University of Southern Queensland
Faculty of Engineering and Surveying

Water Leakage Detection Circuit in External Chiller Unit

A dissertation submitted by

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Abstract

This industrial project is undertaken with the Customer Engineering Department of ADVANTEST (Singapore) Private Limited.

The objective of this project is to design a circuit to detect the water level in the water tank of the External Chiller and a check sheet to detect water leakage in the cooling system.

There are 3 phases to design this project

1) Determine the water evaporation and usage rate in the cooling system and analyze the information to determine the time taken to completely dry up the water tank;
2) Design a water level detection circuit to sound an alarm when the water level is low;
3) Produce a check sheet to aid in the early detection of water leakage in the cooling system.

With the use of the water level detection circuit, time taken to monitor the water level in the water tank can be reduced to zero. Combine with the use of the check sheet, Test System trip caused by water leakage in the cooling system can be eliminated. Hence, no unscheduled downtime for the Test System will occur.

Design considerations that include safety, risk assessment and economic material selection are discussed in this report.

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ENG4111 Research Project Part 1 &
ENG4112 Research Project Part 2

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Chan Siew Yuen

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Signature

20th December 2006

Date

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I would like to thank Advantest (Singapore) management for the use of the External Chiller Unit. I am grateful to Dr. Wang (USQ) for his kind advice and guidance.

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Chapter 1: Introduction

The rationale for this research is that by improving the process of monitoring the water level in the External Chiller, the Test System's downtime and maintenance cost can be reduced. To achieve the objectives, a Water Level Detection Circuit and a "Water Tank Top Up" procedure are introduced. This report focuses on the development of the Water Level Detection Circuit used to detect water level in the Water Tank of the External Chiller.

1.1 A Brief Introduction to Advantest Business

This project is sponsored by Advantest (Singapore) Private Limited, an oversea subsidiary of Advantest Corporation. Advantest is listed in Tokyo Stock Exchange and New York Stock Exchange. It is a world leader in field of test and measurement equipment, offering cutting edge product and services vital to the advancement of electronics, telecommunications and semiconductor industries.

Advantest's businesses can be classified into the following 5 categories:

(1) Automated Test Equipment (ATE)

ATE, also known as semiconductor test systems, help turn advanced semiconductor device into reality by ensuring that they perform according to specification. The semiconductor devices tested are used in consumer products such as mobile phone, computers, memory stick, etc.

(2) Factory Automation

Advantest's test handlers rapidly load and unload semiconductors into the test system, helping to maximize testing throughput.

(3) Device Interfaces

Customized mechanical devices that are necessary for interfacing the semiconductor being tested with test system.

(4) Nanotechnology

Advantest is developing ways to use electron beam lithography to address the advent of nanometer chips and economic hurdles associated with small-lot manufacturing.

(5) Measuring Instruments

Advantest's measuring instruments are used in the development of a broad range of electronics devices and telecommunication technologies.

This project focuses on the Semiconductor Test Systems, which is grouped under Automated Test Equipment.

1.2 Background of Automated Test Equipment

Advantest Semiconductor Test Systems have both Memory and SOC Testers. Memory Tester test the functionality of Memory IC chips such as Dynamic Random Access Memory (DRAM) and Double Data Rate Random Access Memory (DDR RAM), used largely in computing application; and Flash Memory used in digital cellular phones, digital cameras and computers. SOC Tester test the functionality of System on Chip (SOC) devices, a technology that packages of all the necessary electronic circuits and parts for a complete system on one integrated circuit.

Here is an example of Advantest Memory Tester named T5585 Memory Test System as shown in figure 1.1.

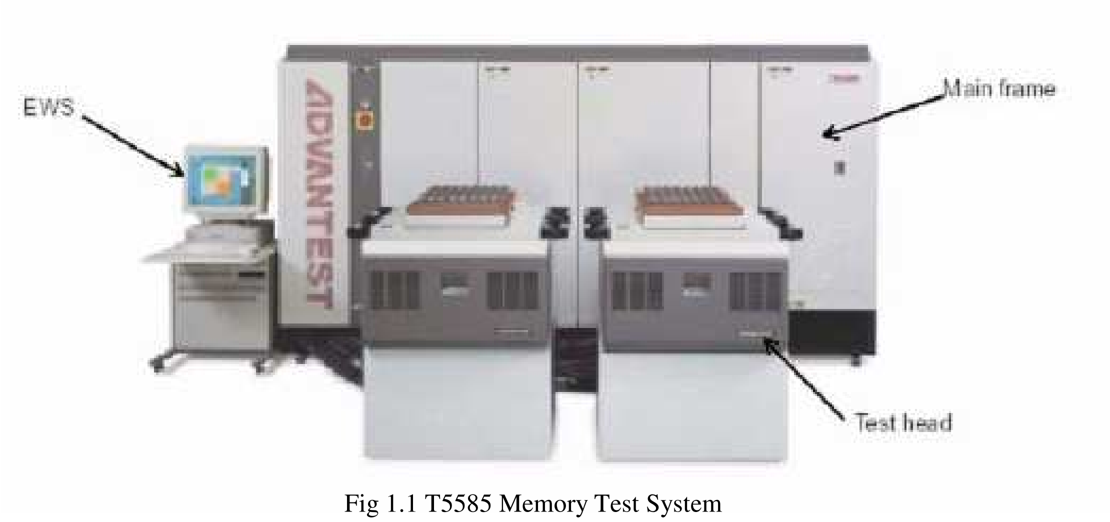


Fig 1.1 T5585 Memory Test System

This memory test system is used for production of DDR RAM devices. It consists of an Environmental Workstation (EWS), Main Frame and Test Head.

The Environment Workstation (EWS) is attached to the test system and acts as an interface between the user and the test system.

The Main Frame houses the system power supplies, the environment controller, the tester controller, and the required hardware components for executing Direct Current (DC) parametric tests, dynamic functionality tests, and Alternating Current (AC) parametric tests on the memory devices.

The Test Head/s depending on user's configuration, consists of Pin Electronics Boards (PE), is the interface between the test system and the Device Under Test (DUT). The Test Head shown above has a parallelism of 128 DUT, meaning it can test 128 numbers of devices per Test Head in one cycle.

1.3 Background of Cooling Unit in Test System

The test system is equipped with Cooling Unit utilizing Flourinert liquid (FC-3283) to reduce the temperature generated by the various printed circuit board installed in the Test Head. The Flourinert liquid is an inert liquid whereby it does not transmit electricity or Electric Static Discharge (ESD); therefore it was able to flow through the components in the Printed Circuit Board when it is in operation. Very High Speed Testing was therefore made possible with the introduction of this cooling system. The Flourinert liquid in the Cooling Unit is cooled by cooling water flowing in and out of the Cooling Unit.

Figure 1.2 shows the simplified block diagram of the Cooling Unit in the test system.

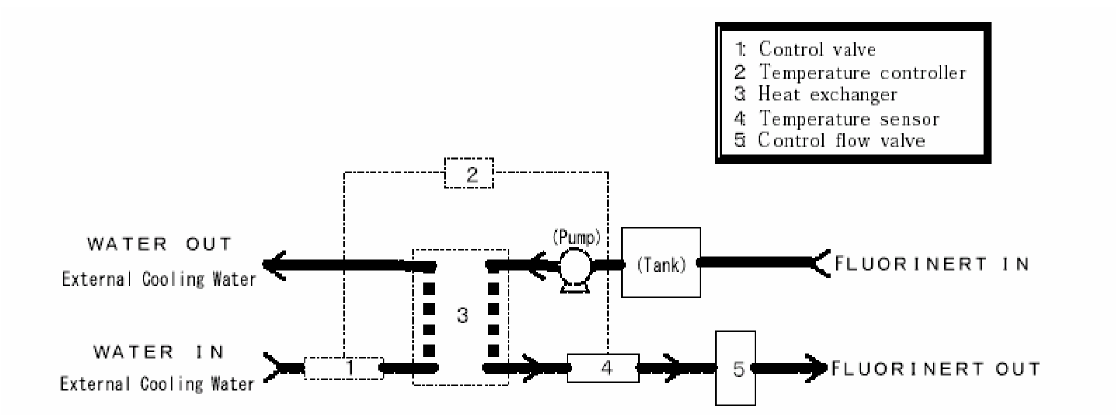


Fig 1.2 Simplified Block Diagram of the Cooling Unit

The Cooling Unit is intended to supply, circulate, and control the temperature of Flourinert liquid to cool the test system. Fluorinert liquid at a temperature of 27°C is fed into the test system to cool the Test Head. Heat is transferred from the components of the Printed Circuit Board in the Test Head. Warm Flourinert liquid, estimated around 31°C, returning from the Test Head, goes back to a Flourinert Tank fully filled with Flourinert liquid. The Flourinert Tank is completely sealed to prevent Flourinert liquid from escaping in the form of Flourinert vapor.

The Pump pumps the warm Flourinert liquid from the Tank into the heat exchanger where it is cooled by the external cooling water to a temperature of 27°C. Then it is fed back into the Test Head. The flow rate of the Flourinert liquid is controlled at 45 liters/min by the Control flow valve.

A temperature sensor located along the Flourinert out piping, detects the temperature of Flourinert liquid. The data from the temperature sensor is feedback to the temperature controller which controls the Control valve to regulate the flow of the external cooling water, enabling temperature control of the Flourinert liquid flowing into the test system. The controlled temperature is fixed at 27.0°C±1.0.

The followings are some requirements for the external cooling water supplied into the Cooling Unit in the test system.

1. External cooling water supply pressure must be between 0.2 to 0.7 MPa with no rapid pressure changes.
2. The minimum differential pressure between the supply pressure and the return pressure must be 0.15Mpa or more. (For example, if the external cooling water return pressure is 0.1 MPa, then the external cooling water supply pressure must be at least 0.25 MPa.)
3. External cooling water quality must conform to "Water Quality Guidelines for Refrigerator and Air Conditioning Equipment" (JRA-GL-02-1994) set down by the Japan Refrigeration and Air-conditioning Association.
4. The temperature of external cooling water must be between 5°C to 22°C. (Temperature change must not be greater than 5%/min.)
5. Maximum flow rate of the external cooling water must not exceed 60 liters/min. (Flow change must not be greater than 5%/min.)

Figure 1.3 shows the side view of the Cooling Unit.

Fig 1.3 Side view of Cooling Unit

Figure 1.4 shows the view of the Cooling Unit during replacement process.

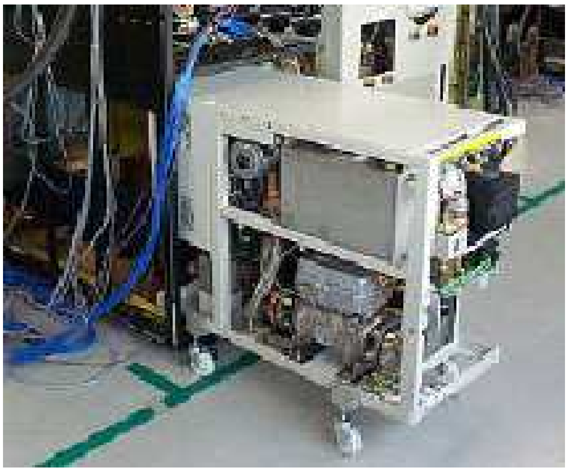


Fig 1.4 Cooling Unit Replacement

1.4 Background of External Chiller Unit

The test floor houses a main chiller, an external chiller and three test systems. Figure 1.5 below shows the current layout of our Chillers and Testers in our Test Floor. Later part of this section will describe the relationship between the main chiller, the external chiller and the cooling unit in the test systems.

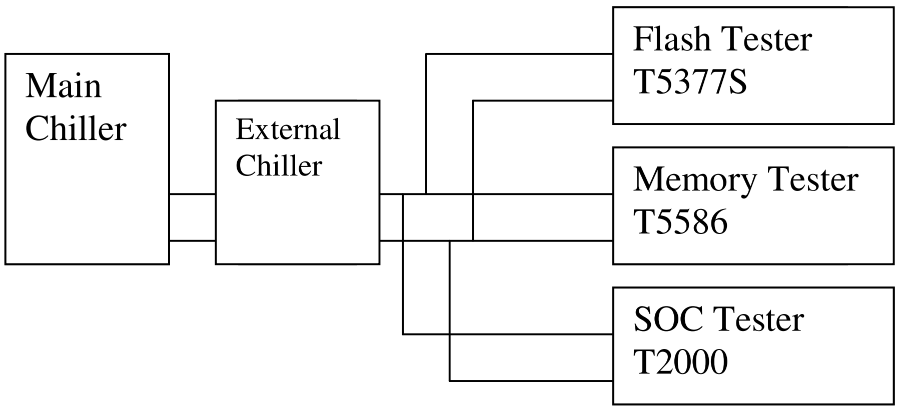


Fig 1.5 Layout of the Test Floor

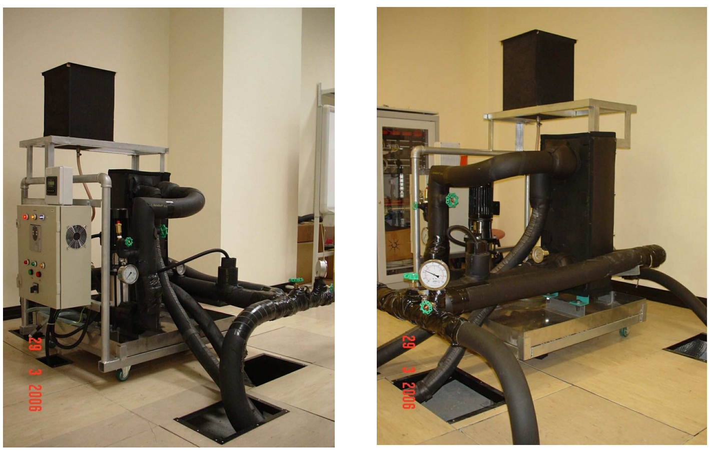


Fig 1.6 Two views of the External Chiller

The Main Chiller is an air cooled chiller; it supplies chilled water with no pressure difference to the External Chiller. The External Chiller as shown in Figure 1.6 will supply chilled external cooling water to the test system with a pressure difference of 0.7MPa. The test system Cooling Unit requirement of external cooling water to have at least a pressure of 0.15 MPa can be fulfilled.

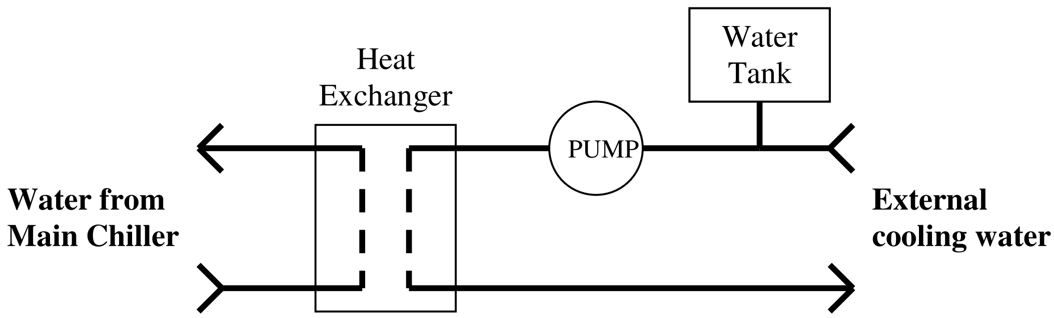


Fig 1.7 Simplified Block Diagram of the External Chiller

The External Chiller operates in the same way as the Cooling Unit in the test system. Figure 1.7 shows the simplified block diagram of the External Chiller. The chilled water from the Main Chiller will enter into the Heat exchanger of the External Chiller to cool down the external cooling water. The chilled cooling water will then be supplied to Cooling Unit to cool down the Flourinert liquid.

The warm cooling water will return to the External Chiller. The pump will pump the cooling water into the Heat exchanger and then supply to the Cooling Unit.
The water tank will supply cooling water into the pipelines when there is a decrease of cooling water. The water tank on the top of the External Chiller is open air type storing the cooling water.

Chapter 2: Problem Encountered

This section describes the problems that will be encountered when there is no Water Leakage Detection Circuit available. It covers the problem arises when there is water leakage. The tedious and time consuming method of monitoring the water level are discussed in section 2.2

2.1 Water Level Low Warning Alarm

The water tank on the top of the External Chiller is open air type storing the cooling water as can be seen in the Figure 2.1. The exterior of the water tank is cover with a black insulating tape to eliminate the reflection caused by the shining surface of the water tank.

Fig 2.1 Top View of the Water Tank in the External Chiller

It is critical to ensure there is sufficient water in the water tank; otherwise a system trip will occur. The four consequences for the system trip will be discussed in more details in section 2.3.1.The water level in the water tank drops regularly. There are two reasons for the water loss; they are water evaporation on the surface to the surrounding environment and the decrease of cooling water in the pipelines.

Therefore to prevent the water level from dropping to critical condition, the water level needs to be monitored daily by a man. Current practice of monitoring the water level is very tedious and time consuming.

2.2 Monitoring Water Level

As discussed in the previous section, to prevent the water level from dropping to critical condition, manpower is utilized to monitor the water level in the water tank and top up if required. Monitoring this water level in the water tank is very tedious and time consuming.

2.2.1 Tedious Checking Method

To monitor the water level in the water tank requires one man, a foldable three steps ladder and a measuring tape. The man has to setup the foldable three step ladder near to the water tank and climb up the ladder and check the water level in the water tank. After confirming the water level are within the safe range, then the man has to dismantle the foldable three step ladder and return the ladder back to the store room about 100 metres away from the External Chiller. The water level height above 200 millimeter is considered to be the safe range.

Figure 2.2 shows a man setting up the foldable three steps ladder, climb up to the top of the ladder and measure the water level in the water tank.

Fig 2.2 Monitoring the water level in the water tank

2.2.2 Time Consuming

The process of monitoring the water level in the water tank is very time consuming. Figure 2.3 shows the flow chart of the steps in monitoring the water level.

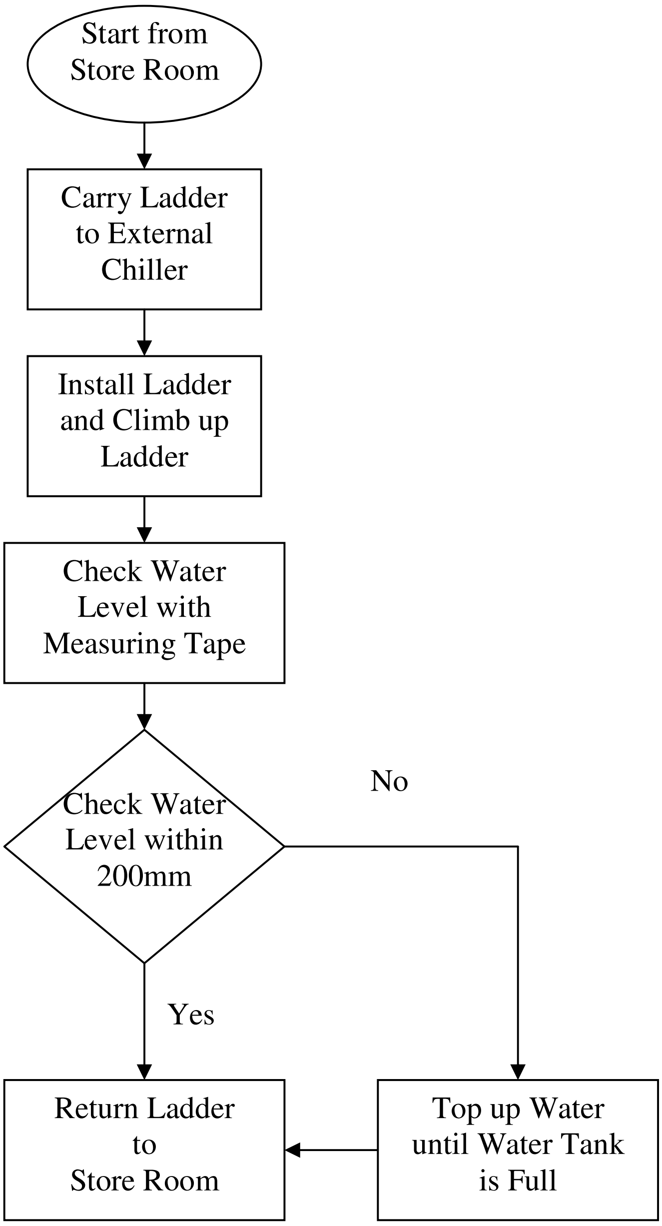


Fig 2.3 Water Level Monitoring Flow Chart

As seen from the flow chart above, the starting point is from the storeroom. Then collect the foldable three steps ladder and walk to the External Chiller which is 100 metres away. Setup the ladder beside the External Chiller and climb up the ladder to the top most rung. Check the water level in the water tank with a measuring tape. Confirm the water level is within the safety range, if within the safety range, disassemble the ladder and return the ladder back to the store room.

The whole procedure requires a single man to perform and estimated 10 minutes are used to perform the procedure. It is a requirement to check the water level each day as the Test Systems are running 24 hours production non-stop.

Each day requires 10 minutes to perform the procedure, in a year there are 365 days and a total of 3650 minutes are spent to monitor the water level.

$$10 * 365 = 3650 \min$$

A total of 60.8 hours are spent to monitor the water level.

$$3650 / 60 = 60.8 hours$$

With respect to Advantest Singapore Pte Ltd. chargeable labor cost of S$160 per hour, the cost of monitoring the water level for a year will come out to be S$9728.

$$60.8 * \$160 = \$9728$$

As seen from the previous flow chart and above calculations, a total of S$9728 will be spent to just monitor the water level in the water tank, this method of monitoring is very tedious, time consuming and very expansive.

2.3 Water Leakage

This section will touch on the problems encountered when there is a water leakage present and no prompt action is taken. Water leakage may occurred in many circumstances, for instance, water coupler was not tighten, water pipe burst or leak, or in worst scenario, water leak into the Flourinert Liquid tank through the Heat Exchanger of the Tester Cooling Unit. Water leak into the Flourinert Liquid tank through the Heat Exchanger will be discussed in more details in Chapter 6, Section 6.2 Risk Assessment.

When water leakage is present and no prompt action is taken, the water level in the water tank will drop until no more water can be supplied into the pipelines. The test system cooling unit cannot efficiently cool down the Flourinert Liquid. Warm Flourinert Liquid will pass through the heated components on the Printed Circuit Boards in the Test Head. The warm Flourinert Liquid cannot efficiently cool down the Printed Circuit Boards. When the temperature on the Printed Circuit Boards reaches 40°C or more, the Printed Circuit Board will send out a Heat Alarm to the Main Frame Tester Processor to shut down the test system. This is known as System Trip.

