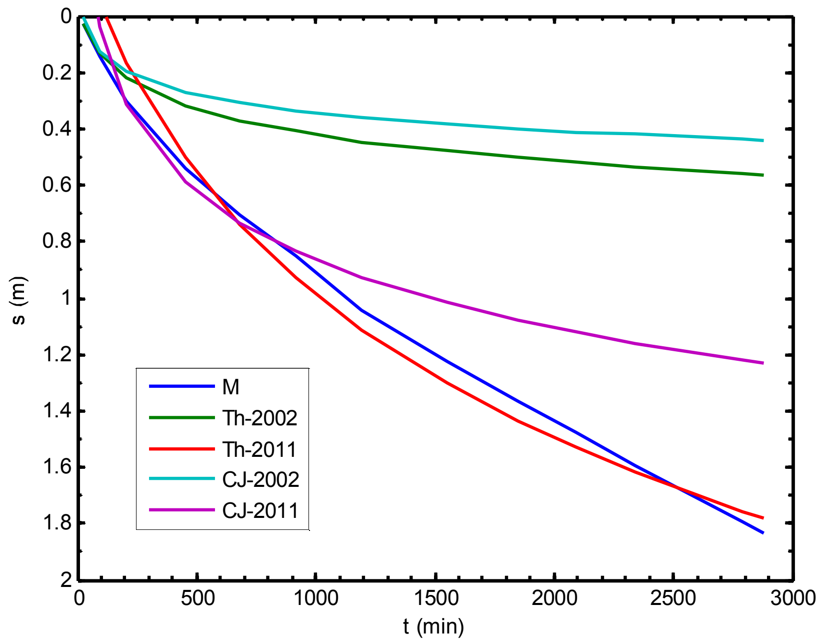


Figure 15. Verification of computed drawdown versus measurements (M) in observation well 9-C TW during 9-A PW constant rate test, using values of T and S estimated from Theis (Th) and Cooper-Jacobs (CJ) methods in Golder's report (2002) and from the present analysis (2011).

4.2.3 Testing of Well 9-C

A total of four steps were executed during the step rate test, at 2,548 gpm, 4,189 gpm, 5,793 gpm and 7,503 gpm. Figure shows a digitized version of the step rate test as reported by Golder. The run time of each step was long enough for the drawdown in the nearby 9-C TW to nearly stabilize during the step. The drawdown in the 9-C Test Well is greater than in the 9-C Production Well for the first step. The constant discharge test of well 9-C consisted of a 26 hour run at a rate of 7,300 gpm, followed by monitored recovery for 48 hours after pumping was ceased, as indicated in the report text. The corresponding figure in Appendix C suggests though that the recovery was monitored for 24 hours (Figure). Table 7 provides a summary of the test and analysis from Golder's report.

Similar analysis to those described above for testing of well 12-A were performed. The results are shown in Figure for observation well 9-C TW. Better agreement to measured drawdown is obtained for the 2011 analysis. No analysis was performed by Golder for 9-A TW. An estimate was though obtained in the present analysis using the Theis method. The Cooper-Jacobs method was not applicable to use.

Table 7. Summary of the 9-C well test, synthesized from Golder's report.

9-C well test (1)								
Well name	Depth drilled	Casing depth	Water level	Dist. P-well	T	S	Analysis method	Comments/ Discrepancies
	(ft)	(ft)	(ft bgs)	(ft)	(ft2/day)			
9-C PW	802	516	28.7	0	4.11E+05	N/A	C-J	
9-C TW	787	711	30.4	60	1.08E+05	0.000188	C-J	
					1.10E+05	0.000198	Theis	S=0.0001 in Table 3
					1.21E+05	N/A	Theis rec	
9-A TW	448		23.1	3511				No annalysis performed

(1) Pump intake at 260 ft bgs; Water temperature 69.4 °C

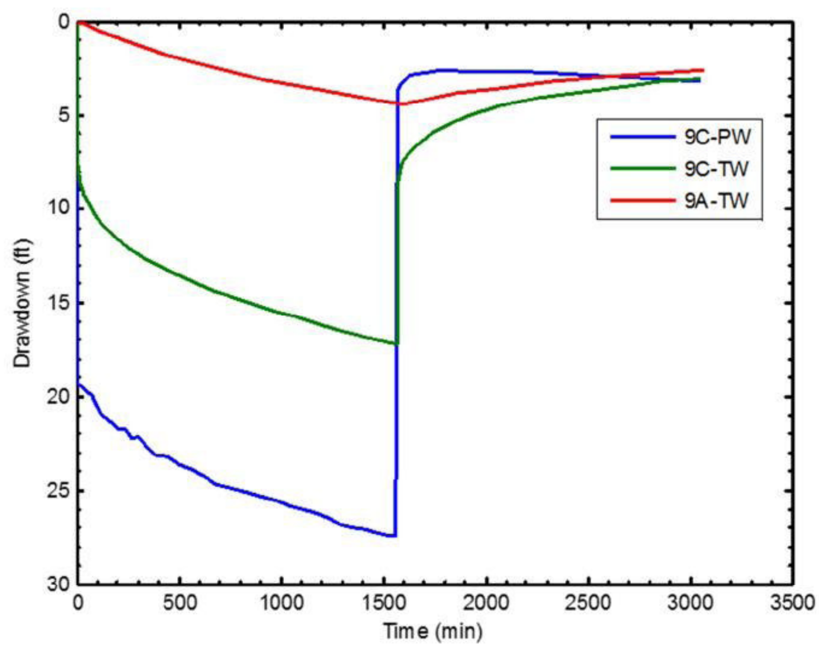


Figure 16. Measured drawdown in 9-C Production Well and observation wells 9C-TW and 9A-TW during the constant discharge test in the 9-C Production Well, digitized from Golder's report.

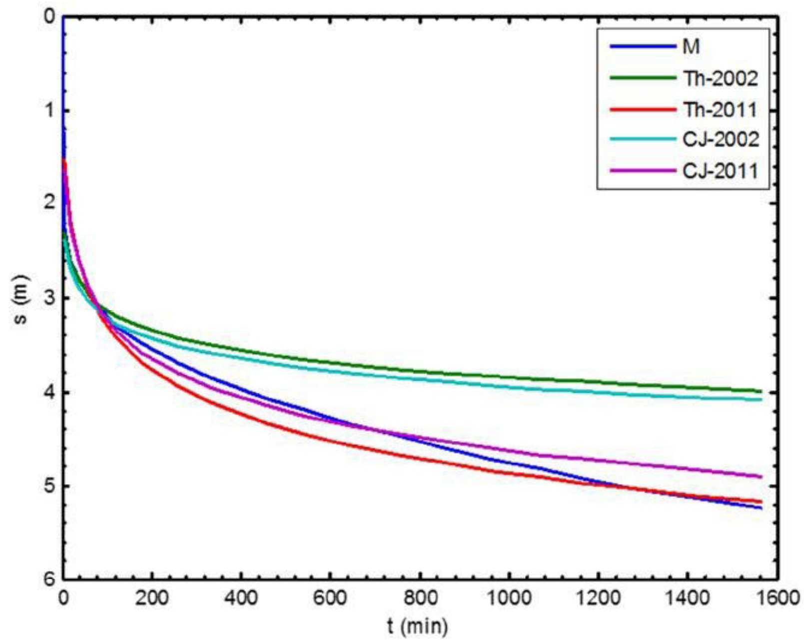


Figure 17. Verification of computed drawdown versus measurements (M) in observation well 9-C TW during 9-C PW constant rate test, using values of T and S estimated from Theis (Th) and Cooper-Jacobs (CJ) methods in Golder's report (2002) and from the present analysis (2011).

4.3 SUMMARY

A summary of T and S values obtained both in the 2002 and 2011 analyses is given in Table 8. To give an indication on how applicable the Cooper-Jacobs approximation is in each case a value of t_{min} is provided, defined as

$$t_{\min} = \frac{r^2 S}{4\,T\,u_{tol}}$$

Where $\boldsymbol{u}_{tol}$ is the maximum value of u typically tolerated by the Cooper-Jacobs method, here taken as 0.02. Thus, the larger the value of tmin, the less applicable it is to use the Cooper-Jacobs method. In most cases, the Cooper-Jacobs method can be considered non-applicable, or at best marginally applicable (Table 8). If one focuses then on the results obtained by the Theis method, then it can be seen that estimates of ***T*** in the 2011 analysis are always smaller than the ones obtained in 2002. On the other hand, ***S*** values are typically greater in the 2011 analysis, with the exception of the 12-A TW analysis for pumping test in well 12-A PW. The ***T*** values of the 2011 Theis analysis are all of a comparable magnitude, or about 2·104 to 5·104 ft2/day. A large range of ***S*** is though observed as in the previous analysis.

Table 8. Summary of T and S values obtained in the 2002 and 2011 analyses.

Pump	Observ	Anal.	2002 analysis				2011 analysis			
well	well	Meth.	T	T	S	tmin	T	T	S	tmin
			(ft2/day)	(m2/s)		(min)	(ft2/day)	(m2/s)		(min)
12-A PW	12-A TW	C-J	3.0E+05	3.3E-01	1.3E-04	2.5E-02	3.8E+04	4.1E-02	3.4E-05	5.6E-02
		Theis	3.5E+05	3.7E-01	4.9E-05	8.9E-03	4.2E+04	4.5E-02	7.1E-06	1.1E-02
12-A PW	9-A TW	C-J	5.0E+04	5.4E-02	7.5E-05	3.1E+02	4.6E+04	4.9E-02	9.3E-05	4.2E+02
		Theis	4.7E+04	5.0E-02	8.8E-05	3.9E+02	3.1E+04	3.3E-02	1.6E-04	1.1E+03
9-A PW	9-A TW	C-J	8.9E+04	9.5E-02	2.1E-02	1.6E+01	2.7E+04	2.9E-02	9.6E-02	2.3E+02
		Theis	5.9E+04	6.4E-02	3.6E-02	3.9E+01	2.3E+04	2.5E-02	1.4E-01	4.0E+02
9-A PW	9-C TW	C-J	3.2E+05	3.4E-01	9.4E-04	6. 6E+02	8.3E+04	8.9E-02	8.8E-04	2.3E+03
		Theis	2.1E+05	2.3E-01	1.3E-03	1.3E+03	3.4E+04	3.6E-02	1.7E-03	1.1E+04
9-C PW	9-C TW	C-J	1.1E+05	1.2E-01	1.9E-04	1.1E-01	5.6E+04	6.0E-02	1.2E-02	1.4E+01
		Theis	1.1E+05	1.2E-01	2.0E-04	1.2E-01	5.0E+04	5.3E-02	1.8E-02	2.3E+01
9-C PW	9-A TW	C-J	-	-	-	-	-	-	-	-
		Theis	-	-	-	-	4.6E+04	4.9E-02	1.7E-02	8.2E+04

Further limitations to the analysis performed here as well as in the 2002 analysis can be outlined as follows. The aquifer loss and well loss components of the pressure drawdown during a step test can be calculated using the following equation:

$$s = P(Q) - P_0 = B \cdot Q + C \cdot Q^2$$

Where:

- s = drawdown [Pa or m]
- P = pressure or water level [Pa or m]
- P_0 = initial pressure or water level [Pa or m]
- Q = pumping rate [m3/s]
- B = aquifer loss coefficient [Pa/m3/s or m/m3/s]
- C = well loss coefficient [Pa/(m3/s)2 or m/(m3/s)2]

Figure 18 shows the correlation between pumping rate and drawdown in the step drawdown test, taking the measured drawdown at the end of each step as reference. The quadratic relationship is indicative of the relatively high well loss. The calculated well loss coefficient (C) in production well 12-C is 1785 m/(m^3/s)^2 (Figure 18). *(Well 12-C is labeled as 12A)*

Correlating the pumping rate in production well 12-C with drawdown in the two observation wells, 12-C and 9-A, also indicates a quadratic relationship (Figure 19 *(Well 12-C is labeled as 12A)* and Figure 20). This has significance for the well test analysis since the groundwater flow may be non-Darcian. The analysis methods as used here and in the Golder report assume this relationship to be linear w.r.t. flow rate and thus the flow governed by Darcy's law.

A blockage is reported at a depth of 705 feet in the 12-C Production Well. It was observed following drilling and the pumping test. The nature of the blockage is indefinite, and potential affects to the pumping tests are unclear at this time. This imposes an uncertainty to the expected characteristics resulting from the tests.

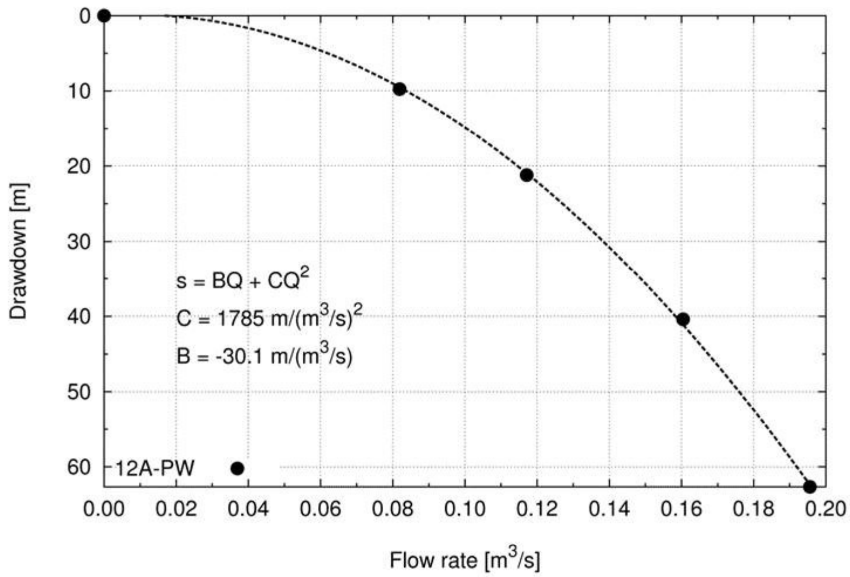


Figure 18. Correlation between pumping rate and drawdown in production well 12-C.

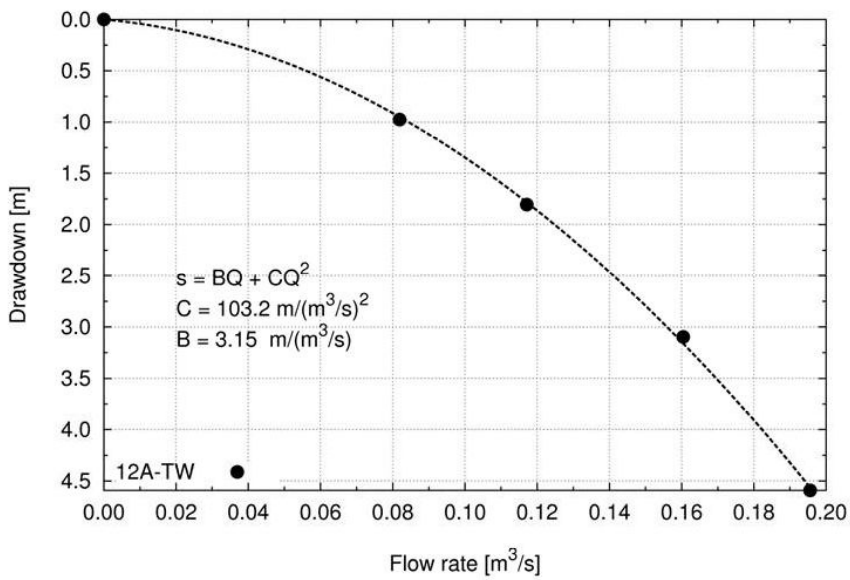


Figure 19. Correlation between pumping rate in production well 12-C and drawdown in observation well 12-C.

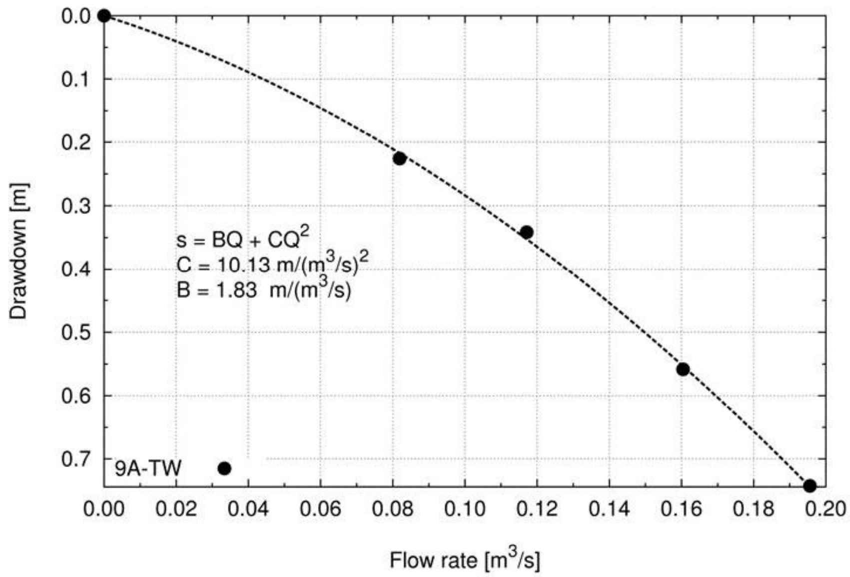


Figure 20. Correlation between pumping rate in production well 12-C and drawdown in observation well 9-A.

4.4 FLUID AND HEAT PRODUCTION CAPACITIES

Due to the blockage at a depth of 705 feet in the 12-C Production Well it is premature to assess the fluid production capacity of the well. However, pumping about 3,000 gpm during the well tests in 2001, did not result in drawdown beyond the depth of the pump. This flow rate may thus likely be considered a minimum capacity. The measured temperature in 12-C Production Well was 89 °C. Given the depth of the well casing and the lack of temperature logging of the well, the possibility of fluid extraction from several depth locations (aquifers) should not be excluded. Further investigations/testing of the well in conjunction with remediation of the blockage will provide more suitable data for estimates on heat production capacity. However, a basis can be set from the limited data available at present as follows. The enthalpy of water at 90 °C is about 377 kJ/kg, and its density is about 965 kg/m^3. At a pumping rate of about 0.19 m^3/s (or roughly 3,000 gpm), the raw heat obtained amounts to about 69 MWt. Figure 21 shows comparable estimates for ranges of temperature and flow rate. Pumping from well 9-A PW at 6,200 gpm (0.39 m^3/s) as in the constant discharge test, and obtaining water temperature of 75 °C, thus results in raw heat of about 120 MWt, whereas pumping from well 9-C PW at 7,300 gpm (0.46 m^3/s) as in the constant discharge test, and obtaining water temperature of 69 °C produces raw heat of about 130 MWt.

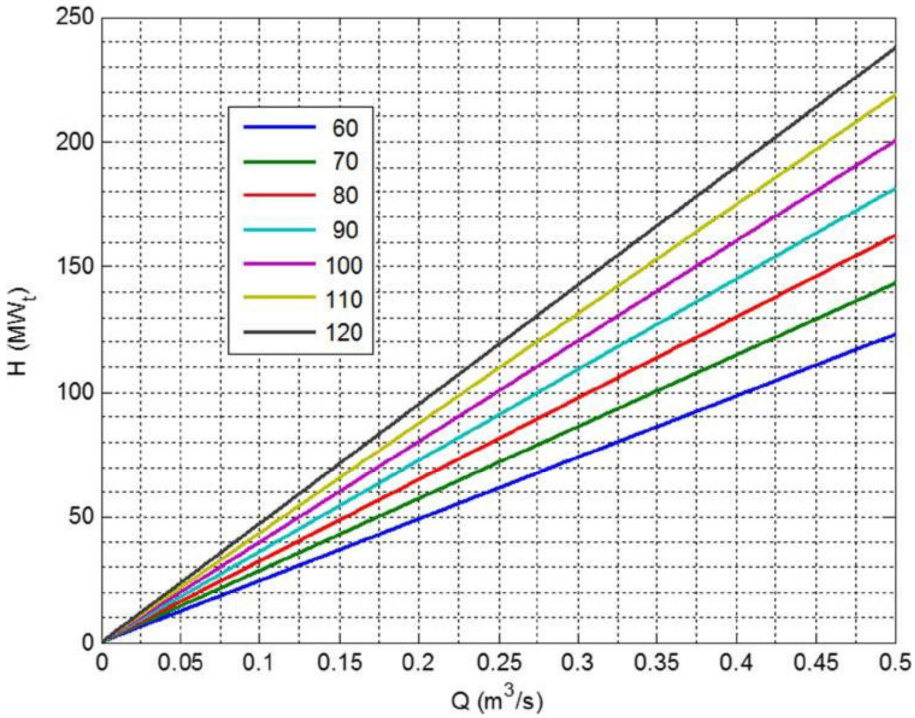


Figure 21. Estimates of raw heat, H (MW), as a function of flow rate, Q (m3/s), for particular water temperatures, T (°C), ranging from 60 to 120 °C.

The present analyses are performed on digitized data from the plots presented in Golder's report. Rather than analyzing the raw data, this approach inevitably introduces some errors to the data set and does not resolve well steep temporal gradients in the timeseries. The values of T and S produced now should therefore not be considered optimized values for the gathered data. However, it is clear from the description above, that the current estimates surpass the previous ones from 2002, providing T values of a more comparable magnitude and typically smaller than indicated in the 2002 analysis. Moreover, the present analysis of the step rate tests indicates a likely non-Darcian flow behavior, with a non-linear drawdown-to-discharge relationship not accounted for in the theoretical analysis presented. This fact further stresses that the T and S produced now should not be considered optimized values for the gathered data. This also provides means to better plan future discharge tests in the wells in question, and in hindsight perform a more complicated analysis on the data already collected if deemed suitable to support new data.

4.5 FLUID CHEMISTRY

4.5.1 General Chemistry

The nature of the fluid from the Lower Klamath Lake Geothermal Area has been evaluated from four chemical analyses sampled from wells 9-A, 9-C and 12-C, see Table 10. A comparison is made with one well from the OIT campus, labeled OIT Geothermal Well. No information is given regarding how the samples were collected from the wells and how the samples were treated during sampling. The charge balance error is relatively high for all the analyses from wells 9 and 12, or about 8 to 11 %. All the following interpretations based on these analyses are therefore hampered by this relatively high error.

In Figure 22 is shown the log (K2/Mg) vs SiO2 content for wells 12-C and 9-C, both the wells are production wells. This plot is often considers to show the temperature of the last equilibrium occurring in the outflow path. The figure infers that geothermal water from well 12-C is in equilibrium with the quartz solubility, suggesting the quartz geothermometer will give a realistic value for the temperature of the geothermal water. For well 9-C, the figure infers that one should apply the chalcedony geothermometer to the water from the well. Based on the two above mentioned geothermometers the inferred temperature of the reservoir water is between 212 °F and about 248 °F, see Figure 22.

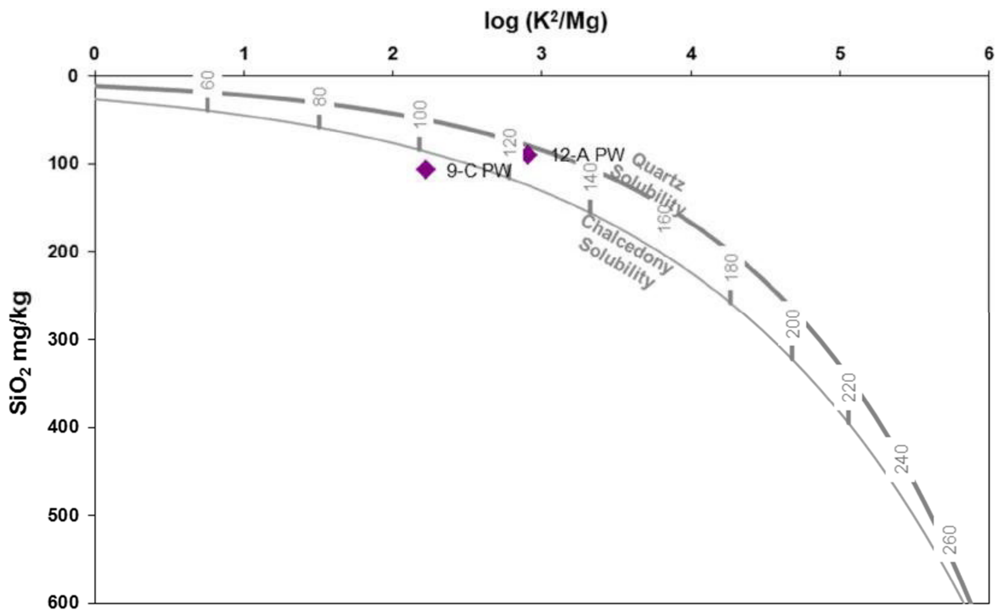


Figure 22. Log (K2/Mg) vs. SiO2 content. The curves show the solubility of quartz and chalcedony. The numbers on the curve are temperatures in °C.

In Figure 23 is shown the Na-K-Mg ternary plot. This plot incorporates two geothermometers, the Na-K geothermometer and the K-Mg geothermometer. The Na-K geothermometer is normally slow reacting geothermometer, therefore is cannot be applied to the relatively cold outflow fluid, but it is more applicable to the deep reservoir temperatures. The K-Mg geothermometers is faster to react than the Na-K geothermometer and is therefore applied to the colder outflow. The deep reservoir temperatures are possibly as high as about 392 °F for well 12-C and about 320 °F for well 9-C. These fluids are partially equilibrated, due to mixing with colder fluid one can assume that these values are minimum values. The water from well 9- A, both production and test wells as well as the OIT geothermal well (not shown) plot on the Na-K axis, due to no (measured) Mg content, therefore this plot cannot be applied to this fluid. These analyses are in particular vulnerable to the quality of the Mg analysis.

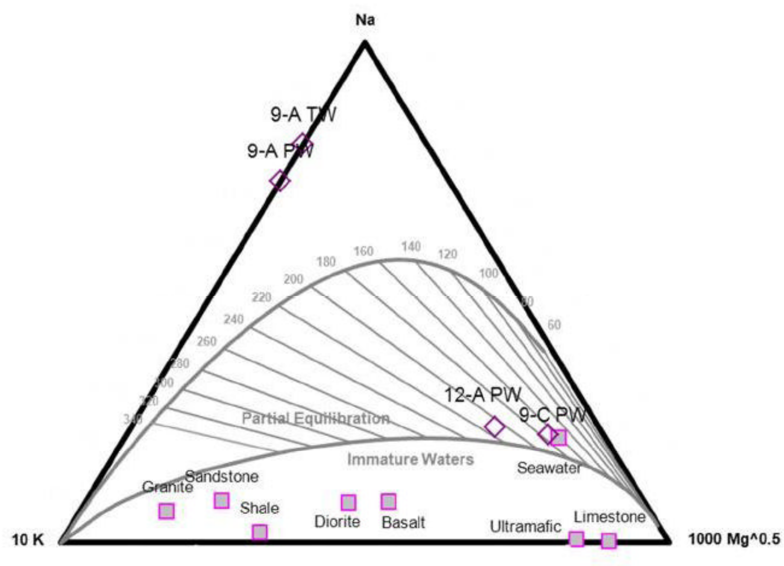


Figure 23. The Na-K-Mg geothermometry plot. The number on the curve are temperatures in ˚C

In Figure 24 is shown the ternary plot Cl-SO4-HCO3. The well samples from wells 9 and 12 are SO4 enriched, which are typical of steam heated waters. However, the OIT sample has a typical composition of volcanic water.

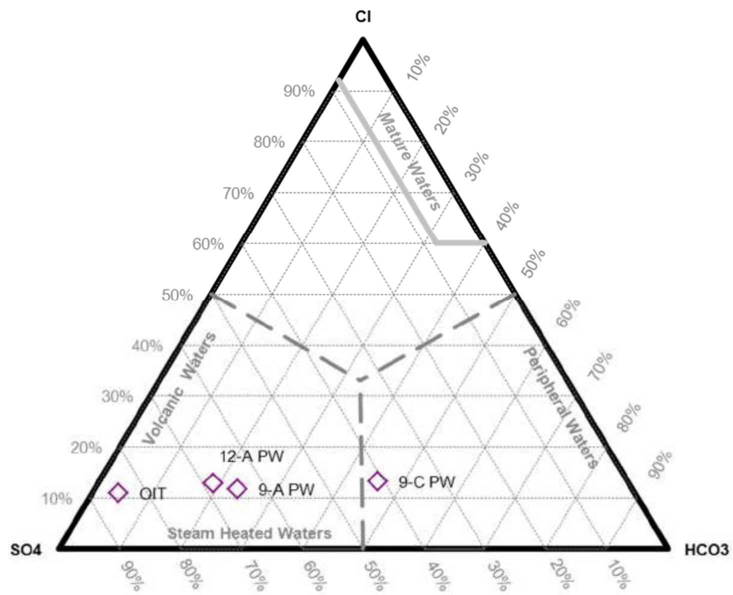


Figure 24. The Cl-SO4-HCO3 plot.

Table 9 details the results of geothermometer calculations from different calibrations. The values should be viewed with the temperature analyses given above.

Table 9. Geothermometers, in °F.

Sample Name	9-A Test Well	9-A Production Well	12-C Production Well	9-C Production Well	OIT Geothermal well
Measured temp		167	192	157	
Chalcedony cond		244	219	239	345
Quartz cond		291	268	286	381
Quartz adiabatic		280	262	277	354
Na-K-Ca	196	221	221	282	207
Na-K-Ca Mg corr	196	221	219	214	207
Na/K Fournier	252	295	378	304	307
Na/K Truesdell	169	217	313	228	230
Na/K Giggenbach	288	331	408	338	342
K/Mg Giggenbach			259	217	

4.5.2 Risk of Scaling and Corrosion

Reservoir fluid salinity is relatively low, pH is near-neutral, and gases are presumably not concentrated (this has however not been confirmed). Therefore, the corrosion and the scaling potential of the geothermal fluid is considered low. This must be studied in greater depths at later stages, when detailed analyses of the fluid are available.

4.5.3 Environmental – Drinking Water Consideration

By comparing the concentrations of various ions, see Table 10, to the US Environmental Protection Agency (EPA) standards for drinking water, it becomes evident that the concentrations of some ions and components found in the water exceed these drinking water standards. The ions and components in questions are: Al, As, Fe, Mn and SO4 in addition to the pH. Of all the ions and components, the arsenic content would presumably be of greatest concern if the water were destined for drinking water usage. According to the EPA, the as content should not exceed 0.010 mg/L. It is interesting to see that the As content of the deep OIT well is similar the 12-C production well and both the wells are above the EPA limit, while the As content of the production well 9-A is lower that the EPA limit. If this water were destined for potable use, a water treatment solution would be required. In this Resource Viability Assessment, it is assumed that all produced water shall be reinjected into the same geothermal reservoir.

Table 10. Composition of geothermal water from wells, ppm.

Sample name	9-A Test Well	9-A Production Well	12-C Production Well	9-C Production Well	OIT Geothermal Well
Sample label	9-A TW	9-A PW	12-C PW	9-C PW	OIT
pH		7.6	8.57	8.15	8.72
Li					0.11
Na	158	157	123	242	202
K	4	6	9	10	9
Ca	9	9.4	15.6	7,2	25.1
Mg			0.1	0,6	
SiO2		112	90	107	242
B	1		0	1	1
Cl		50	49	64	51
F					1
SO4		276	259	197	391
HCO3		100	72	220	20
CO3					12
As		0.007	0.063		0.0591
Sr		0.033	0.06	0.024	
Ba		0.15	0.047	0.044	
Fe					2.83
Mn	0.07		0.01		0.0525
Sum cations	7.43	7.45	6.37	11.19	10.37
Sum anions		8.8	7.95	9.51	10.36
Charge Balance		-8 %	-11 %	8 %	0 %

The main points emerging from the review of the key resource data and reports on the Lower Klamath Lake geothermal area are as follows:

- The geothermal field is probably fed by an upflow of geothermal fluid along a deep-seated fault underlying the Chalk Bluffs escarpment. This upflow spreads out laterally in a reservoir dominated by fractured basaltic rocks and covered by lake-fill sediments. Based on outflow temperatures in wells 12-C, 9-A and 9-C, reservoir temperatures range from 160 - 196°F whereas temperatures of 210 - 250°F may be present deeper within the upflow zone.
- The reservoir shape and volume are not well constrained. In map view, the thermal anomaly is interpreted to be elongated and aligned with the fault-controlled escarpment. The reservoir is estimated to extend approximately 4 miles along the escarpment and be approximately 1.5 miles wide. The thickness of reservoir rocks exposed in the wells is only a few hundred feet. It is likely, however, that the wells will be able to tap a significantly thicker reservoir section.
- Estimates of recoverable heat and electric power generation capacity were made using the volumetric method and a conversion efficiency appropriate for the Kalex SG-2a power generation cycle. In order to cover the likely range of outcomes, three different estimates (Low, Middle and High) were made using three different sets assumptions. The Middle Case yields recoverable thermal output of 45 MWth and a gross electric power generation capacity of 3.2 MWe, both calculated over 15 years. Corresponding numbers for the other two cases are 117 MWth and 8.2 MWe (High Case), and 13,5 MWth and 0.94 MWe (Low Case).
- Review of the well tests carried out in 2002 has uncovered some relatively minor inconsistencies and weaknesses, but the high fluid production capacities indicated by the tests are largely confirmed. Our analysis suggests slightly lower transmissivity values of about 2x104 to 5x104 ft2/day. Storativity values are found to range widely as before. An estimate was also obtained for the well loss coefficient for well 12-C. The results indicate that well production rates similar to those achieved during the constant rate discharge tests are realistic during initial stage of production from the reservoir. It is emphasized, however, that the long-term response of the reservoir to exploitation cannot be predicted with any confidence on the basis of these results. Longer-term testing, including interference testing and tracer testing, would be needed for that. In conclusion, it seems that the production capacity of the three existing wells is sufficient to deliver heat to a Kalex power plant scaled to the size of the underground heat reservoir.
- This report focuses primarily on options for developing the geothermal field based on the existing wells 12-C, 9-A, 9-C. Production potential resulting from deepening of existing wells and drilling of new wells is only touched upon briefly. It is understood that a capacity to reinject all of the geothermal fluid extracted is a definite requirement for the field development. Given these constraints and the production characteristics of the three wells, the best strategy is to base the development on a single production well, 12-C, and one reinjection well. The reason for this is that due to its relatively high outflow temperature well 12-C is the most powerful heat producer despite having less favorable yield/draw-down characteristics than wells 9-A and 9-C. It seems that well 9- C is better suited as a reinjection well than 9-A because of its location at the northeastern margin of the thermal anomaly. In theory, injecting from the cold end of the elongated reservoir should make sweeping of the reservoir heat more effective than injecting into well 9-A which is located much closer to 12-C. The final selection may require more testing.
- The power capacity estimates of the geothermal field have been taken a step beyond the stored-heat estimate given above by matching the Middle Case model to a specific Kalex SG-2a power plant cycle and to the production characteristics of well 12-C. Based on the testing of well 12-C, a production rate of 3,650 gpm is selected for the calculations. In view of the draw-down curve determined for well 12-C, this corresponds to setting the down-hole pump at the maximum depth allowed by the casing. For the power cycle itself, the key assumptions/design requirements are a Start of Run (SOR) flow of 3,650 gpm and temperature of 196°F, an assumed End of Run (EOR) temperature of 178°F, and (a) water cooling tower(s) operating at 49°F.
- Based on these assumptions an initial power plant capacity of 3.5 MWe (gross) or 3.2 MWe (net) is obtained (excluding the downhole pump and lesser parasitic loads associated with the plant). This output is calculated to decline to 3.1 MWe (gross) or 2.7 MWe (net) based on a postulated decline in inlet temperature of 1.2°F over the 15 year lifetime of the reservoir. Approximately 0.4 MWe of the power generated will be needed to run the downhole pump.
- Four High Scenarios have been defined:
    - The first "moderate risk" scenario envisions deepening of Well 9-A from its current 600 feet to around 2,000 feet intersecting an outflow zone at a peak temperature of 203°F. Under this scenario, a Kalex power plant's SOR capacity would rise to 3.8 MW gross or 3.5 MW net.

- The second “moderate risk” scenario envisions drilling a new well a short distance west of Well 12-C and anticipates a 7°F hotter brine than currently produced from Well 12-C. Under this scenario, a Kalex power plant’s SOR capacity would rise to 3.8 MW gross or 3.5 MW net.
- The third “medium risk” scenario envisions deepening of Well 12-13 to reach the basaltic reservoir layer expected below the bottom of the well, and uncovering brine at 203°F, yielding a similar power plant performance to the first and second High scenarios.
- The final “higher risk” scenario speculates on a deeper “step-out” well. This scenario envisions drilling into the assumed reservoir upflow zone targeting a geofluid temperature of 239°F. Under this scenario, a Kalex power plant’s SOR capacity would rise significantly to 5.77 MW gross or 5.37 MW net. Significantly, the capital cost per MW of this Kalex power plant would be substantially reduced in this “higher risk” scenario.
- Several resource-related risks to the power plant project have been identified.
- The heat stored in the reservoir may be insufficient to support the power generation scenario outlined for the Middle Case. Several of the underlying parameters are not known well enough to exclude this possibility. They include the reservoir volume, reservoir temperature, abandonment temperature, and recovery factor.
- Reservoir permeability and natural recharge may be insufficient to limit pressure drawdown to the maximum value assumed in this study. This would reduce the power output because of the limitations on pump depth imposed by the depth of the casing.
- The useful lifetime of the reservoir may be cut short by fast returns of cold water directly from the injection well to the production well. The risk is enhanced by the fractured nature of the reservoir and the location of production and reinjection wells along an assumed permeable fault.

All three risks, can be reduced by longer-term testing of the production well-injection well doublet, including interference and tracer testing.

BIBLIOGRAPHY

Benson, S.M., 1983. Interpretation of interference data from the Klamath Falls, Oregon geothermal resource, Proceedings 9th Workshop Geothermal Reservoir Engineering, Stanford University, Stanford, California, SGP-TR-74, December 1983, p. 187-192.

Black, G., 1994. Low-temperature geothermal database for Oregon, GHC Bulletin, November 1994, p. 19-22.

Boyd, T., 2009. Design of a convection cell for a downhole heat exchanger system in Klamath Falls, Oregon, Proceedings, 24th Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California, February 9-11, 2009, SGP-TR-187, 7 p.

Boyd, T., and Lund, J.W., 2010. Use of promoter pipes with downhole heat exchangers in Klamath Falls, Oregon, Proceedings World Geothermal Congress 2010, Bali, Indonesia, 25-29 April 2010, p. 1-5.

Brown, B., 2000. Klamath Falls geothermal district heating system flow and energy metering, GHC Bulletin, June 2000, p. 10-11.

EGS Inc., Columbia Geoscience, and ThermaSource Inc., 2006. Feasibility study – Deep geothermal well project, prepared for Oregon Institute of Technology, August 2006, 71 p.

French, R.B., and Connard, G.G., 2003. 3D gravity interpretation – Lower Klamath Lake Basin, Oregon, Northwest Geophysical Associates, Inc., www.geosoft.com, 2 p.

Gannett, M.W., Lite Jr., K.E., La Marche, J.L., Fisher, B.J., and Polette, D.J., 2010. Ground-water hydrology of the Upper Klamath Basin, Oregon and California, U.S. Department of the Interior, U.S. Geological Survey, Scientific Investigations Report 2007-5050, Version 1.1, April 2010, 84 p.

Gudmundsson, J.S., Johnson, S.E., Horne, R.N., Jackson, P.B., and Culver, G.G., 1983. Doublet tracer testing in Klamath Falls, Oregon, Proceedings 9th Workshop Geothermal Reservoir Engineering, Stanford University, Stanford, California, December 1983, SGP-TR-74, p. 331-337.

Lienau, P.J., 1978. Agribusiness geothermal energy utilization potential of Klamath and western Snake River basins, Oregon, Final Report no. IDO/1621-1, Geo-Heat Ulilization Center, Oregon Institute of Technology, March 1978, 198 p.

Lienau, P.J., Culver, G., and Lund, J.W., 1989. Klamath Falls geothermal field, Oregon, Case history of assessment, development and utilization, September 1989, 108 p.

Lund, J.W., and Boyd, T., 2009. Geothermal uses and projects on the Oregon Institute of Technology campus, GRC Transactions, vol. 33, p. 63-68.

Lund, J.W., Boyd, T., Hackman, B., and Huffman, B.,2008. Use of promoter pipe with downhole heat exchangers in Klamath Falls, Oregon, Utilisation, p. 264-276.

Lund, J.W., Boyd, T., Hackman, B., and Huffman, B.,2008. Use of promoter pipe with downhole heat exchangers in Klamath Falls, Oregon, GRC Transactions, vol. 32, p. 23-29.

Lund, J.W., and Lund, T.E., 2010. Geothermal heating of Klamath Falls schools, Proceedings, World Geothermal Congress 2010, Bali, Indonesia, 25-29 April 2010, p. 1-7.

Newcomb, R.C., 1958. Yonna Formation of the Klamath River Basin, Oregon, Northwest Science, vol. 32, p. 41-48.

Priest, G.R., Hladky, F.R., and Murray, R.B., 2008. Geological map of the Klamath Falls area, Klamath County, Oregon, State of Oregon, Department of Geology and Mineral Industries, McConnell, V.S., State Geologist, GMS-118, scale 1:24000, 1 plate.

Priest, G.R., Hladky, F.R., and Murray, R.B., 2008. Geological map of the Klamath Falls area, Klamath County, Oregon, State of Oregon, Department of Geology and Mineral Industries, McConnell, V.S., State Geologist, GMS-118, 53 p.

Prucha, R.H., 1987. Heat and mass transfer in the Klamath Falls, Oregon, geothermal system, University of California, Lawrence Berkeley Laboratory, Earth Sciences Division, M.S. Thesis, May 1987, 163 p.

Prucha, R.H., Benson, S.M., and Witherspoon, P.A., 1987. Conceptual model of the Klamath Falls, Oregon geothermal area, Proceedings, 12th Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California, January 20-22, 1987, SGP-TR-109, p. 77-87.

Rafferty, K., 2005. Klamath Falls area geothermal resource areas, Klamath County geothermal agricultural/industrial park preliminary site selection report, December 2005, 51 p.

Sammel, E.A., and Peterson, D.L., 1976. Hydrologic reconnaissance of the geothermal area near Klamath Falls, Oregon, U.S. Department of the Interior, Geological Survey, Water Resources Investigation Open-File Report WRI 76-127, 129 p.

Soule, R., and Tzetos, N., 2002. Lower Klamath Lake Valley terramagnetic survey: interpretation, GeoPotential, Inc., 17 p.

Stark, M., Goldstein, N., Wollenberg, H., Strisower, B., Hege, H., and Wilt, M., 1979. Geothermal exploration assessment and interpretation, Klamath Basin, Oregon – Swan Lake and Klamath Hills area, prepared for the U.S. Department of Energy, Report LBL-8186, May 1979, 75 p.

U.S. Department of Interior, Bureau of Land Management, 2011. Klamath Falls resource area planning update winter 2011, 5 p.

WESCORP, Golder Associates, Inc. 2003. Lower Klamath NWR groundwater program, 2002 groundwater development report, January 2003, 80 p.

WESCORP, Golder Associates, Inc. 2001. Lower Klamath National Wildlife Refuge groundwater investigation, Final Report, January 2001, 47 p.

WESCORP, Golder Associates, Inc. 2002. Groundwater development, Lower Klamath National Wildlife Refuge, February 2002, 80 p.

WILLIAM E. NORK, Inc., 1986. College Industrial Park well no. 1 – Aquifer stress test results, prepared for Oregon Institute of Tehcnology, Geo-Heat Center, October 1986, 49 p.

WILLIAM E. NORK, Inc., 1992. Analysis of pumping tests on OIT injection well no. 2, prepared for Oregon Institute of Tehcnology, January 1992, 94 p.

5 GEOTHERMAL PRODUCTION ESTIMATE

Flow test data will be evaluated to determine geothermal fluid production rate and temperature. Most likely, best case and worst case scenarios will be developed based on this model to develop suitable design parameters for the Kalex cycle design points, providing critical information for optimized definition of the geothermal resource.

