JEMALONG SOLAR STATION PRELIMINARY HAZARD ANALYSIS

Document Reference: HL20160225A

Revision: 2.0 [25 February 2016]

scott lister

Commercial In Confidence

Changes and Approvals

LOG OF CHANGE				
Issue	**Date**	**Author**	**Modification description**	**Peer Review Reference**
1.0	12.2.16	Mat Collin	Initial issue	Howard Lister
2.0	25.2.16	Mat Collin	Final	Howard Lister

APPROVAL RECORD				
	Name	**Role**	**Date**	**Signature**
Created by:	Mat Collin	Senior Consultant	25.2.16	
Reviewed by:	Howard Lister	Principal Consultant	25.2.16	
Authorised by:	Howard Lister	Principal Consultant	25.2.16	

Table of Contents

1. Executive Summary

Vast Solar is proposing to construct a 30MW Concentrating Solar Thermal Power Plant at Jemalong, near Forbes, NSW. Arrays of mirrors known as heliostats will focus the sun's energy on towers, heating liquid sodium. This liquid sodium will then be used to heat an intermediate heat transfer fluid, which will in turn generate steam to drive a turbine and generator.

This report summarises the findings of a Preliminary Hazard Analysis (PHA) conducted for the proposed facility, in support of the Environmental Impact Statement (EIS) accompanying the development application. The PHA has been conducted consistent with the guidance provided by the Department of Planning and Environment's *Hazardous Industry Planning Advisory Paper No.6* Hazard Analysis (HIPAP 6).

The study has analysed the various potential hazardous events at the proposed facility. Whilst the materials handled and nature of operations at the facility present potentially high risks to personnel working on the plant itself, the study has concluded that there is extremely limited potential for *offsite* consequences, which is the key factor for land use planning considerations. Key hazards are as follows:

- A significant quantity of sodium is present at the site and is above the threshold required for designation as a Major Hazards Facility (MHF). A sodium fire or explosion can have significant consequences, including fatalities. Whilst it is well known that small quantities of sodium can result in small explosions, the consequences of incidents involving large quantities of sodium are less well understood. A review of literature indicates that large scale incidents involving sodium are extremely rare but can be expected to be very localised (contained well within the site boundary for this facility). Sodium is used around the world, particularly in the nuclear industry and risks can be reduced to an acceptable level with appropriate safeguards.
- The arrays of heliostats reflect light towards the receiving towers. This glare and glint has the potential to cause an after-image in the eye and has been modelled in a specialist report which is appended to the EIS. The worst case scenario for a pilot would result in the potential for an after-image no stronger than looking directly at the sun. As the solar station is not located near an airfield, a pilot would not be required to look at or near the arrays.
- Liquefied Petroleum Gas (LPG) is used at the site. The stock tanks are located approximately 400m from the site boundary and will have a capacity of no more than 10,000L. The hazards of this LPG storage, whilst significant, are no different to the general risks commonly faced by LPG usage in the broader community (for example for heating and automotive applications). Notwithstanding this, the consequences of a fire or explosion have been modelled quantitatively and are found to be well contained within the site boundaries.

As well as analysing the potential hazards, the PHA also included a review of proposed safety management arrangements at the facility. Smaller power plants are currently operating at the Jemalong site as part of ongoing ‘scale-up’ of this new technology. A formal Safety Management System (SMS) is currently in operation at the site, developed for the 6MWth Pilot Plant currently being commissioned. This SMS is to be adapted and expanded to cover the 30MW Solar Station that is the subject of this PHA. This will be done prior to commissioning of the 30MW facility. The SMS review identified some areas warranting further development for the 30MW, but this does not impact the site’s suitability and is a normal process of scaling up from pilot plant to commercial operation.

In summary, considering both the hazard analysis and the proposed safety management arrangements, it is concluded that the potential offsite risks associated with hazardous materials for the proposed 30MW Jemalong Solar Station are extremely low and acceptable according to the DPE’s risk tolerability criteria.

Notwithstanding that the offsite risks are very low, it is stressed that the risks to onsite personnel associated with sodium are significant. This is not the primary concern for the planning process, although an important consideration. However the facility is likely to be classified as a Major Hazard Facility under WHS legislation and the control of onsite risks will be need to be well justified in the Safety Case required under that regime.

2. Facility Description

2.1 Location

The proposal site is located approximately 36 km west of Forbes within the Forbes Local Government Area. It is accessed from the Lachlan Valley Way to the north, via Wilbertroy Lane and Naroo Lane. The site is part of a 165 ha lot known as 'Hallidays', which in turn is part of the 15,478 ha Jemalong Station, a rural property managed for agricultural production. The site is mostly cleared and relatively flat farmland with a long history of cropping with small remnants of Poplar Box woodland (ranging from 0.1 to 0.5 ha) remaining.

There is no existing infrastructure on the proposed plant site. Directly north of the plant facilities is the 'Hallidays' farm house, contained within the Jemalong Station and owned and maintained by the station owner, Twynam Agricultural Group. The closest waterway to the site is Thurumbidgee Lagoon, filling intermittently when there is good rain, located approximately 400 m to the north of the proposal site. The Lachlan River is located approximately 3.7 km to the north. The site location is shown in Figure 1.

Figure 2 shows the general location of the infrastructure within the facility. For the purpose of determining off site consequences and risk, the facility boundary is considered to be the boudary of the Jemalong Station, which is represented by the diagonal shading on Figure 2. This is not the red line showing the boundary of the Solar Station within the larger Jemalong Station.

The general layout of the heliostat arrays and the location of other facilities are shown in Figure 3. Most processing and storage activities will occur within the bunded power island.

Figure 1: Location of the Jemalong Station and of the Jemalong Solar Station

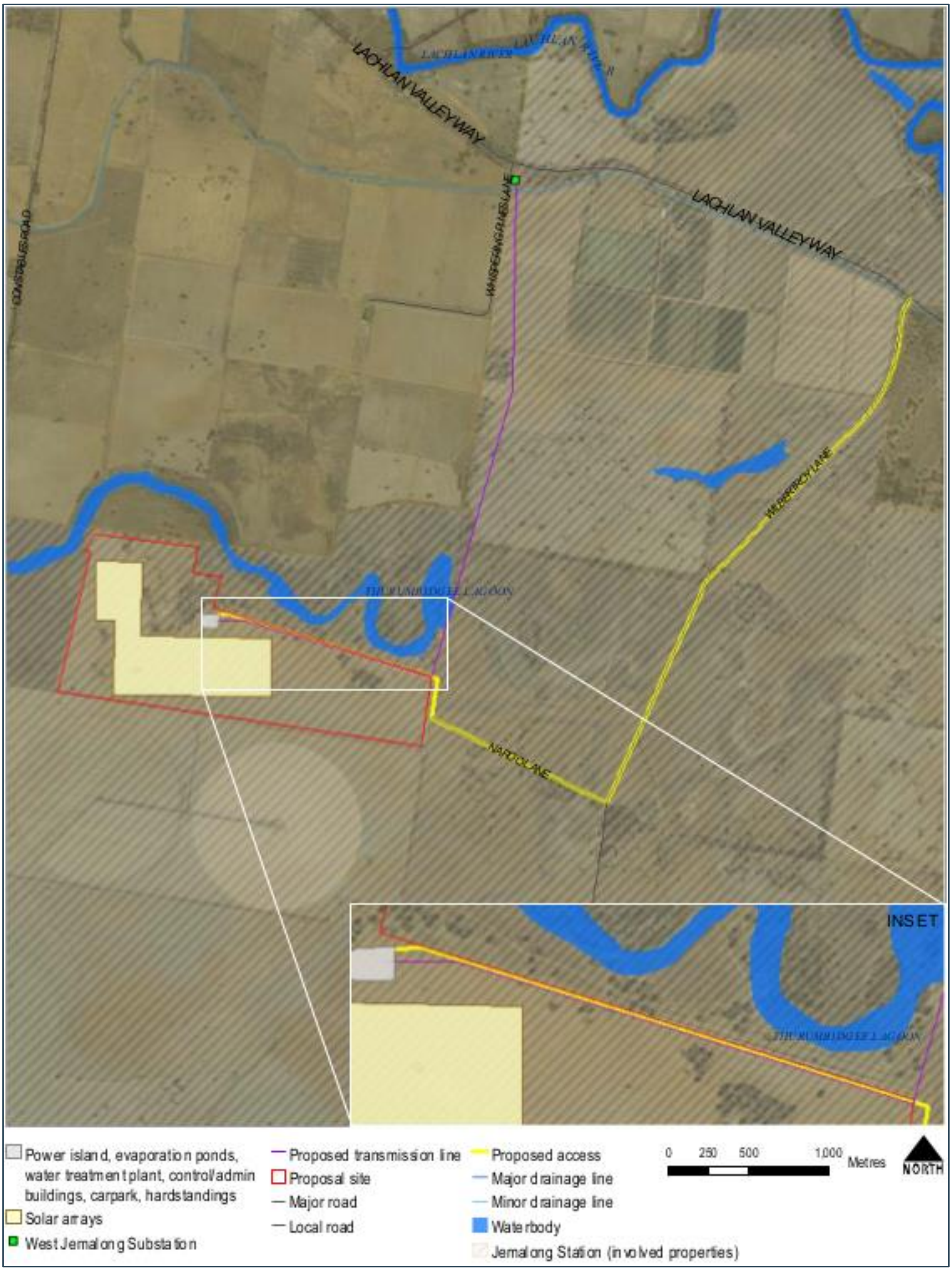


Figure 2: Location of he solar station within the site

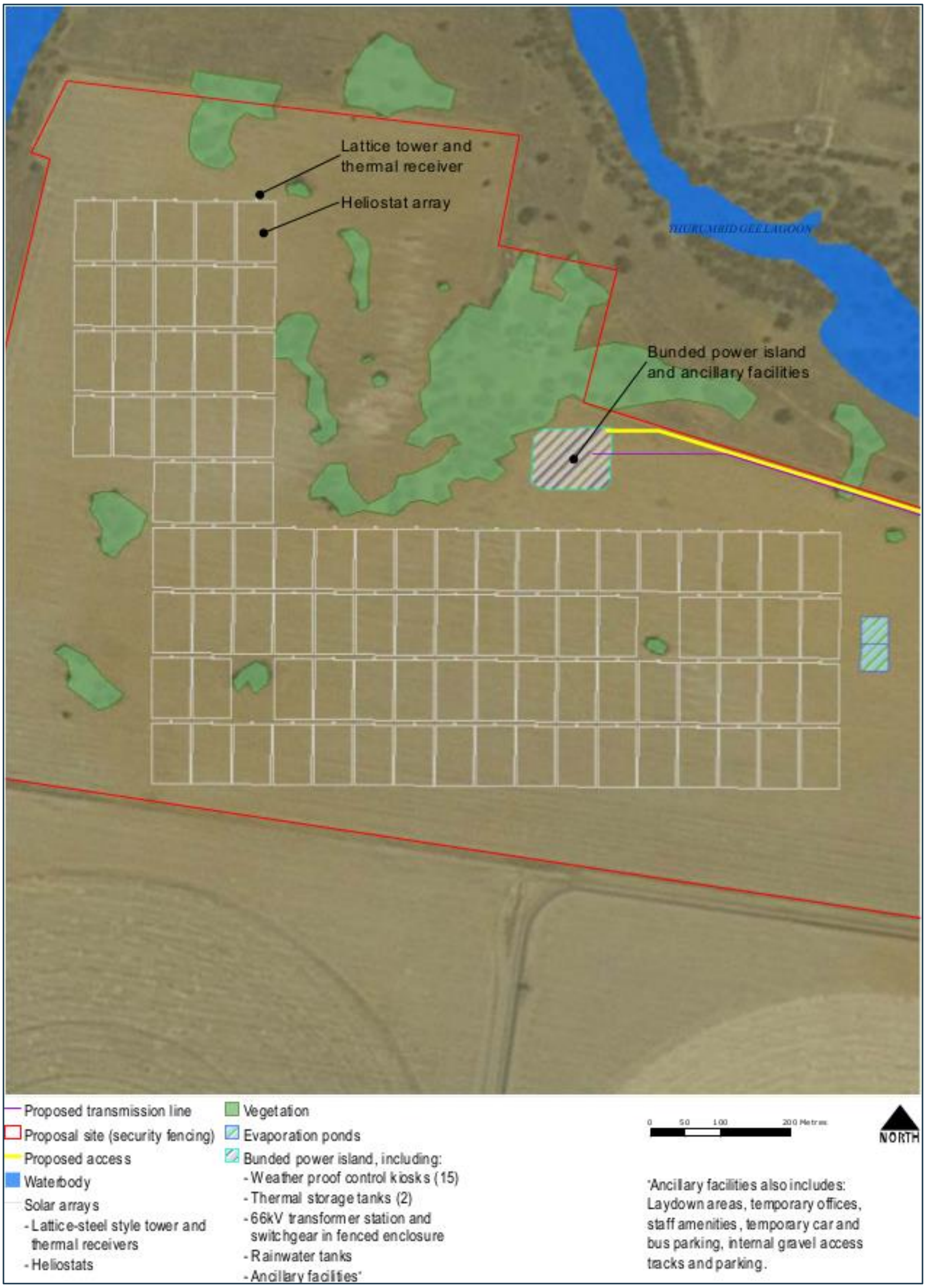


Figure 3: Layout of the infrastructure within the site

2.2 Process description

The proposal contains approximately 90 solar array modules, each covering an area of approximately 70 m x 110 m. Each module has approximately 700 heliostats and a 30 m galvanised lattice steel tower with a thermal receiver at its top. The tower is located to the north of the heliostats. Each thermal receiver is serviced by two pipes; one conveying 'cold' sodium (130ºC) to the receiver, the other returning hot sodium (550ºC+) from the receiver to a central heat exchanger where it is used to heat a molten salt solution.

The molten salt solution is pumped through the central heat exchanger, where it is heated by sodium from the solar array, raising the temperature of the molten salt from approximately 240ºC to approximately 550ºC. When steam generation is required, the heated molten salt is pumped through a boiler, where water is heated to create steam. The steam is used to drive a steam turbine and associated generator, which will supply 66kV AC electricity to the electrical grid.

2.3 Hazardous materials

Table 1 lists all significant quantities of Dangerous Goods that will be stored or used as a part of the project.

Table 1: Dangerous Goods present at the Jemalong Solar Station

Material	Quantity	DG Division	Packing Group	MHF Threshold
Sodium	506t	4.3	I	200t
LPG	20kL (10t)	2.1	-	200t
Thermal Oil	3t	3	II or III	50,000t
Argon	TBC (limited quantities for inert gas blanketing/ purging)	2.2	-	-

In addition to the dangerous goods listed in Table 1, there will be minor quantities of other Dangerous Goods, such as paint, biocide, and lubricating oils.

2.4 Sodium

Sodium is a hazardous material primarily because of its extreme reactivity when it comes in contact with water, oxygen and many other substances. Under the Australian Dangerous Goods Code *[Ref. 006]* it is classified as *Division 4.3 – Substances which in contact with water emit flammable gases.* Sodium melts at 97.8ºC boils at 882.9ºC and will flow easily in a liquid phase, with a viscosity similar to water.

Sodium is seldom encountered in the pure metallic state. It is used in applications that require unusual heat transfer and electrical conductivity properties. In bulk quantities it is used as a heat transfer medium in the nuclear energy industry.

For the 30MW plant, liquid sodium will be present as a heat transfer medium throughout the heliostat arrays with storage and heat exchanger equipment on the power island. Limited quantities of sodium are also expected to be stored on site in packaged form.

2.5 Liquefied Petroleum Gas (LPG)

Liquefied petroleum gas (LPG) is commonly used as fuel in heating appliances, cooking equipment and vehicles. It will be used on site as an auxiliary heating source. It will be stored in two aboveground tanks adjacent to the power island.

2.6 Thermal Oil, Fuels and Lubricants

Thermal oil would be used to pre-heat storage tanks to avoid solidification of molten salt or sodium within the tanks. The thermal oil storage tanks will be located within the bunded power island, which is over 400 m from the site boundary and will not have an impact upon neighboring land users.

Fuels and lubricants would be used for a range of uses on site including running and maintenance of vehicles and machinery. Fuels and lubricants pose a risk to humans if they come in contact with them such as irritation of skin and eyes. They would be stored in the bunded central power island, which is over 400 m from the site boundary and will not have an impact upon neighboring land users.

2.7 Risk and consequence criteria

The risk acceptability criteria applicable to developments of this type have been taken from the NSW Department of Planning and Environment's HIPAP4 *[Ref. 002].* The effects from heat radiation are outlined in Table 2. The effects from an explosion overpressure are outlined in Table 3. The risk criteria adopted for this PHA are outlined in Table 4.

Table 2: Effects of heat radiation

<table>
<tr><th>Heat Radiation</th><th>Effect</th></tr>
<tr><td>1.2 kW/m^2</td><td>Received from the sun at noon in summer</td></tr>
<tr><td>2.1 kW/m^2</td><td>Minimum to cause pain after one minute</td></tr>
<tr><td>4.7 kW/m^2</td><td>Will cause pain in 15-20 seconds and injury after 30 seconds exposure (at least second degree burns will occur)</td></tr>
<tr><td>12.6 kW/m^2</td><td>Significant chance of fatality for extended exposure. High chance of injury
Causes the temperature of wood to rise to a point where it can be ignited by a naked flame after long exposure
Thin steel with insulation on the side away from the fire may reach thermal stress level high enough to cause structural failure</td></tr>
<tr><td>23 kW/m^2</td><td>Likely fatality for extended exposure and chance of fatality for instantaneous exposure
Spontaneous ignition of wood after long exposure
Unprotected steel will reach thermal stress temperatures which can cause failure
Pressure vessel needs to be relieved or failure would occur</td></tr>
<tr><td>35 kW/m^2</td><td>Cellulosic material will pilot ignite within one minute’s exposure
Significant chance of fatality for people exposed instantaneously</td></tr>
</table>

Table 3: Effects of explosion overpressure

Explosion Overpressure	Effect
3.5 kPa	• 90% glass breakage • No fatality and very low probability of injury
7 kPa	• Damage to internal partitions and joinery but can be repaired • Probability of injury is 10%. No fatality
14 kPa	• House uninhabitable and badly cracked
21 kPa	• Reinforced structures distort • Storage tanks fail • 20% chance of fatality to a person in a building
35 kPa	• House uninhabitable • Wagons and plant items overturned • Threshold of eardrum damage • 50% chance of a fatality for a person in a building • 15% chance of a fatality for a person in the open
70 kPa	• Threshold of lung damage • 100% chance of a fatality for a person in a building or in the open • Complete demolition of houses

Table 4: Risk criteria at facility boundary

Criteria	Value
Risk of individual fatality	One in a million per year
Risk of injury from heat radiation	Should not exceed 4.7kW/m^2 at a frequency of more than 50 chances in a million per year
Risk of injury from explosion overpressure	Should not exceed 7kPa at a frequency of more than 50 chances in a million per year

3. Hazard Identification

A Hazard Identification (HAZID) and Hazard and Operability (HAZOP) have been previously undertaken for the 6MW_{th} Pilot Plant. The HAZID contains process safety risks as well as workplace health and safety risks. This pilot facility is subject to similar hazards to the 30MW Solar Station that is the subject of the PHA. The key differences between the 6MWth Pilot Plant and the 30MW Solar Station are:

- Increased quantity of sodium
- Increased number of heliostat arrays
- Use of molten salt as an intermediary heat transfer medium between the sodium and the steam circuit (the 30MW design being inherently safer due to its lack of sodium-water heat exchanger)
- Increased size of steam turbine

The minutes from the pilot plant HAZID are attached in Appendix A and the minutes of the HAZOP have been attached as Appendix B.

Due to the similarity of the hazards posed, the HAZID and HAZOP for the 6MW_{th} Pilot Plant can be used as the basis for the 30MW facility that is the subject of this PHA. Key process hazards or hazards with a potential to have offsite consequences from the HAZID are summarized in Table 5. The HAZID was critically reviewed for its applicability to the 30MW plant and additional hazards are identified in Table 6: New items for HAZIDTable 6.

Table 5: Key hazards

Reference	Hazard	Consequences
12	Reflected light from heliostats	Temporary blindness, including to nearby aviation
18, 23, 24, 31, 32, 33	Loss of containment of sodium	• Sodium fire/explosion • Hydrogen explosion • Smoke from sodium fire
35, 36	Steam explosion	• Burns/death • Ejected debris
50, 75	Loss of containment of flammable or combustible liquid	Fire
69	Electromagnetic Field	Exposure to EMF
74	Loss of containment of LPG	Fire/explosion

Reference	Hazard	Consequences
83	Combustible materials	Fire
84	Flooding	Flood effects (including debris) compromise process pipework integrity. Stored (packaged) sodium presents explosion hazard in water.

Table 6: New items for HAZID

Reference	Hazard	Consequences	Proposed Controls
74 – new consequence	Loss of containment of LPG	Semi-confined vapour cloud explosion within heliostat arrays (due to confining effect of arrays)	• Layout design to consider possibility of gas clouds forming with heliostat arrays • Emergency Response Plan to recognise possibility of vapour cloud explosion in congested or confined areas
New	Low oxygen environment from inert cover gas	Asphyxiation	• Engineering design to mitigate this risk, for example by relief vents being directed to safe locations and adequate ventilation • SMS to include JSA's and procedures for working around low oxygen environments
New	Fire / explosion of packaged sodium (i.e. non-process)	Fire / explosion	• Engineering design of storage areas to be compliant with DG Regs • SMS to include safe storage and handling procedures for sodium

In addition to the HAZID and HAZOP, a review of available literature has been undertaken with respect to incidents involving sodium. Several reports on incidents involving sodium fires and explosions have been reviewed. This includes:

- A sodium fire at processing plant in Newton, Massachusetts, USA in 1993 in which 11 firefighters were injured [Ref. 007].
- A sodium leak at a fast breeder reactor in Monju, Japan in 1995 with no injuries [Ref. 008]
- A sodium leak and fire at Vast Solar's Demonstration Plant at Jemalong in 2015

All of these incidents had fire and explosion consequences contained within a limited area of approximately 20m from the initial sodium fire or explosion. No incidents have been identified of major industrial accidents involving sodium where the consequences went beyond a localised effect (approximately 20m).

Multiple videos of reactions of sodium and water have also been viewed, both in controlled settings and in uncontrolled settings. Again, in all of these videos the consequences of the explosions are restricted to the immediate area from the point of the initial reaction.

No explosions or fires involving sodium, either controlled or uncontrolled, were found where consequences extended beyond approximately 20m.

3.1 Glare and glint

Glare and glint from the heliostats was subject to a specialist report that is discussed in section 5.5 of the EIS. This report concludes that the diffuse glare due from approximately 90 towers provides no significant eye hazards to the nearby points of interest that were considered. If viewed as a group, multiple heliostats could potentially produce a temporary after-image however the tracking algorithms and physical obstructions make this scenario unlikely to occur for any observers at ground level.

It is possible for a collection of heliostats to produce a hazard resulting in an after-image at a distance of 4 km. It also modelled scenarios to represent the condition where all heliostats are in the standby position and produce a combined source of glare. During normal operation, especially in times of high solar energy, it is expected that the heliostats would very rarely all be in this state. It is more probable that a few fields of heliostats may be in standby for maintenance. This reduces the risk to that of a single heliostat. In all cases modelled, even with the conservative assumptions applied, the predicted potential for the after-image is no stronger than looking directly at the sun.

3.2 Sodium

Sodium is most widely known for its violent reaction with water. Pure sodium will break apart water forming sodium hydroxide and liberating hydrogen as a gas, which ignites in the air. The sodium hydroxide can cause burns to the skin and eyes upon contact. It is transported in sealed containers because it will react with the moisture in the air on a humid day.

The hydrogen released during a reaction between water and sodium will, if sufficient oxygen is present, ignite immediately in a series of small flames. The source of ignition is the heat from the exothermic reaction between the sodium and the water. For this reason, hydrogen is unable to build up in large cloud, either confined or unconfined, that can subsequently explode.

Molten sodium is extremely dangerous because it is much more reactive than a solid mass. In the liquid form, every sodium atom is free and mobile to instantaneously combine with any available oxygen atom or other oxidizer, and any gaseous by-product will be created as a rapidly expanding gas bubble within the molten mass. Even a minute amount of water can create this type of reaction. Any amount of water introduced into a pool of molten sodium is likely to cause a violent explosion inside the liquid mass, releasing the hydrogen as a rapidly expanding gas and causing the molten sodium to erupt from the container.

A reaction between sodium and water will frequently result in the ejection of sodium. This will result in a secondary explosion away from the initial explosion if the ejected sodium lands in water. It is possible for a single piece of sodium to be involved in multiple secondary explosions and travel a distance when water is present. It is noted that each piece of sodium that is thrown in an explosion is orders of magnitude smaller than the mass of sodium involved in the initial explosion. For this reason a series of explosions involving sodium will rapidly decay and is confined to the area in the immediate vicinity of the initial explosion.

The sodium storage tank is located over 400 m away from the facility boundary. The closest sodium to the plant boundary is at the northernmost series of solar collection towers, although this will be restricted to sodium within the pipework. This is approximately 120 m from the site boundary.

Because of the rapid decay of a series of sodium explosions it is not credible for any single piece of material to travel the 120 m required to reach the plant boundary. This has been supported by experimental studies in which sodium explosions have been confined to an area, typically with a radius of no more than approximately 20 m.

Liquid sodium must be kept in a closed system because it will auto-ignite in air at temperatures only slightly above its melting temperature. Sodium burns with a yellow flame to produce an ash (sodium oxide), which forms a dense white smoke. Once ignited, sodium is very difficult to extinguish. It will react with water and with any extinguishing agent that contains water. It will also react with many other common extinguishing agents, including carbon dioxide and the halogen compounds and most dry chemical agents. The only safe and effective extinguishing agents are completely dry inert materials, such as soda ash, graphite, diatomaceous earth, or sodium chloride, all of which can be used to bury burning sodium and exclude oxygen from reaching the metal. The extinguishing agent must be absolutely dry, as even a trace of water in the material can react with the burning sodium to cause an explosion.

When molten sodium is involved in a fire, the combustion occurs at the surface of the liquid. An inert gas, such as nitrogen or argon, can be used to form an inert layer over the pool of burning liquid sodium, but the gas must be applied very gently and contained over the surface. Except for soda ash, most of the powdered agents that are used to extinguish small fires in solid pieces or shallow pools will sink to the bottom of a molten mass of burning sodium – the sodium will float to the top and continue to burn. If the burning sodium is in a container, it may be feasible to extinguish the fire by placing a lid on the container to exclude oxygen.

While a sodium leak and an associated fire or explosion would have significant effects on people on site, the consequences will not extend to the nearest plant boundary which is approximately 120 m away from the closest sodium pipework (the array at the northwest corner of the site).

Sodium Research Collaboration

Because of the inexperience in Australia with handling of molten sodium in large quantities, and precipitated by the 2015 fire at Jemalong, Vast Solar is sponsoring a collaborative research program with the Australian National University (ANU) and NSW Fire and Rescue. ANU is constructing a test laboratory to gain better understanding in the following areas:

- Sodium fire hazard identification and risk mitigation as it pertains to the sodium laboratory.
- Testing levels of smoke with respect to the rate of sodium combustion in an enclosed area with volume corresponding to the volume of the ANU laboratory and under various exhaust conditions
- Defining a robust emergency response procedure in the event of a sodium fire.
- Ensuring combustion by-products are contained to the immediate laboratory area.
- Identifying and conducting novel experiments with sodium fires to contribute to the existing literature on sodium fire propagation and mitigation.
- Gaining practical experience with igniting and extinguishing sodium fires.
- Sodium fire hazard identification and risk mitigation as it pertains to the Vast Solar demonstration plant and the planned 30MW plant.
- Defining a robust emergency procedure in the event of a sodium fire.
- Gaining practical experience with igniting and extinguishing sodium fires.
- Defining a general emergency response approach for all possible scales and severities of sodium fires.
- Supervising fire tests conducted by The ANU and Vast Solar.