When system trip occurs, the following problem might surface,

1. Hard Disk Crashed
2. Production Data Lost
3. Test System Board Failure
4. Production Time Lost

The above problems will be discussed in more details in the next few sections.

2.3.1 Hard disk Crashed

When system tripped occurs, the Engineering Work Station will immediately shut down without properly shut down the Hard disk. In this scenario, there is a possibility that the Hard disk will crashed, as it is not properly shut down.

There are two ways the Hard disk will crashed. Firstly, the Hard disk crashed is due to some processes that are working in the background are not saved, and the data in the processes are lost or deleted. Therefore, the Hard disk cannot be boot up normally. In this case, the test system recovery is very simple but time consuming.

Second way in which the Hard disk crashed is during the test system shutdown, the Hard disk is physically damaged. The storing disk media in the Hard disk might be scratched due to sudden stop of the reading needle when the power supply is suddenly cut off. Another problem that might occur is the reading needle is stuck and cannot move after the test system shut down. In this case, the recovery procedure is more tedious and longer and more costly.

In both situations above, to recover the test system, we are required to reload the Software and change the necessary settings. In the second situation, whereby the Hard disk is physically damaged, we first need to purchase a new Hard disk from the SUN System authorized dealer. Changing of the Hard disk in the Engineering Work Station will take about 30 minutes. Please see the Appendix B-1 for the exploded view of the Engineering Work Station.

The Software that are required to reload will be the following,

1. SUN Solaris Operating Software 8
2. Test System Software
3. Any other Software that is require for the production

The total time taken to reload all the above said software will take about 3 hours. After reload all the software, need to run Test System Initialization Program and Diagnostic Program and perform Golden Device Testing to certify the system is suitable for productions. All the testing and running of devices will take about 6 hours to complete.

The recovery time for a Hard disk crashed is very time consuming, it will take about one whole day to recover a test system.

2.3.2 Production Data Lost

The test systems in the test floor are running production 24 hours every day non stop. Each lot of production devices requires at least 3 to 4 hours of running. The information of the production lot is collected automatically by the Engineering Work Station after each production lot is finished.

In the event of a system trip, the test system and the Engineering Work Station will be shut down. All the production information for the current lot of devices will be lost. The devices have to be tested all over again, therefore the lost in production time and the frustration of the people-in-charge of the lot of devices.

2.3.3 Test System Board Failure

In the test system, there are many different Printed Circuit Boards, some are located in the test system Main Frame and some are located in the Test Head as discussed in section 1.2. The Printed Circuit boards in Test Head are Flourinert-cooled whereas the boards in the Main Frame are Air-cooled.

As discussed in section 2.3, the warm Flourinert Liquid cannot efficiently cool down the Printed Circuit Boards in the Test Head. When the temperature on the Printed Circuit Boards reaches 40°C or more, the Printed Circuit Board will send out a Heat Alarm to the Main Frame Tester Processor to shut down the test system. When this happens, one or more Printed Circuit Boards in the Test Head might be damaged by the rising temperature, not to mention, there is also a possibility that the Printed Circuit Boards in the Main Frame may be damaged due to improper system shut down.

To verify any board damages, we have to execute the Test System Initialization Program and the Test System Diagnostic Program. If any board is faulty, the fail board information will show up in one or both the programs. Figure 2.4 is an example of the fail data.

```
******************************************************************************
**        T5585 SYSTEM DIAGNOSTICS    REV:4.03-1(SYS TEST) 3.01(DIAG)        **
**        SYSTEM ID. TYO23                                                   **
**        TH         D TYPE                                                  **
**        START AT   2003/06/05 09:17:24                                     **
**                                                                           **
**                   TEST MODE : MAINTENANCE & PASS PRINT                    **
**                   SPEC      : 100.0%                                      **
**                   UNIT      : Normal                                      **
******************************************************************************
TEST 5304 TH   (  3) DR OUTPUT CURRENT & IMPEDANCE CHECK                 FAIL**
                     SINK                    SOURCE
      SET            25.00MA    -25.00MA     40.00MA    -40.00MA
      UPPER LIMIT    51.22R      51.22R      54.16R      54.16R
      LOWER LIMIT    43.18R      43.18R      40.24R      40.24R
     TH1 209  D      0.252R  *   0.252R  *   0.647R  *   0.647R  *  FAIL*
     TH1 241  D      0.333R  *   0.333R  *   0.673R  *   0.623R  *  FAIL*
     TOTAL COUNT=11520   FAIL COUNT=    8
     TG/TP     SLOT    2     BGR-024923          CGB      IS DOUBTFUL
     TH1       SLOT 237A     BIR-025601X02       DDA      IS DOUBTFUL
     TH1       SLOT DSTA     BGR-024924          BIB      IS DOUBTFUL
     TH1       SLOT DCMA     BGR-024925          BBA      IS DOUBTFUL

INITIALIZE START              2003/06/05 11:25:51

INITIALIZE PASS
INITIALIZE END                2003/06/05 11:25:57

T5585 SYSTEM DIAGNOSTICS END  2003/06/05 11:25:57 (OP.TIME=02:08:33)    FAIL**
```

Fig 2.4 Example of a failed board information

If board failure occurs, the first action is to confirm the fail board. Swapped the suspected fail board with another board of the same part number and execute the Diagnostic test again. If the fail board SLOT location changes, then it is confirmed the board is faulty.

Request for a new board of the same part number and replace with the faulty board. Execute the Test System Initialization Program and the Test System Diagnostic Program to verify the system is without any failures and the test system can then be released for production use.

The total time taken to rectify a board failure situation will depend on the difficulties in trouble shooting the fail system. Estimated time taken for a simple trouble shooting situation including the system recovery from shut down situation will be around 13.5 hours.

2.3.4 Production Time Lost

Production time is lost whenever there is a system trip. The time lost can be in the form of test system recovery time and the time to retest the devices already tested.

As discussed in section 2.3.1 and 2.3.3, the recovery of the Hard disk or board failure means a lost in the amount of production time meaning the time taken to recover the Hard disk or board failure can be use for device production if there is no system trip. Even if no board failure is encountered including Hard disk, it is still a requirement to execute the Test System Initialization Program and Test system Diagnostic Program whenever a system trip occurs. This is to confirm that there is no board failure in the test system and the test system is able to run device production. Executing the 2 mentioned program will take roughly 4 hours to complete, therefore it is a lost of 4 hours production time.

As discussed in the section 2.3.2, devices have to be retested because of the lost in production information. This is a lost in production time too. Table 2.1 below shows the hours lost in production time in three different scenarios.

	Procedure	Time Taken (hrs)	Result
No Board failure (including Hard disk)	Initialization Program	2	Pass
	Diagnostic Program	2	Pass
	Device Retesting	3	
	Total Time Taken	7	
Hard disk crashed (Physically damage)	Hard Disk Change	0.5	
	Software Reload	3	
	Initialization Program	2	Pass
	Diagnostic Program	2	Pass
	Golden Device Testing	2	Pass
	Device Retesting	3	
	Total Time Taken	12.5	
Board failure	Initialization Program	2	Pass
	Diagnostic Program	2	Fail
	Board Confirmation	2	
	Change Board	0.5	
	Initialization Program	2	Pass
	Diagnostic Program	2	Pass
	Device Retesting	3	
	Total Time Taken	13.5	

Note: The time taken to retest the devices is just a wild estimation.

Table 2.1 Production Time Lost in different situation

Chapter 3: Water Evaporation and Usage Rate

This section describes the method used in determine the water evaporation and usage rate in the cooling system. Water evaporation rate is affected by temperature and humidity. Therefore this section will also cover water evaporation rate under different conditions of temperature and humidity. In section 3.3, analysis will be made to determine whether it is more economical to lower down the surrounding temperature to reduce the water evaporation in the water tank.

3.1 Environment Surrounding Water Tank

There are 3 Test Systems running production on the Test Floor. Each Test System produced about 50000 Kilo Joules per hour of heat into the surroundings. The Figure 3.1 shows the amount of Heat generated from the T5585 Test System with maximum configuration. This information is taken from the Product Description Manual of a T5585 Test System.

Maximum configuration
51431 kJ/h

Fig 3.1 Amount of Heat Generated

The current setting for the air conditioning in the Test Floor is 23°C. The ambient temperature surrounding the External Chiller Unit is 29.4 °C ± 1 °C as can be seen in the Figure 3.2 and the Relative Humidity is 39.8% ± 5% as can be seen in Figure 3.3. The reading shows that the area around the External Chiller is warm and dry; therefore the Evaporation rate in the water tank will be high compare with an area where the temperature is cooler and more moisture in the air.

Fig 3.2 Ambient Temperature surrounding the External Chiller

Fig 3.3 Relative Humidity surrounding the External Chiller

3.2 Water Level Data Collection

The method used to determine the water evaporation and usage rate in the water tank is to collect water level data twice per week for a total of 14 weeks, estimated to 3 months of data collection. Water evaporation rate was measured for three areas, the actual water tank, near water tank and away from the water tank.

The first set of data collected is to determine the rate at which water decreases in the water tank including water evaporation and the water that disappear into the pipelines. This data is the actual operational data in the sense that the External Chiller is running at full power supporting 3 Test Systems productions. The data will be discussed more elaborately in section 3.2.1.

The second set of data collected in a pail located near to the External Chiller is to find out what is the water evaporation rate that is occurring in the water tank. The temperature and relative humidity that surround the pail is the same as the water tank in the External Chiller. The pail that is used for this data collection is a 300 mm in diameter by 300 mm in height. The data collected from this experiment can only be treated as an estimated result, as the dimension of the pail is different from that of the water tank, therefore the result is not very accurate. The data and result will be shown in section 3.2.2.

Lastly the third set of data collected is using the same dimensioned pail, but it is located away from the External Chiller to a corner of the room where the temperature is lower. The third set of data collected is to determine the water evaporation rate under different condition. The expected water evaporation rate should be lower than the second experiment due to the lower temperature. The data and result will be shown in section 3.2.3.

3.2.1 Water Level in Water Tank

The first set of data is collected from the water tank directly above the External Chiller. As shown in section 3.1, the ambient temperature is 29.4°C ± 1 °C and the Relative Humidity is 39.8% ± 5%.

On 3rd April 2006, the water in the water tank is top up to its full position at 380 mm. The first water level value is collected at the same moment. Figure 3.4 shows the measurement of the water level in the water tank on the first day of data collection.

Fig 3.4 First measurement of the water level

The water level measurements are collected twice a week, on Monday and Thursday. If a public holiday falls on any of the measurement day, the measurement will be taken on the next working day. In fact, Labor Day, 1st May 2006 falls on Monday of the 5th week data collection, therefore the measurement is taken on the next working day which is on Tuesday, 2nd May 2006.

The data collected for 28 days, a total of 14 weeks is shown in appendix B-2. The first column is the number of collection; the second column shows the number of days since the first collection date; the third column shows the actual day the measurement is collected and lastly the last column shows the height of the water level from the base of the water tank.

The data collection begins from 3rd April 2006 and ends on 6th July 2006. It started with a height of 380 mm on the first day and drop continuously until the water tank was left with 94 mm in height of water.

Plotting a chart with the raw data collected using MATLAB and using “POLYFIT” and “POLYVAL” commands in the MATLAB to draw the line of best fit. Figure 3.5 shows the MATLAB plot of the water level versus number of days.

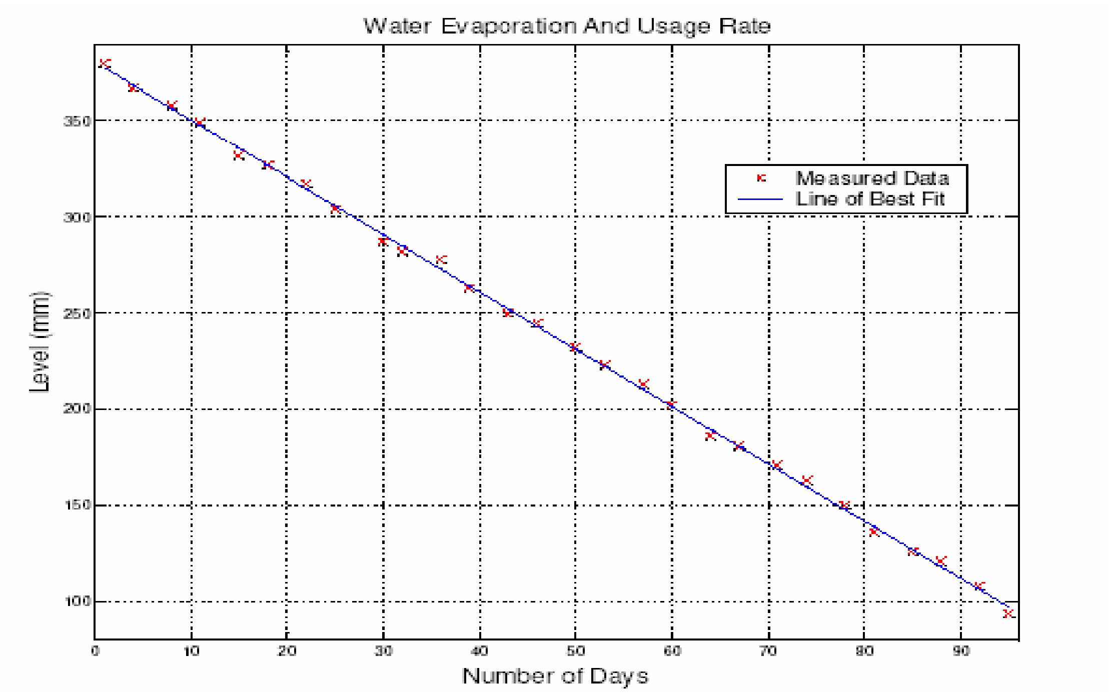


Fig 3.5 Plot of Water Level (mm) versus Number of days

From the figure 3.5, it shows the water level dropping constantly over the days. The water evaporation and usage rate can thus be determined by finding out the gradient of the line of best fit. On the 10th day, the height of the water level is 350 mm. On the 78th day, the height of the water level is 150 mm. Using the equation below, find the gradient of the line of best fit.

$$gradient = \frac{350-150}{10-78}$$

$$= -2.94$$

The gradient of the line of best fit is negative 2.94. This denotes that the water evaporation and usage rate in the water tank is 2.94 mm per day.

The size of the water tank is 330 mm by 330 mm by 460 mm. The water evaporation and usage rate in the water tank is 2.94 mm per day; this denotes that 0.00032017 cubic meter of water is used up per day.

3.2.2 Water Level in Container near External Chiller

The second set of data collected is from a pail located beside the External Chiller. These data will help to determine the estimated water evaporation rate in the water tank. The pail A is located beside the External Chiller; therefore the temperature and relative humidity are the same as that of the External Chiller.

On 3rd April 2006, the first day of the experiment, a pail of water with the height of the water level at 280 mm is placed beside the External Chiller. Figure 3.6 shows the pail of water placed beside the External Chiller.

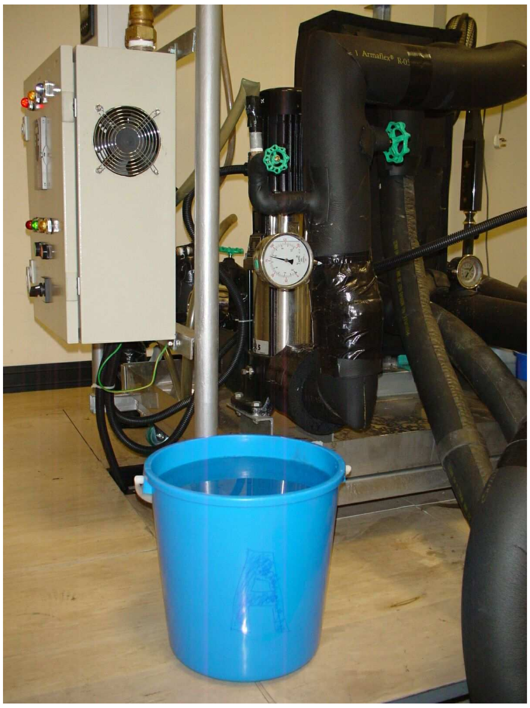


Fig. 3.6 Pail A placed beside the External Chiller

The data collection date from the pail of water is the same as the previous data collection from the water tank. The data is collected twice per week, normally on Monday and Thursday unless holiday fall on either day. Appendix B-3 shows the data collect for the duration of 14 weeks.

On the first day, the water level is recorded as 280 mm in height; on the 95th day, pail A was left with only 75 mm in height of water. Using MATLAB, a plot of the water level versus the number of days is created as well as the line of best fit.

Figure 3.7 shows the MATLAB plot of the water level versus number of days. The estimated water evaporation rate can be determined from the line of best fit.

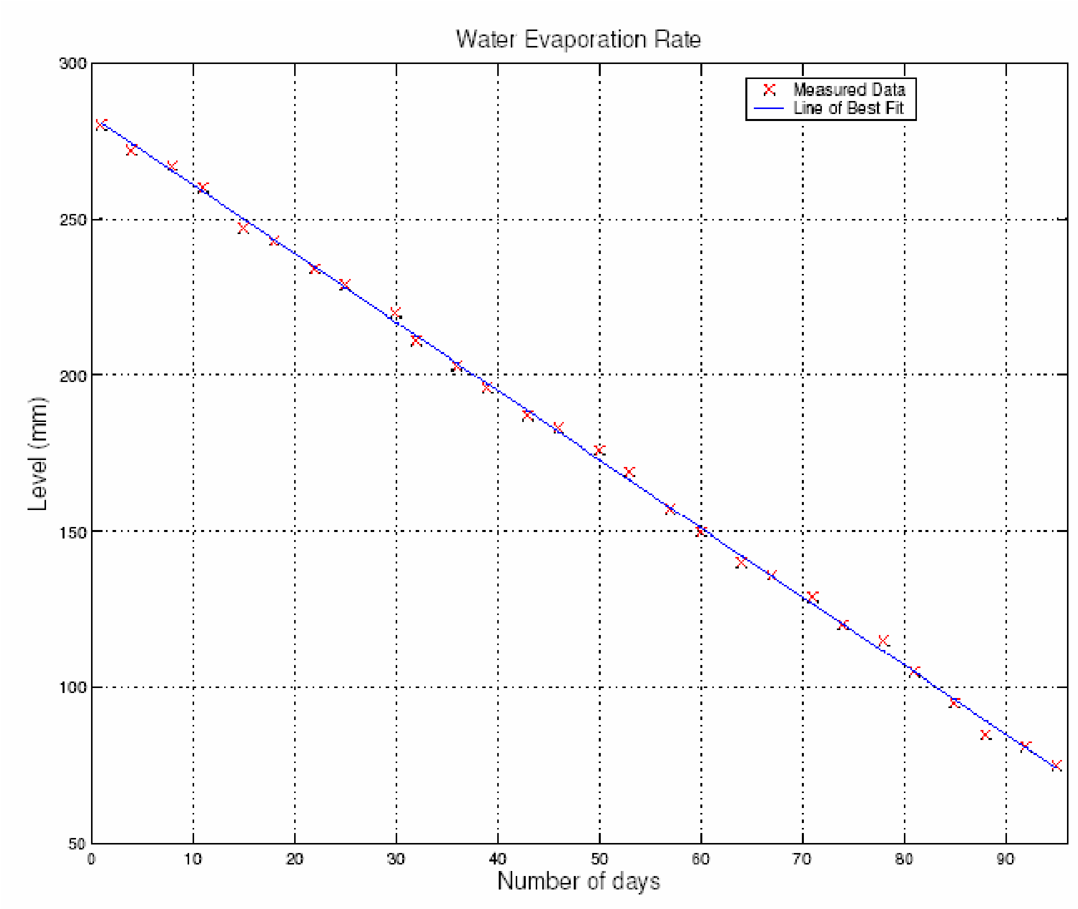


Fig 3.7 Plot of Water Level (mm) versus Number of days

On the 15th day, the height of the water level is 250 mm. On the 83rd day, the height of the water level is 100 mm. Calculate the gradient of the line of best fit yielded the following

$$gradient = \frac{250-100}{15-83}$$

$$= -2.21$$

The gradient of the line of best fit is negative 2.21. This denotes that the estimated water evaporation rate in pail A is 2.21 mm per day. This implies that the possible water evaporation rate in the water tank is 2.21 mm per day.

With the information gained from the two experiments, we can predict the water usage rate as follows,

Water Usage Rate = Water Evaporation and Usage Rate – Water Evaporation rate
= 2.94 – 2.21
= 0.73 mm

The estimated water usage rate in the cooling system is 0.73 mm.

3.2.3 Water Level in Container away From External Chiller

The third set of data collected is from a pail located away from the External Chiller and the test systems, approximately 20 meters away. These data will help to determine the water evaporation rate under different condition. The relative humidity surrounding pail B is the same as that of the External Chiller. The ambient temperature surrounding pail B is 22.9 °C as shown in Figure 3.8.

The method to collect the water level data is the same as the previous 2 experiments. Data is collected every Monday and Thursday for a period of 14 weeks.

On the first day of the experiment, pail B is placed at one corner of the room approximately 20 meters away from the External Chiller. Water was filled into the pail to a height of the 280 mm. Figure 3.8 shows the pail of water placed at one corner of the room.

Fig 3.8 Pail B located away from the External Chiller

As usual, the water level in pail B is recorded on the first day of the experiment, 280 mm in height. Appendix B-4 shows the data collect from pail B for the duration of 14 weeks. On the last day of the experiment, 6th July 2006, the 95th day, pail B was left with only 123 mm in height of water. Using MATLAB, a plot of the water level versus the number of days is created as well as the line of best fit.

Figure 3.9 shows the MATLAB plot of the water level versus number of days.