5.1 OPTIONS AND APPROACH

- This report focuses on options for developing the geothermal field based on the existing wells 9A, 9C and 12C only. Deepening of existing wells and drilling of new wells is not taken into consideration.
- A capacity to reinject all of the geothermal fluid extracted is a definite requirement for field development.

The outflow temperatures and approximate long-term mass flow capacity of the three wells available for field development are summarized in Table 2. Based on these numbers, the most cost efficient development scenario is to use well 12C as a production well and well 9A or 9C as an injection well. The main reason being that the higher outflow temperature of well 12-C more than makes up for its lower flow capacity.

5.2 POWER GENERATION POTENTIAL

5.2.1 Power Cycle Calculations

The available energy to a system is described by the Carnot Efficiency:

$$\eta_c = 1 - T_l / T_h$$

Where:

η_c = efficiency of the Carnot cycle
$T_{rejected}$ = temperature at which heat is rejected by the system (absolute)
$T_{supplied}$ = temperature at which heat is supplied to the system (absolute)

The wider the range of temperature, the more efficient becomes the cycle. The “rejected” temperature is limited by the temperature of the sink of heat, or in the case of geo-source electric generation, is the cooling tower - the atmosphere or the ocean, river. Normally the rejection temperature is in the range 10 - 20˚C. The “supplied” temperature, in the case of geo-source electric generation cycles, is limited by the heat source.

5.2.1.1 Kalex SG-2A Process Description

The design requirement for the geothermal plant will be to produce electricity from a Start of Run (SOR) geothermal fluid flow of approximately 1,766,982 lbs/hr (3,650 gpm) with a temperature of 196°F. The main processing circuit of the Kalex SG-2a process is divided into the Hot End Loop, the Main Cycle and the Internal Loop.

This process description shall be read in conjunction with Figure 25 below. Operating conditions mentioned in the description are representative for the Base Scenario Case (49°F cooling water supply temperature).

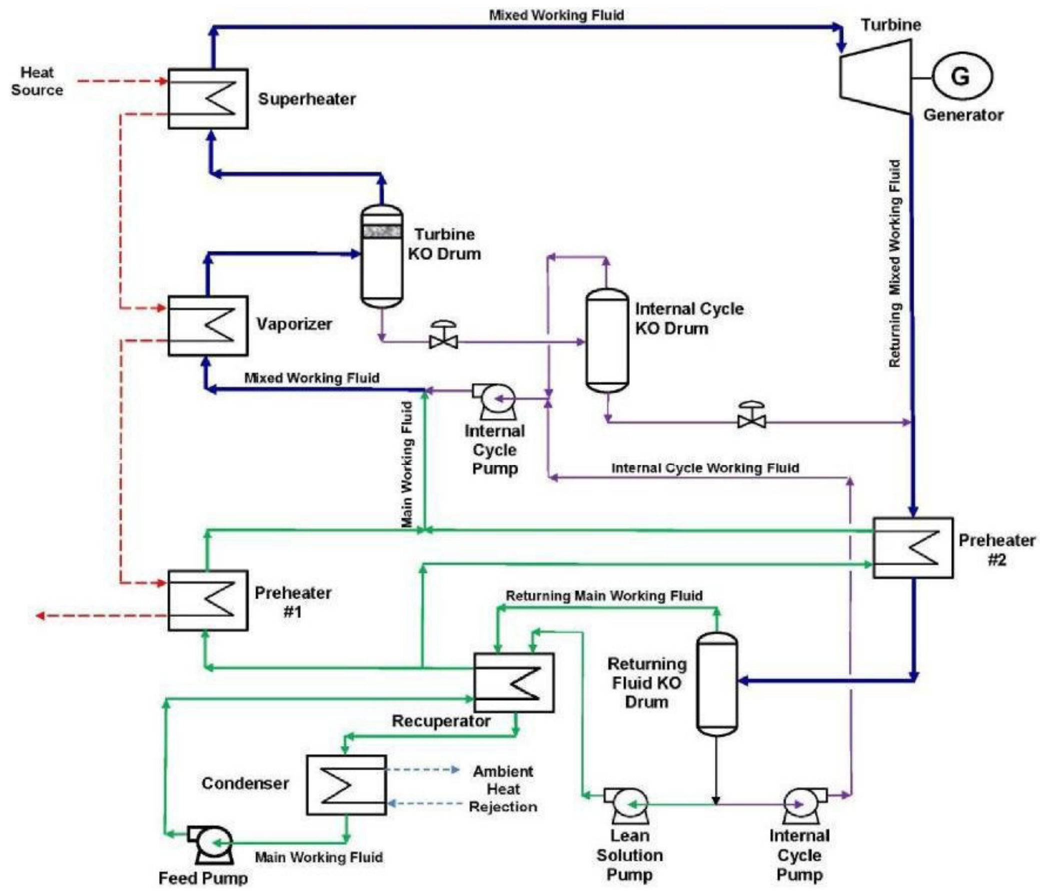


Figure 25. Kalex SG-2a Simplified Flow Diagram

Hot End Loop

A geothermal fluid (brine) of approx. 1,766,982 lb/hr at 196°F is delivered to the plant by Brine Production Pump at pressure. The Brine flows through the Superheater, followed by the Vaporizer, and Preheater # 1, to exchange heat with the ammonia solution working fluid in a closed loop system. The cooled Brine from Preheater # 1 will be injected back to the Brine Injection well at 115°F. The temperature of the Brine after heat exchange is dependent on ambient conditions at site, and due to possible scaling may have a minimum specified return temperature. This can be controlled by reducing heat extracted from the Brine by way of control vales in the hot end loop.

Main Cycle Loop

The Main Cycle loop is a closed system. The working fluid in the closed system is ammonia solution, 91.5 wt% NH_3. Fully condensed working fluid is pumped to approximately 250 psia by the Feed Pump. The working fluid is initially preheated by exchanging heat with the returning stream of the working fluid in the Recuperator. This preheated working fluid is split into two streams. One of the streams exchanges heat in Preheater #2, receiving heat from the Turbine Expander exhaust. The other stream enters Preheater #1 to receive heat from the Brine. The two streams are then combined, and then mixed with enriched internal cycle working fluid from the Internal Cycle Pump. This mixed working fluid enters the Vaporizer and receives heat with the Brine. The mixed working fluid, leaves the Vaporizer at its saturation point and is sent to the Turbine KO Drum. This vessel is provided with a demister to remove any droplets larger than 10µm. The saturated vapor is then superheated in the Superheater receiving heat from the Brine. The superheated working fluid from the Superheater is at approximately 219 psia and 191°F. The superheated working fluid flows to a radial flow turbine (expander). In the turbine, the pressure of the vapor drops to about 112 psia, and the work imparted by the vapor is converted to electrical energy in a generator coupled with the radial flow turbine. For the Base Scenario Case, the gross power output is about 3.55 MW.

The working fluid can bypass the turbine expander through a bypass control valve. This bypass valve is used during start up and shut down of the cycle. In the event of a turbine trip, the bypass valve will open to minimize the interruption and tripping of the main cycle loop circuit.

From the turbine expander, the returning working fluid is mixed with the internal working fluid from the Internal Cycle KO Drum, and the mixed returning fluid is partially condensed by exchanging heat with the main working fluid in Preheater #2. Thereafter, the returning working fluid from Preheater #2 is sent to the Returning Fluid KO Drum. The saturated liquid from this vessel is split into two streams. One stream is pumped to the internal cycle by the Internal Cycle Pump. The other saturated liquid stream is combined with the saturated vapor from the Returning Fluid KO Drum, and is intended to control the ammonia concentration in the working fluid of the main cycle. The combined stream is further condensed in the Recuperator. The exiting two phase flow working fluid is then sent to the Condenser. The completely condensed ammonia from the Condenser is at about 106 psia and 64°F. Cooling water is used as the cooling medium. The fully condensed working fluid then flows to an Accumulator (not shown). The working fluid then flows to Feed Pump, and the main cycle repeats itself.

Internal Cycle Loop

The saturated liquid from Turbine KO Drum is sent through a letdown valve into the Internal Cycle KO Drum where the fluid is again separated into saturated liquid and vapor. The saturated liquid passes through a control valve to reduce the pressure for mixing with the turbine exhaust in the main cycle loop. The saturated vapor is sent to an Absorber (not shown), where the saturated vapor is completely absorbed by the internal cycle working fluid from the Internal Cycle Pump. This enriched internal cycle working fluid is then pumped by the Internal Cycle Pump, P-3 to approximately 223 psia which allows the fluid to be mixed with the main working fluid from Preheaters # 1 and # 2.

5.2.1.2 Kalex SG-2A Power Plant Performance

Based on evaluations of the Lower Klamath Lake Geothermal Area's reservoir volumetric capacity, as well as the performance of the Kalex SG-2a Process at the brine temperatures observed at well 12-C, and those predicted under various scenarios, the performance of the proposed Kalex SG-2a power plant is summarized in Table 11 below.

Table 11. Kalex SG-2A Power Plant Performance

Entiv - Lower Klamath Lake Geothermal Area		Kalex SG-2a Power Plant Performance					Water Cooling @ 49F		
		Flow* (gpm)	Brine Supply Temp (F)	Brine Supply Temp (C)	Brine Return Temp (F)	Brine Return Temp (C)	MW (net)	Net Efficiency*** (%)	Specific Brine Consumption (lb/kW-hr)
Middle Case Base Scenario									
Likely	Start of Run	3,650	196	91	115	46	3.2	7.54%	551
Assumed	End of Run @ 15 years	3,650	178	81	105	41	2.28	5.94%	776
	Average						2.74	6.74%	664
High Scenarios									
Moderate Risk	2nd well by deepening Well 9A	3,650	203**	95	115	46	3.82	7.52%	508
Moderate Risk	2nd well close to Well 12C West @ ~ 1000 m	3,650	203**	95	115	46	3.82	7.52%	508
Medium Risk	2nd well by deepening Well 12/13	3,650	203**	95	115	46	3.82	7.52%	508
Higher Risk	"Step out" 2nd/3rd well @ different locality closer to E-W fault	3,650	239**	115	130	54	5.37	9.38%	329

* Based on Well-12A maximum flow

** Based on geotherm-ometry

*** Net power excludes downhole pump(s), air fan(s) in water cooling tower, & several smaller pumps in the plant.

Base Case Scenario

The Middle Case of the volumetric assessments discussed in Section 3.1.2.3 has been selected as the Base Scenario for this evaluation. The “Likely” Start of Run (SOR) performance uses the actual brine temperature measured during the flow testing performed in two weeks beginning September 5, 2011, as well as the maximum calculated flow potential from Well 12-C. this yields an initial power plant capacity of 3.55 MW gross or 3.2 MW net (excluding downhole pump, air fans in water cooling tower, and smaller pumps in the plant). The End of Run (EOR) performance of the reservoir assumes a conservative annual temperature loss of about 1.2 °Fper year, and over the assumed reservoir life of 15 years, the power plant’s average capacity would be 3.07 MW gross or 2.74 MW net, with average specific brine consumption (net basis) of 664 lb/kW-hr.

High Scenarios

Four High Scenarios have been defined, all within the Upper Limit of the Middle Case volumetric assessment presented in Section 3.1.2.3.

The first “moderate risk” scenario envisions deepening of Well 9-A from its current 600 feet to around 2,000 feet intersecting an outflow zone that has been shown to peak in temperature at around 900 feet in Well 12-C. This well has a higher temperature gradient from grade to 60 feet than does Well 12-C, so it is assumed that a SOR temperature of 203°F will be found in this well. In addition, Well 9-A is believed to be close to a minor fault.

The second “moderate risk” scenario envisions drilling a new well approximately 1,000 meters (3,300 feet) west of Well 12-C. This scenario anticipates intersecting an outflow zone with a brine some 7°F hotter than the geofluid currently produced from Well 12-C. Under this scenario, a Kalex power plant’s SOR capacity would rise to 3.82 MW gross or 3.48 MW net.

The third “medium risk” scenario envisions deepening of Well 12/13 to intersect the basaltic layer, not penetrated in earlier drilling campaigns, and uncovering brines at 203°F, yielding a similar power plant performance to the first High Scenario.

The final “higher risk” scenario speculates on a “step-out” 2nd (or 3rd) deeper well at a locality closer to the known fault to the South and West of Lower Klamath Lake, about 3 miles from Well 12-C. This scenario envisions drilling into the assumed reservoir upflow zone targeting a geofluid temperature of 239°F based on preliminary evaluations of the geothermometry data presented in Section 3.4.1. Under this scenario, a Kalex power plant's SOR capacity would rise significantly to 5.77 MW gross or 5.37 MW net, with a specific brine consumption (net basis) of 329 lb/kW-hr being half that of the Base Case Scenario. Significantly, the capital cost per MW of this Kalex power plant would be substantially reduced in this "higher risk" scenario.

5.2.2 Well Pumps

Based on information available for production well 12-C, two scenarios are presented to indicate the power consumptions of the production pump. Scenario 1 indicates the power consumption at a flow of 3,000 gpm and scenario 2 indicates the power consumption at the maximum allowable flow which may be found by using available information such as the well geometry, see Table 12 and Figure 26, and drawdown characteristics of the well; see Figure 18. Given these constraints, maximum allowable flow is calculated to 3,650 gpm.

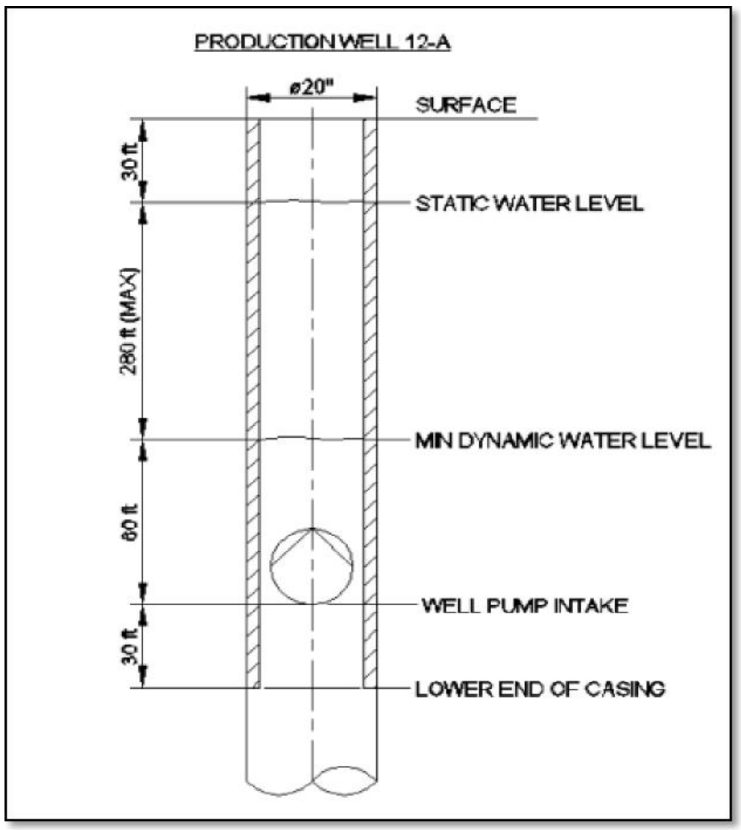


Figure 26. Maximum installation depth of well pump.

Table 12. Characteristics of well 12-C.

	Scenario 1	Scenario 2 (max flow)
Fluid media	Geothermal water	Geothermal water
Fluid temperature	192 °F	192 °F
Casing depth	400 ft	400 ft
Casing diameter	20"	20"
Static water level	30 ft	30 ft
Pump above casing end	30 ft	30 ft
Installation depth, Well pump	370 ft	370 ft
Min water level above pump	60 ft	60 ft
Drawdown in well	190 ft	280 ft
Flow	3,000 gpm	3,650 gpm

Considering the geometry of well 12-C, see Figure 26. Maximum installation depth of well pump, given that the well is straight down, production pump of both line shaft (LSP) and electrical submersible (ESP) types could be applied. Table 13 summarizes the expected power consumption of the production pump. Values are given for the two production scenarios described above.

Table 13. Power consumption of production pump.

	Scenario 1	Scenario 2 (max flow)
Well head pressure	40 PSI	40 PSI
Hydraulic power output (WP)	180 kW	277 kW
Pump efficiency, ESP type	0.8	0.8
Pump efficiency, LSP type	0.7	0.7
Power consumption, ESP type	226 kWe	347 kWe
Power consumption, LSP type	258 kWe	396 kWe

5.3 RESERVOIR RISK

Uncertainties related to the geothermal resource in the Lower Klamath Lake Geothermal Area still pose some risk to the power plant project.

Firstly, it is possible that the heat stored in the reservoir may be insufficient to support the power generation scenario outlined for the Middle Case. As shown in Table 4 and Figure 6, the power output is sensitive to reservoir area and thickness, reservoir temperature, abandonment temperature and recovery factor. The present state of knowledge about the geothermal reservoir still permits relatively large deviation from the reference values of Middle Case as indicated by the upper and lower limits in Table 4. The Low and High Cases defined in Table 3 serve to illustrate the downside risk and upside potential associated with the reservoir. At the present stage of project development, the Low Case estimate of ca. 1 MW_e gross power capacity is a possible outcome although not the most likely one.

Secondly, reservoir permeability and natural recharge may be insufficient to limit pressure drawdown to the maximum value assumed in this study. As may be inferred from Figure 18, Figure 26 and Table 12, the setting depth for the downhole pump in well 12-C will reach the maximum allowed by the production casing at the flow rate assumed in the power plant modeling (3,650 gpm). The test data series from well 12-C (as well as from wells 9-A and 9-C) are too short to allow conclusions to be drawn as to the pressure response of the reservoir to production over the long term. Therefore, it is possible that the drawdown required to sustain the flow specified for the power plant will exceed the depth limit imposed by the depth of the production casing at some time in the future. This would reduce the power output from the well and the power plant.

Thirdly, the useful lifetime of the reservoir may be cut short by fast returns of cold water directly from the injection well to the production well. The risk is enhanced by the fractured nature of the reservoir and the location of production and reinjection wells along an assumed permeable fault.

All three risks, can be reduced by longer-term testing of the production well-injection well doublet prior to committing large amounts of capital to the power plant. Such testing includes interference and tracer testing.

6 NUMERICAL MODELING OF ADANCED LOW TEMPERATURE GEOTHERMAL POWER CYCLES

Two processes were evaluated; the Kalex SG-16 and the Kalina KCS-34g. Both of these cycles were deemed superior to the Kalex SG-2a. Therefore, no modeling of the Kalex SG-2a was conducted. The Kalex SG-16 and the Kalina KCS-34g were evaluated to their improved economics for this project over the Kalex SG-2a process.

Numerical models for both Cycles were developed for the production scenarios developed in Subtask 1.2. In addition to variations in reservoir performance, various working fluid cooling scenarios (air cooled condensers, wet cooling towers, and hybrid cooling system), were simulated to determine theoretical performance under various operating conditions.

6.1 KALEX SG-16

This cycle includes a superheater and is usually chosen for geothermal sources with much higher temperatures than are observed in the Lower Klamath Falls geosource. Furthermore, the SG-16 cycle has no known commercial experience.

The SG-16 process is designed to utilize heat sources with a relatively low initial temperature of less than or equal to 400°F and are intended for relatively small-scale power applications, such that low capital cost and simplicity justly a somewhat lower than maximum possible efficiency. The SG-16 process adopted to the Klamath Falls project uses a mixture of at ammonia and water, with different normal boiling temperatures, as a working fluid. This process configuration generates at the annual design condition:

Gross Generation	9,561 kWe
Process Pumps	372 kWe
Cooling Tower Fans & Circulating Water Pumps	1,041 kWe
Net Process Generation	8,148 kWe
Geo Source Recirculation Pumps	315 kWe
Net Plant Generation	7,833 kWe

The SG-16 Process Flow Diagram is attached in Appendix B1. This process was modeled using Invensys Pro-II. The equipment duties were used for layout and cost estimate purposes.

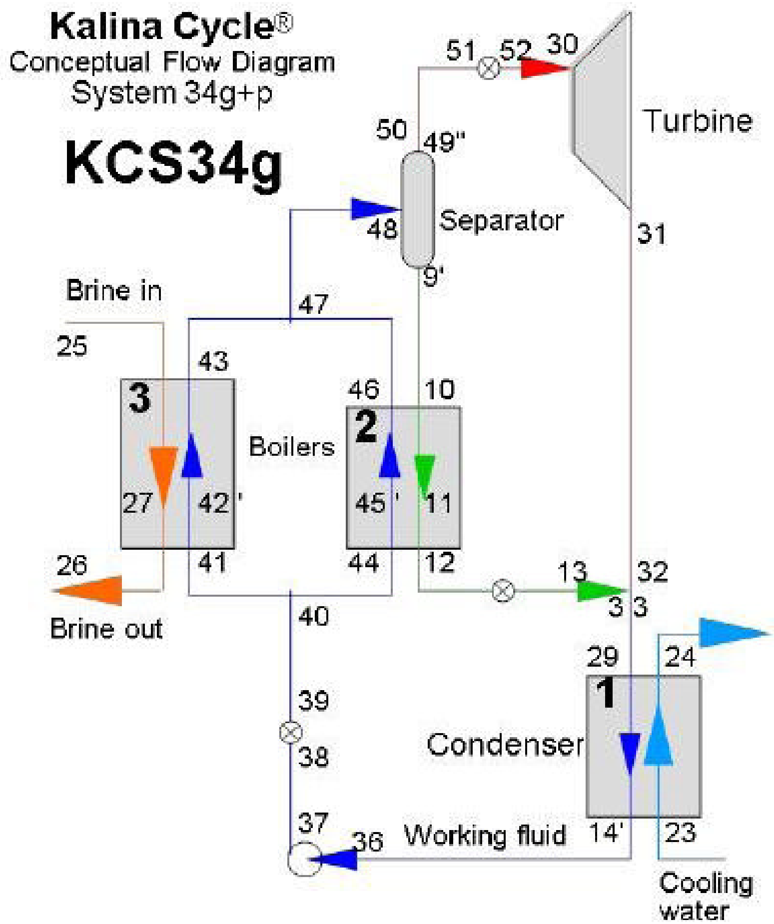
6.2 KALINA CYCLE KCS-34G

The Kalina Cycle KCS-34g was selected due to its ability to extract heat from low temperature geosources, simple design, several commercial applications, and has the ability to produce power at a lower cost compared to the SG-16 process.

Recurrent Engineering was obtained to model the S34g process for the Pilot Project. The modeling included estimating piping pressure losses, and a 12°F condenser pinch. This process configuration generates 9.7 MWe gross and 8.7 MWe net at the annual design condition.

This process configuration generates at the annual design condition:

Gross Generation	9,754 kWe
Process Pumps	334 kWe
Cooling Tower Fans & Circulating Water Pums	1,050 kWe
Net Process Generation	8,370 kWe
Geo Source Recirculation Pumps	315 kWe
Net Plant Generation	8,055 kWe



Kalina Cycle®
Conceptual Flow Diagram
System 34g+p
KCS34g
51
52
30
Turbine
50
49"
Separator
48
31
9'
Brine in
47
25
43
3
46
10
2
Boilers
27
42'
45'
11
26
41
44
12
13
32
3
3
Brine out
40
29
24
1
39
38
Condenser
37
36
Working fluid
14'
23
Cooling
water

Results of the modeling are as follows:

Kalina Cycle Control Data

T25	198	∆T11	5.4
T26	128	∆T10	5.4
T23	53	∆T3	5.4
P30	290	TME	.96
T mass	47,177.3 gpm	ATE	.88
∆T1	9	Cp brine	1
∆Ta	15	Brine flow	5793,204 pph
∆Tw	12	P eff	.8

Heat Exchanger Pressure Drops

∆P 23–24	30	∆P 10–11	2.9
∆P 29–14	1.45	∆P 39– 41	2.5
∆P 41–42	8.7	∆P 11–12	8.7
∆P 42–43	11.6	∆P 49– 30	6

Piping & Valve Pressure Drops

∆P 31– 32	1	∆P 45–46	11.6
∆P 43– 48	5	∆P 46– 48	1.5
∆P 33– 29	.1	∆P 47–48	.5
∆P 38v39	2.5	51	3
∆P 9– 10	.5	52	3
∆P 40– 41	1	∆P 25–27	5
∆P 44–45	8.7	∆P 25–26	5

Summary Results

Turbine mass flow	83.72 kg/s	664,453 lb/hr
Pt 30 Volume flow	6,498.87 L/s	826,220 ft3/hr
Pt 31 Volume flow	15,294.45 L/s	1,944,426 ft3/hr
	kW	BTU/lb
Heat in	118,847.44	464.20
Heat rejected	108,998.69	425.73
Turbine enthalpy drop	10,159.94	39.68
Turbine Work	9,753.54	38.10
Feed pump ∆H 1.22, power	330.65	1.29
Feed + Coolant pump power	1,050.03	4.10
Net Work	8,703.52	33.99
Gross Output	9,753.54	
Cycle Output	9,422.90	
Net Output	8,703.52	
Net thermal efficiency	7.32 %	
Second law limit	16.17 %	
Second law efficiency	45.30 %	
Specific Brine Consumption	665.62 lb/kW-hr	
Specific Power Output	1.50 Watt-hr/lb	

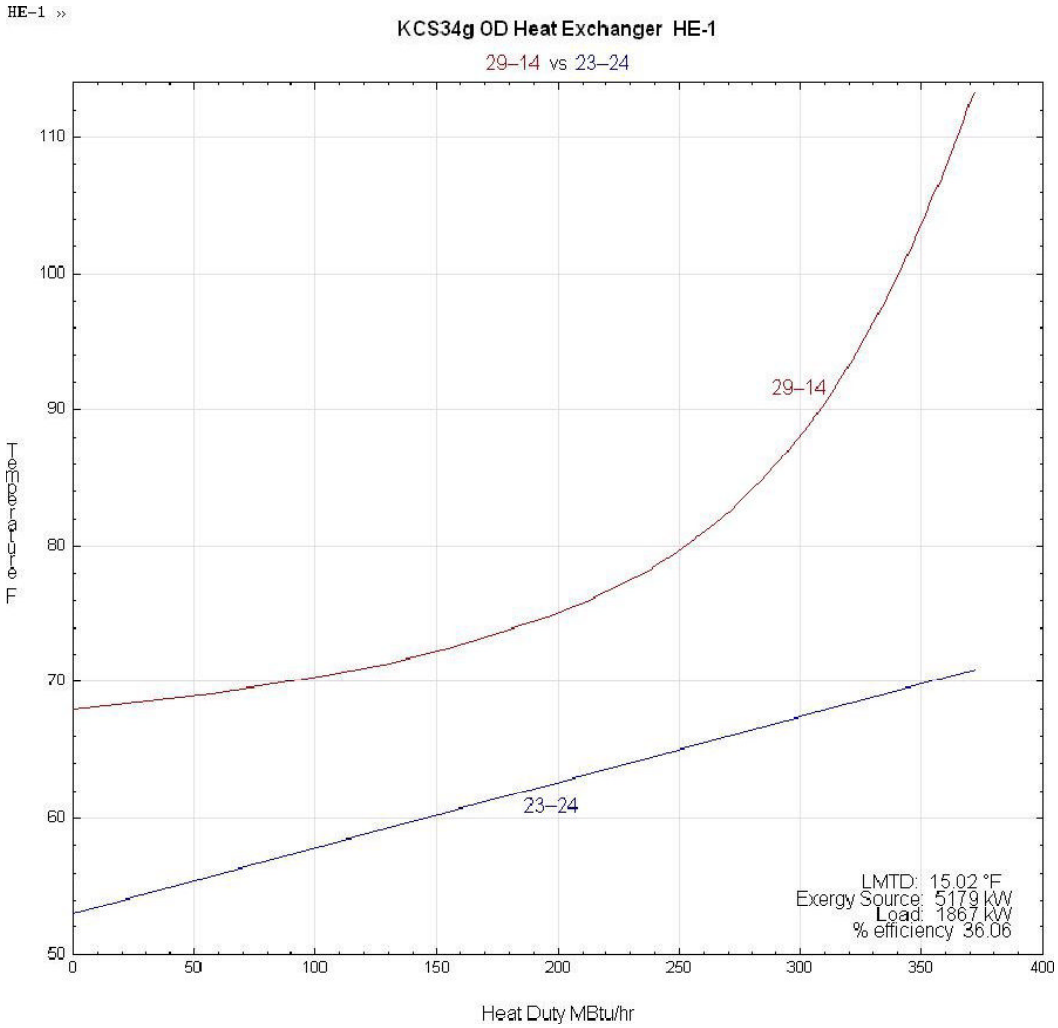
KALINA CYCLE® SYSTEM 34g OD POINTS

2013 Nov 08 14:31:54

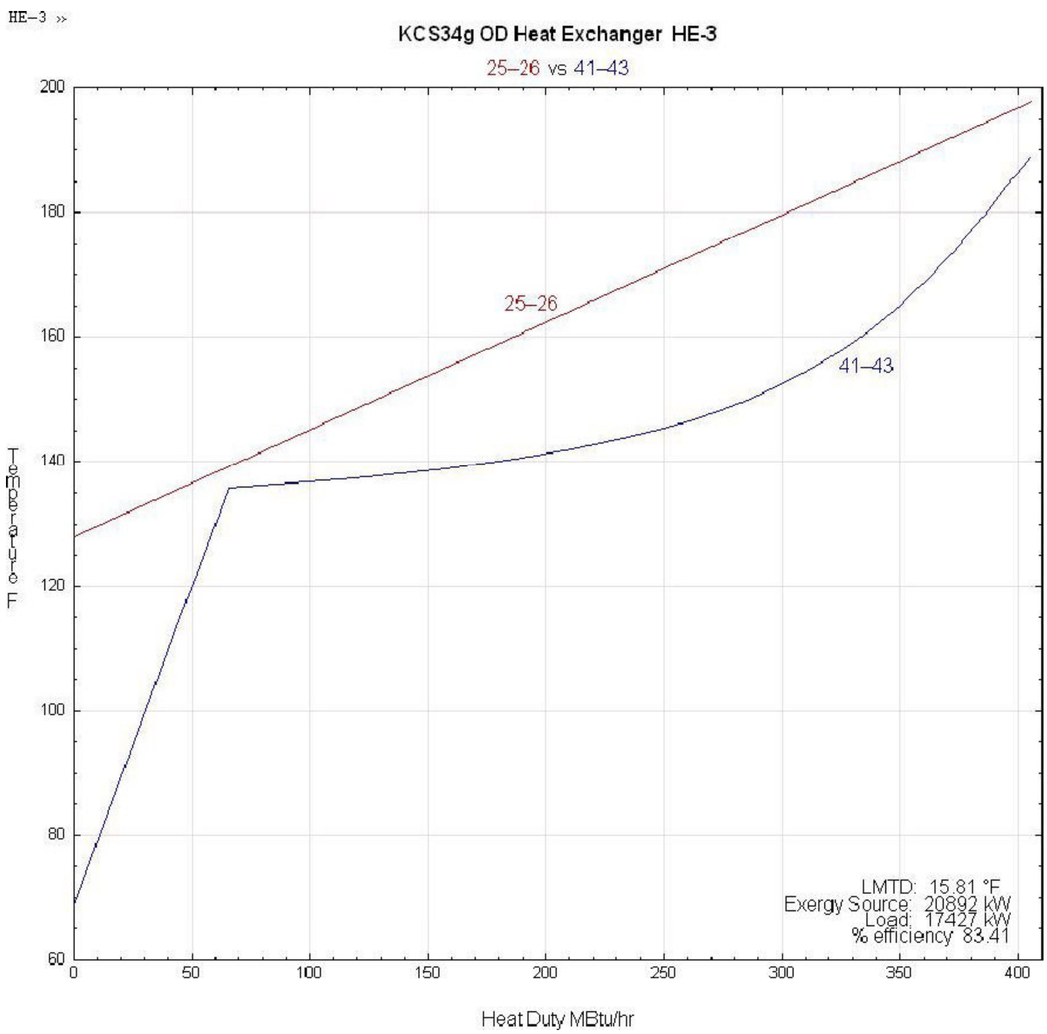
#	P psiA	X	T °F	H Btu/lb	G/(G=1)	Flow lb/hr	Phase
23	•	Water	53	21.00	23.6830	20,689,403	
24	•	Water	70.98	38.98	23.6830	20,689,403	
36	109.58	.88	68	0.41	1	873,598	SatLiquid
37	326.30	.88	68.72	1.62	1	873,598	Liq 70°
38	326.30	.88	68.72	1.62	1	873,598	Liq 70°
39	323.80	.88	68.73	1.62	1	873,598	Liq 70°
40	322.30	.88	68.73	1.62	1	873,598	Liq 69°
41	321.30	.88	68.73	1.62	0.9660	843,886	Liq 69°
42	312.60	.88	135.82	79.65	0.9660	843,886	SatLiquid
43	301	.88	189	482.17	0.9660	843,886	Wet .2395
44	317.80	.88	68.74	1.62	0.0340	29,712	Liq 68°
45	309.10	.88	134.99	78.65	0.0340	29,712	SatLiquid
46	297.50	.88	182.31	467.47	0.0340	29,712	Wet .2563
47	296.50	.88	67.34	0.00	1	873,598	Liq 65°
48	296	.88	187.82	481.67	1	873,598	Wet .2394
49	296	.9874	187.82	611.59	0.7606	664,453	SatVapor
50	296	.9874	187.82	611.59	0.7606	664,453	SatVapor
51	293	.9874	187.31	611.59	0.7606	664,453	Wet 0
52	290	.9874	186.79	611.59	0.7606	664,453	Wet 0
30	290	.9874	186.79	611.59	0.7606	664,453	Wet 0
31	112.13	.9874	102.64	559.42	0.7606	664,453	Wet .0288
32	111.13	.9874	102.29	559.42	0.7606	664,453	Wet .0287
9	296	.5389	187.82	68.90	0.2394	209,145	SatLiquid
10	295.50	.5389	187.71	68.90	0.2394	209,145	Wet .9997
11	292.60	.5389	140.39	13.66	0.2394	209,145	Liq 46°
12	283.90	.5389	130.86	2.72	0.2394	209,145	Liq 54°
13	111.13	.5389	119.46	2.72	0.2394	209,145	Wet .9766
33	111.13	.88	113.48	426.14	1	873,598	Wet .2633
29	111.03	.88	113.43	426.14	1	873,598	Wet .2633
14	109.58	.88	68	0.41	1	873,598	SatLiquid
25	•	Brine	198	166.00	6.6314	5,793,204	
27	•	Brine	139.37	107.37	6.6314	5,793,204	
26	•	Brine	128	96.00	6.6314	5,793,204	

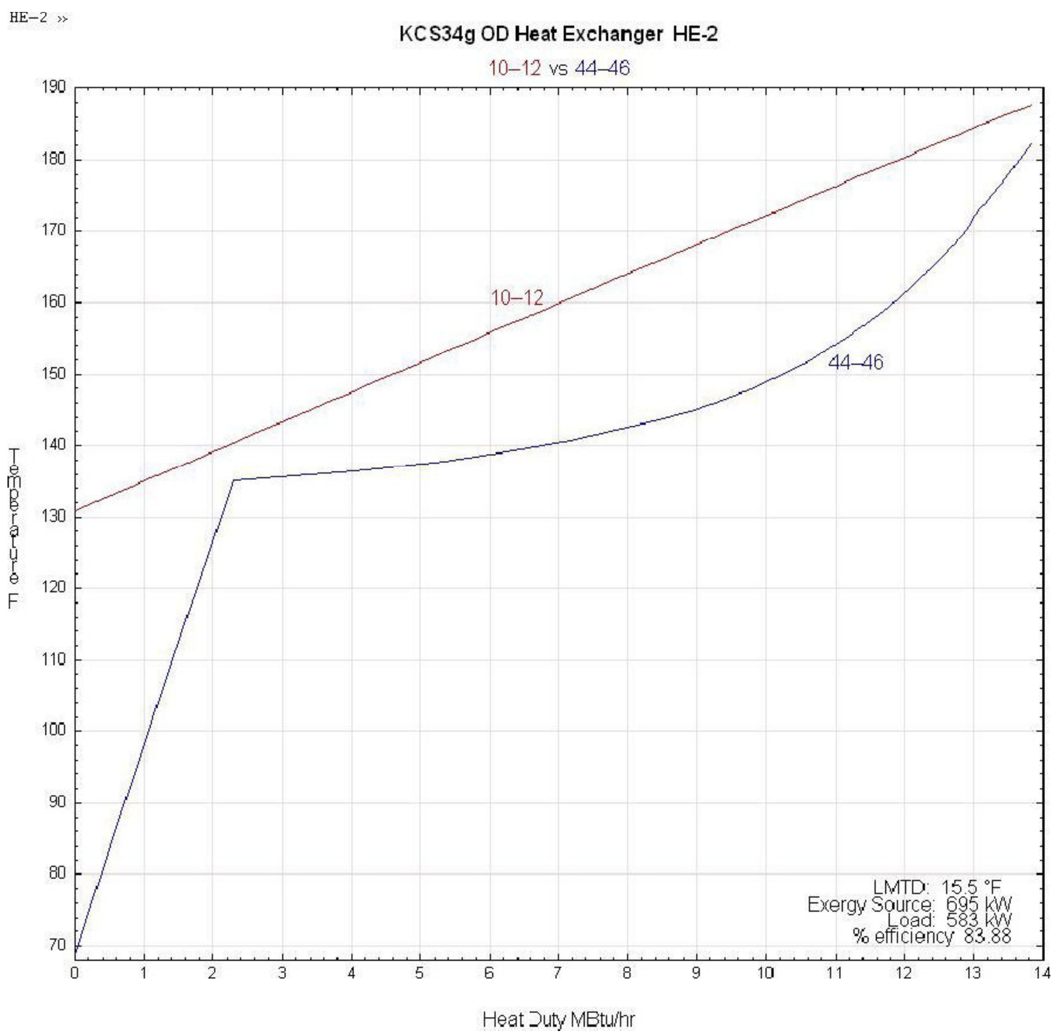
S34g OD HXs:

	MW th	LMTD	∆Ts between streams	
HE–1	108.999	15.02	T29–T24	42.46
			T14–T23	15
HE–2	4.056	15.50	T10–T46	5.4
			T11–T45	5.4
			T12–T44	62.12
HE–3	118.847	15.81	T25–T43	9
			T27–T42	3.54
			T26–T41	59.27



HE-1 »
KCS34g OD Heat Exchanger HE-1
29–14 vs 23–24
110
100
90
80
70
60
50
Temperature F
29–14
23–24
LMTD: 15.02 °F
Exergy Source: 5179 kW
Load: 1867 kW
% efficiency 36.06
0
50
100
150
200
250
300
350
400
Heat Duty MBtu/hr


HE-3 »
KCS34g OD Heat Exchanger HE-3
25–26 vs 41–43
25–26
41–43
Temperature F
Heat Duty MBtu/hr
LMTD: 15.81 °F
Exergy Source: 20892 kW
Load: 17427 kW
% efficiency 83.41
200
180
160
140
120
100
80
60
0
50
100
150
200
250
300
350
400



6.3 ANNUAL PERFORMANCE ESTIMATES

If an 85% capacity factor is assumed for the plant. The first year plant electric production for the Kalex SG-16 cycle could be:

Annual Generation = Capacity Factor * Design Net Capacity, MW * 8766 hours / year
Annual Generation = 0.85 * 8.703MW * 8766 hours / year
Annual Generation = 64,079 MWh / year

The first year plant electric production for the Kalina KCS-34g cycle could be:

Annual Generation = Capacity Factor * Design Net Capacity, MW * 8766 hours / year
Annual Generation = 0.85 * 8.703MW * 8766 hours / year
Annual Generation = 64,079 MWh / year

7 PILOT PROJECT ENGINEERING DESIGN

Once final confirmation of high efficiencies of the Kalex cycles with low temperature geo-resources is confirmed by way of numerical modeling, the engineering design program for the project will commence. The engineering design program will include plant design, balance of plant facilities, and production and injection systems for transporting fluids to and from the pilot facility. The deliverables package will include all materials required to commence construction of the project, inclusive of civil and mechanical drawings, pilot plant layout drawings, heat mass balance diagrams, electrical one line diagrams, process and instrumentation diagrams, equipment and materials specifications, equipment and material lists, equipment/material/construction cost estimates.

Preliminary engineering documents used to develop the cost estimate are attached in Appendix A:

- Process Flow Diagrams
- Heat and Mass Balances
- Sized Equipment Lists
- Electric Load Lists
- Single Line Diagram
- Plot Plans
- GeoSource Pipeline Routing
- Elevation Depictions
- Sized Piping Lines

These engineering documents are considered preliminary and were not developed to construction ready. This was due to the fact the project economics were not feasible and the project owner ceased funding the project.

8 PILOT PROJECT ECONOMIC FEASIBILITY

Upon completion of the Project Engineering Design, an economic feasibility study will commence to determine the financial viability of the project based on the Kalex cycle. This study will include comprehensive analysis and financial models with capital costs, operating costs, installed cost per MWe, avoided cost of electricity, cost/benefit analysis, payback period, Levelized Cost of Energy (LCOE), Return On Investment (ROI), and quantification of any other beneficial attributes, such as climate change benefits, carbon offset, and all other environmental and renewable attributes associated with "low-to-no" emissions/carbon foot print geothermal power facilities. Sensitivity analysis of key parameters will also be performed.

Economic Feasibility for this project is defined by meeting all of the following criteria:

a. The cost of electricity generation is below the price the local electric off-takers are willing to pay,
b. The project has an attractive internal rate of return for equity (12% is assumed to be a minimum, whereas 18% is typical), and
c. A qualified third party assessment of the geothermal source support the project life.

The Cost of Generation is typically based on the following components:

- Fuel (there are no fuel costs in the case of geothermal based electric generation),
- Fixed Operating & Maintenance (those non-fuel and capital cost elements which occur even when the plant is not operating),
- Variable Operating & Maintenance (those cost elements which occur only when the plant is operating), and
- Capital Service (cost associated with paying off the debt and equity).

8.1 CAPITAL COSTS

8.1.1 Purpose

The purpose of this document is to inform ENTIV Organic Energy of the estimating basis used to develop a Budgetary Class IV Cost Estimate, for the Engineering, Procurement and Construction of a Kalex SG-16 Low Temperature Geothermal Cycle Plant. Both a single train (4.3 MW), a double train (2 x 4.3 MW), and a Kalina KCS-34g plant configuration cost estimates were developed.

8.1.2 Project Background

The main objective of this project is to validate the actual performance advantages of an advanced ammonia-water mixed fluid cycle (Kalex) in low temperature geothermal resource application, and to validate that Kalex technology offers significant commercial economic benefits, competitive operational performance in terms of project capacity, availability and operation overhead, is safety, ease of use and efficiency.

The Entiv Organic Project focuses on utilizing an innovative, advanced ammonia-water mixed working fluid energy conversion cycle, specifically designed for low temperature geothermal resources fluids.

The ammonia water working fluid technology and this new patent system are owned by Kalex LLC. In May 2011, Technip and Oski Energy signed an exclusive license purchase agreement with Kalex to jointly license and market Kalex Geothermal Systems Technology worldwide. Technip will cost share a Kalex Technology sublicense to the Entiv Organic Project.

The Kalina KCS-34g process is owned by Recurrent.

The project will be located in Siskiyou County, CA, along the California – Oregon border, specifically in the Lower Klamath Lake National Wildlife Refuge.

All facilities needed to produce 4.3 MW of electrical power, will be built by an Engineering, Procurement and Construction (EPC) contract, utilizing the services of an EPC firm, specialist geothermal consulting engineers, as well as general subcontractors.

The overall project has been divided in three phases, and the main goals on each are as follow:

Phase I: Feasibility Study, Engineering Design and Permitting.

- Detailed assessment of geothermal resources areas.
- Determination of geothermal resources operating parameters.
- Determination of theoretical performance based on numerical models for the selected Kalex cycle.