3.3 Steam Explosion

Steam is heated by passing it through a heat exchanger with the molten salt heat transfer medium. This is not the molten sodium that is used in the solar receiving towers. A loss of containment of steam or a catastrophic failure of the turbine could result in a serious injury or fatality to on site personnel. The boilers and turbine are located within the power island which is around 400 m from the closest site boundary and will not have an offsite impact.

3.4 Electromagnetic Fields

Electromagnetic Fields (EMF) are generated within the generator and along power lines. They are discussed in Section 6.3.1 of the EIS. EMFs at the Solar Station and along the 66kV transmission line would be typical of those at other power producing facilities.

3.5 Fire (excluding Sodium and LPG)

The potential exists for fires to start at the Solar Station in combustible material as well as in thermal oil or other minor quantities of Dangerous Goods. An Emergency Response Plan and Safety Management Plan will address these. Firefighting facilities, such as hose reels and extinguishers will be kept and maintained in accordance with relevant Australian Standards.

With creation of thermal energy and utilisation of flammable chemicals there is an elevated risk of activities resulting in a grass fire. The proposal is unlikely to significantly affect wildfire frequency in the areas adjacent to the subject site. Fire frequency within the site boundary is already likely to be low given the high levels of modification and low fuel loads.

3.6 Flooding

The site is located in close vicinity to the Lachlan River and the Thurumbidgee Lagoon. A Flood Impact Assessment (FIA) has been conducted and is attached as Appendix C to the EIS. This FIA noted that it is recommended to raise infrastructure above a selected flood level or flood proof infrastructure below the 0.5 per cent AEP flood level. This is estimated to be between 0.9 m and 1.1 m above ground level. The current proposal design is consistent with this recommendation; the heliostats would be 0.5 m above the ground surface during normal operations, but could be orientated to a horizontal position during a flood event which would exceed 0.9 m above ground level.

It is recommended that emergency plans for the 30MW plant specifically cater for the eventuality of a major flood, in particular they should prescribe arrangements for ensuring the integrity of sodium-containing process equipment and for properly securing any stored packaged sodium.

3.7 LPG

20kL of LPG is to be stored at site. Design details are not yet formulated but it has been assumed that this will be in two horizontal cylindrical tanks. These tanks will be stored adjacent to the power island. There are several potential consequences from scenarios involving LPG.

A *jet fire* occurs when LPG escapes with velocity through a leak in a vessel or pipe and is ignited. Jet fires are characterized by significant levels of thermal radiation (i.e. they have very hot flames).

A *Boiling Liquid Expanding Vapour Explosion (BLEVE)* can occur when a vessel containing LPG is heated by an external fire. As the temperature within the vessel rises, the LPG will boil and be released through the pressure relief valve. Eventually the vessel can weaken and fail catastrophically producing a fireball-type explosion. This explosion will produce significant levels of thermal radiation, as well as potentially throwing the vessel some distance.

LPG is heavier than air, and when released can form clouds that can travel some distance and then either disperse or ignite. If the cloud is in an open area, a *flash fire* will occur. This is where the cloud ignites and burns. People inside the area of a flash fire are likely to be killed, while people outside of the flash fire generally will survive.

If an LPG cloud gathers in area that is congested with obstacles, such as the Power Island or heliostat arrays, it can become confined. When ignited it can result in a *Vapour Cloud Explosion (VCE)* that will produce a damaging pressure wave that will travel beyond the cloud itself. Total confinement is not necessary for this to occur. In fact regular arrays of obstacles such as the heliostats make for high explosion potential.

4. Consequence Analysis

4.1 Hydrogen

The hydrogen released during a reaction between water and sodium will, if oxygen is present, generally ignite immediately in a series of small flames. The atmosphere contains sufficient oxygen for this to occur. The source of ignition is the heat from the exothermic reaction between the sodium and the water. For this reason, hydrogen is unable to build up in large cloud, either confined or unconfined, that can subsequently explode.

A hydrogen explosion has not been modelled as a significant build up is not credible. Even if large volumes of hydrogen were allowed to build up (for example in a building or the air-cooled condensers), the effects of a vapour cloud explosion would not pose an offsite risk due to the distance to the site boundary.

4.2 LPG

The location of the LPG tanks has not been finalized so it has been assumed that they are located at the north-east corner of the power island, which is the closest location to the site boundary.

The worst case scenario for each potential consequence has been modelled. For all consequences, the worst case scenario typically occurs on still and cloudless nights that allow a vapour cloud to drift across the ground. Solar radiation and wind will result in a more turbulent atmosphere that will help disperse a cloud.Table 7 shows the worst case scenarios for each consequence.

Table 7: Worst case scenarios

Consequence	Worst Case Scenario
BLEVE	Entire LPG storage tank explodes (10kL)
Jet fire	A leak through a hole with a diameter of 100mm, pointing at the site boundary towards north north east.
Flash fire	A leak through a hole with a diameter of 100mm, pointing at the site boundary towards north north east. This area is uncongested. An instantaneous rupture of an entire vessel is not the worst case scenario as it will disperse in all directions on a still cloudless night.
VCE	A leak through a hole with a diameter of 100mm, pointing at the arrays towards south. This area is congested by the heliostats and a VCE could result.
Missile fragments	In event of an explosion or BLEVE, metal fragments can travel considerable distances (up to around 1km)

These worst case scenarios have been modelled using specialist consequence modelling software TNO Effects V10.0. The technical parameters used in the model are shown in

Table 8.

Table 8: Model Inputs

Input	Value	Source or Rationale
Chemical for LPG	Propane	Elgas [Ref. 004]
Air temperature	9.6ºC (Annual average minimum temperature)	BOM [Ref. 001]
Pasquill Atmospheric Stability	F (Very Stable)	Still, cloudless night scenario
Wind Speed	2 m/s	Still, cloudless night scenario
Relative Humidity	• 65% at 9am • 40% at 3pm • An average of 53% used for modelling	BOM [Ref. 001]
Solar Radiation	0 kW/m^2	Still, cloudless night scenario
Vessel pressure	Vapour pressure corresponding to vessel temperature	
Vessel liquid level	80%	TNO Effects Default Value
Type of subsoil below tank	Heavy concrete	
Ground Roughness	Low crops, occasional large objects	
LPG vessel dimensions	• 10.7 m long • 1.22 m diameter • 12.5 m3 volume	Elgas [Ref. 005]
Risk Curve for VCE calculation	10 (Detonation)	Assumed worst case scenario
Fraction of cloud confined	• 0.00 for a flash fire • 1.00 for a VCE	

The results of a BLEVE are shown in Figure 4. The site boundary being used for the purpose of this study is that of the Jemalong Station which is shown by the pink line. The purple contour represents the extent of a BLEVE fireball, which would kill any person within it. The red contour represents the extent of heat radiation of 12.6kW/m^2 which would result in a significant chance of a fatality for extended exposure. The orange contour represents the extent of heat radiation of 4.7kW/m^2 which would result in injury after 30 seconds exposure.

These consequence contours are contained within the Jemalong Station and it is hence concluded that the potential for offsite consequences is insignificant.

It should be noted that wherever there is the potential for explosions (from sodium or LPG for example), there is the possibility of missiles (i.e. metal fragments) going some considerable distance. The chance of a person being struck by fragments is negligible however, and this is traditionally excluded from quantitative assessment.

Figure 4: Modelled results of an LPG BLEVE

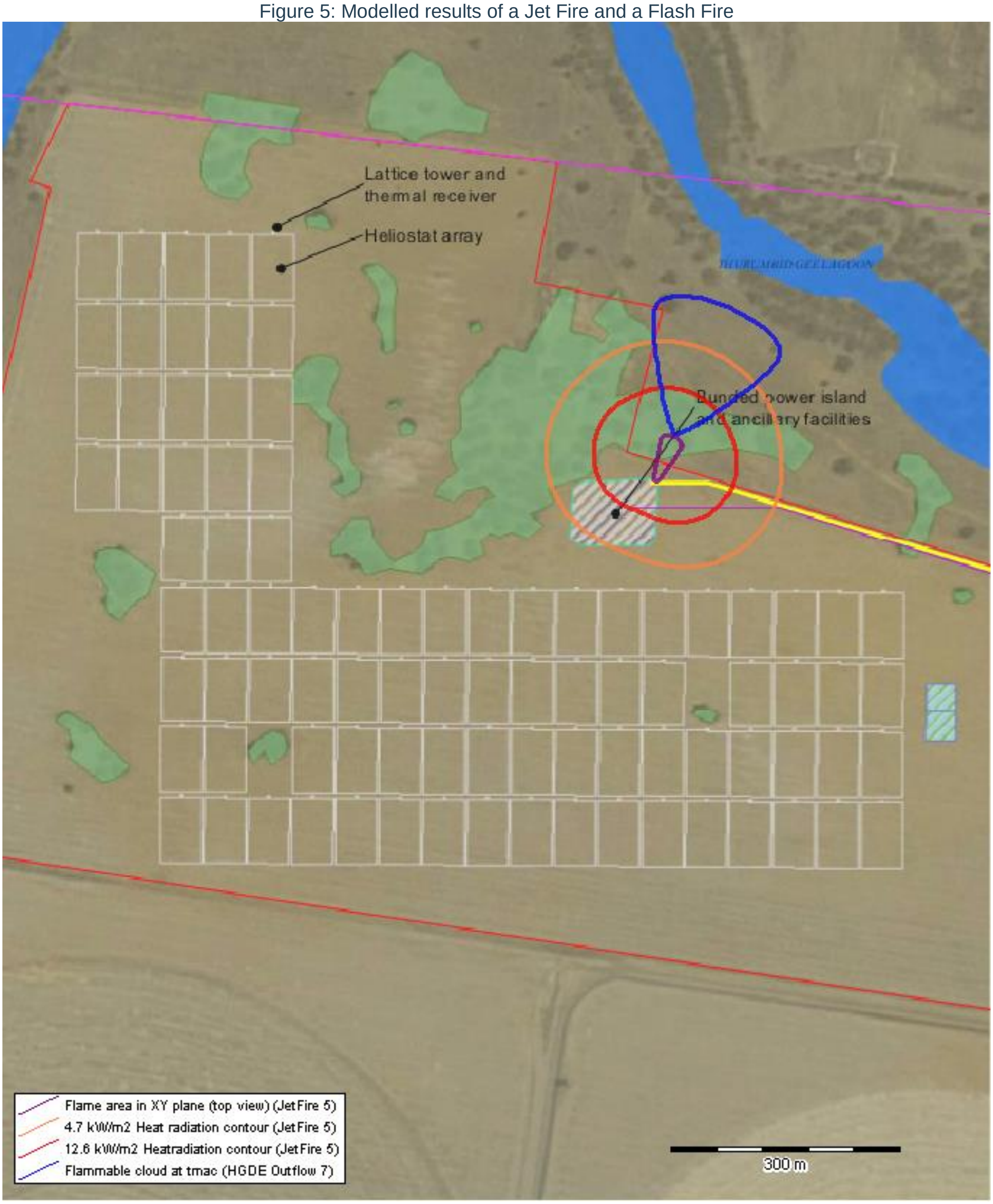
Modelled results showing a Jet Fire and Flash Fire are shown in Figure 5. . The site boundary being used for the purpose of this study is that of the Jemalong Station which is shown by the pink line.

The blue contour represents the area of the LPG cloud where the concentration is between the Lower Flammability Limit (LFL) and the Upper Flammability Limit (UFL) and would form the extent of a Flash Fire.

The purple contour represents the extent of a jet fire flame, people within this area would be killed. The red contour represents the extent of heat radiation of 12.6kW/m^2 from a jet fire flame which would result in a significant chance of a fatality for extended exposure. The orange contour represents the extent of heat radiation of 4.7kW/m^2 from a jet fire flame which would result in injury after 30 seconds exposure.

All of these contours are contained within the larger Jemalong Station.

Figure 5: Modelled results of a Jet Fire and a Flash Fire



The results of a VCE are shown in Figure 4. The site boundary being used for the purpose of this study is that of the Jemalong Station which is shown by the pink line. The blue contour represents the area of the LPG cloud prior to ignition. The purple contour represents the extent of overpressure of 7kPa from the explosion, which represents a 10% chance of injury to persons.

This contours are contained within the larger Jemalong Station.

Figure 6: Modelled results of a Vapour cloude Explosion

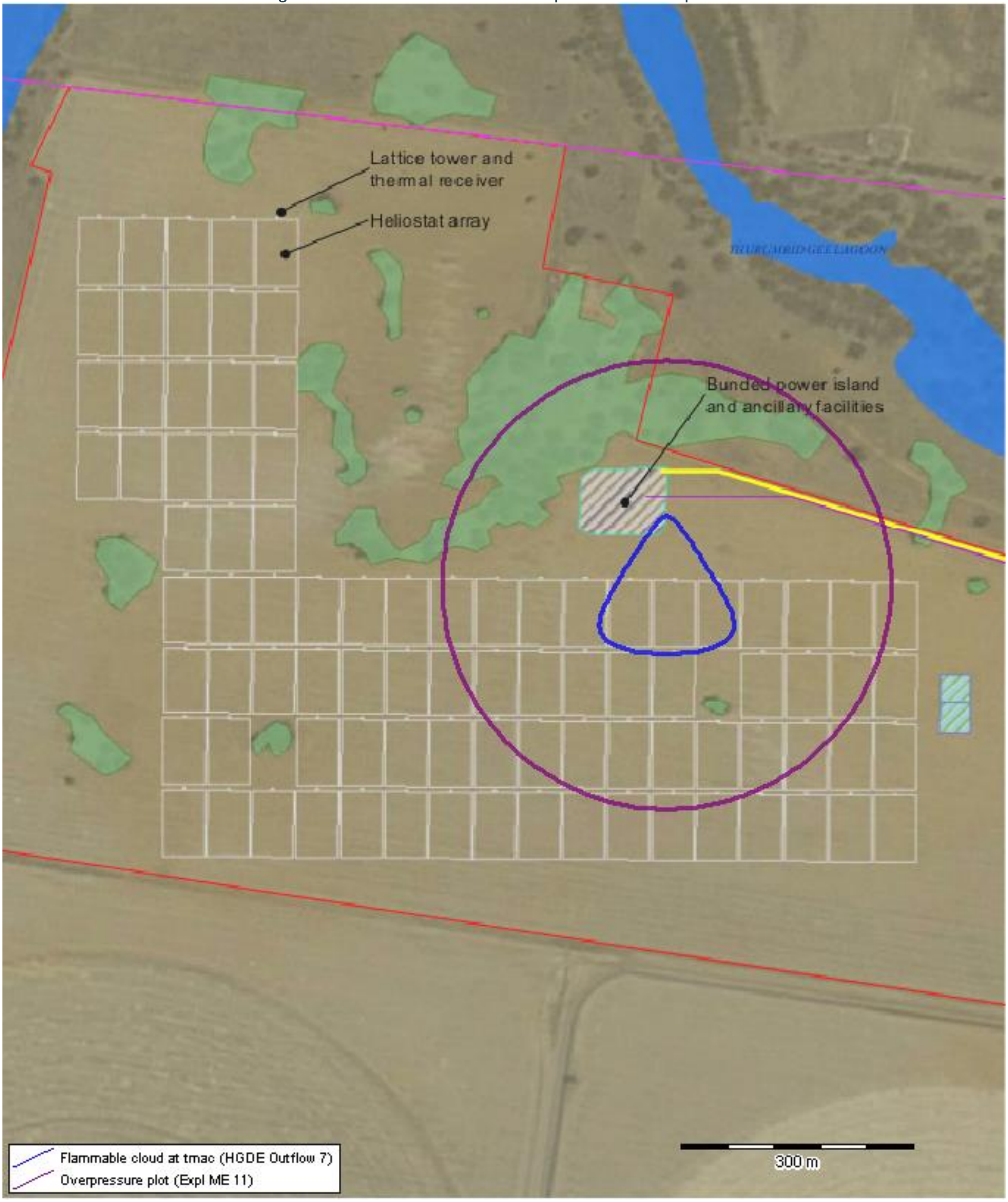


Table 9 shows the distance from the LPG tank to the edge of the consequences from the worst case scenario for each of the four potential consequences.

Table 9: Worst case scenarios results

Consequence	Contour of interest	Distance
BLEVE	Distance of thermal radiation of $4.7kW/m^2$ from LPG tank	357m
Jet fire	Distance of thermal radiation of $4.7kW/m^2$ from LPG tank	181m
Flash fire	Distance of LPG cloud Lower Flammability Limit from LPG tank	266m
VCE	Distance to centre of explosive cloud from LPG tank	153m
	Distance to overpressure of 7kPa from centre of explosion	266m

5. Safety Management System

Both process safety and workplace health and safety (WHS) need to be managed on facilities of this type via a formal Safety Management System (SMS). The SMS would typically incorporate:

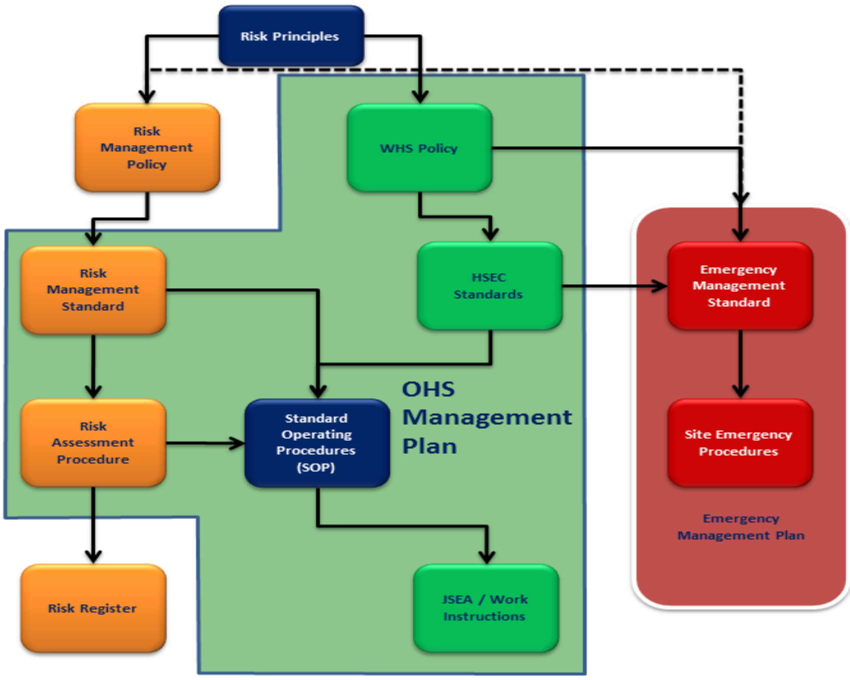
- The safety objectives
- Organisational arrangements and management structure
- The systems and procedures by which these are to be achieved
- The performance standards which are to be met
- The means by which adherence to the performance standards is to be maintained

An SMS is in place for the $6MW_{th}$ Pilot Plant, which is located at the same site as the 30MW Solar Station that is the subject of the PHA. The SMS is described in a series of management plans, in particular the OHS Management Plan at the corporate level, a site specific Safety Management Plan for the construction/commissioning phase, a Risk Management Plan and Emergency Response Plan. The relationship between documents is shown in

Figure 7.

This SMS will be expanded and adapted to form the SMS for the 30MW Solar Station. This will include an increased focus on process safety events in addition to workplace health and safety risks.

Figure 7: Relationship betweem risk and safety plans



5.1 Risk Management Plan

The Risk Management Plan (RMP) is a corporate level plan that defines the relevant overarching processes applicable to risk management for Vast Solar. This includes defining the baseline risk profile of Vast Solar as represented by the entries in the Risk Register.

This RMP also represents the specific but separate risk management tools employed at Vast Solar. This enables Vast Solar to present this information in a concise way to inform external parties.

The RMP also presents Vast Solar's:

- Risk Matrix
- Likelihood and consequence categories
- Risk sale (for threats and benefits)
- Risk Register template

5.2 Occupational Health and Safety Management Plan

The Occupational Health and Safety Management Plan (OHSMP) is a corporate level plan that represents Vast Solar's requirements for the effective management of safety at its facilities. This provides:

- Processes for communication of Vast Solar's policies and plans for the provision of a healthy and safe working environment;
- Mechanisms that enable identification and documentation of hazards associated with exploration and operation activities. This includes documentation of systems used to risk associated with the hazards;
- Communication of hazards and controls with personnel working on Vast Solar activities / sites;
- Processes which ensure personnel are appropriately trained and competent in their roles;
- Vast Solar mechanisms for site occupational health and safety performance measurement, monitoring and reporting; and
- Facilitation for the active involvement of personnel in relevant OHS issues.

The scope of the OHSMP includes:

- Work Health and Safety Policy
- Leadership commitment
- Legal requirements
- Planning Goals
- Risk Management
- Incident and Emergency management
- Consultation and Communication
- Training and Awareness
- Supplier and Contractor Management
- Change Management
- Sodium Safety
- Operations and Maintenance

5.3 Safety Management Plan

The Safety Management Plan (SMP) is a *site specific* plan to:

- Outline the responsibilities of individual roles;
- Define Vast Solar's management of workplace health and safety when constructing the facility; and
- Provide guidance on Vast Solar's obligations under the SMP and the OHSMP.

The content of the plan is similar to that of the OHSMP, although the scope is restricted to the construction and commissioning phase for the Jemalong site.

5.4 Site Emergency Response Plan

The Site Emergency Response Plan (SERP) is to provide standard responses to emergencies to enable quick, safe and effective responses to an emergency in order to:

- Prevent injuries
- Minimize impacts to the environment
- Control sodium incidents
- Mitigate asset damage

The plan applies to any incident that has the potential to occur. It includes:

- Location and access information
- Roles and accountabilities during an emergency
- Classification, communication and organisational plans
- Plans for specific emergencies
- Post emergency plans, including media guidelines, next of kin notification, investigations and work resumption.

5.5 Additional Standards and Procedures

In addition to the four key plans outlined above, there is a range of controlled supporting documentation within the SMS. This includes:

- Policies;
- Standards;
- Safe Operating Procedures; and
- Work Instructions / Job Safety and environmental Analysis

5.6 SMS Review for 30MW Plant

As part of this PHA, the existing SMS was reviewed with a view to ensuring that it would be suitable for management of major hazard facility of this type. If the 30MW plant is approved and goes ahead into detailed design and construction, the SMS will need to be further developed to make it specific to the plant and to bolster process safety management arrangements to reflect the increased magnitude of hazard. The SMS is expected to require approval by both MHF and planning authorities (noting that an approved SMS is normally required as a condition of development consent).

6. Conclusions

The 30MW Jemalong Solar Station presents a number of risks associated with the storage and handling of hazardous materials. These have been analysed in this PHA, supported by various other safety studies for the preceding Demonstration and Pilot Plants. The results of this analysis show that there is very limited potential for offsite risks and that the applicable risk criteria for land use safety planning are therefore easily satisfied.

A Safety Management System is in operation for the existing $6MW_{th}$ Pilot Plant at the Jemalong site. This SMS will be adapted and expanded upon to cover the 30MW Solar Station.

Notwithstanding that the offsite risks are very low, it is stressed that the risks to onsite personnel associated with sodium are significant. This is not the primary concern for the planning process, although an important consideration. However the facility is likely to be classified as a Major Hazard Facility under WHS legislation and the control of onsite risks will be need to be well justified in the Safety Case required under that regime.

The following specific recommendations are made:

1. The 30MW plant should be subjected to HAZOP and the detailed HAZID undertaken for the 6MWth Pilot Plant should be made specific to the 30MW plant and updated to include the particular hazards identified in the PHA (Table 6)
2. Emergency response plans should include specific details of preparations necessary to secure sodium in event of an impending flood (refer section 3.6)
3. The site SMS should be updated for the 30MW plant, with particular focus on the items identified in this PHA report (refer section 5.6)

7. Terms and Abbreviations

The following defines the terms and abbreviations utilised throughout this document.

Term / Abbreviation	Description
AEP	Annual Exceedance Probability
BLEVE	Boiling Liquid Expanding Vapour Explosion
BOM	Bureau of Meteorology
DPE	NSW Department of Planning and Environment
EIS	Environmental Impact Statement
EMF	Electromagnetic Field
FIA	Flood Impact Assessment
HAZID	Hazard Identification
HAZOP	Hazard and Operability Study
HIPAP	NSW DPE's Hazardous Industry Planning Advisory Paper
LFL	Lower Flammability Limit
LPG	Liquefied Petroleum Gas
MHF	Major Hazards Facility
MW / MWth	Megawatt / Megawatt Thermal
OHSMP	Occupational Health and Safety management Plan
PHA	Preliminary Hazard Analysis
RMP	Risk Management Plan
SMP	Safety Management Plan
SMS	Safety Management System

Term / Abbreviation	Description
UFL	Upper Flammability Limit
VCE	Vapour Cloud Explosion

8. References

Number	Reference	Date
[Ref. 001]	Bureau of Meteorology; *Climate statistics for Australian locations – Forbes Airport AWS*	Accessed January 2016
[Ref. 002]	NSW Department of Planning and Environment; *Hazardous industry Planning Advisory Planning No 4 – Risk Criteria for Land Use Safety Planning*	January 2011
[Ref. 003]	International Association of Oil and Gas Producers; *Risk Assessment Data Directory – Storage incident frequencies; Report 434 -03*	March 2010
[Ref. 004]	Elgas; *Is There a Difference Between Propane vs LPG?;* http://www.elgas.com.au/blog/350-propane-lpg-whats-what	Accessed January 2016
[Ref. 005]	*LPG Bulk Storage Tank Solutions For Business;* https://www.elgas.com.au/lpg-tank-bulk-storage-commercial-industrial-sizes-prices-	Accessed January 2016
[Ref. 006]	National Transport Commission; *Australian Dangerous Goods Code;* Edition 7.4	December 2015
[Ref. 007]	United States Fire Administration; *Sodium Explosion Critically Burns Firefighters – Newton, Massachusetts;* Accessed from the US Federal Emergency Management Agency; https://www.usfa.fema.gov/downloads/pdf/publications/tr-075.pdf	1993
[Ref. 008]	Mikami H, Shono A & Hiroi H; *Sodium Leak at Monju – Cause and Consequences;* Accessed from the International Atomic Energy Agency;	1996

Number	Reference	Date
	http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/31/044/31044840.pdf	