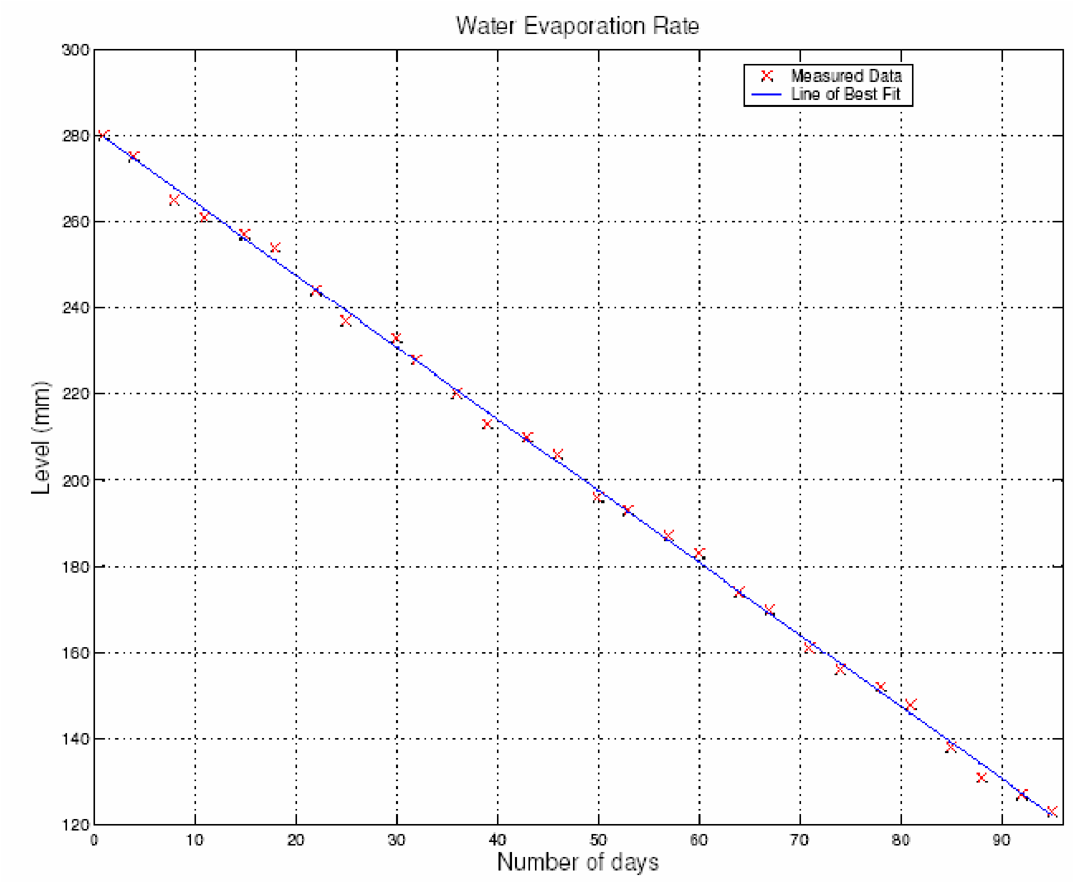


Fig 3.9 Plot of Water Level (mm) versus Number of days

The water evaporation rate at a temperature of 22.9 °C can be determined from the line of best fit from Figure 3.9. On the 12th day, the height of the water level is 260 mm. On the 85th day, the height of the water level is 140 mm. Calculate the gradient of the line of best fit yielded the following

$$gradient = \frac{260-140}{12-85}$$

$$= -1.64$$

The gradient of the line of best fit is negative 1.64. This denotes that the water evaporation rate in pail B is 1.64 mm per day. This implies that if the ambient temperature around the water tank is 22.9 °C, then the estimated evaporation rate might be 1.64 mm per day instead, slightly lower than the current of 2.21 mm per day.

3.3 Water Evaporation Rate Analysis

The first set of data gathered shows that the water evaporation and usage rate in the water during operation is 2.94 mm per day. The second set of data gathered shows that the estimated water evaporation in the water tank is 2.21 mm per day and also implies that the estimated water usage in the cooling system is 0.73 mm per day. This shows that the water evaporation is the main cause for the decrease of water level in the External Chiller.

The ideal countermeasure is to reduce the water evaporation rate to zero. It is impossible to reduce the water evaporation rate to zero, unless the water tank is vacuum sealed; else there will always be water evaporation present.

As can be seen from the third set of data, the water evaporation rate gathered from this experiment is 1.64 mm per day. The ambient temperature is 22.9 °C. An option arises to reduce the ambient temperature surrounding the water tank to 23 °C or lower; then the water evaporation rate can be lowered too.

Following this assumption, plans are made to determine the air conditioning setting that will help to lower down the ambient temperature in the External Chiller area. The plan is to lower down the air conditioning setting one degrees at a time and check the temperature around the External Chiller.

The original setting on the air conditioning unit is 23 °C. It was lower down to 22 °C, after an hour of wait time for the temperature to settle, the temperature measured around the External Chiller is 28.9 °C. The air conditioning setting is lower another degree down and waited for an hour and measured the temperature around the External Chiller, this goes on for 5 hours. At last, at air conditioning setting of 18 °C, the ambient temperature around the External Chiller is 23.2 °C. Based on the above assumption, at 23.2 °C, the water evaporation rate in the water tank will be roughly 1.64 mm per day.

A decrease of 5 °C in the air conditioning setting can yield a saving of 0.57 mm of water per day. The total water evaporation and usage per day at air conditioning setting of 18 °C will be 2.37 mm.

$$\begin{aligned}\text{Water Evaporation and Usage Rate} &= \text{Water Evaporation Rate} + \text{Water Usage rate}\\ &= 1.64 - 0.73\\ &= 2.37\text{ mm}\end{aligned}$$

Comparing the water evaporation and usage rate for the two temperatures, 29.4 °C and 23.2 °C, the interval for the water tank to run dry are 4 months and 5 months respectively. Assuming the starting water level is at 380 mm.

$$\begin{aligned}@\ 29.4\ °C &= \frac{380}{2.94}\\ &= 129\text{ days}\\ &= 4.3\text{ months}\end{aligned}$$

$$\begin{aligned}@\ 23.2\ °C &= \frac{380}{2.37}\\ &= 160\text{ days}\\ &= 5.3\text{ months}\end{aligned}$$

The main advantage for the decrease in the temperature is the reduction of the water evaporation rate. This will help to reduce the water usage and the interval for topping up water in the water tank will be increased.

There are disadvantages in decreasing the temperature too. The electricity bill will go up because the air conditioning unit will require more power as the temperature setting is lowered. This will make the operation cost higher

Another disadvantage is the air conditioning is working harder to lower down the surrounding temperature to 18 °C as set, the compressor in the air conditioning unit might breakdown more easily and thus requires more servicing. This will inadvertently increase the operational cost.

The areas around the External Chiller and the Test Systems will have a temperature of 23 °C ± 1 °C. There are also areas in the Test Floor with a temperature of 18 °C. Some people might not like to work in such a cold environment, they might grumble and complain, and this will affect their work efficiency.

Another disadvantage is the water level in the water tank is still required to be monitor daily and water top up are inevitable.

3.3.1 Advantages and Disadvantages of Lowering Temperature

There are advantages and disadvantages of lowering the air conditioning temperature to reduce the water evaporation rate in the water tank as discussed in section 3.3. Here is the list of the advantages and disadvantages.

Advantages of lowering the air conditioning temperature;
1) Reduce water usage.
2) Increase the interval for topping up the water tank.

Disadvantages of lowering the air conditioning temperature;
1) Operation cost will be higher.
2) The compressor in the air conditioning units might need more servicing.
3) People working in areas where the temperature is 18 °C may complain about working in such cold environment.
4) Water level monitoring and water top up are required.

3.3 Conclusion

There are more disadvantages than advantages in reducing the water evaporation rate. The increase in the interval for topping up the water tank is not significantly long; the difference is only one month. The main disadvantage is the operation cost will go up.

Due to the above reasons, the idea of lowering the air conditioning temperature to reduce the water evaporation rate is put aside until further notice.

The current water evaporation and usage rate of 2.94 mm per day will be used to calculate the top up schedule and for early detection of water leakage. This will be discussed more in depth in section 5.

Chapter 4 Designing and Constructing Jig

The objectives of this project is stated as follows,

1. To eliminate the tedious method of monitoring the water level in the External Chiller Unit;
2. To reduce the water level monitoring time to zero;
3. To aid in the early detection of water leakage present in the cooling system to prevent system trip occurring.

In choosing the countermeasure, all the above mentioned objectives need to be met.

This section covers the selection of the countermeasure to ensure early detection of water leakage from a pool of possible solutions. It will describe the selection of the main elements required to build the water level detection circuit. The design of the water level detection circuit is covered in section 4.3.

4.1 Possible Design Solution

There are three possible design solutions to prevent the water to run dry in the External Chiller, namely,

1. Incorporating Toilet Flush System onto the water tank;
2. Attach a visual water level monitoring tube onto the water tank;
3. Water level detection jig with top up check sheet.

4.1.1 Incorporating Toilet Flush System

One of the possible solutions is incorporating a Toilet Flush System onto the water tank. Figure 4.1 shows the CAD drawing of the Toilet Flush System attached to the water tank.

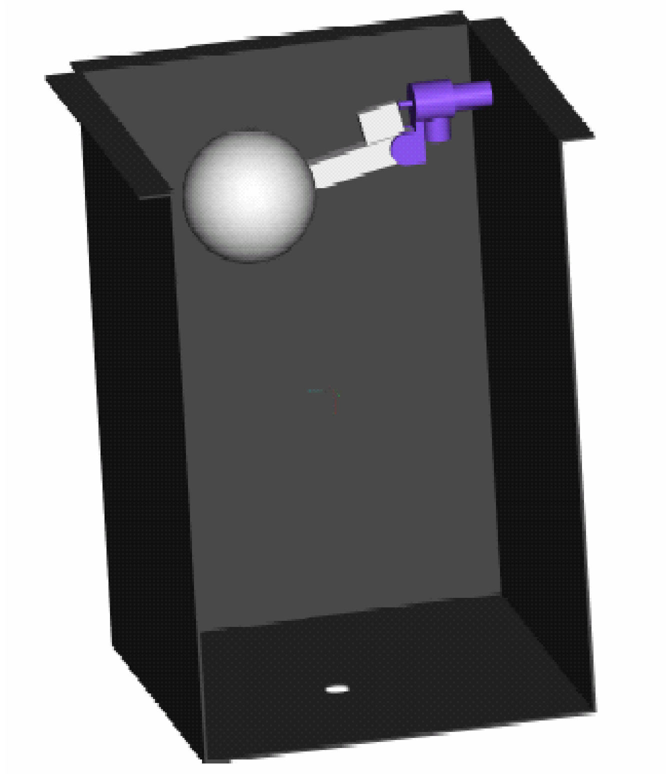


Fig. 4.1 Toilet Flush System attached to the water tank

The spherical object shows in Figure 4.1 is a float attached to a handle. The handle is attached to the rotating axle of the water release catch. The water release catch is fixed to the water tank.

Figure 4.2 shows the spherical float at different position when the water level in the water tank increases or decreases.

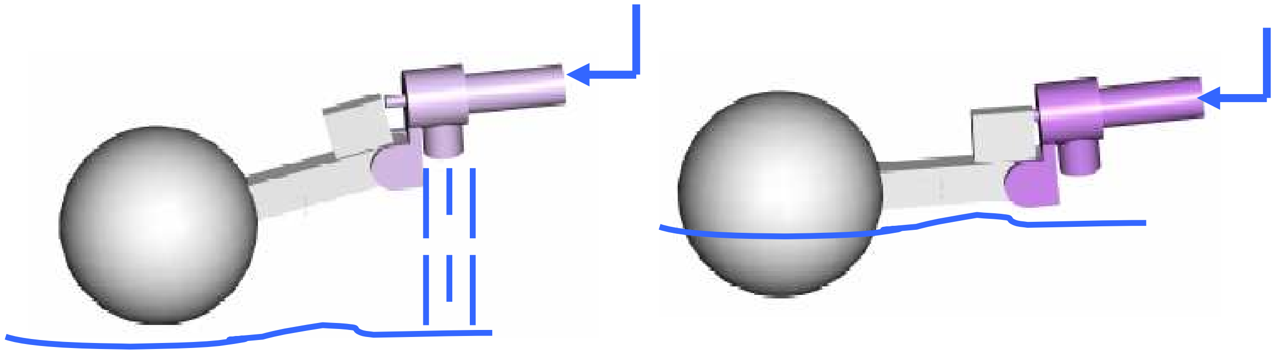


Fig. 4.2 Float position at different water level height

The figure on the left shows that the water level is at slightly low level and the float is hanging freely. The water release catch releases water into the water tank as shown by the three blue downward lines.

The water level in the water tank rises as the water release catch continues to release water. The float will rise with the water level. When the water level rises to the maximum level, the handle attached to the float will press down on the actuator located in the center of the water release catch and stop the discharge of the water.

Whenever the water level becomes low, the float will release the actuator and water will flow from the water release catch.

The main advantage of this design is no water level monitoring time is required. Another advantage is the water tank will be topped up automatically when the water level drops.

The major disadvantage of this design is water leakage cannot be detected. If water leakage present, water level will drop in the water tank and automatically water will be released from the water release catch, therefore water leakage cannot be detected.

4.1.2 Visual Water Level Monitoring Tube

The second design solution is attached a visual water level monitoring tube to the water tank. Figure 4.3 shows a CAD drawing of the visual level monitoring tube attached to the water tank.

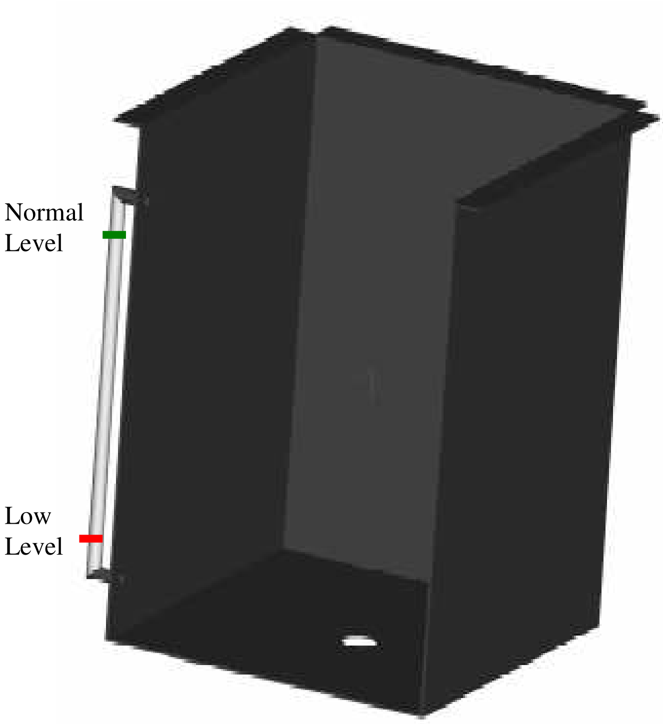


Fig. 4.3 Visual water level monitoring tube

Two indicators are placed onto the visual water level monitoring tube to indicator the water level is at Low or Normal level. When water is present in the water tank, the water level will show on the clear monitoring tube.

Human resource is required to check the water level daily to prevent the water to run dry in the External Chiller. If the water level drops to the low level, water top up is required. Water should be topped up to the normal level as indicator. A water top up check sheet should be provided to monitor the interval of each water top up to detect any water leakage in the cooling system.

The advantage of this design is the elimination of the tedious method of monitoring the water level in the water tank. As discussed in section 2.2.1, a man is required to carry and install a ladder beside the External Chiller, climb up the ladder and measure the water level in the water tank with a measuring tape. With the implementation of the visual water level monitoring tube, the previously method of monitoring can be eliminated and replaced by a man walking up to the External Chiller and check the water level in the monitoring tube.

Together with the implementation of the top up check sheet, this design can have early detection of water leakage in the cooling system to prevent system trip occurring.

The major disadvantage of this design is human resource is still required to check the water level from the monitoring tube daily. Although the time taken required to monitor the water level has decrease significantly, an automatic monitoring device is still preferred.

4.1.3 Water Level Detection Jig with Top up Check Sheet

The third design solution is to build a water level detection jig, independent of the External Chiller. Figure 4.4 shows the CAD drawing of the water level detection jig attached to the water tank.

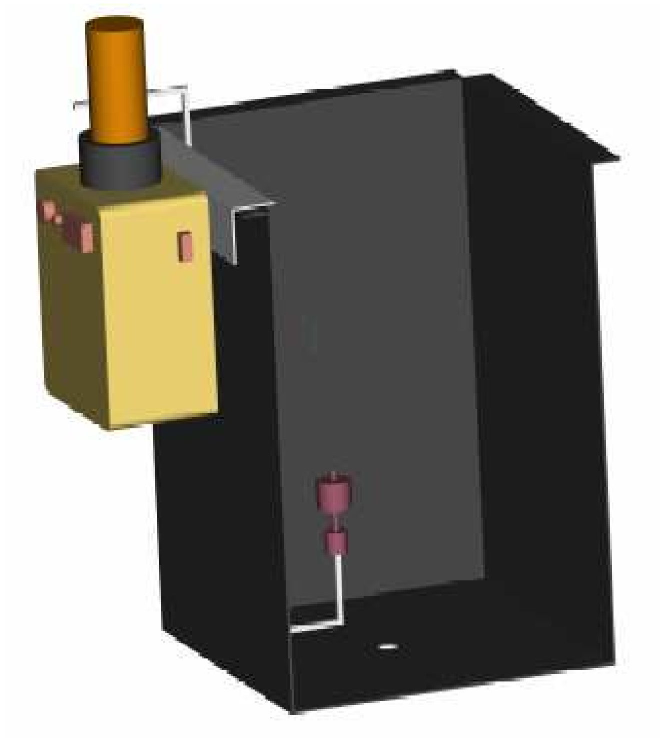


Fig 4.4 Water Level Detection Jig

The water level detection jig consists of a control box, an alarm beacon and a float sensor. The float sensor detects the water level at a height of 100 mm. If the water level is above 100 mm in height, float sensor will not activate. When the water level drops to below 100 mm, the float sensor will activate and send a signal to the control box. The control box will then send a signal to activate the alarm beacon.

When the alarm beacon activated, this represent the water tank needs to be topped up. A man is required to top up water into the water tank to a predefine level and record in the top up check sheet.

The water level detection jig will provide automated water level detection without the use of human resources. It will consists of an alarm to inform users when the water level in the water tank is low. It should be portable and easily maintain. Together with a top up check sheet, it should be able to early detect any water leakage in the cooling system.

The advantage of this design is the elimination of the tedious method of monitoring the water level in the water tank. The monitoring time for monitoring the water level is reduced to zero as the water level detection jig will automatically detect the water level at the low level.

Together with the implementation of the top up check sheet, this design can have early detection of water leakage in the cooling system to prevent system trip occurring.

The disadvantage of this design is the need for periodic maintenance of the water level detection jig annually or half yearly to ensure the functionality of the system.

4.1.4 Countermeasure Selection

Here is a summarize of the advantages and disadvantages of the three possible design solution,

	Eliminates tedious monitoring practice	Reduced monitoring time to zero	Early detection of water leakage	Automatic water top up	Cannot detect water leakage	Water level monitoring required	Periodic maintenance
Toilet Flush System	+	+		+	-		-
Visual Water Level Detection Tube	+		+			-	
Water Level Detection Jig	+	+	+				-

Table 4.1 Summary of the advantages and disadvantages.

Legend
Advantage +
Disadvantage -

Design number 1 and design number 2 does not meet all the requirements of the objectives as stated in section 4.1. Design number 3 meets all the requirements of the objectives.

Design number 3, Water Level Detection Jig with Top up check sheet is the selected countermeasure and will be developed into the Water Leakage Detection System. The design of the water level detection jig will be covered in the section 4.2, 4.3 and 4.4.

4.2 Water Level Detection Jig

The Water Leakage Detection System consists of two design, water level detection jig and water top up check sheet. The design of the water level detection jig will be covered in more details in the subsequent sections. The design of the water top up check sheet will be covered in more details in the section 5.

Figure 4.5 shows the hierarchy of the Water Leakage Detection System.

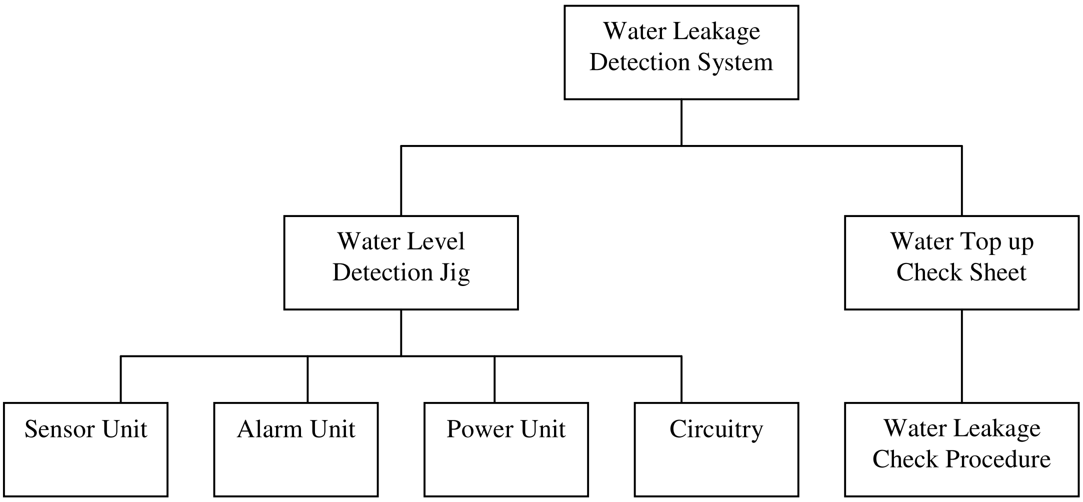


Fig 4.5 Hierarchy of the Water Leakage Detection System

There are four main elements to make up a water level detection jig, sensor unit, alarm unit, power unit and the circuitry. The alarm unit is used to inform users that the water level in the water tank is at low level. The sensor unit is employed to sense the water level in the water tank, send a fail signal when it detects the water level is at low level. The power unit is the unit that will supply electricity to the alarm unit, sensor unit and the circuitry. The circuitry will receive the fail signal from the sensor unit and sends a signal to activate the alarm unit. Figure 4.6 shows the simplified block diagram of the water level detection jig.

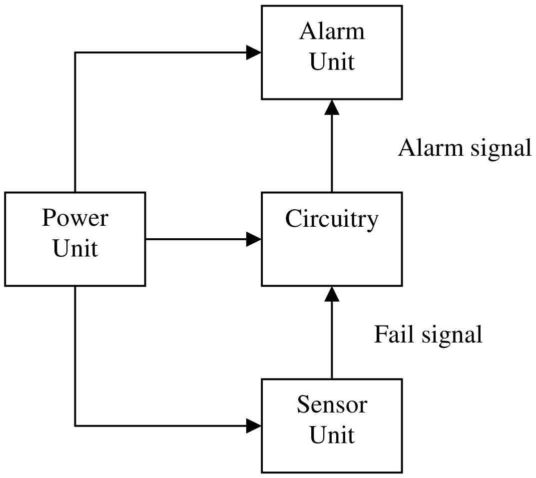


Fig. 4.6 Simplified Block Diagram of the Water Level Detection Jig

The selection of the main elements for the water level detection jig will be covered in section 4.2.1 to section 4.2.4.