- Determination of off-design operating conditions.
- Development of Economic Feasibility Study.
- Development of an Engineering design program, including documentation needed to permit and commence detailed engineering, procurement and construction of the project as well as geothermal power operating facilities permits and drilling permits that will be wholly completed during Phase II.
- Development of the Interconnection studies with the appropriated utility agency.
- Final Phase I report in order to get the GO / NO GO / REDIRECT to Phase II from US DOE.

Phase II: Procurement, Installation and Commissioning of Equipment.

- Development of additional characterization of the geothermal resource in order to determine the optimal location for additional production or injection wells that may be required.
- Completion of the well gathering system
- Design and Installation of Production injection systems for transporting fluids to and from the Plant.

Phase III: Operation and Maintenance

- Validation of the long term viability of Kalex Cycle Plant.
- Operation of the Kalex Plant for a minimum of 2 years, in order to report on the economic, performance and operating characteristics of the facility.
- Development of final report, including validation of technical and economical assumptions, documentation and lessons learned during the operational period.

8.1.3 Responsibilities

- Cost Estimate will be prepared under responsibility of the Estimating Leader
- Chief Estimator from Estimating Department performs checking of the Cost Estimate.
- Project Director or Project Manager approves the Cost Estimate.

8.1.4 Cost Estimate Principles

Currency of Account

Unless specifically mentioned, the currency used in this Cost Estimate is the United States Dollar (USD).

Accuracy and Confidence

This Cost Estimate was performed on the basis of the documents issued by engineering disciplines during the Feasibility Study.

The Capital Class IV Cost Estimate is in accordance with the classification of AACE (Association for the Advancement of Cost Engineering). The typical accuracy range for this class of estimate are -15% to -30% on the low side and +20% to 50% on the high side. See Table 1 for further explanation.

CLASS 4 ESTIMATE	
Description: Class 4 estimates are generally prepared based on limited information and subsequently have fairly wide accuracy ranges. They are typically used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval. Typically, engineering is from 1% to 15% complete, and would comprise at a minimum the following: plant capacity, block schematics, indicated layout, process flow diagrams (PFDs) for main process systems, and preliminary engineered process and utility equipment lists. **Level of Project Definition Required:** 1% to 15% of full project definition. **End Usage:** Class 4 estimates are prepared for a number of purposes, such as but not limited to, detailed strategic planning, business development, project screening at more developed stages, alternative scheme analysis, confirmation of economic and/or technical feasibility, and preliminary budget approval or approval to proceed to next stage.	**Estimating Methods Used:** Class 4 estimates virtually always use stochastic estimating methods such as equipment factors, Lang factors, Hand factors, Chilton factors, Peters-Timmerhaus factors, Guthrie factors, the Miller method, gross unit costs/ratios, and other parametric and modeling techniques. **Expected Accuracy Range:** Typical accuracy ranges for Class 4 estimates are -15% to -30% on the low side, and +20% to +50% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances. **ANSI Standard Reference Z94.2-1989 Name:** Budget estimate (typically -15% to + 30%). **Alternate Estimate Names, Terms, Expressions, Synonyms:** Screening, top-down, feasibility, authorization, factored, pre-design, pre-study.

TABLE 1

AACE Class IV Cost Estimate Description as per Recommended Practice 18R-97

The Cost Estimate excludes certain cost elements, which are listed under "Exclusions".

Costs for all major equipment, materials, subcontracts and labor rates will be based on TECHNIP's in-house data, quotation received from Vendors and construction costs according to information received from subcontractors.

The term "in-house" used hereinafter means pricing by means of TECHNIP's internal tools based on statistical data supported by past and ongoing Projects, Purchase Orders (P.O.) and quotations received for similar items for major Proposals and Projects.

The presentation of the price will be prepared according to Technip standard formats for this kind of projects.

Refer to Attachment 1 for the Estimate Summary Price Sheet Template.

Economic Conditions.

The Economic conditions of the Cost Estimate price are those of 4th Quarter, 2012. Future escalation for the execution of the EPC Project, Taxes and Financing costs, were excluded.

Project Execution Strategy

The Cost Estimate was performed considering an EPC Lump Sum Project, with construction being performed by a contractor in a consortium teaming arrangement, with an appropriated division of risk between Technip and Construction Subcontractor. The execution is bounded by ISBL according with Attachment 2 in which is shown the Plot Plans for each Plant Location.

The Risk distribution Matrix between each party has been determined as follow:

No.	Activity	Remarks	Responsible for additional cost	Responsible
1	Process Performance	LDs for performance		TP (100%)
2	Quantity Grow th	Excluding client changes	Quantity grow th	TP (100%)
3	Engineering Errors	Rew ork	Technip - Engineering/Procurement Technip - Construction impact (*)	TP (100%)
4	Vendor / Material Quality	Inspection by responsible Party	Technip - Procurement Technip - Construction impact (*) Const. Company - Procurement Const. Company - Construction impact	TP (100%) TP (100%) CPY (100%) CPY (100%)
5	Engineering Deliverables	Quality Schedule	Engineering/Procurement - TP 100% Construction impact* - TP 100%	TP (100%) TP (100%)
6	Material Deliveries to site	Schedule	Engineered materials (tagged items) Construction materials supplied	TP (100%) CPY (100%)
7	Labor rate		Const. Company	CPY (100%)
8	Labor productivity		Const. Company	CPY (100%)
9	Quality of construction		Const. Company	CPY (100%)
10	LDs for Delay	Flow dow n according to Contract w ith Entiv (if applicable)	Share in proportion to the interest of the Parties (TBD).	TP (##%) CPY (##%)

Note: * Technip to support risk of construction impact, but only to the extent that (i) it impacts the critical path of the construction schedule and cannot be mitigated by a simple w ork-around and (ii) impact actually results in additional costs incurred.

TP: Technip USA
CPY: Construction Company (TBD)

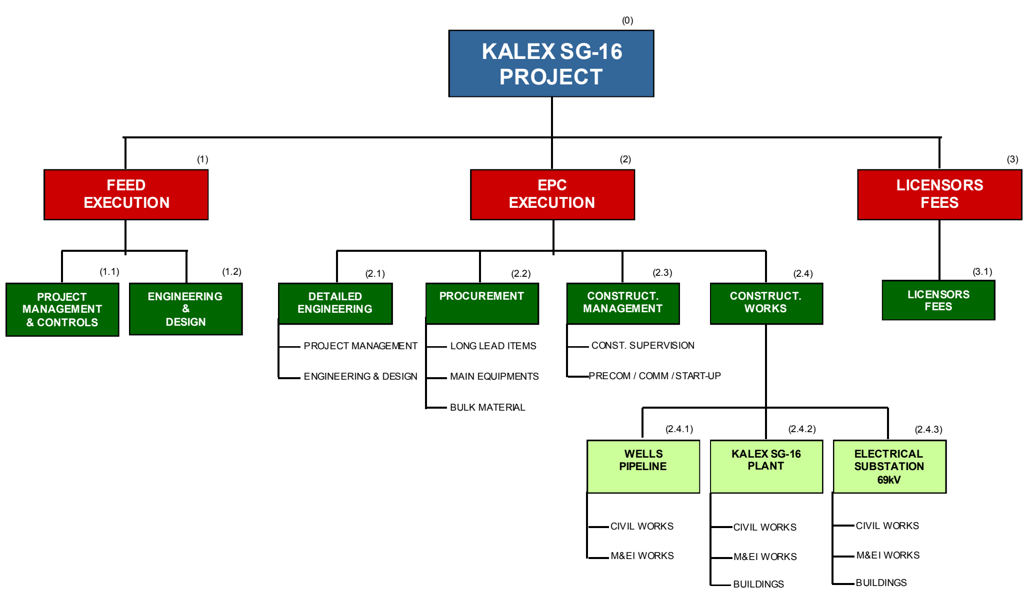
Abbreviations and Definitions

For a common and clear understanding between Client and Technip, the following definitions are using in this Estimating Basis.

US DOE	United States Department of Energy
E & I	Electrical and Instrumentation
EPC	Engineering, Procurement and Construction
FOB	Freight on Board
ISBL	Inside battery limit
OSBL	Outside battery limits
MTO	Material Take-off
U/G	Under Ground
USGC	United States Gulf Coast
WBS	Work Breakdown Structure
COA	Code of accounts
DE	Detailed Engineering
DA	Design allowance

Cost Breakdown Structure (CBS)

The Cost Estimate was prepared according with the following Cost Breakdown Structure:



Summary of Costs

As product of this Feasibility Study, in the following tables is presented a summary of the Capital Cost Estimate +/- 30% according to each Plant Location:

8.1.5 Methodology

Method to perform the cost estimate is described in details in the following sections, and includes information regarding in-house databases, statistical information or factors to be utilized to evaluate quantities, or to account for miscellaneous “extras”.

The following list of main documentation was used as the basis of the Cost Estimate:

DOCUMENT	DEGREE OF COMPLETION
Project Scope of Work	Preliminary
Plot Plan	Preliminary
Process schematics and simplified PFD/UFD	Preliminary
Sized Process Equipment List	Preliminary
Discipline Material Take-offs	Preliminary
Discipline Home Office Man-hours (DE)	Preliminary
Overall Project Master Schedule	Preliminary

Engineered Equipment Pricing

The priced equipment list identifies each tagged component with adopted vendor price or method of pricing. All Equipment’s were estimated on the basis of the Process Equipment List, according with their main technical characteristics. Equipment’s are listed on a piece-by-piece basis.

All Equipment and Material costs were estimated according to the following definition:

Delivery Ex-Works

Packing and sea preservation included (where applicable)

Economic conditions (see above)

Unless specifically mentioned, all drivers (motor or turbine) were considered together with the relevant rotating equipment.

All special materials such lining, refractory, coating on equipment were considered to be included in the equipment cost.

Regarding packages, equipment scope of supply includes platforms & ladders, insulation, instruments, etc.

Equipment’s were split in two categories in order to achieve the accuracy required. Each category is defined as follow:

Category A – “Critical Equipment’s”: This category corresponds to Equipment’s subject to vendor quotations with high relevance into the overall equipment’s price such as: Turbo-expander, Plate Heat Exchangers, Pumps, Cooling Tower, PDC Building and HV Electrical Substation (69kV). Normally, this category represents the Long Lead Items.

Category B – “Other Equipment’s”: This category corresponds to the rest of equipment’s and don’t represent long lead items, its prices were based on quotation received from vendors or by the application of an “in-house” methodology.

The “in-house” methodology is referred to equipment priced through either: (a) estimating by analogy or factored adjustment based on similar equipment; or (b) estimating using specialized Estimating software as Aspentech Kbase.

Equipment with vendor quotations were supported with data sheets coming from process or mechanical department. Vendor quote or quotes used are noted in the “adopted vendor” column of the equipment list.

Bulk Material Cost Estimate

Piping Materials

The Piping design group has provided the following information to support the estimate. Computation of quantities was generated from preliminary plot plan and general arrangements using a transposition methodology. Main considerations taken into account were:

- Pipe MTO quantities were listed by material type, wall schedule, rating and size and were generated for each line. Piping MTO lengths were generated from a piping transposition (lines 3” and larger). Lines 2” and smaller were approximated from the transposition.
- Valve take off by type, size, metallurgy and rating was compiled by Piping based on the red-lined P&ID’s.
- All piping MTO’s were calculated as 45% of the total quantities obtained in the reference plant.
- The entire piping account is priced using the Technip Piping Estimate Worksheet. This worksheet uses the current 2012 pricing for pipe, valves and fittings and estimates shop fabrication costs for large bore piping fabricated as spools.
- No steam tracing is included in this estimate.
- Piping quantities to be electric traced were obtained from the Piping Group and this cost was included in the electrical account of the estimate.

Instrumentation Materials

The Instrumentation design group provided the information regarding with all instrumentation materials needed to operate and control the Plant. The Instrumentation Material Cost Estimate includes the following:

- In-line and tagged instrument items.
- Instrument valves (control, PSV, on-off, regulating).
- DCS or other process control systems.
- No CCTV or telecommunication systems were included in the estimate.
- Analyzer requirements are included in the instrumentation MTO.
- Instrument bulk materials (tubing, conduit, tray, junction boxes, etc.) are included in the instrumentation MTO, and were calculated as 75% of the total quantities obtained in the reference plant (Kalex SG-2a Project)

Electrical Materials

- Electrical material take-off (MTO) covers ISBL, OSBL and Electrical Substation.
- Electrical materials include 1.5MVA transformers, distribution panel boards for ISBL power, lighting fixtures, receptacles, grounding materials, grounding cables and wire, and raceway conduit and fittings.
- Electrical materials include supply, installation and connection of the Power Distribution Center (PDC Building).

Civil and Structural Materials

- MTO’s were developed by the Civil group. Assumptions/comments are as follows.
- Foundations, piling and paving:
- There are not quantities for concrete paving. Plant surface will be filled with 6 inches of gravel.
- Quantity of concrete foundations (spread footing type).
- Quantities for Site preparation
- Rock blasting & excavation is partially included
- Piling is excluded.
- Retaining wall concrete on rock face is excluded.
- Steel
- Individual structural steel member weights segregated by light, medium and heavy were provided by the Structural Group.
- Individual weights for grating, handrail, ladders & stairways were provided by the Structural Group
- Buildings

- Only Control room and PDC building are included in this cost estimate.
- Administrative office and maintenance office buildings are excluded.
- Facilities for toilets, canteen, and recreation areas, are not considered.

Insulation Materials

Piping insulation (both “PP”- personal protection or “H”- heat conservation) has been provided by pipe size, material class, insulation thickness and length.

Miscellaneous Materials

Miscellaneous materials for construction installation have been taken into account as provision.

TECHNIP HOME OFFICE SERVICES COSTS

Detailed Engineering Services

Home office costs are derived based upon the estimated man-hours provided by each engineering department for the execution of the EP work. The home office costs to execute the FEED Phase include the following man hours per category:

- Project Management
- Project Controls
- Process & Technologies
- Design Engineering
- Procurement and Subcontracting Services
- Home Office Construction
- Start-Up
- Clerical Services

Man hour rates used to pricing this portion of the project are inclusive of direct and indirect cost, as well as associated cost such as: telephone, reproduction, main frame, computers, etc., as well as provision for travel expenses and relocation cost if applicable.

Construction Management Services

The Construction Management services cost, cover the field office professional and supervision services.

Construction Management Services include personnel to be deployed at site to perform the following activities: construction supervision, field engineering, quality control, HSE supervision, material management, planning and cost control, subcontract administration, administrative staff and management.

The overall man-month for Construction Management was based on the Construction direct productive man-hour and Technip’s experience on similar projects.

The Construction Management service cost was calculated by multiplying the estimated man-months by a monthly all-in rate, including personnel salaries and other expenses (insurance, living allowances and other benefits) at site.

Catering and accommodation expenses are excluded, as well as camp costs.

CONSTRUCTION

Construction Cost is based on construction bill of quantities developed by each engineering discipline. Principal considerations for this portion of the Cost Estimate were as follow:

Direct Construction Cost

Unit labor factors were assigned against each material line item to generate the total construction man-hours for each discipline.

The installation of equipment’s was based on the weight of the equipment with a set unit installation factor per measure of weight for each one.

The cost for the direct local man-hours (including indirect costs) and/or supply was based on our knowledge of the American construction market. An All-in rate based on Open Shop prevailing wages of around 80 USD/Mh.

In addition to all written above, a dedicated bid for all the Construction works was received from a Specialized Construction Subcontractor. Information was checked and used as reference to determine the final Construction price.

Temporary Facilities

An allowance was made based on a percentage of the total construction cost.

Pre-Commissioning, Commissioning & Start-up assistance

An allowance was made based on a duration based percentage of the total construction cost.

Scaffolding Costs

Allowance for scaffolding cost is embedded in the construction all-in rate.

Operational & Commissioning Spare parts

An allowance was made based on a percentage of the total equipment and bulks cost.

8.1.6 Design Allowances, Technical contingencies and Risk

Design Allowance

Allowance is specific to Equipment. It covers extras for nominal and routine changes that may occur during the normal development of following engineering phases. Allowance was calculated by factoring the cost estimated for equipment's or the costs indicated by Vendors bids. This value is based on statistical data from previous projects. The design allowance is part of the direct base equipment cost and does not represent a Contingency. The Design Allowance used in this cost estimate was 3%.

Technical Contingency and Reworks for Construction works

Technical Contingencies represent undistributed provisions, which cover estimating variances for the specific EPC scope of work. They cover items such as human factor and judgment error in accumulation of estimating scope.

Technical Contingencies cover quantities accuracy, price level accuracy, sizing adjustment on equipment and bulk materials.

Contingencies are expected to be spent. It is mandatory to include these risk and contingencies in the EPC Works Cost estimate.

Reworks for construction works is also included, and represent a provision for construction activities.

The following Technical contingencies were used for this estimate:

- Technical Contingency on Equipment and Bulk materials: 7%
- Technical Contingency on Construction Supervision: 4%
- Technical Contingency on Construction Works: 6%
- Technical Contingency on Home Office Services: 3%
- Technical Contingencies on Miscellaneous works: 5.2%
- The average Technical Contingency based on the technical cost, was around of 5.4%.

<u>FREIGHT, TAXES AND FEES</u>

Freight

For freight, packing and transport of all equipment and bulks to the Project jobsite an allowance of 6% of the total equipment and bulks cost was used.

For imported Equipment's and Materials dedicated customs duties were taken into account, the percentage used is around of 2,5%.

Taxes

Any Taxes are not included in this cost estimate.

Fees

Permit fees, special county fees, duties, and use fees are not included in this cost estimate.

8.1.7 Exclusions

The Capital Cost Estimate does not include the typical qualifications/exclusions list as shown below.

- Project wide incentive / retention costs.
- Capitalized interests.
- Working capital.
- Currency fluctuations.
- Client's Start-Up Manpower.
- Client's Manpower costs.
- Client's recruitment and travel expenses.
- Plant equipment and supplies for operation.
- Operation running costs.
- All typical owner costs (site cost, project financing cost, permits cost, etc.).
- Indirect taxes such as Sales Taxes or GST and VAT.
- Contingency and escalation related to owner costs.
- Third party costs – surveys, independent analysis, etc.
- Piling, soil remediation / soil improvements.
- All scope out of Battery Limit.
- Power lines and grid hook-up.
- Fluids / Consumables / Utilities cost and Feed cost (cost of water and electricity during construction, pre-commissioning, commissioning and start-up, as well as oil feed and other fluids).
- Office furniture for buildings
- Tooling and warehouse spares.
- Client's security requirements
- Client Operators training and training materials.

8.1.8 Summary of Costs ($1,000's of dollars)

	1xSG-16	2xSG-16	KCS-34g
Engineering Services	$5,958	$8,122	$8,322
Procurement Costs	$19,939	$38,638	$28,781
Construction Costs	$11,443	$18,827	$14,873
Construction Supervision	$638	$1,159	$1,718
Miscellaneous Costs	$257	$469	$1,132
Overall Contingency	$2,165	$3,900	$2,474
Total Project Costs	$40,400	$71,115	$57,300

8.2 ANNUAL GENERATION

The electric generation is based on the following criteria:

	Kalex SG-16	Kalina KCS-34g
Initial Resource Temperature, °F	195	198
Geofluid flow, gpm	6,000	6,000
Geothermal Reservoir Life, years	15	15
Annual Geothermal Resource Degradation	.5%	.5%
Average Net Electric Output, kWe	7,833	8,055
Average Annual Capacity Factor	.90	.90
Source Annual Degradation	0.5%	0.5%
Step Up Transformer & Transmission Losses	2%	2%
Average Hours / Year, hours	8,766	8,766

Therefore, the first year annual net generation is:

Annual Net Generation, MWh = Net Electric Output * Capacity Factor * (1-Transmission Losses) * Hours / Year

	Kalex SG-16	Kalina KCS-34g
Annual Net Generation, MWh / year	60,563	62,278

8.3 FINANCE STRUCTURE

The finance structure for this project is evaluated

Debt Service Coverage Ratio	1.8
Term, years	15
Interest Rate	6.0%
Debt / Total Capital	80%
Equity Levered Pretax IRR	8%
Tax Benefits	Not Considered
Green Credits	Not Considered

Therefore, the annual costs associated with the capital for the project are equal to the amortization of principal and paying the interest on a loan over the term of the project at the weighted average cost of capital: The weighted average cost of capital in this case is:

Weighted Average Cost of Capital = Debt / Total Capital Ratio * Debt Cost + (1- Debt / Total Capital Ratio) * Cost of Equity

Weighted Average Cost of Capital = 80% * 6.0% + (1 – 80%) * 8%

Weighted Average Cost of Capital = 6.40%

Therefore, the annual cost of $1,000 capital over a 15 year term is $105.67. Associated with the Total Project Cost, the annual cost of capital becomes:

	Kalex SG-16	Kalina KCS-34g
Annual Cost of Capital, $1,000's / year	$7,519	$6,054

8.4 FIXED O&M

8.4.1 Operating Philosophy

The plant is staffed over an eight week cycle. Four control room operators rotate thru a 4x12 hour shift schedule which lasts eight days. The fifth field operator and the manager come in five days a week (Monday thru Friday) for eight hours during the cycle starting at the sixth hour of the control room operator's shift. The fifth field operator and manager are assist the control room operators as needed. Whereas, the majority of minor maintenance activities are placed on the field operator which allow the Plant Manager to concentrate on managing the operations. The field operator is rotated into a control room operator role and a control room operator is rotated into the field operator role at the end of the eight week cycle. This staffing arrangement offers a low cost, maximum partnered approach.

An on-call out to the facility Mechanical Contractor is contacted If a mechanical problem is realized. Both the Mechanical Contractor and the plant operators participate in the annual maintenance outages. This places both maintenance and operating responsibilities on the operating staff is an effort to minimize conflicts between the roles.

8.4.2 Operating Staff

The annual staff costs for the plant are calculated as follows:

	Control Room Operator	Field Operator	Plant Manager
Exempt	N	N	Y
Count	4	1	1
Salary, $/month			$6,250
Hourly Wage, $/hour	$25	$25	
Straight Hours / Week	40	40	40
Overtime Hours / Week	4		
Weeks / Year	50	50	52
FICA, %	7.65%	7.65%	7.65%
FUTA, %	6.00%	6.00%	6.00%
SUI, %	2.90%	2.90%	2.90%
Worker's Comp, %	5%	5%	
Health Insurance, %			5%
Safety Equipment & Training, $/year	$300	$300	$800
Bonus, $ of Wages	5%	5%	15%
Contingency	5%	5%	
Annual Staff Costs, $/year	$309,752	$67,387	$88,345
Total Annual Staff Costs, $/year	$465,484		

8.4.3 Administration

The project consulting, legal, and accounting costs are estimated at $150,000 per year.

8.4.4 Insurance

The annual plant insurance is based on the following schedule of costs.

Property Insurance including Bus. Interruption	$450,000
Commercial General Liability ($1MM)	$35,000
Umbrella Liability ($35 MM)	$45,000
Directors & Officers Liability ($2MM to $5MM)	$50,000
Environmental Liability ($2,000,000 to $5,000,000	$70,000
Total	$650,000

8.4.5 Property Tax

The property tax basis for the project is assumed to be $30,000,000 or approximately half of the plant and equipment costs for the project. The property tax rate is assumed to be 1% of the basis. Therefore, the annual Property Taxes are expected to be:

Annual Property Tax = Property Tax Basis * Property Tax Rate

Where the Property Tax Basis is 50% of the Total Project Costs

	Kalex SG-16	Kalina KCS-34g
Annual Property Tax, $1,000's / year	$358	$287

8.5 VARIABLE O&M

8.5.1 Consumables, Maintenance Parts & Labor

	$ /	unit	units per year	$ per year
Contracted services	budget			$60,000
Consumables	budget			$40,000
Chemicals	budget			$40,000
Cooling water cost for reject heat	$10.58	hr	7,889	$83,479
Replacement parts	budget			$125,000
Total Annual Costs				$348,479

8.5.2 Wheeling

Wheeling has been estimated based on $3.75/MWh of transmitted power across the grid. However, wheeling costs associated with this project are assumed to be $0/MWh until a final Power Purchase Agreement can be obtained. Basically assuming that the electricity will be sold to the grid directly. All interconnect costs are included in the capital cost estimate.

8.6 COST OF GENERATION

The Cost of Generation is typically based on the following components:

	Kalex SG-16		**Kalina KCS-34g**	
	$1,000's/yr	$/MWh	$1,000's/yr	$/MWh
Cost of Capital	$7,519	$124.15	$6,055	$97.22
Fixed O&M	$1,624	$26.81	$1,553	$24.93
Variable O&M	$349	$5.76	$349	$5.60
Total Cost of Generation	$9,491	$156.72	$7,957	$127.76
Wheeling		3.75		

8.7 ELECTRIC REVENUES

The target market price for the project is $105/MWh based on discussions with potential large local off-takers. The utility pricing in the area ranged from a 2015 year price of $57/MWh to $63/MWh for renewable energy. However, these prices jumped in years 5-7 to nearly $120/MWh. A current electric sales price of $105/Mwh was used for the purposes of the Pilot Project Economic Feasibility. If a two year construction period is assumed, with an annual 2% escalation. The first year electric sales prices is assumed to be $109.24/MWh.

Neither Production Tax Credits, Investment Tax Credits, nor Renewable Energy Credits were considered. These should be considered in future analyses. Production Tax Credit and Renewable Energy Credits could offer as much as $40/MWh for the first 10 years to the project. Whereas, the Investment Tax Credits could reduce the amount of Debt required by almost 30% of the total project cost.

Therefore, first year annual revues are expected to be:

$$1^{st}\text{ Year Annual Revenue} = \text{Net Generation MWh / year} * \$105/\text{MWh} * (1 + 2\%)^2$$

Neither process meets the cost of generation target.

8.8 ECONOMIC FEASIBILITY

The Project Owner was unable to obtain a Power Purchase Agreement which the banks would view as financeable. In other words, the Project Owner was unable to obtain a Power Purchase Agreement near the$140/MWh sales price. Sales prices of near $70/MWh are obtainable. However, green value instruments (Renewable Energy Credits, Production Tax Credits, etc.) are not great enough to bridge the $70/MWh gap.

Therefore, the Project appears to be in-feasible at this time.

9 ENVIRONMENTAL PERMITTING OF PILOT PLANT CONSTRUCTION

Permitting has been completed for the currently planned exploration drilling activities discussed in Subtask 1.1. Should the technical and financial conclusions support development of a Pilot Project, environmental permitting and interconnection studies required for the construction of the demonstration facility, as well as development of the well field gathering system, will also be completed.

The US Fish and Wildlife Service has determined that an Environmental Assessment under the National Environmental Policy Act is sufficient for review – this study will be completed in fall 2012. This approach should ensure that all permitting requirements have been completed prior to the completion of Phase 2 activities.

Preliminary discussions with an area Transmission Service Provider indicate that it is likely that adequate capacity exists in the area to support development of the Pilot Project. These studies are estimated to be complete well in advance of commercial operations of the Pilot Project.

9.1 STATE GEOTHERMAL RESOURCES PROSPECTING PERMIT

Approval to deepen Well 9-A as contained in report prepared for Entive Organic LLC by Technip Mannvit, submitted on June 1, 2012, was obtained on June 11, 2012. The proposed work as detailed is approved subject terms and conditions outlined by California State Lands Commission, Mineral Resources Management.

9.2 RESOURCES AGENCY OF CALIFORNIA – NOTICE OF RECORDS DUE

Resources Agency of California is requesting records covering the operations at the Lower Klamath National Wildlife Refuge on January 30, 2013. These records were not submitted by Entiv Organic Energy, LLC, within the time period requested.

9.3 LOWER KLAMATH PRODUCTION WELLS CULTURAL SURVEY

US Fish and Wildlife Service issued a report instructing any work related to the Lower Klamath Production Wells, Siskiyou County, California, how to protect Archaeological and Historical Resources within the area.

9.4 US DEPARTMENT OF INTERIOR FISH & WILDLIFE SERVICE – SPECIAL USE PERMIT

The US Department of Interior Fish and Wildlife issued instructions on February 12, 2012, for a Special Use Permit regarding the Entiv Organic Energy LLC Project.

9.5 FERC QUALIFIED FACILITY APPLICATION

Has not been filed at this time.

9.6 OTHER PERMITS

Investigations as to other permits required for this project have not been completed at this time.

10 GO/NO GO/REDIRECT DECISION

A Go/No Go/Redirect decision will be made based upon a thorough analysis of all the results from Phase I Tasks and Objectives activities. Key decision criteria to proceed to Phase 2 will include geofluid temperatures and flows, long term sustainability of the geo-resource, expected Kalex pilot plant performance, and attractive rates of return to the local Independent Power Producer (IPP), for which the following minimum criteria will apply:

- Initial resource temperature = 185 deg. F
- Geofluid flow = 3,000 gpm
- Expected geothermal reservoir life = 15 years
- Kalex gross power output = 3 MW
- Levered pre-tax IRR = 8%

As defined and described herein, the Entiv Organic Project will cover all required steps in determining the feasibility of the proposed project during the Phase I activities.

The Recipient shall not continue into Phase II activities without written authorization from DOE. Should Phase II not be initiated, the Phase I Report and all review presentation materials shall serve as the final technical report for DOE purposes.

10.1 FEASIBILITY STUDY TASK RESULTS

10.1.1 Subtask 1 – Geologic Model of Target Geothermal Resource

Task Completed.

10.1.2 Subtask 2 – Geothermal Production Estimate

Task Completed.

10.1.3 Subtask 3– Modeling of Kalex Cycle

Task Completed.

10.1.4 Subtask 4– Pilot Project Engineering Design

Task Completed.

10.1.5 Subtask 5– Pilot Project Economic Feasibility

No Go – No long term revenue contracts could be obtained at the projected cost of generation.

10.1.6 Subtask6– Environmental Permitting of Pilot Plant Construction

No Go – Owner funding ceased due to project in-feasibility, therefore, the Permitting process was not completed.

10.2 SUMMARY AND CONCLUSIONS

The owner funding ceased on this project due to project in-feasibility. Therefore, the project development has stopped and the project appears to be inactive.

APPENDIX A – CONTRIBUTORS

DR. ANDRI ARNALDSSON, RESERVOIR ENGINEERING, VATNASKIL

Dr. Arnaldsson is a geothermal reservoir specialist with Vatnaskil Consulting Engineers. He received a Ph. D. in theoretical chemistry from the University of Washington, Seattle, in 2007. At Vatnaskil, Dr. Arnaldsson' chief responsibilities include geothermal reservoir modeling, scientific computing and numerical analysis as well as extensive programming development and support. He serves as the system administrator for Vatnaskil. Dr. Arnaldsson has contributed significantly to the creation and/or further development of models for some of Iceland's high temperature fields, including Svartsengi/Reykjanes (Reykjanes peninsula), Þeistareykir (NE-Iceland) and Hengill (SW-Iceland). He also has experience with high temperature fields, either through direct projects or as an instructor with the United Nations Geothermal Training Program (UNU-GTP), in Kenya (Olkaria), Costa Rica (Miravalles), Indonesia (Tompaso) along with numerous low temperature fields in Hungary, U.S. and China.

DR. STEINAR THOR GUDLAUGSSON, MANNVIT

Dr. Steinar Thor Gudlaugsson is a Geophysicist and Section Manager of Geothermal Exploration. He has extensive experience within the field of geosciences and energy resources which spans 29 years and includes academic research and teaching, project management and consulting. His main field of expertise is exploration geophysics mainly in the context of petroleum resources. Dr. Gudlaugsson has over 7 years experience within the geothermal field and has been involved in geothermal projects in Iceland, the Philippines, Germany, Hungary and the United States. His geothermal experience includes well logging, prospect analysis, well siting, project evaluation, planning of field development, and assessment of resource and drilling risk. Before joining Mannvit in 2010, Dr. Gudlaugsson held positions at Geysir Green Energy, Iceland GeoSurvey, Iceland´s National Energy Authority, and the University of Oslo.

DR. GÍSLI GUÐMUNDSSON, MANNVIT

Dr Gísli Guðmundsson has been an employee of the consultant since 2004 as a geochemist with a wide experience in geothermal. Gísli completed a B.Sc. degree in geology at the University of Iceland in 1983, continuing postgraduate studies in the USA at the Arizona State University, Tempe, Arizona where he completed his M.Sc. degree in 1989 and his PhD in 1992. His field of expertise spans the fields of geology, chemistry, concrete, inspection work on construction sites, and miscellaneous geothermal work. Prior to joining Mannvit Gísli was for instance, an Associate Research Assistant at the Geology Department of Bristol University, UK, and Research Specialist at Sawyer Research Product Inc., Ohio, USA.

ÞRÖSTUR HRAFNKELSSON, M.SC., VATNASKIL

Þröstur Hrafnkelsson received his B.Sc. degree in Civil and Environmental Engineering from the University of Iceland, and M.Sc. in Civil Engineering from the University of Washington, Seattle. Mr. Hrafnkelsson has 10 years of experience as a civil engineer, particularly within the areas of geotechnical engineering, hydroelectric development, geothermal reservoirs, transportation engineering and groundwater hydrology. Responsibilities in numerous small and large-scale projects include surveying, designing, reviewing, numerical simulations and field engineering. Mr. Hrafnkelsson's involvement in geothermal engineering and groundwater hydrology include surveillance of groundwater production on the Reykjanes peninsula, Iceland, numerical modelling of groundwater and geothermal reservoirs in the greater Reykjavik area, Iceland, and geothermal reservoir modelling in Kosice, Slovakia.

KRISTINN INGASON M.SC., MANNVIT

Kristinn Ingason is a Mechanical Engineer and Section Manager of Geothermal Energy at Mannvit Engineering. Mr. Ingason has over 25 years experience in geothermal utilization and in his work he has been involved in all stages of geothermal projects including feasibility studies, design, construction and commissioning. His field of expertise covers most parts of geothermal power plants such as well design, drilling, steam supply system and power plants. He has been involved in design and construction of both flash plants as well as binary plants. Mr. Ingason has undertaken the responsibility of project management in several geothermal projects, ranging from feasibility studies to construction. Also, he has been site manager and resident engineer in several geothermal projects.

DR. MICHAEL N. MUGERWA, TECHNIP

Dr. Mugerwa is the Program Director for Renewables Projects at Technip. Dr. Mugerwa is a Chemical Engineer with 24 years of professional experience managing and developing renewables, refinery, gas processing, power, chemicals and mineral processing projects in worldwide markets. He is now responsible for the development of EPC projects in the field of renewable energy, developing strategies for Technip's geothermal and biofuels product lines. Dr. Mugerwa was key in developing the strategic partnership between Technip and Mannvit for the geothermal market. He obtained his doctorate degree in Chemical Engineering from the University of Manchester where he also completed his Bachelor's and Master's degrees. He started working in 1986 with KTI, a Technip subsidiary, then later with Technip USA, holding positions as R&D Manager, Business Development Manager, General Manager, Project Manager and Program Director.

DR. SVEINN ÓLI PÁLMARSSON, ENVIRONMENTAL AND WATER RESOURCES ENGINEER, VATNASKIL Dr. Pálmarsson received his M.S. and Ph.D. from the University of California, Davis, in Civil and Environmental Engineering. He is highly qualified in the fields of Geothermal Reservoir Engineering, Environmental Hydrodynamics, Fluid Mechanics, Hydrology, and Numerical Analysis. He has extensive experience in international academic and post-academic research, including developing and managing large-scale projects; has a broad engineering professional experience, including specialty services and project management for the power industry with significant contributions in hydropower applications and in both low- and high-temperature geothermal reservoir modeling projects; is the author of numerous peer-reviewed journal articles and other professional papers. He has projects experience from Iceland, Slovakia, Indonesia, England, Hungary, Germany and the United States.

LAWRENCE B. RHODES – RECURRENT ENGINEERING

Lawrence Rhodes is a Senior Systems Analyst for Recurrent Engineering. He has a B.S. from the California Institute of Technology and an M.S. from Cornell University. Mr. Rhodes has worked on commercializing the Kalina Cycle since 1990, with its originator, Alexander Kalina, and his principal development associate, Richard Pelletier. With the latter, he is responsible for the thermophysical properties implementations and system design programs necessary for Kalina Cycle calculations. Mr. Rhodes has co-authored several of the patents covering aspects of the Kalina Cycle.

CHERYL SANDIFER, TECHNIP

Ms. Sandifer is a Senior Supervising Process Engineer at Technip Stone & Webster Process Technology in Claremont, California. She received her BS in Chemical Engineering from Cal Poly Pomona and holds a California Professional Engineering License. Ms. Sandifer has more than 25 years of Process Engineering and Project Management experience. Most recently, she has been involved in the renewables sector working with technologies in the Waste to Energy and Geothermal fields.

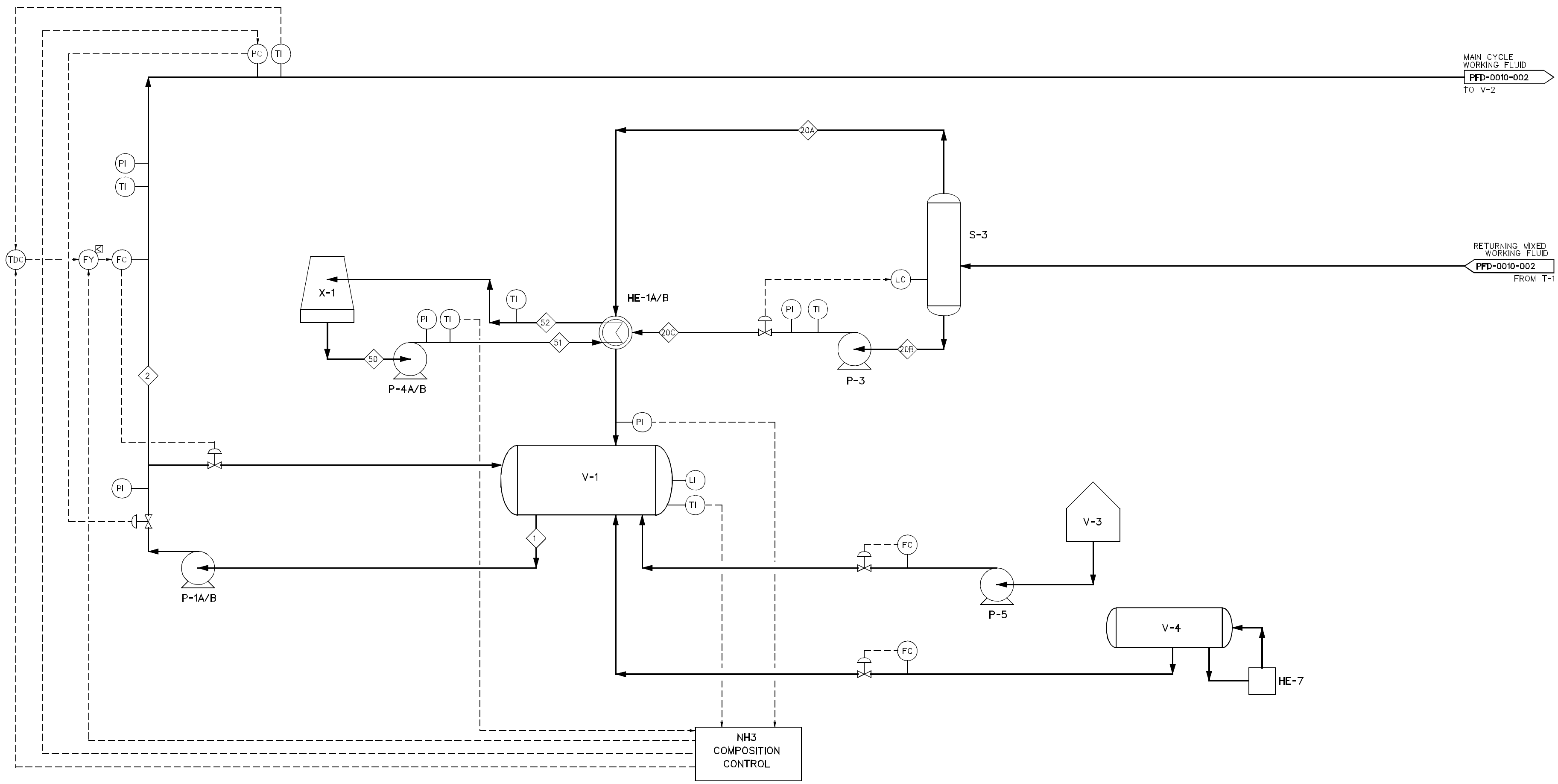
THORSTEINN SIGMARSSON, MECHANICAL ENGINEER, MANNVIT

Mr. Thorsteinn Sigmarsson is a Mechanical Engineer with Mannvit, who possesses experience in steamfield engineering including design, cost estimates, procurement and construction supervision. Þorsteinn has undertaken the responsibility of preliminary design and cost estimate of projects in geothermal development both within and outside Iceland. Mr. Þorsteinn Sigmarsson received a B.Sc. in Mechanical Engineering from University of Aarhus, Denmark in 1993. Þorsteinn joined VGK later Mannvit in year 1997 after working as an Engineer with Héðinn hf. Þorsteinn has participated in design of flash plants in Nesjavellir, Bjarnaflag and Hellisheiði, design of an ORC Plant in Berlin, El Salvador, design of a Kalina plant in Germany and design of a Heat Plant in Hungary. Þorsteinn has participated in a feasibility study for a 5 MW geothermal pilot plant in Greece and project planning studies for Þeistareykir, Bjarnarflag and Krafla extension. Þorsteinn has experience in geothermal site supervision and commissioning from Nesjavellir, Hellisheiði and Hungary.

APPENDIX B – ENGINEERING DOCUMENTS

B1	Kalex SG-16 Process Flow Diagrams
B2	Kalina KCS-34g Process Flow Diagram and Heat and Mass Balances
B3	Kalina KCS-34g Sized Equipment Lists
B4	Kalina KCS-34g Electric Load Lists (includes auxillary loads; e.g. lighting, HVAC, etc.)
B5	Kalex SG-16 Plot Plans
B6	Kalina KCS-34g Plot Plans
B7	GeoSource Pipeline Routing
B8	Kalex SG-16 Iso Elevation Renderings
B9	Kalina KCS-34g Sized Piping Lines
B10	Cost Estimate – Lower Klamath Lake, CA. 1xSG-16 train.
B11	Cost Estimate – Klamath Hills. OR. Kalex 2xSG-16 trains.
B12	Cost Estimate – Klamath Hills, OR Kalina KCS-34g

APPENDIX B1
KALEX SG-16 PROCESS FLOW DIAGRAMS



GENERAL NOTES

LEGEND

- ○ TEMPERATURE, °F
- □ PRESSURE, PSIA
- ◇ STREAM NO.

