Name of SOP	Pool Boiling Experimental Procedure
Effective Date	July 1, 2011
Author	James Strack
Reason for SOP	Check all that apply: [X] Procedure/Process could cause critical injury. [ ] Procedure/Process could cause occupational illness. [ ] Procedure/Process could cause environmental impairment. [ ] Procedure/Process could damage University property. [ ] Supervisor's discretion. <u>Electrical shock hazard:</u> The maximum voltage of the power supply is 120 VAC. The heater is rated for a maximum of 450 W. As configured, the heater can reach a maximum current of 3.75 A. All wiring junctions and connectors have been insulated and are sealed from the experimenter. Thus, the above risks are considered low if the procedure is followed. <u>Burn hazard:</u> The water will be heated up to 100 degrees Celsius with a small amount of boiling. Boiling will be localized over the heated surface and most escaping steam will be condensed in the vent tube. This burn hazard is considered a low risk. The tank body is thermally conductive and will reach the temperature of the bulk fluid. The tank walls may reach as hot as 100 degrees Celsius. Care will be taken by the experimenter not to contact the tank body or the tank base during experiments and temperature readouts will be provided. Warning signs are placed to alert experimenters of the aforementioned hot surfaces. The internal temperature of the heated element will be much higher (up to 670 degrees Celsius). Where possible, the heater is insulated from the environment. Sections of the vessel in thermal contact with the heater are accessible with difficulty from the base of the tank.Warning signs are placed to alert experimenters of the aforementioned hot surfaces.
Approved by (supervisor)	
Date reviewed by JHSC	May 11, 2011

Definitions

Terms	Critical Heat Flux – the heat flux at which a vapour blanket envelopes the heated element leading to a large temperature increase in the wall temperature.
Acronyms	RMM – Risk Management Manual JHSC - Joint Health and Safety Committee EOHSS - Environmental and Occupational Health Support Services EPA – Environmental Protection Act OHSA – Occupational Health and Safety Act CHF – Critical Heat Flux

Requirements

Applicable OHSA regulations and / or codes of practice. 1. RMM #101 - McMaster University Risk Management System
Training and Competency 1. Electrical design and construction is in accordance with the electrical safety code and has been designed with the consultation of a practicing professional electrical engineer.

Description of the Task

Location and time of work	**NRB B115, Various times, Monday to Friday 9 am – 5 pm**
Individuals involved	James Strack and one graduate student within the department of Engineering Physics. Experiment will not be performed individually.
Equipment and supplies required	Variable autotransformer (variac), two multimeters, experimental apparatus.
Personal protective equipment required	Eye goggles, closed toed shoes.

Sequential Steps to Complete the Work Safely

The following is the experimental procedure. A complete data set is obtained when one has the average wall temperature, operating heat flux, heater voltage and current, and bulk fluid temperatures. The heat flux is varied by adjusting the AC voltage to the cartridge heater using a variable autotransformer (variac).

Notes:

- In this configuration the resistance of heater is approximately 32.1 Ω and is expected to draw up to 3.75 A.
- The variac is fused at 10 A to prevent damage to the apparatus in the case of an electrical short circuit.

Precautions:

- Tank surfaces may become hot during the experiment. Avoid touching the tank body during or immediately following the experiment.
- The tank body weighs approximately 50 kg assembled. The tank should be assembled in sections with the help of a second person.

Procedure for Pool Boiling Experimental Facility

1. Before assembling the tank, ensure that:
   a. The variac is set to 0 V, switched off, and is disconnected from the wall outlet.
   b. A properly rated fuse is properly installed in the variac (10 A, 250 VAC).
   c. The heater leads are disconnected from the junction box.
   d. All ten thermocouples are secured to the copper rod through the Teflon insulator and that the thermocouple feed-through fittings are properly tightened in the base.
   e. A clean boiling surface is securely epoxied to the copper rod.

f. All eight bolts are inserted through the tank lower flange from the bottom and that the bolt heads are resting on neoprene padding in the vessel stand.