4.2.1 Selection of Sensor Part

The sensor unit is the main contact with the water in the water tank. It will detect the water level and output a fail signal to the circuitry when the water level becomes low. It must be accurate and reliable. Figure 4.7 shows the different kinds of sensors to detect water level.

Fig 4.7 Water Level Sensors
(Source: The Control Components Australia 2003)

There are many different kinds of sensors available in the market as shown in Figure 4.7. They can be categorized into 2 main types of sensor, namely, Float sensor and Ultrasonic sensor.

The float sensor can be classified into three groups of sensor, namely, vertical float sensor, horizontal float sensor and multiple level float sensor. As the name implies, it utilizes a float with powerful, permanent magnets and encircle a stationary stem. As the float riser or lowers with the water level, the magnetic field generate from within the float actuates a hermetically sealed, magnetic reed switch mounted within the stem. Thus closing the reed switch to form a short for normally open float sensor or opening the reed switch to form an open loop for normally close float sensor (The Control Components Australia 2003, p. D-1).

Figure 4.8 shows the drawing of a typical vertical float sensor.

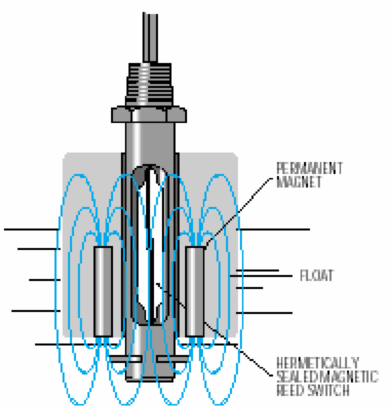


Fig 4.8 Drawing of a typical Vertical Float Sensor
(Source: The Control Components Australia 2003)

The Ultrasonic sensor as the name implies, uses sound wave to detect the water level. The sensor will emits a sound wave and the sound wave will bounce back from the surface of the water and received by the sensor. The sensor then calculates the time taken for the sound wave to travel from the sensor and back, and base on the time taken calculate the distance traveled. And thus compute the water level height. The measurement will be collected at each time interval as specified by users. The Ultrasonic sensor requires calibration with the water level before it can be used. Figure 4.9 shows the ideal position the Ultrasonic sensor should be located in the water tank. The sound path should be perpendicular to the monitored surface, clear of rough walls or other obstructions and clear of the fill path.

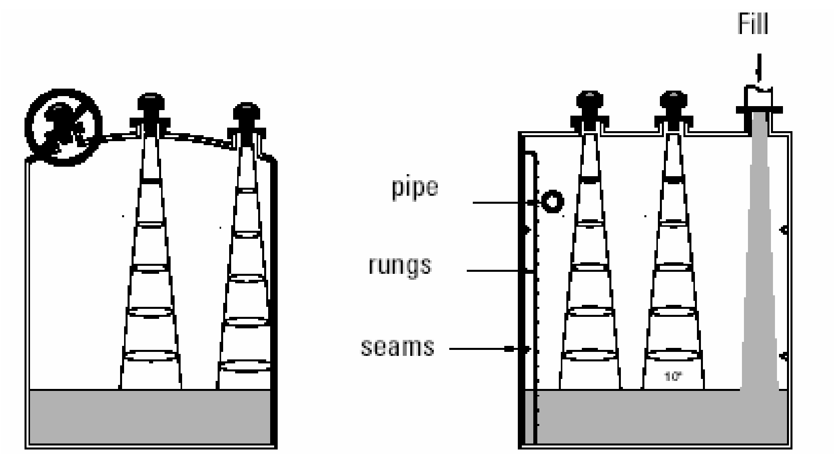


Fig 4.9 Location of the Ultrasonic Sensor
(Source: The Siemens Process Instrumentation 2006)

The water level detection jig does not need high precision device like the Ultrasonic sensor; therefore, a vertical float sensor is used. For the water level detection jig that is currently being design, a single level float sensor is used instead of the multiple level float sensors. Figure 4.10 shows the float sensor used in the water level detection jig. It is a vertical float sensor with its stem and float made of stainless steel material.

Fig 4.10 Vertical Float Sensor

4.2.2 Selection of Alarm Part

The alarm unit is the main media to communicate between the users and the water level detection jig. When the water level is low, the circuitry will send a signal to activate the alarm unit. The alarm unit will notify any person nearby by flashing the light. Figure 4.11 shows three different kinds of alarm available in the market. There is many more alarm available in the market, but for this project only the three alarms shown is considered.

Fig 4.11 From the left, Tower light, Xenon Beacon and Rotating Beacon
(Source: The RS Components Singapore 2006)

The tower light on the left have five different colour lights to represent five different water levels. It will be useful if the water level detection jig can detect 5 different water levels. Currently the water level detection jig in design can only detect a single water level; therefore the tower light is not applicable.

The xenon beacon uses a discharge capacitor operating through a converter circuit ignites xenon gas inside a tube creating a brilliant flash of light. Xenon gas ignites virtually instantaneously so maximum brightness is obtained immediately. Xenon beacon is very efficient; it incorporates a 360-degree light output with the brightest and most effective visual signal (The RS Components Singapore 2006, p. 2).

The rotating beacon uses a parabolic reflector, driven by an electric motor, revolved around a continuously illuminated bulb on the vertical axis of the beacon creating a powerful beam of light traveling through 360-degrees. The rotating beacon is available with either a filament or a tungsten halogen bulb. It has a greater degree of light output than most models, but this is reduced as the parabolic reflector only illuminates one given point at a time (The RS Components Singapore 2006, p. 2).

The xenon beacon is chosen as the alarm unit for the water level detection jig due to its advantage of low current consumption combined with long life.

4.2.3 Selection of Power Source

The power unit is the source of power that will be supplied to the alarm unit, sensor unit and the circuitry. There are currently two possible power source in consideration for the water level detection jig, namely, AC power and battery.

The main advantage of the use of AC power is stable and consistence. Power failure is very seldom occurs in Singapore and the AC power from the power point is very stable with little or no fluctuation. One major disadvantage in using AC power is portability. There will always be a power cord attached to the water level detection jig and there must always be a power point nearby; therefore it is not very portable. Another disadvantage is the requirement of a DC power supply to convert the AC incoming power to a 12 Volts DC supply.

The advantage of the use of battery is portability. No power cord is required and no DC power supply is needed. A 12 volts battery will be able to supply 12 volts DC without any conversion. Therefore the battery is chosen as the power unit of the water level detection jig due to its portability.

There are two groups of battery available in the market. They are non-rechargeable alkaline battery and the rechargeable alkaline battery.
The advantage of non-rechargeable battery is consistent life and consistent power output. The disadvantage of the non-rechargeable battery is the cost of battery replacement.

The advantage of rechargeable battery is no replacement cost. The battery can be recharge for many times. The disadvantage of the rechargeable battery is the power output will drop after each recharge, inconsistent power output.

In view of the above advantages and disadvantages of both the non-rechargeable and recharge battery, non-rechargeable battery is chosen for its reliable power output and its consistent life. Figure 4.12 shows the 12 volts battery that is going to be used in the water level detection circuit.

Fig 4.12 12 Volts Alkaline Battery

4.2.4 Circuit Design

The circuitry is the interface between all the three units. It will receive a fail signal from the sensor unit when detected water level low. After receive the fail signal, it will send a signal to activate the alarm unit to inform users of the water level low. The 12 volts supply will be supply to the circuitry and distributed to the sensor unit and the alarm unit.

The design of the circuitry will be covered in more details in the next section.

4.3 Water Level Detection Circuit Design

The main elements of the water level detection circuit are the float sensor, alarm beacon, battery and the interface circuit. This section will cover the interface circuit design incorporating the float sensor, alarm beacon and the battery.

The circuit design will focus on both the normally open (N.O.) and the normally close (N.C.) float sensor. The battery power source will be 12 volts. The voltage to activate alarm beacon will be 12 volts.

4.3.1 Initial Circuit Design

The initial circuit design is to test out the functionality of the float sensor. The float sensor used in the initial design is a normally open float sensor. Figure 4.13 shows the drawing of the initial circuit design.

The voltage used here is 3 volts dc power source. Instead of the alarm beacon, an LED is used. A resistor, R1, is used to limit the current flow. The resistor value of 270 Ω is used.

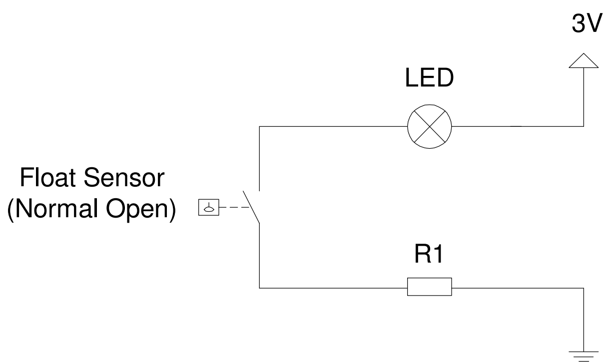


Fig 4.13 Drawing of the initial circuit design

The LED is not activated if the float sensor is not activated. When the float sensor is activated, the float sensor becomes shorted; a 3 volts supply will pass through the LED and the resistor, R1. The LED lights up. The current passing through the LED is calculated as 11 mA.

$$\text{Current, I} = \frac{Voltage}{\text{Re}\,sis\,\tan ce}$$

$$= \frac{3}{270}$$

$$= 11 \text{ mA}$$

From this experiment, the float sensor is verified to be in working condition.

4.3.2 Normally Open Design

The next circuit design is based on the normally open float sensor, 12 volts power source and 12 volts alarm beacon. Figure 4.14 shows the drawing of normally open design circuit. The following are the components used in the design circuit other than the main elements,

1. Two resistors, R1 and R2, 750 KΩ and 270 KΩ respectively;
2. An N-Channel MOSFET, Q1;
3. A latching relay;
4. Two diodes;
5. A fuse;
6. Two push buttons, Reset button and Test button;
7. And a power on switch.

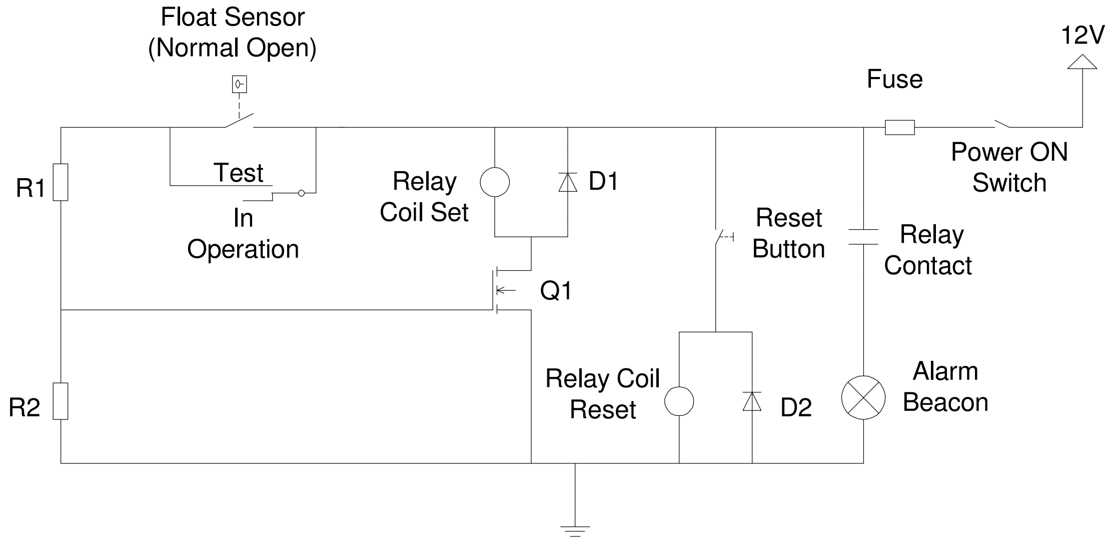


Fig 4.14 Normally Open Float Sensor Circuit Design

When the power on switch is turn on, the circuit is in operation, waiting for the water level to go low. When the water level goes low, the normally open float sensor will be activated and close the circuit. Current will flow through the R1 and R2 resistors. Voltage drop across the R2 resistor will be the Gate-Source Voltage, V_{GS}, required to turn on the N-Channel MOSFET, Q1.

$$V_{GS} = \frac{R2}{R1 + R2} * Voltage$$

$$= \frac{270}{750 + 270} * 12$$

$$= 3.18V$$

Current will flow through the latching relay after Q1 turns on. The latching relay will energized and close the relay contact and activate the alarm beacon.

The latching relay will remain energized even when the power is turn off or when the water was topped up. To reset the latching relay, it is required to press the Reset Button.

The Test Button is added in to let users test the functionality of the circuit. It acts like the float sensor. When the test button is depressed, Q1 will turn on, latching relay will energized and the alarm beacon will be activated. User is required to press the Reset Button to reset the latching relay.

When the alarm is activated, the total current flowing through the circuit is 146.7 mA. The current flowing into the xenon alarm beacon is 130 mA, as specified in the data sheet for xenon alarm in Appendix B-5. A maximum drain current of 0.2 A at a V_{GS} voltage of 3 V, can pass through the N-channel MOSFET, Q1 as specified in the data sheet for the N-Channel MOSFET in Appendix B-6. The latching relay only requires 16.7 mA of current flow to energize the relay, as specified in the data sheet for the latching relay in Appendix B-7. Therefore there is no matching issue with the MOSFET and the latching relay. The current flowing into the two resistors is calculated using ohm's law, a negligible value of 0.012 mA.

$$I_{R1+R2} = \frac{3V}{270K\Omega + 750K\Omega}$$

$$= 0.012 \text{ mA}$$

$$\text{Total Current flow} = I_{XENON\ BEACON} + I_{RELAY} + I_{R1+R2}$$

$$= 130 + 16.7 + 0.012$$

$$= 146.7 \text{ mA}$$

4.3.3 Normally Close Design

The next circuit design is based on the normally close float sensor, 12 volts power source and 12 volts alarm beacon. Figure 4.15 shows the drawing of normally close design circuit. The components used in the normally close circuit design are the same as the normally open circuit design as discussed in section 4.3.2. The different between the normally open design and the normally close design is the location of the test button and the location of the float sensor.

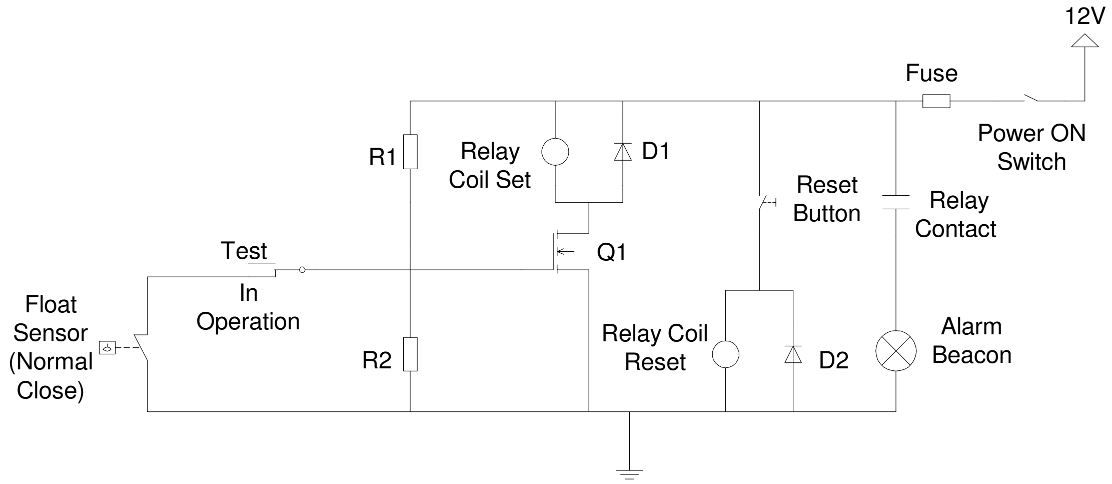


Fig 4.15 Normally Close Float Sensor Circuit Design

The working principle of the above circuit is almost the same as the normally open circuit design as discussed in section 4.3.2. When the power on button is turned on, a current of 0.016 mA will flow through the resistor, R1 and the normally close float sensor and the test button.

$$I_{R1} = \frac{12V}{750K\Omega}$$
$$= 0.016 \text{ mA}$$

When water level low is detected, the float sensor will be activated, float sensor will become open, causing a voltage drop at R2, V_{GS}. The V_{GS} is 3.18V, same as the normally open circuit design. From here on, the working principle is the same as the normally open circuit design as discussed in section 4.3.2. The Q1 will turned on, follow by the latching relay energized and the activation of the alarm.

The latching relay will remain energized until the Reset Button is pressed. The test button resembles a normally close float sensor. When the test button is depress, the open loop will cause the Q1 to turn on, follow by the latching relay energized and the activation of the alarm. User is required to press the Reset Button to reset the latching relay.

As the components used in both the normally open and normally close circuit design are the same, therefore the total current flowing through the circuit when the alarm is activated is the same at 146.7 mA. The difference is there is always an initial current of 0.016 mA flowing in the normally close circuit design.

4.3.4 Final Design Selection

The final design will be selected base on safety and add-on can be easily attached to the circuit. Both the designs are very similar, in the sense that both use the same components and the total current drawn from the battery is the same when the alarm is activated.

The difference between the normally open circuit and the normally close circuit is there is a close loop for the normally close circuit. A current of 0.016 mA is constantly flowing through the normally close circuit. Therefore if the water low level is detected, there will not be a sudden surge of current pumping into the normally close circuit.

As for the normally open circuit, no initial current is supply. If water low level is detected, a surge of current will be pumped into the circuit, at the instance the reed switch in the float sensor closes, sparks might occurred.
For safety reason, the normally close circuit is chosen as the final design. With the normally close circuit, there is another advantage. Add-ons can be easily attached to the circuit. An Omron time counter can be added to the circuit to tell user the time interval between each water top up. Figure 4.16 shows the normally close circuit with the timer counter added on.

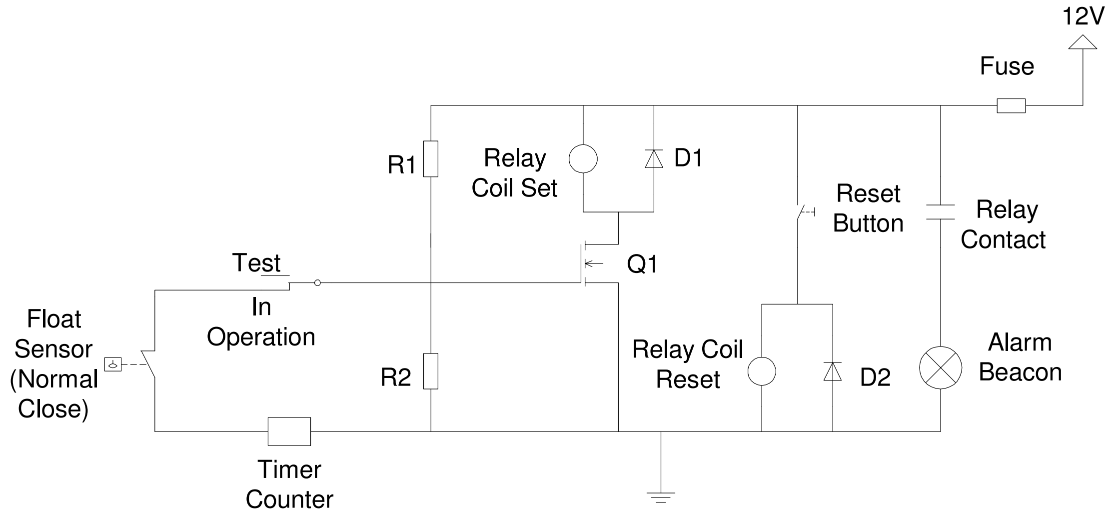


Fig 4.16 Timer counter added into the normally close circuit

4.4 Prototype of the Water Level Detection Jig

With the selection of the sensor unit, alarm unit, power unit and the circuit design, it is time to fabricate into the water level detection jig.

The float sensor has to be placed vertically into the water tank. The float sensor must be secure firmly at a distance of 100 mm from the base of the water tank. A pipe can be used to secure the float sensor to the base of the water tank. Figure 4.17 shows the CAD drawing of the float sensor attached to the brass pipe placed vertically in the water tank.

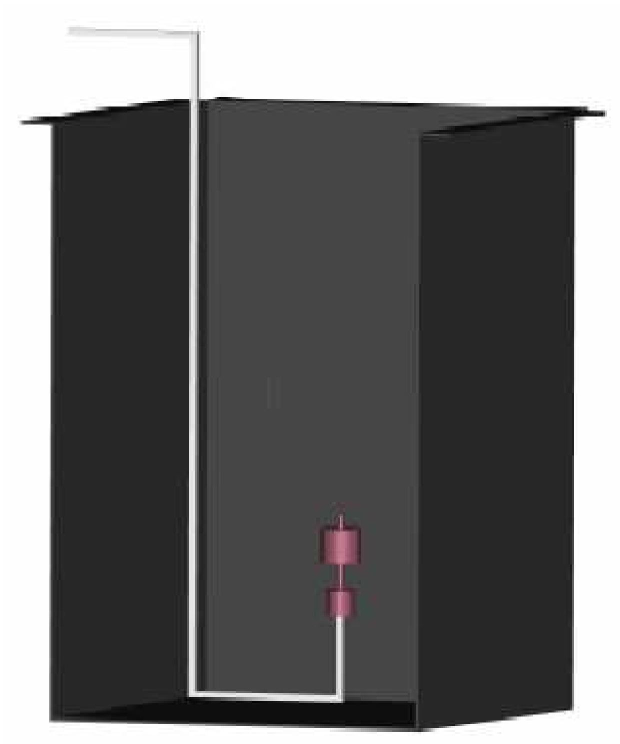


Fig 4.17 Float sensor placed vertically in the water tank

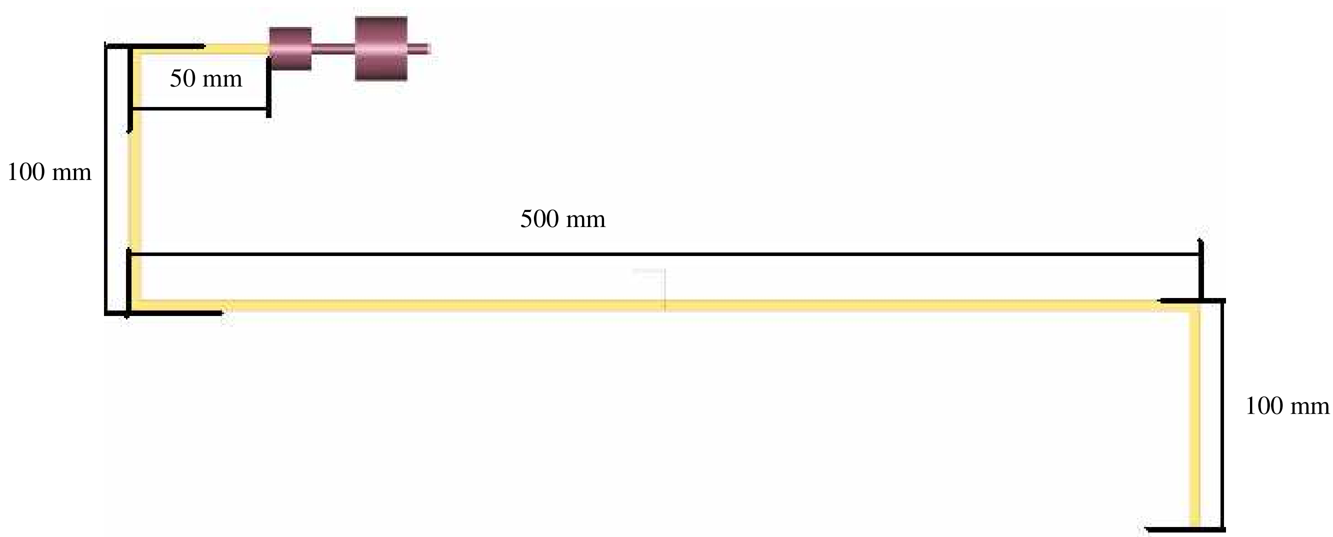


Fig 4.18 Length of brass pipe

The height of the water tank is 460 mm. Therefore a longer mid section is required. Figure 4.18 shows the length of the brass pipe that is required. The total length of the brass pipe required is 750 mm.