REV	DATE	DESCRIPTION	PROCESS	FLOWSHEET	FE/E	STARTUP	DM/FM
A		FOR INFORMATION					

Technip

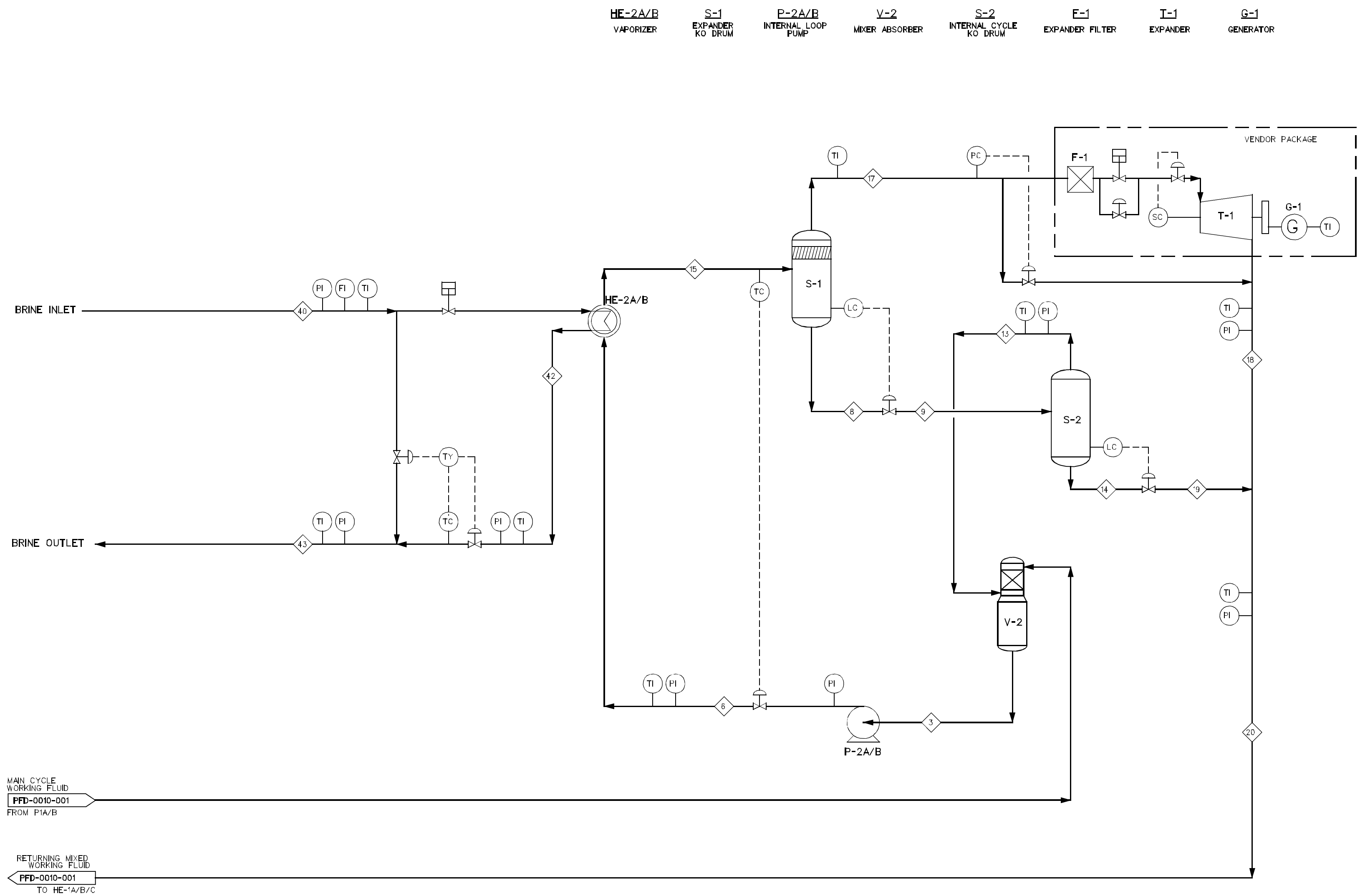
ENTIV ORGANIC ENERGY

PROCESS FLOW DIAGRAM

KALEX SG-16 5.5 MW GROSS GEOTHERMAL PLANT

DRAWING NO.						PAGE	REV
LA032193	000	PFD	00	10	001	1	A
PROJECT	UNIT	DOC TYPE	DISC	SUBJ	SER.NO		

TD-20-163-1



GENERAL NOTES

LEGEND

- ○ TEMPERATURE, °F
- □ PRESSURE, PSIA
- ◇ STREAM NO.

REV	DATE	DESCRIPTION	PROCESS	FLOWSHEET	FE/E	STARTUP	DM/FM
A		FOR INFORMATION					

Technip

ENTIV ORGANIC ENERGY

PROCESS FLOW DIAGRAM

KALEX SG-16 5.5 MW GROSS GEOTHERMAL PLANT

DRAWING NO.	PAGE	REV
LA032193 000 PFD 00 10 002	2	A
PROJECT UNIT DOC TYPE DISC SUBJ SER.NO		

APPENDIX B2

KALINA KCS-34G PROCESS FLOW DIAGRAM AND HEAT AND MASS BALANCES

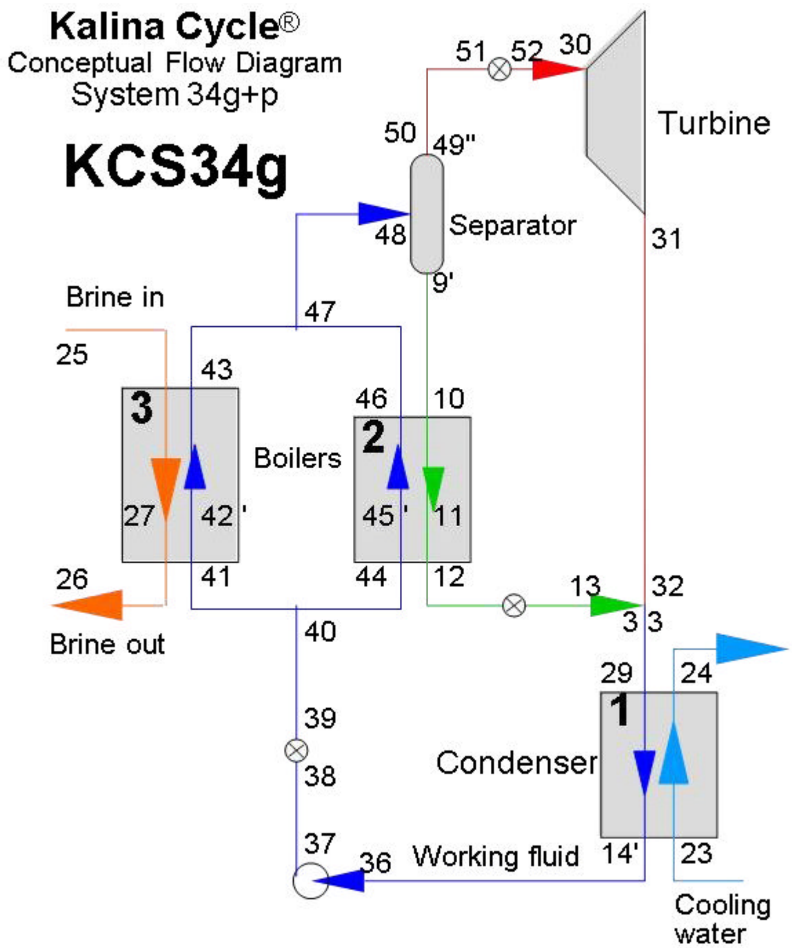
ENTIV TECHNIP Design Balance Rev 4-2

3 December 2013

Notes

With respect to Design Balance Rev 03

1. ATE remains at 88%.
2. Inlet turbine pressure increased to 290 psiA.
3. Composition increased to 0.88.
4. Piping pressure drops added.
5. Coolant flow is set to 41,344 gpm to preserve a 12°F condenser pinch.



Kalina Cycle Control Data

T25	198	∆T11	5.4
T26	128	∆T10	5.4
T23	53	∆T3	5.4
P30	290	TME	.96
T mass	47177.291	ATE	.88
∆T1	9	Cp brine	1
∆Ta	15	Brine flow	5793204
∆Tw	12	P eff	.8

Heat Exchanger Pressure Drops

∆P 23–24	30	∆P 10–11	2.9
∆P 29–14	1.45	∆P 39– 41	2.5
∆P 41–42	8.7	∆P 11–12	8.7
∆P 42–43	11.6	∆P 49– 30	6

Piping & Valve Pressure Drops

∆P 31– 32	1	∆P 45–46	11.6
∆P 43– 48	5	∆P 46– 48	1.5
∆P 33– 29	.1	∆P 47–48	.5
∆P 38v39	2.5	∆P 50– 51	3
∆P 9– 10	.5	∆P 51– 52	3
∆P 40– 41	1	∆P 25–27	5
∆P 44–45	8.7	∆P 25–26	5

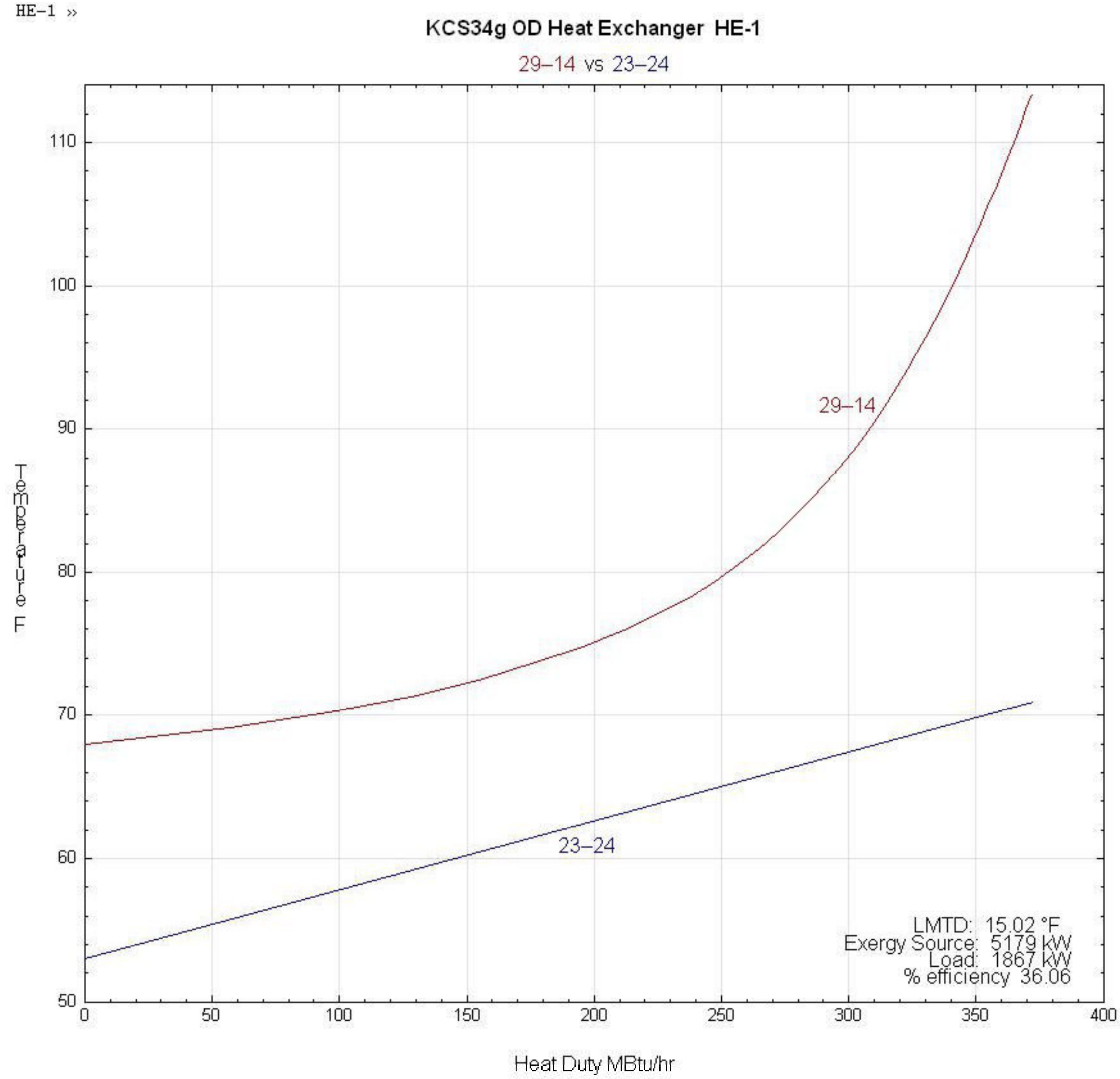
Turbine mass flow	83.72	kg/s	664,453	lb/hr
Pt 30 Volume flow	6,498.87	L/s	826,220	ft^3/hr
Pt 31 Volume flow	15,294.45	L/s	1,944,426	ft^3/hr
		kW		BTU/lb
Heat in	118,847.44		464.20	
Heat rejected	108,998.69		425.73	
Turbine enthalpy drop	10,159.94		39.68	
Turbine Work	9,753.54		38.10	
Feed pump ∆H 1.22, power	330.65		1.29	
Feed + Coolant pump power	1,050.03		4.10	
Net Work	8,703.52		33.99	
		kWe		
Gross Output	9,753.54			
Cycle Output	9,422.90			
Net Output	8,703.52			
Net thermal efficiency	7.32	%		
Second law limit	16.17	%		
Second law efficiency	45.30	%		
Specific Brine Consumption	665.62	lb/kW-hr		
Specific Power Output	1.50	Watt-hr/lb		

KALINA CYCLE® SYSTEM 34g OD POINTS

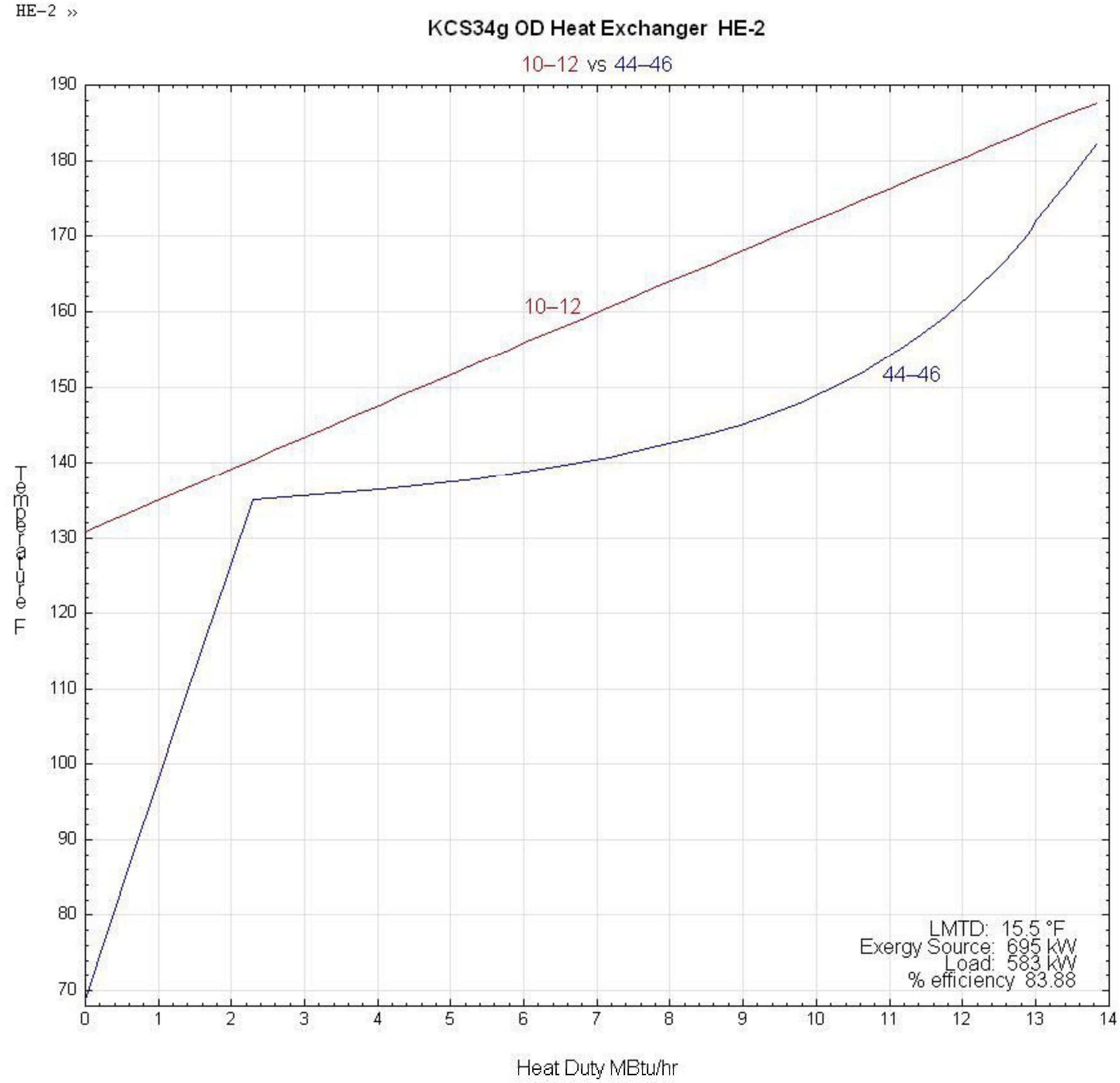
2013 Nov 08 14:31:54

#	P psiA	X	T °F	H Btu/lb	G/(G=1)	Flow lb/hr	Phase
23	•	Water	53	21.00	23.6830	20,689,403	
24	•	Water	70.98	38.98	23.6830	20,689,403	
36	109.58	.88	68	0.41	1	873,598	SatLiquid
37	326.30	.88	68.72	1.62	1	873,598	Liq 70°
38	326.30	.88	68.72	1.62	1	873,598	Liq 70°
39	323.80	.88	68.73	1.62	1	873,598	Liq 70°
40	322.30	.88	68.73	1.62	1	873,598	Liq 69°
41	321.30	.88	68.73	1.62	0.9660	843,886	Liq 69°
42	312.60	.88	135.82	79.65	0.9660	843,886	SatLiquid
43	301	.88	189	482.17	0.9660	843,886	Wet .2395
44	317.80	.88	68.74	1.62	0.0340	29,712	Liq 68°
45	309.10	.88	134.99	78.65	0.0340	29,712	SatLiquid
46	297.50	.88	182.31	467.47	0.0340	29,712	Wet .2563
47	296.50	.88	67.34	0.00	1	873,598	Liq 65°
48	296	.88	187.82	481.67	1	873,598	Wet .2394
49	296	.9874	187.82	611.59	0.7606	664,453	SatVapor
50	296	.9874	187.82	611.59	0.7606	664,453	SatVapor
51	293	.9874	187.31	611.59	0.7606	664,453	Wet 0
52	290	.9874	186.79	611.59	0.7606	664,453	Wet 0
30	290	.9874	186.79	611.59	0.7606	664,453	Wet 0
31	112.13	.9874	102.64	559.42	0.7606	664,453	Wet .0288
32	111.13	.9874	102.29	559.42	0.7606	664,453	Wet .0287
9	296	.5389	187.82	68.90	0.2394	209,145	SatLiquid
10	295.50	.5389	187.71	68.90	0.2394	209,145	Wet .9997
11	292.60	.5389	140.39	13.66	0.2394	209,145	Liq 46°
12	283.90	.5389	130.86	2.72	0.2394	209,145	Liq 54°
13	111.13	.5389	119.46	2.72	0.2394	209,145	Wet .9766
33	111.13	.88	113.48	426.14	1	873,598	Wet .2633
29	111.03	.88	113.43	426.14	1	873,598	Wet .2633
14	109.58	.88	68	0.41	1	873,598	SatLiquid
25	•	Brine	198	166.00	6.6314	5,793,204	
27	•	Brine	139.37	107.37	6.6314	5,793,204	
26	•	Brine	128	96.00	6.6314	5,793,204	

S34g OD HXs:	MW th	LMTD	ΔTs between streams					
HE–1	108.999	15.02	T29–T24	42.46	T14–T23	15		
HE–2	4.056	15.50	T10–T46	5.4	T11–T45	5.4	T12–T44	62.12
HE–3	118.847	15.81	T25–T43	9	T27–T42	3.54	T26–T41	59.27

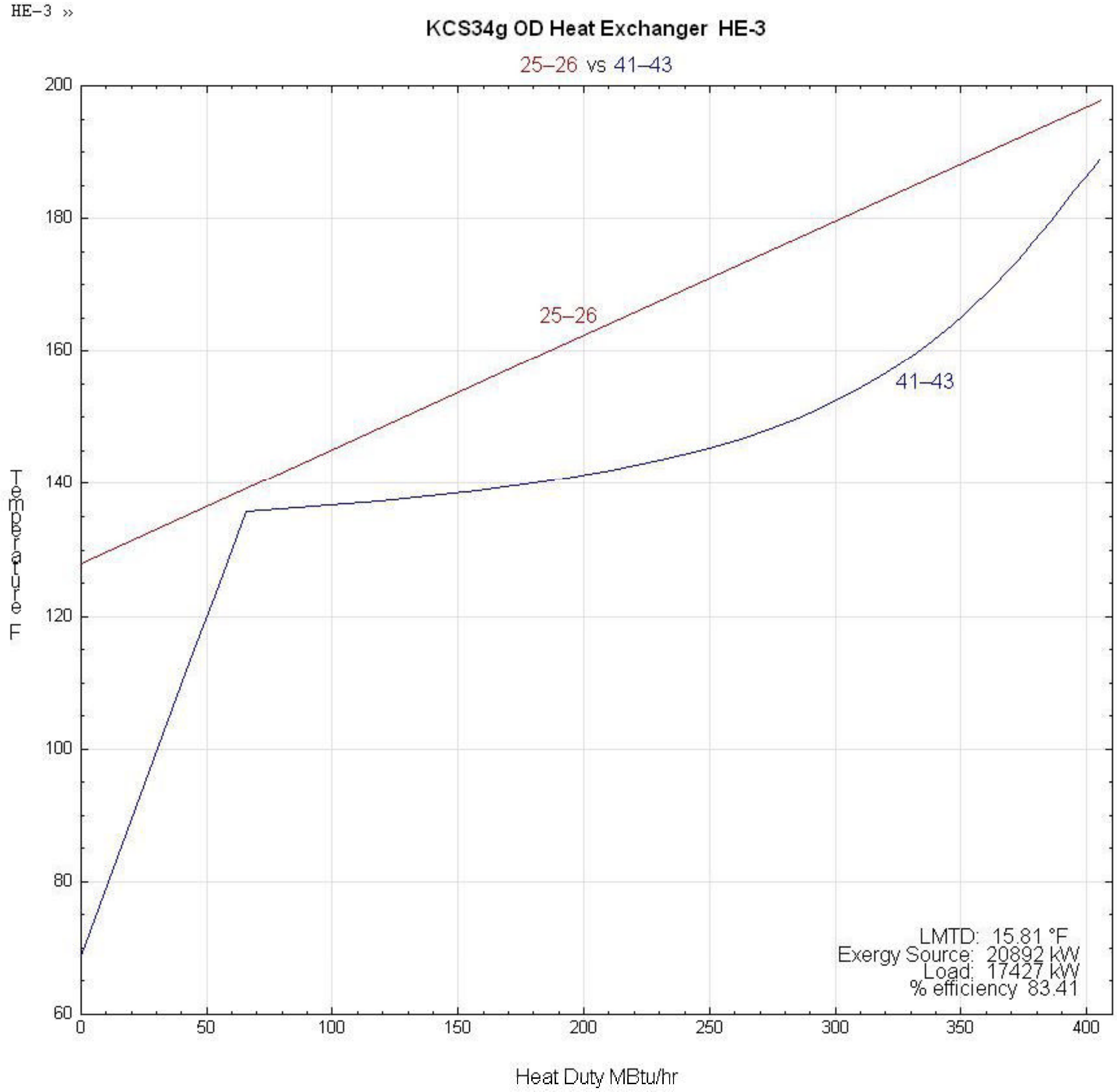

KCS34g OD Heat Exchanger HE-1
29–14 vs 23–24
110
100
90
80
70
60
50
Temperature F
0
50
100
150
200
250
300
350
400
Heat Duty MBtu/hr
29–14
23–24
LMTD: 15.02 °F
Exergy Source: 5179 kW
Load: 1867 kW
% efficiency 36.06

HE-2 »



KCS34g OD Heat Exchanger HE-2
10–12 vs 44–46
10–12
44–46
Temperature F
Heat Duty MBtu/hr
LMTD: 15.5 °F
Exergy Source: 695 kW
Load: 583 kW
% efficiency 83.88

HE-3 »


KCS34g OD Heat Exchanger HE-3
25–26 vs 41–43
25–26
41–43
Temperature F
Heat Duty MBtu/hr
LMTD: 15.81 °F
Exergy Source: 20892 kW
Load: 17427 kW
% efficiency 83.41
0
50
100
150
200
250
300
350
400
60
80
100
120
140
160
180
200

Kalina Cycle Control Data

T25	198	∆T11	5.4
T26	128	∆T10	5.4
T23	53	∆T3	5.4
P30	290	TME	.96
T mass	47177.291	ATE	.88
∆T1	9	Cp brine	1
∆Ta	15	Brine flow	5793204
∆Tw	12	P eff	.8

Heat Exchanger Pressure Drops

∆P 23–24	30	∆P 10–11	2.9
∆P 29–14	1.45	∆P 39– 41	2.5
∆P 41–42	8.7	∆P 11–12	8.7
∆P 42–43	11.6	∆P 49– 30	6

Piping & Valve Pressure Drops

∆P 31– 32	1	∆P 45–46	11.6
∆P 43– 48	5	∆P 46– 48	1.5
∆P 33– 29	.1	∆P 47–48	.5
∆P 38v39	2.5	∆P 50– 51	3
∆P 9– 10	.5	∆P 51– 52	3
∆P 40– 41	1	∆P 25–27	5
∆P 44–45	8.7	∆P 25–26	5

Turbine mass flow	83.72	kg/s	664,453	lb/hr
Pt 30 Volume flow	6,498.87	L/s	826,220	ft^3/hr
Pt 31 Volume flow	15,294.45	L/s	1,944,426	ft^3/hr
		kW		kJ/kg
Heat in	118,847.44		1079.73	
Heat rejected	108,998.69		990.25	
Turbine enthalpy drop	10,159.94		92.30	
Turbine Work	9,753.54		88.61	
Feed pump ∆H 2.83, power	330.65		3.00	
Feed + Coolant pump power	1,050.03		9.54	
Net Work	8,703.52		79.07	
		kWe		
Gross Output	9,753.54			
Cycle Output	9,422.90			
Net Output	8,703.52			
Net thermal efficiency	7.32	%		
Second law limit	16.17	%		
Second law efficiency	45.30	%		
Specific Brine Consumption	665.62	lb/kW-hr		
Specific Power Output	1.50	Watt-hr/lb		

KALINA CYCLE® SYSTEM 34g OD POINTS

2013 Nov 08 14:31:54

#	P bar	X	T °C	H kJ/kg	G/(G=1)	Flow kg/s	Phase
23	•	Water	11.67	48.85	23.6830	2606.821	
24	•	Water	21.65	90.66	23.6830	2606.821	
36	7.555	.88	20	0.95	1	110.071	SatLiquid
37	22.498	.88	20.40	3.78	1	110.071	Liq 39°
38	22.498	.88	20.40	3.78	1	110.071	Liq 39°
39	22.325	.88	20.40	3.78	1	110.071	Liq 39°
40	22.222	.88	20.40	3.78	1	110.071	Liq 39°
41	22.153	.88	20.41	3.78	0.9660	106.328	Liq 38°
42	21.553	.88	57.68	185.27	0.9660	106.328	SatLiquid
43	20.753	.88	87.22	1121.52	0.9660	106.328	Wet .2395
44	21.912	.88	20.41	3.78	0.0340	3.744	Liq 38°
45	21.312	.88	57.22	182.94	0.0340	3.744	SatLiquid
46	20.512	.88	83.51	1087.32	0.0340	3.744	Wet .2563
47	20.443	.88	19.63	0.00	1	110.071	Liq 36°
48	20.408	.88	86.57	1120.36	1	110.071	Wet .2394
49	20.408	.9874	86.57	1422.56	0.7606	83.720	SatVapor
50	20.408	.9874	86.57	1422.56	0.7606	83.720	SatVapor
51	20.202	.9874	86.28	1422.56	0.7606	83.720	Wet 0
52	19.995	.9874	86.00	1422.56	0.7606	83.720	Wet 0
30	19.995	.9874	86.00	1422.56	0.7606	83.720	Wet 0
31	7.731	.9874	39.24	1301.21	0.7606	83.720	Wet .0288
32	7.662	.9874	39.05	1301.21	0.7606	83.720	Wet .0287
9	20.408	.5389	86.57	160.26	0.2394	26.352	SatLiquid
10	20.374	.5389	86.51	160.26	0.2394	26.352	Wet .9997
11	20.174	.5389	60.22	31.77	0.2394	26.352	Liq 26°
12	19.574	.5389	54.92	6.32	0.2394	26.352	Liq 30°
13	7.662	.5389	48.59	6.32	0.2394	26.352	Wet .9766
33	7.662	.88	45.26	991.20	1	110.071	Wet .2633
29	7.655	.88	45.24	991.20	1	110.071	Wet .2633
14	7.555	.88	20	0.95	1	110.071	SatLiquid
25	•	Brine	92.22	386.12	6.6314	729.931	
27	•	Brine	59.65	249.73	6.6314	729.931	
26	•	Brine	53.33	223.30	6.6314	729.931	

S34g OD HXs:	MW th	LMTD	ΔTs between streams °C					
HE–1	108.999	8.34	T29–T24	23.59	T14–T23	8.33		
HE–2	4.056	8.61	T10–T46	3	T11–T45	3	T12–T44	34.51
HE–3	118.847	8.78	T25–T43	5	T27–T42	1.97	T26–T41	32.93

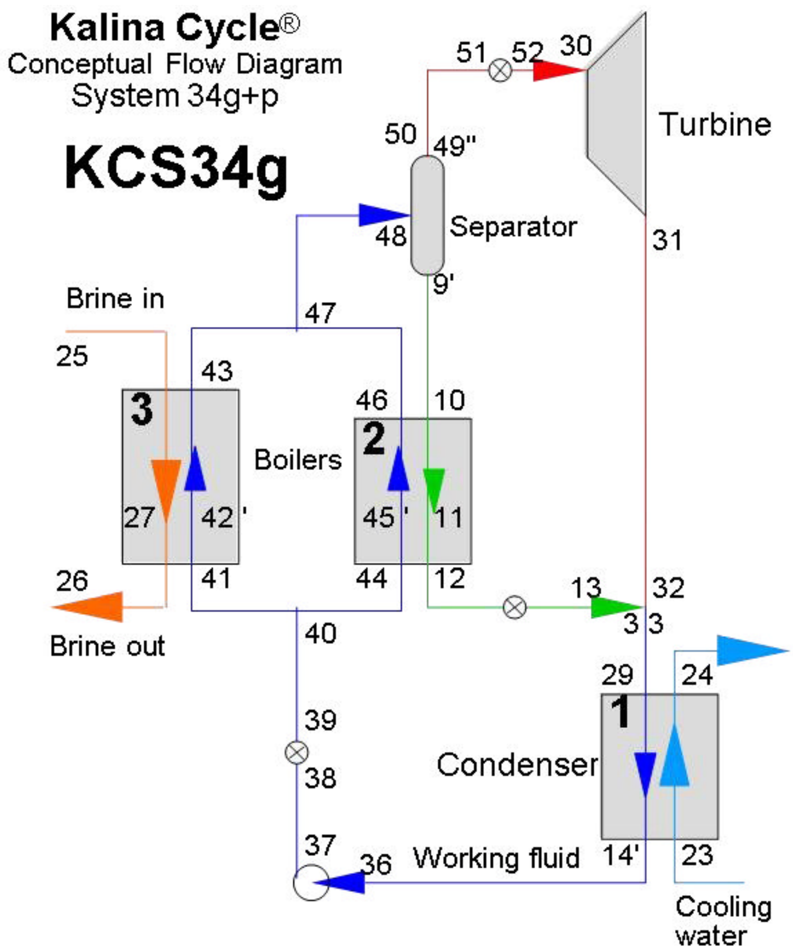
ENTIV TECHNIP Extreme Summer Balance Rev 4-2

3 December 2013

Notes

With respect to Design Balance Rev 4-2

1. Coolant temperature increased to 79°F.
2. ATE decrease to 82%.
3. Inlet turbine pressure is 305 psiA.
4. Composition remains 0.88.
5. Piping pressure drops are not pro-rated.
6. Coolant flow is fixed at 41,344 gpm.



Kalina Cycle Control Data

T25	198	∆T11	4.94
T26	134.7	∆T10	4.93
T23	79	∆T3	5.4
P30	305	TME	.96
T mass	47177.291	ATE	.82
∆T1	9	Cp brine	1
∆Ta	12.75	Brine flow	5793204
∆Tw	12	P eff	.8

Heat Exchanger Pressure Drops

∆P 23–24	30	∆P 10–11	2.9
∆P 29–14	1.45	∆P 39– 41	2.5
∆P 41–42	8.7	∆P 11–12	8.7
∆P 42–43	11.6	∆P 49– 30	6

Piping & Valve Pressure Drops

∆P 31– 32	1	∆P 45–46	11.6
∆P 43– 48	5	∆P 46– 48	1.5
∆P 33– 29	.1	∆P 47–48	.5
∆P 38v39	2.5	∆P 50– 51	3
∆P 9– 10	.5	∆P 51– 52	3
∆P 40– 41	1	∆P 25–27	5
∆P 44–45	8.7	∆P 25–26	5

Turbine mass flow	80.40	kg/s	638,132	lb/hr
Pt 30 Volume flow	5,893.83	L/s	749,299	ft^3/hr
Pt 31 Volume flow	10,307.74	L/s	1,310,451	ft^3/hr
		kW		BTU/lb
Heat in	107,472.04		431.23	
Heat rejected	101,788.97		408.43	
Turbine enthalpy drop	5,938.68		23.83	
Turbine Work	5,701.13		22.88	
Feed pump ∆H 1.03, power	271.59		1.09	
Feed + Coolant pump power	990.96		3.98	
Net Work	4,710.17		18.90	
		kWe		
Gross Output	5,701.13			
Cycle Output	5,429.54			
Net Output	4,710.17			
Net thermal efficiency	4.38	%		
Second law limit	12.56	%		
Second law efficiency	34.89	%		
Specific Brine Consumption	1,229.93	lb/kW-hr		
Specific Power Output	0.81	Watt-hr/lb		

KALINA CYCLE® SYSTEM 34g OD POINTS

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#	P psiA	X	T °F	H Btu/lb	G/(G=1)	Flow lb/hr	Phase
23	•	Water	79	47.00	24.2596	20,629,688	
24	•	Water	95.84	63.84	24.2596	20,629,688	
36	163.27	.88	91.75	27.68	1	850,372	SatLiquid
37	341.30	.88	92.40	28.70	1	850,372	Liq 50°
38	341.30	.88	92.40	28.70	1	850,372	Liq 50°
39	338.80	.88	92.41	28.70	1	850,372	Liq 49°
40	337.30	.88	92.41	28.70	1	850,372	Liq 49°
41	336.30	.88	92.41	28.70	0.9658	821,278	Liq 49°
42	327.60	.88	139.32	83.87	0.9658	821,278	SatLiquid
43	316	.88	189	475.21	0.9658	821,278	Wet .2497
44	332.80	.88	92.42	28.70	0.0342	29,094	Liq 48°
45	324.10	.88	138.52	82.90	0.0342	29,094	SatLiquid
46	312.50	.88	182.83	461.73	0.0342	29,094	Wet .2656
47	311.50	.88	67.31	0.00	1	850,372	Liq 68°
48	311	.88	187.86	474.75	1	850,372	Wet .2496
49	311	.9885	187.86	609.25	0.7504	638,132	SatVapor
50	311	.9885	187.86	609.25	0.7504	638,132	SatVapor
51	308	.9885	187.36	609.25	0.7504	638,132	Wet 0
52	305	.9885	186.86	609.25	0.7504	638,132	Wet .0001
30	305	.9885	186.86	609.25	0.7504	638,132	Wet .0001
31	165.82	.9885	133.71	577.50	0.7504	638,132	Wet .0194
32	164.82	.9885	133.45	577.50	0.7504	638,132	Wet .0194
9	311	.5539	187.86	70.36	0.2496	212,240	SatLiquid
10	310.50	.5539	187.76	70.36	0.2496	212,240	Wet .9997
11	307.60	.5539	143.46	18.43	0.2496	212,240	Liq 43°
12	298.90	.5539	137.02	11.00	0.2496	212,240	Liq 47°
13	164.82	.5539	137.26	11.00	0.2496	212,240	Liq 2°
33	164.82	.88	136.93	436.11	1	850,372	Wet .2677
29	164.72	.88	136.90	436.11	1	850,372	Wet .2677
14	163.27	.88	91.75	27.68	1	850,372	SatLiquid
25	•	Brine	198	166.00	6.8126	5,793,204	
27	•	Brine	142.52	110.52	6.8126	5,793,204	
26	•	Brine	134.70	102.70	6.8126	5,793,204	

S34g OD HXs:	MW th	LMTD	ΔTs between streams					
HE–1	101.789	7.51	T29–T24	41.06	T14–T23	12.75		
HE–2	3.692	7.68	T10–T46	4.93	T11–T45	4.94	T12–T44	44.61
HE–3	107.472	8.00	T25–T43	9	T27–T42	3.2	T26–T41	42.29

Kalina Cycle Control Data

T25	198	∆T11	4.94
T26	134.7	∆T10	4.93
T23	79	∆T3	5.4
P30	305	TME	.96
T mass	47177.291	ATE	.82
∆T1	9	Cp brine	1
∆Ta	12.75	Brine flow	5793204
∆Tw	12	P eff	.8

Heat Exchanger Pressure Drops

∆P 23–24	30	∆P 10–11	2.9
∆P 29–14	1.45	∆P 39– 41	2.5
∆P 41–42	8.7	∆P 11–12	8.7
∆P 42–43	11.6	∆P 49– 30	6

Piping & Valve Pressure Drops

∆P 31– 32	1	∆P 45–46	11.6
∆P 43– 48	5	∆P 46– 48	1.5
∆P 33– 29	.1	∆P 47–48	.5
∆P 38v39	2.5	∆P 50– 51	3
∆P 9– 10	.5	∆P 51– 52	3
∆P 40– 41	1	∆P 25–27	5
∆P 44–45	8.7	∆P 25–26	5

Turbine mass flow	80.40	kg/s	638,132	lb/hr
Pt 30 Volume flow	5,893.83	L/s	749,299	ft^3/hr
Pt 31 Volume flow	10,307.74	L/s	1,310,451	ft^3/hr
		kW		kJ/kg
Heat in	107,472.04		1003.05	
Heat rejected	101,788.97		950.01	
Turbine enthalpy drop	5,938.68		55.43	
Turbine Work	5,701.13		53.21	
Feed pump ∆H 2.39, power	271.59		2.53	
Feed + Coolant pump power	990.96		9.25	
Net Work	4,710.17		43.96	
		kWe		
Gross Output	5,701.13			
Cycle Output	5,429.54			
Net Output	4,710.17			
Net thermal efficiency	4.38	%		
Second law limit	12.56	%		
Second law efficiency	34.89	%		
Specific Brine Consumption	1,229.93	lb/kW-hr		
Specific Power Output	0.81	Watt-hr/lb		

KALINA CYCLE® SYSTEM 34g OD POINTS

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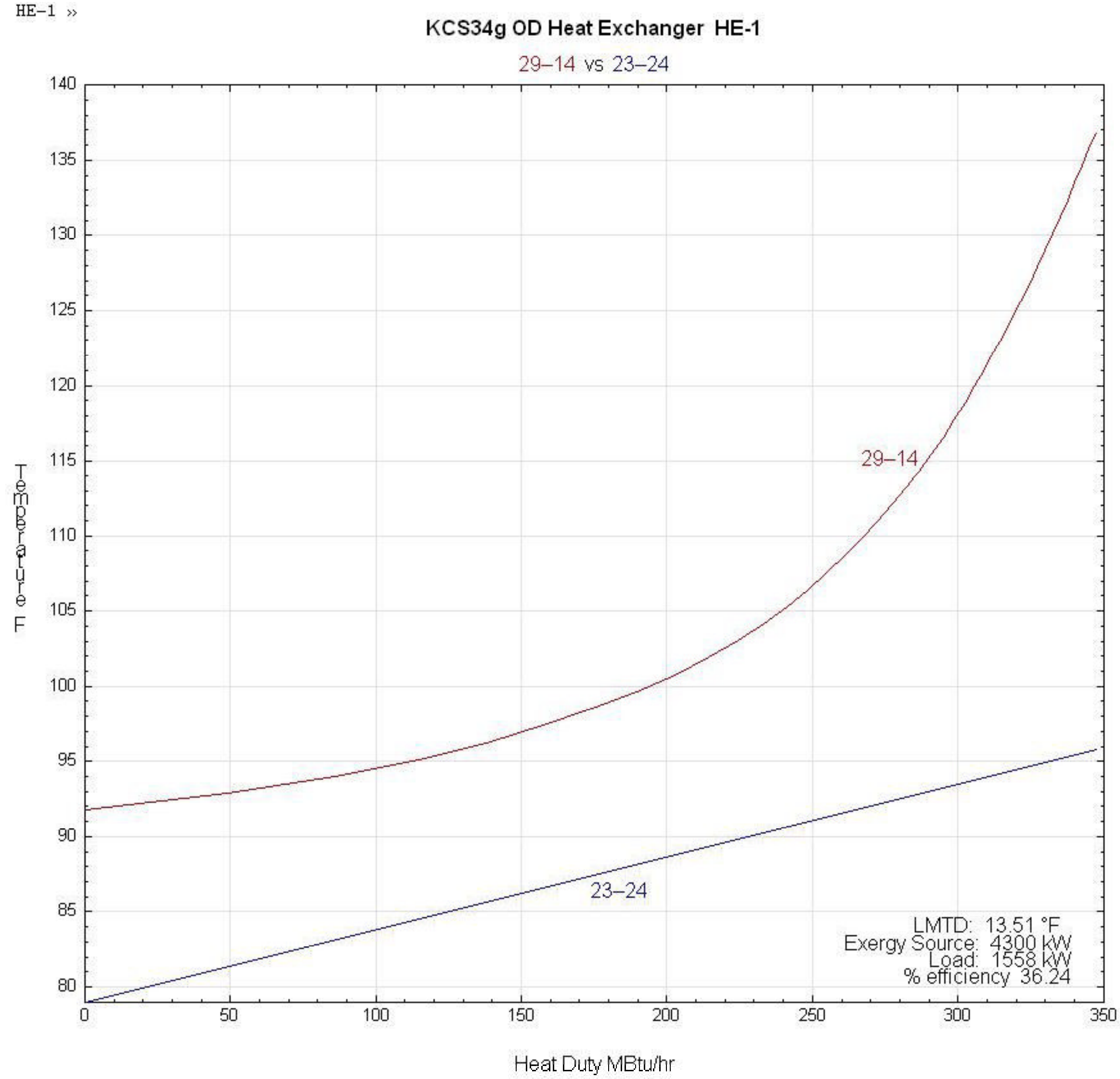
#	P bar	X	T °C	H kJ/kg	G/(G=1)	Flow kg/s	Phase
23	•	Water	26.11	109.32	24.2596	2599.297	
24	•	Water	35.46	148.48	24.2596	2599.297	
36	11.257	.88	33.19	64.38	1	107.145	SatLiquid
37	23.532	.88	33.56	66.76	1	107.145	Liq 28°
38	23.532	.88	33.56	66.76	1	107.145	Liq 28°
39	23.359	.88	33.56	66.76	1	107.145	Liq 27°
40	23.256	.88	33.56	66.76	1	107.145	Liq 27°
41	23.187	.88	33.56	66.76	0.9658	103.479	Liq 27°
42	22.587	.88	59.62	195.08	0.9658	103.479	SatLiquid
43	21.787	.88	87.22	1105.35	0.9658	103.479	Wet .2497
44	22.946	.88	33.56	66.76	0.0342	3.666	Liq 27°
45	22.346	.88	59.18	192.82	0.0342	3.666	SatLiquid
46	21.546	.88	83.79	1073.99	0.0342	3.666	Wet .2656
47	21.477	.88	19.62	0.00	1	107.145	Liq 38°
48	21.443	.88	86.59	1104.27	1	107.145	Wet .2496
49	21.443	.9885	86.59	1417.12	0.7504	80.403	SatVapor
50	21.443	.9885	86.59	1417.12	0.7504	80.403	SatVapor
51	21.236	.9885	86.31	1417.12	0.7504	80.403	Wet 0
52	21.029	.9885	86.03	1417.12	0.7504	80.403	Wet .0001
30	21.029	.9885	86.03	1417.12	0.7504	80.403	Wet .0001
31	11.433	.9885	56.50	1343.26	0.7504	80.403	Wet .0194
32	11.364	.9885	56.36	1343.26	0.7504	80.403	Wet .0194
9	21.443	.5539	86.59	163.65	0.2496	26.742	SatLiquid
10	21.408	.5539	86.53	163.65	0.2496	26.742	Wet .9997
11	21.208	.5539	61.92	42.86	0.2496	26.742	Liq 24°
12	20.608	.5539	58.35	25.58	0.2496	26.742	Liq 26°
13	11.364	.5539	58.48	25.58	0.2496	26.742	Liq 1°
33	11.364	.88	58.29	1014.39	1	107.145	Wet .2677
29	11.357	.88	58.28	1014.39	1	107.145	Wet .2677
14	11.257	.88	33.19	64.38	1	107.145	SatLiquid
25	•	Brine	92.22	386.12	6.8126	729.931	
27	•	Brine	61.40	257.07	6.8126	729.931	
26	•	Brine	57.06	238.88	6.8126	729.931	