Appendix A – HAZID Minutes for $6MW_{th}$ Pilot Plant

HAZARD IDENTIFICATION						RISK RANKING													ACTIONS					ACTIONS TAKEN		
						Health & Safety				Environment				Financial												
No.	Element	Hazard / Threat	Cause	Consequence	Existing Controls	Consequence	Likelihood	Level	Rating	Consequence	Likelihood	Level	Rating	Consequence	Likelihood	Level	Rating	Highest Risk Ranking	Recommended Action (Improve existing controls / implement new controls)	Responsibility	Target Date	Comment	Status of Recommended Action as at 5 Feb 2015	Action Taken as at 5 Feb 2015	Further Actions Required	Target Date
1	**1. Manufacturing**	Rotating Machinery	Exposed Cutting Head	Amputation	Partial Guarding in place	-3 Moderate	4-Likely	High	-12					-2 Minor	4-Likely	Medium	-8	-12	**Hard solution:** Consider design of machine guarding	EMSQ	30/06/2014		Closed	* Partial guarding considered adequate. No further action planned.		
2	**1. Manufacturing**	Noise	Operation of CNC (Computer Numerically Controlled) Routers and air handling systems	Industrial deafness	PPE (hearing protection)	-1 Low	5-Almost Certain	Medium	-5	-1 Low	4-Likely	Low	-4	-1 Low	1-Rare	Very Low	-1	-5	**Hard Solution not viable** **Soft solution:** Monitor	EMSQ	30/06/2014		Ongoing	* Hearing protection provided. * Monitoring ongoing.		
3	**1. Manufacturing**	Manual Handling	Moving cumbersome panels	Pains and Strains, lost time;	Forklift procedures, supervision	-3 Moderate	3-Possible	Medium	-9					-2 Minor	3-Possible	Medium	-6	-9	**Hard solution**: Engineer a lift truck for moving panels	EMSQ	31/03/2014		Closed	* EPS blocks (~140kg) lifted by specialised forklift attachment * Transported to manufacture shed on a truck * In manufacture shed there is a pallet jack or lifted by two people * Transport mirrors out to the field on a trailor (capacity for 18 mirrors at once) * In the field, standard procedure is for two people to lift each individual mirrors Manual handling is ongoing.		
4	**1. Manufacturing**	Sharp Edges	Handling Glass Mirrors; Sharp Edge Tools	Cuts and abrasions	PPE; supervision; procedures	-2 Minor	3-Possible	Medium	-6					-1 Low	3-Possible	Very Low	-3	-6	**Hard solution not viable** **Soft solution**: Specialised PPE	EMSQ	28/02/2014		Closed	* Personel handling glass mirror or sharp edged tools were briefed at the pre-start meeting on 28/1/15		
5	**1. Manufacturing**	Hazardous Chemicals (adhesives and EPS)	Fumes from EPS panel manufacture and use of adhesives	Chronic illness; acute poisoning	Natural ventilation; PPE; supervision; procedures	-2 Minor	3-Possible	Medium	-6	-2 Minor	3-Possible	Medium	-6	-2 Minor	3-Possible	Medium	-6	-6	**Hard solution:** ventilation **Soft solution:** education	EMSQ	31/03/2014		Ongoing	* Fumes no longer a risk - have completed EPS pre-expanding and moulding. This action was completed in a ventilated area. * Natural ventilation is used in manufacturing shed where adhesives are applied.	* Request documentation from Jonno and Yiyang to confirm procedures in place.	13/02/2015
6	**1. Manufacturing**	Mobile Equipment (Forklift)	Struck by equipment	Acute injury; Death	Licensing; supervision;	-3 Moderate	3-Possible	Medium	-9					-2 Minor	3-Possible	Medium	-6	-9	**Hard solution:** plant layout, barriers to be considered, AV alarms; **Soft solution:** VOC (Verification of Competancy)	EM	31/03/2014		Open	* AV alarms not yet functional on forklift, pile driver or utes. * Personel required to have ticket for driving forklifts / drivers license for driving the car. Records kept in training and competancies register. * Barriers not considered practical. Current control: ensure people are aware of forklifts in operation - raised at pre-start 4/02/15	* Investigate any VOC requirements to verify that they can drive a forklift. * Update training and competancies register.	13/02/2015
7	**1. Manufacturing**	Compressed Air	Burst, inappropriate use	Air injection; foreign object injury	Supervision; PPE; SOP	-2 Minor	3-Possible	Medium	-6					-2 Minor	3-Possible	Medium	-6	-6	**Hard solution:** specialised nozzles; **Soft solution:** education	EM	31/03/2014		Open	* No SOP in place however JSA is being written. * Need to confirm use of specialiesd nozzles.	* No SOP in place however JSA is being written, expect to be completed by 13/02/15 * Need to confirm use of specialiesd nozzles.	13/02/2015
8	**1. Manufacturing**	Open flame, hot sparks, hot surfaces	Poor housekeeping; smoking; hot work; mechanical failure	Fire resulting in burns, respiratory injury, asset loss, interruption to production	SOP; housekeeping; FFE	-3 Moderate	2-Unlikely	Medium	-6	-4 Major	2-Unlikely	Medium	-8	-4 Major	2-Unlikely	Medium	-8		**Hard solution:** smoke free workplace, smoke detectors; **Soft solution:** education, drills	EMSQ	30/06/2014		In progress	**Hard solution:** * Smoke free workplace achieved, education included in induction. * No smoke detectors installed. Requirement under the Dolphin Fire Engineering report. Currently no expected completion date. **Soft solution:** * Fire drill not yet held - planned to be held before 5/03/15. * JSAs and SWMS ccompleted for hotworks in field rather than SOPs as these are better suited to construction works. * Welding undertaken only by personel with appropriate ticket. * Training and competancy register exists. Requires update as at 4/02/15 * Note there is are no relevant SOPs. However smoking is included in the Safety Management Plan.	* Fire drill * Update hard and soft copies of JSA and SWMs folders and registe * Update training and competancy register.	13/02/2015
9	**1. Manufacturing**	Electricity	Exposure to electrical conductors; unauthorised electrical work	Electrocution, burns, death	RCD; (Residual Current Device) Electrical testing and tagging; supervision	-3 Moderate	2-Unlikely	Medium	-6					-1 Low	3-Possible	Very Low	-3	-6	**Hard solution not viable** **Soft solution:** VOC	EMSQ			Closed	* Register of Training and Competancies maintained. * Specifically, accredited electrician employed on site Note: RCDs available on site however use of RCDs is not enforced or supervised. Note: PPE standard is enforced	* RCDs are required (refer to AS construction) for all works. Education required. * Testing and tagging eduction required - need to test and tag all electronic devices - extensive update required then maintain system.	5/03/2015
10	**1. Manufacturing**	Dust	Mirror manufacture	Respiratory; housekeeping	Vacuum on machines; housekeeping procedure	-2 Minor	3-Possible	Medium	-6					-1 Low	3-Possible	Very Low	-3	-6	**Hard solution not viable**; **Soft solution:** education, PPE	EMSQ	31/03/2014		In progress	* Minimal education to date. To be raised in pre-start by 28 February 2015.	* To be raised in pre-start by 28 February 2015.	28/02/2015
11	**2. Solar Array**	Sharp Edges	Impact with heliostat	Laceration	None	-2 Minor	3-Possible	Medium	-6									-6	**Hard solution:** review engineering solution; **Soft solution:** education	CTO	31/03/2014		Closed	**Hard solution:** * Engineering solution not viable (would require alternative manufacture process) **Soft solution:** * All personel briefed on importance of care when working with sharp edges during pre-start on 28/02/15 * Personel working specifically in the mirror manufacture briefed on appropriate precautions before beginning works.		
12	**2. Solar Array**	Reflected Light	Exposure to enhanced UV mirror reflection exposure to glare	Chronic illness; temporary blindness	PPE: clothing, sunglasses; education	-2 Minor	3-Possible	Medium	-6									-6	**Hard solution not viable;** **Soft solution:** review O&M procedure	OM	31/03/2014		In progress	* Covered in prestart 4/02/2015 * O&M procedure not yet in place. * Performing SLAM process - site supervisor briefs workers handling mirrors to be aware of reflection risks. * Note concentrated light from single mirror is not dangerous - hot and very bright but not dangerous.	* Write O&M procedure once approaching operation phase.	28/02/2014

HAZARD IDENTIFICATION						RISK RANKING													ACTIONS					ACTIONS TAKEN		
						Health & Safety				Environment				Financial												
No.	Element	Hazard / Threat	Cause	Consequence	Existing Controls	Consequence	Likelihood	Level	Rating	Consequence	Likelihood	Level	Rating	Consequence	Likelihood	Level	Rating	Highest Risk Ranking	Recommended Action (Improve existing controls / implement new controls)	Responsibility	Target Date	Comment	Status of Recommended Action as at 5 Feb 2015	Action Taken as at 5 Feb 2015	Further Actions Required	Target Date
13	**2. Solar Array**	Electricity	Short circuit	Fire resulting in asset damage, lost production	Housekeeping (grass); electrical standards; improved electrical isolation	-2 Minor	1-Rare	Low	-2	-3 Moderate	3-Possible	Medium	-9	-3 Moderate	3-Possible	Medium	-9	-9	**Hard solution:** review biological control; **Soft solution:** vigilance, education	EMSQ	30/04/2014		Closed	**Hard solution:** * Lawn mower is kept on site and plower has been used to maintain short grass. **Soft solution:** * Pre-start meeting on 28/01/14 included a briefing on appropriate fire avoidance practices when working in the field. * An Emergency Management Plan (EMP) and Site Emergency Response Plan (SERP) have been developed to ensure appropriate incident response. * Fire and Rescue NSW, NSW Ambulance were consulted during the development of the EMP and SERP; refer to email dated 13/06/15. HAZMAT also visited the site and provided input. * Dolphin fire engineering undertook a fire risk assessment for the HTF area.		
14	**2. Solar Array**	Tripping	Uneven ground, obstacles	Sprains, strains, fracture	Education; PPE, clothing standard	-2 Minor	3-Possible	Medium	-6					-1 Low	3-Possible	Very Low	-3	-6	**Hard solution:** review of OBS **Soft solution:** induction	EMSQ	30/04/2014		Closed	* Included in site induction		
15	**2. Solar Array**	Biological	Snake, spider, etc..	Poisoning, death	Education, PPE, clothing standard, housekeeping	-4 Major	3-Possible	High	-12	3 Moderate	3-Possible	Medium Opportunity	9	-3 Moderate	3-Possible	Medium	-9	-12	**Hard solution:** minimise biological habitat; **Soft solution:** implement emergency response **Opportunity:** Explore options for biological alternatives to managing vegetation management	CTO	30/09/2014		Ongoing	**Hard Solution:** * Lawn mower kept on site and surrounding grass has been kept short with plower. Requires ongoing attention. **Soft Solution:** * EMP and SERP developed. SERP and snakebite first aid are printed and posted on lunch room wall. First aid kit stored in lunch room draw and clearly marked. * Education is ongoing. Snakes are highlighted in the induction and in multiple pre-start meetings.		
16	**2. Solar Array**	Lightning	Environmental effects	Death, asset damage	Earthed Tower; education; circuit lightning protection	-4 Major	1-Rare	Low	-4					-3 Moderate	1-Rare	Low	-3	-4	**Hard solution not viable** **Soft solution:** Procedure; Lightning tracking	CTO	31/03/2014		In progress	* Standing tower is earthed, towers which are not standing are not yet earthed. Will be earthed before operation. * Lighting tracking - to be inclduded in Adverse Weather Protocol, which is not yet written.	* Look up lightning tracking options. * Include in Adverse Weather Protocol. In particular, instructions to not stand near towers or operate cranes in storms.	
17	**2. Solar Array**	Adverse Weather High wind, hail, dust storm	Environmental effects	Asset damage, Injury	Weather forecast; safe mirror mode for weather event; Designed for wind loads of 150kph but not confirmed	-3 Moderate	3-Possible	Medium	-9					-4 Major	2-Unlikely	Medium	-8	-9	**Hard solution:** confirm engineering standard; **Soft solution:** SOP	CTO	31/03/2014	Impact of dust on array efficiency.	Open	**Hard solution:** * Engineering standard not confirmed. * In field testing has occured - a large storm came through and there was no damage observed to mirrors. * Operation of heliostats in storms / high winds to be included in Adverse Weather Protocol.	* Establish engineering standard. * Write Adverse Weather Protocol	13/02/2015
18	**3. Receiver (includes Tower)**	HTF	Leaks from receiver and piping	Acute injury (burns, blindness), fire risk	Engineered and testing to **AS4041** and supporting standards welded connections on receiver	-3 Moderate	2-Unlikely	Medium	-6	-3 Moderate	2-Unlikely	Medium	-6	-3 Moderate	2-Unlikely	Medium	-6	-6	**Hard solution:** review pipe supports for tower	EM	31/03/2014		In progress	Note that the recommended action is no longer relevant: pipe supports exist but do not relate to potential leaks. Solution adopted: * Welds in receiver have been hydro-tested to AS1210 however are not yet compliant. Tests will continue until receiver passes tests. * Welds in pipes have not yet been tested, however will be hydro-tested to AS4041. Expected completion date of 28/2/15 NOTE: Reciever has been designed such that small leaks will not escape the steel shell - smoke will be visible as Na reacts with air before sodium is able to escape, alerting personel on site as to the problem.		
19	**3. Receiver (includes Tower)**	Falling Objects (gravitational)	Structural failure of tower or tower element	Serious injury	Design and install to AS4055: Wind loading for housing inspection, restricted access	-4 Major	1-Rare	Low	-4	-3 Moderate	2-Unlikely	Medium	-6	-4 Major	1-Rare	Low	-4	-6	**Hard solution:** review of tower raising and lowering;	EMSQ	31/03/2014	To be done in association with EM	Closed	* Foundation design, wind loadings, tail lift loadings and erection procedure completed by MJM Civil Engineers. * Towers were bought from China and assembled on site. * Were erected using a hand winch (hinged on one side) a JSA has been completed for this work.	* Update JSA / SWMS register.	13/02/2015
20	**3. Receiver (includes Tower)**	Falling off tower (gravitational)	Deliberate action	Serious injury	Tilt up tower for maintenance; SOP; security	-4 Major	1-Rare	Low	-4					-4 Major	1-Rare	Low	-4	-4		EMSQ	30/06/2014		No longer relevant	* Tower will be tilted down for maintenance - no ladders required to no risk of falling objects.		
21	**3. Receiver (includes Tower)**	Lightning	Environmental effects	Asset damage, injury	Ref to Risk 16, **Solar Array - Lightning**													0		EMSQ			In progress	Refer to No. 16. Adverse Weather Protocol to be completed.		
22	**3. Receiver (includes Tower)**	Electrical	Exposure to 240V heat trace voltage	Burns, electrocution	Designed and installed to AS3000: Electrical wiring;	-4 Major	2-Unlikely	Medium	-8					-4 Major	2-Unlikely	Medium	-8	-8	**Hard solution:** review of SIL in accordance with VS RM Std, review of SID of circuits	CTO	31/03/2014		Closed	* Heat trace has not been rolled out as at 4/02/15 * Has been designed in accordance with AS3000 * Employed qualified electrician to install electrical side	* Complete works.	
23	**3. Receiver (includes Tower)**	Loss of cover gas (threat)	Leak in pipework, upstream supply cut-off Refer to **Utilities Risks (70)**	Compromise operational integrity resulting in lost production, Contamination	Pressure monitoring									-2 Minor	2-Unlikely	Low	-4	-4	**Hard solution:** confirm control philosophy for cover gas management. **Refer to Utilities Risks**	EM	31/03/2014		Closed	* Non-return valve is strategically placed to prevent loss of pressure within pipe system. * Refer to JV-DRG-PRO-2009 Rev 1.5		
24	**4. Field Piping**	HTF Leak	Material defect, Mechanical failure, Impact by object	Fire, Injury, death Loss of production	Designed to **AS4041** and supporting standards; Restricted movement	-4 Major	2-Unlikely	Medium	-8	-3 Moderate	2-Unlikely	Medium	-6	-4 Major	2-Unlikely	Medium	-8	-8	**Hard solution:** review control philosophy for HTF (catastrophic loss), review access control arrangements in particular relating to vehicles (REF precautionary principle)	EMSQ	31/03/2014		Open	* Design review required	* Design review required of steam and HTF side precautions.	13/02/2015
25	**4. Field Piping**	Electrical (heat trace)	Exposure to electrical conductors; Unauthorised electrical work	Electrocution, Burns, death Fire	Designed to **AS3000**; Electrical testing and tagging; Supervision	-4 Major	2-Unlikely	Medium	-8					-4 Major	2-Unlikely	Medium	-8	-8		EMSQ	31/03/2014		Closed	* Heat trace has not been rolled out as at 4/02/15 * However, has been designed in accordance with AS3000 * Employed qualified electrician to install electrical side		

HAZARD IDENTIFICATION						RISK RANKING													ACTIONS				ACTIONS TAKEN			
						Health & Safety				Environment				Financial												
No.	Element	Hazard / Threat	Cause	Consequence	Existing Controls	Consequence	Likelihood	Level	Rating	Consequence	Likelihood	Level	Rating	Consequence	Likelihood	Level	Rating	Highest Risk Ranking	Recommended Action (Improve existing controls / implement new controls)	Responsibility	Target Date	Comment	Status of Recommended Action as at 5 Feb 2015	Action Taken as at 5 Feb 2015	Further Actions Required	Target Date
26	**4. Field Piping**	Electrical (buried service)	Exposure to electrical conductors; Unauthorised electrical work, rodents	Electrocution, burns, death, Fire, Process interruption	Designed to **AS3000;** Electrical testing and tagging; Supervision	-4 Major	2-Unlikely	Medium	-8					-4 Major	2-Unlikely	Medium	-8	-8	**Hard solution:** **Soft solution:** investigate buried service requirement	EMSQ	30/04/2014	In association with EM	In progress	* Buried service is 55V cable in the middle of the fields. Rolled out but not yet buried. Designed in accordance with AS3000. * Employed qualified electrician	* Requires further understanding of requirements.	13/02/2014
27	**4. Field Piping**	Slips and trips	Deliberate action	Injury	PPE, uniform standard	-3 Moderate	3-Possible	Medium	-9					-2 Minor	3-Possible	Medium	-6	-9	**Hard solution:** identify and install cross-overs to AS1657 **Soft solution:** induction	EMSQ	30/04/2014		In progress	Current controls: * Appropriate footwear, slips and trips highlighted in induction including rules to walk (not jump) over pipes and to take the long way around if required. Planned controls: * To be added to punchlist works after mechanical completion. Punchlist item will require specific access points; potentially including stepovers.		
28	**4. Field Piping**	High Pressure	Mechanical failure	Injury, Loss of system integrity, Production loss	Design to **AS4041** and supporting standards; pressure monitoring,	-3 Moderate	3-Possible	Medium	-9					-3 Moderate	3-Possible	Medium	-9	-9	**Hard solution:** confirm control philosophy	EM	31/03/2014		Open	* Design review required	* Design review required of steam and HTF side precautions.	13/02/2015
29	**4. Field Piping**	Hot surface	Insulation integrity (poor design, maintenance)	Burns, injury, Production loss	Designed to **AS4041** and supporting standards	-2 Minor	3-Possible	Medium	-6					-2 Minor	3-Possible	Medium	-6	-6	**Hard solution:** review and implement QA for design and installation; **Soft solution:** confirm O&M philosophy	EMSQ	31/03/2014		Open	* Insulation not yet installed. * process for insulation installation not yet developed * Maintenance requirements to be included in O&M procedure.	* Develop process for insulation installation * O&M procedure to be drafted .	13/02/2015
30	**Whole System**	Loss of control system (threat)	Loss of power, EMF interference, Physical interruption, Compromised control logic, Lightning, Compromised maintenance, KKS coding error	Loss of system and operational integrity	None	-4 Major	3-Possible	High	-12	-3 Moderate	3-Possible	Medium	-9	-4 Major	3-Possible	High	-12	-12	**Hard solution:** build in failsafe mode for loss of power, build in failsafe mode for loss of control systems	CTO	31/03/2014	Design includes gas powered back up generator.	In progress	* Control system has two parts: 1) Controls mirrors 2) Controls rest of plant With communication between the two parts. * The first control system has two power supplies: mains and battery back up. * The second control system is call a Distributed Control System (DCS) and also has two power supplies: mains and battery back up. The DCS also has two processors for redundancy and security. * This system is not yet installed. Further controls may be put in place following a design review.	* Design review required of steam and HTF side precautions.	13/02/2015
31	**5. Thermal Storage (Hot, Cold, Drain)**	HTF	Structural failure of tanks, piping, pumps, valves as a result of incorrect design, manufacture or material defect. System integrity failure resulting from compromised maintenance Catastrophic failure of other plant (steam generator, turbine, LPG storage) Deliberate interference Exceeding design parameters. Incorrect operating strategy	Serious injury, cascading failure leading to loss of system integrity, loss of production, asset damage, fire	Designed and installed to **AS1200: Pressure Equipment, AS1210: Pressure Vessels, AS1940:The Storage and Handling of Flammable and Combustible Liquids** Design discipline including application of precautionary principle to the sodium circuit.	-5 Catastrophic	2-Unlikely	High	-10	-4 Major	2-Unlikely	Medium	-8	-4 Major	2-Unlikely	Medium	-8	-10	**Hard solution:** Review engineering design to incorporate drainage, ignition sources and water storage. Confirm location of all water outlets (including safety showers, hoses, taps), review placement of fire fighting equipment (FFE) e.g. placement of fire hoses **Soft solution:** develop O&M strategies procedures incorporating non water emergency response, engage with insurer for viable protection plans	EMSQ	28/02/2014	**Include CTO, CEO will also be engaged in solution actions.**	**In progress**	**Hard solution:** * Review engineering design to incorporate drainage, ignition sources (i.e. pumps within hazardous zones) and water storage. This action needs to be addressed. Need to confirm hazardous area status and ignition sources. Bunded HTF area has a slight incline towards south. Need to monitor whether rainwater drains away or remains within bunded area. * Confirm location of all water outlets (including safety showers, hoses, taps). Confirmed and installed as er Dolphin Fire Engineering report * Review placement of fire fighting equipment (FFE) e.g. placement of fire hoses Confirmed and installed as per Dolphin Fire Engineering report **Soft solution:** Develop O&M strategies procedures incorporating non water emergency response, (open) Engage with insurer for viable protection plans. (open)	* Confirm hazardouse area status and ignition sources around HTF * Monitor whether rainwater drains out of HTF bunded area * Develop O&M strategy * Engage with insurance provider	
32	**5. Thermal Storage (Hot, Cold, Drain)**	HTF generating Hydrogen	Water deluge from incorrect emergency response; Flood/deluge event from natural or man-made storage; Incorrect housekeeping using water Deliberate interference System integrity failure resulting from compromised maintenance	Explosion - multiple small explosions from hydrogen ignition from a combination of water and sodium in sufficient quantity resulting in loss of system integrity. Damage caused to LPG storage system from first explosion projectiles. This in turn may result in significant LPG leak and rapidly escalating hazardous situation. Other effects include caustic by-products, dense white smoke, fire Community fear, adverse media response, impact to reputation Death, serious injury Asset loss	Designed and installed to **AS1200: Pressure Equipment, AS1210: Pressure Vessels** Design discipline including application of precautionary principle to the sodium circuit.	-4 Major	3-Possible	High	-12	-3 Moderate	3-Possible	Medium	-9	-4 Major	3-Possible	High	-12	-12	**Hard solution;** confirm requirement for LPG storage, review drainage and bunding, rigorous interrogation of control logic, fail to safe modes and requirements for redundancy. **Soft solution:** full planning engagement with emergency services, procedures and operator training,	EMSQ	31/03/2014	**Include EM, CTO, CEO**	**In progress**	**Hard solution;** confirm requirement for LPG storage, (Complete) review drainage and bunding, (Complete) rigorous interrogation of control logic, (review HTF and steam design and P&IDs) fail to safe modes and (review HTF and steam design and P&IDs) requirements for redundancy. (review HTF and steam design and P&IDs) **Soft solution:** full planning engagement with emergency services, (RFS have been engaged, have conducted a site tour, refer to email dated 13/6/14) procedures and operator training, (to be actioned as part of part of O&M plan)	* Design review required of steam and HTF side precautions. * Develop O&M procedures	13/02/2015
33	**5. Thermal Storage (Hot, Cold, Drain)**	Smoke	Reaction Na with H_20	Dense white smoke (respiratory irritant) Obscures visibility resulting in disorientation and source concealment Secondary injury (slips, trips and impact)	Plant located outside, Designed to AS1668.4: Natural Ventilation in Buildings	-3 Moderate	3-Possible	Medium	-9	-1 Low	3-Possible	Very Low	-3	-2 Minor	3-Possible	Medium	-6	-9	**Hard solution**: investigate other industry responses to similar threats (nuclear power industry)				Open	* Plant is located outside. * Further investigations have not been completed.	* Design review required of steam and HTF side precautions.	13/02/2015
34	**5. Thermal Storage (Hot, Cold, Drain)**	Electricity	Short circuit, arcing, damaged or exposed wiring resulting from poor installation or maintenance	Electrocution, potential for secondary fire or explosion	Designed and installed to AS3000: Electrical wiring Design discipline QA for build and commission	-4 Major	2-Unlikely	Medium	-8	-3 Moderate	2-Unlikely	Medium	-6	-3 Moderate	2-Unlikely	Medium	-6	-8	**Hard solution:** review adequacy of SIL application, equipment choice and locations of power outlets etc… (Safety Integrity Level) **Soft solution:** management controls for HSE and maintenance	EM	31/03/2014	EMSQ to provide support	In progress	* SIL study will not be completed. * Electrical design underway (almost complete) and done in accordance with AS 3000. Will also be installed in accordance with AS 3000. * No management controls in place. Plan to include in O&M plan.	* To be included in O&M plan.	13/02/2015