A box is required to hold the battery, the circuit design, 3 switches and a timer counter. The dimension of the battery is 136.5 mm by 73 mm by 127 mm as specified in the data sheet of the battery in Appendix B-8. Therefore a box must be larger than the size of the battery. Figure 4.19 shows the CAD drawing of the plastic box with battery, circuit board, 2 switches and a timer counter.

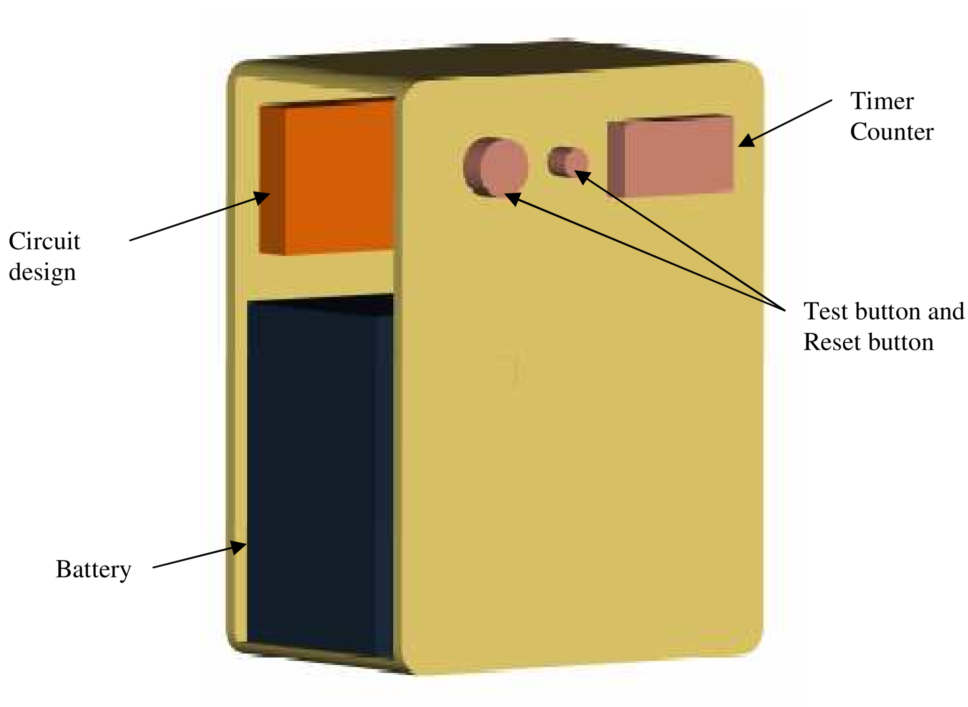


Fig 4.19 Control Box layout

The size of the control box is 150 mm by 100 mm by 200 mm. The material of the control box is plastic, for easy cutting of holes.

The xenon alarm beacon will be placed on top of the control box. Figure 4.20 shows the CAD drawing of the control box with the xenon alarm beacon.

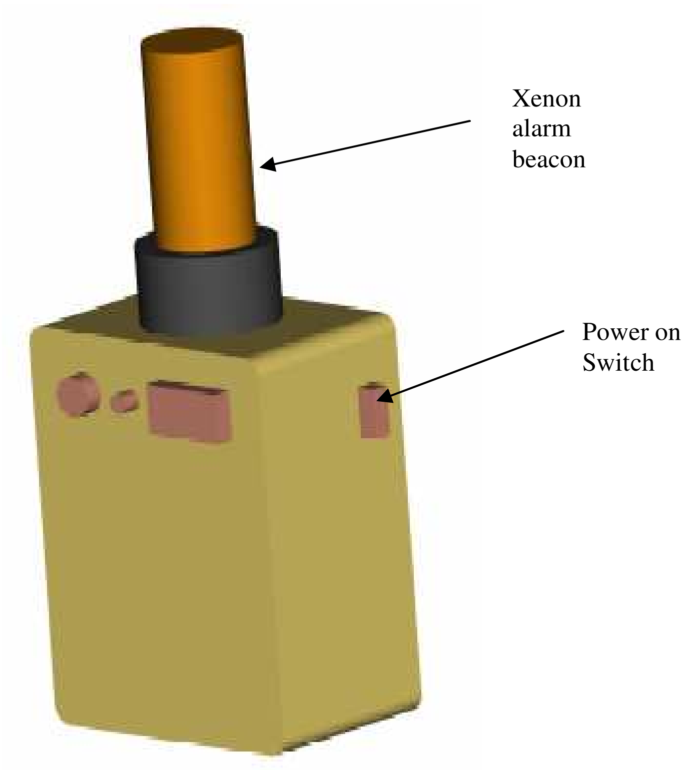


Fig 4.20 Control box with xenon alarm beacon attached

A bracket is required to mount the control box onto the water tank. Figure 4.21 shows the bracket for mounting the control box to the water tank.

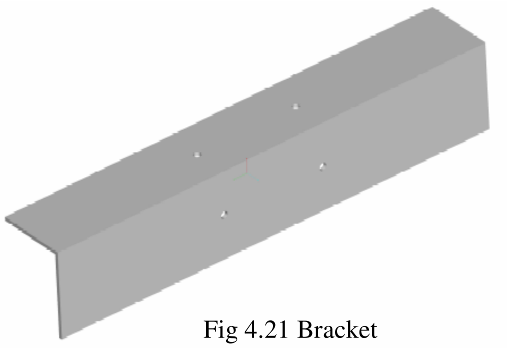


Fig 4.21 Bracket

Assembling all the parts together, the water level detection jig is created. Figure 4.22 shows the picture of the assembled water level detection jig. Figure 4.23 shows the CAD drawing of the assembled water level jig attached to the water tank.

Fig 4.22 Water level detection jig

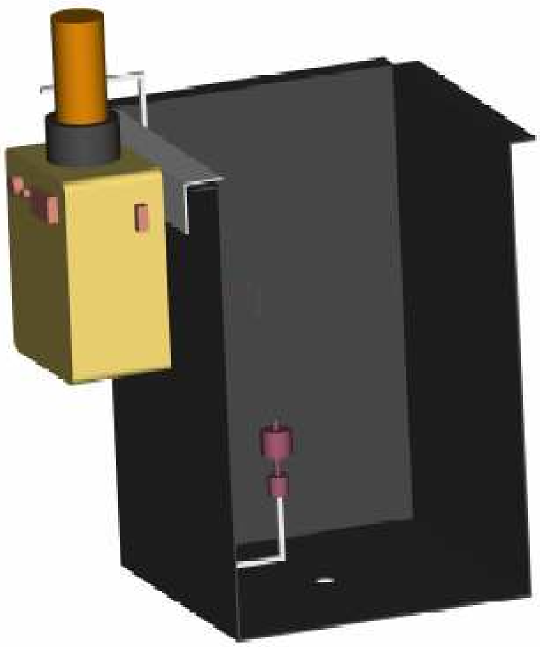


Fig 4.23 Water level detection jig attached to water tank

Figure 4.24 shows the picture of the water level detection jig attached to the water tank.

Fig 4.24 Water level detection jig attached to the water tank

Chapter 5 Designing Top Up Procedure

The water level detection jig as discussed in Section 4 is an electronic gadget to determine the water level in the water tank. It will activate an alarm to alert user to top up the water tank when the water level drops to dangerously low level. It cannot detect the water leakage that might be present in the cooling system.

To aid in the early detection of water leakage in the cooling system, a check sheet is required. This section will discuss the process in designing the water tank top up check sheet.

5.1 Data Requirements

The use of the water tank top up check sheet is to detect any water leakage that is present in the cooling system. There is some specific information required to be collected when the user top up the cooling water in the water tank. The following are information collected during each water top up,

1. Date of Water Top Up - This information is to allow user to compare the present date with the previous water top up date;

2. Hour Meter Information - The data will shows the number of hours the External Cooling Chiller has been running and schedule the next Periodic Maintenance date;

3. Person-in-charge - The person who top up the water in the water tank.

. 5.2 Check Sheet Design

After determine the information required during the water top up action, a check sheet was created, figure 5.1 shows the check sheet design.

Water Tank Top Up Records

No.	Date	Hour as shown on Hour meter	Person-in-Charge	Remarks
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

Fig. 5.1 Preliminary Check Sheet Design

A “Remarks” column is added to allow users to enter any discrepancy occurs, example water leakage present or executing periodic maintenance etc.

Figure 5.2 shows the flow chart of the water leakage detection using the water top up check sheet. Water will be topped up on the first day to a level marked in the water tank at a height of 400 mm measured from the base of the water tank. The date of the water top up will be recorded on the top up check sheet as well as other required information. The external chiller will operate as normal during and after the water top up.

As discussed in section 3.2.1, the water evaporation and usage rate in the water tank is estimated at 2.94 mm per day. It will take an approximately 3 months or more for the water level in the water tank to drop to a height of 100 mm or lower. When the water level in the water tank drops to 100 mm or lower, it will trigger the flow sensor located at a height of 50 mm from the base of the water tank as discussed in section 4.4. The water level detection jig will activate the alarm to alert the user to top up the water tank.

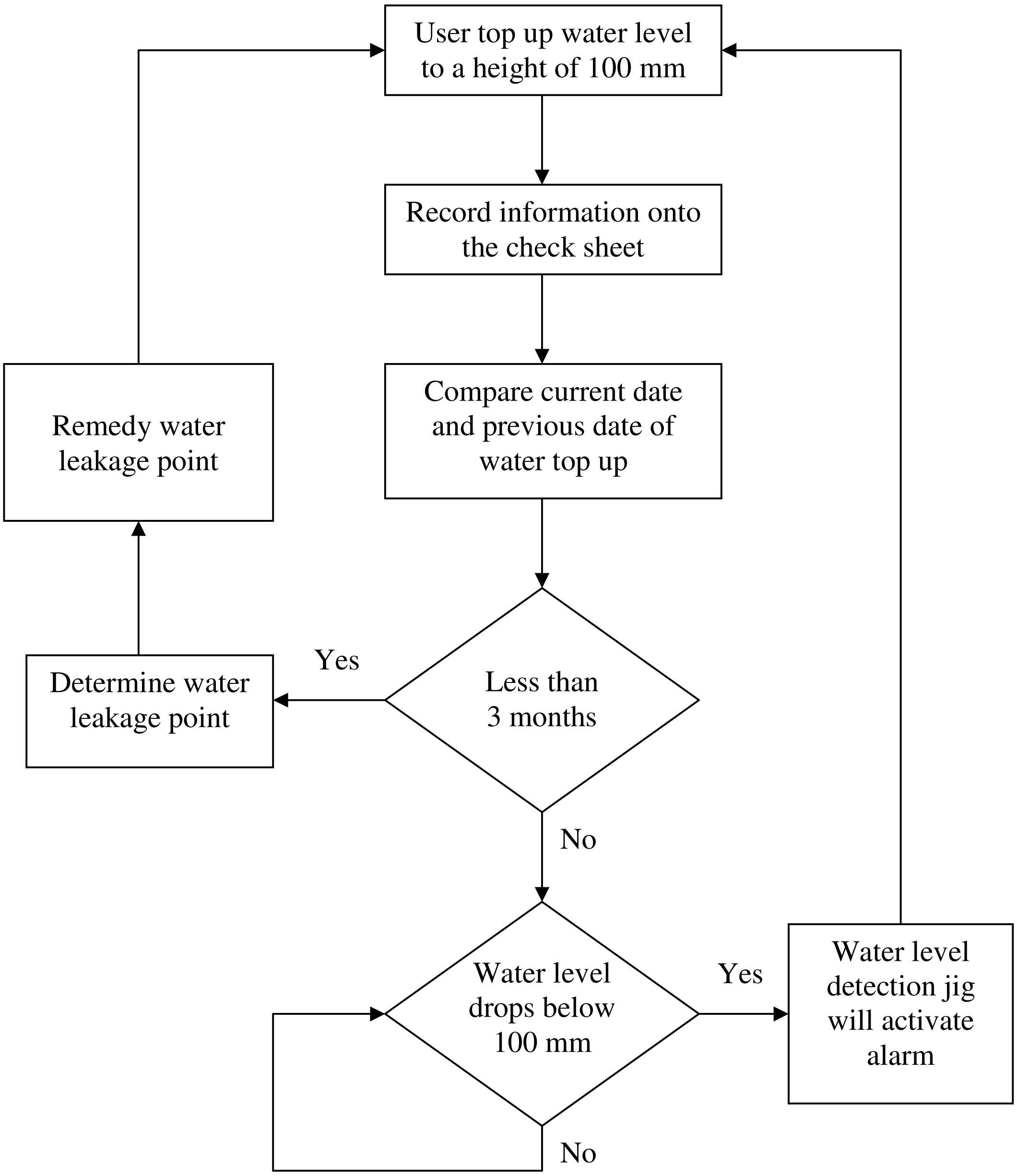


Fig 5.2 Flowchart of the water leakage detection sequence

After user topped up the water level in the water tank to 400 mm level, user will record the date, hour and person-in-charge onto the top up check sheet. User have to compare the date of water top up with the previous top up date, if the difference is more than 3 months, then no water leakage occurs. If the difference is less than 3 months, then water leakage is present. User will be required to determine the leakage point using the water leakage procedure which will be discussed in section 5.5. After remedy the water leakage point, the external chiller can be operated as normal.

In conclusion, using the information recorded during each water tank top up and the water evaporation and usage rate data as discussed in section 3.2.1, early water leakage detection in the cooling system is made possible.

5.3 Placement of Check Sheet

The placement of the water top up check sheet is very important. It must be easily accessible and located at a prominent place, so that user will be happy and oblige to use it. Figure 5.3 shows the prominent location of the check sheet.

Fig 5.3 Prominent location of the check sheet

The water top up check sheet is put inside a plastic folder to water proof the check sheet. The check sheet with the plastic folder is pasted directly under the water level detection jig to remind user to fill up the check sheet after finish topping up the water tank. A pen is also placed beside the check sheet to facilitate user to fill in the required data onto the check sheet.

5.4 Enforcement of Check Sheet

The water top up check sheet is to assist in the early detection of any water leakage present in the cooling system; therefore the information recorded in the check sheet must be very precise and correct at the time of the water top up. User must record each and every water top up performed in the water tank. A single inaccuracy will have disastrous effect on the test system as discussed in section 2.3.

The recording of the water top up check sheet must be enforced at each and every water top up as well as the analysis of the current and previous date of water top up. The following are ways to help in the enforcement of the check sheet,

1. User training , need to educate the user the importance of the check sheet and how to determine if water leakage is present;
2. Warning signs and labels to be placed around the external chiller to alert user to record check sheet after top up water;
3. A reminder is added onto the check sheet to remind user to analysis the information recorded in the check sheet to determine if water leakage is present.

Figure 5.4 shows the new design of the water top up check sheet with a reminder written on the bottom of the check sheet. The reminder reads " Note: When the DATE of the last water top up and the DATE of the current water top up is less than 3 MONTHS, please check for any water leakage. (Follow the Water Leakage Check Procedure)".

Water Tank Top Up Records

No.	Date	Hour as shown on Hour meter	Person-in-Charge	Remarks
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

Note: When the DATE of last water top up and the DATE of current water top up is less than **3 MONTHS**, please check for any water leakage. (Follow the Water Leakage Check Procedure)

Fig 5.4 New design of the water top up check sheet

5.5 Water Leakage Check Procedure

The purpose of the water top up check sheet is to aid in the early detection of water leakage present in the cooling system as discussed in section 5.2. Whereas, the water leakage check procedure is used to confirm and remedy the water leak point. If the difference between the current water top up date and the previous water top up date is less than 3 months, then water leakage is present and user will follow the water leakage check procedure to resolve the water leakage. The water leakage check procedure is shown in Appendix B-6

There are 4 main areas to check for water leakage as shown in the water leakage check procedure. The check points are as follows,

1. Moisture perception alarm generated in the individual tester chiller unit;
2. Water pan in the external chiller and the individual tester chiller unit;
3. Incoming water coupling connected to the individual tester chiller unit;

4. Cooling water pipelines under the floor boards.

5.5.1 Moisture Perception Alarm

Moisture perception alarm is generated by the chiller unit inside the test system. It is generated when water leaked into the chiller unit and contaminated the Flourinert liquid. The problems encountered when the Flourinert liquid is contaminated with water will be discussed in section 6.2.1 as well as the recovery procedure.

5.5.2 Water in the water pan

Water pan are used to collect any water that leaked out from the piping and joints in the chiller unit. All chiller units including the external chiller and the individual tester chiller units have a water pan installed. The water pan is placed at the lowest position of the chiller unit. Figure 5.5 and figure 5.6 shows the location of the water pan in the external chiller and the tester chiller unit respectively.

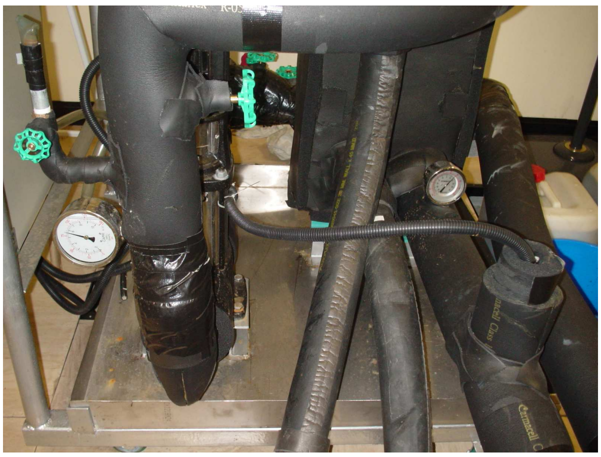


Fig. 5.5 External Chiller Water Pan

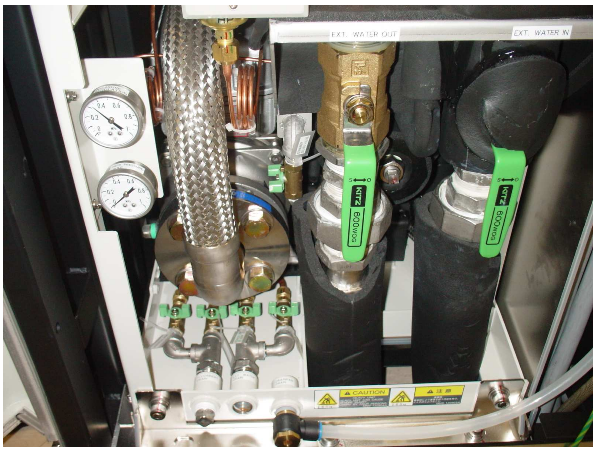


Fig. 5.6 Tester Chiller Unit Water Pan

If water is found in the water pan, that indicates there is a water leakage present in the chiller unit. Using the Chiller Schematics Diagram, trace the water piping and determine the leakage point. Once the leakage point is found, epoxy can be applied to the leak point to stop the leakage.

5.5.3 Incoming water coupling

The incoming cooling water is attached to the tester chiller unit by use of couplings. Figure 5.7 shows the location of the incoming water couplings.

Fig. 5.7 Incoming water couplings

There is a possibility that the coupling is not tighten, so water can leak out from the coupling. Therefore the coupling is one of the main areas to check for water leakage. To resolve the water leakage caused by loosen coupling, use an adjustable wrench to tighten the coupling or rework the coupling.

5.5.4 Cooling water pipelines

There are cooling water pipes lying under the floor boards that transfer cooling water from the external chiller to the individual tester chiller units. In the presence of water leakage, one of the areas to check for leakage is the cooling water pipes.

To check water leakage from the cooling water pipes, firstly is to remove the floor boards with the removal tool. Then visually check for any water puddles formed on the concrete floor around the piping. If found water puddle around one end of the piping, then the leakage is most likely to come from that portion of piping. Next step is to check the piping visually for cracks and seal the cracks with epoxy.

After resolve any water leakage situation, the final steps is to clean up the area and monitor the leakage point for a few days to confirm the water leakage have been contained.

Chapter 6 Safety Precautions and Risk Assessment

People must learn how to work safely to prevent accidents. Carelessness or horseplay causes many accidents. It is sensible to develop safe work habits than to suffer the consequences of an accident. Developing good safety practices should become a habit to be followed on the test floor and should be practiced in everything one does in life.

In this chapter we will discuss on the Warning Labels and their locations. In section 6.2, risk assessment is discussed.

6.1 Warning Labels and Their Locations

The cooling unit in the test system uses warning labels to draw attention in areas where there is possible danger. Here are the definition of the term, Warning, Caution and Note:

WARNING: Misuse of the equipment that comes from neglecting this label may result in minor or even serious injury to the operator.

CAUTION: Misuse of the equipment that comes from neglecting this label may result in damage to the equipment.

