SYSTEM
SOLUTIONS
ENGINEERING

Project:

PORT AUGUSTA GENERATOR FAILURE

Subject:

INVESTIGATION REPORT

Prepared for:

Capital Planning and Evaluation, Infrastructure
Finance and Corporate Services
SA Health,
Government of South Australia.

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REVISIONS

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Revision Status Legend - P – Preliminary; T – Tender; C – Construction; F - Final.

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1 EXECUTIVE SUMMARY

1.1 GENERATOR DESCRIPTION

The Port Augusta Hospital has a backup generator that supples power during any mains (SAPN) power interruption/outage.

The generator is a two stroke diesel generator rated at 170 KVA controlled output, with a 260 Kilowatt alternator and a 219 kilowatt Engine.

The generator was built and installed in 1972 and has done 407 hours work, at the time of our inspection.

1.2 SUMMARY OF GENERATOR FAILURE DURING MAINS POWER OUTAGE

On September 28 2016 South Australia experienced a state wide loss of mains power.

The power outage in Port Augusta lasted approximately 24 hours at which time the Hospital needed to be able to rely solely on the backup generator to provide power to the Hospital essential services.

The generator started as expected, however there were a number of generator failures during the mains outage that effected the ability of the generator to continue to provide power.

Below is a summary of the generator failures that occurred.

- Generator ran for approximately 1-1/4 hours then stopped on an over temperature alarm.
- The generator was manually restarted and an oil leak was noticed in a pipe, so the generator was stopped by maintenance staff and a mechanic called to repair the oil leak. The Hospital was without power for approximately 2-1/2 hours before the generator was repaired and operating again.
- During this time two small generators were sourced that were used to keep fridges running in the pathology are and to keep the communications infrastructure operating.
- The generator then ran for approximately another 1-1/4 hours before a major fuel leak was noticed in a fuel feed hose and the generator was again shut down by maintenance staff and a mechanic called out to repair the fuel leak.
- The Hospital was without power for 3 hours until a temporary generator was sourced through SA Power Networks and connected to the Hospital.
- Repairs to the Hospital generator took 4 hours.
- The Hospital continued to run on the SA Power Networks generator until approximately 4.15pm the following day at which time the SA Power Networks loan generator stopped (Reason unknown).
- The Hospital generator started automatically and provided power for approximately ¾ of an hour, until mains power was restored to the Hospital by SA Power Networks.
- In total the Hospital was without any power at all for approximately 5-1/2 hours during the power outage (of approximately 24 hours).

1.3 GENERATOR FAILURE CAUSES

A number of issues were identified that caused the failures:-

- Overheating due to the generator being under capacity for the current essential load requirements, the age of the generator and the generator never being run at full load.
- Oil Leak in split metal pipe which was an unexpected mechanical failure
- Fuel leak in split rubber hose due to the age at 44 years
- Suitability of existing back-up generator infrastructure

1.4 OTHER ISSUES IDENTIFIED

A number of other maintenance related issues were identified that need to be addressed, being:-

- There is a lack of understanding of manual operation of the changeover system for the generator by maintenance staff.
- Incorrect type of batteries installed recently, namely non-vented batteries were installed however vented batteries should have been installed.

- The generator itself does not have a block heater which means that the engine was trying to supply 90% of its total capacity from a cold start and this would also cause the generator to struggle and may cause damage to the engine.
- Monthly testing is inappropriate and should be undertaken at maximum presented load for a four hour period to prove stable operation
- The generator is now 44 years old replacement parts are becoming harder to source and some may not be available at all.

1.5 PREVENTATIVE MAINTENANCE AND SERVICING

Currently there is no regular preventative maintenance and the generator is only serviced once a year.

The Country Health SA Emergency Generator Maintenance and Testing Procedure documentation requires preventative maintenance to be carried out in line with DPTI Technical Data Schedules E03/ E03A/ E03BA/ E03B/ E03BB.

E03B particularly applies to the Port Augusta Hospital and shows monthly and annual preventative maintenance that needs to be provided.

Fan belts and some hoses have been replaced (done on 28/10/2016) however there are still some fuel lines left to be done. These should be done as soon as possible.

1.6 RECOMMENDATIONS

- Carry out regular load bank testing on the generator with a load bank large enough to fully load the generator to 110% which will clean out the engine and also identify whether the generator is capable of providing full load for a sustained length of time.
- Immediately commence preventative maintenance, as per DPTI Schedule (monthly and annual).
- Replace all remaining original hoses and pipes.
- Prepare and carry out a testing regime and testing strategy and ensure testing of the generator is done every month for 4 hours over that month and under full Hospital load with test result recorded every 15 minutes.
- Carry out a detailed audit of the current Hospital essential loads to determine the current load requirements of the Hospital.
- Due to the age of the generator, reliability and reparability risk due to age and the apparent under capacity of the generator it is recommend to replace the generator with a new generator and associated control system designed for the current load requirements and allowance for some future expansion.