S34g OD HXs:

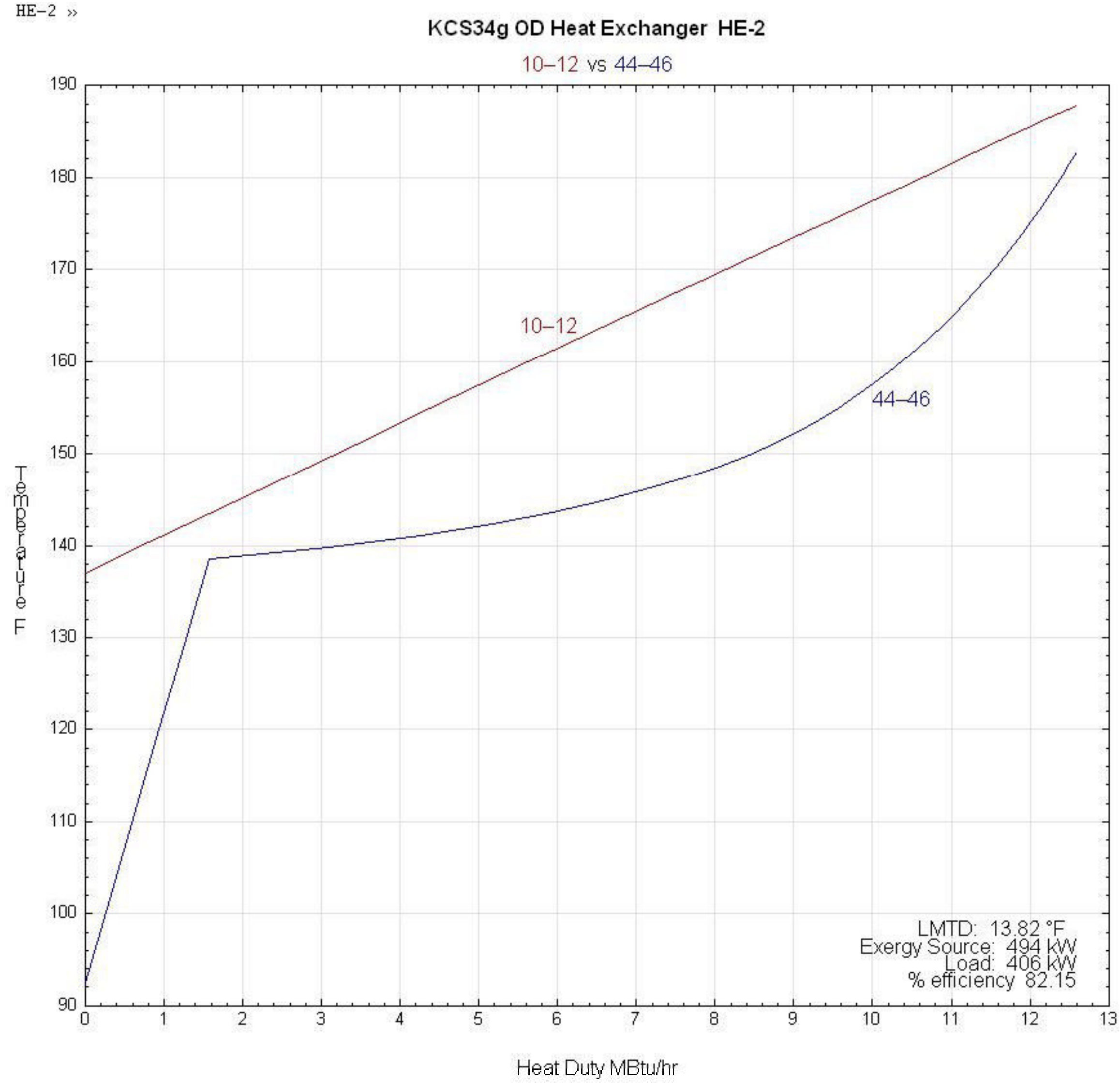
	MW th	LMTD	ΔTs between streams °C					
HE–1	101.789	13.51	T29–T24	22.81	T14–T23	7.08		
HE–2	3.692	13.82	T10–T46	2.74	T11–T45	2.74	T12–T44	24.78
HE–3	107.472	14.4	T25–T43	5	T27–T42	1.78	T26–T41	23.49

HE-1 »

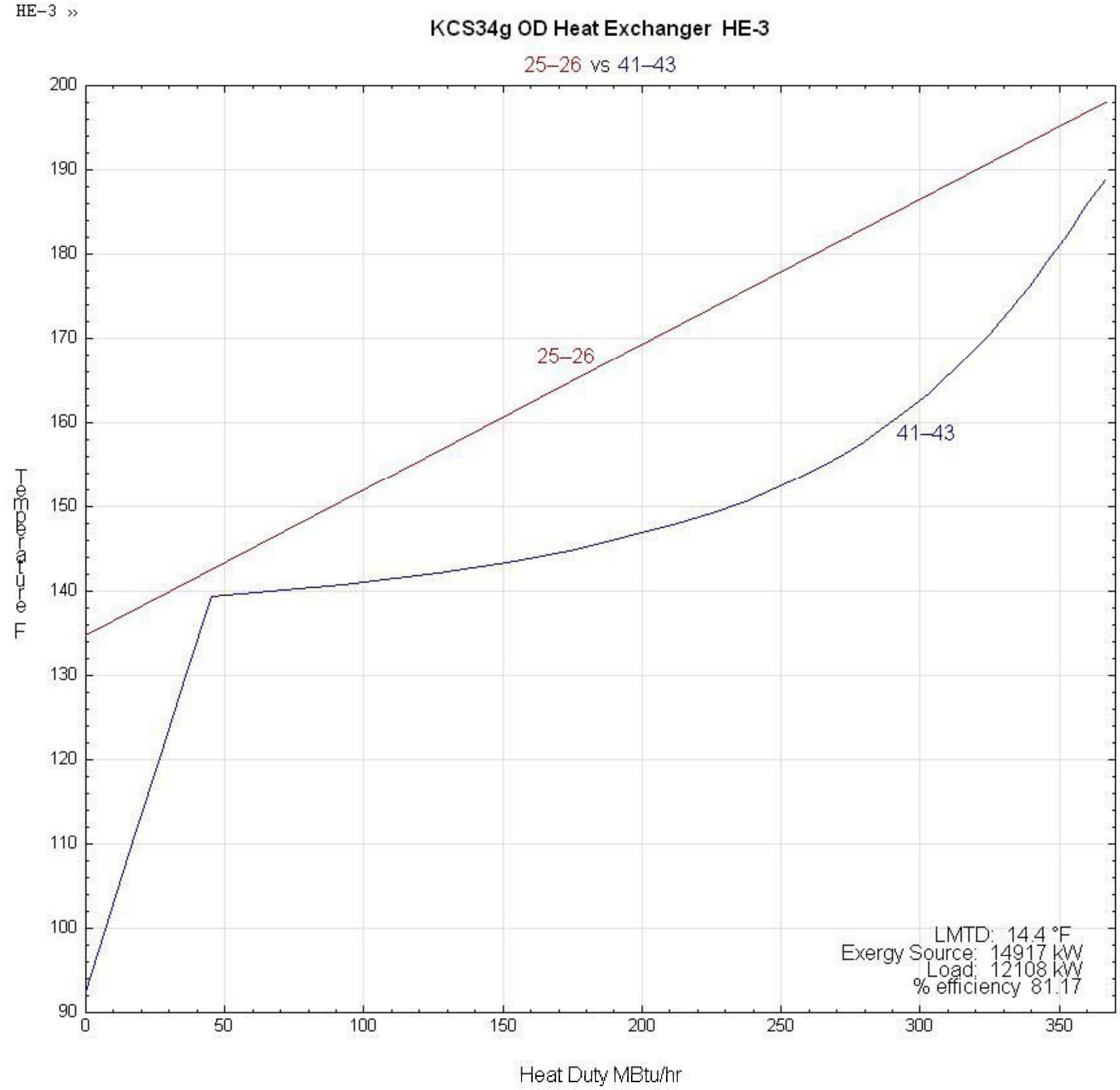


KCS34g OD Heat Exchanger HE-1
29–14 vs 23–24
Temperature F
Heat Duty MBtu/hr
29–14
23–24
LMTD: 13.51 °F
Exergy Source: 4300 kW
Load: 1558 kW
% efficiency 36.24

HE-2 »



KCS34g OD Heat Exchanger HE-2
10–12 vs 44–46
10–12
44–46
Temperature F
Heat Duty MBtu/hr
LMTD: 13.82 °F
Exergy Source: 494 kW
Load: 406 kW
% efficiency 82.15
190
180
170
160
150
140
130
120
110
100
90
0 1 2 3 4 5 6 7 8 9 10 11 12 13


KCS34g OD Heat Exchanger HE-3
25–26 vs 41–43
25–26
41–43
Temperature F
Heat Duty MBtu/hr
LMTD: 14.4 °F
Exergy Source: 14917 kW
Load: 12108 kW
% efficiency 81.17
200
190
180
170
160
150
140
130
120
110
100
90
0
50
100
150
200
250
300
350

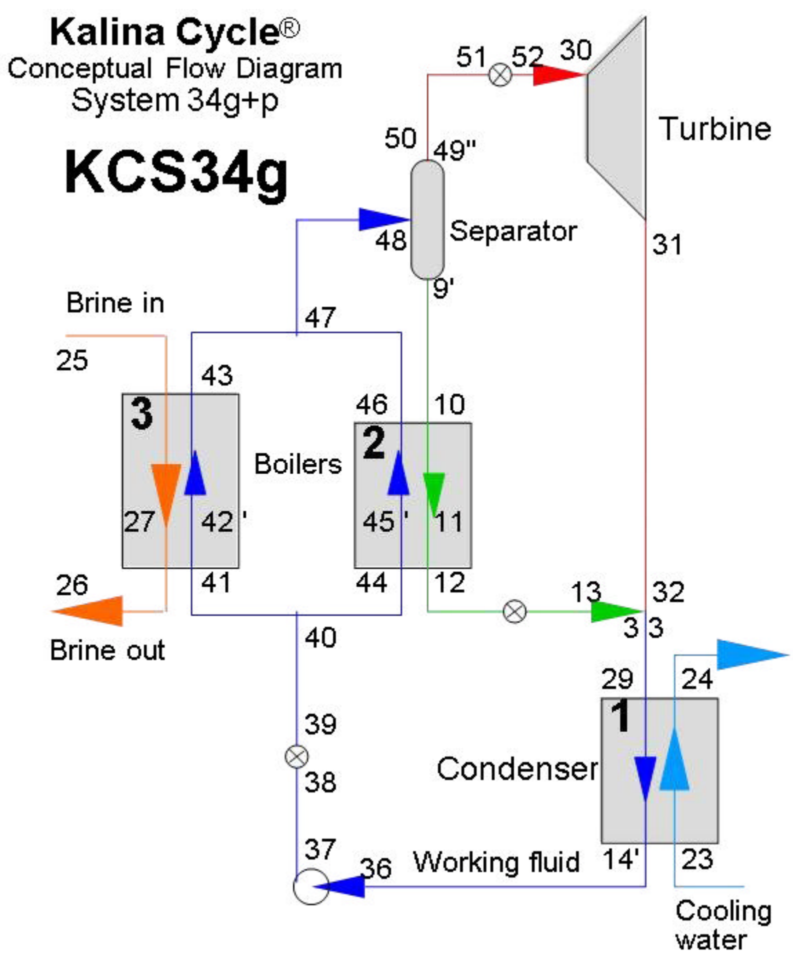
ENTIV TECHNIP Summer Balance Rev 4-2

3 December 2013

Notes

With respect to Design Balance Rev 4-2

1. Coolant temperature increased to 60°F.
2. ATE remains constant at 88%.
3. Inlet turbine pressure is 293 psiA.
4. Composition remains 0.88.
5. Piping pressure drops are not pro-rated.
6. Coolant flow is fixed at 41,344 gpm.



Kalina Cycle Control Data

T25	198	∆T11	5.25
T26	129.6	∆T10	5.3
T23	60	∆T3	5.4
P30	293	TME	.96
T mass	47177.291	ATE	.88
∆T1	9	Cp brine	1
∆Ta	14.4	Brine flow	5793204
∆Tw	12	P eff	.8

Heat Exchanger Pressure Drops

∆P 23–24	30	∆P 10–11	2.9
∆P 29–14	1.45	∆P 39– 41	2.5
∆P 41–42	8.7	∆P 11–12	8.7
∆P 42–43	11.6	∆P 49– 30	6

Piping & Valve Pressure Drops

∆P 31– 32	1	∆P 45–46	11.6
∆P 43– 48	5	∆P 46– 48	1.5
∆P 33– 29	.1	∆P 47–48	.5
∆P 38v39	2.5	∆P 50– 51	3
∆P 9– 10	.5	∆P 51– 52	3
∆P 40– 41	1	∆P 25–27	5
∆P 44–45	8.7	∆P 25–26	5

Turbine mass flow	83.09	kg/s	659,472	lb/hr
Pt 30 Volume flow	6,375.38	L/s	810,520	ft^3/hr
Pt 31 Volume flow	13,759.72	L/s	1,749,312	ft^3/hr
		kW		BTU/lb
Heat in	116,130.92		455.82	
Heat rejected	107,333.73		421.29	
Turbine enthalpy drop	9,094.86		35.70	
Turbine Work	8,731.06		34.27	
Feed pump ∆H 1.17, power	316.27		1.24	
Feed + Coolant pump power	1,035.64		4.06	
Net Work	7,695.43		30.20	
		kWe		
Gross Output	8,731.06			
Cycle Output	8,414.79			
Net Output	7,695.43			
Net thermal efficiency	6.63	%		
Second law limit	15.18	%		
Second law efficiency	43.67	%		
Specific Brine Consumption	752.81	lb/kW-hr		
Specific Power Output	1.33	Watt-hr/lb		

KALINA CYCLE® SYSTEM 34g OD POINTS

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#	P psiA	X	T °F	H Btu/lb	G/(G=1)	Flow lb/hr	Phase
23	•	Water	60	28.00	23.7849	20,676,859	
24	•	Water	77.71	45.71	23.7849	20,676,859	
36	122.44	.88	74.40	7.71	1	869,328	SatLiquid
37	329.30	.88	75.11	8.88	1	869,328	Liq 65°
38	329.30	.88	75.11	8.88	1	869,328	Liq 65°
39	326.80	.88	75.11	8.88	1	869,328	Liq 64°
40	325.30	.88	75.11	8.88	1	869,328	Liq 64°
41	324.30	.88	75.11	8.88	0.9659	839,693	Liq 63°
42	315.60	.88	136.53	80.51	0.9659	839,693	SatLiquid
43	304	.88	189	480.78	0.9659	839,693	Wet .2415
44	320.80	.88	75.12	8.88	0.0341	29,635	Liq 63°
45	312.10	.88	135.70	79.51	0.0341	29,635	SatLiquid
46	300.50	.88	182.42	466.37	0.0341	29,635	Wet .2581
47	299.50	.88	67.33	0.00	1	869,328	Liq 65°
48	299	.88	187.83	480.29	1	869,328	Wet .2414
49	299	.9876	187.83	611.12	0.7586	659,472	SatVapor
50	299	.9876	187.83	611.12	0.7586	659,472	SatVapor
51	296	.9876	187.32	611.12	0.7586	659,472	Wet 0
52	293	.9876	186.81	611.12	0.7586	659,472	Wet 0
30	293	.9876	186.81	611.12	0.7586	659,472	Wet 0
31	124.99	.9876	110.98	564.06	0.7586	659,472	Wet .0267
32	123.99	.9876	110.67	564.06	0.7586	659,472	Wet .0266
9	299	.5419	187.83	69.17	0.2414	209,856	SatLiquid
10	298.50	.5419	187.72	69.17	0.2414	209,856	Wet .9997
11	295.60	.5419	140.95	14.54	0.2414	209,856	Liq 46°
12	286.90	.5419	132.28	4.56	0.2414	209,856	Liq 52°
13	123.99	.5419	124.84	4.56	0.2414	209,856	Wet .9843
33	123.99	.88	119.86	429.00	1	869,328	Wet .2643
29	123.89	.88	119.82	429.00	1	869,328	Wet .2643
14	122.44	.88	74.40	7.71	1	869,328	SatLiquid
25	•	Brine	198	166.00	6.6640	5,793,204	
27	•	Brine	139.98	107.98	6.6640	5,793,204	
26	•	Brine	129.60	97.60	6.6640	5,793,204	

S34g OD HXs:	MW th	LMTD	ΔTs between streams					
HE–1	107.334	14.61	T29–T24	42.11	T14–T23	14.4		
HE–2	3.973	15.04	T10–T46	5.3	T11–T45	5.25	T12–T44	57.16
HE–3	116.131	15.56	T25–T43	9	T27–T42	3.45	T26–T41	54.49

Kalina Cycle Control Data

T25	198	∆T11	5.25
T26	129.6	∆T10	5.3
T23	60	∆T3	5.4
P30	293	TME	.96
T mass	47177.291	ATE	.88
∆T1	9	Cp brine	1
∆Ta	14.4	Brine flow	5793204
∆Tw	12	P eff	.8

Heat Exchanger Pressure Drops

∆P 23–24	30	∆P 10–11	2.9
∆P 29–14	1.45	∆P 39– 41	2.5
∆P 41–42	8.7	∆P 11–12	8.7
∆P 42–43	11.6	∆P 49– 30	6

Piping & Valve Pressure Drops

∆P 31– 32	1	∆P 45–46	11.6
∆P 43– 48	5	∆P 46– 48	1.5
∆P 33– 29	.1	∆P 47–48	.5
∆P 38v39	2.5	∆P 50– 51	3
∆P 9– 10	.5	∆P 51– 52	3
∆P 40– 41	1	∆P 25–27	5
∆P 44–45	8.7	∆P 25–26	5

Turbine mass flow	83.09	kg/s	659,472	lb/hr
Pt 30 Volume flow	6,375.38	L/s	810,520	ft^3/hr
Pt 31 Volume flow	13,759.72	L/s	1,749,312	ft^3/hr
		kW		kJ/kg
Heat in	116,130.92		1060.23	
Heat rejected	107,333.73		979.92	
Turbine enthalpy drop	9,094.86		83.03	
Turbine Work	8,731.06		79.71	
Feed pump ∆H 2.72, power	316.27		2.89	
Feed + Coolant pump power	1,035.64		9.45	
Net Work	7,695.43		70.26	
		kWe		
Gross Output	8,731.06			
Cycle Output	8,414.79			
Net Output	7,695.43			
Net thermal efficiency	6.63	%		
Second law limit	15.18	%		
Second law efficiency	43.67	%		
Specific Brine Consumption	752.81	lb/kW-hr		
Specific Power Output	1.33	Watt-hr/lb		

KALINA CYCLE® SYSTEM 34g OD POINTS

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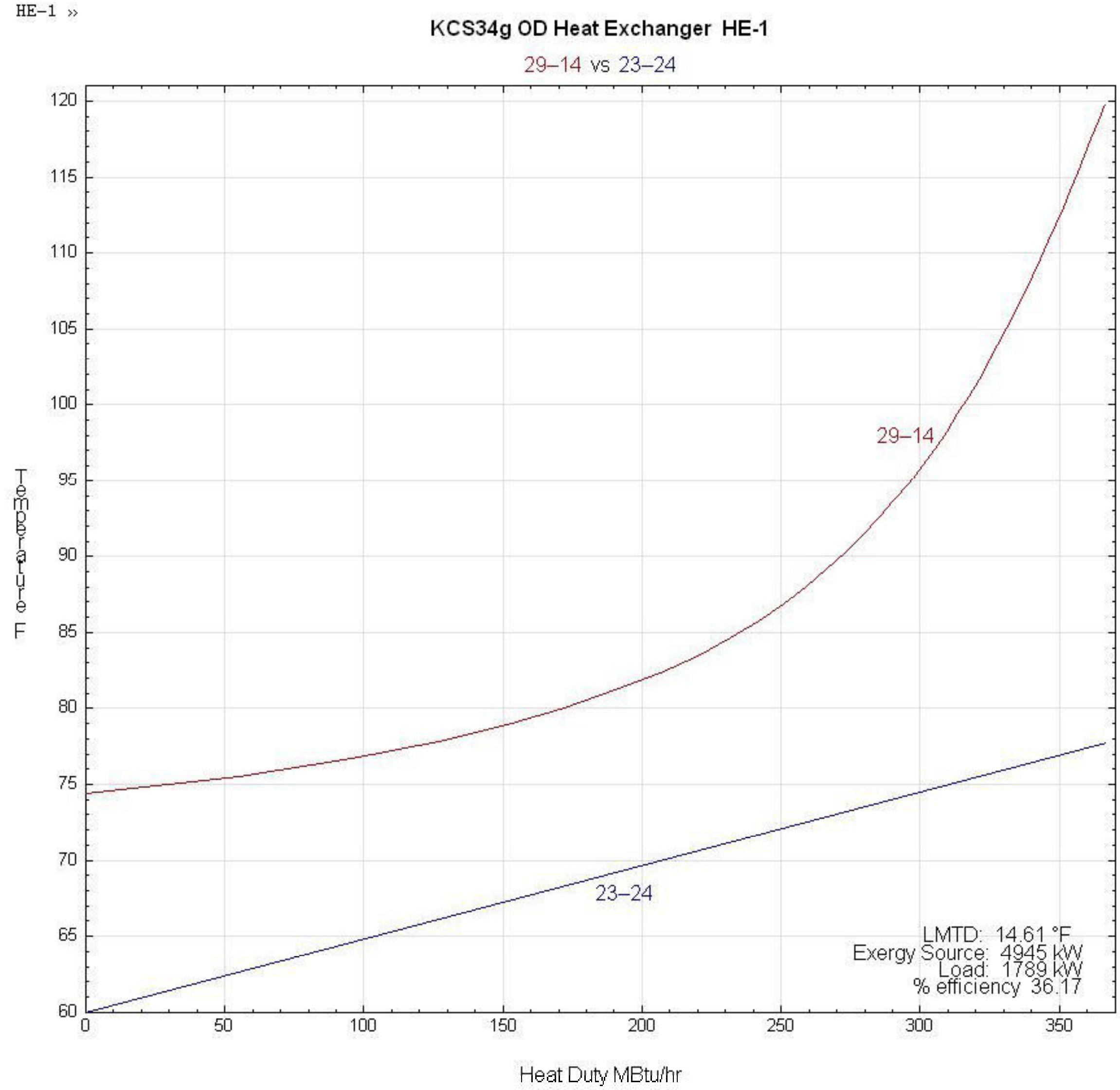
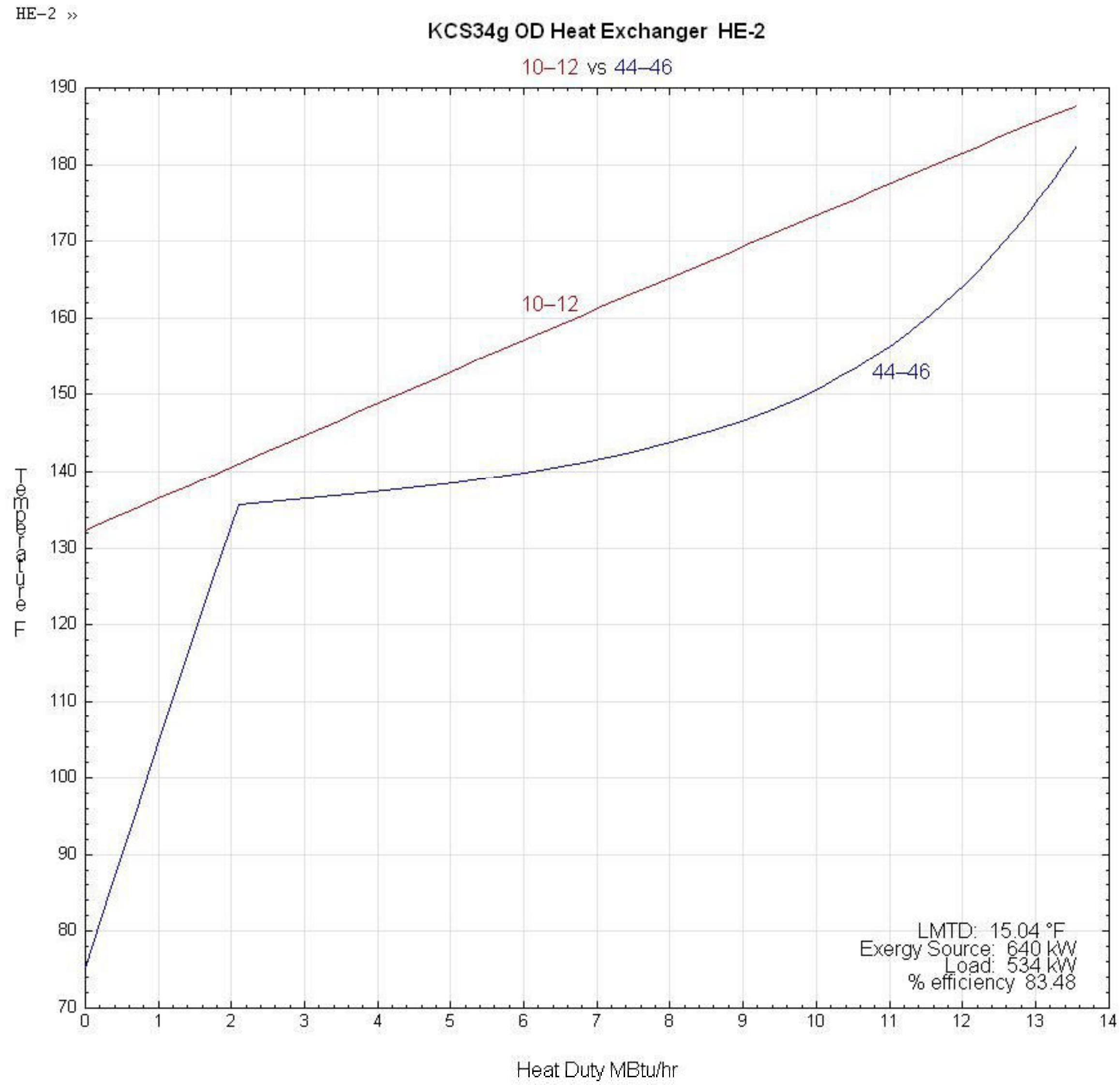
#	P bar	X	T °C	H kJ/kg	G/(G=1)	Flow kg/s	Phase
23	•	Water	15.56	65.13	23.7849	2605.240	
24	•	Water	25.40	106.33	23.7849	2605.240	
36	8.442	.88	23.56	17.94	1	109.534	SatLiquid
37	22.704	.88	23.95	20.65	1	109.534	Liq 36°
38	22.704	.88	23.95	20.65	1	109.534	Liq 36°
39	22.532	.88	23.95	20.65	1	109.534	Liq 36°
40	22.429	.88	23.95	20.65	1	109.534	Liq 35°
41	22.360	.88	23.95	20.65	0.9659	105.800	Liq 35°
42	21.760	.88	58.07	187.26	0.9659	105.800	SatLiquid
43	20.960	.88	87.22	1118.31	0.9659	105.800	Wet .2415
44	22.118	.88	23.96	20.65	0.0341	3.734	Liq 35°
45	21.519	.88	57.61	184.94	0.0341	3.734	SatLiquid
46	20.719	.88	83.57	1084.77	0.0341	3.734	Wet .2581
47	20.650	.88	19.63	0.00	1	109.534	Liq 36°
48	20.615	.88	86.57	1117.16	1	109.534	Wet .2414
49	20.615	.9876	86.57	1421.47	0.7586	83.092	SatVapor
50	20.615	.9876	86.57	1421.47	0.7586	83.092	SatVapor
51	20.408	.9876	86.29	1421.47	0.7586	83.092	Wet 0
52	20.202	.9876	86.00	1421.47	0.7586	83.092	Wet 0
30	20.202	.9876	86.00	1421.47	0.7586	83.092	Wet 0
31	8.618	.9876	43.88	1312.01	0.7586	83.092	Wet .0267
32	8.549	.9876	43.70	1312.01	0.7586	83.092	Wet .0266
9	20.615	.5419	86.57	160.89	0.2414	26.441	SatLiquid
10	20.581	.5419	86.51	160.89	0.2414	26.441	Wet .9997
11	20.381	.5419	60.53	33.82	0.2414	26.441	Liq 26°
12	19.781	.5419	55.71	10.62	0.2414	26.441	Liq 29°
13	8.549	.5419	51.58	10.62	0.2414	26.441	Wet .9843
33	8.549	.88	48.81	997.85	1	109.534	Wet .2643
29	8.542	.88	48.79	997.85	1	109.534	Wet .2643
14	8.442	.88	23.56	17.94	1	109.534	SatLiquid
25	•	Brine	92.22	386.12	6.6640	729.931	
27	•	Brine	59.99	251.17	6.6640	729.931	
26	•	Brine	54.22	227.02	6.6640	729.931	

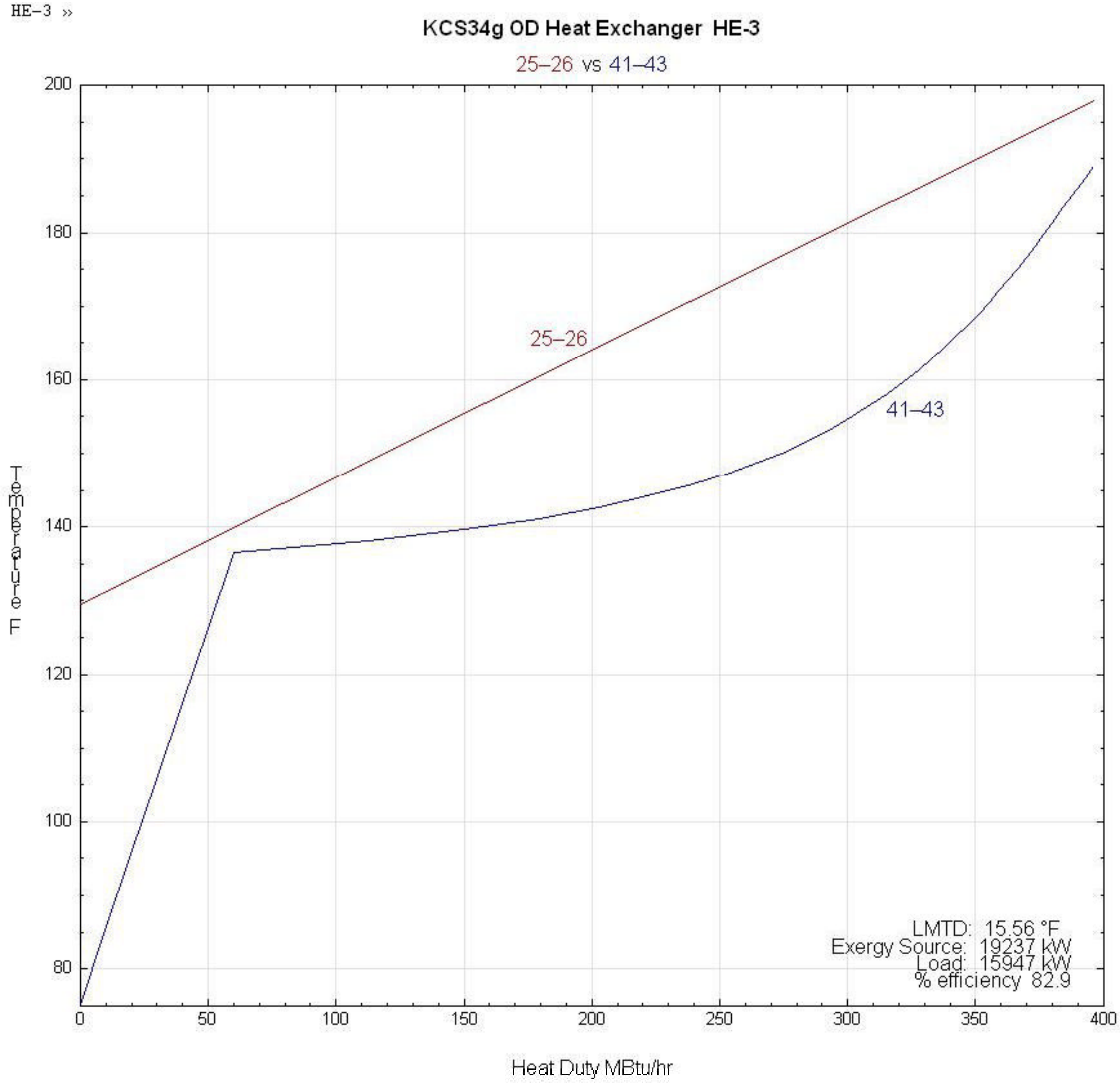
S34g OD HXs:	MW th	LMTD	ΔTs between streams °C					
HE–1	107.334	8.12	T29–T24	23.39	T14–T23	8		
HE–2	3.973	8.36	T10–T46	2.94	T11–T45	2.92	T12–T44	31.75
HE–3	116.131	8.64	T25–T43	5	T27–T42	1.92	T26–T41	30.27

HE-1 »


KCS34g OD Heat Exchanger HE-1
29–14 vs 23–24
Temperature F
Heat Duty MBtu/hr
29–14
23–24
LMTD: 14.61 °F
Exergy Source: 4945 kW
Load: 1789 kW
% efficiency 36.17
0
50
100
150
200
250
300
350
60
65
70
75
80
85
90
95
100
105
110
115
120


HE-2 »
KCS34g OD Heat Exchanger HE-2
10–12 vs 44–46
10–12
44–46
Temperature F
Heat Duty MBtu/hr
LMTD: 15.04 °F
Exergy Source: 640 kW
Load: 534 kW
% efficiency 83.48

HE-3 »



KCS34g OD Heat Exchanger HE-3
25–26 vs 41–43
25–26
41–43
Temperature F
Heat Duty MBtu/hr
LMTD: 15.56 °F
Exergy Source: 19237 kW
Load: 15947 kW
% efficiency 82.9
200
180
160
140
120
100
80
0
50
100
150
200
250
300
350
400

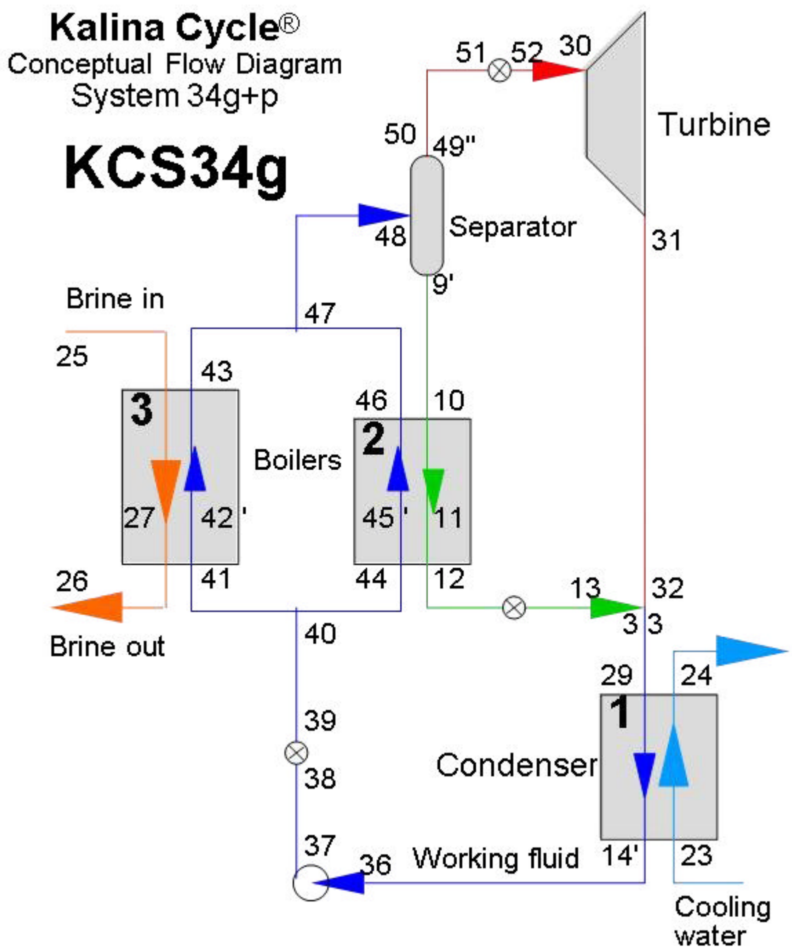
ENTIV TECHNIP Winter Balance Rev 4-2

3 December 2013

Notes

With respect to Design Balance Rev 4-2

1. Coolant temperature reduced to 45°F.
2. ATE is 85%.
3. Inlet turbine pressure is 285 psiA.
4. Composition remains 0.88.
5. Piping pressure drops are not pro-rated.
6. Coolant flow is fixed at 41,344 gpm.



Kalina Cycle Control Data

T25	198	∆T11	5.4
T26	126.7	∆T10	5.6
T23	45	∆T3	5.4
P30	285	TME	.96
T mass	47177.291	ATE	.852
∆T1	5.3	Cp brine	1
∆Ta	15.4	Brine flow	5793204
∆Tw	12	P eff	.8

Heat Exchanger Pressure Drops

∆P 23–24	30	∆P 10–11	2.9
∆P 29–14	1.45	∆P 39– 41	2.5
∆P 41–42	8.7	∆P 11–12	8.7
∆P 42–43	11.6	∆P 49– 30	6

Piping & Valve Pressure Drops

∆P 31– 32	1	∆P 45–46	11.6
∆P 43– 48	5	∆P 46– 48	1.5
∆P 33– 29	.1	∆P 47–48	.5
∆P 38v39	2.5	∆P 50– 51	3
∆P 9– 10	.5	∆P 51– 52	3
∆P 40– 41	1	∆P 25–27	5
∆P 44–45	8.7	∆P 25–26	5

Turbine mass flow	83.36	kg/s	661,638	lb/hr
Pt 30 Volume flow	6,653.44	L/s	845,871	ft^3/hr
Pt 31 Volume flow	17,481.46	L/s	2,222,466	ft^3/hr
		kW		BTU/lb
Heat in	121,054.60		482.85	
Heat rejected	110,342.07		440.12	
Turbine enthalpy drop	11,027.29		43.98	
Turbine Work	10,586.20		42.23	
Feed pump ∆H 1.26, power	334.44		1.33	
Feed + Coolant pump power	1,053.84		4.20	
Net Work	9,532.36		38.02	
		kWe		
Gross Output	10,586.20			
Cycle Output	10,251.76			
Net Output	9,532.36			
Net thermal efficiency	7.87	%		
Second law limit	17.35	%		
Second law efficiency	45.39	%		
Specific Brine Consumption	607.74	lb/kW-hr		
Specific Power Output	1.65	Watt-hr/lb		

KALINA CYCLE® SYSTEM 34g OD POINTS

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#	P psiA	X	T °F	H Btu/lb	G/(G=1)	Flow lb/hr	Phase
23	•	Water	45	13.00	24.1982	20,700,313	
24	•	Water	63.19	31.19	24.1982	20,700,313	
36	95.60	.88	60.40	–8.22	1	855,447	SatLiquid
37	321.30	.88	61.13	–6.97	1	855,447	Liq 77°
38	321.30	.88	61.13	–6.97	1	855,447	Liq 77°
39	318.80	.88	61.13	–6.97	1	855,447	Liq 76°
40	317.30	.88	61.14	–6.97	1	855,447	Liq 76°
41	316.30	.88	61.14	–6.97	0.9657	826,114	Liq 76°
42	307.60	.88	134.63	78.22	0.9657	826,114	SatLiquid
43	296	.88	192.70	493.03	0.9657	826,114	Wet .2267
44	312.80	.88	61.14	–6.97	0.0343	29,333	Liq 75°
45	304.10	.88	133.78	77.20	0.0343	29,333	SatLiquid
46	292.50	.88	185.81	478.49	0.0343	29,333	Wet .2426
47	291.50	.88	67.35	0.00	1	855,447	Liq 63°
48	291	.88	191.52	492.53	1	855,447	Wet .2266
49	291	.9851	191.52	615.75	0.7734	661,638	SatVapor
50	291	.9851	191.52	615.75	0.7734	661,638	SatVapor
51	288	.9851	191.00	615.75	0.7734	661,638	Wet 0
52	285	.9851	190.48	615.75	0.7734	661,638	Wet 0
30	285	.9851	190.48	615.75	0.7734	661,638	Wet 0
31	98.15	.9851	100.36	558.89	0.7734	661,638	Wet .0314
32	97.15	.9851	100.00	558.89	0.7734	661,638	Wet .0313
9	291	.5211	191.52	71.86	0.2266	193,809	SatLiquid
10	290.50	.5211	191.41	71.86	0.2266	193,809	Wet .9997
11	287.60	.5211	139.18	11.13	0.2266	193,809	Liq 51°
12	278.90	.5211	128.03	–1.61	0.2266	193,809	Liq 60°
13	97.15	.5211	115.90	–1.61	0.2266	193,809	Wet .9758
33	97.15	.88	109.88	431.90	1	855,447	Wet .2518
29	97.05	.88	109.83	431.90	1	855,447	Wet .2517
14	95.60	.88	60.40	–8.22	1	855,447	SatLiquid
25	•	Brine	198	166.00	6.7721	5,793,204	
27	•	Brine	138.85	106.85	6.7721	5,793,204	
26	•	Brine	126.70	94.70	6.7721	5,793,204	

S34g OD HXs:	MW th	LMTD	ΔTs between streams					
HE–1	110.342	15.60	T29–T24	46.64	T14–T23	15.4		
HE–2	4.173	16.61	T10–T46	5.6	T11–T45	5.4	T12–T44	66.89
HE–3	121.055	16.29	T25–T43	5.3	T27–T42	4.22	T26–T41	65.56

Kalina Cycle Control Data

T25	198	ΔT11	5.4
T26	126.7	ΔT10	5.6
T23	45	ΔT3	5.4
P30	285	TME	.96
T mass	47177.291	ATE	.852
ΔT1	5.3	Cp brine	1
ΔTa	15.4	Brine flow	5793204
ΔTw	12	P eff	.8

Heat Exchanger Pressure Drops

ΔP 23–24	30	ΔP 10–11	2.9
ΔP 29–14	1.45	ΔP 39– 41	2.5
ΔP 41–42	8.7	ΔP 11–12	8.7
ΔP 42–43	11.6	ΔP 49– 30	6

Piping & Valve Pressure Drops

ΔP 31– 32	1	ΔP 45–46	11.6
ΔP 43– 48	5	ΔP 46– 48	1.5
ΔP 33– 29	.1	ΔP 47–48	.5
ΔP 38v39	2.5	ΔP 50– 51	3
ΔP 9– 10	.5	ΔP 51– 52	3
ΔP 40– 41	1	ΔP 25–27	5
ΔP 44–45	8.7	ΔP 25–26	5

Turbine mass flow	83.36	kg/s	661,638	lb/hr
Pt 30 Volume flow	6,653.44	L/s	845,871	ft^3/hr
Pt 31 Volume flow	17,481.46	L/s	2,222,466	ft^3/hr
		kW		kJ/kg
Heat in	121,054.60		1123.12	
Heat rejected	110,342.07		1023.73	
Turbine enthalpy drop	11,027.29		102.31	
Turbine Work	10,586.20		98.22	
Feed pump ΔH 2.92, power	334.44		3.10	
Feed + Coolant pump power	1,053.84		9.78	
Net Work	9,532.36		88.44	
		kWe		
Gross Output	10,586.20			
Cycle Output	10,251.76			
Net Output	9,532.36			
Net thermal efficiency	7.87	%		
Second law limit	17.35	%		
Second law efficiency	45.39	%		
Specific Brine Consumption	607.74	lb/kW-hr		
Specific Power Output	1.65	Watt-hr/lb		