HAZARD IDENTIFICATION						RISK RANKING													ACTIONS				ACTIONS TAKEN			
						Health & Safety				Environment				Financial												
No.	Element	Hazard / Threat	Cause	Consequence	Existing Controls	Consequence	Likelihood	Level	Rating	Consequence	Likelihood	Level	Rating	Consequence	Likelihood	Level	Rating	Highest Risk Ranking	Recommended Action (Improve existing controls / implement new controls)	Responsibility	Target Date	Comment	Status of Recommended Action as at 5 Feb 2015	Action Taken as at 5 Feb 2015	Further Actions Required	Target Date
35	6. Steam Generator	Water and steam	High temperature, high pressure water and steam in contact with HTF: Leak or rupture of superheater or associated piping Material failure from chemical reaction e.g. corrosion Material failure from poor QA e.g. weld failure	Exposure of high temperature and high pressure steam to sodium stream resulting in uncontrolled reaction including continuing explosions, loss of containment for sodium and steam, dense smoke and structural failure Release of superheated steam resulting in severe injury, multiple death.	Design to AS1200: Pressure Equipment, AS1210 Pressure Vessels Separation of generator (outside) and turbine (inside) Purchase from reputable supplier	-5 Catastrophic	3-Possible	High	-15	-4 Major	3-Possible	High	-12	-5 Catastrophic	3-Possible	High	-15	-15	**Hard solution:** provision of physical barriers to reduce exposure of personnel and other plant, triggering of robust control system protection strategies (including redundancy), identify appropriate corrosion inhibitor, **Confirm ability to bypass steam and sodium from steam generator and pressure relief.** **Soft solution:** rigorous preventative maintenance program, robust inspection and audit regime, strong emphasis in education and induction programs, strategy development with emergency services	EM	31/03/2014	Solutions will also engage with CTO, CEO, EMSQ and specialist third parties The environmental hazard rating includes external stakeholder response **Key Action: Develop a milestone in project schedule to confirm closeout of this action (hard solution)**	In progress	**Hard solution:** provision of physical barriers to reduce exposure of personnel and other plant, (fire wall and HTF bund exist - inside bunded area to be covered with gravel) triggering of robust control system protection strategies (including redundancy), (incomplete - to be reviewed in design review) identify appropriate corrosion inhibitor, (incomplete - to be developed) Confirm ability to bypass steam and sodium from steam generator and pressure relief. (incomplete - to be reviewed in design review) **Soft solution:** rigorous preventative maintenance program, (not yet developed) robust inspection and audit regime, (not yet developed) strong emphasis in education and induction programs, (existing and ongoing) strategy development with emergency services (fires services have visited - were engaged during the development of the EMP)	* Design review required of steam and HTF side precautions. * identify appropriate corrosion inhibitor * Develop rigorous preventative maintenance program * Develop robust inspection and audit regime	13/02/2015
36	6. Steam Generator	Pressure	Uncontrolled release of high pressure steam or water (both at 40 Bar). No contact with sodium	Consequential damage to surrounding equipment Injury, Death	Design to AS1200: Pressure Equipment, AS1210: Pressure Vessels Generator outside, turbine inside Purchase from reputable supplier	-4 Major	3-Possible	High	-12	-1 Low	3-Possible	Very Low	-3	-4 Major	3-Possible	High	-12	-12	**Hard solution:** provision of physical barriers to reduce exposure of personnel and other plant, triggering of robust control system protection strategies (including redundancy), identify appropriate corrosion inhibitor, Confirm NDT for Steam Generator construction prior to delivery. **Confirm ability to bypass steam and sodium from steam generator and pressure relief.** **Soft solution:** rigorous preventative maintenance program, robust inspection and audit regime, strong emphasis in education and induction programs, high quality first response system	EM	31/03/2014	CTO, CEO, EMSQ,specialist third parties	Open	Hard solution: * provision of physical barriers to reduce exposure of personnel and other plant, triggering of robust control system protection strategies (including redundancy), identify appropriate corrosion inhibitor, (To be developed during design review) * Confirm NDT for Steam Generator construction prior to delivery. (to be confirmed) * Confirm ability to bypass steam and sodium from steam generator and pressure relief. (to be completed in review) Soft solution: rigorous preventative maintenance program, (not yet developed) robust inspection and audit regime, (not yet developed) strong emphasis in education and induction programs, (existing and in progress) high quality first response system (expect emergency reponse - refer to EMP)	* Design review required of steam and HTF side precautions.	13/02/2015
37	6. Steam Generator	Hot Surface	Parked															0					No longer relevant	Steam generator will be insulated. Insulation checking will be part of the O&M plan.		
38	6. Steam Generator	Electrical	Short circuit, arcing, damaged or exposed wiring resulting from poor installation or maintenance	Electrocution, potential for secondary fire or explosion Loss of power to control system	Designed and installed to AS3000: Electrical Wiring Design discipline QA for build and commission	-4 Major	2-Unlikely	Medium	-8	-2 Minor	2-Unlikely	Low	-4	-3 Moderate	2-Unlikely	Medium	-6	-8	**Hard solution:** ensure that design allows for a failsafe shutdown as a consequence of power loss, review adequacy of SIL application, equipment choice and locations of power outlets etc... **Soft solution:** management controls for HSE and maintenance	EM	31/03/2014		In progress	* SIL study will not be completed. * Electrical design underway and done in accordance with AS 3000. Will also be installed in accordance with AS 3000.	* Design review required of steam and HTF side precautions. * Failsafe measures to be considered as part of the design review. * No management controls in place. Plan to include in O&M plan.	13/02/2015
39	6. Steam Generator	Caustic By-product	Reaction Na with H_20	Injury resulting from direct contact of caustic by products Clean-up required Consequential damage to plant integrity	Designed for separation of HTF and water,	-3 Moderate	3-Possible	Medium	-9	-3 Moderate	3-Possible	Medium	-9	-4 Major	3-Possible	High	-12	-12	**Hard solution:** multiple level defence strategy	EMSQ	30/04/2014	Financial rating influenced by pollution and clean-up exposure	Open	* To be considered in design review.	* Design review required of steam and HTF side precautions.	13/02/2015
40	6. Steam Generator	Smoke	Reaction Na with H_20	Dense white smoke (respiratory irritant) Obscures visibility resulting in disorientation and source concealment Secondary injury (slips, trips and impact)	Plant located outside, Designed to AS1668.4: Natural Ventilation in Buildings	-3 Moderate	3-Possible	Medium	-9	-1 Low	3-Possible	Very Low	-3	-2 Minor	3-Possible	Medium	-6	-9	**Hard solution:** investigate other industry responses to similar threats (nuclear power industry)	EMSQ	31/03/2014		Open	* Plant is located outside. * Further investigations have not been completed. Plan to complete by 28/2/15	Refer to recommended actions.	28/02/2015
41	6. Steam Generator	Gravity	fall to ground from elevated section of SG	sprains and strains, fracture damaged equipment	Maximum height is 2m. Outlets for maintenance from controlled platforms (temp)	-3 Moderate	2-Unlikely	Medium	-6	-1 Low	2-Unlikely	Very Low	-2	-3 Moderate	2-Unlikely	Medium	-6	-6	**Hard Solution:** Investigate engineering solutions placing maintainable items inside work zone whilst standing at ground level. **Soft Solution:** Maintenance procedures	EM	31/03/2014		Closed	* Idea of this control is to put anything you can at ground level. Design complete and steam generator installed. Has not been designed with access from ground level. Intended response: a work platform will be used. * Further controls employed: - working at heights JSA - employ the SLAM process		
42	6. Steam Generator	Gravity	dropped objects, e.g. tools, parts, etc.	laceration, damaged items	All work required to be done from platforms or on the ground. No vulnerable parts.	-2 Minor	2-Unlikely	Low		-1 Low	1-Rare	Very Low	-1	-2 Minor	2-Unlikely	Low							Closed	* Further controls employed: - employ the SLAM process - barricade drop zones where necessary	* Future action: - raise at start meetings	13/02/2015
43	6. Steam Generator	Gravity	Item dropped onto SG or service lines	damaged plant, leaks	Maximum size of each item insufficient to cause damage under effect of gravity to SG but instruments vulnerable. 3mm stainless pipe installed for HTF lines plus 300mm insulation.	-1 Low	2-Unlikely	Very Low		-1 Low	2-Unlikely	Very Low	-2	-1 Low	2-Unlikely	Very Low			Vehicle not permitted in SG area unless under maintenance. Instruments reviewed for location and vulnerability	EM	31/03/2014		In progress	* There will be no vehicle access as there will be bollards in the way. * The instruments cannot be placed elsewhere: consider further during design review.	* Design review required of steam and HTF side precautions.	13/02/2015
44	6. Steam Generator	Noise	Pumps generating noise, emergency release of steam	Noise above 85 dBA resulting industrial hearing loss, acute ear damage	Emergency release frequency is rare and represents a consequential planned outcome. Frequency managed by control systems.	-3 Moderate	2-Unlikely	Medium	-6					-2 Minor	2-Unlikely	Low	-4	-6	Examine access to motors that produce noise < 85dBA @ 1m.	EMSQ	31/03/2014	In association with EM	Open	Refer to recommended action.		
45	6. Steam Generator	Noise (environmental)	emergency release of steam, pumps	community concern - neighbours	Discussed operations with neighbours. Reviewed noise exposure - est. at 30 dBA.					-1 Low	3-Possible	Very Low	-3	-3 Moderate	3-Possible	Medium	-9			CTO	31/03/2014	In association with CEO and Consultant. Reputational issue and engineering resolution cost.	Ongoing	* Met with Moxies and Stuarts in April / May 2014 discussed project including noise and steam. * No issues with neighbours to date.		
46	7. Turbine Generator	Hot surface	Contact with uninsulated surface	burns	Specified all hot surfaces (+65oC) to be insulated.	-3 Moderate	2-Unlikely	Medium	-6					-2 Minor	2-Unlikely	Low	-4	-6		EM	31/03/2014		In progress	* All surfaces will be insulated * Actions planned: - Check insulation after installation - Include schedule of insulation inspections in O&M plan	* Include in O&M plan	28/02/2015

HAZARD IDENTIFICATION						**RISK RANKING**													**ACTIONS**				**ACTIONS TAKEN**			
						Health & Safety				**Environment**				**Financial**												
No.	**Element**	**Hazard / Threat**	**Cause**	**Consequence**	**Existing Controls**	**Consequence**	**Likelihood**	**Level**	**Rating**	**Consequence**	**Likelihood**	**Level**	**Rating**	**Consequence**	**Likelihood**	**Level**	**Rating**	**Highest Risk Ranking**	**Recommended Action** (Improve existing controls / implement new controls)	**Responsibility**	**Target Date**	**Comment**	**Status of Recommended Action as at 5 Feb 2015**	**Action Taken as at 5 Feb 2015**	**Further Actions Required**	**Target Date**
47	**7. Turbine Generator**	Steam	Mechanical failure of delivery and return system	severe burns	Built to relevant standard (confirm?) Closed system - confirm design with Skoda	-4 Major	2-Unlikely	Medium	-8					-4 Major	2-Unlikely	Medium	-8	-8	Confirm system is closed with no venting outlets except emergency	CTO	31/03/2014		Open	* Design review required of steam and HTF side precautions.	* Design review required of steam and HTF side precautions.	13/02/2015
48	**7. Turbine Generator**	Noise	arising from steam movement through piping and valves	Industrial deafness, unable to hear alarms	Insulated lines. Limited exposure by operator PPE - hearing defenders	-1 Low	3-Possible	Very Low	-3	-1 Low	2-Unlikely	Very Low	-2	-2 Minor	2-Unlikely	Low	-4						Closed	* Turbine generator not yet installed. * No further actions planned beyond those identified ("existing controls")		
49	**7. Turbine Generator**	Gravity	ref SG											-2 Minor	2-Unlikely	Low	-4	-4					Open	* Expect to be able to conduct all routine maintenance from ground level (below 1.3m) * Where this is not possible, personel will be expected to: - employ the SLAM process, and if applicable: - write a working at heights JSA	* Write expected procedures into O&M plan	28/02/2015
50	**7. Turbine Generator**	Oil	Ruptured lines, mechanical failure of pumps	spilt oil resulting slippery surface which a person may slip and fall on. Flammable oil exposure that may ignite and damage turbine.	Built to relevant standard (confirm?)	-3 Moderate	2-Unlikely	Medium	-6	-1 Low	2-Unlikely	Very Low	-2	-3 Moderate	2-Unlikely	Medium	-6	-6	Confirm fire engineering protection levels for turbine area. Examine fire sensors and fire extinguishant.	CTO	31/03/2014		In progress	* Fire protection levels for turbine unconfirmed. A fire engineering report has been completed by Dolphin Fire Engineering for the building and contents and did not raise any issues regarding the turbine. * **No fire sensors in place, no intention to install.** Refer to Dolphin Fire Engineering report which states smoke alarms are required in building - these are not yet installed. * ABE type fire extinguishers currently placed just outside the exits to the building as per the Fire Engineering Report. (E for electrically active equipment, B for flammable liquids) * Can confirm that the turbine generator was built to ISO 12100: 2010 Machinery Safety Standard, ISO 13857: 2008, IEC 60204-1: 2005	* Confirm fire protection levels for turbine * Install smoke alarms as per Dolphin Fire Engineering report (required for occupancy certificate)	28/02/2015
51	**7. Turbine Generator**	Electricity	exposure of live conductors at 415v AC	Electric shock resulting in burns or death	Constructed to relevant standard (confirm?) All live conductors insulated to relevant standard.	-4 Major	1-Rare	Low	-4					-2 Minor	2-Unlikely	Low	-4	-4	**Hard Solution**: Provide spill kits for plant sectors **Soft Solution** - Robust isolation procedure to be developed. Spill control procedures.	EMSQ	30/04/2014		Ongoing	**Recommended action is incorrect** * Planned / ongoing actions: - Construction in accordance with AS 3000 - Engage electrician to complete works		
52	**7. Turbine Generator**	Rotating Machinery	Coupling turbine to generator. Enclosed rotating shaft on oil pumps.	laceration and degloving	All exposed rotating parts are shielded.	-3 Moderate	2-Unlikely	Medium	-6					-3 Moderate	2-Unlikely	Medium	-6	-6	**Hard Solution:** Confirm compliance to AS - machine guarding. **Soft Solution:** Develop robust isolation procedures	EM	31/03/2014	In association with EM	Open	* Required to confirm that the turbine generator has been designed in compliance with relevant AS.	* Required to confirm that the turbine generator has been designed in compliance with relevant AS.	28/02/2015
53	**8. Air Cooled Condenser**	Ref MaccSol RA												-2 Minor	2-Unlikely	Low	-4	-4		EMSQ		Maccsol have been requested to supply their risk analysis for the ACC design.	Open	Has not been received, to be followed up.	Follow up with MaccSol	13/02/2015
54	**8. Air Cooled Condenser**	Hot surfaces	Access to exposed hot piping and manifold	Burns	Supervision. Limited access via elevated walkway	-3 Moderate	3-Possible	Medium	-9					-3 Moderate	3-Possible	Medium	-9	-9	**Hard Solution**: Secure access to elevated area to prevent exposure to hot surfaces. **Soft Solution**: Separate and dedicated Job Safety Analysis for accessing upper sections of ACC.	EMSQ	31/03/2014	In association with EM	Open	* Hard solution has not yet been completed. The ACC has two levels: access to hot surfaces on the first level can be denied through locking the doors. Access to the second level will be denied through placing a chain across the ladder entrance if the hot surfaces are not insulated (this decision has not yet been made). * No JSA written as yet. JSAs will be written only for specific tasks were required. Whether a JSA will be required is determined through conducting a SLAM.	* Determine whether insulation is an appropriate option. If not, then install chain across ladder entrance .	13/02/2015
55	**8. Air Cooled Condenser**	Gravity	Elevated static work platform - main deck and top condenser manifolds, use of vertical ladders > ? Metres. Accessing fans for maintenance purposes. Maintainable equipt at	Fall to ground - death Drop objects - strike person - fracture, laceration. Drop items (not tools) - loss/damage to plant	Engineered access in accordance with relevant standard (confirm?). Handrails installed.	-4 Major	3-Possible	High	-12					-4 Major	3-Possible	High	-12	-12	**Hard Solution**: Investigate mechanical access to elevated work areas in side ACC. Confirm all access complies with working at height Codes of Practice. **Soft Solution**: Develop elevated work standard and associated procedures for ACC.	EMSQ	31/03/2014	In association with EM	Open	* Hard solution has not yet been completed. The ACC has two levels: access to hot surfaces on the first level can be denied through locking the doors. Access to the second level will be denied through placing a chain across the ladder entrance if the hot surfaces are not insulated (this decision has not yet been made). * Review of working at heights code of practice has not yet been completed. * Expect minimal routine work on ACC so unlikely to write a dedicated SOP. Approach to be included in the O&M plan, with focus on SLAM and then completing JSAs as applicable (depending on works).	* Review working at heights code of practice. * Write O&M procedure.	28/02/2015
56	**8. Air Cooled Condenser**	Electricity	Short circuit, arcing, damaged or exposed wiring resulting from poor installation or maintenance	Electrocution, potential for secondary fire or explosion	Designed and installed to AS3000: Electrical wiring Design discipline QA for build and commission	-4 Major	2-Unlikely	Medium	-8	-3 Moderate	2-Unlikely	Medium	-6	-3 Moderate	2-Unlikely	Medium	-6	-8	**Hard solution:** review adequacy of SIL application, equipment choice and locations of power outlets etc… Confirm supply voltage. **Soft solution:** management controls for HSE and maintenance	CTO	31/03/2014	TBC	In progress	* SIL application will not be carried out. * ACC designed to EU standard but customised to meet AS3000. * Field installation will be done in accordance with AS3000. * Normal QA will be carried out. * Supply voltage confirmed 415V 3 phase AC. * Isolation procedure to be developed.	* Develop isolation procedure for inclusion in O&M plan	28/02/2015
57	**8. Air Cooled Condenser**	Noise	Operating fans (60) cycling, steam movement in pipework.	Occupational noise level (85dBA for 8hrs max) exceeded. Neighbours disturbed and unsympathetic		-3 Moderate	3-Possible	Medium	-9	-2 Minor	3-Possible	Medium	-6	-2 Minor	2-Unlikely	Low	-4	-9	Seek noise output details from supplier	EMSQ	31/03/2014	In association with EM	In progress	Intention is to investigate need for insulation of pipes at top of ACC.	Investigate insulation	28/02/2015
58	**9. Feed Water System**	Height	Access to feedwater tank located on roof	Fall to ground resulting in death.	Designed and installed to relevant standard (confirm?)	-4 Major	2-Unlikely	Medium	-8					-4 Major	2-Unlikely	Medium	-8	-8	Confirm application of working at height standard and/or access standard.	EM	31/03/2014		In progress	Fixed platform and ladder to be provided. No standard confirmed.	Install platform and ladder.	28/02/2015
59	**9. Feed Water System**	Noise	Main feedwater pump generating noise levels exceeding 85dBA @ 1m Environmental noise outside boundary. System noise from reticulation	Noised induced hearing loss. Upset neighbours	Pump is located in shed. Designed to relevant Standard (confirm?) Operated during daylight only.	-3 Moderate	2-Unlikely	Medium	-6	-3 Moderate	2-Unlikely	Medium	-6	-3 Moderate	2-Unlikely	Medium	-6	-6	**Hard Solution**: investigate attenuation options for pumps. **Soft Solution**: Engage with neighbours to determine if issues exist.	EMSQ	31/03/2014		Ongoing	* Have spoken to the neighbours * Intend to use local accoustic insulation as required (rock wool - insulation)	* Monitor *Install accoustic insulation as required.	28/02/2015
60	**9. Feed Water System**	Electricity	Short circuit, arcing, damaged or exposed wiring resulting from poor installation or maintenance	Electrocution, potential for secondary fire or explosion	Designed and installed to AS3000: Electrical wiring Design discipline QA for build and commission	-4 Major	2-Unlikely	Medium	-8	-3 Moderate	2-Unlikely	Medium	-6	-3 Moderate	2-Unlikely	Medium	-6	-8	**Hard solution:** review adequacy of SIL application, equipment choice and locations of power outlets etc… Confirm supply voltage. **Soft solution:** management controls for HSE and maintenance	CTO	31/03/2014	In association with EM	In progress	* SIL will not be completed * Supply voltage confirmed to be 24 Vac for all instrumentation with 415V for motorised valves. * All installation and maintenance wlil be undertaken in accordance with AS 3000	* Install and maintain in accordance with AS 3000	31/03/2015
61	**9. Feed Water System**	Hot surfaces	Feedwater system is a closed heated circuit	Burns from exposed surface	All pipework and feedwater tank insulated. Pipe runs routed away from traffic zones.	-3 Moderate	2-Unlikely	Medium	-6					-2 Minor	2-Unlikely	Low	-4	-6	**Hard Solution**: **Soft Solution**: Develop maintenance procedures including inspection regimes to ensure integrity of insulation	CTO	30/09/2014		Open	* To be included in O&M plan	* Write O&M procedure once approaching operation phase.	28/02/2015

HAZARD IDENTIFICATION						RISK RANKING													ACTIONS				ACTIONS TAKEN			
						Health & Safety				Environment				Financial												
No.	Element	Hazard / Threat	Cause	Consequence	Existing Controls	Consequence	Likelihood	Level	Rating	Consequence	Likelihood	Level	Rating	Consequence	Likelihood	Level	Rating	Highest Risk Ranking	Recommended Action (Improve existing controls / implement new controls)	Responsibility	Target Date	Comment	Status of Recommended Action as at 5 Feb 2015	Action Taken as at 5 Feb 2015	Further Actions Required	Target Date
62	**9. Feed Water System**	Pressure	Pressurised system - : Highest pressure at exit to Feedwater pump (48 bar) . Head pressure from feedwater tank.	Exposure to pressurised hot feedwater resulting in burns.	Designed to relevant standard (confirm?)	-3 Moderate	2-Unlikely	Medium	-6	-1 Low	2-Unlikely	Very Low	-2	-2 Minor	2-Unlikely	Low	-4	-6	Enquire of council re disposal of ground water	EMSQ	31/03/2014	In association with CEO	Closed	Recommended action is not relevent to pressure. * Has been designed to ASME B31.1	NOTE: Outside the HZAOP, follow up on feedwater question re: council	
63	**9. Feed Water System**	Chemicals	Corrosion inhibitors.	Exposure to toxic chemicals resulting in an adverse reaction. Exposure to ground water from wash down of spillage.	Pending specific supplier advice reference to GE feedwater corrosion inhibitors MSDS's.	-3 Moderate	2-Unlikely	Medium	-6	-3 Moderate	2-Unlikely	Medium	-6	-2 Minor	2-Unlikely	Low	-4	-6	Confirm status of chemicals via MSDS once selected.	EMSQ	31/03/2014	In association with EM	Open	* Checmicals have not yet been selected.	* Select chemicals and follow up on recommended action.	28/02/2015
64	**9. Feed Water System**	Hot fluids	Stored feedwater in tank and lines Catastrophic failure of feedwater tank and/or lines	Exposure to hot fluids resulting in burns. Major burns and inundation by hot fluid	Design and install to relevant standard (confirm?). Competent installers. Supervision	-3 Moderate	2-Unlikely	Medium	-6	-3 Moderate	2-Unlikely	Medium	-6	-3 Moderate	2-Unlikely	Medium	-6	-6	**Hard Solution**: Investigate practicality of installing a tun dish arrangement for tank failure. **Soft Solution:** Investigate restricted access zone beneath feedwater tank and immediate surrounds.	EM	31/03/2014	Financial assumes containment on site.	In progress	**Hard Solution:** * Determined to be impractical and not consistent with common practice in Australia **Soft Solution:** * Similarly, not consistent with common practice within Australia. **Intended approach:** * Manufacture is in accordance with European standards * A higher corrosion allowance has been made in manufacturing as a further measure to ensure integrity of the de-aerator. * Installation, regular inspection and maintenance approach adopted is consistent with Australian industry standard practice and Welding Technology Institute of Australia (WTIA) best practice. * Any cracks noted during inspections will be treated as per Australian best practice.		
65	**10. Grid Connection**	Noise	Cooling fans from transformer generate noise	Elevated ambient noise levels upsetting neighbours	Only if air cooled.					-1 Low	2-Unlikely	Very Low	-2	-2 Minor	2-Unlikely	Low	-4	-4	Confirm transformer selection and cooling mechanism	CTO	31/03/2014		No longer relevant	No fans on the air cooled transformer.		
66	**10. Grid Connection**	Electricity - (11kv)	Exposure to live electrical conductors	Electrocution - death	Regulated access. Licensed personnel only. Installation to **AS3000**	-4 Major	2-Unlikely	Medium	-8					-4 Major	2-Unlikely	Medium	-8	-8	**Soft Solution:** Review access controls by others with similar installs.	EM	30/04/2014		Closed	* Intended approach is to install access controls as per AS 3000: - Transformer and HV siwtch gear will be fenced off. - HV will only be undertaken by HV accredited personel in accordance with HV protocol. * Not intended to review access controls by others with similar installs.		
67	**10. Grid Connection**	Hot surfaces	Working in vicinity to and exposure to hot surface.	Burns	Regulated access. Licensed personnel only. Installation to **AS3000**	-2 Minor	2-Unlikely	Low	-4					-2 Minor	2-Unlikely	Low	-4	-4					Closed	* Intended approach is to install access controls as per AS 3000: - Transformer and HV siwtch gear will be fenced off. - HV will only be undertaken by HV accredited personel in accordance with HV protocol.		
68	**10. Grid Connection**	Oil	Oil escaping from transformer vessel - leak. Oil system failure resulting in explosion	Substantial asset damage Major injury Ground contamination	Regulated access. Installation to **AS3000**	-3 Moderate	2-Unlikely	Medium	-6	-3 Moderate	3-Possible	Medium	-9	-3 Moderate	2-Unlikely	Medium	-6	-9	Hard Solution: Investigate requirement for blast wall and containment	EM	31/03/2014		In progress	* There are two transformers - one indoor, one outdoor. Indoor is a dry transformer and doesn't require any bunding since no thermal oil. Outdoor transformer will require a bund. * Bund design to be based on AS2067 - 2008 and AS1940 storage and handling of flammable and commbustible materials. * Not yet built. Transformer has not arrived on site. * Intention is to build a bund when foundations are built. The bund design will be submitted to council for approval.	* Build bund * Submit bund design to council for approval	31/03/2015
69	**10. Grid Connection**	EMF	Exposure to electromagnetic field generated by transformer	Personnel with pacemakers adversely affected by EMF resulting in heart attack.		-4 Major	2-Unlikely	Medium	-8					-2 Minor	2-Unlikely	Low	-4	-8	**Hard Solution**: Confirm transformer selection and seek EMF signature data from supplier. **Soft Solution:** Adapt, as required by supplier data , relevant access requirements and controls.	CTO	31/03/2014		Open	* Have not yet requested data from supplier.	* Request data from supplier. Consider options for safe operation.	28/02/2015
70	**11. Utilities**	Electricity	Short circuit, arcing, damaged or exposed wiring resulting from poor installation or maintenance	Electrocution, potential for secondary fire or explosion	Designed and installed to AS3000: Electrical wiring Design discipline QA for build and commission	-4 Major	2-Unlikely	Medium	-8	-3 Moderate	2-Unlikely	Medium	-6	-3 Moderate	2-Unlikely	Medium	-6	-8	**Hard solution:** review adequacy of SIL application, equipment choice and locations of power outlets etc… Confirm supply voltage. **Soft solution:** management controls for HSE and maintenance	CTO	31/03/2014		Open	* Need to determine appropriate approach. Undecided as to whether arc containment will be inside or outside the manufacturing shed.	* Determine whether arc containment will be inside or outside shed. * Complete necessary safety measures.	28/02/2015
71	**11. Utilities**	Compressed Air	System failure in mirror manufacture	Possible uncontrolled air hose resulting in bruising laceration, loss of service,	Standard equipment fittings, regulated air supply. Housekeeping processes and inspection Supervision	-2 Minor	2-Unlikely	Low	-4					-2 Minor	2-Unlikely	Low	-4	-4	**Hard Solution**: Investigate safety nozzles for cleaning nozzles. **Soft Solution:** Develop JSA / SWI for use of air powered tools to highlight hazards.	OM	30/04/2014	In association with EMSQ	Open	* Compressed air is used in welding bay to pump tyres and clean pipes etc. * Development of dedicated JSA / SWMs has begun	* follow up on recommended actions.	13/02/2015
72	**11. Utilities**	Compressed air	Noise	Noise generated by air compressor resulting excessive occupational noise exposure. Noise generated by application nozzle	Equipment compliant to applicable Australian standard. Specialised PPE available	-1 Low	2-Unlikely	Very Low	-2	-1 Low	2-Unlikely	Very Low	-2	-1 Low	2-Unlikely	Very Low	-2	-2	Ref # 68				No longer relevant	No air compressors. Only temporary air compressor for use in welding bay.		
73	**11. Utilities**	Cover gas	System failure resulting from mechanical failure of manifold or delivery line. Loss of cover gas result in in cover gas integrity	Catastrophic loss of sodium from exposure to oxygen. Reaction of sodium resulting in fire or explosion.	Designed and installed in accordance with **Australian Standards**. Reputable supplier and product (Aregon bank)	-3 Moderate	3-Possible	Medium	-9	-3 Moderate	3-Possible	Medium	-9	-4 Major	3-Possible	High	-12	-12	**Hard Solution**: Confirm control system philosophy and associated controls. Review emergency supply of argon and associated utilisation. **Soft Solution**: develop operating procedures for system deviations that threaten plant operating integrity.	CTO	30/04/2014	Financial risk associated with sodium loss	In progress	**Hard solution:** * Control system includes a non-return valve which is placed such that if there is failure on the delivery side, the system is protected and cover gas is not lost. Refer to JV-DRG-PRO-2009 **Soft solution:** * Operating procedures not yet developed.	* Update drawing JV-DRG-PRO-2009 * develop operating procedures * Design review required of steam and HTF side precautions.	13/02/2015
74	**11. Utilities**	LPG	Loss of supply system integrity	Fire or explosion arising from LPG leak during delivery or system integrity failure.. HTF system freezes. HTF system leaks resulting in a vacuum that promotes a leak allowing air to come in contact with the sodium leading formation of oxides. This can interfere with valves and instrumentation	Emergency gas Control system. Designed and built to standard. Reputable supplier of LPG. Regulated installation.	-4 Major	2-Unlikely	Medium	-8	-3 Moderate	2-Unlikely	Medium	-6	-4 Major	2-Unlikely	Medium	-8	-8	**Hard Solution:** Confirm control philosophy includes gas system management. Investigate explosive gas alarms in vicinity of burners and vulnerable plant. Investigate burner ignition confirmation into control system.	EM	31/03/2014		In progress	* Control philosophy to be confirmed in the design review. * No explosive gas alarms currently installed and no plan to do so. * LPG used in the thermal oil heater - which contains an alarm which will go off if no ignition occurs. NOTE: there is also a boiler on site for the construction phase. The boiler has alarms for no ignition and low pressure of supply gas.	* Design review required of steam and HTF side precautions.	13/02/2015
75	**11. Utilities**	Diesel	Fuel spill from backup diesel generator supply system	Fire resulting in asset damage. Thick acrid smoke from uncontrolled combustion of spilt diesel. lost production	Package installation. Installed in accordance with regulations. Competent installers. Reputable supplier of fuel	-3 Moderate	2-Unlikely	Medium	-6	-3 Moderate	2-Unlikely	Medium	-6	-2 Minor	2-Unlikely	Low	-4	-6	**Hard Solution:** Review preferred package for fuel system containment. Investigate alarm to control system Soft Solution: Install spill kits and train personnel for fuel spills.	EM	31/03/2014	ONLY IF REQUIRED. ASSUME GAS Diesel storage volume not confirmed.	Open	No action taken to date. Will follow up on recommended action.	Refer to recommended actions.	13/02/2015