2 INTRODUCTION

2.1 PROJECT

System Solutions Engineering (SSE) has been engaged by SA Health to undertake a comprehensive and independent post incident review of the performance of Port Augusta Hospital emergency stand-by power systems, processes and controls (both planned and actual), following the state wide electrical outages experienced on Wednesday 28 September 2016.

2.2 PROJECT PURPOSE

To ensure that SA Health and Country Health SA understand the causes of any emergency stand-by power electrical system failures at the Port Augusta Hospital in order to identify improvements that can be made and to reassure clinicians and the community that the Port Augusta Hospital has a robust contemporary emergency electrical system.

SA Health and Country Health SA also wish to learn from these failures to improve capability and future performance of the Port Augusta Hospital's emergency stand-by power systems.

SSE has been asked to consider both load considerations as well as mechanical considerations that may have contributed to the generator failure.

2.3 SCOPE

The scope of our engagement with SA Health is to visit the site to investigate the generator condition, review the generator upkeep, to assess the load on the generator and to investigate the events of the failure.

SSE are then to provide an investigation report identifying the cause(s) of the generator failure and other appropriate issues of suitability and capability of the existing emergency stand-by power systems at the Port Augusta Hospital including the following:-

- The appropriateness of the existing stand-by power
- Stand-by power system network components condition, plant reliability and performance assessment
- Identification and description of any failure incidents
- The sites response to the failure incident
- Root cause analysis of any failure incident
- Identification of contributing factors to the failure incident
- Physical e.g. System and plant design including (BMS and controls)
- Availability of accurate and as installed / as built records
- Operating systems and testing processes
- Maintenance activities including frequency and constraints
- Training
- Individual factors
- Identify key single points of failure and determine mitigating / remediation strategies related to the identified causes of the failure incident
- Report any other significant risks related to stand-by power that may be identified by stakeholders during the investigation.
- A review of the testing regime for generators
- Recommendations and where appropriate estimated cost of implementation for future action

2.4 INFORMATION SOURCES

- SSE 2015 report.
- Honeywell service and maintenance reports.
- Discussion with Honeywell staff.
- Discussion with SA Health staff.
- Discussion with generator Service Contractor.
- Site inspection.
- Load readings taken by Honeywell.

2.5 LIMITATIONS

Inspection was of a visual nature and no plant was dismantled as part of the inspection.

Generator loads are based on documented evidence.

At the time of our site inspection the Honeywell electrician was on sick leave which limited the amount of hands on information or testing that could be obtained.

Spot load readings of essential loads were taken by the Honeywell electrician post our inspections, on 07/11/2016 at approximately 1.30 pm to assess what might have been a typical load at a time similar to when the first outage occurred.

3 HISTORICAL INFORMATION

3.1 GENERATOR AGE AND ORIGIN

The generator was manufactured in 1972, making it 44 years old and was originally installed in the Port Augusta Hospital Administration building which was the original Hospital at the time.

The generator was relocated to the New Hospital at the time of construction circa 1997, understood to be a cost saving measure or value management choice at the time given the low hours of operation.

In the 44 years that the generator has been installed, it has only done approximately 407 hours of work, with most of these hours in test mode only.

It has been noted that the generator does not have a block heater which keeps oil and coolant at a warm temperature which assists in starting as the engine is not absolutely cold when it starts. As well as improving starting this allows the lubricants to work immediately which reduces wear and tear and possible damage to the engine.

The generator is understood to be maintained by Honeywell as part of a Facility Management arrangement with Port Augusta Hospital Limited and assigned through the Country Health SA as an agent.

The current Honeywell Site Manager Mr Ritesh Chandra, has only been associated with the site for approximately 12 months and the Honeywell Electrician for approximately 4 years.

Honeywell currently engage a local contractor, Butlers Mechanical Services, to carry out service and maintenance on the generator.

Engine Hour Run Meter

3.2 GENERATOR DESCRIPTION

The generator is a Detroit 2 stroke diesel engine with a Stamford alternator and Detroit control panel.

The output capacities of each of the individual generator components are shown in table one below:-

GENERATOR INDIVIDUAL COMPONENT OUTPUT		
Component	**Kilowatts (KW)**	**Equivalent Amps (A)**
Engine	219 KW (Actual rated output)	
Alternator	260 KW (Actual rated output)	452 A
Control unit	170 KW (Actual rated output)	306 A

Table 1: Generator individual component output

The output from the controller is rated at 170 Kilowatts and the controller is actually protected by 315 amp fuses and as can be seen from the figures in table 1, the engine and alternator should be capable of providing considerably more than the maximum load the fuses are designed to protect against.

As a percentage of the engine output the control panel is approximately 78% of the engine Kilowatt capacity, so at approximately 300 amps of load the engine should only be producing approximately 78% of its power capacity.

315 Amp Fuses Protecting the Output of the Generator

The fuses in the control panel are high rupture fuses which are designed to accept an overload current for a predetermined length of time with the time being inversely proportional to the current (ie higher current shorter time before the fuse ruptures and vice versa).