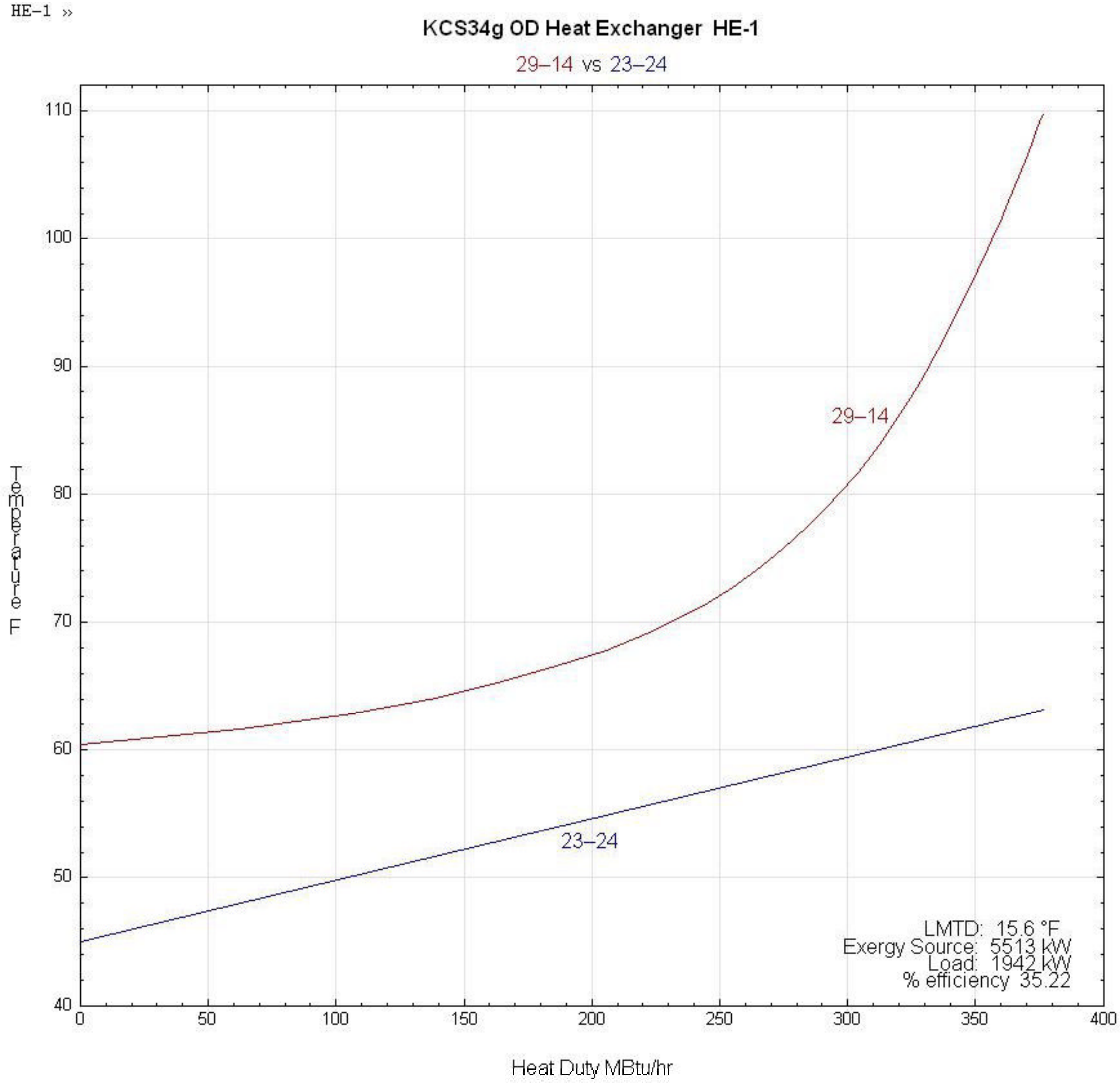
KALINA CYCLE® SYSTEM 34g OD POINTS

2013 Dec 03 11:11:09

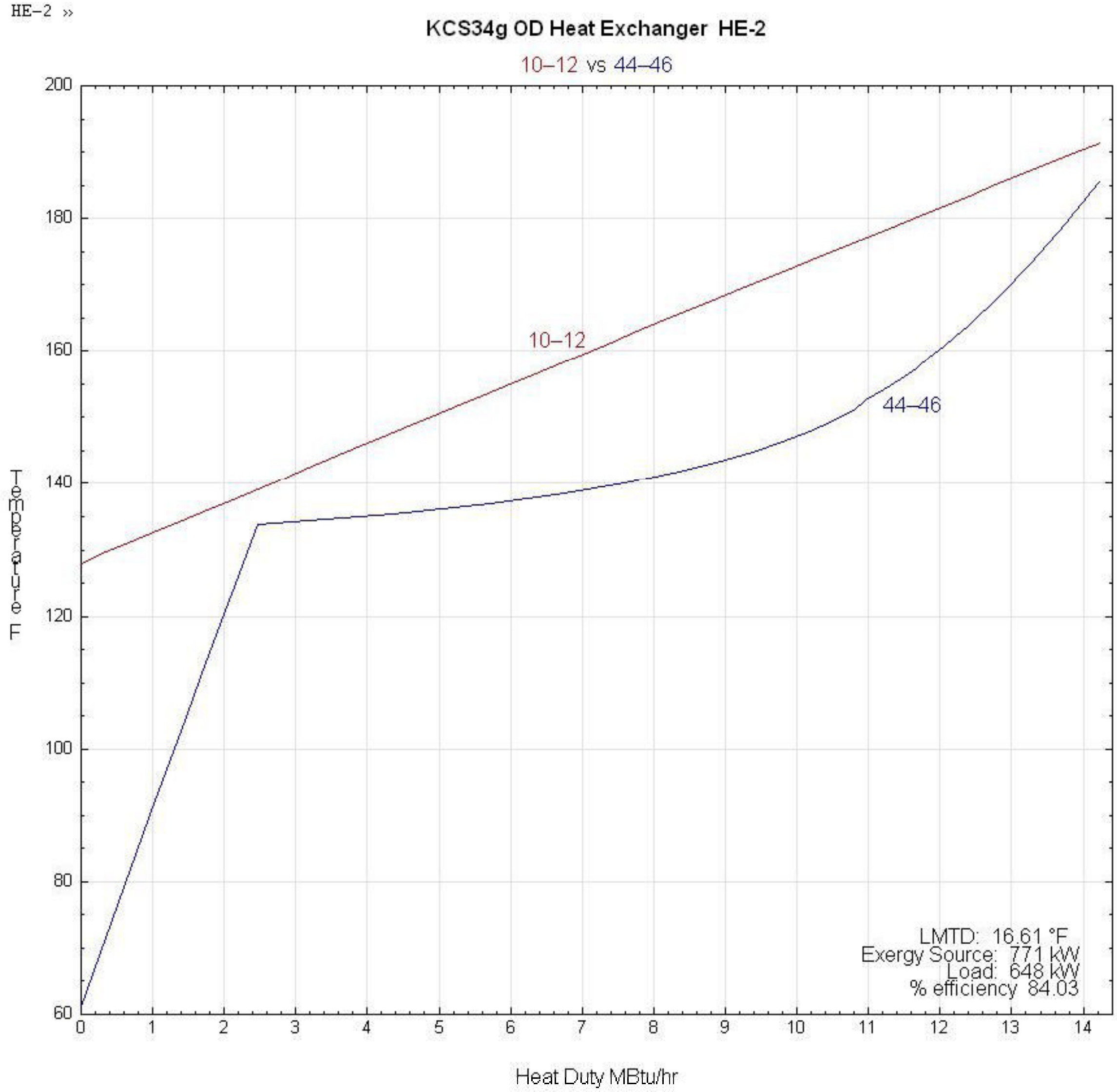
#	P bar	X	T °C	H kJ/kg	G/(G=1)	Flow kg/s	Phase
23	•	Water	7.22	30.24	24.1982	2608.196	
24	•	Water	17.33	72.54	24.1982	2608.196	
36	6.591	.88	15.78	–19.13	1	107.784	SatLiquid
37	22.153	.88	16.18	–16.21	1	107.784	Liq 43°
38	22.153	.88	16.18	–16.21	1	107.784	Liq 43°
39	21.980	.88	16.19	–16.21	1	107.784	Liq 42°
40	21.877	.88	16.19	–16.21	1	107.784	Liq 42°
41	21.808	.88	16.19	–16.21	0.9657	104.089	Liq 42°
42	21.208	.88	57.02	181.93	0.9657	104.089	SatLiquid
43	20.408	.88	89.28	1146.79	0.9657	104.089	Wet .2267
44	21.567	.88	16.19	–16.21	0.0343	3.696	Liq 42°
45	20.967	.88	56.55	179.57	0.0343	3.696	SatLiquid
46	20.167	.88	85.45	1112.97	0.0343	3.696	Wet .2426
47	20.098	.88	19.64	0.00	1	107.784	Liq 35°
48	20.064	.88	88.62	1145.63	1	107.784	Wet .2266
49	20.064	.9851	88.62	1432.25	0.7734	83.365	SatVapor
50	20.064	.9851	88.62	1432.25	0.7734	83.365	SatVapor
51	19.857	.9851	88.33	1432.25	0.7734	83.365	Wet 0
52	19.650	.9851	88.05	1432.25	0.7734	83.365	Wet 0
30	19.650	.9851	88.05	1432.25	0.7734	83.365	Wet 0
31	6.767	.9851	37.98	1299.97	0.7734	83.365	Wet .0314
32	6.698	.9851	37.78	1299.97	0.7734	83.365	Wet .0313
9	20.064	.5211	88.62	167.15	0.2266	24.420	SatLiquid
10	20.029	.5211	88.56	167.15	0.2266	24.420	Wet .9997
11	19.829	.5211	59.55	25.88	0.2266	24.420	Liq 29°
12	19.229	.5211	53.35	–3.75	0.2266	24.420	Liq 33°
13	6.698	.5211	46.61	–3.75	0.2266	24.420	Wet .9758
33	6.698	.88	43.26	1004.60	1	107.784	Wet .2518
29	6.691	.88	43.24	1004.60	1	107.784	Wet .2517
14	6.591	.88	15.78	–19.13	1	107.784	SatLiquid
25	•	Brine	92.22	386.12	6.7721	729.931	
27	•	Brine	59.36	248.53	6.7721	729.931	
26	•	Brine	52.61	220.27	6.7721	729.931	

S34g OD HXs:	MW th	LMTD	ΔTs between streams °C					
HE–1	110.342	8.67	T29–T24	25.91	T14–T23	8.56		
HE–2	4.173	9.23	T10–T46	3.11	T11–T45	3	T12–T44	37.16
HE–3	121.055	9.05	T25–T43	2.94	T27–T42	2.34	T26–T41	36.42

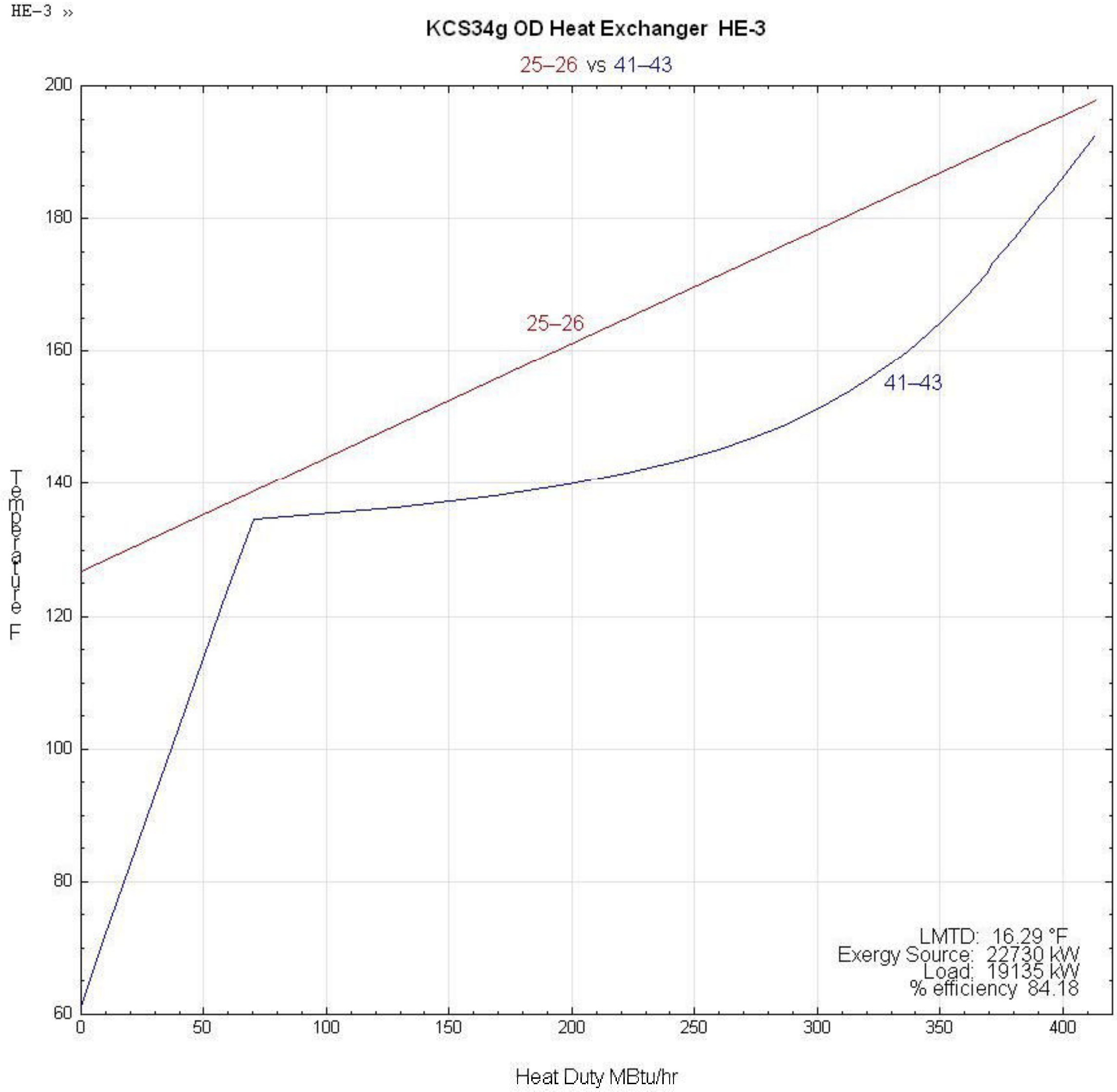
HE-1 »


KCS34g OD Heat Exchanger HE-1
29–14 vs 23–24
29–14
23–24
Temperature F
Heat Duty MBtu/hr
LMTD: 15.6 °F
Exergy Source: 5513 kW
Load: 1942 kW
% efficiency 35.22
110
100
90
80
70
60
50
40
0
50
100
150
200
250
300
350
400

HE-2 »



KCS34g OD Heat Exchanger HE-2
10–12 vs 44–46
10–12
44–46
Temperature F
Heat Duty MBtu/hr
LMTD: 16.61 °F
Exergy Source: 771 kW
Load: 648 kW
% efficiency 84.03



KCS34g OD Heat Exchanger HE-3
25–26 vs 41–43
25–26
41–43
Temperature F
Heat Duty MBtu/hr
200
180
160
140
120
100
80
60
0
50
100
150
200
250
300
350
400
LMTD: 16.29 °F
Exergy Source: 22730 kW
Load: 19135 kW
% efficiency 84.18

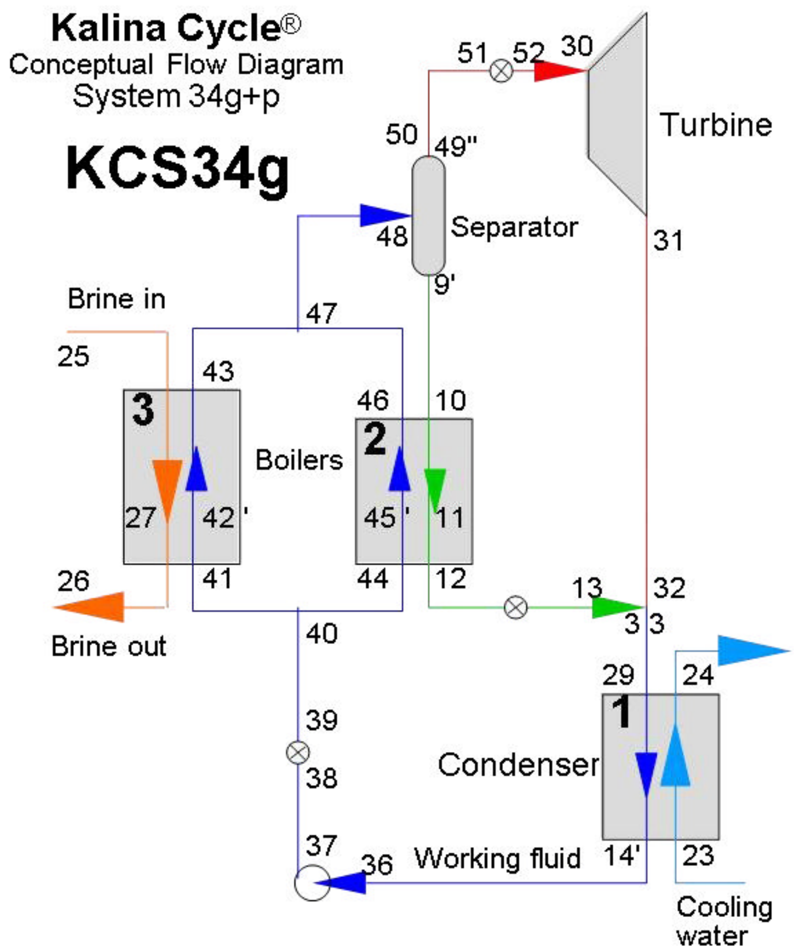
SAMPLE HEAT BALANCE GLOSSARY

5 December 2013

Notes

Annotations are shown in red.

All point numbers referenced in the heat balance correspond to the following diagram:



Kalina Cycle Control Data

T25	*brine inlet temp*	ΔT11	*recuperator boiling pt pinch*
T26	*brine outlet temp*	ΔT10	*recuperator hot-end pinch*
T23	*coolant inlet temp*	ΔT3	*boiler boiling pt pinch*
P30	*turbine inlet pressure*	TME	*turbine mechanical efficiency*
Tmass	*	ATE	*assumed turbine efficiency***
ΔT1	*boiler hot-end pinch*	Cp brine	*brine heat capacity*
ΔTa	*condenser cool-end pinch*	Brine flow	*brine flow rate*
ΔTw	*condenser interior pinch*	P eff	*pump efficiency*

**** Tmass is a stodola constant used to estimate turbine behavior in off-design conditions when vendor data is not yet available.***
***** In this case the ATE value includes internal turbine efficiency and generator efficiency, but they can be listed separately.***

Heat Exchanger Pressure Drops

ΔP 23–24	30	ΔP 10–11	2.9
ΔP 29–14	1.45	ΔP 39–41	2.5
ΔP 41–42	8.7	ΔP 11–12	8.7
ΔP 42–43	11.6	ΔP 49–30	6

Piping & Valve Pressure Drops

ΔP 31–32	1	ΔP 45–46	11.6
ΔP 43–48	5	ΔP 46–48	1.5
ΔP 33–29	.1	ΔP 47–48	.5
ΔP 38v39	*feed control valve*	ΔP 50–51	3
ΔP 9–10	.5	ΔP 51–52	3
ΔP 40–41	1	ΔP 25–27	5
ΔP 44–45	8.7	ΔP 25–26	5

Turbine mass flow	83.36	kg/s	661,638	lb/hr
Pt 30 Volume flow	6,653.44	L/s	845,871	ft^3/hr
Pt 31 Volume flow	17,481.46	L/s	2,222,466	ft^3/hr
		kW		BTU/lb
Heat in	121,054.60		482.85	
Heat rejected	110,342.07		440.12	
Turbine enthalpy drop	11,027.29		43.98	
Turbine Work	10,586.20		42.23	
Feed pump ΔH 1.26, power	334.44		1.33	
Feed + Coolant pump power	1,053.84		4.20	
Net Work	9,532.36		38.02	
		kWe		
Gross Output	10,586.20			
Cycle Output	10,251.76			
Net Output	9,532.36			
Net thermal efficiency	7.87	%		
Second law limit	17.35	%		
Second law efficiency	45.39	%		
Specific Brine Consumption	607.74	lb/kW-hr		
Specific Power Output	1.65	Watt-hr/lb		

KALINA CYCLE® SYSTEM 34g OD POINTS

2013 Dec 03 11:11:09

#	P psiA	X	T °F	H Btu/lb	G/(G=1)	Flow lb/hr	Phase
23	•	Water	45	13.00	24.1982	20,700,313	
24	•	Water	63.19	31.19	24.1982	20,700,313	
36	95.60	.88	60.40	–8.22	1	855,447	SatLiquid
37	321.30	.88	61.13	–6.97	1	855,447	Liq 77°
38	321.30	.88	61.13	–6.97	1	855,447	Liq 77°
39	318.80	.88	61.13	–6.97	1	855,447	Liq 76°
40	317.30	.88	61.14	–6.97	1	855,447	Liq 76°
41	316.30	.88	61.14	–6.97	0.9657	826,114	Liq 76°
42	307.60	.88	134.63	78.22	0.9657	826,114	SatLiquid
43	296	.88	192.70	493.03	0.9657	826,114	Wet .2267
44	312.80	.88	61.14	–6.97	0.0343	29,333	Liq 75°
45	304.10	.88	133.78	77.20	0.0343	29,333	SatLiquid
46	292.50	.88	185.81	478.49	0.0343	29,333	Wet .2426
47	291.50	.88	67.35	0.00	1	855,447	Liq 63°
48	291	.88	191.52	492.53	1	855,447	Wet .2266
49	291	.9851	191.52	615.75	0.7734	661,638	SatVapor
50	291	.9851	191.52	615.75	0.7734	661,638	SatVapor
51	288	.9851	191.00	615.75	0.7734	661,638	Wet 0
52	285	.9851	190.48	615.75	0.7734	661,638	Wet 0
30	285	.9851	190.48	615.75	0.7734	661,638	Wet 0
31	98.15	.9851	100.36	558.89	0.7734	661,638	Wet .0314
32	97.15	.9851	100.00	558.89	0.7734	661,638	Wet .0313
9	291	.5211	191.52	71.86	0.2266	193,809	SatLiquid
10	290.50	.5211	191.41	71.86	0.2266	193,809	Wet .9997
11	287.60	.5211	139.18	11.13	0.2266	193,809	Liq 51°
12	278.90	.5211	128.03	–1.61	0.2266	193,809	Liq 60°
13	97.15	.5211	115.90	–1.61	0.2266	193,809	Wet .9758
33	97.15	.88	109.88	431.90	1	855,447	Wet .2518
29	97.05	.88	109.83	431.90	1	855,447	Wet .2517
14	95.60	.88	60.40	–8.22	1	855,447	SatLiquid
25	•	Brine	198	166.00	6.7721	5,793,204	
27	•	Brine	138.85	106.85	6.7721	5,793,204	
26	•	Brine	126.70	94.70	6.7721	5,793,204	

S34g OD HXs:	MW th	LMTD	ΔTs between streams					
HE–1	110.342	15.60	T29–T24	46.64	T14–T23	15.4		
HE–2	4.173	16.61	T10–T46	5.6	T11–T45	5.4	T12–T44	66.89
HE–3	121.055	16.29	T25–T43	5.3	T27–T42	4.22	T26–T41	65.56

The section above is a heat exchanger summary with duty, log-mean temperature differences, and relevant temperature differences.

A second SI version of the data contained in the last two pages is also included.

APPENDIX B3
KALINA KCS-34G SIZED EQUIPMENT LISTS

Technip

Project Number	Document Number	Revision	Page
LA032193	Kalina Cycle KCS-34g	A	1/4

CLIENT
Entiv Organic Energy
LOCATION
Lower Klamath Lakes
UNIT
GeoThermal - 9.6 MW Gross

EQUIPMENT LIST- HEAT EXCHANGERS

Revision	Date	Description	Checked	Approved
A	15-Jul-13	Issue for Information	CJS	

	REV	ITEM NUMBER	DESIGNATION	PDS REV	NB SHELLS	SHELL DIAMETER/ BUNDLE LENGTH/ TEMA TYPE in	ft	Tema	TOTAL DUTY MMBtu/h	TOTAL HEAT TRANSFER AREA ft2	MATERIALS +corr. Allow. (mm) TUBES SIDE	SHELL SIDE	DESIGN TEMPERATURE Water Side °F	Working Fluid Side °F	DESIGN PRESSURE Water Side psig	Working Fluid Side psig	REMARKS
1		HE-1	Condenser		4				362.780								Hybrid Shell and Plate Type, MOC 316 SS.
2		HE-2	Recuperator		1				13.009								Hybrid Shell and Plate Type, MOC 316 SS.
3		HE-3	Vaporizer		4				394.192								Hybrid Shell and Plate Type, MOC 316 SS.
4		HE-7	Electric Heater		1				0.5								Electric tank heater with a duty of 0.5 MMBtu/hr (reference plant).

Project Number	Document Number	Revision	Page
LA032193	Kalina Cycle KCS-34g	A	2/4

CLIENT
Entiv Organic Energy
LOCATION
Lower Klamath Lakes
UNIT
GeoThermal - 9.6 MW Gross

EQUIPMENT LIST- PUMPS

Revision	Date	Description	Checked	Approved
A	15-Jul-13	Issue for Information	CJS	

	REV	ITEM NUMBER	DESIGNATION	PDS REV	QUANTITY	TYPE OF DRIVER (1)	TYPE OF PUMP (2)	NORMAL FLOW. GPM	SUCTION PRESSURE psig	DIFFER. HEAD ft	DESIGN PUMPING TEMP. °F	MERCHANT SEAL TYPE (3)	ESTIMATE DESIGN POWER CONSUMP kW	Materials CASING	Materials INTERN.	NPSH ALLOW. ft	REMARKS
1		P-1	Feed Pump		1	E	C	2540	99	815	200	D	370	CS	316 SS	7	1 - 100% Pump
2		P-4	Cooling Water Pump		2	E	C	20,500	0.5	95	125	S	490	CS	316 SS	20	2-50% pump
3		P-5	Demin Water Pump		1	E	C	7	0.4	361	110	S	15	SS	316 SS	25	1 - 100% pumps
4		P-6	Geofluid Pump		3	E	C	6000			250		300	CS	316 SS		2 pumps are installed, the other pump is a warehouse spare. Power Estimate by Mannvit
5		P-7	Relief Blowdown Tank Pump		1	E	C	320	3	30	60	D	9	CS	316 SS	30	1 - 100% pumps
6		P-8	Fire Water Pump		1	D	C	3000	3	55	60	S	62	CS	316 SS	33	1- 100% Pumps required (Diesel drive)

(1) T : Turbine D : Diesel motor E : Electric motor VE : Variable speed Electric motor
(2) C : Centrifugal R : Reciprocating M : Metering
(3) S : Simple D : Double T : Tandem

Technip

Project Number	Document Number	Revision	Page
LA032193	Kalina Cycle KCS-34g	A	3/4

CLIENT
Entiv Organic Energy
LOCATION
Lower Klamath Lakes
UNIT
GeoThermal - 9.6 MW Gross

EQUIPMENT LIST- DRUMS

Revision	Date	Description	Checked	Approved
A	15-Jul-13	Issue for Information	CJS	

	REV	ITEM NUMBER	DESIGNATION	PDS REV	QUANTITY	INTERNAL DIAM I.D. ft	HEIGHT OR LENGTH T.L. to T.L. ft	DRUM POSITION (1)	DESIGN TEMP. °F	DESIGN PRESSURE psig	MATERIALS corrosion allowance (in.) (3)	HEAD TYPE (2)	BOOT (4) INTERNAL DIAMETER I.D. in	BOOT (4) HEIGHT T.L. to T.L. ft	REMARKS
1		S-1	Expander Inlet KO Drum		1	12'-0"	16'-2"	V	250	470	C.S + 1/8"	E	---	---	
2		V-1	Accumulator		1	10'-6"	35'-6"	V	200	200/FV	C.S + 1/8"	E	---	---	
3		V-3	Demin. Water Tank		1	8' - 0"	7' - 0"	V	110	1)	SS		---	---	1) Tank Design Pressure is ATM + Liq Level per API 650 (Use sizing of Reference Plant)
4		V-4	Pressurized Ammonia Tank		1	5'-0"	22'-6"	H	150	250	C.S + 1/8"	E	---	---	Use Reference Plant size - sized to hold one truck load of ammonia.
5		V-5	Blowdown Flare Tank		1	18'-0"	36'-0"	V	150	1)	C.S + 1/8"		---	---	1) Tank Design Pressure is ATM + Liq Level per API 650 (Use sizing of Reference Plant)
6		V-6	Fire Water Tank		1	45'-0"	37'-0"	V	150	1)	C.S + 1/8"	N/A	---	---	1) Tank Design Pressure is ATM + Liq Level per API 650 (Use sizing of Reference Plant)
7		V-7	Geofluid Flash Tank		1	13' - 0"	60' - 0"	H	250	200	C.S + 1/8"	E	---	---	
8															
9															
10															
11															
12															
13															
14															

(1) H : Horizontal V : Vertical
(2) E : Elliptical H : Hemispherical F : Flat
(3) Cladding material and surface (ft3) are to be specified in column REMARKS
(4) The material and the lining of the boot are to be specified in column REMARKS if different from those of the shell

Technip

Project Number	Document Number	Revision	Page
LA032193	Kalina Cycle KCS-34g	A	4/4

CLIENT
Entiv Organic Energy
LOCATION
Lower Klamath Lakes
UNIT
GeoThermal - 9.6 MW Gross

EQUIPMENT LIST- MISCELLANEOUS

Revision	Date	Description	Checked	Approved
A	15-Jul-13	Issue for Information	CJS	

	REV	ITEM NUMBER	DESIGNATION	PDS REV	QUANTITY	DESIGN FLOWRATE	REMARKS
1		F-1	Expander Filter		1		By Expander Vendor
2		G-1	Generator		1	9.6 MW Gross	By Vendor
3		T-1	Expander		1		By Vendor
4		X-1	Cooling Tower		1	400 MMBtu/hr	By Vendor (Number of bays TBD)
5		X-3	Instrument Air Package		1	100 SCFM	Delivery Pressure : 100 psig. Delivery Temperature = 95degF. Dew Point = -40degF. Oil Content = 0.1 ppmw max.
6		X-4	Chemical Dosing Unit		1		For cooling tower
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							

APPENDIX B4

KALINA KCS-34G ELECTRIC LOAD LISTS (INCLUDES AUXILLARY LOADS; E.G. LIGHTING, HVAC, ETC.)

Client : ENTIV ORGANIC ENERGY

ELECTRICAL LOAD LIST

LOWER KLAMATH HILLS, GEOTHERMAL PLANT

A	**2/5/2013**	**FOR INFORMATION**			
REV.	**DATE**	**STATUS**	**WRITTEN BY**	**CHECKED BY**	**APPROVED BY**
			(NAME & SIGN)	(NAME & SIGN)	(NAME & SIGN)
DOCUMENT REVISIONS					

Electrical Load Schedule

Technip

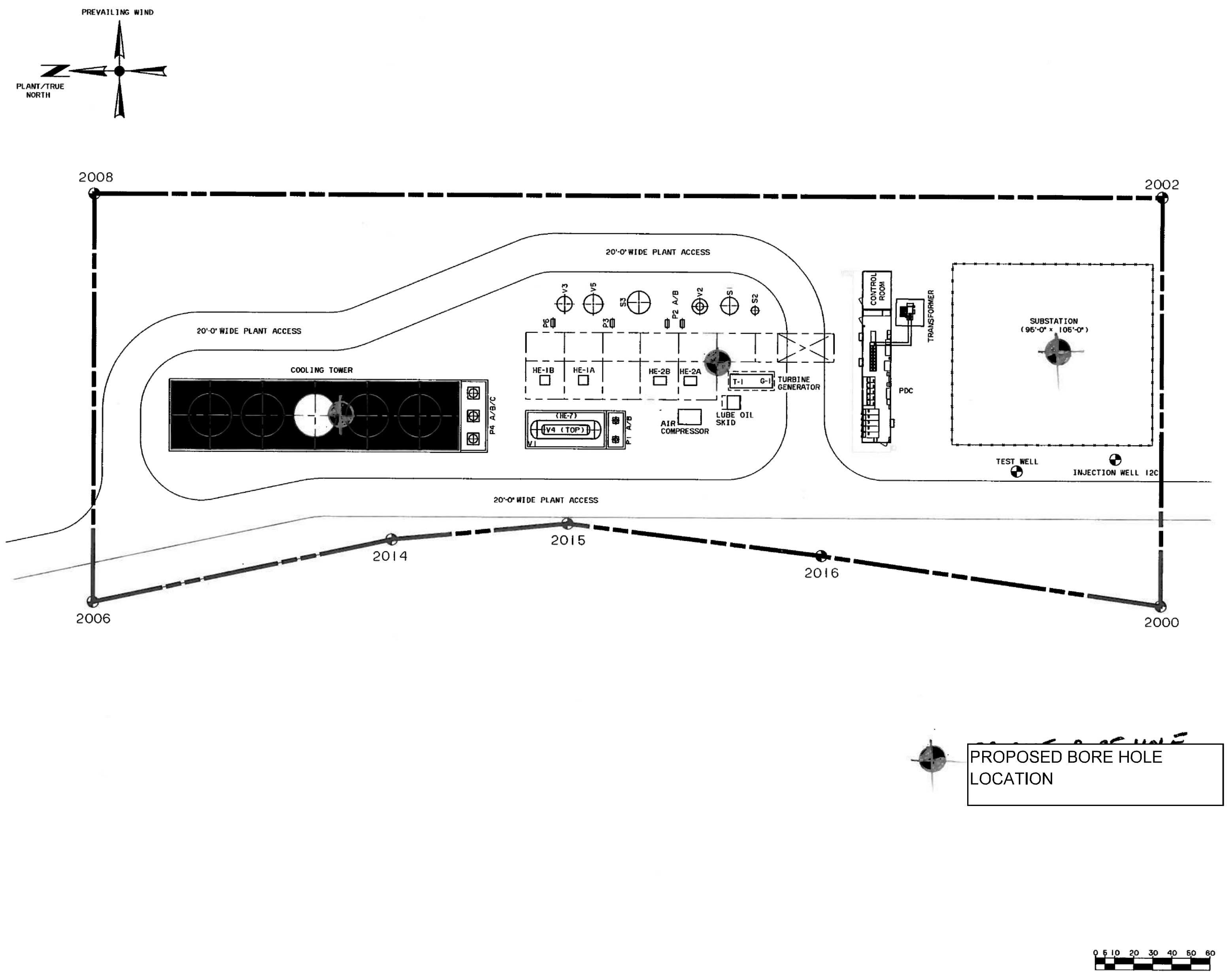
REV. NO	S/N	TAG NO.	DESCRIPTION	DUTY	VOLTAGE (V)	MOTOR LOADS			STATIC LOADS		EFFICIENCY	POWER FACTOR	CALCULATED LOAD						REMARKS
				C/I/S		BkW	BHP	NAMEPLATE RATING (HP)	ABSORBED LOAD kW	FULL LOAD kW			CONTINUOUS kW	CONTINUOUS kVAR	INTERMITTENT kW	INTERMITTENT kVAR	STANDBY kW	STANDBY kVAR	
A	1	MP-1	Feed Pump Motor	C	4000	200	268,20	300			95,6%	0,86	209,21	124,13	-	-	-	-	
A	2	MP-3	Ammonia Condensate Pump Motor	C	460	3	4,02	7,5			91,7%	0,86	3,27	1,94	-	-	-	-	
A	3	MP-4	Cooling Water Pump Motor	C	4000	385	516,29	600			95,7%	0,875	402,30	222,59	-	-	-	-	
A	4	MP-5	Demin Water Pump Motor	C	460	15	20,12	25			93,6%	0,84	16,03	10,35	-	-	-	-	
A	5	MP-6	Geofluid Pump Motor	C	4000	300	402,31	500			95,5%	0,863	314,14	183,90	-	-	-	-	
A	6	MP-7	Relief Blowdown Tank Pump Motor	C	460	4,5	6,03	10			91,7%	0,87	4,91	2,78	-	-	-	-	
A	7	MP-8A	Fire Water Pump Motor	C	460	50	67,05	100			95,4%	0,88	52,41	28,29	-	-	-	-	
A	8	MB-01	Cooling Tower Fan Motor	C	460	99,77	133,79	150			94,1%	0,87	106,03	60,09	-	-	-	-	
A	9	MB-02	Cooling Tower Fan Motor	C	460	99,77	133,79	150			94,1%	0,87	106,03	60,09	-	-	-	-	
A	10	MB-03	Cooling Tower Fan Motor	C	460	99,77	133,79	150			94,1%	0,87	106,03	60,09	-	-	-	-	
A	11	MB-04	Cooling Tower Fan Motor	C	480	99,77	133,79	150			94,1%	0,87	106,03	60,09	-	-	-	-	
A	12	MB-05	Cooling Tower Fan Motor	C	460	99,77	133,79	150			94,1%	0,87	106,03	60,09	-	-	-	-	
A	13		Ammonia Vapor Chiller Compressor Motor	C	460	5,6	7,51	10			91,7%	0,87	6,11	3,46	-	-	-	-	
A	14		Ammonia Vapor Chiller Blower Motor	C	460	0,52	0,70	1			85,5%	0,88	0,61	0,33	-	-	-	-	
A	15		Jockey Pump Motor for Fire Water Diesel Pump	I	460	1,5	2,01	5			89,5%	0,86	-	-	1,68	0,99	-	-	
A	16	HE-07	Pressurized Ammonia Tank Electrical Heater	C	460				15	20	90,0%	0,85	16,67	10,33	-	-	-	-	
A	17		Instrument Air Compressor Motor	C	460	30	40,23	50			94,5%	0,83	31,75	21,33	-	-	-	-	
A	18		Package unit / Auxiliary Load # 1	C	480				10	15	90,0%	0,85	11,11	6,89	-	-	-	-	
A	19	X2	Refrigeration Unit for Non-condensable Gas Removal	C	460	5,6	7,51	10			91,7%	0,87	6,11	3,46	-	-	-	-	
A	20		Lube Oil Auxiliary Pump Motor	C	460	19	25,48	30			93,6%	0,83	20,30	13,64	-	-	-	-	
A	21		Lube Oil Auxiliary Pump Motor	S	460	19	25,48	30			93,6%	0,83	-	-	-	-	20,30	13,64	
A	22		Generator Reservoir Immersion Heater	I	460				24	30	90,0%	0,85	-	-	26,67	16,53	-	-	
A	23		Generator Lube Oil Cooler Fan Motor	C	460	5,6	7,51	10			91,7%	0,87	6,11	3,46	-	-	-	-	
A	24		Chemical Injection Unit	C	460	1,5	2,01	3			89,5%	0,84	1,68	1,08	-	-	-	-	
A	25		Lube Oil Tank Heater # 1	S	460				8	10	90,0%	0,85	-	-	-	-	8,89	5,51	
A	26		Oil/Air Cooler Fan Motor	C	460	0,5	0,67	1			85,5%	0,88	0,58	0,32	-	-	-	-	
A	27		Vacuum Pump Motor	C	460	6		10			91,7%	0,87	0,00	0,00	-	-	-	-	
A	28		Uncondensable Gas Removal System	C	480				1	1,5	90,0%	0,85	1,11	0,69	-	-	-	-	
A	29		Generator Cooling Fan Motor	C	460	15	20,12	25			93,6%	0,84	16,03	10,35	-	-	-	-	
A	30		Generator Cooling Fan Motor	C	460	15	20,12	25			93,6%	0,84	16,03	10,35	-	-	-	-	
A	31		Oil Mist Eliminator	C	480				3	4	90,0%	0,85	3,33	2,07	-	-	-	-	
A	32		Seal Gas Heater	C	480				15	20	90,0%	0,85	16,67	10,33	-	-	-	-	
A	33		DCP for Generation Unit Control Panels	C	480				15	20	90,0%	0,85	16,67	10,33	-	-	-	-	
A	34		UPS Panel for Generation Unit Control Panels	S	480				14,5	18	90,0%	0,85	-	-	-	-	16,11	9,98	
A	35		Generator Space Heater	S	480				2	3	90,0%	0,85	-	-	-	-	2,22	1,38	

Electrical Load Schedule

REV. NO	S/N	TAG NO.	DESCRIPTION	DUTY	VOLTAGE (V)	MOTOR LOADS			STATIC LOADS		EFFICIENCY	POWER FACTOR	CALCULATED LOAD						REMARKS
													CONTINUOUS		INTERMITTENT		STANDBY		
				C/I/S		BkW	BHP	NAMEPLATE RATING (HP)	ABSORBED LOAD kW	FULL LOAD kW			kW	kVAR	kW	kVAR	kW	kVAR	
A	36		Turbo Expander Enclosure Normal Lighting	C	480				1.5	2	90.0%	0.85	1.67	1.03	-	-	-	-	
A	37	DCP-01	Auxiliary Service Panel	C	480				15	24	90.0%	0.85	16.67	10.33	-	-	-	-	
A	38	UPS-01	Welding Receptacle Feeder	S	480				30	40	90.0%	0.85	-	-	-	-	33.33	20.66	
A	39		Substation/MCC Building Load HVAC	C	480				25	36	90.0%	0.85	27.78	17.22	-	-	-	-	
A	40		Control Room HVAC	C	480				30	45	90.0%	0.85	33.33	20.66	-	-	-	-	
A	41	ASP	Plant UPS System Feeder	C	480				20	24	90.0%	0.85	22.22	13.77	-	-	-	-	
A	43		DC System Battery Charger	C	480				3.5	5	90.0%	0.85	3.89	2.41	-	-	-	-	
A	44		Lighting Transformer	C	480				15	24	90.0%	0.85	16.67	10.33	-	-	-	-	
A	45	00-DCP	Small Power / Receptacle Transformer	S	480				15	24	90.0%	0.85	-	-	-	-	16.67	10.33	
A	46	00-DCP	HV Substation Control Room	C	480				30	36	90.0%	0.85	33.33	20.66	-	-	-	-	
A	47		EHT Transformer / Panel	I	480				25	30	90.0%	0.85	-	-	27.78	17.22	-	-	
TOTAL LOADS													**1860.15**	**1095.30**	**56.04**	**34.73**	**114.19**	**71.83**	
TOTAL CONSUMED LOADS													**1860.15**	**1095.30**	**16.81**	**10.42**	**0.00**	**0.00**	

	KVA	KW	KVAR
TOTAL RUNNING LOAD	2178.44	1876.96	1105.72

APPENDIX B5
KALEX SG-16 PLOT PLANS



GENERAL NOTES

PLANT COORDINATES			
POINT	LATITUDE	LONGITUDE	ELEVATION
2000	41.9066257N	-121.6450443W	4085.063
2002	41.90662662N	-121.6442543W	4111.101
2006	41.90816236N	-121.6450481W	4085.394
2008	41.90816373N	-121.6442584W	4128.639
2014	41.90773309N	-121.6449236W	4085.06
2015	41.90748028N	-121.6448911W	4085.06
2016	41.9071141N	-121.6449506W	4085.06