NOTE: For safety and the ease of use of the equipment, this draws attention to details essential for understanding equipment operation and functions.

Figure 6.1 to Figure 6.4 shows a list of warning labels and its explanation that can be found in the cooling unit in the test system.

Fig 6.1 Hazardous Voltage

【CAUTION】

Electrical SHOCK HAZARD.

【Explanation】

If Power is ON, DO NOT REMOVE COVER or touch electrical components or terminals

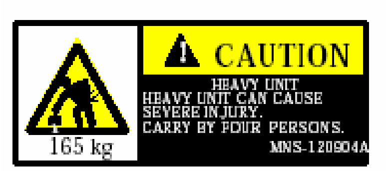


Fig 6.2 Heavy Unit

【CAUTION】

HEAVY UNIT HAZARD.

【Explanation】

Heavy unit can cause severe in jury.

Carry by four persons.

Fig 6.3 Fire Hazard

【WARNING】

FIRE HAZARD.

【Explanation】

Use replacement fuse with same rating and type.

Fig 6.4 Flourinert Hazard

【CAUTION】

Fluorinert may break down at high temperatures.

【Explanation】

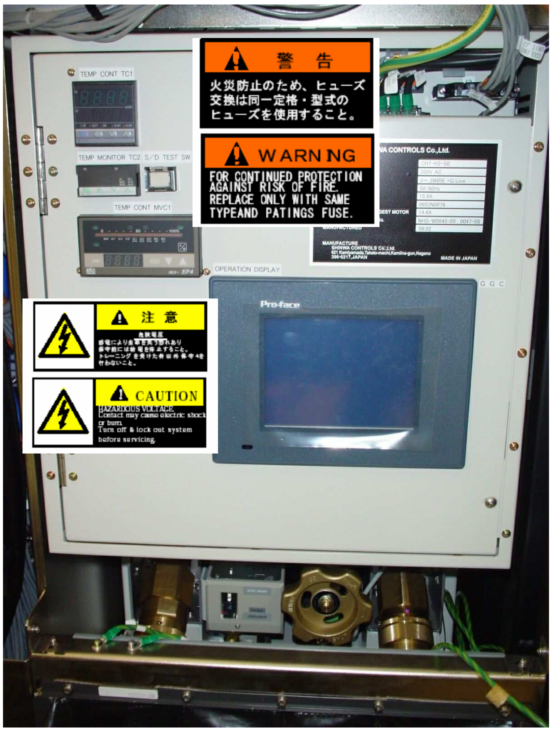
Do NOT breathe, or expose skin to fumes.

Do NOT expose Fluorinert to high temperatures.

Ventilate area well.

Wear safety glasses when handling Fluorinert.

Figure 6.5 shows the locations of the warning labels in the cooling unit in the test system. It is always very important to take note of voltage hazard and heavy unit hazard. It can cause injuries during installation or maintenance works if user is not familiar with the operation of the cooling unit. Users must completely shutdown the test system when performing installation or maintenance works on the cooling unit.



Front of Cooling Unit

Rear of Cooling Unit

Fig 6.5 Location of warning labels in the cooling unit

6.2 Risk Assessment

In the cooling system, there are many risks involve that might have unforeseen effect on the test system. The following are the risks identified,

1) Water contamination.
2) Clogged Strainer.
3) Water quality.
4) Water pressure.

The following sections will give a more detail explanations of each of the risk involved and its' countermeasure, if available.

6.2.1 Water contamination

Water contamination meaning water got mixed with Flourinert liquid in the Cooling Unit. It is a very serious matter. Flourinert liquid is an inert liquid and it flows through the components in the printed circuit board in the test system, whereas water is a conductive liquid, it can transmit electricity. Therefore when water was mixed with Flourinert liquid, the possibility of the water mixture flowing through the components in printed circuit boards is very high. It may cause a short circuit in the test system and test system will shutdown. The boards that are contaminated by the water mixture must be sent for repair immediately.

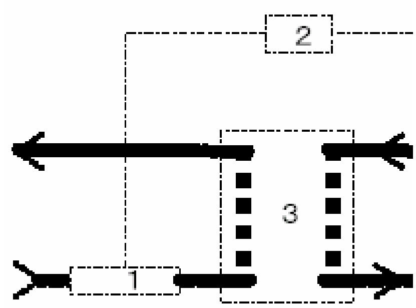
In another scenario, the water mixture didn't cause the test system to trip, but water droplets are introduced and reside in the printed circuit boards. Over prolong period of time, it will cause corrosion on the surface of the printed circuit boards. Failures will starts to appear; then the faulty boards will need to be replaced.

In the worst scenario, the water mixture causes sparks in the printed circuit boards, and the test system will be burnt. This will become a fire hazard.

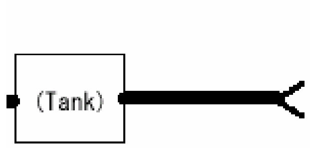
To prevent water mixture to seep into the test system, two water leak sensors are installed.

The location of the water leak sensor is in the Flourinert Tank and Heat exchanger. The purpose of this water leak sensor is to detect the presence of any form of liquid that conducts electricity and immediately send a shutdown signal to the cooling unit to stop the pump. But if user continues to start up the cooling unit for a few times even when the cooling unit is tripped, the water mixture will still be able to seep into the test system to cause problem.

Figure 6.6 shows the location of possible water contamination points in the Cooling Unit.



Heat Exchanger



Flourinert Tank

Fig 6.6 Location of possible water contamination point

There are two possible locations of water contamination points in the Cooling Unit. They are the Heat exchanger and the Flourinert Tank; that is where the two water leak sensor are positioned.

The cause of water contamination in the Flourinert Tank is usually due to users' mistakes. Users are required to top up Flourinert liquid when encountered Flourinert Tank level low in the cooling unit. But instead of Flourinert liquid, they might accidentally pour water or other liquid into the Flourinert Tank and realize their mistake only after they power up the cooling unit. The cooling unit will tripped with error pointing to "Moisture Perception Error".

The cause of water contamination in the Heat exchanger is difficult to trace. The pipelines in the Heat exchanger have very thin walls to ensure the efficiency of the heat transfer. Cracks or holes may be formed in the pipelines of the Heat exchanger, caused by rust corrosion over prolong period of time or unidentified sharp object hitting the walls of the pipelines. External cooling water will leak through the cracks or holes and into the pipelines of the Flourinert liquid. To prevent corrosion to the Heat exchanger, it is recommended to users to change the Heat exchanger after every two years of usage.

The countermeasure to encountering water contamination is never power up cooling unit until recovery is completed. To perform recovery, first, purge out all Flourinert liquid in the Cooling Unit using Dry Nitrogen Gas, 99.9 percent purity, for a day to dry up any water droplets that resides in the Cooling Unit. The second step is to perform leakage check on the Heat exchanger. Remove the external cooling water coupling from the cooling unit. Pump in dry air at a pressure of 0.35 MPa into the external cooling water pipelines in the cooling unit and close all the valves after the pressure is reached. Monitor the external cooling water pressure gauge for 2 hours. If there is no drop in the pressure, then it is confirm that the water leakage is not from the Heat exchanger. The last step is to pour in new Flourinert liquid to power up cooling unit. Do not use the contaminated Flourinert liquid.

6.2.2 Clogged Strainer

A 100 mesh strainer is installed at the external cooling water supply pipeline in the cooling unit in the test system. The purpose of the strainer is to prevent dirt and other unidentified substances from entering into the pipelines and in worst case into the Heat exchanger

Figure 6.7 shows the location of the strainer and its appearance.

Fig 6.7 Strainer location and appearance

Along the route of the external cooling water pipelines, there is a solenoid control valve controlling the amount of water flowing into the Heat exchanger. The solenoid control valve is control by the temperature control unit monitoring the temperature of the Flourinert liquid in circulation in the test system. If the temperature of the Flourinert liquid is above 23.5 °C, then the solenoid valve will open bigger and allow more water to flow into the Heat exchanger. If the temperature is below 23.5 °C, the solenoid valve will close slightly.

If there is no strainer mounted, dirt or other substances will be able to enter the external cooling water pipelines, it will flow through the solenoid control valve, and into the Heat exchanger. If the dirt was deposited on the solenoid control valve plunger, the solenoid valve will be stuck, and the temperature of the Flourinert liquid can never be controlled. In another scenario, if the dirt was to clog the solenoid valve, cooling water cannot circulate, the temperature of the Flourinert liquid will increase and finally damage the components on the printed circuit boards in the test system.

In the worst scenario, the dirt flowed through the solenoid valve and deposit onto the Heat exchanger, and clogged the Heat exchanger; the temperature of the Flourinert liquid will increase and damage the printed circuit boards. A lot of manual work, cutting and welding pipes will be required to replace the Heat exchanger.

That is the importance of the strainer; therefore the strainer must always be mounted onto the cooling unit. The strainer will prevent dirt from entering the external cooling water pipelines. The dirt will accumulate in the strainer. Clogged strainer will have the same effect as the clogged solenoid valve, therefore it is recommended to clean the strainer every half yearly to prevent the strainer from clogging.

Another countermeasure is to ensure the external cooling water is free to dirt or other substances. The external chiller has an open-aired water tank; therefore special care must be taken when working around the water tank. Care must be taken not to deposit any material into the water tank. The water tank must be clean at all times. Periodic maintenance is recommended for the water tank and the strainer.

6.2.3 Water Quality

The external cooling water quality must conform to "Water Quality Guidelines for Refrigerator and Air Conditioning Equipment" (JRA-GL-02-1994) set down by the Japan Refrigeration and Air-conditioning Association. Below shows the items of the "Water Quality Guidelines for Refrigerator and Air Conditioning Equipment" (JRA-GL-02-1994);

Standard Materials

pH (25°C)			: 6.8 to 8.0
Conductivity (25°C)		(µS/cm)	: 400 or less
Chloride ion	Cl^-	($mgCl^-/l$)	: 50 or less
Sulfate ion	SO_4^{2-}	($mgSO_4^{2-}/l$)	: 50 or less
Acid consumption (pH 4.8)		($mgCaCO_3/l$)	: 50 or less
Total hardness		($mgCaCo_3/l$)	: 70 or less

Reference Materials

Iron	Fe	(mgFe/l)	: 1.0 or less
Sulfide ion	S^{2-}	(mgS^{2-}/l)	: No detection
Ammonium ion	NH_4^+	($mgNH_4^+/l$)	: 1.0 or less
Ionized silica	SiO_2	($mgSiO_2/l$)	: 30 or less

If the water quality does not conform to the JRA-GL-02-1994, the external cooling water might react with the piping and rust might form around the solenoid control valve or the Heat exchanger. As discussed in section 6.2.2, if rust formed at the solenoid control valve plunger, the temperature of the Flourinert liquid cannot be controlled. The whole solenoid control valve assembly will need to be replaced and the cooling unit need to be overhauled. If rust formed in the Heat exchanger, cracks might occur and as discussed in section 6.2.1, water contamination will happened.

The countermeasure is to send the external cooling water to a laboratory to be analyzed once every 6 months to ensure the water quality does not drop below the standard.

6.2.4 Water pressure

External cooling water pressure is very critical for the cooling unit in the test system. As stated in the requirement of the external cooling water in Figure 6.8, the minimum differential pressure between the supply pressure and the return pressure must be 0.2 MPa or more.

Requirement of External Cooling Water

Temperature	: 7 °C through 20 °C
Temperature variation	: 1 °C or less per 10 min.
Flow variation	: 5 %/min. or less
Pressure	: 0.2 MPa through 0.7 MPa
Return Pressure	: 0.3 MPa or less

Note: The return pressure must be at least 0.2 MPa lower than the pressure used to supply the cooling water.

Fig 6.8 Requirement of the External Cooling Water

If the external cooling water pressure is not stable, it could cause the cooling unit to malfunction, causing the temperature of the Flourinert liquid to fluctuate. The accuracy of the test system might be affected and in worst case, the test system will trip.

The problem encountered that cause the unstable external cooling water pressure is trapped air bubble exists in the external cooling water piping. The countermeasure is to remove the air bubble from the external cooling water piping by purging the external chiller unit. A valve is installed in the external chiller for this purpose. It is recommended to perform water pressure check during periodic maintenance of the external chiller.

Chapter 7 Implementation Results

The design of the water leakage detection system which incorporates the water level detection jig and the water top up check sheet was completed in mid August. The evaluation of the water leakage detection system was commenced right after it was implemented onto the external chiller.

Three months had past since the evaluation started; the results from this evaluation will be discussed in the next two sections.

7.1 Reduced Monitoring Time

On 14th August, the water leakage detection system was implemented onto the external chiller. Water in the water tank was topped up to a marked height of 400 mm from the base of the water tank. Data was recorded onto the water top up check sheet.

The water level detection jig alarm was activated once on 20th November. It was due to the water level in the water tank drop to below 100 mm. Water was again being topped up to the marked height in the water tank. The water top up data was recorded in the check sheet as shown in figure 7.1.

In the remarks column of the check sheet shown in figure 7.1, it is written “Water Top Up”, no suspect of water leakage. The reason is due to the difference between the date of the current water top up and the previous water top up is more than three months; this implies that the water reduction rate in the water tank is normal, only due to water evaporation and water usage in the cooling system.

Water Tank Top Up Records

No.	Date	Hour as shown on Hour meter	Person-in-Charge	Remarks
1	14/08/06	0000	CHAN SIEW YUEN	INITIAL WATER TOP UP
2	20/11/06	2354	MARK LOH	WATER TOP UP
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

Note: When the DATE of last water top up and the DATE of current water top up is less than **3 MONTHS**, please check for any water leakage. (Follow the Water Leakage Check Procedure)

Fig 7.1 Water Top Up Check Sheet Data

Water level monitoring by user was not required for the duration of the three months of evaluation. The water leakage detection system had resolved one of the problems that were discussed in section 2.

As discussed in section 2.2, the procedure to perform the water level monitoring is very tedious and time consuming. One man was required to set up a foldable three step ladder, climb on top of the ladder and measure the water level with the use of a measuring tape and return the ladder to store room after use.

The time taken to perform the water level monitoring per day is approximately 10 minutes. It was a requirement to perform the check daily and the total number of hours spent to monitor the water level in the water tank for a year was approximately 60.8 hours.

With the implementation of the water leakage detection system, the total number of hours for monitoring the water level for a year is reduced to zero. The method in the monitoring of the water level is changed from human approach to automated alarm system; hence the implementation of the water leakage detection system also eliminates the previous tedious checking method. With the time reduction in monitoring the water level, the total cost saving for a year will be $9728 as calculated in section 2.2.2.

7.2 No System Trip Encountered

As discussed in section 2.3, another problem that might occur prior to the implementation of the water leakage detection system is test system trip due to water leakage in the cooling system.

If there is a water leakage somewhere in the cooling system, the water level in the water tank will drop until no more water can be supplied into the cooling system. This will cause the test system chiller unit to malfunction, temperature of Flourinert liquid will increase and finally the test system will trip. The time taken to recovery the test system will be very time consuming, not including the cost of failure board replacement.

There is no water leakage detection previously. To prevent the water to run dry in the water tank, one man was required to monitor the water level at a daily basis. Water was topped up into the water tank whenever the man thinks it is necessary. There was only one guideline in monitoring the water level, “Top up water when the water level is below the 200 mm mark”. There is still a risk of system trip if the water leakage is massive, the water might run dry in a single day.

With the implementation of the water leakage detection system, user should be able to detect water leakage in the cooling system at the early stage with the use of the water top up check sheet and hence remedy the water leakage before it gets serious.

For the duration of the evaluation of the water leakage detection system, there is no water leakage encountered.

In conclusion, the results from the evaluation of the water leakage detection system are good. The water leakage detection system was able to attain the objective of monitoring time reduction and prevent problems, like system trip from occurring.

Chapter 8 Conclusion

There are two main objectives that this project is required to fulfill, they are as follows,

1. To reduce the water level monitoring time;
2. To detect water leakage in the cooling system before test system trips.

As mentioned in section 7, the water leakage detection system has cut down the water level monitoring time to zero and it is able to detect water leakage during every water top up.

In conclusion, the water leakage detection system has satisfied all the objectives set out and the following is the development cost for the water level detection jig,

Cost Work Sheet for the Water Level Detection Jig			
Item No.	Description	Unit Cost (S$)	Total Cost (S$)
1	High Visibility Flashing Xenon Beacon	77.00	77.00
2	12 Volts 13000 mAh Battery	56.00	56.00
3	Bare PCB (300mm x 200mm)	11.00	11.00
4	Latching Type Relay	14.00	14.00
5	Enhancement N-Channel MOSFET	1.50	1.50
6	Diode	0.50	1.00
7	Resistor (270 Kohms & 750 Kohms)	0.50	1.00
8	Two-position Selector Switch	13.00	13.00
9	Push Button Switch	10.00	20.00
10	Bronze Pipe (1m)	5.00	5.00
11	Normally Closed Float Sensor	50.00	50.00
12	Omron Timer Counter	78.00	78.00
13	Metal L-Shaped Bracket	15.00	15.00
14	Control Box Casing (150mm x 100mm x 200mm)	23.00	23.00
Total Cost of Jig			365.50

Table 8.1 Total Cost of the Water Level Detection Jig

From previously 10 minutes per day of monitoring time, the water leakage detection system had reduced the monitoring time to zero per day; that means a saving of 60.8 hours per year, which is equivalent to S$9728 cost saving per year.

With the implementation of the water leakage detection system, which costs an estimated of S$365.50, it can:

1. Save the user a total of S$9728 per year;
2. Eliminates the tedious method of checking water level;
3. Prevent test system trips due to water leakage;
4. Increase user satisfaction.

8.1 Future Development

There can be more improvement and development for the water leakage detection system. Current water leakage detection system can detect water level low in the water tank and can detect water leakage in the cooling system during every water top up.

If given more time and a bigger budget, the water leakage detection system could be developed into a fully automatic leakage detection system with the use of Programmable Logic Controller (PLC). The use of water top up check sheet could be omitted.

With the use of the PLC, the water level could be monitored daily and if water level drops more than 5mm per day, then an alarm may be activated to alert user that a water leakage is present. This could help to detect water leakage at its earliest stage. Then user can immediately remedy the leakage before any other problem can surface.

If possible, the PLC could be link to the Toilet Flush System as mentioned in section 4.1.1; when the water level drops to low level without activating the leakage alarm, the PLC could activate the Toilet Flush System to top up the water to its full level in the water tank. This will further eliminate the necessity of topping up the water by user. The water leakage detection system could then be termed as a fully automated system

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Appendix A-1:

Project Specification

University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG 4111/4112 Research Project
PROJECT SPECIFICATION

For: Chan Siew Yuen (0050015417)

Topic: Water Leakage Detection Circuit in External Chiller Unit

Supervisors: Dr. Wang Hao

Enrolment: ENG 4111-S1, X, 2006
ENG 4112-S2, X, 2006

Project Aim: To design an electrical circuit to detect water level in the Water Tank of the external Chiller to sound an alarm when the cooling water is very low and establish a system to detect water leakage.

Sponsorship: Employer

Approaches: Issue A, 31st March 2006

1. Research on how the Cooling Unit in the Advantest Tester operate and from there determine the critical point where cooling water might leak into the Flourinert liquid. Research on how the External Chiller operate and the route the cooling water flows.
2. Research on water evaporation rate under different condition and determine the rate at which cooling water level is dropping in the Water Tank. Analysis possible ways to decrease the water evaporation rate in the Water Tank.
3. Design a water level detection circuit to sound an alarm when the water level is low. Determine the component required and source for the required components. Build the water level detection circuit.
4. Trail run the water level detection circuit outside the Water Tank and evaluate the outcome of the water level detection circuit. If the result is not satisfactory, redesign the water level detection circuit.
5. Design a system whereby we can monitor the water level in the Water Tank and determine if a leakage is present.
6. Evaluate the water level detection circuit combine with the water level monitor system to prevent water level to drop to very low level or to determine water when water leakage is present.