4 GENERATOR SERVICING AND TESTING

4.1 GENERATOR SERVICING

There is currently no service contract in place for the servicing of the Port Augusta Hospital Generator with servicing and maintenance only carried out on an as needed basis by a local mechanical contractor, Butlers Mechanical Services, as such, there is no preventative maintenance program for the generator.

There are very few service records that were able to be provided to us. The last service records of any value were the ones that we obtained last year as part of our condition audit from the 2014 annual service.

The 2014 service records indicated a number of faults requiring rectification, mainly relating to coolant and oil leaks, most of which we believe have been addressed.

One item that was raised at the time and has not been addressed is the manual operation of the changeover system. There seems to be a lack of thorough understanding in how the manual control is meant to function or how to actually enact it and this urgently needs to be investigated and documented so that correct testing can be carried out.

The automatic function of the changeover does operate correctly and the generator starts automatically when there is a mains power loss.

Information provided indicates that the generator has one service a year.

Country Health SA have an emergency generator maintenance and testing procedure which requires maintenance in line with DPTI technical data schedules which require monthly minor and annual major services.

Being 44 years old the generator has a number of pipes, hoses and fanbelts that appear to be the original items and well past their serviceable life.

The service Mechanic changed fan belts and some hoses on 28/10/2016 however there are still some fuel lines that need to be replaced.

The recent maintenance issues have been:-

April 06 2016	Cracked elbow on oil feed replaced
Aug 16 2016	Batteries exploded and were replaced

Unfortunately the batteries have been replaced with sealed lead acid type batteries and these batteries are not suitable for use in a situation where they receive trickle charging and need to be replaced with vented batteries. The batteries also need to be in an enclosure as currently the batteries and their terminals are open and at risk of physical damage and inadvertent shorting of terminals.

The last service on the generator was carried out on September 20, 2016 (8 days before the state power outage) after which a 4 hour test was completed.

We were advised that there were no problems during the four hour test after the generator was serviced and for all intents and purpose the generator was in a serviceable condition.

Batteries needing replacing

Fanbelts needing replacing

Fuel pipes needing replacing

4.2 GENERATOR TESTING

Australian Standards AS 3009 specify that a standby generator in a Hospital is to be tested by running for a period of at least four hours, under load, and at intervals of not more than monthly (ie 4 hours a month, every month as a minimum).

Readings need to be recorded during this testing and industry standard practice is to record readings every 15 minutes. The load at which tests should be conducted is a minimum of 40% of rated capacity and manufacturers would usually suggest running at full load during testing.

Readings should be taken of the following as a minimum:-

- Voltage.
- Load Amps.
- Water temperature.
- Oil pressure.
- RPM (revs per minute).
- Oil used.
- Diesel used.

Up until May 2015, generator testing was carried out monthly by starting the generator, without any load connected, and run for approx. 10-15 minutes or so then switched off. There were no records of testing able to be provided before May 2015.

We were advised that 4 hour, on load testing commenced in May 2015 and is now considered to be the minimum requirements for generator testing by the Honeywell however this does not always happen.

Testing is usually carried out at 7pm on the designated day and apparently this time was chosen as there are concerns about the generator's capacity to provide all of the Hospitals essential load requirements.

There is no documented evidence of who, when or why this decision was made however it is believed the decision came out of concerns about the total load on the generator due to electrical loads that have been added to the essential supply over the years and that the generator appeared to be struggling at times during testing.

Testing is carried out when only the essential supply to Wards A/B/C, Accident and Emergency and Reception is being used so does not include essential loads to areas such as Theatres, Theatre Air Conditioning, Kitchen, Renal, Chemotherapy, Pharmacy and Delivery.

This essentially means that the generator is never tested under full essential load conditions and may not be able to support the full essential load requirements of the Hospital.

Further to this, our understanding from discussion with both Honeywell and CHSA Staff is that testing cannot be conducted when Theatre is in use, when Renal or Chemotherapy is in use and if X-Ray need to be used.

Testing must be stopped if any of these services are required to be used when testing is occurring. This appears to be dictated by Doctors/ Surgeons that perform procedures in the Hospital.

Currently there are services operating on all but one night a week (Tuesday), which is when testing is usually carried out, and we understand that this will change soon with Renal operating all nights during the week which means that finding a period of time to conduct monthly 4 hour testing will become more difficult.

Between January 2016 and September 2016 testing was not able to be carried out on the following months:-

- January, due to Hospital operational reasons
- May, cancelled 3 times during month due to Hospital operational reasons
- June, cancelled 2 times during month due to Hospital operational reasons
- July, cancelled once and completed partial test of 3.5 hours on 26th then stopped due to Hospital operational reasons
- August, testing did not occur due to batteries exploding when attempting testing on the 16th

4 hour testing was completed in the following months:-

- February
- March
- April
- September

While writing this report the October test became due. The test was conducted and the generator ran for 4 hours with the peak load being 110 Kilowatts.