DRAWING NO.	DESCRIPTION

REFERENCE DRAWINGS

REV	DATE	DESCRIPTION	PREP	CKD	APPR	DM/PM
B	12-12-12	FOR INFORMATION	GS			
A	11-27-12	FOR INFORMATION	GS			

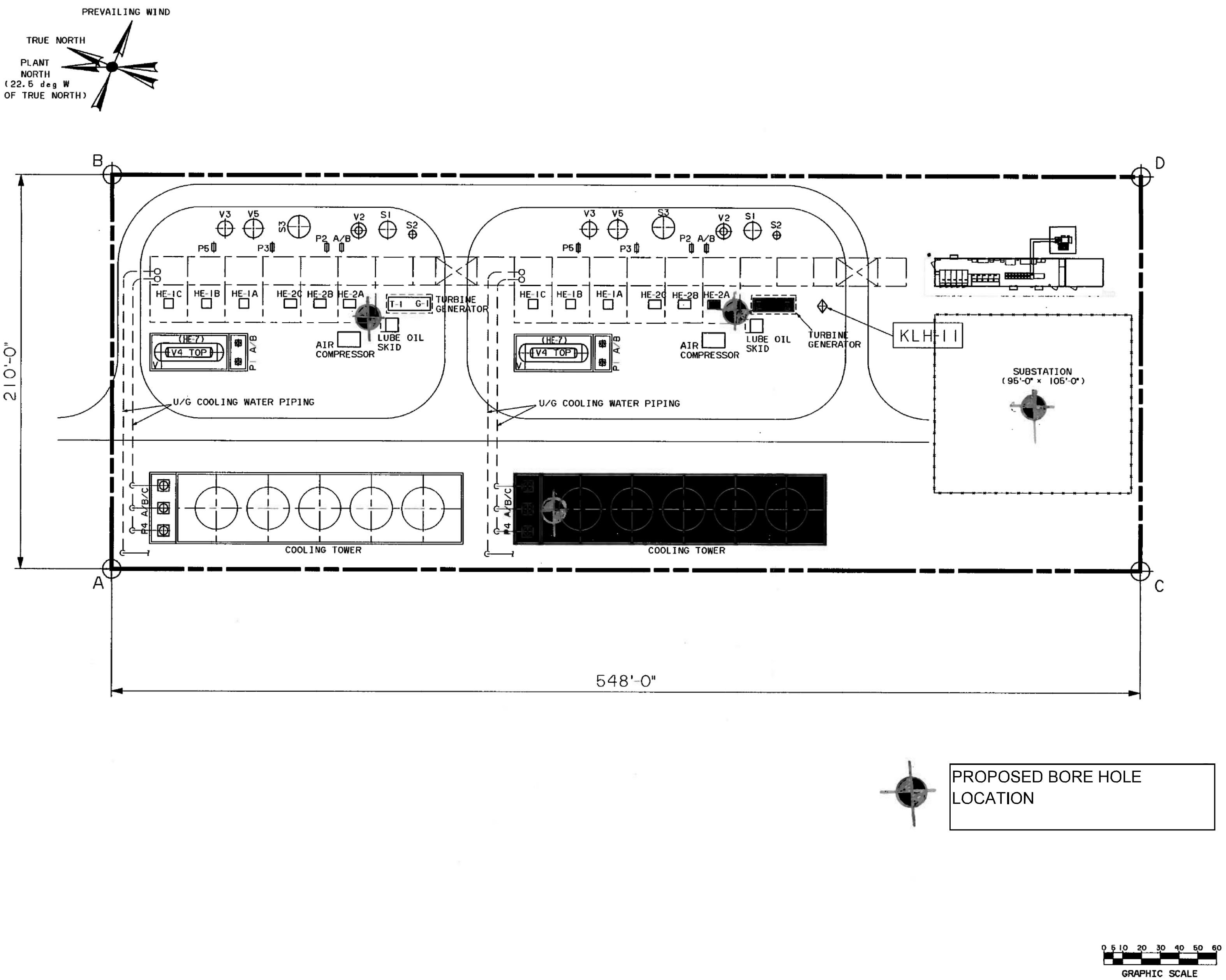
Technip
MANNVIT

ENTIV — LOWER KLAMATH LAKE, CA

ENTIV ORGANIC ENERGY LLC
KALEX SG-16 5.5 MW GEOTHERMAL PLANT
PLOT PLAN

SCALE	DRAWING NO.	PAGE	REV
1"=25'	LA032193 DW 00 51 002	1	B

TO-20-186-0



GENERAL NOTES

A	42.05080447 N -121.7388191W
B	42.05102508 N -121.738104 W
C	42.04941526 N -121.738047 W
D	42.04963577 N -121.737332 W
KLH-11	42.04999288 N -121.7378081 W

REFERENCE DRAWINGS

DRAWING NO.	DESCRIPTION

REV	DATE	DESCRIPTION	PREP	CKD	APPR	DM/PM
B	12-12-12	FOR INFORMATION	GS			
A	11-28-12	FOR INFORMATION	GS			

Technip

ENTIV

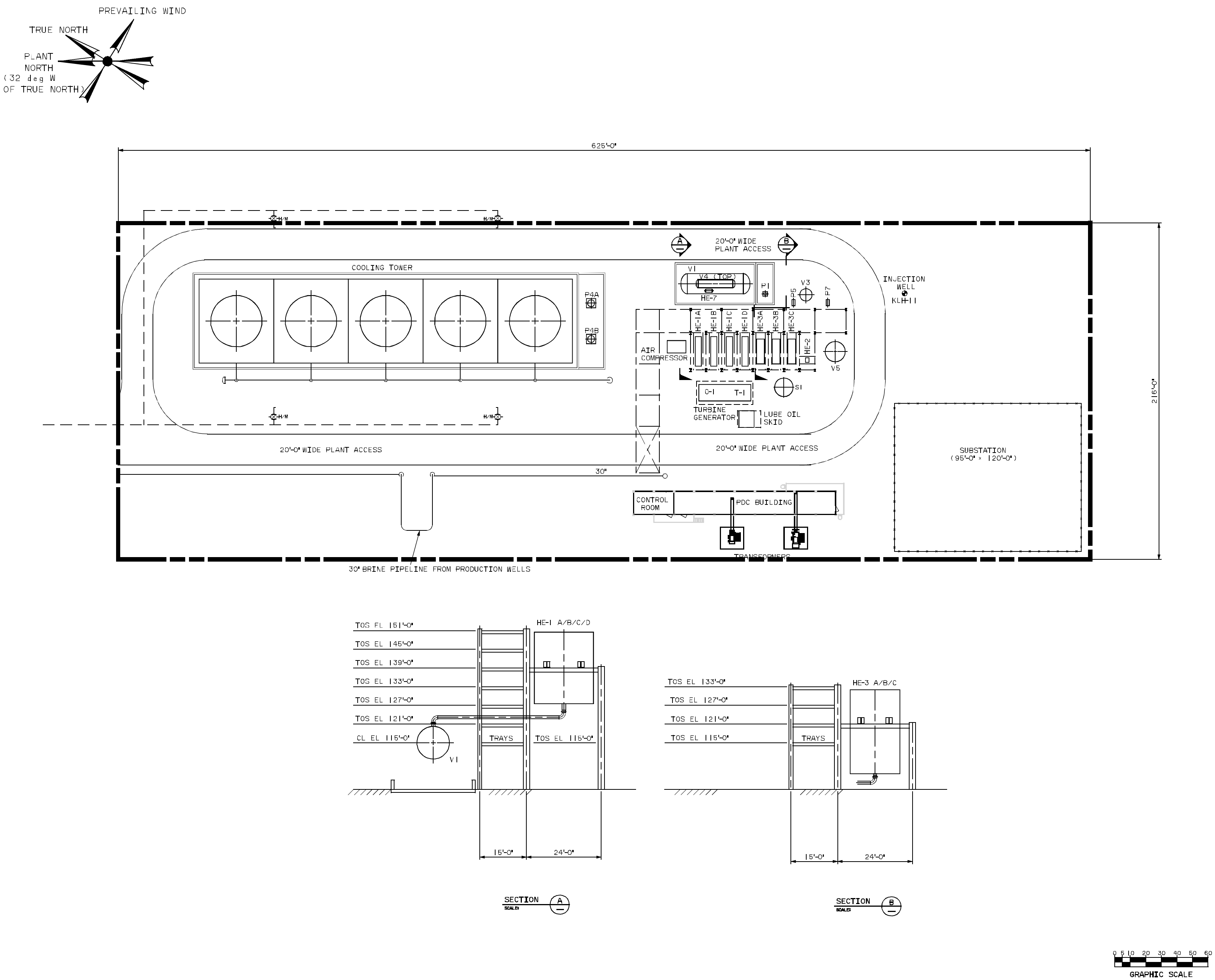
MANNVIT

HILLS
KLAMATH [redacted], OR.

ENTIV ORGANIC ENERGY LLC
KALEX SG-16 5.5 MW GEOTHERMAL PLANT
PLOT PLAN

SCALE	DRAWING NO.						PAGE	REV
	PROJECT	UNIT	DOC TYPE	DISC	SUBJ	SER. NO		
1" = 25'	LA032193		DW	00	51	001	1	B

APPENDIX B6
KALINA KCS-34G PLOT PLANS



GENERAL NOTES

KLH-11 42.04999288 N
-121.7378081 W

DRAWING NO.	DESCRIPTION

REFERENCE DRAWINGS

REV	DATE	DESCRIPTION	PREP	CKD	APPR	DM/PM
D	07-16-13	REVISED FOR INFORMATION	GS			
C	07-08-13	REVISED FOR INFORMATION	GS			
B	04-24-13	REVISED FOR INFORMATION	GS			
A	04-17-13	FOR INFORMATION	GS			

Technip
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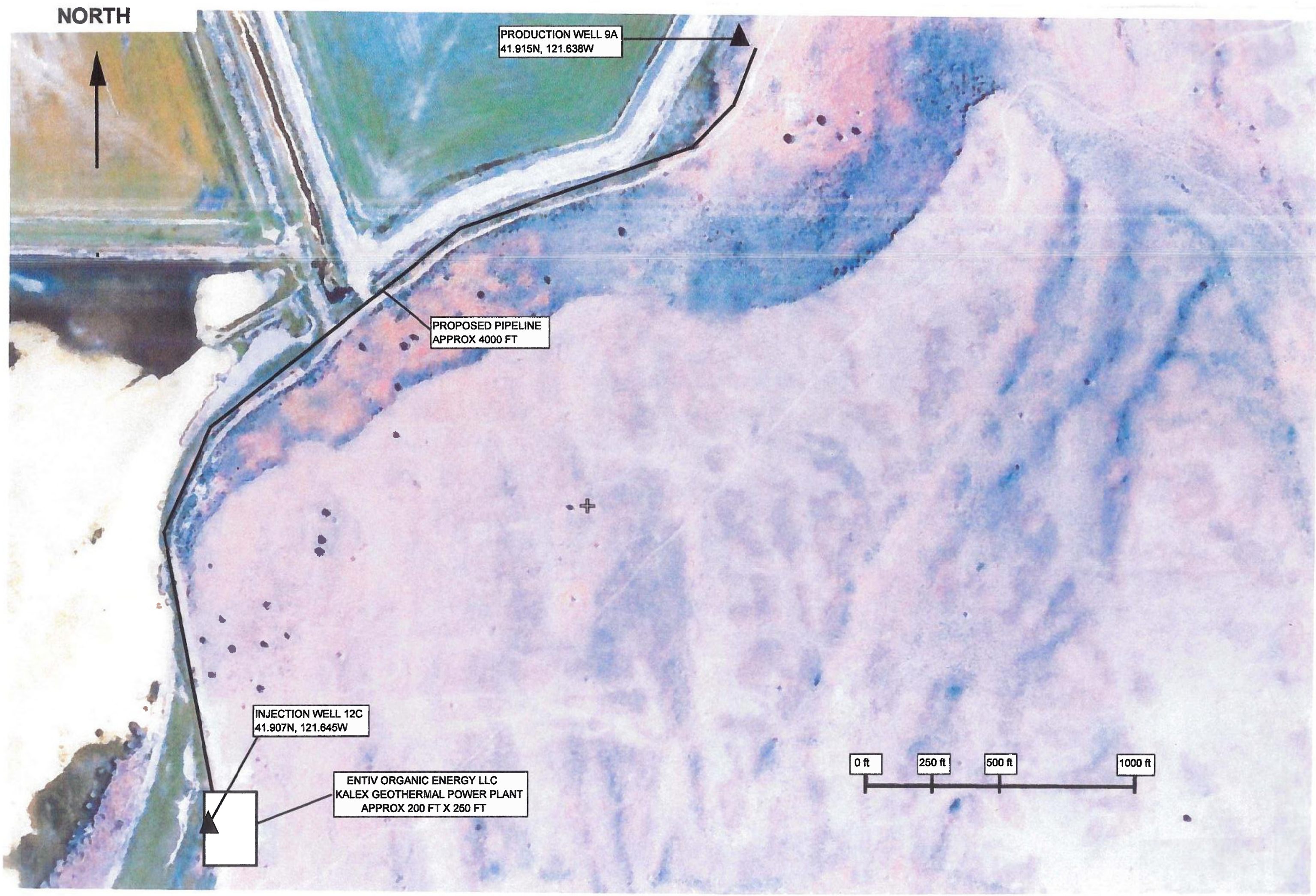
ENTIV — KLAMATH HILLS, OR.

ENTIV ORGANIC ENERGY LLC
KALINA KCS 34g 9.6 MW GEOTHERMAL
POWER PLANT - PLOT PLAN

SCALE	DRAWING NO.	PAGE	REV
1" = 30'	LA032193 DW 00 51 003 (PROJECT UNIT DOC TYPE DISC SUBJ SER.NO)	1	D

TD-20-156-0

APPENDIX B7
GEOSOURCE PIPELINE ROUTING



DRAWING NO.	DESCRIPTION
	REFERENCE DRAWINGS

REV	DATE	DESCRIPTION	PREP	CKD	APPR	DM/PM
A	04-05-12	FOR INFORMATION	GS			

Technip

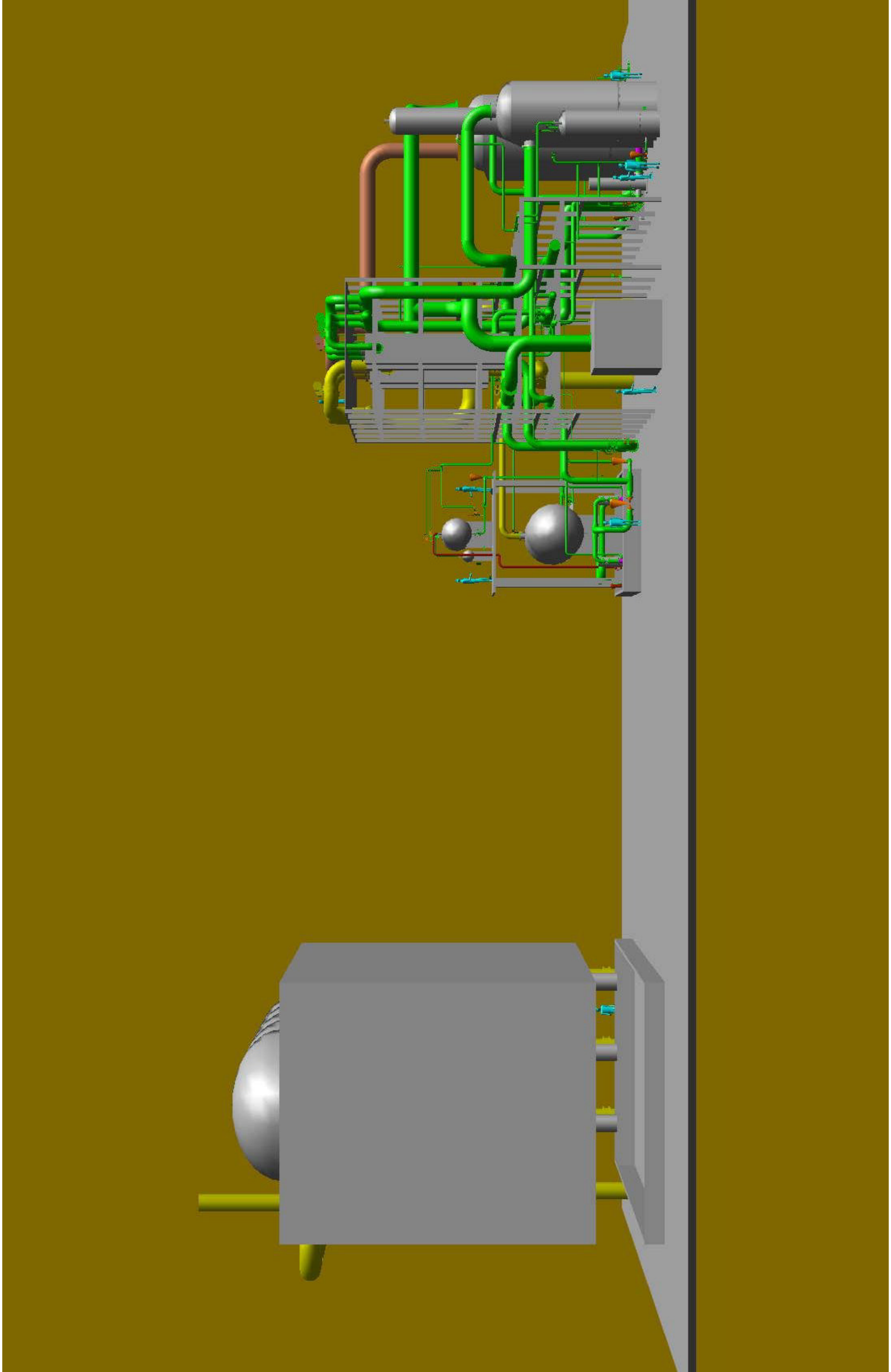
MANNVIT

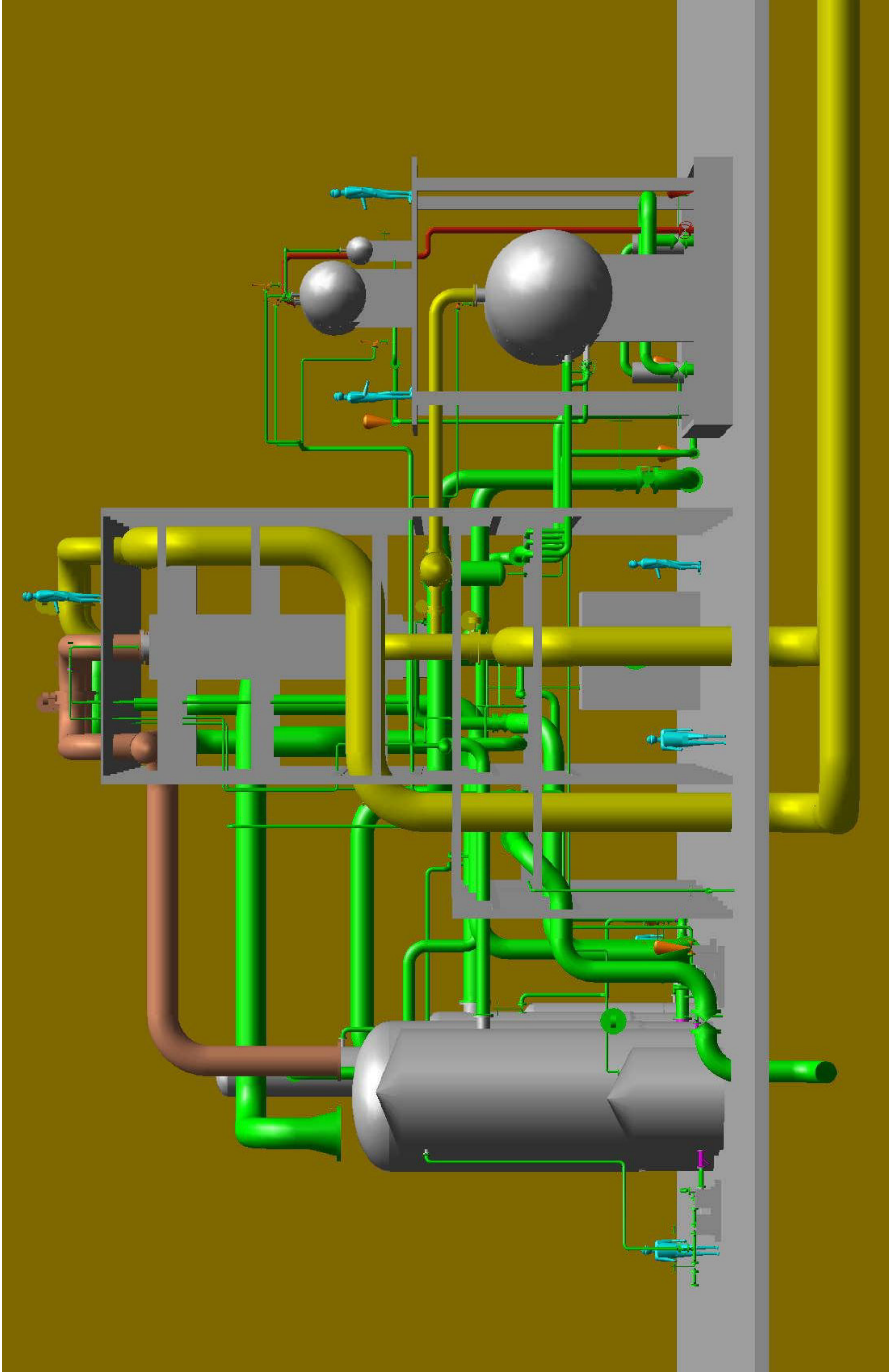
SITE PLAN
ENTIV ORGANIC ENERGY LLC
KALEX GEOTHERMAL POWER PLANT

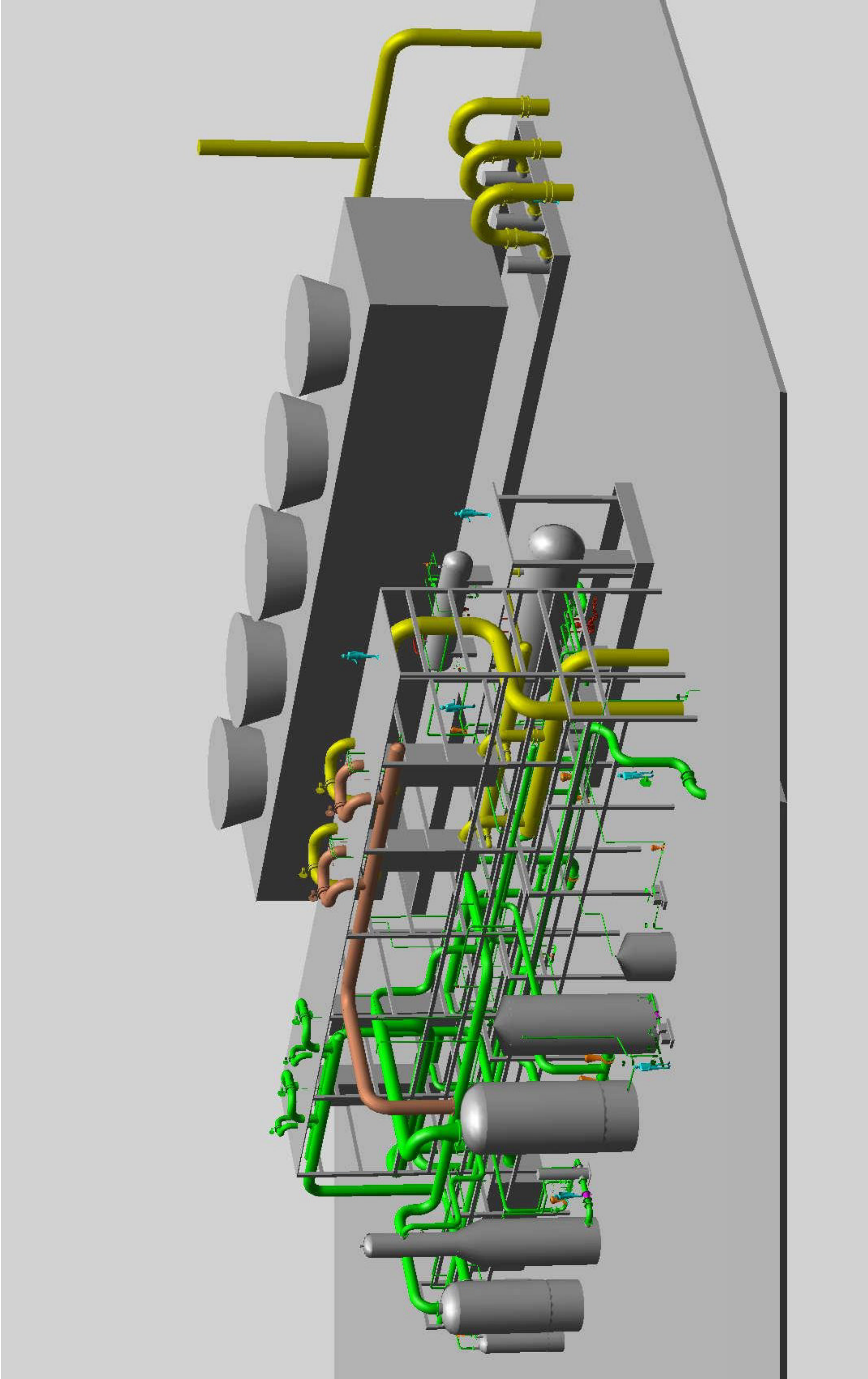
SCALE	DRAWING NO.	PAGE	REV
	LA72I855 (PROJECT) DW (UNIT) 00 (DOC TYPE) 5 (DISC) I (SUBJ) 002 (SER.NO)	I	A

APPENDIX B8

KALEX SG-16 ISO ELEVATION RENDERINGS







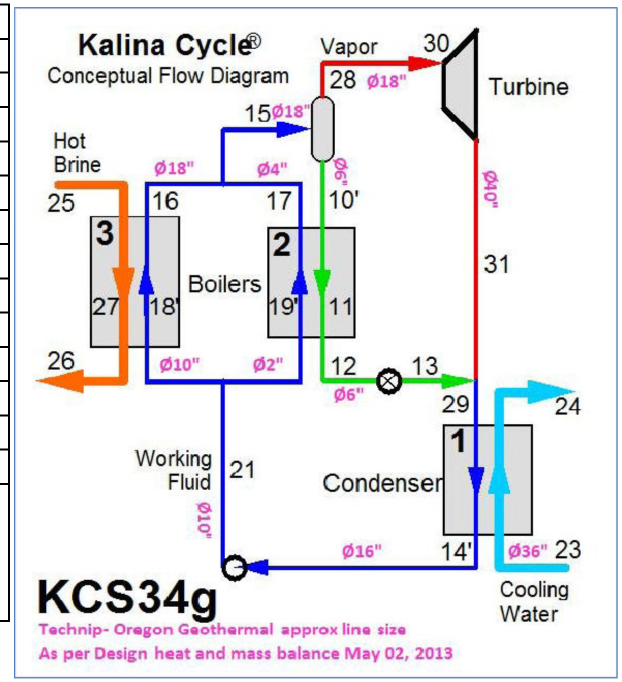
APPENDIX B9
KALINA KCS-34G SIZED PIPING LINES

Line size information for the Oregon Geothermal (Technip), project							6/10/2013
Recurrent's P&ID points	Mass flow (Q)	Sp. Volume	Volume Flow	Velocity* (v)	Area (A)	Diameter (d)	Line size (Round off value)
	lb/hr	ft³/lb	ft³/sec	ft/sec	ft^2	inch	Inch
21 to 16	841,380	0.024185	5.65	13.92	0.4061	8.63	10"
16 to 15	813,790	0.92685	209.52	133.34	1.5713	16.97	18"
17 to 15	27,590	0.89707	6.88	132.00	0.0521	3.09	4"
28 to 30	647,192	1.1973	215.25	132.63	1.6229	17.25	18"
31 to 13	647,192	2.8827	518.24	65.62	7.8980	38.05	40"
From CT	20,599,560	0.016025	91.70	13.92	6.5874	34.75	36"
14 to feed pump suction	841,380	0.024203	5.66	4.46	1.2683	15.25	16"
Feed pump discharge	841,380	0.024185	5.65	10.32	0.5477	10.02	10"
Minimum circulation line	252,414	0.024185	1.70	8.45	0.2007	6.07	6"
Separator to HE-2	194,188	0.021604	1.17	5.81	0.2006	6.06	6"
12 to 13	194,188	0.0206	1.11	5.54	0.2006	6.06	6"

Notes:

(1) The line size is based on design heat balance dated 05/02/2013. This needs to varify with off design heat balances.

(2) Velocity selected based on conventional power plants proven velocities



APPENDIX B10
COST ESTIMATE
LOWER KLAMATH LAKE, CA.
SINGLE KALINA SG-16 TRAIN.

B10 - Summary Price Sheet 4.3 MW Power Plant – Single Train SG-16

ITEM	DESCRIPTION	PROJECT COST (kUSD) POWER PLANT (5.5 MW)	ELECTRICAL SUBSTATION	PIPELINE (PROVISION)	LICENSE FEE	TOTAL PROJECT COST (kUSD)	Weight (%)
1	**ENGINEERING SERVICES**	**5,128**		**480**	**350**	**5,959**	**14.7%**
1.1	Technip Engineering Services	4,872		457		5,329	13.2%
1.2	Manvit Engineering Support	256		24		280	0.7%
1.3	KALEX License				350	350	0.9%
2	**PROCUREMENT COSTS**	**18,270**		**1,669**		**19,939**	**49.4%**
2.1	**PROCESS EQUIPMENT COST**	**11,723**		**720**		**12,443**	**30.8%**
2.1.1	Cooling Tower (EPC Lump Sum - Supply)	1,443				1,443	3.6%
2.1.2	Pressure Vessels	600		434		1,033	2.6%
2.1.3	Heat Exchangers	4,691				4,691	11.6%
2.1.4	Pumps	533		286		820	2.0%
2.1.5	Turbo Generator	3,739				3,739	9.3%
2.1.6	Storage Tanks	475				475	1.2%
2.1.7	General Packages	243				243	0.6%
2.2	**MAIN BULK MATERIAL**	**5,178**		**840**		**6,018**	**14.9%**
2.2.1	Piping, Valves & Fittings (d > 3")	1,317		529		1,846	4.6%
2.2.2	Instrument & Instrumentation materials	521				521	1.3%
2.2.3	Systems (DCS)	483				483	1.2%
2.2.4	PDC Building (EPC Lump Sum - Supply)	1,861				1,861	4.6%
2.2.5	Power cables / transformers & Electrical materials	716		311		1,028	2.5%
2.2.6	Steel Structure	279				279	0.7%
2.2.6	Fire Fighting Equipment						
2.3	**SPARE PARTS**	**89**		**7**		**95**	**0.2%**
2.3.1	Precommissioning Spare parts	39		3		42	0.1%
2.3.2	Commissioning Spare parts	50		4		54	0.1%
2.4	**TRANSPORTATION COSTS**	**1,280**		**103**		**1,383**	**3.4%**
2.4.1	Transportation to Site	1,280		103		1,383	3.4%
3	**CONSTRUCTION COSTS**	**7,031**	**2,379**	**2,033**		**11,442**	**28.3%**
3.1	**POWER PLANT & PIPELINE**	**7,031**		**2,033**		**9,063**	**22.4%**
3.1.1	Site Preparation	537				537	1.3%
3.1.2	General Civil Works	74				74	0.2%
3.1.3	Concrete works	1,097				1,097	2.7%
3.1.4	Piping prefabrication & erection	2,316		1,445		3,761	9.3%
3.1.5	Instrumentation Works	415				415	1.0%
3.1.6	Electrical works	382		326		708	1.8%
3.1.7	Structural Steel erection	270				270	0.7%
3.1.8	Insulation works	152				152	0.4%
3.1.9	Painting works	120				120	0.3%
3.1.10	Storage Tanks Erection	128				128	0.3%
3.1.11	Mechanical Erection & Hoisting	531		132		663	1.6%
3.1.11	Heavy lift	281		56		338	0.8%
3.1.12	Scaffolding, fire & hole watch	521				521	1.3%
3.1.13	Temporary Facilities						
3.1.14	Reworks in Construction Works	205		73		278	0.7%
3.2	**ELECTRICAL SUBSTATION 69kV**		**2,379**			**2,379**	**5.9%**
3.2.1	Electrical Substation 69kV works (EPC Lump Sum)		2,379			2,379	5.9%
4	**CONSTRUCTION SUPERVISION COSTS**	**505**		**133**		**638**	**1.6%**
4.1	Construction Supervision	479		126		605	1.5%
4.2	Vendor Representatives	26		7		33	0.1%
5	**MISCELLANEOUS COSTS**	**203**		**54**		**257**	**0.6%**
5.1	Precomm.-Comm. & Start-Up Assistance	182		48		231	0.6%
5.2	Construction Direct Labor Subcontract						
5.3	Vendor Representatives	21		6		26	0.1%
5	**CONTINGENCY**	**1,784**	**136**	**245**		**2,165**	**5.4%**
5.1	Overall Project Contingency	1,784	136	245		2,165	5.4%
	TOTAL PROJECT COST	**32,921**	**2,515**	**4,614**	**350**	**40,400**	**100.0%**

APPENDIX B11
COST ESTIMATE
KLAMATH HILLS. OR.
TWO KALEX SG-16 TRAINS.

B11 - Summary Price Sheet 8.6 MW Power Plant – Double Train SG-16

ITEM	DESCRIPTION	PROJECT COST (kUSD) POWER PLANT (8.6 MW)	ELECTRICAL SUBSTATION	PIPELINE (PROVISION)	LICENSE FEE	TOTAL PROJECT COST (kUSD)	Weight (%)
1	**ENGINEERING SERVICES**	**6,782**		**640**	**700**	**8,122**	**11.4%**
1.1	Technip Engineering Services	6,442		609		7,052	9.9%
1.2	Manvit Engineering Support	339		31		370	0.5%
1.3	KALEX License				700	700	1.0%
2	**PROCUREMENT COSTS**	**36,057**		**2,581**		**38,638**	**54.3%**
2.1	**PROCESS EQUIPMENT COST**	**23,447**		**1,440**		**24,887**	**35.0%**
2.1.1	Cooling Tower (EPC Lump Sum - Supply)	2,886				2,886	4.1%
2.1.2	Pressure Vessels	1,199		867		2,067	2.9%
2.1.3	Heat Exchangers	9,381				9,381	13.2%
2.1.4	Pumps	1,067		572		1,639	2.3%
2.1.5	Turbo Generator	7,478				7,478	10.5%
2.1.6	Storage Tanks	950				950	1.3%
2.1.7	General Packages	485				485	0.7%
2.2	**MAIN BULK MATERIAL**	**9,912**		**959**		**10,871**	**15.3%**
2.2.1	Piping, Valves & Fit ings (d > 3")	2,634		529		3,163	4.4%
2.2.2	Instrument & Instrumentation materials	1,041				1,041	1.5%
2.2.3	Systems (DCS)	965				965	1.4%
2.2.4	PDC Building (EPC Lump Sum - Supply)	1,861				1,861	2.6%
2.2.5	Power cables / transformers & Electrical materials	2,781		430		3,211	4.5%
2.2.6	Steel Structure	629				629	0.9%
2.2.6	Fire Fighting Equipment						
2.3	**SPARE PARTS**	**175**		**12**		**186**	**0.3%**
2.3.1	Precommissioning Spare parts	76		5		81	0.1%
2.3.2	Commissioning Spare parts	99		7		105	0.1%
2.4	**TRANSPORTATION COSTS**	**2,523**		**171**		**2,694**	**3.8%**
2.4.1	Transportation to Site	2,523		171		2,694	3.8%
3	**CONSTRUCTION COSTS**	**14,089**	**2,509**	**2,230**		**18,827**	**26.5%**
3.1	**POWER PLANT & PIPELINE**	**14,089**		**2,230**		**16,318**	**22.9%**
3.1.1	Site Preparation	1,073				1,073	1.5%
3.1.2	General Civil Works	149				149	0.2%
3.1.3	Concrete works	2,194				2,194	3.1%
3.1.4	Piping prefabrication & erection	4,632		1,445		6,077	8.5%
3.1.5	Instrumentation Works	831				831	1.2%
3.1.6	Electrical works	687		326		1,013	1.4%
3.1.7	Structural Steel erection	607				607	0.9%
3.1.8	Insulation works	304				304	0.4%
3.1.9	Painting works	246				246	0.3%
3.1.10	Storage Tanks Erection	257				257	0.4%
3.1.11	Mechanical Erection & Hoisting	1,063		264		1,327	1.9%
3.1.11	Heavy lift	563		113		676	1.0%
3.1.12	Scaffolding, fire & hole watch	1,073		16		1,089	1.5%
3.1.13	Temporary Facilities						
3.1.14	Reworks in Construction Works	410		66		476	0.7%
3.2	**ELECTRICAL SUBSTATION 69kV**		**2,509**			**2,509**	**3.5%**
3.2.1	Electrical Substation 69kV works (EPC Lump Sum)		2,509			2,509	3.5%
4	**CONSTRUCTION SUPERVISION COSTS**	**1,011**		**148**		**1,159**	**1.6%**
4.1	Construction Supervision	959		140		1,099	1.5%
4.2	Vendor Representatives	52		8		60	0.1%
5	**MISCELLANEOUS COSTS**	**407**		**62**		**469**	**0.7%**
5.1	Precomm.-Comm. & Start-Up Assistance	365		56		420	0.6%
5.2	Construction Direct Labor Subcontract						
5.3	Vendor Representatives	42		6		48	0.1%
5	**CONTINGENCY**	**3,435**	**143**	**322**		**3,900**	**5.5%**
5.1	Overall Project Contingency	3,435	143	322		3,900	5.5%
	TOTAL PROJECT COST	**61,781**	**2,652**	**5,982**	**700**	**71,115**	**100.0%**

APPENDIX B12
COST ESTIMATE
KLAMATH HILLS, OR
KALINA KCS-34G

Technip

Client	ENTIV Organic Energy LLC.	Basis Price	2Q 2013	Job	LA032193
Job Location	Klamath Hills, OR	Currency	10^3 USD	Date	15-Aug-13
Installation	Geothermal Power Plant - Kalina Cycle ™	Rate / USD	1	Revision	B
Capacity	**1 Trains x 9.7 MW Gross (@ 198ºF)**	Project Scope	EPC	By	RR
Associate		Type of Contract	LS	Accuracy:	**+/- 30%**

COST BREAKDOWN STRUCTURE

ITEM	DESCRIPTION	PROJECT COST (kUSD) POWER PLANT (9.7 MW)	ELECTRICAL SUBSTATION	PIPELINE (PROVISION)	LICENSE FEE	TOTAL PROJECT COST (kUSD)	Weight (%)
1	**ENGINEERING SERVICES**	**8,322**				**8,322**	**14.5%**
1.1	Technip Engineering Services	7,138				7,138	12.5%
1.2	Manvit Engineering Support	305				305	0.5%
1.3	Recurrent License Fee & Process Book	879				879	1.5%
2	**PROCUREMENT COSTS**	**26,468**		**2,313**		**28,781**	**50.2%**
2.1	**PROCESS EQUIPMENT COST**	**16,576**		**1,120**		**17,695**	**30.9%**
2.1.1	Cooling Towers	2,056				2,056	3.6%
2.1.2	Pressure Vessels	617		195		812	1.4%
2.1.3	Heat Exchangers	5,549				5,549	9.7%
2.1.4	Pumps	847		450		1,297	2.3%
2.1.5	Turbo Generator	6,847				6,847	11.9%
2.1.6	Storage Tanks	199		207		407	0.7%
2.1.7	General Packages	459		268		727	1.3%
2.2	**MAIN BULK MATERIAL**	**8,133**		**1,023**		**9,155**	**16.0%**
2.2.1	Piping, Valves & Fittings (d > 3")	2,352		820		3,173	5.5%
2.2.2	Instrument & Instrumentation materials	448				448	0.8%
2.2.3	Systems (DCS)	289				289	0.5%
2.2.4	PDC Building (EPC Lump Sum - Supply)	2,797				2,797	4.9%
2.2.5	Power cables / transformers & Electrical materials	1,263		202		1,465	2.6%
2.2.6	Steel Structure	984				984	1.7%
2.2.6	Fire Fighting Equipment						
2.3	**SPARE PARTS**	**128**		**12**		**140**	**0.2%**
2.3.1	Precommissioning Spare parts	56		5		61	0.1%
2.3.2	Commissioning Spare parts	72		7		79	0.1%
2.4	**TRANSPORTATION COSTS**	**1,632**		**158**		**1,791**	**3.1%**
2.4.1	Transportation to Site	1,632		158		1,791	3.1%
3	**CONSTRUCTION COSTS**	**10,876**	**2,214**	**1,783**		**14,873**	**26.0%**
3.1	**POWER PLANT & PIPELINE**	**10,876**		**1,783**		**12,658**	**22.1%**
3.1.1	Site Preparation	1,482				1,482	2.6%
3.1.2	General Civil Works	52				52	0.1%
3.1.3	Concrete works	2,386				2,386	4.2%
3.1.4	Piping prefabrication & erection	2,010		1,419		3,429	6.0%
3.1.5	Instrumentation Works	553				553	1.0%
3.1.6	Electrical works	1,633		137		1,769	3.1%
3.1.7	Structural Steel erection	687				687	1.2%
3.1.8	Insulation works	164		41		204	0.4%
3.1.9	Painting works						
3.1.10	Storage Tanks erection	32				32	0.1%
3.1.11	Mechanical Erection & Hoisting	804		112		916	1.6%
3.1.12	Heavy lift	267		22		289	0.5%
3.1.13	Scaffolding, fire & hole watch	425				425	0.7%
3.1.14	Temporary Facilities						
3.1.15	Reworks in Construction Works	381		52		433	0.8%
3.2	**ELECTRICAL SUBSTATION 69kV**		**2,214**			**2,214**	**3.9%**
3.2.1	Electrical Substation 69kV works (EPC Lump Sum)		2,214			2,214	3.9%
4	**CONSTRUCTION SUPERVISION COSTS**	**1,582**	**64**	**73**		**1,718**	**3.0%**
4.1	Construction Supervision	1,491	51	59		1,601	2.8%
4.2	Vendor Representatives	91	12	14		117	0.2%
5	**MISCELLANEOUS COSTS**	**1,110**	**11**	**12**		**1,132**	**2.0%**
5.1	Precomm.-Comm. & Start-Up Assistance	648	1	1		649	1.1%
5.2	Construction Direct Labor Subcontract	202				202	0.4%
5.3	Vendor Representatives	73	10	11		94	0.2%
5.4	Custom Duties	186				186	0.3%
5	**CONTINGENCY**	**2,112**	**193**	**169**		**2,474**	**4.3%**
5.1	Overall Project Contingency	2,112	193	169		2,474	4.3%
	TOTAL PROJECT COST	**50,469**	**2,481**	**4,349**		**57,300**	**100.0%**

APPENDIX C – PERMITTING DOCUMENTS

C1 State Geothermal Resources Prospecting Permit

C2 Entiv-Notice of Records Due

C3 Lower Klamath Production Wells Cultural Survey, 2002

C4 US Department of Interior Fish and Wildlife Special Use Permit

APPENDIX C1

STATE GEOTHERMAL RESOURCES PROSPECTING PERMIT

STATE OF CALIFORNIA
EDMUND G. BROWN JR., *Governor*

CALIFORNIA STATE LANDS COMMISSION
200 Oceangate, 12th Floor
Long Beach, CA 90802-4331

CURTIS L. FOSSUM, *Executive Officer*
(916) 574-1800 FAX (916) 574-1810
California Relay Service From TDD Phone **1-800-735-2929**
from Voice Phone **1-800-735-2922**

Contact Phone: **(562) 590-5291**
Contact FAX: **(562) 590-5210**

RECEIVED
JUN 14 2012
By

June 11, 2012

File Ref: PRC 8998.2
Well 9-A

Mr. James Buchal
Agent for Entiv Organic Energy LLC
Murphy & Buchal LLP
3425 SE Yamhill Street, Suite 100
Portland, OR 97214

Subject: Deepening of Well 9-A, State Geothermal Resources Prospecting Permit PRC 8998, Siskiyou County

Dear Mr. Buchal:

In accordance with Paragraph 9(a) of the subject permit, an approval is required from this office for all drilling activities on the permitted land. We have reviewed the proposed program to deepen Well 9-A as contained in a report prepared for Entiv Organic LLC by Technip-Mannvit, which was submitted to this office on June 1, 2012. The proposed work as detailed in that program is hereby approved subject to the following:

- A 500-barrel storage tank shall be kept full of water on location during drilling operations, and sufficient resources for well control shall be maintained and available for immediate use at the well site at all times.