HAZARD IDENTIFICATION						RISK RANKING													ACTIONS				ACTIONS TAKEN			
						Health & Safety				Environment				Financial												
No.	Element	Hazard / Threat	Cause	Consequence	Existing Controls	Consequence	Likelihood	Level	Rating	Consequence	Likelihood	Level	Rating	Consequence	Likelihood	Level	Rating	Highest Risk Ranking	Recommended Action (Improve existing controls / implement new controls)	Responsibility	Target Date	Comment	Status of Recommended Action as at 5 Feb 2015	Action Taken as at 5 Feb 2015	Further Actions Required	Target Date
76	11. Utilities	Emissions	Combustion of LPG	Release of NOX's and other combustion products. Aggravated breathing	I installed in accordance with manufacturers specifications. Installation to comply with EPA requirements.	-1 Low	2-Unlikely	Very Low	-2	-1 Low	2-Unlikely	Very Low	-2	-1 Low	2-Unlikely	Very Low	-2	-2					Closed	No requirements.		
77	11. Utilities	Water	Loss of water allowing it to enter HTF zone.	Leaking sodium comes in contact with water causing a fire / explosion	Designed and engineered separation (60m) Dual wall tank Bunded HTF zone .	-4 Major	3-Possible	High	-12	-4 Major	3-Possible	High	-12	-4 Major	2-Unlikely	Medium	-8	-12	**Hard Solution:** Ground drain to water tank diverting water away from plant	EM	31/03/2014		In progress	* There exists an overflow drain from the tank which drains into a retention pond to the east of the water tank (away from the main plant.) NOTE: LPG tank next to water tank is <6m from the pump (3m), the control is a vapour barrier which is currently under construction, to be completed by 13/02/15. Designed to ElGas standards and: - AS 60079 10 1 - 2009 refers to hazardous areas. - AS 1596 refers to distances between LPG plants and other structures / item stores.	* Complete vapour barrier	31/03/2015
78	11. Utilities	Electricity	Short circuit, arcing, damaged or exposed wiring resulting from poor installation or maintenance	Electrocution, potential for secondary fire or explosion	Designed and installed to AS3000: Electrical wiring Design discipline QA for build and commission Competent installers.	-4 Major	2-Unlikely	Medium	-8	-3 Moderate	2-Unlikely	Medium	-6	-3 Moderate	2-Unlikely	Medium	-6	-8	**Hard solution:** review adequacy of SIL application, equipment choice and locations of power outlets etc… Confirm supply voltage. **Soft solution:** management controls for HSE and maintenance	CTO	31/03/2014		No longer relevant	**Repeat of No. 70. Refer above.**		
79	12. Facilities	Electricity	Short circuit, arcing, damaged or exposed wiring resulting from poor installation or maintenance	Electrocution, potential for secondary fire or explosion	Designed and installed to AS3000: Electrical wiring Design discipline QA for build and commission	-4 Major	2-Unlikely	Medium	-8	-3 Moderate	2-Unlikely	Medium	-6	-3 Moderate	2-Unlikely	Medium	-6	-8	**Hard solution:** review adequacy of SIL application, equipment choice and locations of power outlets etc… Confirm supply voltage. **Soft solution:** management controls for HSE and maintenance	CTO	31/03/2014		In progress	* No SIL application will occur. * AS 3000 will be applied * A qualified electrician has been engaged.		
80	12. Facilities	Water	Loss of water supply to ablutions and for drinking. Loss of fire systems water supply	Minor interruption, compromised hygiene Fire protection for facility compromised	Designed, approved and installed in accordance with Development Approval. Fire systems engineer engaged to confirm requirements	-3 Moderate	2-Unlikely	Medium	-6					-1 Low	2-Unlikely	Very Low	-2	-6	**Hard Solution:** Confirm requirements for fire systems in NSW	CTO	31/03/2014		Open	* Currently in consultation with Dolphin Fire Engineering regarding a fire water pump. * Currently no fire water pump connected to water supply.	* Finalise fire water pump arrangements.	13/02/2015
81	12. Facilities	Vehicles	Interaction between personnel and vehicles Collision between vehicles. Collision between vehicle and assert.	laceration, facture Vehicle damage Asset damage - interruption to operations	Vehicle access external to facility designed to Australian Standards for B Double movements. Light vehicle parking provided outside primary pedestrian area. Bollards installed to vulnerable parts of building.	-3 Moderate	3-Possible	Medium	-9	-1 Low	2-Unlikely	Very Low	-2	-3 Moderate	2-Unlikely	Medium	-6	-9	**Hard Solution:** **Soft Solution:** Investigate site traffic management plan	EMSQ	31/03/2014		In progress	* Bollards: completed around LPG tanks, net yet completed around HTF storage. * Traffic Management Plan not yet written. * Parking area and B-double area has been completed.	* Install bollards around HTF storage facility * Write Traffic Management Plan	28/02/2015
82	Operations	Fitness for work	Condition of personnel. Insufficient water consumption. Excessive work effort. Illicit substances	Injury up to death	Regulations codes of Practice Induction procedures	-4 Major	2-Unlikely	Medium	-8					-4 Major	2-Unlikely	Medium	-8	-8	**Hard solution:** Provide adequate continuous potable water supply. Ensure adequate facility ventilation Soft Solution: Develop education programs and procedures	EMSQ	31/03/2014		Closed	**Hard solution:** * Filtered water continuously available in break room * Shed doors are kept open to ensure proper ventilation **Soft solution:** * Fit for work policy has been developed * Importance of hydration highlighted in site induction and personel are encouraged to remain hydrated.		
83	Operations	Fire	uncontrolled heat source	fire in materials inside facility Smoke into neighbours	Fire protection to standard.	-4 Major	2-Unlikely	Medium	-8	-3 Moderate	2-Unlikely	Medium	-6	-4 Major	2-Unlikely	Medium	-8	-8	**Hard solution:** Investigate fire detection systems in accordance with NSWFS standards and vulnerable locations in facility.	EM	31/03/2014	In association with EMSQ & OM	In progress	* Dolphin Fire Engineers were engaged to assess manufacture shed fire safety aspects. Report has been completed. * Actions from report still pending: - Smoke alarms to be installed in manufacture shed.		
84	Operations	Adverse weather event	Mother nature	Interruption to operations Inability to access plant Facility damage		-3 Moderate	2-Unlikely	Medium	-6	-1 Low	2-Unlikely	Very Low	-2	-2 Minor	2-Unlikely	Low	-4	-6	**Soft Solution**: Establish protocols for on line weather warnings. Develop procedures for adverse weather impacts.	EMSQ	30/06/2014	This considers adverse weather as a general impact in addition to the specific events listed above, e.g. lightning etc.	Open	* No protocols in place. Current practice: all site workers check online weather forecasts. * Intention is to write an Adverse Weather Protocol.	* Write an Adverse Weather Protocl * Educate and inform workers.	28/02/2015
85	Maintenance	noxious fumes	Removal of cold trap media and exposure to atmosphere	fire / explosion	Nil - process not yet installed	-3 Moderate	3-Possible	Medium	-9	-2 Minor	3-Possible	Medium	-6	-2 Minor	3-Possible	Medium	-6	-9	**Hard Solution**: investigate methods for media handling with alternative atmospheres. Consider alternatives, e.g. treat as a consumable, divide required to multiple smaller sizes. **Soft solution:** Develop maintenance procedures incorporating the JSA process.	EM	31/03/2014		Open	* Design review required of steam and HTF side precautions.	* Design review required of steam and HTF side precautions.	13/02/2015
86	Maintenance	heat	Cleaning of pipe sections	Fire / explosion	Clean with methylated spirits	-3 Moderate	3-Possible	Medium	-9	-2 Minor	3-Possible	Medium	-6	-2 Minor	3-Possible	Medium	-6	-9	**Hard Solution**: Investigate alternative solutions for removal of sodium from pipe sections that do not involve flammable liquids. **Soft Solution** - Develop maintenance procedures incorporating the JSA process	EM	31/03/2014	Must try to develop solution without trading one hazard for another or elevation of consequential risk.	Ongoing	* Cleaning trials undertaken.	* Best practice cleaning methods to be determined on a case-by-case basis. * Methods will reflect individual component requirements.	
87	Maintenance	heat	Cleaning of pipe sections	Caustic solution that is no longer suitable for standard water use and low pH affecting disposal options	Full water immersion	-2 Minor	3-Possible	Medium	-6	-3 Moderate	3-Possible	Medium	-9	-2 Minor	3-Possible	Medium	-6	-9	**Hard Solution:** review immersion option and possible chemically neutralising water. **Soft Solution**: Refine O & M documentation	EM	31/03/2014	Potential issue of generating a waste product that is not easily disposed of. Need to consider EPA requirements.	Ongoing	* Cleaning trials undertaken.	* Best practice cleaning methods to be determined on a case-by-case basis. * Methods will reflect individual component requirements.	
88	Environment	Solar radiation	Extended exposure of skin to solar radiation from the sun and /or array	Chronic skin damage including skin cancer	PPE, uniform standard	-3 Moderate	3-Possible	Medium	-9					2 Minor	3-Possible	Medium Opportunity	6	-9	**Soft Solution:** Consistent firm reinforcement of uniform and PPE controls. For construction - build into installation contracts.	EMSQ	28/02/2014		Closed	* Work clothes provided * Sun protection included in induction * Enforced on site - same standard applied to all personnel onsite. * Ongoing		

HAZARD IDENTIFICATION						RISK RANKING													ACTIONS				ACTIONS TAKEN			
						Health & Safety				Environment				Financial												
No.	Element	Hazard / Threat	Cause	Consequence	Existing Controls	Consequence	Likelihood	Level	Rating	Consequence	Likelihood	Level	Rating	Consequence	Likelihood	Level	Rating	Highest Risk Ranking	**Recommended Action** (Improve existing controls / implement new controls)	Responsibility	Target Date	Comment	Status of Recommended Action as at 5 Feb 2015	Action Taken as at 5 Feb 2015	Further Actions Required	Target Date
89	**Environment**	Flood	Adverse weather	Significant interruption to operations. Asset damage through inundation, e.g. HTF piping system.	Review requirement for levy. Consult with local expertise. Vulnerable HTF plant within bund	-1 Low	3-Possible	Very Low	-3	-1 Low	3-Possible	Very Low	-3	-3 Moderate	3-Possible	Medium	-9	-9	**Hard Solution:** Review 1:100 or equiv. flood levels and assess against design of plant installation. **Soft Solution:** Consistent firm reinforcement of uniform and PPE controls. For construction - build into installation contracts.	EMSQ	31/03/2014	Assessment based on 1;10 - 1:20 flood experience. New govt flood assessments should be reviewed.	In progress	**Hard solution:** * MJM Civil Engineers designed bund around HTF storage tanks (bund to 218.22m) * Bund was designed to 1952 flood level (218m) * Bund has not yet been built and will be built once construction activities are nearing completion. Note that if the bund is built early it will hinder construction activities significantly. * For bund location, refer to JB-DRG-Gen-0002_2. For intended construction technique, refer to drawing 120214_Bund_Sketch.	* Build bund * Ensure pipe supports are higher than 218m in all un-bunded areas.	31/03/2015

	Count	Percentage	Description
Open	26	29%	No action taken. Requires follow up.
In progress	30	34%	Action taken. Requires follow up.
Ongoing	8	9%	Action taken. Action will be ongoing throughout construction and / or operations.
Closed	20	22%	No further action required since action taken.
No longer relevar	5	6%	No further action required since action no longer relevant.
Total	**89**	**100%**	

Appendix B – HAZOP Minutes for 6MW$_{th}$ Pilot Plant

Client:Vast Solar
Project: Jemalong Solar Station

HAZOP Minute Sheet

REVIEW OF HAZOP ACTION ITEMS 10/02/15

Sub system	1. Solar Array	**Drawing Title**	P&ID Receivers 1, 2 & 3
		Drawing number:	JB-DRG-PRO-2003
Node	1.1 Heliostat Array & Receiver Targeting (5 Arrays of 699 Heliostats in 27 Rows)	**Rev.**	B
		Date:	24/02/2014

Start of Commissioning	**28-Feb-15**
End of Commissioning	**31-Mar-15**
Start of Operations	**01-Apr-15**

Dev No.	Deviation	Op Mode	Cause	Consequence	Safeguard	Rec #	Recommendation	Responsibility	Action	Status (6 Feb 2015)	Reference	Action Taken	Remaining Action	Target Date
1	Heliostats not tracking	ALL	Tracking algorith corrupted	Decline in system performance	Software recognises poor tracking mirror, quarantines it and alerts operator.	1.1.1	Control satisfactory no further action recommended.			To occur during Commissioning	JB-SPE-PRO-0001 3.1.4 Tracking	Normal operation: 1) During start up: field controller sends commands preparing heliostats for tracking, each mirror has an individual controller and if any fails to respond to these initial commands, then the heliostats directly adjacent to that mirror rotate such that they are parrallel to each other and protect the unresponsive mirror from breakages. 2) During tracking (after "Track On" sequence issued): there will be a camera which will use standard chequerboard alogorithms to identify any unresponsive mirrors and isolate these mirrors as above. As a precaution the sampling rate will be no slower than half the theoretical time to ignite indigenous vegetation.	* Complete install of mirrors * Testing and commissioning.	31-Mar
				Refocus on lattice tower causing structural damage	None	1.1.2	Investigate alarm on Reciever temperature outlet to indicate heliostats not tracking receiver	EM	Q1 2014	To occur during Installation	JB-SPE-PRO-0001 3.1.5 Standby, 3.2 Protection from Receiver over temperature.	* Currently there is an Emergency Shutdown System (ESD) which causes all mirrors to redirect away from the reciever. * The ESD will be connected to the thermocouples from the reciever and will activate when the reciever temperature exceeds a certain value. * Note that it would require 5 - 6 entire heliostat rows to be focussed on the one area before significant damage occurs. * Note that the "standby" setting can also be activated which offsets all heliostats from their respctive tracking positions by an offset angle, this offset anly differs across the array.	* Install reciever receiver and receiver thermocouples. * Testing and commissioning.	31-Mar
			Extreme weather event	Damage to heliostats	Interlock with weather station	1.1.3	Investigate response to different weather events (operational mode).	EM	Q2 2014	To occur during Installation	JB-SPE-PRO-0001 3.3 Mitigation against high winds, 3.4 Mitigation against high precipitation.	* Currently setting up weather station * Will interlock with wind and humidity readings. * If the wind is too strong for safe operation, the heliostats will be reorientated to a horizontal position (orientated North and parallel to the ground). * If rain is too heavy for safe operation, the heliostates will be reorientated to the 'stowed' position (orientated west and vertical to the ground).	* Complete installation of weather station. * Testing and commissioning.	31-Mar
			WiFi failure	Inability to control heat flux to the receiver resulting in overheating	Over temperature protection on receiver	1.1.4	Implement protection utilising power trip to heliostats (protection cannot use WiFi).	EM	Q1 2014	To occur during Commissioning	JB-SPE-PRO-0001 3.2 Protection against Receiver over temperature	* Generally if the reciever becomes overheated the ESD will be activated and the mirrors will move into 'standby' mode. * If the WiFi fails and the reciever becomes overheated the first response is to increase the flow rate of HTF in order to minimise overheating. * Without WiFi the mirrors will drift from the reciever within 1 - 2 minutes.	* Install reciever receiver and receiver thermocouples. * Testing and commissioning.	31-Mar
2	Loss of power to array.	ALL	Physical interference to power supply or damage to cables	Heliostats go to standby	Dual function battery voltage regulation and 1hr backup power for heliostats		Control satisfactory no further action recommended.			Completed	JB-SPE-PRO-0001 3.5 Mitigation against loss of power supply	* The battery system is installed.		

Client:Vast Solar
Project: Jemalong Solar Station

HAZOP Minute Sheet

Sub system	2. HTF & Utilities	**Drawing Title**	P&ID HTF Cold Tank
		Drawing number:	JB-DRG-PRO-2001
Node	2.1 HTF Cold Tank & Controls	**Rev.**	B
		Date:	24/02/2014

Dev No	Deviation	Op Mode	Cause	Consequence	Safeguard	Rec #	Recommendation	Responsibility	Action	Status	Reference	Action Taken	Remaining Action	Target Date
3	High Temperature - design T exceeded	ALL	Transfer from HTF Hot Tank	Potential temperature excursions within allowabl	Cold Tank designed to the same pressure and temperature as the Hot Tank.	2.1.1	Commissioning procedure to include test for Hot to Cold Tank transfer.	CTO	Commissioning.	New Risk Assessment Required	JB-SPE-PRO-0004 3.1.5 Draining the HTF Hot Tank (HTF > 300C)	* Cold Tank ***is not*** designed to the same pressure and temperature as the Hot Tank. * If the Hot Tank needs to be drained and the HTF temperature exceeds 300C then it is cooled through transfering heat into steam and using the condensor to dump heat form the steam. Refer to FDs.	* Include test for Hot to Cold Tank transfer in commissioning plan. * Testing and commissioning.	31-Mar
			Inadvertent hot recirculation from receivers	Catastrophic destruction of plant, loss of containment of HTF.	Emergency shutdown system connected to receivers.	2.1.2	Add temp H alarm and HH trip on Cold Tank.	EM	Q1 2014	To occur during Installation	JB-SPE-PRO-0004 3.1.5 Draining the HTF Hot Tank (HTF > 300C) 3.1.9 Mitigation against inadvertent draining of Receivers and HTF field piping	* Refer to FDs, system has been designed with interlocks to prevent inadvertent draining of receivers.	* Consider including H alarm and HH trip on Cold Tank during commissioning.	31-Mar
			Transfer from HTF Hot Tank	Potential damage resulting failure or false reading.	Instruments are seperated from the tank.	2.1.3	Specify instrumentation suitable to high temperature application.	EM	Q1 2014	To occur during Commissioning	NA	* Equipment used is suitable for high temperature applications. * HH alarm to be added during commissioning	* Installation. * Testing and commissioning.	31-Mar
				High temperature denaturing the residual oil - build up of residue effecting performance	Under normal operations the oil system is emptied and isolated.	2.1.4	Ensure oil heater controls allow for emptying and isolating heater coils to minimise heat transfer to thermal oil.	EM	Q2 2014	Open	JB-SPE-PRO-0007	* Reviewed checmical properties of thermal oil and noted that this is an issue requiring consideration.	* Develop solution to mitigate creation of build up inside pipes.	28-Feb
			Cover gas expansion with HTF in hot tan	Loss of containment	System is rated for highest possible pressure scenario.		Control satisfactory no further action recommended.			To occur during Commissioning	JB-SPE-PRO-0006 3.4 Thermal Energy Gathering JB-DRG-PRO-2009 (Rev 1.5)	* Pressure relief valves have been included within the design.	* Update FD (not current, SS) * Installation. * Testing and commissioning.	31-Mar
4	High level - Tank	COM	Tank is overloaded with HTF	Overpressurise Cold Tank	Staged fill of Cold Tank using pressure transfer.	2.1.5	Develop operating procedure for loading that include inventory control.	EMSQ	Q2 2014	Completed	JB-SPE-PRO-0003 3.15 Mitigation against HTF Hot Tank high level	* Both the Hot and Cold Tanks have been sized such that the entire HTF stock can be held within each individual tank without overfilling occuring. * Tanks have been filled with HTF successfully.		
		ALL	Other fluids enter Cold Tank	Overpressurise Cold Tank	LIC H alarm & LIC HH HTF Hot Transfer Pump trip.		Controls sufficient, no further action required.			To occur during Commissioning	JB-SPE-PRO-0003 3.15 Mitigation against HTF Hot Tank high level	* Both the Hot and Cold Tanks have been sized such that the entire HTF stock can be held within each individual tank without overfilling occuring. * System is sealed so other fluids will not enter either Tanks. Refer to FDs for Rapid Drain System details which can be activated in emergencies.	* Testing and commissioning.	31-Mar
5	Contamination - HTF	ALL	Tube leak from thermal oil system	Inadvertent chemical reaction.	Reviewed the PDS of the thermal oil reccomended by the HTF supplier.	2.1.6	Determine and source compatible oil solution to avoid unintended reactions.	EM	Q2 2014	No Longer Relevant	NA	* Thermal Oil system is located on the outside of the Tank. Any leaks will not come into contact with HTF.		
						2.1.7	Confirm behaviour of thermal oil at elevated tempepratures.	EM	Q2 2014	No Longer Relevant	NA	* Thermal Oil system is located on the outside of the Tank. Any leaks will not come into contact with HTF.		
6	Internal access to tank	MAINT	Contaminated environnment	Tank toxic to personnel	Under normal operations tank not accessible	2.1.8	Develop SOP for tank internal maintenance.	EMSQ	Q2 2014	New Risk Assessment Required	NA	* SOP not yet developed.		31-Mar
			Confined space	Requiring confined space entry procedure	Compliance with AS2865.		Controls sufficient, no further action required.			In Progress	NA	* Personel have been trained. * SOP not yet developed.		31-Mar
7	Exposure to HTF byproduct during maintenance	MAINT	Residual HTF in items under maintenance	Hyrdogen generation, explosion/fire resulting in plant damage or personnel injury and dense white smoke	Experiential knowledge in handling and maintenance of HTF decontaminated components. Engaged expert consultants (Creative Engineering) to review current practices. In house training.	2.1.9	Ensure O&M includes protocl addressing HTF contaminated components. Validate with other reputable parties internationally. Apply continual improvement processes to training.	EMSQ	Q3 2014	New Risk Assessment Required	NA	* Have worked with MSSA (sodium supplier) to develop procedures for handling HTF. This decision has not yet been finalised. * A dedicated procedure *may* be produced for cleaning of contaminated parts during the commissioning phase, however it is expected that the cleaning method will be decided on a case-by-case basis. This will take into account Vast Solar's experience to date and the individual component features (e.g. cleaning the Cold Trap will be different to piping).	* Consider developing standardised procedures. * Consider requirements on a case-by-case basis.	31-Mar
8	Loss of containment	MAINT	Wrong parts used or replaced during maintenance or poor maintenance procedure	Critical operational impact on the HTF Cold Tank resulting in potential loss of containment.	Match parts to specification, materials management protocols.	2.1.10	Develop best practice protocols for inventory management.	EMSQ	Q3 2014	To occur during Commissioning	NA	* To be developed	* To be developed	31-Mar
		ALL	Structural failure	Critical operational impact on the HTF Cold Tank resulting in potential loss of containment.	Tank designed to AS1210 Pressure Vessels, tank has larger volume than total HTF, located in restricted access and bunded area on minimum 150mm sand base over clay. In event of loss to bunded area, bund and minimum seperation distances designed to AS/NZS 5026 Storage and Handling of Class 4 Dangerous Goods.	2.1.11	Fully document proposed bund design e.g. add to P&ID.	EM	Q1 2014	Completed	MJM Drawing C_140214_RevisedPlan_C	* Refer to P&ID	* Bund built, still require install of sand base over clay. To be completed once pipe supports are complete.	
						2.1.12	Ensure design verifier has expertise in Class 4.3 or equivalent bund design and containment .	CTO	Q1 2014	No longer relevant	NA	* This was not practical to achieve. * Bunds have been designed by a competent and experienced bund designer.		
						2.1.13	Confirm HTF storage covered in HAZID.	EMSQ	Q1 2014	Completed	HAZID Register	NA		
						2.1.14	Develop response plan to loss of HTF containment.	EMSQ	Q3 2014	Completed	Emergency Management Plan	NA		
9	High flow to Cold Tank.	ALL	Hot Transfer Pumps on overspeed.	No adverse impact.	Designed to meet AS 1210 Pressure Vessels with appropriate erosion and corrosion allowances. Set volume of HTF less than tank volume. Bottom entry to tank minimises HTF vapour formation.		Control satisfactory no further action recommended.			Completed	FP-6962-5-Rev-3	NA		
10	Low Flow to Cold Tank.	ALL	Blockages from the buildup of HTF oxides as a result of fugitive oxygen.	Potentially disrupt instrumentation integrity.	Cover Gas at slight positive pressure and Cold Trap to remove impurities.		Control satisfactory no further action recommended.			To occur during Commissioning	JB-SPE-PRO-0005 Cold Trap 2.2 Governing Principles JB-SPE-PRO-0006 HTF Loop Cold Side 3.1 System Filling	* Actions planned: cover gas storage on site, Cold Trap to be installed and commissioned.	* Installation. * Testing and commissioning.	31-Mar
11	Reverse Flow through Cold Tank.	ALL	Leak in receiver	No adverse impact.	Non-return valves on pumps, in cold trap circuit, mixing line and drain tank line. Removable piece on loading line. Isolation valve on inlet from Steam Generator and controlled sequencing of drain valves on SG line.	2.1.15	Consider interlocking inlet isolation valve with inlet drain isolation valve.	EM	Q1 2014	To occur during Commissioning	JB-DRG-PRO-2003 (1) JB-DRG-PRO-2004 (1) JB-DRG-PRO-2005 (1)	* All safeguard measures included in design. * Removable piece of loading line no longer relevant since loading has been completed.	* Installation. * Testing and commissioning.	31-Mar

Client:Vast Solar
Project: Jemalong Solar Station

HAZOP Minute Sheet

Sub system	2. HTF & Utilities	**Drawing Title**	P&ID HTF Cold Tank
		Drawing number:	JB-DRG-PRO-2001
Node	2.2 HTF Cold Transfer Pumps	**Rev.**	B
		Date:	24/02/2014