Readings were taken on these months however the number of recordings and the items recorded vary month to month and on one month (July) there was only one recorded entry on the test sheets at the very beginning of the test.

1. Recording of readings needs considerable improvement for this site.
2. Agreement on set testing times also needs to be negotiated at this site.

Generator testing should be carried out with the full Hospital essential load on the generator to ensure that the generator has the real capacity to run the full load including start up as would be required when a generator comes on line during a power outage. Without full load testing it can never be guaranteed that the generator is able to support the Hospitals essential load requirements in an emergency.

If the generator cannot support the full Hospital essential load requirements then either items need to be removed from the essential supply or the generator needs to be upgraded to meet current capacity demands.

The first step in assessing the requirement for reducing load, or increasing generator size, should be a detailed study of the current Hospital essential power loads against the Australian standards for essential power in Hospitals (AS 3009) to determine whether there are loads that are not true essential loads but are currently connected to the Generator and should be removed from the generator supply.

Below is a table showing the loads that have been recorded during monthly testing since May 2015:-

PORT AUGUSTA HOPITAL GENERATOR MONTHLY TEST LOADS		
Month	Max load Kilowatts (KW)	Max load Amps (A) (on any phase)
May 2015	120 KW	245 A
June 2015	115 KW	250 A
July 2015	105 KW	200 A
August 2015	140 KW	260 A
September 2015	101KW	205 A
October 2015	110 KW	210A
February 2016	125 KW	230 A
March 2016	110 KW	200 A
April 2016	90 KW	160 A
July 2016	85 KW	180 A
August 2016	100 KW	180 A
September 2016	75 KW	145 A
October 2016	88 KW	145 A

Table 2: Monthly Generator Test Loads

Based on the engine rating of 219 kilowatts we can see that monthly testing does not come close to the maximum motor load.

Below is a table of highest and lowest recorded generator loads as a percentage of the engine capacity:-

MONTHLY TEST LOADS AS A PERCENTAGE OF ENGINE CAPACITY		
Month	Load Kilowatts (KW)	% of ENGINE CAPACITY
August 2015	140 KW	64%
September 2016	75 KW	34%

Table 3: Maximum and Minimum Load Readings as % of Engine Capacity

Throughout the life of the generator it has mainly had minimal or no load connected and only some (7-8) months in the last years of moderate load.

Due to this low loading the engine is likely to have carbon build up and possibly engine bore glazing which could lead to some loss of power in the engine as well as overheating when needing to provide full load.

When diesel engines are only lightly loaded, as part of their maintenance regime, they should be run on a resistive load bank at full load at least annually for a number of hours to work the engine and burn off deposits that settle in the motor due to low loading. It is also prudent to run generators to allow a turnover of fuel.

5 GENERATOR FAILURE EVENTS

5.1 LAST PREVIOUS POWER OUTAGE

The last power outage prior to the September 2016 main power outage event was on 06/07/2015. The outage happened at approximately 10am and only lasted for a couple of minutes. It was noted by the Honeywell maintenance staff that the generator appeared to be "struggling" apparently due to high load, albeit no readings were taken or observed.

5.2 GENERATOR FAILURE EVENTS 28/09/2016

On September 28, 2016, at approximately 11.30am, a mains power loss occurred, which required the Port Augusta Hospital Generator to provide essential power to the Hospital.

The Hospital generator had one failure which caused the generator to stop and two mechanical faults that required shutting down the generator and repairs being carried out on the day. Below is a description of the events that occurred.

1. The Hospital generator started and provided backup power to the site as would be expected when mains power was lost.
2. The Honeywell's maintenance staff claims that at some time after the generator started running they went into the generator plant room and were concerned to hear the generator appearing to be working extremely hard and to see the amp gauge on the control panel indicating the load on the generator as being just below 300 amps.
3. The Honeywell advised us that they contacted the CHSA to advise of their concerns that they thought the generator might be overloaded.

Honeywell was not able to give us an idea as to what approximate time this would have been and it is difficult without this time line to know if there was an opportunity to disconnect any load before the generator stopped. During the time between the automatic starting of the generator and the failure of the generator, the Honeywell Electrician had been attending to manually restarting Hospital plant and equipment that needs to be restarted after any power loss.

At approximately 12.45 pm (approximately 1-1/4 hours after auto starting) the generator stopped. According to the Honeywell electrician there was no indication of any problem until he noticed the lights go out and at that point he realized the generator had stopped.

The Honeywell Electrician went to the plant room and noticed that the generator was stopped and showing a high water temperature alarm. The electrician restarted the generator and after the generator had been running for a short while he noticed an oil leak at the front of the generator engine. He then shut the generator down and notified the Honeywell Facility Manager of the issue.

The Honeywell Facility Manger then advised the CHSA that the generator needed to be repaired and the Hospital would be without any power until the generator was repaired.

As there was no way of knowing how long the generator was going to be out of service, CHSA staff tried to access a hire generator to be installed, however there were no local generators available.