- Drilling personnel shall be certified with Blowout Prevention Equipment (BOPE) and H_2S training within three weeks of the spud date. Contract foremen, tool pushers and drillers shall meet the five-day BOPE training school certification. All other rig crew members (such as derrick man, motor man and floor hands) shall meet the one-day BOPE training school certification. IADC-accredited schools are acceptable. Copies of certifications shall be provided to this office upon completion of training.

- BOPE functional test must be performed and witnessed by the Division of Oil, Gas & Geothermal (DOGGR) prior to commencing drilling and the results thereof shall be sent to this office as soon as available.

- Daily operation reports shall be sent by 8:00 a.m. by fax to (562) 590-5295 or by email to Nimal.Diunugala@slc.ca.gov and Steve.Curran@slc.ca.gov.

- Any changes to the program shall require prior approval of this office.

- Contingent upon issuance of the Permit to Conduct Well Operations by DOGGR.

- If no further well operations are intended subsequent to the completion of proposed well work, the well must be properly abandoned. Abandonment program must be approved by the State Lands Commission prior to commissioning of abandonment work.

- Copies of all DOGGR well summary and history reports, directional surveys, flow tests, etc., shall be sent to this office within 60 days after completion of the program.

This approval is subject to the terms and conditions of the permit, approved procedures for drilling and production operations, and the rules and regulations of the California State Lands Commission. If you have any questions, please contact Steve Curran at (562) 590-5266.

Sincerely,

Marina Voskanian

Marina Voskanian, P.E.
Acting Division Chief,
Mineral Resources Management

cc: Jack Truschel, District Geothermal Engineer
Geothermal District G1
Division of Oil, Gas and Geothermal Resources
801 K Street, MS 20-21
Sacramento, CA 95814

Mike Noonan
Director of Business
Entiv Organic Energy LLC
12080 Homedale Rd.
Klamath Falls, OR 97603

APPENDIX C2
ENTIV-NOTICE OF RECORDS DUE

RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF CONSERVATION
DIVISION OF OIL, GAS, AND GEOTHERMAL RESOURCES

NOTICE OF RECORDS DUE

Sacramento, California
January 30, 2013

Nancy Flores, Agent
Entiv Organic Energy, LLC
c/o CT Corporation System
81 W. 7th Street, Los Angeles, CA 90017

In accordance with Division 3 of the Public Resources Code of California, the following records are due, covering

the operations at the Lower Klamath National Wildlife Refuge II Dated --

of your well -- 9-A API#: 093-90086

-- Field Siskiyou County, Sec. 16, T.47N R.3E M.D. B. & M.

RECORDS: *Records are due within 60 days after completion, suspension, or abandonment of any well, or upon completion of additional work in any well. Records* ***shall*** *be submitted in* ***duplicate****. Division forms must be signed in the spaces provided.*

OIL AND GAS OPERATION

- ☐ Well summary (Form OG 100)
- ☐ Supplementary Notice to Rework
- ☐ Rework History (Form OG 103)

GEOTHERMAL OPERATION

- ☑ Well summary (Form OGG 100)
- ☐ Core or sidewall sample (Form OGG 101)
- ☑ History (Form OGG 103)

LOGS, TESTS, AND SURVEYS: *All logs, tests, and surveys are due within 60 days after completion, suspension, or abandonment of any well, or upon completion of additional work in any well. Logs, tests, and surveys shall be* ***submitted in duplicate.***

- ☐ Electric logs (5") (2)
- ☐ Velocity survey
- ☐ Water analysis
- ☐ R/A survey
- ☐ Directional survey
- ☐ Mud log
- ☐ Oil and/or gas analysis
- ☐ Spinner survey
- ☐ Dipmeter (computed)
- ☑ Pressure measurements (flowing and static)
- ☑ Temperature survey
- ☐ Cement bond log
- ☑ Two copies of all logs run on each well
- ☐ Other ______

REPORTS FOR THE MONTH OF *: Production, oil and gas disposition, and injection reports are due on or before the 30th day of each month for the preceding calendar month. Division forms must be signed in the spaces provided.*

OIL AND GAS OPERATION

- ☐ Production and disposition reports (Form OG110 or computer report)
- ☐ Injection reports (Form OG 110B or computer report)

GEOTHERMAL OPERATION

- ☐ Production reports (Form OGG 110)
- ☐ Injection reports (Form OGG 110B)

NAME	TITLE
Jack Truschel	Geothermal District Engineer
SIGNATURE: J. Truschel	TELEPHONE NUMBER: (916) 323-1787

OG 170 (4/98)

RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF CONSERVATION
DIVISION OF OIL, GAS, AND GEOTHERMAL RESOURCES

API Well No. ____________

WELL SUMMARY REPORT — GEOTHERMAL

Operator	Well				
Field	County	Sec.	T.	R.	B.&M.

Location (Give surface location from property or section corner, street center line.)

Elevation of ground above/below sea level

Latitude/Longitude (NAD 83) Latitude: ________ Longitude: ________

Was the well directionally drilled? ☐ Yes ☐ No **If yes, show coordinates at total depth.**

Commenced drilling (date)	Total depth	True Vertical Depth	Plugged Depth	Depth measurements taken from top of: ☐ Derrick Floor ☐ Rotary Table ☐ Kelly Bushing
Completed drilling (date)				Which is ____ feet above ground

Commenced production/injection (date)	Junk	GEOLOGICAL MARKERS	DEPTH
Name of production/injection zone(s)		Formation and age at total depth	Base of fresh water

DATE	STATIC TEST (Shut-in well head)	PRODUCTION TEST DATA								
		Total mass flow data					Separator data			
	Pressure (psig)	Sfc Pressure (psi)	Orifice (Inches)	Rate (lbs/hr)	Enthalpy (Btu/lb)	Temperature (°F)	Sfc Pressure (psi)	Temperature (°F)	Steam Rate (lbs/hr)	Water Rate (lbs/hr)

CASING AND CEMENTING RECORD (Present Hole)

Size of Casing (API) (inches)	Top of Casing (feet)	Depth of Shoe (feet)	Weight of Casing (lbs/ft)	Grade and Type of Casing	Size of Hole Drilled (inches)	Number of Sacks or Cubic Feet of Cement	Top(s) of Cement in Annulus (feet)

PERFORATED CASING LINER (Size, top, bottom, perforated intervals, size and spacing of perforations, and method.)

Logs/surveys run? ☐ Yes ☐ No If yes, list type(s) and depth(s).

In compliance with Sec. 3215, Division 3, of the *Public Resources Code*, the information given herewith is a complete and correct record of the present condition of the well and all work done thereon, so far as can be determined from all available records.

Name		Title	
Address		City/State	Zip Code
Telephone	Signature	Date	
E-Mail	Fax		

OGG100 (1/09)

SUBMIT IN DUPLICATE

RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF CONSERVATION
DIVISION OF OIL, GAS, AND GEOTHERMAL RESOURCES API Well Number ________

HISTORY OF GEOTHERMAL WELL

Operator ____________________ Field ____________ County ________

Well ____________________ Sec. ______ T. ______ R. ______ B.&M. ______

Name ____________________ (Person submitting report) Title ____________________ (President, Secretary, or Agent)

Address ____________________ City ____________ State ______ Zip Code ______

Telephone ____________ Fax ____________ E-mail ____________

Signature ____________________ Date ____________

History must be complete in all detail. Use this form to report all operations during drilling and testing of the well or during redrilling or altering the casing, plugging, or abandonment, with the dates thereof. Include such items as hole size, production or injection test details, amounts of cement used, top and bottom of plugs, perforation details, sidetracked junk, history and initial production data, and zone temperature.

DATE	**HISTORY**

APPENDIX C3

LOWER KLAMATH PRODUCTION WELLS CULTURAL SURVEY, 2002

U.S. Fish and Wildlife Service

Archaeological and Historical Resources Identification Report

Project Name: Lower Klamath Production Wells, Siskiyou County, California

Report Date: January 15, 2002

This document contains information protected by the 1979 Archaeological Resources Protection Act. Location information on archaeological sites is to be protected from public disclosure and is exempt from Freedom of Information Act.

Prepared by: **Bourdeau**
(name, organization,)

U.S. Fish & Wildlife Service
Archaeological and Historical Resources Identification Report
Under Programmatic Agreement
Appendix B

PROJECT NAME: Lower Klamath Production Wells

LOCATION INFORMATION:

				Township	Range	Section	PROJECT ACRES
County	**Siskiyou**	*State*	**California**	48N 48N 47N	1E 3E 3E	23 19, 20, 33, 16 20	*Total* 7
FWS Unit	**Klamath Basin NWRs**						*APE* 7
USGS Topo	**Sheepy Lake, Hatfield, Lower Klamath Lake**						
Appendix Item	B 6	*Program*	**Refuges**	*Field Contact*	**Hainline**		*Surveyed* 30

UNDERTAKING/APE: (List of activities comprising the undertaking and description of the geographical area in which activities will occur)

Seven 20-22" ground water production wells would be drilled on Lower Klamath NWR for refuge management purposes. Each potential well location is planned to occur as close as practicable to existing disturbed sites and roads. It is estimated that the area of potential effects from this project will be about 1- (continued)

BACKGROUND: (Pertinent environmental, historical, and archaeological information effecting the kinds of cultural resources that may be present, including references to previous surveys and sites in the vicinity and results of record search.)

Date of Record Search: **5/3/2001**

The project area is located around the periphery of the Lower Klamath Lake graben defined by NE and NW trending extensional (normal) faults. The production wells would intercept the defining faults which apparently act as aquifers. Well locations are vegetated by grass and shrubs.

The area is in the traditional territory of the Modoc Tribe and a number of well-known archaeological sites are recorded in the area, including Nightfire Island (Sampson 1983) , the Laird's Bay site (Cressman 1942), the Copic Island site (Cressman n.d.) and the Dayfire Island site (CASIS240) (Bourdeau, in preparation). There are other reported cultural resources near- (continued)

SURVEY INVENTORY:

Survey map attached? **YES**

Survey Methods **100% coverage of the well pad sites and vicinity including locations for water lines leading to canals. Survey was also conducted to relocate previously recorded archaeological sites.**

Survey Conditions **Project surveyed May 29-31, 2001. Good surface visibility at all well locations.**

Survey Problems **Site SIS261 could not be relocated.**

Survey Results **Known sites are near but outside proposed well locations. Sites relocated include SIS229, SIS223, SIS239 and SIS249. SIS261 was not relocated, probably destroyed/removed during quarry operations since the site was recorded in 1954. No previously unrecorded sites located in project APE.**

Recommendations **Wells 2 and 3 are within 200 meters of sites SIS239/SIS249 and SIS223 respectively. No project activities should occur NW of Well 2 or west of Well 3. This recommendation was given to Jim Hainline on May 30, 2001.**

Avoidance/Monitoring Measures (If applicable): **N/A as long as project locations do not change.**

Comments **Site SIS239 as reported by Squire (1954) has been almost completely removed by quarrying. Three obsidian flakes is all that were observed at the reported site location.**

Fran Maiss contacted us on 10/05/01 and informed us that Well 2 needed to be moved ~400m SE. As that moved the project away from the known sites and we had surveyed the proposed new location in May 2001, we gave him approval to make this change without additional survey.

Author Alex Bourdeau — **1/15/2002** *Report Date* — *SHPO Signature* — *Date*

PROJECT NAME: **Lower Klamath Production Wells**

UNDERTAKING APE CONT.

1 acre at each well location. Other considerations at the well locations would be the location of power transmission lines to the wells and water conveyance from the wells which will be marked. An eighth existing well has been identified for purchase on the Tupper Black property adjacent to the refuge. That location along with identified power and water conveyance corridors will be marked as well.

Wells are to be drilled to a depth exceeding 500'. Well tailings would remain on the area of potential efftecs. Pipelines or ditches would be constructed to carry water to serviced wetlands. Electrical power would be run to well heads from the nearest transmission line

BACKGROUND CONT.

near four of the proposed well locations. These sites have been recorded over at least the last fifty years by various archaeologists. Two of the sites (SIS239 and SIS223) are reported to contain human remains. Site reports for those near proposed well locations include: Otey Island Well - SIS261 (Grosscup 1954), Well 2 - SIS239 and SIS249 (Squier 1954), Well 3 - SIS223 (Grosscup 1953) and SIS248 (Aginier 1954) , Well 5 - SIS636 (Brott et al. 1977).

Several of the well locations are at the same or very near locations visited in 2000 for the initial test well project (See Bourdeau FY '01 Test Wells).

Significant earlier ground disturbance has occurred at the locations for the Otey Well, Well 2, Well 3, Well 4, Well 5 and Well 6. This disturbance has included construction, maintenance and use of the Dorris-Brownell Road, canal excavation and maintenance, quarrying, and dispersed recreational camping. Disturbance by looting has been noted at archaeological site SIS223. Archaeological site SIS239 was reported destroyed by quarrying (Squier 1954). Other proposed well locations have not likely been cultivated but they have been grazed by livestock

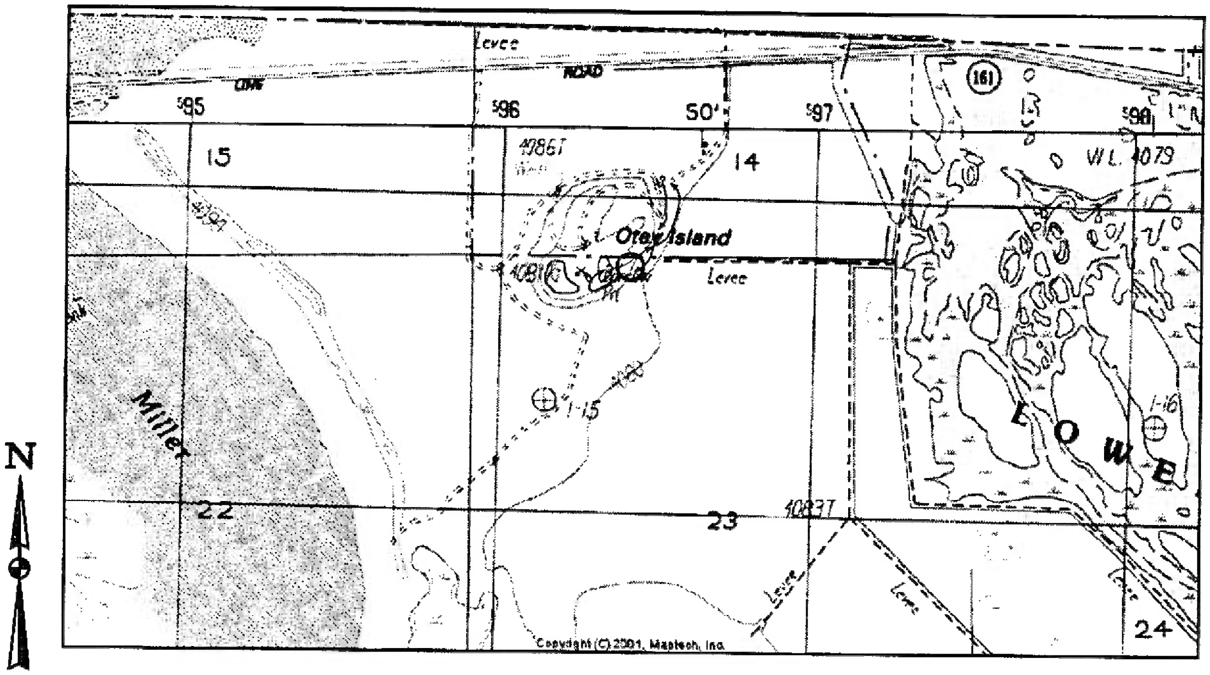
Lower Klamath Lake NWR - Production Well Project

Project and area surveyed map

Otey

Proposed well location ○

(two person transect)



Sheepy Lake, Calif.

0 ½ 1 Mile

Scale 1:24000 0 ½ 1 Kilometer

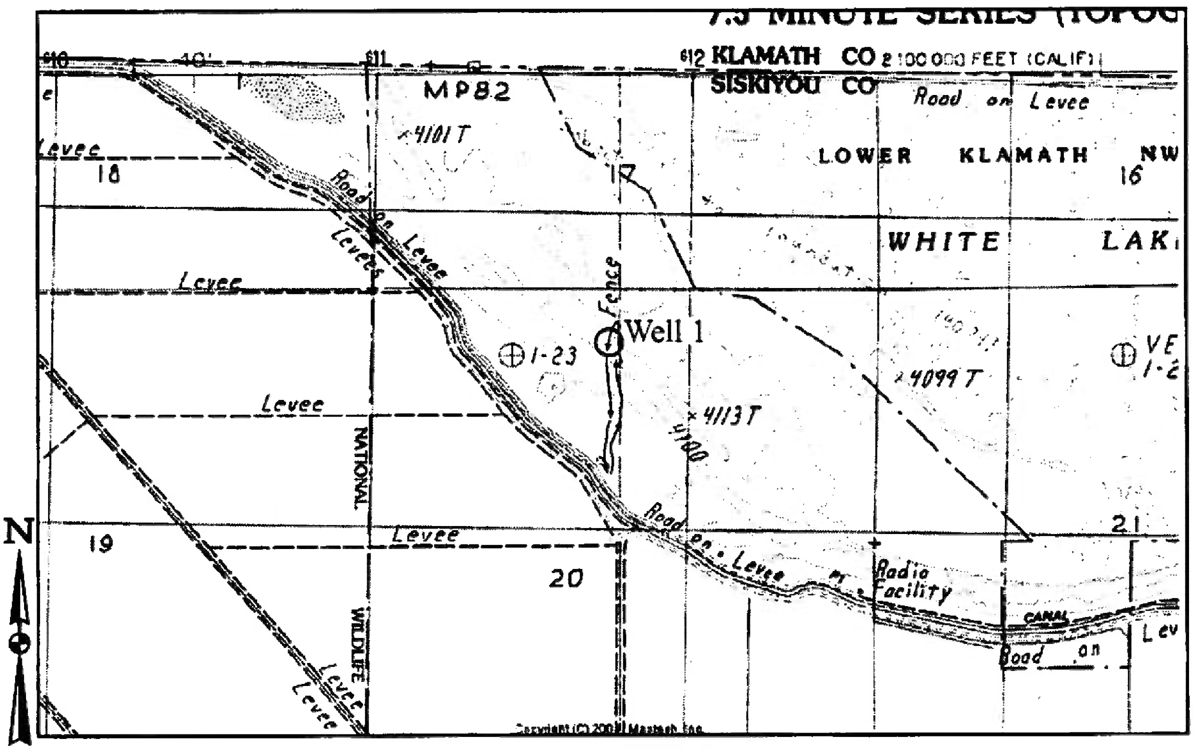
Lower Klamath Lake NWR - Production Well Project

Project and area surveyed map

Well 1

Proposed well location ○

(two person transect ⌒)



Lower Klamath Lake, Calif.-Oreg.

0 ½ 1 Mile

Scale 1:24000 0 ½ 1 Kilometer

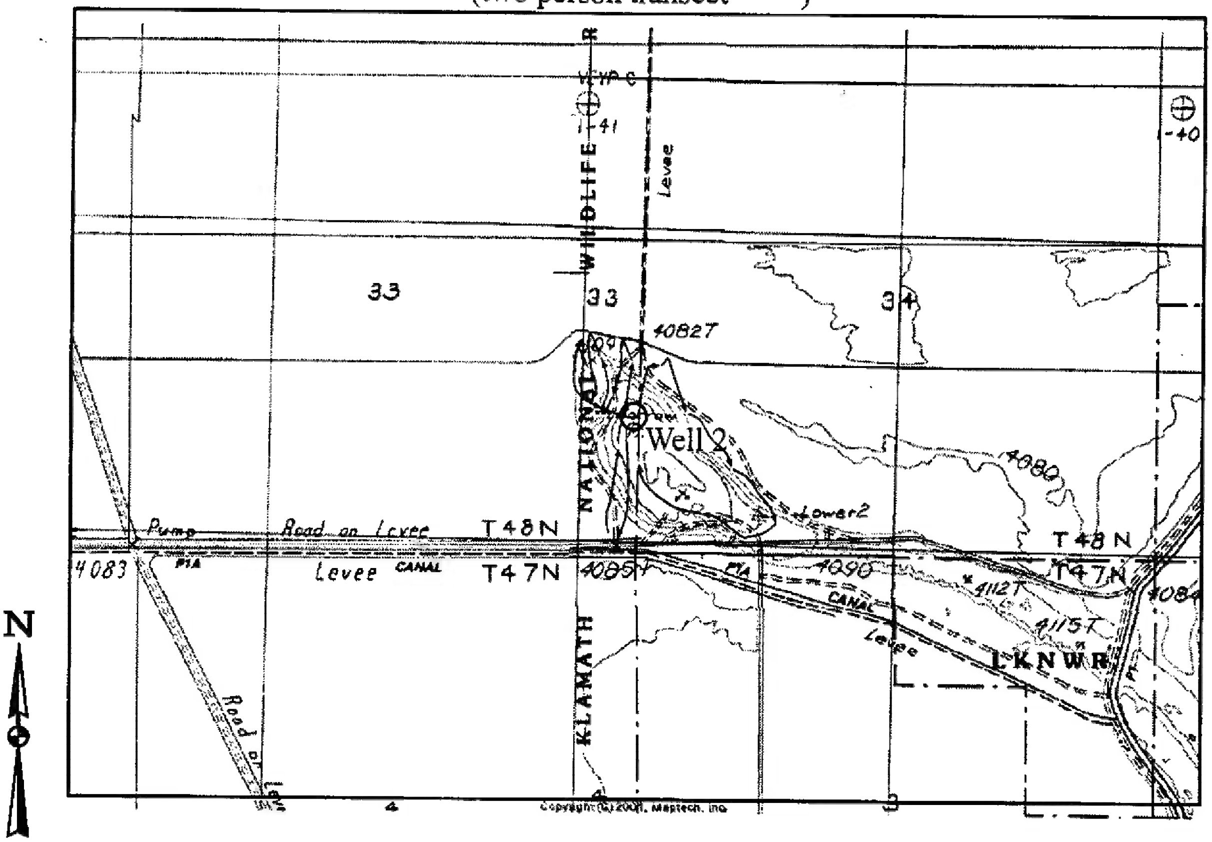
Lower Klamath Lake NWR - Production Well Project

Project and area surveyed map

Well 2

Proposed well location ○

(two person transect ⁓)



Lower Klamath Lake, Calif.-Oreg.

0 ½ 1 Mile

Scale 1:24000 0 ½ 1 Kilometer

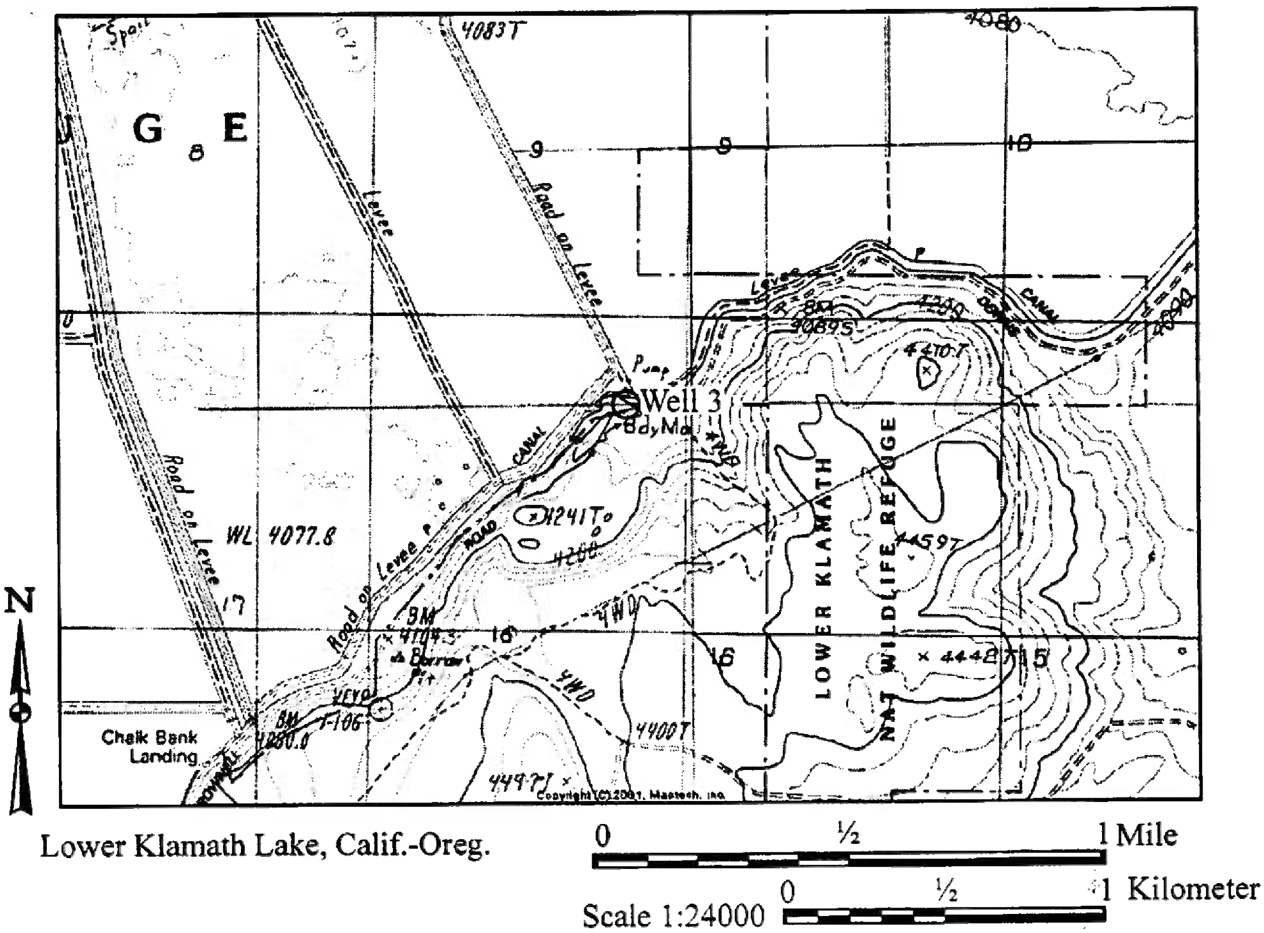
Lower Klamath Lake NWR - Production Well Project

Project and area surveyed map

Well 3

Proposed well location ○

(two person transect ⁓)



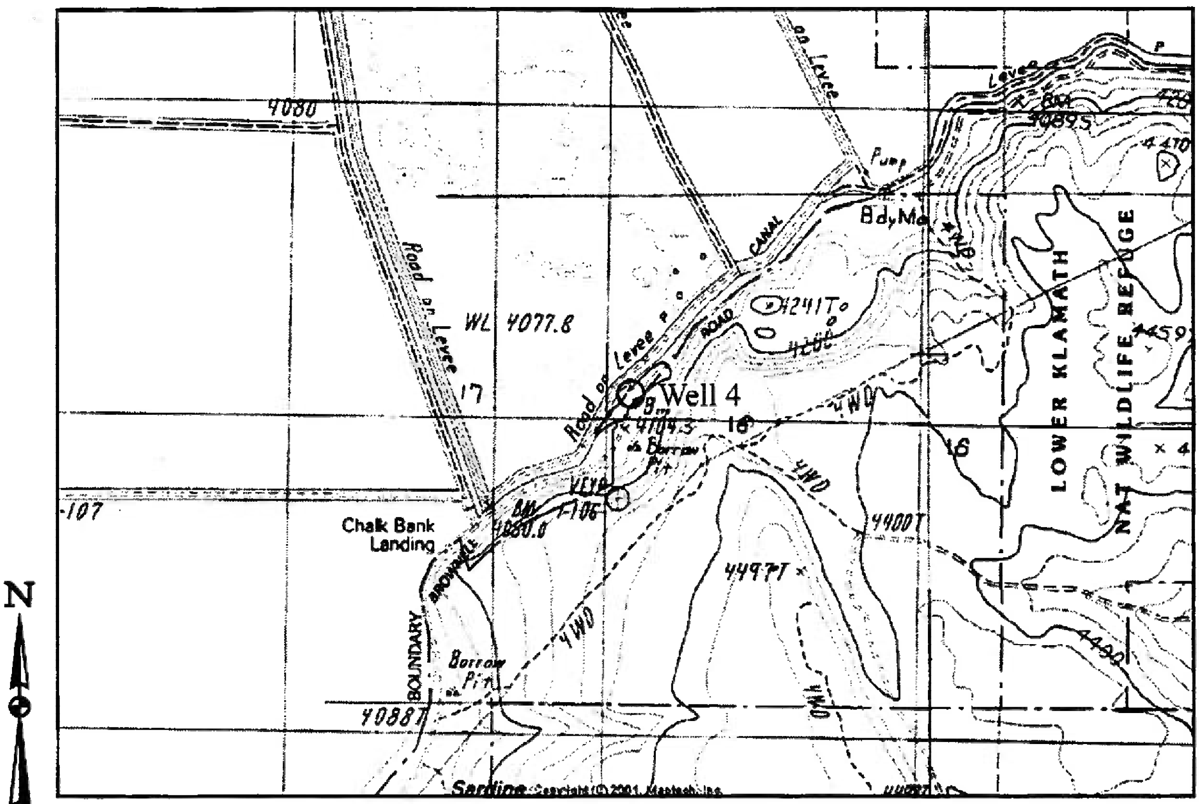
Lower Klamath Lake NWR - Production Well Project

Project and area surveyed map

Well 4

Proposed well location ○

(two person transect —⁀→)



Lower Klamath Lake, Calif.-Oreg.

0 ½ 1 Mile

Scale 1:24000 0 ½ 1 Kilometer

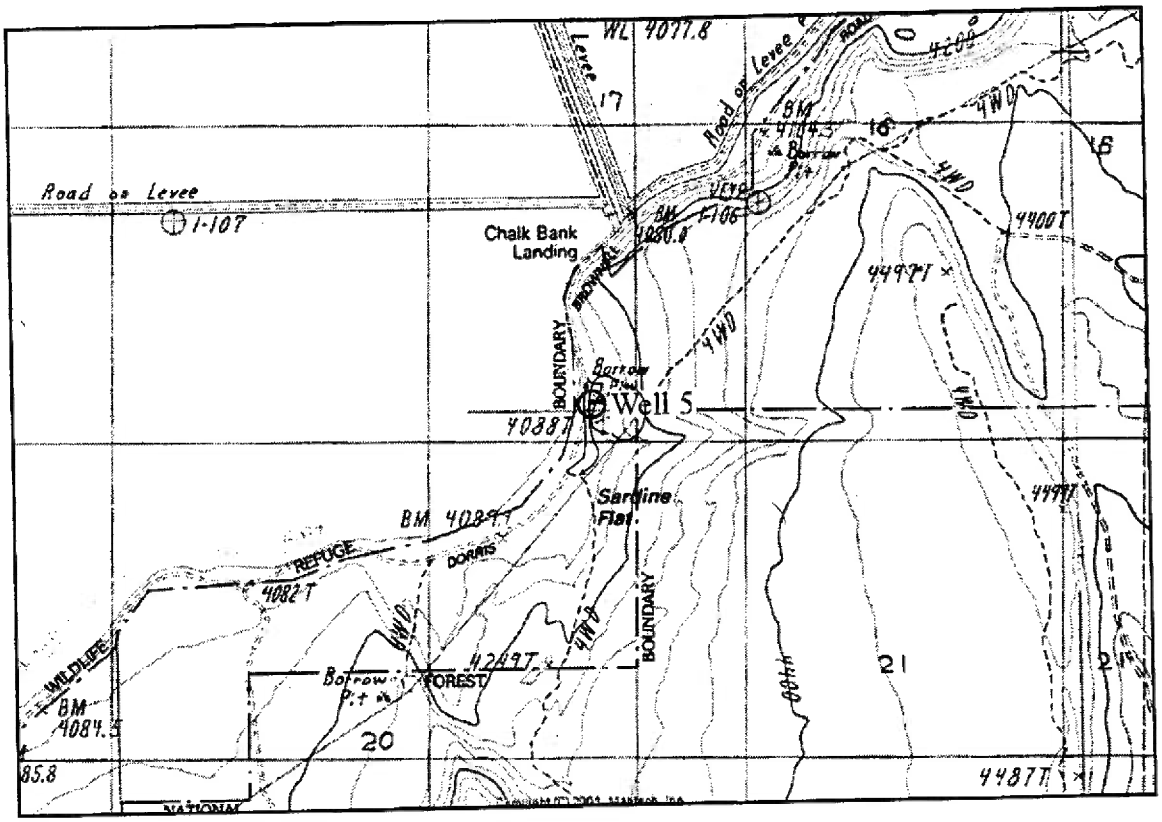
Lower Klamath Lake NWR - Production Well Project

Project and area surveyed map

Well 5

Proposed well location ○

(two person transect —⁀—)



Lower Klamath Lake, Calif.-Oreg.

0 ½ 1 Mile

0 ½ 1 Kilometer

Scale 1:24000

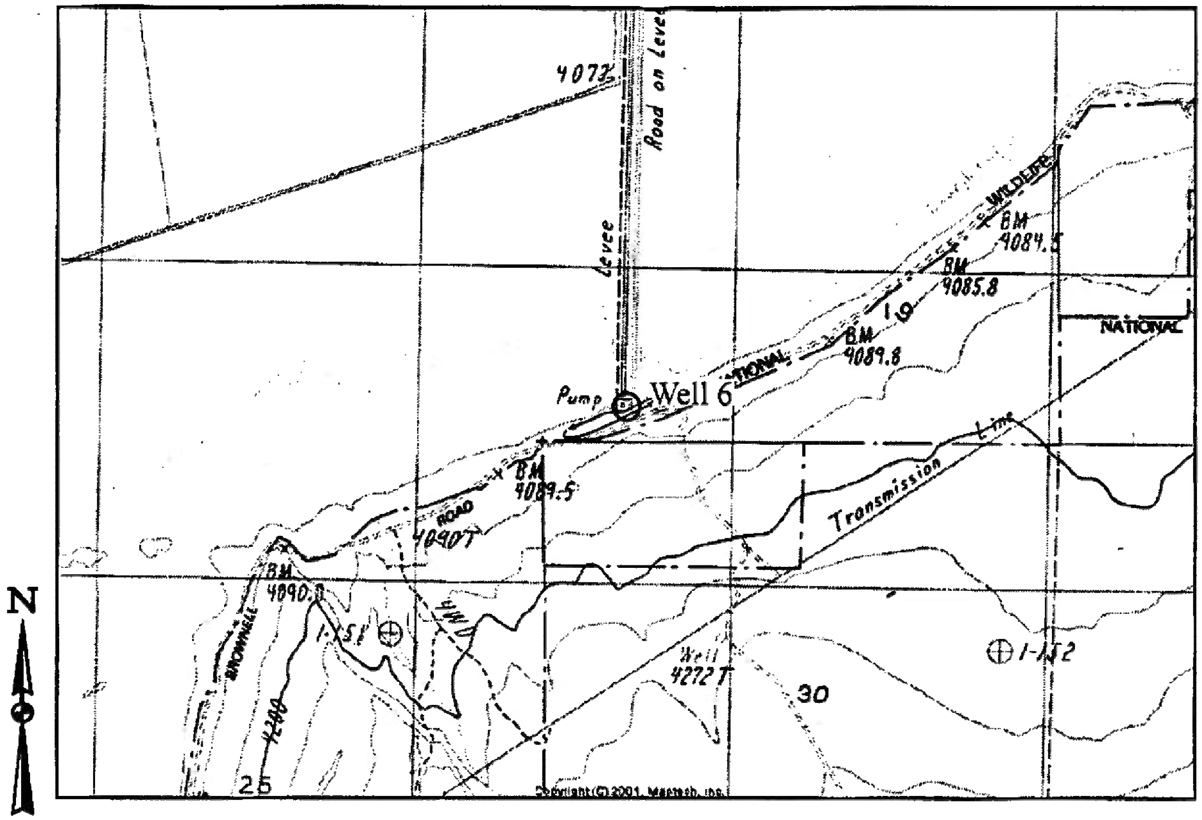
Lower Klamath Lake NWR - Production Well Project

Project and area surveyed map

Well 6

Proposed well location ○

(two person transect ⁓)



Lower Klamath Lake, Calif.-Oreg.

Scale 1:24000

0 ½ 1 Mile

0 ½ 1 Kilometer

APPENDIX C4

US DEPARTMENT OF INTERIOR FISH AND WILDLIFE SPECIAL USE PERMIT

UNITED STATES DEPARTMENT OF THE INTERIOR FISH AND WILDLIFE SERVICE Klamath Basin National Wildlife Refuge Complex 4009 Hill Rd. Tulellake CA., 96134 Telephone: 530-667-2231 SPECIAL USE PERMIT	Station No. To be Credited 81660	Permit Number
	Date 12 Feb 2012	
	Period of Use Feb. 12 2012- Feb 12, 2019	

Permittee Name	Permittee Address:
Entiv Organic Energy LLC	12080 Homedale Road Klamath Falls, Oregon 97603

Purpose (specify in detail privilege requested, or units of products involved)

Building upon previous work the permittee completed in 2011, this permit covers the second phase of a pilot project to investigate, research and develop the geothermal resources on Lower Klamath NWR, located at the existing well sites on LKNWR south of units 9, 12, and adjacent refuge lands.

The permittee will investigate the viability of geothermal production from these wells and provide the refuge a report of that viability. Information collected will include, but is not limited to; well yields, temperatures, water quality, flow, drawdown and pump level testing for selected, existing groundwater wells on Lower Klamath NWR.

Description (specify unit numbers; metes and bounds, or other recognizable designations)

The permittee will have exclusive access to existing wellheads to conduct third source testing of wells, utilizing ground drilling equipment on wells and land currently within compliance of existing NEPA, SHPO and refuge policy.

Amount of fee $____if not a fixed payment, specify rate and unit of charge: **N/A.**

Record of Payments

Special Conditions

Testing will not disturb or alter habitat surrounding these areas. Ingress and egress routes will be designated by the refuge manager. A minimum 500 gallon water tender will be on site at all times in case of wildfire. Strict adherence to cultural resource compliance and close coordination with the refuge at all times is paramount to the success of the project.

This permit is issued by the U.S. Fish and Wildlife Service and accepted by the undersigned, subjected to the terms, covenants, obligations, and reservations, expressed or implied herein, and to the conditions and requirements appearing on the reverse side

Permittee Signature:	Issuing Officer Signature and Title:
[signature] for Entiv Organic Energy	[signature] PL-KBNWR

Form 3-1383 (Rv. 6/85)

General Conditions

1. Payments
All payments shall be made on or before the due date to the local representative of the U.S. Fish and Wildlife Service by a postal money order or check mad payable to the U.S. fish and Wildlife service.

2. Use limitations
The permittee's use of the described premises is limited to the purposes herein specified; does not unless provided for in this permit allow him/her to restrict other authorized entry on to his/her area; and permits the Service to carry on whatever activities are necessary for (1) protection and maintenance of the premises and adjacent lands administered by the Service and (2) the management of wildlife and fish using the premises and other Service lands.

3. Damages
The United States shall not be responsible for any loss or damage to property including but not limited to growing crops, animals, and machinery; or injury to the permittee, or his/her relatives, or to the officers, agents, employees, or any others who are on the premises from instructions or by the sufferance of the permittee or his/her associates, or for damages or interference caused by wildlife or employees or representatives of the Government carrying out their official responsibilities. The permittee agrees to save the United States or any of its agencies harmless from any and all claims for damages or losses that may arise or be incident to the flooding of the premises resulting from any associated Government rive and harbor, flood control, reclamation, or Tennessee Valley Authority activity.

4. Operating Rules and Laws
The permittee shall keep the premises in a neat and orderly condition at all times, and shall comply with all municipal, county, and State laws applicable to the operations under the permit as well as all Federal laws, rules, and regulations governing National Wildlife Refuges and the area described in this permit. The permittee shall comply with all instructions applicable to this permit issued by the refuge officer in charge. The permittee shall take all reasonable precautions to prevent the escape of fires and to suppress fires and shall render all reasonable assistance in the suppression of refuge fires.

5. Responsibility of Permittee
The permittee, by operating on the premises, shall be considered to have accepted these premises with all the facilities, fixtures, or improvements in their existing conditions as of the date of this permit. At the end of the period specified or upon earlier termination, the permittee shall give up the premises in as good order and condition as when received except for reasonable wear, tear, or damage occurring without fault or negligence. The permittee will fully repay the Service for any and all damage directly or indirectly resulting from negligence or failure on his/her part, or the part of anyone of his/her associates, to use reasonable care.

6. Revocation Policy
This permit may be revoked by the Regional Director of the Service without notice for noncompliance with the terms hereof or for violation of general and or specific laws or regulations governing National Wildlife Refuges or for nonuse. It is at all times subject to discretionary revocation by the Director of the Service. Upon such revocation the Service, by and through any authorized representative, may take possession of the said premises for its own and sole use, or may enter and posses the premises as the agent of the permittee and his/her account.

7. Compliance
Failure of the Service to insist upon a strict compliance with any of this permits terms, conditions, and requirements shall not constitute a waiver or be considered as a giving up of the Service's right to thereafter enforce any of the permits terms, conditions, or requirements.

8. Termination Policy
At the termination of this permit the permittee shall immediately give up possession to the Service representative reserving however the rights specified in paragraph 9. The acceptance of any fee for liquidated damages or any other act of administration relating to the continued tenancy is not to be considered as an affirmance of the permittees action nor shall it operate as a waiver of the Governments right to terminate or cancel the permit for the breach of any specified condition or requirement.

9. Removal of Permittee's Property
Upon the expiration or termination of this permit, if all rental charges and or damage claims due to the Government have been paid, the permittee may within a reasonable period as stated in the permit or as determined by the refuge office in charge but not to exceed 60 days, remove all structures, machinery, and/or other equipment, etc., from the premises for which he/she is responsible. Within this period the permittee must also remove any other of his/her property including his/her acknowledged share of production or crops grown, cut harvested, store, or stacked on the premises. Upon failure to remove any of the above items within the aforesaid period, they shall become the property of the United States.

10. Transfer of Privileges
This permit is not transferable, and no privileges herein mentioned may be sublet or made available to any person or interest not mentioned in this permit. No interest hereunder may accrue through lien or be transferred to a third party without the approval of the Regional Director of the U.S. Fish and Wildlife Service and the permit shall not be used for speculative purposes.

11. Conditions of Permit not Fulfilled
If the permittee fails to fulfill any of the conditions and requirements set forth herein, all money paid under this permit shall be retained by the Government to be used to satisfy as much of the permittee's obligation as possible.

12. Official Barred from Participating
No Member of Congress or Resident Commissioner shall participate in any part of this contract or to any benefit that may arise from it, but this provision shall not pertain to this contract if made with a corporation for its general benefit.

13. Nondiscrimination Employment
The permittee agrees to be bound by the equal opportunity clause of Executive Order 11246, as amended.

Privacy Act Statement--Special Use Permit

NOTICE: In accordance with the Privacy Act of 1974, 5 U.S.C. 552a, please be advised that:

1. The issuance of a permit and collection of fees on lands of the National Wildlife Refuge System is authorized by the National Wildlife Refuge System Administration Act (16 U.S.C. 6688dd - 668ee), and the Refuge Recreation Act, (16 U.S.C. 460k-3); implemented by regulations in 50 CFR 25-36.

2. Information collected in issuing a permit may be used to evaluate and conclude eligibility of, or merely document, permit applicants.

3. Routine use disclosures may also be made (1) to the U.S. Department of Justice when related to litigation or anticipated litigation; (2) of information indicating a violation or potential violation of a statute, regulation, rule, order or license, to appropriate Federal, State, local or foreign agencies responsible for investigating or prosecuting the violation or for enforcing or implementing the stature, rule, regulation, order or license; (3) from the record of the individual in response to an inquiry from a Congressional office made at the request of that individual; (4) to provide addresses obtained from the Internal Revenue Service to debt collection agencies for purposes of locating a debtor to collect or compromise a Federal claim against the debtor, or to consumer reporting agencies to prepare a commercial credit report for use by the Department (48FR 54716; December 6, 1983).

4. Any information requested is required to receive this permit. Failure to answer questions may jeopardize the eligibility of individuals to receive permits.