Dev No	Deviation	Op Mode	Cause	Consequence	Safeguard	Rec #	Recommendation	Responsibility	Action	Status	Reference	Action Taken	Remaining Action	Target Date
12	Overpressure pump	ALL	Dead heading of pump as a result of downstream valves inadvertently or failed closed or HTF oxide blockage	Overpressurising leading to a loss of containment.	System rated for pump dead head pressure in accordance with AS 4041. Automated recirculation line and pressure relief installed. Pump overload protection.	2.2.1	Audit and review certificates for critical plant items.	EMSQ	Q1 2014	Completed	Creative Engineering Field Pump specs	* Pump is now located inside the HTF Tanks so will not be deadheaded. * Manufacturer has confirmed that the seals can withstand being dead headed.		
13	Low flow / No flow	ALL	Cold HTF Transfer Pump VSD corrupted signal or incorrect speed setting	HTF stagnates in pipework resulting in loss of production and possible blockage due to HTF solidification. Increased receiver temperatures possible.	Seperated power supplies for 100% duty and standby pumps, HTF drainage system, automated over temperature protection on receivers.	2.2.2	Add low flow alarm on flowmeter.	EM	Q1 2014	To occur during Commissioning	JB-SPE-PRO-0001 Heliostat Array JB-SPE-PRO-0009 Rapid Drain System	* Back up power source installed. Only one pump installed (and only one planned). * HTF Drainage System to be installed, refer to FDs for full operational description. * Automated Receiver Over-Temperature response developed: increase HTF flow and if this does not mitigate the problem, heliostats will commence ESD and track off receiver.	* Installation. * Testing and commissioning.	31-Mar
			Recirculation or relief valves stuck open	HTF stagnates in pipework resulting in loss of production and possible blockage due to HTF solidification. Increased receiver temperatures possible.	Over temperature protection and drain system. Recirculation valves are exercised every day.	2.2.3	Add low flow alarm on flowmeter and ongoing valve integrity monitoring in accordance with O&M.	EM	Q1 2014	No longer relevant	NA	* Re-circulation removed from design.		
			Operator error - valves inadvertantly closed	HTF stagnates in pipework resulting in loss of production and possible blockage due to HTF solidification. Increased receiver temperatures possible.	Existing isolation philosophy relies on single isolation and plant shutdown. Competent operators and appropriate supervision.	2.2.4	Reinforce O&M procedures for plant isolation.	EMSQ	Q2 2014	To occur during Commissioning	NA	* Heat trace and thermal oil system incorporated in design. If the HTF solidifies it can be re-melted.	* O&M plan to be developed	31-Mar
						2.2.5	Update design documents to reflect isolation process refinement.	EM	Q2 2014	Completed	JB-SPE-PRO-0007 Thermal Oil System FD		* Documents to be updated.	
			Blockage/partial blockage through non-return valves or filters as a result of contamination	Receiver starved of HTF resulting in loss in production, increased receiver temperatures and possible blockage due to HTF solidification.	Cold Trap, Heat Trace	2.2.6	Review need for filters post commissioning.	CTO	Q1 2014	To occur during Commissioning	JB-SPE-PRO-0005 Cold Trap 2.2 Governing Principles JB-SPE-PRO-0006 HTF Loop Cold Side 3.1 System Filling	* Cold Trap and Heat Trace incorporated into design.	* Update FDs * Installation. * Testing and commissioning.	31-Mar
14	Pumps Overheating	ALL	Inadvertent dump from HTF Hot Tank	Exceed temperature rating of pumps (300°C) causing seal breakage and loss of containment	During transfer operation pump suction is isolated from cold tank. Resident volume in cold tank will dilute Hot HTF input. Plant likely to be shut down during HTF Hot Tank dump.	2.2.7	Implement temperature interlock on pump suction automatic isolators and confirm control philosophy.	EM	Q1 2014	To occur during Commissioning	JB-SPE-PRO-0004 3.1.4 Draining the HTF Hot Tank (HTF =< 300C) 3.1.5 Draining the HTF Hot Tank (HTF > 300C)	* Pump suction is not isolated from tank since pump is located inside tank. * Refer to FDs	* Testing and commissioning.	31-Mar
			Pump fault	Pump failure	Overload protection on pumps. Maintenance procedures and inspection regime, temperature monitoring and control through the system.		Control satisfactory no further action recommended.			To occur during Installation	Creative Engineering Field Pump specs	* Included in design. * To be installed and commissioned.	* Installation and commissioning. * Maintenance plan to be developed.	28-Feb
15	Low Temperature (nom. <100°C)	ALL	Heat trace failure.	Solidification of HTF in pump or pipework.	Heat trace failure alarm, system drain, temperature monitoring and control through the system.	2.2.8	Confirm temperature sensing protocols.	EM	Q1 2014	Open	JB-SPE-PRO-0007 Thermal Oil System FD	* Temperature monitoring and control will be achieved through the Heat Trace and Thermal Oil System, as well as a number of thermocouples (e.g. within the Receiver). * There is no heat trace alarm planned within the design, instead there will be temperature measurement along the pipes, this is still in development.	* Develop temperature measurement system along the pipes	28-Feb
			Inadvertently isolated pipe sections filled with HTF.	Solidification of HTF in pipework,vacuum generated in pipe.	Heat trace, temperature monitoring and control through the system, pipe can withstand full vacuum.		Controls satisfactory, no action required.			To occur during Commissioning	JB-SPE-PRO-0007 Thermal Oil System FD	* Temperature monitoring and control will be achieved through the Heat Trace and Thermal Oil System, as well as a number of thermocouples (e.g. within the Receiver).	* Installation. * Testing and commissioning.	31-Mar
			Poor installation of insulation or damage.	Solidification of HTF in pump or pipework.	Maintenance procedures and inspection regime, heat trace, system drain, temperature monitoring and control through the system.		Controls satisfactory, no action required.			To occur during Commissioning	JB-SPE-PRO-0007 Thermal Oil System FD	* Heat trace and temperature monitoring planned throughout system. Re-melting possible through use of heat trace and thermal oil heating. * Piping to be fully insulated. * System Drain FDs have been developed.	* O&M plan to be developed. * Installation and application of insulation. * Testing and commissioning.	31-Mar
			Premature pump startup	Solidification of HTF in pump resulting in pump damage.	Heat trace, temperature monitoring and control on tank, motor trip on overload.	2.2.9	Interlock pump switch with temperature alarm and trip.	EM	Q1 2014	Open	NA	* Not yet considered.	* Interlock to be added during commissioning	28-Feb
			Motor failure results in stagnant fluid.	Solidification of HTF in pump or pipework.	Flow monitoring, temperature sensing on the receivers.		Controls satisfactory, no action required.			To occur during Installation	JB-DRG-PRO-2002	* Flow monitors included in design * Thermocouples included in Receiver design	* Installation. * Testing and commissioning.	28-Feb
16	High maintenance.	ALL	Under spec. Not suited for duty.	Premature pump failure resulting downtime and high maintenance cost	Fully attended plant including roving field operators.	2.2.10	Consider condition monitoring on pumps.	CTO	Q1 2014	To occur during Commissioning	NA	* Not yet considered.	* O&M plan to be developed	31-Mar

Client:Vast Solar
Project: Jemalong Solar Station

HAZOP Minute Sheet

Sub system	2. HTF & Utilities	
		Drawing Title P&ID Receivers 1, 2 & 3
		Drawing number: JB-DRG-PRO-2003
Node	2.3 Receivers	**Rev.** B
		Date: 24/02/2014

Dev No	Deviation	Op Mode	Cause	Consequence	Safeguard	Rec #	Recommendation	Responsibility	Action	Status	Reference	Action Taken	Remaining Action	Target Date
17	Overpressure	ALL	Receiver isolation valves inadvertently closed resulting in thermal epansion of contained HTF	Loss of containment. Danger to personnel, plant and property.	PSV discharge to safe location. SOP.	2.3.1	Review options to ensure potential for HTF release is to suitable containment vessel.	EM	Q1 2014	**New Risk Assessment Required**	JB-SPE-PRO-0002 HTF Loop Cold Side	This safeguard is no longer considered practical. * Reciever not yet installed and currently undergoing pressure testing. * Reciever is desiged as a pressure vessel in accordance with AS 1210. The reciever can therefore deal with dead heading the pump and the resulting pressure. * Note the original option of a relief valve (PSV) and containment is higher risk than the adopted solution. Therefore the PSV was removed from design. * If there is a blockage at both the top and bottom of the reciever and pressure builds up to the point of catastrophic failure then there are no practical containment options. * The use of an exclusion zone during operations will be considered in commissioning phase. Refer to next line item.	* Update FDs * An exclusion zone to be considered during the commissioning phase.	28-Feb-15
		OP	Excessive pump speed &/or upstream line restriction/blockage	Loss of containment. Danger to personnel, plant and property.	Receiver designed to AS 1210, 30m exclusion zones around receivers, receiver designed for pressure cycling over 30 year life, pressure, temperature, and flow monitoring on receiver and, relief system operation detection.		Controls satisfactory, no action required.			In Progress	JB-SPE-PRO-0002 HTF Loop Cold Side	* Reciever has been designed to AS 1210. Currently undergoing hydrostatic pressure testing. * Reciever not yet installed so there is no monitoring equipment currently in place. * Exclusion zone to be established during commissioning since not practical during construction	* Update Functional Description * An exclusion zone to be considered during the commissioning phase.	28-Feb-15
18	Receiver overheating	ALL	Failure of "off-track" instruction resulting in continued focus on receiver	Damage to Reciever may lead to loss of containment	Over temperature protection on receiver		Controls satisfactory, no action required.			To occur during Commissioning	JB-SPE-PRO-0002 HTF Loop Cold Side 3.3.2 Receiver Overheating Protection	If the reciever is over heating there are two mitigation methods planned: * Increase HTF flow * Activate Emergency Broadcast Signal (EBS) which moves heliostats off the reciever * Note full piping system not yet installed. EBS is functional however heliostats not completely installed	* Update Functional Description. * Installation. * Testing and commissioning.	28-Feb-15
			Deliberate and unauthorised overriding automatic controls	Damage to receiver may lead to loss of containment	Over temperature protection on receiver	2.3.2	Confine manual operation to commissioning mode only.	EM	Q1 2014	To occur during Commissioning	NA	See above.	* Update Functional Description * Establish automatic operation mode	28-Feb-15
						2.3.3	Update relevant FD & P&ID.	EM	Q1 2014	To occur during Commissioning	JB-SPE-PRO-0002 HTF Loop Cold Side 3.3.2 Receiver Overheating Protection	See above.	* Update Functional Description * Update P&ID	28-Feb-15
			Restricted or no flow as a result of blockage.	Lack of HTF cooling of receiver - possibility of damage and loss of containment.	Over temperature protection on receiver		Controls satisfactory, no action required.			To occur during Installation	JB-SPE-PRO-0002 HTF Loop Cold Side 3.3.2 Receiver Overheating Protection	This safegaurd is no longer in place. * Instead EBS established which moves heliostats off the reciever in case of over temperature in the reciever. This occurs automatically	* Update Functional Description	28-Feb-15
19	High frequency of transients.	OP	Conditions with transients that exceed design parameters (2/day).	Increased plant fatigue resulting in premature failure of receiver.	30 year design life and maintenance based on 2 severe transients per day in accordance with pressure vessel maintenance code (AS3788).		Control satisfactory no further action recommended.			To occur during Installation	NA	* O&M plan not yet developed.	* O&M plan to be developed.	
20	Reverse flow	OP	Rupture or leak of upstream pipe or activation of receiver pressure release valve	Loss of cotainment, danger to personnel, plant and property.	30m exclusion zones around receivers, pressure, temperature, and flow monitoring on receiver and, relief system operation detection, mitigated by ability to isolate pipework to limit containment. All elevated pipe joints to be fully welded.	2.3.4	Update documentation to reflect commitment to elevated welds.	EM	Q1 2014	**New Risk Assessment Required**	JB-SPE-PRO-0002 HTF Loop Cold Side 3.3.2 Receiver Overheating Protection	* Use of 30m exclusion zones around receivers to be considered during commissioning (open) * pressure, temperature, and flow monitoring on receiver and * relief system operation detection (no longer relevant since PSV removed from design) * mitigated by ability to isolate pipework to limit containment (open) * All elevated pipe joints to be fully welded	* Update Functional Description. * An exclusion zone to be considered during the commissioning phase. * Install pressure, temperature and flow monitoring equiment on reciever. Commission.	
21	Thermal cycling fatigue	OP	Premature receiver failure	Loss of cotainment, danger to personnel, plant and property.	Receiver designed to AS 1200 based on 2 years of field trials and FEA, 30m exclusion zones around receivers, receiver designed for temperature cycling over 30 year life, pressure, temperature, and flow monitoring on receiver and, relief system operation detection.	2.3.5	Receiver design to be reviewed in light of FEA results.	EM	Q2 2014	In Progress	Design in development (ongoing)	* Receiver designed to AS 1200 based on 2 years of field trials and FEA (confirmed) * Use of 30m exclusion zones around receivers to be considered during commissioning (open) * Receiver designed for temperature cycling over 30 year life (confirmed) * pressure, temperature, and flow monitoring (confirmed) on receiver and * relief system operation detection (there will be no pressure relief valve, refer to line item above)		
22	Lightning strike	ALL	Structural damage	Structural damage compromising HTF system.	No work conducted at top of tower, extreme weather monitoring and response protocols, lightning mast on top of tower with preferential earth conductor.	2.3.6	Update documentation to reflect extreme weather controls and response.	EMSQ	Q2 2014	To occur during Commissioning	NA	Not yet complete.	* Write Adverse Weather Protocol	
						2.3.7	Lightning protection study and earthing study outcomes to feed into design.	EM	Q2 2014	In Progress	NA	* Earthing installed on tower currently being used for heliostat tests. * Earthing not yet installed on other towers.	* Update design documents. * Ensure lightning protection study and earthing study outcomes fed into design.	
23	Unbalanced HTF Flow through the 5 receivers	OP	Flow sensor failure	Receiver flow valve goes fully close resulting in overheating.	Receiver temperature protection sends mirrors to standby. The design of the control system allows for flow variation.	2.3.8	Non-desirable event must be investigated.	EM	Q1 2014	In Progress	JB-SPE-PRO-0001 Heliostat Array 3.2 Protection against Receiver over temperature	Both controls identified are in the process of being developed. Will be fully tested during commissioning.	* Test mirror redirection and flow variation capability during commissioning.	
			Flow sensor failure	Reciever flow valve goes fully open causing reduction in performance.	The design of the control system allows for flow variation.	As for 2.3.8		EM	Q1 2014	In Progress	JB-SPE-PRO-0003 HTF Cycle (Release Side) - *discusses variable HTF flow rates*	Both controls identified are in the process of being developed. Will be fully tested during commissioning.	* Test mirror redirection and flow variation capability during commissioning.	
24	Tower failure	ALL	Tower unable to support HTF system	Loss of cotainment, danger to personnel, plant and property arising from compromised elevated HTF system.	Tower designed and reviewed to AS 3995 or equivalent with reference to previous experience on 2 prior towers.	2.3.9	Confirm the third party certification process.	CTO	Q1 2014	Completed	MJM Consulting Drawing RT1_140214_ReceiverTowerFooting_C	* MJM Consultant reviewed tower design and confirmed adequacy.	Confirm the third party certification process.	
						2.3.10	Conduct a constructability study workshop.	EMSQ	Q1 2014	No longer relevant		* Tower installed		
						2.3.11	Update BOD to reflect tower design.	EM	Q1 2014	To occur during Commissioning	NA	Not yet complete.	Update BOD to reflect tower design.	31-Mar-15
						2.3.12	Develop SOPs for raising and lowering of tower.	EMSQ	Q2 2014	To occur during Commissioning	NA	* Have developed JSA * SOP to be developed during commissioning.	Develop SOP for raising and lowering of tower.	31-Mar-15
25	Uncontrolled access	ALL	Vehicle collision with pipe	Damage to pipe possibly causing loss of containment.	Designed and defined access routes, personnel management processes.	2.3.13	Review traffic plan for arrays for elevated vulnerability of plant.	EMSQ	Q1 2014	To occur during Commissioning	NA	* Traffic Management Plan not yet developed.	* Develop Traffic Management Plan	31-Mar-15

Client:Vast Solar
Project: Jemalong Solar Station

HAZOP Minute Sheet

Sub system	2. HTF & Utilities	
Node	2.4 Receiver to Cold Tank Return	
Drawing Title	P&ID Receivers 1, 2 & 3	
Drawing number:	JB-DRG-PRO-2003	
Rev.	B	
Date:	24/02/2014	

Dev No	Deviation	Op Mode	Cause	Consequence	Safeguard	Rec #	Recommendation	Responsibility	Action	Status	Reference	Action Taken	Remaining Action	Target Date
26	Overpressure	ALL	HTF Receiver Recirculation Valves fails closed	Dead heading of HTF Cold Transfer pumps	System rated for pump dead head pressure in accordance with AS 4041. Automated recirculation line and pressure relief installed.		Controls satisfactory - no action required			Open	NA	* Automated recirculation line and pressure relief to be installed.	* Confirm system rated for dead head pressure.	28-Feb-15
27	High temperature	ALL	HTF Receiver Recirculation Valves fails open	Hot HTF sent to HTF Cold Tank	Cold Tank designed to the same pressure and temperature ratings as the Hot Tank.		Controls satisfactory - no action required			**New Risk Assessment Required**	JB-SPE-PRO-0004 3.1.5 Draining the HTF Hot Tank (HTF > 300C)	* Cold Tank ***is not*** designed to the same pressure and temperature as the Hot Tank. * If the Hot Tank needs to be drained and the HTF temperature exceeds 300C then it is cooled through transfering heat into steam and using the condensor to dump heat form the steam. Refer to FDs.	* Include test for Hot to Cold Tank transfer in commissioning plan. * Testing and commissioning.	31-Mar-15
28	Low temperature	ALL	Inadvertent closure of Receiver Recirculation Valves	Stagnated flow resulting in HTF cooling and possible solidification.	Heat Trace	2.4.1	Review whether extent of monitoring of line is adequate.	EM	Q1 2014	To occur during Commissioning	JB-SPE-PRO-0007 Thermal Oil System FD	* Heat trace and thermal oil heating will be installed to re-melt any solidified HTF.	* Testing and commissioning.	31-Mar-15
29	Reduced flow	ALL	Receiver Recirculation Valve opens when Hot Tank Supply Valve opens as a result of control system failure in automatic mode or operator error in manual mode.	Reduced flow to Hot Tank causing production capacity loss. Hot HTF flowing to Cold Tank.	Accept production loss. Cold tank designed to take hot HTF.	2.4.2	Consider interlocking of Receiver Recirculation Valve and Hot Tank Supply Valve.	EM	Q1 2014	To occur during Commissioning	JB-SPE-PRO-0004 3.1.5 Draining the HTF Hot Tank (HTF > 300C)	* Cold Tank ***is not*** designed to the same pressure and temperature as the Hot Tank. * If the Hot Tank needs to be drained and the HTF temperature exceeds 300C then it is cooled through transfering heat into steam and using the condensor to dump heat form the steam. Refer to FDs.	* Include test for Hot to Cold Tank transfer in commissioning plan. * Testing and commissioning.	31-Mar-15

HAZOP Minute Sheet

Sub system	2. HTF & Utilities	
Node	2.5 HTF Hot Tank supply line	
Drawing Title	P&ID HTF Hot Tank	
Drawing number:	JB-DRG-PRO-2004	
Rev.	B	
Date:	24/02/2014	

Dev No	Deviation	Op Mode	Cause	Consequence	Safeguard	Rec #	Recommendation	Responsibility	Action	Status	Reference	Action Taken	Remaining Action	Target Date
30	Overpressure	OP	Operator error - HTF Hot Tank shutoff valves inadvertently closed	Dead heading of HTF Cold Transfer pumps	System rated for pump dead head pressure in accordance with AS 4041. Automated recirculation line and pressure relief installed.	As for 2.2.1		EMSQ	Q1 2014	To occur during Commissioning	CE Boiler Feed Pump	* Recirculation has been designed out - using submersible pumps inside the HTF tanks. * Dead heading will not occur since pump inside tank.	* Commissioning	31-Mar-15
			Blocked or restricted non-return valve.	Dead heading of HTF Cold Transfer pumps	System rated for pump dead head pressure in accordance with AS 4041. Automated recirculation line and pressure relief installed.	As for 2.2.1		EMSQ	Q1 2014	To occur during Commissioning	NA	* Using submersible pumps inside the HTF tanks. * Dead heading will not occur since pump inside tank.	* Commissioning	31-Mar-15
31	Low temperature	OP	HTF Supply Valve fails open	Cold HTF sent to Hot Tank degrading performance.	ATL		No further action required.			Open	NA	* No action taken as yet	* Confirm intended action regarding ATL	28-Feb-15
32	Reduced flow	OP	Hot Tank Supply Valve opens when Receiver Recirculation Valve open as a result of control system failure in automatic mode or operator error in manual mode	Cold HTF sent to Hot Tank degrading performance.	ATL	2.5.1	Review O&M procedure to consider such non-critical abnormalities.	EM	Q2 2014	Open	NA	* No action taken as yet	* Confirm intended action regarding ATL. * O&M plan to be developed.	28-Feb-15
33	Containment Fouling	OP	Buildup of deposits from HTF over time	Blackage - valves, mixer, lines	Maintenance regime	2.5.2	Control Satisfactory no further action required			To occur during Commissioning	NA	* Cold trap to be installed. * O&M plan not yet developed.	* O&M plan to be developed	28-Feb-15

Client:Vast Solar
Project: Jemalong Solar Station

HAZOP Minute Sheet

Sub system	2. HTF & Utilities	
Node	2.6 Cold Trap	
Drawing Title	P&ID HTF Cold Trap	
Drawing number:	JB-DRG-PRO-2007	
Rev.	B	
Date:	24/02/2014	

Dev No	Deviation	Op Mode	Cause	Consequence	Safeguard	Rec #	Recommendation	Responsibility	Action	Status	Reference	Action Taken	Remaining Action	Target Date
34	Overpressure	OP	High pressure from HTF Cold Tank	Potential loss of containment.	System rated for pump dead head pressure in accordance with AS4041	As for 2.2.1		EMSQ	Q1 2014	Open	TBC	* Expect that the Cold Trap has been designed in accordance with AS4041, review design docs to check.	* Confirm that cold trap is rated for dead head pressure.	
			Purge/Cover Gas	Overpressure vessel beyond design rating causing possible loss of containment.	Pressure control on Cover Gas supply to cold trap	2.6.1	Ensure appropriate pressure regulating and relief devices installed.	EM	Q1 2014	To occur during Installation	JB-DRG-PRO-2009	* There is a pressure relief device planned to be installed on the Cover Gas supply to cold trap	* Install and commission * Check that there is also a pressure regulation device installed	31-Mar-15
35	High temperature	OP	Thermal oil system doesn't manage temperature to specification.	No cooling of HTF in system (HTF>160 C) resulting in failure to clean and recontamination of HTF impacting on plant life.	Local temperature monitoring on inlet and outlet of Cold Trap and oil cooling jacket.	2.6.2	Consider remote monitoring for research purposes.	EM	Q1 2014	To occur during Installation	JB-SPE-PRO-0005 JB-DRG-PRO-2007	* There are local temperature monitoring devices on inlet and outlet of Cold trap and oil cooling * These devices feed back into the DCS however not determined as to whether the data will be logged	* Determine whether data from temperature devices will be logged. * Install and commission	31-Mar-15
			False temperature readings	No cooling of HTF in system (HTF>160 C) resulting in failure to clean and recontamination of HTF impacting on plant life.	Multiple T measurements, operational history.		Controls satisfactory, no action required.			To occur during Installation	JB-SPE-PRO-0005 JB-DRG-PRO-2007	* There will be two temperature measurement devices on the flow into the HTF cooling system and two on the way out. There will also be temperature sensors on the thermal oil system. * Whether there will be data logging is yet to be determined	* Determine whether data from temperature devices will be logged. * Install and commission.	31-Mar-15
36	No HTF flow	OP	Cold Trap saturated with impurities	Unable to function to specification impacting on plant life.	Service indicator (using flow meter).	2.6.3	In addition to 2.40 develop a monitoring protocol.	EM	Q1 2014	To occur during Installation	JB-SPE-PRO-0005 JB-DRG-PRO-2007	* There will be a flow meter installed on the cold trap input	* Develop a monitoring protocol to monitor flow rate (which will drop when there are a high level of contaminants lodged within the Cold Trap)	31-Mar-15
37	Low flow	OP	Internal leak in regenerator	False indication of scrubbing function completion impacting on plant life.	No specific safeguard other than operational awareness	2.6.4	Consider options to diagnose regenerator leaks.	EM	Q1 2014	To occur during Commissioning	NA	* Action ongoing. Will be written into O&M plan.	* Include in O&M plan	31-Mar-15
38	Misaligned operating regime	OP	Broader JSS operating regime overlooks Cold Trap operating regime.	Cold Trap underperforms impacting on plant life.	Commitment to developing documented O&M regime incorporating Cold Trap requirements.	2.6.5	Confirmation audit.	EMSQ	Q3 2014	To occur during Commissioning	NA	* O&M plan to be developed	* Include in O&M plan	31-Mar-15
39	Exposure to HTF byproduct during maintenance	MAINT	Exposure of HTF residue to atmosphere resulting in spontaneous ignition.	Chemical exposure to personnel. Hydrogen generation, explosion/fire resulting in plant damage or personnel injury and dense white smoke	Experiential knowledge in handling and maintenance of HTF decontaminated components. Engaged expert consultants(Creative Engineering) to review current practices. In house training.	2.6.6	Confirm access parameters in layout.	EM	Q1 2014	To occur during Commissioning	NA	* O&M plan to be developed	* Include in O&M plan	31-Mar-15
						2.6.7	Investigate option for multiple smaller cold traps or smaller variants of existing design presenting reduced hazard potential.	CTO	Q1 2014	No longer relevant	NA	* Cold trap has been designed and is onsite.		
						2.6.8	Rigorous assessment of maintenance processes required for JSS components as part of research undertaking.	CTO	Q2 2014	**New Risk Assessment Required**	NA	* To be written into O&M plan.	* Include in O&M plan	01-Apr-15
						2.6.9	Examine research opportunities to improve knowledge and enhance safety of future development.	CTO	Q2 2014	To occur during Commissioning	NA	* To be investigated during commissioning.	* To be investigated during commissioning.	31-Mar-15
						As for 2.1.9	Ensure O&M includes protocl addressing HTF contaminated components. Validate with other reputable parties internationally. Apply continual improvement processes to training.	EMSQ	Q3 2014	To occur during Commissioning	NA	* To be written into O&M plan.	* Include in O&M plan	31-Mar-15

Client:Vast Solar
Project: Jemalong Solar Station

HAZOP Minute Sheet

Sub system	2. HTF & Utilities	**Drawing Title**	P&ID HTF Hot Tank
		Drawing number:	JB-DRG-PRO-2004
Node	2.7 HTF Hot Tank & controls	**Rev.**	B
		Date:	24/02/2014

Dev No	Deviation	Op Mode	Cause	Consequence	Safeguard	Rec #	Recommendation	Responsibility	Action	Status	Reference	Action Taken	Remaining Action	Target Date
40	Tank operating level exceeded	COM	System overcharged with HTF	Overcharged system is operated beyond hydrostatic parameters.	Inventory control, HH Alarm, HH pump trip.	2.7.1	Consider pressure trip on tank.	EM	Q1 2014	To occur during Commissioning	JB-SPE-PRO-0003 3.15 Mitigation against HTF Hot Tank high level	As per safeguards. Note also that Hot Tank volume is greater than the volume of HTF in the system.	* Install and commission	Mar-15
41	HTF Contamination	ALL	Tube leak from thermal oil system	Inadvertenet chemical reaction.	Reviewed the PDS of the thermal oil reccomended by the HTF supplier.	As for 2.1.6 2.1.7		EM	Q2 2014	No Longer Relevant	NA	* Thermal oil pipes located on the outside of the HTF Tank		
42	Internal access to tank	MAINT	Contaminated environnment	Tank toxic to personnel	Under normal operations tank not accessible	As for 2.1.8		EMSQ	Q2 2014	New Risk Assessment Required	NA	* O&M plan not yet developed	* O&M plan to be developed	Mar-15
			Confined space	Requiring confined space entry procedure	Compliance with AS2865.	As for 2.1.8		EMSQ	Q2 2014	In Progress	NA	* Personel have been trained. * SOP not yet developed.	* Developed SOP	Mar-15
43	Exposure to HTF byproduct	MAINT	Residual HTF in items under maintenance	Hyrdogen generation, explosion/fire resulting in plant damage or personnel injury and dense white smoke	Experiential knowledge in handling and maintenance of HTF decontaminated components. Engaged expert consultants(Creative Engineering) to review current practices. In house training.	As for 2.1.9		EMSQ	Q3 2014	New Risk Assessment Required	NA	* Have worked with MSSA (sodium supplier) to develop procedures for handling HTF. This decision has not yet been finalised. * A dedicated procedure *may* be produced for cleaning of contaminated parts during the commissioning phase, however it is expected that the cleaning method will be decided on a case-by-case basis. This will take into account Vast Solar's experience to date and the individual component features (e.g. cleaning the Cold Trap will be different to piping).	* Consider developing standardised procedures. * Consider requirements on a case-by-case basis.	31-Mar
44	Loss of containment	MAINT	Wrong parts used or replaced during maintenance or poor maintenance procedure	Critical operational impact on the HTF Hot Tank resulting in potential loss of containment.	Match parts to specification, materials management protocols.	As for 2.1.10		EMSQ	Q2 2014	To occur during Commissioning	NA	* To be developed	* To be developed	31-Mar
		ALL	Structural failure	Critical operational impact on the HTF Hot Tank resulting in potential loss of containment.	Tank designed to AS1210 Pressure Vessels, tank has larger volume than total HTF, located in restricted access and bunded area on minimum 150mm sand base over clay. In event of loss to bunded area, bund and minimum seperation distances designed to AS/NZS 5026 Storage and Handling of Class 4 Dangerous Goods	As for 2.1.11 2.1.12 2.1.13 2.1.14		EM	Q1 2014	To occur during Commissioning	NA	Refer to item 8	Refer to item 8	Refer to item 8
45	High flow to Hot Tank.	OP	Cold Transfer Pumps on overspeed.	No adverse impact.	Designed to meet AS 1210 Pressure Vessels with appropriate erosion and corrosion allowances. Set volume of HTF less than tank volume. Bottom entry to tank minimises HTF vapour formation.		Control satisfactory no further action recommended.			Completed	FP-6962-4-Rev 3 Hard copy of Manufacturers Data Report also kept on site (as builts, detailed drawings, test plans, weld information, material spills, hydrostatic test reports)	NA		
46	Low Flow to Hot Tank.	OP	Blockages from the buildup of HTF oxides as a result of fugitive oxygen.	Potentially disrupt instrumentation integrity.	Cover Gas at slight positive pressure and Cold Trap to remove impurities.		Control satisfactory no further action recommended.			To occur during Commissioning	JB-SPE-PRO-0005 Cold Trap 2.2 Governing Principles JB-SPE-PRO-0003 HTF Cycle (Release Side) 3.2.4 Filling	* Actions planned: cover gas storage on site, Cold Trap to be installed and commissioned.	* Installation. * Testing and commissioning.	31-Mar