Honeywell did manage to obtain two small generators that were used to keep drug fridges and the communications infrastructure operating during the times of total power outages during the day.

Eventually SA Power Networks (SAPN) were contacted and they arranged to have a generator shipped up from Adelaide however it was going to be around 7pm before the generator arrived on site and approximately 7.30 when it was connected to the transformer and provided power to the Hospital.

In the meantime Butler Mechanical Services were called and attended site at approximately 1.15 pm and identified a leak in an oil pipe at the front of the motor.

It took approximately 2 hours from the time of the generator failure to the completion of the replacement of the oil pipe and the Hospital generator was back on line at approximately 3.15 pm.

Once the generator was running the Honeywell electrician again busied himself with manual restarting of plant etc around the Hospital.

The Hospital generator had then been running for approximately 1-1/4 hours as the electrician walked back past the generator enclosure when he noticed a mist coming out through the radiator grille. Initially he thought it may have been coolant that was leaking and went in and turned the generator off. This was at approximately 4.30 pm.

CHSA was again notified that the generator was once again in need of repair and had been turned off.

Butler Mechanical Services were again called out and identified that it was actually a rubber diesel feed line at the front of the engine that had split and that it was diesel that was being sprayed out through the radiator.

From the turning off of the generator until the generator was repaired took approximately 4 hours with repairs to the generator finished at approximately 8.30 pm. SAPN had already delivered and connected a generator by 7.30 pm.

The SAPN generator had been connected to the consumer's mains at the Hospital transformer so, to the Hospital's electrical infrastructure it appeared as if the Hospital had mains power restored again and the SAPN loan generator was trying to supply load to both the essential and nonessential Hospital loads.

The Honeywell Electrician said that the SAPN generator was having difficulty delivering the Hospital power demand as it was trying to supply the whole Hospital and was not large enough, so the Honeywell electrician started turning off all non-essential loads until the Hospital was more or less just requiring the minimum amount of essential power (as would be similar to when the Hospital generator is tested).

The Hospital then continued to run on the SAPN generator until approximately 4.15 pm the following day.

According to the Honeywell Facility Manager, the SAPN generator stopped at about 4.15 pm on Thursday 29/09/2016 due to a fault on the generator (nature of fault unknown).

At this time the Hospital generator started and ran without fault for a short period until SAPN had reconnected the mains power supply back to the Hospital at approximately 5.00 pm on Thursday 29/09/2016.

Once the mains power was restored to the Hospital the Hospital generator automatically shut down as it would do normally once mains power had been restored from a power loss.

The generator then had its usual monthly test in October 18th 2016 however the test lasted 3.25 hours (not the full 4 hours) and the load was only 88 Kilowatts.

PORT AUGUSTA HOSPITAL GENERATOR FAILURE TIME LINE		
Time/date	**Event**	**Comments**
28/09/2016		
11.15 am.	Mains power failed and generator started	
	Honeywell Maintenance Manager noticed generator working hard and load was approximately 300 amps on the amp gauge of the generator control panel.	
12.45pm	Generator stopped and had high water temperature alarm. Generator restarted. Oil leak noticed and generator manually stopped. Service mechanic called to repair generator. CHSA staff start process of procuring a second generator as a backup.	Generator had been operating for 1-1/4 hours when it stopped.
1.15 pm	Butlers Mechanical Services attended site to repair oil leak.	
3.15 pm	Repairs completed and generator back on line.	Generator had been out of service and the Hospital was without power for 2.5 hours until the generator was operating again.
4.30 pm	Fuel line ruptured and generator was turned off so repairs to the fuel line could be carried out.	The Hospital generator ran for approximately 1-1/4 hours before a major leak was noticed and the generator shut down.
7.30pm	SAPN generator connected to Hospital transformer	Generator had been out of service and the Hospital without power for 3 hours before the SAPN generator was connected.
8.30 pm	Hospital generator repaired but left off line with the Hospital continuing to run on the SAPN generator.	
29/08/2016		
11.55 am	Mains power was restored to the town but the Hospital continued to run on SAPN generator so as not to interrupt Hospital operations.	
4.15 pm	SAPN generator failed. Hospital generator started.	
5.00 pm	Mains power restored to Hospital. Hospital generator automatically stopped when mains power was restored.	

Table 4: Generator Failure Event Time Line

Based on the recorded events of the day there appear to be three events that caused the Hospital generator to stop or be tuned off by maintenance staff, being:-

- Over temperature which shut the generator down.
- Oil leak with generator shut down by maintenance staff.
- Fuel line rupture with generator shut down by maintenance staff.

6 GENERATOR FAULTS

6.1 GENERATOR ESSENTIAL LOAD

SSE advised Honeywell that we needed to assess the load that would have been placed on the generator during the power loss and that a method needed to be developed which would as close as possible simulate the essential load requirements at the time of the power outage.

This would enable a determination to be made as to whether the generator was actually overloaded or not. This test was carried out on 07/11/2016 at approximately 1.30pm.