As time permits:

7. Improve the water level detection circuit to detect various level in the system and output the information visually.

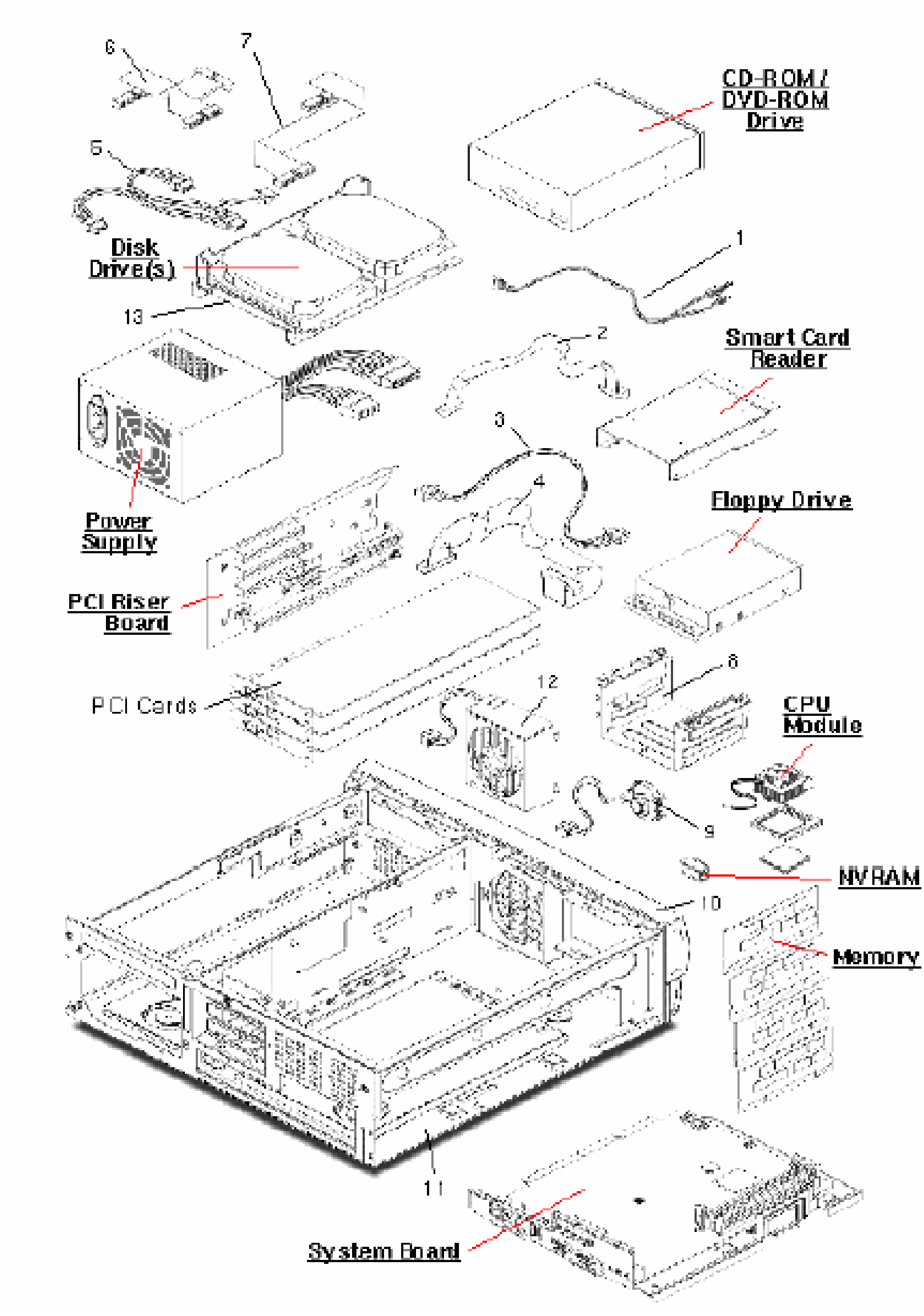
8. Design an automatic water leakage device

Agreed:
Chan Siew Yuen (Student)
31st March 2006

Dr. Wang Hao (Supervisor)

Appendix B-1:

Exploded view of the Engineering Work Station


6
7
CD-ROM / DVD-ROM Drive
5
Disk Drive(s)
1
13
2
Smart Card Reader
3
Power Supply
4
Floppy Drive
PCI Riser Board
8
12
PCI Cards
CPU Module
9
NVRAM
10
Memory
11
System Board

Appendix B-2:

Data Collection from the Actual Water Tank

No.	Day	Date	Level (mm)
1	1	03-Apr	380
2	4	06-Apr	367
3	8	10-Apr	358
4	11	13-Apr	349
5	15	17-Apr	332
6	18	20-Apr	327
7	22	24-Apr	317
8	25	27-Apr	304
9	30	02-May	287
10	32	04-May	282
11	36	08-May	278
12	39	11-May	263
13	43	15-May	250
14	46	18-May	245

No.	Day	Date	Level (mm)
15	50	22-May	232
16	53	25-May	223
17	57	29-May	213
18	60	01-Jun	202
19	64	05-Jun	186
20	67	08-Jun	181
21	71	12-Jun	171
22	74	15-Jun	163
23	78	19-Jun	150
24	81	22-Jun	136
25	85	26-Jun	126
26	88	29-Jun	121
27	92	03-Jul	108
28	95	06-Jul	94

Appendix B-3:

Data Collection from the Pail A near the Water Tank

No.	Day	Date	Level (mm)
1	1	03-Apr	280
2	4	06-Apr	272
3	8	10-Apr	267
4	11	13-Apr	260
5	15	17-Apr	247
6	18	20-Apr	243
7	22	24-Apr	234
8	25	27-Apr	229
9	30	02-May	220
10	32	04-May	211
11	36	08-May	203
12	39	11-May	196
13	43	15-May	187
14	46	18-May	183

No.	Day	Date	Level (mm)
15	50	22-May	176
16	53	25-May	169
17	57	29-May	157
18	60	01-Jun	150
19	64	05-Jun	140
20	67	08-Jun	136
21	71	12-Jun	129
22	74	15-Jun	120
23	78	19-Jun	115
24	81	22-Jun	105
25	85	26-Jun	95
26	88	29-Jun	85
27	92	03-Jul	81
28	95	06-Jul	75

Appendix B-4:

Data Collection from the Pail B away from the Water Tank

No.	Day	Date	Level (mm)
1	1	03-Apr	280
2	4	06-Apr	275
3	8	10-Apr	265
4	11	13-Apr	261
5	15	17-Apr	257
6	18	20-Apr	254
7	22	24-Apr	244
8	25	27-Apr	237
9	30	02-May	233
10	32	04-May	228
11	36	08-May	220
12	39	11-May	213
13	43	15-May	210
14	46	18-May	206

No.	Day	Date	Level (mm)
15	50	22-May	196
16	53	25-May	193
17	57	29-May	187
18	60	01-Jun	183
19	64	05-Jun	174
20	67	08-Jun	170
21	71	12-Jun	161
22	74	15-Jun	156
23	78	19-Jun	152
24	81	22-Jun	148
25	85	26-Jun	138
26	88	29-Jun	131
27	92	03-Jul	127
28	95	06-Jul	123

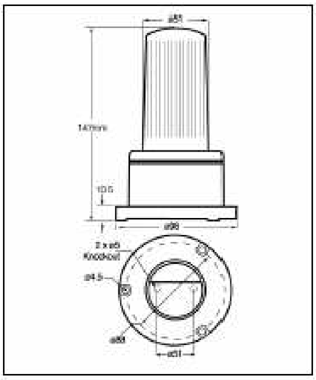
Appendix B-5:

Data sheet for Xenon Alarm

XENON BEACONS

Code No:	Voltage:	Light Source:	Current:
X125-60	12v Dc ---	Xenon 2.0 J	130mA
X125-61	24v Dc ---	Xenon 2.0 J	130mA
X125-62	115v Ac ~	Xenon 2.3 J	30mA
X125-63	230v Ac ~	Xenon 2.7 J	21mA
X125-64	10-100v Dc --- 20-72v Ac ~	Xenon 2.0 J	130mA •

• at 24v Dc



01 02 03 04 05

f.p.m. 60 | °C -25+66 | IP 65 | /60 Hz | Kg 0.25

Appendix B-6:

Data sheet for the N-Channel MOSFET

N-Channel 20–V (D–S) MOSFET

PRODUCT SUMMARY			
$V_{(BR)DSS}$ Min (V)	$r_{DS(on)}$ Max (Ω)	$V_{GS(th)}$ (V)	I_D (A)
20	1.0 @ V_{GS} = 10 V	1.0 to 3.0	0.39
	1.4 @ V_{GS} = 4.5 V		

FEATURES

- Low On-Resistance: 0.75 Ω
- Low Threshold: <1.75 V
- Low Input Capacitance: 65 pF
- Fast Switching Speed: 15 ns
- Low Input and Output Leakage

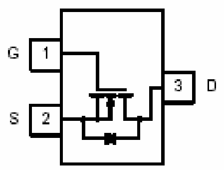
BENEFITS

- Low Offset Voltage
- Low-Voltage Operation
- Easily Driven Without Buffer
- High-Speed Circuits
- Low Error Voltage

APPLICATIONS

- Direct Logic-Level Interface: TTL/CMOS
- Drivers: Relays, Solenoids, Lamps, Hammers, Displays, Memories, Transistors, etc.
- Battery Operated Systems
- Solid-State Relays

TO-236
(SOT-23)



Top View

Marking Code: N1wll
N1 = Part Number Code for TN0201T
w = Week Code
ll = Lot Traceability

ABSOLUTE MAXIMUM RATINGS (T_A = 25°C UNLESS OTHERWISE NOTED)				
Parameter		Symbol	Limit	Unit
Drain-Source Voltage		V_{DS}	20	V
Gate-Source Voltage		V_{GS}	±20	
Continuous Drain Current (T_J = 150°C)	T_A= 25°C	I_D	0.39	A
	T_A= 70°C		0.25	
Pulsed Drain Current[a]		I_{DM}	0.75	
Power Dissipation	T_A= 25°C	P_D	0.35	W
	T_A= 70°C		0.22	
Thermal Resistance, Junction-to-Ambient		R_{thJA}	357	°C/W
Operating Junction and Storage Temperature Range		T_J, T_{stg}	–55 to 150	°C

Notes
a. Pulse width limited by maximum junction temperature.

SPECIFICATIONS (T_A = 25°C UNLESS OTHERWISE NOTED)			Limits			
Parameter	Symbol	Test Conditions	Min	Typ[a]	Max	Unit
Static						
Drain-Source Breakdown Voltage	$V_{(BR)DSS}$	V_{GS} = 0 V, I_D = 10 μA	20	40		V
Gate-Threshold Voltage	$V_{GS(th)}$	V_{DS} = V_{GS}, I_D = 0.25 mA	1.0	1.90	3.0	V
Gate-Body Leakage	I_{GSS}	V_{DS} = 0 V, V_{GS} = ±20 V			± 100	nA
Zero Gate Voltage Drain Current	I_{DSS}	V_{DS} = 16 V, V_{GS} = 0 V			1	μA
		V_{DS} = 14 V, V_{GS} = 0 V, T_J = 55°C			10	
On-State Drain Current[b]	$I_{D(on)}$	V_{DS} = 10 V, V_{GS} = 10 V	0.5	0.75		A
Drain-Source On-Resistance[b]	$r_{DS(on)}$	V_{GS} = 4.5 V, I_D = 0.1 A		1	1.4	Ω
		V_{GS} = 10 V, I_D = 0.3 A		0.75	1.0	
Forward Transconductance[b]	g_{fs}	V_{DS} = 10 V, I_D = 0.2 A		450		mS
Diode Forward Voltage	V_{SD}	I_S = 0.3 A, V_{GS} = 0 V		0.85		V
Dynamic[a]						
Total Gate Charge	Q_g	V_{DS} = 16 V, V_{GS} = 10 V, I_D ≅ 0.3 A		1400		pC
Gate-Source Charge	Q_{gs}			300		
Gate-Drain Charge	Q_{gd}			200		
Input Capacitance	C_{iss}	V_{DS} = 15 V, V_{GS} = 0 V, f = 1 MHz		65		pF
Output Capacitance	C_{oss}			35		
Reverse Transfer Capacitance	C_{rss}			6		
Switching[a, c]						
Turn-On Time	$t_{d(on)}$	V_{DD} = 15 V, R_L = 50 Ω, I_D ≅ 0.3 A, V_{GEN} = 10 V, R_G = 6 Ω		5		ns
	t_r			10		
Turn-Off Time	$t_{d(off)}$			12		
	t_f			6		

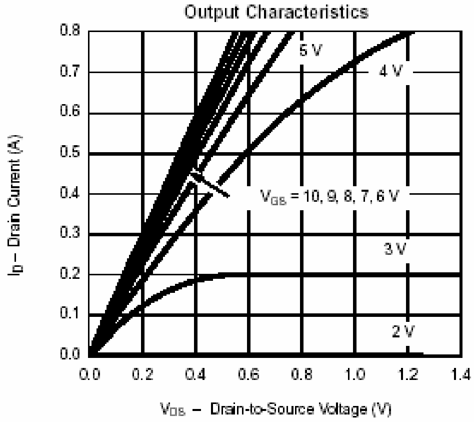
Notes
a. For DESIGN AID ONLY, not subject to production testing.
b. Pulse test: PW ≤ 300 μs duty cycle ≤ 2%.
c. Switching time is essentially independent of operating temperature.

VNBP02

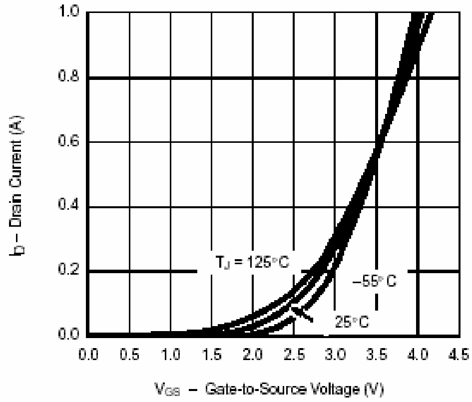
Document Number: 70200
S-04279—Rev. E, 16-Jul-01

TYPICAL CHARACTERISTICS (T_A = 25°C UNLESS OTHERWISE NOTED)

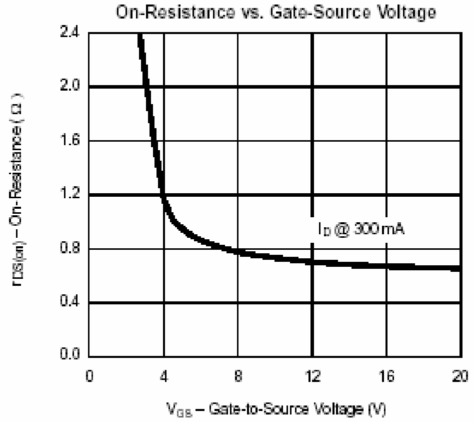
Output Characteristics



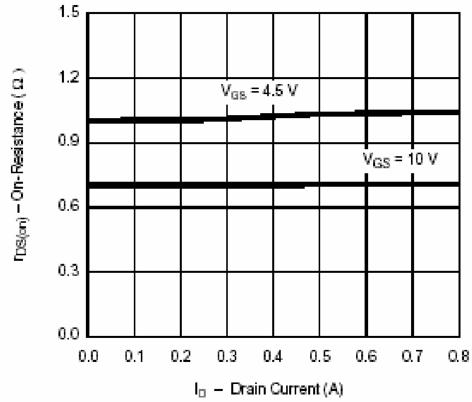
Transfer Characteristics



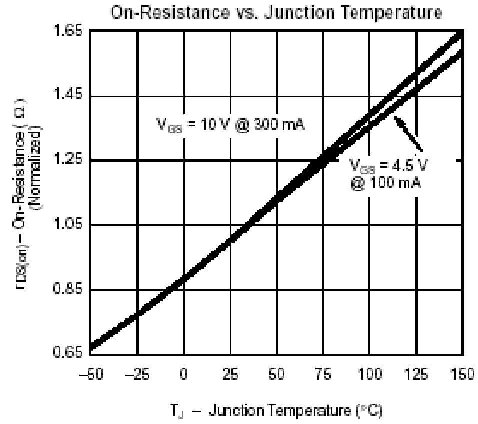
On-Resistance vs. Gate-Source Voltage



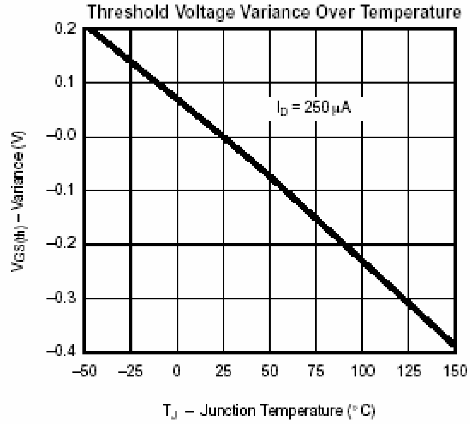
On-Resistance vs. Drain Current



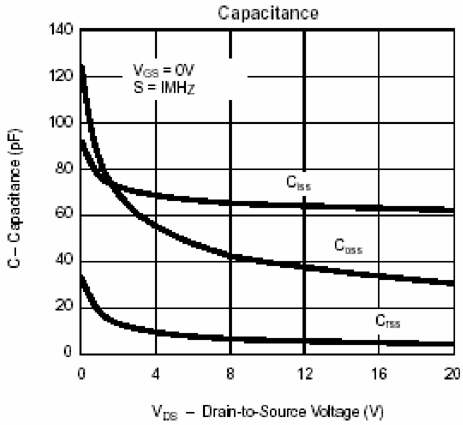
On-Resistance vs. Junction Temperature

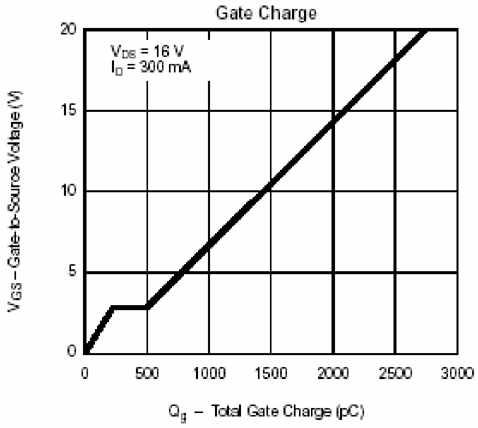


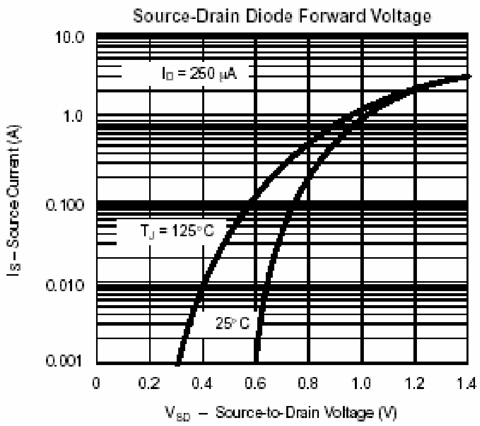
Threshold Voltage Variance Over Temperature



TYPICAL CHARACTERISTICS (T_A = 25°C UNLESS OTHERWISE NOTED)







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Appendix B-7:

Data sheet for the Latching Relay

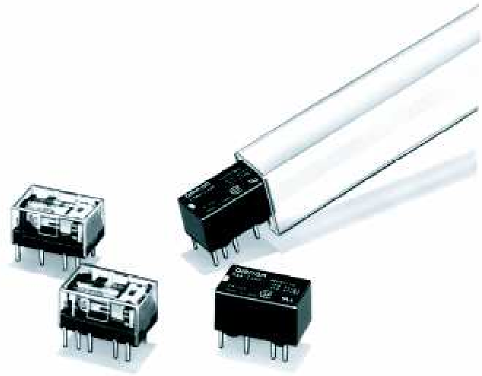
OMRON

PCB Relay

G5A

Subminiature Relay (16 x 9.9 x 8.4 mm (L x W x H)) with DPDT Contact

- Unique moving-loop armature reduces relay size, magnetic interference and contact bounce time.
- Miniature permissible load: 0.01 mA 10 mVDC.
- Bifurcated gold-clad crossbar contact.
- International 2.54-mm terminal pitch.
- Special models available for FCC Part 68 compliance.



FCC

Ordering Information

Classification		Single-side stable	Single-winding latching	Double-winding latching
DPDT	Fully sealed	G5A-234P	G5AU-234P	G5AK-234P

Note: When ordering, add the rated coil voltage to the model number.
Example: G5A-234P 12 VDC
(12 VDC: Rated coil voltage)

Model Number Legend

G5A □ - □ □ □ □ - □ □ **VDC**
1 2 3 4 5 6 7

1. **Relay Function**
   None: Single-side stable
   U: Single-winding latching
   K: Double-winding latching
2. **Contact Form**
   2: DPDT
3. **Contact Type**
   3: Bifurcated crossbar Ag (Au-clad)
4. **Enclosure Ratings**
   4: Fully sealed
5. **Terminals**
   P: Straight PCB
   C: Self-clinching PCB
6. **Special Function**
   None: General-purpose
   FC: FCC part 68 compliance
   U: For ultrasonically cleanable
7. **Rated Coil Voltage**
   3, 5, 6, 9, 12, 24, 48 VDC

Specifications

■ Coil Ratings

Single–side Stable Types

Rated voltage		3 VDC	5 VDC	6 VDC	9 VDC	12 VDC	24 VDC	48 VDC
Rated current		66.7 mA	40 mA	33.3 mA	22.2 mA	16.7 mA	8.3 mA	5.8 mA
Coil resistance		45 Ω	125 Ω	180 Ω	405 Ω	720 Ω	2,880 Ω	8,230 Ω
Coil inductance (H) (ref. value)	Armature OFF	0.048	0.13	0.17	0.43	0.71	2.76	7.44
	Armature ON	0.043	0.12	0.16	0.4	0.68	2.70	7.25
Must operate voltage		70% max. of rated voltage						
Must release voltage		10% min. of rated voltage						
Max. voltage		200% of rated voltage at 23°C						170% of rated voltage at 23°C
Power consumption		Approx. 200 mW						Approx. 280 mW

Single/Double–winding Latching Types

Rated voltage		3 VDC	5 VDC	6 VDC	9 VDC	12 VDC	24 VDC
Rated current		66.7 mA	40 mA	33.3 mA	22.2 mA	16.7 mA	8.3 mA
Coil resistance		45 Ω	125 Ω	180 Ω	405 Ω	720 Ω	2,880 Ω
Coil inductance (H) (ref. value)	**Armature OFF**	0.02	0.06	0.08	0.17	0.29	1.1
	Armature ON	0.02	0.05	0.07	0.14	0.24	0.85
Must operate voltage		80% max. of rated voltage					
Must release voltage		80% min. of rated voltage					
Max. voltage		200% of rated voltage at 23°C					
Power consumption		Approx. 200 mW					

Note: **1.** The rated current and coil resistance are measured at a coil temperature of 23°C with a tolerance of ±10%.
2. Operating characteristics are measured at a coil temperature of 23°C.

■ Contact Ratings

Load	Resistive load (cosϕ = 1)	Inductive load (cosϕ = 0.4) (L/R = 7 ms)
Rated load	0.5 A at 30 VAC; 1 A at 30 VDC	0.1 A at 30 VAC; 0.2 A at 30 VDC
Contact material	Ag (Au-clad)	
Rated carry current	1 A	
Max. switching voltage	125 VAC, 125 VDC	
Max. switching current	1 A	0.5 A
Max. switching power	37.5 VA, 33 W	12.5 VA, 11 W
Failure rate (reference value)	0.01 mA at 10 mVDC	

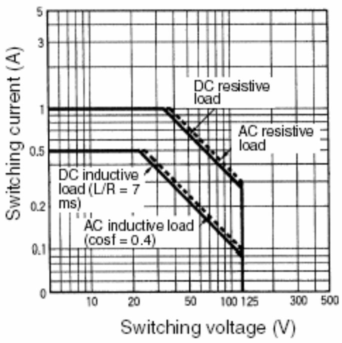
Note P level: $\lambda_{60} = 0.1 \times 10^{-6}$/operation

■ Characteristics

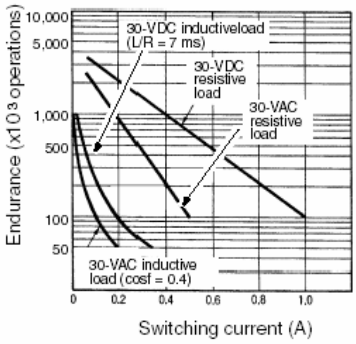
Contact resistance	50 mΩ max.
Operate (set) time	Single-side stable types: 5 ms max. (mean value: approx. 2.4 ms) Latching types: 5 ms max. (mean value: approx. 2 ms)
Release (reset) time	Single-side stable types: 5 ms max. (mean value: approx. 1.1 ms) Latching types: 5 ms max. (mean value: approx. 1.8 ms)
Bounce time	Operate: Approx. 0.5 ms Release: Approx. 0.5 ms
Min. set/reset signal width	Latching type: 7 ms
Max. operating frequency	Mechanical: 36,000 operations/hr Electrical: 1,800 operations/hr (under rated load)
Insulation resistance	1,000 MΩ min. (at 500 VDC)
Dielectric strength	1,000 VAC, 50/60 Hz for 1 min between coil and contacts 1,000 VAC, 50/60 Hz for 1 min between contacts of different polarity 500 VAC, 50/60 Hz for 1 min between contacts of same polarity 100 VAC, 50/60 Hz for 1 min between set and reset coils (double-winding type only)
Impulse withstand voltage	1,500 V (10 x 160 μs) between contacts of same polarity (conforms to FCC Part 68)
Vibration resistance	Destruction: 10 to 55 to 10 Hz, 0.75-mm single amplitude (1.5-mm double amplitude) Malfunction: 10 to 55 to 10 Hz, 0.75-mm single amplitude (1.5-mm double amplitude)
Shock resistance	Destruction: 1,000 m/s^2 (approx. 100G) Malfunction: 300 m/s^2 (approx. 30G)
Endurance	Mechanical: 50,000,000 operations min. (at 36,000 operations/hr) Electrical: 100,000 operations min. (at 1,800 operations/hr)
Ambient temperature	Operating: –40°C to 70°C (with no icing)
Ambient humidity	Operating: 5% to 85%
Weight	Approx. 3 g

Engineering Data

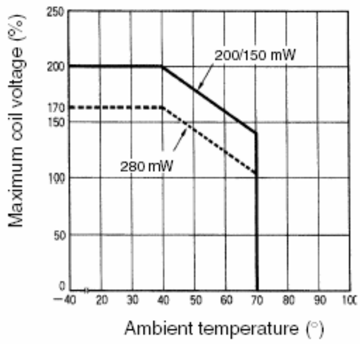
Maximum Switching Power



Endurance



Ambient Temperature vs. Maximum Coil Voltage



Note: The maximum coil voltage refers to the maximum value in a varying range of operating power voltage, not a continuous voltage.