Client:Vast Solar
Project: Jemalong Solar Station

HAZOP Minute Sheet

Sub system	2. HTF & Utilities	**Drawing Title**	P&ID HTF Hot Tank
		Drawing number:	JB-DRG-PRO-2004
Node	2.8 HTF Hot Transfer Pumps	**Rev.**	B
		Date:	24/02/2014

Dev No	Deviation	Op Mode	Cause	Consequence	Safeguard	Rec #	Recommendation	Responsibility	Action	Status	Reference	Action Taken	Remaining Action	Target Date
47	Overpressure	OP	Dead heading of pump as a result of downstream valves inadvertently closing or failing closed or HTF oxide blockage	Overpressurising leading to a loss of containment.	System rated for pump dead head pressure in accordance with AS 4041. Automated recirculation line and pressure relief installed. Pump overload protection.	As for 2.2.1		EMSQ	Q1 2014	In Progress	JB-SPE-PRO-0003 3.12 Mitigation against HTF Hot Transfer Pump 'dead heading' FD JB_SPE_PRO_0003_B	* Pump is now located inside the HTF Tanks so will not be deadheaded. * Manufacturer has confirmed that the seals can withstand being dead headed. * Automated re-circulation line and pressure relief desiged out of system. * Pump overload protection is in the design. FDs to be updated.	* Update FDs and/or F&IDs to show Hot Transfer Pump leak off valve THD10 AA310 (refer to FD JB_SPE_PRO_0003_B)	28-Feb
48	Low flow	OP	Hot HTF Transfer Pump VSD corrupted signal or incorrect speed setting	SG starved of HTF resulting in loss in production, decreased SG temperatures and possible blockage due to HTF solidification.	Seperated power supplies for 100% duty and standby pumps, HTF drainage system, automated over temperature protection on receivers.	As for 2.2.2		EM	Q1 2014	To occur during Commissioning	JB-SPE-PRO-0001 Heliostat Array JB-SPE-PRO-0009 Rapid Drain System	* Back up power source installed. Only one pump installed (and only one planned). * HTF Drainage System to be installed, refer to FDs for full operational description. * Automated Receiver Over-Temperature response developed: increase HTF flow and if this does not mitigate the problem, heliostats will commence ESD and track off receiver.	* Installation. * Testing and commissioning.	31-Mar
			Recirculation valve or relief stuck open	SG starved of HTF resulting in loss in production, decreased SG temperatures and possible blockage due to HTF solidification.	Over temperature protection and drain system. Recirculation valves are exercised every day.	As for 2.2.3		EM	Q1 2014	No longer relevant	NA	* Re-circulation removed from design.		
54	No flow	OP	HTF Transfer Pump VSD trip , control system trip or pump fault	Dead head pump resulting in possible pump damage & loss of production	Pump overload (high T trip). Positive management of the SG Superheater outlet temperature by control system including system trip. Existing isolation philosophy relies on single isolation and plant shutdown. Competent operators and appropriate supervision.	As for 2.9.1 2.2.4		EMSQ	Q2 2014	To occur during Commissioning	JB-SPE-PRO-0003 3.11 Protection against Steam Generator over temperature	* Refer to FD which states that the Emergency Shutdown System (ESD) will be activated when any of 9 conditions are true. One of which is when the Superheated steam outlet temperature exceeds 510C for greater than a set period.	* Installation. * Testing and commissioning. * O&M plan to be developed	31-Mar
			Operator error - V4a or V4b inadvertantly closed	Dead head pump resulting in possible pump damage & loss of production						To occur during Commissioning	JB-SPE-PRO-0003 3.11 Protection against Steam Generator over temperature	* Refer to FD which states that the Emergency Shutdown System (ESD) will be activated when any of 9 conditions are true. One of which is when the Superheated steam outlet temperature exceeds 510C for greater than a set period.	* Installation. * Testing and commissioning. * O&M plan to be developed	31-Mar
			Valve V1 fails closed.	Dead head pump resulting in possible pump damage & loss of production						To occur during Commissioning	JB-SPE-PRO-0003 3.11 Protection against Steam Generator over temperature	* Refer to FD which states that the Emergency Shutdown System (ESD) will be activated when any of 9 conditions are true. One of which is when the Superheated steam outlet temperature exceeds 510C for greater than a set period.	* Installation. * Testing and commissioning. * O&M plan to be developed	31-Mar
			NRV blockage, obstruction	Dead head pump resulting in possible pump damage & loss of production						To occur during Commissioning	JB-SPE-PRO-0003 3.11 Protection against Steam Generator over temperature	* Refer to FD which states that the Emergency Shutdown System (ESD) will be activated when any of 9 conditions are true. One of which is when the Superheated steam outlet temperature exceeds 510C for greater than a set period.	* Installation. * Testing and commissioning. * O&M plan to be developed	31-Mar
49	High temperature	OP	Temperature rating of equipment is exceeded.	Potential damage and loss of containment	Temperature rating of equipment exceeds maximum supply temperature. Temperature alarms in Hot Tank.	As for 2.2.8				To occur during Commissioning	NA	* Temperature rating of thermocouples far exceeds expected temperatures (Hot Tank rated for 575C)	* Update FD. * Installation. * Testing and commissioning.	28-Feb
50	Low temperature (nom. <100°C)	OP	Heat trace failure.	Solidification of HTF in pump or pipework.	Heat trace failure alarm, system drain, temperature monitoring and control through the system.	As for 2.2.9				To occur during Commissioning	NA	* No heat trace alarms planned. There will be a number of temperature monitors which are linked to the heliostat management system and ESD. These will cause appropriate high / low temperature responses.	* Installation. * Testing and commissioning.	28-Feb
			Inadvertently isolated pipe sections filled with HTF.	Solidification of HTF in pipework,vacuum generated in pipe.	Heat trace, temperature monitoring and control through the system, pipe can withstand full vacuum.		Controls satisfactory, no action required. This applies to all HTF pipe sections.			Open	NA	* No heat trace alarms planned. There will be a number of temperature monitors which are linked to the heliostat management system and ESD. These will cause appropriate high / low temperature responses.	* Confirm pipe can withstand full vacuum.	28-Feb
			Poor installation of insulation or damage.	Solidification of HTF in pump or pipework.	Maintenance procedures and inspection regime, heat trace, system drain, temperature monitoring and control through the system.		Controls satisfactory, no action required. This applies to all HTF pipe sections.			To occur during Commissioning	JB-SPE-PRO-0007 Thermal Oil System FD	* Heat trace and temperature monitoring planned throughout system. Re-melting possible through use of heat trace and thermal oil heating. * Piping to be fully insulated. * System Drain FDs have been developed.	* O&M plan to be developed. * Installation and application of insulation. * Testing and commissioning.	31-Mar
51	Low Temperature (nom. <100°C)	OP	Premature pump startup with solidified HTF.	Pump damage.	Heat trace, temperature monitoring on tank, motor trip on overload.	As for 2.2.8		EM	Q1 2014	To occur during Commissioning	NA	* There will be a number of temperature monitors which are linked to the heliostat management system and ESD. These will cause appropriate high / low temperature responses.	* Installation. * Testing and commissioning.	28-Feb
			Motor failure results in stagnant fluid.	Solidification of HTF in pump or pipework.	Flow monitoring, temperature sensing on the receivers.		Controls satisfactory, no action required.			To occur during Installation	NA	* Flow monitors included in design * Thermocouples included in Receiver design	* Installation. * Testing and commissioning.	31-Mar
52	Premature failure of pumps.	OP	Not suited for duty.	Pump damage beyond repair	Fully attended plant including roving field operators. 100% redundancy of pumping train.	As for 2.2.9		CTO	Q1 2014	To occur during Commissioning	JB-SPE-PRO-0003 3.14 Mitigation against HTF Mixing Pump trip	* HTF mixing pumps are arranged in a duty / standby configuration. If the HTF Mixing Pump trips, the standby pump will automatically start.	* Installation. * Testing and commissioning.	31-Mar
53	High flow	OP	Pump overspeed	Thermal shock to steam generator resulting in fatigue potentially resulting in reduced life or additional maintenance.	During startup pump speeds is fixed. A conservative temperature ramp rate to be set during commisioning. Whilst not monitoring for pump overspeed temperature and flow on the line are monitored. Vendor supplied analysis of full cold start of the steam generator.		Ref. Assumption			To occur during Commissioning	JB-SPE-PRO-0003 3.14 Mitigation against HTF Mixing Pump trip	* To be completed during commissioning.	* Testing and commissioning.	31-Mar
			Valve V2 prematurely opens or fails open.	Thermal shock to steam generator resulting in fatigue potentially resulting in reduced life or additional maintenance.	HTF is mixed before entering the SG, temperature monitoring in line, vendor supplied analysis of full cold start of SG.	2.8.1	Consider additional alarms specifically for startup.	EM	Q1 2014	To occur during Commissioning	JB-SPE-PRO-0003 3.2.5 Warming up the Steam Generator	* Mixer to be installed. * Temperature will be monitored in line. * Cold start procedures documented in FDs.	* Installation. * Testing and commissioning.	31-Mar

Client:Vast Solar
Project: Jemalong Solar Station

HAZOP Minute Sheet

Sub system	2. HTF & Utilities	
Node	2.9 Steam Generator HTF supply	
Drawing Title	P&ID Steam Generator	
Drawing number:	JB-DRG-PRO-2005	
Rev.	B	
Date:	24/02/2014	

Dev No	Deviation	Op Mode	Cause	Consequence	Safeguard	Rec #	Recommendation	Responsibility	Action	Status	Reference	Action Taken	Remaining Action	Target Date
54	Low flow	OP	Valve V2 fails closed.	HTF temperature to SG increases beyond allowable operating limits of SG.	Pump trip at high HTF temperature. Positive management of Superheater outlet temperature by control system including system trip		Control satisfactory no action required.			To occur during Commissioning	JB-SPE-PRO-0003 3.11 Protection against Steam Generator over temperature	* Emergency Shutdown System (ESD) will engage if over temperature occurs.	* Installation. * Testing and commissioning.	31-Mar
			Partial blockage of line with HTF contaminants (full blockage not credible)	Pumping power increases to maximum speed to overcome additional line resistance. Potential for pump trip on overload.	Operating temperature of HTF prevents precipitation of contaminants.		Control satisfactory no action required.			No longer relevant		No actions required.		
			Valve V6 inadvertently opens or fails opens (low flow to evaporator)	Surge in Superheater outlet temperature, may result in temperature rating of downstream equipment being temporarily exceeded.	Positive management of Superheater outlet temperature by control system including system trip.		Control satisfactory no action required.			To occur during Commissioning	JB-SPE-PRO-0003 3.11 Protection against Steam Generator over temperature	* Emergency Shutdown System (ESD) will engage if over temperature occurs.	* Installation. * Testing and commissioning.	31-Mar
	No flow	OP	Valve V5 or V7 inadvertently closed by operator or valve V1 fails closed	Dead head HTF Hot Transfer pumps leading to pump damage and loss of production.	Pump overload. Major equipment blocks have individual protections. Refer also node 2.8.	2.9.2	Consider supplementary line relief.	EM	Q1 2014	To occur during Commissioning	JB-SPE-PRO-0003 3.13 Mitigation against HTF Hot Transfer Pump 'dead heading'	'Dead heading' of the HTF Hot Transfer Pump (e.g. due to downstream control valve inadvertently closing) will be mitigated via HTF Hot Transfer Pump leak off valve THD10 AA310	* Installation. * Testing and commissioning.	31-Mar
55	High temperature of SG	ALL	Failure of cold mixing -V2 fails closed, HTF mixing pump fault	HTF temperature to SG increases beyond allowable operating limits of SG.	Pump trip at high HTF temperature. Positive management of Superheater outlet temperature by control system including system trip		Control satisfactory no action required.			To occur during Commissioning	JB-SPE-PRO-0003 3.11 Protection against Steam Generator over temperature	* Emergency Shutdown System (ESD) will engage if over temperature occurs.	* Installation. * Testing and commissioning.	31-Mar
56	Low temperature HTF supply	ALL	Failure of hot HTF transfer system upstream of static mixer	Loss of production due to mixing line wind down, removal of heat from SG. Stangnantion of HTF leading to potential HTF solidification.	Temperature monitoring and alarm for operator response. Heat trace and sufficient thermal inertia remaining in the system. Mixing line wind down removes heat from SG.		Control satisfactory no action required.			To occur during Commissioning	JB-SPE-PRO-0003 3.11 Protection against Steam Generator over temperature	* Temperature monitoring will be in place throughout plant. * Heat trace and thermal oil system will be in place to re-melt HTF if solidification occurs	* Installation. * Testing and commissioning.	31-Mar
57	Fouling of SG.	ALL	Buildup of deposits from HTF over time	Reduced efficiency of steam generator	Cold Trap operated as required on the basis of ongoing analysis.		Controls satisfactory, no further action required. This applies to all fouling from HTF contaminants.			To occur during Commissioning	JB-SPE-PRO-0005 Cold Trap 2.2 Governing Principles	* Actions planned: Cold Trap to be installed and commissioned.	* Installation. * Testing and commissioning.	31-Mar
58	Water ingress to HTF system	START	Water leak into HTF system from pinhole leak during shutdown.	Water accumulates in HTF pipe in sufficient quantities to react violently on HTF system startup causing hydrogen and HTF salt evolution and rapid pressure increase.	Engaged Skoda and W.E. Smith to design SG to applicable standards. Detection of pressure spike or hydrogen evolution triggering a full system automatic shutdown which includes safe venting of reaction products, safe dumping of feedwater, isolation of steam generator and shutdown of pumps	2.9.3	Determine method to detect water in pipe prior to startup.	EM	Q1 2014	To occur during Commissioning	JB-SPE-PRO-0009 3.1.2 Detection of a leak	* Refer to FD: the ESD drains the Evaporator immediately as soon as an "unhealthy" condition occurs. Refer to FD for full list of "unhealthy" condition signals.	* Installation. * Testing and commissioning.	31-Mar

Client:Vast Solar
Project: Jemalong Solar Station

HAZOP Minute Sheet

Sub system	2. HTF & Utilities	**Drawing Title**	P&ID Steam Generator
		Drawing number:	JB-DRG-PRO-2005
Node	2.9 Steam Generator HTF supply (continued)	**Rev.**	B
		Date:	24/02/2014

Dev No	Deviation	Op Mode	Cause	Consequence	Safeguard	Rec #	Recommendation	Responsibility	Action	Status	Reference	Action Taken	Remaining Action	Target Date
59	Overpressure	OP	Pinhole HTF leak to water/steam side of Superheater or Evaporator (Tube to shell).	Small quantities of undetected hydrogen evolved, discharged through boiler startup vent valve (manual valve for manual operation or de-aerator valve for automatic operation).	SG designed to AS1228. Within SG vicinity only hazardous area rated equipment used. Hydrogen vented safely to atmosphere. Hazardous area rated equipment installed in vicinity. Leak detected upon operation commencement using hydrogen detector triggering immediate shutdown and repair.	As for 6.1.1		CTO	Q1 2014	**New Risk Assessment Required**	JB-SPE-PRO-0009 3.1.2 Detection of a leak	* Status of Hazardous Area equipment to be confirmed. Currently contains inappropriate equipment. * Refer to FD: the ESD drains the Evaporator immediately as soon as an "unhealthy" condition occurs. Refer to FD for full list of "unhealthy" condition signals	* Review equipment kept within hazardous area. * Installation. * Testing and commissioning.	28-Feb
			Catastrophic HTF leak to water/steam side of Superheater or Evaporator (Tube to shell).	HTF ingress to shell side of SG, rapid reaction with HTF and rapid buildup of pressure and generation of hydrogen.	Engaged Skoda and W.E. Smith to design SG to applicable standards. Detection of pressure spike or hydrogen evolution triggering a full system automatic shutdown which includes safe venting of reaction products, safe dumping of feedwater, isolation of steam generator and shutdown of pumps.	2.9.5	Ensure the steam pressure relief valves are sized to take into account the surge pressure due to the leak.	EM	Q2 2014	In Progress	JB-SPE-PRO-0009 3.1.3 Draining Evaporator Water	* Immediately upon an 'unhealthy' condition occurring, the ESD drains the Evaporator by opening the Rapid Drain Valve HAD40 AA110 (via power gas solenoid HAD40 AA110S)	* Check pressure rating of valve HAD40 AA110 is appropriate.	28-Feb
						2.9.6	Consider increasing pressure rating of HTF piping in vicinity of SG or equivalent design options.	EM	Q1 2014	To occur during Commissioning	JB-SPE-PRO-0009 3.1.3 Draining Evaporator Water	* Upon opening of HAD40 AA110, water is discharged from the Evaporator via the Rapid Drain Line where it flashes as it passes through the orifice plate.	* Check pressure rating of drain line and piping in vicinity of SG.	28-Feb
			Pinhole water/steam leak to HTF side of Superheater or Evaporator (Shell to tube).	Water and steam in HTF line, chemical reaction of water and steam with HTF, pressure surge	Hydrogen detector on outlet of Evaporator that triggers full shutdown on hydrogen presence. Shell side evacuation of boiler water.	2.9.7	Confirm suitability of analyser.	CTO	Q2 2014	To occur during Commissioning	JB-SPE-PRO-0009 3.1.2 Detection of a leak	* The presence of hydrogen in HTF is detected by analyser TCF10 CA001.	* Installation. * Testing and commissioning.	31-Mar
			Catastrophic water/steam leak to HTF side of Superheater or Evaporator (Shell to tube).	HTF and water mixed in both shell and tube leading to rapid reaction and buildup of pressure and generation of hydrogen resulting in potential for explosion.	Detection of pressure spike and/or hydrogen triggering a full system automatic shutdown which includes venting of reaction products and shutdown of pumps. Shell side evacuation of boiler water.	2.9.8	Ensure the steam pressure relief valves are sized to account for the pressure spike.	EM	Q2 2014	To occur during Commissioning	JB-SPE-PRO-0009 3.1.2 Detection of a leak	* There will be several devices which monitor pressure and trigger a shutdown if spikes occur. Refer to FDs for full detail.	* Installation. * Testing and commissioning.	31-Mar
60	No backup control on hydrogen sensor	ALL	False positive	Unnecessary system shutdown and loss of production. Repeated false positives degenerates confidence in system.	System goes to safe state.	2.9.9	Investigate redundancy options for hydrogen detection using different methods.	EM	Q1 2014	Open	JB-SPE-PRO-0009 3.1.2 Detection of a leak	* Not yet addressed.	* Redundant detection methods to be considered.	28-Feb
			False negative	Failure to detect hydrogen indicating HTF contamination preventing system shutting down when required.	No safeguards against hydrogen detection giving false negative.	2.9.10	Investigate options for in service self testing.	EM	Q1 2014	Open	JB-SPE-PRO-0009 3.1.2 Detection of a leak	* Not yet addressed.	* Self testing to be considered.	28-Feb
61	No backup control on steam outlet pressure sensor	ALL	False positive	Unnecessary system shutdown and loss of production. Repeated false positives degenerates confidence in system.	System goes to safe state.	2.9.11	Investigate incorporation of other pressure sensors.	EM	Q1 2014	Open	JB-SPE-PRO-0009 3.1.2 Detection of a leak	* Not yet addressed.	* To be considered.	28-Feb
		ALL	False negative	Failure to detect pressure surge indicating HTF contamination preventing system shutting down when required.	No safeguards against pressure sensor giving false negative.	As for 2.9.11				Open	JB-SPE-PRO-0009 3.1.2 Detection of a leak	* Not yet addressed.	* To be considered.	28-Feb
62	No backup on temperature sensor on SG HTF inlet	ALL	False positive	Unnecessary system shutdown and loss of production. Repeated false positives degenerates confidence in system.	System goes to safe state.	2.9.12	Consider redundancy or other similar techniques.	EM	Q1 2014	To occur during Commissioning	JB-SPE-PRO-0009 W01MA0R001_A 2.4.2 Technological diagram of turbine 3.1.2 Detection of a leak	* There are two points at which temperature is measured between exiting the superheater and entering the turbine.	* Installation. * Testing and commissioning.	31-Mar
			False negative	Failure to detect high temperature resulting in SG operating outside design envelope.	Superheater outlet high temperature trip.		Controls sufficient, no action required.			To occur during Commissioning	JB-SPE-PRO-0009 W01MA0R001_A 2.4.2 Technological diagram of turbine 3.1.2 Detection of a leak	* There are two points at which temperature is measured between exiting the superheater and entering the turbine.	* Installation. * Testing and commissioning.	31-Mar
63	No backup on temperature sensor on SG HTF inlet	ALL	False positive	Unnecessary system shutdown and loss of production. Repeated false positives degenerates confidence in system.	System goes to safe state.	2.9.13	Consider redundancy.	EM	Q1 2014	No longer relevant		Repeat of item 62		
			False negative	Failure to detect high temperature resulting in SG operating outside design envelope.	Superheater outlet high temperature trip.		Controls sufficient, no action required.			No longer relevant		Repeat of item 62		

Client:Vast Solar
Project: Jemalong Solar Station

HAZOP Minute Sheet

Sub system	2. HTF & Utilities	
Node	2.10 HTF Drain System	
Drawing Title	P&ID HTF Drain Tank	
Drawing number:	JB-DRG-PRO-2006	
Rev.	B	
Date:	24-Feb-14	

Dev No	Deviation	Op Mode	Cause	Consequence	Safeguard	Rec #	Recommendation	Responsibility	Action	Status	Reference	Action Taken	Remaining Action	Target Date
64	High drain flow	ALL	Too many drains opened simultaneously	Inundation of system, drainage impaired.	Designed to mitigate inundation. Drainiage procedure validated at commissioning. Non-critical event.		Controls satisfactory, no action required.			To occur during Commissioning	NA	NA	* Test during commissioning.	31-Mar
			Cover gas	Potential impact of pressurised cover gas affecting drainage.	System designed with cover gas pressure.	2.10.1	Check Cover Gas has no adverse impact in light of final layout.	EM	Q1 2014	To occur during Commissioning	NA	* Not yet addressed.	* Test during commissioning.	31-Mar
			Operation of Transfer Pumps.	Inundation of system.	Drainage system rated at same pressure as the rest of system. Drain valves are interlocked to ensure they can't be opened when transfer pumps are operating.		Controls satisfactory, no action required.			To occur during Commissioning	JB-SPE-PRO-0004 3.1.8 Transfer from the HTF Drain Tank	* Not yet addressed.	* Interlocks to be implemented during commissioning. * Update FDs	31-Mar
65	No flow to drain tank	SHUTDWN	Valve fails closed	HTF left in lines, potentially solidifying and blocking lines.	Heat trace.	2.10.2	Consider proximity switch on valves to positively identify valve position.	EM	Q1 2014	To occur during Commissioning	JB-SPE-PRO-0004 3.6 Mitigation against HTF solidification	* Heat Traceapplied to the HTF Drain Tank, HTF Drain Pumps and associated pipework.	* Installation. * Testing and commissioning.	31-Mar
			Blockage by HTF contaminants	Impedes drainage, continue to inhibit plant operation.	Cold Trap, Heat Trace	As for 2.1.9		EM	Q1 2014	To occur during Commissioning	JB-SPE-PRO-0005 Cold Trap 2.2 Governing Principles JB-SPE-PRO-0006 HTF Loop Cold Side 3.1 System Filling	* Cold Trap and Heat Trace incorporated into design.	* Installation. * Testing and commissioning.	31-Mar
			Header valves not opened by operator	Drain line charged, potential for line to solidify.	Some system monitoring e.g. tank level.	2.10.3	Consider locking open valves.	EM	Q1 2014	Open		* Not yet addressed.	* To be considered.	28-Feb
						2.10.3	Consider if manual valves are required.	EM	Q1 2014	Open		* Not yet addressed.	* To be considered.	28-Feb
		MAINT	Valve Fails Closed	Undetected fugitive HTF left in small pipe sections - potential threat to personnel. Potentially unable to remove plant components for maintenance (isolation philosophy requires system drained)	Experiential history with HTF draining and O&M requirements.	2.10.4	Audit isolation process prior to commissioning.	EMSQ	Q2 2014	To occur during Commissioning	JB-SPE-PRO-0004	* Not yet addressed.	* To be considered during commissioning.	31-Mar
						2.10.5	Consider automatic HTF inventory check.	EM	Q1 2014	To occur during Commissioning	JB-SPE-PRO-0004	* Not yet addressed.	* To be considered during commissioning.	31-Mar
66	Insufficient buffer capacity	ALL	Unable to cope with full flow	System backlog impeding operational cycles.	Designed to mitigate inundation. Drainiage procedure validated at commissioning. Non-critical event.	2.10.6	Check tank sizing	EM	Q1 2014	To occur during Commissioning	NA	* Not yet addressed.	* Test during commissioning.	31-Mar
67	No flow from drain tank	ALL	Failure of heat tracing	Unable to pump from drain tank	System integrity checks i.e. electrical continuity check	2.10.7	Consider fault detection alarm.	EM	Q1 2014	Open	NA	* Rather than electrical continuity check, will install temperature measurement on HTF Tanks. This will be linked to the Emergency Shutdown Procedure.	* To be considered.	28-Feb
			Drain pump failure			As for 2.2.10	Consider condition monitoring on pumps.	EM	Q1 2014	To occur during Commissioning	NA	* Not yet considered.	* O&M plan to be developed	31-Mar
68	HTF exposure	MAINT	Low point drain requires manual operation.	Threat to maintenance personnel	Isolation philosophy	2.10.8	Develop manual containment process that accounts for potential exposure to HTF.	EMSQ	Q2 2014	**New Risk Assessment Required**	NA	* Not yet addressed.	* To be considered and O&M plan developed.	28-Feb

HAZOP Minute Sheet

Sub system	2. HTF & Utilities	
Node	2.11 Cover Gas Supply	
Drawing Title	P&ID Cover Gas System	
Drawing number:	JB-DRG-PRO-2009	
Rev.		
Date:		

Dev No	Deviation	Op Mode	Cause	Consequence	Safeguard	Rec #	Recommendation	Responsibility	Action	Status	Reference	Action Taken	Remaining Action	Target Date
69	Overpressure	ALL	Incorrect setting of regulators	Overpressurise system elements resulting in damage to downstream equipment e.g. regulators	System designed and installed in accordance with relevant Australian Standards.	2.11.1	Confirm pressure setpoints.	EM	Q1 2014	In Progress	JB-SPE-PRO-0006	* The pressure in the Cover Gas system is constantly monitored. During commissioning normal operating pressures for the full range of operating modes will be established. Any significant divergence from these pressure will trigger an alarm requiring operator attention. * Note that the cover gas supply has undergone design change throughout installation and the FDs require updating.	* Update FDs * Testing and commissioning	31-Mar
			Failure of regulator	Overpressurise system elements resulting in damage to downstream equipment e.g. regulators	Pressure regulation and pressure relief at the supply and for each downstream equipment item.		Controls satisfactory, no action required.			In Progress	JB-SPE-PRO-0006	* Note that the cover gas supply has undergone design change throughout installation and the FDs require updating.	* Update FDs * Testing and commissioning	31-Mar
70	No flow - cover gas	ALL	Major leak or line break.	If upstream of last regulator: loss of Cover Gas reserve.	System designed and installed in accordance with relevant Australian Standards. Pressure drop detection.	2.11.2	Consider low pressure alarm on vessels connected to the cover gas system.	EM	Q1 2014	In Progress	JB-SPE-PRO-0006	* Note that the cover gas supply has undergone design change throughout installation and the FDs require updating.	* Update FDs * Testing and commissioning	31-Mar
						2.11.3	Confirm location of bulk storage outside in accordance with Australian Standards.	EM	Q1 2014	In Progress	JB-SPE-PRO-0006	* Note that the cover gas supply has undergone design change throughout installation and the FDs require updating.	* Update FDs * Testing and commissioning	31-Mar
				If downstream of last regulator: complete loss of Cover Gas and potential for oxygen ingress to system.	System designed and installed in accordance with relevant Australian Standards. Pressure drop detection.	As for 2.11.1 2.11.2.		EM	Q1 2014	In Progress	JB-SPE-PRO-0006	* Note that the cover gas supply has undergone design change throughout installation and the FDs require updating.	* Update FDs * Testing and commissioning	31-Mar