The readings obtained by taking measurements with just the essential loads connected are:-

***ESSENTIAL LOAD READINGS TAKEN 07/11/2016**			
RED Phase Amps	White Phase Amps	Blue phase Amps	Total Kilowatts (KW)
390 Amps	325 Amps	300 Amps	198 KW

*This is a simulated load to try and replicate the actual load on the day of the outage. The load may have been higher but there is no data to support this.

As the engine is rated at 219 Kilowatts and the load is approximately 198 kilowatts we can conclude that the engine was working very hard, however a standby diesel generator should be able to provide 100% of its capacity continually and can actually provide an overload for one hour in twelve.

198 Kilowatts is approximately 90% of the engine capacity of 219 kilowatts, so theoretically, if the engine is in good condition, the generator should be able to provide this load with room for more load still available.

6.2 HIGH WATER TEMPERATURE ALARM

After the generator had been running for about 1-1/4 hours the generator stopped.

When the Honeywell Site Electrician went to the generator plant room he noticed a high water temperature alarm activated.

The maximum temperature for the day was approximately 25 degrees so the generator was not operating in high ambient conditions that may have contributed to an overheating problem.

The generator was able to be restarted almost immediately after it stopped, which would indicate that the stoppage was controls based, at a predetermined setting rather than a seizure of the engine caused by overheating.

Other factors that could cause an overheating problem are:-

- Low coolant level
- Stuck or inoperative thermostat
- Damaged water pump
- Blockage in coolant pathways
- Blocked radiator (internal)
- Blocked radiator fins shroud etc.(external)
- Faulty water temperature switch
- Faulty water temperature sender unit
- Fan belt slippage
- Low oil pressure
- Overloading

There is no evidence of there being overheating issues with the generator in the past or during monthly testing including testing in October 2016 (after the failure event) with temperature recordings showing constant water temperatures of 180 degrees F or approximately 80 degrees C which appears to be the correct operating temperature for the engine.

However it must be noted that the generator is never run at or near full capacity as it did on 28th September 2016.

Low oil pressure would have brought up a low oil pressure alarm so we can discount this as a cause as there was no low oil pressure alarm activated.

As there is no record of event (not having computerized controller) the cause of the high temperature alarm is hard to determine. Further investigation would be required to positively identify the cause of the overheating shutdown.

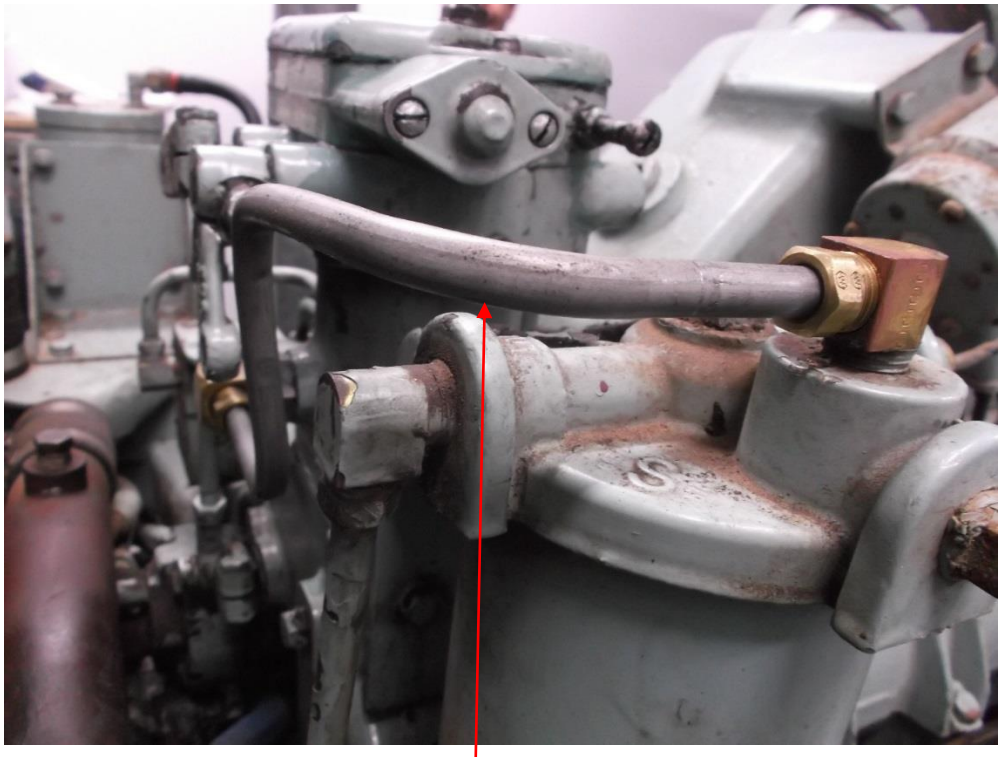
6.3 OIL LEAK

The Honeywell Site Electrician informed us that he restarted the generator after the over temperature shutdown and subsequently noticed an oil leak at the front of the generator engine. The Electrician then shut the generator down and informed his immediate Manager (Honeywell) of the issue.