■ Approved Standards

UL114, UL478 (File No.E41515)/CSA C22.2 No.0, No.14 (File No.LR24825)

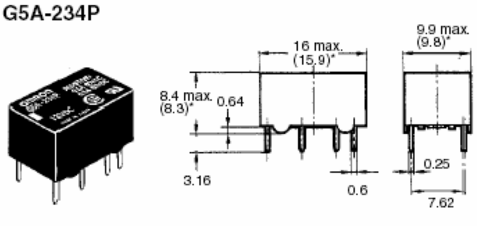
Model	Contact form	Coil ratings	Contact ratings
G5A-234P	DPDT	3 to 48 VDC	0.5 A, 60 VAC 0.5 A, 60 VDC 1 A, 30 VDC
G5AU-234P G5AK-234P		3 to 24 VDC	

Dimensions

Note: 1. All units are in millimeters unless otherwise indicated.

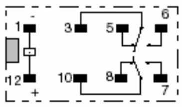
2. Orientation marks are indicated as follows:

G5A-234P



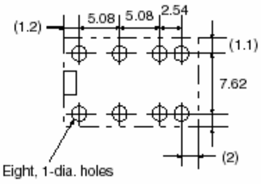
*Average value

Terminal Arrangement/ Internal Connections (Bottom View)

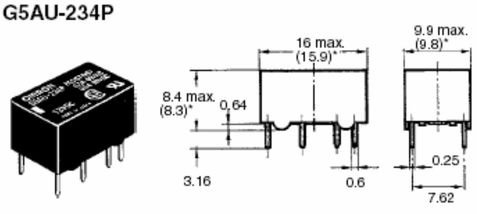


Mounting Holes (Bottom View)

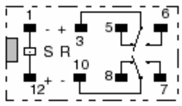
Tolerance: ±0.1

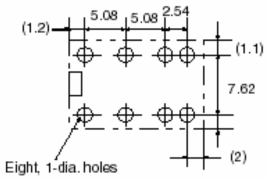


G5AU-234P

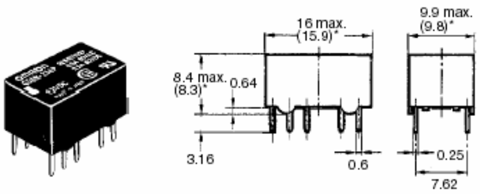


*Average value

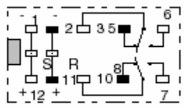




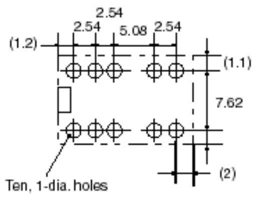
G5AK-234P



*Average value



S: Set coil
R: Reset coil



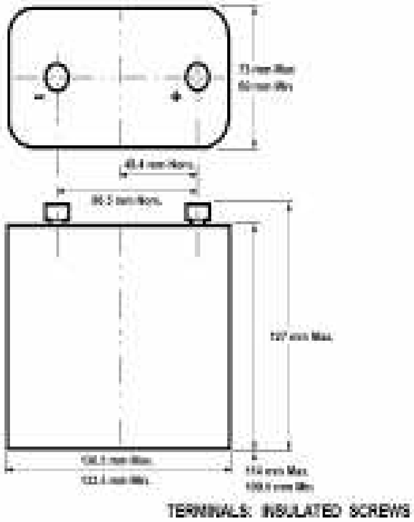
ALL DIMENSIONS SHOWN ARE IN MILLIMETERS.
To convert millimeters into inches, multiply by 0.03937. To convert grams into ounces, multiply by 0.03527.

Appendix B-8:

Data sheet for the 12 Volts Battery

DURACELL® SIZE PC926

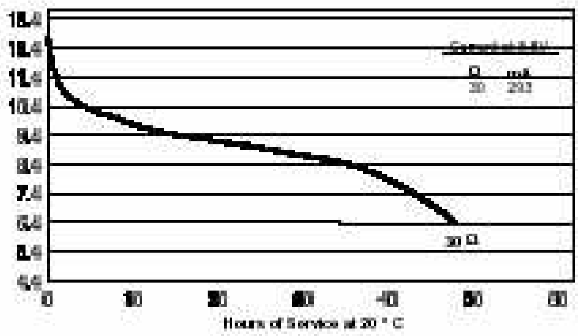
Alkaline Manganese Dioxide Battery



SPECIFICATIONS	
Minimum No Load Voltage:	12 V
Minimum On Load Voltage:	10.8V on 24Ohms at 20D
Minimum Life	36.5 H 30 Ohms Hr/Day 6.4 V
Rated Capacity	13000 mAh on 30Ohms to 6.4V
Volume	1066 cm3
Weight	1389g

Physical Size in mm	Max	Min
Height/Length	127	
Width/Diameter	136.5	132.5
Depth	73	69

Typical Discharge Characteristics



Appendix B-9:

Water leakage check procedure

ADVANTEST
Advantest (Singapore) Pte. Ltd, 438A Alexandra Road, #08-03/06, Alexandra Technopark, Singapore 119967.
Main line : 62743100, fax line : 62744055.

Water Leakage Check Procedure (Rev 2)
Date Checked :
Water Level Detection Jig Timer Counter :
Checked By :
****

Necessary Tools:
(Estimated Man-hours required: 2 hrs)
01) Adjustable Wrench
02) Floor Board Removal Tool
03) Waste Cloths
04) Containers/bottles
05) Chiller Wiring/Schematics Diagram
06) Chiller Moisture Perception Alarm Recovery Manual
****

No.	Item	Inspection/Countermeasure	Record	Remarks
01	Check Moisture Perception Alarm on T5586 Test System	If activated, stop all action and remedy the problem using the Chiller Moisture Perception Alarm Recovery Manual		5mins
02	Check water pan in Chiller of T5586 Test System	If water is found in the water pan, perform Check Item No. 03		5mins
03	Determine leak point using Chiller Schematics Diagram	Remedy leak point		20mins
04	Check incoming water coupling in the Chiller of T5586 Test System	Use Adjustable wrench to remedy the leakage if any		5mins
05	Check Moisture Perception Alarm on T5377S Test System	If activated, stop all action and remedy the problem using the Chiller Moisture Perception Alarm Recovery Manual		5mins
06	Check water pan in Chiller of T5377S Test System	If water is found in the water pan, perform Check Item No. 07		5mins
07	Determine leak point using Chiller Schematics Diagram	Remedy leak point		20mins
08	Check incoming water coupling in the Chiller of T5377S Test System	Use Adjustable wrench to remedy the leakage if any		5mins
09	Check Moisture Perception Alarm on T2000 Test System	If activated, stop all action and remedy the problem using the Chiller Moisture Perception Alarm Recovery Manual		5mins
10	Check water pan in Chiller of T2000 Test System	If water is found in the water pan, perform Check Item No. 11		5mins
11	Determine leak point using Chiller Schematics Diagram	Remedy leak point		20mins

12	Check incoming water coupling in the Chiller of T2000 Test System	Use Adjustable wrench to remedy the leakage if any		5mins
13	Open up the Floor Boards using the Removal Tool and check any puddles of water on the floor along the pipelines	If puddle of water is found near the pipelines, perform Check Item No.14		30mins
14	Inspect the piping for leakage	Check for any cracks in the piping and remedy		10mins
15	Clean up all leakage water with cloth and container	Check no puddle of water lying around		10mins

Appendix B-10:

Flourinert Material Safety Data Sheet (MSDS)

Material Safety Data Sheet

SECTION 1: PRODUCT AND COMPANY IDENTIFICATION

PRODUCT NAME: FC-3283 FLUORINERT Brand Electronic Liquid
MANUFACTURER: 3M
DIVISION: Electronics Markets Materials Division

ADDRESS: 3M Center
St. Paul, MN 55144-1000

EMERGENCY PHONE: 1-800-364-3577 or (651) 737-6501 (24 hours)

Issue Date: 01/27/2004
Supercedes Date: 01/27/2004

Document Group: 06-4521-8

Product Use:
Intended Use: For industrial use only. Not intended for use as a medical device or drug.
Specific Use: Testing Fluid or Heat Transfer Fluid for Electronics

SECTION 2: INGREDIENTS

Ingredient	C.A.S. No.	% by Wt
PERFLUORO COMPOUNDS, (PRIMARILY COMPOUNDS WITH 9 CARBONS)	86508-42-1	100

SECTION 3: HAZARDS IDENTIFICATION

3.1 EMERGENCY OVERVIEW

Specific Physical Form: Liquid
Odor, Color, Grade: Colorless, odorless liquid.
General Physical Form: Liquid
Immediate health, physical, and environmental hazards: None known.

3.2 POTENTIAL HEALTH EFFECTS

Eye Contact:
Contact with the eyes during product use is not expected to result in significant irritation.

Skin Contact:
Contact with the skin during product use is not expected to result in significant irritation.

Inhalation:
No health effects are expected.

Ingestion:
No health effects are expected.

3.3 POTENTIAL ENVIRONMENTAL EFFECTS

This compound is completely fluorinated (perfluorinated), or it contains perfluorinated portions. Perfluoroalkyl groups resist degradation in most natural environments. This low-solubility substance has insignificant toxicity to aquatic organisms (Lowest LL50 or EL50 is >1000 mg/L). LL50 (Lethal Level) and EL50 are similar to LC50 and EC50, but tests the water phase from incompletely-miscible mixtures. Take precautions to prevent direct release of this substance to the environment. ATMOSPHERIC FATE: Perfluoro compounds (PFCs) are photochemically stable and expected to persist in the atmosphere for more than 1000 yrs. PFCs have high global warming potentials (GWP), exceeding 5000 (100-yr ITH). The Ozone Depletion Potential (ODP) is Zero.

SECTION 4: FIRST AID MEASURES

4.1 FIRST AID PROCEDURES

The following first aid recommendations are based on an assumption that appropriate personal and industrial hygiene practices are followed.

Eye Contact: Flush eyes with large amounts of water. If signs/symptoms persist, get medical attention.

Skin Contact: Wash affected area with soap and water. If signs/symptoms develop, get medical attention.

Inhalation: If signs/symptoms develop, remove person to fresh air. If signs/symptoms develop, get medical attention.

If Swallowed: No need for first aid is anticipated.

SECTION 5: FIRE FIGHTING MEASURES

5.1 FLAMMABLE PROPERTIES

Autoignition temperature	Not Applicable
Flash Point	Not Applicable

Flammable Limits - LEL	[Details: Nonflammable]
Flammable Limits - UEL	[Details: Nonflammable]

5.2 EXTINGUISHING MEDIA
Material will not burn.

5.3 PROTECTION OF FIRE FIGHTERS

Special Fire Fighting Procedures: Wear full protective equipment (Bunker Gear) and a self-contained breathing apparatus (SCBA). Water may be used to blanket the fire. Exposure to extreme heat can give rise to thermal decomposition.

Unusual Fire and Explosion Hazards: No unusual fire or explosion hazards are anticipated. No unusual effects are anticipated during fire extinguishing operations. Avoid breathing the products and substances that may result from the thermal decomposition of the product or the other substances in the fire zone. Keep containers cool with water spray when exposed to fire to avoid rupture.

Note: See STABILITY AND REACTIVITY (SECTION 10) for hazardous combustion and thermal decomposition information.

SECTION 6: ACCIDENTAL RELEASE MEASURES

Accidental Release Measures: Observe precautions from other sections. Call 3M- HELPS line (1-800-364-3577) for more information on handling and managing the spill. Evacuate unprotected and untrained personnel from hazard area. The spill should be cleaned up by qualified personnel. Ventilate the area with fresh air. Contain spill. Working from around the edges of the spill inward, cover with bentonite, vermiculite, or commercially available inorganic absorbent material. Mix in sufficient absorbent until it appears dry. Collect as much of the spilled material as possible. Clean up residue with an appropriate organic solvent. Read and follow safety precautions on the solvent label and MSDS. Place in a metal container approved for transportation by appropriate authorities. Seal the container. Dispose of collected material as soon as possible.

In the event of a release of this material, the user should determine if the release qualifies as reportable according to local, state, and federal regulations.

SECTION 7: HANDLING AND STORAGE

7.1 HANDLING
Avoid skin contact with hot material. For industrial or professional use only. No smoking: Smoking while using this product can result in contamination of the tobacco and/or smoke and lead to the formation of the hazardous decomposition products mentioned in the Reactivity Data section of this MSDS. Store work clothes separately from other clothing, food and tobacco products. Use general dilution ventilation and/or local exhaust ventilation to control airborne exposures to below Occupational Exposure Limits. If ventilation is not adequate, use respiratory protection equipment.

7.2 STORAGE
Store away from heat. Keep container tightly closed. Keep container in well-ventilated area.

SECTION 8: EXPOSURE CONTROLS/PERSONAL PROTECTION

8.1 ENGINEERING CONTROLS
Provide appropriate local exhaust when product is heated. Provide appropriate local exhaust ventilation on open containers. For those situations where the fluid might be exposed to extreme overheating due to misuse or equipment failure, use with appropriate local

exhaust ventilation sufficient to maintain levels of thermal decomposition products below their exposure guidelines.

8.2 PERSONAL PROTECTIVE EQUIPMENT (PPE)

8.2.1 Eye/Face Protection

Avoid eye contact.
The following eye protection(s) are recommended: Safety Glasses with side shields.

8.2.2 Skin Protection

Avoid skin contact with hot material. Wear appropriate gloves, such as Nomex, when handling this material to prevent thermal burns. Avoid skin contact.

Select and use gloves and/or protective clothing to prevent skin contact based on the results of an exposure assessment. Consult with your glove and/or protective clothing manufacturer for selection of appropriate compatible materials.
Gloves made from the following material(s) are recommended: Nitrile Rubber.

8.2.3 Respiratory Protection

Under normal use conditions, airborne exposures are not expected to be significant enough to require respiratory protection. Avoid breathing of vapors, mists or spray.
Select one of the following NIOSH approved respirators based on airborne concentration of contaminants and in accordance with OSHA regulations: Half facepiece or fullface air-purifying respirator with organic vapor cartridges. Consult the current 3M Respiratory Selection Guide for additional information or call 1-800-243-4630 for 3M technical assistance. If thermal degradation products are expected, use fullface supplied air respirator.

8.2.4 Prevention of Swallowing

Do not eat, drink or smoke when using this product. Wash exposed areas thoroughly with soap and water.

8.3 EXPOSURE GUIDELINES

None Established

SECTION 9: PHYSICAL AND CHEMICAL PROPERTIES

Specific Physical Form:	Liquid
Odor, Color, Grade:	Colorless, odorless liquid.
General Physical Form:	Liquid
Autoignition temperature	Not Applicable
Flash Point	Not Applicable
Flammable Limits - LEL	[Details: Nonflammable]
Flammable Limits - UEL	[Details: Nonflammable]
Boiling point	123 - 133 °C
Density	1.8 g/ml
Vapor Density	Approximately 18 [@ 23 °C] [Ref Std: AIR=1]
Vapor Pressure	Approximately 14 mmHg [@ 23 °C]
Specific Gravity	Approximately 1.8 [Ref Std: WATER=1]
pH	Not Applicable
Melting point	Not Applicable
Solubility in Water	Nil
Evaporation rate	< 1 [Ref Std: BUOAC=1]
Volatile Organic Compounds	[Details: Exempt]
Percent volatile	Approximately 100 %

VOC Less H2O & Exempt Solvents	[Details: Exempt]
Viscosity	Approximately 0.7 centistoke [@ 25 °C]

SECTION 10: STABILITY AND REACTIVITY

Stability: Stable.

Materials and Conditions to Avoid: Finely divided active metals; Alkali and alkaline earth metals; Heat(greater than 200 °C)

Hazardous Polymerization: Hazardous polymerization will not occur.

Hazardous Decomposition or By-Products

Substance	Condition
Hydrogen Fluoride	At Elevated Temperatures - greater than 200 °C
Perfluoroisobutylene (PFIB)	At Elevated Temperatures - greater than 200 °C

Hazardous Decomposition: If the product is exposed to extreme condition of heat from misuse or equipment failure, toxic decomposition products that include hydrogen fluoride and perfluoroisobutylene can occur.

Hydrogen fluoride (CAS No. 7664-39-3) has an ACGIH Threshold Limit Value - Ceiling of 3 ppm (as fluoride), an OSHA Permissible Exposure Limit - Time Weighted Average of 3 ppm (as fluoride) and a revoked OSHA Permissible Exposure Limit - Short Term Exposure Limit (which is enforced by some State Right-To-Know programs) of 6 ppm (as fluoride). Hydrogen fluoride may cause respiratory tract irritation, dental or skeletal fluorosis and irritation or burns to the eyes or skin, particularly when dissolved in water (hydrofluoric acid). The odor threshold for HF is 0.04 ppm, providing good warning properties for exposure.

Perfluoroisobutylene(CAS No. 382-21-8) has an ACGIH Threshold Limit Value - Ceiling of 0.01 ppm. Perfluoroisobutylene may cause respiratory tract irritation, pulmonary edema, cyanosis, and effect on the hematopoietic system.

SECTION 11: TOXICOLOGICAL INFORMATION

Product-Based Toxicology Information:

A Material Toxicity Summary Sheet (MTSS) has been developed for this product. Please contact the address listed on the first page of this MSDS to obtain a copy of the MTSS for this product.

Please contact the address listed on the first page of the MSDS for Toxicological Information on this material and/or its components.

SECTION 12: ECOLOGICAL INFORMATION

ECOTOXICOLOGICAL INFORMATION

Test Organism	Test Type	Result
Fathead Minnow, Pimephales promelas	96 hours Lethal Concentration 50%	>1000 mg/l

CHEMICAL FATE INFORMATION

Test Type	Result	Protocol
20 days Biological Oxygen Demand	Nil	
Chemical Oxygen Demand	Nil	

SECTION 13: DISPOSAL CONSIDERATIONS

Waste Disposal Method: Reclaim if feasible. As a disposal alternative, incinerate in an industrial or commercial facility in the presence of a combustible material. Combustion products will include HF. Facility must be capable of handling halogenated materials.
To reclaim or return, check product label for contact.

EPA Hazardous Waste Number (RCRA): Not regulated

Since regulations vary, consult applicable regulations or authorities before disposal.

SECTION 14:TRANSPORT INFORMATION

ID Number(s):
98-0211-7366-5, 98-0211-7386-3, 98-0211-8864-8, 98-0212-2887-3, 98-0212-2908-7, 98-0212-3133-1, ZF-0002-1344-5, ZF-0002-1345-2, ZF-0002-1356-9

Please contact the emergency numbers listed on the first page of the MSDS for Transportation Information for this material.

SECTION 15: REGULATORY INFORMATION

US FEDERAL REGULATIONS

Contact 3M for more information.

311/312 Hazard Categories:
Fire Hazard - No Pressure Hazard - No Reactivity Hazard - No Immediate Hazard - No Delayed Hazard - No

STATE REGULATIONS

Contact 3M for more information.

CHEMICAL INVENTORIES

The components of this product are in compliance with the chemical notification requirements of TSCA.

All applicable chemical ingredients in this material are listed on the European Inventory of Existing Chemical Substances (EINECS), or are exempt polymers whose monomers are listed on EINECS.

The components of this product are listed on the Canadian Domestic Substances List.

The components of this product are listed on the Australian Inventory of Chemical Substances.

The components of this product are listed on Japan's Chemical Substance Control Law List (also known as the Existing and New Chemical Substances List.)

The components of this product are in compliance with notification requirements in the Philippines.

Contact 3M for more information.

INTERNATIONAL REGULATIONS

Contact 3M for more information.

This MSDS has been prepared to meet the U.S. OSHA Hazard Communication Standard, 29 CFR 1910.1200.

SECTION 16: OTHER INFORMATION

NFPA Hazard Classification

Health: 3 Flammability: 0 Reactivity: 0 Special Hazards: None

National Fire Protection Association (NFPA) hazard ratings are designed for use by emergency response personnel to address the hazards that are presented by short-term, acute exposure to a material under conditions of fire, spill, or similar emergencies. Hazard ratings are primarily based on the inherent physical and toxic properties of the material but also include the toxic properties of combustion or decomposition products that are known to be generated in significant quantities.

HMIS Hazard Classification

Health: 0 Flammability: 0 Reactivity: 0 Protection: X - See PPE section.

Hazardous Material Identification System (HMIS(r)) hazard ratings are designed to inform employees of chemical hazards in the workplace. These ratings are based on the inherent properties of the material under expected conditions of normal use and are not intended for use in emergency situations. HMIS(r) ratings are to be used with a fully implemented HMIS(r) program. HMIS(r) is a registered mark of the National Paint and Coatings Association (NPCA).

Reason for Reissue: Added OUS stock number.

Revision Changes:
Section 14: ID Number(s) was modified.

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