2. With the help of a second person, carefully lower the main tank body over the lower assembly (lower flange, copper rod, Teflon insulator). A silicone rubber gasket should be installed between the lower flange and the tank body. Align the tank such that the observation windows are rotated perpendicular to the thermocouples installed in the base. Firmly tighten all eight nuts and bolts.
3. Lower the cooling tank onto the top of the tank main body. A silicone rubber gasket should be installed between the tank body and the cooling tank. Firmly tighten all eight nuts and bolts.
4. Insert 1/16" sheathed thermocouples through compression fittings installed in the side of the main tank body.
5. Close the drainage valve. Using the standpipe, fill the vessel tanks with distilled water to a level such that the bottom plate of the cooling tank is in contact with the water.
6. If water is to be circulated through the cooling tank, connect supply and drainage lines. Otherwise insert ¼" NPT drain plugs into the threaded holes in the side of the tank.
7. Fill cooling tank with cold tap water. Adjust the cold water flow rate to keep level constant, if applicable.
8. Check all fittings, bolted connections, and tank seams for leaks. If leaks are detected, open the drain valve, re-seal, tighten any leaking fittings, and repeat step 5.
9. Start LabView and ensure that all temperature readings are sensible.
10. Measure the resistance of the cartridge heater using a multimeter. The resistance is measured across the heater leads and should be approximately 32.1 Ω.
11. Measure resistance between the tank frame and both heater leads. The measured resistance should be very large (on the order of MΩ).
12. Check that frame is grounded to the cold water tap using a multimeter.
13. Configure two multimeters to read AC voltage. Connect one meter to the voltage taps on the junction box (yellow jacks) and set to the 200 V range. Connect the second meter to the current shunt taps on the junction box (blue jacks) and set to the mV range.
14. Connect the heater leads to the junction box; the polarity of the wires does not matter. Connect the junction box to the variac outlet.
15. Adjust the variac to "0" by fully turning the knob counter clockwise.
16. Turn on the variac by toggling the ON/OFF switch.

The system is now live

17. Using a known equivalent resistance of 32.1 Ω, estimate the voltage setting from the desired power level using $P=V^2/R$.
18. Adjust the voltage using the variac to the desired level. Verify that the current draw is reasonable based on $P=VI$.
19. Monitor the temperature readings and acquire data, noting the power level. Enter the multimeter readings

into the provided dialog boxes in the LabView application.

20. Allow the system to reach steady state.

21. Iterate back to step 17 by incrementally raising the power level until CHF is reached.

22. When CHF is reached there will be a rapid increase in the wall temperature of the heater. Turn off power supply by toggling the ON/OFF switch on the variac. If the temperature readings are steadily decaying then there is no current going through the heater.

23. Adjust the current and voltage demanded values back to zero.

24. Disconnect the junction box from the variac outlet socket.

Electrical hazard removed after step 24

25. Open the drain valves to empty the main tank and the cooling tank. This will allow the heated plated to cool more slowly and will prevent heater damage and corrosion.

26. To remove the boiling surface, disassemble the tank in sections. Disassembly procedures follow the reverse of steps 2 to 4.

End of procedure

Contingency Plan and Reporting

Accident / injury response

Provide a safe environment by turning off the power supply. In case of fire, obtain fire extinguisher (located just outside of the lab), pull the pin, aim at the base of the fire and extinguish it. Report any injuries as soon as possible to Dr. David Novog.

In the Case of Serious/Critical Injuries

Provide a safe environment by turning off the power supply. In case of fire, obtain fire extinguisher (located just outside of the lab), pull the pin, aim at the base of the fire and extinguish it. Report any injuries as soon as possible to Dr. David Novog

Equipment Malfunction

The experimental apparatus is designed to accommodate heater failure (i.e. a short circuit or open circuit). The variac is fitted with a fuse. Thus, in the event of a short circuit, a fuse will blow and no current will be provided to the failed heater. The integrity of the heater is checked before each experiment.

Equipment shutdowns

The power supply to the variac can be turned off by

1. Turning the ON/OFF switch located on the variac to the OFF position
2. Disconnecting the variac from the wall socket
3. Disconnecting the junction box from the variac socket.

The active component of the experimental facility is the power supply. The power supply is considered to be in a safe state when all of the following conditions are met:

1. The variac power switch is in the OFF position. The supplied voltage will be zero.
2. The variac power cord is disconnected from the wall socket.
3. The junction box is disconnected from the variac.

The power supply is to be in this state at all times except when an experiment is being performed.

Environmental Responsibility

Waste disposal procedures

Water used is distilled water and no chemicals are added. The lab sinks will be used for water disposal.

Building air quality

No impact.

References

1. OHSA/ regulations
2. EPA and Municipal environmental regulations
3. RMM #100 McMaster University Environmental Health and Safety Policy
4. Material Safety Data Sheets (MSDS)
5. RMM #300 Safety Orientation and Training Program
6. RMM #301 Standard Operating Procedures

Distribution

1. Engineering Physics / CEDT HSC (for review)
2. Dr. David Novog, Supervisor
3. Barry Diacon, Laboratory Technician
4. Ken Leung, Graduate Student