Our understanding from discussion with Butler Mechanical Services is that a split occurred in a metal oil feed line at the front of the motor.

Butler Mechanical services said that they found a thread at a connector had been stripped at some stage when this pipe had been removed and reinstalled. This meant that the fitting was loose and that through vibration etc a rupture developed at a weak point in the pipe (a bend in the pipe).

Butler Mechanical services manufactured a new pipe and installed it to the generator which took approximately 2-1/2 hours.



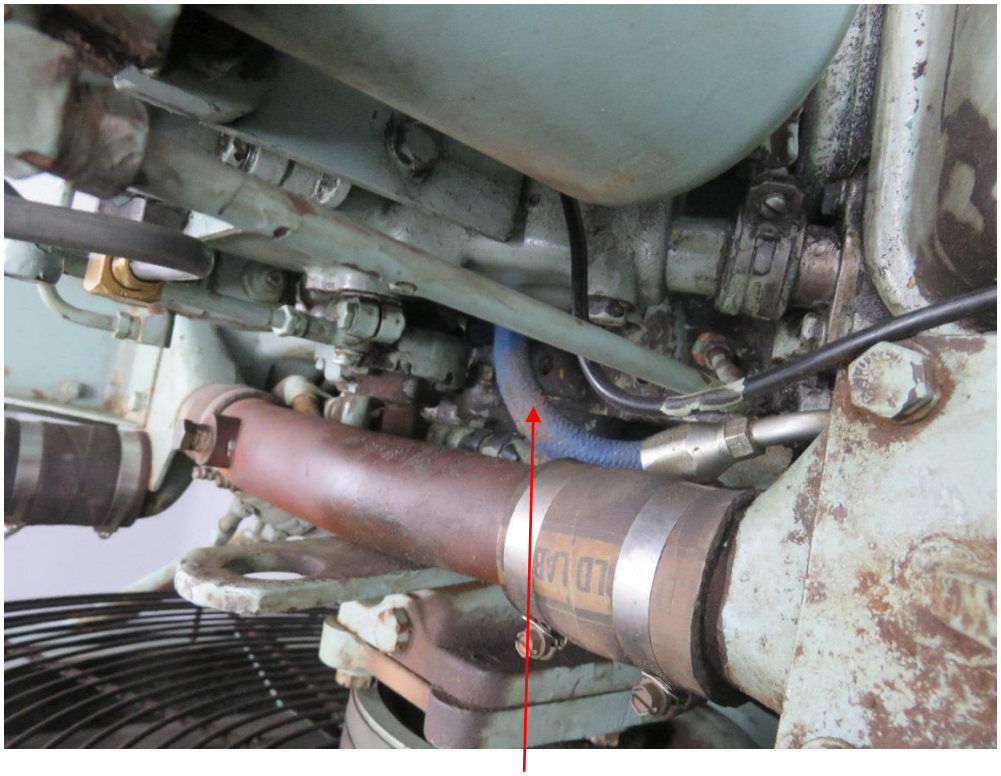
Oil pipe that was replaced by Butler Mechanical Services

6.4 FUEL LINE RUPTURE

Approximately 1-1/4 hours after the generator was put back into service after the oil leak was repaired, another leak developed which turned out be a rubber diesel fuel line that ruptured at the front of the generator engine.

The generator was immediately shut down and Butler Mechanical Services were called out to repair the ruptured fuel line which took approximately 4 hours.

We believe that the ruptured fuel line was the original fuel line making it 44 years old and over time had become brittle and reached a point where it failed and ruptured.



Fuel pipe replaced by Butler Mechanical Services

6.5 DEPOSIT BUILD UP FROM LOW LOADS

With the testing regime of running the generator without load for a very short period of time the generator never achieves proper operating temperature, proper running in to seat rings etc and poor/ incomplete fuel burning in the cylinders results in particle build up which affects the engine performance.

This poor engine performance could result in overheating when the engine is being run at high output as the engine is not able to provide full power.

The best way to ensure that the engine is in good operating condition is to run it at full load regularly.

This can be achieved by providing a suitable load from the facility or if the load is not consistent then a load bank can be connected to a generator to provide a stable load to keep the engine in good condition.

7 HOSPITAL OWNERSHIP AND MAINTENANCE ARRANGEMENT

Our understanding is that the Hospital is not owned by CHSA or SA Health but rather, leased from the Lessor Port Augusta Hospital Limited and that they have engaged Honeywell for the maintenance and repair contract for the main new Hospital. We also understand that Port Augusta Hospital Limited has assigned the administration of the Honeywell contract to CHSA as their Agent.

CHSA administer a number of other buildings on the site as well.

The Honeywell Maintenance Agreement has been negotiated directly between the Building Owner and Honeywell so CHSA or SA Health have no influence on the contract or the contract conditions but are responsible for its administration.