Client:Vast Solar
Project: Jemalong Solar Station

HAZOP Minute Sheet

Sub system	3. Steam Generator & Feedwater		**Drawing Title**	P&ID Steam Generator
			Drawing number:	JB-DRG-PRO-2005
Node	3.1 Steam Supply to Turbine		**Rev.**	B
			Date:	

Dev No	Deviation	Op Mode	Cause	Consequence	Safeguard	Rec #	Recommendation	Responsibility	Action	Status	Reference	Action Taken	Remaining Action	Target Date
71	High temperature	OP	Feedwater temperature too hot	High superheater temperature resulting in equipment downstream of Superheater exceeding allowable temperature limits	High temperature trip on Superheater outlet.		Controls sufficient, no action required.			To occur during Commissioning	JB-SPE-PRO-0003 3.11 Protection against Steam Generator over temperature	* High temperature trip on superheater outlet included in design. Refer to FDs.	* Installation. * Testing and commissioning.	31-Mar
72	Overpressure	OP	Dead head boiler outlet	Inadvertent downstream isolation of SG valves resulting in pressure rating of HP equipment being exceeded, possible loss of containment.	High pressure trip and a pressure safety valve, both alarmed/monitored.		Controls sufficient, no action required.			To occur during Commissioning	JB-SPE-PRO-0003 3.11 Protection against Steam Generator over temperature W01MA0R001_A 2.4.2 Technological diagram of turbine JB-DRG-PRO-2005 P&ID Steam Generator	* High pressure safety valve included on body of evaporator (HAG10 AA910) and on superheater outlet (LBU21 AA910) * Note that no alarm is included since safety valves are extremely loud and can be heard from across the site.	* Installation. * Testing and commissioning.	31-Mar
73	High flow - steam	OP	Superheater output too high	Pressure rating of HP equipment is exceeded, possible loss of containment.	Turbine bypass system (to protect turbine), high pressure trip and a pressure safety valve, both alarmed/monitored.		Controls sufficient, no action required.			To occur during Commissioning	JB-SPE-PRO-0003 3.11 Protection against Steam Generator over temperature W01MA0R001_A 2.4.2 Technological diagram of turbine	* Bypass system included in design, not yet installed. note the bypass system will primarily be used for cases where the generator is not in use. * High pressure safety valve included on body of evaporator (HAG10 AA910) and on superheater outlet (LBU21 AA910) * Note that no alarm is included since safety valves are extremely loud and can be heard	* Installation. * Testing and commissioning.	31-Mar
74	Low flow -insufficient feedwater	OP	Failure of boiler feedwater system	High temperature superheated steam resulting in exceeding downstream equipment operating parameters and compromising boiler integrity.	Monitoring on feedwater system, high temperature trip on Superheater outlet.	3.1.1	Confirm monitoring of feedwater system with vendor.	EM	Q1 2014	To occur during Commissioning	JB-SPE-PRO-0003 3.11 Protection against Steam Generator over temperature	* High temperature trip on superheater outlet included in design.	* Installation. * Testing and commissioning.	31-Mar
75	Contaminated feedwater	ALL	Inadequate water treatement regime.	Fouling of boiler faster than anticipated.	Utilisation of demineralised water and mecahnical de-aeration and blowdown.	3.1.2	Confirm suitability of water cleaning regime with process designers.	EM	Q1 2014	No longer relevant	NA	Decided to use demineralised water.		
76	Inadequate isolation	ALL	Singe isolation may be unsuitable for high temperature/high pressure fluids	Major injury and/or death	Isolation philosophy under development	3.1.3	Compelete isolation standard and communicate to process designers.	EMSQ	Q1 2014	Completed	NA	* Isolation philosophy has been considered. The relevant AS are silent on plants of this size which fall into a grey area. * Have considered the level of maintenance required for HP circuits and determined the double block and bleed isolation is not required. * Generally single isolation has been adopted with some double isolations for instruments.	* Develop O&M plan	28-Feb-15
77	Insufficient control of blowdown discharge	ALL	Insufficient consideration of final discharge point	Possible human exposure and/or emissions off site	Design review process, compliance obligation	3.1.4	Confirm compliance obligations.	EMSQ	Q1 2014	Open	NA	* Not yet addressed.	* This action will be complete following the development of chemical dosing procedures.	31-Mar

Client:Vast Solar
Project: Jemalong Solar Station

HAZOP Minute Sheet

Sub system	2. HTF & Utilities	**Drawing Title**	Basis of Design
		Drawing number:	JB-BOD-GEN-0001
Node	2.12 Thermal Oil Heating System	**Rev.**	
		Date:	

Dev No	Deviation	Op Mode	Cause	Consequence	Safeguard	Rec #	Recommendation	Responsibility	Action	Status	Reference	Action Taken	Remaining Action	Target Date
78	Over temperature	ALL	Vendor supply package malfunction	Potentially exceed allowable limits of downstream equipment	Local and remote temperature monitoring.	2.12.1	Ensure vendor supplied package has appropriate temperature trip.	EM	Q1 2014	To occur during Commissioning	JB-SPE-PRO-0007 3.1 Thermal Oil Heater Package	* General information provided in FDs however specific details required.	* Update FDs * Installation. * Testing and commissioning.	31-Mar
79			Tube leak from HTF system	Inadvertent chemical reaction, possible undetected leak leading to release from HTF tank into Thermal Oil System.	None	2.12.2	Implement engineering solution e.g. sight glass, pressure sensor.	EM	Q1 2014	No longer relevant	NA	* Has been engineered out of design since thermal oil pipes are located outside the Tank.		
			Oil entrapped in heating coils as a result of inadvertent or manual valve closure.	Thermal expansion of oil leading to possible oil coil rupture resulting in loss of containment of oil into HTF. Also potential loss of containment of HTF into Thermal Oil System on reopening of manual valves or externally into environment	Tank heating procedure.	2.12.3	Consider thermal expansion relief solution for isolatable coils.	EM	Q1 2014	Open	JB-SPE-PRO-0007 2.1. Elements	* A thermal oil expansion tank has been included within the design.	* Confirm whether there are options within thermal oil system for drainage. Review P&IDs.	
						2.12.4	Review need for number of isolation valves.	EM	Q1 2014	To occur during Commissioning	JB-SPE-PRO-0007 3.5.1. Preparing the system JB-DRG-PRO-2008	* Isolation valves TBH10 AA010 & AA020 included in design.	* Update FDs and P&ID so that they reference the same valves. * Installation. * Testing and commissioning.	31-Mar
						2.12.5	Include precise procedure in O&M manual.	EM	Q1 2014	To occur during Commissioning	NA	* Not yet developed.	* Develop O&M procedure	31-Mar
			Oil residue in heating coils following drainage	Contaminated oil, decline in thermal performance and possilble blockage of oil heating system.	Oil line gradients promote drainage to oil reservoir, argon cover and purging.	2.12.6	Ensure vendor provides filtration.	EM	Q1 2014	Completed	NA	* Oil lines have been installed with suitable gradient for draining. * Argon cover / purging will not be used for thermal oil system.		28-Feb-15
80	Loss of containment - Oil release	ALL	Broken pipe	Loss of containment - localised oil spill, potential for fire.	Hazardous area rated equipment in vicinity, oil equipment located within bund.	2.12.7	Ensure oil is contained in compliance with the standards	EM	Q1 2014	**New Risk Assessment Required**	JB-SPE-PRO-0007 3.1 Thermal Oil Heater Package	* Each LPG storage tank comes complete with all the necessary instruments and controls for their safe functioning.	* Confirm treatment of hazardous area. * Commissioning.	31-Mar
						2.12.8	Consider in-field and remote emergency stop	EM	Q1 2014	Completed	NA	* Consideration made and decision made was for no in-field remote emergency stop to be installed. Distance from Tanks to current stop considered acceptable.		
						2.12.9	Include details of bunds in P&ID	EM	Q1 2014	No longer relevant	NA	* According to AS1940 the oil storage unit is categorised as "minor storage" and subsequently does not require a bund.	* Bund built, still require install of sand base over clay. To be completed once pipe supports are complete.	
81	Degradation of oil	OP	Accelerated degradation	Declining thermal performance and consoquential operability problems TBD.	Use of argon Cover Gas. Vendor guidance.	2.12.10	Ensure vendor provides oil sample point.	EM	Q1 2014	Completed		* Argon gas will not be used in the thermal oil system. * An oil same point has been provided.		
						2.12.11	Oil quality monitoring	EMSQ	Q1 2014	To occur during Commissioning	NA	* Not yet developed.	* Develop O&M procedure	31-Mar

HAZOP Minute Sheet

Sub system	2. HTF & Utilities	
Node	2.13 LPG Storage Facility	
Drawing Title	Basis of Design	
Drawing number:	JB-BOD-GEN-0001	
Rev.		
Date:		

Dev No	Deviation	Op Mode	Cause	Consequence	Safeguard	Rec #	Recommendation	Responsibility	Action	Status	Reference	Action Taken	Remaining Action	Target Date
82	Inadequate siting of LPG supply and pipework	ALL	Potential obstacle for traffic movement	Installation is struck resulting in a loss of containment of LPG resulting in a potential fire and explosion.	Designed and installed in accordance with AS 1596 including installation of protective barriers around installation and restricted access to the area.	2.13.1	Consider options for siting and protection of LPG supply line.	EM	Q1 2014	Completed	NA	* Bollards are in place	NA	NA
83	Loss of power from the grid	OP	External (many causes)	Not having sufficient power for safe shutdown.	Backup generator (limited to powering emergency shutdown requirements)	2.13.2	Establish emergency control protocols for power loss and emergency shutdown events.	EMSQ	Q1 2014	Completed	JB-SPE-PRO-0007 3.16 Action upon loss of power protection	* Back up batteries installed. * Emergency protocols established	NA	NA
			Internal (major event e.g. fire)	Not having sufficient power for safe shutdown.	Backup generator (limited to powering emergency shutdown requirements)	As for 2.13.2		EMSQ	Q1 2014	Completed	JB-SPE-PRO-0007 3.16 Action upon loss of power protection	* Back up batteries installed. * Emergency protocols established	NA	NA

Client:Vast Solar
Project: Jemalong Solar Station

HAZOP Minute Sheet

Sub system	2. HTF & Utilities	**Drawing Title**	Layout Sodium Unloading Facility (Vendor Dra
		Drawing number:	550-01_200-01-00
Node	2.14 HTF Unloading Facility	**Rev.**	
		Date:	

Dev No	Deviation	Op Mode	Cause	Consequence	Safeguard	Rec #	Recommendation	Responsibility	Action	Status	Reference	Action Taken	Remaining Action	Target Date
84	Overpressure	COM	Valves inadvertently opened	Potential loss of containment.	Two staged pressure reduction coupled with pressure relief valves pre-set to specification (not to exceed maximum allowable ISO tank relief valve set point 4 bar). Typical Purge Gas pressure nominally 5kPa.		Controls satisfactory, no further action reccomended.			Completed		HTF successfully unloaded.		
85	Low HTF temperature	COM	Premature unloading commencement	Solidification causing unloading delay.	Compliance with vendor supplied unloading instructions.		Controls satisfactory, no further action reccomended.			Completed		HTF successfully unloaded.		
			Malfunctioning oil heater	Failure to meet unloading schedule.	Fully monitored system used only once.		Controls satisfactory, no further action reccomended.			Completed		HTF successfully unloaded.		
			Failure of heat trace	Failure to meet unloading schedule.	Heat trace designed to operate at temperatures sufficent to melt HTF.		Controls satisfactory, no further action reccomended.			Completed		HTF successfully unloaded.		
			Oil supply interrupted	Failure to meet unloading schedule.	Fully monitored system used only once.		Controls satisfactory, no further action reccomended.			Completed		HTF successfully unloaded.		
86	Contaminated HTF	COM	Oxygen ingress to system	Blockages by HTF contaminants, potential delay to schedule.	Heat trace.		Controls satisfactory, no further action required.			Completed		HTF successfully unloaded.		
			Initial nitrogen Cover Gas in ISO container	Formation of nitrides inside unloading and operational piping with consequences that are undetermined	Nitrogen is an industry standard cover gas and low quantity.		Controls satisfactory, no further action required.			Completed		HTF successfully unloaded.		
87	Operator Error	COM	Failure to understand process	One off not well understood, potential for operators to not recognise deviation from preferred practice, potential damage to plant, delay to schedule and loss of containment.	Compliance with vendor supplied SOP. OHS plan that covers procedural requirements.	2.14.1	Development of SOP for unloading.	EMSQ	Q2 2014	Completed		HTF successfully unloaded.		
88	Inadequate electrical protection	COM	Unearthed	Potential for electric shock, ignition source.	All equipment fully bonded to earth in accordance with AS 3000.	2.14.2	Ensure SOP covers electrical bonding.	EMSQ	Q2 2014	Completed		HTF successfully unloaded.		
89	Exposure to HTF	COM	HTF Trap maintenance	Maintainers exposed to HTF byproduct	O&M procedures, experiential history with HTF contaminated component maintenance.	2.14.3	Confirm with designer the requirement for HTF trap management.	EM	Q1 2014	Completed		HTF successfully unloaded.		

HAZOP Minute Sheet

Sub system	5. Condensate & Water Makeup	
Node	5.1 Condenser Operation	
Drawing Title	Process Schematic	
Drawing number:	JB-DRG-PRO-1001	
Rev.	A	
Date:	21/02/2014	

Dev No	Deviation	Op Mode	Cause	Consequence	Safeguard	Rec #	Recommendation	Responsibility	Action	Status	Reference	Action Taken	Remaining Action	Target Date
90	Condensor trip	OP	Loss of power	Pressure surge, potentially exceeding allowable limits of condenser and condensate tank, loss of containment.	Pressure relief valve on condenser inlet. System designed to relevant standards using competent engineers		Controls satisfactory, no action required.			To occur during Commissioning	W01LC0R001_A 2.4.4 Technological diagram of condensate system	* P&ID shows safety angle valve (LBU50 AA910)(rupture disk) and closing valve (MAG20 AA810) with a pressure measurement point.	* Compile FD for Air Cooled Condensor * Install and commission	31-Mar-15
			High ambient temperature	Loss of efficiency and production.	Multiple fans, fan control regime.		Controls satisfactory, no action required.			To occur during Commissioning	NA	* Multiple fans included in design	* Develop fan control regime	31-Mar-15
			Loss of vacuum pump	Accumulation of non-condensibles in condenser leading to loss of efficiency and production.	Pressure monitoring on vacuum system provided by vendor.		Controls satisfactory, no action required.			To occur during Installation	NA	* Pressure monitoring included on inlet, outside the vendor package.	* Install and commission.	31-Mar-15
			High turbine exhaust temperature (loss of desuperheating spray function)	Damage to condenser.	Temperature trip on turbine exhaust set lower than upper limit of condenser, that also trips turbine and controlled venting of HP steam.	5.1.1	Consider feed forward signal to HTF system and subsequent response.	EM	Q1 2014	To occur during Commissioning	W01LC0R001_A 2.4.4 Technological diagram of condensate system	* Refer to P&ID which shows temperature measurement device (TRCA MAG20 CT001)	* To be considered during commissioning.	31-Mar-15
			Line break of turbine exhaust	Rapid or slow loss of vacuum, release of HP steam	Turbine trips on high pressure, plant shuts down.		Controls satisfactory, no action required.			To occur during Commissioning	W01LC0R001_A 2.4.4 Technological diagram of condensate system	* Not yet considered	* Probably trip on high pressure. TBC during commissioning.	31-Mar-15
			Turbine bypass malfunction	Rapid or slow loss of vacuum, release of HP steam	Turbine bypass closes on high pressure, plant shuts down		Controls satisfactory, no action required.			To occur during Commissioning		Two possible modes of operation for Bypass malfunction: 1) Open: if this occurs then the turbine will be starved of steam, which will not cause any problems. 2) Closed: safety valves on the superheater outlet and evaporator body would open. Note: relationship between either of these events and the vacuum is not clear.	* To be considered during commissioning.	31-Mar-15
			Condensate level high	Declining condenser performance	Gravity drain to condensate tank; condensate tank has an overflow. Level monitoring.		Controls satisfactory, no action required.			To occur during Commissioning	W01LC0R001_A.drg 2.4.4 Technological diagram of condensate system	* There is no overflow tank in design, considered unnecessary. * Level monitoring is part of design. Level monitor on condensate tank (LICA LCA10 CL001)	* Install and commission.	31-Mar-15

HAZOP Minute Sheet

Sub system	5. Condensate & Water Makeup	
Node	5.2 Condensate Management Control	
Drawing Title	Process Schematic	
Drawing number:	JB-DRG-PRO-1001	
Rev.	A	
Date:	21/02/2014	

Dev No	Deviation	Op Mode	Cause	Consequence	Safeguard	Rec #	Recommendation	Responsibility	Action	Status	Reference	Action Taken	Remaining Action	Target Date
91	Condensate return disruption	ALL	Excess makeup water	Level increases in Condensate Tank	Overflow to drainage tank, later returned to Condensate Tank		Controls satisfactory, no action required			To occur during Commissioning	W01LC0R001_A.drg 2.4.4 Technological diagram of condensate system	* Drainage incorporated into design.	* Install and commission.	31-Mar-15
			Condenser underperforms	Temperature in Condensate Tank increases, potentially exceeding allowable limit of Condensate Tank	High Temperature alarm on Condenser outlet.	5.2.1	Consider adequacy of alarm as a response.	EM	Q1 2014	To occur during Commissioning	W01LC0R001_A.drg 2.4.4 Technological diagram of condensate system	* An alarm will be included for high Condensor tank temperature (rather than Condensor outlet).	* Install and commission.	31-Mar-15
			Recirculation line fails (multiple causes e.g. pumps, control valves)	Level increases in Condensate Tank	Overflow to drainage tank, later returned to Condensate Tank		Controls satisfactory, no action required			To occur during Commissioning	W01LC0R001_A.drg 2.4.4 Technological diagram of condensate system	* Drainage incorporated into design.	* Install and commission.	31-Mar-15
				Level decreases in Condensate Tank, resulting in low alarm and potential to overload deaerator	Level monitoring in Condensate Tank.	5.2.2	Confirm low level trip on Condensate Return Pumps.	EM	Q1 2014	To occur during Commissioning	W01LC0R001_A.drg 2.4.4 Technological diagram of condensate system	* Level monitoring included in design.	* Confirm low level trip during commissioning.	31-Mar-15
			Run out of makeup water	Wind down of steam/condensate mass in circuit, leading to trip resulting in loss of production.	System trip on low level in Condensate Return or Feedwater system.		Controls satisfactory, no action required			To occur during Commissioning	W01LC0R001_A.drg 2.4.4 Technological diagram of condensate system	* Control included in design.	* Install and commission.	31-Mar-15
				No turbine exhaust desuperheating spray leading to increase in turbine exhaust temperature.	System trip on high turbine exhaust temperature.		Controls satisfactory, no action required			To occur during Commissioning	W01LC0R001_A.drg 2.4.4 Technological diagram of condensate system	* Control included in design.	* Install and commission.	31-Mar-15
				Turbine bypass system ineffective	System trip on high turbine exhaust temperature.	5.2.3	Consider interlock.	EM	Q1 2014	To occur during Commissioning	W01LC0R001_A.drg 2.4.4 Technological diagram of condensate system	* Control included in design.	* Install and commission.	31-Mar-15

Client:Vast Solar
Project: Jemalong Solar Station

HAZOP Minute Sheet

Sub system	3. Steam Generator & Feedwater	**Drawing Title**	Process Schematic
		Drawing number:	JB-DRG-PRO-1001
Node	3.2 Feedwater Supply	**Rev.**	A
		Date:	21/02/2014

Dev No	Deviation	Op Mode	Cause	Consequence	Safeguard	Rec #	Recommendation	Responsibility	Action	Status	Reference	Action Taken	Remaining Action	Target Date
92	Feedwater system disruption	ALL	Starve feedwater system due to upstream blockage in Condensate Return system.	Level in feedwater tank drops potentially leading to feedwater pump damage.	Level monitoring on feedwater tank.	5.3.1	Check if makeup water connection can be used as a measure of last resort. No it cannot.	EM	Q1 2014	To occur during Commissioning	W01LA0R001_A 2.4.5 Technological diagram of feedwater system	* Level measured through LICA (LAA10 CL001) * Determined that makeup water connection ***cannot*** be used as a measure of last resort	* Update FDs * Install and commission	31-Mar
			Steam inlet valve fails open.	Overheating of feedwater resulting in exceeding allowable limits. Overpressurise deaerator.	Temperature and pressure monitoring and pressure monitoring valve on feedwater tank.	5.3.2	Consider alarm.	EM	Q1 2014	To occur during Commissioning	W01LA0R001_A 2.4.5 Technological diagram of feedwater system	* Temperature measured through TCR (LAA10 CT001) * Pressure measured through PIR (LAA10 CP001) * Two valves on pressure measurement points: 1) Pressure measurement PIR (LAA10 CP001) with valve LAA10 AA820 2) Pressure measurement PIR (LAA10	* Update FDs * Install and commission * Consider alarm	31-Mar
			Steam inlet valve fails closed.	Insufficient heating of feedwater resulting in reduced deaeraetion. Introduction of excess oxygen to system increasing corrosion and presence of oxygen in condenser	Pressure and temperature monitoring in deaerator.	5.3.3	Consider alarm.	EM	Q1 2014	No Longer Relevant		* Feedwater tank and dearator are the same thing. Refer above.		
			Overflow valve (evaporator to feedwater tank) fails open	Overheating of feedwater resulting in exceeding allowable limits. Overpressurise deaerator.	Temperature and pressure monitoring and pressure monitoring valve on feedwater tank.	As for 5.3.2		EM	Q1 2014	To occur during Commissioning	W01LA0R001_A 2.4.5 Technological diagram of feedwater system	* Temperature measured through TCR (LAA10 CT001) * Pressure measured through PIR (LAA10 CP001) * Two valves on pressure measurement points: 1) Pressure measurement PIR (LAA10 CP001) with valve LAA10 AA820 2) Pressure measurement PIR (LAA10	* Update FDs * Install and commission	31-Mar
			Overflow valve (evaporator to feedwater tank) fails closed	Potential for flooding of evaporator resulting in reduced steam generation.	HP steam quality monitoring.	5.3.4	Review adequacy of control.	EM	Q1 2014	To occur during Commissioning	JB-SPE-PRO-0003 3.11 Protection against Steam Generator over temperature	* Steam temperature is measured at several points in evaporator and superheater. Refer to FD for full description. * Steam *quality* is not monitored.	* Commissioning.	31-Mar
			Feedwater pump trip	Reduced feedwater flow to SG leading to reduced Evaporator level, resulting in reduced Superheater steam temperature.	Redundancy on feedwater pumps, Superheater steam quality monitoring, trip heat source on excessively high temperature.		Controls satisfactory, no further action required.			To occur during Commissioning	JB-SPE-PRO-0003 3.10 Protection against Steam Generator over pressure 3.11 Protection against Steam Generator over temperature W01LA0R001_A 2.4.5 Technological diagram of feed water system	* There will be no redunancy on feedwater pumps. * Superheated steam will be monitored for pressure and temperature as per FDs * ESD will be activated at high temperatures (refer to FDs)	* Update FDs * Install and commission	31-Mar

HAZOP Minute Sheet

Would trip on low water level in evaporator.

	Sub system		4. Steam Turbine & Generator				**Drawing Title**	Process Schematic	
							Drawing number:	JB-DRG-PRO-1001	
	Node		4.1 Turbine and Turbine Bypass				**Rev.**	A	
							Date:	21/02/2014	

Dev No	Deviation	Op Mode	Cause	Consequence	Safeguard	Rec #	Recommendation	Responsibility	Action	Status	Reference	Action Taken	Remaining Action	Target Date
93	Steam bypass system disrupted	ALL	Bypass fails open	Turbine inlet steam pressure drops	Turbine trips on low inlet pressure		Controls satisfactory, no action required.			To occur during Installation	JB-SPE-PRO-0003 3.3 Fixed heat release rate	* Control included in design. * Steam header pressure measured by LBA10 CP001	* Update FDs * Install and commission	31-Mar
			Bypass fails closed	Turbine inlet steam pressure may increase, Turbine Bypass system not available when required upon Turbine trip	HP steam may be vented through safety valve.		Controls satisfactory, no action required.			To occur during Installation	W01MA0R001_A 2.4.2 Technological diagrm of turbine	* Control included in design. * There is a safety angle valve (LBU21 AA910) and pressure measurement point (PIRCA LBA10 CP001) on the steam inlet to the turbine	* Update FDs * Install and commission	31-Mar
			Spray leaking	Water ingress resulting in thermal gradients in pipework, potential for damage to pipe.	Temperature monitoring on exhaust lines, valves are critical item and procured accordingly.	4.1.1	Ensure any leak can't backflow.	EM	Q1 2014	To occur during Installation	W01LC0R001_A 2.4.4 Technological diagram of condensate system	* Control included in design. * Temperature of turbine outlet steam is monitored before entering the ACC (TIRCA MAG20 CT001) * There is a safety angle valve (LBU 50 AA910) located after this temperature monitoring point and before the ACC	* Update FDs * Install and commission	31-Mar
94	Turbine Trip	OP	Various	Turbine Trip	Safely trips in accordance with manufacturers design (all instruments requested by vendor are provided)		Controls satisfactory, no action required.			To occur during Installation	NA	* Control included in design.	* Install and commission	31-Mar

Client:Vast Solar
Project: Jemalong Solar Station

HAZOP Minute Sheet

Sub system	6. Controls	**Drawing Title**	Process Schematic
		Drawing number:	JB-DRG-PRO-1001
Node	6.1 Operating Modes	**Rev.**	A
		Date:	21/02/2014

Dev No	Deviation	Op Mode	Cause	Consequence	Safeguard	Rec #	Recommendation	Responsibility	Action	Status	Reference	Action Taken	Remaining Action	Target Date
95	NOTES:	1. Design of the fully integrated control system under development, there is excluded from this HAZOP study subject to a separate review. 2. Control system design assumptions include: a. General modes of operation broadly considered are;												
96	Major plant shutdown	ALL	Steam ingress to HTF circuit	HTF ingress to shell side of SG, rapid reaction with HTF and rapid buildup of pressure and generation of hydrogen.	Engaged Skoda and W.E. Smith to design SG to applicable standards. Detection of pressure spike or hydrogen evolution triggering a full system automatic shutdown which includes safe venting of reaction products, safe dumping of feedwater, isolation of steam generator and shutdown of pumps.	6.1.1	Assessment of design including the mechansims for failure undertaken by suitable expert.	CTO	Q1 2014	In Progress	JB-SPE-PRO-0009 3.1 Rapid Drain	* Detection of pressure spike or hydrogen evolution causes Emergency Shutdown (ESD) to occur. Refer to FD for details. * ESD has been incorporated into the Direct Control System (DCS)	* Seek review of ESD by a suitable expert. * Installation and commmissioning	31-Mar-15
			Loss of power	System ceases to circulate HTF and steam/condensate, ceases to gather thermal energy and cooling of HTF. Lack of HTF cooling of receiver - possibility of damage and loss of containment	Backaup generator is able to power HTF drainage system, battery UPS is able to power heliostat "off-track" position.	6.1.2	Consider high reliability backup generator.	EM	Q1 2014	To occur during Commissioning	NA	* Battery backup installed.	* Commissioning * Update FDs	31-Mar-15
						6.1.3	Develop dedicated test and maintenance regime for backup generator.	EMSQ	Q2 2014	To occur during Commissioning	NA	* Not yet developed	* O&M plan to be developed.	31-Mar-15
			HTF hot side trip	Heat input reduced to SG ultimately resulting in turbine trip cascading through condensate and feedwater systems.	Controlled shutdown sequence.	6.1.4	Consider impact of reccomended control system adjustments as discussed above.	EM	Q1 2014	To occur during Commissioning	NA	* Controlled shutdown sequence has been devised. * Note that cascading trip does not present a danger to personel or equipment.	* Commissioning * Update FDs	31-Mar-15
			HTF cold side trip	Thermal energy gathering ceases. Potentially HTF hot transfer ceases.	Controlled shutdown sequence.	As for 6.1.3		EMSQ	Q2 2014	To occur during Commissioning	NA	* Controlled shutdown sequence has been devised.	* Commissioning * Update FDs	31-Mar-15