8 CONCLUSION

The Port Augusta Hospital generator is approximately 44 years old however over the life of the generator it has only run for a total of 407 hours at the time of our investigation.

The Hospital is not owned by CHSA or SA Health but is leased and there is a maintenance arrangement between the Facility Owner and Honeywell for maintenance of the New Hospital, administered by CHSA and SA Health under assignment from the Owner Port Augusta Hospital Limited.

This means that there are two Facility Mangers looking after different sections of the complete Hospital facility and this creates complications regarding replacement of obsolete equipment.

Up until May 2015 the generator was only ever tested by starting the generator and running it without load for 10-15 minutes once a month.

In June 2015 testing was changed to be four hour testing once a month and on load, in line with Australian Standards AS 3009 requirements.

Testing is done generally on a Tuesday night and starting anywhere from 7pm to 8.30 pm.

Testing is carried out at night for two reasons, being:-

- Not to interfere with Hospital operations. Due to this requirement testing does not get carried our regularly every month as it should. As an example testing was only completed in 4 out of 9 months between Jan 2016 and Sept 2016.
- To limit the load on the generator due to concerns about the generator being overloaded with the current essential load requirements due to the continual addition of loads to the generator supply over the years since the designed load when it was installed 44 years ago.

The last recorded outage was on 06/07/2015 and was only for a couple of minutes. This information was not part of Honeywell records but was obtained from the SA Health Hospital facility manager. Honeywell reported the generator appeared to be struggling due to high load.

However as the events were of such short duration we cannot say whether the generator may have stabilized once it had the opportunity to get up to operating conditions. There were no records of any earlier outages available

On Wednesday 28th September 2016 a power outage occurred causing the Hospital to rely on their backup generator to provide essential power to the Hospital.

After operating for approximately 1-1/4 hours the generator stopped due to a high water temperature alarm.

After restarting the generator an oil leak from an oil feed pipe at the front of the engine was noticed and the generator was shut down by maintenance staff. The generator was repaired and put back into service.

The generator then ran for approximately 1-1/4 hours when a second leak was noticed and the generator was shut down again.

The second leak appeared as mist coming out of the radiator so initial thoughts were that it was a coolant leak however after further investigation it turned out to be a rubber diesel fuel supply hose that had ruptured.

The oil leak and the fuel leak are purely maintenance related issues with the oil leak being caused by one of two possibilities being:-

- Poor installation practice
- Age of pipe past serviceable life

The fuel hose rupture would most definitely be attributed to the age of the hose as the hose would have become brittle over a lifespan of 44 years and failure was inevitable for a rubber fuel hose of this age at some time.

The two events, oil leak and fuel leak, which resulted in the generator being manually shut down are quite straight forward to understand however the issue of the overheating is not quite so simple.

We do not know if the generator would have overheated a second time had it run for a longer period of time however under test conditions it ran for 3.5 hours without overheating issues after the events of September 28/29 in its October monthly test however only under a low load.

Findings seem to show that the generator was not overloaded at the time of the power failure and that the main causes of failure appear to be age and maintenance related issues.

Essentially the Port Augusta Hospital has an old generator (44 years old) that is

- Never tested under full essential load conditions,
- Has only recently (last 12 months) been tested for 4 hours per month as per Australian Standards recommendations,
- Does not have a preventative maintenance program,
- Is only serviced once a year
- Has perishable items such as hoses, fanbelts etc that may still be the originals from 44 years ago and the main generator outages were caused by mechanical faults needing repair.

9 RECOMMENDATIONS

Recommendations for the Port Augusta Hospital Essential power supply are:-

- Conduct an assessment of the current essential loads and determine if there are loads that should not be on essential power.
- Remove any loads that do not need to be on essential power.
- From the above assessment determine the existing generator load requirements and provide a new generator to meet those loads.
- A monthly testing regime needs to be developed that will allow the generator to be tested at full essential load capacity and to ensure that 4 hour monthly testing can be done every month.
- Regular annual testing at 100% on a load bank needs to be scheduled into a maintenance schedule.
- Monthly and annual maintenance servicing needs to be scheduled for the generator to DPTI or CHSA schedule requirements.
- Replacement of all original pipes and hoses not yet done.
- Accurate records need to be provided as to what is done for each service.
- Monthly test results need to be accurately recorded.
- If the existing generator is capable of providing the current essential power requirements then the generator needs a major inspection and overhaul all items that may need to be replaced due to age and condition. This includes checking compression, oil pressure, coolant pumping and all other critical components and may actually require providing a temporary generator while the Hospital generator receives a major inspection and possible re build.
    - A ball park figure to do this would be $50,000.00 plus cranage and transport to Detroit workshop probably another $10,000.00 then a temporary generator would need to be hired and installed which could run into $10's of thousands of dollars depending on how long the engine was out of service. For the money that would be spent checking and rebuilding the existing engine it would be recommended to replace the generator with a new generator.
- Renegotiate the maintenance contract at the end of the current contract and have DPTI through AGFMA take on the maintenance contract.